Carbohydrate Research, 153 (1986) 33–43
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

THE STRUCTURE AND PROPERTIES OF THE PRODUCTS OF REACTION BETWEEN 3,4,6-TRI-*O*-ACETYL-2-DEOXY-2-NITROSO-α-D-GALACTOPYRANOSYL CHLORIDE AND PYRAZOLE

ZYGFRYD SMIATACZ, ROMAN SZWEDA, AND HENRYK MYSZKA
Institute of Chemistry The University of Gdańsk, 80-952 Gdańsk (Poland)
(Received October 28th, 1985; accepted for publication, January 2nd, 1986)

ABSTRACT

Dimeric 3,4,6-tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-galactopyranosyl chloride reacts with pyrazole in acetonitrile to give 1-(3,4,6-tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-D-*lyxo*-, -β-D-*lyxo*-, and -β-D-*xylo*-hexopyranosyl)pyrazole. The stereospecificity of the reaction depends on the temperature and its duration. Transformations of the type α-D-*lyxo*-←β-D-*lyxo* ⇌ β-D-*xylo* have been observed. The condensation products were modified at C-2 or C-3. The following derivatives have thus been obtained: 1-(α-D-galacto-, 2-acetamido-2-deoxy-α-D-galacto-, -α-D-talo-, and -α-D-*xylo*-hexo-pyranosyl)pyrazole, (*Z*)- and (*E*)-1-(3-azido-2,3-dideoxy-2-hydroxyimino-α- and -β-D-*lyxo*- and -α-D-*xylo*-hexopyranosyl)pyrazole, 1-(3-acetamido-2-acetoxyimino-4,6-di-*O*-acetyl-2,3-dideoxy-α- and -β-D-*lyxo*-hexopyranosyl)pyrazole, as well as (*Z*)- and (*E*)-1-(2,3-dideoxy-2-hydroxyimino-α-D-*threo*-hexopyranosyl)pyrazoles.

INTRODUCTION

3,4,6-Tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-hexopyranosyl chlorides have been employed[1] in the synthesis of α-glycosides and we have reported the synthesis of *N*-glycosylpyrazoles using 3,4,6-tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-glucopyranosyl chloride[2]. We now report on the reaction of 3,4,6-tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-galactopyranosyl chloride (1) with pyrazole.

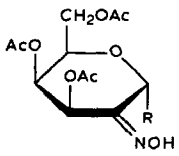
RESULTS AND DISCUSSION

The reaction of **1** with 2 mol of pyrazole afforded 1-[3,4,6-tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-D-*lyxo*- (**3**), -β-D-*lyxo*- (**4**), and -β-D-*xylo*-hexopyranosyl]-pyrazole (**5**).

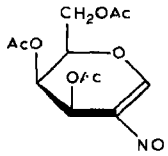
The stereospecificity of the reaction depends on the temperature and its duration. Thus, reaction at ~80° gave exclusively **3**, whereas **3**, **4**, and **5** were formed at ~20°. On prolonged reaction (7 days) at ~20°, **4** and **5** were quantitatively transformed into **3**. The transformations of **4** and **5** into **3** were not observed

0008-6215/86/$ 03.50

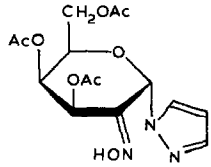
when they were isolated and solutions in acetonitrile or acetonitrile containing small amounts of pyrazole or triethylamine were boiled under reflux. However, if catalytic amounts of **1** were added to the acetonitrile, **4** and **5** were transformed into **3**. In acetonitrile containing hydrogen chloride, **4** was transformed into **3**, but **5** remained unchanged. Further, if, to a solution at 20° in which the reaction between the chloride and pyrazole occurred, ethanol was added at a moment of disappearance of **1** (indicated by t.l.c.) and the solution was heated or maintained at room temperature, **4** and **5** disappeared and, in addition to **3**, ethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-D-*lyxo*-hexopyranoside (**7**) could be isolated. The reaction of **1** with ethanol in acetonitrile also gave **7**. A reversible transformation of **4** ⇌ **5** occurred in refluxing acetonitrile or at 20° in this solvent after the addition of catalytic amounts of pyrazole or triethylamine, but not with catalytic amounts of hydrogen chloride. Acetylation of **4** and **5** (→**8** and **9**) prevented the above transformations.



