Heteroatom Chemistry
Volume 14, Number 2, 2003

Arylation Reaction of *N*-Dichlorophosphoryl-*P*-trichlorophosphazene

M. Arslan,[1] F. Aslan,[2] and A. I. Ozturk[2]

[1]*Chemistry Department, Firat University, TR-23169 Elazig, Turkey*

[2]*Chemistry Department, Harran University, TR-63100 Sanliurfa, Turkey*

Received 4 July 2002

ABSTRACT: *The reactions of* N-*dichlorophosphoryl*-P-*trichlorophosphazene ($Cl_3P{=}N{-}POCl_2$) with phenylmagnesium chloride, o-tolylmagnesium chloride, p-tolylmagnesium chloride, p-chlorophenylmagnesium chloride, 2-mesitylmagnesium bromide, and 2-thienyl lithium were studied. The resulting pentaaryl phosphazenes $R_3P{=}N{-}P(O)R_2$ were separated by using column chromatography, their structures were defined by IR, elemental analysis, ^1H, ^{13}C, ^{31}P NMR, and mass spectroscopy.* © 2003 Wiley Periodicals, Inc. Heteroatom Chem 14:138–143, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.10114

INTRODUCTION

Only a few short-chain phosphazenes have been characterized in detail [1–9]. The reactions of compound **1** with amines and alcohols have been reviewed [10,11]. The structures of **1** [12] and some of its derivatives, such as its pentaamide derivative $(PhNH)_3P{=}N{-}P(O)(NHPh)_2$ [13], its geminal-bis(diisopyropylamino) derivative $Cl[NCH(CH_3)_2]_2P{=}N{-}P(O)Cl_2$ [14], and its geminal-bis(2,4,6-*tert*-butylphenoxide) $Cl(OC_6H_2Bu^t\text{-}2,4,6)_2\text{-}P{=}N{-}P(O)Cl_2$ and bis(2,6-di-*tert*-butyl-4-methylphenoxide) $Cl(OC_6H_2Bu^t\text{-}2,6\text{-}Me\text{-}4)_2P{=}N{-}P(O)Cl_2$ derivatives [15] have been reported. These molecules can be used as structural models for the inorganic polymers with a large range of properties [2,16] and applications [17–24].

Three routes can accomplish the synthesis of phosphazenes that contain alkyl or aryl groups bonded directly to phosphorus by direct synthesis, Friedel–Craft reactions, and the interaction of organometallic compounds with halophosphazenes [1]. The reactions between halogenophosphazenes and main group organometallic reagents have been studied during last 30 years [2,25], but these reactions can be complex, and some of the earlier work in this area has had to be reinterpreted as the degree of complexity has been recognized [26]. Several transition-metal-containing cyclic phosphazenes have been synthesized [27]. In the synthesis of alkyl- and aryl-substituted phosphazenes, a halophosphazene is reacted with an organolithium or Grignard reagent [28–33]. Although there are many publications about cyclic, polymeric alkyl-, or arylphosphazenes [34–40], the synthesis of linear alkyl-substituted phosphazenes has been performed with only limited success [41,42].

Here we report the reactions of $Cl_3P{=}N{-}P(O)Cl_2$ (**1**) with aryllithium and aryl-Grignard reagents. Pentasubstituted phosphazenes were obtained as major products.

RESULTS AND DISCUSSION

The reaction of **1** with 10 equiv. of phenylmagnesium chloride, *o*-tolylmagnesium chloride, *p*-tolylmagnesium chloride, *p*-chlorophenylmagnesium

Correspondence to: M. Arslan; e-mail: marslan07@yahoo.com.
Contract grant sponsor: Scientific and Technical Research Council of Turkey.
Contract grant number: TBAG-1611.

chloride, 2-mesitylmagnesium bromide, and 2-thienyl lithium in toluene gave the pentasubstituted compounds as the main products.

$$\underset{\mathbf{1}}{Cl_3P{=}N{-}P(O)Cl_2} + 5\ R{-}MgX(\text{or } R{-}Li) \longrightarrow \underset{\mathbf{2\text{–}7}}{R_3P{=}N{-}P(O)R_2}$$

They were isolated from the reaction mixture by column chromatography and characterized by elemental analysis, ^1H, ^{13}C, ^{31}P NMR, mass spectrometry, and FT-IR. The solvents used for the purification of the compounds could not be removed completely as observed by ^1H, ^{13}C NMR spectra. Thus the presence of these trace amounts of solvent affect the elemental analysis, in particular the carbon value. The physical properties, molecular weights, and analytical data are given in Table 1. (Structures of **2–7** are shown in Scheme 1.)

