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C-5 Modified *S*-Benzoxazolyl Sialyl Donors: Towards More Efficient Selective Sialylations

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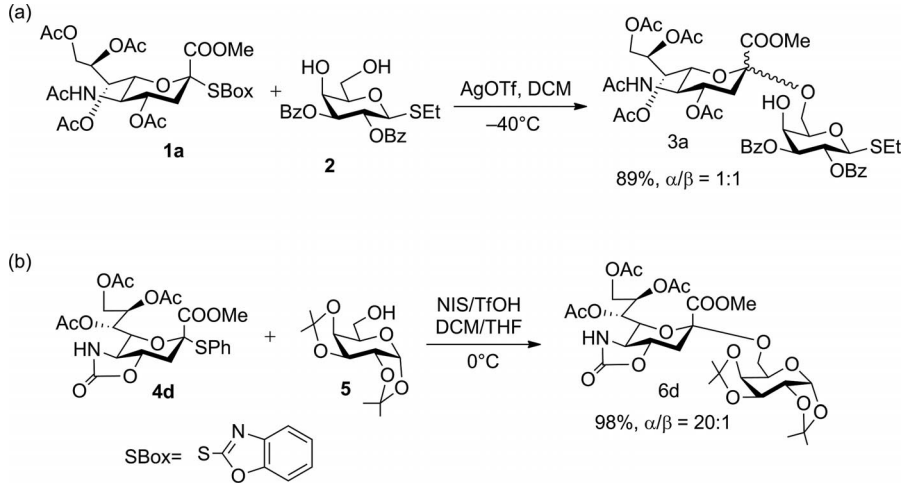
We previously reported that the selective activation of an *S*-benzoxazolyl (SBox) sialyl donor over a galactosyl acceptor equipped with a thioethyl anomeric moiety can be performed in high yield but with poor stereoselectivity. To optimize this strategy, which allows the synthesis of complex carbohydrates to be shortened, a range of SBox sialyl donors modified at C-5 were synthesized and tested. In particular, the combination of the SBox leaving group and an oxazolidinone at C-4,5 allowed superior stereocontrol in various solvents and at different temperatures. Nearly complete stereoselectivity was obtained in the presence of bismuth(III) triflate in a dichloromethane/tetrahydrofuran (1:1) solvent system.

Introduction

Sialic acid containing glycoconjugates are natural complex molecules, which are involved in numerous biological phenomena, ranging from cell–cell adhesion and mobility to oncogenesis and recognition by viruses and bacteria.[1,2] Therefore, the synthesis and biomedical investigations of sialic acids and bioconjugates thereof is an important tool for a better understanding of their biological roles and for designing sialotherapeutics. Glycosylations to form anomeric linkages of sialic acid (sialylations) are often complicated by the intrinsic structural features of sialic acid, resulting in poor yields and/or stereoselectivities.[3–5] Although notable progress has been made in this research field in the last decade, good yields along with complete control of stereoselectivities for the synthesis of sialosides is still a goal to be reached. Perhaps one of the most challenging linkages to be stereocontrolled is the synthesis of α(2–6)-sialosides, which in general can be accomplished in high yields but with modest stereoselectivities. On the other hand, this type of linkage is very common in glycoconjugates and therefore is associated with many important biological phenomena. For example, hemmaglutinin of the human influenza A virus can specifically recognize α(2–6)-linked sialic acid. Previously, we reported that the use of thioimidoyl leaving groups allows high yields in sialylations



Scheme 1. (a) Selective activation for the synthesis of sialosides; (b) 4,5-oxazolidinone-directed α-sialylation.

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of various galactosyl acceptors to be achieved.[6] In addition, we demonstrated that sialyl thioimidate donor **1a** can be selectively activated over galactosyl acceptors equipped with an *S*-ethyl anomeric moiety (Scheme 1a). Because the resulting disaccharide is already equipped with the thioethyl leaving group, it can be glycosidated directly to obtain larger oligosaccharides without the necessity to perform the intermediate protecting group manipulations between the glycosylation steps. This approach has been already adopted by other research groups.[7,8] For instance, Hung et al. reported a very efficient one-pot synthesis of a hemmaglutinin-binding trisaccharide (and its analogs) by selective activation of donor **1a** over an *S*-tolyl acceptor in high yields.[8] Unfortunately, only modest stereoselectivities were observed in sialylations of primary galactosyl acceptors, and this important drawback stands out as a significant limitation in the broadening of the scope of this promising selective activation concept.

