Synthesis of Tetrazolyl Derivatives of 3-Deoxy-D-*glycero*-D-*galacto*-2-nonulosonic Acid (KDN) as Useful Glycosyl Donors, and Their Application for *O*- and *C*-Glycosylations[1)]

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The reaction of methyl 4,5,7,8,9-penta-*O*-acetyl-3-deoxy-D-*glycero*-D-*galacto*-2-nonulopyranosonate (3) with *S*,*S*′-bis(1-phenyl-1*H*-tetrazol-5-yl) dithiocarbonate (4) gave methyl (1-phenyl-1*H*-tetrazol-5-yl 4,5,7,8,9-tetra-*O*-acetyl-3-deoxy-2-thio-D-*glycero*-*β*-D-*galacto*-2-nonulopyranosid)onate (5) and methyl (1-phenyl-5-thioxo-1*H*,4*H*-tetrazol-4-yl 4,5,7,8,9-penta-*O*-acetyl-2,3-dideoxy-D-*glycero*-α- and -*β*-D-*galacto*-2-nonulopyranosid)onate (6, 7). The structures were elucidated by means of ultraviolet (UV), circular dichroism (CD), and ^{13}C-nuclear magnetic resonance (^{13}C-NMR) spectral examination, and X-ray crystal analysis. These *S*- and *N*-glycosides were applied to *O*-glycosylation with suitable promoters, and when palladium (II) was used as a promoter, glycosylation of 5 with 2-propanol gave the corresponding glycosides in good yield. Moreover, the *S*-glycoside was applied to *C*-glycosylations.

Keywords KDN; glycosyl donor; *S*-glycoside; *O*-glycosylation; *C*-glycosylation; X-ray analysis

In our glycosylation studies[2-5)] with 3-deoxy-D-*glycero*-D-*galacto*-nonulosonic acid (**1**, KDN), using the 2-halogenous derivatives as glycosyl donors, the major problem was the low yield owing to side reactions and the instability of the glycosyl donor. Recently, many preparations of *S*-glycosides as glycosyl donors for *O*-glycosylation have been reported. We have developed the useful coupling reagent, *S*,*S*′-bis(1-phenyl-1*H*-tetrazol-5-yl) dithiocarbonate (**4**), for introduction of the 1-phenyl-1*H*-tetrazol-5-thio group.[6,7)] This compound (**4**) formed *S*-glycosyl derivatives with D-glucose and *N*-acetylneuraminic acid by reacting at the anomeric hydroxyl group,[8,9)] and characteristic *O*-glycosylation using these *S*-tetrazolyl derivatives as useful and stable glycosyl donors was achieved by various activating methods.[8-10)] Moreover, C–C coupling reactions of the *S*-tetrazolyl derivatives with *O*-silylated ketones, Grignard reagents, and carbanions were achieved.[11,12)]

