Micellar General Base-catalysed Hydrolysis of Diphenyl *p*-Nitrophenyl Phosphate

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Summary Micelles of the functional surfactant (II) derived from histidine catalyse the hydrolysis of diphenyl *p*-nitrophenyl phosphate; deuterium kinetic solvent isotope effects, $k(H_2O)/k(D_2O)$ *ca.* 2·5, suggest that (II) acts as a general base rather than as a nucleophilic catalyst.

THERE are a number of examples of catalysis by micelles or comicelles of nucleophilic surfactants, of reactions of carboxylic esters or related compounds in which the nucleophile, usually an amino-group, attacks the acyl group of the ester,[1,2] and nucleophilic attack has been observed upon the phosphoryl group of phosphate esters by micellized choline derivatives.[3] We report a general base-catalysed hydrolysis of diphenyl *p*-nitrophenyl phosphate (I) in the presence of the surfactant (II) derived from L-histidine. The surfactant (II) is an effective enantioselective micellar catalyst for the deacylation of optically active *p*-nitrophenyl esters.[2]

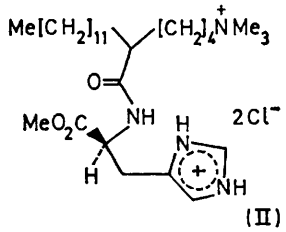
TABLE 1

Deuterium isotope effect and effect of Brij[a]

10^4 [(II)]/M	[Brij]/M	$10^5 k_\psi/s^{-1}$
17·8		112
17·8		44·3[b]
19·9		113
19·9		44·6[b]
17·8		89·2[c]
17·8		32·7[b,c]
19·9		92·0[c]
19·9		31·5[c,d]
3·0	0·01	2·2[d]
3·0	0·01	2·2[e]
6·0	0·01	4·2[e]

[a] Polyoxyethylene-20-cetyl ether; reactions were at pH (pD) 8·5 unless specified. [b] In D_2O. [c] pH 8·0. [d] 3×10^{-4} M (I). [e] 6×10^{-4} M (I).

The relation between the first-order rate constant, k_ψ, and surfactant concentration is typical of micellar catalysis (Figure); with a rate enhancement at pH 8 of 95-fold using $1·4 \times 10^{-5}$ M-(I) at 25·0°. The slight dependency of k_ψ on pH is probably due to a minor incursion of OH^- attack by micelles of (II), *cf.*, ref. 4. This conclusion is supported by



(II)

the small effect of relatively high concentration of fluoride ion; the rate is increased *ca.* four-fold by 0·01 M-fluoride ion in 1·37 mM-(II) at pH 8·0. [Fluoride and hydroxide ion have similar reactivities toward (I) in the presence of inert cationic micelles.[4]]

TABLE 2

Values of pK_a

10^4 [(II)]/M	pK_a
1·0	7·45
2·0	7·38
5·0	6·70
8·0	6·60

If reaction is carried out using a low concentration of (II) comicellized with the nonionic surfactant Brij, good first-order kinetics are observed from the time of mixing, and the reaction is first order with respect to (II) (Table 1), showing that there is no build up of a reaction intermediate in high concentration, but phosphoryl imidazole could be an intermediate in low concentration; *cf.*, ester hydrolyses catalysed by functional micelles.[1,2] This possibility is excluded, however, by the value of the kinetic solvent deuterium isotope effect, $k(H_2O)/k(D_2O) = 2·5$—2·8 (Table 1) which is

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too high for a reaction in which imidazole acts as a nucleophile, but is consistent with its activating a water molecule.[5]

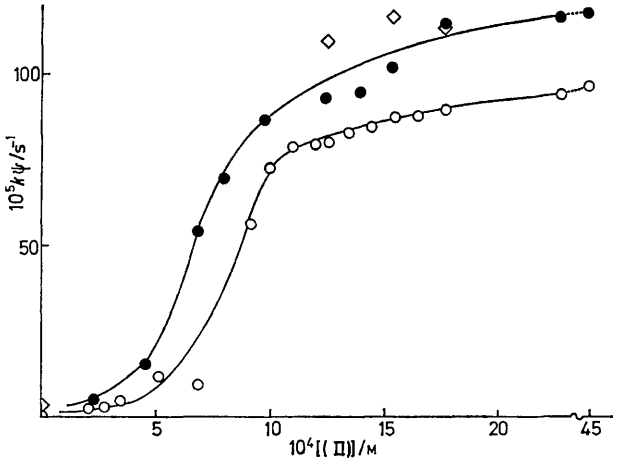
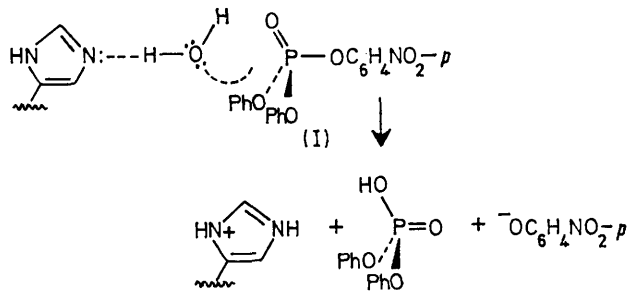


FIGURE. Relation between k_ψ and [(II)] at 25·0° in 0·015 M borate buffer. ○ pH 8·0; ● pH 8·5; ◇ pH 9·17.

The imidazole group was unprotonated in all our experiments. The apparent values of the pK_a were determined spectrophotometrically above and below the critical micelle concentration (*ca.* 2×10^{-4} M). As expected pK_a is decreased by micellization (Table 2). The mechanism observed here contrasts with the hydroxide-ion catalysis of phosphate ester hydrolysis promoted by conventional micelles.[3b] Furthermore, involvement of histidine in general base-catalysed formation of a carbon–oxygen bond may provide a model for the mode of production of phosphatyl-serine intermediates in *E coli* alkaline phosphatase[6]-catalysed hydrolyses.



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