

[CONTRIBUTION FROM THE CHEMICAL LABORATORIES OF THE COLLEGE OF LIBERAL ARTS OF NORTHWESTERN UNIVERSITY AND OF THE SCHOOL OF CHEMISTRY AND PHYSICS OF THE PENNSYLVANIA STATE COLLEGE

PSEUDO BASES. II. EQUILIBRIA AND RATE OF CHANGE OF TAUTOMERIC BASES IN THE PYRAZINE SERIES. THE EFFECT OF CONJUGATION

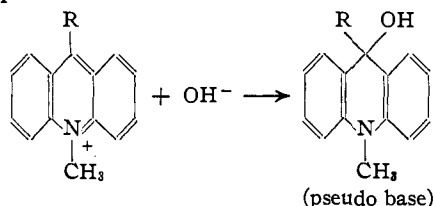
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RECEIVED DECEMBER 5, 1930

PUBLISHED APRIL 6, 1931

In this paper is described a kinetic study of the reaction of sodium hydroxide on certain quaternary pyrazinium salts, namely, 1,2,5-trimethylpyrazinium iodide, 1,2,2,5,5-pentamethyldihydropyrazinium iodide and 1,2,2,3,5,5,6-heptamethyldihydropyrazinium iodide, using a conductivity method to follow the progress of the reaction. The bases isolated from these salts were described in the first paper of this series.¹ Further information upon the relationship of these bases to the other possible tautomeric forms is now presented.

Hantzsch and Kalb,² in their work on pseudo bases, made a kinetic study of the reaction between aqueous potassium hydroxide and N-methylpyridinium, N-methylquinolinium and N-methylacridinium salts, using a conductivity method to measure the concentration of strong base, and showed that in the first two cases the equilibrium in the system $[R-N=C-R]^+ OH^- \rightarrow R-N-C(OH)-R$ favored the strong quaternary base. In the case of 5-phenyl-10-methylacridinium sulfate quite anomalous results were obtained which were not at all in keeping with the reaction which they postulated



as the rate determining step. However, the compound isolated from the reaction has all the properties of the pseudo base.

Preliminary experiments consisting of solubility determinations described in this paper have shown that the rate determining step is probably the crystallization of the so-called "pseudo base" from the solution and that in the reaction written above the equilibrium is shifted to the right in virtue of the insolubility of the product.

No similar anomalies were found in the pyrazine series, where all the bases are soluble in water. Here there is certain evidence for the type of

¹ Aston, *THIS JOURNAL*, **52**, 5254 (1930).

² Hantzsch and Kalb, *Ber.*, **32**, 3109 (1899).

reaction postulated by Hantzsch in addition to reactions of an entirely different type. These were discussed in the previous paper.

Experimental Method and Results

Preparation of Materials.—1,2,5-Trimethylpyrazinium iodide was recrystallized from absolute alcohol to constant analysis. 1,2,2,5,5-Pentamethyl and 1,2,2,3,5,5,6-heptamethyldihydropyrazinium iodide were recrystallized from methyl alcohol-*n*-butyl alcohol mixtures to constant analysis.

Conductivity water was prepared by distillation from alkaline permanganate with the usual precautions. Its specific conductance was always less than 2×10^{-6} ohm⁻¹ cm.⁻¹.

Sodium hydroxide solutions of known concentration were prepared by dilution of an accurately standardized carbonate-free stock solution with conductivity water.

Standard hydrochloric acid solutions were prepared by dilution of constant boiling hydrochloric acid with conductivity water and their strengths checked gravimetrically. Potassium chloride, used for cell constant determination, was recrystallized to constant conductivity.

Apparatus for Measuring Conductivities.—A Wheatstone bridge arrangement was used.³

A calibrated Kohlrausch slide wire bridge with end coils, an enclosed dial six decade resistance box, wound for use with high frequencies, and Brown tunable telephone receivers with a total resistance of 120 ohms were used. The alternating current (1000 cycles) was furnished by a microphone hummer. These instruments were those furnished by Leeds and Northrup. The bridge was neither grounded nor shielded.⁴ The lead resistances were each 0.05 ohm. The capacity of the conductivity cell was balanced in all measurements with suitable fixed and variable radio condensers. Readings were always taken within a few tenths of a per cent. of the center of the bridge. A thermostat was used which kept constant temperature to 0.01°. It was filled with ordinary water grounded through the cooling coils. Temperatures were measured accurately to 0.05° by thermometers certified by the Bureau of Standards.

Weights and volumetric apparatus were calibrated.

Conductivity of 1,2,5-Trimethylpyrazinium iodide.—Washburn conductivity cells were used, Type B for solutions above 0.002 *N* and Type A for more dilute solutions. The constant of cell B was determined at 25.11° to 0.03% using a solution containing 0.7455 g. of potassium chloride in 500 cc., which has a specific conductance of 0.002770 at 25.10° according to Kohlrausch.⁵ The Kohlrausch standard was used because the data were to be used in conjunction with other data using this standard. The constant of cell A was measured to 0.05% by intercomparison with cell B.

The 1,2,5-trimethylpyrazinium iodide used was found to have an equivalent weight of 252.8 (calcd., 250.05) by the Volhard method. Solutions were made up by dissolving weighed quantities of salt and diluting to a known volume with conductivity water. The found equivalent weight was used in computing the normality. All conductivity measurements were made at 25.11° with a precision of at least 0.05%. The results are given in Table I.

The values of the specific conductance (Col. 2) have been corrected for the specific conductance of the water. The limiting equivalent conductance Λ_0 was obtained using the extrapolation method of Randall.⁶

³ Washburn and Bell, *THIS JOURNAL*, **35**, 177 (1913).

⁴ See Jones and Josephs, *ibid.*, **50**, 1049 (1928).

⁵ Landolt-Börnstein-Roth-Scheel. "Tabellen," 1923, p. 1098.

⁶ Randall, *THIS JOURNAL*, **38**, 788 (1916).

TABLE I
CONDUCTIVITY OF 1,2,5-TRIMETHYLPYRAZINIUM IODIDE AT 25°

G. per liter	Specific conductance $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^3$	Concn. eqts. per liter $\times 10^2$	Λ	$\frac{\Lambda}{\alpha \text{LiIO}_3}$
15.758	5.467	6.235	87.65	106.9
7.878	2.953	3.115	94.75	109.95
3.950	1.5705	1.5630	100.5	112.3
1.971	0.8143	0.7795	104.5	113.4
0.9830	.4153	.3889	106.8	113.4
.24575	.1081	.09720	113.1	114.8
	Extrapolated 0		115.0	

The values of the equivalent conductance Λ (Col. 4) were divided by $\alpha = \Lambda/\Lambda_0$ for lithium iodate at 18° at the same concentration, obtained from his tables. The quotients thus obtained (Table I, Col. 5) were plotted against \sqrt{C} and the curve extrapolated to zero concentration. The value of Λ_0 thus obtained was checked by reference to the Λ/Λ_0 values for hydrochloric acid. The two agreed within 0.4%. By subtracting the value of the limiting conductance of the iodide ion at 25.11° ($\Lambda_{01^-} = 76.7$)⁷

from this value of Λ_0 , the limiting conductance of the positive ion is found to be $\Lambda_{0\text{Py}^+} = 38.3$ at 25.11°.

By the use of indicators it was estimated that the basic nitrogen atom in 1,2,5-trimethylpyrazinium iodide had a basic dissociation constant of less than 3×10^{-10} , corresponding to less than 0.02% dissociation in 0.001 *N* solution. The effect of basic dissociation is thus not detectable in our measurements and does not affect the value of the limiting conductance.

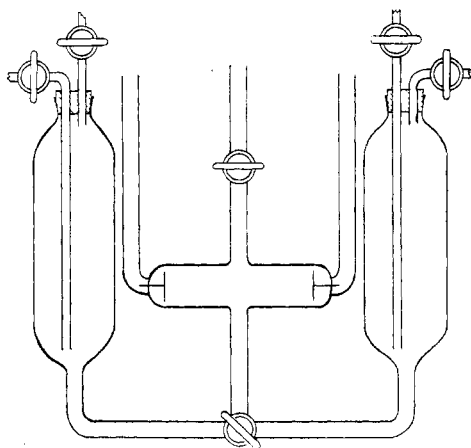


Fig. 1.—Mixing apparatus and cell.

