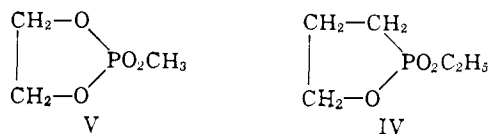ratios for the fully esterified phostonate IV and phosphate V shows that each reacts about 10^6 times as fast with alkali as its acyclic analog.[37]

$$\begin{array}{cc} \text{CH}_2-\text{O} & \text{CH}_2-\text{CH}_2 \\ | \quad \diagdown \text{PO}_2\text{CH}_3 & | \quad \diagdown \text{PO}_2\text{C}_2\text{H}_5 \\ \text{CH}_2-\text{O} & \text{CH}_2-\text{O} \\ \text{V} & \text{IV} \end{array}$$

The large rates of hydrolysis for the cyclic five-membered phosphates have been shown to be related in large part (but not completely) to thermochemical strain in the ring.[38,39] The cause of this thermochemical strain has not been established. In all probability, a part of it is simple angle strain.[40] The idea that part of the strain may arise from distortion of a natural dihedral angle between C–O–P bonds in phosphates[39] has also been discussed, but seems relatively unlikely. If such were the fact, then the rate enhancements in the

esters of phosphoric acid would probably greatly exceed that for the phostonates, since the bonding for C–C–P and C–O–P are quite different.

The negative shift for the phosphorus n.m.r. signal for the highly reactive as opposed to the normal phosphates and phosphonates suggests that the phosphorus atom is less shielded in the cyclic, five-membered esters.[36] This interpretation (which must be accepted with considerable caution) is consistent both with the more rapid rate of hydrolysis and the strain for the five- ring; quite possibly the $p\pi$–$d\pi$ overlap between phosphorus and oxygen is diminished in the cyclic compound because of geometrical considerations. X-Ray investigations of the detailed structure of some of these compounds have been begun in the laboratories of Professor W. N. Lipscomb.

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Secondary Valence Force Catalysis. I. Kinetics of Schiff Base Hydrolysis in the Presence of Micelle-Forming Detergents[1]

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The kinetics of the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine in aqueous solution at 25° and ionic strength 0.05 were investigated in the pH range 1–13 in (a) the absence of detergent, (b) the presence of sodium lauryl sulfate, (c) the presence of cetyltrimethylammonium bromide, and, in part, (d) the presence of a nonionic detergent. From this and related data, rate constants for the individual steps of the hydrolysis reaction were approximately evaluated for the aqueous, anionic micellar, cationic micellar, and nonionic micellar phases. The second-order rate constant for the attack of hydroxide ion on the protonated Schiff base is substantially the same for the aqueous and cationic micellar phases but is markedly reduced in the anionic micellar phase. The observed rate constant for the attack of water on the protonated substrate is largely independent of the nature of the phase in which the reaction occurs. In the region of rate-determining carbinolamine decomposition, the reaction rate is strongly inhibited in the anionic micellar phase compared to that in the aqueous, cationic micellar, or nonionic micellar phases. Several of these results were substantiated in a similar study of the kinetics of hydrolysis of benzhydrylidenedimethyl- ammonium ion in the presence and absence of micelle-forming detergents. Values of pK_a for protonated p-chlorobenzylidene-1,1-dimethylethylamine were determined as 6.55 in aqueous solution, 7.02 in the anionic micelle, 4.96 in the cationic micelle, and less than 5 in the nonionic micelle.

Introduction

Ideally, model reactions for enzymatic processes should include an association, through weak binding forces, of substrate and catalyst or other reactant leading to a facilitation of bond-changing reactions and conferring specificity on the reaction. Reactions occurring in or on micelles, in inclusion compounds, and in ice may exhibit these characteristics in a modest degree. For example, Duynstee and Grunwald have reported 4- to 50-fold increases in the rate of attack of hydroxide ion on certain cationic dyes upon their incorporation into a cationic micelle formed from cetyltrimethylammonium bromide.[2] Cramer and co-workers have demonstrated cyclodextrin-catalyzed decomposition, involving phosphorylation of the cyclo-

