CHAPTER V

MICELLAR EFFECT ON HYDROLYSIS OF CHEMICAL WARFARE SIMULANTS

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CHAPTER V: MICELLAR EFFECT ON HYDROLYSIS OF CHEMICAL WARFARE SIMULANTS

5.0 INTRODUCTION

Phosphorus triesters are widely used as insecticides and organophosphorus based chemical warfare agents.\textsuperscript{1-10} The chemical warfare agents are neurotoxin and irreversibly inhibit acetylcholinesterase.\textsuperscript{1-2} Owing to their toxicity and lingering effects on the environment, considerable effort has been directed towards methods\textsuperscript{11-79} of facilitating the controlled decomposition of these materials particularly through hydrolysis.

In the previous chapters synthesis and spectroscopic characterization of N-methyl substituted hydroxamic acids and thiohydroxamic acids, pK\textsubscript{a} determination of hydroxamic acids by nucleophilic substitution reactions, solvent effect on hydrolysis reaction and micellization of cationic surfactants i.e. cetyltriphenylphosphonium bromide have been discussed. In this chapter, studies of the micellar effect on the hydrolysis of some simulants of chemical warfare agents using N-substituted hydroxamic acids (Fig. 5.1) have been undertaken.

In the present investigation p-nitrophenyl p-toluene sulphonate (PNPTs), p-nitrophenyl diphenyl phosphate (PNPDPP) and parathion have been taken. An attempt has also been made to study some reaction in microemulsions. The extensive use of organophosphorus pesticides can also lead to poisoning due to the occupational or incidental exposure of large number of people worldwide. Herein, novel micellar media and some N-substituted hydroxamic acids have been used for detoxification of nerve agent i.e.sarin.

\textsuperscript{*} Part of this work has been accepted for publication in Journal of Dispersion Science and Technology. 2008, 29, 1381 - 1384.
Fig. 5.1 N-substituted hydroxamic acids and thiohydroxamic acids.
5.1 PRESENT INVESTIGATION

In the present study, the most effective classes of N-methyl substituted hydroxamic acids and thiohydroxamic acids were used for the cleavage of p-nitrophenyl p-toluene sulphonate (PNPTs), p-nitrophenyl diphenyl phosphate (PNPDPP) and parathion in micellar media at 9.0 pH in 4.6 % (v/v) acetonitrile and N-phenylbenzohydroxamic acid (PBHA) for the hydrolysis of chemical warfare agent (Sarin) in micellar media at 9.0 pH in 4.6 % (v/v) acetonitrile. Scheme 5.1 shows the hydrolysis of p-nitrophenyl p-toluene sulphonate with nucleophile 1b.

Scheme 5.1

Scheme 5.2 shows the reaction of p-nitropenyl di phenyl phosphate (PNPDPP) with 1b and parathion with nucleophiles 1a, 1b, 1c, 1d, 2a, 2b and 2c in different cationic surfactant.

Scheme 5.2
Scheme 5.3 shows the detoxification reaction of sarin with nucleophile 4a in the presence of cationic surfactant i.e. cetyltrimethylammonium bromide (CTAB).

The different cationic surfactant used in this investigation are shown in scheme 5.4. The surfactants were chosen for this investigation, on the basis of their CMC value, chain length, counter ion and head group. The CMC value is only criteria for chosen of surfactant for micellar mediated kinetics. The low CMC values of surfactants always preferred for micellar based hydrolysis reaction. The physicochemical behaviour of all these surfactant has been discussed in Chapter-IV (Section B).
Cetyltrimethylphosphonium bromide (CTAB)

Tetradecyltriphenylphosphonium bromide (C₁₄PPh₃Br)

Cetyltributylphosphonium bromide (C₁₆Pbu₃Br)

Cetyldiethylethanol amine (C₁₆DEEA)

Scheme-5.4
5.2 EXPERIMENTAL

Material

The preparation of N-methyl p-chlorohydroxamic acids and N-methyl p-chloro thiohydroxamic acid were discussed in chapter II. N-phenylbezohydroxamic acid, cetyltrimethylammonium bromide, cetylpyridinium bromide, cetyltributylphosphonium bromide, cetyltrimethylenehetanol amine, cetyldiethylehtanol amine and cetyltrimethylammonium hydroxide were procured from Sigma. Tetradecyltriphenylphosphonium bromide and cetyltriphenylphosphonium bromide were obtained from Prof. R. M. Palepu, St. Francis Xavier University, Antigonish, Canada. All the substrates were prepared at Defence Research Development Establishment, Gwalior by following methods.

