Fig. 1.—Plot of $1/[\eta]^a$ vs. t: -$\triangle$-$\triangle$-$\triangle$, 30°; -X-X-X, 40°; -O-O-O, 50°.

progresses, but they are nearly constant. Moreover if we put in (7)

$$\left[(M_0/K)^{\frac{1}{a}} \Gamma\left(2 + \frac{1}{a}\right)\right]^a = A \text{ (a const.)} \qquad (11)$$

and introduce (10), we get

$$\lambda t = A/[\eta]^{*a} + \ln p \qquad (12)$$

This equation should give a straight line by plotting $1/[\eta]^{*a}$ against t. The experimental data for the relation between t and $1/[\eta]^{*a}$, plotted in Fig. 1, show a linear relationship within the experimental error.

The values of A were calculated from (11) by use of the experimental values of K and a. A/λ was calculated from the slope of the straight line in Fig. 1. The values of λ from these relations, as is shown in Table IV, almost agree with the values of λ in the 4th column in Table III.

TABLE IV

Temp., °C.	A	A/λ	$\lambda \times 10^4$
30	0.0115	25.70	4.47
40	.00957	8.50	11.28
50	.00827	2.29	36.18

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF CORNELL COLLEGE]

Factors Affecting the Rate of Hydrolysis of Ketimines

BY J. B. CULBERTSON

Earlier work on the preparation of ketimines (references 1, 2 and 4) has indicated wide variation in the ease of their hydrolysis to the corresponding ketones. Certain structural relations have appeared to be connected with this variation in rate of hydrolysis. It has been the purpose of this study to investigate some of these structural influences. To this end variously substituted diphenyl ketimine hydrochlorides have been prepared—their rates of hydrolysis, ultraviolet absorption spectra and ionization of the free ketimines as bases determined. Two types of substituent effects have appeared to be established; (1) a tautomerism and/or resonance, and (2) steric hindrance. Two other intramolecular factors suggested from earlier work on ketimines, and analogous compounds, have been considered. They are: (1) the relative negativity of the radicals attached to the carbimino group, and (2) strength of the free ketimines as bases. From the data of this report there is only meager evidence for the operation of any such factors.

This report represents an investigation of the rates of hydrolysis of variously substituted diphenyl ketimines—as hydrochloride salts in dilute aqueous solution—to their corresponding ketones. The general reaction is: $[R\text{-}C(=NH_2)\text{-}R_1]^+Cl^- + HOH \rightarrow R\text{-}CO\text{-}R_1 + NH_4^+Cl^-$.

A number of reports has indicated wide variation in the rate of this hydrolysis with structural differences. The early work of Moureu and Mignonac[1] pointed out that diaryl ketimines were more stable toward hydrolysis than the alkyl aryl ketimines. They were unable to prepare dialkyl ketimines. Later work[2] revealed striking effects of other structural differences.[3] Especially the

work of Hoesch[4] on the preparation of polyhydroxy diphenyl ketones by way of intermediate ketimines has suggested the latter as much more stable toward hydrolysis than the unsubstituted diphenyl ketimine.

To gain some idea of the structural relations involved, measurements have been made on the rates of hydrolysis and ionization constants as bases of a selected group of substituted diphenyl ketimines. Table I lists these data. Large variations in rates of hydrolysis are evident.

Two factors have appeared to play significant roles in affecting this sensitiveness of ketimines toward hydrolysis: (1) a ketimine–enamine tautomerism and/or resonance, (2) steric hindrance (ortho-effect).

(1) The imine-enamine tautomerism has been suggested by the early work of Collie[5] and of Best

(1) C. Moureu and G. Mignonac, *Compt. rend.*, **156**, 1801 (1913); **169**, 237 (1919); **170**, 936 (1920); *Ann. Chim.*, [9] **14**, 322 (1920).
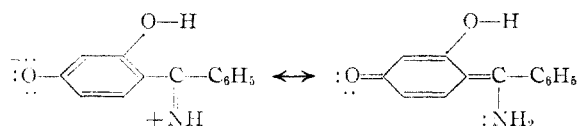
(2) P. Bruylants, *Bull. sci. acad. roy. Belg.*, [5] **8**, 7 (1922); *Bull. soc. chim. Belg.*, **32**, 307 (1923); L. Bary, *ibid.*, **31**, 397 (1922); De Boosere, *ibid.*, **32**, 26 (1923); R. Breckpot, *ibid.*, **32**, 386 (1923); and M. Jaspers, *ibid.*, **34**, 182 (1925).

