The Synthesis and Spectra of α,β-Unsaturated Aliphatic Azoxy Compounds[1-3]

BERNARD T. GILLIS AND JACK D. HAGARTY

Chemistry Department, Duquesne University, Pittsburgh, Pennsylvania

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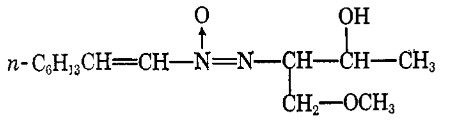
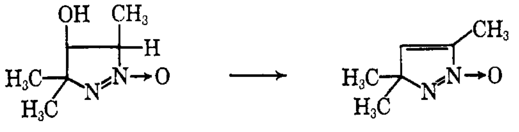
Per acid oxidation of α,β-unsaturated aliphatic azo compounds has resulted in the formation of the corresponding α,β-unsaturated aliphatic azoxy compounds. The position of the oxygen atom in the azoxy group has been found to depend on alkyl substitution. Thus, 2-(methylazo)propene (IV) and 1-(methylazo)cyclohexene (VI) gave 2-(methyl-NNO-azoxy)propene (V) and 1-(methyl-NNO-azoxy)cyclohexene (VII), respectively. Oxidation of 2-(methylazo)isobutene (VIII) and 2-(methylazo)-3-methyl-2-butene (X) resulted in 1-(methyl-NON-azoxy)-isobutene (IX) and 1-(methyl-NON-azoxy)-3-methyl-2-butene in mixture, respectively. Ultraviolet, infrared, and nmr spectral data support the structure assignments given for these compounds.

Although the chemistry of aliphatic azoxy compounds in general has been little studied, the α,β-unsaturated compounds have seldom been encountered. The only known examples include the naturally occurring α,β-unsaturated aliphatic azoxy compound elaiomycin (I)[4] and a cyclic unsaturated azoxy compound (III) which was obtained by Freeman[5] by base-catalyzed dehydration of II.



$n\text{-}C_6H_{13}CH{=}CH{-}\overset{\overset{O}{\uparrow}}{N}{=}N{-}\underset{CH_2{-}OCH_3}{CH}{-}\overset{OH}{CH}{-}CH_3$

I



II III

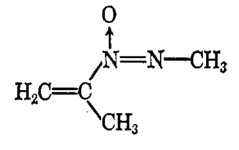
The determination of the position of the oxygen atom of unsymmetrical aliphatic azoxy compounds by chemical means has been difficult.[6] Freeman,[7] however, used nmr very successfully to solve this problem. He discovered that both alkyl groups of an unsymmetrical azoxy compound undergo a reduction in electron density compared with the corresponding azo compounds but that the group attached to the oxidized nitrogen undergoes the greater reduction of electron density. This is reflected by a greater downfield shift in the nmr spectra when compared to the downfield shift of the protons of the group attached to the unoxidized nitrogen.

A convenient synthesis of α,β-unsaturated aliphatic azoxy compounds was made possible when the corresponding unsaturated azo compounds became available in this laboratory.[8] Peracetic acid was chosen as the oxidant, chiefly owing to its availability. When an ether solution of 2-(methylazo)propene (IV) was treated with 1 equiv of commercial 40% peracetic acid, an exothermic reaction ensued. The yellow color of the azo compound slowly faded as the per acid was added. After neutralization of the acetic acid with sodium carbonate, drying, and removal of the ether, distillation furnished a 44% yield of the azoxy compound, 2-(methyl-NNO-azoxy)propene (V).

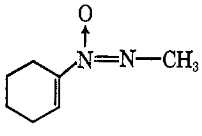
It was assumed that, with 1 equiv of per acid, oxidation would occur at the more electron rich of the two nitrogen atoms and that the carbon–carbon double bond would not be epoxidized. However, it was not known which nitrogen atom would be preferred.

The infrared spectrum of the oxidized compound showed the disappearance of the N=N band at 6.6 μ and the appearance of new intense peaks at 6.75 and 7.65 μ, characteristic of the azoxy group. The C=C stretching frequency, which occurred at 6.1 μ in the azo compound, was diminished in intensity and shifted to near 6.0 μ. No N—H or C=O absorptions were present. The ultraviolet spectrum showed an absorption maximum at 223 mμ (ε of 7690).

