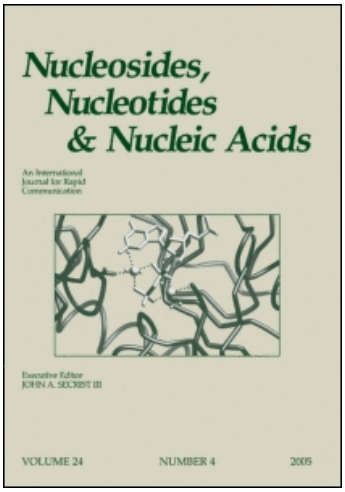

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Regioselective Glycosylation: Synthesis of α-Indoline Nucleosides

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REGIOSELECTIVE GLYCOSYLATION: SYNTHESIS OF α-INDOLINE NUCLEOSIDES

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▫ *Novel indoline ribonucleosides with the α-N-glycoside configuration are synthesized with very high regioselectivity in 90–96% yield, using TMS protected indolines and 2,3-O-(1-methylethylidene)-5-O-(triphenylmethyl)-α/β-D-ribofuranose. The structures of these ribonucleosides were elucidated with X-ray crystallography as well as 2D (NOESY, COSY, and HMQC) NMR spectroscopy.*

Keywords Coenzyme B_{12}, Biosynthesis, Regioselective, Glycosylation

INTRODUCTION

Studies of the role of the axial nucleotide in the enzymatic activation of 5′-deoxyadenosylcobalamin (coenzyme B_{12}, AdoCbl, Figure 1) require coenzyme analogs with altered axial nucleotides.[1] Although some such analogs may be obtained by guided biosynthesis,[2] using fermentation of appropriate bacteria on media supplemented with the desired axial base, analogs with indole axial nucleotides (which mimic the natural structure but lack the coordinating nitrogen) cannot, as these organisms fail to glycosylate indoles to make the required nucleoside precursor.[3] It is thus necessary to develop a chemical method for the semisynthesis of AdoCbl analogs with altered axial nucleotides by coupling the desired nucleoside to the nucleotide-free cobinamide, Factor-B,[4] or cobyric acid.[4,5] For this

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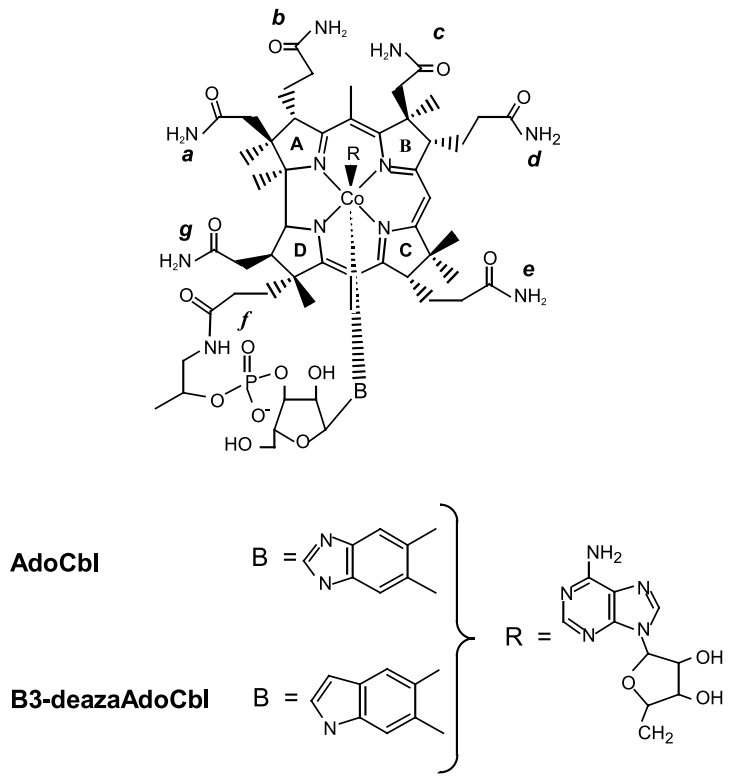


FIGURE 1 Structure of coenzyme B_{12} and B3-deazaAdoCbl.

purpose, a critical step is the synthesis of the nucleoside, which has the unusual α-*N*-glycosidic bond configuration. Since indoles are poor nucleophiles, the typical strategy is to glycosylate the reduced indoline, followed by reoxidation to give the indole nucleoside.[6,7] Thus, synthesis of indoline ribonucleosides with the unusual α-configuration is a priority in this work.

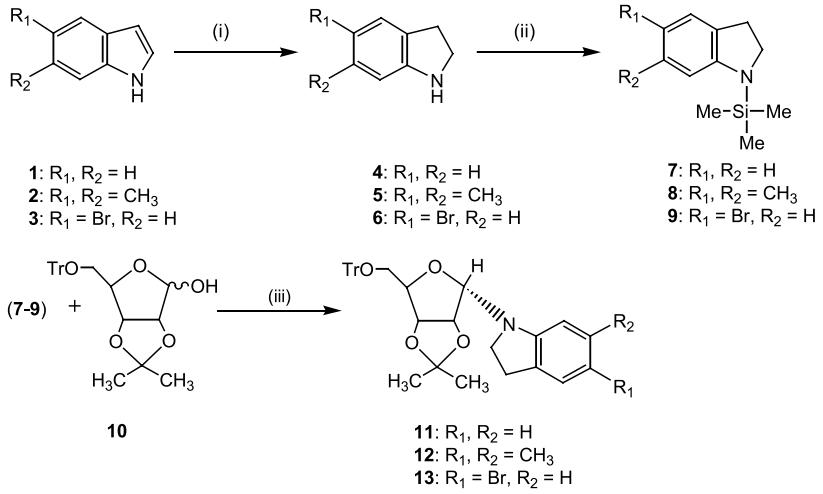
While many routes exist for synthesis of β-*N*-glycosides, there are few methods available for the α-anomers. Mukaiyama et al.[8] showed that the reaction of 1-hydroxy sugars such as 2,3-*O*-(1-methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose[9] or 5-*O*-benzoyl-2,3-*O*-(1-methylethylidene)-D-ribofuranose[10] with trimethylsylated benzimidazole and other nitrogenous bases including nucleoside bases and azides, using 2-fluoro-1-methylpyridinium tosylate as condensing reagent, gives predominantly alpha ribonucleosides. However, as much as 47% of the β-anomer is obtained, requiring difficult separations of these isomeric mixtures by column chromatography. So far, no full characterization and isolation of these compounds has been reported. There are reports[10,11] of the use of ribofuranosyl chlorides for α-glycosylation, but these also produce mixtures of α- and β-*N*-glycosides. To date, there has not been a single report of reactions that produce the

α-nucleoside exclusively. We now report the synthesis of *a*-indoline ribonucleosides in excellent yield without the formation of any detectable β-ribonucleoside.