(3) The extraordinarily stable ethyl cyclopropyl ketimine hydrochloride reported by DeBoosere was shown by Cloke to be the isomeric 2-ethylpyrroline salt (J. B. Cloke, THIS JOURNAL, **51**, 1174 (1929)).

(4) K. Hoesch, *Ber.*, **48**, 1122 (1915); K. Hoesch and T. V. Zarzecki, *ibid.*, **50**, 462 (1917).

(5) J. N. Collie, *J. Chem. Soc.* **71**, 299-311 (1897).

TABLE I

Ketimine	Hydrolysis of hydrochloride, $k_v \times 10^3$		Half-life period, min. at 25°	Basic strength, $k_b \times 10^9$
	0°	25°		
Diphenyl	5.5	77^d	9.0	150
2-Methyldiphenyl	0.28^a	4.2	165	62
3-Methyldiphenyl	5.4^a	76^d	9.1	
4-Methyldiphenyl	2.6^a	33.8	20.5	
2-Chlorodiphenyl	2.0	29	23.9	3.9
3-Chlorodiphenyl	27	378^d	1.8	4.9
4-Chlorodiphenyl	9.2^b	129^d	5.4	
2-Hydroxydiphenyl		12	57.8	1.0
3-Hydroxydiphenyl	8.9	125^d	5.5	120
4-Hydroxydiphenyl		7	99	28
2-Methoxydiphenyl	1.1	14.9	47	196
3-Methoxydiphenyl	4.5	63^d	11	39
4-Methoxydiphenyl	1.4^c	20^d	35	
2,4-Dimethyldiphenyl		3.5	198	62
2,5-Dimethyldiphenyl		3.7	187	62
3,5-Dimethyldiphenyl	3.6	50^d	13.9	150
2,6-Dimethyldiphenyl		0.08 (at 100°)	8670 (at 100°)	19.5
2,4-Dihydroxydiphenyl		0.48	1444	1.0
2-Methoxy-4-hydroxy-diphenyl		0.77	900	9.8
2,4-Dimethoxydiphenyl		1.45	478	2000
2,4,6-Trihydroxydiphenyl		0.082	8450	1.6
2,4-Dihydroxy-6-methyl-diphenyl		0.20	3466	56

^{a} Measured by Cloke and co-workers, Rensselaer Polytechnic Institute, Troy, N.Y.; refer to Doctor's Dissertation, J. B. Cloke, Department of Chemistry, University of Chicago, 1931. ^{b} Measured by Ingle, Master's Thesis, University of Chicago, 1926. ^{c} Measured by B. White, Master's Thesis, University of Chicago, 1927. ^{d} Calculated from value measured at 0°, assuming 14-fold increase for the 25-degree rise in temperature.

and Thorpe.[6] Moureu and Mignonac[7] gave support to such tautomerism in their observation that such ketimines as ethyl phenyl ketimine could be converted into ketisoketimines and ammonia. Such a change would suggest a labile hydrogen on the carbon next to the carbimino group, thus

(a) C_6H_5—C(=NH)—CH_2CH_3 $\longrightarrow$
(imine form)
                    C_6H_5—C(—NH_2)=CH—CH_3
                    (amine form)

(b) C_6H_5—C—CH_2—CH_3
              ‖
              NH

C_6H_5—C=CH—CH_3

C_6H_5—C—CH_2—CH_3
        ‖
        N

C_6H_5—C=CH—CH_3 + NH_3
(a ketisoketimine)

The fact that ethyl phenyl ketimine may be converted quantitatively, on the one hand by heating into the ketisoketimine and ammonia, and on the other by hydrolysis to the ketone, furnishes quite definite evidence for this tautomeric relation. Through the study of certain physical data on the nitrogen analogs of ethyl acetoacetate and related compounds, Auwers and Susemihl[8] considered

(6) S. R. Best and J. F. Thorpe, J. Chem. Soc., 95, 1506–1537 (1909), and other articles of a long series; J. F. Thorpe, Proc. Chem. Soc., 95, 309 (1910).

(7) C. Moureu and G. Mignonac, Compt. rend., 158, 1395–1400 (1914); 159, 149–152 (1914).