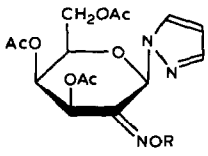
1 R = Cl
7 R = OEt



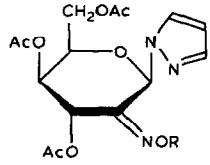
2



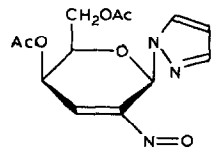
3



4 R = H
8 R = Ac



5 R = H
9 R = Ac



6

These facts together with the properties[3] of **1** suggest that **3**, the thermodynamic product, is formed[1] by addition of pyrazole to a reactive intermediate **2** which is one of the products of transformation of **1** in solution[1,3]. On the other hand, **4**, a kinetic product, is formed by S_N2 reaction of **1** with the more nucleophilic nitrogen (N-2) atom of pyrazole, a mechanism facilitated under conditions where the transformation of **4** into **3** occurs. The reaction is catalysed by hydrogen chloride which can also be generated from **1** added in catalytic amounts. During the transformation **4**→**3**, **2** was formed, as indicated by the appearance of **7** when ethanol was added, and **1** was absent (t.l.c.). The formation of **2** by the pathway **4**→**1**→**2** was supported by the fact that, after acetylation of **4** (→**8**), **3** could not be

formed. On the other hand, the formation of **2** from **4** by elimination of the aglycon was ruled out by the fact that reaction **4**→**3** did not proceed in the presence of the base (pyrazole or triethylamine).

The formation of **5** from **4**, through a reactive intermediate **6**, can be explained by analogy with the formation of some of the products of the reaction of 3,4,6-tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-glucopyranosyl chloride with pyrazole[2] and consideration of the findings concerning the formation and properties of arylazo-enopyranosides[4] and AcO-3 in 3,4,6-tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-D-hexopyranoside[5].

The results of the reaction of pyrazole with the α-D-*galacto* compound **1** differ from those of the α-D-*gluco* isomer[2]. The difference can be attributed to the axial AcO-4 in **1**. This fact, in conjugation with the interactions of the dipoles of bulky substituents[6–9] at C-1,2,3, explains the interconversion **4** ⇌ **5** as well as the absence of an α-D-*xylo* product.

The structures of **3–5** were confirmed by the ^{1}H-n.m.r. data. The larger chemical shift of H-1 in **3** (δ 7.10), as compared with those (δ 6.85 and 6.80, respectively) for **5** and **4**, is due to the equatorial and axial orientation, respectively, of H-1, whereas the $J_{3,4}$ values for **3** and **4** (~3 Hz) and for **5** (1.5 Hz) are indicative of the D-*lyxo* and D-*xylo* configurations, respectively. Also, the $[\alpha]_D$ values for **3** (+95°), and **5** (−12°) and **4** (−51°) confirm the α and β configurations.

The structures of **3–5** were also confirmed by chemical transformations. Deoximation of **3** with acetaldehyde, borohydride reduction of the resulting ketone, and then acetylation gave 1-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-pyrazole {**10**, $[\alpha]_D^{20}$ +90° (chloroform), $J_{1,2}$ 3, $J_{2,3}$ 9.5, $J_{3,4}$ 3 Hz}. The borohydride reduction step was highly stereoselective. However, the deoximation step was difficult and the yields were low. Slightly better results were obtained with **11**, but they were inferior to those for oxime derivatives of glycosides[10], thus showing that the rate of deoximation was affected by the aglycon.

The hydrogenation of **3** over Pd/C followed by *N*-acetylation gave the 1-(2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-D-glycopyranosyl)pyrazoles with the α-D-*galacto* (**13**; $J_{1,2}$ 3, $J_{2,3}$ 8, $J_{3,4}$ ~3 Hz) and α-D-*talo* (**14**; $J_{1,2}$ ~1.5, $J_{2,3} \approx J_{3,4} \approx 3.5$ Hz) configurations, as well as 1-(2-acetamido-4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*xylo*-hexopyranosyl)pyrazole [**12**, $J_{1,2}$ ~3.5 Hz; δ 4.55 (m, H-2), 2.10 (H-3*e*), 1.65 (m, H-3*a*), 3.62 (m, H-4), 1.93 (2 OAc), 1.75 (NHAc)]. The reduction was slow, the yields were low, and the reaction was not stereospecific. The ratio of products with equatorial and axial NHAc groups was 1:1.

