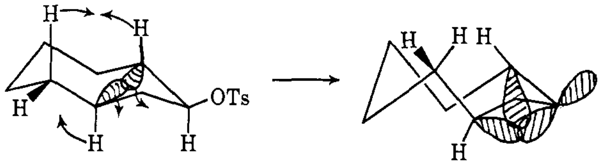
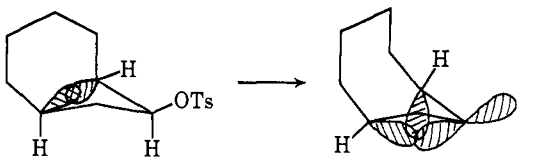
Using conditions which permitted the isolation of *trans*-2-cycloocten-1-ol from *exo*-bicyclo[5.1.0]oct-8-yl bromide (aqueous dioxane with calcium carbonate)[10] the solvolysis of IV was found to give *trans*-3-cycloocten-1-ol. This was identified by its rapid reaction with phenyl azide to give a triazoline. The *cis* isomer is quite unreactive toward this reagent.[11]

If one accepts the postulate that maximum boiling must be maintained during the reaction,[12] the observations are explicable.



The type of rotation shown above, which is required in order to give the bicyclo[5.1.0]oct-2-yl cation, is opposed by hydrogen–hydrogen repulsion, as well as carbon–carbon repulsion. On the other hand, a process leading to the *trans*-3-cycloocten-1-yl cation need not involve such interaction. Similar considerations apply to the reaction of II. The formation of the bicyclo[4.1.0]-heptane-7-methyl cation *via* the type of rotation described above would require a marked distortion of the cyclohexane ring. However, the process leading to the vinylcyclohexyl cation does not pose such difficulty.

The situation with I is quite different than that for IV. Here the rotation will relieve strain in the cyclohexane ring. In I, the ring is flattened by fusion onto a cyclobutane ring, and the rotation is in a direction to restore the normal conformation of the cyclohexane ring. Thus it is not unreasonable that the process will occur.



These ideas appear to correlate a variety of observations which have been made concerning the solvolyses of cyclobutyl derivatives. They will accommodate the difference in reactivity and mode of reaction which has been observed with the *cis*- and *trans*-3-substituted cyclobutyl derivatives[13] and also predict a specific stereochemistry for the ring opening to a homoallyl derivative. This will be discussed in detail at a later time.

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(10) G. H. Whiham and M. Wright, *Chem. Commun.*, 294 (1967).

(11) The use of phenyl azide was based on the observation that *trans*-cyclooctene reacts rapidly with this reagent (K. Ziegler and H. Wilms, *Ann.*, **567**, 1 (1950)) whereas *cis*-cyclooctene reacts only slowly (K. Alder and G. Stein, *ibid.*, **501**, 41 (1933). The triazoline was identified by its ultraviolet spectrum and mass spectrum, which were very similar to those for the adduct from *trans*-2-cycloocten-1-ol.

(12) This is, of course, the explanation used for the stereochemistry of the solvolytic ring opening of cyclopropyl derivatives: R. B. Woodward and R. Hoffmann, *J. Am. Chem. Soc.*, **87**, 395 (1965); C. H. DePuy, L. G. Schnack, and J. W. Hausser, *ibid.*, **88**, 3343 (1966); U. Schollkopf, K. Fellenberger, M. Patsch, P. von R. Schleyer, T. Su, and G. W. van Dine, *Tetrahedron Letters*, 3639 (1967).

(13) I. Lillien and R. A. Doughty, *ibid.*, 3953 (1967); I. Lillien, G. F. Reynolds, and L. Handloser, *ibid.*, 3475 (1968).