(8) K. v. Auwers and W. Susemihl, Ber., 63, 1072 (1930).

them to display ketimine–enamine tautomerism and concluded that they existed principally as enamines.[9]

In view of these considerations, Stieglitz suggested that the marked stability toward hydrolysis of the polyhydric diphenyl ketimine salts of Hoesch[4] might be due to a benzoid-imine and quinoid-amine tautomerism, as here illustrated for 2,4-dihydroxydiphenyl ketimine salt ion

p-quinoid-amine (A)

benzoid-imine   o-quinoid-amine (B)

Shift of phenolic "H" either from the para- or the ortho-position, to produce the quinoid-amine forms (A) or (B), may be considered possible, though the former is no doubt more probable. The quinoid-amine forms should not be subject to hydrolysis. Hence extensive existence in these forms might account for the slow speed of hydrolysis of the phenolic ketimines prepared by Hoesch. Such a tautomerism has been indicated by a comparative study[10] of various properties of 2,4-dihydroxydiphenyl ketimine with those of its ortho-monomethyl and dimethyl ethers and with the unsubstituted diphenyl ketimine. Comparative rates of hydrolysis, colors of the free bases and salts, solubilities in different solvents, and other properties were uniformly found to suggest this tautomerism.

Resonance between imine and amine forms may be a concurrent stabilizing factor

(9) Closely related to the ketimines of this report is the dye, auramine. The dual behavior of this compound has suggested a tautomeric equilibrium for it

$(CH_3)_2$$^+$NH—$C_6H_4$—C(=NH)—$C_6H_4$N($CH_3)_2$ $\rightleftharpoons$
            $(CH_3)_2$$^+$N=$C_6H_4$=C(—$NH_2$)—$C_6H_4$N($CH_3)_2$

The first of these is a benzoid-imine (ketimine) and the second a quinoidamine structure. The fact that auramine undergoes a measurable (W. C. Holmes and J. F. Darling, THIS JOURNAL, 46, 2343 (1924)), though slow, hydrolysis to Michler ketone indicates the benzoid-imine type of structure.

(10) J. B. Culbertson, Doctor's Dissertation, University of Chicago, 1927.

However it may be expected that this shift of electron density from oxygen toward nitrogen should lead to the dropping of a proton by oxygen and the gain of one by the nitrogen. The net result would be tautomerism. A similar outcome could be realized from resonance of a phenolate ion

An extension of this investigation suggested a consideration of the three monohydroxydiphenyl ketimines. For this purpose these compounds, together with their methyl ethers, have been prepared and studied. And as supplementary material, two other polyhydric phenolic ketimines reported by Hoesch, 2,4,6-trihydroxydiphenyl and 6-methyl-2,4-dihydroxydiphenyl ketimines, have been included in the study. An inspection of hydrolysis constants (Table I) for these phenolic ketimines reveals a very marked effect of hydroxy-groups in para- and ortho-positions. It is of critical importance to note that the 3-hydroxydiphenyl ketimine is even more rapidly hydrolyzed than the unsubstituted diphenyl ketimine. Where there is no possibility of quinoid-amine structure, we find the possible effect of increasing the rate of hydrolysis due to the base-weakening action of the phenolic group in the ketimine structure.[11]

Resonance would appear to be the prime factor in the comparatively slow rates of hydrolysis displayed by the 2- and 4-methoxydiphenyl ketimines
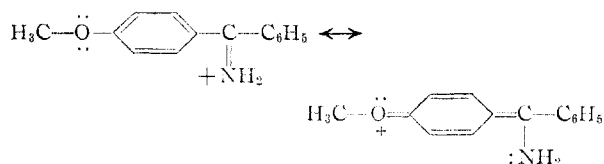
Further evidence on the existence of this ketimine–enamine tautomerism, or resonance, has been obtained in ultraviolet absorption spectra data. For this purpose a number of the ketimine salts listed in Table I were chosen for examination. The plotted absorption data are shown in Figs. 1, 2 and 3. These reveal a definite distinction between those ketimines which might display tautomerism or resonance and those which would not. Of the first group, 4-hydroxy-, 2,4-dihydroxy- and 2,4-dimethoxydiphenyl ketimine hydrochlorides show pronounced absorption in the general region of 260 to 380 mμ. There are two peaks of absorption within this region. The 2-hydroxy- and 2-methoxydiphenyl ketimine salts show one peak of absorption around 275 mμ. In the second group comprising those compounds which could not display tautomerism, namely, diphenyl and the 3-hydroxy-, 3-methoxy-, 4-methyl-, 2-chloro- and 4-chloro-diphenyl ketimine hydrochlorides, one band of absorption with peak at about 250 mμ appears. The 2-methyl- compound gives a band with peak at about 275 mμ, just as shown by 2-hydroxy- and 2-methoxy-diphenyl ketimines. Since structurally the 2-

methyl- compound could not display tautomerism or resonance, this bit of evidence would suggest that the latter two compounds also do not, or only feebly, enter into this relation.

