PART I:  THE PREPARATION AND REACTIONS OF $\alpha$-HYDROXY- AND $\alpha$-ALKOXYALKYLIDENETRIPHENYLPHOSPHAZINES

PART II:  THE SYNTHESIS OF 1,3,4-OXADIAZOLES VIA TRIPHENYLPHOSPHINE DERIVATIVES

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

Glory Barayuga Merrill, B.A.

The Ohio State University
1972

Approved by

[Signature]
Adviser
Department of Chemistry
dedicated to dwight, tessie and alan
ACKNOWLEDGMENTS

I wish to extend my sincere appreciation to Professor Harold Shechter for his assistance and guidance in this work and for his invaluable help for the preparation of this manuscript. I also wish to thank my colleagues for many helpful discussions and donations of time.

I am also grateful to the Department of Chemistry and the National Institutes of Health for their financial support.
VITA

November 19, 1945. . . . . Born - Ilocos Norte, Philippines

1963 . . . . . . . . . . . . Become naturalized USA citizen

1963 . . . . . . . . . . . . Graduated W.R. Farrington High School, Honolulu, Hawaii

1966 . . . . . . . . . . . . B.A., University of Hawaii, Honolulu, Hawaii

1966-1968 . . . . . . . . Teaching Assistant, Department of Chemistry, The Ohio State University, Columbus, Ohio

1968-1972 . . . . . . . . Research Associate, Department of Chemistry, The Ohio State University, Columbus, Ohio
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PART I

THE PREPARATION AND REACTIONS OF \( \alpha \)-HYDROXY- AND
\[ \alpha \]-ALKOXYALKYLIDENETRIPHENYLPHOSPHAZINES
INTRODUCTION

Phosphazines \( \underline{1} \) were first obtained from diazo compounds and tertiary phosphines \( \underline{1} \) (Equation 1). This method was subsequently employed to prepare a variety of triphenylphosphazines \( \underline{2} \) (2). The success of this method depends on the availability of the diazo compound.

A second and much later method for synthesis of triphenylphosphazenes \( \underline{2} \) (3, 2e, 12b) involves reaction of triphenyldibromophosphorane, hydrazones, and triethylamine or sodium amide in ammonia (Equations 2, 3).

\[
\begin{align*}
\text{(2)} & \quad \text{PBr}_2 + R\overset{\text{C = NH}_2 + \text{Et}_3\text{N}}{\xrightarrow{\text{R}}}
\end{align*}
\]

\[
\begin{align*}
\text{Br}^- & \quad \text{Br}^+ \quad \text{Et}_3\text{N or NaNH}_2/\text{NH}_3
\end{align*}
\]

Relatively recently (4) there have been developed in this laboratory two new methods for synthesis of phosphazines: (1) reaction of aminotriphenylphosphinimine with aldehydes and ketones in the presence of molecular sieves (Equation 4) and (2) reaction of hydrazintriphenylphosphonium bromide and aldehydes or ketones to

\[
\frac{2}{3}
\]
\[
\text{P = NNH}_2 + O = C<_{R, R'} \rightarrow \text{C}<_{R, R'} - \text{H}_2 \text{O}
\]
\[
\text{P = N-N = C}<_{R, R'} \frac{2}{3}
\]
give triphenylphosphininium bromides \( \frac{2}{3} \), which are subsequently treated with base (Equations 5, 6).

\[
[\text{Ph}_3\text{PNHNH}_2]^+\text{Br}^- + O = C<_{R, R'} \rightarrow [\text{Ph}_3\text{PN-N = C}<_{R, R'}]^+\text{Br}^- \frac{2}{3}
\]

\[
[\text{Ph}_3\text{PN = C}<_{R, R'}]^+\text{Br}^- \xrightarrow{\text{Base}} \text{Ph}_3\text{P=N=N = C}<_{R, R'} \frac{2}{3}
\]

\( \alpha \)-Hydroxybenzylidenetriphenylphosphazene \( \frac{2}{3} \) and its keto isomer, \( N \)-benzamidotriphenylphosphinimine \( \frac{2}{3} \) were obtained (4b, 5) in this laboratory from reactions of (1) triphenyldibromophosphorane,


benzhydrazide, and triethylamine in benzene-tetrahydrofuran (Equation 7), and (2) hydrazinotriphenylphosphonium bromide, pyridine, and

\[
\text{Ph}_3\text{PBr}_2 + \text{H}_2\text{NNHCPH} + \text{Et}_3\text{N} \xrightarrow{\text{PhH/THF 34%}} \text{Ph}_3\text{P=N=N = C}<_{\text{OH}} \frac{2}{3}
\]

benzoyl chloride to form \( N \)-benzamidotriphenylphosphiniminium bromide, followed by reaction with bases (Equations 8, 9, 10).
The purpose of the present study was to investigate possible methods for the synthesis of previously unknown triphenylphosphazenes 6, and to study their possible synthetic utility as Wittig reagents

\[
\text{Ph}_3\text{P}=\text{N}-\text{N}=\text{C}_\text{OMe} \quad \text{where } R = \text{H}, \text{alkyl}, \text{aryl}
\]

(Equation 11) and as precursors to (a) \(\alpha\)-methoxyphosphoranes 7, (b) \(\alpha\)-methoxyhydrazones 8, and (c) \(\alpha\)-methoxydiazo compounds 9 (Equations 12-14), the last two of which are also precursors to divalent carbon intermediates 10 (Equation 15). It was hoped that the chemistry of species such as 10 could be studied.

\[
\text{Ph}_3\text{P}=\text{N}-\text{N}=\text{C}_\text{OMe} + \text{R}^'\text{C}=\text{C} \quad \overset{-\text{Ph}_3\text{P}=\text{O}}{\text{R}''} \rightarrow \text{R}^'\text{C}=\text{N}-\text{N}=\text{C}_\text{OMe}
\]

(Equation 11)

\[
\text{Ph}_3\text{P}=\text{N}-\text{N}=\text{C}_\text{OMe} \quad \overset{\text{hv or } \Delta}{\text{R}} \rightarrow \text{Ph}_3\text{P}=\text{C}_\text{OMe}
\]

(Equation 12)
$$\text{Ph}_3\text{P}=\text{N}$$-\text{N}=\text{C} \xrightarrow{\text{hv or } \Delta} \text{R} \xrightarrow{\text{MeO}} \text{C} = \text{N} - \text{NH}_2$$

(13)

$$\text{Ph}_3\text{P}=\text{N}$$-\text{N}=\text{C} \xrightarrow{\text{H}_2\text{O}} \text{R} \xrightarrow{\text{CH}_3\text{O}} \text{C} = \text{N} - \text{NH}_2$$

(14)

$$\text{R} \xrightarrow{\text{N}_2} \text{C} = \text{N} - \text{NH}_2 \xrightarrow{\text{[0]}} \text{R} \xrightarrow{\text{H}_2\text{O}} \text{C} = \text{N}_2 \xrightarrow{-\text{N}_2} \text{R} \xrightarrow{\text{MeO}} \text{C}^+$$

(15)
HISTORICAL

Phosphazines have inherently polar ylidic phosphorus-nitrogen bonds (Equation 16). They are reactive towards both electrophilic and nucleophilic reagents (6). Phosphazines behave as bases in that

\[
\begin{align*}

\begin{align*}
\begin{array}{c}
\text{3} \\
\text{P=N-N=C} \quad \leftrightarrow \\
\text{R} \\
\text{RR}
\end{array}
\quad \leftrightarrow \\
\begin{array}{c}
\text{3} \\
\text{P - N - N = C} \\
\text{R} \\
\text{RR'}
\end{array}
\end{align*}
\]

\]

they react with dry hydrogen chloride to give salts from which they are regenerated by the action of stronger base (1, 2e, 7) (Equation 17).

\[
\begin{align*}
\text{(7) L. Horner and E. Lingnau, Ann., 591, 135 (1955).} \\

\begin{align*}
\begin{array}{c}
\text{3} \\
\text{P = N-N = C} \quad HCl/\text{CHCl}_3 \\
\text{R} \\
\text{RR'}
\end{array}
\quad \frac{\text{NaOH/CHCl}_3}{\text{}} \\
\begin{array}{c}
\text{3} \\
\text{P-N=N=C} \\
\text{R} \\
\text{RR'}
\end{array}
\quad \frac{\text{Br}^-}{+}
\end{align*}
\]

\]

7
Phosphazinium salts are usually stable toward moisture, unlike their parent phosphazines, which are hydrolyzed rather easily in either basic or acidic medium to produce triphenylphosphine oxide and hydrazones (1, 2e, 6) (Equations 18, 19).

\[
\phi_3^+ - N - N = C_{R \rightarrow R'} + \text{OH} \rightarrow H_2O
\]

\[
[\phi_3^+ - N - N = C_{R \rightarrow R'}] \rightarrow \phi_3P=O + R_{R'} \rightarrow C = N-NH_2 + \text{OH}
\]

(18)

\[
\phi_3^+ - N - N = C_{R \rightarrow R'} + H^+ \rightarrow [\phi_3^+ - N - N = C_{H \rightarrow R'}] \rightarrow H_2O
\]

\[
\phi_3^+ - N - N = C_{H \rightarrow R'} \rightarrow H^+ + R_{R'} \rightarrow C = N-NH_2 + \phi_3P=O
\]

(19)

Most phosphazines alkylate and acylate on α-nitrogen rather than on carbon to yield phosphiniminium salts (2e, 3) (Equations 20, 21), which can be hydrolyzed to triphenylphosphine oxide and hydrazones; upon further hydrolysis, hydrazine and ketones or aldehydes (2e) (Equation 22) are obtained.

\[
\phi_{3-P}^+ - N = C_{R \rightarrow R'} + R-X \rightarrow [\phi_{3-P} - N - N = C_{R \rightarrow R''}]^+X^-
\]

(20)
\[
\phi_3^+ P - N - N = C_{R}^{R'} + R''^O X \rightarrow [\phi_3 P - N - N = C_{R}^{R'} + X^-] + \phi_3 P O
\]

\[
[\phi_3 P - N - N = C_{R}^{R'} + X^-] + OH^- \rightarrow R_{R'}^C = N - N_{R''}^H + \phi_3 PO
\]

\[
H_3O^+ \rightarrow R_{R'}^C = O + R''^N NhNH_2
\]

Unlike other phosphazines, \(\alpha\)-ketotriphenyl phosphazenes react with methyl iodide to give cleavage products: \(\alpha\)-diazoo ketones and methyltriphenyl phosphonium iodide (2) (Equation 23).

\[
R - C \cdot - C = N - N = P\phi_3 + CH_3I \rightarrow RCCN_2R' + [\phi_3 PCH_3]^+ I^- \quad (23)
\]

To account for formation of \(\alpha\)-diazoo ketones, it was suggested that the phosphazines are in equilibrium with triphenylphosphine and the diazo compounds (2e) (Equation 24).

\[
R - C = N - N - P\phi_3 \leftrightarrow R - C - R' + P\phi_3 \quad (24)
\]

The position of equilibrium is highly influenced by the alkyl substituents and determines the course of the reaction of the phosphazine with methyl iodide. Strongly electronegative substituents, such as acyl groups, diminish the electron density around the
$\text{Ar}_3\text{P}^- - \text{N}^+ - \text{bond},$ weakening it, and shifting the equilibrium. Indeed, $\alpha$-ketotriphenylphosphazines in chloroform solution show a strong absorption band at 4.75 $\mu$m, a characteristic band of diazo compounds.

Phosphazines react with 2,4-dinitrofluorobenzene to give 2,4-dinitrophenylhydrazones and triphenylphosphine oxide (2e) (Equation 25).

$$\text{Ar}_3\text{P} = \text{N} - \text{N} = \underset{\text{R}}{\text{C}} + \underset{\text{NO}_2}{\text{O}} \quad 1. \text{abs MeOH} \quad \rightarrow \quad \text{Ar}_3\text{P} = \text{O}$$

$$+ \underset{\text{R'}}{\text{C} = \text{N} - \underset{\text{H}}{\text{H}}} \underset{\text{NO}_2}{\text{O}_2\text{N}}$$

(25)

Triphenylphosphazines undergo a Wittig-type (8) reaction with


carbonyl compounds to form azines (3a) (Equation 26). The reaction

$$\text{Ar}_3\text{P} = \text{N} - \text{N} = \underset{\text{R}}{\text{C}} + \underset{\text{H}}{\text{C} = \text{O}} \rightarrow \underset{\text{R'}}{\text{C} = \text{N} - \text{N} = \underset{\text{H}}{\text{C}}}$$

(26)

of ketenes with phosphazines, however, gives $\alpha$-iminonitriles instead of the expected ketene azines (2e) (Equation 27).

Nitroso compounds react with phosphazines in two ways. Nitrosobenzene affords triphenylphosphine oxide, nitrogen, and
benzophenone-anil (9) (Equation 28). Trifluoronitrosomethane gives

\[ \phi_3P = N - N = \phi\phi_2 + \phi-N = 0 \rightarrow \phi_2C = N\phi + N_2 + \phi_3P = 0 \]  

(28)

triphenylphosphinetrifluoromethylimine (10) (Equation 29).

\[ \phi_3P = N - N = CH_2 + O = N - CF_3 \rightarrow \phi_3P = NCF_3 + \text{other products} \]  

(29)

Dimethyl acetylenedicarboxylate adds to triphenylphosphazenes,
but the mode of addition is determined by the nature of the phosphazine. For example, dimethyl acetylenedicarboxylate adds to triphenylfluorenylidene phosphazine across the phosphorus-nitrogen
double bond, but adds to triphenylcarboalkoxylidenephosphazine across the carbon-nitrogen double bond \((11)\) (Equations 30, 31).

\[
\phi_3P = N - N = \begin{array}{c}
\text{phenyl}
\end{array} + H_3C\text{CO}_2\text{CC} \equiv \text{C-CO}_2\text{CH}_3 \rightarrow \phi_3P = \text{C(CO}_2\text{CH}_3)\text{-C(CO}_2\text{CH}_3) = \text{NN}
\]

\[
\phi_3P = N - N = \text{CHCO}_2\text{R} + H_3\text{CC} \equiv \text{CCH}_3 \rightarrow \phi_3P = \text{N - N = C} \begin{array}{c}
\text{H}
\end{array} \begin{array}{c}
\text{C}
\end{array} \begin{array}{c}
\text{CO}_2\text{R}
\end{array} \begin{array}{c}
\text{CO}_2\text{CH}_3
\end{array} \begin{array}{c}
\text{CO}_2\text{CH}_3
\end{array}
\]

The synthetic utility of phosphazines for generation of phosphoranes has been investigated \((1, 2a-b, 7, 12)\). Thermolysis of diphenylmethylenetriphenylphosphazine affords the corresponding phosphorane, along with triphenylphosphine and benzophenone azine.


(2a) (Equation 32), the phosphazine decomposes to diazodiphenylmethane,

\[ \phi_3P = N - N = C \quad \xrightarrow{190^\circ} \quad \phi_3P = \phi_2 \]

\[ \phi_3P + \phi \quad \xrightarrow{-N_2} \quad [\phi_2C] \quad \xrightarrow{\phi_2C=N_2} \quad \phi_2C=N-N=O \]

which loses nitrogen to give transient carbenic intermediates (12b). This is the only case reported where a phosphorane has been isolated from decomposition of a phosphazine. However, the intermediacy of phosphoranes is indicated in other systems. Thermolysis of methylenetriphenylphosphazine in the presence of cuprous chloride and benzophenone yielded 1,1-diphenylethylene and triphenylphosphine oxide quantitatively (12a) (Equation 33).

\[ \phi_3P = N - N = C \quad \xrightarrow{32\%} \quad \phi \quad \xrightarrow{31\%} \quad \phi_3P + Cu_2Cl_2 \quad \xrightarrow{4 \text{ hr}} \Delta \]

\[ \phi \quad C = CH_2 \quad \phi_3P = 0 \]

62\% 51\%

Triphenylphosphine, diazomethane, benzophenone, and cuprous chloride under similar conditions gave only 23% of the olefin.
The products of photolytic decomposition of phosphazenes can be rationalized by highly reactive divalent carbon intermediates (12b) (Equation 34).

\[ \phi_3 P = N - N = C \xrightarrow{\phi} \phi_3 C = N_2 \xrightarrow{\text{hv}} [\phi_2 C^+] \xrightarrow{\text{products}} (34) \]

The mass spectral fragmentation pattern exhibits three additional decomposition pathways for triphenylphosphazenes (13):

1. elimination of hydrogen cyanide (Equation 35);

\[ \phi_3 P = N - N = C \xrightarrow{H} \xrightarrow{-e^-} [\phi_3 P = NH]^+ + HCN \]  \hspace{1cm} (35)

2. loss of triphenylphosphine (Equation 36); or

\[ \phi_3 P = N - N = C \xrightarrow{C} \xrightarrow{-e^-} [N_2 CH - C - \phi]^+ + \phi_3 P \]  \hspace{1cm} (36)

3. ejection of nitrogen (Equation 37).

\[ \phi_3 P = N - N = C \xrightarrow{\phi} \xrightarrow{-e^-} [\phi_3 P = C \xrightarrow{\phi}]^+ + N_2 \]  \hspace{1cm} (37)

\(\alpha\)-Ketotriphenylphosphazenes have been utilized to synthesize \(\beta\)-ketoesters (2f) (Equation 38). Similarly, partial conversion of \(\alpha\)-diazo ketones to methyl ketones may be effected by use of
triphenylphosphazenes (2c) (Equation 39).

$$
\begin{align*}
\text{R-C-CH}_2\text{N}_2 + \text{PF}_3 & \rightarrow \text{PF}_3 = \text{N} - \text{N} = \text{CH}_2 \text{C R} \\
\text{R-C-CH}_2 = \text{NNH}_2 & \xrightarrow{\text{Base, } \Delta} \text{R - C - CH}_3
\end{align*}
$$

Phosphazenes have been utilized to synthesize α-ketoaldehydes by the action of nitrous acid (2g) (Equation 40).

$$
\begin{align*}
\text{R - C - CH} = \text{N - N} & \xrightarrow{\text{HNO}_2} \text{R - C - CHO + N}_2 + \text{N}_2\text{O} \\
\text{R C - CH} = \text{NNH}_2 & \xrightarrow{\text{HNO}_2} \text{R - C - CH}_2 = \text{NNH}_2
\end{align*}
$$

Similarly, α, β-diketoesters have been synthesized (2h) (Equation 41).

$$
\begin{align*}
\text{R - C - C - CO}_2\text{C}_2\text{H}_5 & \xrightarrow{\text{HNO}_2} \text{R - C - C - OCO}_2\text{C}_2\text{H}_5
\end{align*}
$$
RESULTS AND DISCUSSION

α-Hydroxybenzylidenetriphenylphosphazine has been prepared in 34% yield previously (4) by reaction of triphenyldibromophosphorane with benzhydrazide and triethylamine in benzene-tetrahydrofuran (Equation 42). However, cleavage of ethers and particularly

\[
\begin{align*}
\text{Ph}_3\text{PBr}_2 + \text{H}_2\text{NNHCPh} + 2\text{Et}_3\text{N} & \rightarrow \text{Ph} - \text{C} = \text{N} - \text{N} = \text{PPh}_3 \\
& + 2\text{Et}_3\text{NHBBr} \\
\end{align*}
\]

34%

89%
tetrahydrofuran by triphenyldibromophosphorane to yield bromides occurs readily (14) (Equation 43).

---


\[
\begin{align*}
\text{O} + \text{Ph}_3\text{PBr}_2 & \rightarrow \text{Ph}_3\text{P} = 0 + \text{Br} \quad 75.1\% \\
\end{align*}
\]

The low yield of α-hydroxybenzylidenetriphenylphosphazine in the previous work might result from competitive reactions of triphenyldibromophosphorane with tetrahydrofuran. Indeed, it has been presently found that when tetrahydrofuran is eliminated as a solvent— that is, benzhydrazide is added as a solid suspension of
triphenyldibromophosphorane and triethylamine in benzene--the yield of α-hydroxybenzylidenetriphenylphosphazine increases more than two-fold (Equation 44). When reaction is effected with p-tolylhydrazide (Y = CH₃), the yield of the expected phosphazine is 68%.

\[
\begin{align*}
Y & \text{CNHNNH}_2 + \text{Ph}_3\text{PBr}_2 + 2 \text{Et}_3\text{N} \overset{\text{benzene}}{\rightarrow} \text{Ph}_3\text{PNH}_2 \\
\text{Y} & \overset{\text{OH}}{\text{C}} = \text{N} - \text{N} = \text{Ph}_3\text{P} + 2\text{Et}_3\text{NHBr}
\end{align*}
\]

where Y = H, yield = 72%

Y = CH₃, yield = 68%

Unfortunately, extension of the above reaction to other benzhydrazides fails to give the desired products efficiently. p-Methoxybenzhydrazide appears to yield the desired α-hydroxy(p-methoxybenzyldene)triphenylphosphazine, but seems to react further either as an ether or as an alcohol yielding an additional phosphazine 11d or 12 (Equations 45, 46), which is inseparable from 11c.

\[
\begin{align*}
\text{PhPBr}_2 + \text{H}_2\text{NNH} & \overset{\text{2Et}_3\text{N}}{\rightarrow} 2\text{Et}_3\text{NHBr} \\
\text{Ph}_3\text{P} & = \text{N} - \text{N} = \text{C} \overset{\text{OMe}}{\text{O}} \text{Me}
\end{align*}
\]
\[
\text{Ph}_3\text{P} + \text{Ph}_3\text{PBr}_2 \xrightarrow{?} \text{Ph}_3\text{P} = N - N = \text{C} \quad \text{Br}
\]

or

\[
\text{Ph}_3\text{P} = N - N = \text{C} \quad \text{Br} \quad \text{OMe}
\]

\[\text{(46)}\]

p-Nitrobenzhydrazide gives a black mixture from which triphenylphosphine oxide and triethylammonium bromide are isolable.