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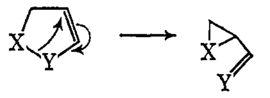
## Valence Rearrangement of Hetero Systems. The 4-Isoxazolines

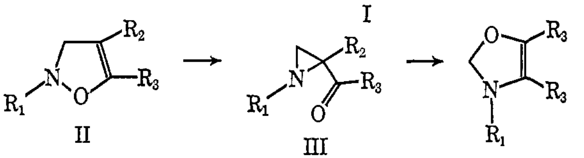
*Sir:*

When two hetero atoms of higher electronegativity than carbon, *e.g.*, nitrogen, oxygen, halogens, are linked together through a single bond, it is well known that such linkages are considerably weaker than similar bonds with carbon.[1] The origins of this effect are not at present clear, but repulsion between the necessarily higher nuclear charges and/or the nonbonded electron pairs may be responsible. Whatever its source, this effect was considered to be a potential driving force in the development of new synthetic procedures, *e.g.*, eq 1, where X and Y are atomic species of the types mentioned.[2] Accordingly we have examined the 4-isoxazolines (II), since they were readily available from nitrones and acetylenes, and have herein demonstrated the existence of the facile thermal valence rearrangements of 4-isoxazolines (II) to 2-acylaziridines (III) and subsequently to 4-oxazolines (IV).[3] The relative rates of the two steps are dependent on the various substituents $R_1$, $R_2$, and $R_3$, and so we have used a series of substituting functions to allow the isolation of the separate steps.

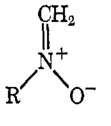


(1)

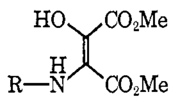
I



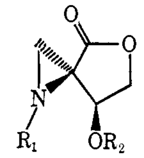
II III IV



V



VI



VII

Addition of *t*-butylmethylenenitrone[4] (V, R = *t*-butyl) to dimethyl acetylenedicarboxylate proceeded rapidly and quantitatively at 0° (nmr control) to the isoxazoline[5] II ($R_1$ = *t*-butyl; $R_2 = R_3 = CO_2Me$; $\lambda_{max}$ (ethanol) 289 m$\mu$ ($\epsilon$ 3260); $\nu_{max}$ (neat) 1760, 1715, 1660 cm$^{-1}$; nmr (carbon tetrachloride), $\tau$ 8.88 (9 H, singlet), 6.33 (3 H, singlet), 6.18 (3 H, singlet), 5.82 (2

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(1) Data on bond dissociation energies that have been determined, with criticisms of the methods and results, are listed in several places, *e.g.*, T. I. Cottrell, "The Strengths of Chemical Bonds," 2nd ed., Butterworth & Co. (Publishers) Ltd., London, 1958; J. A. Kerr, *Chem. Rev.*, **66**, 496 (1966).

(2) System I may be regarded as an example of a more general process, *i.e.*

which is exemplified by the well-known benzidine rearrangement and Fischer indole synthesis (X = Y = N). Aryl peroxides are only reported as very unstable reaction intermediates; *cf.* C. Walling and S. A. Buckler, *J. Am. Chem. Soc.*, 77, 6032 (1955).

(3) This work was initiated at Imperial College, London, and we thank Professor D. H. R. Barton for the use of facilities.

(4) J. E. Baldwin, A. K. Qureshi, and B. Sklarz, *Chem. Commun.*, 373 (1968).

(5) Satisfactory analytical data have been obtained. *Anal.* Found: C, <±0.2; H, <±0.3; N, <±0.5.

