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Synthesis of the New Adducts of Imines and Enamines with PH Acids and Their Derivatives

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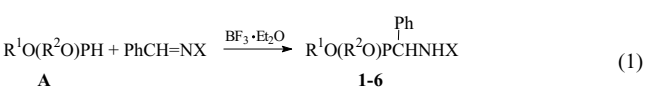
ABSTRACT: *Nucleophilic or radical addition of esters of trivalent organophosphorus acids with PH fragments to various imines and enamines is proposed as convenient methods for the synthesis of new substituted aminomethyl organophosphorus compounds with three-, four-, and five-coordinated phosphorus. Also the new functionalized derivatives of these compounds with acyl and methanesulfonyl moieties are synthesized, and some properties of the obtained compounds are presented.* © 2009 Wiley Periodicals, Inc. Heteroatom Chem 20:70–80, 2009; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.20513

INTRODUCTION

The reaction of PH-containing esters of trivalent organophosphorus acids with organic compounds, containing multiple bonds, provides a convenient synthetic route to various aminomethyl organophosphorus compounds, which present a great interest as promising polydentate ligands and biologically active compounds [1–4]. In the present work, we report here the results of the nucleophilic or radical addition of the esters of trivalent organophosphorus acids with PH fragments to various imines and enamines, resulting in the formation of corresponding adducts in high yield. Further acylation of these adducts with NH fragments yields the new amides and sulfonylamides of functionalized aminomethyl organophosphorus acids as promising substances especially with antioxidative fragments of 2,6-di-tert-butyl-4-methylphenol and oleic acid (cf. [5–7]).

RESULTS AND DISCUSSION

In the present work, we showed that the reaction of alkyl or trimethylsilylhypophosphites **A** with various imines is a convenient route to functionalized aminomethylphosphonites **1–6**. So hypophosphites **A** readily reacts with imines in the presence of boron trifluoride diethyl etherate as a catalyst exclusively by the regioselective addition involving the PH fragment to give phosphonites **1–5** in high yield. Note that the phosphonite **6** is obtained without a catalyst, but this reaction proceeds during 24 h (Eq. (1); cf. [8,9]). It is necessary to remove the catalyst from the reaction mixture before its distillation using diethylamine.



(1)

R^1=R^2= Bu (**1**), Me_3Si (**4-6**); R^1 = Et (**2**), Bu (**3**); R^2 = Me_3Si (**2,3**); X = Me (**1-4**), t-Bu (**5**), Me_3Si (**6**).

It is necessary to remove the catalyst from the reaction mixture before its distillation using diethylamine. Trimethylsilyl hypophosphite **B** formed from ammonium hypophosphite and chlorotrimethylsilane easily reacts with 2 equivalents of aromatic imines in methylene chloride and provides aryl-substituted bis(aminomethyl)-phosphinates **C** as intermediates. The corresponding

Dedicated to Professor Ivan F. Lutsenko (1912–1993).

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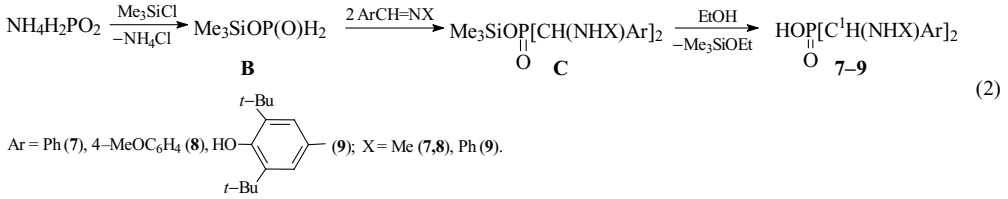
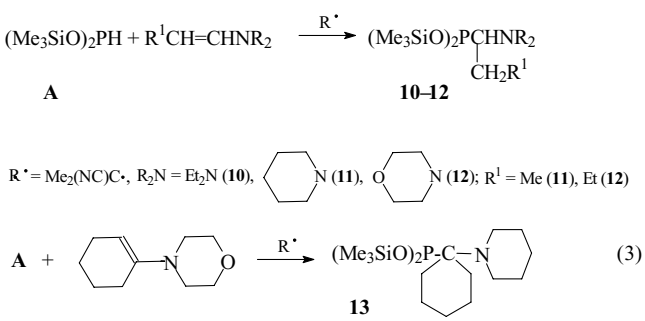
phosphinic acids **7–9** were isolated in high yield by additional treatment of the reaction mixture with excess of ethanol (Eq. (2); cf. [10]).



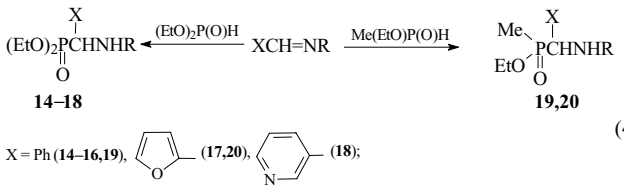
(2)

In contrast, the addition of bis(trimethylsiloxy)phosphine **A** to enamines proceeds only in the presence of azobis(isobutironitrile) at 100–120°C to give phosphonites **10–13** in high yields (Eq. (3)). Note that the influence of dialkylamino fragments on the orientation of the radical addition in these reactions is more preferable (cf. [11]).