(2) The second factor which has appeared affecting the stability of aromatic ketimines toward hydrolysis is that of steric hindrance. An examination of the ketimines listed in Table I reveals, apart from any tautomerism or resonance, some special effect of groups in ortho position to the carbimino group. Of the three monohydroxydiphenyl ketimines the hydrolysis rates of the o- and p-substituted forms are not far different. That of the m-compound is very much faster. It may be expected, according to the tautomeric factor, that the p-compound should have a definitely slower rate than the o-compound. The comparably slow rate for the o-form might be due largely to steric hindrance. The three monomethoxy diphenyl ketimines display a similar relationship. As noted before resonance may account for the moderately slow rates for the p- and o-methoxy-substituted compounds. However, the retarding influence of the substituent in the o-position predominates to give this compound the slower rate of hydrolysis. The hydrolytic rate of the m-compound is again very much faster, where neither retarding influence of resonance nor steric hindrance can operate. The three monomethyldiphenyl ketimines furnish a still more striking illustration of o-substitution effect. Here no tautomerism or resonance can be involved. We see that the rate of hydrolysis of the o-form is very much less than that of the other two forms, which are not far different. A similar relation exists among the chloro-diphenyl ketimines.

A comparison of the poly-substituted phenolic ketimine hydrolysis rates furnishes additional evidence of steric hindrance. The 2,4-dihydroxydiphenyl ketimine has a slow rate of hydrolysis, due perhaps (as already pointed out) rather largely to tautomerism. Both p- and o-quinoid tautomerism were mentioned as possible. The 2,4,6-trihydroxydiphenyl ketimine has an even slower rate than might be predicted on the basis of one more possible o-p-quinoid tautomerism. This *extra* slower rate may be due to the combined retarding effects of *two* o-substituents, *i.e.*, to steric hindrance. The 2,4-dihydroxy-6-methyldiphenyl ketimine displays a distinctly slower rate of hydrolysis than the 2,4-dihydroxy compound. This increase in resistance to hydrolysis would appear to be due to the retarding influence of a methyl group in o-position.

As a further check upon this pronounced retarding effect of substituents in o-positions to the carbimino group of these ketimines, study was made of four dimethyldiphenyl ketimines. With this series there should be no tautomerism or resonance, the basic strengths[12] of the free ketimines are not far different, and the relative negativities[12] of the variously substituted dimethylphenyl radicals should not vary much. Any pronounced differences in rates of hydrolysis would then appear attributable to steric hindrance. Reference to Table I

(11) Later reference to this factor.
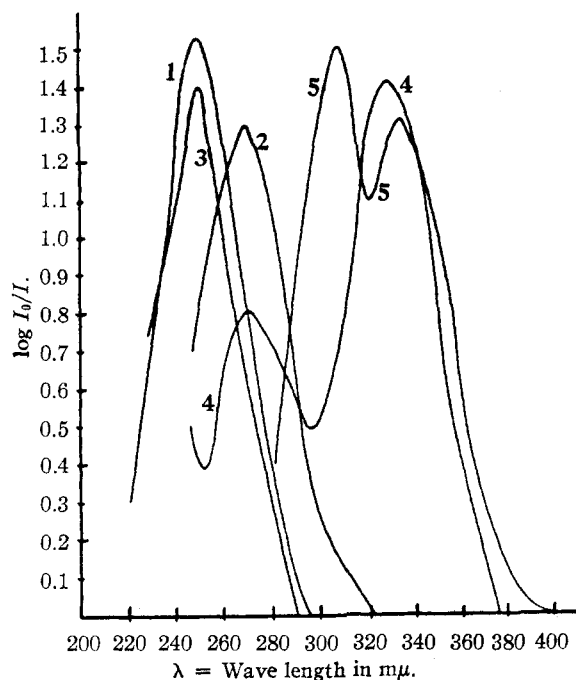
(12) Later reference to these factors.