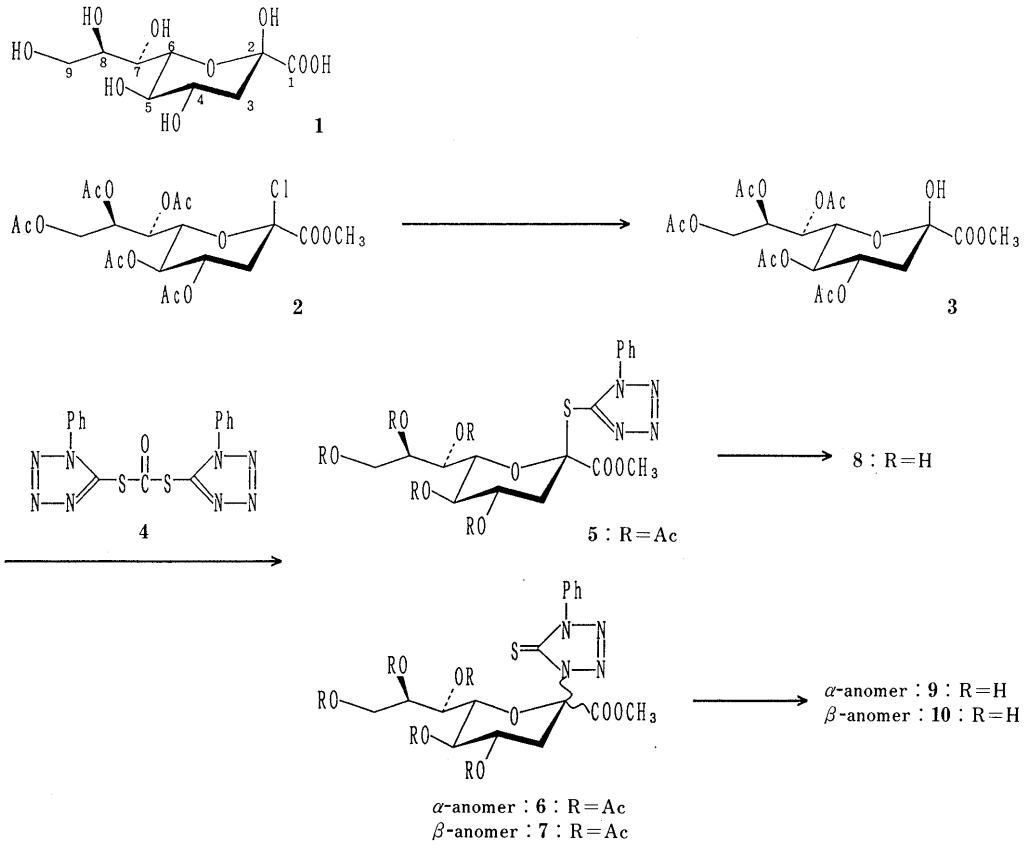

Chart 1. Synthesis of Tetrazolyl Derivatives of KDN

We thought that the versatile reagent **4** could be employed to improve the performance of **1** as a glycosyl donor. In this paper, we with to report the synthesis of three types of tetrazolyl derivatives of **1** using **4**, and the application of these tetrazolyl derivatives for *O*- and *C*-glycosylations using various activating methods.

Synthesis of Tetrazolyl Derivatives of 1 The starting material, methyl 4,5,7,8,9-penta-*O*-acetyl-3-deoxy-D-*glycero*-D-*galacto*-2-nonulopyranosonate (**3**),[13] was prepared from methyl 4,5,7,8,9-penta-*O*-acetyl-2-chloro-2,3-dideoxy-D-*glycero*-β-D-*galacto*-2-nonulopyranosonate (**2**). Treatment of **3** with **4** in acetonitrile in the presence of 4-dimethylaminopyridine afforded methyl (1-phenyl-1*H*-tetrazol-5-yl 4,5,7,8,9-tetra-*O*-acetyl-3-deoxy-2-thio-D-*glycero*-β-D-*galacto*-2-nonulopyranosid)onate (**5**) and methyl (1-phenyl-5-thioxo-1*H*,4*H*-tetrazol-4-yl 4,5,7,8,9-penta-*O*-acetyl-2,3-dideoxy-D-*glycero*-α- and -β-D-*galacto*-2-nonulopyranosid)-onates (**6**, **7**) in yields of 62%, 4% and 7%, respectively.

In the previous study of *N*-acetylneuraminic acid,[9] a similar reaction of methyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-D-*glycero*-β-D-*galacto*-nonulopyranosonate with **4** gave the α- and β-anomers of the *S*-tetrazol-5-yl derivative and the tetrazol-5-yl thionate derivative. The present result is different, although the reason is not clear.

Structural Elucidation of 5, 6 and 7 Mass spectra (MS), elementary analyses, and the ^{1}H-NMR spectra (Table I) of **5**, **6** and **7** show that they have the same elemental components and the same structure of the KDN moiety. Ultraviolet (UV) spectra (Fig. 1) of these compounds suggested that **5** is the *S*-tetrazol-5-yl derivative, and **6** and **7** are 5-thioxotetrazol-4-yl derivatives of **1**. The compounds were deacetylated with potassium carbonate in methanol to give **8**, **9** and **10**, respectively, in almost quantitative yields. The structure of crystalline 8 was elucidated by X-ray diffraction analysis.[14] Figure 2 shows the crystal structure of **8**, and the positional parameters and B_{eq} are listed in Table II. Figure 3 shows the CD spectra of **8**, **9** and **10** in methanol. The previous study of the CD spectrum of **1** indicated that the peak around 220—230 nm is due to the n–π* Cotton effect of

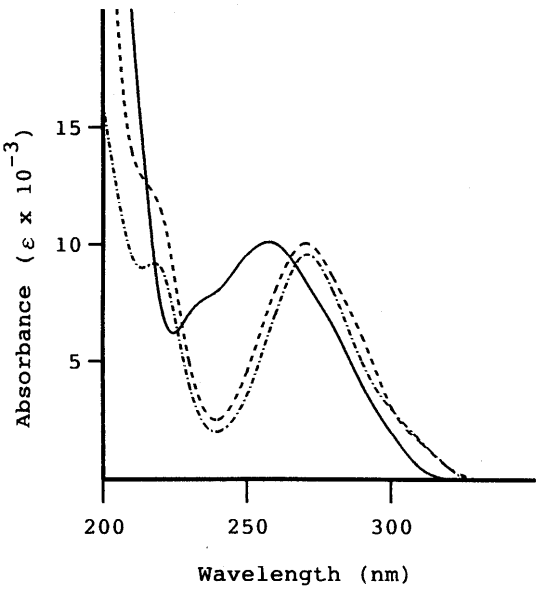

Fig. 1. UV Absorption Spectra of **5**, **6**, and **7**
——, **5**; – – –, **6**; – · –, **7**.

