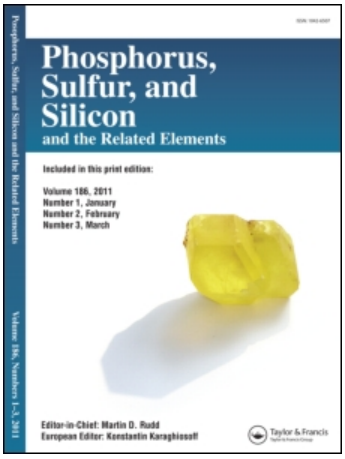

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CHLOROMETHYL-DICHLOROPHOSPHANE: A USEFUL REAGENT FOR THE SYNTHESIS OF NEW HETEROCYCLES WITH DICOORDINATE PHOSPHORUS

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CHLOROMETHYL-DICHLOROPHOSPHANE: A USEFUL REAGENT FOR THE SYNTHESIS OF NEW HETEROCYCLES WITH DICOORDINATE PHOSPHORUS

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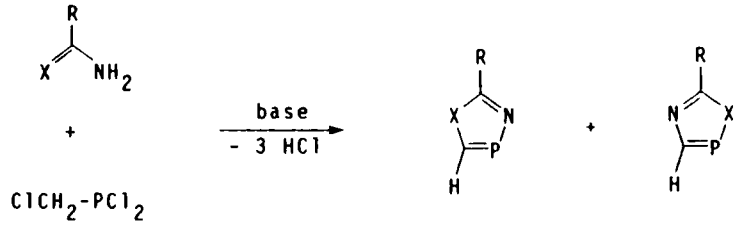
Only a limited number of heterophospholes are known. A general synthesis[1] involves the [4 + 1]-cyclocondensation of a reactive phosphorus(III) compound with an appropriate four-membered chain, as in the synthesis of the 2H-1,2,3-diazaphospholes.[2] The limiting factor in this case is the poor availability of four-membered chains with the necessary functionality at the ends.

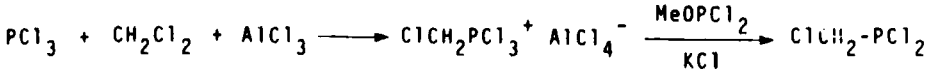
On the other hand the [3 + 2]-cyclocondensation of amidine type compounds with α-haloketones provides a very general approach to five-membered 6π-heterocycles like imidazoles[3] and thiazoles.[4] In looking for a possibility also to synthesize azaphospholes by a [3 + 2]-cyclocondensation, we tried chloromethyl-dichlorophosphane as a reagent to condense with amidine-type compounds. This reagent is similar to α-haloketones in its functionality and we expected the cyclocondensation to yield new heterophospholes with two heteroatoms at one and two bond distances from the phosphorus.



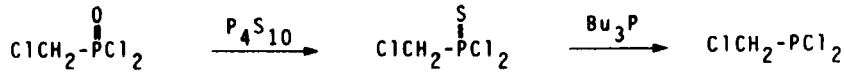
1

In the following I'll summarize our results concerning the cyclocondensation reaction of chloromethyl-dichlorophosphane with amidine-type compounds.

Chloromethyl-dichlorophosphane is not available commercially. A useful laboratory synthesis was described in 1981 by Lutsenko.[5] Phosphorus trichloride is first alkylated by methylene chloride in the presence of aluminum chloride. The resulting chlorophosphonium-tetrachloroaluminate is then reduced with $MeOPCl_2$, yielding 45% of chloromethyl-dichlorophosphane.

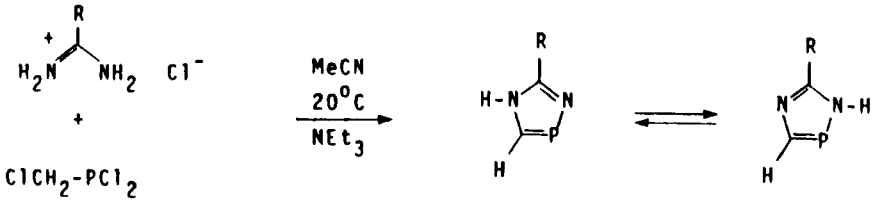


A. A. Prishchenko, E.S. Novikova und I. F. Lutsenko
Zh. Obshch. Khim. 51, 484 (1981). 2



We used chloromethyl-dichlorophosphane oxide as starting material. We first converted it into the sulfide with P_4S_{10} and then desulfurized it by means of tributylphosphane, the overall yield being 68%.

