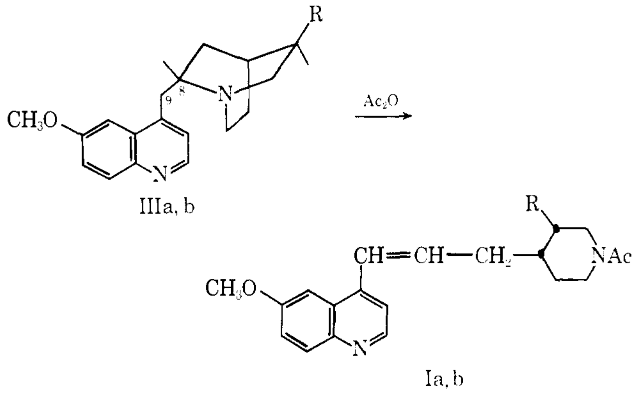
duce acetoxyl at C$_9$,[8] but this facile ring opening precludes the use of this method.



IIIa, b

Ia, b

The sequence of reactions outlined constitutes a synthesis of racemic 6-methoxyrubanol and partial syntheses of quinine and quinidine.

Acknowledgment. This work was supported in large part by the U. S. Army Medical Research and Development Command under Contract No. DA-49-193-MD-2956. We are grateful to Dr. Milan Uskoković and his colleagues and to Dr. Philip Kumler for a number of helpful discussions.

(8) See, for example, the production of 4-acetoxypicoline from 4-picoline N-oxide: V. Boekelheide and W. J. Linn, *J. Amer. Chem. Soc.*, **76**, 1286 (1954).

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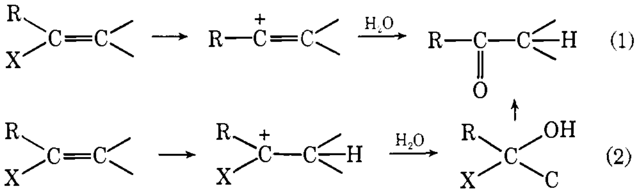
Hydration *vs.* Solvolysis of an Activated Vinyl Halide

Sir:

It has been recently proposed that hydrolysis of "activated" vinyl halides proceeds *via* S_N1 solvolysis to a vinyl carbonium ion, eq 1.[1] Equally plausible under some, but not all, of the conditions used is hydrolysis *via* protonation of the alkene, as in eq 2 (*cf.* ref 1f).



Impetus to published studies was given by the work of Grob on hydrolysis of α-bromostyrenes.[1a] The postulated vinyl carbonium ion mechanism for this system was based largely on findings with α-bromo-p-aminostyrene. In 80% ethanol, the hydrobromide salt, with 0–5 equiv of triethylamine, hydrolyzed much more rapidly than the p-methoxy derivative, which in turn hydrolyzed faster than the parent α-bromostyrene. Our interest in the hydration of styrenes in general,[2] and of aminostyrenes in particular,[3] prompted us to examine the hydrolysis of α-bromo-p-aminostyrene in sufficient detail to allow a clearer delineation of mechanism. A study of the behavior of first-order rate constants in aqueous buffer and perchloric acid solutions establishes that the vinyl carbonium ion mechanism for this compound is definitely incorrect, and that hydrolysis most probably occurs *via* acid-catalyzed hydration, eq 3–8.

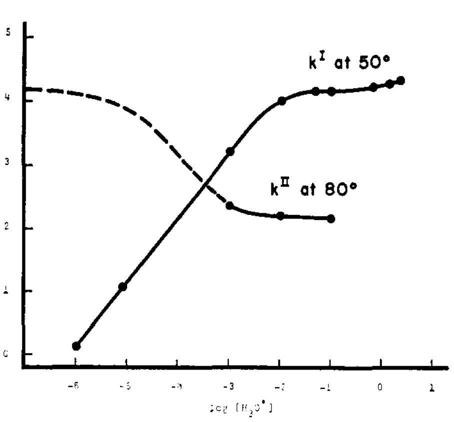


Figure 1. Plot of log $k_{\text{obsd}}{}^{\text{I}}$ and log $k_{\text{obsd}}{}^{\text{II}}$ against log [H$_3$O$^+$].

Hydrolysis occurs in two stages. In solutions of higher acidity, the ultraviolet spectrum of the styrene disappears completely before any ketone spectrum appears, and is replaced by the spectrum of a metastable intermediate. The spectrum of this intermediate then slowly changes to that of the end product, p-aminoacetophenone. Rate constants for stage I (50°) and the much slower stage II (80°) were successively determined by quantitatively following changes in absorptivity at optimum wavelengths.

In solutions over a narrow pH range, around 4.5, stages I and II are competitive, and the spectrum of the intermediate builds up momentarily, then declines, while styrene disappears and ketone appears. In solutions of high pH, stage II was much faster than stage I, *i.e.*, the intermediate did not make its appearance, and the first-order rates of styrene disappearance and ketone appearance were identical.