In the reactions of halophosphazene with organolithium or Grignard reagents, P—N bond cleavage can compete with halogen replacement [43]. The ring-opened process can be observed in cyclophosphazenes [1]. Thus, phosphazene degradation accompanies substitution. This decreases the yields of final products. From hexachlorocyclotriphosphazatriene and methyllithium, for example, ring-opened phosphazenes and small amounts of monomethyl and dimethyl chlorocyclotriphosphazatriene were obtained [38]. The nature of solvent and of the reagents may also affect the yield. In addition, the steric hindrance plays an important role in such reactions. In the reaction of *m*-, *p*-, and *o*-tolylmagnesium bromide with chlorophosphazenes, the nucleophilic attack of the *m*-isomer appears to be more difficult and essentially lacks with the *o*-isomer [42]. In our study, the pentasubstituted phosphazene is obtained in 10% yield from the reaction with *o*-tolylmagnesium chloride. 2-Mesitylmagnesium bromide gives the lowest yield because of the high steric hindrance.

The characteristic stretching peaks in the IR spectra of the phosphazenes have been assigned as in Table 2. The P=N and P=O stretching vibrations, 1180–1330 and 1160–1230 cm^{-1} respectively, are characteristic of phosphazenes. Compared to **1** these peaks are shifted to longer wavelengths for **2–7**.

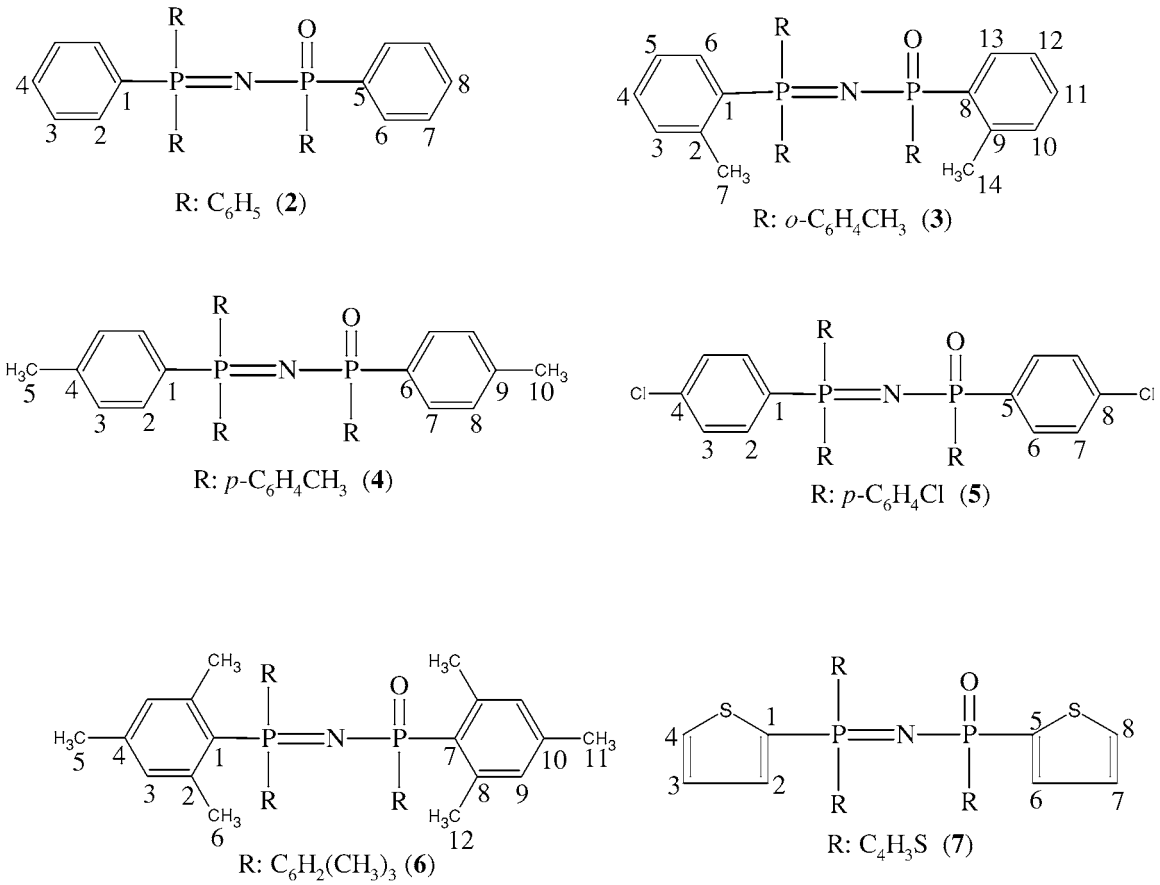
The NMR data of **1–7** are presented in Table 3–5. The AB spin pattern in the ^{31}P NMR spectra indicate that the phosphazene skeleton is intact. While phosphorus signals of **1** are observed at the high field, the signals of the aryl-substituted phosphazenes move to the lower field (Table 3). The 2-thienyl-substituted phosphazene (**7**) shows the least difference from **1**.