The nmr spectrum exhibited singlets at 2.2 (3 H), 3.2 (3 H), 5.1 (1 H), and 6.1 ppm (1 H). These values represent a shift of all peaks from those of the azo compound. In particular, the N-methyl proton peak is shifted considerably upfield. The fact that this peak is shifted upfield rather than downfield from the parent azo spectra indicates[7] that the azoxy oxygen does not reside on the nitrogen bearing the methyl group. This spectral data along with the elemental analysis support the assignment of structure V [2-(methyl-NNO-azoxy)propene] to the product.



V



VII

When 1-(methylazo)cyclohexene (VI) was treated with a 20% excess of 40% peracetic acid in ether as the solvent, the reaction was again rapid and exothermic. A work-up of the reaction similar to the previous oxidation furnished a 66% yield of the corresponding azoxy compound. Like V, the product showed strong absorptions in the infrared at 6.75 μ with the absence of the previous N=N absorption. Diminished C=C absorption near 6.0 μ was also evident. A single ultraviolet absorption maximum occurred at 233 mμ (ε 7460). The nmr spectrum of the product showed a peak in the vinyl region at 6.9 (1 H), an N-methyl peak at 3.2 ppm (3 H), and two complex multiplets in the methylene region (8 H). Again the shift of the N-methyl proton peak was upfield, which placed the oxygen atom on the nitrogen adjacent to the carbon–

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[2] Presented in part at the 150th National Meeting of the American Chemical Society, Atlantic City, N. J., 1965, Abstract of Papers, p 278.

[3] Abstracted in part from the Ph.D. dissertation of J. D. Hagarty, Duquesne University, 1966.

[4] C. L. Stevens, B. T. Gillis, and T. H. Haskell, *J. Am. Chem. Soc.*, **81**, 1435 (1959), and previous papers and references cited therein.

[5] J. P. Freeman, *J. Org. Chem.*, **27**, 2881 (1962).

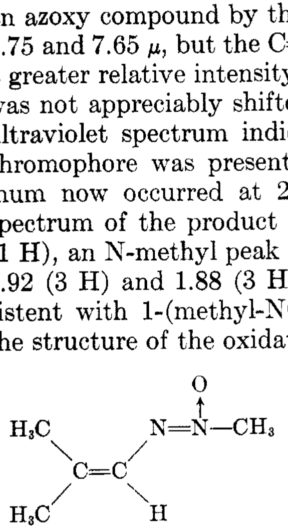
[6] B. T. Gillis and K. F. Schimmel, *ibid.*, **27**, 413 (1962).

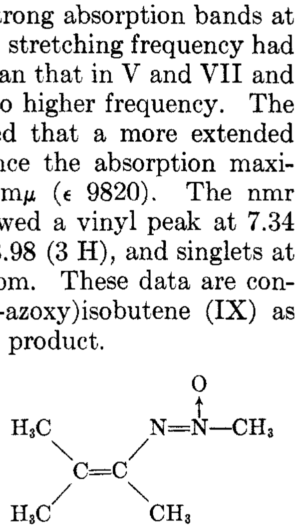
[7] J. P. Freeman, *ibid.*, **28**, 2508 (1963).

[8] B. T. Gillis and J. D. Hagarty, *J. Am. Chem. Soc.*, **87**, 4576 (1965).

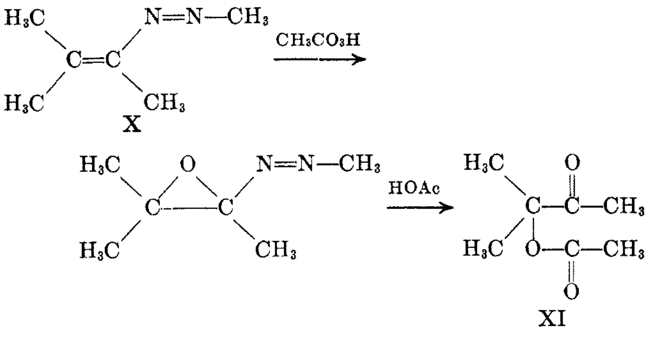
carbon double bond. This compound was thus 1-(methyl-NNO-azoxy)cyclohexene (VII).