The use of hydrazides and triphenyl dibromophosphorane for preparation of \(\alpha\)-hydroxyarylidenetriphenylphosphazines appears limited if there are complicating functional groups in the hydrazides.

A more general synthesis of \(\alpha\)-hydroxyarylidenetriphenylphosphazines has thus been developed as described in the following 3-step procedure: Preparation of hydrazinotriphenylphosphonium bromide from triphenyl dibromophosphorane, hydrazine, and triethylamine; acylation to the \(N\)-arylaminotriphenylphosphiniminium bromide; and dehydrobromination to \(\alpha\)-hydroxyarylidenetriphenylphosphazine (Equations 47, 48, 49).

\[\text{Ph}_3\text{PBr} + \text{NH}_2\text{NH}_2 + \text{Et}_3\text{N} \xrightarrow{\text{benzene}} \text{[Ph}_3\text{PNHNH}_2^+\text{Br}^- + \text{Et}_3\text{NHBr} \quad \text{(47)}\]

\[\text{[Ph}_3\text{PNHNH}_2^+\text{Br}^- + \text{Y} \xrightarrow{\text{benzene}} \text{[Ph}_3\text{PNHNHC} -\text{Y}^+\text{Br}^- \quad \text{(48)}\]

\[\text{[Ph}_3\text{PNHNHC} -\text{Y}^+\text{Br}^- + \text{Et}_3\text{N} \xrightarrow{\text{benzene}} \text{Ph}_3\text{P} = N - N = \text{C} \quad \text{OH} \quad \text{(49)}\]
Hydrazinotriphenylphosphonium bromide is a stable, storable reagent that can be prepared in large quantities. This reagent reacts in high yield with acyl chlorides in the presence of pyridine (15) to form N-acylamidotriphenylphosphiniminium bromides (see Table 1).

(15) Use of triethylamine as base gives a mixture of unreacted hydrazinotriphenylphosphonium bromide, phosphiniminium bromide, phosphazine, and 1,3,4-oxadiazole; see part II.

N-Arylamidotriphenylphosphiniminium bromides are quite stable under ambient conditions. They are easily dehydrobrominated upon treatment with triethylamine to yield substituted α-hydroxyarylidenedetriphenylphosphazines (Equation 49).

Substituted α-hydroxyarylidenedetriphenylphosphazines are stable, provided they are kept under nitrogen in the absence of moisture. Unlike other phosphazines, which are generally yellow, α-hydroxyarylidenedetriphenylphosphazines are white solids, except for the α-hydroxy(p-nitrobenzylidene) derivative. However, in solution, the phosphazines are colored; pale yellow in benzene and deep yellow in tetrahydrofuran and chloroform. Evaporation of the solvent gives back a white solid identical to starting material. These color changes suggest that α-hydroxyarylidenedetriphenylphosphazines exist in different tautomeric forms: (a) their enolic isomers, α-hydroxyarylidenedetriphenylphosphazine 13; (b) their closed forms, 3-aryl-1-triphenylphospha-2,4,5-oxadiazolines 14; or (c) their keto
<table>
<thead>
<tr>
<th>Acyl Chloride</th>
<th>Phosphininium Bromide Yield</th>
<th>Phosphazine Yield$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>H–C–O–CCl</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>H$_3$C–O–CCl</td>
<td>89</td>
<td>95</td>
</tr>
<tr>
<td>H$_3$CO–O–CCl</td>
<td>80.7</td>
<td>96</td>
</tr>
<tr>
<td>Cl–O–CCl</td>
<td>93.2</td>
<td>95</td>
</tr>
<tr>
<td>O$_2$N–O–CCl</td>
<td>81.3</td>
<td>97</td>
</tr>
<tr>
<td>CH$_3$CH$_2$CCl</td>
<td></td>
<td>61</td>
</tr>
<tr>
<td>CH$_3$CCl</td>
<td>57</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ Based on phosphininium bromide
isomers, N-arylamidotriphenylphosphinimines $15$ (Equation 50).

\[
\begin{align*}
Y - \text{C} = N - N & \equiv \text{PPh}_3 \\
\overset{13}{\downarrow} & \equiv \overset{14}{\uparrow} \\
Y - \text{C} \equiv \text{NHN} & \equiv \text{PPh}_3 \\
\overset{15}{\downarrow} & = \overset{12}{\uparrow}
\end{align*}
\]

where $Y = \text{H}, \text{CH}_3, \text{OCH}_3, \text{Cl}, \text{NO}_2$

The infrared spectra of the solid compounds obtained by dehydrobrominating N-arylamidotriphenylphosphiniminium bromides with triethylamine show no carbonyl peaks, thus tautomer $13$ or $14$ is the structure of the solid phosphazines. Tautomers $13$ and $14$ are indistinguishable in the infrared since (a) they both have $C=\text{N}$ (c. $6.25 \mu$), (b) they may contain either H-bonded OH ($13$) or NH ($14$) which absorb in the same regions ($2.96 \mu$), or (c) they have $\overset{\geq}{\text{P=\text{N}}} -$ ($13$) or $\overset{\geq}{\text{P-\text{N}}} -$ and $\overset{\geq}{\text{P-\text{O}}} -$ groups which absorb in very broad regions which overlap (16). The nmr spectra of the phosphazines suggest that in CDCl$_3$ solution, tautomer $13$ exists. It has been reported that $J_{\text{PNH}} = 10-30$ Hz (17) for a variety of phosphorus-nitrogen compounds. The observed absorption here is a broad singlet (width at half height $< 3$ Hz), thus in CDCl$_3$ solution, tautomer $14$ is less than
5%. The mass spectral fragmentation patterns of the solid compounds show both \( \text{Ph}_3\text{P-NH}^+ \) (m/e = 277) and \( \text{Ph}_3\text{P=O}^+ \) (m/e = 278), the former being more abundant. Thus, tautomer 15 cannot be excluded as a possible structure for the solid.

Upon heating solutions of the \( \alpha \)-hydroxyarylidenedetriphenylphosphazenes or prolonged storing of the solids, tautomer 15 is formed, as shown by the appearance of a carbonyl peak (c. 5.97 \( \mu \)) in the infrared spectrum and a change in melting point. It seems evident from the available data that the three tautomeric forms exist and are interconvertible. \( \alpha \)-Hydroxyarylidenedetriphenylphosphazine will be used in the dissertation as the general name for these compounds.

\( \alpha \)-Hydroxyarylidenedetriphenylphosphazenes react with acids to form their conjugate acids (Equation 51). The infrared spectra of these

\[
\begin{align*}
\text{Y} & \xrightarrow{\text{OH}} \text{C} = \text{N} - \text{N} = \text{PPh}_3 & & \xrightarrow{\text{HX}} & \text{Y} & \xrightarrow{\text{CNHNHPPh}_3} \text{X}^- (51)
\end{align*}
\]

where \( \text{Y} = \text{H}, \text{CH}_3, \text{OCH}_3, \text{Cl}, \text{NO}_2 \)

salts show carbonyl absorption peaks (5.90-6.05 \( \mu \)).

Previous studies have revealed that the nature of the phosphazine determines the path of its reaction with methyl iodide. \( \alpha \)-Ketophosphazenes (2c) are converted by methyl iodide to the diazo compound and
methyltriphenylphosphonium iodide (Equation 52). However, diarylphosphazenes are methylated on \(\alpha\)-nitrogen by methyl iodide yielding the phosphonium salts (3b, 4) (Equation 53).

\[
\begin{align*}
\text{R-CCH} & = N - N - \text{PPh}_3 + \text{CH}_3\text{I} \rightarrow \text{RCHN}_2 + [\text{Ph}_3\text{PCH}_3]^+\text{I}^- \\
\text{R-C} & = N - N = \text{PPh}_3 \xrightarrow{\text{CH}_3\text{I}/\Delta \text{ or CH}_3\text{I}/\text{EtOAc} / \Delta} \text{R-C} = N - N = \text{PPh}_3^+\text{I}^- 
\end{align*}
\]

(52)

(53)

In the present work, it was hoped that \(\alpha\)-hydroxybenzylidenetriphenylphosphazenes would react in yet a different pathway to yield \(\alpha\)-methoxyarylenetriphenylphosphazenes (Equation 54).

\[
\begin{align*}
\text{Y}=\text{O} & \xrightarrow{\text{OH}} \text{C} = N - N = \text{PPh}_3 \rightarrow \text{Y}=\text{O} & \xrightarrow{\text{CCH}_3} \text{C} = N - N = \text{PPh}_3
\end{align*}
\]

(54)

Addition of methyl iodide to a solution of \(\alpha\)-hydroxybenzylidene- triphenylphosphazene failed to give the desired \(\alpha\)-methoxybenzylidene- triphenylphosphazene. Solvents, reaction time, and temperature were varied. Instead, the reaction yielded a white precipitate of the phosphiniminium salt and unreacted phosphazene. The presence of \(\text{N}\text{-methyl-N-benzamidotriphenylphosphiniminium bromide}\_16\) is detectable in the nmr. Absorptions at 3.30 \& (\(\delta\), \(J = 10 \text{ Hz}\)) are very similar to those previously (3b) found for the methyl protons for \([\text{Ph}_3\text{PN-(CH}_3\text{)}\text{N=CR}_2]^+\text{X}^-\).

Methylation of \(\alpha\)-hydroxybenzylidenetriphenylphosphazene with diazomethane, methyl fluorosulfonate, and dimethyl sulfate, respectively, was then investigated. These methylating agents are
more reactive and thus less discriminating than is methyl iodide. Reaction of α-hydroxybenzylidenetriphenylphosphazine with these individual methylating agents gave many products. All attempts to separate these mixtures failed.

The apparent indiscriminate methylation of α-hydroxybenzylidenetriphenylphosphazine may be rationalized by reaction at various electron-rich sites in the phosphazine other than oxygen in the various tautomers.

α-Hydroxybenzylidenetriphenylphosphazine was then treated with n-butyllithium (Equation 56) to yield lithium salt 17. Methylation of 17 with methyl iodide also afforded product mixtures.

\[
\begin{align*}
\text{OH} & \\
\phi-C = N - N = \text{PPh}_3 & \xrightarrow{\text{p-BuLi}} \text{PhC} \xrightarrow{\text{OLi}} N - N = \text{PPh}_3
\end{align*}
\]

It was then evident that α-hydroxybenzylidenetriphenylphosphazine does not methylene to yield α-methoxybenzylidenetriphenylphosphazine cleanly, and thus another method was developed to obtain these products.

Hydrazine derivatives are known to react with orthoesters to form hydrazimidocarboxylate esters 18 (18,19) (Equations 57, 58).
\( \text{RNHN} = \text{C} \text{OR}^\text{n} \text{R}^\text{1} \text{8} \)

\( \alpha \)-Methoxybenzylidenetriphenylphosphazinium bromide, the hydrobromide salt of \( \alpha \)-methoxybenzylidenetriphenylphosphazaine, might be regarded as a hydrazimidocarboxylate ester \( \text{18} \), where \( R = \text{PPh}_3 \), \( R' = \text{Ph} \), and \( R'' = \text{CH}_3 \).

\[
\text{CH}_3\text{CNHNH}_2 + \text{H} - \text{C} - \text{OC}_2\text{H}_5 \rightarrow \text{CH}_3\text{CNHN} = \text{C} \text{OC}_2\text{H}_5
\]

\( \text{57} \)

\[
\text{H}_3\text{C} - \text{O} - \text{SNHNH}_2 + \text{R} - \text{C} - \text{OC}_2\text{H}_5 \rightarrow \text{H}_3\text{C} - \text{O} - \text{SNHN} = \text{C} \text{OC}_2\text{H}_5
\]

\( \text{58} \)

In the present study, hydrazinotriphenylphosphonium bromide was treated with excess trimethyl orthobenzoate in methanol for 3 weeks to yield \( \alpha \)-methoxybenzylidenetriphenylphosphazinium bromide (Equation 59).

\[
\text{OC}(\text{OCH}_3)_3 + \left[ \text{H}_2\text{NNNH} \text{PPh}_3 \right]^+ \text{Br}^- \rightarrow \left[ \begin{array}{c} \text{Ph} \\ \text{H}_3\text{C} \end{array} \right] = \text{NNHPPPh}_3 \right]^+ \text{Br}^-=
\]

\( \text{59} \)

Addition of acid (trifluoroacetic acid) does not influence the rate of conversion to \( \text{19} \). Heating or addition of base (triethylamine) accelerate reaction to give \( \text{19} \), but complicating by-products are formed. As yet only reaction at room temperature without any catalyst...
### TABLE 2
**TRIPHENYLPHOSPHAZINIUM SALTS FROM HYDRAZINO(TRIPHENYLPHOSPHONIUM BROMIDE AND TRIMETHYL ORTHOESTERS**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Structure</th>
<th>Yield, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td><img src="structure19.png" alt="Structure" /></td>
<td>87.5</td>
</tr>
<tr>
<td>20</td>
<td><img src="structure20.png" alt="Structure" /></td>
<td>88.9</td>
</tr>
<tr>
<td>21</td>
<td><img src="structure21.png" alt="Structure" /></td>
<td>84</td>
</tr>
</tbody>
</table>
gives reasonably pure product.

Reaction of trimethyl orthoacetate with hydrazinotriphenylphosphonium bromide in methanol gives \( \alpha \)-methoxyethylenetriphenylphosphazinium bromide \( \text{20} \) (Equation 60). Likewise, treatment of

\[
\begin{align*}
\text{CH}_3\text{-C} & \quad \text{CH}_3 + \left[\text{H}_2\text{NNHPPH}_3\right]^+ \text{Br}^- \quad \text{HOCH}_3 \\
\text{OCH}_3 & \quad \text{OCH}_3
\end{align*}
\]

\( \text{20} \)

\[
\left[ \begin{array}{c}
\text{CH}_3 \\
\text{OCH}_3
\end{array} \right] \text{C} = \text{N} - \text{N} - \text{PPh}_3 \\
\text{H} \quad \text{Br}^-
\]

hydrazinotriphenylphosphonium bromide with trimethyl orthoformate in methanol yields \( \alpha \)-methoxymethylenetriphenylphosphazinium bromide \( \text{21} \) (Equation 61) (Table 2).

\[
\begin{align*}
\text{H} - \text{C} & \quad \text{OCH}_3 + \left[\text{H}_2\text{NNHPPH}_3\right]^+ \text{Br}^- \quad \text{CH}_3\text{OH} \\
\text{OCH}_3 & \quad \text{OCH}_3
\end{align*}
\]

\( \text{21} \)

\[
\left[ \begin{array}{c}
\text{H} \\
\text{OCH}_3
\end{array} \right] \text{C} = \text{N} - \text{N} - \text{PPh}_3^+ \text{Br}^-
\]

This method of preparation of \( \alpha \)-methoxyalkyldenedetriphenylphosphazinium bromides appears to be quite efficient. Extension of this method to other orthoesters would yield a variety of \( \alpha \)-alkoxyalkyldenedetriphenylphosphazinium and \( \alpha \)-alkoxyaryldenedetriphenylphosphazinium bromides \( \text{22} \).

\[
\left[ \begin{array}{c}
\text{C} = \text{N} - \text{N} - \text{PPh}_3 \\
\text{R'O}
\end{array} \right] \text{Br}^- \\
\text{22}
\]

where \( \text{R} = \text{H}, \text{alkyl}, \text{aryl} \)

\( \text{R'} = \text{alkyl} \)
A probable mechanism for reaction of orthoesters with hydrazinotriphenylphosphonium bromide to give phosphazinium salts is summarized in Equations 62 - 66, and is analogous to that proposed earlier (19a) for the formation of ester p-tosylhydrazones.

\[
\begin{align*}
[\text{Ph}_3\text{PNHNH}_2]^+\text{Br}^- & \iff \text{Ph}_3\text{P} = \text{NNH}_2 + \text{Br}^- + \text{H}^+ \\
\text{H}^+ + R - C - \text{OR}' & \iff R - C - \text{OR}' + \text{OR}' \\
R - C - \text{OR}' & \iff \left[ \begin{array}{c} 
R \\
\text{OR}' \\
\text{OR'}
\end{array} \right]^+ + \text{R'OH} \\
\left[ \begin{array}{c} 
R \\
\text{OR}' \\
\text{OR'}
\end{array} \right]^+ + \text{H}_2\text{NNHPPPh}_3 \text{Br}^- & \iff \text{H}^+ \left[ \begin{array}{c} 
R \\
\text{OR}' \\
\text{NNHPPPh}_3
\end{array} \right]^+ \\
\left[ \begin{array}{c} 
R \\
\text{OR}' \\
\text{NNHPPPh}_3
\end{array} \right]^+ \text{Br}^- & \iff R - C = N - \text{NNHPPPh}_3\text{Br}^- + \text{R'CH}
\end{align*}
\]

The triphenylphosphazinium bromides 19-21 obtained in this study exist in syn and anti forms as indicated by the presence of two nmr signals for their methoxyl protons (see Table 3). Syn and anti isomers have been previously observed for ester p-tosylhydrazones (19), and other hydrazones (20). The syn protons always resonate downfield from the corresponding anti protons (21). Reaction (in methanol)
TABLE 3
CHEMICAL SHIFTS FOR THE METHOXY PROTONS OF THE SYN AND ANTI ISOMERS OF TRIPHENYLPHOSPHAZINIUM BROMIDES \(19 - 21\), USING TETRAMETHYLSILANE AS STANDARD.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Structure</th>
<th>(\text{syn}(\delta)) (CDCl(_3))</th>
<th>(\text{anti}(\delta)) (CDCl(_3))</th>
<th>ratio(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>(\text{PhC} = N - N^+_{\text{H}} - \text{PPPh}_3\text{Br}^-)</td>
<td>3.95</td>
<td>3.64</td>
<td>5:2</td>
</tr>
<tr>
<td>20</td>
<td>(\text{CH}<em>3\text{C} = N - N^+</em>{\text{H}} - \text{PPPh}_3\text{Br}^-)</td>
<td>3.90</td>
<td>3.41</td>
<td>1:1</td>
</tr>
<tr>
<td>21</td>
<td>(\text{H} - \text{C} = N - N^+_{\text{H}} - \text{PPPh}_3\text{Br}^-)</td>
<td>3.53</td>
<td>3.32</td>
<td>2:1</td>
</tr>
</tbody>
</table>

\(^a\) From reaction before recrystallization
affords the syn isomer as the major product, but recrystallization from methanol-ethyl acetate give predominantly the anti isomer.

The α-methoxyalkylidenetriphenylphosphazinium bromides are white, hygroscopic compounds, which are storable in the absence of moisture for extended periods. Under atmospheric conditions or in wet solvents, these reagents hydrolyze rather easily. α-Methoxymethylene-triphenylphosphazinium bromide 21 hydrolyzes the fastest among the three phosphazinium salts 19 - 21 prepared. The hydrolysis may be followed by the appearance of an infrared carbonyl absorption (5.9 - 6.05 μ). The hydrolyses yield the more stable N-acylamidotriphenylphosphiniminium bromides prepared earlier in this work. The mechanism of hydrolysis may occur as envisaged in Equations 67 - 69.
The triphenylphosphazinium bromides 19 - 21 upon treatment with bases afford their conjugate base, the α-methoxyalkylidenetriphenylphosphazines 22 - 24 (Equation 70).

\[
\begin{align*}
\text{Ph}_3\text{P}^+ \text{NHNH}_2 \text{C} - \text{R} & \rightleftharpoons \text{Ph}_3\text{PNHNHC}^+ \text{R} \\
& \text{Br}^- \\
& \text{H}^+ + \text{CH}_3\text{OH}
\end{align*}
\]  

(69)

\[
[\text{Ph}_3\text{PNN}_\text{H} = \text{C}^+ \text{OCH}_3_\text{R}] \text{Br}^- \xrightarrow{\text{Base}} \text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C}^\text{OCH}_3_\text{R}
\]

(70)

where 

<table>
<thead>
<tr>
<th>R</th>
<th>22</th>
<th>23</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ph</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The bases employed are triethylamine, tetramethylguanidine, basic alumina, and sodium hydroxide in chloroform (two phases). Each gives a yellow oil that exhibits the same ir spectrum as α-methoxyalkylidenetriphenylphosphazine (see Appendix ). Again syn and anti isomers of α-methoxyalkylidenetriphenylphosphazines are indicated by the presence of two methoxyl protons in the nmr. These phosphazines are highly reactive and must be prepared immediately before use.