TABLE I. Proton Chemical Shifts and Spin-Coupling Data at 300 MHz

Compound	Solvent[a]	Chemical shift (ppm)									
		3_{ax}	3_{eq}	4	5	6	7	8	9	9′	$COOCH_3$
5	A	2.59	2.97	4.88	4.74	4.16	5.19	4.87	3.95	4.06	3.81
6	A	3.20	2.91	5.16	5.01	5.24	5.44	5.22	4.11	4.39	3.83
7	A	2.39	3.58	5.61	5.12	3.96	5.38	5.22	4.22	4.62	3.85
8	B	2.03	2.51	4.01	3.54	4.26	3.83	3.68	3.61	3.80	3.36
9	C	2.85	—	—	3.64	4.69	3.88	—	—	—	3.83
10	C	2.07	3.10	4.31	3.72	3.45	—	3.84	3.62	3.79	3.82
11	A	1.90	2.66	4.88	4.85	4.12	5.34	5.40	4.15	4.28	3.80
12	A	1.77	2.58	5.30	4.86	4.18	5.40	5.28	4.16	4.80	3.78
14	A	1.80	2.59	5.02	4.78	4.26	5.33	5.26	4.08	4.29	3.77
15	A	1.91	2.73	5.12	4.75	4.16	5.26	5.10	3.96	4.19	3.75

a) A, $CDCl_3$; B, D_2O; C, CD_3OD.

Compound	Coupling constant (Hz)									
	$J_{3a,3e}$	$J_{3a,4}$	$J_{3e,4}$	$J_{4,5}$	$J_{5,6}$	$J_{6,7}$	$J_{7,8}$	$J_{8,9}$	$J_{8,9'}$	$J_{9,9'}$
5	13.1	11.6	4.9	9.7	10.3	1.8	9.0	4.8	2.4	12.6
6	13.3	12.0	4.7	9.4	10.6	2.0	8.5	4.9	2.4	12.4
7	14.0	11.2	5.5	9.6	10.4	2.1	4.8	6.4	2.2	12.5
8	14.2	11.8	4.9	9.3	9.7	0.5	8.0	6.2	2.0	11.3
9	13.0	11.0	—	10.0	10.0	1.5	8.2	—	—	—
10	14.1	10.9	5.4	9.0	10.1	1.1	—	5.0	2.5	11.3
11	13.0	11.9	4.7	9.5	9.9	2.0	9.1	4.5	2.5	12.5
12	12.9	11.6	5.1	9.6	10.0	2.1	4.1	7.4	2.1	12.3
14	13.2	11.0	5.0	9.4	10.6	2.0	8.6	5.0	2.4	12.5
15	13.0	11.8	5.0	9.6	10.0	2.0	8.5	4.7	2.2	12.3

