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The Reaction of Triphenylphosphine With Trihalo-Acid Derivatives - A Convenient Preparation Of α-Halo Vinyl Esters and Nitriles.

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The reaction of triphenylphosphine with activated polyhalo-compounds has been reported to involve initial nucleophilic attack by phosphorus on halogen rather than attack by phosphorus on carbon (eq.1). The resulting dichlorophosphonium ion and the

$$(1) \qquad (C_6H_5)_3P + CX_3R \longrightarrow (C_6H_5)_3\overset{(+)}{P}X + \overset{(-)}{C}X_2R$$

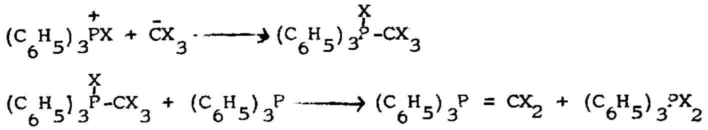
$$R = \text{halogen}^{1,2},\ -CHO^3,\ -COC_6H_5{}^4,\ -CONR_2{}^5$$

anion may combine to give either C- phosphonium salts or enol-phosphonium salts (6).

When carbon tetrahalides react with triphenylphosphine, the intermediate phosphonium salt reacts with a second equivalent of the phosphine to form a dihalomethyleneylid and a dihalophosphorane (1,2) (eq.2). If the reaction is carried out in the presence

$$(2) \qquad (C_6H_5)_3P + CX_4 \longrightarrow \left[(C_6H_5)_3\overset{+}{P}X + \overset{-}{C}X_3\right]$$

$$X = Cl, Br$$



$$(C_6H_5)_3\overset{+}{P}X + \overset{-}{C}X_3 \longrightarrow (C_6H_5)_3\overset{X}{\overset{|}{P}}-CX_3$$

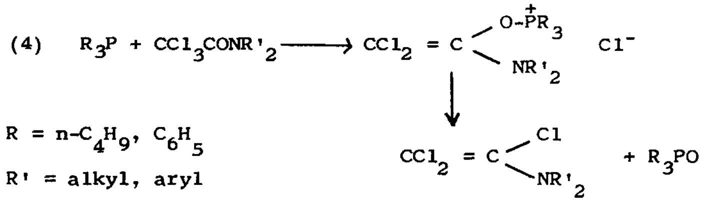
$$(C_6H_5)_3\overset{X}{\overset{|}{P}}-CX_3 + (C_6H_5)_3P \longrightarrow (C_6H_5)_3P = CX_2 + (C_6H_5)_3PX_2$$

of an aldehyde, like benzaldehyde, the resulting products are the dihaloolefin, the benzal halide, and phosphine oxide (eq.3).

$$(3)\quad (C_6H_5)_3P=CX_2 + C_6H_5CHO \longrightarrow (C_6H_5)_3P=CX_2 + (C_6H_5)_3PO$$

$$(C_6H_5)_3PX_2 + C_6H_5CHO \longrightarrow (C_6H_5)_3PO + C_6H_5CHX_2$$

This convenient preparation of α-haloylids, as pointed out by Johnson (7), provides a valuable method for the preparation of vinyl halides. Unfortunately, extension of this simple mode of preparation to other analogues of the carbon tetrahalides has not yet proven to be feasible. For example, trichloroacetamides react with tertiary phosphines to form an enol-phosphonium salt which collapses to give a vinyl amine and the phosphine oxide (5) (eq.4). No α-haloylid of the type $R\text{-}C(X)=P(C_6H_5)_3$ is formed. Ylids of this type, however, can be prepared by direct chlorination and subsequent dehydrochlorination of other ylids (8), but the simplicity of the carbon tetrahalide type of reaction is lost.



$$(4)\quad R_3P + CCl_3CONR'_2 \longrightarrow CCl_2=C\begin{cases}O\text{-}\overset{+}{P}R_3\\NR'_2\end{cases} Cl^- \;\longrightarrow\; CCl_2=C\begin{cases}Cl\\NR'_2\end{cases} + R_3PO$$

$R = n\text{-}C_4H_9,\ C_6H_5$

$R' =$ alkyl, aryl

In contrast to the behavior of the trichloroacetamides, however, we have found that methyl trichloroacetate reacts with triphenylphosphine in a manner analogous to the carbon tetrahalides, and provides a simple and convenient route to α-chloro vinyl esters (eq.5). The mechanism of the reaction appears to be similar to that of the car-

