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HETEROCYCLIC PHOSPHINIC ACIDS. I. SUBSTITUENT EFFECTS ON PHOSPHINIC ESTER HYDROLYSIS

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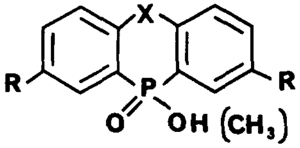
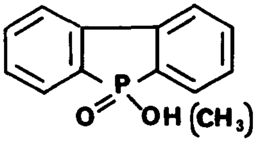
A series of heterocyclic phosphinic acids and their respective methyl esters (Ia-e) were synthesized in an attempt to determine if there are abnormal across-the-ring field effects on reactivity at phosphorus. The rates of alkaline hydrolysis of the esters were studied at 0°C in 60% dimethoxyethane-water. The rate data is summarized in Table I.



Ia-e



II

Ia X = CH_3 ; R = H
Ib X = C(O) ; R = H
Ic X = S ; R = CH_3
Id X = S(O) ; R = CH_3
Ie X = $S(O)_2$; R = CH_3

Table I

Relative Rates of Alkaline Hydrolysis of Esters Ia-e at 0°C in 60% DME-H_2O

Compound	Rel. Rate	Compound	Rel. Rate
Ia	1.4	Id	19.0
Ib	930.0	Ie	202.0
Ic	1.0[a]	II	8.8

[a] The average rate constant for compound Ic is 2.44×10^{-4} M^{-1} sec^{-1}.

For reactions where there is a constant steric effect (this case), it has been stated that Hammett σ_p values can be used for ortho substituents in attempts to correlate reactivity[2]. The plot of log k vs. $\Sigma\,\sigma$ values[3] for compounds Ia-e gives a reasonable straight line (slope = 3.5), except that Ib is considerably faster than the σ value would predict. In order to determine whether this effect is general for the carbonyl group in these compounds, the "pKa's" of the acids were determined[4]. The plot of pKa versus $\Sigma\,\sigma$ gave an excellent straight line for compounds Ib-e[5], which indicates that there is no special effect for the carbonyl compound Ib.

A possible explanation of this result would be to postulate a change in mechanism for the hydrolysis of Ib. The mechanism for phosphinate hydrolysis has been shown to involve attack at phosphorus to form a pentacovalent intermediate, with subsequent breakdown of the intermediate[6]. An alternate mechanism for Ib might involve attack of hydroxide at carbonyl carbon to form a ketal anion, which would attack phosphorus intramolecularly. Attack at carbon is favored on steric grounds, and the pentavalent intermediate formed after intramolecular attack would have a dibenzbicycloheptane-like structure. This possibility is under investigation.

Compound II was studied in order to determine if the orientation of the phenyl rings makes a difference on the reactivity at phosphorus. A comparison between Ia and methyl diphenylphosphinate has already been made[6a]. These compounds have varying degrees of non-planarity[7], and the results indicate little difference between the two. Compound II is planar, and there should be more interaction between the ring and the empty d-orbitals of phosphorus. However, the difference in rate between Ia and II is nearly equal to that predicted from the σ_p value of the CH_3 group. It seems therefore that the size of the d-orbitals on phosphorus allows them to overlap with the p-orbitals of benzene in spite of the non-planarity of the system.

References:

1. Taken from the M.S. thesis of Mr. Howard K. Norrish. This work was supported by a research grant from the American University of Beirut, Arts and Sciences Research Committee.

2. L.P. Hammett, *Physical Organic Chemistry*, 2nd Edition, McGraw-Hill Book Co., New York, 1970, pp 367-368. C.L. Liotta, Chem. Comm., 338 (1968).

3. There are no σ values reported for the X-groups of our compounds; therefore the best approximation is to use the σ_p values for -XCH_3, ie., for Ia - CH_2CH_3; Id - S(O)CH_3. This approximation would give an incorrect intercept but a correct slope. The σ_p values are those of McDaniel and Brown, cf. H. McDaniel and H.C. Brown, J. Org. Chem., 23, 420 (1958).

4. The acids were soluble only in absolute ethanol. The results cannot be considered to be thermodynamic pKa's but rather half-deprotonation values.

5. For some unknown reason the pKa of Ia was off the line by 0.4 pKa units. The values, determined at 20°C., are Ia 9.5, Ib 8.25, Ic 8.9, Id 8.35, Ie 8.15, II 8.63.

6. a) P. Haake, C.E. Diebert, and R.S. Marmor, Tetrahedron Letters, 5247 (1968). b) Robert D. Cook, Patricia C. Turley, Curtis E. Diebert, Arthur H. Fierman, and Paul Haake, results to be published elsewhere.

7. Methyl diphenylphosphinate has been shown to have an "A-frame" conformation for the phenyl rings, cf. M.-U. Haque and C.A. Caughlan, Chem. Comm., 921 (1966). Compound Ia will have a non-planar geometry somewhat like 9,10-dihydroanthracene (butterfly conformation). Compound II corresponds to Moffitt's case I, which is the best conformation for phenyl-3d-orbital interaction for diphenylsulfone. This compound provides the closest analogy to the phosphinates, cf. H.P. Koch and W.E. Moffitt, Trans. Faraday Soc., 47, 7 (1951).