Preparation of Parathion

Parathion was prepared by the reaction of diethyl chloro thiophosphate with p-nitrophenol in the presence of triethyl amine scheme 5.5.

\[
\begin{align*}
\text{C}_2\text{H}_5\text{O}-\text{P}^\text{-Cl} + \text{HO-} & \text{OC}_2\text{H}_5 \text{NO}_2 \rightarrow \text{C}_2\text{H}_5\text{O}-\text{PO-} & \text{OC}_2\text{H}_5 \text{NO}_2 \\
\text{Diethyl chloro phosphorothioate} & \text{p-nitrophenol} & \text{p-nitrophenyl diethyl phosphorothioate (Parathion)}
\end{align*}
\]

Scheme 5.5
Preparation of PNPDPP

Similarly \( p \)-nitrophenyl diphenyl phosphate was prepared by the reaction of diphenyl chloro phosphate with \( p \)-nitrophenol in the presence of triethylamine scheme 5.6.

\[
\begin{align*}
\text{Diethyl chlorophosphate} & \quad + \quad \text{\textit{p-nitrophenol}} \\
\rightarrow & \quad \text{\textit{p-nitrophenyl diphenyl phosphate}}
\end{align*}
\]

Scheme 5.6

Preparation of \( p \)-nitrophenyl \( p \)-toluene sulphonate

The \( p \)-nitrophenyl \( p \)-toluene sulphonate was prepared by the reaction \( p \)-toluene sulphonyl chloride with \( p \)-nitrophenol in the presence of triethylamine scheme 5.7.

\[
\begin{align*}
\text{\textit{p-Toluene sulphonyl chloride}} & \quad + \quad \text{\textit{p-nitrophenol}} \\
\rightarrow & \quad \text{\textit{p-nitrophenyl p-toluene sulphonate}}
\end{align*}
\]

Scheme 5.7
Preparation of Stock Solution

Due to solubility problem, the stock solution of PNPTs sulphonate, PNPDPP and parathion, (0.0015 M) was prepared in 50% (v/v) acetonitrile-water media. Substrate stock solution of 0.0015 M was prepared with triply distilled water.

5.3 GENERAL METHOD

The kinetic experiments were performed at 9.0 pH, by using borate (0.01 M) buffer solution. During the course of reaction, ionic strength was maintained using 0.1 M KCl. All the reactions were followed by monitoring the release of p-nitrophenoxide ion at 400 nm by using Varian Carry -50 and Systronics 104 spectrophotometers. Pseudo-first order rate constants $k'$ were derived from plots of $\log (A_\infty - A_0) / (A_\infty - A_t)$ versus time. The values of rate constants were reproducible within ±3%. To obtained pH 11.0, the 0.1 M solution of NaOH and 0.05 M solution of phosphoric acid were mixed in desired composition. The pH of the reaction medium was measured before and after the reaction using Systronics 335 pH-meter. For all the kinetic runs the ionic strength of the reaction medium was maintained using 0.1 M KCl. The pseudo-first order rate constants ($k_{obs}$) were evaluated by fitting the absorbance vs. time trace to a standard exponential model. The kinetics was all determined under pseudo-first order conditions where the nucleophile (hydroxamic acid, $1.0 \times 10^{-3}$ M) was taken in large excess over the substrate ($1.0 \times 10^{-3}$ M). Some absorption spectra of the hydrolysis reactions are shown in Figs. (5.2-5.5). The absorption band centered at $\lambda = 400$ nm increase with time.
**Fig. 5.2** Repeat scans graph showing increasing absorbance at 400 nm. [PNPTs] = 1.0 \times 10^{-4} \text{ M}, [\text{HA}] = 1.0 \times 10^{-3} \text{ M}, [\text{KCl}] = 1.0 \text{ M Temp. 27 }^\circ\text{C}.

**Fig. 5.3** Repeat scans graph showing increasing absorbance at 400 nm. [PNPDPP] = 1.0 \times 10^{-4} \text{ M}, [\text{HA}] = 1.0 \times 10^{-3} \text{ M}, [\text{KCl}] = 1.0 \text{ M Temp. 27 }^\circ\text{C}.
Fig. 5.4 Repeat scans graph showing increasing absorbance at 400 nm. 
[Parathion] = 1.0 x 10^{-4} M, [HA] = 1.0 x 10^{-3} M, [KCl] = 1.0 M Temp. 27 °C.