In the ^1H NMR spectra of the aryl-substituted phosphazenes (**2–7**), the protons in the phosphoryl ($-P(O)Ar_2$) and in the phosphazene ($Ar_3P{=}N-$) moiety can be distinguished in some cases, the latter being more shielded than the former. The 2:3 ratio of integral intensities for the two sets of protons is observed. There are also two sets of carbon atoms

TABLE 1 Physical Properties, Molecular Weight, and Analytical Data of **1–7**

				Mol. Weight [a]				
Compound	*R*	*m.p. (°C)*	*Yield (%)*	*Calcd*	*Found*		*Calcd*	*Found*
1	Cl	32	51	269.5	–		–	–
2	C_6H_5	151	35	477	476 (M − 1)	C	76.46	75.31
					183 ($C_{12}H_8P^+$)	H	5.28	5.25
					151 ($C_{12}H_7^+$)	N	2.93	2.85
3	*o*-$C_6H_4CH_3$	145	10	547	–	C	76.77	75.78
						H	6.44	6.85
						N	2.56	2.80
4	*p*-$C_6H_4CH_3$	181	15	547	547	C	76.77	75.61
					90 ($C_7H_6^+$)	H	6.44	6.32
					92 ($C_7H_8^+$)	N	2.56	2.43
5	*p*-C_6H_4Cl	142	20	647	647	C	55.46	56.43
					75 ($C_6H_3^+$)	H	3.10	3.39
					47 (CCl^+)	N	2.16	1.90
6	$C_6H_2(CH_3)_3$	201	6	687	688 (M + 1)	C	78.60	74.32
					M −105	H	8.01	8.79
					91 ($C_7H_7^+$)	N	2.04	1.99
7	C_4H_3S	173	15	507	507	C	47.32	46.44
					38 ($C_3H_2^+$)	H	2.98	2.52
					44 (CS^+)	N	2.76	2.59

[a]Molecular weight and only the first two peaks of MS in the relative abundance order are shown.



SCHEME 1 The structures of the compounds **2–7**.

with the same ratio between the integral intensities of the signals of similar carbons. This observation indicates that aryl groups have replaced all chlorine atoms in **1**.

The protons next to the phosphorus atoms are very well characterized by the ^{1}H NMR spectra that show peaks at the lowest down field of the aromatic protons (Table 4). The methyl protons of **3, 4**, and **6** give singlets at $\delta = 2.05$ and 2.13, $\delta = 2.20$ and 2.28, and $\delta = 2.10$, 2.18, 2.20, 2.28, respectively. The phenyl protons are observed at $\delta = 7.63$–7.70, $\delta = 7.63$–7.72, $\delta = 7.51$–7.57, $\delta = 7.63$–7.68 as doublets at the lower downfield for compounds **2, 3, 4**, and **5**, respectively. While the aromatic protons appear at $\delta = 6.50$–6.65 for **6**, four protons are shown as two doublets at $\delta = 7.45$–7.48 and $\delta = 7.73$–7.77 for **7**.

