

On Formaldehyde *O*-Methyloxime and its Trimer 1,3,5-Trimethoxyhexahydro-1,3,5-triazine

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Formaldehyde *O*-methyloxime has been obtained from the reaction between methoxyamine and formaldehyde and also by methylation of formaldehyde oxime.

The compound has been found to be monomeric on the basis of its mass spectrum and ^1H NMR spectra in D_2O . However, in acid solution, the trimerization product, 1,3,5-trimethoxyhexahydro-1,3,5-triazine, is formed. In contrast to trimeric formaldehyde oxime, this compound could be extracted from the neutralized solution. Its mass spectrum showed a molecular ion with m/e 177, in agreement with its formulation as a trimer.

In another paper,¹ we have shown by NMR spectroscopic measurements that an equilibrium exists in aqueous solution between monomeric formaldehyde oxime, $\text{H}_2\text{C}=\text{NOH}$, and its trimer, 1,3,5-trihydroxyhexahydro-1,3,5-triazine. An investigation of formaldehyde *O*-methyloxime has shown that this compound is, similarly, able to trimerize and moreover, it has been possible to isolate the trimer by extraction of the solution and to determine its molecular weight by mass spectrometry.

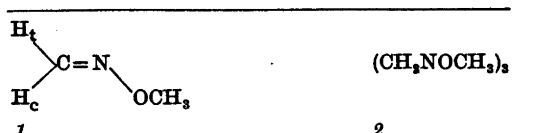
The NMR spectrum of formaldehyde *O*-methyloxime has been studied earlier by Shapiro *et al.*^{2,3} but the compound was not isolated. It was extracted with various solvents and the solutions used directly for the NMR spectroscopic measurements. Furthermore, the possibility of polymerization was disregarded.

We have isolated formaldehyde *O*-methyloxime as a lowboiling liquid by distillation of an aqueous solution of methoxyamine and formaldehyde. Its identity was proved by mass spectrometry and by infrared spectroscopy,

the IR spectrum being similar to that of gaseous monomeric formaldehyde oxime.⁴ It was also formed in low yield by methylation of formaldehyde oxime with dimethyl sulfate or methyl iodide in strongly basic solution; in ether solution formaldehyde oxime reacts with methyl iodide to form *N*-methyl-1,3,5-trihydroxyhexahydro-1,3,5-triazinium iodide.¹

The ^1H NMR spectrum of formaldehyde *O*-methyloxime in CCl_4 shows two doublets at δ 6.31 and 6.92, due to the CH_2 protons, with a coupling constant $J=9.0$ Hz; these values agree well with those reported by Shapiro *et al.*^{2,3} The CH_3 protons give rise to a singlet at δ 3.84. In D_2O , the CH_2 signals appear at δ 6.62 and 7.09 (10 °C); further, the spectrum was unchanged after an interval of several days (Table 1). However, when the solution was acidified, two new signals appeared at δ 4.44 and 3.61 in a ratio of 2:3. These signals are assigned to the CH_2 and CH_3 groups, respectively, of 1,3,5-trimethoxyhexahydro-1,3,5-triazine, the trimer of formaldehyde *O*-methyloxime. Thus, it may be concluded that hydrogen ions catalyze the trimerization. This process is reversible in acid media with the equilibrium being shifted towards the monomer at higher pH and higher temperature. A solution of equimolecular amounts of formaldehyde and methoxyammonium chloride in D_2O at $\text{pH} \approx 1$ immediately showed only the signals of the trimer at δ 3.86 and 3.61 (39 °C) but on neutralization the signals of the monomer appeared. However, no change in the ratio of the concentrations of the two compounds was observed when an acid solu-

Table 1. ¹H NMR spectra (δ values) of formaldehyde O-methyloxime (1) and its trimer, 1,3,5-trimethoxyhexahydro-1,3,5-triazine (2).

