Reactivities of 2-*C*- and 3-*C*-Nitro-α- and β-D-*erythro*-Hex-2-enopyranoside Derivatives towards Methanol and AM1 Studies upon Their Stereoselectivities[1)]

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The rates of the reactions of six nitro enosides with methanol-d_4 in dimethyl sulfoxide-d_6 were determined by ^{1}H NMR spectroscopy. Their reactivities and stereoselectivities were discussed including the results of AM1 calculations of model compounds.

Many sugars with a nitro group have been synthesized and their versatilities as synthetic intermediates are widely accepted.[2)] To our best knowledge, however, there is no report upon their quantitative reactivities towards nucleophiles. In this paper we describe the reactions of 2-*C*- and 3-*C*-nitro-α- and β-D-*erythro*-hex-2-enopyranoside derivatives with methanol-d_4 in dimethyl sulfoxide-d_6, which could be monitored by ^{1}H NMR spectroscopy. Molecular orbital calculation is not reported for stereoselectivity in nucleophilic addition reactions to nitro enosides. Semiempirical molecular orbital calculation (AM1 method[3)]) has been applied to this subject and reproduced the almost all stereoselectivities observed herewith by the use of 4,6-*O*-methylene derivatives as model compounds for the 4,6-*O*-benzylidene derivatives.

Results and Discussion

The reactions of nitro enosides, **1**—**4**, **6**, and **7**, with methanol-d_4 in dimethyl sulfoxide-d_6 at 60 °C were monitored by ^{1}H NMR spectroscopy. As shown in Fig. 1, for example, fairly good linear relationship was observed on plotting the logarithms of the ratios of (product+remaining starting material)/remaining starting material against reaction time. The rates thus estimated were shown in Table 1. The structures of the products, **12**, **24**, **26**, and **28**, were determined by comparison of the respective ^{1}H NMR spectra with those of the corresponding nondeuterated authentic specimen. Authentic samples of **13**, **15**, **17**, **19**, and **21** were prepared by treatment of appropriate nitro enosides **1**—**4** with methanol in dimethyl sulfoxide at 60 °C and/or in the presence of sodium methoxide. The following observations were noteworthy. Firstly, the reaction of 2-*C*-nitro-α-D-2-enopyranoside **7** in dimethyl sulfoxide-d_6 afforded almost exclusively the S_N2' product[4)] **26**. Secondly, in the cases of 3-*C*-nitro-α-D-2-enopyranosides **3** and **4**, axial attack occurred exclusively to give **19** and **21**, respectively, in the presence of small amounts of sodium methoxide, whereas equatorial attack predominated over axial attack in methanol–dimethyl sulfoxide, producing **15** and **17**, respectively. In order to clarify the effect of the anomeric methoxyl group, similar reaction of 1,5-anhydro-3-nitro-2-enitol derivative **5** was performed. Instead of the addition reaction, however, double bond migration occurred to give 1-enitol **28** in almost quantitative yield. As reported previously,[5)] triethylamine caused the same double bond migration to give nondeuterio compound

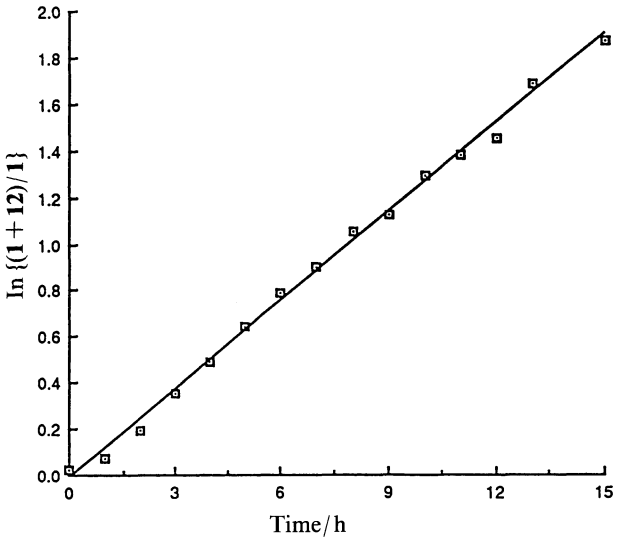
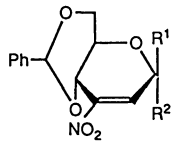


Fig. 1. Plot of ln {(1+12)/1} versus reaction time for determination of rate constant for addition reaction of **1** with methanol-d_6 in DMSO-d_6 at 60 °C.