In the ^{13}C NMR spectra (Table 5), the carbon atoms attached directly to phosphorus atoms are generally observed at lowest field and with the largest J_{PC} values. Ipso carbon atoms in the $-POAr_2$ moiety are shielded more than in the $-PNAr_3$ moiety.

TABLE 2 Characteristic IR Vibrations (in cm^{-1}) of **1–7**

Compound	$\nu_{C-H\ ar.}$	$\nu_{C-H\ al.}$	$\nu_{P=N}$	$\nu_{P=O}$	ν_{P-N}	ν_{P-Cl}
1	–	–	1338	1263	770	650
2	3021–3075	–	1265	1174	748	–
3	3005–3051	2859–2967	1211	1192	760	–
4	3019–3071	2866–2975	1234	1168	761	–
5	3014–3079	2852–2956	1241	1170	742	–
6	3024	2851–2953	1194	1180	754	–
7	3097	3054–3075	1247	1180	746	–

TABLE 3 ^{31}P NMR Data of **1–7**

Compound	δ_{PN}	δ_{PO}	J_{PNP}
1	−2.6	−10.6	21.3
2	15.5	14.4	ND
3	14.8	14.6	ND
4	15.4	13.8	ND
5	14.7	14.2	ND
6	24.9	20.2	1.93
7	0.60	−10.3	8.10

ND: Not determined.

TABLE 4 ^{1}H NMR Data of **2–7**

2	7.19 (H^8, H^7, $^5J_{PCCCCH}$: 1.9), 7.30 (H^3, $^4J_{PCCCH}$: 4.7), 7.41 (H^4, $^4J_{PCCCH}$: 6.0), 7.63 (H^2, $^3J_{PCCH}$: 7.2), 7.70 (H^6, $^3J_{PCCH}$: 6.6) ($H^{7,8}$:H^3:H^4:H^2:H^6 = 3.50:3.45:1.70:3.40:1.92)
3	2.05 (H^7), 2.13 (H^{14}), 7.72 (H^{13}, $^3J_{PCCH}$: 7.4), 7.63 (H^6, $^3J_{PCCH}$: 7.8), 7.33 (H^5, $^4J_{PCCCH}$: 6.1), 7.13 (H^{12} and H^{10}, $^4J_{PCCCH}$: 7.4), 7.08 (H^4, $^5J_{PCCCCH}$: 7.3), 6.98 (H^3, $^4J_{PCCCH}$: 7.4), 6.90 (H^{11}, $^5J_{PCCCCH}$: 4.5) (H^7:H^{14}:H^{11}:H^3:H^{13}:H^6:H^5:$H^{12,10}$:H^4 = 3.6:2.4:0.8:1.2:0.7:1.2:1.2:1.8:1.2)
4	2.20 (H^{10}), 2.28 (H^5), 6.95 (H^8, $^4J_{PCCCH}$: 5.5), 7.10 (H^3, $^4J_{PCCCH}$: 5.5), 7.51 (H^2, $^3J_{PCCH}$: 8.1), 7.57 (H^7, $^3J_{PCCH}$: 7.9) (H^5:H^{10}:H^3:H^8:H^2:H^7 = 5.4:3.4:3.2:2.1:3.2:2.1)
5	7.26 (H^7, $^4J_{PCCCH}$: 6.3), 7.43 (H^3, $^4J_{PCCCH}$: 6.1), 7.63 (H^2, $^3J_{PCCH}$: 8.5), 7.68 (H^6, $^3J_{PCCH}$: 9.0) (H^7:H^3:H^2:H^6 = 3.6:5.8:5.5:3.5)
6	2.10 (H^5), 2.18 (H^{11}), 2.20 (H^{12}), 2.28 (H^6), 6.50 and 6.65 (H^3 and H^9, $^4J_{PCCCH}$: 3.6) ($H^{3,9}$:H^6:H^{12}:H^{11}:H^5 =1.8:3.1:2.1:1.1:1.6)
7	6.98 (H^7, $^4J_{PCCCH}$: 1.8), 7.15 (H^3, $^4J_{PCCCH}$: 2.1), 7.45 (H^6, $^3J_{PCCH}$: 4.3), 7.48 (H^8, $^4J_{PCSCH}$: 4.3), 7.73 (H^2, $^3J_{PCCH}$: 5.1), 7.77 (H^4, $^4J_{PCSCH}$: 5.1) (H^7:H^3:H^6:H^8:H^2:H^4 = 2.8:4.2:2.8:2.8:4.3:4.3)

