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Studies on the Polymerization of Acrolein Oxime. XVII.[†] The Structure of the β-Form of the Bicyclic Trimer from Methacrylaldehyde Oxime

Tadatoshi OTA,* Seizo MASUDA, Hitoshi TANAKA, Yasuo INAZAWA, and Masaru KIDO[††]
Department of Applied Chemistry, Faculty of Engineering, Tokushima University,
Minamijosanjima-cho, Tokushima 770
[††]*Tokushima Research Institute, Ōtsuka Pharmaceutical Co. Ltd., Kawauchi-cho, Tokushima 771-01*

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The thermal oligomerization of methacrylaldehyde oxime leads to 2,4,7-trimethylperhydroisoxazolo[2,3-*a*]pyridine-2,7-dicarbaldehyde dioxime (**1**). The β-form of **1** was separated, and its crystal structure was determined by X-ray analysis. It is monoclinic with space group $P2_1/c$, $a=13.274(11)$, $b=8.652(7)$, $c=11.618(14)$ Å, $\beta=96.73(8)°$, and $Z=4$. The molecules are linked by two N···O hydrogen bonds, with the N(13)···O(14) and N(8)···O(18) distance of 2.824(5) and 2.897(5) Å respectively.

In the course of a study of the thermal polymerization of α,β-unsaturated aldehyde and ketone oximes, which have a vinylic double-bond conjugated with a hydroxyiminomethyl group, it has been found that methacrylaldehyde oxime (MAOM) and 3-methyl-3-buten-2-one oxime preferentially give a bicyclic trimer and a dimer respectively.[1,2] The bicyclic trimer from MAOM, 2,4,7-trimethylperhydroisoxazolo[2,3-*a*]pyridine-2,7-dicarbaldehyde dioxime (**1**), is isomeric. In our previous paper,[3] the crystal structure of the α-form of **1** was determined by means of X-ray diffraction; the chemical structure of the β-form was assumed on the basis of the spectrometrical data because of the very low yield and the failure to crystallize.

The present paper will describe the separation of the β-form and its X-ray structure analysis.

Experimental

Oligomerization of MAOM. Methacrylaldehyde was prepared by the Mannich reaction of propionaldehyde and formaldehyde,[4] and then oximated with hydroxylamine hydrochloride according to the procedure of Mowry.[5] The oligomerization of MAOM was carried out at 80 °C for 100 h in an ampoule. After the unreacted MAOM had been removed under reduced pressure, the residue was poured into a large amount of ether to precipitate the α-form of **1**. The precipitates were filtered off, and then the ether solution was concentrated and subjected to a large amount of hexane so that a yellow powder containing seven or more compounds was precipitated. The β-form was separated from the yellow powder by preparative TLC on silica gel in chloroform-ethyl acetate (7: 1) and recrystallized form its methanol solution. Colorless columnar crystals with the melting point of 192 °C (decomp). IR: 3325 (ν_{OH}), 1640 ($\nu_{C=N}$), 1380 (δ_{CH3}), and 930 cm^{-1} (ν_{NO}). MS *m/e* (relative intensity): 225 (M$^+$, 15), 240 (100), and 211 (38). ^{1}H-NMR (DMSO-d_6): $\delta=$ 10.67 (1H, s, OH), 10.55 (1H, s, OH), 7.31 (1H, s, CH=N), 7.21 1H, s, CH=N), 3.00 (1H, broad m, H(9), $J_{9.4}=4$ Hz), 2.25 (1H, t, H(3), $J_{3.3}=11$, $J_{3,9}=11$ Hz), 2.08 (1H, broad m, H(4)), 1.89 (1H, q, H(3), $J_{3,9}=7$ Hz), 1,75 (2H, broad d, H(6)), 1.39 (2H, broad m, H(5)), 1.29 (3H, s. CH$_3$), 1.20 (3H, s, CH$_3$), and 0.94 (3H, d, CH$_3$, $J_{10,4}=7$ Hz).

