Table III

Material	Mol. wt. found	Concentration of solution, g. substance in g. $CHCl_3$
A	613.0	1.1759–22.0973
	768.8	1.7813–22.0090
D	601.6	1.0264–24.3599
	727.7	2.4065–21.1223
E	665.2	2.2251–21.9102
	683.3	1.3468–24.1594

5.0 g. dissolved in 14 g. of acetonitrile was used. No reaction between the solvents and materials B to E occurred during the determinations, as evidenced by ^{31}P n.m.r. measurements. Material A was decomposed partly in methyl acetate as well as in acetonitrile. No other suitable solvents for material A could be found.

Determinations by means of an osmometer failed; entirely unsatisfactory data were obtained, probably resulting from some hydrolysis of the very small amount of substance which is used during the determinations.

N.m.r. Measurements. All the phosphorus n.m.r. measurements were made with the Varian V-4300-C spectrometer operating at 24.6 Mc./sec., in conjunction with an apparatus for "continuous averaging."[21]

The curves were cut out and weighed for quantitative analysis. The chemical shifts 16, 29, and 42 for P_t, P_m, and P_b are identical with those published in earlier papers[9,10] (compared to 85% phosphoric acid as external standard). The proton n.m.r. measurements were made with the Varian A-60 spectrometer.

Calculation of the Ratio of the Compounds II, III, IV or III, IV, V in the Products from the Ratio of the N.m.r. Peaks of P_b, P_m, P_t. To illustrate the manner by which the relative amounts of the various components, in mole per cent, were determined from the n.m.r. spectra, we give a sample calculation. In mixture B, for example

$$P_m + P_t + P_b = \Sigma P_B$$

where P_i refers to the area under the ith peak and is proportional to the number of P_i atoms; material B is composed of compounds II, IV, and V; P_m occurs in II, IV, and V; P_t occurs in IV and V; P_b occurs in IV only; in IV, $P_b = P_{tIV}$ and $P_{mIV} = P_{tIV} + P_b$; in V, $P_{tV} = P_{mV}$ and $P_{tV} = \Sigma P_t - P_{tIV}$.

Experimentally $P_b/\Sigma P_B = 9.8\%$; $P_m/\Sigma P_B = 78.7\%$, and $P_t/\Sigma P_B = 11.5\%$. Therefore

$$IV = P_b + P_{tIV} + P_{mIV} = 9.8 + 9.8 + 19.6 = 39.2\%$$

$$V = 2(\Sigma P_t - P_{tIV}) = 2(11.5 - 9.8) = 3.4\%$$

$$III = \Sigma P_m - P_{mIV} - P_{mV} = 78.7 - 19.6 - 1.7 = 57.4\%$$

Acknowledgment. We wish to thank the Deutsche Akademische Austauschdienst, Bad Godesberg, Germany, for awarding a fellowship to one of us (G. B.).

The Structure of Sugar Osazones[1]

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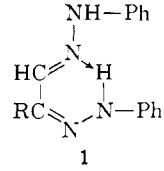
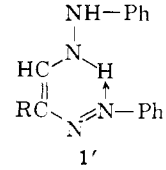
Contribution from the Institut de Chimie des Substances Naturelles, Gif-sur-Yvette, Centre National de la Recherche Scientifique, Paris, France.
Received September 17, 1964

The open-chain chelate structure of sugar osazones, first proposed by Fieser and Fieser, is confirmed now by n.m.r. spectral data. A long-range, spin–spin coupling between the C-1 proton and the nonchelated NH proton was observed, which is a decisive proof in favor of the **1** *and* **1′** *chelate structures. Additional support came from deuteration and high-resolution n.m.r. spectroscopy (100 Mc.) using the double resonance method. A quasi-aromatic structural formula is advanced.*

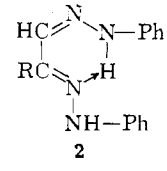
The structure of sugar osazones and related compounds was controversial for a long time. On theoretical grounds Fieser and Fieser[2] proposed two alternate chelate structures **1** and **2**, these being stabilized by their ability to exist in the tautomeric forms **1′** and **2′**.



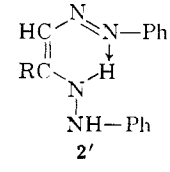
1



1′



2



2′

The first chemical evidence supporting the open-chain chelate structure was advanced by Mester,[3a] who also favored[3-5] structure **1**. Additional support

(1) Paper presented at the International Carbohydrate Symposium, July 13–17, 1964, Münster (Westfallen), Germany.

