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REACTIONS OF PHOSPHOROUS AMIDES WITH 3-HYDROXY-2,2,4-TRIMETHYL-3-PENTENOIC ACID β-LACTONE

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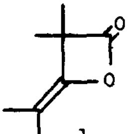
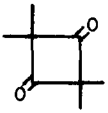
We wish to report results of a study of the reactions of $[(CH_3)_2N]_3P$, $CH_3OP[N(CH_3)_2]_2$ and $(CH_3O)_2PN(CH_3)_2$ with the lactone dimer (1) of dimethylketene. These results have bearing on the question of the relative nucleophilicities or basicities of phosphorus and nitrogen towards carbonyl carbon. A comparison is made of these reactions to those previously reported[1] for $(CH_3O)_3P$ with 1 and with tetramethyl-1,3-cyclobutanedione (2), particularly with regard to the possible importance of cyclic pentacovalent phosphorane intermediates in these systems.

The reaction of excess $[(CH_3)_2N]_3P$ with 1 proceeded readily at 120° in the absence of solvent to give 3 as the major distillable product (monitored vpc).



1



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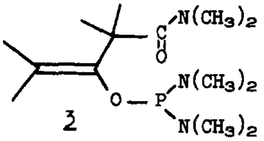

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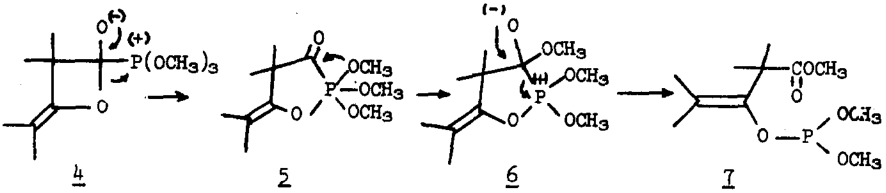
This product is entirely analogous to 7 previously shown[1] to result from the reaction of $(CH_3O)_3P$ with 1.* Formation of 7 was rationalized via the following sequence:



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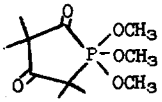
[*] That $[(CH_3)_2N]_3P$ should react in the same manner as $(CH_3O)_3P$ is perhaps not surprising but is not necessarily predicted. The above amide and phosphite give analogous alkylidene phosphorane products on reaction with trans-1,2-dibenzoylethene[2], give similar cyclic 1,3,2-dioxaphospholenes with α-diketones[3], and probably yield initially the same type of cyclic 1,4,2-dioxaphospholanes with aldehydes[4,5]. The adducts of the trisdimethylaminophosphine with α-diketones have a greater tendency to exist in open chain dipolar form than do their trialkyl phosphite counterparts[3,16]. This may strongly affect the outcome of reactions potentially involving cyclic phosphorane intermediates, e.g., the postulated trisdimethylamino phosphine-aromatic aldehyde adduct is a transient one and breaks up to the phosphine oxide and stilbene oxide.[4] With hexafluoroacetone, $(CH_3O)_3P$ leads to the 1,3,2-dioxaphospholane[6] while the amide gives as major product trisdimethylaminodifluorophosphorane.[7]

The cyclic oxyphosphorane 5 was invoked as a possible intermediate in attempted explanation of retention of the enol structure of 1 in product 7. Analogously, phosphorane 8 was suggested to explain formation of 9, in which the keto structure is retained from reaction of $(CH_3O)_3P$ with 2. In these reactions, the incipient enolate ion 10 is in a sense trapped via formation of 5 and 8.

8


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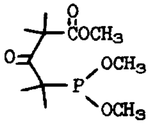

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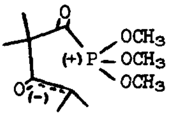
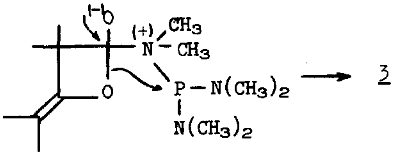
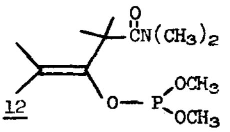


Reactions of 1 and 2 with amines and with alcohols[8] result in identical products regardless of the dimer used, presumably via ring opening to a common enolate-ion intermediate.