Kinetics of the Reaction of 1,2,5-Trimethylpyrazinium Iodide and Sodium Hydroxide.—The mixing apparatus and cell used in this reaction is illustrated in Fig. 1.

The quantities of the solutions of alkali and salt to be mixed were placed, respectively, in the two cylinders, which were then swept out with a current of carbon dioxide-free nitrogen and allowed to reach the temperature of the thermostat. The solutions were then mixed by forcing the contents of one cylinder completely into the other. The start of the reaction was taken as the end of this operation. Thorough mixing was effected by a

⁷ Noyes, *THIS JOURNAL*, 34, 479 (1912).

current of nitrogen and forcing the mixture back and forth from one cylinder into the other. The solution was then forced into the conductivity cell, which had been previously swept with nitrogen. The constant of this cell was determined as previously. A measurement of the conductivity of the mixture was made as soon as possible after mixing and at

TABLE II
CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING 25 CC. OF 0.06236 *N* SODIUM HYDROXIDE AND 25 CC. OF 0.06236 *N* 1,2,5-TRIMETHYL-PYRAZINIUM IODIDE AT 25.11°

Time, min.	Specific conductance ohm ⁻¹ cm. ⁻¹ × 10 ³	(Py ⁺) = (OH ⁻) moles/liter × 10 ²	<i>k</i> ₂ , min. ⁻¹	<i>k</i> ₄ , min. ⁻¹ × 10 ⁻³
0	8.913	3.118	..	..
8.42	7.390	1.897	..	..
11.92	7.025	1.708	85.75	5.02
22.22	6.419	1.405	71.8	5.11
42.5	5.840	1.120	68.2	6.09
73.8	5.435	0.916	60.8	6.64
112.9	5.145	.776	59.2	7.63
142.6	5.007	.704	59.3	8.42
180.2	4.878	.638	58.3	9.14
210.4	4.799	.597	54.4	9.12
264.3	4.689	.545	51.9	9.53
339.7	4.581	.492	49.0	10.0
408.9	4.509	.456	48.4	10.6
506.9	4.435	.419	..	..

TABLE III
CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING 25 CC. OF 0.01542 *N* SODIUM HYDROXIDE AND 25 CC. OF 0.01542 *N* 1,2,5-TRIMETHYL-PYRAZINIUM IODIDE AT 25.11°

Time, min.	Specific conductance ohm ⁻¹ cm. ⁻¹ × 10 ³	(Py ⁺) = (OH ⁻) moles/liter × 10 ²	<i>k</i> ₂ , min. ⁻¹	<i>k</i> ₄ , min. ⁻¹ × 10 ⁻³	<i>k</i> ₂ calcd., min. ⁻¹
0	2.563	0.771	..	..	..
7.3	2.519	.750	..	..	..
19.5	2.445	.715	69.9	9.77	Ref.
32.3	2.389	.687	..	..	..
45.3	2.329	.658	68.5	10.0	68.4
69.5	2.240	.615	..	..	67.2
88.5	2.185	.590	66.4	11.2	66.3
114.7	2.117	.557	..	..	65.5
143.3	2.056	.528	65.5	12.4	64.6
190.2	1.972	.488	63.5	13.0	63.4
322.2	1.814	.413	62.3	15.1	61.0
411.8	1.741	.379	60.3	15.9	60.0
1133.5	1.4761	.2547	55.8	21.9	55.9
1323.6	1.4425	.2391	54.8	22.9	55.3
1638.4	1.4000	.2193	51.4	23.4	54.6
2173.5	1.3518	.1966	44.1	22.4	53.9
2871.5	1.3147	.1793	..	..	..

TABLE IV

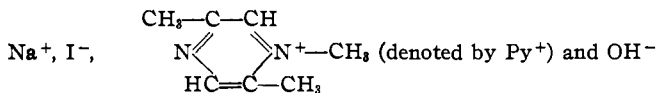
CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATION AFTER MIXING 25 CC. OF 0.03128 *N* SODIUM HYDROXIDE AND 25 CC. OF 0.01564 *N* 1,2,5-TRIMETHYL-PYRAZINIUM IODIDE AT 25.11°

Time, min.	Specific conductance $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^3$	(Py ⁺) moles/liter $\times 10^2$	(OH ⁻) moles/liter $\times 10^2$	k_3 , min.^{-1}	k_4 , $\text{min.}^{-1} \times 10^{-3}$	k_3 calcd., min.^{-1}
0	4.367	0.782	1.564	..	..	..
9.5	4.229	.716	1.499	83.9	5.60	89.2
12.5	4.189	.696	1.477	85.1	5.76	88.7
18.0	4.126	.665	1.446	82.4	5.69	88.1
32.2	3.992	.600	1.382	77.7	5.62	86.7
47.7	3.881	.545	1.327	85.2	6.42	85.3
84.3	3.696	.456	1.238	78.2	6.32	83.3
119.5	3.572	.3953	1.177	78.1	6.64	81.9
162.5	3.465	.3435	1.126	77.1	6.84	80.6
248.7	3.323	.2746	1.057	79.7	7.54	78.9
334.6	3.230	.2302	1.012	80.2	7.92	77.8
445.8	3.149	.1913	0.973	80.4	8.26	76.8
556.5	3.091	.1638	.946	80.6	8.52	76.1

convenient intervals thereafter. Times were measured using an ordinary watch except for the first part of the reaction, when a stop watch was used. The conductivity of the mixture at zero time was obtained by extrapolation. Representative results of runs at different concentrations are given in the Tables II, III, IV.

In Cols. 1 and 2 are given, respectively, the time after the start of the reaction (*t*) and the value of the specific conductance (κ) of the reacting solution at that time. Duplicate experiments showed that values of κ were reproducible to 0.1%.

Initially the reacting solution contains the ions



Its initial conductivity shows that the base formed from the last two ions is a strong electrolyte. The fall in conductivity is due to the change of this base into one very much weaker whose dissociation will be assumed to be negligible. The four strong electrolytes which can be formed from the above ions will be assumed to be completely dissociated. In Tables II and III, Col. 3, and Table IV, Cols. 3 and 4, the calculated concentrations of Py⁺ and OH⁻ are given.

At the end of the runs where equivalent quantities of the salt and sodium hydroxide are mixed, the final solution will contain the weak base and sodium iodide at concentrations equal to those of the reactants, $a = b$, at the start. At any previous time during the reaction, the composition of the solution with respect to the ions would be reproduced by

adding 1,2,5-trimethylpyrazinium hydroxide (x equivalents per liter) to the final solution until the conductivity reached the measured value, assuming the effect of the weak base to be negligible, so that $(\text{Py}^+) = (\text{OH}^-) = x$.

In the run with the sodium hydroxide in excess of the pyrazinium salt, their initial stoichiometrical concentrations in the mixture being, respectively, a and b , the final concentrations of sodium iodide and sodium hydroxide are b and $(a - b)$ at any previous time $(\text{Py}^+) = x$ and $(\text{OH}^-) = x + a - b$, where x has the same significance as before.

If Λ/Λ_0 were unity for all the electrolytes, x could be calculated from the difference between the observed and final values of the specific conductance using the value of Λ_0 for the pyrazinium hydroxide. As this was not the case, x was calculated by a method similar to that which Sherrill used to calculate the conductivity of mixtures of potassium sulfate and sodium chloride.⁸ This method gave values accurate to 0.1%. Although based on the theory of constant ion mobility and incomplete dissociation, its validity as an empirical method is not altered when complete ionization is assumed. It amounts to applying corrections for the changing deviation of the Λ/Λ_0 values from unity. In making the calculations the following data were used: limiting conductances of the four ions at 25.11°, $\Lambda_{0\text{Na}^+} = 51.3$, $\Lambda_{0\text{I}^-} = 76.7$, $\Lambda_{0\text{OH}^-} = 193.0$,⁹ $\Lambda_{0\text{Py}^+} = 38.3$, and also plots of " K " = $(\Lambda/\Lambda_0)^2 C/1 - \Lambda/\Lambda_0$ against $\Sigma i = \Lambda/\Lambda_0 C$ for sodium iodide, sodium hydroxide, 1,2,5-trimethylpyrazinium iodide and its hydroxide for which the following values were used: NaI: Σi : 0.05439, 0.02800, 0.00733; " K ": 0.3639, 0.2428, 0.1119;¹⁰ NaOH: Σi : 0.04421, 0.01818, 0.00943, 0.00829, 0.006698; " K ": 0.6635, 0.3743, 0.2809, 0.2469, 0.2324;¹¹ PyI: Σi : 0.04752, 0.02568, 0.01366, 0.007085; " K ": 0.1522, 0.1202, 0.09433, 0.07085. Values of Σi and " K " for the pyrazinium hydroxide were obtained from the extrapolated zero time value of the specific conductance in each of the runs where the concentrations of all the substances present are known, using the $\Sigma i - "K"$ curves for the other three salts and the limiting conductances of the four ions, by a method obvious from the definitions of these quantities and the calculations in Sherrill's paper.