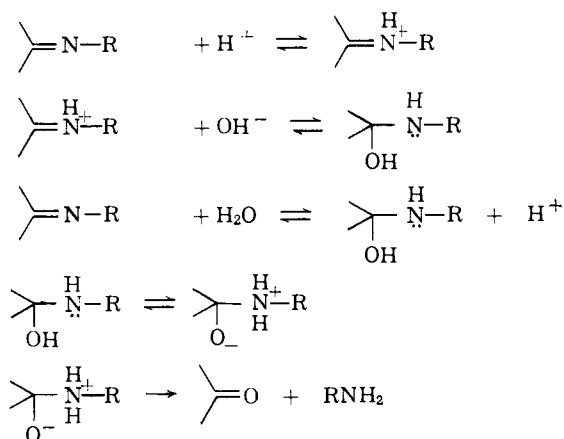(2) E. F. J. Duynstee and E. Grunwald, *J. Am. Chem. Soc.*, 81, 4540, 4542 (1959).

dextrin, of *sym*-diphenyl pyrophosphates.[3,4] Although only modest rate increases were observed, these reactions are of considerable interest since they demonstrate a marked degree of substrate specificity, only those substrates which can be included within the cyclodextrin cavity being subject to such catalysis. Finally, rather large rate increases, relative to the rates in liquid water, have been observed for several second-order reactions in ice,[5-7] probably as a result of the approximation of reactants in liquid regions between ice crystals.[6] A critical discussion of several additional reactions falling into this general class has been presented by Jencks.[8]

We have undertaken the study of the kinetics of several reactions in the presence of micelle-forming detergents. This paper is concerned with one such reaction, the hydrolysis of Schiff bases. This appeared to be a favorable case for such a study since (1) the mechanism of these reactions, as the result of a number of studies, is rather well understood,[9-13] and (2) previous studies have indicated that the rate of Schiff base hydrolysis is markedly influenced by the presence of micelle-forming detergents.[14,15]

The Schiff bases chosen for detailed study are *p*-chlorobenzylidene-1,1-dimethylethylamine (I) and benzhydrylidenedimethylammonium iodide (II). The mechanism
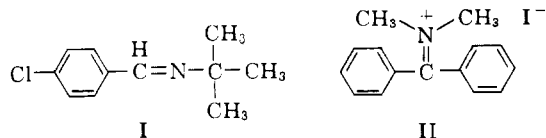
anism of the hydrolysis of benzylidene-1,1-dimethylethylamines has been the subject of a previous study.[11] We reiterate here the principal conclusions derived from that work which are relevant to the results presented below. The pH-independent reaction which occurs above pH 9 is almost certainly the consequence of rate-determining attack of hydroxide ion on the protonated Schiff base. Under more acidic conditions, in which the Schiff base is converted to the conjugate acid, the attack of water on the protonated Schiff base becomes the important reaction pathway. Finally, under still more acidic conditions, in which first-order rate constants decrease with decreasing pH, a transition in rate-determining step occurs and carbinolamine decomposition becomes rate determining. The hydrolysis of the cationic Schiff base, benzhydrylidene-dimethylammonium ion, exhibits a base-catalyzed reaction, a consequence of the attack of hydroxide ion on this substrate, and a pH-independent reaction under less basic conditions reflecting a transition to rate-

determining attack of water as the predominant reaction pathway.[12]

At least three factors may account for alteration of the rate of an organic reaction in aqueous solution when the reactant or reactants are incorporated into or onto a micelle: approximation effects, electrostatic effects, and medium effects. Approximation effects arise for reactions in or on micelles if reactants are concentrated or diluted by incorporation of one or more reactants into the micellar phase. Alterations in stability of reactants or transition state by electrostatic effects due to the micellar charges or by short range interactions involving the molecules which constitute the micelle may clearly affect reaction rates. These cases have been discussed by Duynstee and Grunwald.[2]

We wish to emphasize, at the outset, that the quantitative evaluation of rate constants for reactions occurring in micellar phases involves a number of problems, indicated below. Consequently, some of the values arrived at, although probably not greatly in error, must be considered approximations only and cannot be relied upon as precise values.

Experimental

Materials. *p*-Chloro- and *p*-methoxybenzylidene-1,1-dimethylethylamine were prepared as previously described.[11] Benzhydrylidenedimethylammonium iodide was prepared by the method of Hauser and Lednicer.[16] Sodium lauryl sulfate and cetyltrimethylammonium bromide were obtained from commercial sources and purified according to the procedure of Duynstee and Grunwald.[2] The nonionic detergent composed of dodecylphenol condensed with 18 molecules of ethylene oxide was a gift of the General Aniline and Film Corp. and was employed without further purification. Reagent grade inorganic salts were employed without further purification. Solutions of the Schiff base in redistilled ethanol were prepared just prior to use. Distilled water was employed throughout.

