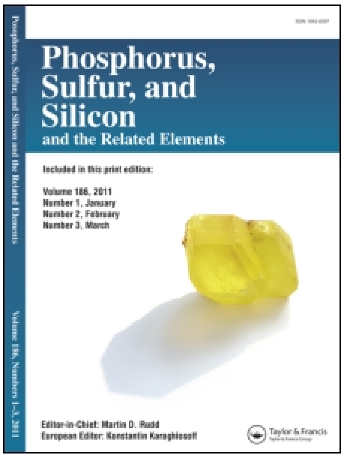


Phosphorus, Sulfur, and Silicon and the Related Elements
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713618290

Structure - Reactivity of Mixed Carboxylic Phosphoric Imides

Valerie Mizrahi[a]; Tomasz A. Modro[a]
[a] Department of Organic Chemistry, University of Cape Town, South Africa

To cite this Article Mizrahi, Valerie and Modro, Tomasz A.(1983) 'Structure - Reactivity of Mixed Carboxylic Phosphoric Imides', Phosphorus, Sulfur, and Silicon and the Related Elements, 18: 1, 141 — 144

To link to this Article: DOI: 10.1080/03086648308075987

URL: http://dx.doi.org/10.1080/03086648308075987

Phosphorus and Sulfur, 1983, Vol. 18 pp. 141-144
0308-664X/83/1801-0141/$18.50/0

STRUCTURE - REACTIVITY OF MIXED CARBOXYLIC PHOSPHORIC IMIDES

VALERIE MIZRAHI and TOMASZ A. MODRO
Department of Organic Chemistry, University of Cape Town,
South Africa

Abstract The title compounds comprise carboxylic and phosphoric amide functions modified at nitrogen by another acyl group.

$X_2P(O)\text{-}NR\text{-}C(O)R'$ (1)

X-ray crystallography revealed intramolecular interactions between carbonyl oxygen and phosphorus in (1). Under conditions of electron impact all substrates (1) isomerise to the corresponding O-phosphoryl imidates $X_2P(O)\text{-}O\text{-}C(NR)R'$. Solvolysis of (1) depends on medium acidity; in neutral media the exclusive attack at phosphorus was observed, while the acid catalyzed solvolysis involves both N-acyl linkages and the reaction proceeds via the carbonyl oxygen protonated intermediate. Hydration parameter treatment was applied to the hydrolysis of (1). Nucleophilic behavior of (1) was studied in alkylation of their conjugate basis derived from secondary substrates (1, R=H).

INTRODUCTION

The major differences between carboxylic and phosphoric amides are their reactivity in acidic solvolysis and their conformational preferences. Carboxylic amides protonate at the oxygen atom giving relatively stable conjugate acid, which then reluctantly reacts with nucleophilic solvent.[1] Phosphoric amides protonate at the nitrogen atom giving the highly reactive intermediate, from which amine group can be easily displaced according to the $S_N2(P)$ mechanism.[2] As far as the conformations are concerned, for the secondary carboxylic amides the trans geometry of the OCNH group is preferred, while the secondary phosphoric amides show higher ability for the cis conformation of the OPNH linkage. As a consequence of such geometry, secondary carboxylic amides form in the solid state polymeric aggregates and phosphoric analogues exist in many cases as hydrogen bonded dimers (Fig. 1).[3] Our interest in compounds containing the C(O)-N and P(O)-N amide functions led us to investigate mixed imide system (1) which incorporates these two functions in a single molecular framework.

$$X_2P(O)\text{-}NR\text{-}C(O)R' \qquad (1)$$

RESULTS AND DISCUSSION

The determined crystal structure[4] of the secondary imide (1a, 1, X=MeO; R=H; R'=Ph) demonstrated the following structural parameters (Fig. 2): (i) The planarity of the P(O)NHC(O) fragment; (ii) Cis-trans orientation with the P=O and C=O dipoles oriented at 127° to one another; (iii) Syn-coplanarity of the phosphoryl and N-H groups, involved in the dimeric hydrogen bonding association; (iv) An intramolecular close contact between the nucleophilic oxygen of the C=O group and the phosphorus atom.

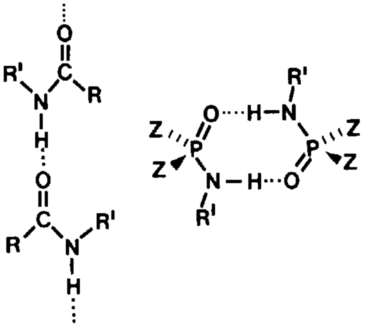


FIGURE 1 Typical hydrogen bonding in secondary amides

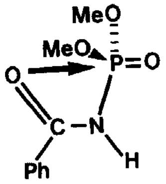
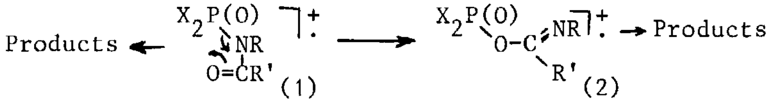


FIGURE 2 Benzoic-dimethylphosphoric imide (1a)

The parameter (iv) represents an "early stage" of nucleophilic substitution at the phosphoryl centre, or an "early stage" of the rearrangement of imide (1) to the O-phosphorylated benzimidate (2). The intramolecular N → O phosphoryl transfer in (1) was demonstrated in a study of the M.S. of these compounds.[5] In addition to the expected fragmentation of the parent imides, all substrates (1) give products resulting from fragmentation following the initial isomerisation to imidates (2).



$$\text{Products} \longleftarrow \left[X_2P(O)\text{-}NR\text{-}C(=O)R'\right]^{+\cdot}\ (1) \longrightarrow \left[X_2P(O)\text{-}O\text{-}C(=NR)R'\right]^{+\cdot}\ (2) \longrightarrow \text{Products} \qquad (1)$$

We carried out MO calculations on the model imide molecule (1b, 1, X=R=R'=H) and its rearrangement product (2a, 2, X=R=R'=H).[6] We have optimised the geometry/energy for several P-O bond distances (Figure 3). Calculations indicate that the rearrangement is concerted in nature and that the imide structure 1 is more stable than its isomeric O-phosphoryl derivative 2.