As a part of a parallel investigation, we reported that the introduction of a C-5 oxazolidinone moiety can dramatically improve the efficiency of sialylation for the synthesis of α(2–6) linkages, obtaining high yields and stereoselectivity in the presence of various solvents and temperatures (Scheme 1b).[9,10] Similar observations were concomitantly reported by the groups of Takahashi and Crich.[11–14] To adapt both thioimidoyl and the C-5 modification approaches to chemical sialylation, herein we report a cooperative study of these two concepts. For this purpose we prepared a range of SBox sialyl donors (**1b**–**d**, Figure 1) modified at C-5 and performed a comprehensive study of their (2–6)-sialidations with diacetone galactose **5** and thioethyl acceptor **2** under various reaction conditions.

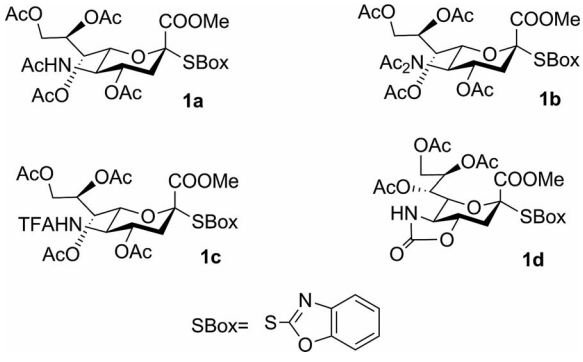
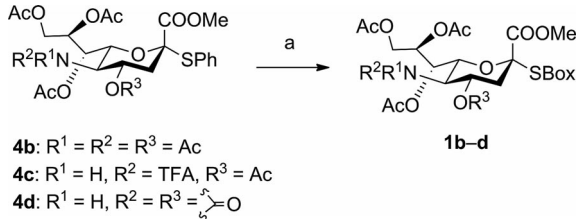


Figure 1. SBox sialyl donors **1a**–**d**.

Results and Discussion

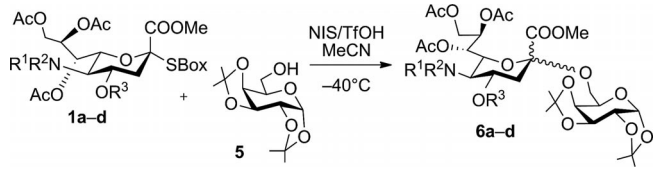
We found that the synthesis of sialyl donors **1b**–**d** could be achieved by direct conversion of the respective C-5 modified thiophenyl donors **4b**–**d**[15–17] in the presence of iodine chloride followed by treatment with 2-mercaptobenzoxazole (in the presence of DIPEA) or its potassium salt in the presence of 18-crown-6 (Scheme 2).



Scheme 2. Synthesis of SBox sialyl donors **1b**–**d**. Reagents and conditions: (a) 1. ICl (1 M in DCM), DCM, 3 Å MS; 2. KSBox, 18-crown-6, acetone or HSBox, DIPEA, DCM, 62–72%.

In our previous study we reported[6] that the coupling between SBox sialyl donor **1a** and diacetone galactose acceptor **5** in the presence of *N*-iodosuccinimide (NIS) and triflic acid in acetonitrile gives disaccharide **6a** with a good yield of 70% (Table 1, Entry 1). Because relatively low stereoselectivity was detected (α/β = 1.6:1), we assumed that these reaction conditions (NIS/TfOH, MeCN) would be a good starting point for studying the effect of various C-5 protecting groups in new sialyl donors **1b**–**d**. Immediately it became apparent that the introduction of an additional acetyl group resulted in a dramatic increase in the reactivity of sialyl donor **1b** in comparison to that of its monoacetylated counterpart **1a**. Thus, disaccharide **6b** was formed nearly instantaneously and was isolated in 96% yield (Table 1, Entry 2). This increase in reactivity of *N*-acetylacetamido-protected sialic acid derivatives correlates well with the study of *S*-methyl sialyl donors by Boons.[15] Unfortunately, the stereoselectivity of this reaction remained low, and disaccharide **6b** was obtained as a 1.2:1 mixture of α/β-anomers. A somewhat different effect was observed with 5-trifluroacetamido-protected sialyl donor **1c**. Whereas no notable increase in reactivity was detected in comparison to that of *N*-acetamido donor **1a**, a slightly improved yield of 78% and a notably higher stereoselectivity (α/β = 5:1) were observed (Table 1, Entry 3). A further improvement in stereoselectivity (α/β = 10:1) was achieved in the coupling of C-5 oxazolidinone modified SBox donor **1d**. Resulting disaccha-

