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The Reactions of Hydridophosphorane with Vilsmeier Reagents

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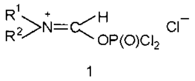
ABSTRACT

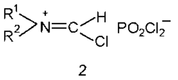
Reactions of hydridophosphorane **3** *with Vilsmeier reagents, HCONR^{1}R^2/POCl$_3$, afford novel N,N-disubstituted amino bisphosphoranyl methanes***4***. The formation of* **4** *might occur via the intermediate* **5***, which then reacts further with excess* **3***.* © 1997 John Wiley & Sons, Inc. Heteroatom Chem **8**: 517–520, 1997

INTRODUCTION

The Vilsmeier reagents, HCONR^{1}R^2/POCl$_3$, have found extensive application in the synthesis of aldehyde derivatives and formamidines [1]. The structure of the Vilsmeier reagents has been studied with the aid of NMR spectroscopy [2]. This study showed that the reagents are an equilibrium mixture of two iminium salts, the more reactive being the beta-phosphoryliminium chloride **1** rather than the beta-chloroiminium phosphate **2.**

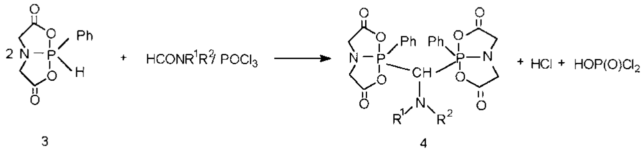


1



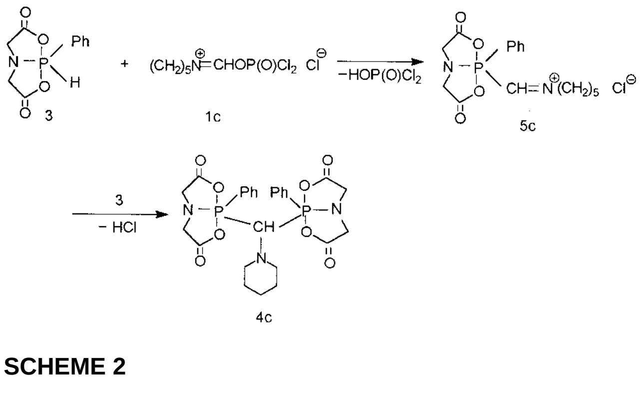
2

In principle, the Vilsmeier reactions involve electrophilic substitution of carbon, oxygen, and nitrogen nucleophiles with iminium salts **1.** However, the action of the Vilsmeier reagents on phosphorus nucleophiles is much less well understood. This prompted us to investigate the applicability of the Vilsmeier reagents for reactions with phosphorus compounds. In the present work, we wish to report the results of the reaction of hydridophosphorane **3**



a: R^1=R^2=CH$_3$
b: R^1=CH$_3$ R^2=C$_6$H$_5$
c: R^{1}R^2=(CH$_2$)$_5$
d: R^1=R^2=C$_2$H$_5$
e: R^{1}R^2=(CH$_2$CH$_2$)$_2$O

SCHEME 1



SCHEME 2

Dedicated to Prof. William E. McEwen on the occasion of his seventy-fifth birthday.

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TABLE 1 ^{1}H and ^{31}P NMR Data of Compounds **4**

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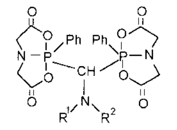