α-Methoxybenzylidenetriphenylphosphazine in benzene was treated with hydrogen chloride gas under ambient conditions to give N-benzamidotriphenylphosphiniminium chloride. α-Methoxybenzylidenetriphenylephosphazine is envisaged to react with hydrogen chloride to give its conjugate acid which then undergoes hydrolysis affording the observed product (Equation 71).
Triphenylphosphazenes have been reported to undergo reactions of the Wittig type with aldehydes to give azines (3a) (Equation 72).

\[
\text{Ph}_3\text{P} = \text{N} = \text{N} = \text{C} \quad + \quad \text{O} = \text{C} \quad \rightarrow \quad \text{Ph}_3\text{P} = \text{O}
\]

(72)

In the present study, \(\alpha\)-methoxybenzylidenetriphenylphosphazene and \(p\)-nitrobenzaldehyde have been found to yield the expected azine \(25\) in excellent yield (96\%) (Equation 73).

\[
\text{Ph}_3\text{P} = \text{N} = \text{N} = \text{C} \quad + \quad \text{O}_2\text{N} - \text{OCH}_3
\quad \rightarrow \quad \text{Ph}_3\text{P} = \text{O} + \text{O}_2\text{N} - \text{C} = \text{N} - \text{N} = \text{C} \quad (25)
\]

(73)

The structure of azine \(25\) has been proven by its acid catalyzed hydrolysis to the known benzoylhydrazone \(26\) (Equation 74).

\[
\text{O}_2\text{N} - \text{C} = \text{N} - \text{N} = \text{C} \quad \text{OCH}_3
\quad \rightarrow \quad \text{O}_2\text{N} - \text{C} = \text{N} - \text{NCPh}
\]

(74)

Likewise, \(p\)-methoxybenzaldehyde reacts with \(\alpha\)-methoxybenzylidenetriphenylphosphazene to give the corresponding azine \(27\) (74\%) (Equation 75).

\[
\text{H}_3\text{CO} - \text{O} + \text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \quad \text{OCH}_3
\quad \rightarrow \quad \text{H}_3\text{CO} - \text{O} \quad \text{C} = \text{N} - \text{N} = \text{C} \quad (27)
\]

(75)
Extension of the above reactions to other $\alpha$-methoxyalkyldenetriphenyl-phosphazenes and other carbonyl compounds (Equation 76) provides a new

$$\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \overset{\text{OCl}_3}{\text{R}} \quad + \quad \overset{\text{R'}}{\text{R''}} \text{C} = \text{O} \quad \rightarrow \quad \overset{\text{R}}{\text{R''}} \text{C} \text{N} - \text{N} = \text{C} \overset{\text{R}}{\text{R''}}$$

(76)

where $\text{R}$, $\text{R}'$, $\text{R}'' = \text{H}$, alkyl, aryl

and valuable method for the synthesis of methoxy azines 28. Some limitations for this general synthesis exist. For example, treatment of $\alpha$-methoxybenzylidenetriphenylphosphazene with fluorenone fails to yield any of the desired azine 29. Unreacted fluorenone is recovered quantitatively. This failure to react may be due to (a) steric hindrance and/or (b) lesser reactivity of fluorenone as compared to aldehydes.

$$\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \overset{\text{OCH}_3}{\text{Ph}} \quad + \quad \overset{\text{O}}{\text{Ph}} \quad \rightarrow \quad \overset{\text{C} = \text{N} - \text{N}}{\text{Ph}}$$

(77)

Phosphazenes are hydrolyzed to triphenylphosphine oxide and hydrazones (1, 2e, 6) (Equation 78). In the present study, it was hoped

$$\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \overset{\text{R}}{\text{R'}} \quad \rightarrow \quad \text{Ph}_3\text{P} = \text{O} + \overset{\text{R}}{\text{R'}} \text{C} = \text{NNH}_2$$

(78)
that the hydrolysis of α-methoxybenzylidenetriphenylphosphazene would afford methyl benzoate hydrazone \( \text{8a} \), which might then be oxidized by lead tetraacetate (22), silver (I) oxide (23), manganese dioxide (24), or mercuric oxide (25) to methoxyphenylidazomethane \( \text{(31)} \), a precursor to

\[
\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \overset{\text{Ph}}{\text{OCH}_3} \xrightarrow{\text{H}_2\text{O}} \text{Ph}_3\text{P} = \text{O} + \text{Ph} \overset{\text{H}_3\text{CO}}{\text{C} = \text{N} - \text{NH}_2} \text{8a}
\]

products \( \leftarrow [\text{Ph} \overset{\text{N}}{\text{N} = \text{Ph}} \overset{\text{H}_3\text{CO}}{\text{C} = \text{N}_2}] \leftarrow \text{Ph} \overset{\text{H}_3\text{CO}}{\text{C} = \text{N}_2} \leftarrow [\text{0}]
\]

\[
\text{34} \quad \text{31}
\]

Hydrolysis of α-methoxybenzylidenetriphenylphosphazene fails to give isolable methyl benzoate hydrazone \( \text{8a} \); rather, 1,2-dihydro-3,6-diphenyl-1,2,4,5-tetrazine is obtained in 37% yield. The dihydrotetrazine is oxidized easily to 3,6-diphenyl-1,2,4,5-tetrazine by air and by dichlorodicyanoquinone (Equations 80, 81).

\[
\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \overset{\text{Ph}}{\text{OCH}_3} \xrightarrow{\text{H}_2\text{O}} \text{Ph} \overset{\text{EtOH}}{\text{C} = \text{N} - \text{N} = \text{Ph}}
\]

(22) T. C. Holton, Ph.D. Dissertation, The Ohio State University, 1971.
1,2-Dihydro-3,6-diphenyl-1,2,4,5-tetrazine may be envisaged to arise from (a) hydrolysis of α-methoxybenzylidenetriphenylphosphazine to the desired methyl benzoate hydrazone $8a$, (b) reaction of the hydrazone with the most nucleophilic agent in the reaction mixture, itself, and (c) elimination of 2 equivalents of methanoic (Equations 82, 83).

\[
\begin{align*}
\text{Ph} & \quad \text{N} \quad \text{N} \quad \text{Ph} \quad \xrightarrow{\text{DDQ} \quad -2\text{H}} \quad \text{Ph} \quad \text{O} \quad \text{N} \quad \text{N} \quad \text{Ph} \\
\text{H}_3\text{CO} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{OCH}_3 & \quad \xrightarrow{\text{H}_2\text{O}} \quad \text{Ph} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{H}_2\text{O} + \text{Ph}_3\text{PO} \\
\text{H}_3\text{CO} & \quad \text{C} \quad \text{N} \quad \text{H}_2\text{NH}_2 & \quad \xrightarrow{\text{H}_3\text{CO}} \quad \text{Ph} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{H} \quad \text{H}_2\text{N} \quad \text{NH} \quad \text{CCH}_3 \\
\text{H}_3\text{CO} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{OCH}_3 & \quad \xrightarrow{\text{CH}_3\text{OH}} \quad \text{Ph} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{Ph} \\
\text{H}_3\text{CO} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{Ph} & \quad \xrightarrow{\text{CH}_3\text{OH}} \quad \text{Ph} & \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{Ph} \\
\end{align*}
\]

The failure to isolate methyl benzoate hydrazone $8a$ might be due to its sensitivity towards nucleophilic attack. Further study of this system is warranted.

α-Methoxybenzylidenetriphenylphosphazine upon storage as a neat
oil turns magenta. Chromatography affords 3,6-diphenyl-1,2,4,5-tetrazine (Equation 84). The formation of the tetrazine may be

\[
\text{Ph}_3\text{CO} \quad \text{C} = \text{N} - \text{N} \equiv \text{PPh}_3 \xrightarrow{24^h} \quad \text{Ph} \quad \text{N} - \text{N} \quad \text{Ph}
\]

rationalized by hydrolysis, as above, of the phosphazine \(24^h\) and subsequent autoxidation to the observed product.

Previous workers have shown that triphenylphosphazines decompose thermally and photochemically to triphenylphosphoranes and nitrogen \((2a)\), azines, triphenylphosphine, and triphenylphosphine oxide \((2a, 4)\), and products rationalizable by the intermediacy of carbenes \((12b)\) (Equations 85 - 87). In this present study it was hoped that thermolysis

\[
\text{Ph}_3\text{P} = \text{N} - \text{N} \equiv \text{C} \quad \text{Ph} \quad \xrightarrow{\Delta} \quad \text{Ph}_3\text{P} = \text{C} \quad \text{Ph} \quad + \text{N}_2 \quad \text{(85)}
\]

\[
\xrightarrow{\Delta, \text{hv}} \quad \text{Ph}_2\text{C} = \text{N} - \text{N} \equiv \text{CPh}_2 \quad \text{(86)}
\]

\[
\xrightarrow{\text{hv}} \quad \text{Ph}_2\text{C} = \text{N}_2 \rightarrow \text{Ph}_2\text{C} + \quad \text{(87)}
\]

and/or photolysis of \(\alpha\)-methoxybenzylidenediethylphosphazine would yield \(\alpha\)-methoxybenzylidenediethylphosphorane \(30\) (Equation 88) or \(\alpha\)-methoxyphenyldiazo methane \(31\) (Equation 89). Phosphoranes such as \(30\) could then be treated with carbonyl compounds in a Wittig-type reaction to yield enolic ethers such as \(32\), whereas \(\alpha\)-methoxydiazo
The reaction of triphenylphosphine with nitrogen dioxide in the presence of light gives the following products: 

\[ \text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \xrightarrow{hv/\Delta} \text{Ph}_3\text{P} = \text{C} - \text{OCH}_3 + \text{N}_2 \]  

\[ \text{Ph}_3\text{P} = \text{C} - \text{Ph} \xrightarrow{hv/\Delta} \text{Ph}_3\text{P} + \text{Ph} - \text{C} - \text{OCH}_3 \]

\[ \text{compound } \text{32 could be a convenient source of methoxy carbene } \text{34} \]

and/or its subsequent products.

\[ \text{Ph} - \text{C} - 0\text{CH}_3 \xrightarrow{N_2} \text{Ph} - \text{C} = 0\text{CH}_3 \rightarrow \text{products} \]

Vacuum thermolysis of \( \alpha \)-methoxybenzylidene triphenylphosphazene yields a solid residue composed primarily of triphenylphosphine (96%) and a volatile fraction (48.5% assumed stoichiometry overall yield). The volatile fraction on separation by vpc consists of benzaldehyde (60 mole %), acetophenone (19%), methyl benzoate (7.6%), methanol (5.3%), toluene (5%), benzaldehyde dimethyl acetal (6.2%), and formaldehyde (8.7%). Methoxyphenylidiazomethane as yet has not been detected.

\[ \text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \xrightarrow{hv/\Delta} \text{Ph}_3\text{P} + \text{PhCH} + \text{Ph} - \text{C} - \text{OCH}_3 + \text{PhCOCH}_3 \]

\[ + \text{HOCH}_3 + \text{PhCH}_3 + \text{PhCH}(\text{OCH}_3)_2 + \text{HCH} \]
A probable mechanism for thermolysis of 2\(\text{a}\) is (a) decomposition to triphenylphosphine and \(\alpha\)-methoxyphenylidiazomethane 33 (Equation 93), and (b) further decomposition of the diazo compound to methoxyphenyl carbene 34 (Equation 94), and subsequent rearrangement and fragmentation of the unstable carbene (Equation 95). Methyl benzoate, a minor product,

\[
\text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \quad \text{OCH}_3 \quad \text{Ph} \quad \text{Ph}_3\text{P} + \quad \text{Ph} \quad \text{H}_9\text{CO} \quad \text{C} = \text{N}_2
\]
\[
2\text{a} \quad 33
\]

\[
\text{Ph} \quad \text{C} = \text{N}_2 \quad \text{Ph} - \quad \text{C} \quad \text{OCH}_3
\]
\[
\text{Ph} \quad \text{C} \quad \text{OCH}_3 \quad \text{products}
\]

probably arises from reaction of \(\alpha\)-methoxyphenylidiazomethane and/or \(\alpha\)-methoxyphenyl carbene with traces of oxygen in the reaction mixture. Oxygen trapping is known to occur in other diazo and carbenic systems; reaction of carbenes with oxygen is believed to involve triplet processes (26).

(26) W. Kirmse, "Carbene, Carboide und Carbenanaloge," Verlag Chemie, Weinheim (Germany), 1969.

The other products are envisaged to arise from intramolecular rearrangement and/or insertions. Rearrangement of methoxyphenyl carbene 34 by migration of the methyl group gives acetophenone (Equation 96). Similar rearrangements of other \(\alpha\)-methoxycarbenes 35.
have been observed (27) from decomposition of sodium salts of ester

(27) R. V. Hoffmann, private communication, The Ohio State University, Columbus, Ohio.

p-tosyl hydrazones (Equation 97), but in small yields.

\[
\begin{align*}
\text{Ph} - & \xrightarrow{\Delta} \text{CH}_3 \\
\xrightarrow{\text{O}} & \text{Ph} \quad \text{CCH}_3
\end{align*}
\]

(96)

Alkoxy carbones 36 are isoelectronic with azo compounds 37 and thus these two classes of compounds may have similar chemical properties. Azo compounds are known (28) to eliminate nitrogen to give alkanes by concerted bond breakage to radicals which may recombine and by cage reactions (Equations 98, 99). By analogy, methoxyphenylcarbene may (a) fragment stepwise into methyl and benzoyl
\[ R - N = N - R' \quad \longrightarrow \quad N_2 + R' + R' \quad \longrightarrow \quad \text{products} \quad (98) \]
\[ R - N = N - R' \quad \longrightarrow \quad R - R' + N_2 \quad (99) \]

and then phenyl radicals \((\text{Equation } 100)\), \((b)\) lose carbon monoxide with concerted bond breakage to give phenyl and methyl radicals \((\text{Equation } 101)\), and/or \((c)\) lose carbon monoxide in a cage-like process to give toluene \((\text{Equation } 102)\). Hydrogen abstraction by benzoyl

\[
\begin{align*}
\text{Ph} - \overset{\ddagger}{C} = \overset{\circ}{O} - \text{C}_6\text{H}_5 \quad &\longrightarrow \quad \cdot \text{CH}_3 + \overset{\circ}{\text{PhC}=\text{O}} \quad \leftarrow \quad \text{PhC} = \overset{\circ}{O} \\
&\quad \downarrow \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \ qua

\text{Ph} - \overset{\ddagger}{C} = \overset{\circ}{O} - \text{C}_6\text{H}_5 \quad \longrightarrow \quad \text{CO} + \overset{\circ}{\text{Ph}} + \cdot \text{CH}_3 \\
\text{Ph} - \overset{\ddagger}{C} = \overset{\circ}{O} - \text{C}_6\text{H}_5 \quad \longrightarrow \quad \text{Ph} - \cdot \text{CH}_3 + \text{CO} \quad (102) \]

radical will yield benzaldehyde, recombination of methyl and phenyl radicals will give toluene, whereas reaction of methyl radical with oxygen will give methanol and formaldehyde \((28)\).

Another fragmentation pattern for methoxyphenylcarbene, as implicitly suggested earlier \((19a)\) in decomposition of methyl benzoyl p-tosylhydrazone, is collapse to phenylcarbene \((38)\) and formaldehyde via intramolecular hydrogen transfer \((\text{Equation } 103)\). Subsequent

\[
\text{Ph} - \overset{\ddagger}{C} \quad \text{O} \quad \overset{\circ}{-} \quad \text{C} - \text{H} \quad \longrightarrow \quad \text{Ph} - \overset{\ddagger}{C} - \text{R} + \text{H}_2\text{C} = \text{O} \quad (103) \]

oxygen trapping of phenylcarbene can give benzaldehyde \((\text{Equation } 104)\).

\[
\text{Ph} \quad \overset{\ddagger}{\text{C}} \quad + \quad \overset{\circ}{\frac{1}{2} \text{O}_2} \quad \longrightarrow \quad \text{PhCH} \quad (104) \]
Benzaldehyde dimethyl acetal might arise from reaction of methoxyphenylcarbene with methanol formed (Equation 105) or from benzaldehyde and methanol (Equation 106).

\[
\begin{align*}
\text{Ph} & - \overset{+}{\text{C}} - \text{OCH}_3 + \text{HOCH}_3 \rightarrow \text{Ph} \overset{\text{OCH}_3}{\text{C}} \text{OCH}_3 \\
\text{PhCH} + \text{HOCH}_3 & \rightarrow \text{Ph} \overset{\text{H}}{\text{C}} - \text{OCH}_3
\end{align*}
\]

(105)  

(106)

A limited study has been made of photolysis of \(\alpha\)-methoxybenzylidenetriphenylphosphazine in cyclohexane, using a 450 watt Hanovia medium pressure lamp through Pyrex. The reaction yields benzaldehyde (22.2%), benzyl methyl ether (22.8%), methyl benzoate (5.8%), other volatile products, and triphenylphosphine oxide (94%) (Equation 107).

\[
\text{Ph}_3\text{P} \rightleftharpoons N - N = \text{C} \overset{\text{OCH}_3}{\text{Ph}} \overset{\text{hv}}{\rightarrow} \overset{\text{O}}{\text{PhCH}} + \text{PhCH}_2\text{OCH}_3 + \text{PhCOCH}_3 \\
\text{+ Ph}_3\text{P}=\text{O} \text{ + volatile products}
\]

(107)

The photolysis products possibly arise from molecular fragmentation of the phosphazine to triphenylphosphine and diazo compound and subsequent reaction processes (Equation 108). Such a process is

\[
\text{Ph}_3\text{P} \rightleftharpoons N - N = \text{C} \overset{\text{OCH}_3}{\text{Ph}} \rightarrow \text{Ph}_3\text{P} + \text{Ph} \overset{\text{N}_2}{\text{C}} \text{OCH}_3 \rightarrow \text{products}
\]

(108)

\[
\text{Ph}_3\text{P} \rightleftharpoons N - N = \text{C} \overset{\text{Ar}}{\text{Ar}} \rightarrow \text{Ph}_3\text{P} + \text{Ar} \overset{\text{N}_2}{\text{C}} \text{Ar} \rightarrow \text{products}
\]

(109)

analogous to photolytic decomposition of diaryltriphenyolphosphazines previously reported (125), in which triphenylphosphine and
triphenylphosphine oxide were isolated and products rationalizable from the intermediate diazo compounds and/or their subsequent carbenes obtained (Equation 109).

Triphenylphosphine obtained in the present photolytic study is apparently trapped by oxygen to give triphenylphosphine oxide (Equation 110). Such oxygen trapping has been reported in earlier work (12b), and it has been presently found that it is extremely difficult to remove all oxygen from the present small scale highly dilute photochemical experiments.

Methoxyphenylidiazomethane is subsequently decomposed presumably to carbene 3\(\text{a}^1\), as in the thermolytic decomposition. In the photochemical system, in addition to benzaldehyde and methyl benzoate, benzyl methyl ether is produced (Equation 111). This ether possibly arises from reaction of excited \(\alpha\)-methoxyphenylidiazomethane 3\(\text{a}^1\) and/or \(\alpha\)-methoxyphenylcarbene 3\(\text{a}^1\) with solvent by hydrogen abstraction (Equation 112).

\[
\begin{align*}
\text{Ph} &\quad \text{C} = \text{N}_2 \quad \text{hv} \quad \text{Ph} &\quad \text{C} : \\
\text{OCH}_3 &\quad &\text{OCH}_3 &\quad \text{PhCCH} \\
\text{Ph} &\quad \text{C} &\quad \text{O}_2 &\quad \text{PhCOCH}_3 \\
\text{OCH}_3 &\quad &\text{[2H]} &\quad \text{PhCH}_2\text{OCH}_3 \\
\end{align*}
\]

\[
\begin{align*}
\text{Ph} &\quad \text{C} = \text{N}_2 , \quad \text{Ph} &\quad \text{C} : \\
\text{OCH}_3 &\quad &\text{OCH}_3 &\quad \text{PhCOCH}_3 &\quad \text{SH} &\quad \text{Ph} &\quad \text{C} &\quad \text{CH}_2 \\
\text{H} &\quad &\text{OCH}_3 &\quad &\text{OCH}_3 &\quad &\text{OCH}_3 \\
\end{align*}
\]

(110)
Thermal and photolytic decomposition of α-alkoxyaryldenetriphenylphosphazenes thus appear to lead to interesting chemistry of alkoxycarbenes and their precursors. Further investigation of these systems is warranted to understand fully their molecular rearrangements and fragmentations and to learn about the electronic multiplicity of the divalent carbon intermediates.
EXPERIMENTAL

General Information

Melting points Melting points were determined either on a Fisher-Johns melting point block or a Thomas Hoover apparatus (uncorrected).

Analyses Analyses were performed by Micro-Analysis, Inc., of Wilmington, Delaware, and Chem-Analysts of Tempe, Arizona.

Chemicals and solvents Benzene, reagent grade, was distilled over lithium aluminum hydride and stored over molecular sieves before use. Triethylamine, pyridine, and tetramethylguanidine were distilled over barium oxide and stored over molecular sieves before use. Methanol and 2-propanol were distilled over magnesium wire immediately before use. Ethyl acetate and the various aldehydes and ketones were dried over molecular sieves.

Infrared spectra All spectra were obtained on a Perkin-Elmer Infracord Spectrophotometer. Potassium bromide pellets were employed for solids, and liquids were scanned neat between sodium chloride plates.

Mass spectra Mass spectra were taken on an AEI MS902 double focusing mass spectrometer.

nmr The nmr of various products were determined on Varian A-60 and A60-A, or Jeol Co. MH100 instruments using dilute chloroform-d or dimethyl sulfoxide-d6 solutions, with tetramethylsilane as
the internal standard.