(2) L. F. Fieser and M. Fieser, "Organic Chemistry," D. C. Health and Co., Boston, Mass., 1944, p. 353.

(3) (a) L. Mester, *J. Am. Chem. Soc.*, 77, 4301 (1955); (b) L. Mester and A. Major, *ibid.*, **79**, 3232 (1957).

(4) B. Jambor and L. Mester, *Acta Chim. Acad. Sci. Hung.*, **9**, 485 (1956).

(5) L. Mester and F. Weygand, *Bull. soc. chim. France*, 350 (1960).

(21) M. P. Klein and G. W. Barton, Jr., *Rev. Sci. Instr.*, **34**, 754 (1963).

Table I. Nuclear Magnetic Resonance Spectral Data (p.p.m.)

Compd.	In dimethyl sulfoxide			In deuteriopyridine		
	N-H (chelated)	N-H	C-1-H	N-H (chelated)	N-H	C-1-H
3 Dehydro-D-glucose phenylosazone	12.45	9.35	...	12.95	9.61	...
4 Dehydro-D-glucose phenylosazone acetate	12.48	9.55	...	12.90	10.05	...
5 D-Glucose phenylosazone	12.20	10.66	7.89	12.65	11.20	8.68
6 D-Galactose phenylosazone acetate	12.20	10.80	7.73	12.86	11.49	8.05
7 D-Glycerosazone	12.05	10.70	7.79	12.63	11.27	8.23
8 D-Galactose phenylhydrazone acetate	...	10.12	[a]	...	11.00	7.58
9 Glyoxal bisphenylhydrazone	...	10.33	7.69	...	11.10	8.12

[a] Signal included in the benzene peaks.

came from X-ray data presented by Bjamer, Dahm, Furberg and Petersen,[6a] and also from complete oxidation of sugars by 1-methylphenylhydrazine.[6b]

The recently published work of Wolfrom, Fraenkel, Lineback, and Komitsky,[7] on the basis of the n.m.r. spectra of acetylated sugar osazones, supports the chelate structure **2**. Structure **1** however is now known to be the correct one according to the evidence presented in this paper.

The evidence for the chemical shift of the C-1 proton and the protons bonded to nitrogen in sugar osazones, dehydroosazones, and a number of related compounds in dimethyl sulfoxide and deuteriopyridine is given in Table I.

In each of the compounds (**3** to **7**) a signal corresponding to a chelated N-H proton is present between 12 and 13 p.p.m., but it is absent in **8**, the aldehydo phenylhydrazone structure of which compound has been proved,[8,9] and also in the symmetric bisphenylhydrazone **9**.

The nonchelated imino proton signal of **8** at 11 p.p.m. in deuteriopyridine (at 10.12 p.p.m. in dimethyl sulfoxide) is also present in the compounds **3** to **7**. A strong signal in the same region corresponding by integration to two protons was found in **9**. Furthermore a signal in the 7- to 8-p.p.m. region, corresponding to the C-1 proton, is present in the spectra of the compounds **5** to **9**, but it is absent in the cyclic compounds[10] **3** and **4**.

The identity of the signals corresponding to the NH protons in dehydro-D-glucosazone with signals in the spectra of sugar osazones suggests a great similarity in the chelate structure of the two types of compounds.

Since the axial position of the C-3 hydroxyl has been proved in dehydro-D-glucosazone,[10] the chelation cannot be located between the C-2 phenylhydrazine residue and the C-3 hydroxyl as was proposed by Henseke[11] for the sugar osazones. The possibility of such a chelation in sugar osazones was excluded also by X-ray spectroscopy.[6a,12] Thus the chelation must be located between the two phenylhydrazine residues in the dehydroosazones as well in the sugar osazones according to the chelated structures proposed by Fieser and Fieser.

A more exact deliniation of these chelate structures has been made possible by exchange of the hydrogens bonded to nitrogen with deuterium oxide in deuteriochloroform.

In deuteriochloroform (Table II) the signal of the free imino proton is located between 7 and 8 p.p.m. and disappears easily on shaking with deuterium oxide. The signal at 12 to 13 p.p.m., corresponding to the proton involved in the chelation, disappears somewhat less easily on deuteration, because shaking and heating are needed. The signal of the C-1 proton is located at 7.56 p.p.m. in compounds **6** and **11**, while in the spectra of compounds **7** and **10** it is overlapped by the signals of the aromatic rings. In compound **4** there is no C-1 proton.

