

Cationic Cyclization Reactions of 6-Methylhept-5-en-2-one Oxime; X-Ray Crystal Structure of 3-Isopropylidene-2-methyl- Δ^1 -pyrroline

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Summary The heterolytic cleavage of the nitrogen–oxygen bond of 6-methylhept-5-en-2-one oxime under various conditions has led to two types of cationic cyclization reactions producing Δ^1 -pyrrolines whose structures have been proved by ^{13}C n.m.r. spectroscopy and X-ray crystallography.

WHEREAS the field of cationic cyclizations has borne much fruit in carbocycle synthesis,¹ heterocycle synthesis by cationic cyclization has been less fully investigated.² We now report the initial results of our investigation into the structure of cationic cyclization products arising from 6-methylhept-5-en-2-one oxime (**1**).

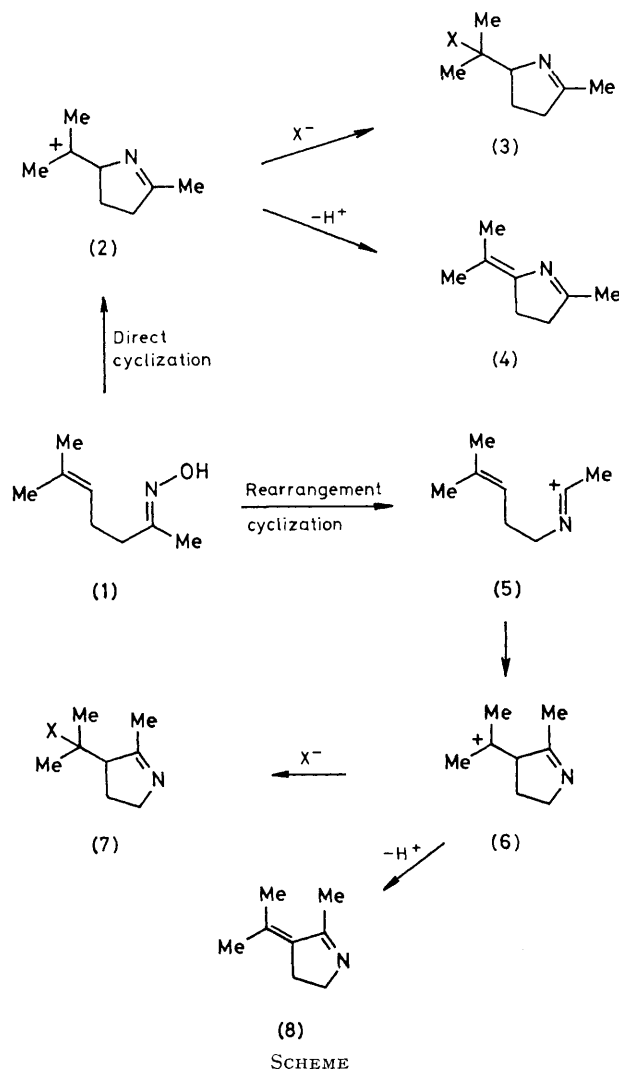
For this purpose, we define two possible modes of cyclization which might occur upon heterolysis of an oxime nitrogen–oxygen bond: the direct and rearrangement cyclizations (Scheme). The former [*e.g.* (**1**) \rightarrow (**2**)] would entail intramolecular olefin capture of a partially positive nitrogen³ formed by acid-catalysed cleavage, and would probably be concerted so as to avoid a discrete nitrenium ion intermediate. The latter process [*e.g.* (**1**) \rightarrow (**6**)] would occur *via* a nitrilium ion intermediate (**5**) formed by Beckmann rearrangement⁴ of the oxime.

Wagner-Jauregg and Roth reported⁵ that treatment of the oxime (**1**) with zinc dust in acetic acid produced a mixture of pyrrolines (**3**, X = OH or H) which must have arisen by the direct cyclization route. The structure of the reduced pyrroline (**3**, X = H) was confirmed by independent synthesis, but the structure of the alcohol (**3**, X = OH) was not. Because of the uniqueness of the reaction, and because we felt that the two possible pyrroline alcohols (**3** and **7**, X = OH) would have been indistinguishable by the methods of analysis used,⁵ we repeated the experiment. In our hands, no reduced product (**3** or **7**, X = H) was found. The only product isolated was the pyrroline (**3**, X = OAc) arising by the direct cyclization pathway. The fact that the acetate rather than the alcohol was obtained may be attributed to a careful work-up at 0 °C which avoided the use of the strongly basic conditions employed previously. That the product obtained is indeed (**3**) and not (**7**) is apparent from the off-resonance decoupled ^{13}C n.m.r. spectrum. Specifically, the multiplicities of the C-3 and C-5 pyrroline ring atom signals are definitive: the resonance of the carbon bearing nitrogen in both (**3**) and (**7**) should be downfield of the allylic ring carbon signal, and should be a doublet in (**3**) and a triplet in (**7**). A triplet at 39.1 p.p.m. and a doublet at 80.1 p.p.m. indicate structure (**3**) to be correct.