Table 1. Glycosylation of sialyl donors **1a**–**d** with glycosyl acceptor **5**.[a]



Entry	Donor	Time [min]	Product	Yield [%]	Ratio (α/β)
1[6]	**1a**	960	**6a**	70	1.6:1
2	**1b**	5	**6b**	96	1.2:1
3	**1c**	960	**6c**	78	5:1
4	**1d**	60	**6d**	50	10:1

[a] Yields were calculated on anomeric mixtures isolated by size-exclusion chromatography (LH-20), and the α/β ratio was calculated by integration of free-standing signals in the ^{1}H NMR spectrum.

ide **6d** was isolated in an average yield of 50% (Table 1, Entry 4).

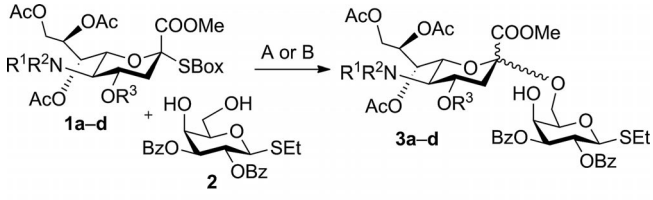
This initial comparison study supports the general belief that modification at C-5 has a profound effect on the outcome of sialylations.[18] The acquired results indicate that diacetyl modification increases the reactivity and yield, whereas oxazolidinone modification provides better stereocontrol of the sialylations. Overall, these results correlate well with our earlier study of sialyl donors equipped with a thiophenyl leaving group, wherein similar trends in yields and stereoselectivities were obtained.[9] Extended experimental and direct comparison data are available as a part of the Supporting Information.

As sialyl thioimidates offer a significant advantage over conventional thioglycosides by offering the possibility of their selective activation over other leaving groups, further study emphasized the reaction conditions that would allow for selective activation. For this purpose, we investigated the selective activation of sialyl donors **1a**–**d** over thioglycoside acceptor **2**. To ensure the selective nature of activation of the SBox leaving group, its activation was performed in the presence of AgOTf, reaction conditions under which the *S*-ethyl moiety remains entirely inert. Previously, we noticed that silver triflate promoted reactions are extremely sluggish in MeCN; therefore, these sialylations were initially performed in dichloromethane at –40 °C.[6] Although nearly quantitative yield for the formation of disaccharide **3a** was achieved, no stereoselectivity preference was detected (Table 2, Entry 1). In an attempt to invert the stereoselectivity, we sialidated donor **1c** by using tetrahydrofuran/dichloromethane, a solvent system that was found advantageous for the α-stereoselective sialylation of thioglycosides.[10] Also herein, disaccharide **3c** was obtained predominantly as the α-anomer (α/β = 2:1), but with a notable decrease in yield (Table 2, Entry 5). Further improvement in stereoselectivity emerged with the application of sialyl donor **1d** in dichloromethane at –78 °C. Thus, disaccharide **3d** was obtained with good stereoselectivity and moderate yield (α/β = 11:1, 50%; Table 2, Entry 6). The increase in yield along with a slight decrease in stereoselectivity was recorded in the presence of a mixture of dichloromethane/tetrahydrofuran (1:1) at 0 °C (α/β = 6:1, 74%; Table 2, Entry 6). By lowering the temperature to –40 °C it was possible to reach a higher stereoselectivity (α/β = 15:1, 54%; Table 2, Entry 7).

This result is an indication that oxazolidinone-protected sialyl donor **1d** provides superior stereoselectivity for the formation of the α-(2–6) linkage through selective activation. Relatively high yields and/or stereoselectivities have also been achieved in several solvent systems at different temperatures when **1d** was used as the donor, proving the importance of oxazolidinone protection at C-5 (see the Supporting Information).