For numbering see Scheme 1; coupling constants *J* (Hz).

TABLE 5 ^{13}C NMR Data of **2–7**

2	128.0 (C^6, $^2J_{PCC}$: 12.6), 128.9 (C^2, $^2J_{PCC}$: 12.8), 131.6 (C^7, $^3J_{PCCC}$: 9.8), 133.0 (C^3, $^3J_{PCCC}$: 11.1), 130.0 (C^8, $^4J_{PCCCC}$: 2.4), 132.5 (C^4, $^4J_{PCCCC}$: 2.8), 130.5 (C^5, $^1J_{PC}$: 52.2), 139.0 (C^1, $^1J_{PC}$: 173.2)
3	21.8 (C^{14}, $^3J_{PCCC}$: 3.9), 22.8 (C^7, $^3J_{PCCC}$: 4.4), 124.9 (C^{13}, $^2J_{PCC}$: 12.2), 126.1 (C^6, $^2J_{PCC}$: 13.3), 129.0 (C^8, $^1J_{PC}$: 101.2), 130.2 (C^{11}, $^4J_{PCCCC}$: 1.8), 131.2 (C^{10}, $^3J_{PCCC}$: 12.6), 132.3 (C^4, $^4J_{PCCCC}$: 2.6), 132.6 (C^3, $^3J_{PCCC}$: 8.8), 133.2 (C^{12}, $^3J_{PCCC}$: 9.6), 134.8 (C^5, $^3J_{PCCC}$: 13.5), 137.2 (C^1, $^1J_{PC}$: 130.8), 141.5 (C^9, $^2J_{PCC}$: 11.0), 142.9 (C^2, $^2J_{PCC}$: 9.2)
4	21.8 (C^{10}), 21.9 (C^5), 128.3 (C^6, $^1J_{PC}$: 111.8), 128.6 (C^7, $^2J_{PCC}$: 12.8), 129.5 (C^2, $^2J_{PCC}$: 13.4), 131.6 (C^8, $^3J_{PCCC}$: 10.2), 133.0 (C^3, $^3J_{PCCC}$: 11.5), 137.2 (C^1, $^1J_{PC}$: 137.6), 139.7 (C^9, $^4J_{PCCCC}$: 1.7), 142.5 (C^4, $^4J_{PCCCC}$: 2.8)
5	128.3 (C^5, $^1J_{PC}$: 108.0), 128.6 (C^6, $^2J_{PCC}$: 13.3), 129.7 (C^2, $^2J_{PCC}$: 13.6), 132.9 (C^7, $^3J_{PCCC}$: 10.3), 134.1 (C^3, $^3J_{PCCC}$: 12.3), 137.2 (C^1, $^1J_{PC}$: 135.0), 137.0 (C^8, $^4J_{PCCCC}$: 3.1), 139.9 (C^4, $^4J_{PCCCC}$: 3.2)
6	21.2 (C^5 and C^{11}), 23.0 (C^6, $^3J_{PCCC}$: 3.7), 23.7 (C^{12}, $^3J_{PCCC}$: 4.1), 128.5 (C^7, $^1J_{PC}$: 112.1), 130.6 (C^3, $^3J_{PCCC}$: 11.8), 131.7 (C^9, $^3J_{PCCC}$: 11.2), 135.5 (C^1, $^1J_{PC}$: 126.0), 138.5 (C^{10}, $^4J_{PCCCC}$: 2.4), 140.7 (C^4, $^4J_{PCCCC}$: 2.7), 141.6 (C^2 and C^8, $^2J_{PCC}$: 10.7)
7	128.0 (C^6, $^2J_{PCC}$: 15.7), 129.0 (C^2, $^2J_{PCC}$: 16.0), 131.8 (C^7, $^3J_{PCCC}$: 5.7), 133.3 (C^5, $^1J_{PC}$: 132.8), 133.8 (C^8, $^3J_{PCSC}$: 11.6), 135.2 (C^3, $^3J_{PCCC}$: 5.9), 138.6 (C^4, $^3J_{PCSC}$: 12.7), 142.0 (C^1, $^1J_{PC}$: 190.5)