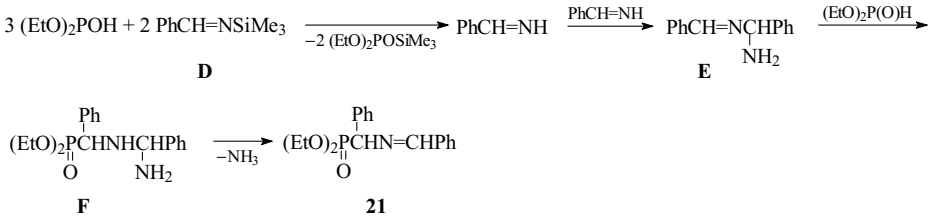
(3)

Diethyl phosphite and *O*-ethyl methylphosphite containing PH fragments easily add to aromatic imines without any catalyst by heating to 90–100°C to give the corresponding aminomethylphosphonates **14–18** and phosphinates **19,20** with NH fragments (Eq. (4); cf. [1]).



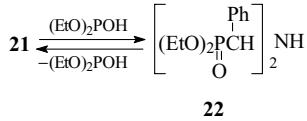
(4)

Under the same condition, the reaction of excess diethyl phosphite with *N*-trimethylsilylbenzalimine **D** [12] is more complicated, and phosphonate **21** is isolated after distillation of the reaction mixture. The proposed scheme of this reaction includes the desilylation of starting imine **D** and the formation of dimer **E**, which adds diethyl phosphite, and the final phosphonate **21** is formed via the elimination of ammonia from intermediate **F** by distillation (Eq. (5); cf. [13]).



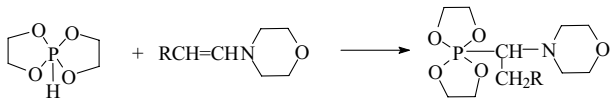
(5)

The excess diethyl phosphite slowly added to phosphonate **21** giving bisphosphonate **22**, but after distillation of the reaction mixture the starting compounds were obtained (Eq. (6)).



(6)

Also we have developed the methods for the synthesis of new phosphoranes with aminomethyl fragments via smooth addition of hydrospirophosphorane **G** to enamines. Thus phosphorane **G** easily adds to enamines in methylene chloride to give aminomethyl phosphoranes **23–25** in high yield (Eq. (7); cf. [14,15]).

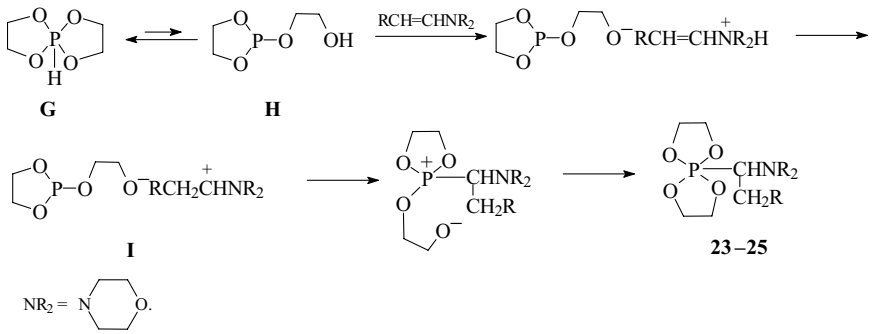


(7)

R = Me (**23**), Et (**24**), Ph (**25**).

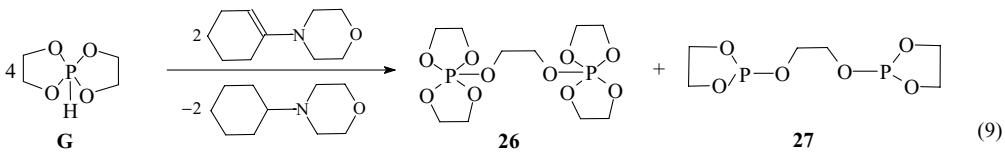
No doubt, this reaction takes place due to reactive phospholane **H**, which is in tautomeric equilibrium with phosphorane **G** [16]. The proposed

scheme (Eq. (8)) consist of formation of highly reactive aminomethylating cations **I** and following formation of phosphoranes **23–25**.



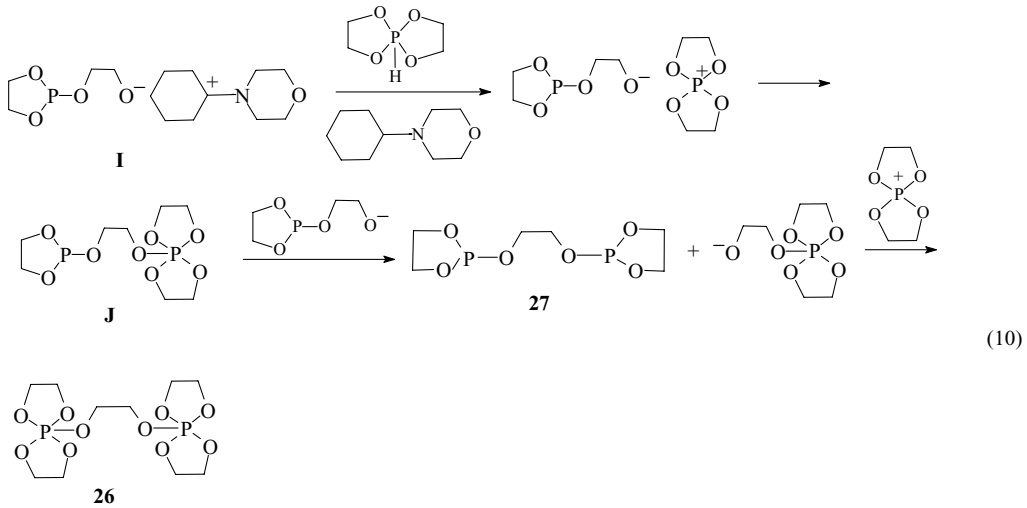
(8)

Note the similar reaction of phosphorane **G** with cyclic enamine proceeds as a slow redox process under the same conditions, yielding bisphosphorane **26** and bispospholane **27** (Eq. (9); cf. [16,17]).