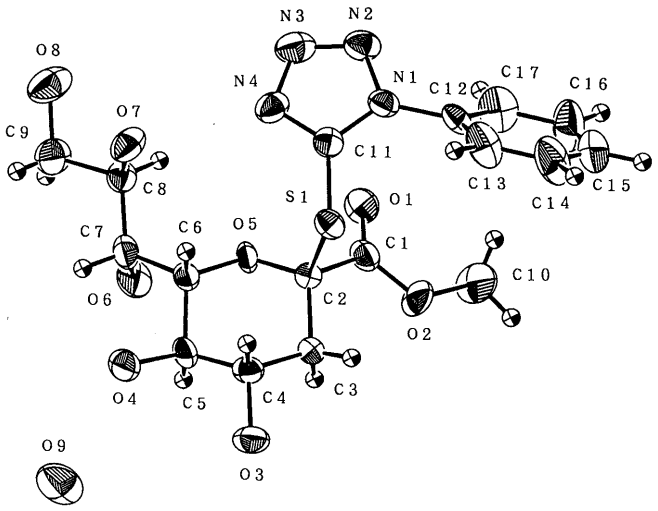

Fig. 2. Crystal Structure of **8**

TABLE II. Positional Parameters and B_{eq} for **8**

Atom	x	y	z	B_{eq}
S(1)	0.2312 (2)	0.0159	0.1314 (2)	2.80 (8)
O(1)	0.2093 (8)	−0.3262 (8)	0.0930 (5)	3.7 (3)
O(2)	0.4437 (7)	−0.251 (1)	0.0757 (5)	4.8 (3)
O(3)	0.6449 (6)	0.0373 (8)	0.3791 (5)	3.6 (3)
O(4)	0.3995 (7)	0.013 (1)	0.5003 (4)	4.4 (3)
O(5)	0.2470 (6)	−0.1912 (7)	0.2742 (4)	2.5 (2)
O(6)	0.2180 (8)	−0.3287 (9)	0.4469 (5)	4.2 (3)
O(7)	−0.0725 (7)	−0.0747 (8)	0.3537 (5)	3.9 (3)
O(8)	−0.2548 (8)	−0.268 (1)	0.4282 (7)	5.4 (4)
O(9)	0.615 (1)	0.008 (1)	0.6669 (6)	6.8 (4)
N(1)	0.0030 (9)	−0.093 (1)	−0.0160 (5)	2.9 (3)
N(2)	−0.137 (1)	−0.143 (1)	−0.0235 (7)	3.7 (4)
N(3)	−0.175 (1)	−0.133 (1)	0.0670 (7)	4.2 (4)
N(4)	−0.0598 (9)	−0.077 (1)	0.1355 (6)	3.6 (4)
C(1)	0.318 (1)	−0.252 (1)	0.1181 (7)	3.2 (4)
C(2)	0.3265 (9)	−0.140 (1)	0.2019 (6)	2.4 (3)
C(3)	0.489 (1)	−0.094 (1)	0.2448 (6)	2.8 (4)
C(4)	0.490 (1)	−0.003 (1)	0.3381 (7)	2.9 (4)
C(5)	0.411 (1)	−0.076 (1)	0.4148 (6)	3.0 (4)
C(6)	0.249 (1)	−0.109 (1)	0.3647 (6)	2.6 (3)
C(7)	0.157 (1)	−0.190 (1)	0.4337 (6)	3.2 (4)
C(8)	−0.009 (1)	−0.206 (1)	0.3900 (7)	3.0 (4)
C(9)	−0.097 (1)	−0.256 (1)	0.4711 (8)	4.4 (5)
C(10)	0.448 (1)	−0.347 (2)	−0.009 (1)	7.8 (8)
C(11)	0.053 (1)	−0.053 (1)	0.0822 (7)	2.8 (4)
C(12)	0.084 (1)	−0.094 (1)	−0.1036 (6)	3.0 (4)
C(13)	0.159 (1)	0.023 (1)	−0.1288 (8)	4.8 (5)
C(14)	0.237 (2)	0.019 (2)	−0.2100 (8)	6.0 (6)
C(15)	0.242 (2)	−0.097 (2)	−0.2654 (9)	6.5 (8)
C(16)	0.169 (2)	−0.215 (2)	−0.243 (1)	6.2 (7)
C(17)	0.089 (1)	−0.211 (1)	−0.160 (1)	4.8 (5)

$B_{eq} = (4/3)\,\Sigma_i \Sigma_j \beta_{ij} a_i \cdot a_j$.

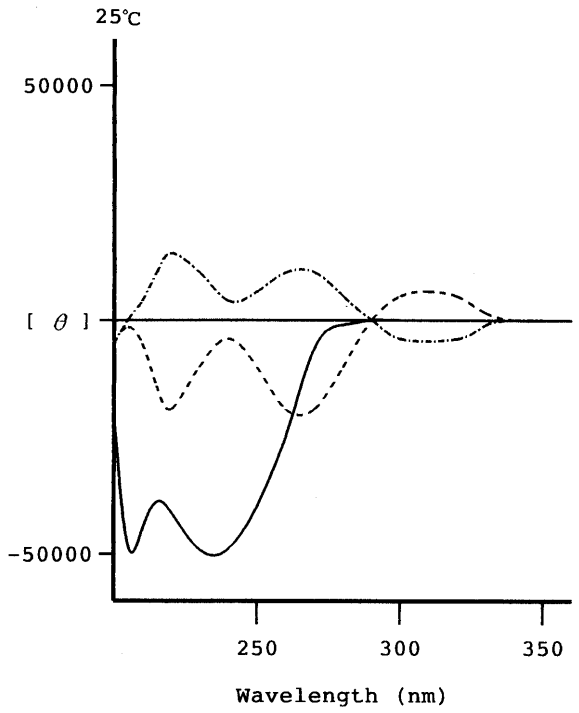

Fig. 3. CD Curves of **8**, **9**, and **10**
——, **8**; – – –, **9**; ·–·–·, **10**.