The room temperature cyclocondensation of acetamidinium chloride with chloromethyl-dichlorophosphane in acetonitrile in the presence of a stoichiometric amount of triethylamine yields the previously unknown 2-methyl-1,3,4-diazaphosphole as a mixture of the 1*H*- and 3*H*-isomers. The hydrogen exchange in chloroform between the two isomers is slow on the n.m.r. time scale, so that both of them can be characterized by means of n.m.r..



3

	R = Me	60%	40%
	R = Ph		100%
R = Me;	$\delta^{31}P$ =	+199.0	+208.6
	$^2J_{PCH}$ =	29.3 Hz	57.2 Hz
R = Ph;	$\delta^{31}P$ =		+185.4
	$^2J_{PCH}$ =		53.3 Hz

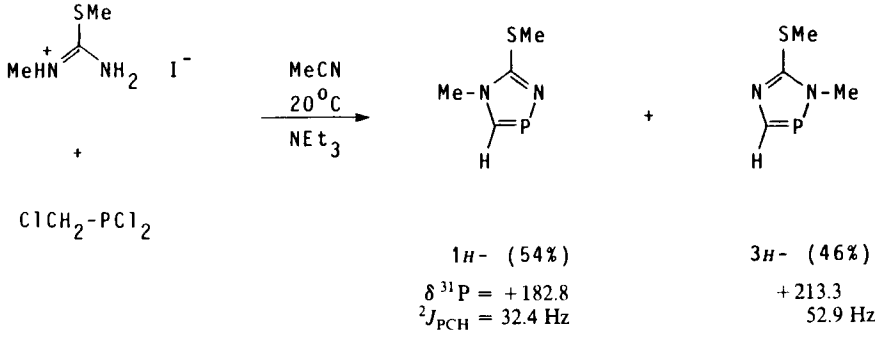
The ^{31}P-, ^{13}C- and ^1H-n.m.r. spectra clearly show the presence of a —CH=P— moiety as a part of a 1,3,4-diazaphosphole ring. The signals of the ^{31}P-nucleus are shifted to lower field with respect to the resonance of the starting dichlorophosphane (+160). The chemical shift of the phosphorus in these heterocycles can be compared with the one observed in some electron-rich 1,2,3-diazaphospholes.[6]

The signals are split into doublets owing to a two-bond coupling with only one adjacent hydrogen atom. The hydrogen is in a cis position with respect to the

phosphorus lone pair and the observed $^2J_{PCH}$ coupling constants are therefore large with values between 30 and 60 Hz.

It is worth noting the remarkable difference between the values of the $^2J_{PCH}$ coupling constants in the two isomers, depending on the position of the triply-coordinated nitrogen with respect to the phosphorus. The coupling constant in the 3*H*-diazaphosphole is almost twice the coupling constant in the 1*H*-isomer. It can be used, therefore, to distinguish the two isomers.

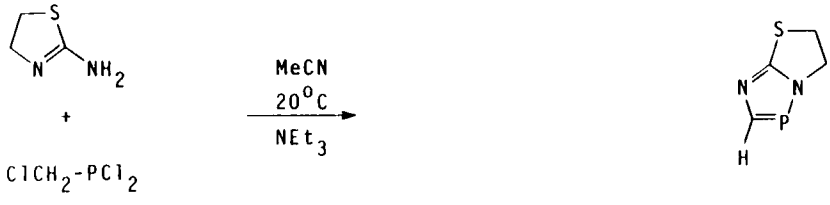
Similarly, benzamidinium chloride reacts with chloromethyl-dichlorophosphane under the same conditions yielding 2-phenyl-3*H*-1,3,4-diazaphosphole as the only product.



