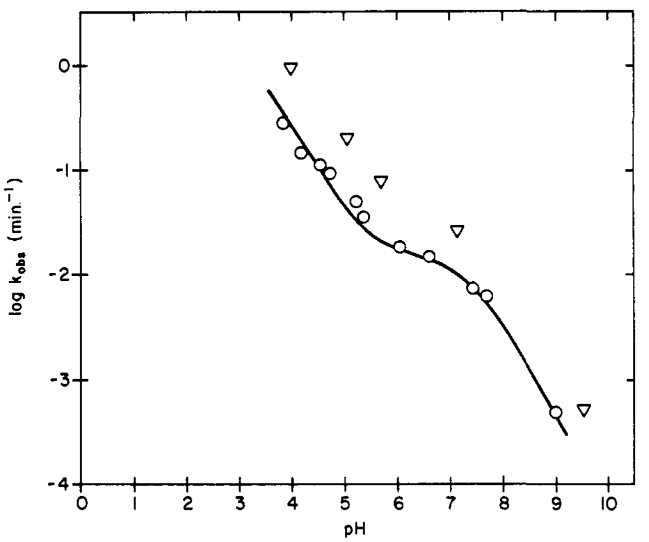

Figure 1. Plot of log k_{obsd} as a function of pH; (○) 50% v/v dioxane-water; (△) 20% v/v dioxane–water; $\mu = 0.2$, 25°. Solid line calculated from equation in text.

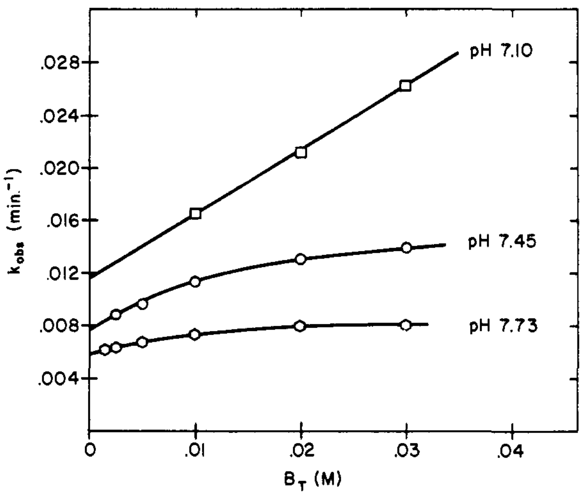

Figure 2. Plots of k_{obsd} *vs.* total phosphate buffer concentration ($\mu = 0.2$, 25°).

includes an additional uncatalyzed dehydration term, k_2, and the associated $k_{-2}(OH^-)$ term.[7] The appropriate equation for k_{obsd} as a function of pH is $k_{obsd} = [A(H^+) + B](H^+)/[(H^+) + C]$ and yields the theoretical curve of Figure 1. Limiting values of the above equation can be generated by assuming that (1) at pH >7.5 $B \gg A(H^+)$ and $C \gg (H^+)$; (2) at pH <4.5 $A(H^+) \gg B$ and $(H^+) \gg C$.[8] The profile, therefore, arises from the near proximity of a kinetically generated titration curve of the form $A'(H^+)/[B' + (H^+)]$ and a hydronium term $A'(H^+)$ with the constants A' differing by a factor of *ca.* 3×10^5. The above assumptions are equivalent to allowing changes in the rate-determining step. Mechanism I may be analyzed in terms of rate-determining transitions from uncatalyzed to base-catalyzed ring closure and ultimately rate-determining dehydration of carbinolamine with increasing pH. A choice between the two schemes is problematic. Although there is ample chemical evidence for the lyate species catalysis employed in either sequence, the magnitude of the hydronium ion term in mechanism II demands a Brønsted α (0.4) considerably less than those generally observed with aromatic amines.[9]

The observed buffer catalysis (acetate, formate, and phosphate) can be rationalized by including general acid catalyzed dehydration of carbinolamine or general base catalysis of ring closure. Whereas k_{obsd} is linearly related to acetate and formate concentrations, a saturation phenomenon is encountered with phosphate buffer[10] (Figure 2) which provides additional evidence for the existence of **3**. Again this may be ascribed to a change in rate-determining step, in terms of mechanism I from general base catalysis of ring closure to hydronium ion catalysis of carbinolamine dehydration.