Kinetic measurements were carried out spectrophotometrically at 25° with a Zeiss PMQ II spectrophotometer as previously described.[9,17] All kinetic runs were carried out in water containing approximately 3% ethanol at an ionic strength of approximately 0.05. In reactions involving the use of high concentrations of substrate, quartz inserts were employed to reduce the op-

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Table I. Apparent Values of pK_a for Protonated p-Chlorobenzylidene-1,1-dimethylethylamine in the Presence of Varying Concentrations of Detergents[a]

NaLS, M	CTAB, M	NID, M	pK_a^{app} [b]	pK_a^m [c]	K_1, M	K_4, M
. . .	. . .	. . .	6.55			
0.005			6.82		4.2×10^{-5}	1.4×10^{-5}
0.01			7.04			
0.02			7.00	7.02		
	0.004		5.80		5.4×10^{-6}	2.1×10^{-4}
	0.01		5.49		6.1×10^{-6}	2.4×10^{-4}
	0.02		5.30		6.1×10^{-6}	2.4×10^{-4}
	0.03		5.10			
	0.04		4.98			
	0.05		4.96	4.96		
		0.01	5.45			
		0.05	5.05			

[a] Measured in aqueous solution at approximately 25°, ionic strength 0.05. [b] Measured values of pK_a at each detergent concentration. [c] Estimated values of pK_a for the dissociation in the micelle; $pK_a^m = -\log K_2$ (see text).

tical path length. Measurements of pH were made with a glass electrode and a Radiometer PHM 4c pH meter.

Determinations of values of pK_a for the protonated Schiff base in the presence and absence of detergents were performed spectrophotometrically as previously described.[11]

Results and Discussion

First-order rate constants for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine at 25° and ionic strength 0.05 are plotted as a function of pH in Figure 1. The indicated curves were obtained for this
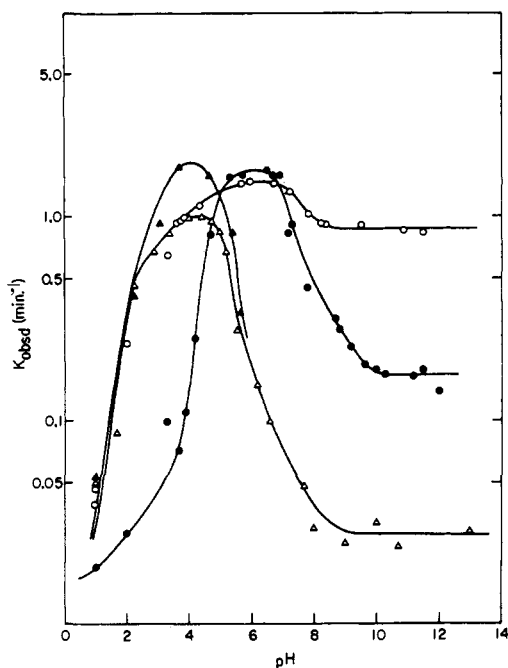

Figure 1. First-order rate constants for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine in water (O), in the presence of 0.01 M NaLS (●), in the presence of 0.05 M CTAB (△), and in the presence of 0.05 M NID (▲) as a function of pH at 25° and ionic strength 0.05. Cyanoacetate, acetate, phosphate, and carbonate buffers (0.02 M) were employed in the appropriate pH regions.

reaction in the absence of detergent, in the presence of 0.01 M sodium lauryl sulfate (NaLS), in the presence of 0.05 M cetyltrimethylammonium bromide (CTAB),

and in the presence of 0.05 M of a nonionic detergent (NID) formed from dodecylphenol and 18 moles of ethylene oxide. Under conditions in which the substrate is present predominantly as the free base, ultraviolet light absorption by the nonionic detergent interfered with the spectrophotometric assay employed to follow the reaction kinetics. Consequently, the reaction kinetics in the presence of this detergent were studied only under acidic conditions. The pH–rate profile for the hydrolysis reaction in the absence of detergent is similar to, but not identical with, that previously obtained at ionic strength 0.50.[11] Under basic conditions, in which the attack of hydroxide ion on the protonated Schiff base is the rate-determining step, the observed hydrolysis rate is strongly inhibited by all three detergents. In contrast, under slightly acidic conditions, in which attack of water on the protonated Schiff base is rate determining, the observed rate is only slightly affected by any of the detergents. Under still more acidic conditions, in which decomposition of the carbinolamine becomes rate determining, the rate of the reaction is little affected by either CTAB or NID, but is strongly inhibited by NaLS. The evaluation of the individual rate constants for the reactions occurring in the aqueous and micellar phases is considered below.