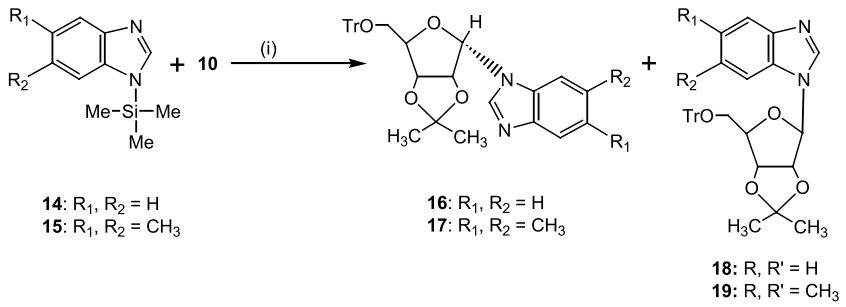
RESULTS AND DISCUSSION

Scheme 1 shows the synthetic route for the synthesis of protected indolines and their coupling to protected D-ribofuranose to form the α-indoline ribonucleosides exclusively. The dimethyl indole base **2** was synthesized in fairly good yield by a literature method[12,13] starting from readily available 5-nitropseudocumene.[12] 5-Nitropseudocumene was converted into 2,4,5-trimethylaniline[12] by tin chloride reduction in hydrochloric acid. The amine was further converted to the formamide in 90% yield by refluxing in formic acid. Thermal cyclization of the amide using freshly prepared *tert*-butoxide affords the indole in fairly good yield (40%). The dimethylindole was converted to the dimethyindoline **5** in 90% yield using sodium cyanoborohydride in acetic acid at ambient temperature.[14] For the coupling reaction, the free base was protected with trimethylsilyl chloride to give the silylated base[15] in excellent yield. 5,6-Dimethyl-1-trimethylsilanyl-2,3-dihydro-1H-indole **8** was prepared in 98% yield from dimethylindoline at −70°C. Similarily, the TMS-bromoindoline **9** was prepared in 95% yield from corresponding 5-bromoindoline base. 2,3-*O*-(1-Methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose was easily prepared in fairly good yield from D-ribose in two steps.[9]

Freshly prepared, silylated dimethyindoline base **8** was then coupled to an anomeric mixture of the protected sugar 2,3-*O*-(1-methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose, **10** (a mixture of α- and β-anomers),[9] using 2-fluoro-1-methylpyridinium p-toluene sulfonate as a condensing agent[8] (Scheme 1). For this



SCHEME 1 Reagents and conditions: (i) sodiumcyanoborohydride, AcOH; (ii) butyllithium, trimethylsilylchloride, −70°C; (iii) 2-fluoromethylpyridinium tosylate, *N,N'*-diisopropylethylamine, methylene chloride, 0 to −30°C.



SCHEME 2 Reagents and conditions: (i) 2-fluoromethylpyridinium tosylate, *N*,*N*′-diisopropylethylamine, methylene chloride, 0 to −30°C.

coupling reaction, 2-fluoro-1-methylpyridinium p-toluene sulfonate and the sugar were stirred in methylene chloride under basic condition, using *N*,*N*-diisopropylethylamine as a base, for 2–3 h at −30°C, and the silylated indoline was added to the reaction mixture at −10°C in dry methylene chloride under argon atmosphere. The reaction proceeds smoothly and can be monitored by NMR. The reaction was highly regioselective and crude reaction mixtures showed exclusively *a*-ribonucleosides with no trace of β-nucleosides by NMR. After completion of the reaction, the organic layer was thoroughly washed with water, and the solvent was removed under reduced pressure. The unreacted base was removed by washing with hexane, and the resulting solid was dried under reduced pressure to afford the pure α-ribonucleoside in 96% yield. The method does not require further complicated purification. α-Indoline and 5-bromoindoline ribonucleosides were

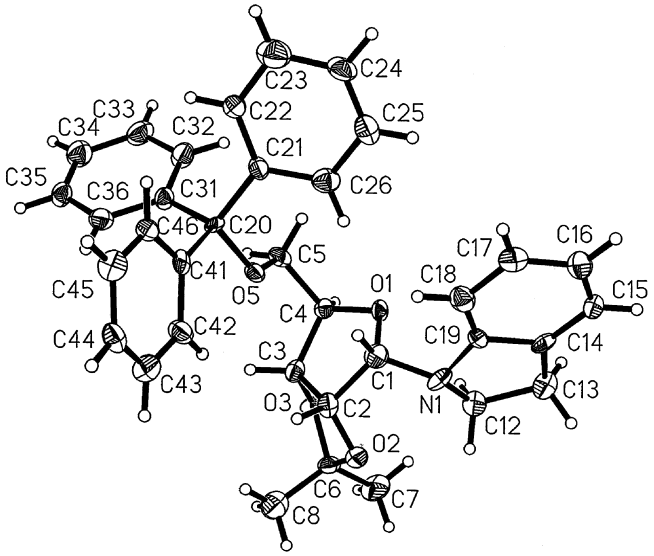


FIGURE 2 ORTEP diagram of compound **11**.

similarily prepared in 90 and 92% yield, respectively, from corresponding TMS protected indoline bases. The indoline ribonucleoside was easily purified by stirring in hexane at room temperature. These α-ribonucleosides can be easily converted to the corresponding indole nucleosides in excellent yield at moderate temperature using manganese dioxide and molecular sieves in benzene.[7]

The dimethylbenzimidazole and benzimidazole α-ribonucleosides were similarily prepared from 5,6-dimethyl-1-(trimethylsilyl)-1H-benzimidazole[16] or 1-(trimethylsilyl)-1H-benzimidazole and **10** using 2-fluoro-1-methylpyridinium *p*-toluene sulfonate as a condensing agent[8] (Scheme 2) and isolated in pure form for spectroscopic comparison. The reaction of trimethylsilylated benzimidazole with 2,3-*O*-(1-methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose gives the α-anomer in 70–80% yield and β-anomer in 20–30% yield. The spectroscopic data and characterization of these ribonucleosides has been not reported in the literature,[8] so it is necessary to characterize these ribonucleosides by 2D NMR. The isomers were separated with some difficulty.

The anomeric configuration of **11** was confirmed by X-ray crystallography (Figure 2). Suitable crystals for X-ray diffraction were grown by slow crystallization at low temperature in ethyl acetate/hexane (1:1). A summary of crystallographic data for the indoline nucleoside **11** is given in Table 1. The indoline moiety is nearly planar, the glycosidic bond length is 1.444 Å (Table 2), and the glycosidic

TABLE 1 Crystal Data and Structure Refinement for Compound **11**

Empirical formula	C_{35} H_{35} N O_4
Formula weight	533.64
Temperature	293(2) K
Wavelength	0.71073 A
Crystal system, space group	Orthorhombic, P2(1)2(1)2(1)
Unit cell dimensions	a = 6.964(7) A alpha = 90°
	b = 16.69(2) A beta = 90
	c = 24.63(2) A gamma = 90°
Volume	2863(5) A^3
Z, Calculated density	4, 1.238 Mg/m^3
Absorption coefficient	0.080 mm^{-1}
F(000)	1136
Crystal size	0.15 × 0.15 × 0.8 mm
Theta range for data collection	2.06 to 20.01 deg.
Index ranges	$0 \leq h \leq 6$, $0 \leq k \leq 16$, $0 \leq l \leq 23$
Reflections collected/unique	1583/1577 [R(int) = 0.1602]
Completeness to 2theta =	20.01 99.7%
Refinement method	Full-matrix least-squares on F^2
Data/restraints/parameters	1577/210/361
Goodness-of-fit on F^2	0.568
Final R indices [I > 2sigma(I)]	R1 = 0.0555, wR2 = 0.1105
R indices (all data)	R1 = 0.1888, wR2 = 0.1544
Absolute structure parameter	−9(7) (Undetermined)
Largest diff. peak and hole	0.179 and −0.191 $e.A^{-3}$