The values thus obtained were: PyOH: Σi : 0.05028, 0.02153, 0.01413; " K ": 0.7585, 0.2012, 0.1647. Comparison with the values of " K "

⁸ Sherrill, *THIS JOURNAL*, **32**, 741 (1910).

⁹ Values obtained from the tables of Noyes and Falk, *THIS JOURNAL*, **34**, 479 (1912), the temperature coefficients of Kohlrausch, Landolt-Börnstein-Roth-Scheel, "Tabellen," 1923, p. 1104, and the data of Randall and Scalione for NaOH, *THIS JOURNAL*, **49**, 1491 (1927).

¹⁰ From the data of Jones. Landolt-Börnstein-Roth-Scheel, "Tabellen," 1923, p. 1091.

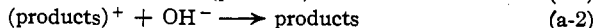
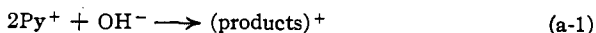
¹¹ From the data of Randall and Scalione, Ref. 9.

for sodium hydroxide shows that the base is a strong electrolyte. The calculation of x from the observed specific conductances is most simply made by plotting for each run the concentration of pyrazinium hydroxide against the specific conductance, calculated by Sherrill's method for mixtures of sodium iodide and sodium hydroxide at the fixed concentrations b and $a - b$, with the pyrazinium hydroxide at various rounded concentrations. Values of x are then read from the plot.

The values of k_3 in Tables II and III, Col. 4, and Table IV, Col. 5, are calculated from the equation

$$\frac{d(\text{Py}^+)}{dt} = \frac{d(\text{OH}^-)}{dt} = k_3(\text{Py}^+)^2(\text{OH}^-) \quad (1)$$

applying to the consecutive reactions



(a-1) controlling the rate $d(\text{Py}^+)/dt$.

Those of k_4 in Tables II and III, Col. 5, and Table IV, Col. 6, are calculated from the equation

$$\frac{d(\text{Py}^+)}{dt} = \frac{d(\text{OH}^-)}{dt} = k_4(\text{Py}^+)^2(\text{OH}^-)^2 \quad (2)$$

applying to the reaction



Both k_3 and k_4 are instantaneous values calculated by the method of Bray,¹² using the slopes of tangents to plots of $1/(2\text{Py}^+)^2$ against the time when

$(\text{Py}^+) = (\text{OH}^-)$ and of $1/(\text{Py}^+)$ against the time when $(\text{OH}^-) > (\text{Py}^+)$. The plot of $1/2(\text{Py}^+)^2$ against time for the data in Table III is shown in Fig. 2.

The values of k_3 and k_4 are accurate to about 5%. A comparison between trends of their values points to a simultaneous disappearance of base by reactions (a-1) and (b), whence

$$\frac{d(\text{Py}^+)}{dt} = k'_{\text{iii}}(\text{Py}^+)^2(\text{OH}^-) + k'_{\text{iv}}(\text{Py}^+)^2(\text{OH}^-)^2 \quad (3)$$

where k'_{iii} and k'_{iv} are, respectively, the true specific reaction rate constants of (a-1)

and (b). Combination of (1) and (3) gives

$$k_3 = k'_{\text{iii}} + k'_{\text{iv}}(\text{OH}^-) \quad (4)$$

¹² Bray, *J. Phys. Chem.*, 9, 573 (1905).

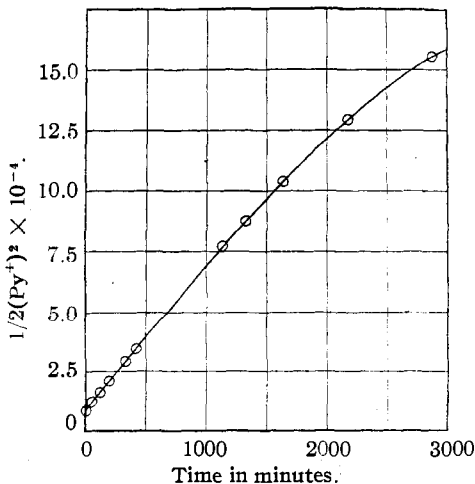


Fig. 2.—Graph from data in Table III.

Since k'_{iii} and k'_{iv} will vary with the salt concentrations, for any particular starting concentrations (4) defines a curve. If such a curve can be extrapolated to $(OH^-) = 0$ at this point $k_3 = k'_{iii}$ gives the value of k'_{iii} at the total salt concentration which the solution reaches when $(OH^-) = 0$. Thus, in general, (4) defines a family of curves. In Fig. 3 the values of k_3 for each of the runs are plotted against (OH^-) . The data of Tables II⁷ and III lie on two distinct curves aa and bb. Extrapolation of each curve to $(OH^-) = 0$ gives $k'_{iii} = 38$ and $k'_{iii} = 47$, respectively. The only electrolyte present at $(OH^-) = 0$ in both cases is sodium iodide at concentrations 0.03118 and 0.00771, respectively. According to the Brönsted¹³ theory of reaction rate, the limiting relation for the effect of

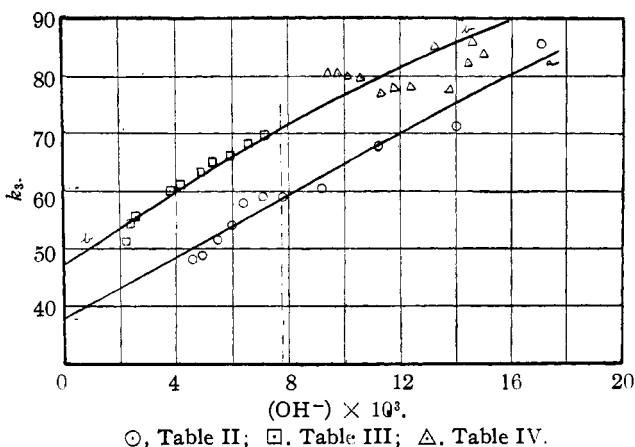


Fig. 3.—Effect of (OH^-) and concn. of total salt on k_3 .

salts on the specific reaction rate constant k' for a reaction between ions of the type, $2A + B \rightarrow$ products, is

$$\log k' = \log k + (Z_A^2 + 2Z_A Z_B) \sqrt{\mu}$$

where μ is the ionic strength of the solution and Z_A and Z_B are the charges on the ions, k being the value of the constant when $\mu = 0$.

