The Addition of the Cyanide Ion to the *N*-Methyl-3-carbamoylpyridinium Ion in Reversed Micelles

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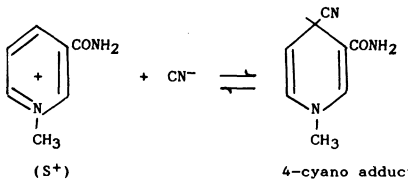
The addition reaction of the cyanide ion to the *N*-methyl-3-carbamoylpyridinium ion was carried out in reversed micelle systems, and the functions of the electric charge of surfactants and of the entrapped water in the micelle were studied by measuring the rate and equilibrium constants. Reversed micelles formed by hexadecyltrimethylammonium bromide (HTAB), a cationic surfactant, not only enhanced the reaction, but also stabilized the product, 4-cyano-1,4-dihydro-*N*-methylnicotinamide (P), which is thermodynamically unstable in aqueous media. This was in contrast to sodium 1,2-bis(2-ethylhexyloxycarbonyl)ethanesulfonate (AOT), an anionic surfactant, reversed micelles. In both reversed micelle systems the reaction could be controlled by varying the water content, although neither is favorable for the reaction at a higher water content. From the distribution measurements and spectroscopic studies, it can be suggested that the reaction occurred preferably in the micellar phase, especially in the water pool. Three kinds of effects were proposed for interpreting the enhancement as compared to the reaction in aqueous systems. The first was the local concentration of reaction species in the water pools, and the second was the lower micropolarity of water pools. The third concerned the electric nature of the surfactant and reactant ions.

The active site of enzyme provides a specific microenvironment, one in which the nature of the medium, such as the pH, the polarity and the viscosity, is quite different from that of bulk water, resulting in the enhancement of the reactivity of the substrates. Thus, the reaction pathway, the rate, and the equilibrium of an enzyme-substrate complex reaction can be controlled by adjusting the physicochemical conditions of the microenvironment.[1] From the physicochemical point of view, the issue of the microenvironment is very interesting to study.

Some reversed micelles[2–5] afford to substrates a microenvironment similar to that afforded by enzymes, because the water in the interior cores of reversed micelles is considered to be less polar and more viscous than in the bulk phase, so that the water pools in the reversed micelles might subrogate the active sites of enzymes for substrates. It has also been proposed, for the reversed micelles formed out of some kinds of functionalyzed surfactants, that the interfaces between the water pools and the hydrophilic groups of the surfactants inside of the micelles are activated and that the inner surfaces of the micelles can mimic the active sites of enzymes.[6] It must be noted here that, contrary to the cases of aqueous micelle systems, in reversed micelle systems the reactivity of substrates can easily be controlled by changing the content of water in the systems and by adjusting the physicochemical properties of the water in the pools.

Baumrucker et al.[7] and Bunton et al.[8] found that the rate and equilibrium constants for the addition of cyanide ion to a series of *N*-alkyl-3-carbamoylpyridinium ions remarkably increased in aqueous micelle systems with normal alkyltrimethylammonium salts and 3-(dodecyldimethylammonio)-1-propanesulfonate as surfactants.

In this work, we wish to report on an addition reaction similar to the one mentioned above, but carried out in some reversed micelle systems. As a reacting cation, the water-soluble *N*-methyl-3-carbamoylpyridinium (S^+) ion was used. The stoichiometric relation is shown by Eq. 1. We examined the functions of the electric charge of the surfactants and the entrapped water in the micelles by measuring the rate and equilibrium constants of the reactions as well as the stability of the product, the i.e., 4-cyano-1,4-dihydro-*N*-methylnicotinamide or simply, the 4-cyano adduct (P).



(1)

Experimental

Materials. The *N*-methyl-3-carbamoylpyridinium chloride (S) was obtained from Wako Chemicals and was twice recrystallized from methanol (MeOH). The water used was distilled by the use of an all-glass distillation apparatus. The sodium cyanide was of reagent grade. The chloroform and 2,2,4-trimethylpentane (isooctane) were dried and stored over a type 4A Molecular Sieve which had been activated by heating at 200 °C under reduced pressure for several hours and, then cooled in vacuo over silica gel; they were used as soon as possible.

The hexadecyltrimethylammonium bromide (HTAB), the cationic surfactant, was commercially obtained and was twice recrystallized from acetone–MeOH. The sodium 1,2-bis(2-ethylhexylcarbonyl)ethane sulfonate (AOT), the anionic surfactant, was obtained from Nikko Chemicals; its purity was more than 99.9%. Both the surfactants were dried at 60 °C in vacuo over P_2O_5 and used immediately.