TABLE 2 Bond Lengths (Å) and Angles (°) for Compound **11**

O(1)–C(1)	1.443(14)	O(1)–C(4)	1.437(14)
O(2)–C(2)	1.413(14)	O(3)–C(6)	1.439(15)
O(3)–C(3)	1.440(15)	O(5)–C(5)	1.399(14)
O(5)–C(20)	1.484(14)	N(1)–C(12)	1.480(16)
N(1)–C(1)	1.444(15)	C(1)–C(2)	1.565(17)
C(2)–C(3)	1.525(17)	C(3)–C(4)	1.523(16)
C(4)–C(5)	1.553(16)	C(6)–C(8)	1.494(16)
C(6)–C(7)	1.536(18)	C(12)–C(13	1.571(15)
C(13)–C(14)	1.534(19)	C(14)–C(15)	1.379(17)
C(20)–C(41)	1.503(17)	C(20)–C(31)	1.528(17)
C(1)–O(1)–C(4)	111.5(10)	C(6)–O(2)–C(2)	107.1(11)
C(6)–O(3)–C(3)	106.7(11)	C(5)–O(5)–C(20)	119.5(10)
C(19)–N(1)–C(1)	115.4(12)	C(19)–N(1)–C(12)	113.1(11)
C(1)–N(1)–C(12)	115.3(12)	O(1)–C(1)–N(1)	110.6(11)
O(1)–C(1)–C(2)	103.8(11)	N(1)–C(1)–C(2)	117.4(12)
O(2)–C(2)–C(3)	107.1(12)	O(2)–C(2)–C(1)	113.1(11)
C(3)–C(2)–C(1)	105.3(11)	O(3)–C(3)–C(4)	108.3(12)
C(4)–C(3)–C(2)	106.8(12)	O(1)–C(4)–C(3)	105.4(11)
O(1)–C(4)–C(5)	112.0(11)	C(3)–C(4)–C(5)	111.5(11)
O(5)–C(5)–C(4)	107.6(11)	O(2)–C(6)–O(3)	105.0(12)

torsion angle, C(19)–N(1)–C(1)–O(1) is −79.9°, slightly outside the narrow range of −30° to −72° observed for other α-ribonucleosides.[17]

In the NMR, the anomeric protons of the α-indoline ribonucleosides appeared at δ 5.32–5.45 ppm and the 1′–2′ coupling constant was 3.8 Hz for each compound. For comparison, the protected α- and β-ribonucleosides of benzimidazole and 5,6-dimethylbenzimidazole (Scheme 2) had $J_{1'-2'}$ = 3.8 Hz for the α-anomers, but 3.0 or 3.2 Hz for the β-anomers. While literature reports[18–20] suggest that the anomeric configuration of such nucleosides can be established based on the chemical shift difference of the isopropylidene methyl groups, the indoline ribonucleosides do not follow this rule. Thus, while the benzimidazole α-ribosides have isopropylidene methyl group chemical shift separations of ≤ 0.2 ppm (0.16 and 0.20 ppm) and the β-ribosides have a 0.27 ppm methyl separation, the α-indoline ribosides have an isopropylidene separation of 0.22 or 0.23 ppm.

EXPERIMENTAL SECTION

General Information

Unless otherwise noted, all reactions were conducted in flame-dried glassware with magnetic stirring under an atmosphere of dry nitrogen. Solvents were distilled prior to use. Dichloromethane, benzene, and ether were distilled from calcium hydride. Flash column chromatography was performed using silica gel 230–400 mesh. Compounds on thin-layer chromatography were visualized by illumination

under UV light (254 nm). Evaporations were carried out under reduced pressure with a water bath below 40°C. All solvents were dried and purified before use. All reagents were commercially available and used without further purification. All reactions were monitored by thin-layer chromatography (TLC) using Merck silica gel 60, F-254.

Physical Measurements

^{1}H NMR and ^{13}C NMR spectra were recorded on a Varian INOVA-500 and VXR-400 NMR spectrometers using the residual proton resonance of the solvent as an internal reference at 25°C. Two-dimensional NMR (COSY, NOESY, and HMQC) spectra were obtained at 25°C on a Varian INOVA-500 NMR spectrometer using TMS as internal reference. Chemical shifts are reported in parts per million (δ), and signals are expressed as s (singlet), d (doublet), t (triplet), q (quartet), and m (multiplet). The multiplicities of the ^{13}C NMR signals were determined by the HMQC and DEPT technique. Mass data (FD, MALDI and FAB) were obtained at the University of Illinois using a micromass Quattro-I mass spectrometer. Melting points are uncorrected.

5,6-Dimethylindole (2). To dry precooled, vigorously stirred *tert*-butyl alcohol (50 mL), clean potassium metal (2 g) was added in small portions under a nitrogen atmosphere. After complete dissolution, the mixture was stirred at 40°C for 10 min and N-(2,4,5-trimethylphenyl)formamide (3.8 g, 23 mmol) was added and the temperature was slowly raised to remove the excess solvent completely. At a temperature of 270–280°C, fumes evolved, and heating was continued at this temperature until the fuming ceased. The reaction mixture was cooled to room temperature, the residue was dissolved in a mixture of methylene chloride and methanol (1:1), and silica gel (10 g) was added to the flask. Following removal of the solvent under reduced pressure, the resulting powder was loaded onto a silica gel column and was eluted with a 5–30% methylene chloride: hexane concentration gradient, which yielded a yellow low melting solid.[12,13] Yield: 1.35 g, 40%; ^{1}H NMR ($CDCl_3$): δ 2.40 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 6.48 (t, J = 2Hz, 1H, indole), 7.10 (t, J = 2.5 Hz, 1H, indole), 7.18 (s, 1H, indole), 7.45 (s, 1H, indole), 7.63 (bs, 1H, NH); ^{13}C NMR ($CDCl_3$): δ 20.00 (CH_3), 20.40 (CH_3), 101.69 (CH), 111.34 (CH), 120.63 (CH), 123.31 (CH), 126.10 (Cquat), 128.30 (Cquat), 130.85 (Cquat), 134.71 (Cquat); MS (EI) *m/z*: 145 (M^+), 119, 94; HRMS: *m/z*: 146.0972 (calcd for $C_{10}H_{12}N$; 146.0976) (M + H).

5,6-Dimethyl-2,3-dihydro-1H-indole (5). A solution of dimethylindole **2** (0.470 g, 3.2 mmol) in acetic acid was stirred for 10 min at 12°C and sodium cyanoborohydride (0.8 g, 12 mmol) was added portion-wise under a nitrogen atmosphere at the same temperature. The reaction mixture was stirred for 2 h and was monitored by TLC. After completion of the reaction, the mixture was neutralized

with 50% sodium hydroxide (10 mL). Finally, ether (50 mL) was added and the mixture was stirred for 30 min. The ether layer was separated, the extraction was repeated two more times, and the combined ether layers were washed with brine. After removal of the ether layer, a viscous oil was obtained that was purified on silica gel column. Yield: 0.428 g, 90%; mp 35–38°C dec; white solid; ^{1}H NMR ($CDCl_3$): δ 2.14 (s, 3H, CH_3), 2.17 (s, 3H, CH_3), 2.98 (t, J = 8.4 Hz, 2H, CH_2), 3.30 (bs, 1H, NH), 3.53 (t, J = 8.8 Hz, 2H, CH_2), 6.544 (s, 1H, Ar), 6.93 (s, 1H, Ar); ^{13}C NMR ($CDCl_3$): δ 19.19 (CH_3), 19.93 (CH_3), 29.67 (CH_2), 47.53 (CH_2), 111.52 (CH), 125.82 (CH), 126.86 (Cquat), 127.05 (Cquat), 135.10 (Cquat), 149.16 (Cquat); MS (EI) *m/z*: 147 (M^+), 132, 117; HRMS: *m/z*: 148.1127 (calcd for $C_{10}H_{14}N$; 148.1125) (M + H).

5-Bromo-2,3-dihydro-1H-indole (6). 5-Bromo-2,3-dihydro-1H-indole **6** was prepared from 5-bromoindole as described for 5,6-dimethylindoline **5**, above. Yield: 0.9 g, 90%; low melting solid. ^{1}H NMR ($CDCl_3$): δ 2.99 (t, J = 8 Hz, 2H, CH_2), 3.53 (t, J = 8.5 Hz, 2H, NCH_2), 3.7 (bs, 1H, NH), 6.46 (d, J = 8.5 Hz, 1H, Ar), 7.06 (d, J = 6.5 Hz, 1H, Ar), 7.17 (s, 1H, Ar); ^{13}C NMR ($CDCl_3$): δ 29.62 (CH_2), 47.47 (CH_2), 110.01 (Cquat), 110.50 (Cquat), 127.44 (CH), 129.68 (CH), 131.71 (CH), 150.55 (Cquat); MS (EI) m/z: 198 (M^+), 118 (M-Br); HRMS: *m/z*: 271.02149 (calcd for $C_{11}H_{16}SiBrN$; 271.0214).