Fig. 5.5 Repeat scans graph showing increasing absorbance at 400 nm in 
microemulsion medium. [PNPDPP] = 1.0 x 10^{-4} M, [HA] = 1.0 x 10^{-3} M, [KCl] = 1.0 M Temp. 27 °C
5.4 RESULTS AND DISCUSSION

The pH dependent pseudo first order rate constants for the reaction of \( p \)-nitro phenyl \( p \)-toluene sulphonate (PNPTs), \( p \)-nitrophenyl diphenylphosphate (PNPDPP) and parathion cleavages at 27°C were determined at different pH values between (7-12) by following the release of \( p \)-nitrophenoxide ion at 400 nm spectrophotometrically with the N-methyl \( p \)-chloro benzohydroxamate ion (\( \alpha \)-nucleophile), in large excess over the substrate in each case. All the reactions followed rate equation 1.

\[
k_{\text{obs}} = k_0 + k_{\text{Nu}} [HA]
\]  \hspace{1cm} (1)

\[
k_0 = k_{\text{H}_2\text{O}} + k_{\text{OH}^-} [\text{OH}^-]
\]  \hspace{1cm} (2)

The pH rate constant profiles data for PNPTs, PNPDPP and parathion are shown in Table 5.1. The observed rate constant increases with pH. The apparent pK\(_a\) obtained from the pH rate constant profile (Figs 5.6 - 5.7) is in good agreement with the pK\(_a\) value of 8.85 for 1b determined by pH / potentiometric method \(^{78-79}\). It is evident that the anion of hydroxamic acid (\( N-O^- \)) acts as a reactive species in the reaction of esters hydrolysis. Consequently, the pK\(_a\) for the conversion of the \( N-OH \) to \( N-O^- \) form plays an important role for the cleavage of esters hydrolysis.
**TABLE 5.1**

pH-Dependent Pseudo-First-order Rate Constant for the Nucleophilic Substitution Reaction of esters with N-methyl p-chloro benzo- hydroxamate ion at 27 °C.

<table>
<thead>
<tr>
<th>pH</th>
<th>$k_{obs} \times 10^3 /s^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PNPTs</td>
</tr>
<tr>
<td>7.0</td>
<td>-</td>
</tr>
<tr>
<td>8.0</td>
<td>0.02</td>
</tr>
<tr>
<td>9.0</td>
<td>0.07</td>
</tr>
<tr>
<td>10.0</td>
<td>0.46</td>
</tr>
<tr>
<td>11.0</td>
<td>1.19</td>
</tr>
<tr>
<td>12.0</td>
<td>3.97</td>
</tr>
</tbody>
</table>
Fig. 5.6 pH rate profile for the reaction of parathion with nucleophile 1b.

Fig. 5.7 logk_{obs} vs pH graph for reaction of parathion with nucleophile 1b.
Cationic surfactant displayed the highest esterolytic activity among all the catalytic systems towards hydrolysis of carboxylate and organophosphorus esters. All the reactants are partitioned into the surfactant micelles by columbic and hydrophobic interactions, and the observed rate accelerations are largely due to the enhanced localization of the reactants and also of the typical physicochemical properties of micellar environment, which are considerably different from those of the bulk solvents. Moreover, the anionic nucleophiles having strong interactions with cationic micellar aggregates would exhibit higher rate enhancement. The effects of surfactant concentration on the hydrolysis of PNPTs, PNPDP and parathion in the presence of nucleophile lb are shown in Table 5.2 and Fig.5.8.

In order to see effect of different cationic surfactant on observed rate constant for the hydrolysis of parathion have been determined in the presence of various surfactants using nucleophile la, lb, lc, ld, 2a, 2b, and 2c. (Table-5.3). The cationic surfactants play a significant role in the kinetics of hydrolysis reaction. Under comparable conditions C_{16}PPh_{3}Br has more catalytic activity towards hydrolysis of parathion. i.e. low CMC value of cetyltriphenylphosphonium bromide surfactants increases aggregation number of micelles, the micellar surface appears to be saturated with counter ions, and the fractional coverage \( \beta = 1-\alpha \), is constant the rate of reaction should increase as substrate is taken up by the micelles but once substrate is fully bound, the rate should be independent of added surfactant or counter ion.
Table 5.2
The effect of cationic surfactant on the hydrolysis of PNPTs, PNPDP and Parathion in the presence of nucleophile 1b.