X-Ray Measurements. A crystal $0.4\times0.4\times0.1$ mm^3 in size was used for the X-ray measurements. The unit-cell dimensions were determined precisely by the least-squares fit of 2θ values of 16 reflections measured on a Syntex R-3 automated four-circle diffractometer with graphite-monochromated Mo $K\alpha$ radiation. The crystal data are as follows;[**] $C_{12}H_{21}N_3O_3$, M. W.=255.32, monoclinic, space group $P2_1/c$, $a=13.274(11)$, $b=8.652(7)$, $c=11.618(14)$ Å, $\beta=96.73(8)°$, $U=1325$ Å^3, $Z=4$, $D_x=1.28$ g cm^{-3}, μ(Mo $K\alpha$)$=1.0$ cm^{-1}.

The reflections within the range of $2\theta<45°$ were collected by the use of an ω-scan mode. The intensities of three reference reflections were measured periodically; they showed no significant fluctuation during the data collection. A total of 1743 independent reflections were collected, among which 1214 reflections with $I\geqq1.96\sigma(I)$ were used for structure refinement. The intensities were corrected for Lorentz and polarization effects, but not for absorption.

Structure Determination and Refinement. The structure was solved by the direct method using the MULTAN program.[6] The atomic parameters were refined by the block-diagonal least-suqares method. The function minimized was $\Sigma w(|F_o|-|F_c|)^2$, where w was fixed as unity for non-zero reflections. The final value of R was 0.063. All the calculations were carried out on a NOVA 3 computer connected to the diffractometer, using the Syntex XTL programs. The atomic scattering factors were taken from the "International Tables for X-Ray Crystallography."[7]

Other Measurements. The ^{1}H-NMR spectra were recorded on a JEOL JNM-FX200 spectrometer (200 MHz), and the ^{13}C-NMR spectra, on a Hitachi R-42 spectrometer (22.6 MHz). The mass spectra were taken on a Shimadzu LKB-9000 mass spectrometer.

Results and Discussion

The atomic parameters, bond distances, and bond angles are listed in Tables 1—3 respectively.[8] Figure 1 shows a perspective drawing of the β-form of **1** and numbering scheme of the atoms. The six-membered ring has a chair form, while the five-membered ring, which is in a half-chair form, is fused to the six-membered ring through two equatorial-type bonds. The two rings are approximately coplanar to each other. The methyl group at the C(4) carbon is axial, while the methyl and hydroxyiminomethyl groups at the C(7) carbon are axial and equatorial respectively. In addition, the

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[†] Part XVI: T. Ota, S. Masuda, H. Tanaka, and M. Kido, *Bull. Chem. Soc. Jpn.*, **55**, 171 (1982).

[**] There is a printing error in one of our published papers, *Bull. Chem. Soc. Jpn.*, **53**, 3240 (1980). The correct space group of the α-form of **1** is $P2_1/c$.

TABLE 1. ATOMIC COORDINATES, MULTIPLIED BY 10^4 FOR NON-HYDROGEN ATOMS AND BY 10^3 FOR HYDROGEN ATOMS, WITH ESTIMATED STANDARD DEVIATIONS IN PARENTHESES