Table II. Nuclear Magnetic Resonance Data (p.p.m.) in Deuteriochloroform

	N-H (chelated)	N-H	C-1-H
4 Dehydro-D-glucose phenylosazone acetate	12.50	7.97	...
6 D-Galactose phenylosazone acetate	12.34	7.89	7.54
7 D-Glycerosazone	12.16	7.78	[a]
10 D-Glucose 1-methyl-phenyl-2-phenylosazone acetate	12.54	...	[a]
11 D-Arabinose phenylosazone acetate	12.42	7.88	7.56

[a] Signal included in the benzene peaks.

The fact that the substitution of the α-imino hydrogen of the C-1 phenylhydrazine residue with a methyl group in compound **8** is without noteworthy influence on the position of the signal corresponding to the chelated NH group, while the signal of the nonchelated NH group disappears proves that the position of the nonchelated imino group in the sugar osazones is the same as the position of the methyl group in the 1-methylphenyl-2-phenylosazones (Figure 1), which is a chemically well defined position.[3,13] This fact supports structures **1** and **1'** rather than structures **2** and **2'**.

(6) (a) K. Bjamer, S. Dahm, S. Furberg, and C. S. Petersen, *Acta Chem. Scand.*, **17**, 559 (1963); (b) O. L. Chapman, W. J. Welstead, Jr., T. J. Murphy, and R. W. King, *J. Am. Chem. Soc.*, **86**, 732 (1964).

(7) M. L. Wolfrom, G. Fraenkel, D. R. Lineback, and F. Komitsky, *J. Org. Chem.*, **29**, 457 (1964).

(8) M. L. Wolfrom and C. C. Christman, *J. Am. Chem. Soc.*, **53**, 3413 (1931).

(9) L. Mester and A. Major, *ibid.*, 77, 4297 (1955).

(10) L. Mester and E. Moczar, *J. Org. Chem.*, **29**, 247 (1964).

(11) G. Henseke and H.-J. Binte, *Chimia* (Aarau), **12**, 103 (1958).

(12) S. Furberg, Oslo, private communication.

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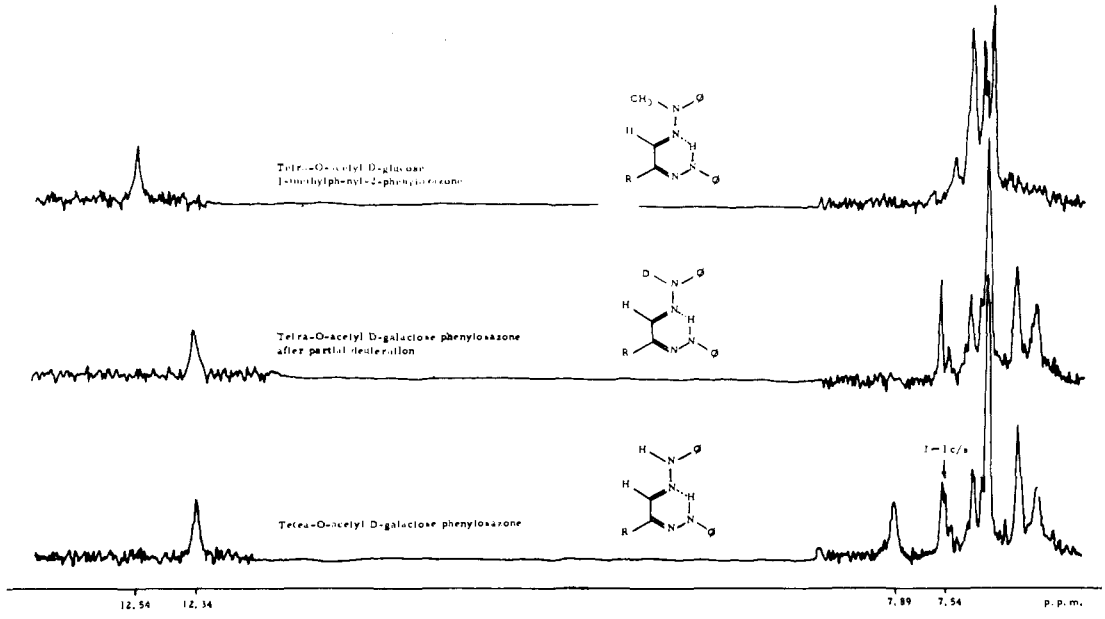


Figure 1. N.m.r. spectra (60 Mc., $CDCl_3$) of tetra-O-acetyl-D-galactose phenylosazone.