(9)

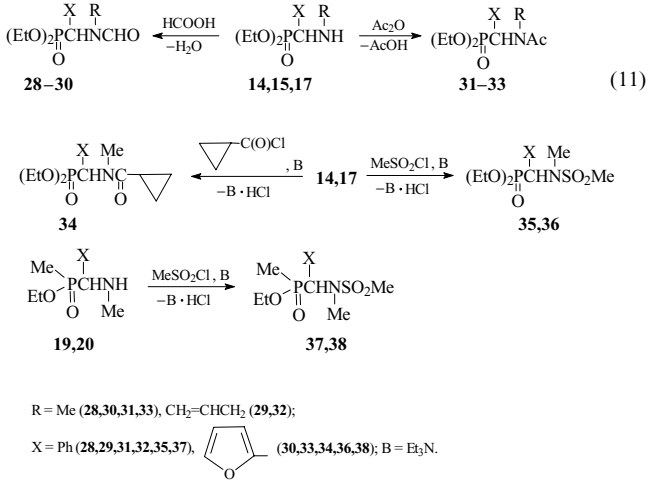
Another route of this reaction may be accounted for the attack of sterically hindered cation **I** is more preferable at P—H bond of hydrospirophosphorane **E**. The following symmetrization of intermediate **J** yields the final products **26** and **27** (Eq. (10)).



(10)

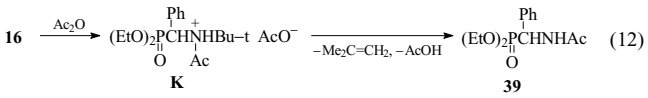
Organophosphorus-substituted carboxamides of various structures are widely used in organic synthesis and present certain interest as effective ligands and biologically active compounds [1,2]. Also phosphorus-containing amides and their derivatives, including a PCHN fragment with a chiral carbon atom, are promising organophosphorus biomimetics of amino acids and can be used in various stereoselective processes [3,18,19]. We have proposed facile synthetic routes to new representatives of this type of compounds—the phosphorus-containing carboxamides and also methane sulfonamides, based on readily accessible adducts of imines and PH acids with NH fragments. Thus adducts **14,15,17** with NH fragment are readily formylated and acylated to give amides **28–33**, and

in the presence of triethylamine the former smoothly reacts with cyclopropylcarbonyl and methanesulfonyl chlorides yielding amide **34** and sulfonamides **35–38** (Eq. (11)).



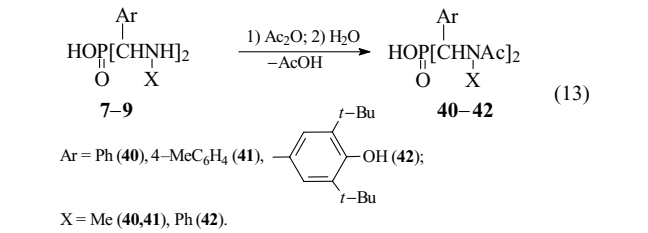
(11)

In contrast, under similar conditions adduct **16** reacts with acetic anhydride via elimination of tert-butyl group in intermediate **K** giving phosphorus-containing acetamide **39** (Eq. 12).



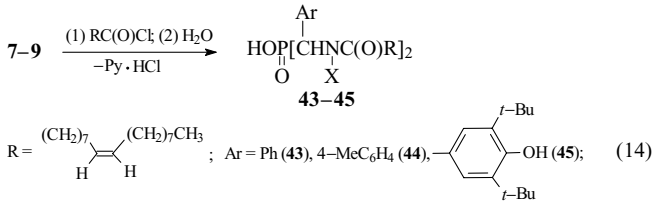
(12)

The several phosphorus-substituted amides of acetic and oleic [(*Z*)-octadec-9-enoic] acids are synthesized on the basis of arylsubstituted bis(aminomethyl)phosphinic acids **7–9**. So phosphorus-substituted acetamides **40–42** were prepared in high yields by heating a mixture of amines **7–9** with excess acetic anhydride followed by the treatment of the reaction mixture with water and recrystallization of the product in aqueous ethanol (Eq. (13)).



(13)

The reaction of amines **7–9** with excess oleoyl chloride in the presence of pyridine under the same conditions gave phosphorus-substituted oleamides **43–45** in high yield (Eq. (14)).



(14)

The synthesized compounds **28–45** are promising ligands and biologically active substances, for example, antioxidants **9,42,45**; also phosphorus-substituted oleamides **43–45** can be applied as micelle-forming agents.

The structures of organophosphorus-substituted amines and amides **1–45** were confirmed by the ^{1}H, ^{13}C, and ^{31}P NMR spectra, which show characteristic signals of the PCHN and PCHNC(O) fragments and signals of substituted aromatic fragments (see Tables 1 and 2). The elemental analysis data of synthesized compounds are summarized in Table 3.

