

titrated with Et_3N in an inert solvent the products are benzonitrile and ethyl isocyanate (both isolated). These rearrangement products could be derived from an intermediate unsaturated β -lactim (X), or by decomposition of VII to benzonitrile oxide and ethyl isocyanide followed by recombination and oxygen transfer either through XI or the 1,3-dipolar addition product XII (Scheme I). Benzonitrile oxide and ethyl isocyanide do yield benzonitrile and ethyl isocyanate rapidly under the reaction conditions. The conjugate acid of XII (as BF_4^- salt, m.p. $110\text{--}113^\circ$)¹³ also gives the same two products when titrated with Et_3N . Since these results do not exclude X as an intermediate and since there is the further possibility of solvent cage recombination here, a detailed study of the mechanism of this rearrangement is being undertaken.

(13) Prepared by alkylation of the known free base: R. Lenaers, C. Moussebois, and F. Eloy, *Helv. Chim. Acta*, **45**, 441 (1962).

(14) National Institutes of Health Predoctoral Fellow, 1962-1964.

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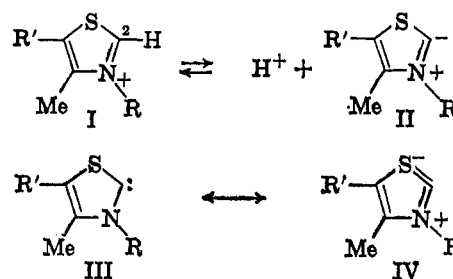
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Heterocyclic Nitrogen Ylides¹

Sir:

Studies of the mechanism of thiamine action first established the importance of heterocyclic ylides as



(2) an inductive effect (the reason HCN is a stronger acid than acetylene and $\text{Et}-\overset{+}{\text{N}}\equiv\text{C}-\text{H}$ ($\rightarrow\text{H}^+ + \text{EtNC}$) is a stronger acid than either), (3) stabilization of the ylidic species (II) by a resonance contribution from the carbene-like structure (III), and (4) $d-\sigma$ overlap of the electron pair of the anion with an empty d -orbital of sulfur (IV).

In a future communication³ we shall describe some experiments designed to test the importance of $d-\sigma$ overlap in these systems. We now wish to present kinetic evidence intended to give a qualitative estimate of the magnitude of the inductive and related effects. The experiments involve an n.m.r. study of the rates of deuterium incorporation in heavy water buffers, of a number of five-membered aromatic positively charged polynitrogen heterocyclic salts. Some of the preliminary results are summarized in Table I.

These results show first that acidity in these systems

TABLE I

	Ref.	Rate ^a	Relative rate ^b
V	c	$t_{1/2} = 14$ min. at pD 12.95, NaOD-KCl buffer	1
VI	d	$t_{1/2} = 4.5$ min. at pD 8.92, borate buffer	3×10^4
VII	e	$t_{1/2} = 5.1$ min. in 2.04 N DCl-D ₂ O	(5×10^{18})
VIII	f	$t_{1/2} = 6.2$ min. at pD 8.85, borate buffer	3×10^4

^a The rates were measured by n.m.r. at approximately 31° ; the reproducibility is about 20%. Under widely varying buffer concentrations and buffer types at a single pH the variation in rate constant is less than a factor of 2 for V, VI, and VIII. ^b Assuming the rate is first order in substrate and OH^- . Within the errors this is true for V, VI, and VIII. For VII the major contribution to the rate seems to come from other bases so a relative rate cannot really be reported. ^c G. Dedichen, *Chem. Ber.*, **39**, 1831 (1906). ^d O. Wallach, *ibid.*, **15**, 644 (1882). ^e New compound, prepared by ethylation of 1-ethyltetrazole [F. G. Fallon and R. M. Herbst, *J. Org. Chem.*, **22**, 933 (1957)]. A satisfactory analysis was obtained; see text for structure proof. ^f H. von Pechmann and P. Runge, *Chem. Ber.*, **27**, 2920 (1894).

reaction intermediates.² The lability of the 2-hydrogen in the thiazolium ring of thiamine (I) has been ascribed to the combined effect of a number of factors^{2a} including (1) high s -character of the C-H bond (the reason acetylene is a stronger acid than ethane),

(1) This research was supported by a grant from the U. S. Public Health Service (GM-09317).

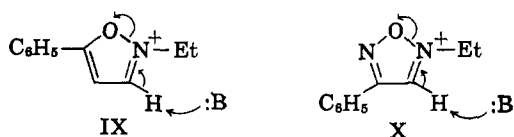
(2) (a) R. Breslow, *J. Am. Chem. Soc.*, **80**, 3719 (1958); (b) F. H. Westheimer, *Advan. Enzymol.*, **24**, 467 (1962).

is strongly dependent on the positioning of the nitrogen atoms. In the imidazolium salt (VI) where a much greater percentage of the positive charge is localized at the two positions α to the forming carbanion, the exchange rate is 30,000 times that of the pyrazolium

(3) R. A. Olofson and J. M. Landesberg, unpublished results; Abstracts, 144th National Meeting of the American Chemical Society, Los Angeles, Calif., April, 1963, p. 45M.

salt (V) where only one of the two positively charged nitrogens is α to the forming carbanion.