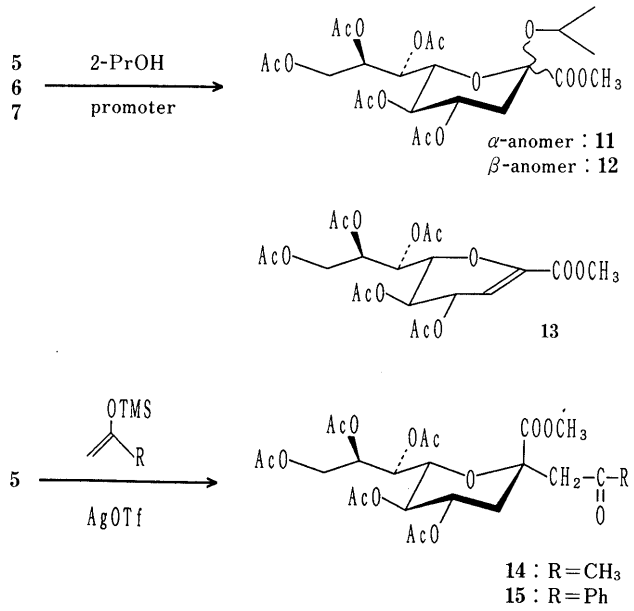

Chart 2. *O*- and *C*-Glycosylation of **5**, **6**, and **7**

the carboxyl group and the negative Cotton effect was assigned to the α-anomer and the positive one to the β-anomer.[2,3,13] In Fig. 3, characteristic peaks were observed at 220 nm in the spectra of **9** and **10**. In the case of the nucleoside derivatives of **1**,[4] the configurations of the anomeric position could not be elucidated from the CD spectrum, but were deduced from the coupling pattern of C-1 in gated proton-decoupled and selective proton-decoupled ^{13}C-NMR analyses. Therefore, ^{13}C-NMR analysis was applied to elucidate the anomeric configurations of **9** and **10**, and $J_{C1,3ax}$ values of 3 Hz (**9**) and 0 Hz (**10**) were observed. We concluded that the anomeric configuration of **9** is α and that of **10** is β.

***O*-Glycosylation of 5, 6 and 7 with 2-Propanol** The reaction of **5**, **6** and **7** with 2-propanol in dichloromethane under various conditions, as shown in Table III, gave methyl (isopropyl 4,5,7,8,9-penta-*O*-acetyl-3-deoxy-D-*glycero*-α- and -β-D-*galacto*-2-nonulopyranosid)onate (**11**, **12**) and methyl 4,5,7,8,9-penta-*O*-acetyl-2,6-anhydro-2,3-dideoxy-D-*glycero*-D-*galacto*-non-2-enonate (**13**). When silver triflate (AgOTf) was used as a promoter (run 1—3), the reaction of **5** gave **11** and **12** in 39% yield, but that of

TABLE III. Reaction Conditions and Yields of *O*-Glycosylation

Run	Donor	2-PrOH	Promoter (1.2 eq)	Time (h)	Temp	Yield (%)		
						11	**12**	**13**
1	**5**	1.2 eq	AgOTf	72	r.t.	22	17	18
2	**6**	10	AgOTf	72	r.t.		No reaction	
3	**7**	10	AgOTf	72	r.t.		No reaction	
4	**5**	1.2	$PdCl_2(CH_3CN)_2$/2AgOTf	1	4 °C	59	38	0
5	**6**	1.2	$PdCl_2(CH_3CN)_2$/2AgOTf	3	r.t.	31	30	9
6	**7**	1.2	$PdCl_2(CH_3CN)_2$/2AgOTf	3	r.t.	34	25	11
7	**2**	5	AgOTf	3	r.t.	26	28	14

6 or **7** gave no product. On the other hand, when a novel promoter system, $PdCl_2(CH_3CN)_2$/2AgOTf,[10,15] was used (runs 4—6), the reaction of **5** gave **11** and **12** in almost quantitative yield, but **6** or **7** gave a mixture of both **11** and **12** in about 60% yield. These results suggested that the palladium promoter system activated the anomeric position by the mechanism called "remote activation".[15,16] The reaction of the 2-chloro derivative (**2**) with 2-propanol gave **11** and **12** in 54% yield (run 7).

The configurations at the anomeric position of **11** and **12** were elucidated by applying the empirical rule[2-5] that the 3-H_{eq} signal of the α-anomer in the ^{1}H-NMR spectrum is usually observed at lower field than that of the β-anomer (Table I).

***C*-Glycosylation of 5** The reaction of **5** with 2-trimethylsilyloxypropene gave methyl [4,5,7,8,9-penta-*O*-acetyl-2-*C*-(2-oxopropyl)-2,3-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranos]onate (**14**) and **13**, in yield of 19% and 62%, respectively. The reaction of **5** with 1-phenyl-1-(trimethylsilyloxy)ethylene gave methyl [4,5,7,8,9-penta-*O*-acetyl-2-*C*-(2-oxo-2-phenylethyl)-2,3-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranos)onate (**15**) and **13**, in yields of 23% and 56%, respectively. The configurations at the anomeric position of **14** and **15** were elucidated by applying the empirical rule[5] that the coupling constant of H-7 and H-8 in the ^{1}H-NMR spectrum of the α-anomer is larger than that of the β-anomer (α: 6—9 Hz, β: 3—5 Hz).