Preparation of Solutions I and II. Each reversed micelle

system was formed by adding a ternary mixture of an organic solvent, a surfactant, and S (Solution I) to a quaternary mixture of an organic solvent, water, a surfactant, and NaCN (Solution II). The HTAB was dissolved in chloroform/isooctane mixture (3:2 volume ratio). The AOT was dissolved in isooctane. Each solution will hereafter be denoted as a mother solution.

Then, to prepare Solution I, a relatively small amount of the S/MeOH solution was dissolved in the mother solution. The concentration of HTAB or AOT in the mother solution before dissolving the S/MeOH solution was always kept at 0.2 M (1 M=1 mol dm^{-3}). The concentration of S in Solution I was in the range from 2 to 4×10^{-4} M, corresponding to the amount and concentration of the MeOH solution of S. The content of MeOH was within a 0.5% volume ratio. Special care was taken to exclude moisture during the above procedures. To prepare Solution II, various amounts of NaCN aqueous solutions were added, solubilized in the mother solution, and kept at 1×10^{-2} M. However, the molar ratio of water to HTAB or AOT in this solution was variable.

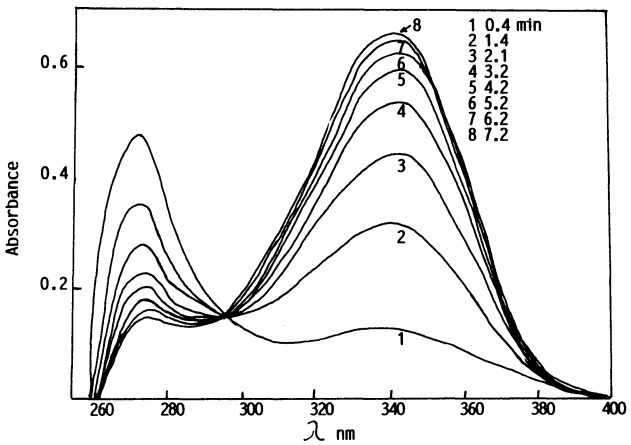


Fig. 1. Ultraviolet spectra of HTAB reversed micelle solution containing *N*-methyl-3-carbamoylpyridinium chloride and sodium cyanide at various reaction time. [HTAB]=0.2 M, R=2.7, $[NaCN]_{aq}$= 0.06 M.

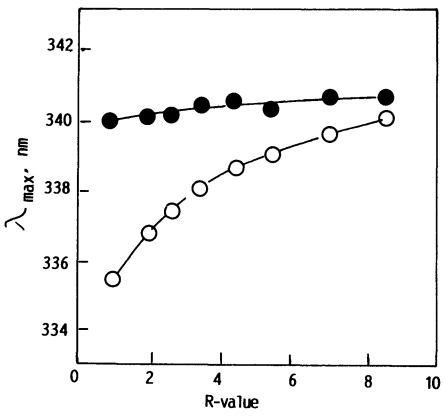


Fig. 2. The wavelength of maximum absorption, λ_{max}, of 4-cyano-1,4-dihydro-*N*-methylnicotinamide, P, in reversed micelles. ●, 0.2 M HTAB; ○, 0.2 M AOT.

By mixing equal amounts of Solutions I and II, we prepared the system for Reaction 1. In Solution II and the resultant reaction system, water was estimated to induce the formation and/or the growth of reversed micelles, which might not have appeared or developed yet, in the mother solution and also in Solution I. Solutions I and II as well as their mixed systems were found to be transparent and colorless.

Kinetics. Kinetic measurements were carried out spectrophotometrically with the aid of a Shimazu UV-265 spectrophotometer thermoregulated at 25±0.1 °C. The addition reaction (Reaction 1) was followed by measuring the OD (optical density) at 340 nm, where the absorption maximum of the reaction product, P, was found nearby, as is shown in Fig. 1. Although the wavelength of maximum absorption, λ_{max}, of P depended upon the composition of the reaction system, its variation was rather slight (Fig. 2) and, was considered to be tolerable in fixing the measured wave length of absorption at 340 nm for the kinetic study.

The reaction was initiated by the addition of 1.5 ml of a substrate solution (Solution I) to 1.5 ml of a cyanide solution (Solution II) in a moisture-proof cell in the spectrophotometer.