Fig. 1.—0.0001 molar solutions in ethanol: (1) -diphenyl ketimine hydrochloride; (2) 2-hydroxy-; (3) 3-hydroxy-; (4) 4-hydroxy-; (5) 2,4-dihydroxy-.
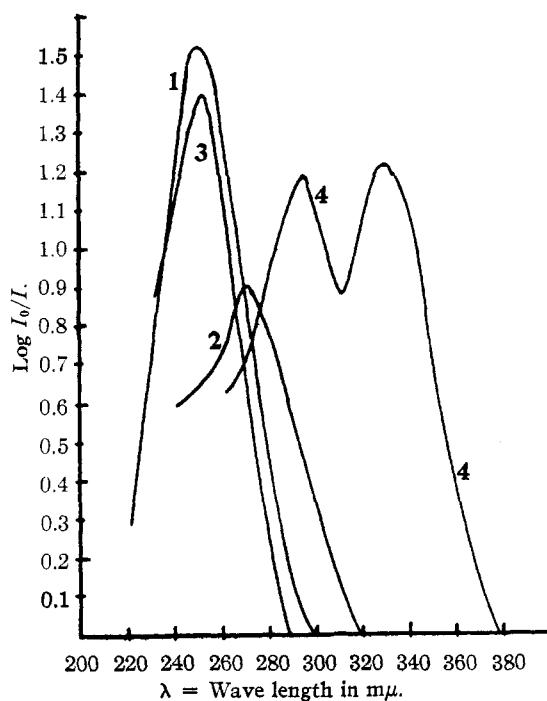

Fig. 2.—0.0001 molar solutions in ethanol: (1) -diphenyl ketimine hydrochloride; (2) 2-methoxy-; (3) 3-methoxy-; (4) 2,4-dimethoxy-.

shows that the 2,4-dimethyl- and 2,5-dimethyl-diphenyl ketimines have nearly the same hydrolysis velocities while this velocity for the 3,5-dimethyl-diphenyl ketimine is much faster. In each of the first two compounds there is the retarding effect of one methyl radical in ortho-position. In the 2,6-dimethyldiphenyl ketimine both positions ortho- to the carbimino group are substituted by
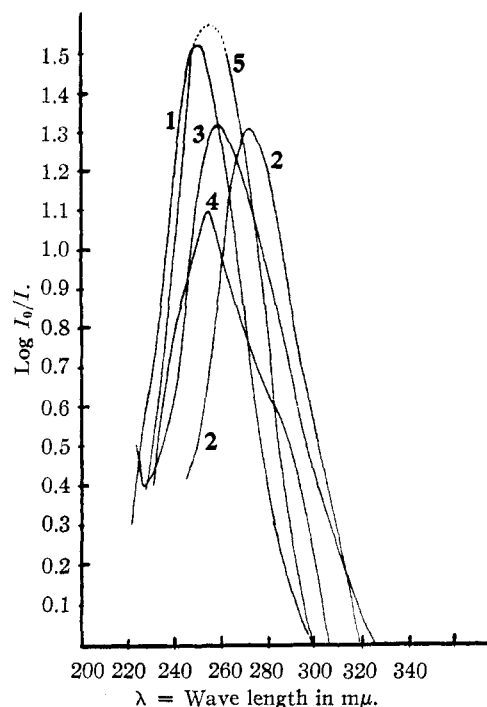
Fig. 3.—0.0001 molar solutions in ethanol: -diphenyl ketimine hydrochloride; (2) 2-methyl-; (3) 4-methyl-; (4) 2-chloro-; (5) 4-chloro-.

methyl radicals. The retarding effect was far more than anticipated. In fact, no measurable hydrolysis took place at 25°, or even 35°, over a period of three weeks in $M/100$ aqueous solutions. It was only on refluxing (approximately 100°) the aqueous solution for some hours that appreciable hydrolysis was effected.

Two other factors have been suggested as possibly operative in affecting ketimine hydrolysis. (1) Moureu and Mignonac[1] mentioned that ketimines were more stable toward hydrolysis as the electronegative character of the radicals attached to the imino-function increased. They reported no quantitative hydrolysis rate measurement, nor did they indicate any basis for the meaning of electronegativity. Our attempts to correlate these ketimine rates of hydrolysis with the radical electronegativity series of Kharasch[13] have been inconclusive, possibly due to predominance of the "other factors." (2) Stieglitz and his co-workers[14] found that iminoester hydrochlorides, compounds closely analogous to ketimine salts, were hydrolyzed to oxo-esters at slower rates the greater the strength of the imino esters as bases. Again it has been difficult to establish this as an operating factor among these ketimines due to the conflicting "other factors." Probably these "electro-negativity" and "basic strength" factors are closely related to electron densities resulting from resonance and inductive effects.

An interpretive variant on the rates of hydrolysis displayed by these ketimines is suggested by Hammett's treatment of substituent effects upon equilibrium and rate constants of benzene side chain

(13) M. S. Kharasch and R. Marker, THIS JOURNAL, 48, 3130 (1926) J. Chem. Ed., 8, 408 (1928).