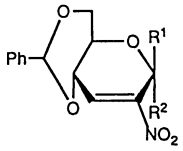
Table 1. Rate Constants for Addition Reactions of 3-Nitro-2-enopyranoside Derivatives with Methanol-d_6[a)]

Compound	Rate constant/s
1	3.3×10^{-5}
2	5.7×10^{-5}
3	3.3×10^{-6}
4	5.0×10^{-6}
6	9.3×10^{-4}
7[b)]	3.0×10^{-4}

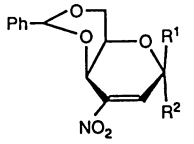
a) The rate constants of nitro alkenes (15 mg) with methanol-d_4 (0.05 ml) in dimethyl sulfoxide-d_6 (0.35 ml) at 60 °C were determined by ^{1}H NMR spectroscopy. b) The rate constant for S_N2' reaction instead of addition reaction.



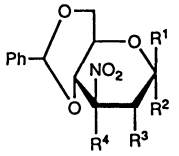
1 R^1 = OMe, R^2 = H
2 R^1 = OPh, R^2 = H
3 R^1 = H, R^2 = OMe
4 R^1 = H, R^2 = OPh
5 R^1 = R^2 = H



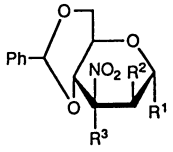
6 R^1 = OMe, R^2 = H
7 R^1 = H, R^2 = OMe
8 R^1 = R^2 = H



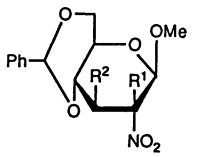
9 R^1 = OMe, R^2 = H
10 R^1 = H, R^2 = OMe



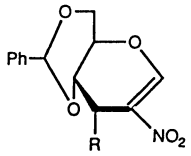
11 R^1 = R^3 = OMe, R^2 = R^4 = H
12 R^1 = OMe, R^2 = H, R^3 = OCD_3, R^4 = D
13 R^1 = OPh, R^2 = R^4 = H, R^3 = OMe
14 R^1 = OPh, R^2 = H, R^3 = OCD_3, R^4 = D
15 R^1 = R^4 = H, R^2 = R^3 = OMe
16 R^1 = H, R^2 = OMe, R^3 = OCD_3, R^4 = D
17 R^1 = R^4 = H, R^2 = OPh, R^3 = OMe
18 R^1 = H, R^2 = OPh, R^3 = OCD_3, R^4 = D



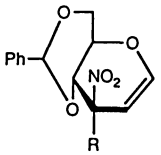
19 R^1 = R^2 = OMe, R^3 = H
20 R^1 = OMe, R^2 = OCD_3, R^3 = D
21 R^1 = OPh, R^2 = OMe, R^3 = H
22 R^1 = OPh, R^2 = OCD_3, R^3 = D



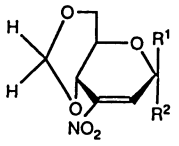
23 R^1 = H, R^2 = OMe
24 R^1 = D, R^2 = OCD_3



