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MECHANISTIC STUDIES ON THE THIATION OF CARBONYLS BY LAWESSON'S REAGENT: THE ROLE OF A 3-COORDINATE PHOSPHORUS(V) SPECIES.

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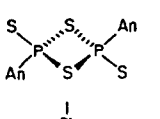
Abstract: Structural, kinetic, and spectroscopic studies show that the mechanism for the thiation of organic carbonyls by Lawesson's reagent involves momomeric RPS_2 intermediates.

Anisyldithiophosphinic anhydride, $An_2P_2S_4$ (1, An = 4-$MeOC_6H_4$) is the most widely used reagent for the thiation of carbonyl compounds (eq. 1).[1,2]

(1)

Little has been reported on how this reaction occurs.[3] Our studies have uncovered several unexpected features which provide the basis for a coherent mechanism which is presented here.

We began by examining the effectiveness of structural analogs 1 for effecting the thiation of carbonyls. We chose compounds 1-5, all of which feature organothiophosphoryl moieties. The



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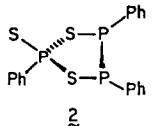

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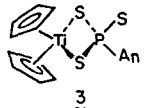

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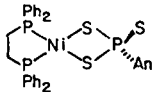

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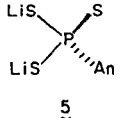


5

titanium and nickel complexes were recently reported by us;[4] we anticipated that the oxophilicity of the titanium atom would enhance the reactivity of the thiophosphoryl group in 3. The relative reactivity of compounds 1-5 toward Ph_2CO was easily checked by monitoring the appearance of the distinctive blue color of Ph_2CS. Surprisingly compounds 3, 4, and 5 were found

to be completely unreactive toward Ph_2CO despite their close structural similarity to 1. This result provided the first clue that intact 1 is not an active thiation agent. The fact that 5, prepared in situ from 1 and Li_2S, is inert to Ph_2CO indicates that the thiation reaction is probably not driven by nucleophilic attack upon the substrate's carbonyl center.[5] These findings are in accord with the observation that the facility of reaction 1 (R = Ph) correlates with the nucleophilicity of the carbonyl in the order R' = NMe_2 > OMe > Ph. Compound 2[6] does convert Ph_2CO to Ph_2CS, but much more slowly than 1. The electrophilic character of the active form of 1 is further highlighted by the vigor of its reaction with neat DMSO which yields both Me_2S and Me_2S_2.[7] We find that DMSO is cleanly converted to Me_2S by 1 (0.5 equiv.) when the reaction is conducted at room temperature in THF. This reaction has synthetic potential as an alternative to the use of P_4S_{10}.[8]

When the reaction of 1 with Ph_2CO in THF is monitored by ^{31}P NMR spectroscopy, one observes (Figure 1) a steady decrease in the signal for 1[9] concomitant with the appearance of

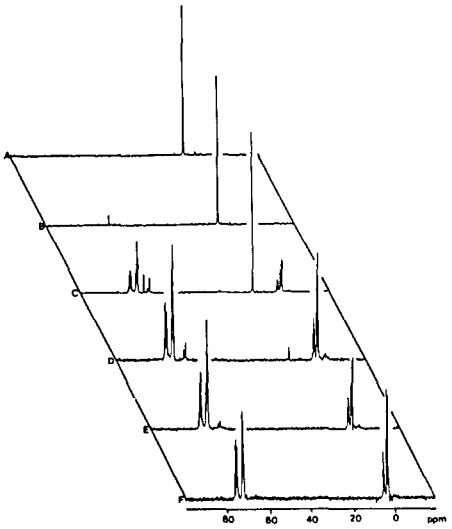


Figure 1. 101 MHz ^{31}P NMR spectra for the reaction of $An_2P_2S_4$ and Ph_2CO (2 equiv.) in THF. Spectra were recorded hourly from t=0 to t=5h.

clusters of resonances centered at 72 and 3 ppm. We tentatively ascribe these resonances to oligomers of the type $[AnP(S)(\mu\text{-}O)]_n$. We have recently shown that solutions prepared in this way are a reactive source of the AnPSO moiety and convert to $[AnP(S)(\mu\text{-}O)]_3$ relatively slowly.[10]

The kinetics of the reaction of 1 (0.0036 M) and Ph_2CO (0.036, 0.071, 0.107, and 0.143 M; each experiment was run in duplicate or triplicate) in toluene were determined spectrophotometrically at 70°C by monitoring the appearance of Ph_2CS (λ_{max} = 605 nm). Plots of $(A_\infty\text{-}A_t)^{1/2}$ vs. time were linear as was the plot of k_{obs} vs. $[Ph_2CO]$ (Figure 2).