The dependence of $k_{\text{obsd}}{}^{\text{I}}$ (extrapolated values in buffers) on [H$_3$O$^+$] over the entire acidity range is shown graphically in Figure 1. The acidity dependence of $k_{\text{obsd}}{}^{\text{I}}$ unequivocally rules out the vinyl carbonium ion mechanism, since an opposite behavior is required by that mechanism. That is, the rate constant should remain unchanged in solutions of low acidity ($[\text{S}] \gg [\text{SH}^+]$) and be inversely dependent on [H$_3$O$^+$] in solutions of high acidity ($[\text{SH}^+] \gg [\text{S}]$).

The behavior of $k_{\text{obsd}}{}^{\text{I}}$ does correspond to that expected for the acid-catalyzed hydration of eq 3–5, as expressed in the rate eq 9 (k_4 and $K_{\text{SH}^+}{}^{\text{c}}$ are medium dependent constants). Indeed, it parallels that found in the hydration of unsubstituted p-aminostyrene to 1-p-aminophenylethanol.[3] Thus, $k_{\text{obsd}}{}^{\text{I}}$ increases linearly with [H$_3$O$^+$] in media of low acidity in which the ground state is essentially free α-bromo-p-aminostyrene, S (rate eq 9a). In media of higher acidity in which the ground state is essentially SH$^+$, N-protonated styrene, $k_{\text{obsd}}{}^{\text{I}}$ is independent of the acidity (rate eq 9b). The

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(1) (a) C. A. Grob and G. Cseh, *Helv. Chim. Acta*, **47**, 194 (1964); (b) L. L. Miller and D. A. Kaufman, *J. Amer. Chem. Soc.*, **90**, 7282 (1968); (c) C. A. Grob and R. Spear, *Tetrahedron Lett.*, 1439 (1969); (d) S. A. Sherrod and R. C. Bergman, *J. Amer. Chem. Soc.*, **91**, 2115 (1969); (e) M. Hanack and T. Bassler, *ibid.*, **91**, 2117 (1969); (f) S. J. Huang and M. V. Lessard, *ibid.*, **90**, 2432 (1968); (g) P. E. Peterson and J. M. Indelicato, *ibid.*, **91**, 6194 (1969); **90**, 6515 (1968).

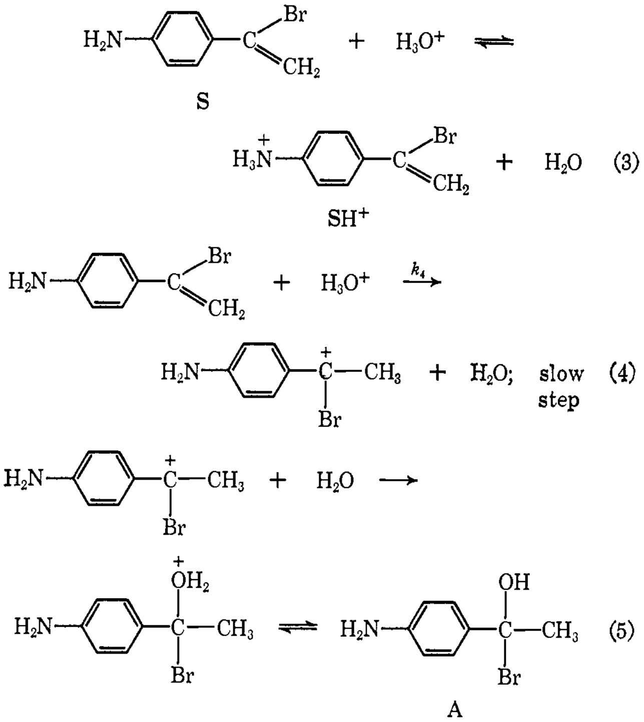
(2) W. M. Schubert, B. Lamm, and J. R. Keeffe, *ibid.*, **86**, 4727 (1964); W. M. Schubert and B. Lamm, *ibid.*, **88**, 120 (1966).

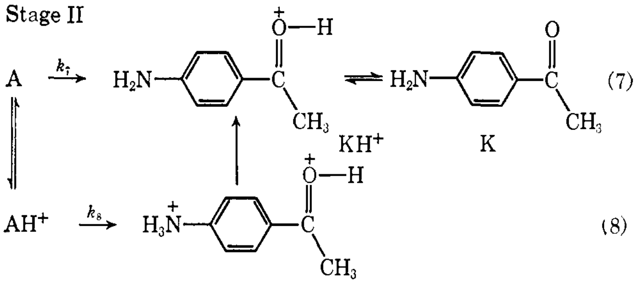
(3) James L. Jensen, Ph.D. Thesis, University of Washington, 1967.

relatively slight increase, 60%, in k_{obsd}^{I} between 0.1 and 2.4 *M* $HClO_4$ is attributable to a medium effect, as found for hydration of unsubstituted *p*-aminostyrene.[3] In the intermediate pH range, the unsimplified rate eq 9 applies, since the ground state consists of both S and SH^+, in equilibrium.