EXPERIMENTAL

The ^{1}H, ^{13}C, and ^{31}P NMR spectra were registered on the Varian VXR-400 and Bruker Avance-400 spectrometer (400, 100, and 162 MHz, respectively) in $CDCl_3$ (**1–6, 10–45**), CD_3COOD (**7–9**) or D_2O (**14**) against TMS (^{1}H and ^{13}C) and 85% H_3PO_4 in D_2O (^{31}P). All reactions were carried out under dry argon in anhydrous solvents. The starting hypophospites **A**, imines, and enamines were prepared as described in [20,21].

*O,O-Dibutyl N-Methylamino(phenyl)methylphosphonite (**1**).* To a stirred mixture of dibutoxyphosphine (3.6 g) and benzal(methyl)imine (2.4 g), boron trifluoride diethyl etherate (0.1 g) was added. The mixture was stirred for 0.5 h, and the solution diethylamine (3 g) in 40 mL of pentane was added, and the mixture was boiled for 0.5 h. The precipitate that formed was filtered off, the solvent was distilled off, and the residue was distilled to obtain 4.9 g of phosphonite **1**.

Phosphonites **2–6** were synthesized by the same method. Phosphonite **6** was synthesized without a catalyst; this reaction mixture was left for 24 h.

*Bis[N-methylamino(phenyl)methyl]phosphinic Acid (**7**).* A mixture of 8.3 g of ammonium hypophosphite, 25.2 g of benzal(methyl)imine, and 17 g of chlorotrimethylsilane in 60 mL of methylene chloride was heated under reflux with stirring for 2 h. Ammonium chloride was filtered off, the solvent

TABLE 1 Yields, Products Constants, and NMR Spectral Data (δ in ppm, J in Hz) for the $PC^1H(C^2)NHC^3$ Fragments[a] of Amines **1–25**[a]

Compound No.	Yield (%)	Bp (°C) (p, mmHg) (mp (°C))	δ (H) C^1H d	$^2J_{PH}$	δ (H) C^3H_ns	δ (C^1) d	$^1J_{PC}$	δ (C^2) d	$^2J_{PC}$	δ (C^3) d	$^3J_{PC}$	δ_P, s[b]
1	85	124 (1)	3.37	<1	2.21	70.87	9.0	139.01	10.2	35.29	9.0	170.64
2	84	93 (1)	3.68	<1	2.30[d]	73.40	11.6	138.86	9.5	35.35	9.9	157.81
			3.65	<1	2.35[d]	73.07	14.2	138.79	9.9	35.62	8.4	159.22
3	82	120 (1)	3.56	<1	2.14	7.40	12.2	138.90	10.6	35.38	10.0	157.83
			3.58	<1	2.15	73.12	14.4	138.90	10.6	35.60	9.5	159.67
4	83	100 (1)	3.38[c]	<1	2.41[d]	75.61, 75.64	18.1 18.1	138.83	8.7	35.69	9.1	146.36
5	74	103 (1)	3.64[c]	1.5	0.95[e]	66.93	22.5	142.74	10.4	52.11	7.1	144.55
6	78	102 (1)	3.80[c]	2.2	0.17[f]	64.73	23.9	142.56	12.5	0.63[f]	s	144.47
7	92	(214)	4.69	8.0	2.55	61.58	95.2	m[g]	–	31.89	s	19.94
				8.1	2.55	61.32	94.1	m[g]	–	31.95	s	19.66
8	90	(208)	4.54	8.0	2.56	60.95	97.3	132.28	s	31.60	s	21.00
			4.39	8.2	2.55	60.55	96.2	132.28	s	31.66	s	21.52
9	87	(181)	4.44	16.1	–	55.13	101.0	127.73	s	148.38	13.0	40.06
			4.77	16.0	–	55.28	98.4	127.73	s	148.16	12.2	39.65
10	80	115 (1)	m[g]	–	m[g]	69.42	19.0	19.49	17.5	54.58	10.1	156.24
11	81	110 (1)	m[g]	–	m[g]	76.85	18.8	17.34	18.9	52.50	9.9	154.40
12	78	152 (1)	m[g]	–	m[g]	73.63	19.6	18.98	18.1	51.35	9.7	154.11
13	59	149 (1)	m[g]	–	m[g]	62.61	27.9	23.40	19.8	52.04	9.8	161.48
14	88	123 (1)	3.54	19.2	1.90	61.49	152.4	134.66	3.3	33.30	17.7	20.47
15	85	133 (1)	4.06	22.8	3.01[h]	60.27	153.3	137.24	4.0	50.0	17.9	21.41
16	80	138 (1), (59)	4.20	25.2	0.91[e]	56.31, 56.22	152.0, 152.0	141.00	s	52.13	14.1	22.32
17	83	126 (1)	3.96	21.6	2.17	56.91	159.8	151.33	s	34.81	16.6	18.69
18	85	154 (2)	3.89	20.0	2.11	60.94	152.9	132.76	3.8	34.91	17.8	20.35
19	84	122 (1)	3.80	17.2	2.16	65.82, 65.73	99.4, 98.9	137.40	s	34.96	15.9	47.07
			3.71	14.0	2.14	66.06, 65.98	100.5 100.8	137.01	4.2	34.89	16.9	46.08
20	86	121 (1)	3.91	17.2	2.19	59.59, 59.50	103.4, 104.7	151.56	s	35.13, 35.06	14.3 15.0	45.12
			3.82	14.8	2.18	59.50, 59.44	104.7, 106.0	151.26	3.5	35.06, 34.99	15.0 14.9	44.01
21	78	198 (1)	4.71	18.8	8.12[i]	72.71	151.52	135.79	7.6	163.26	15.5	17.53