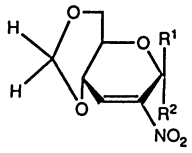
25 R = OMe
26 R = OCD_3



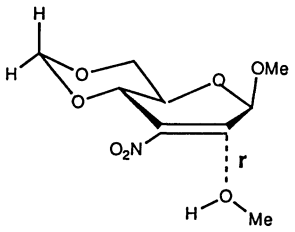
27 R = H
28 R = D



29 R^1 = OMe, R^2 = H
30 R^1 = H, R^2 = OMe



31 R^1 = OMe, R^2 = H
32 R^1 = H, R^2 = OMe



27, which then equilibrated to its 3-epimer, giving a 2.5 : 1 mixture of **27** and its 3-epimer. Unfortunately, similar reaction of 1,5-anhydro-2-nitro-2-enitol derivative **8** afforded a so complicated mixture that a further examination was abandoned. Similar treatment of the *β*-D-*threo* isomer **9** and its *α*-anomer **10** also failed, because degradation occurred gradually during the reaction. Thus the reactivities towards methanol determined herewith were limited to the *erythro* isomers of methyl 2- and 3-nitro enosides (**1**, **3**, **6**, and **7**) and those of phenyl 3-nitro enosides (**2** and **4**). The reactivities decreased according to the sequence of **6**>**7**>**2**>**1**>**4**>**3**, in which the rate of **7** shows exceptionally that of the S_N2' reaction.

Although the chemical shifts of carbons in CMR are affected by many factors,[6] the electron density of the carbon atoms is one of the important factors. Expecting that a carbon atom having lower electron density should appear at lower field and show higher electrophilicity, we next measured ^{13}C-spectra of these methyl glycoside derivatives. This expectation was indeed realized; the alkenic carbon atoms of the *β*-position of

α-nitro-olefin moiety appeared at 136.0, 134.4, 131.9, and 129.7 ppm in chloroform-*d* for **6**, **7**, **1**, and **3**, respectively, and the reactivity decreased according to this order.

The finding that phenyl enosides **2** and **4** were more reactive than the corresponding methyl analogs **1** and **3** should be explained by the higher electron-withdrawing ability of the phenyl group than the methyl group. An electron-withdrawing action of the nitro group and that of the anomeric, acetal carbon atom are cooperative in 2-nitro enosides **6** and **7**, whereas competitive in 3-nitro enosides **1** and **3**. Therefore π-electrons on the C-2–C-3 bond should be readily moved in the 2-nitro enosides compared with the 3-nitro enosides and the former would be more reactive toward nucleophiles than the latter, as observed herewith. The higher reactivities of the β-D-anomers than the corresponding α-D-anomers are likely, because the α-D-anomer should be more stable than the β-D-anomer owing to anomeric effect.[7] Furthermore, if the 2-nitro enosides **6** and **7** take the $^{\circ}H_5$ conformations, destablization due to $A^{(1,2)}$ strain[8] is present in the β-D-anomer **6**, but absent in the α-D-anomer **7**. On the other hand, $A^{(1,2)}$ strain is present in both α- and β-anomers of 3-nitro enosides **1** and **3**. If this is the case, the difference of reactivity between **6** and **7** should be larger than that between **1** and **3**.[9]

In general nucleophilic addition reaction to Michael acceptor generates two chiral centers; one causes by the addition of a nucleophile and the other the subsequent protonation. The stereoselectivity caused by protonation in addition of alkoxide anions to simple α-nitro-olefin was reproduced by molecular orbital calculation by Hori and co-workers.[10] Stereoselectivities observed herewith are arisen by the former process but not the latter process, because the protonation was thermodynamically controlled under our employed conditions. Our argument, therefore, is focussed on the former process. In general nucleophilic addition reactions to a six-membered Michael acceptor give an anionic chair- or boat-form intermediate, depending on the direction of an approaching nucleophile. Axial attack gives the chair intermediate, whereas equatorial attack the boat one owing to stereoelectronic effect[11] (maximum overlap between the molecular orbital of an incoming nucleophile and that of the electron-withdrawing group). Our discussion of the stereoselctivity observed in nitro enosides includes this effect.[2a] Therefore we have interested in whether or not the effect can be reproduced by molecular orbital calculation to such a complex nitro enoside.