Solvent	°C	pH	Chemical shifts					% trimer ^e
			1			2		
								
			H _t	H _c	CH ₃	CH ₂	CH ₃	
CDCl ₃	39					3.94	3.54	
CCl ₄	39		6.31	6.92 ^a	3.84	3.77	3.48	0
CF ₃ COOD	39		6.48	7.04	3.88	3.73	3.56	25
D ₂ O	39	7.00				4.12	3.52 ^c	
D ₂ O	10	6.25	6.62	7.09 ^b	3.87			0
D ₂ O	10	1.20	6.62	7.09 ^b	3.87	4.44	3.61	26 ^d
D ₂ O	39	1.20	6.62	7.09	3.88	—	3.63	2.4

^a $J(\text{H}_c\text{H}_t) = 9.0$ Hz. ^b $J(\text{H}_c\text{H}_t) = 7.1$ Hz. ^c No transformation to the monomer occurred in a solution of the trimer in pure water. ^d Unchanged on addition of NaOD to pH = 12 and heating to 39°C, but the signals of the trimer shifted to 4.12 and 3.53 (cf. Ref. 1). ^e % trimer in solution of monomer.

tion of the two compounds in equilibrium was made alkaline (Table 1). The trimer was isolated by neutralizing an acid solution of the trimer, and extracting with ether. On evaporation of the ether, the trimer was obtained as a white crystalline substance which could be recrystallized from pentane. Its ¹H NMR spectrum in D₂O at 39°C showed two singlets at δ 4.12 and 3.52 (ratio of integrals 2:3) in agreement with the values found for the trimer in the solution containing both monomer and trimer at 39°C and pH = 12. Its mass spectrum showed a molecular ion with m/e 177, in agreement with its formulation as a trimer.

The polymerization of formaldehyde oxime seems to be unique among the aldehyde oximes. We have investigated, by NMR spectroscopy, the possibility that acid would catalyze trimerization of acetaldehyde oxime but there was no indication of this. Its ¹H NMR spectrum was studied in D₂O and CD₃OD solution at various temperatures and pH values, but the spectra showed only the signals of the monomer, studied earlier by Karabatsos and Taller.⁵

This behaviour may be explained in terms of steric hindrance in the case of the higher homologues, and an increased carbonium ion character in formaldehyde oxime.

EXPERIMENTAL

The NMR spectral data (Table 1) were obtained at 60 MHz with a Varian A-60A spectrometer. (CH₃)₃SiCH₂CH₂CH₂SO₃Na (DSS) was used as internal standard in D₂O; TMS was used for the measurements in CCl₄ and CDCl₃. The IR spectra were recorded with a Perkin-Elmer Model 337 grating spectrophotometer. The mass spectra were obtained with an A.E.I. MS 902 mass spectrometer. For the pH measurements, a pH meter 22 from Radiometer, Copenhagen, was used.

Formaldehyde O-methyloxime. Methoxyamine⁶ (2.4 g), placed in a distillation flask, was cooled in acetone-dry ice, and 40% aqueous formaldehyde (3.5 ml) was added. The mixture was heated slowly, the receiver being cooled in acetone-dry ice. A colourless liquid passed over and was collected until the thermometer of the column had reached 25°C. Yield 2.55 g (87%). The b.p. of the pure compound was 12–12.5°C/760 mmHg.

The use of free methoxyamine is not essential in this preparation. Formaldehyde O-methyloxime was obtained in 78% yield by the addition of sodium hydroxide and formaldehyde to a solution of methoxyammonium chloride (4.2 g) in water (20 ml).

The same compound was also obtained, but in low yields (4–22%) and in an impure state, by methylation of an aqueous solution of triformoxime hydrochloride with dimethyl sulfate and sodium hydroxide, or by methylation of formaldehyde oxime in 1-butanol with methyl iodide and sodium 1-butanolate. IR

(CCl₄ and CS₂): 3005 m (ν CH₃), 2978 m (ν_{as} CH₃), 2946 s (ν_{as} CH₃), 2908 m (ν_s CH₃), 2832 m, 1900 w (2 \times ω CH₃), 1873 w (ν NO + ν OCH₃), 1641 w (ν C=N), 1604 m (ν OCH₃ + δ CNO), 1460 m (δ CH₂), 1432 w (δ_{as} CH₃), 1373 w (δ_s CH₃), 1208 w, 1151 w (ρ CH₃), 1055 vs (ν OCH₃), 950 s (ω CH₃), 823 s (ν NO), 562 m (δ CNO).