The apparent value of pK_a of the conjugate acid of p-chlorobenzylidene-1,1-dimethylethylamine was determined spectrophotometrically in aqueous solution and in the presence of varying concentrations of NaLS, CTAB, and NID. The results are summarized in Table I. For the interpretation of these results, it is convenient to define the following four equilibrium constants

$$K_1 = \frac{(S)_{aq}(H^+)}{(SH^+)_{aq}}; \quad K_2 = \frac{(S)_m(H^+)}{(SH^+)_m}$$

$$K_3 = \frac{(S)_{aq}(M)}{(S)_m}; \quad K_4 = \frac{(SH^+)_{aq}(M)}{(SH^+)_m}$$

in which S and SH^+ refer to the Schiff base and its conjugate acid respectively, M refers to the micelle, and the subscripts $_{aq}$ and $_m$ refer to the aqueous and micellar phases, respectively. It is clear that $K_1K_4 = K_2K_3$. The apparent dissociation constant for the protonated Schiff base, K_{app}, in the presence of micelle-forming detergent is given by

$$K_{app} = \frac{[(S)_{aq} + (S)_m](H^+)}{(SH^+)_{aq} + (SH^+)_m} \quad (1)$$

In terms of the equilibrium constants defined above

$$K_{app} = K_2 \frac{K_3 + (M)}{K_4 + (M)} \quad (2)$$

Under conditions in which (M) $\gg K_3$ and K_4, K_{app} becomes independent of detergent concentration and equal to the dissociation constant for the protonated Schiff base in the micellar phase. From the data in Table I, it is clear that these conditions are approximately met in solutions of NaLS more concentrated than 0.02 M and in solutions of CTAB more concentrated than 0.04 M. Values of pK_a for the conjugate acid of the Schiff base in the NaLS and CTAB micellar phases are included in Table I. Although insufficient data concerning the variation in K_{app} with the concentration of NID was collected to permit a reasonably accurate determination of the pK_a in this micellar phase, the fact that the K_{app} changed rather little in going from 0.01 M to 0.05 M detergent compared to the change in going from water to 0.01 M detergent suggests that the pK_a is probably slightly less than 5.

Alterations of the pK_a of indicators in the presence of micelle-forming detergents have been observed previously and accounted for in terms of local alterations in hydrogen ion concentration in the vicinity of the micelle.[18] Since it is to be expected that the hydrogen ion concentration will be greater near the surface of the anionic micelle and lower near the surface of the cationic micelle than in the bulk phase, such an interpretation is in qualitative agreement with the observed values of pK_a for the present system. In addition, it is expected that the anionic micelle would electrostatically stabilize and the cationic micelle would electrostatically destabilize the protonated Schiff base, an expectation which also suffices to account qualitatively for the observed results. The decreased basicity of the Schiff base in the nonionic micellar phase may reflect both stabilization of the free base and destabilization of the conjugate acid by the hydrophobic molecules which constitute this micelle.

The variation in pK_a for the conjugate acid of p-chlorobenzylidene-1,1-dimethylamine in the presence of micelle-forming detergents serves as a model for related observations in biochemical systems. Pyridoxal phosphate is bound in Schiff base linkage to the ε-amino group of a lysine residue of several enzymes.[19–23] The pK_a values for the protonated forms of these Schiff bases show wide variation from enzyme to enzyme. For example, glutamic–aspartic transaminase[24] and glutamic acid decarboxylase[25] exhibit values of pK_a of 6.2 and 5.6, respectively, compared to a value

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above 13 for pyridoxylidenemethylamine in aqueous solution.[26]

Equation 2 may be rearranged to yield

$$K_3 = \frac{K_1(M)(K_2 - K_{app})}{K_2(K_{app} - K_1)} \quad (3)$$

This equation, together with the data in Table I, permits the calculation of approximate values of K_3 and K_4 for NaLS and CTAB. The molar concentration of micelles, (M), was obtained from the relationship in

$$(M) = \frac{(detergent) - (c.m.c. \text{ of detergent})}{degree \text{ of association}}$$

which the degree of association was taken as 100,[27] an assumption that does not alter any of the conclusions derived hereafter. The calculated values are presented in Table I.

