

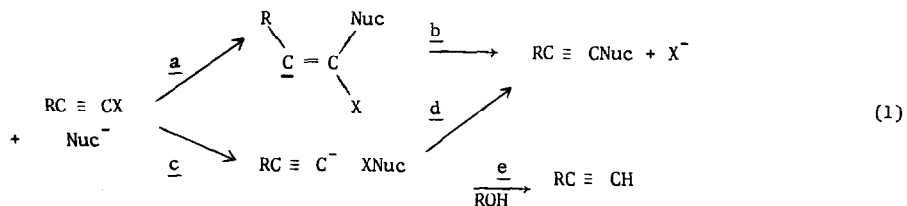
NUCLEOPHILIC SUBSTITUTION AT AN ACETYLENIC CARBON. CARBON VERSUS HALOGEN ATTACK BY PHOSPHORUS  
NUCLEOPHILES

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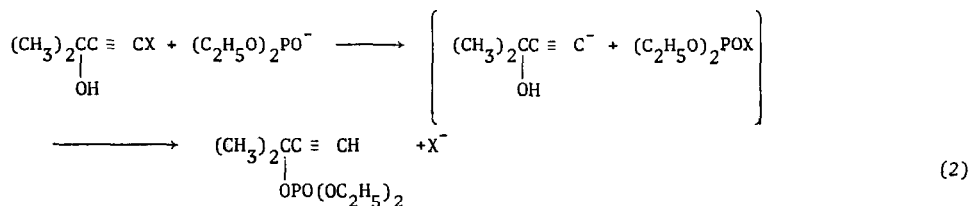
In 1962, there were four papers on the subject of nucleophilic substitution at an acetylenic carbon: these involved thiolate (1,2), phosphine (1,3), amine (3), and phosphite (4). Recognizing that haloalkynes could be attacked at several points in different ways (5), our group still favored steps a and b of eq 1 for their systems (1,2,5). Arens rightly suggested



that steps a and b could not possibly be general and argued that steps c and d would in fact be more reasonable (6). Other substitution paths have since been proposed (7). Here we take up the duality of mechanism for which most workers and reviewers have accepted the Arens route for phosphorus nucleophiles in scheme 1 (7-11).

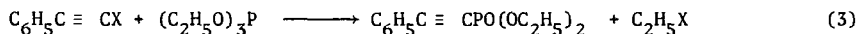
If steps a and c are assumed to be rate-determining, we can use the element effect and traps to distinguish between them. When  $k(\text{Br})/k(\text{Cl}) \gg 1$  and the acetylide ion can be "caught" by a proton donor, we shall assume that this is strong evidence for the halogen abstraction route (c,e). When  $k(\text{Cl})/k(\text{Br}) > 1$  and the substitution product forms in the presence of available protons, we shall assume that this is evidence for  $\alpha$ -carbon attack (a,b).

French workers have shown that process 2 at  $-78^\circ$  in THF yields 70% of the phosphate, when  $\text{X} = \text{Br}$ (9). For  $\text{X} = \text{Cl}$ , the rate is much lower: we obtained a 33% yield of the same product



after 5 hr at 106° in THF and a 56% yield after 3 hr at 108° in THF-ethanol (1:1). In process 1, when R = phenyl and Nuc<sup>-</sup> = (C<sub>4</sub>H<sub>9</sub>)<sub>3</sub>P, the results of our kinetic study show that k(Br)/k(Cl) = 14 for DMF at 0°; trapping trials with added methanol (12.4M) at 25° indicate complete diversion to phenylacetylene when X = Br, and formation of both tributylphenylethynylphosphonium chloride and phenylacetylene when X = Cl. The preceding comparisons indicate the results to be expected in eq 1, when halogen abstraction (c,d) is the major or exclusive substitution path.