(*Continued*)

TABLE 1 Continued

Compound No.	Yield (%)	Bp (°C) (p, mmHg) (mp (°C))	δ (H) C^1H d	$^2J_{PH}$	δ (H) C^3H_ns	δ (C^1) d	$^1J_{PC}$	δ (C^2) d	$^2J_{PC}$	δ (C^3) d	$^3J_{PC}$	δ_P, s[b]
22	97	[j]	3.72	20.1	–	56.25[k]	154.1	134.68	3.2	56.25[k]	17.4	19.79
			4.03	19.8	–		–	–	–	–	–	20.08
23	92	(61)	m[g]	–	2.72[l], 2.73[l]	72.74	159.8	21.69	5.5	50.53	2.3	−6.73
24	93	(81)	m[g]	–	2.73[l], 2.74[l]	70.57	158.2	30.69	4.8	50.63	s	−6.52
25	90	(27)	m[g]	–	2.75[l], 2.76[l]	70.81	158.8	29.80	13.8	50.60	s	−6.76

[a]For compounds, n_D^{20}: **14**, 1.4929; **15**, 1.5038; **17**, 1.4741; **18**, 1.4929; **19**, 1.5209; **20**, 1.4912; **21**, 1.5475. All signals of alkyl, aryl, heterocyclic, and trimethylsilyl groups are in the standard area. The ^{1}H NMR spectra of products fragments show expected signals that look like sometimes as overlapping multiplets. According to the NMR spectra, the compounds **2,3,7–9,19,20,22** are mixtures of two stereoisomers. Their ratio was determined from the ^{1}H and ^{31}P NMR spectra. The spectral parameters of the major isomer are given first; for compound **22** there are only ^{1}H and ^{31}P NMR spectral parameters for minor isomer due to its low content. The ratio for compounds: **2**, 55 : 45; **3**, 60 : 40; **7**, 70 : 30; **8**, 80 : 20; **9**, 65 : 35; **19**, 60 : 40; **20**, 55 : 45; **22**, 95 : 5. In ^{1}H NMR spectra, fragment NH for all compounds, except **6**, look like bright signals at 1.4–2.5 ppm; for **6** 1.39 dd (NH, $^3J_{PH}$ 4.9, $^3J_{HH}$ 10.2). Fragment PCH_3 in ^{1}H NMR spectra for compounds, **19**: 1.05 d ($^2J_{PH}$ 13.2) and 1.31 d ($^2J_{PH}$ 14.4); **20**: 1.22 d ($^2J_{PH}$ 14.4) and 1.36 d ($^2J_{PH}$ 14); in ^{13}C NMR spectra for compounds, **19**: 11.44 d ($^1J_{PC}$ 93.9) and 12.39 d ($^1J_{PC}$ 96.3); **20**: 12.80 d ($^1J_{PC}$ 96) and 11.85 d ($^1J_{PC}$ 94.5).
[b]Data of ^{31}P $\{^1H\}$ spectra.
[c]For compounds, $^3J_{HH}$, **4**: 4.0; **5**: 4.3; **6**: 10.2.
[d]For compounds, d, $^3J_{HH}$, **2**: 4.4 and 5.3; **4**: 6.0.
[e]Fragment Me_3C.
[f] Fragment Me_3SiN.
[g]The overlapping multiplets.
[h]ABX multiplet: 2.89 (H_A), 3.14 (H_B), $^2J(H_AH_B)$ 14.4, $^3J(H_AH_X)$ 6.4, $^3J(H_BH_X)$ 4.8.
[i]dd, $^4J_{PH}$ 2.4.
[j] This compounds is decomposed by heating into starting substances.
[k]dd.
[l]Two t for compounds, $^3J_{HH}$, **23**: 4.0 and 4.4; **24**: 4.4 and 4.4; **25**: 4.2 and 4.2.

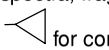
TABLE 2 Yields, Products Constants, and NMR Spectral Data (δ in ppm, J in Hz) for the $PC^1H(C^2)N(C^3)C^4(O)$ Fragments[a] of Amides **28–45**[a]