1-(Trimethylsilanyl)-2,3-dihydro-1H-indole (7). To a solution of indoline **4** (5.0 g, 42 mmol) in ether, a solution of n-butyllithium (1.6 M) (25 mL, 39 mmol) was added dropwise during 30 min maintaining the temperature at −70°C. After addition, a solid separated out and the mixture was stirred for an additional 15 min. Finally, a solution of chlorotrimethylsilane (4.2 g, 39 mmol) in dry ether (25 mL) was added over one h at the same temperature and the reaction mixture was stirred for 10 h at 25°C. After completion of the reaction, which was monitored by ^{1}H-NMR, the reaction mixture was filtered through a Buchner funnel under a nitrogen atmosphere, and the filtrate was concentrated under reduced pressure. The viscous residue was distilled under vacuum at 90°C. Yield: 7.6 g, 95%; ^{1}H NMR ($CDCl_3$): δ 0.34 (s, 9H, CH_3), 3.071 (t, J = 9 Hz, 2H, CH_2), 3.68 (t, J = 8.5 Hz, 2H, CH_2), 6.64–6.66 (m, 2H, Ar), 7.04 (t, J = 7.5 Hz, 1H, Ar), 7.12 (d, J = 7.5 Hz, 1H, Ar), ^{13}C NMR ($CDCl_3$): δ 0.722 (CH_3, $SiMe_3$), 29.87 (CH_2), 48.97 (CH_2), 108.77 (CH), 116.71 (CH), 124.47 (CH), 127.02 (CH), 131.73 (Cquat), 152.09 (Cquat); MS (EI) m/z: 191 (M^+), 176 (M-15), 118, 91.

5,6-Dimethyl-1-trimethylsilanyl-2,3-dihydro-1H-indole (8). 5,6-Dimethyl-1-trimethylsilanyl-2,3-dihydro-1H-indole was prepared from **8** as described for **7**, above. Yield: 0.63 g, 98%; ^{1}H NMR ($CDCl_3$): δ 0.34 (s, 9H, CH_3), 2.14 (s, 3H, CH_3, Ar), 2.17 (s, 3H, CH_3, Ar), 2.93 (t, J = 9 Hz, 2H, CH_2, indoline), 3.57 (t, J = 8.5 Hz, 2H, CH_2, indoline), 6.4 (s, 1H, Ar), 6.42 (s, 1H, Ar); ^{13}C NMR ($CDCl_3$): δ−0.624 (CH_3), 18.98 (CH_3, Ar), 20.26 (CH_3, Ar), 29.78 (CH_2, indoline), 49.23 (CH_2, indoline), 110.43 (CH), 124.35 (Cquat), 125.85 (CH), 129.28 (Cquat), 134.65 (Cquat), 150.20

(Cquat); MS (EI) m/z: 219 (M^+), 204 (M-15), 189, 174, 159, 144, 130, 118, 91; HRMS: *m/z*: 220.1525 (calcd for $C_{13}H_{22}SiN$; 220.1520) (M + H).

5-Bromo-1-trimethylsilanyl-2,3-dihydro-1H-indole (9). Yield: 2.19 g, 95%; low melting solid. ^{1}H NMR ($CDCl_3$): δ 0.288 (s, 9H, CH_3), 3.005 (t, J = 8.8 Hz, 2H, CH_2), 3.638 (t, J = 9.6 Hz, 2H, CH_2), 6.43 (t, J = 8.4Hz, 1H, Ar), 7.05 (d, J = 9.2 Hz, 1H, Ar), 7.15 (s, 1H, Ar); ^{13}C NMR ($CDCl_3$): δ −0.844 (CH_3), 29.70 (CH_2), 49.33 (CH_2), 108.17 (Cquat), 109.84 (CH), 127.29 (CH), 129.56 (CH), 134.35 (Cquat), 151.50 (Cquat); MS (EI) *m/z*: 270 (M^+), 190, 175, 160.

2,3-*O*-(1-Methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose (mixture of α/β anomers) (10). Yield: 4.25 g, 85%; amorphous solid; mp 95–98°C dec; ^{1}H NMR ($CDCl_3$): δ 1.34 (s, 3H, CH_3), 1.36 (s, 3H, CH_3), 1.477 (s, 3H, CH_3), 1.54 (s, 3H, CH_3), 3.01 (dd, J = 3.0, 7.5 Hz), 3.33 (dd, J = 3.5, 6.5 Hz, 1H), 3.39–3.45 (m, 1H), 3.78 (d, J = 9.5 Hz, 1H), 3.94 (d, J = 11.50 Hz, 1H), 4.18 (broad triplet, 1H), 4.346 (t, J = 3Hz, 1H), 4.58 (d, J = 5.5 Hz, 1H), 4.64 (d, J = 6 Hz, 1H), 4.71–4.73 (m, 1H), 4.77 (d, J = 6 Hz, 1H), 5.32 (d, J = 9.5 Hz, 1H), 5.70 (dd, J = 3.5, 7.0 Hz, 1H), 7.22–7.40 (m, 15 H, trityl); ^{13}C NMR ($CDCl_3$): 24.69 (CH_3), 25.03 (CH_3), 26.08 (CH_3), 26.45 (CH_3), 64.99 (CH_2, 5′), 65.35 (CH_2), 79.35(CH), 80.00 (CH), 81.89 (CH), 82.09 (CH), 85.95 (CH), 86.89 (CH), 87.43 (CH), 88.03 (CH), 97.93 (CH), 103.39 (CH), 112.15 (Cquat), 113.04 (Cquat), 127.12 (CH), 127.38 (CH), 127.90 (CH), 127.99 (CH), 128.49 (CH), 128.59 (CH), 142.79 (Cquat), 143.40 (Cquat); HRMS: *m/z*: 433.2215 (calcd for $C_{27}H_{29}O_5$; 433.2014) (M + H); MS: (FAB) *m/z* 433, 243.[9]

1-(5-*O*-Triphenylmethyl-2,3-*O*-isopropylidene-α-D-ribofuranosyl) indoline (11). To a precooled mixture of 2-fluoro-1-methylpyridinium tosylate (1.7 g, 6.0 mmol) in dry, degassed methylene chloride (10 mL) at −30 to −40°C was slowly added, a mixture of 2,3-*O*-(1-methylethyledene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose[9,21] **10** (1.8 g, 4.2 mmol) in methylene chloride (10 mL) and *N*,*N*-diisopropylethylamine (0.5 mL) under nitrogen, and this mixture was stirred for 3 h at −30°C. During addition of the sugar, the reaction temperature was maintained carefully. After 3 h, the temperature was raised to −10°C, the cooling bath was removed from the reaction mixture and it was replaced with ice bath. A solution of 1-(trimethylsilyl)-2,3-dihydro-1H-indole, **7** (2.0 g, 10 mmol) was prepared in degassed dry methylene chloride and slowly added to the above mixture at −10°C and the resulting solution was stirred for 6 h and then further stirred for 6 h at room temperature. Complete conversion of the starting material was confirmed by TLC (benzene: ether 8:2) as well as ^{1}H NMR. After completion, the reaction mixture was poured into water (50 mL) the organic layer was separated and dried over anhydrous sodium sulfate, and the methylene chloride was removed under reduced pressure. The residue was washed with hexane thoroughly by stirring in hexane and the resulting solid was dried under reduced pressure to afford the