Atom	x	y	z	B_{eq}/Å^2 a)	Atom	x	y	z	B/Å^2
O(1)	7912(2)	2646(4)	2844(3)	3.6	H(31)	925(3)	178(5)	470(3)	10(9)
O(14)	6136(3)	−580(5)	−58(3)	5.0	H(32)	890(3)	329(5)	546(3)	52(11)
O(18)	11032(2)	3784(4)	2233(3)	4.4	H(4)	750(3)	83(5)	620(3)	44(11)
N(8)	7644(3)	1221(5)	3405(3)	2.5	H(51)	628(3)	−147(6)	546(4)	84(15)
N(13)	5914(3)	162(5)	967(3)	3.8	H(52)	599(3)	64(5)	509(3)	40(11)
N(17)	10217(3)	4294(5)	2827(3)	3.5	H(61)	562(3)	−88(5)	328(4)	66(13)
C(2)	8745(4)	3372(6)	3625(4)	3.1	H(62)	678(3)	−174(5)	356(3)	52(12)
C(3)	8772(3)	2465(6)	4746(4)	3.5	H(9)	721(3)	276(5)	477(3)	55(11)
C(4)	7521(4)	303(6)	5398(4)	3.3	H(101)	891(3)	−73(5)	582(3)	72(13)
C(5)	6458(4)	−266(7)	4968(5)	4.2	H(102)	838(3)	−169(5)	470(3)	52(11)
C(6)	6336(4)	−605(6)	3654(4)	4.0	H(103)	808(3)	−196(5)	608(3)	98(14)
C(7)	6600(3)	788(6)	2912(4)	2.7	H(111)	603(3)	302(4)	258(3)	42(10)
C(9)	7737(3)	1691(6)	4630(4)	2.7	H(112)	572(3)	253(5)	365(3)	69(13)
C(10)	8291(4)	−1009(7)	5467(5)	4.4	H(113)	514(3)	166(5)	250(3)	41(10)
C(11)	5826(4)	2091(7)	2912(5)	4.3	H(12)	733(3)	−4(5)	146(4)	49(12)
C(12)	6672(3)	165(6)	1711(4)	3.4	H(151)	782(3)	510(5)	423(3)	52(11)
C(15)	8468(4)	5038(6)	3785(5)	4.0	H(152)	901(3)	561(5)	433(4)	62(13)
C(16)	9677(3)	3144(6)	3024(4)	3.0	H(153)	838(3)	571(4)	319(3)	36(10)
					H(16)	981(3)	201(5)	268(3)	38(10)
					HO(14)	549(3)	−59(5)	−52(4)	82(15)
					HO(18)	1137(3)	464(5)	222(4)	45(12)

a) Equivalent isotropic thermal parameters were calculated from the refined anisotropic thermal parameters.[9]

TABLE 2. BOND DISTANCES, WITH ESTIMATED STANDARD DEVIATIONS IN PARENTHESES

Bond distance	l/Å	Bond distance	l/Å
O(1)–N(8)	1.461(5)	O(1)–C(2)	1.478(6)
O(14)–N(13)	1.414(5)	O(18)–N(17)	1.419(5)
N(8)–C(9)	1.471(6)	N(8)–C(7)	1.484(6)
N(13)–C(12)	1.248(6)	N(17)–C(16)	1.263(6)
C(2)–C(3)	1.517(7)	C(2)–C(15)	1.505(7)
C(2)–C(16)	1.504(7)	C(3)–C(9)	1.520(7)
C(4)–C(5)	1.523(7)	C(4)–C(9)	1.543(7)
C(4)–C(10)	1.522(8)	C(5)–C(6)	1.544(8)
C(6)–C(7)	1.545(7)	C(7)–C(11)	1.525(7)
C(7)–C(12)	1.509(7)		

methyl and hydroxyiminomethyl groups at the C(2) carbon are on the same side of the average coplane of the rings, and on the opposite side, respectively, with the methyl group at the C(7) carbon.

In the previous paper,[3] the chemical structure of the β-form has been spectrometrically assumed. However. the results of X-ray analysis show that the crystal structure of the β-form differs from the estimated one and is the same as that of the α-form, except that the methyl groups at the C(4) and C(7) carbons are axial. This finding is also supported by the ^{1}H-NMR spectra. The C(4) proton resonates at 2.08 ppm with the coupling constant $J_{4,9}=4$ Hz; *i.e.*, the H(4) hydrogen is equatorial, and the C(4) carbon is thus axial. On the basis of these results, a schematic drawing of **1** is shown in Fig. 2.

The mass spectra of both α- and β-forms have a molecular ion peak at m/e 255, and they give similar fragmentation patterns except for the base ion peaks,