Compound No.	Yield (%)	Bp (°C) (p, mmHg) (mp (°C))	n_D^{20}	Ratio (%)	δ (H) C^1H d	$^2J_{PH}$	δ (H) C^3H_3s	δ (C^1) d	$^1J_{PC}$	δ (C^2) d	$^2J_{PC}$	δ (C^3) s	δ (C^4) d	$^3J_{PC}$	δ_P, s[c]
28	75	178 (2)	1.5071	60	5.93	21.6	2.83	50.06	158.0	131.33	3.4	30.71	161.43	4.9	17.03
				40	5.02	22.8	2.63	57.70	156.8	131.63	4.2	27.12	162.14	5.3	17.13
29	79	174 (2)	1.5119	55	6.17	22.4	–	51.63	158.1	134.38	4.9	45.81[b]	162.63	4.4	17.84
				45	4.82	24.0	–	58.50	153.2	134.34	4.0	48.18	162.78	4.0	17.55
30	83	148 (1)	1.4855	60	6.24	22.4	2.73	46.03	161.0	146.54	10.6	31.71	162.48	4.2	15.09
				40	5.26	23.2	2.83	53.14	161.7	146.73	12.3	28.06	163.34	4.6	15.49
31	87	182 (1)	1.5059	85	6.08	22.8	2.69	51.60	159.3	132.85	4.5	32.24[b]	169.86	5.4	18.26
				15	4.88	24.0	2.62	58.69	157.8	132.42	4.5	29.83	170.26	3.3	17.74
32	74	172 (1)	1.5115	98	6.58	22.8	–	52.80	158.1	135.22	5.2	48.98	170.70	4.4	18.31
				2	–	–	–	–	–	–	–	–	–	–	18.68
33	85	170 (2)	1.4829	85	6.57	23.2	2.82	47.41	161.3	147.69	12.1	32.78	170.12	3.5	16.01
				15	5.25	24.6	2.88	53.92	161.6	147.01	14.9	30.07	169.97	4.0	15.82
34	83	165 (1), (48)	–	100	6.83	23.2	3.06	48.10, 48.06	160.9 160.8	148.09	12.3	32.30[b]	173.26	3.3	16.05
35	74	181 (1)	1.5083	100	5.44	24.8	2.95	57.71	159.7	132.84	5.8	31.72	37.89[d]	s	17.26
36	70	172 (1)	1.4859	100	5.48	25.6	2.83	52.00	166.7	146.30	13.5	31.73	36.61[d]	s	14.45
37	72	164 (1)	1.5228	60	5.11	16.4	3.00	61.24	99.8	132.65	7.2	32.25[b]	37.26[d]	s	44.27
				40	5.22	17.6	2.97	60.20	106.7	132.11	s	31.66[b]	37.48[d]	s	44.84
38	78	194 (3)	1.5014	60	5.34	18.0	2.88	54.36	109.4	146.39	12.3	32.28[b]	36.24[d]	s	42.83
				40	5.24	17.6	2.85	54.57	103.6	145.62	6.2	31.69[b]	36.06[d]	s	42.28
39	59	169 (1), (42)	–	100	6.10[e]	21.12	–	50.31	155.6	136.66	s	–	169.53	7.6	19.79
40	82	(96)	–	70	6.03	16.2	3.07	54.51	98.2	130.06	5.1	33.80	170.86	5.2	37.12
				30	5.04	16.0	2.98	54.28	100.4	129.56	4.0	33.32	171.13	4.1	35.88
41	86	(89)	–	75	5.96	16.1	3.06	53.60	100.0	131.39	7.2	33.53	170.63	4.0	37.70
				25	6.02	16.0	2.98	53.40	100.2	130.79	8.0	33.27	170.77	4.0	36.26

(*Continued*)

TABLE 2 Continued

Compound No.	Yield (%)	Bp (°C) (p, mmHg) (mp (°C))	n_D^{20}	Ratio (%)	δ (H) C^1H d	$^2J_{PH}$	δ (H) C^3H_3s	δ (C^1) d	$^1J_{PC}$	δ (C^2) d	$^2J_{PC}$	δ (C^3) s	δ (C^4) d	$^3J_{PC}$	δ_P, s[c]
42	74	(139)	–	97	6.35	16.2	–	58.12	104.0	[f]	–	[f]	169.16	s	34.65
				3	–	–	–	–	–	–	–	–	–	–	34.35
43	78	oil	–	75	6.23	16.0	3.12	54.38	98.1	[f]	–	33.66	172.56	s	35.95
				25	6.31	16.1	3.07	53.94	103.0	[f]	–	33.66	172.72	s	33.38
44	80	oil	–	60	6.06	16.0	3.06	53.96	100.4	[f]	–	34.21	173.10	s	36.25
				40	6.13	16.2	3.01	54.05	99.2	[f]	–	34.79	173.55	s	33.55
45	72	oil	–	65	5.98	16.1	–	60.29	102.0	[f]	–	[f]	174.69	s	35.11
				35	6.09	16.3	–	60.40	100.1	[f]	–	[f]	174.11	s	36.77

[a]All signals of alkyl, aryl, and oleoyl groups are in the standard area. The ^1H NMR spectra of products fragments show expected signals that look like sometimes as overlapping multiplets. According to the NMR spectra, the compounds **28–33,40–45** are mixtures of two stereoisomers. Their ratio was determined from the ^1H and ^{31}P NMR spectra. The spectral parameters of the major isomer are given first; for compounds **32,42** there are only ^1H NMR and ^{31}P NMR spectral parameters for minor isomers due to its low contents. In ^1H NMR spectra, fragment NCHO for compounds: **28**, 7.88 s and 8.35 s, **29**, 8.12 s and 8.91 s, **30**, 7.94 s and 8.34 s; fragment $CH_3C(O)$ for compounds: **31**, 1.77 s and 1.93 s, **32**, 1.95 s, **33**, 1.79 s and 2.07 s; **39**, 2.00 s, **40**, 1.99 s and 1.80 s, **41**, 2.00 s and 2.03 s; fragment CH_3SO_2 for compounds: **35**, 2.48 s, **36**, 2.56 s, **37**, 2.22 s and 2.32 s; **38**, 2.53 s and 2.50 s; fragment $CH_3P(O)$ for compounds: **37**, 0.91 d ($^2J_{PH}$ 13.6) and 1.40 d ($^2J_{PH}$ 14.0), **38**: 1.13 d ($^2J_{PH}$ 14.0) and 1.44 d ($^2J_{PH}$ 14.4). In ^{13}C NMR spectra, fragment Me_{Ac} for compounds: **31**, 20.89 s and 20.86 s, **32**, 21.77 s, **33**, 21.34 s and 20.65 s, **39**, 22.20 s, **40**, 22.03 s and 21.70 s, **41**, 22.04 s and 21.55 s, **42**, 23.68 s, fragment  for compound **34**: 7.93 s and 8.24 s (2 CH_2), and 11.23 s (CH), fragment $CH_3P(O)$ for compounds: **37**, 13.68 d ($^1J_{PC}$ 92.9) and 13.45 d ($^1J_{PC}$ 92.6), **38**: 13.50 d ($^1J_{PC}$ 95.6) and 13.13 d ($^1J_{PC}$ 98.8).

