The pharmacological properties of this compound are currently being investigated as is the detailed mechanism of the electrode reaction and the possibility of electrochemical synthesis of a variety of related pyrimidine oligomers.

Acknowledgments. The authors would like to thank the National Science Foundation and the Faculty Research Committee of the University of Oklahoma for financial support of this work. One of us (D. v. d. H.) was supported by a National Institutes of Health Development Award 5-K4-GM-42572.

Supplementary Material Available. A listing of the structure factor amplitudes will appear following these pages in the microfilm edition of this volume of the journal. Photocopies of the supplementary material from this paper only or microfiche (105 × 148 mm, 24× reduction, negatives) containing all of the supplementary material for the papers in this issue may be obtained from the Journals Department, American Chemical Society, 1155 16th St., N.W., Washington, D. C. 20036. Remit check or money order for $3.00 for photocopy or $2.00 for microfiche, referring to code number JACS-74-5255.

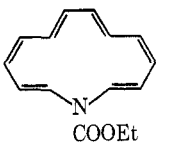
Shozo Kato, M. Poling
D. van der Helm, Glenn Dryhurst*
Department of Chemistry, University of Oklahoma
Norman, Oklahoma 73069
Received March 27, 1974

1*H*-Aza[13]annulene and Derivatives[1]

Sir:

The hetero[13]annulene system was recently described by Schröder and coworkers in the form of urethane, **1**, which apparently lacks aromatic character.[2] Nonetheless, the basic question as to whether an *unrestricted* (as opposed to bridged) hetero[13]annulene is capable of realizing its 14π aromatic potential has remained largely unanswered because of two undesirable structural features of **1**: (i) the molecule incorporates a strongly electron-withdrawing N substitutent and one known to prevent the development of aromatic character in the related hetero[9]annulene (heteronin) frame[3] and (ii) serious pairwise interference of the four "inner" protons (Dreiding molecular model) in the planar form needed for π delocalization. Bearing these two points in mind and having ourselves recently prepared[4] a potential photoprecursor, **2**, of the general aza[13]annulene frame, we resolved to examine the question of aromaticity in this intriguing heteromonocycle. We now relate our findings and conclusions on the subject.

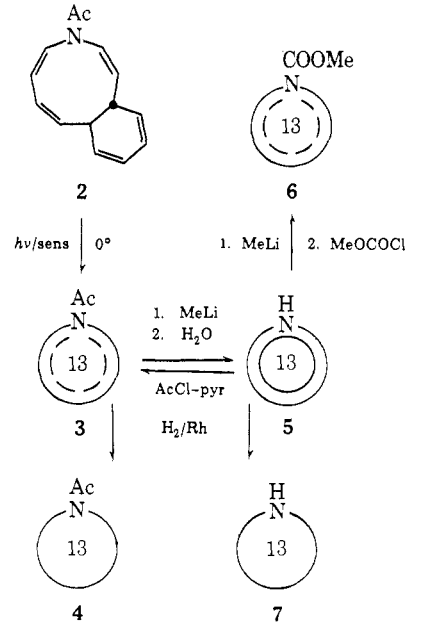
Brief (*ca.* 80 min) sensitized irradiation of **2** in acetone, at 0°, yields a mixture of three identifiable bicyclic[5] (*ca.* 50%) and one monocyclic (*ca.* 20%) isomers. These were separated by chromatography on alumina at *ca.* −15°, and the desired monocycle, **3**, was obtained pure



1

by successive low-temperature recrystallization. It is a bright yellow crystalline solid, mp 40–42°, displaying the following spectral characteristics: ν_{CO}^{KBr} 1670 cm^{-1}, $\lambda_{max}^{C_6H_{14}}$ 238 nm (ϵ 27,400), 260 (32,000), and 350 (4,000); nmr (100 MHz, $CDCl_3$) multiplets at τ 2.5–3.0 (2 H) and 3.3–4.2 (10 H), and a sharp singlet at τ 7.80 (3 H); *m/e* 213 (P^+, 26%). Chemically, the monocyclic frame of **3** was established by catalytic hydrogenation (Rh/C) to the perhydro counterpart **4** (ν_{CO}^{neat} 1645 cm^{-1}, *m/e* 225 (P^+, 51%)). Exposure of **3** to methyllithium in THF at *ca.* −70° followed by protonation (methanol at −70° then water at 0°) yielded the key amine **5**. When pure (sublimation) this substance is a bright yellow, air-sensitive solid characterized by $\lambda_{max}^{C_6H_{14}}$ 297 and 360 nm in a ratio of *ca.* 7.5[6]; nmr (100 MHz, acetone-d_6, −6°) τ 0.6 (br, s, N–H), 2.8–3.2 (5 H, m), 3.86 (1 H, t, J = 10.0 Hz), 4.1–4.5 (2 H, m), 4.88 (1 H, dd, J = 16.0, 6.0 Hz), 5.99 (1 H, dd, J = 16.0, 10.0 Hz), 6.52 (1 H, dd, J = 16.0, 8.0 Hz), 7.22 (1 H, dd, J = 14.5, 11.5 Hz; "inner" α proton coupled to N–H); *m/e* 171 (P^+, 15%). Chemically, the presence of a monocyclic frame in this substance was demonstrated by the following transformations: (i) conversion to the methoxycarbonyl derivative **6** (yellow crystals mp 51–52.5°; ν_{CO}^{KBr} 1710 cm^{-1}, $\lambda_{max}^{C_6H_{14}}$ 231 nm (ϵ 23,500), 263 (21,350), and 335 (4,500); nmr (100 MHz, $CDCl_3$) multiplets at 2.9–3.4 (2 H) and 3.6–4.2 (10 H) and a sharp singlet at τ 6.20 (3 H); *m/e* 229 (P^+, 88%)) on successive low-temperature treatment with methyllithium and methyl chloroformate in THF, (ii) reversion to **3** (nmr) on exposure to acetyl chloride–pyridine, and (iii) catalytic hydrogenation (Rh/C) to the perhydro analog **7** (*m/e* 183; P^+, 22%).

