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AN N.M.R. INVESTIGATION OF THE ALDOPENTOSE OXIMES

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ABSTRACT

The solution behavior of the aldopentose oximes **1–4** (*arabino, lyxo, ribo,* and *xylo*) has been studied by ^{1}H (400 MHz) and ^{13}C (100 MHz) n.m.r. spectroscopy. ^{1}H And ^{13}C chemical-shift assignments have been made for the acyclic *E* and *Z* forms of each configurational isomer in $^{2}H_2O$. The ^{13}C chemical shift assignments have been made primarily through the use of (1-^{13}C)-enriched compounds and 2D ^{13}C-^{1}H shift-correlation spectroscopy. Analysis of the ^{1}H-^{1}H spin-coupling constants indicates that the arabinose and lyxose oximes adopt an extended zig-zag conformation, whereas the ribose and xylose oximes adopt a bent or sickle conformation.

INTRODUCTION

The stereochemistry of oximes and the effect of their configurational features on their n.m.r. parameters has long been a popular area of interest. Karabatsos *et al.*[1,2] originally investigated effects on ^{1}H-n.m.r. chemical shifts in order to distinguish the *E* and *Z* isomers of oximes. They showed that the H-1 proton in the *E* isomer resonated upfield from the H-1 proton of its *Z*-configured partner. Later, ^{13}C-n.m.r. chemical shifts were used to distinguish the two oxime isomers[3]. Then more recently $^{1}J_{C,N}$ (ref. 4), $^{1}J_{C,H}$ (ref. 5), and $^{1}J_{C,C}$ (ref. 6) coupling constants were measured for several isomeric pairs, and a correlation was established between the magnitude of the coupling constant and the stereochemical arrangement.

The determination of the structure of carbohydrate oximes by n.m.r. spectroscopy has received much less attention. Ito *et al.*[7] recorded the ^{1}H-n.m.r. spectra of arabinose, ribose, and xylose oximes and assigned the chemical shifts for H-1. Additional proton resonances for these molecules were not resolved at 60 MHz and therefore were not assigned.

Finch and Merchant investigated the preferred solution conformation of D-arabinose and D-glucose oximes[8]. They showed that D-arabinose oxime exists almost exclusively in the acyclic *E* and *Z* forms. D-Glucose oxime, however, while existing predominantly in the acyclic *E* and *Z* forms (70%), contains α- and β-pyranose forms as well.

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Later, these same authors[9] proposed that the mutarotation of (*Z*)-D-arabinose oxime proceeds via a cyclic *N*-arabinosylhydroxylamine intermediate, but no physical evidence had been obtained for the existence of this species.

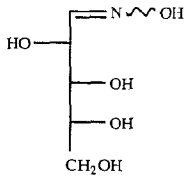
In this report, the complete ^{1}H- and ^{13}C-n.m.r. chemical-shift assignments for the *E* and *Z* isomers of each aldopentose oxime (arabinose, lyxose, ribose, and xylose; **1–4**) have been collected and are discussed. The ^{13}C chemical shifts have been assigned primarily through 2D heteronuclear shift-correlation spectroscopy and the use of (1-^{13}C)-enrichment. The availability of the ^{13}C-enriched compounds made it possible to detect the proposed cyclic intermediate in the arabinose oxime mutarotation reaction discussed above. In addition, through the use of ^{1}H–^{1}H coupling constants, the preferred solution conformation of each acyclic form has been determined.

EXPERIMENTAL

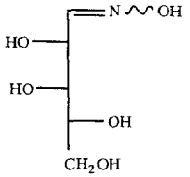
Materials. — D-Arabinose, D-lyxose, D-ribose, D-xylose, hydroxylamine hydrochloride, sodium methoxide (4.6M solution in methanol), HPLC-grade methanol, and deuterium oxide ($^{2}H_2O$, 98 atom%) were purchased from Aldrich. D-(1-^{13}C)Arabinose, D-(1-^{13}C)lyxose, D-(1-^{13}C)ribose, and D-(1-^{13}C)xylose were obtained from Omicron Biochemicals, Inc., South Bend, IN.

Instrumentation. — All n.m.r. spectra were recorded at ambient temperature (~25°), unless stated otherwise, using a Varian XL-400 spectrometer (^{1}H, 400 MHz; ^{13}C, 100 MHz) equipped with a 5 mm $^{1}H/^{13}C$ dual probe, on 75mM aldopentose

Aldopentose oximes



D-Arabinose oxime
1



D-Lyxose oxime
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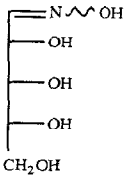

D-Ribose oxime
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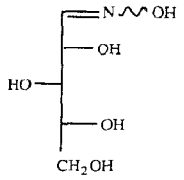


D-Xylose oxime
4

oxime samples in ^2H_2O. The 1D ^1H-spectra were recorded over an 8000 Hz range using 32K memory data points zero filled to 64K before Fourier transformation. The pulse repetition time was 4.0 s, digital resolution 0.25 Hz/point.