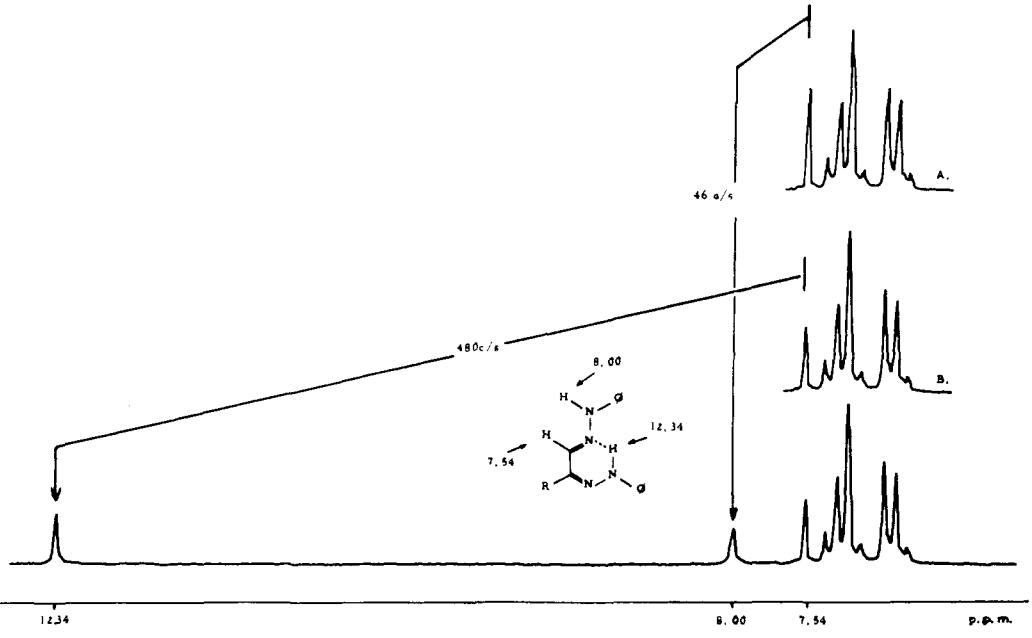


Figure 2. High-resolution n.m.r. spectrum (100 Mc., $CDCl_3$) of tetra-O-acetyl-D-galactose phenylosazone. Decoupling of the C-1 proton (7.54 p.p.m.): A. decoupling figure by irradiation of the nonchelated N–H proton (8.00 p.p.m.); B. decoupling showing no coupling with the chelated N–H proton (12.34 p.p.m.).

Moreover, a long-range spin–spin coupling between the C-1 proton and the nonchelated NH proton was observed, which is a decisive proof in favor of the structures **1** and **1′**. The weak splitting ($J \sim 1$ c.p.s.) of the C-1 proton at 7.56 p.p.m. in compounds **6** and **11** disappears during exchange of the nonchelated NH proton by deuterium oxide, giving place to a singular but more accentuated peak (Figure 1).

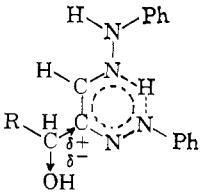
High-resolution n.m.r. spectroscopy (100 Mc.) using the double resonance method (Figure 2) also confirmed that the C-1 proton is coupled with the nonchelated NH proton at 8.0 p.p.m. and not with the chelated NH proton at 12.34 p.p.m.

A similar long-range spin–spin coupling between the C-1 proton and the α-imino proton was reported in the *syn* isomers of aldehyde 2,4-dinitrophenylhydrazones.[14] The position of the C-1 proton and the α-imino proton in these compounds and in the **1** and **1′** forms of the sugar osazones is very similar. A similar coupling between the C-1 proton and the distant free NH proton in the **2** and **2′** forms of the sugar osazones is highly improbable. Thus, evidence presented in this communication favors structures **1** and **1′** of the chelated structures proposed by Fieser and Fieser for sugar osazones.