[b]d, $^3J_{PC}$ for compounds: **29**, 4.3, **31**, 4.2, **34**, 5.3, **37**, 3.9 and 4.0, **38**, 5.2 and 5.4.

[c]Data of ^{31}P $\{^1H\}$ spectra.

[d]Fragment $MeSO_2$.

[e]dd, $^3J_{HH}$ 10, 9.28 d (NH, $^3J_{HH}$10).

[f] The signals of aromatic fragments are overlapping multiplets.

was removed in a vacuum, and 60 mL of ethanol was added to the residue. The mixture was heated to boil; the precipitate that formed was filtered off and washed with 20 mL of ethanol and 20 mL of ether. The resulting white fine crystals were kept in vacuum of 1 mmHg for 1 h to obtain compound **7**, yielding 28 g.

The acids **8,9** were prepared by the same procedure.

*O,O-Bis(trimethylsilyl) 1-(diethylamino)butylphosphonite (**10**).* A mixture of 7.2 g of bis(trimethylsiloxy)phosphine, 3.5 g of 1-(diethylamino)-1-butene, and 0.1 g of azobis(isobutyronitrile) was heated to 110–130°C for 2.5 h and then distilled in a vacuum to obtain 7.4 g of phosphonite **10**.

Phosphonites **11–13** were prepared similarly.

*O,O-Diethyl N-Methylamino(phenyl)methylphosphonate (**14**).* A mixture with 25.7 g of diethyl phosphite and 13.8 g of benzal(methyl)imine was heated at 90–100°C for 1 h, and the mixture was left for 48 h at 20°C, then was distilled, yielding 26.3 g of phosphonate **14**.

The compounds **15–21** were prepared similarly.

*Bis[diethoxyphosphoryl(phenyl)methyl]amine (**22**).* A mixture of 2.9 g of diethyl phosphite and 6.7 g of phosphonate **21** was left for 1 month at 20°C, then was kept in vacuum of 1 mmHg for 2 h to obtain amine **22**, yielding 9.5 g. According to ^{31}P NMR data, amine **22** contains as impurity of diethyl phosphite, 3%.

*5-(1-Morpholinopropyl)-1,4,6,9-tetraoxa-5-phosphaspiro[4.4]nonane (**23**).* 1-Morpholino-1-propene having a weight of 6.9 g was added to a solution of 4.1 g of hydrospirophosphorane **G** in 5 mL of methylene chloride. The mixture was left for 24 h. Then solvent was removed, and 50 mL of hexane was added to the residue. The white crystals were filtered off and washed with 10 mL of hexane, then were kept in a vacuum of 1 mmHg for 1 h to obtain 6.9 g of compound **23**.

The compounds **24** and **25** were prepared similarly.

*1,2-Bis(1,4,6,9-tetraoxa-5-phosphaspiro[4.4]non-5-yloxy)ethane (**26**) and 1,2-bis(1,3,2-dioxaphospholan-2-yloxy)ethane (**27**).* Twelve grams of 1-Morpholino-1-cyclohexene was added to a solution of 5.5 g of hydrospirophosphorane **G** in 5 mL of methylene chloride. This mixture was left for 2 weeks, then solvent was removed, and 5 mL of diethyl ether was added to the residue. The white crystals were filtered off and washed with 3 mL of hexane and then were kept in a vacuum of 1 mmHg for 0.5 h to obtain 3 g of bisphosphorane **26**, yielding 92%, mp 152°C. In ^{1}H NMR spectrum, δ (ppm): 3.5–3.7 m (cyclic CH_2, 16H), 3.9–4.0 m (bridged CH_2, 4H). In ^{13}C NMR spectrum, δ (ppm): 60.08 d (cyclic CH_2, $^{2}J_{PC}$ 7.9 Hz), 66.87 t (bridged CH_2, $^{2}J_{PC} = {}^{3}J_{PC}$ 14.7 Hz). In ^{31}P NMR spectrum, δ (ppm): −27.44. The solvent was removed from combined ether solutions, the residue was distilled to obtain 1.4 g of bisphospholane **27**, yielding 65%, bp 120°C under 0.05 mmHg, n_D^{20} 1.4890. In ^{1}H NMR spectrum, δ (ppm): 3.55–3.65 m (cyclic CH_2, 8H), 3.80–3.95 m (bridged CH_2, 4H). In ^{13}C NMR spectrum, δ (ppm): 64.86 d (cyclic CH_2, $^{2}J_{PC}$ 8.9 Hz), 62.68 dd (bridged CH_2, $^{2}J_{PC} = 11.9$ Hz, $^{3}J_{PC} = 4.2$ Hz,). In ^{31}P NMR spectrum, δ (ppm): 134.46.

The constants and NMR spectral data of compounds **26** and **27** are coincided with the data from the literature [16,17,22].

*O,O-Diethyl N-Formyl-N-methylamino(phenyl)-methylphosphonate (**28**).* A mixture of 12 g of phosphonate **14** and 3.5 g of 95% formic acid in 35 mL of toluene was refluxed with a water trap until water no longer separated. The solvent was then removed, and the residue was distilled to obtain 10 g of phosphonate **28**.