The 1D ^{13}C-spectra were recorded over a 25125 Hz range using 32K memory data points zero filled to 64K before Fourier transformation. The pulse width was 6 μs and the pulse repetition time was 1.3 s. This resulted in a digital resolution of 0.79 Hz/point.

Two-dimensional ^{13}C-^1H chemical shift correlation spectra were obtained on a Varian XL-400 spectrometer operating with software version 6.1. The HETCOR standard pulse sequence was used, which incorporates quadrature detection in both domains. The fixed delays correspond to a $^1J_{C,H}$ coupling constant of 140 Hz. The data matrix was 512 × 2048 data points; recycle delay 2.0 s; number of intervals 64; number of transients 128.

Mass spectra of the per-*O*-trimethylsilyl derivatives of the aldopentose oximes were obtained with a VG 7070 mass spectrometer operated in the electron-ionization mode. Samples were introduced via a Hewlett Packard 5790 gas chromatograph equipped with a DB5 column (0.32 mm o.d. × 15 m). The molecular ion $(M)^+$, used to characterize the products of all syntheses, occurred at *m/z* 525. These values increased by 1 amu for (1-^{13}C)-enriched compounds. Melting points were obtained on a Mel-Temp apparatus (Laboratory Devices, Cambridge, MA) and are uncorrected.

Compounds. — The synthetic procedure described for arabinose oxime by Hockett *et al.*[10] was modified and this modification was used for all the aldopentose oximes. Hydroxylamine hydrochloride (1.7 g, 24 mmol) was dissolved in 10 mL of HPLC-grade methanol with stirring. The solution was neutralized with sodium methoxide in methanol (6 mL, 27 mmol), and subsequently cooled and filtered. The filtrate was transferred to a 50 mL round-bottom flask and heated to reflux. The crystalline aldopentose (arabinose, lyxose, ribose, or xylose) was then slowly added (1.5 g, 10 mmol) and the solution was heated 0.5 h under reflux. The solution was allowed to cool and concentrated *in vacuo* at 30°. The resulting syrup was dissolved in 30 mL of H_2O, and deionized by treatment batchwise and separately with Dowex 50-X8 (H^+) and Dowex 1-X8 (OAc^-) resins. Then the solution was again evaporated to dryness *in vacuo* at 30°. D-Arabinose and D-ribose oximes crystallized from ethanol with melting points of 135–136° and 138–139° respectively [lit. 136–7° (ref. 10); 142° (ref. 7)]. The yield in these two instances was greater than 90%. D-Lyxose and D-xylose oximes remained as syrups. Their per-*O*-trimethylsilyl derivatives were injected into a Hewlett-Packard 5890A gas chromatograph equipped with a DB-1701 column (0.256 mm o.d. × 15 m) and programmed from 60 to 270° at 20°/min. The *xylo* derivative had a retention time of 3.44 min and its peak accounted for 100% of the area in the chromatogram. The *lyxo* derivative had a retention time of 3.41 min and was 98% pure by the same criterion. The apparent yields in these two instances were greater than 90%, but some water probably remained in solution.

RESULTS

Proton chemical shift assignments. — The ^{1}H-n.m.r. chemical-shift assignments for the *E* and *Z* isomers of each aldopentose oxime in ^2H_2O are listed in Table I. The signals for H-1 of the two isomers were identified using an established rule that hydrogen directly bonded to the imino carbon will resonate