The equilibrium constants for incorporation of the protonated and free base forms of the Schiff base into NaLS micelles have been calculated from one set of data only. Since an error of a few hundredths of a pH unit in the determination of the relevant pK_a values introduces a sizable error into the equilibrium constants, these values must be accepted as gross approximations only. The calculated equilibrium constants indicate, in accord with expectations based on electrostatic arguments, that the cationic Schiff base is incorporated into the anionic micelle more readily than the free Schiff base, but that the free Schiff base is incorporated much more readily than its conjugate acid into the cationic micelle.

From the data contained in Figure 1 and Table I, it is possible to estimate some, but not all, of the individual rate constants for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine in the micellar phases. From the calculated values of K_3 and K_4, the equilibrium constants for the incorporation of the free base and protonated forms of the Schiff base into the micelles, it is estimated that about 70% of the free base and about 85% of the protonated form are incorporated into the micelle in the presence of 0.01 M NaLS. In the presence of 0.05 M CTAB, the corresponding values are 99 and 70%. Thus, in regions of pH in which the rates are not greatly depressed in the presence of detergent, the observed rate constants are reasonably accurate measures of the rate constants for reactions in the micellar phases. On the other hand, under conditions in which the observed rates are strongly depressed by the presence of detergent, the rate constants may include sizable or even predominant contributions from the reaction in aqueous solution despite the fact that most of the substrate is present in the micellar phase. For example, if a substrate were incorporated into a micelle to the extent of 90% and the rate constant for the reaction in the micellar phase were 10% of that in the aqueous phase, the observed rate constant would contain equal contributions from the reaction in water and that in the micelle. In an effort to define the magnitude of the rate constants for detergent-inhibited reactions in micellar phases, a study of the variation in first-order rate constant as a function of detergent concentration was carried out.

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Table II. Effect of Detergent Concentration on the First-Order Rate Constants for Detergent-Inhibited Hydrolysis of p-Chlorobenzylidene-1,1-dimethylethylamine at 25°

NaLS, M	CTAB, M	pH 9.50	k_{obsd}, min.$^{-1}$ pH 4.12	pH 10.6
...		0.90	1.08	
0.002		0.60	0.69	
0.004		0.38	0.40	
0.006		0.28	0.31	
0.010		0.17	0.26	
0.014		0.17	0.19	
0.020		0.15	0.16	
0.030		0.12	0.15	
0.050		0.098		
0.080		0.079		
	...			0.74
	0.002			0.43
	0.004			0.25
	0.006			0.20
	0.010			0.097
	0.014			0.088
	0.020			0.067
	0.050			0.028

Table III. Estimated Rate Constants for the Hydrolysis of p-Chlorobenzylidene-1,1-dimethylethylamine in Aqueous and Micellar Phases at 25° and Ionic Strength 0.05

Phase	k_1,[a] min.$^{-1}$	k_{calcd},[b] M^{-1} min.$^{-1}$	k_{H_2O},[c] min.$^{-1}$	k_{obsd}^{pH},[1] min.$^{-1}$
Water	0.87	2.5×10^7	1.45	0.040
NaLS	0.08	0.8×10^6	2.2	0.00014[d]
CTAB	0.028	3.1×10^7	1.8	0.035
NID	...	...	2.2	0.035

[a] Observed first-order rate constant for the pH-independent reaction above pH 9. [b] Calculated second-order rate constant for the attack of hydroxide ion on the protonated Schiff base. [c] Observed first-order rate constants for the attack of water on the protonated Schiff base (see text). [d] Calculated from data at pH 4.

In Table II, first-order rate constants for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine are presented as a function of NaLS concentration at pH 4.1 and 9.5 and as a function of CTAB concentration at pH 10.6. In all cases, the first-order rate constants decrease with increasing detergent concentration. However, these results do serve to establish that, under these conditions, appreciable reaction does occur in the micellar phases since the rate constants do not decrease linearly with detergent concentration. That is, the rate constants decrease less rapidly than the fraction of substrate present in the aqueous phase. Maximum values for the rate constants in the micellar phases have been calculated from the observed rate constants at the highest concentration of detergent employed in each case. These values are probably not greatly in error since the rate constants for reactions in the presence of NaLS appear to be approaching a limiting value and the value in the presence of CTAB is supported by additional data presented below.