For the above reactions where all the electrolytes are uni-univalent, μ is the total concentration of electrolyte, $Z_A = +1$ and $Z_B = -1$ whence

$$\log k'_{iii} = \log k_{iii} - \sqrt{\mu} \quad (5)$$

Similar considerations give rise to the limiting equation

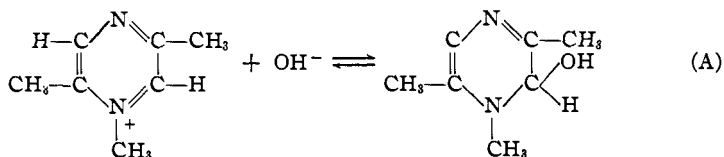
$$\log k'_{iv} = \log k_{iv} - 2 \sqrt{\mu} \quad (6)$$

for calculating the effect of salt on k'_{iv} . Using (5) and the value of $k'_{iii} = 47$ at $\mu = 0.00771$ obtained by extrapolation of bb to $(OH^-) = 0$, it is found that $k_{iii} = 57.5$ at $\mu = 0$ and that $k'_{iii} = 38.3$ at $\mu = 0.03118$. The agreement of this value with that obtained by extrapolating curve aa

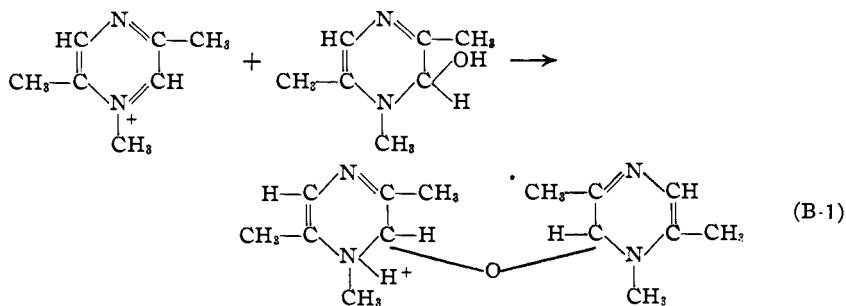
¹³ Brönsted. *Z. physik. Chem.*, 102, 169 (1922); Brönsted and Livingston. *THIS JOURNAL*, 49, 439 (1927); Beard and Taylor. *ibid.*, 51, 1975 (1929).

is closer than the accuracy of the extrapolation or that of (5) at such high values of the ionic strength. The data of Table IV are in accord with our assumptions. At the end of this run the values of (OH^-) , the sodium iodide concentration, and the total salt concentrations are the same as those at the start of the run in Table III. This point is indicated in Fig. 3 by the broken vertical line. The two sets of data fall into the same curve bb at this point. For the run in Table III after 19.5 minutes, when $\mu = 0.01486$, the value of $k'_{\text{iii}} = 43.44$ (calculated from (5) and $k_{\text{iii}} = 57.5$ at $\mu = 0$). From the values $k_3 = 69.9$ and $(\text{OH}^-) = 0.00715$ at this point, using (4), $k'_{\text{iv}} = 37.1 \times 10^2$. By relation (6) k_{iv} at $\mu = 0$ is then calculated to be 65.0×10^2 . The values of k_3 calcd. in Table III (Col. 6) and Table IV (Col. 7) are calculated from the above values of k_{iii} and k_{iv} at $\mu = 0$ and (OH^-) using relations (5), (6) and (4). The agreement with the experimental values is within the experimental error. Further, relations (5) and (6) are limiting relations which, although holding quite well when $\mu < 0.01$, become far from accurate as μ increases. For this reason no values of k_3 calcd. are given for Table II.

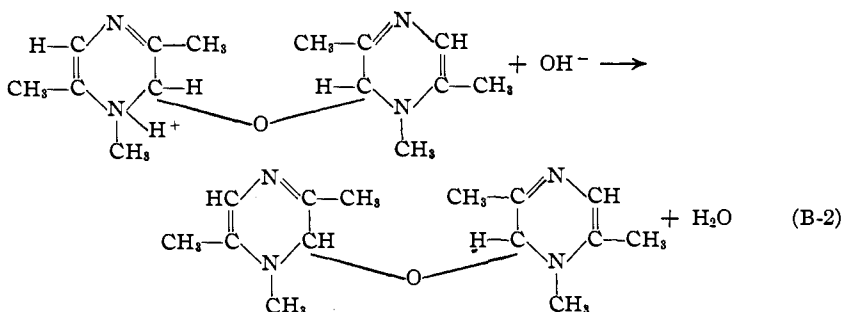
Since, from statistical considerations, reaction through triple or quadruple collisions is generally regarded as improbable, reactions (a-1) and (b) must be considered as taking place in two steps, the first step being a rapid equilibrium and the second a dimolecular reaction. It will be assumed that both (a-1) and (b) have the same reversible step



The initial value of the conductivity points to only very small equilibrium amounts of the pseudo base. Denoting the pseudo base by $\text{P} - \text{OH}$, $K_A = (\text{P} - \text{OH})/(\text{Py}^+)(\text{OH}^-)$ is the equilibrium constant of reaction A. If this is followed by the slow reaction



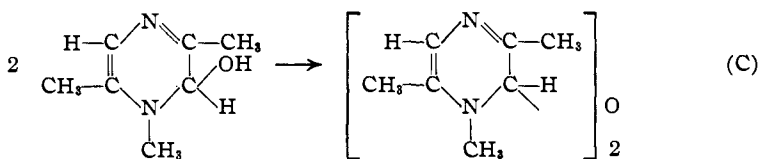
succeeded by the rapid reaction



(B-1) therefore controlling the rate of the entire process, then

$$\begin{aligned}
 \frac{d(\text{Py}^+)}{dt} &= k_B(\text{P} - \text{OH})(\text{Py}^+) \\
 \frac{d(\text{Py}^+)}{dt} &= K_A k_B (\text{Py}^+)^2 (\text{OH}^-) = k_{iii}' (\text{Py}^+)^2 (\text{OH}^-).
 \end{aligned}$$

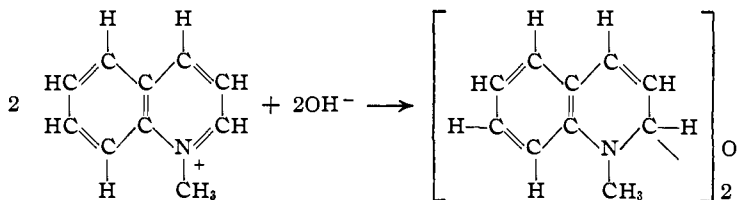
If the slow reaction taking place is



yielding the same ether as above

$$\begin{aligned}
 \frac{d(\text{Py}^+)}{dt} &= \frac{d(\text{P} - \text{OH})}{dt} = k_o(\text{P} - \text{OH})^2 = K_A^2 k_o (\text{Py}^+)^2 (\text{OH}^-)^2 \\
 \frac{d(\text{Py}^+)}{dt} &= k_{iv}' (\text{Py}^+)^2 (\text{OH}^-)^2.
 \end{aligned}$$

The formation of such ethers is characteristic of pseudo bases in the quinoline series.¹⁴ Hantzsch and Kalb found that such an ether precipitated from dilute solution of N-methylquinolinium hydroxide (N/16)



with a corresponding decrease in conductivity.² Such ethers yield the salt of the original base upon treatment with acid.^{2,15} It has been shown that the final product obtained in the above reactions can be changed back into the original pyrazinium salt by the addition of acid. A run was made using the same concentrations as that in Table II in which 25

¹⁴ La Coste, *Ber.*, 15, 189 (1882).

¹⁵ Decker, *ibid.*, 35, 3073 (1902).

cc. of 0.06237 *N* sodium hydroxide and 25 cc. of 0.06237 *N* 1,2,5-trimethylpyrazinium iodide were allowed to react for 307 minutes (83.6% completion) in the absence of oxygen, at 25.00°; 50 cc. of 0.06268 *N* hydrochloric acid was then added and the mixture allowed to stand for six days at 25.00°; 25 cc. of this mixture was then mixed with 25.0 cc. of 0.03128 *N* sodium hydroxide at 25.11° in the apparatus of Fig. 1. The conductivity of the solution was followed and compared with that of a blank, using exactly the same quantities but adding the 0.06268 *N* hydrochloric acid before the original sodium hydroxide, and thus preventing the original reaction. The values of the specific conductance at various times after mixing are shown in Fig. 4 for both runs. The zero time for

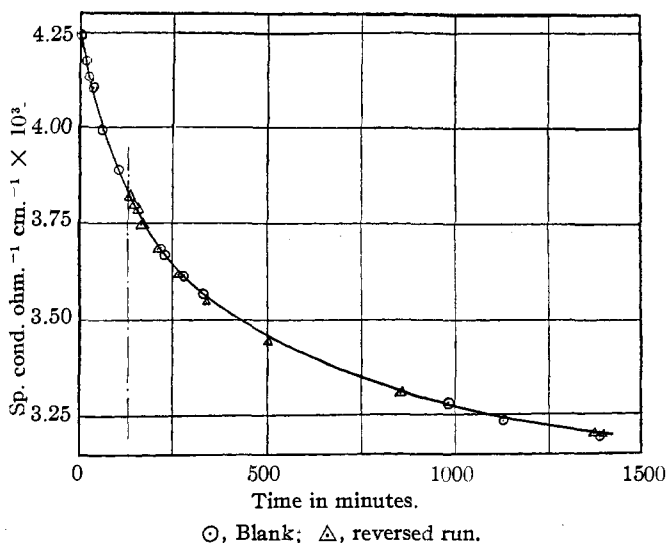


Fig. 4.—Specific conductances in reversed and blank runs.