\[ k_{obs} \times 10^3/s^{-1} \]

<table>
<thead>
<tr>
<th>surfactant 10^-3 M</th>
<th>PNPTs</th>
<th></th>
<th></th>
<th>PNPDPP</th>
<th></th>
<th></th>
<th>PARATHION</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CTAB</td>
<td>CPB</td>
<td>C16Ph3Br</td>
<td>CTAB</td>
<td>CPB</td>
<td>C16Ph3Br</td>
<td>CTAB</td>
<td>CPB</td>
<td>C16Ph3Br</td>
</tr>
<tr>
<td>0</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.19</td>
<td>0.19</td>
<td>0.19</td>
</tr>
<tr>
<td>1.8</td>
<td>0.12</td>
<td>0.31</td>
<td>0.62</td>
<td>1.53</td>
<td>1.60</td>
<td>3.70</td>
<td>1.46</td>
<td>1.47</td>
<td>2.17</td>
</tr>
<tr>
<td>3.6</td>
<td>1.29</td>
<td>1.58</td>
<td>2.12</td>
<td>4.91</td>
<td>5.80</td>
<td>7.86</td>
<td>1.77</td>
<td>1.87</td>
<td>2.75</td>
</tr>
<tr>
<td>9.0</td>
<td>3.97</td>
<td>4.16</td>
<td>12.5</td>
<td>14.6</td>
<td>15.5</td>
<td>28.8</td>
<td>2.43</td>
<td>2.74</td>
<td>3.04</td>
</tr>
<tr>
<td>12.0</td>
<td>8.61</td>
<td>10.92</td>
<td>14.9</td>
<td>26.1</td>
<td>26.4</td>
<td>41.0</td>
<td>2.40</td>
<td>2.61</td>
<td>2.95</td>
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<tr>
<td>15.0</td>
<td>8.02</td>
<td>9.49</td>
<td>11.7</td>
<td>24.8</td>
<td>25.0</td>
<td>34.8</td>
<td>2.30</td>
<td>2.50</td>
<td>2.84</td>
</tr>
<tr>
<td>18.0</td>
<td>7.48</td>
<td>8.92</td>
<td>10.4</td>
<td>19.9</td>
<td>20.9</td>
<td>32.8</td>
<td>2.31</td>
<td>2.33</td>
<td>2.43</td>
</tr>
</tbody>
</table>
Fig. 5.8 Effect of surfactant concentration on the reaction of parathion with nucleophile 1b.
Table 5.3
Reaction on Parathion with N-methyl substituted benzohydroxamate ion and N-methyl substituted benzothiohydroxamate ion in different cationic surfactant in aqueous medium at 9.0 pH and 27°C. $\mu = 0.1$M KCl Parathion = $1.0 \times 10^{-4}$M, [HA] = $1.0 \times 10^{-3}$M.

<table>
<thead>
<tr>
<th>Cleophile</th>
<th>CTAB</th>
<th>CPB</th>
<th>C$_{12}$PP$_3$Br</th>
<th>C$_{14}$PP$_3$Br</th>
<th>C$_{16}$PP$_3$Br</th>
<th>C$_{16}$PP$_4$Br</th>
<th>C$_{16}$DMEA</th>
<th>C$_{16}$DEEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>1.19</td>
<td>1.28</td>
<td>1.12</td>
<td>1.32</td>
<td>1.62</td>
<td>0.54</td>
<td>1.33</td>
<td>1.44</td>
</tr>
<tr>
<td>1c</td>
<td>1.47</td>
<td>1.53</td>
<td>1.46</td>
<td>1.82</td>
<td>2.08</td>
<td>0.80</td>
<td>1.55</td>
<td>1.72</td>
</tr>
<tr>
<td>1d</td>
<td>1.29</td>
<td>1.38</td>
<td>1.22</td>
<td>1.62</td>
<td>1.71</td>
<td>0.74</td>
<td>1.40</td>
<td>1.52</td>
</tr>
<tr>
<td>1b</td>
<td>1.77</td>
<td>1.87</td>
<td>1.50</td>
<td>2.33</td>
<td>2.75</td>
<td>1.10</td>
<td>1.71</td>
<td>2.39</td>
</tr>
<tr>
<td>2a</td>
<td>0.21</td>
<td>0.26</td>
<td>0.49</td>
<td>0.56</td>
<td>0.58</td>
<td>0.28</td>
<td>0.38</td>
<td>0.43</td>
</tr>
<tr>
<td>2b</td>
<td>0.12</td>
<td>0.18</td>
<td>0.32</td>
<td>0.44</td>
<td>0.51</td>
<td>0.22</td>
<td>0.34</td>
<td>0.39</td>
</tr>
<tr>
<td>2c</td>
<td>0.10</td>
<td>0.13</td>
<td>0.21</td>
<td>0.36</td>
<td>0.47</td>
<td>0.16</td>
<td>0.28</td>
<td>0.33</td>
</tr>
</tbody>
</table>
This surfactant offer head group that are significantly bulkier and also possess aromatic moiety at micellar surface. Many factors are likely to influence these differences in the rate of hydrolysis, substrates hydrophobicity and properties of surfactant undoubtedly play key role for the reaction in micellar media. The cationic micelles bring reactants closer by hydrophobically binding the substrates and electrostatically attracting the negatively charged nucleophile. Initially an increase in the surfactant concentration generates more cationic micelles and increases the initial rate. As the number of micelles becomes large, virtually all the substrates get associated to the micellar phase. Further addition of surfactants proliferate the number of micelles, which simply take up the nucleophilic anion into the “Stern layer”. The hydrolytic efficiency of N-methyl substituted hydroxamic acids and thiohydroxamic acids were influenced by carbonyl group and thio carbonyl group. N-methyl substituted hydroxamic acids show 40-fold rate acceleration effect as compare to their thio analogous over the reaction in aqueous media in the presence of different cationic surfactant shown in Table (5.3).