Distribution Measurement. The distribution of S between chloroform and aqueous phase was examined as follows, although the organic phase was different from that in the reversed micelle systems. Aqueous solutions of S with concentrations of 3×10^{-4}, 3×10^{-3}, and 3×10^{-2} M were prepared. Equal volumes of one of the aqueous solutions and chloroform were mixed in a vial, which was then sealed with a screw cap and vigorously shaken for about 12 hours at 25 °C. After the vial has been allowed to stand until the two liquid phases had completely separated, the solute concentration in the aqueous phase was determined spectrophotometrically.

Results and Discussion

Rate and Equilibrium Constants of the Addition Reaction in Reversed Micelles. In the reaction mixture, the initial concentrations S^+ and cyanide ions, $[S^+]^i$ and $[CN^-]^i$, were 1—2×10^{-4} M and 5×10^{-3} M respectively. Within 30 min, all the reactions were regarded as having reached their final states, as may be seen in Figs. 1 and 3a. In aqueous systems, a remarkable spectral shift from 340 nm to 320 nm, which suggested the formation of the 2- or 6-cyano adduct, were observed.[9] However, in reversed micelle systems, no spectral change was observed, even after 2 hours, suggesting that less rearrangement of the 4-cyano adduct to the 6- or 2-cyano adduct occurs. Since $[CN^-]^i$ was sufficiently higher than $[S^+]^i$, Reaction 1 was expected to proceed with a pseudo first order in the earlier stage of the reaction. To examine this expectation, we traced the reaction in the plot of log (OD^f_{340}—OD_{340}) vs. time, where OD_{340} is the measured optical density at 340 nm and where OD^f_{340} denotes the value of OD_{340}, when the reaction was estimated to be at its final state. As may be seen in Fig. 3b, all the plots were linear with a correlation

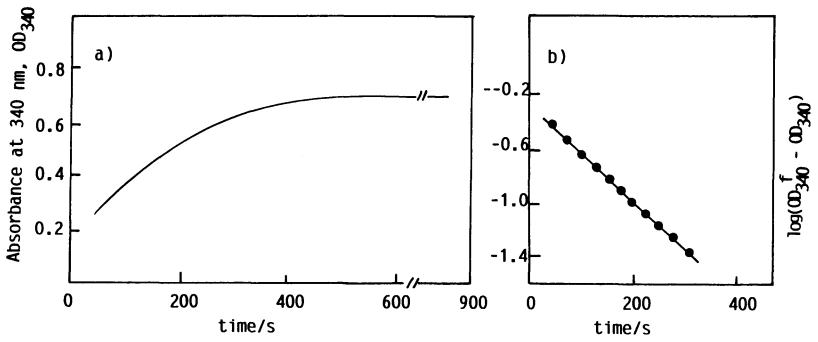


Fig. 3. Determination of first-order rate constants for the addition reaction. a) Absorption change at 340 nm at time; b) Plots of log (OD^{f}_{340}—OD_{340}) against time.

coefficient of 0.998 or over. Therefore, Reaction 1 in this work might be analyzed, at least mathematically, according to a pseudo first order rate equation with respect to the S^+ ion. The rate constant, k_{ob}, can be given as the negative slope of the above-mentioned plot.

The reversibility of Reaction 1 was examined as follows. When the reaction was considered to be practically completed after 30 min, we added a small amount of 1 M acetic acid and found that the absorbance at 265 nm increased according to the decrease in $[CN^-]$. Also, we found that the absorbance at 340 nm increased when we added NaCN. From the above results, we could conclude that the reaction is reversible. Therefore, the effect of the backward reaction on k_{ob} was considered. According to Lindquist and Cordes,[9] who worked on the reversible addition reaction of the CN^- ion to the 4-position of the *N*-methyl-3-carbamoylpyridinium ion in the aqueous micelle systems, we have:

$$k_2 = k_{ob}/([CN^-] + K^{-1}), \quad (2)$$

where K is the equilibrium constant of Reaction 1 and can be given by Eq. 3 in terms of the equilibrium concentrations of the P, CN^-, and S^+ ions, which are written as $[P]^{eq}$, $[CN^-]^{eq}$, and $[S^+]^{eq}$ respectively.

$$K = [P]^{eq}/([CN^-]^{eq}\cdot[S^+]^{eq}) \quad (3)$$

Here, the quantities, k_2, k_{ob}, and K must be the apparent ones, because these values were determined on the basis of the concentrations of the reacting species, which were evaluated over the total volume of the system, while the systems in this work are heterogeneous from the microscopical point of view and so the chemical species would be unevenly distributed or localized.