Bearing in mind earlier findings concerning the properties of the RO (R = Ac or Bz) group in the moiety R–O–C–C=N–YH (Y = O, NPh)[4,5], **3–5** were utilised for the preparation of derivatives modified at C-3. Thus, reaction of **3** with sodium azide in boiling ethanol gave **15–17** in the ratio 6:5:1. Compound **15** is a product of equatorial substitution of AcO-3 by azide (→D-*lyxo* isomer, $J_{3,4}$ ~3 Hz). Compounds **16** and **17** are products of axial substitution, namely, the (*Z*)- [$J_{3,4}$ 1.5 Hz, δ 6.80 (H-1), 4.38 (H-3), and 4.75 (H-4)] and (*E*)-2-hydroxyimino-D-*xylo*

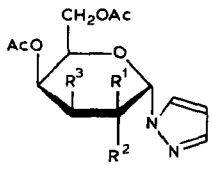
TABLE I

^{1}H-N.M.R. DATA[a]

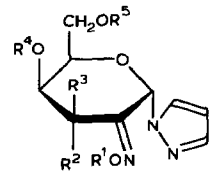
Compound	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*Ac*	*N-H*	*Pyrazole*	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	J_{gem}
3	7.10s	—	6.57d	5.64dd	4.48m	4.10m	1.98, 3 H 2.00, 3 H 2.14, 3 H	—	6.42, 1 H 7.62, 1 H 7.72, 1 H	—	—	3.5	3.5	
4	6.80s	—	6.10d	5.58dd	4.20m	4.08m	1.98, 3 H 2.00, 3 H 2.10, 3 H	—	6.40, 1 H 7.60, 1 H 7.74, 1 H	—	—	3.0	3.0	
5	6.85s	—	6.02d	5.48dd	3.98–4.38m		1.96, 3 H 2.05, 3 H 2.15, 3 H	—	6.46, 1 H 7.65, 1 H 7.80, 1 H	—	—	1.5	3.0	
7	6.15s	—	5.98d	5.62dd	4.50m	4.15m	2.02, 3 H 2.05, 6 H	—	—	—	—	2.5	3.0	
10	6.37d	5.37dd	6.15dd	5.57dd	4.77m	4.00m	1.87, 6 H 2.02, 6 H	—	6.32, 1 H 7.70, 2 H	3.0	9.5	3.0	3.0	
11	6.82s	—	4.92d	4.05dd	3.82m	3.52m	—	—	6.35, 1 H 7.75, 2 H	—	—	4.0	—	
12	5.75d	4.55m	2.10dd[b] 1.65dd[c]	3.62m	3.87–4.07m		1.75, 3 H 1.93, 6 H	6.77d	6.33, 1 H 7.68, 2 H	3.5	9.0[d] 3.0[e]	2.0[f] 3.0[g]	—	14 8
13	5.75d	4.93m	6.18dd	5.42dd	3.90–4.20m		1.90, 3 H 1.92, 3 H 1.96, 3 H 2.11, 3 H	6.50d	6.30, 1 H 7.58, 2 H	3.5	8.0	3.0	3.0	

14	5.65d	3.45m	4.70m	3.82m	3.92–4.32m		1.90, 3 H 1.95, 6 H 2.10, 3 H	—	6.35, 1 H 7.60, 2 H	1.5	3.0	2.5	—	
15	6.95s	—	5.00d	5.55dd	4.25m	3.95m	1.85, 3 H 2.02, 3 H	—	6.35, 1 H 7.65, 2 H	—	—	3.0	3.0	
16	6.80s	—	4.38d	4.75dd	3.87–4.35m		1.83, 3 H 1.92, 3 H	—	6.38, 1 H 7.65, 2 H	—	—	1.5	3.0	
17	6.20s	—	5.30d	4.80dd	3.95–4.30m		1.93, 3 H 2.00, 3 H	—	6.34, 1 H 7.77, 2 H	—	—	1.5	3.0	
18	6.82s	—	5.85dd	5.62dd	4.30m	3.94m	1.85, 6 H 1.99, 3 H 2.00, 3 H	6.96d	6.38, 1 H 7.60, 2 H	—	—	3.0	3.0	
19	6.73s	—	3.35dd[b] 2.97dd[c]	5.20m	3.87–4.25m		1.83, 3 H 1.98, 3 H	—	6.30, 1 H 7.65, 2 H	—	—	2.0[f] 3.0[g]	—	16
20	6.80s	—	3.15dd[b] 2.72dd[c]	5.10m	3.87–4.25m		1.87, 3 H 1.90, 3 H 1.98, 3 H	—	6.25, 1 H 7.55, 2 H	—	—	1.5[f] 3.0[g]	—	16
21	6.37s	—	5.42d	4.48dd	4.30m	4.12m	1.98, 3 H 2.10, 3 H	—	6.30, 1 H 7.60, 2 H	—	—	3.0	3.0	
22	6.62s	—	5.50m	5.15dd	4.62dd	4.25m	2.06, 6 H 2.10, 3 H 2.15, 3 H	6.87d	6.38, 1 H 7.62, 2 H	—	—	3.0	3.0	