Semiempirical molecular orbital calculation (AM1 method) was performed by the use of 4,6-*O*-methylene derivatives **29**—**32** as model compounds for the respective 4,6-*O*-benzylidene derivatives. Optimized pyranoside conformations of 3-*C*-nitro-β-D- **29** and 2-*C*-nitro-α-D-2-enopyranoside **32** had a $^{\circ}H_5$ like structure and that of 3-*C*-nitro-α-D-2-enopyranoside **30** had the five coplanar atoms, formed by movement of *O*-5 in the $^{\circ}H_5$ conformation to the double bond plane. More deformation was observed for 2-*C*-nitro-β-D-2-enopyranoside **31**, in which C-1 moved up to take a $^{1,4}B$ like structure even started from the $^{\circ}H_5$ conformation. In this conformation the anomeric methoxyl group occupies a sterically unfavorable flag-pole like position. The steric destabilization should be, however, compensated by anomeric effect and $A^{(1,2)}$ strain; the latter is present in the $^{\circ}H_5$ conformation, but not in the $^{1,4}B$ like one. Therefore the $^{1,4}B$ like structure calculated has possibility for 4,6-*O*-benzylidene-2-*C*-nitro-β-D-2-enopyranoside **6**, being not yet established experimentally. Although steric relationship between the nitro group and O-1 in 2-*C*-nitro-β-D-2-enopyranoside **31** is very similar to that between the nitro group and O-4 in 3-*C*-nitro-2-enopyranosides **29** and **30**, the optimized structures of the latter two compounds did not take boat-like conformations, because O-4 could not move to make such a conformation owing to the 1,3-dioxane ring. Instead of the movement of O-4, the nitro plane deviated from the double bond plane by 31° for **29** and 28° for **30** to reduce the $A^{(1,2)}$ strain at the cost of the conjugation of these functions. Heat of formation of optimized compounds, **29**—**32**, were −614.1, −623.5, −625.9, and −631.9 kJ mol^{-1}, respectively. As expected, the α-D-anomers **30** and **32** are more stable than the corresponding β-D-anomers **29** and **31**. The energy levels of the lowest unoccupied molecular orbital of these nitro enosides, which localized mainly at the C-2–C-3 bond and the nitro group, followed the sequence; −1.16867 eV for **31**<−1.09549 for **32**<−1.02881 for **30**<−0.99108 for **29**. Unfortunately this sequence can not account for the relative reactivities of **1**, **3**, **6**, and **7**. Neither atomic charge at C-2 for **29** and **30** or at C-3 for **31** and **32** nor their bond length at C-2–C-3 gave a good correlation for the reactivities. Then a methoxide ion or methanol was put on just above or below the β-position of the α-nitro-olefin moiety of these model compounds. Its distance was fixed at 2.0 Å and others were full optimized. The full optimized structures are fairly good agreement with those predicted by the stereoelectronic effect, that is, axial and equatorial attacks respectively give a chair and a boat intermediate. However, calculation of axial attack of both methanol and a methoxide ion to **31** gave exceptionally a $^{1,4}B$ like conformation instead of a $^{4}C_1$ like one. These results are predictable from stereoelectronic effect, because the starting 2-nitro enoside **31** has the $^{1,4}B$ like structure as described above. The $^{1,4}B$ form calculated is free from $A^{(1,3)}$ strain,[8] which is assumed to be one of important factors for determining the direction of an approaching nucleophile.[2a] Therefore, the $^{1,4}B$ form is likely to be more stable than the alternative $^{4}C_1$ form, because the latter is destabilized by $A^{(1,3)}$ strain between the nitronate and the adjacent methoxyl group. However, if the starting 2-nitro enoside **6** has the $^{\circ}H_5$ form, the $^{1,4}B$ form dose not seem to be an intermediate, at least preliminary one, because of violation of the least-motion principle.[12]