TABLE 3. BOND ANGLES, WITH ESTIMATED STANDARD DEVIATIONS IN PARENTHESES

Bond angle	ϕ/°	Bond angle	ϕ/°
N(8)–O(1)–C(2)	106.9(3)	O(1)–N(8)–C(9)	101.6(3)
O(1)–N(8)–C(7)	108.1(3)	C(9)–N(8)–C(7)	114.3(4)
O(14)–N(13)–C(12)	110.7(4)	O(18)–N(17)–C(16)	108.9(4)
O(1)–C(2)–C(3)	104.4(4)	O(1)–C(2)–C(15)	108.0(4)
O(1)–C(2)–C(16)	104.6(4)	C(3)–C(2)–C(15)	111.7(4)
C(3)–C(2)–C(16)	113.1(4)	C(15)–C(2)–C(16)	114.2(4)
C(2)–C(3)–C(9)	102.8(4)	C(5)–C(4)–C(9)	106.8(4)
C(9)–C(4)–C(10)	116.2(4)	C(5)–C(4)–C(10)	111.5(4)
C(4)–C(5)–C(6)	111.8(4)	C(5)–C(6)–C(7)	113.5(4)
N(8)–C(7)–C(6)	104.1(4)	N(8)–C(7)–C(11)	114.3(4)
N(8)–C(7)–C(12)	106.8(4)	C(6)–C(7)–C(11)	112.3(4)
C(6)–C(7)–C(12)	106.3(4)	C(11)–C(7)–C(12)	112.3(4)
N(8)–C(9)–C(3)	100.4(4)	N(8)–C(9)–C(4)	110.1(4)
C(3)–C(9)–C(4)	121.2(4)	N(13)–C(12)–C(7)	120.5(4)
N(17)–C(16)–C(2)	119.8(4)		

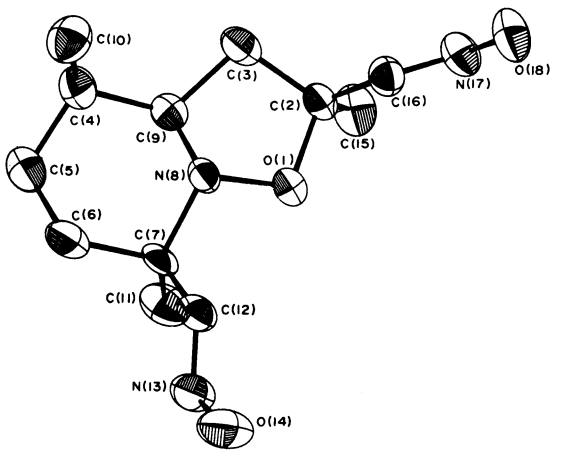
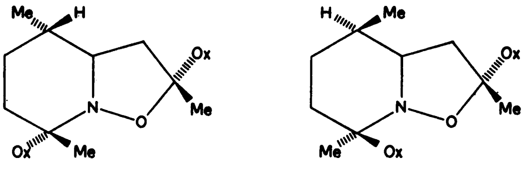


Fig. 1. A perspective drawing of the β-form molecule and the numbering scheme. Thermal ellipsoids of non-hydrogen atoms were drawn by ORTEP.[10]



β-form α -form

Fig. 2. Schematic drawing of isomeric **1**.

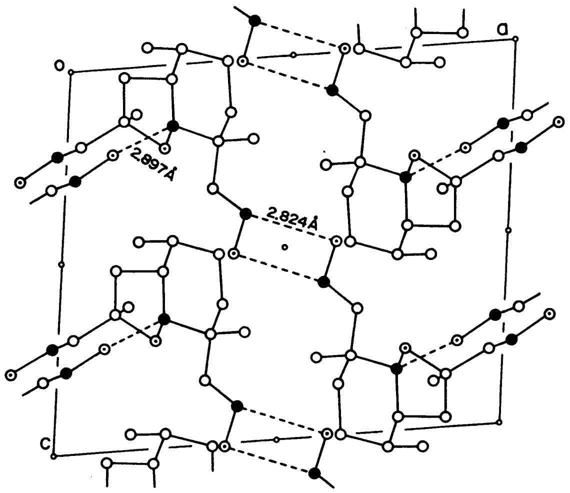


Fig. 3. Orthogonal projection of the crystal structure viewed along the b axis.
○: Carbon ●: nitrogen, ⊙: oxygen.

which appear at *m/e* 211 (the lost of the hydroxyiminomethyl radical) for the former and at *m/e* 240 (the lost of the methyl radical) for the latter. These observations show that the axial substituent at the C(7) carbon is more liable to be eliminated than the equatorial one because of steric hindrance.