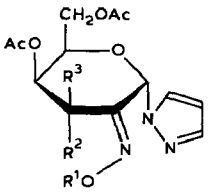
[a]Chemical shifts (δ scale) and coupling constants (Hz, ±0.5 Hz) determined by first-order analysis. [b]H-3*e*. [c]H-3*a*. [d]$J_{2,3a}$. [e]$J_{2,3e}$. [f]$J_{3e,4}$. [g]$J_{3a,4}$.



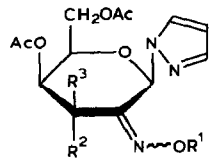
10 $R^1 = H, R^2 = R^3 = OAc$
12 $R^1 = H, R^2 = NHAc, R^3 = H$
13 $R^1 = H, R^2 = NHAc, R^3 = OAc$
14 $R^1 = NHAc\ R^2 = H, R^3 = OAc$



11 $R^1 = R^2 = R^4 = R^5 = H, R^3 = OH$
15 $R^1 = R^2 = H, R^3 = N_3$
16 $R^1 = R^3 = H, R^2 = N_3$
18 $R^1 = Ac, R^2 = H, R^3 = NHAc$
20 $R^1 = Ac, R^2 = R^3 = H$
} $R^4 = R^5 = Ac$



17 $R^1 = H, R^2 = N_3, R^3 = H$
19 $R^1 = Ac, R^2 = R^3 = H$



21 $R^1 = R^2 = H, R^3 = N_3$
22 $R^1 = Ac, R^2 = H, R^3 = NHAc$

isomers [$J_{3,4}$ 1.5 Hz, δ 6.20 (H-1), 5.30 (H-3), 4.80 (H-4)]. The D-*lyxo* and D-*xylo* configurations were assigned on the basis of the $J_{3,4}$ values which, according to the findings of Coxon[11], are ~3 and 1–1.5 Hz for $J_{a,e}$ and $J_{e,e}$, respectively. Compound **18** was obtained from **15** by reduction (H_2/Pd/C) of the N_3 group followed by acetylation. The reduction of the azide group in **15** proceeded rapidly and selectively in the presence of the oximino grouping. Hence, **15** can be used as a starting reagent for preparation of *N*-(3-amino- or 2,3-diamino-glycosyl) derivatives.

Treatment of **3** with sodium borohydride in *N,N*-dimethylformamide at ambient temperature resulted in substitution of AcO-3 by hydrogen to afford **19** [(*E*)-isomer, δ 6.75 (H-1), 3.35 (H-3*e*), 2.97 (H-3*a*)] and **20** [(*Z*)-isomer, δ 6.80 (H-1), 3.15 (H-3*e*), 2.72 (H-3*a*); *E*/*Z* 2:1] identified as their acetates. Compounds **19** and **20** are precursors of *N*-(2-amino-2,3-dideoxy- or 3-deoxy-glycosyl) derivatives.

Treatment of **4** or **5** with sodium azide in boiling ethanol gave **21**, the product of equatorial substitution of AcO-3 by N_3 ($J_{3,4}$ 3 Hz). Hydrogenation (Pd/C) of **21** followed by *N*-acetylation gave **22**.

EXPERIMENTAL

Melting points are uncorrected. Optical rotations were determined (Hilger–

Watt instrument) for solutions in chloroform. T.l.c. was performed on Silica Gel G with *A*, carbon tetrachloride–acetone (3:1); *B*, toluene–ethyl acetate (2:1); *C*, carbon tetrachloride–acetone (1:1); and *D*, carbon tetrachloride–acetone (1:2). Column chromatography was performed on Kieselgel (<0.08 mm). ^{1}H-N.m.r. spectra ($CDCl_3$, internal Me_4Si) were recorded with a Tesla-BS 487C (80 MHz) spectrometer. I.r. spectra were recorded for Nujol mulls with a Perkin–Elmer 257 spectrophotometer. Field-desorption mass spectra were recorded on a MAT 711 mass spectrometer.