Gas chromatography Gas chromatography was used for product identification and determination of product composition. The instruments employed were an F and M Scientific 720 Dual Column Programmed Temperature Gas Chromatograph, equipped with a hot-wire detector and connected to a 1.25 millivolt full scale deflection Honeywell recorder and an Aerograph A-90, equipped with a hot-wire detector, connected to a one millivolt full-scale deflection series SR Sargent recorder. The columns used were Carbowax 20M on Chromsorb W, 16 ft x \(\frac{1}{4}\) in, and 20\% SE-30 on 60/80 Chromsorb W, 10 ft x \(\frac{1}{4}\) in. The carrier gas was helium.

Volatile products were identified by comparison of their gas chromatographic retention times to those of authentic samples. Product compositions were determined by comparing peak areas (29). Absolute yields were checked both by use of an internal standard and measuring the peak areas of a weighed amount of standard vs that of a weighed amount of sample.


Recrystallization α-Methoxyalkyldenetriphenylphosphazinium bromides were recrystallized from methanol-ethyl acetate without external heating.
Preparation of N-Acylamidotriphenylphosphiniminium Bromides

1. N-Benzamidotriphenylphosphiniminium Bromide

Hydrazinotriphenylphosphonium bromide (30) (9.46 g, 20 mmole)


was added to a solution of benzoyl chloride (2.8 g, 20 mmole), and pyridine (1.6 g, 20.2 mmole) in benzene (100 ml). After the addition, the suspension was refluxed under nitrogen for 6 hr. The precipitate was collected, washed with cold water, and with petroleum ether, and then dried. Recrystallization from 2-propanol gave white crystals of N-benzamidotriphenylphosphiniminium bromide (7.9 g, 83%) mp 179-183° (lit 4b 180°).

2. N-(p-Methoxybenzamido)triphenylphosphiniminium Bromide

To hydrazinotriphenylphosphonium bromide (37.3 g, 0.10 mmole) in dry benzene (500 ml) were added pyridine (8.2 ml, 0.102 mole) and anisoyl chloride (17.1 g, 6.10 mole) in benzene (100 ml). The resulting mixture was refluxed for 5 hr, cooled, and filtered. The white solid was washed with cold distilled water and with petroleum ether, and then dried in vacuo. The crude product was recrystallized from chloroform-2-propanol, giving rhomboid white crystals of N-(p-methoxy-benzamido)triphenylphosphiniminium bromide containing 0.5 mole of 2-propanol of crystallization (43.6 g, 80.7%), mp 188-190° (the bromide turns red and evolves gas on melting); nmr (CDCl₃)
δ 2.24 (s, 1), 3.83 (s, 3), 6.7-8.2 (complex m, 19), and 9.22 (d, 1), with 2-propanol absorptions at 1.08 (d, 3) and 4.00 (septet, ½). The ir spectrum is reproduced in the Appendix.

**Anal.** Calcd. for C_{26}H_{24}BrN_{2}O_{2}P·\frac{1}{2}C_{3}H_{6}O: C, 61.48; H, 5.25; N, 5.21. Found: C, 62.83; H, 5.49; N, 4.94.

3. **N-(p-Methylbenzamido)triphenylphosphiniminium Bromide**

Hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole) was added to a stirred solution of pyridine (0.80 g, 10 mmole), p-methylbenzoyl chloride (1.55 g, 10 mmole) and benzene (50 ml). The resulting mixture was refluxed under nitrogen for 6 hr and then cooled. Anhydrous ether (10 ml) was added to precipitate all of the phosphiniminium salt. The white solid was collected, washed with cold water and petroleum ether, and dried *in vacuo* to give white

N-(p-methylbenzamido)triphenylphosphiniminium bromide (4.36 g, 89%) mp 177-178° (turns red) nmr δ 2.25 (s, 3), 6.7-8.2 (complex m, 19), 9.18 (d, 1). The ir spectrum is reproduced in the Appendix. An analytical sample was recrystallized from chloroform-2-propanol; the nmr of this sample showed 2-propanol absorptions, integrating to 0.5 mole.

**Anal.** Calcd. for C_{26}H_{24}BrN_{2}O_{2}·\frac{1}{2}C_{3}H_{6}O: C, 63.54; H, 5.21; N, 5.37. Found: C, 63.10; H, 5.55; N, 4.99.

4. **N-(p-Nitrobenzamido)triphenylphosphiniminium Bromide**

A mixture of hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole), p-nitrobenzoyl chloride (1.86 g, 10 mmole) pyridine
(0.80 g, 10 mmole) in benzene (100 ml) was refluxed overnight under nitrogen, cooled, and filtered. The filter cake was washed with cold water and petroleum ether, dried in vacuo, tritured with hot chloroform, and dried, affording pale yellow crystals of N-(p-nitrobenzamido)triphenylphosphiniminium bromide (4.23 g, 81.3%) mp 201-202° (the bromide turns red and gas evolves upon melting). The ir spectrum is reproduced in the Appendix. The yellow filtrate was evaporated in vacuo to give α-hydroxy-(p-nitrobenzylidene)triphenylphosphazine (0.66 g, 14.5%) mp 177-178°, identical to a sample prepared later in this work.

Anal. Calcd. for C_{25}H_{21}BrN_{3}O_{3}P: C, 57.48; H, 4.05; N, 8.04. 
Found: C, 57.29, H, 4.17, N, 7.87.

5. N-(p-Chlorobenzamido)triphenylphosphiniminium Bromide

p-Chlorobenzoyl chloride (1.5 g, 20 mmole) was added to a suspension of hydrazinotriphenylphosphonium bromide (7.46 g, 20 mmole) and pyridine (1.6 g, 20 mmole) in dry benzene (100 ml) under nitrogen. After refluxing for 8 hr and cooling, the white precipitate was collected, washed with cold water and petroleum ether, and then dried in vacuo. Recrystallization from chloroform-2-propanol gave white needles of N-(p-chlorobenzamido)triphenylphosphiniminium bromide (9.58 g, 93.2%), mp 183-184° (the bromide turns red and gas evolves with heating), nmr δ2.12 (broad s, 1), 7.06-8.2 (complex m, 19), 9.75 (d, 1, J_{P-NH} = 30 Hz). The ir spectrum is reproduced in the Appendix.
Anal. Calcd. for C_{25}H_{21}BrClN_{2}OP\cdot\frac{1}{2}C_{3}H_{8}O: C, 58.74, H, 4.65, N, 5.17; Found: C, 60.19, H, 4.42, N, 5.43.

6. N-Acetamidotriphenylphosphiniminium Bromide

Acetyl chloride (0.79 g, 10 mmole) and pyridine (0.82 g, 10.2 mmole) were added simultaneously dropwise to a stirred suspension of hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole) in benzene (50 ml). After refluxing overnight under nitrogen, the white precipitate was collected, washed with cold water, and dried. N-Acetamidotriphenylphosphiniminium bromide (2.16 g, 57%), mp 182-184, was obtained. The ir and nmr spectra are reproduced in the appendices.

7. N-Propionamidotriphenylphosphiniminium Bromide

A mixture of propionyl chloride (0.88 g, 10 mmole), pyridine (0.82 g, 10.2 mmole), and hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole) in benzene (100 ml) was refluxed for 10 hr under nitrogen. The white filter cake was washed with cold water and dried in vacuo. Recrystallization from chloroform-2-propanol gave N-propionamidotriphenylphosphiniminium bromide (2.62 g, 61%), mp 178-181°C (turns yellow). The ir and nmr spectra are reproduced in the appendices.

Preparation of α-Hydroxyarylidene triphenylphosphazines via

N-Acylamidotriphenylphosphiniminium Bromide

1. α-Hydroxy(p-methoxybenzylidene)triphenylphosphazene

A mixture of N-(p-methoxybenzamido)triphenylphosphiniminium bromide (1.14 g 2.0 mmole) and triethylamine (0.21 g, 2.0 mmole) in
benzene (100 ml) was stirred at room temperature overnight under nitrogen and filtered. The filtrate on evaporation gave α-hydroxy(p-methoxybenzylidene)triphenylphosphazine (0.81 g, 96%), mp 160-165° (turns red); nmr δ 6.7-8.0 (complex m, 19), 4.6 (broad, 1), 3.80, 3.79 (s, 3).

**Anal.** Calcd. for C₂₆H₂₃N₂O₂P: C, 73.22; H, 5.46; N, 6.57.
Found: C, 73.45; H, 5.54; N, 6.55.

2. **α-Hydroxy(p-methylbenzylidene)triphenylphosphazine**

N-(p-Methylbenzamido)triphenylphosphiniminium bromide (1.96 g, 4.0 mmole) and triethylamine (0.41 g, 4.1 mmole) in benzene (100 ml) were stirred at room temperature under nitrogen for 14 hr. Evaporation of the filtrate yielded white crystals of α-hydroxy(p-methylbenzylidene)-triphenylphosphazine (1.56 g, 95%), mp 170-171°; nmr δ 2.32, 2.37 (s, 3), 4.78 (broad s, 1), 7.0-7.98 (complex m, 19). The ir spectrum is reproduced in the appendix. An analytical sample recrystallized from chloroform-ethyl acetate melted at 197-200°.

**Anal.** Calcd. for C₂₆H₂₃N₂OP: C, 76.08; H, 5.65; N, 6.83.
Found: C, 76.05; H, 5.67; N, 6.80.

3. **α-Hydroxy(p-nitrobenzylidene)triphenylphosphazine**

Triethylamine (0.41 g, 4.1 mmole) was added to a stirred suspension of N-(p-nitrobenzamido)triphenylphosphiniminium bromide (2.09 g, 4.0 mmole) in benzene (250 ml). The colorless mixture became yellow upon addition of the amine, the color intensifying with time. After stirring for 10 hr at room temperature under nitrogen, the
mixture was filtered. The white filter cake was triethylammonium bromide (0.72 g, 99%). The filtrate was evaporated in vacuo. The bright yellow crystalline material was identified as α-hydroxy(p-nitrobenzylidene)triphenylphosphazine (1.71 g, 97%), mp 185-186°; nmr δ 7.3-8.2 (complex m, 19), 5.92 (broad, 1). The ir spectrum is reproduced in the appendix.

**Anal. Calcd. for C_{25}H_{30}N_{3}O_{3}P:** C, 68.02; H, 4.57; N, 9.52.

**Found:** C, 67.61; H, 4.85; N, 9.01.

4. **α-Hydroxy(p-chlorobenzylidene)triphenylphosphazine**

Tetramethylguanidine (0.23 g, 2.0 mmole) was added to a stirred mixture of N-(p-chlorobenzamido)triphenylphosphinininium bromide (1.23 g, 2.0 mmole) in benzene (150 ml) under nitrogen. The mixture was stirred for 24 hr. Evaporation of the filtrate and trituration of the residue with ethyl acetate gave fine, white crystals of α-hydroxy(p-chlorobenzylidene)triphenylphosphazine (0.82 g, 95%), mp 198-199°. The ir spectrum is reproduced in the appendix.

**Anal. Calcd. for C_{25}H_{30}ClN_{3}O_{3}P:** C, 69.68; H, 4.68; N, 6.50.

**Found:** C, 69.66; H, 4.68; N, 6.37.

**Preparation of α-Hydroxybenzylidenedetriphenylphosphazines via Triphenyldibromophosphorane**

1. **α-Hydroxybenzylidenedetriphenylphosphazine**

A freshly prepared suspension of triphenyldibromophosphorane (31) (105.5 g, 0.25 mole) in benzene (800 ml) was allowed to warm to 10-14°. Triethylamine (51.5 g, 0.51 mole) was added dropwise to the
stirred mixture under nitrogen. Simultaneously, benzhydrazide (34.0 g, 0.25 mole) was added portionwise through a solid-addition flask during the 3 hr period. The mixture was stirred for 24 hr at room temperature. After filtering, the filter cake was washed with dry benzene. The red filtrate was combined with the washings and evaporated in vacuo. The resultant oil was triturated with ethyl acetate for 0.5 hr to give fine, white crystals of $\alpha$-hydroxybenzylidenetriphenylphosphazine (71.2 g, 72%), mp 185-187°C (lit $^{1b}$ 183-186°C); nmr (CDCl$_3$) $\delta$ 4.8 (s, 1), 7.3-8.0 (complex m, 20).

2. $\alpha$-Hydroxy(p-methylbenzylidene)triphenylphosphazine

p-Methylbenzhydrazide (3.78 g, 25 mmole) was added over 0.5 hr through a solid addition flask to a stirred suspension of triphenyl-dibromophosphorane (10.6 g, 25 mmole) and triethylamine (5.1 g, 51 mmole) in benzene (300 ml) under nitrogen at 10-14°C. After stirring for 20 hr, the mixture was filtered and washed with benzene. Evaporation of the red filtrate and washings gave an oil. Trituration of the oil with ethyl acetate yielded fine, white crystals of $\alpha$-hydroxy(p-methylbenzylidene)triphenylphosphazine (6.92 g, 65%), mp 197-200°C; nmr (CDCl$_3$) $\delta$ 7.14-7.8 (complex m, 19), 5.2 (broad s, 1), and 2.32 (s, 3).

The ir spectrum of this phosphazine was identical to that of the $\alpha$-hydroxy(p-methylbenzylidene)triphenylphosphazine prepared previously.
in this work.

3. Attempted preparation of $\alpha$-Hydroxy(p-nitrobenzylidene)triphenylphosphazine

To freshly prepared triphenyldibromophosphorane (4.22 g, 20 mmole) in benzene (100 ml) under nitrogen at 10-14°C were added triethylamine (2.0 g, 20 mmole) and benzhydrazide (1.81 g, 10 mmole) over 0.5 hr. The mixture turned orange. After stirring for 20 hr, the reaction mixture was black. TLC indicated at least 8 components. The isolable products were triphenylphosphine oxide and triethylammonium bromide.

4. Attempted Preparation of $\alpha$-Hydroxy(p-methoxybenzylidene)triphenylphosphazine

Triethylamine (2.0 g, 20 mmole) and p-methoxybenzhydrazide (1.66 g, 10 mmole) were added simultaneously over 0.5 hr to a freshly prepared suspension of triphenyldibromophosphorane (4.42 g, 10 mmole) in benzene (100 ml) at 10-14°C under nitrogen. The mixture was stirred for 24 hr and filtered. Evaporation of the red filtrate gave an oil, which on trituration with ethyl acetate gave a white solid. TLC of the crude product indicated two major components. The presence of $\delta_{C-N}=6.24 \mu$, $\delta_{P-N}=7.45 \mu$, and $-OCH_3=8.05 \mu$ is shown by the IR spectrum of the mixture, and the aromatic: methoxyl proton ratio (30:3) in the NMR is greater than the anticipated ratio (19:3) for $\alpha$-hydroxy(p-methoxybenzylidene)triphenylphosphazine. Sodium fusion demonstrated the presence of bromine. It was concluded that the product was a mixture of $\alpha$-hydroxy(p-methoxybenzylidene)triphenylphosphazine and
α-hydroxy(p-bromobenzylidene)triphenylphosphazene or α-bromo-(p-methoxybenzylidene)triphenylphosphazene. The products had very similar solubilities and ir values. All efforts to separate them failed. Attempts to Prepare α-Methoxybenzylidenetriphenylphosphazene or its Salt

1. Reaction of Methyl Iodide with α-Hydroxybenzylidenetriphenylphosphazene Anion

α-Hydroxybenzylidenetriphenylphosphazene (1.98 g, 5.0 mmole) in benzene (50 ml) was saturated with nitrogen. n-Butyl lithium (5.0 mmole) in pentane was added dropwise at room temperature. The colorless solution changed immediately to yellow. After the solution had been stirred 1 hr, excess methyl iodide was added and the mixture was stirred overnight. At the end of this period, no lithium iodide had precipitated. The solution was evaporated. Tlc of the reaction product indicated a mixture of at least five components. The infrared of the mixture exhibits absorptions of both >C=O (6.0 μ) and >C=N (6.16μ) and both >P=N (7.65μ) and >P-N (7.0 and 9.0 μ) functions. Efforts to separate the mixture by column chromatography failed; fractional crystallization in a variety of solvents led only to triphenylphosphine oxide (0.29 g, 25%).

2. Reaction of Methyl Iodide with α-Hydroxybenzylidenetriphenylphosphazine

α-Hydroxybenzylidenetriphenylphosphazene (1.98 g, 5.0 mmole) dissolved in benzene was reacted with excess methyl iodide at room
temperature. After 1 hr of stirring, a white precipitate appeared. The mixture was stirred for 5 additional hrs. The white precipitate was collected, washed with ether, and dried in vacuo. Its infrared spectrum was very similar to that of \(N\)-benzamidotriphenylphosphiniminium bromide: 6.0 \( \mu \) (\(N\)-C=O) 7.0 and 9.0 \( \mu \) (\(\phi_3P^+\cdotN^-\)) and transparent in the \(\gamma\)C=N- region. The nmr of the crude mixture shows absorptions at \(\delta\) 3.30 (d, \(J = 10\) Hz) attributable to the \(\phi_3P^+\cdotN(CH_3)\) group and at \(\delta\) 7.0-8.2 attributable to the aromatic hydrogens; there is no signal indicating any methoxyl hydrogens. Thus, this method failed to give any \(\alpha\)-methoxybenzylidenetriphenylphosphazinium bromide.

3. Reaction of Diazomethane with \(\alpha\)-Hydroxybenzylidenetriphenylphosphazincine

Diazomethane (5.0 mmole) in ether was added dropwise to a stirred solution of \(\alpha\)-hydroxybenzylidenetriphenylphosphazincine (1.98 g, 5.0 mmole) in benzene (50 ml). Gas evolution was noted. Evaporation of the solvent gave a yellow oil. The crude mixture was found to have at least four components by tlc. Again, efforts to isolate any of these failed.

4. Reaction of Methyl Fluorosulfonate with \(\alpha\)-Hydroxybenzylidenetriphenylphosphazincine

Methyl fluorosulfonate (0.11 g, 1.0 mmole) was added dropwise to a stirred benzene solution (10 ml) of \(\alpha\)-hydroxybenzylidenetriphenylphosphazincine (0.40 g, 1.0 mmole) under nitrogen. Stirring was continued for 0.5 hr. The solution was evaporated. The infrared of the white solid indicated the presence of \(\gamma\)C=O (6.0 \(\mu\)), but no
\[ \gamma C=N - (6.2 \mu) \]. Treatment of the white solid with base gave a yellow oil whose nmr is dissimilar to that of authentic \( \alpha \)-methoxybenzylidene-triphenylphosphazene prepared later in this work.

5. Reaction of Methyl Fluorosulfonate with \( \alpha \)-Hydroxybenzylidenetriphenylphosphazene in Dimethylformamide

A dimethylformamide (20 ml) solution of either \( \alpha \)-hydroxybenzylidenetriphenylphosphazene (0.40 g, 1.0 mmole) or its keto form at -20° was treated with methyl fluorosulfonate (0.11 g, 1.0 mmole). After 20 minutes of stirring, the mixture was vacuum distilled. The infrared spectrum of the solid residue shows absorptions for both \( \gamma N-C=O \) (6.03 \( \mu \)) and \( \gamma C=N - (6.14 \mu) \) groups. The nmr (Me\(_2\)SO-d\(_6\)) of the crude mixture shows no -OCH\(_3\) absorption signal.

Reactions of Hydrazinotriphenylphosphonium Bromide with Orthoesters

1. Reaction with Trimethyl Orthobenzoate

Trimethyl orthobenzoate (18.2 g, 0.10 mole) was added all at once to a solution of hydrazinotriphenylphosphonium bromide (18.65 g, 50 mmole) in anhydrous methanol (500 ml) under nitrogen. The solution was stirred for 3 weeks. Evaporation of the solvent afforded an oil, which upon trituration with ethyl acetate gave fine white crystals identified as \( \alpha \)-methoxybenzylidenetriphenylphosphazinium bromide (21.5 g, 87.5%), mp 144-145° (the bromide turns yellow when heated); nmr (CDCl\(_3\)) \( \delta \) 3.95 and 3.64 (s, 3, ratio 5:2), 7.38-8.1 (complex m, 19), 10.1 (d, 1, \( J_{P-NH} = 10 \) Hz). The two singlets were attributed to the methoxyl groups of the syn and anti isomers. The mass spectrum of the
product exhibited major peaks at 410 (minus HBr) and at 277 ($\phi_3$PNH$^+$). Upon recrystallization of the product from methanol-ethyl acetate, its mp rose to 161-162$^\circ$ and the ratio of the singlets (nmr) changed from 5:2 to 1:7. The infrared spectrum of the product was identical in each case (see appendix for ir spectrum).

**Anal.** Calcd. for C$_{21}$H$_{24}$BrN$_2$OP: C, 63.55; H, 4.92; N, 5.70; P, 6.31. Found: C, 63.72; H, 4.91; N, 5.52; P, 5.94.

2. **Reaction with Trimethyl Orthoacetate**

A mixture of anhydrous methanol (200 ml), trimethyl orthoacetate (4.81 g, 40 mmole), and hydrazinotriphenylphosphonium bromide (7.46 g, 20 mmole) was stirred for 2.5 weeks at room temperature under nitrogen. The solution was then evaporated in vacuo. Trituration of the resultant oil with ethyl acetate gave $\alpha$-methoxyethylidenetriphenylphosphazinium bromide (7.63 g, 88.9%), fine white crystals, mp 156-158$^\circ$ (gas evolves on melting); nmr $\delta$ 10.35 (d, 1, $J = 15$ Hz), 7.5-8.1 (complex m, 15) 3.9 and 3.4 (s, 3) 2.13 and 2.04 (s, 3). The nmr shows that the product is a mixture of syn and anti isomers in a 1:1 ratio. (See appendix for ir spectrum).