Hudson and Searle[9] have recently suggested that a series of very interesting reactions of carbonyl compounds (acetyl chloride,[9] benzaldehyde,[9,10] CS_2[11] and phenylisocyanate[9,12]) with diphenylphosphinous and dialkylphosphorous amides [Ph_2PNR_2 and $(RO)_2PNR'_2$] be interpreted in terms of attack by the relatively "hard" nitrogen atom rather than the "softer" phosphorus atom at the "hard" carbonyl carbon center.[13] Nitrogen attack is also helpful in rationalizing the reported[14] formation of $RO(AcO)PN(C_2H_5)_2$ and $(C_2H_5)_2NAc$ on reaction of $ROP[N(C_2H_5)_2]_2$ with acetic anhydride[*] and the ring expansion observed[15] on condensation of phospholidines with ethyl isocyanate. Indeed, one may write a very plausible mechanism for formation of 3 involving intermediate 11 resulting from nitrogen attack.

11


This mechanism predicts that reaction of $(CH_3O)_2PN(CH_3)_2$ with 1 should give amide 12. In fact, however, a 1:1 molar ratio mixture of reactants at 115° in the absence of solvent yields the carboxylic ester (13) exclusively (v.p.c.). Similarly, dimer 1 with $CH_3OP[N(CH_3)_3]_2$ at 25° gives only carboxylic ester (14).

12


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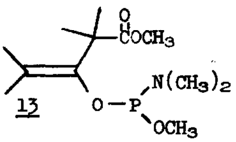

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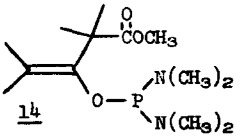

We have been unable to write a plausible mechanism for formation of 13 and 14 which involves

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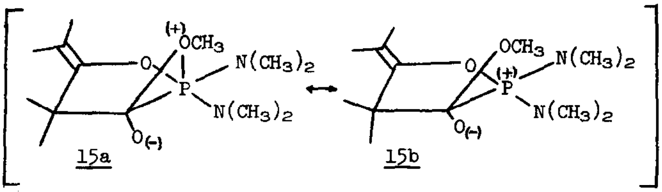
[*] This is another example (see first footnote) in which the chemistry of a phosphorous amide is not predicted by the reactions of trialkyl phosphites which proceed with acetic anhydride in normal Arbuzov fashion to $AcP(O)(OCH_3)_2$ and CH_3OCOCH_3.

attack by nitrogen at carbonyl carbon. We also hesitate to suggest intermediates analogous to 11 resulting from oxygen attack since this requires that oxygen be more nucleophilic than either nitrogen or phosphorus. The placement of the carbonyl in a 4-membered ring may affect the relative "hardness" of the carbon atom. A nucleophilicity or basicity order N > P is not unreasonable. But that oxygen should be more nucleophilic or basic than nitrogen or phosphorus in these molecules would seem highly unusual and unlikely. Although direct evidence is lacking, it appears that results with the amides, as well as those with the phosphites, can be well accommodated by a sequence like 1) involving attack by phosphorus on carbonyl carbon.

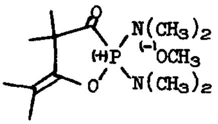
Many of the previously reported reactions involving apparent nitrogen attack to which we have referred may also be interpreted in terms of attack by phosphorus but in a much less straight forward manner. Results in our system thus would appear to be anomalous. We have made no attempt to differentiate between kinetic and thermodynamic control in the use of the terms "nitrogen attack," "phosphorus attack," etc. in discussing either our results or those of others. Contrasting patterns of product formation could arise from the predominance of kinetic factors in one instance and thermodynamic ones in another. It seems quite possible that with 1 and 2 rapid ring expansion precludes reversal of the initial step and leads to kinetically controlled products. A more extensive discussion of these possibilities is reserved for a full paper.

The preferential methoxy translocation noted in our systems may be rationalized within the context of the phosphorane mechanism in terms of structures which place a positive charge on phosphorus. Both bridged structures in which P-O bond breaking is well advanced (15b) and non-bridged forms (16) might be considered.* Charge at the migrational origin will be better stabilized by remaining amino groups than by methoxyls. Alternatively, migration may be configurationally controlled.



15a

15b



16

Structures of products were based on elemental analysis, infrared and n.m.r. data.

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[*] The bridged transition state is depicted as a square pyramid. Although we have no firm grounds for choosing this over the alternative trigonal bipyramidal configurations, it does allow for the preferred 90° OPO bond angle[17] and moves the migrating group into close proximity to the carbonyl. Full dissociation of a form such as 16 is unlikely since polymerization of 1, observed with sodium methoxide,[8] is not found in reactions of 1 with phosphites.

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