nucleoside in excellent yield. Yield: 2.0 g, 90%; mp 120–22°C dec; R_{fj}. 0.6; White solid; ^{1}H NMR ($CDCl_3$): δ 1.39 (s, 3H, CH_3, isopropylidene), 1.61 (s, 3H, CH_3, isopropylidene), 2.93–2.99 (m, 2H, CH_2, indoline), 3.28 (dd, J = 4.5, 5.0 Hz, 1H, 5′), 3.35 (dd, J = 4.5, 5 Hz, 1H, 5″), 3.51–3.58 (m, 1H, CH of NCH_2, indoline), 3.60 (q, 1H, CH, indoline), 4.19–4.20 (m, 1H, CH, 4′), 4.70–4.72 (m, 1H, CH, 3′), 4.85–4.87 (m, 1H, CH, 2′), 5.45 (d, J = 3.78 Hz, 1H, CH, 1′), 6.76 (t, J = 7.5 Hz, 1H, CH, Ar), 6.81 (d, J = 8 Hz, 1H, Ar), 7.06–7.12 (m, 2H, Ar), 7.25–7.48 (m, 15H, Ar, trityl); ^{13}C NMR ($CDCl_3$): δ 25.56 (CH_3), 27.48 (CH_3), 28.26 (CH_2), 47.31 (CH_2), 63.89 (CH_2), 80.67 (C 3′), 81.49 (C 2′), 82.00 (C 4′), 86.04 (Cquat), 92.83 (C 1′), 108.92 (CH, Ar), 114.01 (Cquat), 119.19 (CH), 124.60 (CH), 126.98 (CH), 127.75 (CH), 128.70 (CH), 136.23 (Cquat), 144.05 (Cquat), 149.05 (Cquat); HRMS: *m/z*: 534.2644 (calcd for $C_{35}H_{36}NO_4$; 534.2643) (M + H); MS: (FAB) *m/z*: 534, 491, 430, 355, 281, 243, 165.

1-(5-*O*-Triphenylmethyl-2,3-*O*-isopropylidene-α-D-ribofuranosyl)-5,6-dimethylindoline (12). The dimethylindoline nucleoside was prepared from **8** as described for compound **11**. Purification was carried out using methylene chloride as eluent. Yield: 96%. White foam. Rf; 0.6 (methylene chloride), ^{1}H NMR ($CDCl_3$): δ 1.38 (s, 3H, CH_3, isopropylidene), 1.60 (s, 3H, CH_3, isopropylidene), 2.17 (s, 3H, CH_3, Ar), 2.19 (s, 3H, CH_3, Ar), 2.85–2.90 (m, 2H, CH_2, indoline), 3.26 (dd, J = 4.5, 5.5 Hz, 1H, 5′), 3.32 (dd, J = 4.5, 6.0 Hz, 1H, 5″), 3.45 (q, 1H, indoline), 3.53 (q, 1H, indoline), 4.19 (q, J = 4.5 Hz, 1H, 4′), 4.64–4.66 (m, 1H, 3′), 4.80–4.82 (m, 1H, H 2′), 5.41 (d, J = 3.7 Hz, 1H, 1′), 6.61 (s, 1H, Ar), 6.88 (s, 1H, Ar), 7.22–7.28 (m, 9H, trityl), 7.45 (d, 6H, trityl); ^{13}C NMR ($CDCl_3$): δ 19.16 (CH_3, Ar), 20.20 (CH_3, Ar), 25.56 (CH_3, isopropylidene), 27.511 (CH_3, isopropylidene), 28.10 (CH_2, indoline), 47.26 (CH_2, indoline), 64.02 (CH_2, 5′), 80.91 (C 3′), 81.58 (C 2′), 81.93 (C 4′), 86.64 (Cquat), 93.20 (C 1′), 110.60 (CH), 113.89 (Cquat), 125.83 (CH), 127.02 (CH), 127.83 (CH), 128.57 (CH), 135.01 (Cquat), 143.61 (Cquat), 143.79 (Cquat), 148.15 (Cquat), HRMS: *m/z*: 562.2966 (calcd for $C_{37}H_{40}NO_4$; 562.2967) (M + H); MS: (FAB), *m/z*: 562, 561, 338, 337, 244, 243; Anal. Calcd. for $C_{37}H_{39}NO_4 \cdot {}^1\!/_2\, H_2O$: C, 77.85; H, 7.06; N, 2.45. Found: C, 77.97; H, 6.53; N, 2.24.

1-(5-*O*-Triphenylmethyl-2,3-*O*-isopropylidene-α-D-ribofuranosyl)-5-bromoindoline (13). Yield: 92%. White foam. Rf; 0.7 (methylene chloride); ^{1}H NMR ($CDCl_3$): δ 1.38 (s, 3H, CH_3, isopropylidene), 1.60 (s, 3H, CH_3, isopropylidene), 2.85–2.90 (m, 2H, CH_2, indoline), 3.24 (dd, J = 4.5 Hz, 1H, 5′), 3.41 (dd, 1H, 5″), 3.47–3.49 (q, 1H, NCH_2, indoline), 3.56 (q, 1H, NCH_2, indoline), 4.14–4.17 (m, 1H, CH, 4′), 4.65–4.67 (m, 1H, CH, 3′), 4.77–4.79 (m, 1H, CH, 2′), 5.32 (d, J = 3.8 Hz, 1H, CH, 1′), 6.63 (d, J = 8.5 Hz, 1H, Ar), 7.10 (d, J = 8.5 Hz, 1H, Ar), 7.12 (s, 1H, Ar), 7.18–7.25 (m, 9H, trityl), 7.41 (d, J = 7 Hz, 6H, trityl); ^{13}C NMR ($CDCl_3$): δ 25.53 (CH_3, isopropylidene), 27.46 (CH_3, isopropylidene), 28.03 (CH_2, indoline), 47.49 (CH_2, indoline), 63.80 (CH_2, 5′), 80.67 (C 3′), 81.33 (C 2′),

82.06 (C 4′), 86.74 (Cquat), 92.77 (C 1′), 110.30 (CH), 110.93, 114.17 (Cquat), 127.05 (CH), 127.78 (CH), 128.68 (CH), 129.92 (Cquat), 132.82, 143.68, 149.10 (Cquat); HRMS: *m/z*: 612.1735 (calcd for $C_{35}H_{34}BrNO_4$; 612.1747) (M + H); MS: *m/z*: 615, 614, 613, 612, 611, 243.

1-(5-*O*-Triphenylmethyl-2,3-*O*-isopropylidene-α-D-ribofuranosyl)-benzimidazole (16). Yield: 1.72 g, 70%; white crystalline solid; mp 195–198°C; R_f. 0.6; ^{1}H NMR ($CDCl_3$): δ 1.31 (s, 3H, CH_3), 1.47 (s, 3H, CH_3), 3.29 (dd, J = 2.5, 8.3 Hz, 1H, 5′), 3.65 (dd, J = 2.5, 7.5 Hz, 1H, 5″), 4.58 (bt, 1H, 4′), 4.86 (d, J = 6.5 Hz, 1H, 3′), 5.06 (t, J = 4.5 Hz, 1H, 2′), 6.70 (d, J = 3.8 Hz, 1H, 1′), 7.28–7.32 (m, 6H, Ar & trityl), 7.35 (t, 6H, Ar), 7.45 (d, J = 8.0 Hz, 6H, Ar), 7.84 (d, J = 8Hz, 1H, Ar), 8.34 (s, 1H, imidazole); ^{13}C NMR ($CDCl_3$): δ 24.37 (CH_3), 25.88 (CH_3), 65.83 (CH_2, 5′), 80.07 (2′), 82.02 (4′), 82.70 (3′), 87.16 (1′), 87.88 (Cquat), 109.33 (CH), 113.59 (Cquat), 120.31 (CH), 122.46 (Cquat), 123.12 (CH), 127.47 (CH), 128.12 (CH), 128.52 (CH), 133.09 (Cquat), 142.46 (Cquat), 142.91 (Cquat), 143.25 (CH); HRMS: *m/z*: 533.2433 (calcd for $C_{34}H_{33}N_2O_4$; 533.2439) (M + H); MS: (FAB) *m/z*: 535, 534, 533, 381, 365, 337, 243; Anal. Calcd. for $C_{34}H_{33}N_2O_4$: C, 76.65; H, 6.05; N, 5.26. Found: C, 76.38; H, 5.84; N, 5.11.