For numbering see Scheme 1; coupling constants *J* (Hz).

The electron impact MS of **4, 5**, and **7** showed the well-defined molecular ions at *m/z* 547 (6%), 647 (4%), and 507 (1%), respectively. The parent ion peaks are obsersved at *m/z* 476 (15%) as M − 1 for **2** and at 688 (1%) as M + 1 for **6**. The peaks at *m/z* values of 76 (dominant ion, $C_6H_4^+$, 100%), 399, 401, 321, 183, and 151 correspond to the loss of C_6H_5, $C_{12}H_8P$ groups for **2**. The dominant ion peaks at *m/z* 90 ($C_7H_6^+$, 100%), 75 ($C_6H_3^+$, 100%), 582 (M − 105, $C_8H_9^+$, 100%), 38 ($C_3H_2^+$, 100%) for **4, 5, 6**, and **7**, respectively.

CONCLUSION

Pentaaryl-substituted phosphazenes were isolated from the nucleophilic substitution of *N*-dichlorophosphoryl-*P*-trichlorophosphazene by phenylmagnesium chloride, *o*-tolylmagnesium chloride, *p*-tolylmagnesium chloride, *p*-chlorophenylmagnesium chloride, 2-mesitylmagnesium bromide, 2-thienyl lithium. The products were defined as diphenylphosphinyl-triphenylphosphazene, bis(*o*-tolyl)phosphinyl-tris(*o*-tolyl)phosphazene, bis(*p*-tolyl)phosphinyl-tris(*p*-tolyl)phosphazene, bis(*p*-chlorophenyl)phosphinyl-tris(*p*-chlorophenyl)phosphazene, bis(2-mesityl)phosphinyl-tris(2-mesityl)-phosphazene, and bis(2-thienyl)phosphinyl-tris(2-thienyl)phosphazene.

EXPERIMENTAL SECTION

General Remarks

Solvents and other liquids used in the experimental works were dried by conventional methods. All reactions were monitored by using Kieselgel 60 F254 (silica gel) precoated TLC plates and the separating conditions were determined. The separation of products was carried out by flash column chromatography, using Kieselgel 60 (60–230 mesh).

IR spectra were recorded with an ATI Unicam Mattson 1000 FTIR spectrophotometer. ^{1}H, ^{13}C, ^{31}P NMR spectra were recorded using a Bruker DPX-400 High Performance Digital FT-NMR spectrometer operating at 400.13, 100.63, and 161.98 MHz, respectively. All data was recorded for solutions in $CDCl_3$. The ^{1}H and ^{13}C chemical shifts were measured using $SiMe_4$ as an internal standard, the ^{31}P chemical shifts, using 85% H_3PO_4 as an external standard. Chemical shifts downfield from the standard are assigned positive δ values. Electron impact mass spectra were obtained by Micromass UK Platform-II spectrometer. Microanalysis was carried out by LECO 932 CHNS-O apparatus. The starting material **1** was prepared by the method of Emsley,

Moore, and Udy and purified by vacuum distillation [44].