Similarly, a colorless liquid with an odor similar to that of V and VII was obtained by oxidation of 1-(methylazo)isobutylene (VIII) with peracetic acid. The infrared spectrum of the product was indicative of an azoxy compound by the strong absorption bands at 6.75 and 7.65 μ, but the C=C stretching frequency had a greater relative intensity than that in V and VII and was not appreciably shifted to higher frequency. The ultraviolet spectrum indicated that a more extended chromophore was present since the absorption maximum now occurred at 286 mμ (ϵ 9820). The nmr spectrum of the product showed a vinyl peak at 7.34 (1 H), an N-methyl peak at 3.98 (3 H), and singlets at 1.92 (3 H) and 1.88 (3 H) ppm. These data are consistent with 1-(methyl-NON-azoxy)isobutene (IX) as the structure of the oxidation product.


IX


XII

When 2-(methylazo)-3-methyl-2-butene (X) was treated with peracetic acid under the same conditions which had been employed for the other azo compounds, no azoxy compound was isolated. The major product and only one obtained in pure form was a colorless liquid with an ester odor which was shown to be 3-acetoxy-3-methyl-2-butanone (XI). This product may arise as follows.



An alternate possible mechanism would involve formation of the azoxy compound followed by acetolysis, similar to acetolysis or hydrolysis of elaiomycin.[4]

A further attempt to obtain an azoxy compound from 2-(methylazo)-3-methyl-2-butene (X) was made using *m*-chloroperbenzoic acid as the oxidant. A mixture was obtained which eluded all attempts at separation. The ultraviolet spectrum of the mixture showed that the extended chromophore was present, as in IX. The infrared and nmr spectra of the product indicated that the azoxy compound XII was present.

Experimental Section[9]

2-(Methyl-NNO-azoxy)propene (V).—To 7.2 g (0.086 mole) of 2-(methylazo)propene (IV) in 100 ml of anhydrous ether was added 22 g (0.11 mole) of 40% peracetic acid.[10] The mixture was stirred and allowed to reflux slowly during the addition. After several hours, the acid was neutralized by adding solid sodium carbonate. Subsequent washings with 10% sodium carbonate removed the last traces of acid. The ether solution was dried over anhydrous magnesium sulfate. After filtration, the ether was removed by distillation. A distillation of the remaining liquid at reduced pressure yielded 3.8 g (44%) of V: bp 84–86° (150 mm), n^{25}_{D} 1.4660, $\lambda_{max}^{95\%\ EtOH}$ 223 mμ (ϵ 7690).

Anal. Calcd for $C_4H_8N_2O$: C, 47.96; H, 8.05; N, 28.00. Found: C, 48.06; H, 8.03; N, 27.88.

1-(Methyl-NNO-azoxy)cyclohexene (VII).—To 11.5 g (0.093 mole) of 1-(methylazo)cyclohexene (VI), n^{30}_{D} 1.4987, dissolved in 75 ml of ether was added 23 g (0.12 mole) of 40% peracetic acid.[10] The addition was carried out so as to maintain a rapid reflux. Stirring was carried out and continued for 1 hr after addition was completed. The acid was neutralized by adding solid sodium carbonate and then washing three times with a saturated solution of sodium carbonate. The ether was removed after drying over anhydrous magnesium sulfate and the remaining liquid was distilled to give 8.7 g (66%) of VII: bp 132–135° (2 mm), n^{30}_{D} 1.5045, $\lambda_{max}^{95\%\ EtOH}$ 233 mμ (ϵ 7460).

Anal. Calcd for $C_7H_{13}N_2O$: C, 59.59; H, 8.64; N, 20.00. Found: C, 59.76; H, 8.75; N, 19.98.