There are characteristic bond angles which are common to the α- and β-forms. The axial conformation of the substituents at the C(4) and C(7) atoms always gives larger substituent-related interbond angles than do the equatorial ones; *i.e.*, the C(5)–C(4)–C(10), C(9)–C(4)–C(10), C(5)–C(4)–H(4), C(9)–C(4)–H(4), N(8)–C(7)–C(11), C(6)–C(7)–C(11), N(8)–C(9)–C(12), and C(6)–C(7)–C(12) angles are larger in the axial position of C(10), C(11), C(12), and H(4) atoms than those in the equatorial ones.

Figure 3 shows the crystal structure of the β-form viewed along the b axis. There are two intermolecular hydrogen bonds; the N(13)···H(14)–O(14) $(1-x, -y, -z)$ and N(8)···H(18)–O(18) $(2-x, 0.5+y, 0.5-z)$, with angles of 158(4) and 156(4)° respectively. The bond distances of N(13)···O(14), N(13)···H(14), O(14)–H(14), N(8)···O(18), N(8)···H(18), and O(18)–H(18) are 2.824(5), 1.91(5), 0.96(5), 2.897(5), 2.08(4), and 0.87(4) Å respectively.

The ^{13}C-NMR peak assignments are shown in Table 4, together with those of the α-form. These peak position were assigned by using the off-resonance technique and on the basis of the molecular structure determined by X-ray analysis. The signals assignable to the C(10) and C(11) carbons in the β-form and the C(12) carbon in the α-form are shifted to higher magnetic fields due to the axial position of the methyl and hydroxyiminomethyl groups. Since the carbon at the 4-position in a piperidine ring is known to resonate in a higher field than that at the 3-position,[11] the peak assignment of three methylene carbons seems to be reasonable.

TABLE 4. ASSIGNMENT OF ^{13}C-NMR PEAKS OF **1**

Carbon	Multiplicity	Peak position/ppm from TMS	
		α-Form	β-Form
–C(10)H$_3$	q	27.42	12.59
–C(11)H$_3$	q	18.79	10.86
–C(15)H$_3$	q	24.42	24.38
$>$C(3)H$_2$	t	30.16	30.78
$>$C(5)H$_2$	t	35.28	27.15
$>$C(6)H$_2$	t	44.41	41.75
$\succ$C(4)H	d	36.44	30.47
$\succ$C(9)H	d	65.99	59.13
$\succ$C(2)–O	s	77.62	77.16
$\succ$C(7)–N	s	60.75	61.41
–C(12)H=N	d	150.40	156.54
–C(16)H=N	d	154.44	154.41

s: Singlet, d: doublet, t: triplet, q: quartet.

Reference

1) T. Ota, E. Matsushima, and S. Masuda, *Polym. J.*, **11**, 909 (1979).

2) T. Ota, S. Masuda, and H. Tanaka, *Chem. Lett.*, **1981**, 411.

3) T. Ota, S. Masuda, and M. Kido, *Bull. Chem. Soc. Jpn.*, **53**, 3240 (1980).

4) A. F. Maclean and B. G. Frenz, U. S. Patent, 2848499 (1958); *Chem. Abstr.*, **53**, 3062a (1959).

5) D. J. Mowry and R. R. Morner, *J. Am. Chem. Soc.*, **69**, 1831 (1949).

6) G. Germain, P. Main, and M. M. Woolfson, *Acta Crystallogr., Sect. A*, **27**, 368 (1971).

7) "International Tables for X-Ray Crystallography,"

Kynoch Press, Birmingham (1974), Vol. IV, p. 71.

8) The F_o-F_c table, thermal parameters, bond distances, and bond angles related to hydrogen atoms are kept as Document No. 8302 at the Chemical Society of Japan.

9) A. Ouchi, M. Shimol, T. Takeuchi, and H. Saito, *Bull. Chem. Soc. Jpn.*, **54**, 2290 (1981).

10) C. K. Johnson, *ORTEP*, ORNL-3794, Oak Ridge National Laboratory, Tennessee (1965).

11) I. Morishima, K. Okada, T. Yonezawa, and K. Goto, *J. Am. Chem. Soc.*, **93**, 3922 (1971).