Both nerve agent and pesticide act as phosphorylating agents, reacting with the sarin moiety of the enzyme acetylcholine esterase. They inhibit its regulation of the in vivo concentration of the neurotransmitters acetylcholine with major effect on the nervous system. A successful test of the phosphorolytic potential of hydroxamate ion towards nerve agent i.e. sarin in aqueous CTAB solution was studied. Table 5.4 summarizes the kinetics of hydrolysis sarin with nucleophile 4a, monitored by release of fluoride ion as a function of time by fluoride ion selective electrode with Thermoelectron Orion 710 A+ potentiometer. The electrode was dipped in a thermo-stated glass reaction vessel. Linear response of electrode towards fluoride ions was ensured by plotting a calibration curve of potassium fluoride over a range of 1 to 100 x 10⁻⁵ M.
Table 5.4
Hydrolysis of sarin with nucleophile 4a in the presence of CTAB at pH : 9.5, Temp : 298 K, $\mu = 0.05$ M KCl, Sarin = $5 \times 10^{-5}$ M

<table>
<thead>
<tr>
<th>[CTAB] x $10^{-3}$M</th>
<th>[PBHA] x $10^{-5}$M</th>
<th>$k_{obs}$ $10^3$/s$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>2.94</td>
</tr>
<tr>
<td>-</td>
<td>1.25</td>
<td>3.85</td>
</tr>
<tr>
<td>2.0</td>
<td>-</td>
<td>4.04</td>
</tr>
<tr>
<td>2.0</td>
<td>25.0</td>
<td>4.75</td>
</tr>
</tbody>
</table>
General Mechanism:

It is now generally believed that nucleophilic substitution at tetracoordinate pentavalent phosphorus occurs by associative (AE) mechanisms through a pentacoordinate trigonal bipyramidal (TBP) intermediate or transition state (Scheme 5.8). The mechanism giving rise to a TBP transition state is denoted as $S_{N2}(P)$ since it resembles the one occurring in bimolecular nucleophilic substitution reactions at a saturated carbon atom. Such a concerted process will take place with inversion of configuration at phosphorus.

If the transition state is long-lived enough to turn into an intermediate then the mechanism is referred to as an addition-elimination. In the framework of this stepwise process, formation of the intermediate is followed by the detachment of the leaving group, again with inversion of configuration at phosphorus. However, the intermediate can undergo pseudo rotation prior to the departure of the leaving group and in such case retention of configuration at phosphorus will be observed. The first two mechanisms are often denoted as ‘in-line displacement’ and the last one as an ‘adjacent mechanism’.

\[ \text{Scheme 5.8} \]
A large amount of data on acyl transfer at carbon-, phosphorus- and sulfur-based acyl sites, shows that the reaction flux (associative versus dissociative) is controlled by

(i) leaving group ability
(ii) internal nucleophilicity of the substrate (related to the pKₐ of the ionized proton)
(iii) stability of the putative unsaturated intermediate

Scheme 5.9 display the three possible pathways for the attack of nucleophiles and similar substrates. Fission of P-OAr followed by present study.
Menger and Portnoy proposed the first quantitative treatment describing inhibition of ester saponification by anionic micelle. Micelles bound hydrophobic esters, and anionic micelle excluded hydroxide ion and is inhibited the reaction, whereas cationic micelles speeded specification by attracting OH\(^-\). They assumed that dilute non-ionic substrate partition between water and micelles (Scheme 5.10).