4

Compound	^{1}H NMR ($CDCl_3$)						^{31}P NMR ($CDCl_3$)
	CH	R^1	R^2	cyclic-NCH_2	m.p-C_6H_5	o-C_6H_5	
4a	4.80 (t, ^2J 15.65)	2.46 (d, ^4J 3.6)	2.48 (d, ^4J 3.6)	3.44-3.96	7.36-7.62	7.75-7.95	-36.88
4b	5.80 (t, ^2J 18.78)	2.98 (dd, ^4J 4.0, ^3J 3.0)	6.65-6.85 (m,p-NC_6H_5) 7.08-7.28 (o-NC_6H_5)	3.46-3.83	7.26-7.57	7.67-7.81	-38.90
4c	4.76 (t, ^2J 15.65)	1.28 (br,$NCH_2(C\underline{H}_2)_3CH_2$) 2.69 (br,$NC\underline{H}_2(CH_2)_3C\underline{H}_2$)		3.32-4.02	7.40-7.61	7.80-7.96	-36.75
4d	4.90 (t, ^2J 15.65)	0.79 (br, CH_3) 2.68(br, CH_2)		3.34-4.00	7.40-7.63	7.80-8.00	-37.42
4e	4.68 (t, ^2J 16.69)	2.79 (br, $N(C\underline{H}_2CH_2)O$) 3.37 (br, $N(CH_2C\underline{H}_2)_2O$)		3.22-4.04	7.35-7.68	7.71-8.03	-37.42

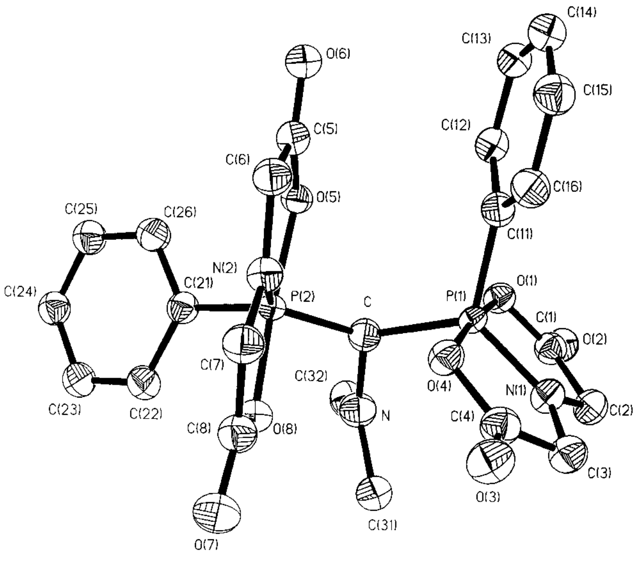
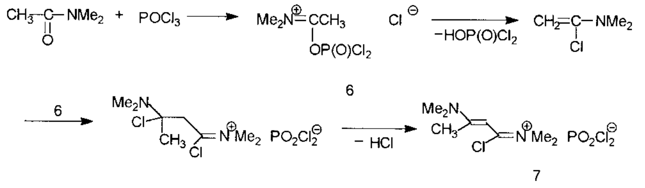


FIGURE 1 Molecular configuration for **4a.**



SCHEME 3

with Vilsmeier reagents. Also reported here are new observations concerning the reaction pathways.

RESULTS AND DISCUSSION

Since the phosphorus atom in hydridophosphoranes is relatively nucleophilic [3,4], it is conceivable that the pentacoordinate phosphorus atom could attack the carbon atom of the iminium salts **1**, leading to P–C bond formation. To achieve this objective, we selected compound **3** as a model nucleophile, because of its stability and remarkable nucleophilicity, and performed the following reaction (Scheme 1):

The reaction was performed in a one-pot procedure using $HCONR^1R^2$ as the solvent at 30–45°C. Following solvent removal and water washing, products **4** were obtained in acceptable yields and easily isolated in pure form by recrystallization. Their structures were confirmed by spectroscopic criteria (Tables 1 and 2) and quantitative elemental analyses (Table 3).

Our investigation shows that a plausible pathway for this reaction would consist of two steps; in the first step, the nucleophilic phosphorus center attacks the electrophilic central carbon of iminium salts **1** with elimination of $HOP(O)Cl_2$ to give the intermediate **5**. The species **5** then react further with another mole of **3** in a manner such that the phosphorus atom attacks the electrophilic exocyclic carbon of **5** with elimination of HCl (Scheme 2).