Also in agreement with the assigned mechanism for stage I is the finding of general catalysis in acetic acid (pH 5) and hydrogen phthalate (pH 6) buffers.[2,3] Values of k_4 at 50° and $\mu = 0.1$ *M* for H_3O^+ and HOAc are 1.4 and 1.3 × 10^{-4} l. mol^{-1} sec^{-1}, respectively. Based on the kinetic data $K_{SH^+}^{c}$, at 50° and $\mu = 0.1$ *M*, has the value 10^{-2}.

Stage I





$$k_{obsd}^{I} = \frac{[S]}{[S] + [SH^+]} k_4[H_3O^+] = \frac{[SH^+]}{[S] + [SH^+]} K_{SH^+}^{c} k_4 \qquad (9)$$

$$\text{when } [SH^+] \ll [S],\ k_{obsd}^{I} = k_4[H_3O^+] \qquad (9a)$$

$$\text{when } [SH^+] \gg [S],\ k_{obsd}^{I} = K_{SH^+}^{c} k_4 \qquad (9b)$$

$$k_{obsd}^{II} = \frac{1}{[A] + [AH^+]}(k_7[A] + k_8[AH^+]) \qquad (10)$$

As regards stage II, a reasonable mechanism is given by eq 7 and 8 (rate eq 10). The constancy of the first-order rate constant, k_{obsd}^{II}, in the media of higher acidity is attributed to the failure of reaction 7 to compete with reaction 8, due to a low relative concentration of free *p*-aminophenyl-1-aminoethanol (*i.e.*, $[AH^+] >>> [A]$ and eq 10 reduces to $k_{obsd}^{II} = k_8$). Values of k_{obsd}^{II} have not been measured below 10^{-3} *M* H_3O^+ due to the overlap with stage I at lower acidity. However, as the acidity of the medium is reduced, solvolysis of free amine A should contribute, and since $k_7 > k_8$, k_{obsd}^{II} should increase and then reach the limiting value k_7 when the ground state is essentially all A. The inferential extension of the behavior of k_{obsd}^{II} in solutions of lower acidity is represented by the dashed portion of the line of Figure 1. The qualitative aspect of the dashed portion is consistent with the observation that at 50°, stage II competes with stage I at around pH 4.5, and is not seen in the solutions of lowest acidity. The specific position of the dashed portion of the line is based on the working hypothesis that k_7/k_8 is 100 and $K_{AH^+}^{c}$ is 10^{-5}.[4] In any event, for solvolysis of AH^+ to contribute significantly when $[H_3O^+]$ is as low as 10^{-3} *M* requires that the NH_2 *vs.* NH_3^+ substituent effect (k_7/k_8) be small in comparison to, for example, benzyl halide solvolysis. This is perhaps not surprising for a transition state having protonated ketone character, thereby reducing the demand placed upon the *para* substituent.

As a final point of interest, at 50° in 0.1 *M* $HClO_4$, k_{obsd}^{I} (for the net change: $SH^+ + H_2O \rightarrow tr^+$) is 560 times as great as k_{obsd} for the hydration of unsubstituted *p*-aminostyrene. The large activating effect of the α-bromo substituent may in part be a reflection of the response of substituent polarizability to the high electron demand placed upon the substituent.[5]

(4) The value of K_{AH^+} has not been determined. However, the intermediate is a significantly stronger base than α-bromo-*p*-aminostyrene, based on a comparison of the effect of acidity on the spectra of the intermediate and the styrene at the same concentration.

(5) (a) W. M. Schubert, J. M. Craven, and H. Steadly, *J. Amer. Chem. Soc.*, **81**, 2695 (1959); (b) W. M. Schubert, R. B. Murphy, and J. Robins, *Tetrahedron*, **17**, 199 (1962).

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Synthesis and Structure of $(C_5H_5CoCO)_2(GeCl_2)_2Fe(CO)_4$. A Novel Metal–Metal Heterocycle

Sir:

Organometallic derivatives of silicon and its congeners are well known to form cyclic compounds $(R_2M)_n$; in the case of tin, *n* ranges from 4 to 9.[1] In contrast, simple cyclic metal–metal bonded structures of transition metals have been observed only with three-membered rings, as in $Os_3(CO)_{12}$[2] or $[MnFe_2(CO)_{12}]^-$.[3] Larger numbers of transition metal atoms seem to adopt a more highly condensed cluster arrangement wherein the number of metal–metal bonds is greater than the number of metal atoms present,[4] as in $Rh_4(CO)_{12}$[5] and

(1) H. Gilman, W. H. Atwell, and F. K. Cartledge, *Advan. Organometal. Chem.*, 4, 1 (1966).

(2) E. R. Corey and L. F. Dahl, *Inorg. Chem.*, **1**, 521 (1962).

(3) U. Anders and W. A. G. Graham, *Chem. Commun.*, 292 (1966).

(4) On this definition, the anion $[Re_4(CO)_{16}]^{2-}$ would be regarded as a cluster, as it was in fact termed by the discoverers: R. Bau, B. Fontal, H. D. Kaesz, and M. R. Churchill, *J. Amer. Chem. Soc.*, **89**, 6374 (1967).

(5) C. H. Wei, G. R. Wilkes, and L. F. Dahl, *ibid.*, **89**, 4792 (1967).