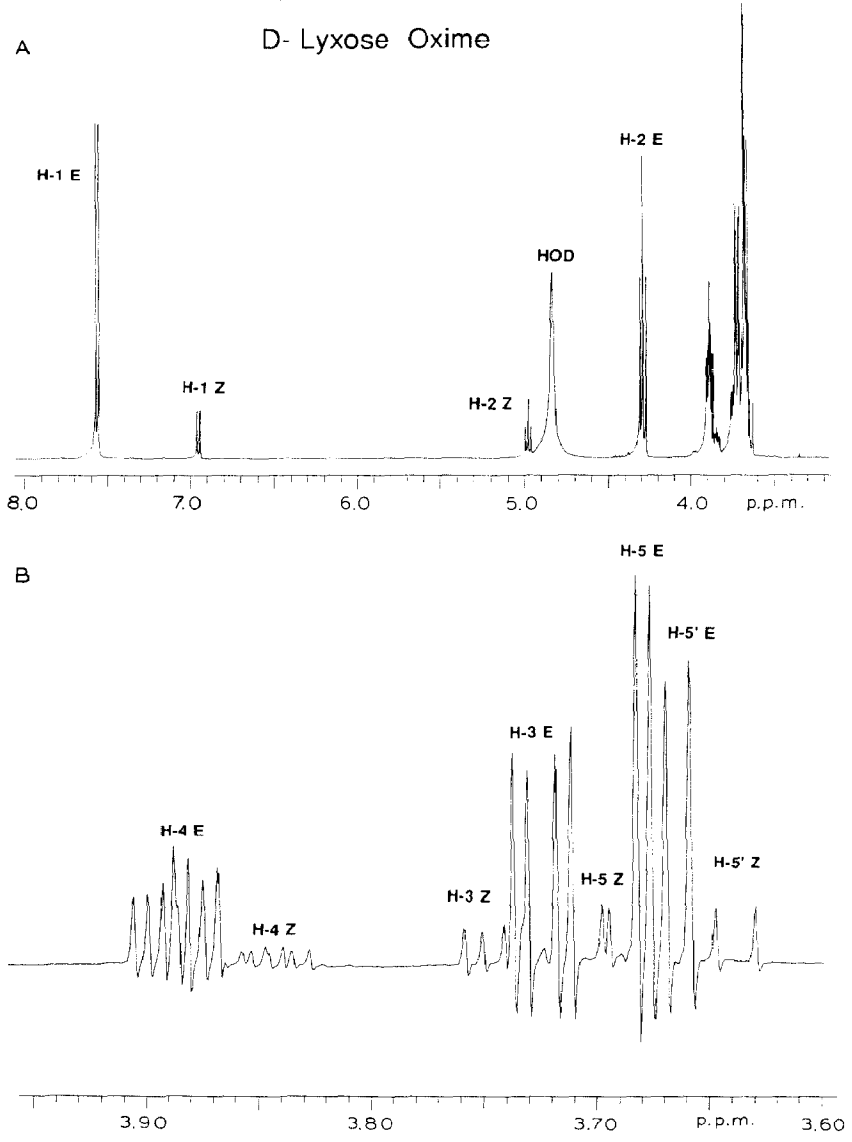


Fig. 1. (A) High resolution ^{1}H-n.m.r. spectrum (400 MHz) of D-lyxose oxime in ^2H_2O. Assignments for H-1*E*, H-1*Z*, H-2*Z* and H-2*E* were made as described in the text. (B) Resolution enhanced segment of *A* showing signals for H-3, H-4, H-5, and H-5′ of both *E* and *Z* isomers. If all the resonances of H-5 and H-5′ were visible there would be a total of 16 lines. However, the central 4 lines of the quartets for the *Z* and *E* isomers are coincident.

downfield when *cis* to the *N*-hydroxyl (*E* form), relative to hydrogen that is *trans* to the *N*-hydroxyl (*Z* form)[1]. As shown in Fig. 1, the H-1 signal of (*E*)-D-lyxose oxime appears downfield 0.62 p.p.m. from the H-1 signal of the *Z* form. This downfield shift (0.62 ±0.02 p.p.m.) of H-1 of the *E* form compared to H-1 of the *Z* form persists throughout the aldopentose series (Table I).

In addition, H-1 assignments could be further verified using $^3J_{1,2}$ coupling constants (Table V). The $^3J_{1,2}$ is larger for the *E* form than for the *Z* form[7].

Assignments for H-2 were based on previous observations that protons α to the imino carbon behave similarly to those attached directly to the imino carbon. In the aldopentose series, H-2*Z* protons appear downfield by 0.64 ±0.05 p.p.m. (Table I). Karabatsos *et al.*[2] attributed this deshielding of α-methine hydrogens to steric interactions. The closer the α-methine H is to the C=N plane (*i.e.*, the smaller the dihedral angle between H–Cα and the C=N bond) the further downfield Hα appears. Due to the repulsion of O-2 and O-3 by the *N*-hydroxyl in the *Z* isomers, the movement of H-2*Z* is restricted, and it is forced to eclipse the C=N plane (deshielded). In contrast, the *N*-hydroxyl will not restrict the rotational movement of H-2*E*, and as a result this proton will be more shielded than H-2 of the *Z* isomer.