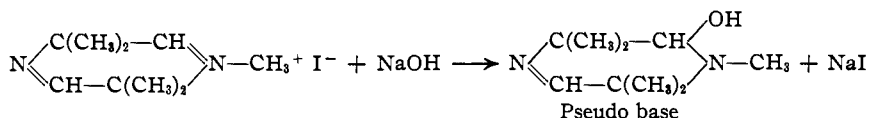
the blank run is at zero, that for the reversed run is indicated by the broken vertical line at 130 minutes, the time scales being the same. Both sets of data are thus seen to lie on the same curve. The results show that 72.8% of the original salt was present after reversal; that is, that 67.5% of the reacted 1,2,5-trimethylpyrazinium iodide had been regenerated.

An attempt to isolate this ether, described in the previous paper, resulted in a product which decomposed so rapidly that analytical evidence as to its nature was meaningless. Its reactions are now being studied.

The reactions B and C above present certain analogies with hemiacetal and acetal formation, respectively. Such reactions are known to occur simultaneously.

The Reaction between 1,2,2,5,5-Pentamethyldihydropyrazinium Iodide and Sodium Hydroxide in Water at 0°.—A preliminary study of this

reaction by the method just described showed that the changes were too rapid to measure both at 25 and 0°. When equivalent quantities of the two solutions were mixed the conductivity of the solution was 14% greater than that calculated for a concentration of sodium iodide,¹⁶ corresponding to that formed in the reaction

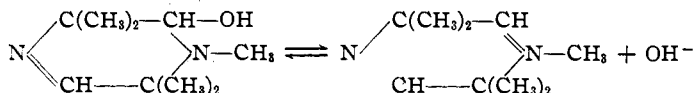


which has already been shown to take place by the isolation of the pseudo base.¹

Ten cc. of 0.01092 *N* sodium hydroxide was mixed with 10 cc. of 0.01092 *N* 1,2,2,5,5-pentamethyldihydropyrazinium iodide (specific conductance 5.59×10^{-4} ohm⁻¹ cm.⁻¹ at 0°. The observed specific conductance of the solution immediately after mixing at 0° was 4.06×10^{-4} ohm⁻¹ cm.⁻¹ calculated for 0.00546 *N* NaI at 0°, 3.57×10^{-4} ohm⁻¹ cm.⁻¹; diff. due to base, 0.49×10^{-4}).¹⁷

A value of the limiting equivalent conductance at 25.00° $\Lambda_0 = 109.6$ for 1,2,2,5,5-pentamethyldihydropyrazinium iodide was calculated approximately from $\Lambda = 97.6$ at 0.01092 *N*, measured at 25.00°, assuming $\Lambda/\Lambda_0 = 0.89$ (the value for 1,2,5-trimethylpyrazinium iodide at the same concentration). For 1,2,2,5,5-pentamethyldihydropyrazinium hydroxide $\Lambda_0 = 226.9$ at 25.00° calculated from Λ_0 for the iodide and the limiting equivalent conductances $\Lambda_{\text{OH}^-} = 192.7$ $\Lambda_{\text{I}^-} = 76.5$ at 25.00°.

Below are given values of *K* for the equilibrium



calculated from conductance measurements on 1,2,2,5,5-pentamethyl-6-hydroxytetrahydropyrazine, using the relationship $K = (\Lambda/\Lambda_0)^2 C / (1 - \Lambda/\Lambda_0)$, taking $\Lambda_0 = 226.9$ as found above.

TABLE V
EXPERIMENTAL DATA

Concn. eqts./liter	Specific conductance ohm ⁻¹ cm. ⁻¹ × 10 ⁵	Λ	Λ/Λ_0	$K \times 10^4$
0.00589	6.21	10.6	0.0466	1.34
.01100	7.59	6.9	.0303	1.34

The values of the specific conductance taken within fifteen minutes of mixing increased 60% on standing for twenty-four hours. They are in rough agreement with the difference obtained above at 0° (0.49×10^{-4}

¹⁶ Compare Stewart and Maeser, *THIS JOURNAL*, **46**, 2583 (1924).

¹⁷ From the data of Jones, "International Critical Tables," Vol. VI, p. 235.

ohm⁻¹ cm.⁻¹ due to 0.005 *N* solution of the base). These values of *K* are probably much too high for the pseudo basic system which, in the previous paper, was shown to be a weaker base than the unmethylated nitrogen, to which therefore a large part of the conductivity must be due. The complete stability of the base in water for intervals of at least an hour was shown in the previous paper and therefore these results indicate that the equilibrium between 1,2,2,5,5-pentamethyldihydropyrazinium hydroxide and 1,2,2,5,5-pentamethyl-6-hydroxytetrahydropyrazine is established rapidly and greatly favors the latter.

Conductivity of 1,2,2,3,5,5,6-Heptamethyldihydropyrazinium Iodide at 25.00°.—Two Freas conductivity cells with cell constants 0.3496 and 0.3370 were used. The constants were determined using a solution of 0.7476 g. of potassium chloride in 1000 g. of water whose specific conductance was taken as 0.0014104 (the Kohlrausch value corrected to the standards of Parker and Parker).¹⁸ The results are given in Table VI. The theoretical equivalent weight of 308.2 was used in the computations. The accuracy is the same as previously.

TABLE VI.

CONDUCTIVITY OF 1,2,2,3,5,5,6-HEPTAMETHYLDIHYDROPYRAZINIUM IODIDE AT 25.00°

G. per liter	Specific conductance, ohm ⁻¹ cm. ⁻¹ × 10 ³	Concn. eqts. per liter × 10 ²	Λ	$\frac{\Lambda^{\alpha}}{\alpha \text{ std.}}$
3.438	1.0343	1.1155	92.8	104.4
3.387	1.0148	1.0985	92.5	103.9
1.695	0.5283	0.5500	96.1	104.5
0.8468	.2708	.2748	98.5	104.5
.8465	.2694	.2746	98.2	104.2
.4230	.1386	.1372	101.1	105.4
	Extrapolated	0	104.7	104.7

^α α std. = Λ/Λ_0 for 1,2,5-trimethylpyrazinium hydroxide.

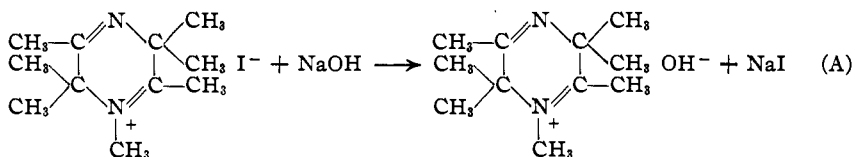
The value of Λ_0 was obtained using the extrapolation method of Randall. From $\Lambda_{01^-} = 76.9$ and $\Lambda_{0\text{OH}^-} = 194.0$,¹⁹ the limiting equivalent conductance of 1,2,2,5,5,6-heptamethyldihydropyrazinium hydroxide at 25.00° was calculated to be $\Lambda_0 = 222.0 \pm 1\%$.

The Reaction between 1,2,2,3,5,5,6-Heptamethyldihydropyrazinium Iodide and Sodium Hydroxide in Water at 25.00°.—This reaction was studied using the same Freas cells at 25.00 ± 0.05°: 10 cc. of the solution of the pyrazinium salt was allowed to come to temperature in the thermostat; 10 cc. of the sodium hydroxide solution, withdrawn from the thermostat, was then introduced into the cell by a pipet and the contents of the

¹⁸ "International Critical Tables," Vol. VI, p. 230.

