

AZOCINYL DIANIONS, THEIR GENERATION AND PROTONATION^{1a}

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The four double bonds in simple azocines are known to lack appreciable conjugative interaction due to the preferred tub conformation of these heterocycles.² Nevertheless, it has been shown by several electrochemical techniques that azocines undergo ready two-electron reduction to give planar dianions which have been suggested to be aromatic.³ In the present work, we have investigated the generation of azocinyl dianions by alkali metal reduction and studied their behavior toward several proton sources. The results establish the presence in azocinyl dianions of a high degree of π -electron delocalization and substantiate the expectancy based on theoretical prediction that these π -equivalent analogs of the cyclooctatetraenyl dianion are in fact aromatic.

Allowing dilute solutions of various 2-methoxyazocines³ in anhydrous THF or 1,2-dimethoxyethane (DME) to stand at room temperature in the presence of small pieces of potassium metal (2 equiv) results in gradual dissolution of the metal and formation of colored solutions of the dipotassium salts. As the extent of methyl substitution on the azocine ring increases, the reaction becomes increasingly sluggish. This difficulty is easily obviated by performing the reduction in anhydrous liquid ammonia. Under either set of conditions, precipitation of these salts occurs when the concentration levels are too high (ca. 0.25 M in THF); therefore, only dilute solutions of these salts may be obtained. However, in the case of the 3,5,6,8-tetramethyl derivative (1), the solubility was somewhat improved and the nmr spectrum of the salt was recordable. In Table I is summarized the chemical shifts of 1 and its dianion, generated under conditions where care was taken to obtain relatively complete reduction. For purposes of comparison, the spectral data for 1,3,5,7-tetramethylcyclooctatetraene (2) and its dianion were also recorded.

Table I. Summary of Chemical Shift Data (δ , THF solution, 40°C)^a

Compound	Neutral species	Dianion ^b
1,3,5,7-Tetramethylcyclooctatetraene (<u>2</u>)	5.41 (s, 4H, vinyl protons) 1.70 (s, 12H, four-CH ₃)	5.56 (s, 4H, vinyl protons) 2.55-3.04 (multiplet, 12H, four-CH ₃)
3,5,6,8-Tetramethyl-2-methoxyazocine (<u>1</u>)	5.72 (s, 1H, H ₇) 4.90 (s, 1H, H ₄) 1.82 (s, 6H, two-CH ₃) ^c 1.65 (s, 6H, two-CH ₃) ^c	5.62 (s, 1H, H ₇) 5.09 (s, 1H, H ₄) 2.34-2.62 (m, 12H, four-CH ₃)

^aBased on the signals for THF relative to TMS as internal standard (δ 3.60 and 1.75). ^bDipotassium salt. ^cThese absorptions were hidden by the THF solvent peak. Rather than attempt a difficult dissection, we have cited the chemical shift data obtained in a related solvent after applying a small correction factor. For 2, $\delta_{\text{TMS}}^{\text{CDCl}_3}$ 5.43 and 1.72; for 1, $\delta_{\text{TMS}}^{\text{CCl}_4}$ 5.70, 4.88, 1.80, and 1.63.

As shown in Table I, the nmr spectrum of the dipotassium salt of 2 in THF displays a four vinyl proton singlet at δ 5.56 and a complex twelve proton multiplet centered at ca. δ 2.80. On the basis of the known relationship⁴ between the charge at a particular carbon atom and the chemical shift of a proton attached to it, passage of 2 to its dianion can be anticipated to result in shielding of the vinyl protons by ca. 2.5 ppm. Because the observed net effect is only 0.15 ppm, deshielding of these protons due to the aromatic ring current must be substantial.⁵ The strong deshielding of the substituent methyl groups also confirms this conclusion. As regards the dianion of 1, all the nmr features are also uniquely congruent with a planar delocalized structure endowed with an appreciable ring current. The combined effects of charge density and aromaticity are again reflected in the deshielding of the methyl resonance lines by 0.6-0.8 ppm. The observed convergence of the vinyl protons at C₄ and C₇ in passing from the neutral heterocycle to the azocinyl dianion is particularly interesting and suggests that the aromatic nature of the dianion exerts a levelling effect which offsets to a measurable extent the varying degrees of electronic deshielding (due chiefly to the nitrogen atom) at the ring carbons of the neutral azocine.

The protonation of azocinyl dianions was next considered. The dipotassium salts were generated by dissolving the azocines in anhydrous NH₃-THF (9:1) and adding freshly cut potassium metal portionwise until the blue color persisted (> mole equiv of K were necessary

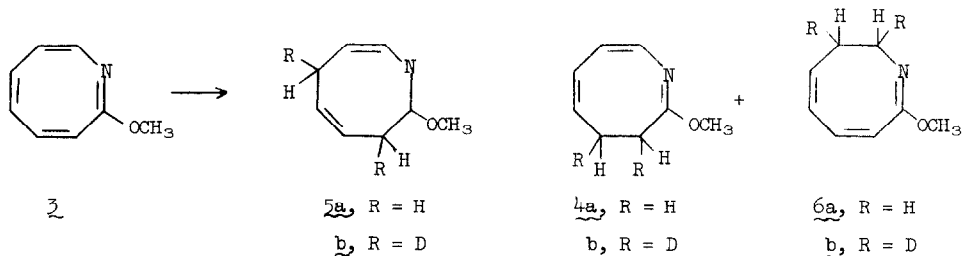
to reach this point). For quenching experiments conducted at 0-25°, the ammonia was evaporated under a stream of dry nitrogen and the residual mixture was treated directly with the proton source. The results of treating the azocinyl dianions with water at 25° are summarized in Table II. In the case of 2-methoxyazocine (3), three dihydroazocines were ob-