Table 2. Heat of Formation Calculated by AM1 Method as a Function of Approach of Methanol to the Nitro Sugars[a)]

Distance r/Å	Heat of formation/kJ mol^{-1}											
	Compound **29**			Compound **30**			Compound **31**			Compound **32**		
	α-Attack	β-Attack	ΔH[c)]	α-Attack	β-Attack	ΔH	α-Attack	β-Attack	ΔH	α-Attack	β-Attack	ΔH
2.1	−820.1	−827.1	7.0	−829.7	−825.8	−3.9	−833.3	−840.7	7.4	−840.1	−838.1	−2.0
2.0	−802.5	−807.3	4.8	−810.0	−806.3	−3.7	−812.9	−825.8	12.9	−824.5	−819.7	−4.8
1.9	−782.3	−785.3	3.0	−786.8	−786.1	−0.7	−792.3	−809.3	17.0	−807.2	−799.4	−7.8
1.8	−761.5	−764.2	2.7	−765.8	−767.3	1.5	−772.9	−793.5	20.6	−790.4	−779.3	−11.1
1.7	−742.1	−745.0	2.9	−746.1	−751.3	5.2	−756.5	−780.2	23.7	−776.2	−762.0	−14.2
1.6	−724.7	−728.4	3.7	−729.4	−738.0	8.6	−743.3	−769.4	26.1	−765.1	−749.9	−15.2
1.5	−704.6	−709.5	4.9	−710.7	−721.8	11.1	−728.0	−755.2	27.2	−751.1	−734.8	−16.3

a) Methanol was put on just above or below the β-position of nitro alkene moiety and its distance (r) made a reaction coordinate and others were full optimized. b) α-Attack and β-attack refer to the axial and equatorial attack, respectively. c) The energy difference of these two pathways; calculated by heat of formation of the α-attack minus that of the β-attack.

As expected from the steric and electrostatic repulsion, a methoxide ion approached predominantly from the *trans* side of the oxygen atom at the γ-position of the α-nitro-olefin moiety; the energy differences calculated between *trans* and *cis* approach were 40.6, 25.8, 10.2, and 16.2 kJ mol^{-1}, respectively, for **29**, **30**, **31**, and **32**. Similar calculation by the use of methanol instead of a methoxide ion revealed that the *trans* approach was more favorable than the *cis* approach by 4.8, 3.6, and 13.0 kJ mol^{-1} for **29**, **30**, and **31**, respectively, but for **32** the *cis* approach exceptionally predominated by 4.7 kJ mol^{-1}. The present calculation thus qualitatively reproduced the experimental results observed in 2-nitro-α-D-2-enopyranoside **7**; methanolic sodium methoxide exclusively added from the *trans* side of O-4, whereas methanol from the *cis* side.[4)] Similar trend is experimentally observed in the case of 3-*C*-nitro-α-D-2-enopyranoside **3**, that is, methanol predominantly added from the same side of the anomeric methoxyl group in DMSO, while methanolic sodium methoxide exclusively from the opposite side. The latter observation is in good agreement with the present calculation, whereas the former is not. Approach of methanol rather than a methoxide ion is more likely under the former reaction conditions. This experimental results seemed to be realized by the following calculation. The distance between C-2 and the methanolic oxygen atom makes the reaction coordinate (r) and others were full optimized. In the case of 3-C-nitro-α-D-2-enopyranoside **30**, the *cis* approach (equatorial attack) to the anomeric methoxyl group is favorable in a short distance, whereas the *trans* approach (axial attack) favorable in a long distance, as shown in Table 2. Such a crossing was not observed in the other nitro enosides and stereoselectivities calculated were in good agreement with the experimental results. Undoubtedly methanol is less reactive than a methoxide ion, therefore, a transition state of the reaction with methanol should be more close to the product than that with a methoxide ion from Hammond's postulate.[13)] If the distance in a transition state is around 1.7 Å, the predominant *cis* attack of methanol to **3** (*cis*:*trans*=3:1) can be reproduced by the calculation. Furthermore, if the more reactive nitro enosides have the lower heat of formation in complexes, the differences of heat of formation between the complex and the starting nitro enoside reflect the relative reactivities. The energy differences calculated according to the equation, $\Delta H_f = H_c - H_s$, in which H_c and H_s indicate the heat of formation of the complex and that of the starting nitro enoside, were −167.6, −158.5, −150.1, and −143.8 kJ mol^{-1} at 1.8 Å and −154.3, −144.3, −130.9, and −127.8 kJ mol^{-1} at 1.7 Å, respectively, for **31**, **32**, **29**, and **30**. The rates indeed decrease according to this sequence.

