the presence of a small amount of ester–enzyme complex in which the spin label is more immobilized than in the free ester but less immobilized than in the acyl enzyme.

The K_s values for the nonspecific substrates (+)- and (−)-I at pH 7.0 are lower than the K_s values for many specific substrates of chymotrypsin.[7] The low K_s values may reflect a large amount of "wrong-way"[8] or nonproductive binding of the substrates to the enzyme. In the chymotrypsin-catalyzed hydrolysis of ester I, as in many chymotrypsin-catalyzed reactions,[9] greater enantiomeric specificity is found in the catalytic steps of the reaction than in the binding step. However, the stereospecificity observed for the catalytic steps in the case of this nonspecific ester substrate is much lower than that found in the reactions of specific substrates with the enzyme.[10-12] Indeed, our results lead to the interesting conclusion that *the enantiomeric specificity in the chymotrypsin-catalyzed reaction of the nonspecific ester substrate I is only slightly greater than that found in the hydrolysis of the closely related ester III catalyzed by the model enzyme, cyclohexaamylose.*[13]

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(7) B. Zerner, R. P. M. Bond, and M. L. Bender, *J. Amer. Chem. Soc.*, **86**, 3674 (1964).
(8) J. R. Rapp, C. Niemann, and G. E. Hein, *Biochemistry*, **5**, 4100 (1966).
(9) D. W. Ingles and J. R. Knowles, *Biochem. J.*, **108**, 561 (1968).
(10) R. J. Foster and C. Niemann, *J. Amer. Chem. Soc.*, **77**, 1886 (1955); R. J. Foster, H. J. Shine, and C. Niemann, *ibid.*, **77**, 2378 (1955); D. W. Ingles, J. R. Knowles, and J. A. Tomlinson, *Biochem. Biophys. Res. Commun.*, **23**, 619 (1966).
(11) H. T. Huang and C. Niemann, *J. Amer. Chem. Soc.*, **73**, 3223 (1951).
(12) J. de Jersey and B. Zerner, *Biochemistry*, **8**, 1967 (1969).
(13) K. Flohr, R. M. Paton, and E. T. Kaiser, *Chem. Commun.*, 1621 (1971).

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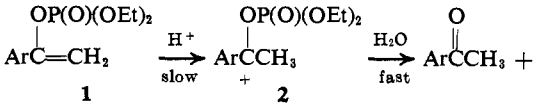
Bond Cleavage in Acid-Catalyzed Hydrolysis of Vinyl Phosphates[1]

Sir:

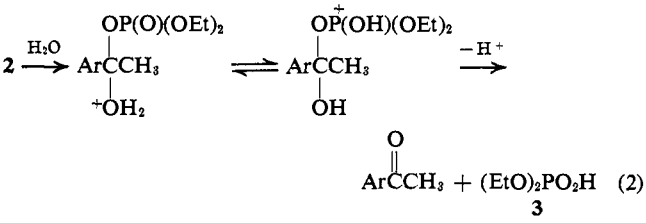
Results reported herein reveal that, contrary to prior belief, the acid-catalyzed hydrolysis of simple vinyl phosphates proceeds with C–O, rather than P–O, bond cleavage.

The acid-catalyzed hydrolysis of diethyl α-arylvinyl phosphates has been shown to proceed by the $A_{SE}2$ mechanism involving rate-determining proton transfer to the double bond (eq 1).[2,3] However, these kinetic studies are not informative as to the mechanism of the conversion of the cation intermediate **2** to the acetophenone and diethylphosphoric acid (**3**).



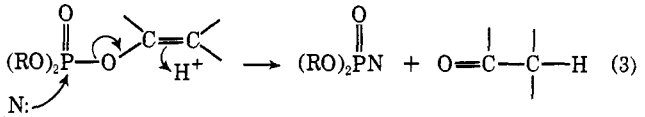
(EtO)$_2$PO$_2$H (1)
3

One possibility would be attack of water at carbon and eventual C–O bond cleavage (eq 2). This mechanism is similar to that for the acid-catalyzed hydration of olefins[4] and an analogous bond cleavage route was assumed to be operative in the hydrolysis of α-arylvinyl acetates.[5]



3 (2)

However, for the acid-catalyzed hydrolysis of vinyl phosphates a different mechanism has been proposed. This was originally suggested by Cramer and Lichtenthaler,[6] and involves nucleophilic attack on phosphorus with P–O bond cleavage (eq 3). Variations of this mechanism have been utilized by research workers in the field[3] and incorporated in reviews on the subject.[7,8] These mechanisms differ as to the nature of the nucleophile and the timing of the steps, but agree on P–O bond cleavage.