1*H*- (54%)
$\delta^{31}P = +182.8$
$^2J_{PCH} = 32.4$ Hz

3*H*- (46%)
+213.3
52.9 Hz

4

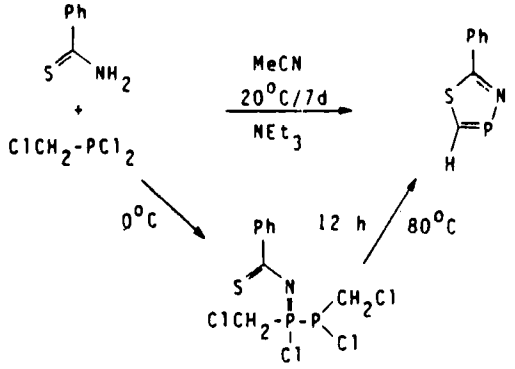


3*H*- (100%)
$\delta^{31}P = +193.7$
$^2J_{PCH} = 54.1$ Hz

Isothiuronium-type compounds react with our phosphorus reagent in a similar way. The cyclocondensation of S-methyl-*N*-methyl-isothiuronium iodide leads to a mixture of the 1*H*- and 3*H*-1,3,4-diazaphospholes now having an S-methyl group in the 2-position. Note that also, in this case, the $^2J_{PCH}$ coupling constant in the 3*H*-isomer is much larger than in the 1*H*-isomer.

The 2-aminothiazolidine has to be placed in the category of three-membered chains. From its reaction with chloromethyl-dichlorophosphane, only one product can be detected and isolated. The $^2J_{PCH}$ coupling constant tells us that it is a 3*H*-1, 3, 4-diazaphosphole, now having the positions 2 and 3 linked by a saturated three-membered chain. The compound is therefore a phosphapentalene derivative.

Thioamides are another type of compound that offer an appropriate three-membered chain for a [3 + 2]-cyclocondensation.

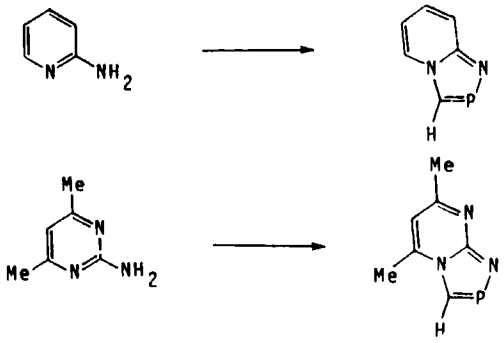


5

Reacting thiobenzamide with chloromethyldichlorophosphane in the presence of a stoichiometric amount of triethylamine in refluxing acetonitrile, overnight or at room temperature for one week, yields a 1,3,4-thiazaphosphole, unsubstituted in the 5-position. The downfield shift of the ^{31}P resonance compares well with the one found in other thiazaphospholes[7]. This is at present the only method available to synthesize a 1,3,4-thiazaphosphole unsubstituted in the 5-position. The reaction resembles strongly the Hantzsch thiazole synthesis from thioamides and α-haloketones[4].

Yet things are a little more complicated. When carrying out the same reaction at 0°C, we were surprised to detect in the ^{31}P-n.m.r. spectrum the presence of a AB spin system, due to a compound having two different phosphorus atoms. The coupling constant of 270 Hz indicated the presence of a P—P bond and the ^{13}C-n.m.r. spectrum showed that there was still a considerable amount of unreacted thiobenzamide. The compound could be isolated and proved to be the condensation product of one molecule of thiobenzamide and two molecules of chloromethyldichlorophosphane. The proposed structure of a diphosphanemonoimine is supported by the ^{13}C- and ^{1}H-n.m.r. data. This compound seems to be an intermediate in the formation of the 1,3,4-thiazaphosphole ring. In fact, by refluxing it with stoichiometric amounts of triethylamine and thiobenzamide overnight, the 1,3,4-thiazaphosphole is formed.

Up to this point, all of the cyclocondensations yielded monocyclic 6π-heterophospholes. Starting with nitrogen heterocycles like α-aminopyridine, which can be regarded as cyclic amidines, condensed 10π-heterophospholes could also be obtained. I'll show you in the following only two representative examples of such syntheses, but it works with many other derivatives of α-aminopyridine as well.

