

Reactions of Nitroalkenes with Ynamines; Synthesis of Stable Four-membered Cyclic Nitrones and X-Ray Crystal Structure of 2-(*NN*-Diethylcarbamoyl)-2,4-dimethyl-3-phenyl-2,3-dihydroazete 1-Oxide

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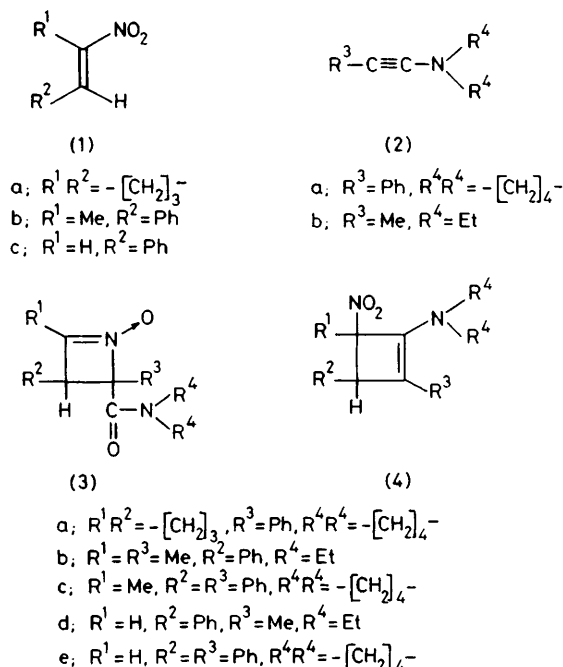
Summary 2,3-Dihydroazete 1-oxides (**3b—e**), the first examples of crystalline, 'stable,' four-membered cyclic nitrones, are formed by reaction of 1-nitroalkenes with ynamines, and other products are 3-nitrocyclobutenes; the structure of the cyclic nitron (**3b**) has been determined by X-ray crystallography.

CYCLOBUTENES are formed thermally under mild conditions either by reaction of electron-rich alkenes (*e.g.* enamines) with electron-deficient acetylenes [acetylene(di)carboxylic acid esters^{1,2} or 1-*t*-butyl-2-nitroacetylene³] or by reaction

of electron-deficient alkenes (*e.g.* 1-cyanoalkenes) with electron-rich acetylenes (ynamines^{4,5}). We describe here the reactions of 1-nitroalkenes and ynamines.

1-Nitrocyclopentene (**1a**)⁶ was treated with an equimolar amount of 1-phenyl-2-(pyrrolidin-1-yl)acetylene (**2a**) in light petroleum for 16 h at room temperature. A tan precipitate was filtered off,[†] and orange crystals (m.p. 80—81 °C; 40% yield) were obtained from the filtrate. This product was identified as the bicycloheptene (**4a**); ¹H n.m.r.: δ (CDCl₃) 3.65—3.45 (dd, 1H, 5-H); ¹³C n.m.r.: δ (CDCl₃) 94.3 (s, C-1), 51.5 (d, C-5) p.p.m.; i.r. (KBr): ν_{max} 1635 (C=C), 1525 and 1350 cm⁻¹ (NO₂).

[†] This product proved to be a 1:1 addition product (mass spectrum and elemental analyses), the structure of which is not yet elucidated.



The reaction of *E*-2-nitro-1-phenylpropene (**1b**)[†] with 1-diethylaminopropyne (**2b**) in the same way gave a white crystalline product, m.p. 126–128 °C (30% yield), the structure of which was determined by a single-crystal X-ray analysis. It surprisingly proved to be the cyclic nitrone (**3b**); ¹H n.m.r.: δ (CDCl₃) 3.93 (d, *J* 2 Hz, 1H, 3-H); ¹³C n.m.r.: δ (CDCl₃) 165.4 (s, C=O), 147.2 (s, C-4), 88.8 (s, C-2), and 54.7 (d, C-3) p.p.m.