This suggestion is supported by the fact that when an equivalent of **3** is added to a solution of the $C_5H_{10}NCHO/POCl_3$, ^{31}P NMR spectra of the mixture exhibit, in addition to signals for unreacted starting material **3** (δ − 48.0) and product **4c** (δ − 36.7), another peak (δ − 26.2) that can be assigned to the intermediate **5c.** Moreover, addition of the second equivalent of **3** results in complete conversion to **4c** along with disappearance of **5c.**

Although in our experiments the intermediate **5c** was not isolated, the proposed structure is further supported by the following observations: (1) the ^{31}P NMR chemical shift of **5c** is downfield relative to that of **3** and **4c** due to the effect of the electron-withdrawing group ($CH=N^{\oplus}(CH_2)_5$) and (2) the mass spectrum of **4c** gives a fragment corresponding to **5c,** indicating its stability.

To further ascertain the configuration of **4,** we have performed an X-ray single-crystal diffraction study on compound **4a** as shown in Figure 1. Crystallographic analysis has shown that the geometry about both phosphorus atoms was a distorted trigonal bipyramid. The dihedral angle formed by the two equatorial planes is 58.4°. Important bond lengths and angles are given in Table 4.

TABLE 2 ^{13}C NMR Data of Compounds **4**

Compound	*CH*	*C=0*	*Cyclic-NCH$_2$*	*R^1*	*R^2*	*C$_6$H$_5$P*
						128.59 (d, ^3J 8.79, meta)
						132.47 (d, ^2J 14.65, ortho)
	75.17	167.90				133.05 (para)
4a	(t, ^1J 137.74)	(d, ^2J 19.35)	46.17	43.69	44.22	135.06 (d, ^1J 167.03, ipso)
					114.28 (ortho)	128.88 (d, ^2J 11.04, ortho)
					119.54 (meta)	132.73 (para)
	73.04	166.67			128.6 (para)	133.57 (d, ^3J 5.67, meta)
4b	(t, ^1J 139.93)	(d, ^2J 21.03)	46.36	38.68	131.85 (ipso)	135.00 (d, ^1J 150.5, ipso)
					23.74 (para)	128.82 (d, ^2J 8.03, ortho)
					26.76 (meta)	132.61 (para)
	78.40	166.98	46.47		53.99 (ortho)	133.73 (meta)
4c	(t, ^1J 136.96)	(d, ^2J 11.74)	(d, ^2J 23.49)			135.18 (d, ^1J 151.8, ipso)
					14.386 (CH$_3$)	128.88 (d, ^2J 8.58, ortho)
					47.87 (CH$_2$)	132.73 (para)
	74.63		46.42			134.15 (d, ^3J 5.02, meta)
4d	(t, ^1J 136.96)	166.99	(d, ^2J 17.67)			133.06 (d, ^1J 150.0, ipso)

TABLE 3 Quantitative Elemental Analyses Data of Compounds **4**

			Elemental Analyses (%)					
			Calculated			*Found*		
Compound	*M.P. (°C)*	*Yield (%)*	*C*	*H*	*N*	*C*	*H*	*N*
4a	211–212	66.6	51.79	4.72	7.88	52.01	4.62	7.88
4b	247–249	72.3	56.47	4.57	7.05	56.17	4.80	6.86
4c	218–220	40.8	54.45	5.10	7.33	54.65	5.15	6.87
4d	214–215	33.5	53.48	5.21	7.49	53.06	5.13	7.88
4e	238–239	70.5	52.18	4.73	7.30	52.43	4.70	7.41