1-(5-*O*-Triphenylmethyl-2,3-*O*-isopropylidene-β-D-ribofuranosyl)-benzimidazole (18). Yield: 0.49 g, 20%; white solid; mp 80–85°C; R_f. 0.5; ^{1}H NMR ($CDCl_3$): δ 1.39 (s, 3H, CH_3), 1.65 (s, 3H, CH_3), 3.42 (dd, J = 4.53, 6.42 Hz, 1H, 5′), 3.49 (dd, J = 3.39, 7.18 Hz, 1H, 5″), 4.48 (m, 1H, 4′), 4.83 (q, J = 1H, 3′), 5.03 (q, 1H, 2′), 6.02 (d, J = 3.4 Hz, 1H, 1′), 7.24–7.40 (m, 16H, trityl, Ar), 7.47 (d, J = 7.71 Hz, 1H, Ar), 7.62 (d, J = 7.93 Hz, 1H, Ar), 7.85 (d, J = 8.31 Hz, 1H, Ar), 8.11 (s, 1H, imidazole); ^{13}C NMR ($CDCl_3$): δ 25.39 (CH_3), 27.29 (CH_3), 63.46 (CH_2, 5′), 81.09 (3′), 84.36 (2′), 84.55 (4′), 87.34 (Cquat), 92.41 (1′), 111.88 (CH), 114.98 (Cquat), 120.28 (CH), 123.04 (Cquat), 123.57 (Cquat), 127.27 (CH), 127.95 (CH), 128.15 (CH), 128.60 (CH), 133.09 (Cquat), 140.36 (CH), 143.18 (CH); HRMS: *m/z*: 533.2445 (calcd for $C_{34}H_{33}N_2O_4$; 533.2439) (M + H); MS: (FAB), *m/z*: 535, 534, 533, 381, 365, 337, 243; Anal. Calcd. for $C_{34}H_{33}N_2O_4$: C, 76.65; H, 6.05; N, 5.26. Found: C, 76.39; H, 5.81; N, 5.11.

CONCLUSIONS

We have shown for the first time that the reaction of trimethylsilyl indoline with 2,3-*O*-(1-methylethylidene)-5-*O*-(triphenylmethyl)-α/β-D-ribofuranose, in the presence of 2-fluoro-1-methylpyridinium tosylate under basic conditions, produces α-ribonucleosides exclusively, the anomeric configuration of which was confirmed by X-ray crystallography (for **11**) as well as 2D NMR spectroscopy. The new finding here is that the all of these glycosylation reactions are absolutely stereoselective for the α-anomer, which is easily purified without any complication.

APPENDIX

TABLE A1 Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters ($A^2 \times 10^3$) for Compound **11**

	x	y	z	U(eq)
O(1)	322(13)	4557(5)	9807(3)	34(3)
O(2)	1109(16)	6443(5)	9689(4)	44(3)
O(3)	3388(14)	5693(6)	9300(4)	46(3)
O(5)	−1065(13)	4272(5)	8700(3)	32(3)
N(1)	−1453(17)	5507(7)	10,318(4)	34(3)
C(1)	−960(2)	5236(8)	9779(6)	45(5)
C(2)	120(2)	5840(9)	9400(5)	38(5)
C(3)	1630(2)	5342(8)	9104(5)	37(5)
C(4)	1490(2)	4493(8)	9327(5)	32(4)
C(5)	600(2)	3912(8)	8903(5)	39(5)
C(6)	2930(2)	6496(9)	9469(6)	40(5)
C(7)	4340(2)	6716(8)	9923(5)	65(6)
C(8)	2980(2)	7071(7)	9004(5)	63(6)
C(12)	190(2)	5700(9)	10,675(5)	51(5)
C(13)	−540(2)	5450(9)	11,254(5)	56(5)
C(14)	−2470(2)	5038(8)	11,148(6)	38(5)
C(15)	−3700(2)	4639(8)	11,493(5)	43(5)
C(16)	−5290(2)	4275(8)	11,293(6)	53(5)
C(17)	−5740(2)	4297(8)	10,744(6)	48(5)
C(18)	−4480(2)	4706(8)	10,391(6)	45(5)
C(19)	−2900(2)	5059(8)	10,583(6)	28(4)
C(20)	−2370(2)	3803(7)	8343(5)	23(4)
C(21)	−3420(2)	3157(9)	8682(5)	36(4)
C(22)	−4220(2)	2495(8)	8456(6)	40(5)
C(23)	−5410(3)	1958(9)	8751(7)	71(6)
C(24)	−5540(2)	2104(8)	9300(6)	54(5)
C(25)	−4780(2)	2737(8)	9539(6)	55(5)
C(26)	−3660(2)	3281(8)	9240(6)	48(5)
C(31)	−1230(2)	3401(9)	7887(5)	34(4)
C(32)	−110(2)	2702(9)	7999(6)	50(5)
C(33)	970(2)	2321(8)	7584(6)	60(6)
C(34)	1030(2)	2651(9)	7057(6)	61(6)
C(35)	−50(2)	3322(9)	6967(5)	43(5)
C(36)	−1200(2)	3719(8)	7362(6)	43(5)
C(41)	−3720(2)	4415(9)	8114(5)	34(4)
C(42)	−3340(2)	5244(8)	8144(5)	44(5)
C(43)	−4590(2)	5779(10)	7914(5)	56(6)
C(44)	−6240(2)	5546(10)	7681(5)	45(5)
C(45)	−6690(2)	4749(9)	7634(5)	52(5)
C(46)	−5420(2)	4195(9)	7852(5)	37(5)

U(eq) is defined as one third of the trace of the orthogonalized Uij tensor.

TABLE A2 Bond Lengths (Å) and Angles (°) for **11**

O(1)–C(1)	1.443(14)
O(1)–C(4)	1.437(14)
O(2)–C(6)	1.381(17)
O(2)–C(2)	1.413(14)
O(3)–C(6)	1.439(15)
O(3)–C(3)	1.440(15)
O(5)–C(5)	1.399(14)
O(5)–C(20)	1.484(14)
N(1)–C(19)	1.413(16)
N(1)–C(1)	1.444(15)
N(1)–C(12)	1.480(16)
C(1)–C(2)	1.565(17)
C(2)–C(3)	1.525(17)
C(3)–C(4)	1.523(16)
C(4)–C(5)	1.553(16)
C(6)–C(8)	1.494(16)
C(6)–C(7)	1.536(18)
C(12)–C(13)	1.571(15)
C(13)–C(14)	1.534(19)
C(14)–C(15)	1.379(17)
C(14)–C(19)	1.425(16)
C(15)–C(16)	1.358(18)
C(16)–C(17)	1.387(16)
C(17)–C(18)	1.412(17)
C(18)–C(19)	1.336(18)
C(20)–C(41)	1.503(17)
C(20)–C(31)	1.528(17)
C(20)–C(21)	1.549(16)
C(21)–C(22)	1.356(17)
C(21)–C(26)	1.399(15)
C(22)–C(23)	1.422(19)
C(23)–C(24)	1.378(16)
C(24)–C(25)	1.321(17)
C(25)–C(26)	1.403(17)
C(31)–C(36)	1.398(16)
C(31)–C(32)	1.432(17)
C(32)–C(33)	1.417(17)
C(33)–C(34)	1.412(17)
C(34)–C(35)	1.368(18)
C(35)–C(36)	1.422(17)
C(41)–C(46)	1.394(18)
C(41)–C(42)	1.412(17)
C(42)–C(43)	1.371(17)
C(43)–C(44)	1.339(18)
C(44)–C(45)	1.372(18)
C(45)–C(46)	1.385(17)
C(1)–O(1)–C(4)	111.5(10)
C(6)–O(2)–C(2)	107.1(11)
C(6)–O(3)–C(3)	106.7(11)
C(5)–O(5)–C(20)	119.5(10)
C(19)–N(1)–C(1)	115.4(12)
C(19)–N(1)–C(12)	113.1(11)