Further refinement of the reaction conditions required the search for different promoters that could allow even higher yields while maintaining the high stereoselectivity for the coupling of **1d** and acceptor **2** (Table 3). Similarly to that reported for acetamido donor **1a**,[6] we noticed that the activation of oxazolidinone-protected donor **1d** with Cu(OTf)$_2$ lead to a notable increase in the reaction time in comparison to AgOTf-promoted activations. Resultantly, coupling product **3d** was obtained after 3 d in average yields. Nevertheless, good stereoselectivities were maintained in tetrahydrofuran used either as a mixture with dichloromethane or neat (Table 3, Entries 1 and 2). Further improvement emerged with the glycosylation of sialyl donor **1d** with acceptor **2** in the presence of bismuth(III) triflate in dichloromethane/tetrahydrofuran. In this case, the desired disaccharide was obtained in an improved yield and with nearly complete stereoselectivity (66%, α/β = 20:1; Table 3, Entry 3). These reaction conditions appear optimal for the

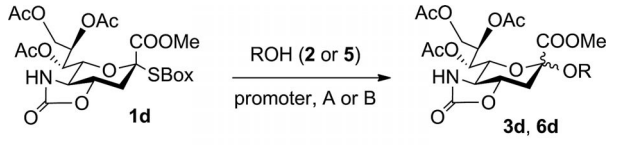
Table 2. Glycosylation of sialyl donors **1a**–**d** with glycosyl acceptor **2**.[a]



Entry	Donor	Conditions	Product	Yield [%]	Ratio (α/β)
1[6]	**1a**	A, –40 °C	**3a**	98	1:1
2	**1a**	A	**3a**	<5	–
3	**1b**	A	**3b**	76	1:1.3
4	**1c**	A	**3c**	96	1:4
5	**1c**	B	**3c**	67	2:1
6	**1d**	A	**3d**	50	11:1
7	**1d**	B	**3d**	74	6:1
8	**1d**	B, –40 °C	**3d**	54	15:1

[a] Yields were calculated on anomeric mixtures isolated by size-exclusion chromatography (LH-20), and the α/β ratio was calculated by integration of free-standing signals in the ^{1}H NMR spectrum.

Table 3. Glycosylation of sialyl donor **1d** under different reaction conditions.[a]



Entry	Product	Promoter	Conditions	Time [min]	Yield [%]	Ratio (α/β)
1	**3d**	Cu(OTf)$_2$	A	4320	57	9:1
2	**3d**	Cu(OTf)$_2$	B	4320	40	13:1
3	**3d**	Bi(OTf)$_3$	A	960	66	20:1
4	**6d**	Bi(OTf)$_3$	A	5	92	7:1

[a] Yields were calculated on anomeric mixtures isolated by size-exclusion chromatography (LH-20), and the α/β ratio was calculated by integration of free-standing signals in the ^{1}H NMR spectrum.

formation of the α-(2–6) linkage through selective activation of the SBox leaving group over thiogalactosyl acceptor **2** at this stage. An excellent yield and somewhat lower stereoselectivity was also observed for the coupling of **1d** with acceptor **5** under practically the same reactions conditions (92%, α/β = 7:1; Table 3, Entry 4). Sialylations of **1a**–**c** in the presence of $Bi(OTf)_3$ gave similar results to those shown for silver triflate promoted couplings (see the Supporting Information for further details).

Conclusions

C-5 modified SBox sialyl donors **1b**–**d** were synthesized and tested towards traditional and selective glycosylations under several reaction conditions. The general outcome of the sialylations was somewhat similar to that previously observed for thiosialyl donors. In fact, an increase in reactivity was observed for the C-5 modifications as in diacetyl and trifluoroacetyl when compared to the common acetamido donor; however, the stereoselectivity of the sialylation reaction was dependent on the reaction conditions. In fact, whereas the use of acetonitrile for the traditional sialylations allowed better α-stereocontrol, selective sialylations required further tuning of the reaction conditions to obtain good α-stereoselectivities. Very differently from other C-5 modifications is the behavior of SBox sialyl donor **1d** bearing an oxazolidinone moiety at C-4,5. As already noticed for thiosialyl donors, the presence of the *trans*-fused ring system allows better stereocontrol of sialylations. In particular, in the presence of bismuth(III) triflate it was possible to improve the stereoselectivity of the selective activation of the SBox sialyl donor over the thioethyl galactosyl acceptor to nearly complete α-stereoselectivity. This finding will allow for more efficient selective α(2–6) sialylations and may provide a new tool for performing high-throughput sequential glycosylations in one pot. Further investigations of other galactosyl acceptors are currently ongoing.