(14) J. Stieglitz, et al., Am. Chem. J., 39, 53, 447, 586 (1908).
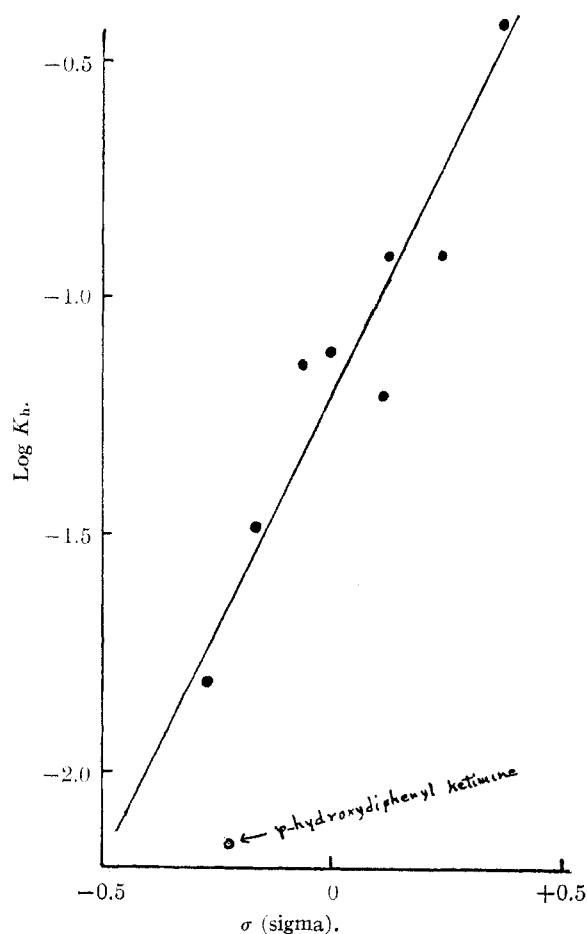
Fig. 4.

reactions.[15] Figure 4 represents plots of the log-arithms of the hydrolysis rate constants against sigma values of seven mono meta- and para-substituted ketimines. These lie along a straight line with a median deviation of about 0.06 if the point for p-hydroxydiphenyl ketimine is omitted. The deviation of this from the more closely linear relationship of the other substituents would suggest that some other effect is operative with this p-hydroxy group. This may be the tautomerism already suggested for this compound, if the reso-nance and inductive electronic effects are involved in the sigma values. The ortho substituted com-pounds deviate widely from this linear relation, suggestive of steric hindrance effect. The moder-ately large positive value of rho, 2.00, is indicative of a favorable effect of low electron density at the carbimino reactive center and of a pronounced nucleophilic character for the reacting unit, water or the $\overline{OH}$ ion, determining the rate of reaction.

The $M/100$ aqueous solutions of the different ketimine hydrochlorides varied initially in pH from 3.5 to 5.3, and decreased in acidity toward the pH of 5.6 for the ammonium chloride formed in the hydrolysis. To check any variable catalytic factor in these hydrogen ion concentration differ-ences, determinations were made upon the rates of hydrolysis of 2,4-dihydroxy- and 2,4-dimethoxy-

diphenyl ketimine hydrochlorides in solutions to which hydrochloric acid equivalent to the ketimine salt was added. With this large hydrogen ion concentration change, the hydrolysis rates were altered (both decreases) insufficiently to appreciably effect the order of comparative values.

Some of the ketimines of this study hydrolyzed so rapidly that measurements were made at 0° for satisfactory results. To compare their rates with the others measured at 25°, a conversion factor was obtained by measuring the hydrolysis rates of four representative ketimines at 0 and 25°. The ones suitable for this were the 2-methyl-, 4-methyl-, 2-chloro- and 2-methoxy-diphenyl keti-mines. The values obtained are recorded in Table I. They range from 13.2- to 14.7-fold increase for the 25° change in temperature. The rounded average factor of 14 was chosen to convert the K_v values of those ketimines, which could only be measured at 0°, to 25° for general comparison.

Experimental

Preparation of Ketimines.—Two general procedures have been employed. (1) The method of Moureu and Mig-nonac[1] involving the condensation of nitriles with Grignard reagents was used to prepare all of the ketimines of Table I except the polyphenolic compounds and 2-methoxy-4-hydroxydiphenyl ketimine. (2) The method of Hoesch[4] was used for the latter group of ketimines.