Consider now the Arbuzov process 3: we find k(Cl)/k(Br) = 1.2 for THF at 77°. Rate data and product ratios in the presence of added ethanol are shown in Figure 1. Essentially no phenylacetylene forms when X = Cl. But when X = Br, the ratio [C<sub>6</sub>H<sub>5</sub>C≡CPO(OC<sub>2</sub>H<sub>5</sub>)<sub>2</sub>]/[C<sub>6</sub>H<sub>5</sub>C≡CH] at 77° is ca.7 in 1 M ethanol in THF, ca.1 in 7 M ethanol in THF, and ca.0.5 in pure ethan-



ol. Our interpretation is that phenylchloroacetylene follows steps a and b of eq 1 in THF and in THF-ethanol (0-4M); phenylbromoacetylene appears to take both branches in eq 1, of which the lower appears to be strongly medium dependent. The possibility that both halides proceed on step c of eq 1 to an ion pair which is then partitioned so differently, seems improbable. Contrary to some opinion, the examples of process 3 indicate that phosphorus nucleophiles sometimes prefer to attack the α-carbon rather than halogen in a haloalkyne.

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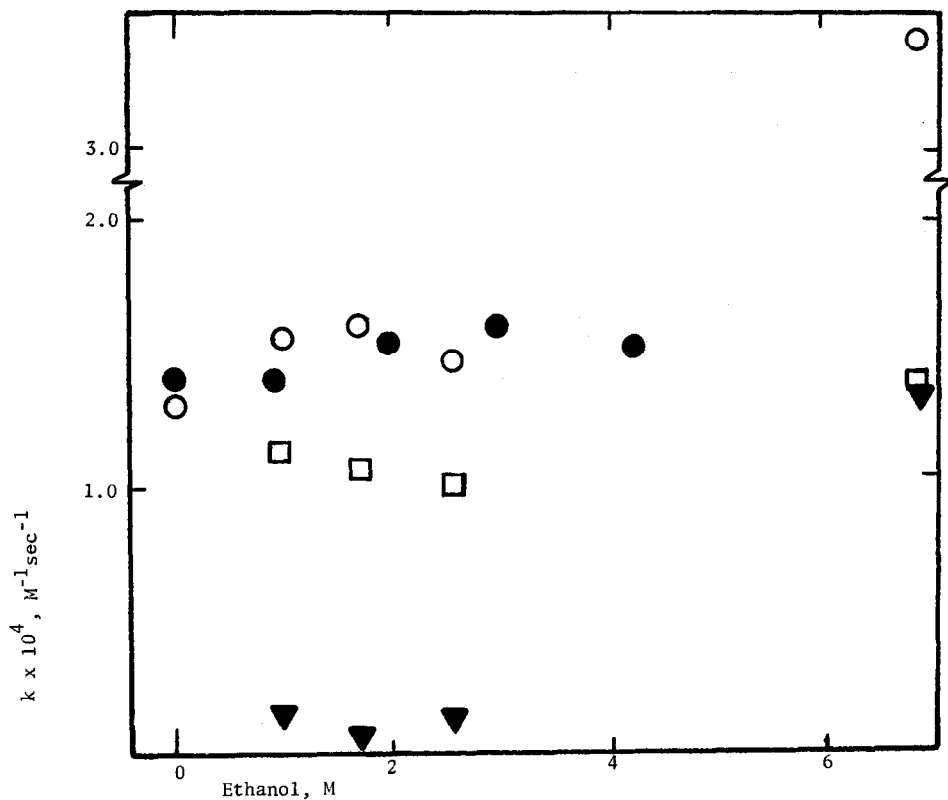


Figure 1. The reaction between  $C_6H_5C \equiv CX$  and  $(C_2H_5O)_3P$  at  $77^\circ$  in tetrahydrofuran with added ethanol. For  $X = Br$ , rate constants for the disappearance of  $C_6H_5C \equiv CBr$  (○) and the appearance of  $C_6H_5C \equiv C-PO(OC_2H_5)_2$  (□) and  $C_6H_5C \equiv CH$  (▼) are shown. For  $X = Cl$ , rate constants for the disappearance of  $C_6H_5C \equiv CCl$  are shown (●).