When $[CN^-]^i$ is sufficiently higher than $[S^+]^i$, the value of $[CN^-]^{eq}$ in Eq. 3 can be approximately substituted by a constant, $[CN^-]^i$. The ratio of $[P]^{eq}$ to $[S^-]^{eq}$ is approximately equal to the ratio, $OD^{f}_{340}/(\varepsilon_{340}\cdot[S^+]^i - OD^{f}_{340})$, at the reaction equlibrium. The symbol ε_{340} represents the molar extinction coefficient of P at 340 nm. For the value of OD_{340} at the reaction equilibrium, we adopted the value of OD^{f}_{340}. The value of ε_{340}, which is considered to be constant through each measurement, was determined following the usual procedure from the relationship between the absorbance of P at 340 nm and that of the S^+ ion at 265 nm in the course of the reaction, where the isosbestic point was always observed. This also indicates that Reaction 1 proceeds stoichiometrically in reversed micelles, while the succeeding reaction scarcely proceeds at all, reflecting the formation of the 2- or 6-cyano adduct.

Equation 3 reduced to Eq. 4 for the experimental determination of K:

$$K = OD_{340}^{f}/(\varepsilon_{340}\cdot[S^+]^i - OD_{340}^{f})[CN^-]^i \quad (4)$$

Then, we estimated the value of k_2 for each course of reaction, according to Eq. 2. As k_{ob} and $[CN^-]$, we adopted, respectively, the value of k_{ob} in the earlier stage of reaction and the value of $[CN^-]^i$.

We estimated the values of k_2 and K in the reversed micelle systems under the initial conditions that the concentrations of the surfactant and the CN^- ion were 0.2 M and 5×10^{-3} M respectively. The ratio of the water to the surfactant, R, was varied from less than unity to nearly ten. We show the plots of k_2 and K vs. R in Figs. 4 and 5. It was found that the formation of P is greatly favored in the reversed micelles, especially with smaller R values, compared with the reaction in pure water, where k_2 and K are estimated to be 0.016 $M^{-1}\,s^{-1}$ and 0.238 M^{-1} respectively.[9] In the reversed micelle systems with HTAB or AOT as the surfactant, the value of k_2 reached a thousand times or a hundred times, respectively, as much as the value in pure water, while a several or ten thousand-fold increase in K was estimated at the maximum. However, the values of k_2 and K both decreased with

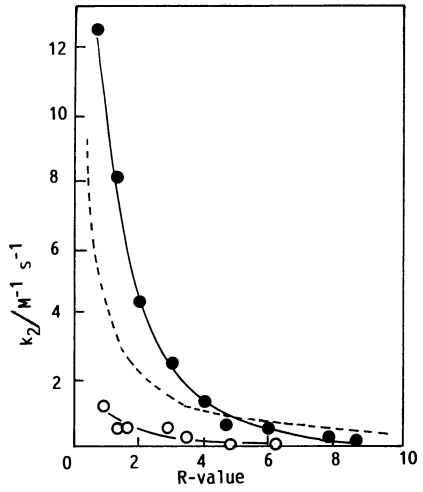


Fig. 4. Second-order rate constants, k_2, for the addition reaction in reversed micelles as a function of R-value at 25 °C. ●, 0.2 M HTAB; ○, 0.2 M AOT; broken line, a theoretical plot which took account of the localization effect of reactants.

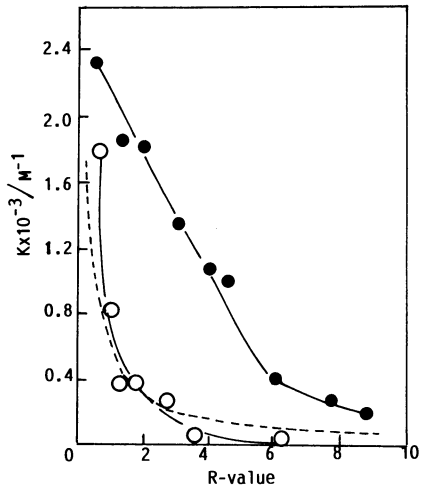


Fig. 5. Equilibrium constants, K, for the addition reaction in reversed micelles as a function of R-value at 25 °C. ●, 0.2 M HTAB; ○, 0.2 M AOT; broken line, a theoretical plot which took account of the localization effect of reactants.

the increase in R, as is seen in Figs. 4 and 5. The inconstancy of k_2 and K may be interpreted as reflecting the heterogeneity of the reversed micelle systems and the nature of the microenvironment surrounding each chemical species concerned.