Assignments for H-3, H-4, and H-5, which resonate between 3.60 and 3.80 p.p.m. (Table I) were based primarily on coupling constants and selective-decoupling data.

Carbon chemical shift assignments. — The carbon chemical shifts for the *E* and *Z* isomers of the aldopentose oximes are listed in Table II. Carbon resonances were assigned by inspection of the spectra of (1-^{13}C)-enriched compounds, and by 2D ^{13}C-^{1}H correlation spectroscopy (Fig. 2). The sp^2-hybridized carbon of the

TABLE I

PROTON CHEMICAL SHIFTS FOR ALDOPENTOSE OXIMES IN ^2H_2O

Oxime	*Chemical shifts*[a] *(δ)*					
	H-1	*H-2*	*H-3*	*H-4*	*H-5*	*H-5'*
1 (*E*)-D-Arabinose	7.58	4.50	3.67	3.76	3.83	3.66
(*Z*)-D-Arabinose	6.94	5.10	3.82	3.77	3.84	3.64
2 (*E*)-D-Lyxose	7.55	4.27	3.71	3.87	3.67	3.63
(*Z*)-D-Lyxose	6.93	4.96	3.73	3.83	3.69	3.63
3 (*E*)-D-Ribose	7.45	4.42	3.78	3.65	3.77	~3.63
(*Z*)-D-Ribose	6.86	5.08	3.81	3.64	3.74	3.61
4 (*E*)-D-Xylose	7.51	4.36	3.73	3.75	3.69	3.63
(*Z*)-D-Xylose	6.88	4.96	3.79	3.76	3.69	3.63

[a]Values are reported in p.p.m. relative to internal sodium 4,4-dimethyl-4-silapentane-1-sulfonate (DSS) and are accurate to ±0.02 p.p.m.

aldopentose oximes resonates between 152.8 and 155.0 p.p.m. In general, the signal for C-1 of the *Z* form is downfield (~1.0 p.p.m.) from that for the *E* isomer. However, C-1 of (*E*)-lyxose oxime resonates at lower field than C-1 of (*Z*)-lyxose oxime. Accordingly, the chemical shift of C-1 may not be used as a criterion for assignment.

In order to assign the C-1 signals to an *E* or *Z* isomer three criteria were used. The first two criteria were the magnitudes of the $^1J_{C1,C2}$ and $^1J_{C1,H1}$ coupling constants (Table III). As was shown earlier[6], $^1J_{C1,C2}$ for *E* aldoximes is larger than $^1J_{C1,C2}$ for *Z* aldoximes. In the case of the aldopentose oximes the difference is approximately 8 Hz (Table III). Furthermore, $^1J_{C1,H1}$ is larger in the *Z* form than in the *E* form, a difference that has been attributed to the N–C–H bond-angle difference[5]. Finally, it is reasonable to predict by thermodynamic arguments that there should be more *E* form than *Z* form. In the former, the *N*-hydroxyl is *trans* to C-2, whereas in the latter this relationship is *cis*. As shown in Table IV, there is at least four times as much *E* isomer as *Z* isomer in each oxime solution.

In the spectrum of each aldopentose oxime, the signal for C-2 of the *E* isomer appears downfield by ~4.0 p.p.m. compared to that for the *Z* form. The shielding of C-2*Z* is due primarily to a γ-gauche interaction with the *N*-hydroxyl[11]. The