Experimental

Kinetic Study. A nitro enoside (15 mg) was added to 0.35 ml of dimethyl sulfoxide-d_6 in a NMR sample tube and the sample tube was inserted in a 90 MHz NMR spectrometer (JEOL; JNM-FX90Q), which had been warmed at 60 °C. After dissolving the nitro enoside, sensitivity of the spectrometer was adjusted and then 0.05 ml of methanol-d_4 was added. The sample tube was sealed with laboratory film and started measurement automatically according to the intervals programmed. The reaction was monitored by integration of peaks due to alkenic, anomeric, and/or benzylidene methine protons. The reaction rate was estimated from the slope of reaction time vs. ln{(A+B)/A}, in which A and B are a remaining starting material and product(s), respectively (see, Fig. 1).

AM1 Calculations. Molecular orbital calculation was performed with a FACOM M-360AP computer at the Education Center for Information Processing of Yokohama City University. The optimized structure calculated at 2.0 Å was used as input data at 2.1 and 1.9 Å. The output data obtained at 1.9 Å was then used as input data at 1.8 Å and similar procedure repeated until 1.5 Å.

General. All melting points are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were recorded at 270 MHz with JEOL spectrometer (JNM-EX270) and 22.5 MHz with JEOL spectrometer (JNM-FX90Q), respectively, in $CDCl_3$ with Me_4Si as the internal standard. IR spectra were recorded for KBr pellets. Solutions were dried over $MgSO_4$ and evaporated under diminished pressure. Column chromatography was

conducted on silica gel (Wakogel C-300). Products, **12**, **24**, **26**, and **28**, were identical with the nondeuterated authentic specimen of **11**,[14] **23**,[2a] **25**,[4], and **27**,[15] respectively, by ^{1}H NMR spectroscopy.

^{13}C NMR data for **1**: δ=98.8 (C-1), 131.9 (C-2), 150.1 (C-3), 72.8 (C-4), 69.9 (C-5), 68.6 (C-6), and 102.4 (PhC),
for **3**: δ=95.9 (C-1), 129.7 (C-2), 150.1 (C-3), 73.4 (C-4), 64.9 (C-5), 69.1 (C-6), and 102.6 (PhC),
for **6**: δ=97.7 (C-1), 147.4 (C-2), 136.0 (C-3), 73.9 (C-4), 70.5 (C-5), 69.5 (C-6), and 103.0 (PhC),
and for **7**: δ=94.7 (C-1), 147.7 (C-2), 134.4 (C-3), 75.0 (C-4), 63.6 (C-5), 69.9 (C-6), and 103.3 (PhC).

The remaining authentic samples were prepared as follows.