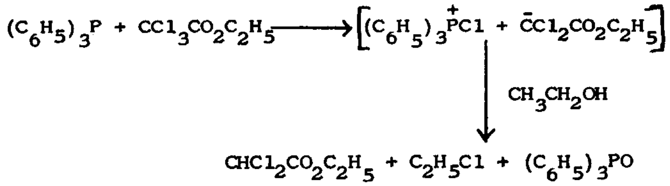
$$(5)\quad CCl_3CO_2CH_3 + 2(C_6H_5)_3P \longrightarrow \left[(C_6H_5)_3P=C(Cl)CO_2CH_3 + (C_6H_5)_3PCl_2\right]$$

$$\Big\downarrow\ 2R\text{-}C_6H_4CHO$$

$$R\text{-}C_6H_4CH=C(Cl)CO_2CH_3 + R\text{-}C_6H_4CHCl_2 + 2(C_6H_5)_3PO$$

bon tetrahalides, since ethyl dichloroacetate is formed in 98% yield (determined by GLC) when ethyl trichloroacetate reacts with triphenylphosphine in ethanol solution. The formation of ethyl dichloroacetate is consistent with initial attack by phosphorus on halogen to give a chlorophosphonium ion pair and subsequent solvolysis of the ion pair to yield the dichloroacetate (eq.6). The results of some typical aldehydes in this reaction are summarized in Table I. Elemental analysis, infrared, and NMR spectra are in complete agreement with the assigned structures.

(6)



$$\begin{tikzcd}
(C_6H_5)_3P + CCl_3CO_2C_2H_5 \arrow[r] & \left[(C_6H_5)_3\overset{+}{P}Cl + \bar{C}Cl_2CO_2C_2H_5\right] \arrow[d, "CH_3CH_2OH"] \\
& CHCl_2CO_2C_2H_5 + C_2H_5Cl + (C_6H_5)_3PO
\end{tikzcd}$$

Table I

$$2(C_6H_5)_3P + CCl_3CO_2CH_3 + R\text{-}C_6H_4CHO \longrightarrow R\text{-}C_6H_4CH = C(Cl)CO_2CH_3$$

R	% Yield[a]	b.p. °C	m.p.	cis-trans[b]
p-H	70	124°/5mm.	- - -	17:83
p-CH_3	74	96°/1mm.	- - -	17:83
p-Cl	60	- - - - -	84-85°	- - -
p-NO_2	65	- - - - -	134-135°	0:100

a - all yields are isolated yields.

b - the cis-isomer is that isomer which has the phenyl group and carboalkoxy group on the same side of the carbon-carbon double bond.

A typical procedure is as follows: To a dry-nitrogen flushed flask was added 52.5g. (0.20 mole) of triphenylphosphine and 24.0g. (0.20 mole) of p-tolualdehyde and 150 ml. of dry methylene chloride. To this solution, 17.8g. (0.10 mole) of methyl trichloroacetate was slowly added. As the addition of the trichloroacetate proceeded, the temperature rose to reflux and the reaction mixture passed through a variety of color changes (yellow ⟶ orange ⟶ red). After the addition was completed, the reaction mixture was heated at reflux for forty hours, cooled to room temperature, and the solvent removed on a rotary evaporater. The remaining solid was extracted with hexane, and the resulting hexane extracts were fractionated to give 15.7g. (74%) of methyl α-chloro-*p*-methyl-cinnamate; b.p. 80-96° (1mm.) - a mixture of *cis*-*trans* isomers. The ratio of *cis*-*trans* isomers was determined by GLC (before distillation) to be 17:83. The assignments of the isomer geometry were made by NMR.

The reaction could be carried out to give similar results by mixing the triphenylphosphine and the methyl trichloroacetate with subsequent addition of the appropriate aldehyde. Hydrolysis of an aliquot of the reaction mixture before addition of the aldehyde showed a negligible amount (by GLC) of methyl dichloroacetate. This ester would be formed by hydrolysis of the ion pair in equation 6. The absence of this ester upon hydrolysis, indicated that little, if any, of this ion pair was present in solution and again suggested the ylid as the reactive intermediate.

It should be pointed out that *N*,*N*-diethyltrichloroacetamide is inert to triphenylphosphine under our reaction conditions.

This reaction is not necessarily limited to α-chlorovinyl esters, as we have also found that other polyhalo-compounds, such as tribromoacetate esters and trichloroacetonitrile, react similarly to give α-bromovinyl esters and α-chlorovinyl nitriles (eq.7&8).

$$(7) \qquad 2(C_6H_5)_3P + CBr_3CO_2CH_2CH_3 + C_6H_5CHO \longrightarrow C_6H_5CH = C(Br)CO_2CH_2CH_3$$

$$(8) \qquad 2(C_6H_5)_3P + CCl_3CN + C_6H_5CHO \longrightarrow C_6H_5CH = C(Cl)CN$$

These reactions thus provide a convenient and facile route to α-haloylids, and the reactions of these ylids provide convenient routes to α-hlaovinyl derivatives by subsequent reaction with the appropriate carbonyl moiety. The ready availability of the starting materials and the ease of this reaction should make this reaction an attractive route to these types of compounds.

Work is continuing on the reaction of these intermediates with other carbonyl moieties and the overall scope of this reaction and its mechanism.

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