(1) A preparation of 3-chlorodiphenyl ketimine hydro-chloride is taken as representative of the first procedure. The Grignard reagent was made in the usual manner from 1.216 g. (0.05 mole) of magnesium and 7.83 g. (slightly less than 0.05 mole) of bromobenzene with 70 ml. of dry ether, to which 5.50 g. (0.04 mole) of 3-chlorobenzonitrile dissolved in dry ether was added. The Grignard–nitrile addition compound was decomposed with an ice and ammonium chloride mixture at about −15°. The ether layer containing the ketimine was decanted and the aqueous layer extracted several times with ether. The ether solution was dried over anhydrous sodium sulfate. (Anhydrous calcium sulfate, Drierite, is also satisfactory.) Dry hydrogen chloride was passed into the filtered dry ether solution to precipitate the ketimine hydrochloride. The latter was quickly separated by suction filtration and washed with dry ether. Purifica-tion was effected by solution of the hydrochloride in the minimum quantity of absolute methyl alcohol followed by precipitation upon slowly stirring in dry ether (usually 2 to 5 volumes required for complete separation of the salt). Generally a second or third recrystallization from the alco-hol–ether mixture was necessary to get a pure product. (In some cases chloroform may be used effectively to replace the alcohol.)

The 3-chlorobenzonitrile was prepared from 3-chloro-aniline through a Sandmeyer reaction, following the general procedure described in ref. 16.

The monohydroxydiphenyl ketimines were prepared as described above except that an extra equivalent of Grignard reagent was required to react at the phenolic group. The hydroxybenzonitriles were prepared from the hydroxybenz-aldehydes through dehydration of their oximes.

(2) The polyphenolic ketimines were prepared essentially as described by Hoesch.[4] They were purified by solution in methyl alcohol and precipitation on addition of ether.

The 2-methoxy-4-hydroxydiphenyl ketimine hydrochlo-ride formed a stable double salt with zinc chloride from which the former was not readily separated. The substitution of anhydrous aluminum chloride for the zinc chloride re-sulted in a satisfactory preparation for this ketimine salt.

The identities of the ketimines have been generally es-tablished through melting points of the ketones produced on hydrolysis and by determination of the ionized chlorine from the hydrochlorides. Melting points of all ketones agreed with those which have been recorded in the chemical literature.

Other identifying data are given in Table II.

TABLE II

DIPHENYL KETIMINE HYDROCHLORIDES

Substituent	Ionic chlorine, % Theory	Found
2-Cl-	14.09	14.05
3-Cl-	14.09	14.14
2-OH-	15.20	15.29
3-OH-	15.20	15.41
4-OH-	15.20	15.24
2-OCH₃-	14.34	14.63
3-OCH₃-	14.34	14.52
2,4-Di-CH₃-	14.43	14.69
2,5-Di-CH₃-	14.43	14.77
3,5-Di-CH₃-	14.43	14.78
2,6-Di-CH₃-	14.43	14.65
2-OCH₃-4-OH-	13.45	13.37
2,4-Di-OCH₃-	12.78	12.71

Due to some doubt regarding the identities of 2,6-dimethyldiphenyl ketimine and its ketone, additional data are given for them as follows. The ketimine base was a white solid melting at 67–68°; mixture with ketone at 59–63°. Nitrogen analyses by the Kjeldahl–Gunning procedure gave: (1) for the free base 6.77, calcd. for $C_{15}H_{15}N$, 6.70; (2) for the hydrochloride 5.90, calcd. for $C_{15}H_{16}NCl$, 5.71. The presumed ketone gave negative tests for nitrogen. The ketimine was soluble in dilute HCl, the ketone insoluble.

Measurement of Hydrolysis Velocities.—Two general procedures have been employed to follow the course of these hydrolyses, depending upon suitability to the compound under consideration. (a) The first procedure is essentially the one employed by Stieglitz and Derby[17] for measuring hydrolysis velocities of imino-esters. (b) The second procedure was developed for use in following the hydrolysis velocity of 2,4-dihydroxydiphenyl ketimine hydrochloride. The first proved inapplicable here because the ketimine base is insoluble in CCl₄ or other suitable extracting solvent. A measured sample (100 ml.) of the hydrolyzing solution was added to a tall glass-stoppered cylinder, the ketone which had been formed extracted with benzene, and the benzene layer siphoned off into a small weighed beaker. Four such extractions were made, the benzene evaporated, and the residual ketone weighed. Due to the fact that the ketone, sparingly soluble in water, begins to separate after some hours, it was necessary to measure out 100-ml. aliquots as soon as the solution of the ketimine hydrochloride was complete. These were placed in small conical flasks in the thermostat and one of them withdrawn at each interval of time for determination of its ketone content.