Location of the Addition Reaction in the Reversed Micelle Systems. From the thermodynamic or macroscopic point of view, the presence of micelle yields no new phase. However, in order to elucidate the nature of any reaction concerned with the micelle, we should discuss the reaction from the microscopic point of view, which divides the reaction system into a number of subphases. For Reaction 1, therefore, we divided each reversed micelle system into two subphases, i.e.,

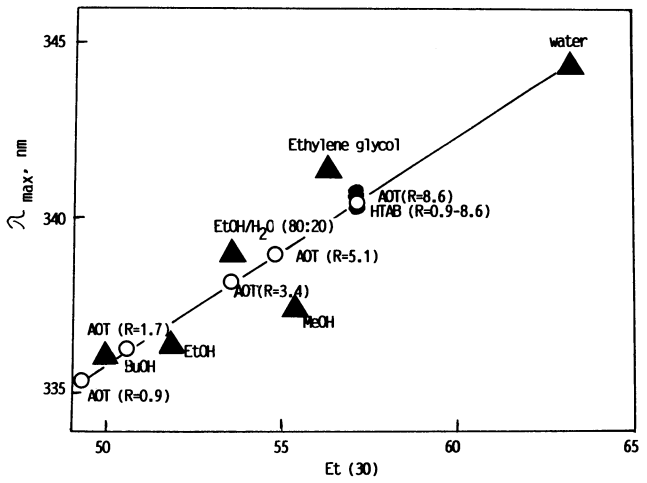


Fig. 6. Absorption maxima of 4-cyano-1,4-dihydro-*N*-methylnicotinamide, P, in several solvents as a function of the Dimroth's solvent-polarity parameter, Et(30). ▲, various solvents; ●, 0.2 M HTAB; ○, 0.2 M AOT.

the bulk phase and a pseudophase in colloidal dispersion. The former phase consists of an organic medium and various solutes, while the latter one, hereafter called the "micellar phase", consists mainly of a surfactant, water, and solutes. A small amount of a surfactant is dissolved in the bulk phase, with its concentration at cmc. The micellar phase will be subdivided into the outer shell, which mainly consists of the surfactant, and the water pool. In the detailed discussion, the water will be distinguished between that bound to the ionic heads of the surfactants at the inner surface of the micelle and the other water which constitutes the water pool.[10] Here, we will call the former the "interface zone", and the latter, the "center zone".

In the distribution measurements of S, the concentration ratio of the S^+ ion in chloroform to water was found to be less than 0.05. The ratio for the CN^- ion may be expected to be much less than that for the S^+ ion, in view of the more polar structure of the CN^- ion than the S^+ ion. Therefore, the greater parts of the reactants, the S^+ and CN^- ions, were estimated to be present preferably in the micellar phase, especially in the water pool.

To estimate the location of P in reversed micelle systems, we applied to these systems the relation between the value of λ_{max} and the polarity of the surrounding medium adjacent to P. First, Reaction 1 was carried out in various solvents, and the value of the λ_{max} of P was measured. The value in each solvent was then plotted against the Dimroth's solvent polarity parameter, Et(30), as is shown by the solid triangles in Fig. 6.[11] From the values of the λ_{max} of P in various HTAB or AOT reversed micelle systems, as may be seen in Fig. 2, we could read the corresponding values of Et(30) of the reversed micelle systems on the

calibration line in Fig. 6.

Since the reversed micelle system is microscopically heterogeneous, the Et(30) value of a reversed micelle system is considered to be the average of the Et(30) values for the microenvironments. Therefore, the estimated value of Et(30) from the measurement of λ_{max} would approximately disclose the average location of P.

In the HTAB reversed micelle systems with various R values, it was found that the λ_{max} of P or Et(30) remains nearly constant halfway between water and MeOH (Figs. 2 and 6). In other words, the environment around P is like the MeOH–water mixture in terms of the polarity. Concerning the polarity of the MeOH–water mixture, we show the plots of the λ_{max} of P in the mixture against its composition in Fig. 7. According to Sunamoto et al.,[5b] the micropolarity of the water pool in HTAB reversed micelles with smaller values of R can be estimated to be near to that of MeOH from the fluorescence maximum of *O*-methylpyranine. Therefore, it seems that it can be roughly concluded that the P in the HTAB reversed micelle systems is in the water pool. The question is where P exists inside the water pool with respect to its microscopic location. If P is dissolved homogeneously throughout in the water pool, the value of the λ_{max} of P in the HTAB reversed micelle systems would vary between those in MeOH and water with the variation in R, since the nature of the water pool must approach that of the bulk water with the increase in R, while approaching that of MeOH with the decrease in R. The results shown in Figs. 2 and 6 deviate the homogeneous distribution of P in the water pool. Also, it can be deduced, from an argument similar to that above, that P is not concentrated in the center zone of the water pool. The true situation is possibly some kind of localized concentration of P near the interface zone of the water pool, and the interface zone is not much affected by the variation in R. The penetration of P into the palisade layer of the surfactant might be a result of the electrically neutral and hydrophobic nature of P. The nearly constant value of λ_{max} has previously been explained. The fact that the value of λ_{max} of P in the HTAB reversed micelles is not the same as that in MeOH, but lies halfway between those in MeOH and water, suggests that the value of λ_{max} depends not only on the polarity of the medium, but also on the specific interaction between solute and medium. Thus, the result on *O*-methylpyranine seems to differ somewhat from the result on P in this work.