$(C_6H_5)_3P{=}N{-}P(O)(C_6H_5)_2$ (**2**). Phenylmagnesium chloride 13.5 ml, 2 M in THF was slowly added dropwise to **1** (1.46 g, 5.4 mmol) in 150 ml of benzene in the reaction vessel by stirring for 0.5 h at ambient temperature and was then refluxed for 24 h. After the reaction was complete, the precipitated salt ($MgCl_2$) was filtered off and the solvent was removed under vacuum. The residue was examined by TLC, using chloroform/acetone (2:1), R_f value is 0.51. They were separated by using column chromatography. After the solvent was removed, a white solid formed in 35% yield, m.p. 151°C.

$(o\text{-}CH_3C_6H_4)_3P{=}N{-}P(O)(o\text{-}CH_3C_6H_4)_2$ (**3**). *o*-Tolylmagnesium chloride (22 ml, 1 M in THF) and **1** (1.18 g, 4.4 mmol in 150 ml of benzene) were used for the preparation of **3** as for **2**. The residue was chromatographed ($R_f = 0.63$, chloroform/acetone 4:1). Compound **3** was obtained in 10% yield, m.p. 145°C.

$(p\text{-}CH_3C_6H_4)_3P{=}N{-}P(O)(p\text{-}CH_3C_6H_4)_2$ (**4**). *p*-Tolylmagnesium chloride (27 ml, 1 M in ether) and **1** (1.45 g, 5.3 mmol in 150 ml of toluene) were used for the preparation of **4** as for **2**. The residue was chromatographed ($R_f = 0.40$, chloroform/acetone 3:1). Compound **4** was obtained in 15% yield, m.p. 181°C.

$(p\text{-}ClC_6H_4)_3P{=}N{-}P(O)(p\text{-}ClC_6H_4)_2$ (**5**). *p*-Chlorophenylmagnesium chloride (20.4 ml, 1 M in THF) and **1** (1.11 g, 4.1 mmol in 150 ml of toluene) were used for the preparation of **5** as for **2**. The residue was chromatographed ($R_f = 0.55$, chloroform/acetone 8:1). Compound **5** was obtained in 20% yield, m.p. 142°C.

$[(CH_3)_3C_6H_2)]_3P{=}N{-}P(O)[(CH_3)_3C_6H_2)]_2$ (**6**). 2-Mesitylmagnesium bromide (28 ml, 1 M in ether) and **1** (1.51 g, 5.6 mmol in 150 ml of toluene) were used for the preparation of **6** as for **2**. The residue was chromatographed ($R_f = 0.55$, chloroform/acetone 5:1). Compound **6** was obtained in 6% yield, m.p. 201°C.

$(C_4H_3S)_3P{=}N{-}P(O)(C_4H_3S)_2$ (**7**). 2-Thienyl lithium (28 ml, 1 M in THF) and **1** (1.51 g, 5.6 mmol in 150 ml of toluene) were used for the preparation of **7** as for **2**. The residue was chromatographed ($R_f = 0.38$, chloroform/acetone 2:1). Compound **7** was obtained in 15% yield, m.p. 173°C.