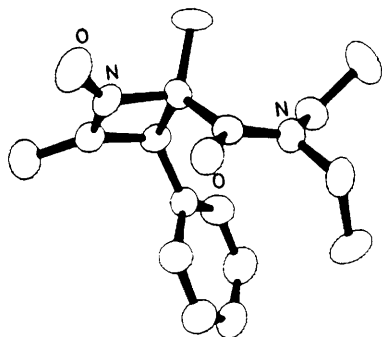


FIGURE. Structure of the cyclic nitrone (**3b**).

Crystal data: (**3b**), C₁₆H₂₂N₂O₂, monoclinic, space group *P*2₁/*c*, *a* = 9.902(3), *b* = 13.789(4), *c* = 11.176(3) Å, β = 101.06(3)°, *Z* = 4. 1848 reflections with *I* > σ(*I*) (counting statistics), measured using the ω-2θ scan tech-

[†] The *Z*-isomer of (**1b**) (D. B. Miller, P. W. Flanagan, and H. Shechter, *J. Org. Chem.*, 1976, **41**, 2112) reacted with (**2b**) to yield the 2,3-dihydro-azete 1-oxide (**3b**) with the same stereochemistry.

§ 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.

¶ Our results do not disprove an independent concerted [2 + 2] pathway to the 3-nitrocyclobutene.

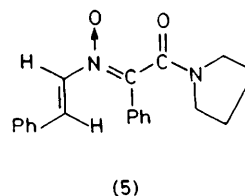
nique (3° < 2θ < 25°) on a Philips PW 1100 automatic diffractometer with graphite-monochromatized Mo-*K*_α radiation. The structure, which was solved by direct methods⁷ and refined in the usual way (anisotropic temperature factors for non-hydrogen atoms, isotropic for hydrogen) to a final weighted *R*-factor of 5.6%, is shown in the Figure.§

Similar cyclic nitrones were formed in reactions of the nitro-compound (**1b**) with (**2a**) and of (*E*)-1-nitro-2-phenylethene (**1c**) with (**2a**) and (**2b**) (see Table).

TABLE. Cyclic nitrones (**3**) from the reactions of the nitroalkenes (**1b**) and (**1c**) with the ynamines (**2a**) and (**2b**).

Nitro-compound	Ynamine	Nitrone	M.p. (t/°C)	% Yield
(1b)	(2b)	(3b)	126–128	30 ^a
(1b)	(2a)	(3c)	156–158	10
(1c)	(2b)	(3d)	118 (decomp.)	25 ^a
(1c)	(2a)	(3e) ^b	105 (decomp.)	35 ^c

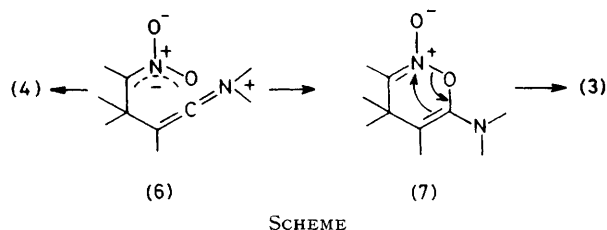
^a Work-up of the filtrate gave other 1:1 addition products (oils) the structure of which have not yet been fully elucidated; on the basis of ¹H n.m.r. and ¹³C n.m.r. spectra these products are most likely the 3-nitrocyclobutenes (**4**). ^b In solution (e.g. CHCl₃) (**3e**) isomerizes completely at room temperature to the non-cyclic nitrone (**5**), m.p. 128–130 °C; ¹H n.m.r. δ (CDCl₃) 7.92 and 7.68 (ABq, *J* 13 Hz, 2H, vinyl), comparable with data for the starting compound (**1c**); δ 8.05 and 7.63 (ABq, *J* 14 Hz, 2H, vinyl); ¹³C n.m.r. δ (CDCl₃) 162.5 (s, C=O) and 141.5 (s, C=N-O) p.p.m.; i.r. (KBr): ν_{max} 1645 vs, br (C=O and C=N→O) and 1435 cm⁻¹ (N-O). ^c A red product was isolated from the filtrate, m.p. 101–102 °C (31% yield), which proved to be the cyclobutene (**4e**); ¹H n.m.r.: δ (CDCl₃) 5.16 (s, 1H, 3-H) and 4.28 (s, 1H, 4-H); i.r.: (KBr) ν_{max} 1650 (C=C), 1535 and 1345 cm⁻¹ (NO₂).