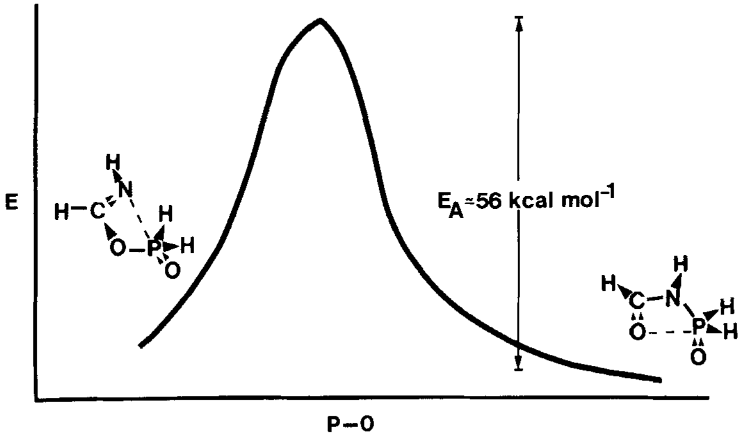


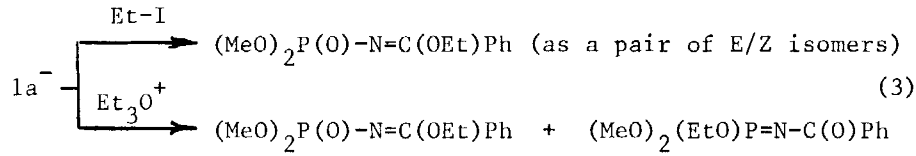
FIGURE 3 Energy vs. P-O distance plot for 1b 2a rearrangement.

The solvolysis of substrates 1 was studied[7] in order to evaluate the relative reactivities of the N-carbonyl and N-phosphoryl bonds. Under neutral conditions the cleavage by a nucleophile Nu-H directly reflects the relative susceptibilities of the two acyl centers in 1.

$$1 + \text{Nu-H} \left[\begin{array}{l} \xrightarrow{\text{P-N cleavage}} X_2P(O)Nu + R'C(O)NHR \\ \xrightarrow{\text{N-C cleavage}} X_2P(O)NHR + R'C(O)Nu \end{array} \right. \qquad (2)$$

Neutral hydrolysis and alcoholysis of N-acyl phosphoramidates (1, X=RO) proceeds with the exclusive cleavage of the P-N bond, while the phosphinic derivative (1, X=Et) has been found to be indefinitely stable in aqueous or alcoholic solutions. This is interpreted in terms of the oxyphosphorane intermediate which has to then undergo pseudorotation prior to the product - determining P-N cleavage step. Under acidic conditions some of substrates react according to both pathways of eq. (2). The rate measurements show that the introduction of a second acyl group has opposite effects upon the two amide bonds: it dramatically stabilises the P-N function, whereas it significantly labilises the N-C bond. The ionization behavior and rate profiles for hydrolysis of 1 are in accordance with carbonyl oxygen protonation of the substrate. The hydration parameter treatment[8] applied to the acid catalyzed hydrolysis of 1 has revealed unusually low hydration requirement of the rate determining transition state. This indicates intramolecular stabilisation of the tetrahedral intermediate by the P=O group.

The nucleophilicity of the OCNPO imide group in 1 was probed by ethylation of the sodium salt of 1a.[9] Depending on the alkylating agent, the reaction gives the carbonyl oxygen or carbonyl and phosphoryl oxygens alkylated products.



$$1a^- \xrightarrow{Et\text{-}I} (MeO)_2P(O){-}N{=}C(OEt)Ph \text{ (as a pair of E/Z isomers)}$$

$$1a^- \xrightarrow{Et_3O^+} (MeO)_2P(O){-}N{=}C(OEt)Ph + (MeO)_2(EtO)P{=}N{-}C(O)Ph \qquad (3)$$

REFERENCES

1. T.A. Modro, K. Yates and F. Beaufays, Can. J. Chem., 55, 3050 (1977).
2. J. Rahill and P. Haake, J. Am. Chem. Soc., 103, 1723 (1981).
3. M.P. du Plessis, T.A. Modro and L.R. Nassimbeni, J. Org. Chem., 47, 2313 (1982).
4. V. Mizrahi and T.A. Modro, Cryst. Str. Comm., 11, 627 (1982).
5. V. Mizrahi and T.A. Modro, J. Org. Chem., 47, 3533 (1982).
6. S.A. Glover, V. Mizrahi and T.A. Modro, J. Chem. Soc. Perkin Trans. 2, 1983, in press.
7. V. Mizrahi and T.A. Modro, J. Org. Chem., 1983, in press.
8. K. Yates and R.A. Mc Clelland, J. Am. Chem. Soc., 89, 2686 (1967).
9. V. Mizrahi, T.F. Hendrickse and T.A. Modro, Can. J. Chem., 61, 118 (1983).