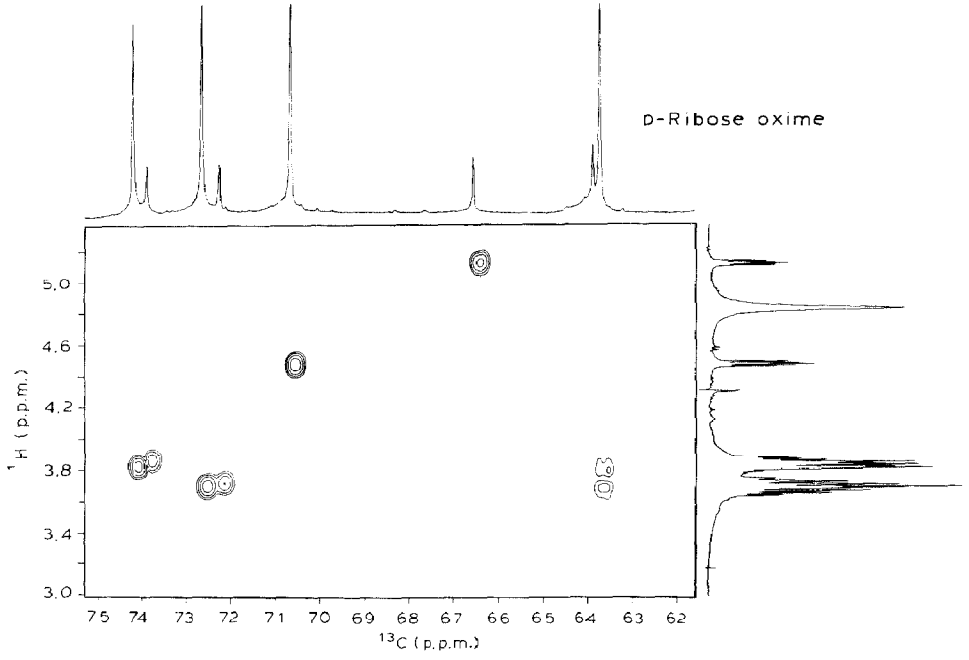


Fig. 2. The 2D heteronuclear correlation (HETCOR)[22] spectrum of D-ribose oxime. The proton assignments in Table I and the cross peaks in this spectrum allow a complete assignment of the carbon resonances.

TABLE II

CARBON CHEMICAL SHIFTS FOR ALDOPENTOSE OXIMES IN ^2H_2O

Oxime	*Chemical shifts*[a] *(δ)*				
	C-1	*C-2*	*C-3*	*C-4*	*C-5*
1 (*E*)-D-Arabinose	154.0	70.1	73.7	72.2	64.2
(*Z*)-D-Arabinose	155.0	66.0	73.0	72.3	64.4
2 (*E*)-D-Lyxose	153.8	70.2	73.2	71.7	64.3
(*Z*)-D-Lyxose	153.3	65.0	73.1	72.0	64.3
3 (*E*)-D-Ribose	152.8	71.1	74.6	73.1	64.1
(*Z*)-D-Ribose	153.2	67.0	74.3	72.7	64.3
4 (*E*)-D-Xylose	153.2	71.3	73.5	72.5	64.2
(*Z*)-D-Xylose	153.8	66.9	73.0[b]	72.9[b]	64.1

[a]Values are reported in p.p.m. downfield from TSP and are accurate to ±0.1 p.p.m. The anomeric-carbon signal of external β-D-(1-^{13}C)glucopyranose (97.4 p.p.m.) was used as the reference signal. [b]These assignments may be reversed.

TABLE III

^{13}C-^{13}C AND ^{13}C-^{1}H COUPLING CONSTANTS FOR ALDOSE OXIMES IN ^2H_2O

Oxime	*Coupled nuclei (J in Hz*[a]*)*	
	C-1, C-2	*C-1, H-1*
1 (*E*)-D-Arabinose	53.6	167.6
(*Z*)-D-Arabinose	45.8	179.6
α-D-Arabinopyranose	ND[b]	154.1
β-D-Arabinopyranose	ND	161.8
2 (*E*)-D-Lyxose	53.6	167.7
(*Z*)-D-Lyxose	45.3	179.2
3 (*E*)-D-Ribose	53.8	167.9
(*Z*)-D-Ribose	45.3	179.8
4 (*E*)-D-Xylose	53.6	167.9
(*Z*)-D-Xylose	45.3	178.8
5 (*E*)-D-Glucose	ND	167.2
(*Z*)-D-Glucose	ND	181.3
α-D-Glucopyranose	ND	163.7
β-D-Glucopyranose	ND	154.7

[a]Values are accurate to ±0.1 Hz. [b]Not determined.

observation that the chemical shift of C-2*E* is greater than that of C-2*Z* was made earlier by Hawkes *et al.*[3] on a series of aldoximes.

The chemical shifts for C-3 and C-4 of each isomer were determined unambiguously by 2D shift-correlation spectroscopy. Signals for C-5 were assigned by their characteristic upfield position (Table II).

Tautomeric forms in aqueous solution. — The tautomeric distribution in ^2H_2O at 30 ±1°, as determined for the aldopentose oximes and glucose oxime by ^{1}H-n.m.r. integration, is given in Table IV. As was shown earlier by Finch and Merchant[8], in addition to the *E* and *Z* forms glucose oxime exists in the α- and β-pyranose forms as well. At 30° in ^2H_2O, the α-pyranose form of glucose oxime was not detected in the ^{1}H-n.m.r. spectrum in this investigation, but it was detected in the ^{13}C spectrum. Funcke *et al.*[12] observed that C-1 of β-D-glucopyranose oxime resonates at 93.0 p.p.m. in dimethyl sulphoxide-d_6. In ^2H_2O the C-1 signal of the β-pyranose form appears at 92.2 p.p.m. and that for C-1 of the α-pyranose form at 90.2 p.p.m.