(3)

The evidence on which this mechanism was proposed[6] consisted primarily of rate comparisons and product formation from the attack of nucleophiles besides water such as dialkylphosphoric acids and iodide ion. Since the kinetic arguments are clearly invalid for deductions regarding the steps after the rate-determining step, and the results involving nucleophiles other than water need not be applicable to the hydrolysis reaction, it appeared desirable to establish the position of bond cleavage in the hydrolysis reaction using isotopic labeling.[9]

The incorporation of ^{18}O label in the product diethylphosphoric acid (**3**) from hydrolysis of diethyl α-phenylvinyl phosphate (**1a**, Ar = Ph) was examined for 310 min reaction time in 1:1 mixtures of 0.25 *M* aqueous HCl and dioxane at 70°. The kinetics of the reaction of **1a** have been determined from 25 to 70° in 0.01–4.5 *M* acid solutions in water, and found to proceed by the $A_{SE}2$ pathway (eq 1).[2,3] Dioxane was added in

(1) This investigation was supported by Public Health Service Research Grant No. 5 R01 GM16818-03 from the National Institute of General Medical Sciences.
(2) R. D. Frampton, T. T. Tidwell, and V. A. Young, *J. Amer. Chem. Soc.*, **94**, 1271 (1972).
(3) C. A. Bunton and L. Robinson, *ibid.*, **91**, 6072 (1969).
(4) A. J. Kresge, Y. Chiang, P. H. Fitzgerald, R. S. McDonald, and G. H. Schmid, *ibid.*, **93**, 4907 (1971).
(5) D. S. Noyce and R. M. Pollack, *ibid.*, **91**, 119 (1969).
(6) (a) F. Lichtenthaler, *Chem. Rev.*, **61**, 607 (1961); (b) F. W. Lichtenthaler and F. Cramer, *Chem. Ber.*, **95**, 1971 (1962).
(7) T. C. Bruice and S. J. Benkovic, "Bio-Organic Mechanisms," Vol. II, W. A. Benjamin, New York, N. Y., 1966, pp 106–108.
(8) G. Hilgetag and H. Teichmann, *Z. Chem.*, **11**, 1 (1971).
(9) The mechanism of hydrolysis of certain vinyl phosphates has been examined using ^{18}O labeling, but these studies do not reveal the position of acid-catalyzed cleavage of the vinyl phosphate linkage: K. J. Schray and S. J. Benkovic, *J. Amer. Chem. Soc.*, **93**, 2522 (1971); J. F. Marecek and D. L. Griffith, *ibid.*, **92**, 917 (1970).

the present case to improve solubility and is not expected to affect the position of bond cleavage. The oxygen in the product acetophenone rapidly equilibrates with the solvent under these conditions and could not be used as a criterion of bond cleavage.[10]

Hydrolysis experiments were carried out using both normal ester in ^{18}O-labeled water and labeled ester (prepared by the sequence in eq 4) in normal water.

$$PhC(O)CH_2Cl \xrightarrow[HCl]{H_2{}^*O} PhC(\,{}^*O)CH_2Cl \xrightarrow{(EtO)_3P} PhC(\,{}^*OPO_3Et_2)=CH_2 \quad (4)$$

1a

The reaction product was made basic and extracted with $CHCl_3$, then the aqueous layer was acidified and extracted with ether, and the ether layer was evaporated and weighed. This residue was treated with ethereal diazomethane and the resultant methyl diethyl phosphate (**4**) from **3** was isolated by vpc (10 ft × $^3/_8$ in. SE-52 on Chromosorb W at 155° and 120 ml/min of He) and the ^{18}O content was calculated from the mass spectrum of **4** by the method of Swain.[11] Authentic samples of labeled and unlabeled **3** were prepared by the reaction of diethyl chlorophosphate ($(EtO)_2POCl$) with each batch of labeled water used and normal water, respectively. Acid prepared in this way was either esterified directly with diazomethane or subjected to the workup conditions and then esterified. The ^{18}O content was the same in both cases, showing that there was no exchange during work-up. The results of the labeling experiments are shown in Table I.