Phenyl 4,6-*O*-Benzylidene-3-deoxy-2-*O*-methyl-3-*C*-nitro-β-D-glucopyranoside (13). A solution of **2**[16] (53 mg, 0.15 mmol) in 0.1 M (1 M=1 mol dm^{-3}) MeONa (1 ml) was stirred for 15 min and partitioned between EtOAc and aqueous NaCl. The combined organic layers were washed with water, dried, and evaporated to give 53 mg (95%) of crystalline residue, the ^{1}H NMR spectrum of which showed it to be pure **13**. An analytical sample was prepared by recrystallization from MeOH; mp 174—175 °C; $[\alpha]_D^{25}$ −64.6° (*c* 1.0, $CHCl_3$); IR 1561 cm^{-1} (NO_2); ^{1}H NMR δ=5.11 (1H, d, $J_{1,2}$=7.5 Hz, H-1), 4.06 (1H, dd, $J_{2,3}$=10.2 Hz, H-2), 4.77 (1H, t, $J_{3,4}$=10. 2 Hz, H-3), 4.18 (1H, dd, $J_{4,5}$=9.3 Hz, H-4), 3.62 (1H, dt, $J_{5,6a}$=10.4, $J_{5,6c}$=5.0 Hz, H-5), 3.86 (1H, t, $J_{6a,6c}$=10.4 Hz, H-6a), 4.43 (1H, dd, H-6e), 5.56 (1H, s, PhCH), and 3.64 (3H, s, OMe). Found: C, 61.92; H, 5.53; N, 3.68%. Calcd for $C_{20}H_{21}NO_7$: C, 62.01; H, 5.46; N, 3.62%.

Methyl 4,6-*O*-Benzylidene-3-deoxy-2-*O*-methyl-3-*C*-nitro-α-D-gluco (15) and -D-mannopyranoside (19). A solution of **3**[17] (128 mg, 0.44 mmol) in dimethyl sulfoxide (3.5 ml) and MeOH (0.5 ml) was warmed at ca. 60 °C for 3 d. The mixture was diluted with EtOAc and washed with water. The organic layer was evaporated and the resultant residue was washed with water and dissolved in EtOAc. The solution was dried and evaporated to give 127 mg of residue, which was chromatographed with 40 : 1 (v/v) C_6H_6–EtOAc as eluant to give successively 39 mg (30%) of starting material **3**, 20 mg (14%) of α-D-*manno* isomer **19** (syrup), and 67 mg (47%) of α-D-*gluco* isomer **15**.

The physical data for **19**; $[\alpha]_D^{25}$ +11.4° (*c* 1.0, $CHCl_3$); IR 1561 cm^{-1} (NO_2); ^{1}H NMR δ=4.85 (1H, d, $J_{1,2}$=1.5 Hz, H-1), 4.07 (1H, dd, $J_{2,3}$=3. 8 Hz, H-2), 4.85 (1H, t, $J_{3,4}$=10. 5 Hz, H-3), 4.56 (1H, dd, $J_{4,5}$=9.3 Hz, H-4), 3.83 (1H, dt, $J_{5,6a}$=10.0, $J_{5,6c}$=4.2 Hz, H-5), 3.93 (1H, t, $J_{6a,6c}$=10.0 Hz, H-6a), 4.33 (1H, dd, H-6e), 5.70 (1H, s, PhCH), 3.43 (3H, s, OMe), and 3.41 (3H, s, OMe). Found: C, 55.45; H, 5.95; N, 4.43%. Calcd for $C_{15}H_{19}NO_7$: C, 55.38; H, 5.89; N, 4.31%.

Compound **15** was recrystallized from isopropyl alcohol; mp 160—160.5 °C; $[\alpha]_D^{25}$ +71.4° (*c* 1.0, $CHCl_3$); IR 1554 cm^{-1} (NO_2); ^{1}H NMR δ=5.00 (1H, d, $J_{1,2}$=3.3 Hz, H-1), 3.94 (1H, dd, $J_{2,3}$=10.3 Hz, H-2), 4.96 (1H, t, $J_{3,4}$=10.3 Hz, H-3), 4.07 (1H, dd, $J_{4,5}$=8.9 Hz, H-4), 3.87 (1H, m, $J_{5,6a}$=10.0, $J_{5,6e}$=3.9 Hz, H-5), 3.80 (1H, t, $J_{6a,6c}$=10.0 Hz, H-6a), 4.35 (1H, dd, H-6e), 5.53 (1H, s, PhCH), 3.24 (3H, s, OMe), and 3.29 (3H, s, OMe). Found: C, 55.48; H, 5.91; N, 4.40%. Calcd for $C_{15}H_{19}NO_7$: C, 55.38; H, 5.89; N, 4.31%.