![Scheme 5.10](image)

The substrate in water, \(S_w\), is assumed to be in equilibrium with substrate in micelle \(S_m\), and followed eq.3.

\[
k_w = \frac{[S_m]}{[S_w][D_n]}
\]  

(3)

The association constant (binding constant) \(K_s\) is written in terms of micellized surfactant, \([D_n] = [\text{surfactant}]_{T} - \text{cmc}\), where the cmc is assumed to give the concentration of monomeric surfactant. The dependence of the first-order rate constant on the surfactant concentration based on scheme and eq.4 give,

\[
k_v = \frac{k_w + k_M K_s [D_n]}{1 + K_s [D_n]}
\]  

(4)

where \(k_M\) and \(k_w\) are first-order rate constants in micellar and aqueous media.
Rate effects on bimolecular reactions in association colloids are rationalized by the pseudo phase model, in which the aggregates and bulk solvent, typically water are regarded as distinct reaction regions. The over all reaction rate is the sum of the rates in each pseudo phase depend upon the rate constants and reactant concentration in each pseudo phase (Scheme-5.11).

\[
\begin{align*}
\text{Parathion}_w + D_n & \xrightleftharpoons{K_m^\text{Parathion}} \text{Parathion}_m \\
+ \quad \text{HA}_w + D_n & \xrightleftharpoons{K_m^{\text{HA}}} \text{HA}_m \\
\end{align*}
\]

Scheme 5.11

In Scheme X, subscripts w and m indicate aqueous and micellar pseudophase, respectively, and \(D_n\) represents the micellized surfactant, that is, \([D_n]\) = \([D_T]\)-cmc, where \([D_T]\) is the stoichiometric surfactant concentration and cmc the critical micellar concentration, obtained under the experimental conditions as the minimum surfactant concentration required to observe any kinetic effect. The observed rate constant surfactant concentration profiles are analysed by eq. (5).

\[
k_{\text{obs}} = \frac{k_r^w + k_r^m}{V} - \frac{K_m^p K_m^{HA} [D_n][HA]_r}{(1 + K_n^p [D_n])(1 + K_m^{HA} [D_n])} 
\]  

(5)

The hydroxamate ion concentration in the micellar pseudophase has been defined as the local, molar concentration within the micellar pseudophase: \([HA]_r = [HA]_m/D_n V\) denotes the micellar fractional volume in which the reaction occurs. \(V\) was assumed equal to the partial molar volume of the interfacial reaction.
region in the micellar pseudophase, determined by Bunton et al.\textsuperscript{80}, as 0.14 dm\textsuperscript{3} mol\textsuperscript{-1}. Micellar binding of both substrates, Parathion and hydroxamate ion is governed by hydrophobic interactions and the equilibrium constants $K_{m_{\text{Parathion}}}$ and $K_{m_{\text{HA}}}$ are expressed by referring this contributions to the total volume of the observed rate constants, $k_{\text{obs}}$. Second order rate constants at the micellar interface and association constants of the hydroxamate ions to the cationic micelles (obtained by fitting Eq. (5) to the experimental data are given in Table 5.5.)

**Table 5.5**

Kinetic parameters obtained by applying pseudophase model for the nucleophilic reaction of parathion with nucleophile 1b in presence of cationic micelles.

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>$k_{1}^{m}/(\text{M}^{-1}\cdot\text{s}^{-1})$</th>
<th>$K_{m_{\text{Parathion}}}/(\text{M}^{-1})$</th>
<th>$K_{m_{\text{HA}}}/(\text{M}^{-1})$</th>
<th>$k_{5}^{m}/(\text{M}^{-1}\cdot\text{s}^{-1})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTAB</td>
<td>0.19</td>
<td>140\textsuperscript{*}</td>
<td>120</td>
<td>1.07 x 10\textsuperscript{-2}</td>
</tr>
<tr>
<td>CPB</td>
<td>0.19</td>
<td>135</td>
<td>120</td>
<td>1.16 x 10\textsuperscript{-2}</td>
</tr>
<tr>
<td>C\textsubscript{18}PPh\textsubscript{3}Br</td>
<td>0.19</td>
<td>130\textsuperscript{*}</td>
<td>180</td>
<td>0.12</td>
</tr>
</tbody>
</table>