Conclusion

The reaction of **3** with the useful coupling reagent **4** gave the desired derivative (**5**) and the thioxotetrazol-4-yl derivatives (**6**, **7**). The structures were elucidated by means of UV, CD, ^{13}C-NMR spectra, and X-ray crystal analysis. The usefulness of these tetrazolyl derivatives was demonstrated for *O*- and *C*-glycosylations under various conditions. In particular, the reaction promoted with $PdCl_2(CH_3CN)_2$/2AgOTf gave the *O*-glycosides in satisfactory yield. The *C*-glycosylations of **5** with trimethylsilyloxy derivatives gave the corresponding α-anomers. These results suggested that other applications of the tetrazolyl derivatives for syntheses of *O*-, *C*-, or *N*-glycosides should be possible. This approach deserves further study.

Experimental

Melting points were measured with a Yamato melting point apparatus and are uncorrected. Optical rotations were measured with a Jasco DIP-4 polarimeter. Thin layer chromatography (TLC) was performed on Silica gel (Merck) plates, and spots were detected by spraying with 5% sulfuric acid solution. Fast atom bombardment mass spectra (FAB-MS), infrared (IR), and UV spectra were measured with JEOL JMS-DX300, JASCO FT/IR-7300, and Hitachi 340 instruments, respectively. CD spectra were measured in a 0.1 cm cell with a JASCO J-720 spectropolarimeter. The ^{1}H-NMR spectra were measured with Varian VXR-300 spectrometer. Tetramethylsilane (TMS) in $CDCl_3$ or sodium 3-(trimethylsilyl)-1-propanesulfonate (DDS) in D_2O was used as an internal reference. Column chromatography was conducted on Silica gel 60 (70—230 mesh).

Methyl 4,5,7,8,9-Penta-*O*-acetyl-3-deoxy-D-*glycero*-D-*galacto*-2-nonulopyranosonate (3) A solution of **2** (5.0 g, 9.79 mmol) in CH_3CN (50 ml) and H_2O (50 ml) was stirred for 3 h at room temperature. The solution was neutralized with $NaHCO_3$ solution and the mixture was evaporated to dryness. The residue was purified on a column of silica gel with ether–hexane (2:1) to give **3** (4.63 g, 96%) as colorless prisms, which gave physicochemical data in accordance with published values.[12]

Reaction of 3 with *S,S'*-Bis(1-phenyl-1*H*-tetrazol-5-yl) Dithiocarbonate (4) A solution of 4-dimethylaminopyridine (682 mg, 5.58 mmol) in CH_3CN (7 ml) was added to **3** (2.5 g, 5.08 mmol) and **4** (2.13 g, 5.58 mmol) in CH_3CN (50 ml) under stirring at room temperature, and the mixture was stirred for 18 h. The solution was evaporated, and the residue was dissolved in ethyl acetate. The organic layer was washed with aqueous $NaHCO_3$ and brine, dried and evaporated. The residue was chromatographed on silica gel with ether–hexane (1:1) to yield methyl (1-phenyl-1*H*-tetrazol-5-yl 4,5,7,8,9-penta-*O*-acetyl-3-deoxy-2-thio-D-*glycero*-β-D-*galacto*-2-nonulopyranosid)onate (**5**) (2.05 g, 62%) and methyl (1-phenyl-5-thioxo-1*H*,4*H*-tetrazol-4-yl 4,5,7,8,9-penta-*O*-acetyl-2,3-dideoxy-D-*glycero*-α- and -β-D-*galacto*-2-nonulopyranosid)onate (**6**) (133 mg, 4%), (**7**) (232 mg, 7%), each as an amorphous powder.

5: $[\alpha]_D^{26}$ +28.4° (c=0.25, $CHCl_3$). FAB-MS m/z: 653 (M^++1). *Anal.* Calcd for $C_{27}H_{32}N_4O_{13}S$: C, 49.69; H, 4.94; N, 8.58. Found: C, 49.69; H, 4.92; N, 8.32. IR ν_{max}^{KBr} cm^{-1}: 1752, 1372, 1236, 1056.

6: $[\alpha]_D^{26}$ −45.5° (c=0.22, $CHCl_3$). FAB-MS m/z: 653 (M^++1). *Anal.* Calcd for $C_{27}H_{32}N_4O_{13}S$: C, 49.69; H, 4.94; N, 8.58. Found: C, 49.58; H, 4.89; N, 8.61. IR ν_{max}^{KBr} cm^{-1}: 1751, 1372, 1236, 1055.

7: $[\alpha]_D^{26}$ +63.3° (c=0.24, $CHCl_3$). FAB-MS m/z: 653 (M^++1). *Anal.* Calcd for $C_{27}H_{32}N_4O_{13}S$: C, 49.69; H, 4.94; N, 8.58. Found: C, 49.78; H, 4.83; N, 8.52. IR ν_{max}^{KBr} cm^{-1}: 1754, 1372, 1235, 1055.