Methyl 4,6-*O*-Benzylidene-3-deoxy-2-*O*-methyl-3-*C*-nitro-α-D-mannopyranoside (19). A solution of **3** (58.6 mg, 0.2 mmol) in 0.1 M MeONa (1.3 ml) was stirred for 15 min and processed as described above to give 65 mg of syrup, the ^{1}H NMR spectrum of which showed it to be almost pure **19**.

Phenyl 4,6-*O*-Benzylidene-3-deoxy-2-*O*-methyl-3-*C*-nitro-α-D-gluco (17) and -D-mannopyranoside (21). A solution of **4**[18] (150 mg, 0.41 mmol) in dimethyl sulfoxide (3.5 ml) and MeOH (0.5 ml) was warmed at ca. 60 °C for 3 d and processed as described above to give 155 mg of residue. The residue was chromatographed with 40 : 1 (v/v) C_6H_6–EtOAc as eluant to give 113 mg (71%) of α-D-*gluco* isomer **17** (contaminated with α-D-*manno* isomer **21**) as the first fraction and 36 mg (23%) of α-D-*manno* isomer **21** (syrup) as the second one. An analytical sample of **17** was obtained by recrystallization from isopropyl alcohol; mp 172.5—174 °C; $[\alpha]_D^{25}$ +158.8° (*c* 1.1, $CHCl_3$); IR 1556 cm^{-1} (NO_2); ^{1}H NMR δ=5.78 (1H, d, $J_{1,2}$=3.3 Hz, H-1), 4.09 (1H, dd, $J_{2,3}$=10. 2 Hz, H-2), 5.19 (1H, t, $J_{3,4}$=10.2 Hz, H-3), 4.17 (1H, dd, $J_{4,5}$=9.7 Hz, H-4), 4.04 (1H, dt, $J_{5,6a}$=10.2, $J_{5,6e}$=4.6 Hz, H-5), 3.81 (1H, t, $J_{6a,6e}$=10.2 Hz, H-6a), 4.29 (1H, dd, H-6e), 5.55 (1H, s, PhCH), and 3.45 (3H, s, OMe). Found: C, 62.20; H, 5.55; N, 3.82%. Calcd for $C_{20}H_{21}NO_7$: C, 62.01; H, 5.46; N, 3.62%.

The physical data for **21**; $[\alpha]_D^{25}$ +89.0° (*c* 1.0, $CHCl_3$); IR 1562 cm^{-1} (NO_2); ^{1}H NMR δ=5.59 (1H, d, $J_{1,2}$=1.4 Hz, H-1), 4.20 (1H, dd, $J_{2,3}$=3.7 Hz, H-2), 4.99 (1H, dd, $J_{3,4}$=10.3 Hz, H-3), 4.56 (1H, dd, $J_{4,5}$=9.3 Hz, H-4), 3.90 (1H, dt, $J_{5,6a}$=10.3, $J_{5,6c}$=4.2 Hz, H-5), 3.82 (1H, t, $J_{6a,6e}$=10.3 Hz, H-6a), 4.17 (1H, dd, H-6e), 5.64 (1H, s, PhCH), and 3.38 (3H, s, OMe). Found: C, 61.73; H, 5.46; N, 3.81%. Calcd for $C_{20}H_{21}NO_7$: C, 62.01; H, 5.46; N, 3.62%.

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9) In the 3-nitro enosides, however, the β-D-anomers were more reactive than the α-D-anomers by 10 times, whereas the difference of reactivity decreased to 3.1 times in the 2-nitro enosides. Therefore it is likely that the rate constant for the addition reaction of **7** should be smaller than the value (which shows the rate constant for S_N2' reaction) obtained herewith.

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