Experimental Section

General Synthesis of Sialyl Donors 1b–d: To a solution of **4b**–**d**[15–17] and activated 3 Å molecular sieves in anhydrous CH_2Cl_2 was added at 0 °C iodine monochloride (1 M in CH_2Cl_2). The reaction mixture was then stirred at 0 °C for 3 h. Upon completion, the reaction mixture was diluted with dichloromethane, filtered over Celite, washed with sodium thiosulfate and then brine, concentrated, and dried in vacuo to afford the chlorinated product. This product was immediately dissolved in anhydrous acetone and KSBox[19] was added with 18-crown-6 ether. Alternatively, the residue was dissolved in dry CH_2Cl_2 and 2-mercaptobenzoxazole (HSBox) was added followed by the addition of DIPEA; the reaction mixture was stirred at room temperature under an argon atmosphere for 16 h. Upon completion, the reaction mixture was diluted with CH_2Cl_2 and washed with 1% aq. NaOH and then brine, evaporated under reduced pressure, and concentrated in vacuo. The residue was purified by column chromatography (5% acetone/toluene) to afford **1b**–**d**.

General Glycosylation Procedure: A solution of donor **1b**–**d** was stirred in a 2:1 molar ratio with acceptor **2**[20] or **5** in the desired solvent (2 mL/0.1 mmol of donor) with activated molecular sieves (3 Å) overnight under an argon atmosphere. The reaction was promoted the next day with NIS/TfOH (2 equiv./1 equiv. donor) or AgOTf (2 equiv./1 equiv. donor) or $Bi(OTf)_3$ (3 equiv./1 equiv. donor) or $Cu(OTf)_2$ (3 equiv./1 equiv. donor). The reaction mixture was stirred until TLC analysis indicated that the reaction had gone to completion or no further reaction was observed after more than 24 h. The reaction mixture was then diluted with CH_2Cl_2, filtered through Celite, and washed with a saturated solution of $NaHCO_3$ [if AgOTf, $Cu(OTf)_2$, or $Bi(OTf)_3$ was used] or NaS_2O_3 (if NIS/TfOH was used) and brine. The organic phase was filtered and concentrated in vacuo. The residue was purified by size-exclusion column chromatography (Sephadex LH-20; MeOH/CH_2Cl_2, 1:1) to afford **3b**–**d**.