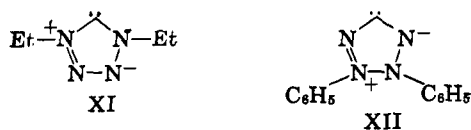
A much more striking result is the rate enhancement derived from adding extra electronegative atoms to the imidazolium ring. Addition of two nitrogen atoms, which gives the tetrazolium salt (VII), increases the exchange rate by a factor of 2×10^9 . VII undergoes rapid *base-catalyzed* exchange in 2 *N* DCl at room temperature. If this is a simple inductive effect, it is one of the most powerful inductive effects known. Our preliminary observation that a number of triazolium salts (of widely varied structure) undergo base-catalyzed deuterium incorporation at intermediate acidities (pH 5 to 8)⁴ is also in accord with these results. A parallel rate effect is found when one compares the rates of base-induced ring scission of isoxazolium salts (IX) and furazanum salts (X). IX and X react at comparable rates at pH 4⁵ and 3.25 *N* HClO₄,⁶ respectively. In these compounds loss of the labile proton



is the rate-determining step so the presence of a discrete ylidic intermediate cannot be demonstrated.

These results prompted us to investigate deuterium incorporation into a position β to the formal positive charge. We believed we might be able to accomplish this by capitalizing on the great accelerating effect of added electronegative atoms, and the compound we chose to study was the 2,3-diphenyltetrazolium salt (VIII). As predicted, this compound does undergo deuterium exchange and at a rate essentially the same as that of the imidazolium salt (VI), a compound in which one is able to place the positive charge (using classical octet resonance structures) on the nitrogens next to the forming anion in the usual manner. The intervening zwitterionic intermediate from VIII violates the very definition of ylide which requires the plus and minus charges to be on adjacent atoms.

It should be noted that in both tetrazolium salts, VII and VIII, the effect of the additional nitrogen atoms may be more than purely inductive. The carbene forms of the zwitterions (structures of type III) have a new possibility for resonance in which the negative charge can be placed on the electronegative element (*cf.* XI and XII), and this would tend to favor ionization^{1a} (though this effect is probably not very important). We are continuing our study of these



exchange reactions in the hope of better understanding and separating these effects.

Finally it is of interest to note that the tetrazolium salt (VII) undergoes ring cleavage under more basic conditions to yield nitrogen and diethylcarbodiimide.

(4) R. A. Olofson and W. R. Thompson, unpublished results.

(5) R. B. Woodward and R. A. Olofson, *J. Am. Chem. Soc.*, **83**, 1007 (1961).

(6) R. A. Olofson and J. S. Michelman, *ibid.*, **86**, 1863 (1964).

These reactions are general for 1,4-disubstituted tetrazolium salts and constitute a general method for generating carbodiimides (and a very useful method for generating very reactive carbodiimides) cleanly and quantitatively *in situ*. We shall soon report the applications of these tetrazolium salts as peptide forming reagents.

(7) National Institutes of Health Predoctoral Fellow, 1962-1964.

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Stereospecific Synthesis of Tricyclo[7.1.0.0^{5,7}]decan-3-ol¹

Sir:

According to a previous discussion,² the pentahomocyclopentadienyl system is of considerable interest in connection with the phenomena of homoconjugation and homoaromaticity. We now report a stereospecific synthesis of the parent alcohol, and in the accompanying communication³ we outline the behavior of the corresponding carbonium ion intermediate in acetolysis of the toluenesulfonate.

The parent alcohol V with the proper configuration and spacing of cyclopropane rings and functional group around an inside eight-membered ring was obtained by the series of reactions, I \rightarrow V. Epoxidation of 1,3,6-cyclooctatriene (I) with 30% hydrogen peroxide and acetonitrile⁴ in methanol gave rise to a monoepoxide fraction containing the isomers II and III in *ca.* equal proportions.⁵ The desired isomer⁶ II was isolated by preparative vapor phase chromatography⁷ (v.p.c.). Its structure was clear from its infrared and n.m.r. spectra. A very distinctive difference between II and III is the presence of an allylic epoxide proton signal at τ 6.5 in isomer II, whereas the two epoxide proton signal for isomer III occurs at τ 7.1.

Lithium aluminum hydride reduction of epoxide II in tetrahydrofuran proceeded exclusively at the allylic position⁸ to yield diene⁶ IV. The product was homogeneous in v.p.c. on several columns and displayed an appropriate infrared spectrum. Its n.m.r. spectrum displayed signals for four vinyl protons, a proton α to the hydroxyl group, two bisallylic protons, and four allylic protons at τ 4.39 (complex multiplet), 6.21 (pentuplet), 7.19 (triplet), and 7.64 (triplet), respectively.

(1) (a) Research sponsored by the U. S. Army Research Office (Durham).

(b) Research was supported in part by a grant from the Petroleum Research Fund administered by the American Chemical Society. Grateful acknowledgment is hereby made to the donors of this fund.

(2) (a) S. Winstein and J. Sonnenberg, *J. Am. Chem. Soc.*, **81**, 6524 (1959); (b) *ibid.*, **83**, 3235, 3244 (1961).

(3) S. Winstein, P. Bruck, P. Radlick, and R. Baker, *ibid.*, **86**, 1867 (1964).

(4) G. Payne, *Tetrahedron*, **18**, 763 (1962).

(5) From epoxidation with perbenzoic acid in benzene, the monoepoxide fraction contains only 20% of II. We are indebted to M. Mousseron of the University of Montpellier, Montpellier, France, for the information that, with myrcene, the use of hydrogen peroxide and acetonitrile instead of monophtalic acid shifts the predominant position of monoepoxidation from the trisubstituted olefinic group to one of the two conjugated olefinic groups. This difference in selectivity between ordinary peracids and hydrogen peroxide-acetonitrile may have wide application.

(6) Satisfactory carbon and hydrogen analyses were obtained for the new compounds here mentioned.

(7) An XF-1150 silicone nitrile on Chromosorb W column was employed.

(8) A. Cope and P. Peterson, *J. Am. Chem. Soc.*, **81**, 1643 (1959).