These assignments were verified using the values of $^1J_{C1,H1}$ coupling constants (Table III). When H-1 is axial (β-pyranose) the coupling constant is 154.7 Hz. When H-1 is equatorial (α-pyranose) the coupling constant is 163.7 Hz. This 9 Hz difference in $^1J_{C1,H1}$ is analogous to the 9 Hz difference between the values for α- and β-glucopyranose[13].

As was discussed earlier[9], Finch and Merchant proposed that the mutarotation reaction of (*Z*)-D-arabinose oxime proceeds via a cyclic intermediate, as is present in the glucose oxime system. It is possible to detect in the ^{1}H-n.m.r. spectrum of arabinose oxime a small resonance at 4.20 p.p.m. having a $^3J_{1,2}$ coupling of 8.71 Hz. This large coupling constant is indicative of a pyranose ring in which H-1 and H-2 are both axial. In the $^1C_4$ pyranose conformation, α-D-arabinose oxime would exhibit such a coupling constant.

To further substantiate the presence of a cyclic form of D-arabinose oxime, the ^{13}C-n.m.r. spectrum of the (1-^{13}C)-enriched oxime was investigated. At 92.6 and 92.0 p.p.m. two small resonances appear, with $^1J_{C1,H1}$ values of 161.8 and 154.1 Hz, respectively. These resonances correspond to β- and α-D-arabinopyranose oxime respectively.

In addition to D-arabinose oxime, D-xylose oxime was found to show a small resonance at 4.23 p.p.m. in its ^{1}H spectrum, with a $^3J_{1,2}$ coupling of 8.79 Hz. This corresponds to a diaxial relationship, and may be assigned to β-D-xylopyranose oxime. Resonances corresponding to cyclic structures in solutions of D-ribose and D-lyxose oxime were not observed.

Conformation of aldopentose oximes. — It is well known that acyclic carbohydrates having derivatized hydroxyls tend to adopt planar zig-zag arrangements, or if this produces unfavorable 1,3 interactions a "bent" or "sickle" conformation is adopted[14,15]. It is further known that the barriers to rotation about carbon–carbon single bonds are low, and that carbohydrates having derivatized hydroxyls exist as equilibrium mixtures of several possible conformers[16,17]. It seems reasonable therefore that the aldopentose oximes may exhibit more than one conformation.

The conformations of acyclic carbohydrates are important in chemical and biochemical systems. It has been shown that conformational preferences have profound effects on chemical reactivity. Reversible and irreversible cyclization reactions are one class of reactions where acyclic conformation has been implicated as a major determinant[18,19]. In this section the preferred solution conformation of each *E* and *Z* aldopentose oxime is discussed in terms of ^{1}H-^{1}H coupling and the Karplus relationship[20].

Arabinose oxime. The *E* and *Z* configurational isomers of D-arabinose oxime adopt very similar conformations. The values of $^3J_{2,3E} \cong {}^3J_{2,3Z} \cong 2.6$ Hz indicate that H-2 and H-3 are *gauche* in each configuration.