From the data contained in Table II and the equilibrium constants in Table I, it is possible to calculate first-order rate constants for these reactions in the micellar phases. However, it is important to realize that such calculations would have doubtful meaning since, as the detergent concentration increases, the size and structure of the micelles are altered. This alteration is likely to affect both the equilibrium constants for incorporation of the substrates into the micelles, particularly since we have assumed a single degree of association for the detergents independent of detergent concentration, as well as the reaction rates in the micellar phases. Consequently, we shall employ the rate constants obtained by the approximation indicated above.

The estimated rate constants for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine in aqueous and micellar phases are collected in Table III. The indicated rate constants for the pH-independent reaction above pH 9 are those observed at the highest concentrations of detergent employed and are, as noted above, maximum values. Second-order rate constants

for the attack of hydroxide ion on the protonated Schiff base were calculated from the measured values of pK_a and the first-order rate constants in basic solution. In order to ensure that in the micellar phase, as in the aqueous phase, the reaction in basic solution is in fact the attack of hydroxide ion on the protonated Schiff base rather than the attack of water on the free substrate, the first-order rate constants for the hydrolysis of p-methoxybenzylidene-1,1-dimethylethylamine in basic solution were measured in the presence of NaLS and CTAB. In the presence of 0.01 M NaLS, a first-order rate constant of 0.35 min.$^{-1}$ was obtained, compared with a value of 0.17 min.$^{-1}$ for the chloro derivative, and in the presence of 0.01 M CTAB a first-order rate constant of 0.31 min.$^{-1}$ was obtained, compared with a value of 0.13 min.$^{-1}$ for the chloro derivative. These results strongly suggest that, in both micellar phases, the reaction in base involves rate-determining attack of hydroxide ion on the protonated species.[11] The calculated rate constants indicate that the attack of hydroxide ion on the protonated Schiff base is retarded at least 20-fold upon incorporation of the substrate into the anionic micelle formed from NaLS but is relatively unaffected upon incorporation of the substrate into the cationic micelle.

The magnitude of rate constants for the attack of water on the protonated Schiff bases in the micellar phases was estimated from the first-order rate constants for these reactions at the spectrophotometrically determined pK_a values. This procedure is necessary since values of pK_a estimated from the break in the pH–rate profile occur at higher values of pH than those determined spectrophotometrically. This result indicates that the transition to rate-determining carbinolamine decomposition becomes important before the Schiff base is completely converted to its conjugate acid.[11] The rate constants for the attack of water on the protonated Schiff base in the anionic, cationic, or nonionic micelle are similar to that for this reaction in the aqueous phase. The observed rate constants at pH 1, in the region of rate-determining carbinolamine decomposition, were taken from the data in Figure 1 with the exception of the value for NaLS. In contrast to the other reactions, the hydrolysis rates in the presence of NaLS do not decrease linearly with hydrogen ion in acidic solution but tend to level off below pH 4. The reason for this behavior is not known although it may indicate that the decomposition of the protonated carbinolamine is kinetically important in the presence of this detergent. The indicated value in

Table III was obtained by extrapolation from data at pH 4.1 at the highest concentration of detergent employed (Table II). The rates of hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine in the region of rate-determining carbinolamine decomposition are similar in the cationic, nonionic, and aqueous phases. In contrast, the rate of this reaction in the anionic micellar phase is decreased, by more than two orders of magnitude, relative to the rate in the aqueous phase.