Methyl (1-Phenyl-1*H*-tetrazol-5-yl 3-Deoxy-2-thio-D-*glycero*-β-D-*galacto*-2-nonulopyranosid)onate (8) Anhydrous potassium carbonate (106 mg, 0.77 mmol) was added to a solution of **5** (1.00 g, 1.53 mmol) in MeOH (100 ml) at room temperature. The mixture was stirred for 1 h at room temperature, neutralized with acetic acid (150 mg) and evaporated to dryness. The residual syrup was purified on a column of silica gel with $CHCl_3$–MeOH (10:1) to give **8** in quantitative yield. mp 148—150 °C. $[\alpha]_D^{26}$ −338.2° (c=0.22, MeOH). FAB-MS m/z: 443 (M^++1). *Anal.* Calcd for $C_{17}H_{22}N_4O_8S$: C, 46.15; H, 5.01; N, 12.66. Found: C, 46.04; H, 5.08; N, 12.58. IR ν_{max}^{KBr} cm^{-1}: 3379, 2935, 1750, 1399, 1077.

Methyl (1-Phenyl-5-thioxo-1*H*,4*H*-tetrazol-4-yl 2,3-Dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranosid)onate (9) Anhydrous potassium carbonate (11 mg, 0.08 mmol) was added to a solution of **6** (100 mg, 0.15 mmol) in MeOH (10 ml) at room temperature. The reaction mixture was processed as described for **8** to give **9** in quantitative yield. $[\alpha]_D^{26}$ −115.3° (c=0.21, MeOH). FAB-MS m/z: 443 (M^++1). *Anal.* Calcd for $C_{17}H_{22}N_4O_8S\cdot H_2O$: C, 44.34; H, 5.25; N, 12.17. Found: C, 44.70; H, 5.14; N, 11.97. IR ν_{max}^{KBr} cm^{-1}: 3386, 2952, 1761, 1348, 1063.

Methyl (1-Phenyl-5-thioxo-1*H*,4*H*-tetrazol-4-yl 2,3-Dideoxy-D-*glycero*-β-D-*galacto*-2-nonulopyranosid)onate (10) Anhydrous potassium carbonate (11 mg, 0.08 mmol) was added to a solution of **7** (100 mg, 0.15 mmol) in MeOH (10 ml) at room temperature. The reaction mixture was processed as described for **8** to give **10** in quantitative yield. $[\alpha]_D^{26}$ +22.2° (c=0.33, MeOH). FAB-MS m/z: 443 (M^++1). *Anal.* Calcd for $C_{17}H_{22}N_4O_8S$: C, 46.15; H, 5.01; N, 12.66. Found: C, 46.33; H, 5.11; N,

12.79. IR ν_{max}^{KBr} cm^{-1}: 3396, 2952, 1752, 1354, 1064.

***O*-Glycosylation of 5,6, and 7 with 2-Propanol** a) Silver triflate (95 mg, 0.37 mmol) was added to a mixture of **5** (200 mg, 0.31 mmol), 2-propanol (22 mg, 0.37 mmol), and molecular sieves 4A (1.00 g) in dry dichloromethane (40 ml) at 4 °C. The mixture was stirred for 72 h at room temperature, and neutralized with triethylamine. Insoluble materials were removed by filtration, the filtrate was evaporated, and the residue was purified on a column of silica gel with ether–hexane (1 : 1) to give methyl (isopropyl 4,5,7,8,9-penta-*O*-acetyl-3-deoxy-D-*glycero*-α- and -β-D-*galacto*-2-nonulopyranosid)onate (**11**) (36 mg, 22%), (**12**) (28 mg, 17%), and methyl 4,5,7,8,9-penta-*O*-acetyl-2,6-anhydro-2,3-dideoxy-D-*glycero*-D-*galacto*-non-2-enonate (**13**) (91 mg, 62%).

b) Silver triflate (307 mg, 1.20 mmol) was added to a mixture of bis-(acetonitrile)palladium (II) chloride (156 mg, 0.60 mmol) and molecular sieves 4A (3.0 g) in dry dichloromethane (120 ml) at 4 °C. The mixture was stirred for 10 min at 4 °C, and 2-propanol (36 mg, 0.60 mmol) and **5** (326 mg, 0.50 mmol) were added at 4 °C. The mixture was stirred for 1 h at room temperature, and neutralized with triethylamine. Insoluble materials were removed by filtration, the filtrate was evaporated, and the residue was purified on a column of silica gel with ether–hexane (1 : 1) to give **11** (158 mg, 59%) and **12** (101 mg, 38%).

11: mp 114—116 °C. $[\alpha]_D^{22}$ −21.3° (c=0.57, $CHCl_3$). FAB-MS m/z: 535 (M^++1). *Anal.* Calcd for $C_{23}H_{34}O_{14}$: C, 51.68; H, 6.41. Found: C, 51.88; H, 6.23. IR ν_{max}^{KBr} cm^{-1}: 1748, 1376, 1230, 1055.