The results indicate predominant, and perhaps exclusive, acid-catalyzed hydrolysis of **1a** by C–O bond cleavage, corresponding to the scheme in eq 2. A similar mechanism probably holds for acid-catalyzed hydrolysis of other vinyl phosphates with close structural similarity to **1a**, but it is unsafe to extend this conclusion to more complicated structures where neighboring group participation may occur,[9] or ionized substrates may be involved.[12]

Table I. ^{18}O Content of $(EtO)_2P(O)OMe$ Obtained from Hydrolysis of $PhC(OPO_3Et_2)=CH_2$ (**1a**)

Excess ^{18}O content, $PhC(OPO_3Et_2)=CH_2$,[a] %	Excess ^{18}O content, solvent H_2O,[a,b] %	Excess ^{18}O content, product $(EtO)_2P(O)OMe$,[a] %
0.0 ± 0.3	3.3 ± 0.4	0.9 ± 0.3
6.9 ± 0.8	0.0 ± 0.1	7.4 ± 0.6
0.0 ± 0.3	7.4 ± 0.9	0.1 ± 0.3

[a] Obtained from the ratio of the mass spectral ions (M + 2)/M with natural abundance subtracted out. Deviations are averages of at least four determinations. [b] Determined from authentic $(EtO)_2P(O)OMe$ prepared from diethyl chlorophosphate and labeled water.

It has been noted before[2] that 4-coordinate phosphorus is reluctant to undergo substitution *via* 5-coordinate intermediates, as would be required for P–O cleavage. This barrier can be relieved in the hydrolysis of strained cyclic phosphates, where the reactions occur with Berry pseudorotation[13] or turnstile rotation.[14]

(10) D. Samuel and B. L. Silver, *Advan. Phys. Org. Chem.*, 3, 123 (1965).
(11) C. G. Swain, G.-I. Tsuchihashi, and L. J. Taylor, *Anal. Chem.*, 35, 1415 (1963).
(12) S. J. Benkovic and K. J. Schray, *Biochemistry*, 7, 4090 (1968).
(13) F. H. Westheimer, *Accounts Chem. Res.*, 1, 70 (1968).
(14) I. Ugi, D. Marquarding, H. Klusacek, P. Gillespie, and F. Ramirez, *ibid.*, 4, 288 (1971).

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Book Reviews

Organosilicon Derivatives of Phosphorus and Sulfur. By S. N. Borisov, M. G. Voronkov, and E. Ya. Lukevits (Academy of Sciences of the Latvian SSR, Riga). Plenum Press, New York, N. Y. 1971. xiv + 343 pp. $25.00.

This volume is the latest in a series of monographs in inorganic chemistry edited by Eugene G. Rochow. Although it is a translation of the original Russian text published in 1968, it has been updated to include literature references up to June 1, 1969. The book is truly a comprehensive review to the international literature on the rapidly expanding field of organosilicon derivatives containing heteroatoms. In this respect, it fills many gaps and completes the international chain of contributions to this area of heteroorganic chemistry.

The text is equally divided between organosilicon derivatives of phosphorus and sulfur. The chapter subheadings are systematically divided into preparative methods, physical properties, chemical properties, and practical applications of the various bond grouping combinations (*i.e.*, Si–O–P, Si–N–P). There are also a sufficient number of tables of known members of each class of organosilicon compounds to make literature searching a lot easier.

The book contains sections on organosilicon ylides, derivatives of sulfur-containing heterocycles such as penicillin and thiophenes, and several other topics interesting to the synthetic chemist. In general, this volume would be most appealing and useful to the industrial chemists and a good number of academic researchers in this particular field. It is a "practical" reference book in the field of organosilicon derivatives of phosphorus and sulfur, and if for nothing else can be strongly recommended for its comprehensive literature in this area.

J. P. Marino, *University of Michigan*

Hydrides of the Elements of Main Groups I–IV. By E. Wiberg and E. Amberger. American Elsevier, New York, N. Y. 1971. 775 pp. $85.00.

It would be nice if a monumental effort like this (3800 references) could be on the shelves of everyone interested in the field of hydride chemistry. However, at the price, I doubt that many chemists can justify the expense. Unfortunately, the present-day strain on library budgets will undoubtedly even preclude the purchase of this book by many libraries. The reviewer can appreciate the expense of the translation of this work from the German but doubts that an $85.00 price tag is justified. Perhaps the publishers anticipated a greater devaluation of the American Dollar than actually occurred!

The book contains a short introductory chapter on the hydrides in general and nine additional chapters on the hydrides of the alkali metals, the alkaline-earth metals, boron, aluminum, gallium–indium–thallium, silicon, germanium, tin, and lead, respectively.