The *anti* nature of H-3 with respect to H-4 in both the *E* and *Z* isomers is

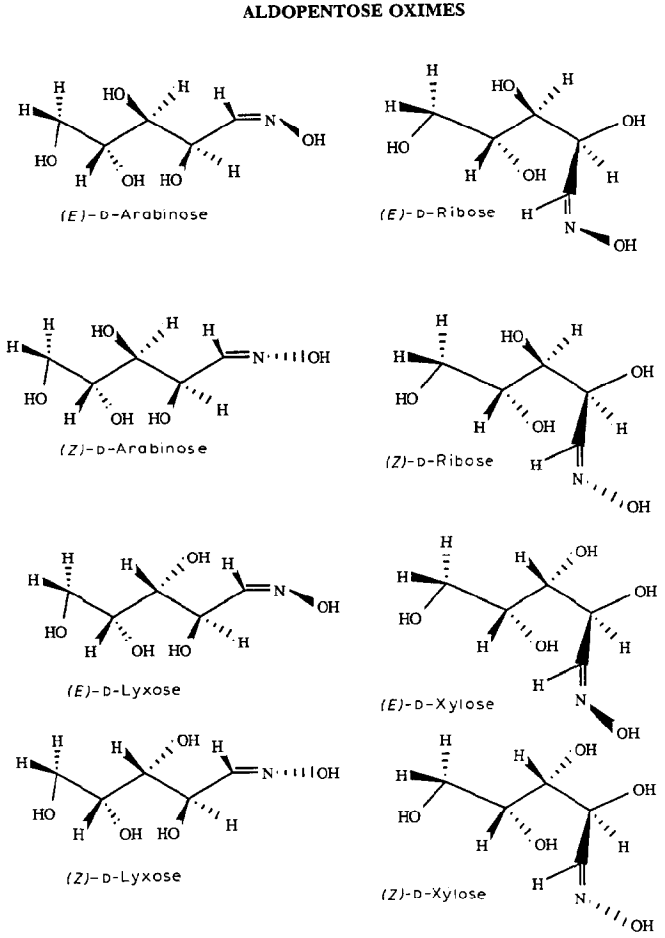


Fig. 3. The preferred conformation of each aldopentose oxime in ^2H_2O as deduced from the ^{1}H-^{1}H spin-coupling constants. Arabinose and lyxose oximes adopt an extended zigzag conformation, whereas the ribose and xylose oximes adopt a bent or sickle conformation.

TABLE IV

PROPORTION OF TAUTOMERIC FORMS AT 30° IN ^2H_2O

Oxime	*Tautomer (%)*[a]			
	E	Z	*α-Pyranose*	*β-Pyranose*
D-Arabinose	79	19	3	
	74[b]	23[b]	2[b]	<1[b]
D-Lyxose	85	15		
D-Ribose	82	18		
D-Xylose	80	18		3
D-Glucose	66	14		20
	62[b]	14[b]	2[b]	22[b]

[a]Values were determined by ^{1}H-n.m.r. integration and are accurate to ±1%. No entry means that form was not observed. [b]Values determined by ^{13}C-n.m.r.

TABLE V

PROTON-PROTON COUPLING CONSTANTS FOR ALDOPENTOSE OXIMES IN ^2H_2O

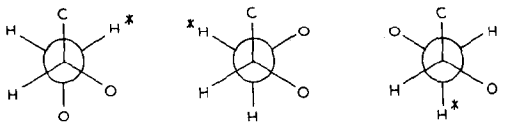
Oxime	*Coupled protons (J in Hz)*[a]					
	1,2	*2,3*	*3,4*	*4,5*	*4,5'*	*5,5'*
1 (*E*)-D-Arabinose	5.9	2.9	8.4	2.9	6.1	−11.8
(*Z*)-D-Arabinose	5.7	2.4	8.7	2.6	6.1	−11.9
2 (*E*)-D-Lyxose	7.0	7.6	2.6	5.2	7.1	−11.5
(*Z*)-D-Lyxose	6.8	6.9	3.2	4.8	7.2	[b]
3 (*E*)-D-Ribose	7.3	4.5	7.7	4.2	[b]	−13.1
(*Z*)-D-Ribose	6.2	3.7	8.0	2.9	6.2	−11.7
4 (*E*)-D-Xylose	6.6	6.0	3.5	4.5	6.9	−11.6
(*Z*)-D-Xylose	6.0	5.1	4.2	4.6	6.8	−11.6

[a]Values are accurate to ±0.2 Hz. [b]Not determined because of resonance overlap.

clearly evident from $^3J_{3,4E} \cong {}^3J_{3,4Z} > 8$ Hz. These two important couplings indicate that each isomer adopts an extended zigzag arrangement as shown in Fig. 3. The assignment of an extended planar conformation to the *E* form is in agreement with the results of an earlier study[8].

Other conformations of (*E*)- and (*Z*)-arabinose oxime contribute very little to the total population. Inspection of models shows that other rotamers about C-2–C-3 or C-3–C-4 would lead to increased parallel interactions or would be inconsistent with coupling data.

By using the ^3J values tabulated in Fig. 4 (ref. 15) and the observed values in Table V it was possible to calculate the distribution of hydroxymethyl rotamers. This was accomplished by equating the observed values for $J_{4,5}$ and $J_{4,5'}$ (Table V) to the



	O_e	O_g	O_t
$^3J_{H,H}$	3.1	2.8	10.7
$^3J_{H,H^*}$	10.7	0.9	5.0

Fig. 4. The rotamers[15] (O_e, O_g, O_t) of the hydroxymethyl group in a polyol, with their corresponding coupling constants in Hz. The derivation of the symbols is: O_e, oxygen extends the carbon chain; O_g, oxygens *gauche*; and O_t, oxygens *trans*.

sum of the products of the ^3J and its amount (x) for each conformer and knowing that $\Sigma x = 100$. It was then possible to calculate the percent distribution by solving a three by three matrix for each rotamer (O_e, O_g, O_t)*. The distribution for the hydroxymethyl group in (*E*)-D-arabinose oxime is very similar to that for the C-5 hydroxymethyl group of D-arabinitol[15]. The O_e (53%) and O_g (47%) forms are approximately equally populated. Given the similarity between $^3J_{4,5}$ and $^3J_{4,5'}$ for the *Z* and *E* forms the *Z* form is expected to have a comparable rotamer distribution.