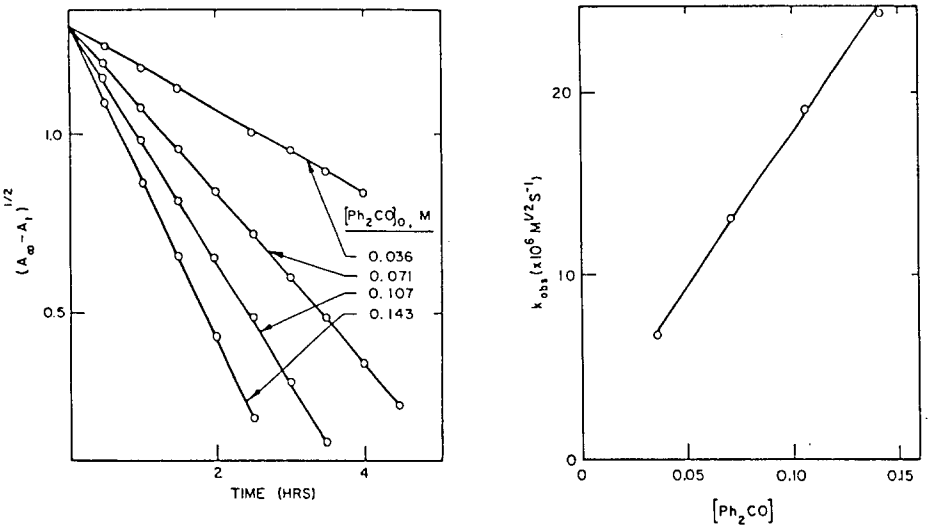


Figure 2. A. Plots of $(A_\infty - A_t)^{1/2}$ vs. time where A is the absorbance at 605 nm for Ph_2CS. B. Plot of k_{obs} vs. $[Ph_2CO]_o$.

The kinetic data conform to the rate law shown below.

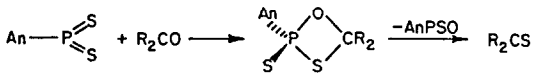
$$\frac{d[Ph_2CS]}{dt} = 1.63 \times 10^{-4} M^{-1/2} s^{-1} [Ph_2CO][An_2P_2S_4]^{1/2}$$

This result is consistent with the rapid symmetrical cleavage of 1 yielding monomeric $AnPS_2$ which binds the ketone in a subsequent, slower step.

The species $AnPS_2$, a 3-coordinate phosphorus(V) species, would be expected to be a potent electrophile[11] thus accounting for its enhanced reactivity toward nucleophilic substrates such as amides and sulfoxides.[10] Monomeric $AnPS_2$ is expected to be structurally analogous to 2,4,6-$(t\text{-Bu})_3C_6H_2PS_2$ which has recently been characterized by single crystal x-ray diffraction.[12] Other aspects of the chemistry of 1 indicate that its dissociation is facile. The strongest peak in its 70 eV electron impact mass spectrum corresponds to $AnPS_2$. The ^{31}P NMR spectrum of a freshly prepared solution, equimolar in 1 and $(Che)_2P_2S_4$[13] (Che = 3-cyclohexenyl), consists of four comparably intense peaks assignable to 1 (14.8ppm), $(Che)_2P_2S_4$ (43.2 ppm), and $An(Che)P_2S_4$ (18.6, 39.0 ppm).

To summarize, the thiation of organic carbonyls by 1 can be rationalized in terms of nucleophilic attack of carbonyl oxygen upon $AnPS_2$ monomers (eqs. 2, 3).

(2)



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