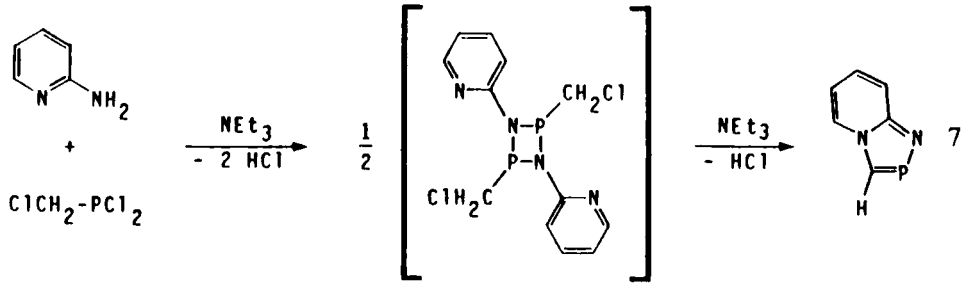


	$\delta^{31}P$	$^2J_{PCH}$ [Hz]
	+195.0	30.3
	+197.2	29.0

6

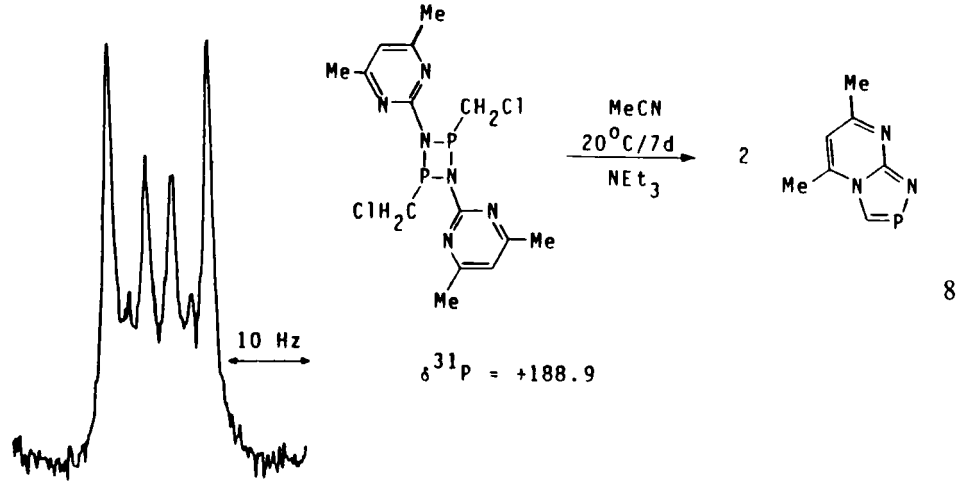
α-Aminopyridine reacts smoothly with chloromethyl-dichlorophosphane, yielding the unsubstituted pyrido-1,3,4-diazaphosphole as colorless crystals with a naphthalene-like smell. Starting with 2-aminopyrimidine, the corresponding pyrimido-1,3,4-diazaphosphole can be isolated. The $^2J_{PCH}$ coupling constants of about 30 Hz indicate that the 1*H*-isomers are formed as the only products.

The formation of just this one isomer for the cyclocondensation suggests a two-step mechanism.



The first step is the well-known condensation of a primary amine and a dichlorophosphane, yielding a diazadiphosphetidine[8]. The second step involves the nucleophilic displacement of the chlorine by the pyridinic nitrogen with the formation of the 1,3,4-diazaphosphole ring, accompanied by a simultaneous fragmentation of the diazadiphosphetidine ring and the evolution of hydrogen chloride.

This mechanism is supported by the isolation of a small amount of such a diazadiphosphetidine in one case and its conversion to the corresponding diazaphosphole. The presence of a diazadiphosphetidine framework is best shown by means of ^{1}H-n.m.r. spectroscopy. The protons of the CH_2-group are the $A_2A'_2$-part of an $A_2A'_2XX'$ spin system which gives rise to the

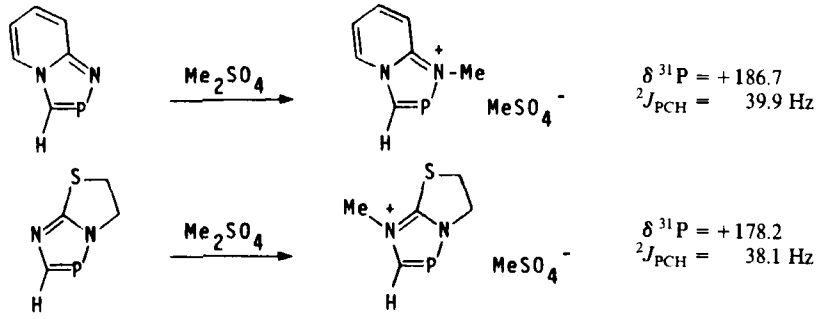


characteristic splitting shown.

As we have seen, chloromethyl-dichlorophosphane is a general reagent for introducing the —CH=P— moiety in heterophospholes by means of a [3 + 2]-cyclocondensation.