Scheme I



(1) Early portions of this work were presented Oct 15, 1973 at the Symposium on Organic Synthesis, 5th Northeast Regional Meeting of the American Chemical Society, Rochester, N. Y.

(2) G. Schröder, G. Frank, and J. F. M. Oth, *Angew. Chem.*, **85**, 353 (1973); *Angew. Chem., Int. Ed. Engl.*, **12**, 328 (1973), and private communication from Professor Schröder.

(3) For recent reviews on the subject see A. G. Anastassiou, *Accounts Chem. Res.*, **5**, 281 (1972); A. G. Anastassiou in "Topics in Nonbenzenoid Aromatic Chemistry," T. Nozoe, R. Breslow, K. Hafner, S. Ito, and I. Murata, Ed., Hirokawa Publishing Company, Tokyo, 1973, pp 1–27.

(4) A. G. Anastassiou, E. Reichmanis, and R. L. Elliott, *Tetrahedron Lett.*, 3805 (1973).

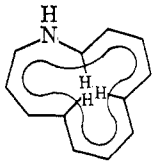
(5) This portion of the work will be described in a later report.

(6) The intense air sensitivity of the substance precluded a quantitative determination of extinction coefficients at this early stage.

While the data relating to **3** and **6** serve to unequivocally establish the presence of monocyclic frames, they lack the type of information needed for structural detail; it is not clear, for instance, whether the molecule incorporates any trans double bonds and if so how many. On the other hand, brief examination of the nmr spectrum of the parent, **5**, reveals that the molecule (and likewise **3** and **6** which have been directly correlated to **5**) does indeed possess trans double bonds. Specifically it is noted that, unlike **3** and **6**, **5** displays three high field 1H signals (τ 5.99–7.22) whose major splitting (14.5–16 Hz) is clearly indicative of trans ethylenic H–H coupling. Furthermore, the significant upfield displacement of these resonances relative to the major absorption manifold (τ 2.8–4.88) serves to clearly trace their origin to a set of strongly shielded "*inner*" protons and hence to establish the presence of *significant ring diamagnetism in* **5**.[7] Conversely, the absence of such high field resonances in the nmr spectra of derivatives **3** and **6** established that these molecules are devoid of ring diamagnetism. In other words, the obvious conclusion to be drawn from the nmr information is that *1H-aza[13]annulene* (**5**) *is endowed with aromatic character while its N-substituted derivatives* **3** *and* **6** *are not.* This interpretation draws added support from a comparison of thermal stabilities. In brief, we find that while **5** remains essentially unchanged on heating in deaerated (Ar) benzene-d_6 at 56° for 4.5 hr, the acetamide (**3**) cleanly and rapidly ($t_{1/2}$ < 1 hr) rearranges to a tricyclic isomer[5] under analogous conditions.

No doubt the effect of the substitutent is primarily electronic restricting the availability of the nitrogen lone pair for delocalization into the ring. In other words, the present situation strictly parallels that described earlier for the heteronins.[3]

The exact location of the trans bonds in **5** was established by successive double irradiation of the entire low-field nmr region (τ 0.6–4.88) which revealed an arrangement of alternating cis and trans bonds (no vicinal coupling between protons bound to different trans functions) and one in which the trans bond directly linked to nitrogen consists of an "*inner*" α-proton (highest field dd signal (J = 14.5, 11.5 Hz) reducing to a clean doublet (J = 14.5 Hz) upon decoupling from the N–H proton) and an "*outer*" β-hydrogen. It follows that the 1*H*-aza[13]annulene described here is structured as shown in **8**.