**Anal.** Calcd. for C$_{21}$H$_{24}$BrN$_2$OP: C, 58.74; H, 5.17; N, 6.52. Found: C, 58.67; H, 4.94; N, 6.31.

3. **Reaction with Trimethyl Orthoformate**

A mixture of anhydrous methanol (200 ml), hydrazinotriphenylphosphonium bromide (7.46 g, 20 mmole) and trimethyl orthoformate (4.24 g, 40 mmole) was saturated with nitrogen, stoppered and stirred
for 2 weeks at room temperature. The solvent and excess trimethyl orthoformate were evaporated in vacuo. The viscous, colorless oil on trituration with ethyl acetate gave \( \alpha \)-methoxymethyleneetriphenylphosphazinium bromide (7.05 g, 84%), white crystals, mp 99-102°C, nmr (CDCl\(_3\)) \( \delta \) 7.34-8.08 (complex m, 16), 3.53 and 3.32 (s, 3). The two singlets arise from the syn and anti isomers of the phosphazinium bromide in a ratio of 2:1. The bromide is hygroscopic.

**Anal.** Calcd. for C\(_{30}\)H\(_{19}\)BrN\(_2\)OP: C, 57.98; H, 4.62; N, 6.76; Found: C, 57.85, H, 4.62, N, 6.76.

Reactions of \( \alpha \)-Methoxyalkyldenetriphenylphosphazinium Bromide with Bases

**A. Reaction of \( \alpha \)-Methoxybenzylidenetriphenylphosphazinium Bromide**

1. **With Tetramethylguanidine**

   Tetramethylguanidine (0.12 g, 1.0 mmole) was added dropwise under nitrogen to a stirred suspension of \( \alpha \)-methoxybenzylidenetriphenylphosphazinium bromide (0.49 g, 1.0 mmole) in benzene (50 ml) or tetrahydrofuran (50 ml). The colorless solution turned yellow. After stirring for 10 hr, the mixture was filtered. The filtrate was evaporated in vacuo. Prolonged pumping gave a yellow oil, impure \( \alpha \)-methoxybenzylidenetriphenylphosphazinium, containing a small amount of tetramethylguanidine. The nmr (CDCl\(_3\)) of the oil exhibited absorptions at \( \delta \) 7.10-7.96 (complex m, 20), 4.25 and 3.54 (s, 3). The ratio of the singlet absorptions, attributable to the syn and anti isomers, was 3:2. In order to obtain a pure derivative suitable for analysis, the oil was
reacted with hydrogen chloride in benzene. The white solid, identical 
to the benzamidetriphenylphosphiniminium chloride prepared earlier in 
this work, apparently resulted from hydrolysis due to traces of water.

2. With Sodium Hydroxide

α-Methoxybenzylidenetriphenylphosphazinium bromide (0.49 g, 
1.0 mmole) was dissolved in chloroform (10 ml). The chloroform 
solution was washed 3 times with sodium hydroxide solution (1 N, 5 ml 
portions) and once with saturated sodium chloride (5 ml). The 
chloroform layer was dried over magnesium sulfate. The yellow solution 
was evaporated in vacuo (prolonged pumping), and identified as 
α-methoxybenzylidenetriphenylphosphazine (0.37 g, 90%); nmr (CDCl₃) 
δ 7.10-7.96 (complex m, 20), 4.25 and 3.54 (s, 3). The infrared was 
transparent in the carbonyl region but shows absorption at 6.26 μ 
(s, C=N-), 7.70 μ (doublet, -OCH₃), and 8.4 μ (νP=N-). Attempts to 
obtain a solid failed.

3. Over Alumina

α-Methoxybenzylidenetriphenylphosphazinium bromide (0.98 g, 
2.0 mmole) was chromatographed on Woelm alumina (basic, grade I) with 
chloroform. The first band was collected and evaporated in vacuo 
yielding a yellow oil (0.67 g, 82%). The infrared of the yellow oil 
was identical to that of the α-methoxybenzylidenetriphenylphosphazine 
prepared in the previous two experiments and is reproduced in the 
appendix. The phosphazine is too unstable for satisfactory chemical 
analysis.
4. **With Triethylamine**

Triethylamine (0.10 g, 1.0 mmole) was added to a stirred mixture of \( \alpha \)-methoxybenzylidenetriphenylphosphazinium bromide (0.49, 1.0 mmole) in benzene (50 ml). The yellow mixture was refluxed for 0.5 hr, cooled and filtered. Evaporation of the filtrate gave \( \alpha \)-methoxybenzylidenetriphenylphosphazene (0.35 g, 85%), a yellow oil whose ir and nmr are identical to that of the phosphazene above.

**B. Reaction of \( \alpha \)-Methoxyethylidenetriphenylphosphazinium Bromide over Alumina**

Chromatography of \( \alpha \)-methoxyethylidenetriphenylphosphazinium bromide (0.508 g, 1.16 mmole) on a short column of basic alumina (Woelm, grade I, chloroform) gave a yellow material. Evaporation of solvent yielded a yellow oil identified as \( \alpha \)-methoxyethylidenetriphenylphosphazene (0.394 g, 93%), nmr \( \delta \) 2.01, 2.25 (s, 3), 3.50, 3.86 (s, 3), 7.35-8.01 (complex m, 15). (See Appendix for ir).

**C. Reaction of \( \alpha \)-Methoxymethylethenetriphenylphosphazinium Bromide over Alumina**

\( \alpha \)-Methoxymethylethenetriphenylphosphazinium bromide (0.683 g, 1.65 mmole) was chromatographed on basic alumina (Woelm, grade I, chloroform) under nitrogen. The first band was collected. The yellow solution was evaporated, yielding \( \alpha \)-methoxymethylethenetriphenylphosphazene (0.387 g, 70%), a yellow oil. The phosphazene is highly unstable (see Appendix for ir and nmr).
Reactions of α-Methoxybenzylidenetriphenylphosphazine

1. Reaction with p-Nitrobenzaldehyde

α-Methoxybenzylidenetriphenylphosphazine (0.70 g, 1.7 mmole) was prepared in situ in benzene (40 mL) under nitrogen. p-Nitrobenzaldehyde (0.26 g, 1.7 mmole) was added to the solution. After refluxing for 1.5 hr, the solution was evaporated in vacuo. Chromatography on silica gel (grade I, benzene) gave yellow crystals of the p-nitrobenzalaldazine of methyl benzoate (0.46 g, 96%), mp 104-105°; nmr (CDCl₃) δ 4.04 (s, 3), 7.38-7.65 (complex m, 5), 7.71-8.1 (complex m, 2), 7.9 (d, 2), and 8.6 (s, 1).

Anal. Calcd. for C₁₅H₁₃N₃O₃: C, 63.59; H, 4.63; N, 14.83
Found: C, 63.36; H, 4.57; N, 14.63.

The p-nitrobenzalaldazine of methyl benzoate was dissolved in chloroform. A small amount of methanol was added to the chloroform, then hydrochloric acid (2 ml, 0.5 N). The two-phase mixture was stirred vigorously for 0.5 hr. The chloroform layer was collected, washed with 3 ml water, and dried by passing through a cone of Drierite. The yellowish solution was evaporated in vacuo. The solid residue was recrystallized from ethanol to yield pale yellow needles of the benzoylhydrazone of p-nitrobenzaldehyde, mp 242-243° (lit 32 to 243°). The second crop yielded unreacted azine, mp 104-105°.

2. Reaction with p-Methoxybenzaldehyde

p-Methoxybenzaldehyde (0.14 g, 1.0 mmole) was added dropwise to a benzene (30 ml) solution of α-methoxybenzylidenetriphenylphosphazine (0.41 g, 1.0 mmole). The solution was refluxed under nitrogen for 4 hr. Evaporation of solvent yielded a yellow oil, which upon chromatography on silica gel (grade I, benzene) gave 0.22 g of a pale yellow oil. The nmr spectrum of the oil showed it to be a mixture of p-methoxybenzaldehyde (9%) and p-methoxybenzaldazine of methyl benzoate (91%); the yield of the azine is thus 0.20 g (74%).

3. Reaction with Fluorenone

Fluorenone (0.18 g, 1.0 mmole) and α-methoxybenzylidenetriphenylphosphazine (0.41 g, 1.0 mmole) in benzene (40 ml) under nitrogen was stirred at room temperature for 24 hr. At the end of this time, tlc of the reaction mixture showed no reaction. The mixture was then heated for 4 hr. The solvent was removed in vacuo and the solid residue chromatographed on silica gel (grade I, benzene). The yellow solid (0.18 g, 100%) was identical to authentic fluorenone in its ir, mp, and rf.

4. Reaction on Storage

α-Methoxybenzylidenetriphenylphosphazine (0.41 g, 1.0 mmole) gave a purple solid on storage in a flask. The mixture was chromato- graphed on silica gel (grade I, petroleum ether) to give 3,6-diphenyl-1,2,4,5-tetrazine (0.020 g, 13%), mp 194-195° (lit 33 195°).

5. **Hydrolysis**

Neat α-methoxybenzylidenetriphenylphosphazine (0.21 g, 0.5 mmole) was dissolved in 80% ethanol solution (10 ml). The yellow oil became colorless upon dissolving. Evaporation of solvent after storing overnight gave a yellow oil. Recrystallization from minimum ethanol yields yellow crystals of 1,2-dihydro-3,6-diphenyl-1,2,4,5-tetrazine (0.022 g, 37%), mp 190-191.5° (lit 33 193-195°), exact mass = 236.10599 daltons (calcd. 236.10619). Oxidation of a small amount of the dihydrotetrazine with excess dichlorodicyanoquinone gave purple crystals of 3,6-diphenyl-1,2,4,5-tetrazine, mp 195°, identical with material prepared in the previous experiment.

6. **Thermolysis**

A freshly prepared solution of α-methoxybenzylidenetriphenylphosphazine (0.20 g, 0.57 mmole) in benzene (20 ml) which is saturated with nitrogen was evaporated in vacuo. Prolonged pumping at 0.6 mmHg was effected to remove traces of solvent and some of the excess triethylamine used in the preparation of the phosphazine. The neat yellow oil was pyrolyzed at 250-200° for 5 min at 0.6 mmHg. The volatile products, collected in a trap at -78°, weighed 0.058 g. This volatile colorless liquid on vapor phase chromatography gave 8 peaks, identified by retention time of authentic samples on SE-30 and Carbowax 20M as formaldehyde, methanol, triethylamine, toluene, benzaldehyde, acetophenone, methyl benzoate, and benzaldehyde dimethyl acetal. A weighed amount of the colorless oil was added to a weighed amount of
chlorobenzene as an internal standard and vapor phase chromatographed
to confirm absolute weights of material present. The yield of volatile
products, excluding triethylamine, was 27.3 mg (48.5 mole %). The
percent mole ratios of the volatile material are 8.7 (formaldehyde),
5.3 (methanol), 5 (toluene), 60 (benzaldehyde), 19 (acetophenone),
7.6 (methyl benzoate), and 6.2 (benzaldehyde dimethyl acetal).

The solid residue in the reaction flask was chromatographed to
give triphenylphosphine (0.140 g, 96%) and minor traces of 5 other
compounds.

7. **Photolysis**

α-Methoxybenzylidenetriphenylphosphazine (0.019 g, 0.19 mmole)
was prepared freshly from its hydrobromide salt and triethylamine in
cyclohexane (50 ml). The reaction mixture was photolyzed overnight
(450 watt Hanovia lamp, medium pressure, through pyrex). The concentrated
material was injected into a vapor phase chromatography column.
Retention times were compared to standards and revealed the presence of
cyclohexane, triethylamine, benzaldehyde, benzyl methyl ether, methyl
benzoate, and other unidentified peaks. A weighed amount of acetophenone was used to calibrate the recorder response, and this factor,
plus the weight of solution, plus the peak areas of a weighed injection
of sample was used to calculate the absolute weights of products. The
overall mole percent yields are 5.8% methyl benzoate, 22.2% benzaldehyde,
and 22.8% benzyl methyl ether.
APPENDIX I

Infrared Spectra
Figure 3.
APPENDIX II

Nuclear Magnetic Resonance Spectra
PART II

THE SYNTHESIS OF 1,3,4-OXADIAZOLEs VIA TRIPHENYLPHOSPHINE DERIVATIVES
INTRODUCTION

Walker and Shechter (1) discovered that aryl chlorides react


with hydrazinotriphenylphosphonium bromide or N-benzamidostriphenylphosphinimine in the presence of triethylamine to yield 2,5-diaryl-1,3,4-oxadiazoles (Equations 1, 2).

\[ \text{Ph}_3\text{P} = \text{N} - \text{NHC}_\text{Ar} + \text{ArCCl} + \text{Et}_3\text{N} \quad (2) \]

The present work involves the study of the scope, limitations, and possible mechanistic details of the above reactions.
1,3,4-Oxadiazoles have been known since the 1860's and their chemistry has been reviewed several times.


1,3,4-Oxadiazoles have been synthesized by various methods. Cyclodehydration of N,N'-diacylhydrazines to 1,3,4-oxadiazoles has been effected by heat (3a) and by dehydrating agents (Equation 3)

such as sulfur trioxide in dimethylformamide (3b), phosphorus pentoxide (3c), zinc chloride (3d), thionyl chloride (3e), fuming sulfuric acid (3f), chlorosulfonic acid (3g), phosphorus pentachloride (3d), phosphorus oxychloride (3h, 3k), phosphoric acid esters (3i), and acid anhydrides (3j).

Bis-α-chlorobenzylidenehydrazines react with hot water (3h) or silver nitrate (4) to form 1,3,4-oxadiazoles (Equation 4).

\[
\begin{align*}
\text{Cl} & \text{N} \text{N} = \text{Cl} \\
\text{Ph} & \text{Ph} \\
\text{H}_2\text{O}, \Delta/\text{AgNO}_3 \\
\text{Ph} & \text{Ph} \\
\text{N} & \text{N} \\
\end{align*}
\]

Diazotization may also yield the heterocyclic ring, such as bis-α-amino-benzylidenehydrazines and nitrous acid (5) (Equation 5). N-Acyl-hydrazides and trifluoroacetic acid (6) (Equation 6) react to form 1,3,4-oxadiazoles.

(4) E. Beckmann and E. Günther, Ann., 252, 44 (1889).

(5) A. Pinner, Ann., 297, 221 (1897).
Hydrazones and semicarbazones of aldehydes in the presence of oxidizing agents, such as halogens, give 1,3,4-oxadiazoles (7) (Equations 7 and 8).


Acylthiosemicarbazide in the presence of lead oxide lose hydrogen sulfide and cyclize (Equation 9) to 1,3,4-oxadiazoles (8).

\[
\begin{align*}
\text{Ph} & \quad \text{CNHNHC} & \quad \text{NH-Ph} & \quad \overset{\text{PhBO}}{\text{H}_2\text{S}} & \rightarrow \text{PhNH} \\
& \quad \text{N} & \quad \text{N} & \quad \text{N} & \quad \text{N}
\end{align*}
\]

Tetrazoles when acylated by acyl chlorides or acid anhydrides undergo ring cleavage, loss of molecular nitrogen, and ring closure to form 1,3,4-oxadiazoles (9) (Equation 10). \(^{15}\text{N}\) labelling experiments (9b) at the 1- and 4- positions show that one-half of the \(^{15}\text{N}\) is retained in the oxadiazole ring and one-half in the nitrogen expelled.

The rearrangement mechanism was thus postulated as illustrated above (Equation 10).

3,6-Diphenyl-1,2,4,5-tetrazine when heated with concentrated hydrochloric acid gives 2,5-diphenyl-1,3,4-oxadiazole and 1,2-dihydro-3,6-diphenyl-1,2,4,5-tetrazine (10) (Equation 11). Moreover, in the presence of peracetic acid and sodium acetate (oxidizing the dihydrotetrazin) the reaction affords the oxadiazole quantitatively (11) (Equation 12).

\[ \begin{align*}
\text{Ph} & \quad \begin{array}{c}
\downarrow \text{conc HCl} \\
\text{Ph} + \text{Ph} \quad \text{Ph} + \text{Ph} \quad \text{Ph}
\end{array} \\
\text{N} & \quad \text{N} \\
\text{N} & \quad \text{N} \\
\text{N} & \quad \text{N} \\
\text{N} & \quad \text{N}
\end{align*} \]

Monohydrazides react with substituted imidochlorides (2e), imino ethers (12), imino ether hydrochlorides (12,13) or phenylisocyanide dichlorides (14) to give 2,5-disubstituted-1,3,4-oxadiazoles (Equations 13-16).

(10) A. Pinner, Ber., 27, 984 (1894).

\[ \text{NaOCOCCH}_3 + \text{CH}_3\text{COCH}_2 \]

Monohydrazides are also cyclized by cyanogen bromide (15) in alcohol or other solvents to form 5-substituted-2-amino-1,3,4-oxadiazoles (Equation 17).


(17)
1,3,4-Oxadiazoles are also formed by reaction of diazomethane, methyl lithium and aroyl bromides (16) (Equation 18).

(16) E. Müller and D. Ludsteck, Ber., 88, 921 (1955).

\[
\text{CH}_3\text{Li} + N_2\text{CH}_2 \rightarrow \text{LiCH}_2\text{N}^+\text{CBr} \\
\phi - \text{C} - \text{N} = \text{N} = \text{CH} \\
\phi - \text{N} = \text{N} - \text{O} - \text{H}
\]

1,3,4-Oxadiazole, the parent heterocycle, has been recently prepared by reaction of triethyl orthoformate and formic acid hydrazide (17a, 17c), followed by distillation (Equation 19). A variety of substituted 1,3,4-oxadiazoles have been prepared by this method (17). The reaction first yields 1-acyl-2-ethoxyalkylidene-hydrazines which (a) condense to the oxadiazole under the influence of heat (Equation 20); or (b) when R' = H, react with the hydrazide to form \(N,N'-\text{big}(\text{acylamido})\text{formamidine} \) (Equation 21), which then
reacts with the triethyl orthoester to produce the desired oxadiazole (Equation 22). Ainsworth (17c) isolated both intermediates 1 and 2 of the reaction to provide additional evidence for the mechanism.

\[
\text{H} \text{CNH} \text{NH}_2 + \text{H} \text{C}-\text{OC}_2\text{H}_5 \xrightarrow{\Delta} \text{H} \text{H}_2\text{O} \quad \text{(19)}
\]

\[
\text{R} - \text{CNH} \text{NH}_2 + \text{R'OC}_2\text{H}_5 \quad \xleftrightarrow{\quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad} \quad \text{(20)}
\]

where \( R, R' = \text{H, Alk, Aryl} \)

\[
\text{R} - \text{C} - \text{NHN} = \text{C} \xrightarrow{\Delta} \text{R} - \text{C} - \text{NN} = \text{C} \quad \text{(21)}
\]

\[
\text{R} - \text{R'OC}_2\text{H}_5 \quad \xrightarrow{\Delta} \quad \text{O} \quad \text{R} - \text{C} - \text{NH} \quad \text{R} - \text{R'OC}_2\text{H}_5 \quad \text{(22)}
\]

Heating tetrasaclyhydrazines leads to elimination of acid anhydride and formation of 1,3,4-oxadiazoles (2d) (Equation 23).
As noted in the introduction, aroyl chlorides and hydrazino-
triphenylphosphonium bromide or phosphazines, in the presence of
organic bases, also yield 1,3,4-oxadiazoles (1).

Other methods of preparation of 1,3,4-oxadiazoles are discussed
in reference 2.