The chemistry of the new 1,3,4-diazaphospholes resembles strongly that of the 1,2,3-isomers[1]. They both contain a nitrogen and a phosphorus in the same dicoordinate state as members of the same ring and offer the possibility of comparing directly their reactivity towards an alkylating agent.

Neither of the two diazaphospholes shown reacts with methyl iodide. Using a stronger alkylating reagent like dimethyl sulfate, we observed in both cases only the alkylation of the pyridinic nitrogen, the phosphorus remaining dicoordinated.

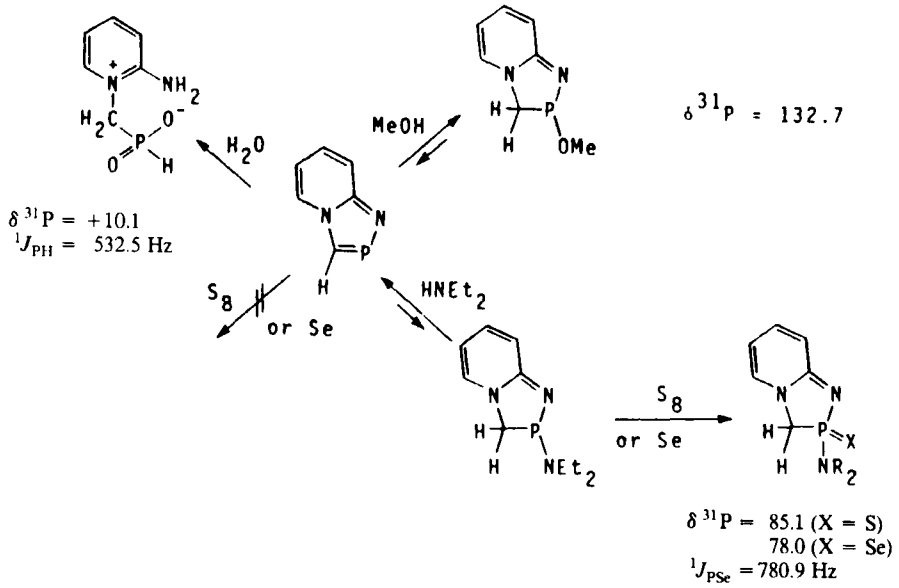


9

This result demonstrates clearly the low nucleophilicity of the dicoordinate phosphorus in heterophospholes. The alkylation of the phosphorus would force it to assume a pyramidal geometry, would decouple it from the delocalized π-system and would result in the loss of resonance energy. On the other hand, alkylation of the pyridinic nitrogen leaves the delocalized π-system unchanged.

As a part of an aromatic π-system, the P=C double bond in part loses its reactivity. Nevertheless, a certain degree of unsaturation remains. This becomes evident in the reactions of the pyrido-1,3,4-diazaphosphole with some protic reagents.

In the presence of excess water, two equivalents add and split the diazaphosphole ring. The addition of methanol is much slower and yields

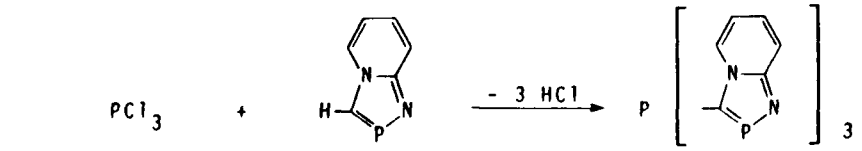


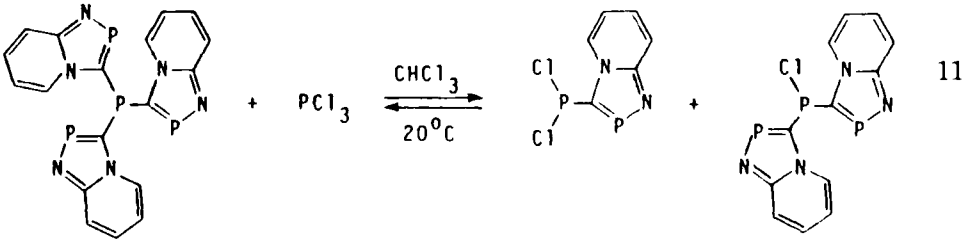
10

the 4,5-dihydro derivative. The diazaphosphole reacts neither with diethylamine, nor with oxidizing agents like sulfur or selenium. Nevertheless, the simultaneous action of both gives the dihydrodiazaphospholyl sulfide, resp. selenide. We interpret this result in terms of a low equilibrium concentration of the amine adduct which reacts with sulfur or selenium.