(continued)

Table A2 Continued

C(1)–N(1)–C(12)	115.3(12)
O(1)–C(1)–N(1)	110.6(11)
O(1)–C(1)–C(2)	103.8(11)
N(1)–C(1)–C(2)	117.4(12)
O(2)–C(2)–C(3)	107.1(12)
O(2)–C(2)–C(1)	113.1(11)
C(3)–C(2)–C(1)	105.3(11)
O(3)–C(3)–C(4)	108.3(12)
O(3)–C(3)–C(2)	101.8(10)
C(4)–C(3)–C(2)	106.8(12)
O(1)–C(4)–C(3)	105.4(11)
O(1)–C(4)–C(5)	112.0(11)
C(3)–C(4)–C(5)	111.5(11)
O(5)–C(5)–C(4)	107.6(11)
O(2)–C(6)–O(3)	105.0(12)
O(2)–C(6)–C(8)	111.4(14)
O(3)–C(6)–C(8)	111.8(12)
O(2)–C(6)–C(7)	108.5(13)
O(3)–C(6)–C(7)	107.0(13)
C(8)–C(6)–C(7)	112.8(13)
N(1)–C(12)–C(13)	103.3(11)
C(14)–C(13)–C(12)	104.4(11)
C(15)–C(14)–C(19)	119.0(15)
C(15)–C(14)–C(13)	131.1(14)
C(19)–C(14)–C(13)	109.8(14)
C(16)–C(15)–C(14)	120.0(14)
C(15)–C(16)–C(17)	121.7(16)
C(16)–C(17)–C(18)	118.3(15)
C(19)–C(18)–C(17)	120.6(14)
C(18)–C(19)–N(1)	131.2(14)
C(18)–C(19)–C(14)	120.4(15)
N(1)–C(19)–C(14)	108.4(13)
O(5)–C(20)–C(41)	104.4(10)
O(5)–C(20)–C(31)	110.5(11)
C(41)–C(20)–C(31)	110.3(12)
O(5)–C(20)–C(21)	109.8(11)
C(41)–C(20)–C(21)	112.2(12)
C(31)–C(20)–C(21)	109.6(11)
C(22)–C(21)–C(26)	118.4(14)
C(22)–C(21)–C(20)	122.7(12)
C(26)–C(21)–C(20)	118.9(14)
C(21)–C(22)–C(23)	122.8(14)
C(24)–C(23)–C(22)	115.4(16)
C(25)–C(24)–C(23)	123.6(17)
C(24)–C(25)–C(26)	120.4(15)
C(25)–C(26)–C(21)	119.1(15)
C(36)–C(31)–C(32)	118.4(14)
C(36)–C(31)–C(20)	121.5(14)
C(32)–C(31)–C(20)	120.0(13)
C(33)–C(32)–C(31)	121.2(14)
C(32)–C(33)–C(34)	120.3(15)
C(35)–C(34)–C(33)	116.8(16)
C(34)–C(35)–C(36)	125.5(14)
C(31)–C(36)–C(35)	117.8(14)

(continued)

Table A2 Continued

C(46)–C(41)–C(42)	116.3(15)
C(46)–C(41)–C(20)	121.9(14)
C(42)–C(41)–C(20)	121.7(15)
C(43)–C(42)–C(41)	119.7(15)
C(44)–C(43)–C(42)	122.2(16)
C(43)–C(44)–C(45)	120.8(17)
C(44)–C(45)–C(46)	118.0(16)
C(45)–C(46)–C(41)	122.9(14)

TABLE A3 Anisotropic Displacement Parameters ($A^2 \times 10^3$) for **11**

U11	U22	U33	U23	U13	U12	
O(1)	44(7)	35(6)	23(5)	0(5)	11(6)	8(6)
O(2)	57(9)	36(7)	40(7)	−3(6)	8(7)	−1(7)
O(3)	44(8)	33(7)	60(7)	−11(6)	−12(7)	−6(7)
O(5)	37(7)	30(6)	31(6)	8(5)	−7(6)	−3(6)
N(1)	24(8)	35(8)	44(8)	−20(8)	4(8)	16(8)
C(1)	45(9)	47(8)	43(8)	0(7)	−9(8)	−5(8)
C(2)	36(8)	46(8)	34(8)	1(7)	4(7)	16(7)
C(3)	38(8)	44(8)	30(7)	−6(7)	4(7)	−4(7)
C(4)	32(8)	33(7)	31(7)	−1(7)	−9(7)	1(7)
C(5)	41(9)	33(8)	44(8)	8(7)	7(7)	−8(7)
C(6)	50(9)	26(7)	44(8)	−3(7)	−8(8)	−6(7)
C(7)	56(11)	67(11)	71(11)	−16(10)	−14(10)	−26(10)
C(8)	57(12)	69(11)	63(10)	−7(10)	10(10)	−11(10)
C(12)	59(9)	51(8)	44(8)	0(7)	2(8)	1(8)
C(13)	63(9)	61(9)	45(8)	−9(7)	−1(7)	−1(8)
C(14)	40(8)	28(7)	44(8)	−17(7)	5(7)	9(7)
C(15)	59(9)	41(8)	29(7)	−5(7)	5(7)	2(7)
C(16)	60(9)	53(9)	48(8)	−2(7)	16(8)	−4(8)
C(17)	45(9)	42(8)	58(8)	−4(7)	0(7)	−2(7)
C(18)	47(9)	44(8)	45(8)	7(7)	−1(7)	5(7)
C(19)	34(8)	24(7)	28(8)	7(7)	−8(7)	8(7)
C(20)	23(7)	18(7)	27(7)	−10(7)	9(7)	3(7)
C(21)	38(8)	43(8)	29(7)	7(7)	−5(7)	−12(7)
C(22)	44(8)	40(8)	36(8)	0(7)	5(7)	−8(7)
C(23)	69(10)	62(9)	81(9)	6(8)	−5(8)	−12(8)
C(24)	50(9)	49(8)	62(9)	11(8)	−2(8)	−21(7)
C(25)	62(9)	59(9)	45(8)	11(7)	4(8)	3(8)
C(26)	42(9)	44(8)	57(8)	−3(7)	6(8)	−4(7)
C(31)	38(8)	36(8)	28(7)	−2(7)	4(7)	6(7)
C(32)	57(9)	52(8)	41(8)	−8(7)	−4(8)	7(8)
C(33)	74(10)	47(8)	59(9)	−17(7)	0(8)	6(8)
C(34)	71(10)	55(9)	56(9)	−4(7)	−5(8)	8(8)
C(35)	47(9)	48(8)	35(8)	−2(7)	−12(7)	6(7)
C(36)	48(9)	35(8)	47(8)	2(7)	−5(8)	−1(7)
C(41)	37(8)	45(8)	20(7)	1(7)	18(7)	0(8)
C(42)	50(9)	37(8)	46(8)	10(7)	−6(8)	−1(7)
C(43)	63(9)	52(9)	52(8)	−7(7)	−4(8)	−7(8)
C(44)	46(9)	51(8)	37(8)	12(7)	4(7)	13(8)
C(45)	41(9)	60(9)	54(8)	−3(7)	0(8)	4(8)
C(46)	42(9)	35(8)	34(7)	3(7)	4(7)	−9(7)

The anisotropic displacement factor exponent takes the form: $-2\ pi^2\ (h^2\ a^{*2}\ U11 + \ldots + 2\ h\ k\ a^*\ b^*\ U12)$.