Dimeric 3,4,6-tri-*O*-acetyl-2-deoxy-2-nitroso-α-D-galactopyranosyl chloride[12] (**1**) had m.p. 125–127°, $[\alpha]_D^{20}$ +134° (*c* 0.5, chloroform); lit.[1] m.p. 128–131°, $[\alpha]_D^{23}$ +128°.

*1-(3,4,6-Tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-* (**3**) *and -β-*D-lyxo- (**4**), *and -β-*D-xylo-*hexopyranosyl)pyrazole* (**5**). — (*a*) A solution of **1** (2 mmol, 1.348 g) and pyrazole (8.4 mmol, 0.548 g) in acetonitrile (30 mL) was boiled under reflux until **1** was transformed into one product (t.l.c.; solvent *A*, 35 min), and then concentrated. A solution of the residue in chloroform (30 mL) was washed with water (2 × 10 mL), dried (Na_2SO_4), and concentrated, and the residue was crystallised from chloroform–hexane to give **3** (85%), m.p. 158–159°, $[\alpha]_D^{20}$ +95°, R_F (solvent *A*) 0.30; ν_{max} 3340 (OH) and 1755 cm^{-1} (ester CO).

Anal. Calc. for $C_{15}H_{19}N_3O_8$: C, 48.78; H, 5.18; N, 11.38. Found: C, 48.87; H, 5.22; N, 11.31.

(*b*) A solution of **1** (6 mmol, 4.044 g) and pyrazole (25.2 mmol, 1.644 g) in acetonitrile (90 mL) was kept for 48 h at ~20°. T.l.c. (solvent *B*) then revealed the complete conversion of **1** into three products (R_F 0.49, 0.27, and 0.23). A portion (45 mL) of the solution was processed as in (*a*). Column chromatography (solvent *B*) gave, first, **3** (50%), R_F 0.49 (solvent *B*).

Eluted second was **5** (~8%), isolated as a syrup, $[\alpha]_D^{20}$ −12°, R_F 0.27 (solvent *B*); ν_{max} 3380 (OH) and 1750 cm^{-1} (ester CO).

Anal. Calc. for $C_{15}H_{19}N_3O_8$: C, 48.78; H, 5.18; N, 11.38. Found: C, 48.72; H, 5.16; N, 11.34.

Eluted third was **4** (15%), isolated as a syrup, $[\alpha]_D^{20}$ −51°, R_F 0.23 (solvent *B*); ν_{max} 3390 (OH) and 1755 cm^{-1} (ester CO).

Anal. Found: C, 48.75; H, 5.14; N, 11.36.

A second portion (15 mL) was kept at ~20°. After 7 days, one substance (**3**), R_F 0.49 (solvent *B*), was present.

A third portion (15 mL) was boiled under reflux for 0.5 h. The presence of one substance (**3**), R_F 0.49 (solvent *B*), was then ascertained by t.l.c.

The fourth portion (15 mL), after the addition of ethanol, was kept at ~20° for ~60 h. Two products, R_F 0.49 and 0.55 (solvent *B*), were then present. The mixture was processed as in (*a*) and column chromatography (solvent *A*) gave **3** and **7**.

Conventional treatment of **5** with acetic anhydride–pyridine afforded 1-(2-acetoxyimino-3,4,6-tri-*O*-acetyl-2-deoxy-β-D-*xylo*-hexopyranosyl)pyrazole (**9**,

50%), isolated as a syrup, $[\alpha]_D^{20}$ −48°, R_F 0.35 (solvent *B*); ν_{max} 1760 cm^{-1} (ester CO). Mass spectrum (f.d.): *m/z* 411 (M^+).

Likewise, **4** gave 1-(2-acetoxyimino-3,4,6-tri-*O*-acetyl-2-deoxy-β-D-*lyxo*-hexopyranosyl)pyrazole (**8**, 50%), isolated as a syrup, $[\alpha]_D^{20}$ −75°, R_F 0.28 (solvent *B*); ν_{max} 1755 cm^{-1} (ester CO). Mass spectrum (f.d.): *m/z* 411 (M^+).

(*c*) A solution of **4** or **5** (0.25 mmol, 0.084 g) in acetonitrile (5 mL) was boiled under reflux for 1 h. T.l.c. (solvent *B*) then indicated partial interconversion.

(*d*) A solution of the mixture of **4** and **5** (0.25 mmol) and **1** (catalytic amount) in acetonitrile (5 mL) was boiled under reflux for 1 h or was kept for 5 days at 20°. T.l.c. (solvent *B*) then indicated complete conversion of **4** and **5** into **3**.