¹⁹ Calculated from data in "International Critical Tables," Vol. VI, p. 230, $\Lambda_{0\text{OH}^-}$ being somewhat weighted by comparison with a value calculated from the data of Randall on sodium hydroxide.

cell mixed by thorough shaking in the thermostat. The temperature in the cell immediately after mixing, by actual test, was never more than 0.1° above that of the thermostat, due to the transference of the sodium hydroxide. The conductivity of the solution was measured as soon as possible after mixing. The specific conductances of certain mixtures at various time intervals are given in Col. 2, Tables VIII, IX, X and XI, the times being given in Col. 1. To save space only a few of the values are given for each run. The zero time values were obtained by extrapolation. Times were measured as before. The fall in conductivity is due to the slow production of a weaker base, whose dissociation was shown to be negligible from the final conductivity of the reaction mixture. For the runs using equal quantities the initial specific conductance due to the base was obtained from the extrapolated zero time values of the specific conductance by subtracting the estimated specific conductance due to the sodium iodide assuming that the metathesis reaction



takes place completely. For the runs where excess of the dihydropyrazinium iodide was present the estimated specific conductance of this excess was also subtracted. The values of Λ for sodium iodide and the dihydropyrazinium iodide used in the calculation were read from plots of Λ against \sqrt{C} and were taken at a concentration equal to the sum of the over-all concentrations of the sodium iodide and dihydropyrazinium iodide plus the concentration of ionized pyrazinium base. A decrease in the mobility of one pair of ions due to the presence of the remaining ions was thus corrected for as far as possible. The data on sodium iodide were from Jones.²⁰ Assuming that the pyrazinium base yielded the same positive ion as the salt, the limiting equivalent conductance of the base was taken as that of 1,2,2,3,5,5,6-heptamethylpyrazinium hydroxide $\Lambda_0 = 222.0$. This does not allow for a decrease in mobility of the type mentioned above. The error thus introduced is probably not more than 5%. From these results the values of the basic dissociation constants in Table VII were calculated. The concentrations of the pyrazinium base, C_b , pyrazinium iodide, C_{PYI} , and sodium iodide, calculated on the assumption of complete metathesis, are given in Cols. 1, 2 and 3, respectively. Columns 4 and 5 contain, respectively, the total specific conductance and that due to the base. The calculated values of Λ/Λ_0 for the base are given in col. 6. The values of K_B given in Col. 7 are calculated from the relations

²⁰ "International Critical Tables." Vol. VI, p. 230.

$$K_B = \frac{(\Delta/\Delta_0)^2 C_b}{1 - \Delta/\Delta_0} \quad (1)$$

$$K_B = \frac{\Delta/\Delta_0 C_b (C_{PyI} + \Delta/\Delta_0 C_b)}{(1 - \Delta/\Delta_0) C_b} \quad (2)$$

where C_b and C_{PyI} are, respectively, the concentrations of pyrazinium base and iodide. Relation 1 was used when C_{PyI} was zero and relation 2 when the pyrazinium iodide was present.

TABLE VII
DISSOCIATION CONSTANTS AT 25.00°

Over-all concn. PyOH eqts./liter $\times 10^3$	Concn. PyI eqts./liter $\times 10^3$	Concn. NaI eqts./liter $\times 10^3$	Total sp. cond. ohm ⁻¹ cm. ⁻¹ $\times 10^4$	Sp. cond. of base ohm ⁻¹ cm. ⁻¹ $\times 10^4$	Δ/Δ_0	K_B $\times 10^3$
5.497	0	5.497	13.51	6.89	0.565	4.03
2.745	0	2.745	7.455	4.100	.672	3.78
1.374	0	1.374	3.938	2.293	.752	3.13
2.748	2.748	2.748	8.99	3.060	.502	4.15

In Col. 3, Tables VIII, IX, X and XI, the values of the concentration of pyrazinium base whose dissociation constant is calculated above were estimated from the total specific conductance given in Col. 2 with the aid of graphs prepared for each run as follows: the specific conductance due to rounded concentration of the base was estimated from the Δ/Δ_0 values calculated from K_B appearing at the head of the table using either (1) or (2). The specific conductances, calculated as above, due to the sodium iodide and to the pyrazinium iodide, when present, were added

TABLE VIII
CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING EQUAL QUANTITIES OF 0.01099 N SODIUM HYDROXIDE AND 0.01099 N 1,2,2,3,5,6-HEPTAMETHYLDIHYDROPYRAZINIUM IODIDE AT 25.0° (THREE RUNS). $K_B = 4.1 \times 10^{-3}$

Time, min.	Specific conductance, ohm ⁻¹ cm. ⁻¹ $\times 10^3$	Concn. PyOH, C_b , eqts./liter $\times 10^3$	$\frac{d1/C_b}{dt}$ liter/mol./min.	α	k , min. ⁻¹
0.00	1.351	5.49	..	..	..
2.17	1.338	5.31	..	..	..
4.17	1.328	5.20	..	..	..
5.32	1.320	5.11	..	..	..
12.60	1.289	4.77	2.05	0.592	5.84
27.00	1.236	4.21	2.15	.613	5.73
39.0	1.194	3.78	2.25	.654	5.28
68.7	1.106	2.955	2.45	.674	5.39
83.6	1.076	2.691	2.51	.689	5.40
96.2	1.051	2.477	2.69	.703	5.44
115.7	1.014	2.175	2.78	.723	5.31
133.3	0.989	1.980	2.92	.738	5.36
160.5	.951	1.690	3.04	.762	5.24
189.2	.922	1.485	3.10	.780	5.10
246.3	.875	1.155	3.41	.813	5.16

TABLE IX

CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING EQUAL QUANTITIES OF 0.0055 *N* SODIUM HYDROXIDE AND 0.0055 *N* 1,2,2,3,5,5,6-HEPTAMETHYLDIHYDROPYRAZINIUM IODIDE AT 25.00°. $K_B = 3.78 \times 10^{-8}$

Time, min.	Specific conductance $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^3$	Concn. PyOH, C_b eqts./liter $\times 10^3$	$\frac{d1/C_b}{dt}$ liter/mol./min.	α	k_i min. ⁻¹
0	0.7455	2.750	..	..	..
5.1	.7338	2.638	..	..	..
7.25	.7235	2.597	..	..	..
10.00	.7222	2.537	2.79	0.686	5.93
15.2	.7120	2.450	..	..	..
19.9	.7033	2.370	..	..	..
31.1	.6833	2.205	..	..	..
35.5	.6765	2.150	2.95	.713	5.81
55.7	.6465	1.907	3.01	.732	5.61
112.4	.5820	1.428	3.20	.775	5.33
244.1	.4979	0.860	3.75	.840	5.32
246.2	.4969	.854	..	..	..

TABLE X

CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING EQUAL QUANTITIES OF 0.00275 *N* SODIUM HYDROXIDE AND 0.00275 *N* 1,2,2,3,5,5,6-HEPTAMETHYLDIHYDROPYRAZINIUM IODIDE AT 25.00°. $K_B = 3.13 \times 10^{-8}$

Time, min.	Specific conductance $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^3$	Concn. PyOH C_b eqts./liter $\times 10^3$	$\frac{d1/C_b}{dt}$ liter/mol./min.	α	k_i min. ⁻¹
0	0.3988	1.372	...	..	..
6.75	.3930	1.328	...	..	..
9.75	.3908	1.312	...	..	..
13.6	.3875	1.289	...	..	..
18.0	.3843	1.265	...	..	..
22.25	.3812	1.243	3.403	0.767	5.82
30.25	.3758	1.204	...	..	..
42.6	.3678	1.146	...	..	..
54.5	.3601	1.092	3.513	.785	5.70
73.3	.3496	1.020	3.572	.795	5.65
124.5	.3256	0.859	3.608	.812	5.47
160.9	.3118	.770	...	..	..
214.4	.2957	.669	3.715	.842	5.24
313.7	.2730	.532	...	..	..
401.3	.2593	.455	...	..	..

to that of the base. The values of the total specific conductance thus obtained were plotted against the total concentration of the pyrazinium base.