TABLE 4 Important Molecular Parameters of Compound **4a**

Bond	*Lengths^a (Å)*	*Angle*	*Degrees^a*	*Dihedral Angle^b*	*Degrees*
$P_{(1)}–O_{(1)}$	1.768(1)	$O_{(1)}P_{(1)}O_{(4)}$	173.22(7)	plane1–plane2	58.43
$P_{(1)}–O_{(4)}$	1.760(1)	$O_{(1)}P_{(1)}N_{(1)}$	86.91(8)	plane1–plane3	79.31
$P_{(1)}–N_{(1)}$	1.651(1)	$O_{(1)}P_{(1)}$	87.28(7)	plane2–plane4	118.37
$P_{(1)}–C$	1.870(2)	$O_{(1)}P_{(1)}C_{(11)}$	92.97(7)	plane3–plane4	136.25
$P_{(1)}–C_{(11)}$	1.825(2)	$O_{(4)}P_{(1)}N_{(1)}$	87.48(7)		
$P_{(2)}–O_{(5)}$	1.784(1)	$O_{(4)}P_{(1)}C$	92.74(7)		
$P_{(2)}–O_{(8)}$	1.741(1)	$O_{(4)}P_{(1)}C_{(11)}$	93.18(7)		
$P_{(2)}–N_{(2)}$	1.658(1)	$N_{(1)}P_{(1)}C$	124.32(8)		
$P_{(2)}–C$	1.872(2)	$N_{(1)}P_{(1)}C_{(11)}$	120.95(8)		
$P_{(2)}–C_{(21)}$	1.827(2)	$CP_{(1)}C_{(11)}$	114.63(8)		
		$O_{(5)}P_{(2)}O_{(8)}$	172.75(6)		
		$O_{(5)}P_{(2)}N_{(2)}$	86.30(7)		
		$O_{(5)}P_{(2)}C$	86.91(6)		
		$O_{(5)}P_{(2)}C_{(21)}$	93.03(6)		
		$O_{(8)}P_{(2)}N_{(2)}$	87.95(8)		
		$O_{(8)}P_{(2)}C$	93.47(7)		
		$O_{(8)}P_{(2)}C_{(21)}$	93.75(7)		
		$N_{(2)}P_{(2)}C$	130.31(7)		
		$N_{(2)}P_{(2)}C_{(21)}$	121.85(7)		
		$CP_{(2)}C_{(21)}$	107.62(7)		

[a] Numbers in parentheses are estimated standard deviations in the least significant digits.

[b] Plane 1 = $C_{(21)}N_{(2)}C$; plane 2 = $CN_{(1)}C_{(11)}$; plane 3 = $C_{(21)}–C_{(26)}$; plane 4 = $C_{(11)}–C_{(16)}$.

As indicated in Figure 1, the steric crowding in compound **4a** is rather severe. Attempts to conduct the reaction of **3** with the Vilsmeier reagent **6** (from N,N-dimethylacetamide and phosphoryl chloride) have not been successful. This may be due to steric hindrance; on the other hand, the iminium salt **6** is frequently converted to iminium salt **7** via a self-condensation reaction (Scheme 3) [1].

EXPERIMENTAL

^{1}H, ^{31}P, and ^{13}C NMR spectra were taken on a BRUKER AC-P200 spectrometer. ^{1}H and ^{13}C chemical shifts are reported in parts per million relative to internal tetramethylsilane. ^{31}P chemical shifts are reported in parts per million relative to 85% phosphoric acid (external). Quantitative elemental analyses were run on a Yana MT-3 instrument. Mass spectra were recorded on a Hewlett-Packard 5988 instrument. All operations were carried out under a nitrogen atmosphere. The formamides were obtained from commercial sources.

General Procedure for Preparation of Compounds 4

Phosphorus oxychloride (0.967 g, 6.3 mmol) was added to the corresponding formamide (15 mL) at 0°C. After addition, the reaction mixture was stirred at 30°C for 30 minutes, then the hydridophosphorane [5] (3.00 g, 12.6 mmol) was added. The mixture was heated at 30–40°C for about 10 hours and poured into cold water. The precipitate was filtered off and recrystallized from dichloromethane-diethyl ether to **4,** which is of sufficient purity to afford good elemental analysis.

ACKNOWLEDGMENTS

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