(*e*) A solution of **4** (0.25 mmol, 0.084 g) and hydrogen chloride as catalyst in acetonitrile (5 mL) was boiled under reflux for 1.5 h or kept for 7 days at 20°. T.l.c. (solvent *B*) then indicated complete conversion of **4** into **3**, whereas **5** remained unchanged under those conditions.

(*f*) A solution of **8** or **9** (0.25 mmol) and a catalytic amount of **1** (or pyrazole or hydrochloric acid) was boiled under reflux for 0.5 h. T.l.c. (solvent *B*) then indicated that no reaction had occurred.

*Ethyl 3,4,6-tri-*O*-acetyl-2-deoxy-2-hydroxyimino-α-*D-lyxo-*hexopyranoside* (**7**). — To a solution of **1** (0.5 mmol, 337 mg) in acetonitrile (5 mL) was added ethanol (0.125 mL), and the mixture was kept for 48 h at 20° and then concentrated. A solution of the residue in chloroform (50 mL) was washed with water (2 × 15 mL), dried (Na_2SO_4), and concentrated, and the residue was crystallised from chloroform–hexane to give **7** (75%), m.p. 106–107°, $[\alpha]_D^{20}$ +65°, R_F 0.54 (solvent *B*); ν_{max} 3350 (OH) and 1760 cm^{-1} (ester CO).

Anal. Calc. for $C_{14}H_{21}NO_9$: C, 48.42; H, 6.09; N, 4.03. Found: C, 48.52; H, 6.12; N, 4.08.

*1-(2,3,4,6-Tetra-*O*-acetyl-α-*D*-galactopyranosyl)pyrazole* (**10**). — (*a*) A solution of **3** (2 mmol, 0.738 g), acetaldehyde (6 mmol), and M hydrochloric acid (2 mL) in acetonitrile (20 mL) was stirred for 8 days at ~20°. T.l.c. (solvent *A*) then indicated that the conversion of **3** was not complete. The mixture was cooled to 0° and treated with sodium borohydride (0.01 mol, 0.378 g) in small portions. The resulting solution was stirred for 6 h at ~20°, then cooled to 0°, neutralised with acetic acid, and concentrated, and the residue was treated with acetic anhydride–pyridine. Column chromatography (solvent *A*) of the crude product gave **10** (20%), isolated as a syrup, $[\alpha]_D^{22}$ +90°, R_F 0.50 (solvent *A*); ν_{max} 1755 cm^{-1} (ester CO)..

Anal. Calc. for $C_{17}H_{22}N_2O_9$: C, 51.25; H, 5.57; N, 7.03. Found: C, 51.27; H, 5.61; N, 7.00.

(*b*) A solution of **3** (2 mmol, 0.738 g) in dry methanol (20 mL) containing triethylamine (7 mmol, 0.706 g) was kept at 20° for 16 h and then concentrated, and the residue was crystallised from ether to give 1-(2-deoxy-2-hydroxyimino-α-D-*lyxo*-hexopyranosyl)pyrazole (**11**, 70%), m.p. 75–80°, $[\alpha]_D^{21}$ +140°, R_F 0.17 (solvent *C*); ν_{max} 3280 cm^{-1} (OH). Mass spectrum (f.d.): *m/z* 243 (M^+).

A solution of **11** (2 mmol, 0.486 g) in acetonitrile (20 mL) containing acetal-

dehyde (6 mmol) and M hydrochloric acid (2 mL) was kept for 48 h at 20°. T.l.c. (solvent *D*) then revealed one major product. The stirred solution was cooled to 0° and treated with sodium borohydride (0.01 mol, 0.378 g), and stirring was continued for 4 h at 20°. The mixture was then processed as in (*a*). Column chromatography (solvent *A*) of the crude product gave **10** (50%).

*1-(2-Acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-α-*D*-galacto- and -α-*D*-talo-pyranosyl)pyrazole* (**13** *and* **14**) *and 1-(2-acetamido-4,6-di-*O*-acetyl-2,3-dideoxy-α-*D*-xylo-hexopyranosyl)pyrazole* (**12**). — A solution of **3** (2 mmol, 0.738 g) in ethanol (40 mL) was stirred under hydrogen (1 atm.) in the presence of 5% Pd/C (0.5 g) for 10 days at ~20°. The catalyst was then removed, the filtrate was concentrated to dryness, and the residue was treated conventionally with pyridine–acetic anhydride. Column chromatography (solvent *A*) of the crude product afforded **12** (17%), isolated as a syrup, $[\alpha]_D^{20}$ +85°, R_F 0.27 (solvent *A*); ν_{max} 3260 (NH), 1760 (ester CO), and 1670 cm^{-1} (amide CO).