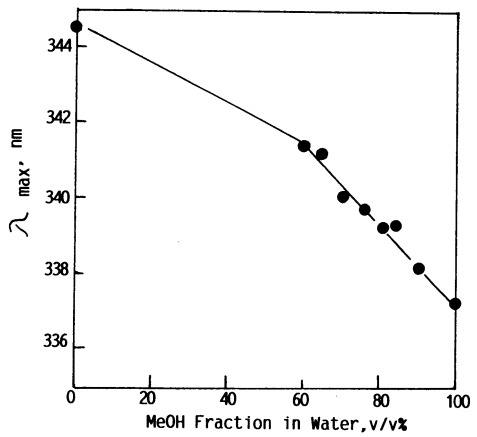


Fig. 7. The wavelength of maximum absorption, λ_{max}, of 4-cyano-1,4-dihydro-*N*-methylnicotinamide, P, in mixed solvents of MeOH–H_2O.

In the AOT reversed micelle systems, the dependency of λ_{max} or Et(30) on R was remarkable in comparison with the HTAB reversed micelle systems. Also, it was found that the λ_{max} in the AOT systems is always shorter than in the HTAB systems and that the microenvironment of P in the AOT systems is lower in polarity than that in the HTAB systems. Sunamoto et al.[5b] estimated that the polarity of water pools in the AOT reversed micelles is intermediate between those of MeOH and water, while that in the HTAB reversed systems is nearly that of MeOH, as has already been mentioned. In other words, the polarity of the water pools themselves in the AOT reversed micelles is higher than that in the HTAB reversed micelles; this is contrary to the case of the microenvironment of P. From the above facts, it can be deduced that the greater of the P in the AOT reversed systems is much more concentrated in the interface zone of the water pool, and is surrounded by a more nonpolar or hydrophobic environment, than in the HTAB reversed systems. That is, the P in an AOT micelle might exist mainly in or near the palisade layer of the surfactant, with its polar head turned toward the center of the water pool. The remarkable variation in the λ_{max} of P with the variation of R suggests a gradual change in the surfactant shell of the AOT micelle, which forms entirely, or at least in large part, of the microenvironment of P. It seems most likely that an increase or decrease in R is accompanied by an increase or decrease of the micellar size, which causes the molecular packing of the surfactant shell to tighten or loosen. In the micelle of a smaller size, which is supposed to have a more loosely packed shell, P must penetrate more deeply inside the surfactant shell or the palisade layer of the micelle.

From the location of the reaction species, the main fields of the forward and backward processes in Reaction 1 were identified approximately as follows. The forward reaction, in which S^+ and CN^- ions are the principal species, proceeds in the interior of the water pool, while the backward one, with the P proceeds in the outer sphere of the water pool. The discrepancy in site between the two opposing reactions might require some modification of Eqs. 2 and 3, which need the same sites for both reactions. Therefore, the following discussion of the values of k_2 and K,

which are based on Eqs. 2 and 3, might be regarded as rather qualitative and might have to be modified by taking into account, e.g., the transport or the diffusion process of the reaction species between the different sites.

Factors Responsible for the Enhancement of the Addition Reaction in Reversed Micelle Systems. Three kinds of effects may be proposed for interpreting the enhancement of the addition reaction in the reversed micelle systems as compared to that in the aqueous systems. The first is the local concentration of reaction species in the water pool rather than in the whole volume of each system. When the reaction is a bimolecular process, as it was in this work, the localization of the reaction species results in the enhancement of the reaction rate and equilibrium (k_2 and K) by the factor of the effective concentration to nominal, e.g., by a multiplication factor of about 300 and 40 times for R at 1 and 10 respectively.