2-(Methyl-NON-azoxy)isobutene (IX).—To an ether solution of 8.3 g (0.085 mole) of 2-(methylazo)isobutene (VIII), n^{20}_{D} 1.4560, was added 21 g (0.105 mole) of 40% peracetic acid.[10] The mixture was stirred for 1 hr after addition was complete and the acid was neutralized with solid anhydrous sodium carbonate. Filtration, removal of the ether, and distillation at reduced pressure yielded 3.4 g (34%) of a colorless liquid, bp 82–84° (90 mm), n^{20}_{D} 1.5014, which was shown to be IX. An analytical sample was prepared by gas chromatography, which showed only one major peak. Spectral and analytical data were obtained on this sample: n^{25}_{D} 1.5215, $\lambda_{max}^{95\%\ EtOH}$ 286 mμ (ϵ 9820).

Anal. Calcd for $C_5H_{10}N_2O$: C, 52.59; H, 8.84; N, 24.54. Found: C, 52.45; H, 8.72; N, 24.69.

Reaction of 2-(Methylazo)-3-methyl-2-butene (X) with Peracetic Acid.—When 12 g (0.060 mole) of 40% peracetic acid[10] was added to 5.9 g (0.053 mole) of X dissolved in 100 ml of ether, a vigorous exothermic reaction ensued. The mixture was stirred for 2 hr after addition was complete. The acetic acid was neutralized by adding solid anhydrous sodium carbonate until no more carbon dioxide was evolved and then it was washed three times with 5% sodium bicarbonate solution. After drying over anhydrous magnesium sulfate, the ether was removed and the remaining liquid was vacuum distilled. A colorless, sweet-smelling liquid was obtained: bp 55–58° (2 mm), n^{25}_{D} 1.4339. The yield was 4.2 g (57%) of 3-acetoxy-3-methyl-2-butanone (XI). The compound exhibited no ultraviolet spectrum. Infrared showed 5.75 and 5.82 (C=O st) and 8.0 μ (CO st). Nmr showed singlets at 1.40 and 2.04 ppm in the ratio of 1:1. An analytical sample, n^{20}_{D} 1.4232, was obtained by gas chromatography.

Anal. Calcd for $C_7H_{12}O_3$: C, 58.31; H, 8.39. Found: C, 58.06; H, 8.43.

Reaction of 2-(Methylazo)-3-methyl-2-butene (X) with *m*-Chloroperbenzoic Acid.—To 5.4 g (0.05 mole) of X, n^{25}_{D} 1.4680, in 100 ml of anhydrous ether was added a saturated solution of 10.0 g (0.055 mole) of *m*-chloroperbenzoic acid in ether. The reaction was rapid and was moderated by cooling in a water bath. Stirring was continued for 1 hr after addition was complete. The solution was washed three times with saturated sodium carbonate solution and was dried over anhydrous sodium sulfate. The drying agent was filtered off and the ether was removed by distillation. Final distillation of the remaining liquid produced 0.9 g of unreacted X and 2.2 g (42%) of crude 2-(methyl-NON-azoxy)-3-methyl-2-butene (XII): n^{20}_{D} 1.4778; ultraviolet $\lambda_{max}^{95\%\ EtOH}$ 282 mμ (ϵ 2050), 227 mμ (ϵ 3360); infrared 6.7 and 7.6 (azoxy) and 6.1 μ (C=C st), lack of NH band but some C=O st impurity; nmr singlets of approximately equal intensity at 4.32, 1.85, 1.50, 1.42, and 1.23 ppm.

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[9] Boiling points and melting points are uncorrected. Microanalyses were performed by Alfred Bernhardt, Mülheim, Germany. The infrared spectra were measured with a Perkin-Elmer Model 137 double-beam spectrophotometer. The ultraviolet spectra were taken on a Beckman Model DB spectrophotometer and the nmr spectra were obtained on a Varian Model A-60 at 60 Mc with carbon tetrachloride as solvent and tetramethylsilane as an internal standard. Gas chromatography was performed on a Wilkens Autoprep Model A-700.

[10] Donated by the FMC Corp., Becco Division, Buffalo, N. Y.