Direct aromatic electrophilic substitution of an oxadiazole
is difficult (2e). Sulfonation and nitration of the ring fail to
give the desired products (18). Ring cleavage occurs in the presence


of acid or base yielding acyl hydrazides, or on further hydrolysis
hydrazine and carboxylic acids (19) (Equation 24). Increasing


\[
\begin{align*}
    \text{R-} & \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{R} \\
    \text{R-} & \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{R} \\
\end{align*}
\]

\[300 - 350^\circ \rightarrow \left( \frac{\text{O}}{\text{R} \quad \text{C} \quad \text{R}} \right) + \left( \text{R} \quad \text{N} \quad \text{N} \quad \text{R} \right) \]

\[\text{R-} \quad \text{C} \quad \text{N} \quad \text{N} \quad \text{C} \quad \text{R} \quad \overset{\text{H}^+}{\text{or } \text{O} \quad \text{OH}} \rightarrow \text{R-C-NH}_2 \quad \text{R}' \quad \text{H}_2\text{O}, \text{H}^+ \rightarrow \text{NH}_2\text{NH}_2 + \text{RCO}_2\text{H} + \text{R}'\text{CO}_2\text{H}\]
susceptibility towards hydrolysis parallels increasing solubility in water as shown:

\[
\begin{align*}
\text{Ar} & < \text{Ar} \\
\text{Alk} & < \text{Alk}
\end{align*}
\]

The phenyl rings on 2,5-diaryl-1,3,4-oxadiazoles generally exhibit normal aromatic chemistry. For example, 2,5-bis(p-nitrophenyl)-1,3,4-oxadiazole is reduced by phenylhydrazine to 2,5-bis(p-aminophenyl)-1,3,4-oxadiazole (Equation 25).

\[
\text{O}_2\text{N} - \begin{array}{c} \text{N} \\�N \text{O} \end{array} - \begin{array}{c} \text{N} \\�N \text{O} \end{array} - \text{NO}_2 \xrightleftharpoons{\text{PhNHNNH}_2} \begin{array}{c} \text{H}_2\text{N} \\�N \text{O} \end{array} - \begin{array}{c} \text{N} \\�N \text{O} \end{array} - \text{NH}_2
\]  

(25)

1,3,4-Oxadiazoles are very stable thermally and have been employed for high temperature baths (3c). They exhibit strong fluorescence in solution upon absorption of ultraviolet light. Thus, oxadiazoles are used as scintillation indicators (2e), as photosensitive material in films (2e), and as a protective agent against ultraviolet light (3e-g). These heterocycles have been used for drug synthesis, for preparation of dyes, and for the production of polymers (2e). Thus, an extensive literature exists on these interesting and versatile compounds.
RESULTS AND DISCUSSION

In the initial work (1) from this laboratory, 2,5-diphenyl-1,3,4-oxadiazoles were found to be formed by treatment of either hydrazinotriphenylphosphonium bromide or α-hydroxybenzylidenetriphenylphosphazine with aroyl chlorides and triethylamine. In the present study, an investigation of the above two methods of preparation of 1,3,4-oxadiazoles has been made to ascertain their scope and limitations, and possibly to determine their reaction pathways. In addition to the above, two other methods are studied and developed. The four methods of preparation of 1,3,4-oxadiazoles investigated in the present study are reactions of: (a) acyl chlorides with hydrazinotriphenylphosphonium bromide; (b) N-acylamidotriphenylphosphininium bromides with acyl chlorides; (c) α-hydroxyarylidenedetriphenylphosphazenes with acyl chlorides; and (d) triphenyldibromophorane with N,N'-diacylhydrazines (Figure 1). Each method necessitates the use of an anhydrous medium and an inert atmosphere. Each gives good yields of the desired 1,3,4-oxadiazoles (Tables 1, 2).

Method A. 1,3,4-Oxadiazoles \( \_2 \) are prepared by this method from hydrazinotriphenylphosphonium bromide \( \_4 \) and acyl chlorides \( \_5 \) in triethylamine or tetramethylguanidine (Equation 26). A suspension of the reactants \( \_4 \) and \( \_5 \) in anhydrous benzene or tetrahydrofuran is
Figure 1.
\[
\begin{align*}
\text{PhFNNH}_{2}\text{Br}^{+} + 2\text{RCCl} \xrightarrow{3\text{Bz; 70-85\%}} & \quad \begin{array}{c}
\text{N} \\
\text{N}
\end{array} \\
\text{R} & \quad \text{R} \\
\text{N}
\end{align*}
\]

where \( R = R' \)

refluxed for several hours under nitrogen to afford symmetrically substituted 1,3,4-oxadiazoles in high yields (70-85\%). This route lends itself to large scale preparations.

Hydrazinotriphenylphosphonium bromide \( h \) is a stable, storable reagent. It may be prepared in large quantities from triphenylphosphine, bromine, hydrazine, and triethylamine (20) (Equations 27, 28).


\[
\begin{align*}
\text{Ph}_3\text{P} + \text{Br}_2 \xrightarrow{\text{benzene; 0-60\°C}} & \quad \text{Ph}_3\text{PBr}_2 \\
\text{Ph}_3\text{PBr}_2 + \text{NH}_2\text{NH}_2 \xrightarrow{\text{Et}_3\text{N; benzene; 10-140\°C/N}_2} & \quad [\text{Ph}_3\text{PNHNNH}_2]^{+}\text{Br}^{-} + \text{Et}_3\text{NHBr}
\end{align*}
\]

Reagent \( h \) need not be isolated before use; thus a large scale one-pot synthesis of 1,3,4-oxadiazoles from readily available starting materials can be effected.

The use of aromatic acid chlorides result in successful preparation of 1,3,4-oxadiazoles. However, acetyl chloride and propionyl chloride fail to give detectable quantities of the desired
TABLE I

2,5-DIARYL-1,3,4-OXADIAZOLES PREPARED IN THIS STUDY

\[
\begin{array}{c}
\text{N} \quad \text{N} \\
\text{R} \quad \text{R}'
\end{array}
\]

where R = \(\text{O} - \text{X} \) and R' = \(\text{O} - \text{Y}\)

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<th>X</th>
<th>Y</th>
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<th>Method</th>
<th>Method</th>
<th>Method</th>
<th>Method</th>
<th>One Pot</th>
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<td>H</td>
<td>P-H</td>
<td>136.5-137°</td>
<td>137-138°</td>
<td>84.5%</td>
<td>85%</td>
<td>68%</td>
<td>70%</td>
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<td>CH₃</td>
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<th>Literature mp</th>
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<th>Yield(^f)</th>
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</thead>
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<td>p-NO(_2)</td>
<td>207-209(^a)</td>
<td>206.5-208(^c)</td>
<td>94%</td>
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<tr>
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</tr>
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<td>OCH(_3)</td>
<td>p-CH(_3)</td>
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<td>149.5-150(^a)</td>
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<tr>
<td>Cl</td>
<td>p-CH(_3)</td>
<td>205-208</td>
<td>205-206(^c)</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>CH(_3)</td>
<td>p-NO(_2)</td>
<td>228-230</td>
<td>229-230(^a)</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>NO(_2)</td>
<td>p-CH(_3)</td>
<td>228-230</td>
<td>229-230(^a)</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Cl</td>
<td>p-OCH(_3)</td>
<td>159-161</td>
<td>160-161.5(^c)</td>
<td>77</td>
<td></td>
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<tr>
<td>NO(_2)</td>
<td>p-OCH(_3)</td>
<td>229-231</td>
<td>229-230(^a)</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>NO(_2)</td>
<td>p-Cl</td>
<td>256-259</td>
<td>254-259(^d)</td>
<td>89</td>
<td></td>
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<tr>
<td>CH(_3)</td>
<td>m-CH(_3)</td>
<td>76-78</td>
<td></td>
<td>84</td>
<td></td>
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<tr>
<td>CH(_3)</td>
<td>m-NO(_2)</td>
<td>173-175</td>
<td></td>
<td>86</td>
<td></td>
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<tr>
<td>H</td>
<td>R'=CH(_2)</td>
<td>101-103</td>
<td>101-102.5(^a)</td>
<td>56</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Reference 9a.  
\(^b\)Reference 29.  
\(^c\)Reference 3e.  
\(^d\)Reference 3f.  
\(^e\)Reference 3b.  
\(^f\)Pathway from Figure 1.  
\(^g\)Based on last step.
oxadiazoles. This failure is not clearly understood. The use of other aliphatic acid chlorides was not investigated further.

Method A is an excellent way to prepare 2,5-diaryl-1,3,4-oxadiazoles. But as yet, 2,5-dialkyl-1,3,4-oxadiazoles (where R = CH₃, CH₃CH₂) have not been obtained by this route.

Method B. This new method of preparation of 1,3,4-oxadiazoles involves reaction between N-acylamidotriphenylphosphiniminium bromides \( I \) and acyl chlorides \( 2 \) in the presence of triethylamine or tetramethylguanidine (Equation 29). A suspension of reactants \( 2, I \),

\[
\begin{align*}
[\text{Ph₃P}NHNHCR]^+\text{Br}^- & + R'\text{CCl} \xrightarrow{2B; 56-91\%} \text{N} \text{N} \\
& \quad R \quad \text{O} \\
& \quad R' \\
\end{align*}
\]

and base in anhydrous medium is refluxed for a few hours under nitrogen to yield unsymmetrically substituted 1,3,4-oxadiazoles in excellent yields (Tables 1, 2).

\( N \)-Acylamidotriphenylphosphiniminium bromides are stable under ambient conditions. They are obtained from reaction of hydrazinotriphenylphosphonium bromide with acyl chlorides in the presence of pyridine (21) (Equation 30). The use of pyridine or other

(21) See PART I of this dissertation for further details on the preparation of these reagents \( I \) and \( 2 \).

weak base is imperative in the preparation of \( N \)-acylamidotriphenylphosphiniminium bromides \( I \) because these salts react further with
TABLE II

2-ALKYL-5-ARYL-1,3,4-OXADIAZOLES

Prepared in this Study from N-Acylamidotriphenylphosphininium Bromides (R = alkyl) and Acyl Chlorides (R' = aromatic).

<table>
<thead>
<tr>
<th>R</th>
<th>R'</th>
<th>mp (obs)</th>
<th>mp (lit)</th>
<th>yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₃</td>
<td>Ph</td>
<td>64-66°</td>
<td>65-66°ₐ</td>
<td>46%</td>
</tr>
<tr>
<td>CH₃</td>
<td>p-CH₂Ph</td>
<td>103-105</td>
<td>103.5-104.5ₐ</td>
<td>55</td>
</tr>
<tr>
<td>CH₃</td>
<td>p-CH₃OPh</td>
<td>90-91</td>
<td>91-92ₐ</td>
<td>45</td>
</tr>
<tr>
<td>CH₃</td>
<td>p-NO₂Ph</td>
<td>165-167</td>
<td>166ₐ</td>
<td>52</td>
</tr>
<tr>
<td>CH₃</td>
<td>p-ClPh</td>
<td>105-107</td>
<td>107ₐ</td>
<td>56</td>
</tr>
<tr>
<td>C₆H₅</td>
<td>p-NO₂Ph</td>
<td>132-135</td>
<td>133-134ₐ</td>
<td>55</td>
</tr>
<tr>
<td>C₆H₅</td>
<td>p-ClPh</td>
<td>94</td>
<td>93-94ₐ</td>
<td>56</td>
</tr>
<tr>
<td>C₆H₅</td>
<td>Ph</td>
<td>115@ 0.2mmₕ</td>
<td>105@ 0.1mmₕ,ₗ</td>
<td>40</td>
</tr>
<tr>
<td>C₆H₅</td>
<td>p-CH₃OPh</td>
<td>146@ 0.1mmₕ</td>
<td>135@ 0.05mmₕ,ₗ</td>
<td>36</td>
</tr>
</tbody>
</table>

ₐSee reference 9a.

ₗSee reference 17b.

ₕBoiling points.
\[
\text{[Ph}_3\text{PNNH}_2\text{]}^+\text{Br}^- + \text{RCIC} \quad \xrightarrow{\text{N}} \quad \text{[Ph}_3\text{PNNHCRCR}][\text{Br}^-] (30)
\]

where R = aryl, alkyl

stronger base to give triphenylphosphazenes 2, the conjugate base, which give oxadiazoles with the acyl halide present (see method C). When R has a strongly electron-withdrawing group, like a nitro group, even pyridine is sufficient to effect the conversion of the bromide to the phosphazene.

Aromatic acid chlorides (R' = aryl) give 2,5-diaryl-1,3,4-oxadiazoles and 2-aryl-5-aryl-1,3,4-oxadiazoles in good yield. Phenylacetyl chloride and propionyl chloride fail to react with N-acylamidotriphenylphosphiniminium bromides to give the desired 1,3,4-oxadiazoles in detectable quantities. This failure of the latter two acid chlorides to yield oxadiazoles is not well understood.

Method C: \(\alpha\)-Hydroxyarylidenetriphenylphosphazenes 2 react with acyl chlorides 2 and triethylamine or tetramethylguanidine affording unsymmetrically substituted 1,3,4-oxadiazoles (Table 1) in excellent yields (Equation 31). A solution of a phosphazene 2, an acyl chloride

\[
\text{R - C = N - N = PPh}_3 + \text{R}'\text{CIC} + \text{Et}_2\text{N} \quad \xrightarrow{\text{OH}} \quad \text{[Ph}_3\text{PNNHCRCR}][\text{Br}^-] (31)
\]

2, and base in anhydrous medium is stirred at room temperature for
several hours or is refluxed for 2 hours under nitrogen.

α-Hydroxyarylidenediarylphosphazenes are prepared by two methods: (a) reaction of benzhydrazides with triphenyl dibromophosphorane; or (b) reaction of N-acylamidotriphenylphosphiniminium bromides with triethylamine or tetramethylguanidine (19) (Equations 32, 33).

\[
\begin{align*}
\text{Ph}_3\text{PBr}_2 + R\text{-CNHNH}_2 & \rightarrow \text{Et}_3\text{N} \quad \text{Ph}_3\text{P} = \text{N} - \text{N} = \text{C} \quad \text{R} & \quad \text{OH} \\
\text{[Ph}_3\text{PNH}_2\text{NCH}]^+\text{Br}^- & \quad \text{Et}_3\text{N} & \quad \text{Et}_3\text{N} \\
\text{where } R = \text{aryl}
\end{align*}
\]

The use of acyl chlorides (R' = aryl) results in successful preparation of 1,3,4-oxadiazoles in excellent yield. The aliphatic acid chlorides (R = CH₃, CH₂CH₂) employed in this investigation failed to give the desired product. Perhaps, these acyl chlorides react further with the reaction intermediate so as to prevent cyclization to the 1,3,4-oxadiazole.

The three methods of preparation of 1,3,4-oxadiazoles previously described are very similar. Method A differs from methods B and C in that organo-phosphorus intermediates were isolated. It might be envisaged that the final steps of each method proceed through the same reaction mechanism from α-hydroxyarylidenediarylphosphazene.

Several plausible mechanisms for the 1,3,4-oxadiazole synthesis from α-hydroxyarylidenediarylphosphazenes and acyl chlorides in
base are summarized in Figure 2: (1) formation of $\alpha$-acyloxyarylidene-
triphenylphosphazene $2$ which undergoes an intramolecular Wittig
reaction (1); (2) formation of a phosphazinium salt $10$ which loses
hydrogen chloride and triphenylphosphine oxide and cyclizes; (3)
formation of a hydrazimido chloride $11$ which then loses hydrogen
chloride and undergoes ring closure.

Mechanism 1 involves formation of $\alpha$-acyloxyhydroxyarylidenedetri-
phenylphosphazene $2$. An intermediate ester such as $2$ might be formed
in two ways: (1a) reaction of triethylamine with phosphazene $8$ to
give the conjugate base of $8$ which then attacks the acyl chloride
(Equation 34); and/or (1b) nucleophilic attack of the hydroxyl group
of phosphazene $8$ on the acyl chloride and subsequent loss of hydrogen
chloride (Equation 35). Acylation via mechanism 1a requires the

\[ \text{la} \quad \text{Ph}_3\text{P} = N - N = C^{\text{OH}} \xrightarrow{\text{base}} [\text{Ph}_3\text{P} = N - N = C^{\text{R}}]^{\text{BH}^+} \]

\[ \xrightarrow{\text{R'CCl}} \quad \text{Ph}_3\text{P} = N - N = C^{\text{R}} + \text{BHCl} \]

\[ 2 \quad O = C^{\text{R'}} \]

\[ \text{lb} \quad \text{Ph}_3 = N - N = C^{\text{Cl}} + C^{\text{C}} \xrightarrow{\text{base}} \text{Ph}_3\text{P} = N - N = C^{\text{R}} \]

\[ \xrightarrow{-\text{BHCl}} \quad 2 \quad O = C^{\text{R'}} \]

acidity of $\alpha$-hydroxyarylidenedetriphenylphosphazene $8$ to be sufficient
to be converted by triethylamine or tetramethylguanidine to its
conjugate base, whereas acylation via mechanism 1b necessitates that the hydroxyl oxygen be more nucleophilic than the phosphinimyl nitrogen towards acyl chlorides. The reaction intermediate, α-acyloxyarylidenetriphenylphosphazine 2, may then undergo an intramolecular Wittig reaction between its ester carbonyl and ylidylic functions (1) (Equation 36) to form betaine 12 which eliminates triphenylphosphine oxide and yields 1,3,4-oxadiazole 3. An analogous betaine intermediate

\[ \text{Ph}_3\text{P}^- \text{N} \text{C} - \text{R} \quad \xrightarrow{\text{σ}} \quad \text{Ph}_3\text{P}^- \text{N} \text{C} - \text{R} \]

\[ \text{12} \]

\[ \text{12} \quad \xrightarrow{\text{Ph}_3\text{P} = \text{O} + \text{R}' -} \quad \text{Ph}_3\text{P} \]

\[ \text{2} \]

has been proposed for the formation of 1,2,3-triazoles in reaction of phosphoranes with azides (22). The rapid ring closure of


α-acyloxyarylidenetriphenylphosphazine 2 might be expected because of the favorable geometry of the transition state for reaction to give the very stable products, triphenylphosphine oxide and 1,3,4-oxadiazoles.

Mechanism 2 requires acylation of α-hydroxyarylidenetriphenylphosphazin e 2 to occur on phosphinimyl nitrogen to form betaine 13,
which then loses chloride ion giving phosphazinium salt 10 (Equation 37). Such an acylation is analogous to benzycylation of

\[
\text{Ph}_3\text{P} - \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{OH} \end{array} \xrightarrow{\text{R'CCL}} \left[ \begin{array}{c} \text{Ph}_3\text{P} - \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{O} \text{R} \end{array} \text{Cl} \end{array} \right]^{+} \quad (37) 
\]

methylenetriphenylphosphazine (23) (Equation 38). Phosphazinium salt

\[
\text{Ph}_3\text{P} = \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{H} \text{H} \end{array} \xrightarrow{\text{PhCCl}} \left[ \begin{array}{c} \text{Ph}_3\text{P} - \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{O} \text{C} \text{Ph} \end{array} \text{Cl} \end{array} \right]^{+} \quad (38) 
\]

10 may then form 1,3,4-oxadiazole 2 in three different ways as summarized in Equations 39, 40, 41.

\[
\left[ \begin{array}{c} \text{Ph}_3\text{P} - \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{O} \text{C} \text{R} \end{array} \text{Cl} \end{array} \right]^{+} \xrightarrow{-\text{Ph}_3\text{P}=\text{O}} \left[ \begin{array}{c} \text{R'} \text{C} \equiv \text{N} = \begin{array}{c} \begin{array}{c} + \text{N} \text{N} \text{C} \\ \text{O} \text{R} \end{array} \text{Cl} \end{array} \right]^{+} \quad (39) 
\]

\[2a\]

\[\text{Et}_3\text{N} \xrightleftharpoons{\text{Et}_3\text{NHCl}} \text{R'C} \equiv \text{N} = \begin{array}{c} \text{N} \text{N} \text{C} \\ \text{O} \text{R} \end{array} \xrightarrow{14} \]

Mechanisms 2a-2c differ in the order in which elimination of triphenylphosphine oxide, loss of hydrogen chloride, and cyclization occur. Mechanism 2a illustrates formation of \(N\)-acyl nitrilimine \(\text{14}\), an intermediate previously (9) proposed in the formation of
1,3,4-oxadiazoles from tetrazoles and acyl chlorides. Mechanisms 2b and 2c require the intermediacy of betaine 12 invoked earlier in mechanism 1.

Mechanism 3 necessitates generation of hydrazimido chloride 11. This sequence thus involves formation of betaine 13 as in mechanism 2, but then elimination of triphenylphosphine oxide must occur faster than loss of chloride ion (Equation 42). Such a reaction might take

\[
\text{Ph}_3\text{P} = N - N = \overset{\text{O}}{\text{R}} \xrightarrow{\text{R'} \text{C-Cl}} \text{Ph}_3\text{P} = N - N = \overset{\text{O}}{\text{R}}
\]

\[
\text{R'} \text{C} = N - N = \overset{\text{OH}}{\text{R}} + \text{Ph}_3\text{P} = \text{O}
\]

place because two stable products are initially produced. Hydrazimido chloride 11 then loses hydrogen chloride to yield N-acynitrilimine 14, which subsequently cyclizes to 1,3,4-oxadiazole. N-Acynitrilimines 14 have been proposed previously (24) in the formation of 1,3,4-oxadiazoles from hydrazones 15, the tautomeric forms of hydrazimido chlorides 11 (Equation 43).


\[
\]
A limited study has been made of the mechanisms of formation of 1,3,4-oxadiazoles in the present systems. It has been reported (23) that phosphazines react with benzoyl chloride in the absence of base to give isolable phosphazinium salts (Equation 38). In the present study, \(\alpha\)-hydroxybenzylidenetriphenylphosphazene was treated with an equivalent amount of benzoyl chloride in benzene without base. The experiment yields \(N\)-benzamidotriphenylphosphiniminium chloride, 2,5-diphenyl-1,3,4-oxadiazole, triphenylphosphine oxide, and benzoyl chloride (Equation 44). That \(N\)-benzamidotriphenylphosphiniminium chloride is obtained signifies that \(\alpha\)-hydroxybenzylidenetriphenylphosphazene acts as a base with respect to hydrogen chloride. Since none of the intermediates 2, 10, and 11 were isolated, this experiment proved inconclusive.
Since intermediates 9, 10, and 11 could not be isolated, methylation of α-hydroxybenzylidenetriphenylphosphazine 16 with a variety of reagents was studied in the hope that these experiments might help predict the site of acylation of phosphazene 16. Methylation (25) of phosphazene 16 gives product mixtures, however, and thus these experiments are not very informative. Perhaps these results imply that acylation occurs at more than one site, and thus formation of oxadiazoles might proceed by more than one mechanism.

The reactions carried out in the present study do not distinguish between mechanisms 1,2, or 3. Isolation or detection of kinetically significant intermediates would obviously resolve the problem. At present, formation of 1,3,4-oxadiazoles might be envisaged to proceed through either α-acyloxyarylidenediphenylphosphazine 9, or phosphazinium salt 10, or hydrazimido chloride 11, or any combination of the above intermediates.