The addition to the P=C double bond may be followed by a 1,2-elimination reaction, restoring the aromatic system and resulting in a substitution at the heterophosphole.

An example is the reaction with phosphorus trichloride.

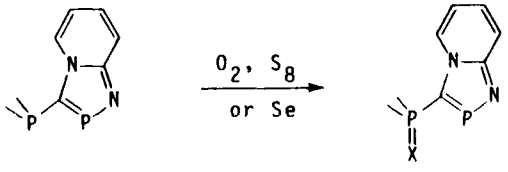




11

δP(II) =	+235.2	+243.6	+237.5
δP(III) =	−74.7	+123.1	24.3
$^2J_{PCP}$[Hz] =	5.4	166.1	69.7

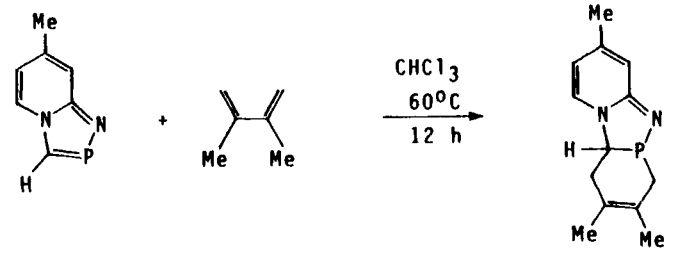
Its addition is followed by the elimination of hydrogen chloride. Choosing a proper stoichiometry, the tris(diazaphospholyl)phosphane can be isolated. With phosphorus trichloride it enters an exchange of substituents and gives the chlorophosphanes with one and two diazaphospholyl groups in an equilibrium process with the starting components. This equilibrium, which involves the breaking of P—C bonds, is fast at room temperature, whereas the exchange of substituents between triphenylphosphane and phosphorus trichloride requires temperatures of 200°C and more[9]. The mobility is certainly the consequence of the addition/elimination mechanism operating in this case.



12

X =	O	S	Se
δP(II) =	+242.8	+240.5	+239.7
δP(IV) =	−2.0	−3.4	−26.4
$^2J_{PCP}$[Hz] =	44.9	40.3	36.7

Oxygen, sulfur or selenium oxidize only the central phosphorus of the tris(diazaphospholyl)phosphane, the dicoordinate phosphorus is not involved.



13

$\delta\ ^{31}P = +55.5$

Like acyclic phosphaalkenes[10], the pyrido-1,3,4-diazaphospholes react as dienophiles. The cycloaddition of 2,3-dimethylbutadiene gives a tricyclic compound with the phosphorus in a bridgehead position.

REFERENCES

1. A. Schmidpeter, Phosphorus Sulfur, Plenary Lecture, IRIS-V, this issue; A. Schmidpeter and K. Karaghiosoff, Nachr. Chem. Tech. Lab., **33**, 793 (1985).
2. J. H. Weinmaier, G. Brunnhuber and A. Schmidpeter, Chem. Ber., **113**, 2278 (1980).
3. A. J. Elliot, H. Guzik and J. R. Soler, J. Heterocycl. Chem., **19**, 1437 (1982).
4. R. H. Wiley, D. C. England and L. C. Behr, Org. Reactions, **6**, 367 (1951).
5. A. A. Prishchenko, E. S. Novikova and I. F. Lutsenko, Zh. Obshch. Khim., **51**, 484 (1981).
6. J. Högel, A. Schmidpeter and W. S. Sheldrick, Chem. Ber., **116**, 549 (1983).
7. A. Schmidpeter, K. Karaghiosoff, C. Cleve and D. Schomburg, Angew. Chem., **97**, 125 (1985); Angew. Chem. Int. Ed. Engl., **24**, 123 (1985).
8. O. J. Scherer, Nachr. Chem. Tech. Lab., **28**, 392 (1980).
9. M. Fild and R. Schmutzler in G. M. Kosolapoff and L. Maier, Organic Phosphorus Compounds, Wiley-Interscience, **4**, 82 (1973).
10. R. Appel, F. Knoch and R. Zimmermann, Chem. Ber., **118**, 814 (1985).