If the following reaction is responsible for the disappearance of the pyrazinium base, and if, as before, C_b represents the over-all concentration of pyrazinium base, then

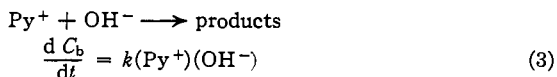


TABLE XI

CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS AFTER MIXING EQUAL QUANTITIES OF 0.00550 *N* SODIUM HYDROXIDE AND 0.01099 *N* 1,2,2,5,5,6-HEPTAMETHYLDIHYDROPYRAZINIUM IODIDE AT 25.00°. $K_B = 4.15 \times 10^{-3}$

Time, min.	Sp. cond. $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^3$	Concn. PyOH, C_b , eqts./liter $\times 10^3$	$\frac{dC_b}{dt}$ liter/min. $\times 10^2$	(OH ⁻), eqts./liter $\times 10^3$	(Py ⁺), eqts./liter $\times 10^3$	k , min. ⁻¹
0	0.8990	2.750	..	...	...	..
8.2	.8790	2.535	..	...	...	..
11.04	.8715	2.457	2.49	1.251	3.998	4.98
16.00	.8590	2.330	..	...	...	..
19.75	.8510	2.245	2.32	1.157	3.904	5.13
25.90	.8373	2.110	..	...	...	..
29.65	.8293	2.030	2.02	1.085	3.832	4.85
32.75	.8235	1.972	..	...	...	..
35.2	.8185	1.925	..	...	...	..
48.1	.7955	1.697	1.70	0.904	3.651	5.15
67.5	.7665	1.425	1.28	.771	3.518	4.72
96.3	.7315	1.105	..	...	...	..
118.0	.7120	0.932	..	...	...	..

and when no excess of either ion is present

$$\frac{dC_b}{dt} = k(\Lambda/\Lambda_0)^2 C_b^2$$

or

$$\frac{d}{dt} \frac{1}{C_b} = (\Lambda/\Lambda_0)^2 k = \alpha^2 k \quad (4)$$

For the runs in Tables VIII, IX and X, where the reactants were in equal concentrations, the values of $1/C_b$ were plotted against t . Such a plot from the data of Table VIII is given in Fig. 5. The slopes of the tangents to these curves are given in Col. 4 of these tables. Column 6 gives the values of k calculated from these slopes using Equation 4, and the values of $\alpha = \Lambda/\Lambda_0$ (Col. 5), calculated from (1) and the value of K_B . For the run in Table XI, where the reactants were not equal, the values of k in Col. 7 were calculated by Equation 3 from the slopes of the tangent to a plot of the concentration of pyrazinium base against time (Col. 4), and the values of $(\text{OH}^-) = \Lambda/\Lambda_0 C_b$ and $(\text{Py}^+) = \Lambda/\Lambda_0 C_b + 0.002747$ (Cols. 5 and 6), $\alpha = \Lambda/\Lambda_0$ being calculated from (2).

The Rate of Disappearance of 1,2,2,3,5,5-Hexamethyl-6-methylene-tetrahydropyrazine from its Water Solutions at 25.00°.—This base was obtained as an oil on adding 40% potassium hydroxide to solutions of 1,2,2,3,5,5,6-heptomethyl-dihydropyrazinium iodide. It was described in the previous paper. A freshly distilled sample (b. p. (6.5 mm.) 78°) was used. Twenty cc. of water in the type of cell used in the previous experiment was allowed to come to equilibrium with the thermostat;

0.0489 g. of base was added and the cell shaken. The change in conductivity of the resulting 0.01357 M solution was observed as it fell with

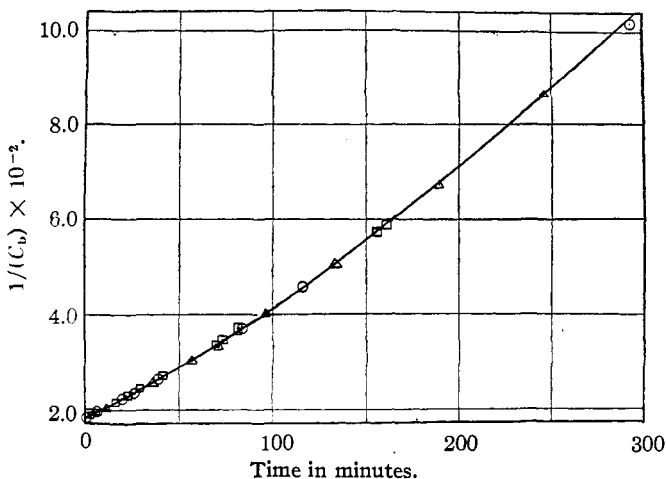


Fig. 5.—Graph from the data of Table VIII: \odot , \square , \triangle , respective points of three runs.

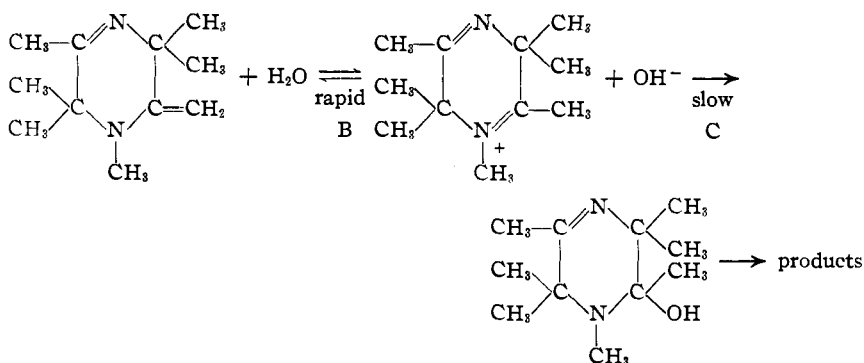
the time. Zero time was taken as that just after shaking. The results are given in Table XII. From the extrapolated zero time value of the

TABLE XII

CHANGE OF SPECIFIC CONDUCTANCE AND CALCULATED CONCENTRATIONS IN A WATER SOLUTION OF 1,2,2,3,5,5-HEXAMETHYL-6-METHYLENE-TETRAHYDOPYRAZINE AT 25.00°

Time, min.	Specific conductance $\text{ohm}^{-1} \text{cm.}^{-1} \times 10^2$	Concn. PyOH, C_b , eqts./liter $\times 10^2$	$\frac{d(1/C_b)}{dt}$, liter/mol./min.	α	k , min. ⁻¹
0	1.226	1.300	..	..	..
3.25	1.184	1.228	..	..	..
4.83	1.164	1.196	1.36	0.439	7.06
6.71	1.141	1.157	..	..	..
18.75	1.016	0.969	..	..	..
23.75	0.973	.907	1.45	.484	6.19
31.55	.912	.822	..	..	..
36.0	.879	.778	..	..	..
42.3	.8355	.721	..	..	..
55.2	.7570	.625	1.74	.545	5.86
62.9	.7150	.577	..	..	..
71.9	.6680	.522	1.93	.572	5.89
83.5	.6188	.468	2.02	.595	5.71
90.2	.5920	.440	..	..	..

specific conductance, $1.226 \times 10^{-2} \text{ ohm}^{-1} \text{ cm.}^{-1}$, assuming dissociation into 1,2,2,3,5,5,6-heptamethyldihydropyrazinium and hydroxide ions (*i. e.*, $\Lambda_0 = 222$) a value of K_B for the dissociation B



was calculated. This gave

$$K_B = \frac{(\text{Py}^+)(\text{OH}^-)}{(\text{undissociated base})} = \frac{(\Lambda/\Lambda_0)^2}{1 - \Lambda/\Lambda_0} = 3.79 \times 10^{-3}$$

which compares very favorably with those in Table VII. The difference is probably caused by the uncertainty of the extrapolation due to difficulty in estimating the starting time. The concentrations of the base (C) given in Col. 3, Table XII, are calculated from the specific conductances in Col. 2, assuming $K_B = 4.1 \times 10^{-3}$ (taken from Table VII). Column 6 gives the values of k calculated from the α -values in Col. 5 and the slopes of the tangents to the curve $1/C$ against time (Col. 4), using Equation 4 as was done in Tables VIII to X, with which the results agree quite well.

These results show that on mixing 1,2,2,3,5,5,6-heptamethyldihydropyrazinium iodide with sodium hydroxide, the equilibrium B is rapidly established, giving rise to the same system yielded by dissolving 1,2,2,3,5,5-hexamethyl-6-methyl-tetrahydropyrazine in water. In the previous paper the decrease in basicity of the solution was shown to be accompanied by decomposition. Reversal experiments as in the case of 1,2,5-trimethylpyrazinium hydroxide pointed to decomposition also. The rates show that this decomposition is probably controlled by the rate of formation of the pseudo base from its ions (reaction C above). In support of this view, the strong basicity of the system indicates that equilibrium, with the pseudo base, which, as in the case of 1,2,2,5,5-pentamethyldihydropyrazinium hydroxide, would give rise to a weak base, is not reached. Consequently, as was pointed out in the previous paper, the equilibrium B must be reached through an enolic type of change, not through the pseudo base.