A wide variety of conditions and several substrates were investigated in unsuccessful attempts to improve the low yield for this reaction. Platinum (black) or tin in acetic acid catalysed the direct cyclization, but with no improvement in yield. Zerovalent metal catalysis suggests a surface-catalysed phenomenon, and this possibility is currently under investigation.

Under conditions of anhydrous aprotic acid catalysis (*e.g.*, P_2O_5 , CCl_4 , reflux), the oxime (**1**) will rearrange to a nitrilium ion, and in the absence of any external nucleophile will cyclize and lose a proton to form an isopropylidenepyrroline in 60–65% yield, as indicated by ^1H and ^{13}C n.m.r., i.r., and high-resolution mass spectroscopy. Because we were unable to distinguish between two possible structures (**4**) and (**8**) spectroscopically, we undertook a single crystal X-ray determination of the tetraphenylborate salt of the protonated compound.

Crystal data. $\text{C}_{35}\text{H}_{40}\text{BNO}$, $M = 502$, orthorhombic, space group $Pbca$, $a = 18.221(2)$, $b = 19.688(2)$, $c = 16.421(2)$ Å, $U = 5891(1)$ Å³, $Z = 8$, $F(000) = 2160$. The structure was



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solved by direct methods (MULTAN⁶) from data collected to $2\theta = 115^\circ$ on a Syntex P2₁ automated diffractometer using Ni-filtered Cu-*K* radiation ($\lambda = 1.5418 \text{ \AA}$). For the 2020 observed reflections and with anisotropic thermal parameters for nonhydrogen atoms $R = 0.078$. The asymmetric unit consists of the heterocyclic cation, a tetra-

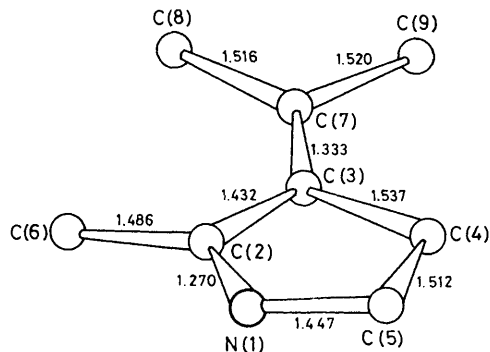


FIGURE. Structure of the Δ^4 -pyrroline (**8**) formed from (**1**). Bond distances are in Å.

† The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW. Any request should be accompanied by the full literature citation for this communication.

¹ Cf. S. W. Baldwin and J. C. Tomesch, *J. Org. Chem.*, 1980, **45**, 1455; W. S. Johnson, G. W. Daub, T. A. Lyle, and M. Niwa, *J. Am. Chem. Soc.*, 1980, **102**, 7800; P. T. Lansbury, *Acc. Chem. Res.*, 1972, **5**, 311.

² See however D. J. Hart, *J. Org. Chem.*, 1981, **46**, 367.

³ P. T. Lansbury in 'Nitrenes,' ed. W. Lwowski, Interscience, New York, 1970, ch. 11.

⁴ L. G. Donaruma and W. Z. Heldt, *Org. React.*, 1960, **11**, 1.

⁵ T. Wagner-Jauregg and M. Roth, *Helv. Chim. Acta*, 1962, **45**, 771.

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

phenylborate anion, and a molecule of acetone of solvation.†

The structure of the heterocycle (Figure) confirms that the isopropylidene-pyrroline (**8**) was formed. This is the first example to our knowledge of a nitrilium ion generated from an oxime capturing an aliphatic double bond to form a nitrogen heterocycle. Since an equilibrium mixture of geometrical isomers (*ca.* 70% *E* and 30% *Z*) of the starting oxime (**1**) was used, and since the rearrangement step is stereospecific, the *real* yield of the rearrangement cyclization is quite good. Experiments to manipulate the geometry of the oxime to increase the isolated yield of the pyrroline (**8**) are in progress.

Finally, during our studies on several oximes, we have in no case observed mixtures containing both types of products [*i.e.*, (**3**) or (**4**) and (**7**) or (**8**)]. Thus the two reaction pathways appear to be mutually exclusive.

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