Anal. Calc. for $C_{15}H_{21}N_3O_6$: C, 53.09; H, 6.24; N, 12.38. Found: C, 53.09; H, 6.35; N, 12.25.

Eluted second was **13** (12%), isolated as a syrup, $[\alpha]_D^{20}$ +45°, R_F 0.14 (solvent *A*); ν_{max} 3255 (NH), 1750 (ester CO), and 1665 cm^{-1} (amide CO). Mass spectrum (f.d.): *m/z* 397 (M^+).

Eluted third was **14** (26%), isolated as a syrup, $[\alpha]_D^{20}$ +20°, R_F 0.10 (solvent *A*); ν_{max} 3250 (NH), 1760 (ester CO), and 1650 cm^{-1} (amide CO). Mass spectrum (f.d.): *m/z* 397 (M^+).

*1-(4,6-Di-*O*-acetyl-3-azido-2,3-dideoxy-2-hydroxyimino-α-*D*-lyxo-hexopyranosyl)pyrazole* (**15**), *and* (Z)- (**16**) *and* (E)-*1-(4,6-di-*O*-acetyl-3-azido-2,3-dideoxy-2-hydroxyimino-α-*D*-xylo-hexopyranosyl)pyrazole* (**17**). — A solution of **3** (3 mmol, 1.107 g) in ethanol (75 mL) was stirred and boiled under reflux with a suspension of sodium azide (0.03 mol, 1.95 g). T.l.c. (solvent *B*) after 3.5 h showed complete conversion of **3** into three products. The solution was filtered and concentrated, and the residue was extracted with ether. The extract was filtered, diluted with chloroform (200 mL), washed with water (2 × 25 mL), dried (Na_2SO_4), and concentrated. Column chromatography of the resulting syrup (solvent *B*) gave, first, **15** (35%), m.p. 73–75°, $[\alpha]_D^{22}$ +99°, R_F 0.54 (solvent *B*); ν_{max} 3290 (OH), 2110 (N_3), and 1745 cm^{-1} (ester CO).

Anal. Calc. for $C_{13}H_{16}N_6O_6$: C, 44.32; H, 4.55; N, 23.86. Found: C, 44.33; H, 4.51; N, 23.55.

Eluted second was **16** (30%), isolated as a syrup, $[\alpha]_D^{20}$ +117°, R_F 0.44 (solvent *B*); ν_{max} 3300 (OH), 2100 (N_3), and 1755 cm^{-1} (ester CO).

Anal. Found: C, 44.16; H, 4.53; N, 23.67.

Eluted third was **17** (8%), isolated as a syrup, $[\alpha]_D^{20}$ +77°, R_F 0.38 (solvent *B*); ν_{max} 3240 (OH), 2100 (N_3), and 1740 cm^{-1} (ester CO).

Anal. Found: C, 44.20; H, 4.62; N, 23.72.

*1-(3-Acetamido-2-acetoxyimino-4,6-di-*O*-acetyl-2,3-dideoxy-α-*D*-lyxo-hexopyranosyl)pyrazole* (**18**). — A solution of **15** (1 mmol, 0.352 g) in ethanol (25 mL)

was hydrogenated in the presence of 5% Pd/C (200 mg) for 2 h at ~20°, and the product was acetylated as described above. Crystallisation of the crude product from ethanol gave **18** (91%), m.p. 141–145°, $[\alpha]_D^{20}$ +142°, R_F 0.71 (solvent *B*); ν_{max} 3245 (NH), 1750 (ester CO), and 1660 cm^{-1} (amide CO).

Anal. Calc. for $C_{17}H_{12}N_4O_8$: C, 49.76; H, 5.36; N, 13.66. Found: C, 49.57; H, 5.55; N, 13.58.

(E)- (**19**) *and* (Z)-*1-(2-Acetoxyimino-4,6-di-*O*-acetyl-2,3-dideoxy-α-*D*-threo-hexopyranosyl)pyrazole* (**20**). — To a solution of **3** (1 mmol, 0.369 g) in *N,N*-dimethylformamide (15 mL) was added sodium borohydride (8 mmol, 0.015 g) in 3 portions during 1 h. The mixture was stirred for 20 h at ~20°, and the excess of borohydride was then decomposed by the addition of methanol (5 mL) with cooling. Column chromatography (solvent *A*) of the crude product obtained on acetylation afforded, first, **19** (40%), isolated as a syrup, $[\alpha]_D^{21}$ +67°, R_F 0.43 (solvent *A*); ν_{max} 1750 cm^{-1} (ester CO).