Methyl [Benzoxazol-2-yl-4,7,8,9-tetra-*O*-acetyl-5-(*N*-acetyl)acetamido-3,5-dideoxy-2-thio-α-D-glycero-D-galactonon-2-ulopyranoside]-onate (1b): To a solution of **4b**[15] (1.7227 g, 2.75 mmol) and activated 3 Å molecular sieves (2.75 g) in anhydrous CH_2Cl_2 (27.5 mL) was added iodine monochloride (1 M in CH_2Cl_2, 3.0 mL, 3.03 mmol) at 0 °C. The reaction mixture was stirred at 0 °C for 3 h. Upon completion, the reaction mixture was filtered over Celite, washed with sodium thiosulfate and then brine, concentrated, and dried in vacuo to afford the chlorinated product. This product was immediately dissolved in anhydrous acetone (13.8 mL) and KSBox[19] (0.572 g, 3.03 mmol) was added followed by 18-crown-6-ether (0.073 g, 0.275 mmol). The reaction mixture was then stirred at room temperature under an argon atmosphere for 16 h. Upon completion, the reaction mixture was evaporated under reduced pressure to remove acetone, dissolved in CH_2Cl_2, washed with 1% NaOH (1×) and brine (3×), evaporated under reduced pressure, and concentrated in vacuo. The residue was purified by column chromatography (5% acetone/toluene) to afford **1b** as a white foam (1.31 g, 72%). R_f = 0.51 (acetone/toluene, 1:4). $[\alpha]_D^{26}$ = 7.73 (c = 1, $CHCl_3$). Data for **1b**α: ^{1}H NMR ($CDCl_3$): δ = 1.96, 1.97, 2.01, 2.05 (4 s, 12 H, OCOCH_3), 2.30, 2.37 (2 s, 6 H, COCH_3), 2.28–2.35 (m, $J_{3ax,3eq}$ = 12.9 Hz, $J_{3ax,4}$ = 10.7 Hz, 1 H, 3-H_{ax}), 3.12 (dd, $J_{3ax,3eq}$ = 12.9 Hz, $J_{3eq,4}$ = 5.1 Hz, 1 H, 3-H_{eq}), 3.81 (s, 3 H, OCH_3), 4.15 (dd, $J_{9b,8}$ = 7.2 Hz, $J_{9b,9a}$ = 12.6 Hz, 1 H, 9b-H), 4.14–4.24 (m, $J_{5,4}$ = 10.6 Hz, $J_{5,6}$ = 10.1 Hz, 1 H, 5-H), 4.33 (dd, $J_{9a,8}$ = 2.8 Hz, 1 H, 9a-H), 5.03 (dd, $J_{6,7}$ = 1.7 Hz, 1 H, 6-H), 5.10 (dd, $J_{7,8}$ = 7.0 Hz, 1 H, 7-H), 5.20–5.26 (m, 1 H, 8-H), 5.50–5.61 (ddd, $J_{3ax,4}$ = 10.7 Hz, 1 H, 4-H), 7.60–7.75 (m, 4 H, aromatic) ppm. ^{13}C NMR ($CDCl_3$): δ = 20.7, 20.9, 25.9, 27.9, 29.7, 39.3, 53.7, 56.8, 61.4, 66.9, 67.2, 69.8, 72.8, 76.6, 77.0, 77.4, 86.6, 110.9, 120.1, 124.7, 126.0, 141.6, 152.5, 256.9, 167.5, 169.5, 169.8, 170.1, 170.5 ppm. HR MS (FAB): calcd. for $C_{29}H_{35}N_2O_{14}S$ $[M + H]^+$ 667.1809; found 667.1803.

Methyl [Benzoxazol-2-yl-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-5-trifluoroacetamido-α-D-glycero-D-galactonon-2-ulopyranoside]-onate (1c): To a solution of **4c**[16] (777 mg, 1.19 mmol) and activated 3 Å molecular sieves (1.19 g) in anhydrous CH_2Cl_2 (11.9 mL) was added iodine monochloride (1 M in CH_2Cl_2, 1.3 mL, 1.31 mmol) at 0 °C. The reaction mixture was then stirred at 0 °C for 3 h. Upon completion, the reaction mixture was washed with sodium thiosulfate and then brine, concentrated, and dried in vacuo to afford the chlorinated product. This product was immediately dissolved in anhydrous CH_2Cl_2 (5.95 mL) and 2-mercaptobenzoxazole (HSBox, 2.69 mg, 1.78 mmol) was added followed by the addition of DIPEA (294 μL, 1.78 mmol) dropwise. The reaction mixture was stirred at room temperature under an argon atmosphere for 16 h. Upon completion, the reaction mixture was evaporated under reduced pressure and concentrated in vacuo. The residue was purified by column chromatography (5% ethyl acetate/toluene) to afford **1c** as a

white foam (528 mg, 65%). R_f = 0.58 (ethyl acetate/toluene, 2:3). $[\alpha]_D^{26}$ = 16.1 (c = 0.5, $CHCl_3$). Data for **1c**α: ^{1}H NMR ($CDCl_3$): δ = 1.94, 1.95, 2.03, 2.05 (4 s, 12 H, OCOCH_3), 2.43 (dd, $J_{3ax,3eq}$ = 12.9 Hz, $J_{3ax,4}$ = 11.8 Hz, 1 H, 3-H_{ax}), 2.98 (dd, $J_{3eq,4}$ = 4.8 Hz, 1 H, 3-H_{eq}), 3.80 (s, 3 H, OCH_3), 3.97 (dd, $J_{5,NH}$ = 10.2 Hz, $J_{5,6}$ = 10.7 Hz, 1 H, 5-H), 4.16 (dd, $J_{9b,9a}$ = 12.6 Hz, 1 H, 9b-H), 4.33 (dd, $J_{9a,8}$ = 2.2 Hz, 1 H, 9a-H), 4.41 (dd, $J_{6,7}$ = 1.8 Hz, 1 H, 6-H), 5.08 (ddd, $J_{4,5}$ = 10.4 Hz, 1 H, 4-H), 5.21–5.27 (m, 2 H, 7-H, 8-H), 6.89 (d, 1 H, NH), 7.33–7.76 (m, 4 H, aromatic) ppm. ^{13}C NMR ($CDCl_3$): δ = 6.3, 20.2, 20.5, 20.6, 20.8, 36.0, 49.8, 53.7, 61.6, 67.2, 68.3, 69.9, 74.4, 76.5, 77.0, 77.4, 86.2, 110.9, 120.1, 124.7, 126.0, 141.5, 167.6, 169.8, 170.2, 170.5, 170.8 ppm. HRMS (FAB): calcd. for $C_{27}H_{30}F_3N_2O_{13}S$ $[M + H]^+$ 679.14207; found 679.14203.