The actual enhancement deviated more or less from the expectation; we took account of the concentration effect and adopted the values obtained by Lindquist and Cordes[9] for the reaction in pure water as the basis of comparison. The expected values are shown in Figs. 4 and 5. The deviation differed in degree between the results in the HTAB and AOT systems. Since S^+ and CN^- are presumed to be dissolved in the water pool, the difference in the reaction constants between the HTAB and AOT systems can be partly attributed to the difference in nature between the water pools of the two systems. As has already been established,[5b] the micropolarity of the water pools at a small water content is near to that of MeOH for the HTAB reversed micelles and intermediate between those of MeOH and water for the AOT reversed micelles. The lower micropolarity of the water pools seems to contribute to the enhancement of the reaction in the HTAB systems. Although Lamborg et al.[16] have reported that the addition of a 1-methylpyridinium compound with the cyanide ion was strongly dependent upon the dielectric constant of the solvent, it has not yet been studied quantitatively. Therefore, in order to examine the relation between the polarity of a medium and the reactivity, we measured the values of k_2 and K of the addition reaction in the mixed solvents of MeOH and water, as is shown in Figs. 8 and 9. As the fraction of MeOH in the solvent, i.e., the polarity of the medium, approaches that of pure MeOH, the values of k_2 and K were found to increase with the acceleration. Thus, the significantly high values of k_2 and K in the HTAB systems at lower R were elucidated, at least quantitatively. For the AOT systems, the effect of the micropolarity of the water pools on the addition reaction seems to be negligible, judging from the results in Figs. 8 and 9, which shar the polarity halfway between MeOH and water.

The third effect is connected with the electric nature

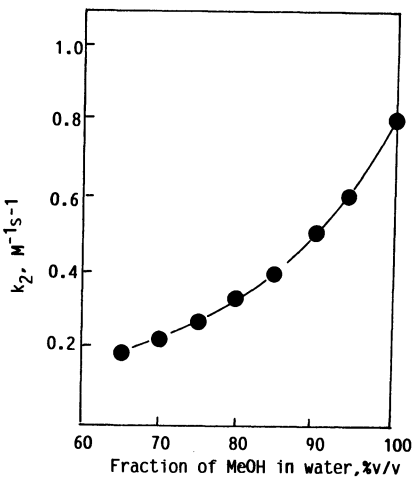


Fig. 8. Second-order rate constants, k_2, for the addition reaction in MeOH–H_2O mixed solvents at 25 °C.

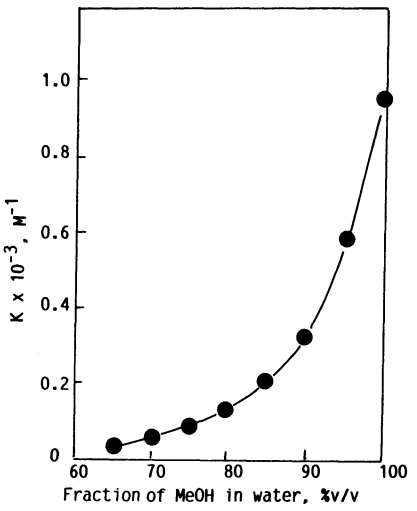


Fig. 9. Equilibrium constants, K, for the addition reaction in MeOH–H_2O mixed solvents at 25 °C.

of the surfactant and the reactant ions. No doubt, the electrostatic attraction and/or repulsion between various ions plays a principal role in determining the spatial distribution of the reactant ions in the water pools and will affect the addition reaction. It can be supposed in each HTAB reversed micelle that the S^+ and CN^- ions are concentrated in the center zone and near the interface zone of the water pool due to the electrostatic repulsion and to the attraction with the cationic head of the surfactant respectively. The above situation might serve to attenuate the first and second kinds of effects, i.e., localized concentration of the reactants and the lowering of the polarity of microenvironment, on the reaction in the reversed micelle systems with relatively large R values. However, with a decrease in R, the concentration of CN^- ions will soon become saturated in the interface zone and increase throughout the region of the water pool, since [CN^-] in this work

is set relatively high (5×10^{-3} M). Then, the above-mentioned attenuating effect will disappear. With a very small R, the repulsion between the S^+ ion and the cationic head might promote the forward reaction, that is, a charge neutralization, and result in a significant increase in k_2 and K.