Lyxose oxime. The (*E*)-D-lyxose oxime assumes predominantly the fully extended zigzag conformation. The $^3J_{2,3E}$ and $^3J_{3,4E}$ values 7.6 and 2.6 Hz, respectively, clearly indicate an *anti* disposition for H-2*E* and H-3*E* and a *gauche* relationship between H-3*E* and H-4*E*. The $^3J_{1,2E}$ coupling is large (7.0 Hz), indicating a dihedral angle of 120° between H-1*E* and H-2*E*, which means that the C=N moiety is in the same plane as the extended carbon chain.

The *Z* isomer also assumes predominantly the extended planar zigzag conformation. However the magnitudes of $^3J_{2,3Z}$ and $^3J_{3,4Z}$ compared to those for the *E* form may indicate a small twist of the C-2–C-3 bond to avoid a 1,3 interaction between O-2 and *N*-OH.

The calculated distribution of the hydroxymethyl rotamers in (*E*)-lyxose oxime is 52% O_e, 20% O_g, and 28% O_t. It is surprising that the O_g state is populated at all, albeit to a small extent, because of the 1,3 interaction that arises between O-3 and O-5 in this conformation. (*Z*)-Lyxose oxime has a hydroxymethyl-rotamer distribution of 55% O_e, 22% O_g, and 23% O_t.

Ribose oxime. Unlike arabinose and lyxose oximes, ribose oxime does not adopt the planar zigzag conformation because of the unfavorable 1,3 parallel interaction between O-2 and O-3 in the extended form. Instead the *E* and *Z* isomers essentially adopt a sickle conformation in which H-2 and H-3 are *gauche*, as is indicated by the $^3J_{2,3}$ values ($^3J_{2,3E}$ = 4.5 Hz and $^3J_{2,3Z}$ = 3.7 Hz). The zigzag form

*See Fig. 4 for definitions.

would give rise to a large value for $^3J_{2,3}$ due to the *anti* arrangement in this conformation. The coupling constants do support a $_2G^-$ (sickle) conformation[21] generated from the zigzag form by clockwise rotation about C-2–C-3.

The distribution calculated for the hydroxymethyl group of the *Z* form indicates that O_e and O_g rotamers are approximately equally represented at 54 and 46% respectively. These values are similar to those for arabinose oxime, discussed above. The distribution for the *E* form was not calculated because $^3J_{4,5E}$ was not determined, owing to resonance overlap.

Xylose oxime. As is evident from the similarity of their coupling constants, (*E*)- and (*Z*)-xylose oximes adopt very similar conformations. In order to avoid a parallel 1,3 interaction between O-2 and O-4 in the extended zigzag arrangement, a rotamer state in which C-2–C-3 twists to allow H-2 and H-3 to become nearly antiparallel (Fig. 3) is probably extensively populated. In this form ($_2G^-$) H-3 and H-4 are *gauche*.

In addition to the $_2G^-$ sickle form, the observed couplings are also consistent with a "U" conformation, that is a $_2G^-$ sickle plus a C-3–C-4 twist ($_4G^-$). This state would involve an unfavorable parallel interaction between C-1 and C-5 and is probably not populated.

The hydroxymethyl-rotamer distributions for (*E*)- and (*Z*)-D-xylose oxime are similar. The O_e form predominates in both isomers (53 and 52%, respectively). The O_g and O_t rotamers are present to the extent of 27 and 20%, respectively, in the *E* form, and 28 and 20% in the *Z* form.

SUMMARY

This report has demonstrated that the differences in n.m.r. chemical shifts between *E* and *Z* aldopentose oximes are most significant at H-1, H-2, and C-2. The magnitudes of the chemical shift differences are large enough to differentiate the isomers. In addition to chemical shift differences, examination of the $^3J_{H1,H2}$, $^1J_{C1,H1}$ and $^1J_{C1,C2}$ values is useful in assigning signals to specific isomeric forms.

The detection of cyclic forms in arabinose and xylose oximes supplies evidence for the possible involvement of these forms in the mutarotation reaction.

Evidence has been presented that the aldopentose oximes adopt planar zigzag arrangements unless this produces unfavorable 1,3-interactions.

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