However on account of the behavior of the sugar osazones and considering their ultraviolet spectral data,[3] it seems to be probable that the sugar osazones

(14) G. J. Karabatsos, B. L. Shapiro, F. M. Vane, J. S. Fleming, and J. S. Ratka, *J. Am. Chem. Soc.*, **85**, 2784 (1963).

are stabilized neither in the **1** nor in the **1′** form, but they are present in a quasiaromatic structure between the resonance limit forms **1** and **1′**, as represented by the following structure:



This structure is supported by X-ray data.[6a,12] The electron density projection shows that the six-membered chelate ring is approximately planar and also essentially coplanar with the two benzene rings. Furthermore, their bond angles lie in the neighborhood of 120°. This is what should be expected in an aromatic system.

The quasiaromatic nature of the chelate structure was also substantiated by polarographic analysis.[4] The stabilization energy of the chelated sugar phenylosazones was found to be about 10 kcal./mole higher, than for the nonchelated sugar methylphenylosazones. This value is much higher than the usual chelation energy.

Besides, the proposed structure may explain the sharp difference between the C-1 and C-2 phenylhydrazone groups in almost all their reactions, such as methylation,[15] osotriazole formation,[16] etc., as well as the privileged position[17–19] of the C-3 hydroxyl in the sugar osazones. This is due to the electron-attractive effect of the quasiaromatic chelate system.

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Experimental

N.m.r. Spectra. The n.m.r. spectra of the compounds reported in this communication were determined at 60 Mc. with tetramethylsilane as an internal reference on an A-60 Varian Associates spectrometer, Palo Alto, Calif.

High-resolution n.m.r. spectrum at HR 100 Mc. of tetra-O-acetyl-D-galactose phenylosazone and decoupling with the double resonance method was determined by Dr. A. Melera, Service Center of the Varian A. G., Zurich, Switzerland.

All the compounds used had melting points reported in the literature.[20–27]

Deuteration. Deuteration of the nonchelated imino group was effected by shaking the deuteriochloroform solution of the acetylated osazones with deuterium oxide at room temperature for a few minutes. The deuteration of the imino group involved in the chelation was achieved by shaking the deuteriochloroform solution with deuterium oxide in a fused glass tube and by heating in a water bath for 10 to 30 min.

Acknowledgment. We would like to express our appreciation to Professor M.-M. Janot (Paris) for his suggestion, and to Mrs. M. Mester and Mrs. L. Allais for their assistance.

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(21) E. Fischer, *ibid.*, **17**, 579 (1884).
(22) M. L. Wolfrom, M. Konigsberg, and S. Soltzberg, *J. Am. Chem. Soc.*, **58**, 490 (1936).
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Conformations of the Furanose Ring in Nucleic Acids and Other Carbohydrate Derivatives in the Solid State[1]

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Contribution from the Department of Biological Structure, University of Washington, Seattle, Washington 98105. *Received July 6, 1964*

Conformations of the furanose ring in nucleic acids and other carbohydrate derivatives arrived at from X-ray and neutron diffraction data are presented. The puckering in the furanose ring, involving the C-2′ or C-3′ atom, results in four conformeric possibilities: C-2′-endo, C-3′-exo, C-3′-endo, and C-2′-exo; their differences and similarities are discussed. The puckering when described as a twist of the C-2′–C-3′ bond relative to the plane defined by C-1′, O-1′, and C-4′ falls into the following classes: C-2′-endo–C-3′-exo, C-3′-endo–C-2′-exo, C-3′-endo–C-2′-endo, and C-2′-exo–C-3′-exo. The reactions of some cis and trans 1,2-glycols in "mobile" and "rigid" furanose systems are correlated with the projected valency angles formed by the hydroxyl groups. The influence of puckering on furanoside molecular parameters is discussed. The molecular parameters presented will be of considerable help in constructing accurate models of nucleic acids. Presence of an "equatorial" hydroxyl group on the out-of-plane carbon atom leads to rehybridization of the carbon atom orbitals, as seen by the shortening of the C–OH bond length and the widening of the C–C–OH bond angle, with a resulting change in the C–H bond character. It is noted that the interaction of the C-5′ protons with the ring protons is different for the three favored orientations of the C-5′–O-5′ bond.

(1) This work was supported by U. S. Public Health Service Grant AM 3288 of the National Institutes of Health.