TABLE A4 Hydrogen Coordinates ($\times 10^4$) and Isotropic Displacement Parameters ($A^2 \times 10^3$) for Compound **11**

	x	y	z	U(eq)
H(1A)	−2136	5067	9596	54
H(2A)	−776	6080	9140	46
H(3A)	1505	5367	8708	45
H(4A)	2769	4304	9428	38
H(5A)	1505	3814	8612	47
H(5B)	289	3404	9073	47
H(7A)	4248	6330	10,211	78
H(7B)	4037	7239	10,061	78
H(7C)	5627	6718	9782	78
H(8A)	2059	6913	8736	75
H(8B)	4244	7070	8846	75
H(8C)	2685	7599	9132	75
H(12A)	497	6266	10,661	62
H(12B)	1323	5394	10,572	62
H(13A)	357	5085	11,427	67
H(13B)	−701	5917	11,484	67
H(15A)	−3438	4619	11,863	52
H(16A)	−6106	4004	11,530	64
H(17A)	−6840	4048	10,613	58
H(18A)	−4755	4730	10,022	54
H(22A)	−3968	2386	8092	48
H(23A)	−6061	1538	8584	85
H(24A)	−6203	1738	9514	64
H(25A)	−4974	2821	9908	67
H(26A)	−3095	3719	9410	57
H(32A)	−82	2495	8349	60
H(33A)	1639	1852	7660	72
H(34A)	1775	2424	6784	73
H(35A)	−36	3536	6619	52
H(36A)	−1896	4175	7274	52
H(42A)	−2240	5426	8319	53
H(43A)	−4287	6321	7919	67
H(44A)	−7086	5930	7549	53
H(45A)	−7806	4585	7461	62
H(46A)	−5715	3654	7823	45

TABLE A5 Torsion Angles [deg] for **11**

C(4)–O(1)–C(1)–N(1)	−154.3(11)
C(4)–O(1)–C(1)–C(2)	−27.5(14)
C(19)–N(1)–C(1)–O(1)	−79.9(15)
C(12)–N(1)–C(1)–O(1)	55.0(16)
C(19)–N(1)–C(1)–C(2)	161.3(12)
C(12)–N(1)–C(1)–C(2)	−63.9(17)
C(6)–O(2)–C(2)–C(3)	17.4(15)
C(6)–O(2)–C(2)–C(1)	132.9(13)
O(1)–C(1)–C(2)–O(2)	−99.2(13)
N(1)–C(1)–C(2)–O(2)	23.2(19)
O(1)–C(1)–C(2)–C(3)	17.4(15)

(continued)

Table A5 Continued

N(1)–C(1)–C(2)–C(3)	139.8(13)
C(6)–O(3)–C(3)–C(4)	−136.3(11)
C(6)–O(3)–C(3)–C(2)	−24.0(13)
O(2)–C(2)–C(3)–O(3)	4.5(13)
C(1)–C(2)–C(3)–O(3)	−116.1(11)
O(2)–C(2)–C(3)–C(4)	118.0(12)
C(1)–C(2)–C(3)–C(4)	−2.6(16)
C(1)–O(1)–C(4)–C(3)	26.2(14)
C(1)–O(1)–C(4)–C(5)	−95.2(13)
O(3)–C(3)–C(4)–O(1)	95.7(13)
C(2)–C(3)–C(4)–O(1)	−13.2(15)
O(3)–C(3)–C(4)–C(5)	−142.6(11)
C(2)–C(3)–C(4)–C(5)	108.4(13)
C(20)–O(5)–C(5)–C(4)	−171.4(10)
O(1)–C(4)–C(5)–O(5)	69.0(13)
C(3)–C(4)–C(5)–O(5)	−48.8(15)
C(2)–O(2)–C(6)–O(3)	−32.6(15)
C(2)–O(2)–C(6)–C(8)	88.5(13)
C(2)–O(2)–C(6)–C(7)	−146.7(11)
C(3)–O(3)–C(6)–O(2)	36.1(14)
C(3)–O(3)–C(6)–C(8)	−84.9(14)
C(3)–O(3)–C(6)–C(7)	151.2(11)
C(19)–N(1)–C(12)–C(13)	−10.3(16)
C(1)–N(1)–C(12)–C(13)	−146.2(12)
N(1)–C(12)–C(13)–C(14)	6.9(15)
C(12)–C(13)–C(14)–C(15)	173.9(15)
C(12)–C(13)–C(14)–C(19)	−1.9(16)
C(19)–C(14)–C(15)–C(16)	0(2)
C(13)–C(14)–C(15)–C(16)	−175.6(14)
C(14)–C(15)–C(16)–C(17)	0(2)
C(15)–C(16)–C(17)–C(18)	0(2)
C(16)–C(17)–C(18)–C(19)	0(2)
C(17)–C(18)–C(19)–N(1)	−179.0(13)
C(17)–C(18)–C(19)–C(14)	−1(2)
C(1)–N(1)–C(19)–C(18)	−36(2)
C(12)–N(1)–C(19)–C(18)	−172.3(14)
C(1)–N(1)–C(19)–C(14)	145.3(12)
C(12)–N(1)–C(19)–C(14)	9.5(16)
C(15)–C(14)–C(19)–C(18)	1(2)
C(13)–C(14)–C(19)–C(18)	177.2(13)
C(15)–C(14)–C(19)–N(1)	179.4(13)
C(13)–C(14)–C(19)–N(1)	−4.3(16)
C(5)–O(5)–C(20)–C(41)	−168.5(10)
C(5)–O(5)–C(20)–C(31)	−49.9(15)
C(5)–O(5)–C(20)–C(21)	71.1(14)
O(5)–C(20)–C(21)–C(22)	−158.9(13)
C(41)–C(20)–C(21)–C(22)	85.5(17)
C(31)–C(20)–C(21)–C(22)	−37(2)
O(5)–C(20)–C(21)–C(26)	24.8(18)
C(41)–C(20)–C(21)–C(26)	−90.8(17)
C(31)–C(20)–C(21)–C(26)	146.4(14)
C(26)–C(21)–C(22)–C(23)	5(2)
C(20)–C(21)–C(22)–C(23)	−171.0(14)

(continued)

Table A5 Continued

C(21)–C(22)–C(23)–C(24)	−7(2)
C(22)–C(23)–C(24)–C(25)	6(3)
C(23)–C(24)–C(25)–C(26)	−4(3)
C(24)–C(25)–C(26)–C(21)	2(2)
C(22)–C(21)–C(26)–C(25)	−3(2)
C(20)–C(21)–C(26)–C(25)	174.0(13)
O(5)–C(20)–C(31)–C(36)	−101.0(16)
C(41)–C(20)–C(31)–C(36)	14(2)
C(21)–C(20)–C(31)–C(36)	137.9(14)
O(5)–C(20)–C(31)–C(32)	76.2(16)
C(41)–C(20)–C(31)–C(32)	−168.9(13)
C(21)–C(20)–C(31)–C(32)	−44.9(19)
C(36)–C(31)–C(32)–C(33)	−2(2)
C(20)–C(31)–C(32)–C(33)	−179.5(14)
C(31)–C(32)–C(33)–C(34)	3(2)
C(32)–C(33)–C(34)–C(35)	−3(2)
C(33)–C(34)–C(35)–C(36)	1(2)
C(32)–C(31)–C(36)–C(35)	1(2)
C(20)–C(31)–C(36)–C(35)	177.8(13)
C(34)–C(35)–C(36)–C(31)	0(2)
O(5)–C(20)–C(41)–C(46)	−165.9(11)
C(31)–C(20)–C(41)–C(46)	75.4(16)
C(21)–C(20)–C(41)–C(46)	−47.1(17)
O(5)–C(20)–C(41)–C(42)	15.1(17)
C(31)–C(20)–C(41)–C(42)	−103.7(15)
C(21)–C(20)–C(41)–C(42)	133.9(14)
C(46)–C(41)–C(42)–C(43)	−1(2)
C(20)–C(41)–C(42)–C(43)	178.0(12)
C(41)–C(42)–C(43)–C(44)	3(2)
C(42)–C(43)–C(44)–C(45)	−4(2)
C(43)–C(44)–C(45)–C(46)	2(2)
C(44)–C(45)–C(46)–C(41)	0(2)
C(42)–C(41)–C(46)–C(45)	0(2)
C(20)–C(41)–C(46)–C(45)	−179.5(12)

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