REFERENCES

[1] Allcock, H. R. Phosphorus–Nitrogen Compounds; Academic Press: New York, 1972.
[2] Evans, T. L.; Allcock, H. R. J Macromol Sci, Chem 1981, 16A, 409.
[3] Allcock, H. R.; Ngo, D. C.; Parvez, M.; Whittle, R. R.; Birdsall, W. J. J Am Chem Soc 1991, 113, 2628.
[4] Maracek, A. Collect Czech Chem Commun 1990, 55, 2453.
[5] Bullock, C.; Keat, R. Inorg Chem Acta 1979, 33, 245.
[6] Kireev, V. V.; Kolesnikov, G. S.; Titov, S. S. Zhur Obshch Khim 1970, 40, 2015.
[7] Khodak, A. A.; Gilyarov, V. A.; Shcerbina, I. I.; Kabachnik, M. I. Izvest Akad Nauk SSSR Ser Khim 1979, 1884.
[8] Kılıç, A.; Kılıç, Z.; Shaw, R. A. Phosphorus, Sulfur, and Silicon 1991, 56, 157.
[9] Xu, K.; Angell, C. A. Inorg Chem Acta 2000, 298, 16.
[10] Shaw, R. A. Pure Appl Chem 1980, 52, 1063.
[11] Shaw, R. A. J Organomet Chem 1988, 341, 357.
[12] Belaj, F. Acta Cryst B 1993, 49, 254.
[13] Allcock, H. R.; Tollefson, N. M.; Arcus, R. A.; Whittle, R. R. J Am Chem Soc 1985, 107, 5166.
[14] Kılıç, Z.; Gündüz, N.; Yıldız, M.; Kılıç, A.; Mor, S.; Ercan, F.; Hökelek, T.; Ülkü, D. Heteroat Chem 1994, 5, 349.
[15] Kılıç, A.; Begeç, S.; Kılıç, Z.; Hökelek, T. J Mole Struc 2000, 516, 255–262.
[16] Kartikeyan, S.; Neilson, R. H. Inorg Chem 1999, 38, 2079.
[17] Allcock, H. R.; Crane, C. A.; Morrissey, C. T.; Olshavsky, M. A. Inorg Chem 1999, 38, 280.
[18] Reed, C. S.; Taylor, J. P.; Coleman, M. M.; Allcock, H. R. Polym Eng Sci 2000, 40(2), 465.
[19] Prange, R.; Allcock, H. R. Macromolecules 1999, 32, 6390.
[20] Allcock, H. R.; Ravikiran, R.; O'Connor, S. J. M. Macromolecules 1997, 30, 3184.
[21] Allcock, H. R.; Prange, R. Macromolecules 2001, 34, 6858.
[22] Allcock, H. R.; Prange, R.; Hartle, T. J. Macromolecules 2001, 34, 5463.
[23] Allcock, H. R.; Laredo, W. R.; deDenus, C. R.; Taylor, J. P. Macromolecules 1999, 32, 7719.
[24] Förster, S.; Kramer, E. Macromolecules 1999, 32, 2783.
[25] Harris, P. J.; Desorcie, J. L.; Allcock, H. R. J Chem Soc, Chem Commun 1981, 852.
[26] Allcock, H. R.; Desorcie, J. L.; Riding, G. H. Polyhedron 1987, 6(2), 119.
[27] Allcock, H. R.; Desorcie, J. L.; Wagner, L. J. Inorg Chem 1985, 24, 333.
[28] Shaw, R. A.; Fitzsimmons, B. W.; Smith, B. C. Chem Rev 1962, 62, 207.
[29] Allcock, H. R.; Patterson, D. B.; Evans, T. L. J Am Chem Soc 1977, 99, 6095.
[30] Allcock, H. R.; Chu, C. T.-W. Macromolecules 1979, 12, 551.
[31] Paddock, N. L.; Ranganathan, T. N.; Todd, S. M. Can J Chem 1971, 49, 164.
[32] Biddlestone, M.; Shaw, R. A. Phosphorus 1973, 3, 95.
[33] Allen, C. W. J Chem Soc, Chem Commun 1970, 152.

[34] Harris, P. J.; Williams, K. B.; Fisher, B. L. J Org Chem 1984, 49, 406.
[35] Harris, P. J.; Schwalke, M. A.; Liu, V.; Fisher, B. L. Inorg Chem 1983, 22, 1812.
[36] Allcock, H. R.; Coggio, W. D. Macromolecules 1993, 26, 764.
[37] Allen, C. W.; Moeller, T. Inorg Chem 1968, 7(11), 2177.
[38] Harris, P. J.; Fadeley, C. L. Inorg Chem 1982, 22(3), 561.
[39] Allcock, H. R.; Harris, P. J.; Nissan, R. A. J Am Chem Soc 1981, 103(9), 2256.
[40] Allcock, H. R.; Harris, P. J. J Am Chem Soc 1979, 101(21), 6221.
[41] Vandi, A. F.; Moeller, T. Chem Ind 1962, 221.
[42] Moeller, T.; Vandi, A. J Am Chem Soc 1962, 3511.
[43] Allcock, H. R.; Harris, P. J.; Connolly, M. S. Inorg Chem 1981, 20, 11.
[44] Emsley, J.; Moore, J.; Udy, P. B. J Chem Soc A 1971, 2863.