The demonstration of the imminium cation intermediate over this broad pH range implies that the duality of mechanism proposed for the Mannich condensation in acidic and basic media involving the imminium cation and carbinolamine as the respective reactive intermediates[3] may not be general and gives insight into the mechanism of methylene transfer from tetrahydrofolic acid, a subject to be discussed in a forthcoming publication.

Acknowledgment. This work was supported by a grant from the National Science Foundation (6B-7246).

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[7] (a) For mechanism I, $A = k_3k_1/(k_{-1} + k_3)$, $B = k_3'k_1K_{WD}/(k_{-1} + k_3)$, $C = k_3'K_{WD}/(k_{-1} + k_3)$; mechanism II, $A = k_3k_1/(k_{-1} + k_3)$, $B = k_3k_2(k_{-1} + k_3)$, $C = k_{-2}K_{WD}/(k_{-1} + k_3)$. K_{WD} is defined as the autoprotolysis constant of 50% dioxane–H_2O. The above scheme as defined does not include the possibility that an alternative carbinolamine would also yield product. Thus the parameters *A*, *B*, and *C* may not be uniquely defined by these sets of rate constants. (b) An alternate description of k_{obsd} as a function of pH which yields a theoretical curve similar to the above except at pH <4 is given by $\{[A'(H^+) + B](H^+)/[(H^+) + C]\}K_a/K_a + (H^+)$. The value of $pK_a \cong 3.76$ (the macroscopic pK_a of the quinoxaline nitrogens) was determined spectrophotometrically.

[8] Reiterative calculations fix $-\log C$ as 7.45.

[9] W. P. Jencks, *Progr. Phys. Org. Chem.*, **2**, 63 (1964).

[10] The unique behavior of phosphate buffer is not altered by changes in solvent (20% v/v dioxane–H_2O) or ionic strength.

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The Influence of Steric Inhibition of Resonance on Ion Intensities in Mass Spectra

Sir:

The recognition of quantitative correlations between structure and reactivity in substituted aromatic compounds in the 1930's[1] led to investigations of deviations from these correlations caused by nonbonded interactions between several substituents. For example, modification of the reactivities of the dimethylamino[2] and nitro[3] groups by *ortho* substituents has been interpreted in terms of large deviations from coplanarity of the substituent and the ring, so that resonance effects of these substituents are greatly reduced.[4]

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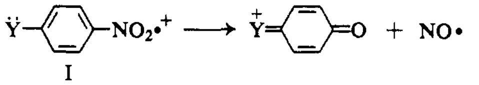
[1] L. P. Hammett, "Physical Organic Chemistry," McGraw-Hill Book Co., Inc., New York, N. Y., 1940, Chapter VII.

[2] F. H. Westheimer and R. P. Metcalf, *J. Am. Chem. Soc.*, **63**, 1339 (1941).

[3] W. C. Spitzer and G. W. Wheland, *ibid.*, **62**, 2995 (1940).

Quantitative correlations of ion intensities in mass spectra with electronic effects of substituents in solution chemistry, the Hammett σ constants, have recently been demonstrated.[5] The quantitative effect of steric inhibition of resonance is demonstrated here for the first time.

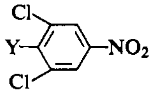
The choice of a well-studied system was limited to the few systems for which electronic effects of substituents have been relatively thoroughly explored.[6] The frequently observed loss of NO from nitrobenzenes[7] (reaction 1), whose substituent dependence is marked by strong susceptibility to stabilization of the product ion



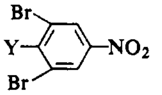
(1)

I

by electron donors in the *para* position,[8] is suited to these studies. In the decomposition of blocked compounds such as II and III, large *ortho* substituents might prevent stabilization of the $(M - NO)^+$ ion if the Y group is large. The blocking substituents were chosen to be halogens, relatively unreactive aromatic substi-