H, singlet), which like all such compounds we have examined is thermally very labile, since at 80° in the dark, under nitrogen, it was isomerized to the 4-oxazoline IV ($R_1$ = *t*-butyl; $R_2 = R_3 = CO_2Me$; nmr (carbon tetrachloride), $\tau$ 4.63 (2 H, singlet, methylene group of 2-unsubstituted 4-oxazoline), whose structure was proven by hydrolysis with dilute hydrochloric acid to formaldehyde (2,4-dinitrophenylhydrazone) and the enol[5] VI ($R_1$ = *t*-butyl; $\lambda_{max}$ (ethanol) 267 m$\mu$ ($\epsilon$ 12,000); $\nu_{max}$ (mull) 1740, 1650 1635, 1545, 1520 cm$^{-1}$; nmr (dimethyl sulfoxide), $\tau$ 8.7 (9 H, singlet), 6.41 (3 H singlet), 6.29 (3 H, singlet), 3.40–2.85 (2 H, broad exchangeable)). In order to accelerate the first step, II to III, relative to the subsequent step, III to IV, we made use of an N-aryl substituent[4] since this would be expected to further weaken the N–O bond. In that event, the nitrone V (R = 2,4,6-trimethylphenyl) reacted rapidly with the acetylene and gave the acylaziridine[5] III ($R_1$ = 2,4,6-trimethylphenyl; $R_2 = R_3 = CO_2Me$) directly at room temperature. The structure of this substance is based on its spectral properties, $\lambda_{max}$ (ethanol) 236 ($\epsilon$ 5600), 290 m$\mu$ ($\epsilon$ 1525), ascribed to the 2,4,6-trimethylaniline moiety; $\nu_{max}$ (mull) 1740, 1715 cm$^{-1}$; nmr (deuteriochloroform), which besides signals typical of 2,4,6-trimethylanilino and carboxymethyl groups, showed an AB quartet, $\tau$ 6.92 and 6.78 (2 H, $J$ = 2.3 Hz), typical of the methylene group of an aziridine.[6] Chemical evidence of this structural assignment was obtained by reduction (sodium borohydride) to the lactone[5] VII ($R_1$ = 2,4,6-trimethylphenyl; $R_2$ = H); $\lambda_{max}$ 236, 291 m$\mu$; $\nu_{max}$ (mull) 3400, 1750 cm$^{-1}$; nmr (deuteriochloroform), $\tau$ 7.17 (AB quartet, $J$ = 2 Hz), 6.86 (1 H, exchangeable), 5.42 (3 H, multiplet). Acetylation of this lactone gave a monoacetate, VII ($R_1$ = 2,4,6-trimethylphenyl; $R_2 = COCH_3$), $\nu_{max}$ (mull) 1770, 1740 cm$^{-1}$, whose nmr spectrum was now amenable to detailed analysis.[7] Final confirmation of structure III for the acylaziridine was achieved by hydrogenolysis (5% Pd–C) to mesidine and dimethyl 1-oxo-1,2-propanedicarboxylate (2,4-dinitrophenylhydrazone).[8] When the acylaziridine III ($R_1$ = 2,4,6-trimethylphenyl; $R_2 = R_3 = CO_2Me$) was refluxed in toluene it was isomerized to the 4-oxazoline IV ($R_1$ = 2,4,6-trimethylphenyl; $R_2 = R_3 = CO_2Me$; nmr (deuteriochloroform), $\tau$ 4.59 (2 H, singlet)), as a highly labile compound readily hydrolyzed to formaldehyde and the enol[5] VI (R = 2,4,6-trimethylphenyl).[9]

By further selection of substituents we have been able to slow down the first reaction, II to III, and thereby directly observe the conversion of a 4-isoxazoline to the acylaziridine. Thus, when *t*-butylnitrone V (R = *t*-butyl) was added to 3-methylbutyn-3-ol, it produced at 74° (10 min) the labile isoxazoline II ($R_1$ = *t*-butyl; $R_2$ = H; $R_3 = (CH_3)_2COH$; nmr (deuteriochloroform), $\tau$ 8.88 (9 H, singlet), 8.58 (6 H, singlet), 6.03 (2 H, doublet, $J$ = 2.0 Hz), 5.32 (1 H, triplet, $J$ = 2.0 Hz)) which rearranged at 78° (2 hr) (nmr control) to the acylaziridine[5] III ($R_1$ = *t*-butyl; $R_2$ = H; $R_3 = (CH_3)_2COH$; $\lambda_{max}$ (ethanol) 215 m$\mu$ ($\epsilon$ 1540); $\nu_{max}$ 3250, 1705 cm$^{-1}$; nmr (deuteriochloroform), $\tau$ 8.95 (9 H, singlet), 8.60 (6 H, doublet), 8.11, 7.81 (2 H, multiplet), 7.31 (1 H, quartet), 4.91 (1 H, exchangeable)). The nmr spectrum of this compound was readily simplified by use of 1-deuterio-3-methylbutyn-3-ol, whereupon the corresponding acylaziridine III ($R_1$ = *t*-butyl; $R_2 = {}^2H$; $R_3 = (CH_3)_2COH$) exhibited in its nmr spectrum the required AB pattern ($J$ = 1.5 Hz).

