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THE ACID-INDUCED DECOMPOSITION OF 7-SUBSTITUTED 3-DIAZO-2-NORBORNANONES. KINETIC STUDIES

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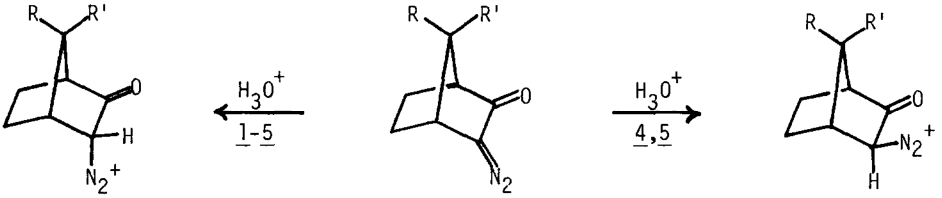
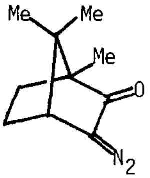
Abstract. Introduction of a *syn*-7 isopropyl or *t*-butyl substituent in 3-diazo-2-norbornanone results in a 10-fold and 200-fold reduction, respectively, in the rate constant for its decomposition in aqueous acid.

In the accompanying Communication[1] we have reported the effects of the introduction of 7-isopropyl and 7-*t*-butyl groups in 3-diazo-2-norbornanone (1) on the product distribution in its acid-induced decomposition in aqueous medium and in D_2O. We have interpreted these observations in terms of irreversible *exo* protonation of 1[2] and its *anti*-7 isopropyl (2) and *t*-butyl (3) derivatives and of both *exo* and *endo* protonation of its *syn*-7 isopropyl (4) and *t*-butyl (5) derivatives (Scheme 1). We report here the results of kinetic studies that corroborate these conclusions and provide evidence regarding the origin of medium effects on product distribution.[3]



1 R = R'= H
2 R = i-Pr, R' = H
3 R = *t*-Bu, R' = H
4 R = H, R' = i-Pr
5 R = H, R' = *t*-Bu

Scheme 1



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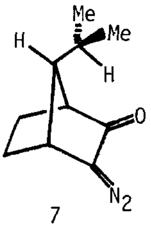

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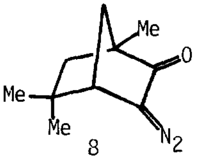

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The rates of decomposition of α-diazo ketones 2, 4, 5, and 6 at 25.0°C in dilute hydrochloric acid at a series of acid concentrations of constant ionic strength were followed by ultraviolet spectroscopy. Plots of observed pseudo-first order rate constants, k_{obs}, versus acid concentration were linear in all cases and gave the second-order rate constants for protonation, k_{H^+} (Table), from eq. (3) (where D is diazo ketone), based on the A-S_E2 mechanism [eqs. (1) and (2)], in which the protonation step is rate-determining, *i.e.*, $k_2 \gg k_{-1}$.

$$D + H^+ \underset{k_{-1}}{\overset{k_{H^+}}{\rightleftharpoons}} DH^+ \quad (1) \qquad\qquad DH^+ \xrightarrow{k_2} \text{products} \quad (2)$$

$$\text{rate} = k_{H^+}[H^+][D] = k_{obs}[D] \quad (3)$$

The rates of decomposition of α-diazo ketones 1 and 3 under these conditions were too rapid to be measured by this method; they and those of 2 and 6 were determined in buffer solutions of acetic acid (HA) and acetate ion (A^-). The observed rate constants, k_{obs}, were obtained by uv spectroscopy at a series of buffer concentrations of constant ionic strength and buffer ratio of 1.0. Plots of k_{obs} versus acetic acid concentration, [HA], were curved, in accord with eq. (5), based on a kinetic scheme given by eqs. (1), (2), and (4). The values

$$D + HA \underset{k_{-3}}{\overset{k_{HA}}{\rightleftharpoons}} DH^+ + A^- \quad (4)$$

$$k_{obs} = \frac{k_{HA}[HA] + k_{H^+}[H^+]}{\frac{k_{-3}}{k_2}[HA] + 1} \quad (5)$$

of k_{HA} were determined by a curve fitting programme,[6] and these and those of k_{H^+} are given in the Table.[7]

Comparison of the k_{H^+} values for the *syn*-7-substituted derivatives 4 and 5 with those for 1 and the *anti*-7-substituted derivatives 2 and 3 confirms the postulate that *syn*-7 isopropyl and *t*-butyl groups retard the protonation of 1 in aqueous acid. The retardation by the *t*-butyl group is relatively large (1:5 ∿ 2 x 10^2) while the effect of the isopropyl group is smaller (1:4 ∿ 10) and similar to that of the *syn*-7-methyl group in 3-diazocamphor (6), which is ascribable to the existence of 4 in the preferred conformation 7.[1] Combination of the present results with the product distribution studies leads to the individual estimates of k_{H^+} for *exo* and *endo* protonation given in the Table.[8]