The mechanistic details for preparation of 1,3,4-oxadiazoles via methods A, B, and C are not yet resolved. But yields obtained for 2,5-diaryl-1,3,4-oxadiazoles highly recommend the present methods for preparing these compounds. Methods B and C are more versatile than A, in that unsymmetrically substituted 2,5-diaryl-1,3,4-oxadiazoles are obtained in the former methods. Method A is superior for obtaining symmetrically substituted oxadiazoles, since organophosphorus
intermediates need not be isolated.

Another method studied for preparation of 1,3,4-oxadiazoles involves reaction of triphenyl dibromophosphorane and \( N, N' \)-diacylhydrazines in the presence of triethylamine (Equation 45; Table I). \( N, N' \)-Diacylhydrazines are readily obtained from carboxylate esters and hydrazine hydrate and acyl chlorides (Equations 46, 47).

\[
\text{Ph}_3\text{PB}r_2 + R - \text{CNHNH}R' \xrightarrow{\text{Et}_3\text{N}} \text{PhH, N}_2 \xrightarrow{\text{Et}_3\text{P} = 0 + \text{Et}_3\text{N} \cdot \text{HCl}}
\]

+ \text{Ph}_3\text{P} = 0 + \text{Et}_3\text{N} \cdot \text{HCl}

\[
\text{RCOCH}_3 + \text{NH}_2\text{NH}_2 \cdot \text{H}_2\text{O} \xrightarrow{0} \text{RCNHNH}_2
\]

\[
\text{RCNHNH}_2 + R'\text{CCl} \xrightarrow{0} \text{RCNHNH}R'
\]

Triphenyl dibromophosphorane is prepared in situ conveniently from triphenylphosphine and bromine under nitrogen (26) (Equation 48).


\[
\text{Ph}_3\text{P} + \text{Br}_2 \xrightarrow{\text{benzene, N}_2, 0 - 6^\circ} \text{Ph}_3\text{PB}r_2
\]

The attractive feature of this new route to 1,3,4-oxadiazoles is that it makes use of readily available starting materials. A minor
disadvantage is the high reactivity of triphenyldibromophosphorane. Triphenyldibromophosphorane is unstable under ambient conditions, thus requiring immediate use after preparation. The reaction necessitates an anhydrous medium and an inert atmosphere. This method of preparation of 1,3,4-oxadiazoles has not been thoroughly investigated in the present study, and thus its scope and/or limitations are as yet unknown.

A possible mechanism for 1,3,4-oxadiazole formation for the present method is summarized in Figure 3. Elimination of triphenylphosphine oxide to give \( \text{N-acynitrilimine} \) is analogous to formation of nitriles from amides and triphenyldibromophosphorane (27).
In the present dissertation, four methods of preparation of 1,3,4-oxadiazoles have been developed. These methods include (A) reaction of hydrazinotriphenylphosphonium bromide, acyl chlorides and bases; (B) treatment of \(N\)-aclyamidotriphenylphosphinimium bromides with acyl chlorides and bases; (C) reaction of \(\alpha\)-hydroxyaryldenetriphenylphosphazines with aryl chlorides and bases; and (D) reaction of triphenyldibromophosphorane with \(N,N\)-daiacylhydrazines and base. Each method gives excellent yields of 2,5-diaryl-1,3,4-oxadiazoles. Phenylacetyl chloride reacts with \(N\)-benzamidotriphenylphosphinimium bromide to form the corresponding oxadiazole. But as yet, reactions of either acetyl or propionyl chloride via methods A, B, or C have failed to give 1,3,4-oxadiazoles. These failures to yield oxadiazoles are not presently understood. A mechanistic study was initiated but the experiments do not allow differentiation between the three possible mechanisms proposed.

Further studies on these systems are warranted. Reactions of other aliphatic acyl chlorides in methods A, B, and C need to be investigated. Isolation of the products in the acetyl and propionyl chloride reactions should be done to fully understand their failure to yield oxadiazoles. Method D should be extended to other \(N,N\)-diacylhydrazines.
EXPERIMENTAL

General Information

Melting points Melting points were determined either on a Fisher-Johns melting point block or on a Thomas Hoover apparatus (uncorrected).

Boiling points Boiling points were determined on a semi-micro scale and are uncorrected.

Analyses Analyses were performed by Micro-Analysis, Inc., of Wilmington, Delaware.

Chemicals and solvents Benzene and tetrahydrofuran, reagent grade, were distilled over lithium aluminium hydride and stored over molecular sieves type 4A under nitrogen prior to use. Triethylamine and tetramethylguanidine were distilled over barium oxide and stored over molecular sieves type 4A before use. Acyl chlorides, reagent grade, were used as received from commercial sources.

Infrared spectra All spectra were obtained on a Perkin-Elmer Infracord Spectrophotometer employing potassium bromide pellets for solids and neat compound between salts for liquids.

nmr The nmr of various products were determined on Varian A-60 and A-60A, or Jeol Co. MH100 instruments using dilute chloroform-d solution with tetramethylsilicone as an internal standard.
Reocrystallizations In the recrystallizations, unless otherwise specified, two crops were collected.

Suspensions Hydrazinotriphenylphosphonium and N-acylamidotripheny1-phosphininum bromides and acid hydrazides are only sparingly soluble in benzene, thus reactions with these reagents were carried out as suspensions in benzene, with mechanical stirring.

Fluorescence All 1,3,4-oxadiazoles isolated in this work gave strong characteristic fluorescence under the influence of ultra-violet light.

Preparation of 1,3,4-Oxadiazoles via Hydrazinotriphenylphosphonium Bromide (28).

(28) Prepared according to method described in Part I.

1. 2,5-Diphenyl-1,3,4-oxadiazole

   Under N₂: Hydrazinotriphenylphosphonium bromide (7.46 g, 20 mmole) in benzene (100 ml) was refluxed under nitrogen. Triethylamine (6.16 g, 61 mmole) and benzoyl chloride (5.62 g, 40 mmole) in benzene (20 ml) were added dropwise simultaneously to the stirred mixture. After the addition the mixture was refluxed overnight, cooled, and filtered. The filter cake gave white crystals of triethylammonium bromide (9.1 g, 99.5%). The filtrate was evaporated in vacuo, and either (a) recrystallized from ethanol (two crops) to give pure 2,5-diphenyl-1,3,4-oxadiazole (4.0 g, 84.5%), white crystals, mp 136.5-137° (lit 9a 137-138°); or (b) chromatographed on silica gel
(act. grade I, eluant: benzene) to give the oxadiazole (4.3 g, 97%), mp 136.5-137.5°. Evaporation of the mother liquor in (a) or further elution with chloroform in (b) yielded triphenylphosphine oxide (5.5 g, 99%).

In air: Repetition of the above reaction in air gave triethylammonium bromide (7.5 g, 82.1%), hydrazinotriphenylphosphonium bromide (0.6 g, 8%), and an orange filtrate. The orange filtrate was evaporated in vacuo, then recrystallized from the minimum amount of ethanol to give fluffy white crystals of the oxadiazole (1.53 g, 36%), mp 136-137°.

2. 2,5-Bis(p-methylphenyl)-1,3,4-oxadiazole

p-Methylbenzoyl chloride (3.1 g, 20 mmole) and triethylamine (3.03 g, 30 mmole) were added simultaneously to a stirred mixture of hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole) in benzene (200 ml) under nitrogen. The resulting mixture was refluxed for 8 hr. The white precipitate was collected and washed with benzene. The filtrate and the washings were evaporated in vacuo and recrystallized from ethanol yielding 2,5-bis(p-methylphenyl)-1,3,4-oxadiazole (1.9 g, 77%), mp 175-176° (lit 9a 175-176°).

3. 2,5-Bis(p-methoxyphenyl)-1,3,4-oxadiazole

A solution of anisoyl chloride (1.7 g, 10 mmole) in benzene (15 ml) was added to a mixture of hydrazinotriphenylphosphonium bromide (1.87 g, 5.0 mmole), triethylamine (1.51 g, 15 mmole) and benzene (200 ml) under nitrogen. After the addition was completed, the stirred mixture was refluxed for 10 hr, cooled, and filtered. The
filtrate was evaporated and the residue was recrystallized from ethanol affording white crystals of 2,5-bis(p-methoxyphenyl)-1,3,4-oxadiazole (1.01 g, 72%), mp 165.5-167° (lit 3b 166-167°).

4. 2,5-Bis(p-chlorophenyl)-1,3,4-oxadiazole

Hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole), p-chlorobenzoyl chloride (3.5 g, 20 mmoles), and triethylamine (3.03 g, 30 mmole) in benzene (250 ml) were refluxed overnight under nitrogen. The reaction mixture was evaporated, washed with cold water, and dried. Recrystallization from ethanol afforded white crystals of 2,5-bis(p-chlorophenyl)-1,3,4-oxadiazole (2.1 g, 71%), mp 242-244° (lit 29 242-243°).


5. 2,5-Bis(p-nitrophenyl)-1,3,4-oxadiazole

A mixture of hydrazinotriphenylphosphonium bromide (3.73 g, 10 mmole) and p-nitrobenzoyl chloride (3.7 g, 20 mmole) and triethylamine (3.02 g, 30 mmole) in benzene (250 ml) was refluxed overnight under nitrogen, cooled and evaporated. The residue was washed with cold water, dried, and recrystallized from dimethylformamide to give yellow-brown crystals of 2,5-bis(p-nitrophenyl)-1,3,4-oxadiazole (2.46 g, 79%), mp > 500° (lit 3b 309-311°).
Preparation of 1,3,4-Oxadiazoles via N-Acylamidotriphenylphosphiniminium Bromide

1. 2,5-Diphenyl-1,3,4-oxadiazole

Benzoyl chloride (0.70 g, 5.0 mmole) in benzene (10 ml) was added dropwise to a stirred refluxing mixture of N-benzamidotriphenylphosphiniminium bromide (2.39 g, 5.0 mmole) and triethylamine (1.01 g, 10 mmole) and benzene (100 ml) under nitrogen. The reaction mixture was refluxed for 6 hr after the addition. After cooling, the mixture was filtered and washed with benzene. The combined filtrate was evaporated and recrystallized from ethanol (3 crops) to give white fluffy crystals of 2,5-diphenyl-1,3,4-oxadiazole (0.94 g, 85%), mp 136.5-137.5° (lit \(^9\text{a}\) 137-138°).

2. 2-(p-Methylphenyl)-5-phenyl-1,3,4-oxadiazole

a) A stirred mixture of triethylamine (1.01 g, 10 mmole), N-benzamidotriphenylphosphiniminium bromide (2.39 g, 5.0 mmole) and p-methylbenzoyl chloride (0.77 g, 5.0 mmole) in benzene was refluxed under nitrogen for 8 hr. The filtrate was evaporated \(\text{in vacuo}\) and the residue was recrystallized from ethanol to give 2-(p-methylphenyl)-5-phenyl-1,3,4-oxadiazole (0.96 g, 80%), mp 126° (lit \(^9\text{a}\) 125-126°).

b) Benzoyl chloride (0.14 g, 1.0 mmole) was added all at once to a stirred mixture of N-(p-methylbenzamido)triphenylphosphiniminium bromide (0.49 g, 1.0 mmole), triethylamine (0.2 g, 2.0 mmole) and benzene (50 ml) under nitrogen. After refluxing overnight, the reaction mixture was cooled and filtered. The residue left after
evaporation was recrystallized from ethanol affording 2-(p-methylphenyl)-5-phenyl-1,3,4-oxadiazole (0.17 g, 72%), mp 126°, rf and mp identical to those of the material obtained in a) above.

3. 2-(p-Methoxyphenyl)-5-phenyl-1,3,4-oxadiazole

a) Under nitrogen, N-benzamidotriphenylphosphiniminium bromide (4.77 g, 10 mmole) was added through a solid addition flask to a stirred mixture of p-anisoyl chloride (1.7 g, 10 mmole) and triethylamine (2.0 g, 20 mmole) in benzene (1200 ml). After the addition, the mixture was refluxed for 8 hr. The reaction mixture was then evaporated in vacuo, washed with cold water, and dried. Upon recrystallization from ethanol, white crystals of 2-(p-methoxyphenyl)-5-phenyl-1,3,4-oxadiazole (2.16 g, 86%), mp 149-150° (lit 9a 149-149.5°) were obtained.

b) N-(p-Methoxybenzamido)triphenylphosphiniminium bromide (0.51 g, 1.0 mmole), triethylamine (0.20 g, 2.0 mmole) and benzoyl chloride (0.14 g, 1.0 mmole) in benzene (50 ml) were refluxed overnight under nitrogen. The filtrate was evaporated in vacuo and the resulting solid was recrystallized from ethanol to give 2-(p-methoxyphenyl)-5-phenyl-1,3,4-oxadiazole (0.20 g, 80%), mp 149-150°, identical to the material in a) above.

4. 2-(p-Chlorophenyl)-5-phenyl-1,3,4-oxadiazole

a) Tetramethylguanidine (2.3 g, 20 mmole) and N-benzamidotriphenylphosphiniminium bromide (4.77 g, 10 mmole) were added to a solution of p-chlorobenzoyl chloride (1.75 g, 10 mmole) in
benzene (200 ml) under nitrogen. After refluxing overnight, the mixture was evaporated. The residue was washed with cold water, dried, and recrystallized from ethanol yielding 2-(p-chlorophenyl)-5-phenyl-1,3,4-oxadiazole (1.92 g, 75%), mp 157° (lit 3e 157-158°).

b) To a stirred refluxing mixture of N-(p-chlorobenzyamide)triphenylphosphiniminium bromide (0.51 g, 1.0 mmole) in tetrahydrofuran (60 ml) were added triethylamine (0.20 g, 2.0 mmole) and benzoyl chloride (0.14 g, 1.0 mmole) under nitrogen. The reaction mixture was refluxed for 8 hr., cooled, and evaporated. After washing with cold water, the residue was recrystallized from ethanol affording white crystals of 2-(p-chlorophenyl)-5-phenyl-1,3,4-oxadiazole (0.21 g, 82%), mp 157-158°, identical to the material in a) above.

5. 2-(p-Nitrophenyl)-5-phenyl-1,3,4-oxadiazole

a) A mixture of N-benzamidotriphenylphosphiniminium bromide (2.39 g, 5.0 mmole) and p-nitrobenzoyl chloride (0.93 g, 5.0 mmole) in benzene (200 ml) was refluxed under nitrogen overnight. After evaporation of solvent, the solid was pulverized, washed with water, dried and washed with ethanol. Pale yellow crystals of 2-(p-nitrophenyl)-5-phenyl-1,3,4-oxadiazole (2.5 g, 94%), mp 207-209° (lit 3e 206.5-208°) were obtained.

b) Tetramethylguanidine (0.23 g, 2.0 mmole) and benzoyl chloride (0.14 g, 10 mmole) were added to a stirred mixture of N-(p-nitrobenzamidotriphenylphosphiniminium bromide (0.52 g, 11.0 mmole) in benzene (100 ml). The resulting mixture was refluxed under nitrogen
for 8 hr. The yellowish solid obtained after the evaporation of the solvent was washed with cold water and with ethanol. The solid was the expected 2-(p-nitrophenyl)-5-phenyl-1,3,4-oxadiazole (0.25 g, 86%), mp 207-209°. A mixed mp of the oxadiazole obtained in (5a) and (b) showed no depression.

6. 2,5-Bis(p-methylphenyl)-1,3,4-oxadiazole

p-Methylbenzoyl chloride (0.15 g, 1.0 mmole) was added to a refluxing mixture of triethylamine (0.20 g, 2.0 mmole) and N-(p-methylbenzamido)triphenylphosphiniminium bromide (0.49 g, 1.0 mmole) in benzene (50 ml). The refluxing was continued for 6 hr. under nitrogen. The residue, after evaporation of the filtrate, was recrystallized from ethanol to give 2,5-bis(p-methylphenyl)-1,3,4-oxadiazole (0.19 g, 76%), white crystals, mp 175-176° (lit 9a 175-176°).

7. 2,5-Bis(p-methoxyphenyl)-1,3,4-oxadiazole

N-(p-Methoxybenzamido)triphenylphosphiniminium bromide (1.01 g, 2.0 mmole), triethylamine (0.40 g, 4.0 mmole), and p-methoxybenzoyl chloride (0.34 g, 2.0 mmole) in tetrahydrofuran (80 ml) were refluxed under nitrogen overnight. The filtrate was evaporated in vacuo. Recrystallization of the solid residue afforded white crystals of 2,5-bis(p-methoxyphenyl)-1,3,4-oxadiazole (0.47 g, 83%), mp 165-166.5° (lit 9b 166-167°).

8. 2,5-Bis(p-chlorophenyl)-1,3,4-oxadiazole

N-(p-Chlorobenzamido)triphenylphosphiniminium bromide (0.51 g, 1.0 mmole) was added to a stirred mixture of p-chlorobenzoyl chloride
(0.18 g, 1.0 mmole), triethylamine (0.20 g, 2.0 mmole), and benzene (60 ml) under nitrogen. The resulting suspension was refluxed, with stirring, for 10 hr. The solid residue, after evaporation of the solvent, was washed with cold water, dried, and recrystallized from ethanol, yielding white crystals of 2,5-bis(\(p\)-chlorophenyl)-1,3,4-oxadiazole (0.25 g, 84%), mp 242-244° (lit \(^{29}_{\text{b}}\) 242-243°).

9. 2,5-Bis(\(p\)-nitrophenyl)-1,3,4-oxadiazole

\(p\)-Nitrobenzoyl chloride (0.19 g, 1.0 mmole) was added to the yellow mixture of \(\text{N-}(p\text{-nitrobenzamido})\text{triphenylphosphiniminium bromide (0.52 g, 1.0 mmole) and triethylamine (0.20 g, 2.0 mmole) in benzene (100 ml) under nitrogen. After refluxing for 8 hr, the mixture was evaporated. The residue was washed with cold water, dried, and recrystallized from \(\text{N,N-dimethylformamide, affording yellow-brown crystals of 2,5-bis(p-nitrophenyl)-1,3,4-oxadiazole (0.28 g, 90%), mp > 300° (lit }^{3b} 309-310°).}

10. 2-(\(p\)-Methoxyphenyl)-5-(\(p\)-methylphenyl)-1,3,4-oxadiazole

a) A mixture of \(\text{N-}(p\text{-methoxybenzamido})\text{triphenylphosphiniminium bromide (0.51 g, 1.0 mmole), \(p\)-methylbenzoyl chloride (0.15 g, 1.0 mmole), and triethylamine (0.20 g, 2.0 mmole) in benzene (50 ml) was refluxed under nitrogen overnight. The filtrate was evaporated and the residue was recrystallized from ethanol yielding 2-(\(p\)-methoxyphenyl)-5-(\(p\)-methylphenyl)-1,3,4-oxadiazole (0.21 g, 79%), mp 148-150° (lit \(^{9a}\) 148.5-150°).

b) To a stirred refluxing mixture of \(\text{N-}(p\text{-methylbenzamido})\text{triphenylphosphiniminium bromide (0.49 g, 1.0 mmole) and triethylamine
(0.20 g, 2.0 mmole) in tetrahydrofuran (60 ml) was added p-anisoyl chloride (0.17 g, 1.0 mmole). After refluxing for 10 hr. under nitrogen, the mixture was evaporated in vacuo. The residue was washed with cold water, dried, and recrystallized from ethanol. White crystals of 2-(p-methoxyphenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole (0.22 g, 82%), mp 149-150° (lit 9a 148.5-150°), were obtained.

11. 2-(p-Chlorophenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole

\[ N-(p-Chlorobenzamido)triphenylphosphiniminium bromide (0.51 g, 1.0 mmole), p-methylbenzoyl chloride (0.15 g, 1.0 mmole), triethylamine (0.20 g, 2.0 mmole), and benzene (50 ml) were refluxed under nitrogen for 8 hr. After evaporation of the solvent, the white solid was washed with cold water, dried, and recrystallized from ethanol, affording 2-(p-chlorophenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole (0.25 g, 92%), mp 205-208° (lit 3e 205-206°).

12. 2-(p-Chlorophenyl)-5-(p-methoxyphenyl)-1,3,4-oxadiazole

A benzene (50 ml) mixture of \[ N-(p-chlorobenzamido)triphenylphosphiniminium bromide (0.51 g, 1.0 mmole), triethylamine (0.20 g, 2.0 mmole), and p-anisoyl chloride (0.17 g, 1.0 mmole) was refluxed under nitrogen for 10 hr. Evaporation of the filtrate gave a white solid which was recrystallized from ethanol to give 2-(p-chlorophenyl)-5-(p-methoxyphenyl)-1,3,4-oxadiazole (0.22 g, 77%), mp 159-161° (lit 3e 160-161.5°).

13. 2-(p-Methylphenyl)-5-(p-nitrophenyl)-1,3,4-oxadiazole

p-Methylbenzoyl chloride (0.15 g, 1.0 mmole) was added to a
stirred refluxing mixture of \( N-(p\text{-nitrophenylbenzamido}) \)triphenylphosphiniminium bromide (0.52 g, 1.0 mmole) and triethylamine (0.20 g, 2.0 mmole) in benzene (100 ml) under nitrogen. After refluxing overnight, the solvent was stripped from the mixture. The residue was washed with cold water, dried, and recrystallized from ethanol. Pale yellow crystals of 2-(\( p\text{-methylphenyl} \))-5-(\( p\text{-nitrophenyl} \))-1,3,4-oxadiazole (0.24 g, 85%), mp 228-230° (lit 9a 229-230°), were obtained.