Anal. Calc. for $C_{15}H_{19}N_3O_7$: C, 51.00; H, 5.41; N, 11.89. Found: C, 50.94; H, 5.37; N, 11.82.

Eluted second was **20** (20%), isolated as a syrup, $[\alpha]_D^{20}$ +56°, R_F 0.33 (solvent *A*); ν_{max} 1745 cm^{-1} (ester CO).

Anal. Found: C, 50.96; H, 5.38; N, 11.85.

*1-(4,6-Di-*O*-acetyl-3-azido-2,3-dideoxy-2-hydroxyimino-β-*D*-lyxo-hexopyranosyl)pyrazole* (**21**). — A solution of **4** or **5** (1 mmol, 0.364 g) in ethanol (30 mL) was stirred and boiled under reflux with sodium azide (4 mmol, 0.26 g) for 2 h, and then processed as described for the preparation of **15** and **16**. Column chromatography (solvent *A*) of the syrupy residue gave **21** (60%), isolated as a syrup, $[\alpha]_D^{20}$ −68°, R_F 0.40 (solvent *A*); ν_{max} 2100 (N_3) and 1740 cm^{-1} (ester CO).

Anal. Calc. for $C_{13}H_{16}N_6O_6$: C, 44.32; H, 4.55; N, 23.86. Found: C, 44.38; H, 4.57; N, 23.90.

*1-(3-Acetamido-2-acetoxyimino-4,6-*O*-acetyl-2,3-dideoxy-β-*D*-lyxo-hexopyranosyl)pyrazole* (**22**). — A solution of **21** (0.5 mmol, 0.176 g) in ethanol (15 mL) was hydrogenated in the presence of 5% Pd/C (100 mg) for 3 h at ~20°, and then processed as described for the preparation of **18**. Column chromatography (solvent *A*) of the crude product after acetylation afforded **22** (80%), isolated as a syrup, $[\alpha]_D^{21}$ −30°, R_F 0.70 (solvent *A*); ν_{max} 3255 (NH), 1745 (ester CO), and 1655 cm^{-1} (amide CO). Mass spectrum (f.d.): *m/z* 410 (M^+).

REFERENCES

1 R. U. Lemieux, T. L. Nagabhushan, and S. W. Gunnar, *Can. J. Chem.*, 46 (1968) 405–411; R. U. Lemieux, Y. Ito, K. James, and T. L. Nagabhushan, *ibid.*, 51 (1973) 7–18.
2 Z. Smiatacz, R. Szweda, and J. Drewniak, *Carbohydr. Res.*, 143 (1985) 151–159.
3 R. U. Lemieux, T. L. Nagabhushan, and K. James, *Can. J. Chem.*, 51 (1973) 1–6.
4 P. M. Collins, D. Gardiner, S. Kumar, and W. G. Overend, *J. Chem. Soc., Perkin Trans. 1*, (1972) 2596–2610.
5 R. U. Lemieux, F. F. Z. Georges, and Z. Smiatacz, *Can. J. Chem.*, 59 (1981) 1433–1438.
6 E. J. Corey, *J. Am. Chem. Soc.*, 75 (1953) 2301–2304.

7 C. DJERASSI, L. E. GELLER, AND E. J. EISENBRAUN, *J. Org. Chem.*, 25 (1960) 1–6.
8 N. L. ALLINGER, J. ALLINGER, L. E. GELLER, AND C. DJERASSI, *J. Org. Chem.*, 25 (1960) 6–12.
9 M. MILJKOVIĆ, M. GLIGORIJEVIĆ, T. SATOH, AND D. MILJKOVIĆ, *J. Org. Chem.*, 39 (1974) 1379–1384.
10 R. U. LEMIEUX, R. A. EARL, K. JAMES, AND T. L. NAGABHUSHAN, *Can. J. Chem.*, 51 (1973) 19–26.
11 B. COXON, *Tetrahedron*, 21 (1965) 3481–3503.
12 R. U. LEMIEUX, T. L. NAGABHUSHAN, AND I. K. O'NEILL, *Tetrahedron Lett.*, (1964) 1909–1916.