It is obvious that this procedure is feasible only for ketimines whose rates of hydrolysis are slow, so that the time interval while the ketone is being extracted from the hydrolyzing solution (and the temperature changing) is small compared to the time between determinations. Also it can be applied only where the ketone is not appreciably volatilized on complete evaporation of the benzene. With carefully applied technique, this "ketone extraction" procedure has appeared to give some of the best results attained, where applicable, in the measurement of ketimine hydrolysis rates.

Due to the sparing solubility of the 2,4-dihydroxydiphenyl ketimine hydrochloride, measurements of its hydrolysis rate were made from $M/200$ solutions and 100-ml. samples were taken for each determination. All other ketimine hydrochlorides were measured from $M/100$ solutions and 50-ml. samples. Depending upon their general stabilities, some ketimine hydrolysis rates were made at 0° and others at 25°. Only the "titration" procedure was used at 0°. An ice-pack arrangement covered the outside of the pipet employed to withdraw samples at 0°. The 2,6-dimethyldiphenyl ketimine was run at 100° to obtain a measurable rate of hydrolysis.

All data obtained have been found to fit the equation for a first order reaction.

Temperature Coefficients of Hydrolysis Velocities for Ketimines.—The hydrolysis rates of four ketimines (2-

methyl-, 4-methyl-, 2-chloro- and 2-methoxydiphenyl ketimines) were measured at 0 and 25°. The K_v values are recorded in Table I. These range from 13.2- to 14.7-fold increase within this 25 degree interval, or a rounded average value of 14-fold. This value has been assumed for converting hydrolysis constants of other ketimines, whose hydrolysis measurement could only be made satisfactorily at 0°, to values at 25° for sake of general comparison. The K_v values for 2,4-dihydroxydiphenylketimine have been measured at 25 and 35°, giving, respectively, 0.00048 and 0.00151. This is a little more than a three-fold increase for a ten degree rise in temperature, higher than for the other ketimines measured at 0° and 25°. This corresponds to an energy of activation of 20,920 cal. per mole, distinctly higher than for the other four ketimines ranging around 17,000 cal. per mole.

Effect of Hydronium, H Ion, Concentration upon Ketimine Hydrolysis.—To gain some idea of effect of variation in H ion concentration upon hydrolysis rates of ketimines, measurements were made upon 2,4-dihydroxy- and 2,4-dimethoxydiphenyl ketimine hydrochlorides in solutions where HCl equivalent to the ketimine salt was added. At 25° a K_v of 45×10^{-3} was obtained for the former and 71×10^{-3} for the latter.

Basic Strength of the Ketimines.—Only the glass electrode proved satisfactory as a tool for measuring the H ion concentration of ketimine hydrochlorides as a basis for calculating strengths of the ketimines as bases. In the initial work on this a vacuum tube amplifying set was made patterned after the model of DeEds,[18a] with some suggestions from the model of Gilbert and Cobb.[18b] Also at first glass electrodes were made from Corning No. 015 tubing according to the procedure of MacInnes and Dole,[19] later the Leeds and Northrup glass electrode was employed. For the inside reference a quinhydrone electrode in 0.1 N HCl was used. The electrodes were calibrated in 0.05 M potassium hydrogen phthalate and standard buffer solutions. A saturated calomel cell was the outside reference electrode. Measurements were made in $M/256$ ketimine hydrochloride solutions, repeated until consistent results were attained. In each case potentials were observed over intervals of time and the potential of initial solution obtained by extrapolation to zero time. In many cases the ketimine hydrochlorides were recrystallized between successive measurements to detect possible effects of impurities. All solutions were made in conductivity water. Some time later all measurements were repeated with a Coleman style 200 electrometer with good checking results. The K_b values calculated from these pH determinations are recorded in Table I.

Ultraviolet Absorption Spectra of Ketimine Hydrochlorides.—Hilger medium quartz spectrograph was employed with a Hilger sector photometer, and with a hydrogen discharge tube as source of light. Absolute ethyl alcohol was used as solvent. Complete absorption was found for these ketimine hydrochlorides in the ultraviolet from about 310 mμ wave length for tenfold dilutions through 0.001 M. Selective absorption appeared with 0.0001 M solutions, so all of the observations were made at this concentration.

The results are shown in Figs. 1, 2 and 3.

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