Similarly to the case of the HTAB systems, but with the inverse type of ionic distribution, it can be supposed in each AOT micelle that the CN^- and S^+ ions have a tendency to concentrate in the center zone and near the interface zone of the water pool respectively. At higher R values, the divided concentrations of both reactant ions would contribute to the values of k_2 and K in the AOT reversed micelle systems, much like those in the HTAB systems. At very small R values, the situation must be the same as between both kinds of reversed micelle systems; i.e., there is a significant increase in k_2 and K. However, in the intermediate region of R, there are some differences between the two reversed micelle systems in the distribution patterns of the ions in the water pools. In other words, the saturation of CN^- ions in the center zone of the water pool in the AOT systems may be expected to occur somewhat later than the saturation in the interface zones of the HTAB systems. The difference in porofile between the plots for the HTAB and AOT systems, as is seen in Figs. 4 and 5, is considered to be due to the differences in R for the saturation of CN^- ions between the respectively preferred zones.

The Stability of the 4-Cyano Adduct in Reversed Micelles. Lindquist and Cordes[9] reported that the peak near 345 nm slowly decreased in magnitude, while, at the same time, a new absorption peak appeared near 305 nm together with increased absorption near 265 nm, they suggested that the spectral shift might be a rearrangement of P to the 6- and 2-cyano adduct, as has already been described. Therefore, it was supposed that P is not stable thermodynamically in an aqueous medium.[9] It can be considered that the stability of P in MeOH is higher than in an aqueous medium, but such a spectral shift was observed in concentrated MeOH (95%) after 48 hours (Fig. 10). As the water fraction in the mixed solvents of MeOH–H_2O increased, a remarkable shift from 340 to 310 nm was observed. The 4-cyano adduct, P, formed in AOT reversed micelles was relatively stable, thus making it possible to estimate the equilibrium constant approximately, but a distinct spectral shift was observed after 2 hours (Fig. 10). It was supposed that AOT itself acts against the P as a base, resulting in the formation of nitrile.[14]

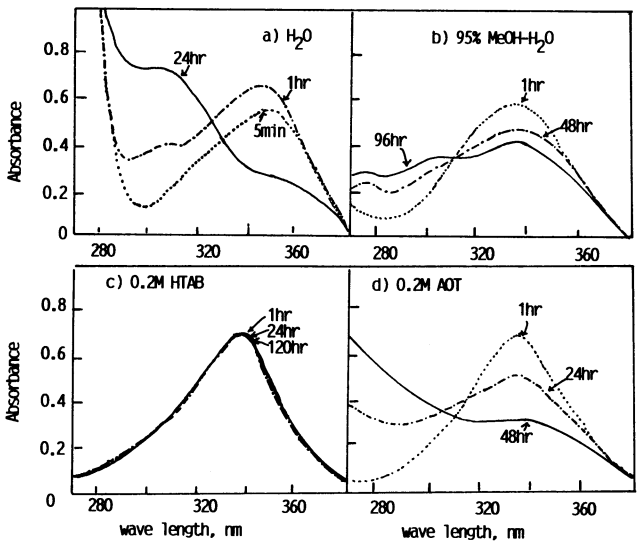


Fig. 10. Ultraviolet spectra for solutions containing initially *N*-methyl-3-carbamoylpyridinium chloride and sodium cyanide. a) H_2O; [S]=6.3×10^{-4} M, [NaCN]=5.0×10^{-1} M, b) 95%MeOH–H_2O, c) 0.2 M HTAB (R=1.0) and d) 0.2MAOT (R=1.0); [S]=1.5×10^{-4} M, [NaCN]=5.0×10^{-3} M.

On the other hand, such a spectral shift was not observed in HTAB reversed micelles even after they had stood 5 days. It can thus be concluded that the P in HTAB reversed micelles is especially stable. This shows that the microenvironment surrounding the P in HTAB reversed micelles contributes to the stability of the P, most likely because of the specific nature of the water pool.

In conclusion, it became evident that the reaction field provided by HTAB reversed micelles not only enhanced the addition reaction, but also stabilized the P, which is thermodynamically unstable in an aqueous medium. This is in contrast to the AOT reversed micelle system. These results might be related to the postulate that a cationic charge, such as the lysine residue of alcohol dehydrogenase located very close to the bound NADH may protect the NADH from hydration decay.[15] Therefore, it is not too much to say that the HTAB reversed micelle systems provide a field advantageous for synthesizing the dihydro compounds, for the dihydro-compounds produced by the addition of the cyanide ion to pyridinium salt or isoquinolinium salt are usually less stable and can not easily be isolated.[12,17]

Also, it should be noted that reversed micelle systems can control the addition reaction by varying the water content, although they may be unfavorable for reactions at higher water contents.

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