12: $[\alpha]_D^{22}$ −8.2° (c=0.69, $CHCl_3$). FAB-MS m/z: 535 (M^++1). *Anal.* Calcd for $C_{23}H_{34}O_{14}$: C, 51.68; H, 6.41. Found: C, 51.95; H, 6.19. IR ν_{max}^{KBr} cm^{-1}: 1752, 1380, 1230, 1054.

13: $[\alpha]_D^{26}$ −12.2° (c=0.30, $CHCl_3$). FAB-MS m/z: 474 (M^+). *Anal.* Calcd for $C_{20}H_{26}O_{13}$: C, 50.63; H, 5.52. Found: C, 50.90; H, 5.54. IR ν_{max}^{KBr} cm^{-1}: 2975, 1736, 1650. ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 2.03—2.10 (each 3H, s×5, $COCH_3$), 3.80 (3H, s, $COOCH_3$), 4.18 (1H, dd, J=6.4, 12.5 Hz, 9-H), 4.33 (1H, dd, J=3.0, 9.4 Hz, 6-H), 4.56 (1H, dd, J=2.6, 12.5 Hz, 9′-H), 5.21 (1H, dd, J=6.9, 9.4 Hz, 5-H), 5.37 (1H, ddd, J=2.6, 5.8, 6.4 Hz, 8-H), 5.48 (1H, dd, J=3.0, 5.8 Hz, 7-H), 5.56 (1H, dd, J=3.1, 6.9 Hz, 4-H), 5.96 (1H, d, J=3.1 Hz, 3-H).

***C*-Glycosylation of 5 with 2-Trimethylsilyloxypropene** Silver triflate (398 mg, 1.55 mmol) was added to a mixture of **5** (200 mg, 0.31 mmol), 2-trimethylsilyloxypropene (202 mg, 1.55 mmol), and molecular sieves 4A (1.00 g) in dry dichloromethane (40 ml) at 4 °C. The mixture was stirred for 72 h at room temperature, and neutralized with triethylamine. Insoluble materials were removed by filtration, the filtrate was evaporated, and the residue was purified on a column of silica gel with ether–hexane (1 : 1) to give methyl [4,5,7,8,9-penta-*O*-acetyl-2-*C*-(2-oxopropyl)-2,3-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranos]onate (**14**) (31 mg, 19%), and **13** (91 mg, 62%). $[\alpha]_D^{22}$ −21.5° (c=0.40, $CHCl_3$). FAB-MS m/z: 533 (M^++1). *Anal.* Calcd for $C_{23}H_{32}O_{14}$: C, 51.88; H, 6.06. Found: C, 51.72; H, 5.99. IR ν_{max}^{KBr} cm^{-1}: 1768, 1706, 1355, 1234, 1041.

***C*-Glycosylation of 5 with 1-Phenyl-1-(trimethylsilyloxy)ethylene** Silver triflate (362 mg, 1.41 mmol) was added to a mixture of **5** (183 mg, 0.28 mmol), 1-phenyl-1-(trimethylsilyloxy)ethylene (271 mg, 1.41 mmol), and molecular sieves 4A (0.90 g) in dry dichloromethane (40 ml) at 4 °C. The reaction mixture was processed as described for **14** to give methyl [4,5,7,8,9-penta-*O*-acetyl-2-*C*-(2-oxo-2-phenylethyl)-2,3-dideoxy-D-*glycero*-α-D-*galacto*-2-nonulopyranos]onate (**15**) (38 mg, 23%) and **13** (74 mg, 56%). $[\alpha]_D^{22}$ −7.5° (c=0.40, $CHCl_3$). FAB-MS m/z: 595 (M^++1). *Anal.* Calcd for $C_{28}H_{34}O_{14}$: C, 56.56; H, 5.76. Found: C, 56.41; H, 5.88. IR ν_{max}^{KBr} cm^{-1}: 2967, 1753, 1380, 1211, 1041.

X-Ray Diffraction Analysis The cell dimensions and diffraction intensities were measured on a Rigaku four-circle diffractometer (AFC-5R). The collected reflection intensities were corrected for Lorentz and polarization factors, but not for absorption. The structure was solved by direct methods using the program MITHRIL.[17] The positions of all hydrogen atoms were calculated. Atomic scattering factors were taken from the International Tables for X-Ray Crystallography.[18] All calculations were performed using the TEXSAN[19] crystallographic software package of Molecular Structure Corporation.

Crystal Data for **8**: monoclinic space group $P2_1$, a=8.8502(6)Å, b=9.7169(9)Å, c=13.1723(8)Å, β=99.432(6)°, Z=2, D_{calcd}=1.315 g/cm^3, Cu radiation. The final residuals for 279 variables refined against 2061 data with $|F| \geqq 3\sigma(F)$ ($3° < 2\theta < 140°$) were R=7.6% and 10.4%.

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References and Notes

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