The extents of this distribution increased with increasing substrate hydrophobicity and overall rates of reactions anionic substrate also increased with increasing hydrophobicity. Kinetic data also is treated in terms of distribution of initial and transition states between water and micelles\textsuperscript{80-82}. The pseudophase and transition state models differ only in their description of transfers between regions and the choice between them is a matter of convenience\textsuperscript{80}.

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When amphiphile is at or below the kinetic cmc, that is, the concentration at which micelles form under the experimental conditions, \( k_2 = k_2^m \). In this model \( k_2^m \), the second-order rate constant in the micellar pseudophase, is expressed in units of local molarity of \( \text{Nu}^- \) in its reaction volume \( V \), and not its stoichiometric concentration in solution. For example, binding of \( \text{Nu}^- \) to cationic aggregates, whose volume is much smaller than that of the total solution, strongly enhances its local molarity. This increase accounts for much or all, of the ‘micellar catalysis’ and depends on several variables including amphiphile chain length and concentration and types of inert and reactive counterions.

The treatment fits extensive data if applied to reactions of dilute nucleophilic anions with nonionic substrates, it fits variations of \( k_{\text{obs}} \) with concentrations of ionic amphiphile, inert ions and \( \text{Nu}^- \), and substrate hydrophobicity with rate constants in the micellar and aqueous pseudophase (Scheme XI). The distribution of organic substrates are described by a binding constant \( K_s \). The micellar surface acts as a selective ion exchanger and counterion competition is characterized by an independently measurable empirical ions exchange constant \((K^{\text{iex}})^{84}\).

Scheme 5.11 represents the quantitative treatment of the rate data for the reaction of paraoxon with hydroxamate ions in \( \text{CTA}^+ \) cationic micelles. We assume that the presence of cationic surfactant does not change the pK\(_a\) of the hydroxamic acids in water.
5.7 EFFECT OF MICROEMULSION ON HYDROLYSIS OF PHOSPHATE ESTERS

Microemulsion has been used as chemical reactors because of their special interfacial properties allowing an intimate contact, at monoscale level, of hydrophilic and hydrophilic domains. The dynamic character of these nanoreactors is one of the most important features, which has to be taken into account for a comprehensive understanding of chemical reaction carried out in this media.

Most of the target organophosphorus compounds (nerve agents, insecticides and their simulants) are sparingly soluble in water. Thus the utility of micellar surfactant systems is partially a consequence of their capacity to solublize these organic materials in aqueous media. However, under micellar conditions, one can not solublize large enough quantities of substrate to achieve practical decontamination.

A microemulsion (ME) is a thermodynamically stable and optically clear dispersion of hydrocarbon droplets suspended in water (oil in water or O/W) or water droplet suspended in hydrocarbon (water in oil W/O). The droplets are small (60-600Å) and form spontaneously when specific proportions of water, oil (e.g. a hydrocarbon) surfactant and a cosurfactant (often a short chain alcohol) are mixed. Surfactant and a cosurfactant form an interface between the droplet and the continuous phase, which is somewhat comparable to the stern layer of surfactant micelles.

The hydrolysis of carboxylate and phosphate esters in several catalytic systems has been reviewed.\textsuperscript{85-86} The contribution of Menger et al.\textsuperscript{85} deserves special mention in this context. They documented the dual catalytic efficiency of the microemulsion system containing hypochlorite ion for the
hydrolytic decomposition of Sarin and VX along with the catalytic oxidation of sulfur mustard.

Bhattacharya and co-worker\textsuperscript{87} investigated hydrolysis reactions of $p$-nitrophenyl alkanoates at pH 8.7 of varying chain lengths mediated by (dialkylamino) pyridine-functionalized amphiphiles in three different (an oil-in water, a water-in oil and a bicontinuous oil-water) microemulsion media. Durst \textit{et al.}\textsuperscript{88} reported catalytic hydrolysis of phosphate esters using iodosobenzoate (IBA) in microemulsion composed of hexadecane in water stabilized cetyltrimethylammonium bromide and $n$-butanol over a range of water mass fraction.