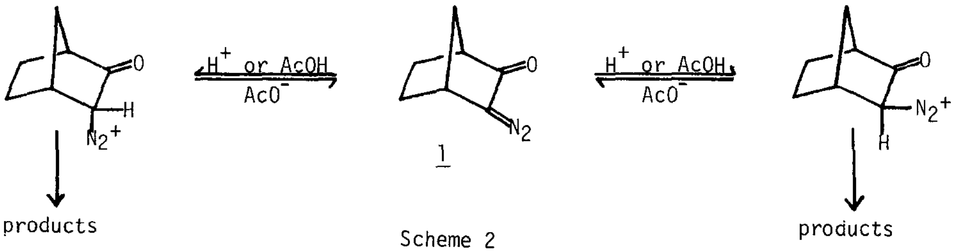
Table. Rate Constants for the Decomposition of 3-Diazo-2-norbornanones in Aqueous Acid and in Buffer Solutions at 25.0°C

α-Diazo Ketone	k_{H^+} ($M^{-1}s^{-1}$)	k_{HA} ($M^{-1}s^{-1}$)	$(k_{H^+})_{exo}$[c] ($M^{-1}s^{-1}$)	$(k_{H^+})_{endo}$[c] ($M^{-1}s^{-1}$)
4[a]	7.84 ± 0.16		7.4	0.47
5[a]	0.345 ± 0.003		0.28	0.06
6[a]	8.19 ± 0.12[d]			
6[b]	10	0.05		
2[a]	51.0 ± 2.1			
2[b]	56	0.45	55	0.8
3[b]	81	0.83	80	1.2
1[b]	74	0.10		

[a] In aqueous hydrochloric acid. [b] In aqueous acetic acid/sodium acetate; $[AcOH]/[AcO^-] = 1.00$, except for 6, for which five values of $[AcOH]/[AcO^-]$ (0.250 - 4.00) were used and the rate constants listed are average values. [c] These partial rate constants are based on the mid-points of the ranges for *exo* and *endo* protonation.[1] [d] *Cf.* the values for 6 in perchloric acid and aqueous dioxane: 2.34 $M^{-1}s^{-1}$.[4]

The postulate that in aqueous acid the protonation step is rate-determining [A-S_E2 mechanism) was confirmed by the measurement of the deuterium isotope effect for the reaction of 4 in aqueous acid: $k_{H^+}/k_{D^+} = 2.38 \pm 0.06$. This value may be compared with that reported by Dahn and Ballenegger[4] for 6 in perchloric acid and aqueous dioxane: $k_{H^+}/k_{D^+} = 1.9$. The following activation parameters were obtained for 4 in aqueous acid: $\Delta H^{\ddagger} = 13.7$ kcal mol^{-1}, $\Delta S^{\ddagger} = -8.4$ e.u.

The results obtained in buffered solutions show that in the presence of acetate ion the loss of nitrogen from the protonated diazo ketones becomes partially rate-determining because the acetate ion acts as a base in the deprotonation of the diazonium ion, DH^+ [eq. (4)]. This corroborates the proposal of Friedman[9] and Edwards[10] and their coworkers that under such conditions interconversion of *endo* and *exo* diazonium ion occurs resulting in the formation of a significant proportion of products from the latter (Scheme 2).[11]



Scheme 2

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References and Notes

1. P. Yates and J.D. Kronis, Tetrahedron Lett., submitted.
2. P. Yates and R.J. Crawford, J. Am. Chem. Soc., **88**, 1561 (1966); R.A. Blattel and P. Yates, Tetrahedron Lett., 1073 (1972).
3. Dahn[4] and Albery[5] and their coworkers have previously reported kinetic studies of the acid-induced decomposition of 3-diazocamphor (**6**) and 3-diazo-2-butanone.
4. H. Dahn and M. Ballenegger, Helv. Chim. Acta, **52**, 2417 (1969); G. Fierz, J.F. McGarrity, and H. Dahn, Helv. Chim. Acta, **58**, 1058 (1975).
5. W.J. Albery, A.N. Campbell-Crawford, and K.S. Hobbs, J. Chem. Soc. Perkin II, 2180 (1972), and subsequent papers in this series.
6. A.J. Kresge, private communication.
7. Values of k_{H^+} and k_{HA} determined by this method are expected to be less accurate than the values of the former determined in aqueous acid (the method does not permit the assessment of error limits). Thus the concordance between the values of k_{H^+} for **2** and **6** given by the two methods is considered to be satisfactory and to give credence to the kinetic analysis of the results in buffered solutions.
8. Although the k_{H^+} values of **2** and **3** are similar to that of **1**, as expected, their k_{HA} values are significantly greater than the k_{HA} value of **1**; a similar effect of the *anti*-7-methyl group in **6** can be discerned, if account is taken of the effect of the *syn*-7-methyl group. We are uncertain of the origin of this increase in k_{HA} values brought about by *anti*-7 substituents.
9. L. Friedman, in 'Carbonium Ions,' eds. G.A. Olah and P.v.R. Schleyer, Wiley-Interscience, New York, Vol. 2, 1968, ch. 16.
10. O.E. Edwards, J. Dixon, J.W. Elder, R.J. Kolt, and M. Lesage, Can. J. Chem., **59**, 2096 (1981).
11. We now consider this to be a better interpretation of earlier work from this Laboratory on the decomposition of **6** and 3-diazoisofenchone (**8**) than that originally proposed: R.A. Blattel and P. Yates, Tetrahedron Lett., 1069 (1972).

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