14. 2-(\( p\text{-Methoxyphenyl} \))-5-(\( p\text{-nitrophenyl} \))-1,3,4-oxadiazole

\( N-(p\text{-Nitrobenzamido}) \)triphenylphosphiniminium bromide (0.52 g, 1.0 mmole) was added all at once to a stirred solution of \( p\text{-anisoyl chloride} \) (0.17 g, 1.0 mmole) and triethylamine (0.20 g, 2.0 mmole) in benzene (100 ml). The resulting suspension was stirred under nitrogen for 6 hr, cooled, and the benzene evaporated. After washing with cold water, the residue was dried and recrystallized from ethanol, affording yellow crystals of 2-(\( p\text{-methoxyphenyl} \))-5-(\( p\text{-nitrophenyl} \))-1,3,4-oxadiazole (0.25 g, 84%), mp 229-231° (lit 9a 229-230°).

15. 2-(\( p\text{-Chlorophenyl} \))-5-(\( p\text{-nitrophenyl} \))-1,3,4-oxadiazole

\( N-(p\text{-Nitrobenzamido}) \)triphenylphosphiniminium bromide (0.52 g, 1.0 mmole), \( p\text{-chlorobenzoyl chloride} \) (0.18 g, 1.0 mmole), and triethylamine (0.20 g, 2.0 mmole) in benzene (100 ml) were refluxed for 10 hr under nitrogen. The yellow mixture was evaporated, washed with cold water, and dried. The residue was pulverized and washed with a small amount of ice-cold ethanol to give
2-(p-chlorophenyl)-5-(p-nitrophenyl)-1,3,4-oxadiazole (0.26g, 89%),
yellow crystals, mp 256-260° (lit 254-259°).

16. 2-Methyl-5-phenyl-1,3,4-oxadiazole

To a stirred suspension under nitrogen of N-acetamidotriphenyl-
phosphiniminium bromide (2.08 g, 5.0 mmole) and triethylamine (1.01 g,
10 mmole) in benzene (150 ml) was added benzoyl chloride (0.70 g,
5.0 mmole). After refluxing overnight, the mixture was cooled and
solvent removed on a rotary evaporator. The residue was ground and
washed several times with ether. The combined ether washings were
evaporated and the remaining solid chromatographed on silica gel
(grade I, benzene), affording 2-methyl-5-phenyl-1,3,4-oxadiazole
(0.37 g, 46%), white crystals, mp 64-66° (lit 9a 65-66°).

17. 2-Methyl-5-(p-methylphenyl)-1,3,4-oxadiazole

p-Methylbenzoyl chloride (0.75 g, 5.0 mmole) was added dropwise
to a stirred refluxing mixture of N-acetamidotriphenylphosphiniminium
bromide (2.08 g, 5.0 mmole) and triethylamine (1.01 g, 10 mmole) in
benzene (150 ml) under nitrogen. The reaction mixture was refluxed
for 8 hours after the addition was complete. After evaporation of the
solvent, the residue was pulverized. The fine powder was extracted
with ether in a Soxhlet extractor. The ether extract was evaporated
and the residue was chromatographed on silica gel (grade I, benzene)
to give 2-methyl-5-(p-methylphenyl)-1,3,4-oxadiazole (0.48 g, 55%), white
crystals, mp 103-105° (lit 9a 103.5-104.5°).
18. 2-(p-Methoxyphenyl)-5-methyl-1,3,4-oxadiazole

Under nitrogen, a mixture of p-anisoyl chloride (0.85 g, 5.0 mmoles), N-acetamidotriphenylphosphiniminium bromide (2.08 g, 5.0 mmoles) and triethylamine (1.01 g, 10 mmoles) in benzene (150 ml) was refluxed overnight. The residue after evaporation was pulverized and extracted with ether in a Soxhlet extractor. Evaporation of ether and chromatography on silica gel (grade I, benzene) gave white crystals of 2-(p-methoxyphenyl)-5-methyl-1,3,4-oxadiazole (0.43 g, 45%), mp 90-91° (lit 9a 91-92°).

19. 2-Methyl-5-(p-nitrophenyl)-1,3,4-oxadiazole

p-Nitrobenzoyl chloride (0.93 g, 5.0 mmole), N-acetamidotriphenylphosphiniminium bromide (2.08 g, 5.0 mmole) and triethylamine (1.01 g, 10 mmole) in benzene (150 ml) was refluxed under nitrogen for 8 hr. The benzene was stripped, the residue pulverized and extracted with ether in a Soxhlet extractor. The ether extract was evaporated and chromatographed on silica gel (grade I, benzene). Pale yellow crystals of 2-methyl-5-(p-nitrophenyl)-1,3,4-oxadiazole (0.58 g, 56%) were obtained, mp 165-167° (lit 9a 166°).

20. 2-(p-Chlorophenyl)-5-methyl-1,3,4-oxadiazole

p-Chlorobenzoyl chloride (0.88 g, 5.0 mmole) was added to a stirred refluxing mixture of N-acetamidotriphenylphosphiniminium bromide (2.08 g, 5.0 mmole) and triethylamine (1.01 g, 10 mmole) in benzene (150 ml). After refluxing overnight, the mixture was evaporated. The ground solid was placed in a Soxhlet extractor and extracted with
ether. Evaporation of the solvent and chromatography on silica gel (grade I, benzene) yielded white crystals of 2-methyl-5-(p-chlorophenyl)-1,3,4-oxadiazole (0.51 g, 52%), mp 105-107° (lit 9a 107°).

21. 2-(p-Chlorophenyl)-5-ethyl-1,3,4-oxadiazole

N-Propionamidotriphenylphosphiniminium bromide (2.15 g, 5.0 mmole), triethylamine (1.01 g, 10 mmole), and p-chlorobenzoyl chloride (0.88 g, 5.0 mmole) in benzene (50 ml) were refluxed under nitrogen overnight. The mixture was evaporated in vacuo, washed with a minimum amount of cold water, dried, and recrystallized from 95% ethanol to give white crystals of 2-(p-chlorophenyl)-5-ethyl-1,3,4-oxadiazole (0.58 g, 56%), mp 94° (lit 17b 93-94°).

22. 2-Ethyl-5-(p-nitrophenyl)-1,3,4-oxadiazole

A stirred mixture of p-nitrobenzoyl chloride (0.93 g, 5.0 mmole) N-propionamidotriphenylphosphiniminium bromide (2.15 g, 5.0 mmole) and triethylamine (1.01 g, 1.0 mmole) in benzene (50 ml) was refluxed for 10 hr under nitrogen. The pale yellow mixture was evaporated in vacuo. The solid residue was washed with a small amount of cold water and dried. Recrystallization from chlorobenzene affords yellow crystals of 2-ethyl-5-(p-nitrophenyl)-1,3,4-oxadiazole (0.60 g, 55%), mp 132-135° (lit 17b 133-134°).

23. 2-Ethyl-5-phenyl-1,3,4-oxadiazole

N-Propionamidotriphenylphosphiniminium bromide (4.3 g, 10 mmole), triethylamine (2.02 g, 20 mmole), and benzoyl chloride (1.4 g, 10 mmole) in benzene (125 ml) were refluxed overnight under nitrogen.
The mixture was evaporated in vacuo. The residual oil was washed several times with ether. The ether was distilled off from the combined washings. The resultant liquid was purified by vacuum distillation to give 2-ethyl-5-phenyl-1,3,4-oxadiazole (0.70 g, 50%) bP0.2 115° (lit 17b bP0.1 105°).

24. 2-Ethyl-2-(p-methoxyphenyl)-1,3,4-oxadiazole

N-Propionamidotriphenylphosphiniminium bromide (4.3 g, 10 mmole), triethylamine (2.02 g, 20 mmole), and p-methoxybenzoyl chloride (1.71 g, 10 mmole) in benzene (100 ml) were refluxed overnight under nitrogen. The mixture was evaporated in vacuo. The residual oil was washed several times with ether. The ether was distilled off from the combined washings. The resultant liquid was purified by vacuum distillation to give a colorless liquid, 2-ethyl-5-(p-methoxyphenyl)-1,3,4-oxadiazole (0.74 g, 36%), bP0.1 146° (lit 17b bP0.05 135°).

25. 2-Benzyl-5-phenyl-1,3,4-oxadiazole

N-Benzamidotriphenylphosphiniminium bromide (0.48 g, 1.0 mmole), triethylamine (0.20 g, 2.0 mmole), and phenylacetyl chloride (0.15 g, 1.0 mmole) in benzene (50 ml) were refluxed under nitrogen overnight. The mixture was evaporated, washed with cold water, dried, and recrystallized from ethanol to give 2-benzyl-5-phenyl-1,3,4-oxadiazole (0.13 g, 56%), mp 101-103° (lit 9a 101-102.5°).

Attempted Preparation of 2-Methyl-5-phenyl-1,3,4-oxadiazole

Acetyl chloride (0.79 g, 10 mmole) was added dropwise to a suspension of N-benzamidotriphenylphosphiniminium bromide (4.77 g, 10 mmole) and triethylamine (2.02 g, 20 mmole) in benzene (110 ml).
The reaction mixture became warm and turned yellow upon the addition of the chloride. The resulting suspension was stirred overnight at room temperature. The yellow filtrate was evaporated in vacuo. Tlc of the yellow residue showed no 1,3,4-oxadiazole present. Elution with chloroform–ethanol on silica gel (grade I) did not give any material.

The reaction conditions were varied, but still no detectable amount of the desired oxadiazole was obtained.

**Attempted Preparation of 2-Ethyl-5-phenyl-1,3,4-oxadiazole**

Propionyl chloride (0.92 g, 10 mmole) was added dropwise to a suspension of N-benzamidetriphenylphosphiniminium bromide (4.77 g, 10 mmole) and triethylamine (2.02 g, 20 mmole) in benzene (100 ml). The resulting yellow suspension was stirred overnight at room temperature under nitrogen. After filtration, the filtrate was evaporated in vacuo. Tlc of the residue gave no indication of the presence of the desired 1,3,4-oxadiazole. Reaction conditions for the experiment were varied, but still no oxadiazole was obtained.

The use of other N-acylamidotriphenylphosphiniminium bromides also failed to give detectable amounts of the corresponding oxadiazoles.

**Preparation of 1,3,4-Oxadiazoles via α-Hydroxy aryldenetriphenylphosphazines**

1. **2-(p-Methylphenyl)-5-phenyl-1,3,4-oxadiazole**

   α-Hydroxy-(p-methylbenzylidene)triphenylphosphazine (0.82 g, 2.0 mmole), triethylamine (0.20 g, 2.0 mmole), and benzoyl chloride
(0.28 g, 2.0 mmole) in benzene (50 ml) were stirred overnight under nitrogen at room temperature. The white precipitate was collected by filtration, washed with benzene, and identified as triethylammonium chloride (0.27 g, 100%), mp 254°C (dec)(lit 30 254°C). The filtrate and

(30) Handbook of Chemistry and Physics, Chemical Rubber Publishing Co.,
Cleveland, 1965.

the washings were combined, evaporated in vacuo, and recrystallized from ethanol (3 crops) yielding 2-(p-methylphenyl)-5-phenyl-1,3,4-oxadiazole (0.39 g, 83%), mp 125°C (lit 9a 126-127°C). Evaporation of the mother liquor gave triphenylphosphine oxide (0.52 g, 93.9%) mp 156°C.

2. 2,5-Bis(p-methylphenyl)-1,3,4-oxadiazole

p-Methylbenzoyl chloride (0.31 g, 2.0 mmole) was added to a solution of α-hydroxy(p-methylbenzylidene)triphenylphosphazine (0.82 g, 2.0 mmole) and triethylamine (0.20 g, 2.0 mmole) in benzene (50 ml) under nitrogen and stirred for 1½ hr. The filtrate was evaporated in vacuo. Recrystallization of the solid residue from ethanol gave 2,5-bis(p-methylphenyl)-1,3,4-oxadiazole (0.46 g, 92%), white crystals, mp 174-176°C (lit 9a 175-176°C).

3. 2-(p-Methoxyphenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole

Triethylamine (0.20 g, 2.0 mmole) and anisoyl chloride (0.34 g, 2.0 mmole) were added dropwise simultaneously to a stirred solution of α-hydroxy-(p-methylbenzylidene)triphenylphosphazine
(0.82 g, 2.0 mmoles) under nitrogen. After an hour the addition was complete and a white precipitate had begun to appear. The stirring was continued for 8 hr. The mixture was filtered, evaporated and recrystallized from ethanol. White crystals of 2-(p-methoxyphenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole (0.53 g, 99%) mp 149-150° (lit 9a 149.5-150°) were obtained.

4. 2-(p-Methylphenyl)-5-(p-nitrophenyl)-1,3,4-oxadiazole

A mixture of α-hydroxy(p-methylbenzylidene)triphenylphosphazine (0.82 g, 2 mmoles), triethylamine (0.20 g, 2.0 mmoles), and p-nitrobenzoyl chloride (0.37 g, 2.0 mmoles) in benzene (50 ml) was refluxed under nitrogen for 2 hr. The mixture was evaporated in vacuo, washed with water, dried, and washed with ethanol affording 2-(p-methylphenyl)-5-(p-nitrophenyl)-1,3,4-oxadiazole (0.54 g, 96%), pale yellow crystals, mp 228-230° (lit 9a 229-230°).

5. 2-(p-Chlorophenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole

α-Hydroxy(p-chlorobenzylidene)triphenylphosphazine (0.86 g, 2.0 mmoles) and triethylamine (0.20 g, 2.0 mmoles) in benzene (50 ml) were refluxed for 4 hr and then stored overnight under nitrogen. The filtrate was evaporated in vacuo and recrystallized from ethanol. White crystals of 2-(p-chlorophenyl)-5-(p-methylphenyl)-1,3,4-oxadiazole (0.51 g, 94%), mp 205° (lit 3e 205-206°) were obtained.

6. 2-(p-Methoxyphenyl)-5-(p-nitrophenyl)-1,3,4-oxadiazole

To α-hydroxy(p-nitrobenzylidene)triphenylphosphazine (0.88 g, 2.0 mmoles) in benzene (100 ml) were added dropwise simultaneously
triethylamine (0.20 g, 2.0 mmole) and \( p \)-methoxybenzoyl chloride (0.34 g, 2.0 mmole). After the addition, the solution was refluxed for 6 hr, cooled, and evaporated. The solid was washed with cold water, dried, and recrystallized from chlorobenzene to give yellow crystals of 2-(\( p \)-methoxyphenyl)-5-(\( p \)-nitrophenyl)-1,3,4-oxadiazole (0.58 g, 98\%), mp 229-231° (lit 9a 229-230°).

7. 2-(\( m \)-Methylphenyl)-5-(\( p \)-methylphenyl)-1,3,4-oxadiazole

A solution of \( m \)-methylbenzoyl chloride (0.31 g, 2.0 mmole), \( \alpha \)-hydroxy(\( p \)-methylbenzylidene)triphenylphosphazine (0.82 g, 2.0 mmole), and triethylamine (0.20 g, 2.0 mmole) in benzene (50 ml) was stirred for 24 hr under nitrogen at room temperature. Evaporation of the filtrate gave a white solid which was recrystallized from ethanol. The white crystals were identified as 2-(\( m \)-methylphenyl)-5-(\( p \)-methylphenyl)-1,3,4-oxadiazole (0.42 g, 84\%), mp 76-78°; nmr δ 2.40 (s, 3), 2.42 (s, 3), 7.2-7.92 (complex \( m \), 8).

Anal. calcd. for C\(_{16}\)H\(_{14}\)N\(_2\)O: N, 11.19; Found: N, 10.92.

8. 2-(\( p \)-Methylphenyl)-5-(\( m \)-nitrophenyl)-1,3,4-oxadiazole

\( m \)-Nitrobenzoyl chloride (0.37 g, 2.0 mmole) was added all at once to a stirred solution of \( \alpha \)-hydroxy(\( p \)-methylbenzylidene)triphenylphosphazine (0.82 g, 2.0 mmole), and triethylamine (0.20 g, 2.0 mmole), in benzene (50 ml) under nitrogen. After stirring 14 hr at room temperature, the reaction mixture was evaporated in vacuo. The solid residue was washed with cold water and dried. Recrystallization from ethanol yielded pale yellow crystals of 2-(\( p \)-methylphenyl)-5-(\( m \)-nitrophenyl)-1,3,4-oxadiazole (0.48 g, 86\%), mp 173-175°, nmr δ 2.46 (s, 3),
7.25-9.3 (complex m, 8).

    Anal. Calcd. for C_{19}H_{11}N_{3}O_{3};  N, 14.94;  Found:  N, 14.73.

**Attempted Preparation of 2-Methyl-5-phenyl-1,3,4-oxadiazole**

A solution of acetyl chloride (0.08 g, 1.0 mmole) in benzene (10 ml) was added dropwise to a solution of α-hydroxybenzylidenetriphenylphosphazine (0.40 g, 1.0 mmole) and triethylamine (0.10 g, 1.0 mmole) in benzene (50 ml) under nitrogen. The solution immediately became warm and turned yellow. After stirring overnight under nitrogen, the filtrate was evaporated. TLC of the residue did not give any 2-methyl-5-phenyl-1,3,4-oxadiazole. Variation of reaction conditions did not yield any of the oxadiazole.

**Attempted Preparation of 2-Ethyl-5-phenyl-1,3,4-oxadiazole**

Propionyl chloride (0.09 g, 1.0 mmole) was added to a stirred solution of α-hydroxybenzylidenetriphenylphosphazine (0.40 g, 1.0 mmole) and triethylamine (0.10 g, 1.0 mmole) in benzene (100 ml) under nitrogen at room temperature. After stirring for 20 hr, the reaction mixture was filtered. Evaporation of the filtrate in vacuo gave a yellow solid. All attempts to isolate the desired oxadiazole failed.

Other attempts were made to obtain oxadiazoles using other α-hydroxyaryldienetriphenylphosphazines, and acetyl or propionyl chloride with base, but all failed.

**Preparation of 1,3,4-Oxadiazoles via triphenylidibromophosphorane (31)**

1. **2,5-Diphenyl-1,3,4-oxadiazole**

Triethylamine (2.12 g, 21 mmole) was added dropwise and N,N'-dibenzoylhydrazine (2.40 g, 10 mmole) was added portionwise simultaneously through a solid-addition flask to a stirred suspension of freshly prepared triphenyldibromophosphorane (31) (4.22 g, 10 mmole) in dry benzene (100 ml) under nitrogen. The mixture was stirred at room temperature overnight. The solvent was evaporated and the resulting solid was washed with cold water and dried in vacuo. Chromatography on silica gel (act. I, benzene) gave 2,5-diphenyl-1,3,4-oxadiazole (1.53 g, 68%), mp 136.5-137.5°C (lit.\(^9\) 137-138°C).

2. **2-(p-Methylphenyl)-5-phenyl-1,3,4-oxadiazole**

At 10-14°C under nitrogen, N-benzoyl-N'-(p-methylbenzoyl)hydrazine (2.40 g, 10 mmole) was added in portions through a solid-addition flask to a stirred suspension of triethylamine (2.12 g, 21 mmole) and triphenyldibromophosphorane (4.22 g, 10 mmole) in benzene (200 ml). After stirring 10 hr, the solvent was stripped from the mixture. The residue was washed with cold water, dried, and recrystallized from ethanol. White crystals of 2-(p-methylphenyl)-5-phenyl-1,3,4-oxadiazole (1.5 g, 62%), mp 126°C (lit.\(^9\) 125-126°C) were obtained.

2,5-Diphenyl-1,3,4-oxadiazole from Triphenyolphosphine

Bromine (1.60 g, 10 mmole) in benzene (30 ml) was added dropwise to a stirred solution of triphenyolphosphine (2.62 g, 10 mmole) in benzene (300 ml) at 0-6°C under nitrogen. After the addition the mixture was stirred for 0.5 hr. Anhydrous hydrazine (0.32 g, 10 mmole) and triethylamine (1.01 g, 10 mmole) were added dropwise simultaneously
at 10-14°. After the mixture had warmed to room temperature, benzoyl chloride (2.81 g, 20 mmole) and triethylamine (3.03 g, 3 mmole) were added. The resulting mixture was then refluxed overnight, cooled, filtered, and washed with ether. The combined filtrate was evaporated in vacuo and recrystallized from ethanol (three crops) to give 2,5-diphenyl-1,3,4-oxadiazole (1.55 g, 70%), white crystals, mp 137-138° (lit.9a 137-138°).

**Attempted Isolation of an Intermediate from the Reaction of α-Hydroxybenzylidenetriphenylphosphazine and Benzoyl Chloride**

A solution of α-hydroxybenzylidenetriphenylphosphazine (0.40 g, 1.0 mmole) and benzoyl chloride (0.14 g, 1.0 mmole) in benzene (100 ml) was stirred under nitrogen for 8 hr. The precipitate was collected and washed with benzene. The filter cake was identified as N-benzamidotriphenylphosphiniminium chloride (0.22 g, 50%). The filtrate was evaporated. Tlc of the solid residue showed the presence of triphenylphosphine oxide and 2,5-diphenyl-1,3,4-oxadiazole.