Methylphenylacridinium Hydroxide.—In Fig. 6 is shown a graph of $1/(\Lambda - \Lambda_\infty)$ against the time where Λ is the total equivalent conductance of the solution at various times after mixing $1/128 N$ solutions of 5-phenyl-10-methylacridinium chloride and sodium hydroxide at 0° and

Λ_{∞} is the equivalent conductance due to sodium chloride at the end of the reaction at 0°. $\Lambda - \Lambda_{\infty}$ is thus the equivalent conductance of methylphenylacridinium hydroxide. This graph points to a heterogeneous reaction.

5-Phenyl-10-methylacridinium hydroxide (methylphenylacridol) was precipitated from phenylmethylacridinium sulfate with sodium hydroxide and its solubility determined at room temperature (25°) by shaking the base with boiled distilled water. The excess solid was filtered off and an excess of sulfuric acid added. The concentration of phenylmethylacridinium salt in the resulting solution was estimated colorimetrically by comparison with a solution of 5-phenyl-10-methylacridinium sulfate

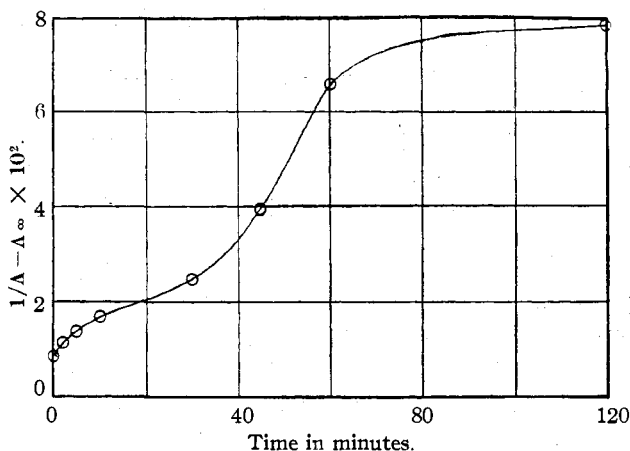
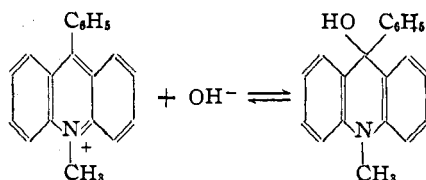


Fig. 6.—Graph of Hantzsch's data on phenylmethylacridinium hydroxide.

of known concentration containing the same concentration of acid. The original yellow color of the solution of the base did not change in shade or intensity on adding the acid. Since the solid base is colorless, this indicates that the color of the solutions of the salt and base are due to the acridinium ion, and that in the saturated solution the phenylmethylacridinium hydroxide is almost completely ionized. The solubility was found to be 1.25×10^{-4} mole per liter. This value is 3.2% of the concentration responsible for the initial $1/\Lambda - \Lambda_{\infty}$ value in Fig. 6, which must, therefore, be due to supersaturation. The fall in conductivity is due to precipitation from the supersaturated solution. The value of $\Lambda - \Lambda_{\infty}$ at equilibrium should, therefore, be less than 3.2% of the initial value, since the solubilities were determined at 25°. The corresponding value of $1/\Lambda - \Lambda_{\infty}$ is seen to be in agreement with this. It thus appears that the equilibrium in the reaction

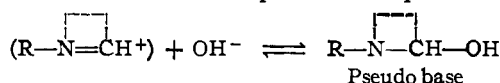
²¹ Hantzsch and Kalb, Ref. 2. For convenience these authors' terms are used.



is shifted to the right due to the insolubility of the base, which is largely ionized into the two ions on the left. The rate-controlling step in the measurements of Hantzsch is this rate of crystallization.

Discussion of Results

On the basis of the above results and a reinterpretation of the data of Hantzsch and Kalb, it seems that the position of equilibrium in the reaction



depends on the conjugation in the ring and the tendency of the $\text{N}=\text{C}$ double linkage to add OH^- . In the case of 1,2,5-trimethylpyrazinium hydroxide and 5-phenyl-10-methylacridinium hydroxide, for example, the equilibrium is to the left.

The experiments of Hantzsch and Kalb² and of Decker²² have demonstrated this to be true also for methylpyridinium, methylquinolinium, and methylisoquinolinium hydroxides. In all of these compounds the ring is completely conjugated. In the quinolinium series the condensation reaction yielding an ether is a general reaction. 1,2,5-Trimethylpyrazinium hydroxide also undergoes this reaction, yielding an ether.

In the case of 1,2,2,5,5-pentamethyldihydropyrazinium hydroxide the double linkage forming part of the pseudo basic system is not conjugated through the ring system, and consequently the double bond has a greater tendency to become saturated by adding OH^- . In consequence the equilibrium favors the weakly basic pseudo base.

The rapid equilibrium 1,2,2,3,5,5,6-heptamethyldihydropyrazinium hydroxide with 1,2,2,3,5,5-hexamethyl-6-methylene-tetrahydropyrazine accounts for the apparently weak basicity of the quaternary base ($K_B = 4 \times 10^{-3}$). Such an equilibrium is possible in the case of 1,2,5-trimethylpyrazinium hydroxide but not in the case of 1,2,2,5,5-pentamethyldihydropyrazinium hydroxide. The conjugation in the pyrazinium nucleus probably opposes the reaction in the case 1,2,5-trimethylpyrazinium hydroxide and hence accounts for lack of evidence of a similar equilibrium in this case.

Gastaldi and Princivale²³ have recently obtained evidence for the reaction

²² Decker. *J. prakt. Chem.*, 192, 425 (1911).

²³ Gastaldi and Princivale, *Gazz. chim. ital.*, 59, 791 (1929); 60, 296 (1930); Princivale, *ibid.*, 60, 298 (1930).

base strength of the system is $K_B = 4 \times 10^{-3}$. A decomposition takes place at a rate proportional to the first power of the concentrations of the pyrazinium and hydroxide ions. The rate of formation of the pseudo base is hypothesized as the controlling step in this reaction.

5. The solubility of 5-phenyl-10-methylacridinium hydroxide has been found to be 1×10^{-4} mole/liter at room temperature and solutions of the base appear to be highly ionized. The initial high value of the conductivity on mixing 5-phenyl-10-methylacridinium chloride and sodium hydroxide is shown to be due to supersaturation.

6. The significance of the results is discussed in the light of ring conjugation, which seems to be the determining factor in the quaternary base-pseudo base equilibria.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, YALE UNIVERSITY]

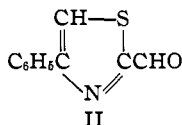
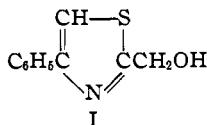
SYNTHESIS OF 4-PHENYLTHIAZOLE-2-METHANOL AND SOME OF ITS DERIVATIVES. VIII

BY JOHN F. OLIN¹ AND TREAT B. JOHNSON

RECEIVED DECEMBER 8, 1930

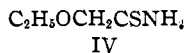
PUBLISHED APRIL 6, 1931

In the carrying out of our research program dealing with the chemistry of thiazoles, it was necessary to develop practical methods of synthesizing certain thiazoles containing the simplest primary alcohol and an aldehyde group in position 2 of the thiazole ring. The derivatives selected for synthesis were the alcohol and aldehyde of 4-phenylthiazole which are represented by formulas I and II, respectively. These have been prepared by



methods which undoubtedly will be of general application for further important syntheses in this series.

The starting points of our research were the thioamides of benzoylglycolic and ethoxyacetic acids, which are represented by formulas III and IV, respectively.



By interaction of these thioamides III and IV with bromoacetophenone, the benzoate and ethyl ether of the alcohol I are obtained easily in excellent yields. Both derivatives are convertible by hydrolysis into the alcohol I. The benzoate undergoes saponification with alkali easily, while acid hydroly-

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