Some microemulsion recipes has been used in this investigation for effective decontamination media for detoxification of organophosphorus toxicants. Microemulsion was prepared according to method \textsuperscript{87} by mixing $n$-hexane, surfactant (CTAB, CPC, and CTAOH,) and $n$-butanol (co-surfactant) by titrating the slurry with water, agitating mildly to give a clear solution. The pH of microemulsion solution was determined by directly immersing a glass electrode into the microemulsion solutions. The pH of the microemulsion was the same as that of the aqueous solutions, which indicate that the pH of the water pool is close to that of initial buffer system. Table 5.6 records a few of the microemulsion recipes that were prepared. All the microemulsions (1-3) contained large weight percentage of water and therefore, regarded as O/W microemulsions in which microdroplets of $n$-hexane (oil) are dispersed in aqueous buffer.

Table 5.7 summarises hydrolytic reaction in microemulsion medium with nucleophile 1b. The O/W microemulsion (ME-1) offers several practical advantages
### TABLE 5.6
Composition by weight percent of cationic microemulsions

<table>
<thead>
<tr>
<th>ME</th>
<th>Surfactant</th>
<th>Co-Surfactant</th>
<th>Oil</th>
<th>Buffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.05</td>
<td>5.05</td>
<td>2.0</td>
<td>87.9</td>
</tr>
<tr>
<td>2</td>
<td>9.4</td>
<td>9.4</td>
<td>45.85</td>
<td>35.35</td>
</tr>
<tr>
<td>3</td>
<td>5.0</td>
<td>5.0</td>
<td>87.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

### TABLE 5.7
Kinetic rate data for the nucleophilic reaction of PNPDP with the nucleophile 1b in the presence of cationic microemulsions at 27°C.

$[\text{PNPDP}] = 1.0 \times 10^{-4} \text{M}, \ [\text{HA}] = 1.0 \times 10^{-3} \text{M}$  
$\text{pH} = 9$

<table>
<thead>
<tr>
<th>Surfactant</th>
<th>$k_{\text{obs}}.10^{3}/s^{-1}$</th>
<th>$k_{\text{rel}}$</th>
<th>$k_{\text{obs}}.10^{3}/s^{-1}$</th>
<th>$k_{\text{rel}}$</th>
<th>$k_{\text{obs}}.10^{3}/s^{-1}$</th>
<th>$k_{\text{rel}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTAOH</td>
<td>13.3</td>
<td>221.6</td>
<td>8.3</td>
<td>138.3</td>
<td>4.7</td>
<td>78.3</td>
</tr>
<tr>
<td>CPB</td>
<td>8.1</td>
<td>135.0</td>
<td>5.6</td>
<td>93.3</td>
<td>3.1</td>
<td>51.6</td>
</tr>
<tr>
<td>C16DMEA</td>
<td>9.2</td>
<td>153.3</td>
<td>6.2</td>
<td>103.3</td>
<td>3.2</td>
<td>53.3</td>
</tr>
</tbody>
</table>

$k_{\text{rel}} = k_{\text{obs}}(\text{ME})/ k_{\text{obs}}(\text{aqueous})$

$k_{\text{obs}}(\text{aqueous}) = 0.06 \times 10^{3}/s^{-1}$
This solubilizes hydrophobic substrate molecules into a water-rich medium. The oil droplets provide very large surface area to the aqueous phase where reaction between added substrate molecules and the catalytic sites of PCBHA nucleophile, is facilitated. Examination of the results of the present studies in ME media shows that nucleophile 1b -CTAOH coaggregate solutions are truly catalytic recipes for esterolysis with significant rate enhancement over background.

5.8 Conclusion

The hydrolysis of organophosphorus based chemical warfare agents are one of the challenging field of ongoing research. The results indicate that N-methyl substituted hydroxamic acids are potent nucleophile towards detoxification reaction. This study specially focused on detoxification of simulants of chemical warfare agents by nucleophilic added hydrolysis. This study concentrated of nucleophile 1b due to its easy preparation better stability, pKₐ value just near to aqueous medium. The kinetic data indicate that it shows better nucleophilic activities with micellar and microemulsiom medium in the hydrolysis reaction. Some thiohydroxamic acids were used for detoxification reaction. Thiohydroxamic acids were not show better catalytic activity as compare to their oxygenated analogue. This study is worthy of kinetics of detoxification of organophosphorus compounds, a comparative catalytic activities of hydroxamic acids, role of different surfactant on the basis of their head group and effect of electrophilic center on kinetics.
5.9 REFERENCES