8

Finally, we note that while potentially capable of assuming planarity, without developing prohibitive σ-strain or excessive "*inner*" proton crowding (Dreiding molecular model), **8** is not believed to be entirely flat insofar as the protons associated with the trans bonds show temperature-dependent nmr chemical shifts indicative of enhanced ring diamagnetism at the lower temperatures.[8]

Acknowledgment. We are grateful to the National Foundation (GP-38553X) and the donors of the Petroleum Research Fund, administered by the American Chemical Society, for support of this work. We are also indebted to Mr. Larry McCandless for the determination of the nmr spectra.

(7) Upon contacting Professor Schröder on the matter (April 17, 1974), we learned that he made similar observation with a geometrical isomer of **5**, namely a 1*H*-aza[13]annulene incorporating only two trans bonds. See G. Schröder, G. Frank, H. Röttele, and J. F. M. Oth, *Angew. Chem.*, **86**, 237 (1974).

(8) In brief, we note that the "*inner*" protons bound to the trans function directly linked to nitrogen as well as those associated with a remote trans group undergo significant upfield shift on lowering the temperature, while the "*outer*" hydrogens of these two functions are shifted to lower field. The effect on the protons bound to the third trans group is precisely the reverse, *i.e.*, here the "*inner*" hydrogen resonance shifts to lower field while the "*outer*" proton signal moves to higher field, indicating possibly that this trans function has rotational mobility. Interestingly, there is an alternate interpretation of the unusual temperature-dependent behavior of this trans bond to which Professor Schröder indicated preference in private discussion we had on the matter. In brief, the suggestion here is that the "inner"–"outer" proton assignment in the ambient temperature nmr spectrum must be reversed thus leading to normal temperature-induced shifts. It is not clear, of course, within the frame of this interpretation as to why the "inner" proton of this bond should, under normal conditions, resonate at substantially *lower* field than its "outer" counterpart. In contrast with **5**, all nmr resonances of **3** retain essentially the same chemical shifts on cooling from *ca.* +40 to −60°. A complete analysis of the variable-temperature nmr spectra of **5** and **3** will be given in the full report.

(9) NDEA Graduate Fellow, 1971–1974.

A. G. Anastassiou,* R. L. Elliott[9]
Department of Chemistry, Syracuse University
Syracuse, New York 13210
Received April 26, 1974

Gas Phase Reactions. Ionization by Proton Transfer to Superoxide Anions

Sir:

Gas phase proton transfer reactions leading to negative ions have been studied by high pressure (10 Torr) mass spectrometry,[1] ion cyclotron resonance,[2] and flowing afterglow[3] techniques. The recent development of an atmospheric pressure ionization (API) mass spectrometer[4] has made it possible to study negative ion formation at atmospheric pressure. We have found[4] that certain drugs, including the commonly used barbiturates and 5,5-diphenylhydantoin, are ionized in the API source by proton transfer to Cl^-. Ordinary carboxylic acids (acetic, benzoic) are not ionized under these conditions. In the API source these acids can be ionized, however, by proton transfer to superoxide anion (eq 1). Superoxide anions can be generated

$$O_2^- + HA \longrightarrow A^- + HO_2 \qquad (1)$$

easily by employing oxygen or air as the carrier gas. A study of the properties of O_2^- indicated that this ion is strongly basic in the gas phase. Reaction 1 occurs for many acidic organic compounds.

(1) (a) R. Yamdagni and P. Kebarle, *J. Amer. Chem. Soc.*, **95**, 4050 (1973); (b) K. Hiraoka, R. Yamdagni, and P. Kebarle, *ibid.*, **95**, 6833 (1973).

(2) J. I. Brauman and L. K. Blair, *J. Amer. Chem. Soc.*, **92**, 5986 (1970); (b) J. I. Brauman and L. K. Blair, *ibid.*, **93**, 4315 (1971); (c) M. T. Bowers, D. H. Aue, H. M. Webb, and R. T. McIver, Jr., *ibid.*, **93**, 4314 (1971); (d) R. T. McIver, Jr., and J. R. Eyler, *ibid.*, **93**, 6334 (1971); (e) R. F. McIver, Jr., J. A. Scott, and J. M. Riveros, *ibid.*, **95**, 2706 (1973); (f) R. T. McIver, Jr., and J. H. Silvers, *ibid.*, **95**, 8462 (1973).

(3) (a) D. K. Bohme, E. Lee-Ruff, an l L. B. Young, *J. Amer. Chem. Soc.*, **94**, 5153 (1972); (b) D. K. Bohme, E. Lee-Ruff, and L. B. Young, *ibid.*, **92**, 330 (1970).

(4) (a) E. C. Horning, M. G. Horning, D. I. Carroll, I. Dzidic, and R. N. Stillwell, *Anal. Chem.*, **45**, 936 (1973); (b) D. I. Carroll, I. Dzidic, R. N. Stillwell, M. G. Horning, and E. C. Horning, *ibid.*, **46**, 706 (1974).