Methyl [Benzoxazol-2-yl-7,8,9-tri-*O*-acetyl-5-*N*,4-*O*-carbonyl-3,5-dideoxy-2-thio-α-D-glycero-D-galactonon-2-ulopyranoside]onate (1d): To a solution of **4d**[17] (446 mg, 0.85 mmol) and activated 3 Å molecular sieves (0.85 g) in anhydrous CH_2Cl_2 (8.5 mL) was added iodine monochloride (1 M in CH_2Cl_2, 0.93 mL, 0.93 mmol) at 0 °C. The reaction mixture was stirred at 0 °C for 3 h. Upon completion, the reaction mixture was washed with sodium thiosulfate and then brine, concentrated, and dried in vacuo to afford the chlorinated product. This product was immediately dissolved in anhydrous CH_2Cl_2 (4.25 mL). HSBox (192 mg, 1.27 mmol) was added followed by the addition of DIPEA (210 μL, 1.27 mmol) dropwise. The reaction mixture was stirred at room temperature under an argon atmosphere for 16 h. Upon completion, the reaction mixture was evaporated under reduced pressure and concentrated in vacuo. The residue was purified by column chromatography (2% acetone/dichloromethane) to afford **1d** as a white foam (527 mg, 62%). R_f = 0.61 (acetone/toluene, 2:3). $[\alpha]_D^{26}$ = –22.1 (c = 1.1, $CHCl_3$). Data for **1d**α: ^{1}H NMR ($CDCl_3$): δ = 1.92, 2.01, 2.09 (3 s, 9 H, OCOCH_3), 2.70 (t, $J_{3ax,3eq}$ = 12.4 Hz, 1 H, 3-H_{ax}), 3.09 (t, $J_{5,6}$ = 10.0 Hz, $J_{5,NH}$ = 1.6 Hz, 1 H, 5-H), 3.17 (dd, $J_{3eq,4}$ = 3.8 Hz, 1 H, 3-H_{eq}), 3.79 (s, 3 H, OCH_3), 4.01–4.11 (ddd, $J_{3ax,4}$ = 1.9 Hz, $J_{4,5}$ = 10.8 Hz, 1 H, 4-H), 4.24 (dd, $J_{9b,8}$ = 3.4 Hz, $J_{9b,9a}$ = 12.8 Hz, 1 H, 9b-H), 4.30 (dd, $J_{9a,8}$ = 2.2 Hz, 1 H, 9a-H), 4.37 (dd, $J_{6,7}$ = 1.8 Hz, 1 H, 6-H), 5.04 (dd, $J_{7,8}$ = 9.2 Hz, 1 H, 7-H), 5.30–5.34 (m, 1 H, 8-H), 5.35 (d, 1 H, H-NH), 7.33–7.75 (m, 4 H, aromatic) ppm. ^{13}C NMR ($CDCl_3$): δ = 21.1, 21.3, 21.5, 38.5, 54.5, 58.1, 61.9, 68.5, 69.5, 77.2, 77.7, 78.1, 87.5, 111.6, 120.7, 125.5, 126.5, 142.2, 153.0, 159.4, 168.5, 170.0, 171.1, 172.1 ppm. HRMS (FAB): calcd. for $C_{24}H_{27}N_2O_{12}S$ $[M + H]^+$ 567.12847; found 567.12842.

Supporting Information (see footnote on the first page of this article): Selected NMR spectra and full characterization of new compounds.

Acknowledgments

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