In a fashion similar to that frequently observed for enzyme-catalyzed reactions, it might be expected that, at sufficiently elevated concentrations of substrate, saturation of the micelles with substrate would be observed. Such saturation would be reflected in a gradual return of the observed rate constants to the values found in the absence of detergent as the substrate concentration is increased. This expectation was not fulfilled indicating that the distribution law yielding constant values for K_3 and K_4 is valid. As is indicated in Table IV, first-

Table IV. Effect of Substrate Concentration on the First-Order Rate Constants for the Hydrolysis of p-Chlorobenzylidene-1,1-dimethylethylamine in the Presence of Detergents at 25° and Ionic Strength 0.05

Substrate, M	k_{obsd}, min.$^{-1}$			
	CTAB[a]		NaLS[b]	
	0.004 M	0.01 M	0.004 M	0.01 M
2×10^{-4}	1.1	0.74		
4×10^{-4}	1.1	0.71		
1×10^{-3}	0.92	0.77		
1.4×10^{-3}	0.95	0.76		
2×10^{-3}	0.95	0.75		
3.3×10^{-5}			0.33	
6.7×10^{-5}			0.33	
1×10^{-4}			0.38	0.094
2×10^{-4}			0.37	0.15
4×10^{-4}			0.31	0.16
1×10^{-3}			0.32	0.19
1.4×10^{-3}			0.34	0.18
2×10^{-3}			0.27	0.18

[a] pH 5.62. [b] pH 10.26.

order rate constants for the hydrolysis of the Schiff base were independent of substrate concentration over a substantial concentration range in the presence of CTAB at pH 5.62 and in the presence of NaLS at pH 10.26. At the highest concentration of substrate employed, the concentration of detergent exceeded that of substrate by only a factor of two. Estimations based on the equilibrium constants for incorporation of the substrate into the micelles (Table I) and on the rate constants in the micellar phases (Table III) suggest that, under the conditions of these experiments, the observed rates are mostly due to reaction in the aqueous phase.

In an effort to corroborate several of the above conclusions regarding the relative rates of p-chlorobenzylidene-1,1-dimethylethylamine hydrolysis in water and in the anionic and cationic micelles, the effect of NaLS and CTAB on the rate of hydrolysis of the cationic Schiff base, benzhydrylidenedimethylammonium ion
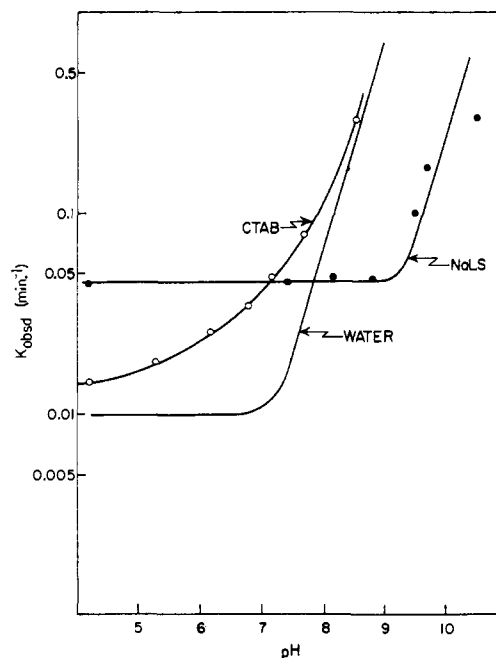

Figure 2. First-order rate constants for the hydrolysis of benzhydrylidenedimethylammonium ion in water in the presence of 0.05 M CTAB (O), and in the presence of 0.01 M NaLS (●) as a function of pH at 25° and ionic strength 0.05; 0.02 M phosphate and carbonate buffers employed in the appropriate pH regions.

was studied. This molecule is, in many respects, a simpler substrate for study since, clearly, it cannot dissociate a proton to form a free base. In Figure 2, the first-order rate constants for the hydrolysis of the cationic Schiff base are plotted as a function of pH in aqueous solution and in the presence of 0.01 M NaLS and 0.05 M CTAB. The results for the reaction in the absence of detergent were taken from a previous study of this reaction at ionic strength 0.50.[12] Although the pH–rate profile for the hydrolysis reaction in the presence of CTAB does not lend itself to a simple kinetic explanation, it appears safe to draw the following reasonable conclusions from the data in this figure. Relative to the rates in aqueous solution, the incorporation of the substrate into the NaLS micelle inhibits the attack of hydroxide ion but accelerates, slightly, the rate of attack of water. On the other hand, both rates are little affected, in comparison to those in aqueous solution, upon incorporation of the substrate into the CTAB micelle. These results are similar to those obtained for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine.

As mentioned above, the pH–rate profile for the hydrolysis of p-chlorobenzylidene-1,1-dimethylethylamine strongly suggests a transition in rate-determining step with changing pH.[11] This conclusion is strongly corroborated by the differential responses of the Schiff base hydrolysis rates to the detergents in various pH ranges.