We believe that the experiments reported here define the over-all pathway II to IV through III. Each step is thermally induced,[10] and the rates and products were not influenced by oxygen, radical inhibitors or small amounts of acids and bases.[11]

The literature contains few references to 4-isoxazolines;[12] in several cases mention has been made of their instability and in some cases rearrangement products have been isolated.[13] Most of the rearrangement products obtained from such compounds can be understood in terms of the sequence which we have here elucidated. The second step, III to IV, is probably related to the reversible thermal opening of aziridines studied recently by other workers.[14] The application of the general expression 1 (and larger ring analogs) to other systems is in hand.

**Acknowledgment.** We thank Eli Lilly and Company for their support of this work.

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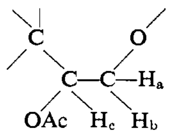
(6) For chemical shifts and couplings in arizidines *cf.* A. T. Bottini and J. D. Roberts, *J. Am. Chem. Soc.*, **80**, 5203 (1958).

(7) The presence of the unit



was demonstrated by spin decoupling (100 MHz): $\tau$ 5.58 ($H_a$, quartet, $J_{ab}$ = 11 Hz, $J_{ac}$ = 3 Hz), 5.30 ($H_b$, quartet, $J_{bc}$ = 7 Hz), 4.45 ($H_c$, quartet). The residual spectrum was essentially similar to that of VII ($R_2$ = H); the identity of shifts for the aziridine methylene favors a *trans* relationship between this methylene group and the acetoxyl function.

(8) T. Nishikawa, *Rept. Res. Sci. Dept. Kyushu Univ.*, **1**, 58 (1950); *Chem. Abstr.*, **46**, 2499 (1952).

(9) The spectral evidence shows that this enol (VI, R = 2,4,6-trimethylphenyl) is a mixture of *cis* and *trans* isomers.

(10) Photochemically induced isomerisms of *isoxazoles* have already been described: E. F. Ullman and B. Singh, *J. Am. Chem. Soc.*, **89**, 6911 (1967); E. F. Ullman and B. Singh, *ibid.*, **88**, 1844 (1966).

(11) There are acid-catalyzed reactions of 4-isoxazolines upon which we will report later. These take on an entirely different path.

(12) C. Harries and L. Jablonski, *Chem. Ber.*, **31**, 1371 (1898); R. Huisgen and H. Seidl, *Tetrahedron Letters*, 2019 (1963); R. Grigg, *Chem. Commun.*, 607 (1966); J. E. Bunney and M. Hooper, *Tetrahedron Letters*, 3857 (1966); E. Winterfeldt and W. Krohn, *Angew. Chem. Intern. Ed. Engl.*, **6**, 709 (1967).

(13) S. Takahashi and H. Kano, *Chem. Pharm. Bull.* (Tokyo), **12**, 1290 (1964); S. Takahashi and H. Kano, *J. Org. Chem.*, 30, 1118 (1965); R. M. Acheson, A. S. Bailey, and J. A. Selby, *Chem. Commun.*, 835 (1966); A. R. Gagneux and R. Goschke, *Tetrahedron Letters*, 5451 (1966).

(14) R. Huisgen, W. Seheer, and H. Huber, *J. Am. Chem. Soc.*, **89**, 1753 (1967); also A. Padwa and W. Eisenhardt, *Chem. Commun.*, 380 (1968).

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*Received July 31, 1968*

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## Bicyclo[2.1.1]hex-2-ene. Electrophilic Addition Reactions

*Sir:*

Electrophilic additions to norbornenes and substituted norbornenes have been the object of extensive