Table II. Summary of Protonation Data (H₂O) for the Azocinyl Dianions (25°)

Starting azocine	% Composition of Quenched Reaction Mixture			
	3,4-Dihydro (4) ^a	3,6-Dihydro (5) ^a	7,8-Dihydro (6) ^a	Others
2-Methoxy (3)	27 (a)	65 (a)	8 (a)	--
8-Methyl-2-methoxy (7)	45 (c)	50 (c)	---	5 ^b
3,8-Dimethyl-2-methoxy (8)	76 (d)	16 (d)	---	8 ^b
4,6,8-Trimethyl-2-methoxy (9)	33 (e)	38 (e)	22 (e)	7
3,5,6,8-Tetramethyl-2-methoxy (1)	94 (f)	---	---	6 ^c

^aSatisfactory elemental analyses were obtained for all dihydroazocines. ^bThe exclusion of the 7,8-dihydroazocine in this mixture is not inferred. ^cThe exclusion of the 3,6- and 7,8-dihydroazocines in this mixture is not inferred.

tained and these products were collected by preparative vpc. The most rapidly eluted substance was characterized as 3,6-dihydro derivative 5_a (65%) on the basis of its ultraviolet absorption [$\lambda_{\text{max}}^{\text{isooctane}}$ 233 nm (ϵ 1700)] and nmr spectrum [$\delta_{\text{TMS}}^{\text{CDCl}_3}$ 6.59 (d, $J = 7.5$ Hz, H₆), 5.60 (m, H₄, H₅), 4.66 (q, $J = 7.5$ Hz, H₇), 3.76 (s, -OCH₃), 2.95 and 2.55 (m, 2H each, methylene protons)] to which double resonance techniques were applied. The second product, likewise a colorless liquid, was identified as 3,4-dihydro-2-methoxyazocine (4_a, 27%). In particular, the ultraviolet spectrum (isooctane) displayed a lone maximum at 263 nm (ϵ 4900) and the nmr spectrum showed the usual doublet ($J = 9$ Hz) for H₆ at δ 6.36 in addition to multiplets centered at δ 5.67 (H₅, H₈) and 5.10 (H₇) and singlets at 3.73 (-OCH₃) and 2.56 (methylene protons). The third and minor product was found to be the 7,8-dihydro isomer (6_a, 8%) as judged from its ultraviolet [$\lambda_{\text{max}}^{\text{isooctane}}$ 246 nm (ϵ 3860)] and nmr spectra [$\delta_{\text{TMS}}^{\text{CDCl}_3}$ 6.30-5.40 (m, 4H, vinyl protons), 3.87 (t, $J = 6$ Hz, 8-CH₂), 2.72 (s, -OCH₃), and 2.54



(m, γ -CH₂)].

Independent chemical evidence for the formation of the dianion was provided by D₂O quenching. The gross structures of the three products followed from the identity of their vpc retention times and ultraviolet spectra with those of 4a-6a. However, it was clear from nmr and mass spectral evidence that these dihydroazocines contained two D atoms. Furthermore, the positions of entry of the D atoms were unequivocally those expected from respective direct deuteration of the dianion, thus precluding rearrangement reactions resulting from prototropic shifts during the entire procedure. Although such equilibrations do not occur under the above conditions, stronger bases can promote rearrangement as illustrated by the quantitative conversion of 5a to 4a with powdered KOtBu in THF (25°, 14 hr).

When the dianion of 2 was quenched with water, the three analogous dihydroazocines were produced (Table II). In contrast, the dianions of 7 and 8 gave chiefly 3,4- and 3,6-dihydroazocines, whereas tetramethyl derivative 1 afforded the 3,4-dihydro isomer in 94% yield. Although variation of the proton source (CH₃OH, t-BuOH, etc) did not significantly alter the product ratios, temperature effects were noted in certain cases. These results provide insight into the mechanism of protonation of such dianions which will be elaborated upon in the full paper.⁶

REFERENCES AND FOOTNOTES

- (1) (a) *Unsaturated Heterocyclic Systems*. LXVII; (b) Goodyear Tire and Rubber Company Fellow, 1969-1970.
- (2) L. A. Paquette and T. Kakihana, *J. Am. Chem. Soc.*, **90**, 3897 (1968).
- (3) L. A. Paquette, J. F. Hansen, T. Kakihana, and L. B. Anderson, submitted for publication.
- (4) G. Fraenkel, R. E. Carter, A. McLachlan, and J. H. Richards, *J. Am. Chem. Soc.*, **82**, 5846 (1960).
- (5) The same effect, although to slightly different extents, have previously been reported for (a) cyclooctatetraenyl dianion [T. J. Katz, *ibid.*, **82**, 3785 (1969)] and (b) monohomocyclooctatetraenyl dianion [M. Ogliaruso, R. Rieke, and S. Winstein, *ibid.*, **88**, 4731 (1966)].
- (6) This work was supported by grants from the National Institutes of Health (GM-14853) and Eli Lilly and Company.