This reaction provides the first synthesis of 'stable' well-characterized four-membered cyclic nitrones. Black *et al.*⁸ reported the formation of 3,3,4-trimethyl-2,3-dihydroazete 1-oxide by the base-catalysed cyclization of the corresponding γ-tosyloxyketoxime. The nitrone structure was assigned mainly on the basis of an i.r. absorption at 1627 cm⁻¹ (C=N→O).

The formation of two different types of products, cyclobutenes (**4**) and four-membered cyclic nitrones (**3**), can be accounted for by assuming that the first step involves a nucleophilic attack by the electron-rich ynamine at the 2-position of the nitroalkene to give a 1,4-dipolar intermediate (**6**). This intermediate can react further in two ways, either by formation of a second carbon-carbon bond to give the 3-nitrocyclobutene (**4**),¶ or by formation of a

carbon-oxygen bond to produce a cyclic nitronic ester (7) that is formally a [4 + 2] cycloadduct (Scheme).**



SCHEME

Participation of a 1-nitroalkene in [4 + 2] cycloaddition reactions as a 4 π -component is rare but not unique since it has recently been described by Pitacco and Valentin⁹ for

reactions with 4-*t*-butyl-1-(piperidin-1-yl)cyclohexene. The corresponding [4 + 2] cycloadduct, a cyclic nitronic ester, was isolated. In solution rapid equilibration of the nitronic ester with the 4-*t*-butyl-6-(2-nitroalkyl)-1-(piperidin-1-yl)-cyclohexene took place.

The nitronic esters (7) have hitherto not been isolated, however, because they can rearrange rapidly by cleavage of the weak N-O bond and formation of a 2,3-dihydroazete 1-oxide. Such a reaction has a striking analogy in the thermal isomerization of 5-alkoxy-isoxazoles to alkyl 2*H*-azirine-2-carboxylates, which represents a similar ring-contraction with simultaneous formation of a carbonyl group.¹⁰

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** The reaction described by Jäger and Viehe³ between a nitroacetylene and an ynamine might involve a similar 1,4-dipolar intermediate that reacts further *via* a [4 + 2] cycloadduct.

¹ R. Fuks and H. G. Viehe, in 'Chemistry of Acetylenes,' ed. H. G. Viehe, Marcel Dekker, New York, 1969, p. 425.

² D. N. Reinhoudt, *Adv. Heterocyclic Chem.*, 1977, **21**, 253.

³ V. Jäger and H. G. Viehe, *Angew. Chem.*, 1970, **82**, 836.

⁴ J. Ficini, A. Eman, and A. M. Touzin, *Tetrahedron Letters*, 1976, 679.

⁵ J. Ficini, J. d'Angelo, A. Eman, and A. M. Touzin, *Tetrahedron Letters*, 1976, 683.

⁶ E. J. Corey and H. Estreicher, *J. Amer. Chem. Soc.*, 1978, **100**, 6294.

⁷ G. Germain, P. Main, and M. M. Woolfson, *Acta Cryst.*, 1971, **A27**, 368.

⁸ D. St. C. Black, R. F. C. Brown, B. T. Dunstan, and S. Sternhell, *Tetrahedron Letters*, 1974, 4283.

⁹ G. Pitacco and E. Valentin, *Tetrahedron Letters*, 1978, 2339.

¹⁰ T. Nishiwaki, T. Kitamura, and A. Nakano, *Tetrahedron*, 1970, **26**, 453.