II



III

tuents in mass spectral processes, rather than the methyl groups more characteristic of solution studies,[2,3] for the latter are not necessarily inert under electron-impact conditions. Taking the hydroxy substituent, small enough not to see interference by *ortho* halogens, as a reference point, the relative intensities of the rearrangement peak ($Z = [(M - NO)^+]/[M\cdot^+]$) were determined for several substituents of differing size and compared with available[8] data showing strong resonance interaction when the group is not blocked. The data at 75 V are given in Table I. They indicate a dramatic reduction in the intensity of the product ion when the substituent *para* to the nitro group is so large that its plane is twisted through nonbonded interaction with vicinal groups, in analogy with solution chemistry. In this fashion stabilization of the reaction product by the methoxy and dimethylamino substituents through quinonoid resonance forms, postulated[7-9] to explain several aspects of the loss of NO from nitrobenzenes, becomes impossible, and the intensity of the ion drops by a factor greater than an order of magnitude. The substitutent is retained, so that Z values cannot be correlated at 75 V with rates;[10] the principal decomposition of the $(M - NO)^+$ ion, loss of CO, could not be eliminated entirely at ionizing voltages where the $(M - NO)^+$ ion was sufficiently intense to allow confidence in the data.[11] Data were collected instead 3.0 V above the appearance potential of each molecular ion,[12] a point at which the energy content of each molecular ion type should be similar[13,14] and at which further decomposition of the $(M - NO)^+$ ion is almost suppressed. These data show a similar trend (Table II), indicating that the intensities at 75 V in Table I reflect rates of formation.

Table I. Relative Intensities for the Loss of NO from Hindered Nitrobenzenes

	Z/Z_0		
Y	I	II	III
HO	1.0	1.0	1.0
H_2N	1.2	1.0	0.70
CH_3O	1.4	0.06	0.08
$(CH_3)_2N$	0.83	0.04	0.03

Table II. Low-Voltage Relative Intensities for the Loss of NO from Hindered Aromatics

	Z/Z_0		
Y	I	II	III
HO	1.0	1.0	1.0
H_2N	1.0	0.83	0.70
CH_3O	0.83	0.25	0.28
$(CH_3)_2N$	0.49	0.08	<0.05

These experiments significantly enlarge the applicability of results from solution chemistry to mass spectrometric studies. In spite of general uncertainty over energy distribution in ions and the lack of a general scheme for mass spectral *ortho* effects, in at least this series the structural characteristics of the ionic species are similar to those naively inferred from solution chemistry. The electronic effects of substituents, now generally accepted as an important factor determining rates of mass spectral decompositions, can now be supplemented by a well-defined effect based on the size of substituents, as displayed by steric inhibition of resonance. The value of such steric effects as a diagnostic tool for mechanistic elucidation is demonstrated in a following article.[15,16]

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(4) For reviews see: (a) G. S. Hammond and M. F. Hawthorne, "Steric Effects in Organic Chemistry," M. S. Newman, Ed., John Wiley & Sons, Inc., New York, N. Y., 1956, p 164; (b) R. W. Taft, Jr., in ref 4a, p 556.

(5) M. M. Bursey and F. W. McLafferty, *J. Am. Chem. Soc.*, **88**, 529 (1966).

(6) For a review, see: M. M. Bursey, *Org. Mass Spectrom.*, **1**, 31 (1968).

(7) J. H. Beynon, R. A. Saunders, and A. E. Williams, *Ind. Chim. Belge*, **29**, 311 (1964), and references cited therein.

(8) M. M. Bursey and F. W. McLafferty, *J. Am. Chem. Soc.*, **88**, 5023 (1966).

(9) S. Meyerson, I. Puskas, and E. K. Fields, *ibid.*, **88**, 4974 (1966).

(10) M. M. Bursey and F. W. McLafferty, *ibid.*, **89**, 1 (1967).

(11) This situation parallels previous experience.[8]

(12) Data were measured by the vanishing-current technique, which is sufficiently accurate for studies of this sort.

(13) F. W. McLafferty and M. M. Bursey, *J. Org. Chem.*, **33**, 124 (1968).

(14) I. Howe and D. H. Williams, *J. Am. Chem. Soc.*, **90**, 5461 (1968).

(15) M. M. Bursey, submitted for publication.

(16) Support of the University Research Council of the University of North Carolina is gratefully acknowledged.

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Transannular Interactions in Tetrafluoro[2.2]paracyclophane

Sir:

It has been reported that benzene and hexafluorobenzene form a weak intermolecular charge-transfer com-