The assignments have been made on the basis of those made for formaldehyde oxime by Califano and Lüttke.⁴

MS: The mass spectrum was obtained at 70 eV with an ion source temperature of 150 °C and using the glass inlet system; (*m/e* (% rel. int.): 60 (2.4), 59 (100, [M]), 58 (5.3), 44 (34.4, [CH₂NO⁺]), 43 (2.8), 31 (24.8, [CH₃O⁺]), 30 (5.1), 29 (11.4), 28 (29.1), 27 (8.1).

1,3,5-Trimethoxyhexahydro-1,3,5-triazine.

Methoxymmonium chloride⁶ (2.1 g) was dissolved in 3 ml of water, the solution was cooled at ca. 10 °C and 1.75 ml of aqueous formaldehyde (40 %) was added. An exothermic reaction occurred (the temperature rose to ca. 30 °C). The solution was cooled and adjusted to pH=7 with 2 M NaOH (to complete the reaction with formaldehyde) and was left for 10 min in ice. Then 4 ml of 4 M hydrochloric acid was added and the solution was cooled in ice for 2 h. The solution was neutralized, saturated with NaCl and extracted with 3 \times 25 ml of ether. The dried (MgSO₄) ether solution on evaporation gave 340 mg of white crystals (43 %), which were recrystallized from pentane, m.p. 137–138 °C. Anal. C₆H₁₂N₃O₃: C, H, N.

The trimer was also obtained when hydrochloric acid was added to an aqueous solution of monomeric formaldehyde *O*-methyloxime and the neutralized solution was extracted with ether but yields were lower because a solution of the monomer in equilibrium with the trimer contains only ca. 25 % of the trimer.

The molecular weight of this compound follows from its mass spectrum: The mass spectrum was obtained at 70 eV with an ion source temperature below 90 °C and using the direct inlet system; *m/e* (% rel. int.): 177 (2.2, [M]), 119 (5.4), 118 (100), 86 (2.4), 66 (2.8), 60 (47.3, [CH₂NHOCH₃⁺]), 59 (90, [CH₂NOCH₃⁺]), 58 (7.9), 44 (12.5), 42 (20.7, [CH₂NCH₃⁺]), 41 (2.0). The base peak *m/e* 118 is assigned to the ionized dimer.

IR (KBr): 2985 s, 2940 s, 2895 s, 2865 s, 2813 s, 1460 s, 1450 m, 1417 w, 1362 s, 1327 w, 1300 w, 1179 m, 1151 m, 1047 vs, 1013 w, 990 w sh, 978 m, 950 s sh, 943 s, 925 s, 905 m, 862 w, 841 w, 771 s, 740 s, 644 w, 609 w, 562 s, 548 w sh, 516 w, 471 m.

Acetaldehyde oxime was prepared according to Wieland.⁷ After two distillations it still contained some paraldehyde, according to NMR spectroscopy and gas chromatography. It was rendered analytically pure by cooling until it had crystallized, followed by recrystallization from hexane. M.p. 46–47 °C. (lit.⁷ 47).

¹H NMR spectra. Weighed amounts of the compounds were dissolved in D₂O and the solutions adjusted to the desired pH value by the addition of 1 M DCl in D₂O or 1 M NaOD in D₂O.

The results obtained with formaldehyde *O*-methyloxime are shown in Table 1. The NMR spectrum of acetaldehyde oxime was identical to that reported by Karabatsos and Taller,⁸ there being no indication of the formation of a cyclic trimer, either on addition of acid or on cooling a CD₃OD solution to –55 °C.

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