Compounds **29–33** and **39** were obtained similarly.

*O,O-Diethyl N-(Cyclopropylcarbonyl)-N-methylamino(2-furyl)methylphosphonate (**34**).* A solution of 3.8 g of cyclopropylcarbonyl chloride in 10 mL of diethyl ether was added dropwise with stirring and cooling to 10°C to a solution of 8.7 g of phosphonate **17** and 5 g of triethylamine in 25 mL of diethyl ether. The mixture was allowed to stand at 20°C for 12 h, the precipitate that formed was filtered off, the solvent was removed, and residue was distilled to obtain 9.2 g of phosphonate **34**.

Sulfonamides **35–38** were obtained similarly.

*Bis[N-acetyl-N-methylamino(phenyl)methyl]phosphinic Acid (**40**).* A mixture of 3.1 g of amine **7**, 15 mL of acetic anhydride, and 20 mL of methylene chloride was heated under reflux with stirring for 2 h, after which 20 mL of water was added, and the mixture was heated to boil. The solvents were then removed in a vacuum. Twenty milliliters of water, 5 mL of ethanol, and 5 mL of ether were added to the residue, and the crystals were filtered off, washed with ether, and exposed to a vacuum of 1 mmHg for 1 h to obtain 3.2 g of acid **40**.

TABLE 3 Elemental Analyses Data of Compounds **1–45**[a]

Compound No	Empirical Formula	Formula Weight	Calcd (%)		Found (%)	
			C	H	C	H
1	$C_{16}H_{28}NO_2P$	297.38	64.62	9.49	64.35	9.33
2	$C_{13}H_{24}NO_2PSi$	285.40	54.71	8.48	54.59	8.39
3	$C_{15}H_{28}NO_2PSi$	313.45	57.48	9.00	57.19	9.12
4	$C_{14}H_{28}NO_2PSi_2$	329.52	51.03	8.56	50.90	8.49
5	$C_{17}H_{34}NO_2PSi_2$	371.61	54.95	9.22	54.71	9.18
6	$C_{16}H_{34}NO_2PSi_3$	387.69	49.57	8.84	49.40	8.79
7	$C_{16}H_{21}N_2O_2P$	304.33	63.15	6.96	62.97	7.09
8	$C_{18}H_{25}N_2O_4P$	364.38	59.33	6.92	59.12	6.97
9	$C_{42}H_{57}N_2O_4P$	684.89	73.66	8.39	73.52	8.26
10	$C_{14}H_{36}NO_2PSi_2$	337.58	49.81	10.75	49.70	10.66
11	$C_{14}H_{34}NO_2PSi_2$	335.56	50.11	10.21	49.95	10.09
12	$C_{14}H_{34}NO_3PSi_2$	351.56	47.83	9.75	47.68	9.59
13	$C_{16}H_{36}NO_3PSi_2$	377.60	50.90	9.61	50.74	9.52
14	$C_{12}H_{20}NO_3P$	257.27	56.02	7.84	55.89	7.78
15	$C_{14}H_{22}NO_3P$	283.31	59.35	7.83	59.16	7.64
16	$C_{15}H_{26}NO_3P$	299.35	60.19	8.76	60.02	8.65
17	$C_{10}H_{18}NO_4P$	247.23	48.58	7.34	48.43	7.26
18	$C_{13}H_{21}N_2O_3P$	258.26	60.46	8.20	60.28	8.03
19	$C_{11}H_{18}NO_2P$	227.24	58.14	7.98	58.98	7.92
20	$C_9H_{16}NO_3P$	217.21	49.77	7.43	49.68	7.30
21	$C_{18}H_{22}NO_3P$	331.35	65.25	6.69	65.12	6.52
22	$C_{22}H_{33}NO_6P_2$	469.46	56.29	7.08	55.93	6.91
23	$C_{11}H_{22}NO_5P$	279.28	47.31	7.94	47.58	8.08
24	$C_{12}H_{24}NO_5P$	293.30	49.14	8.25	48.90	8.35
25	$C_{13}H_{26}NO_5P$	307.33	50.81	8.53	51.00	8.54
28	$C_{13}H_{20}NO_4P$	285.28	54.73	7.07	54.60	6.98
29	$C_{15}H_{22}NO_4P$	311.32	57.87	7.12	57.66	7.01
30	$C_{11}H_{18}NO_5P$	275.25	48.00	6.59	47.86	6.47
31	$C_{14}H_{22}NO_4P$	299.30	56.18	7.41	55.88	7.27
32	$C_{16}H_{24}NO_4P$	325.34	59.07	7.44	58.93	7.30
33	$C_{12}H_{20}NO_5P$	289.28	49.82	6.97	49.59	6.68
34	$C_{14}H_{22}NO_5P$	315.31	53.33	7.03	53.02	6.91
35	$C_{13}H_{22}NO_5PS$	335.36	46.56	6,61	46.35	6.49
36	$C_{11}H_{20}NO_6PS$	325.33	40.61	6.20	40.38	6.03
37	$C_{12}H_{20}NO_4PS$	305.33	47.20	6.60	47.02	6.42
38	$C_{10}H_{18}NO_5PS$	295.30	40.67	6.14	40.52	6.01
39	$C_{13}H_{20}NO_4P$	285.28	54.73	7.07	54.92	7.02
40	$C_{20}H_{25}N_2O_4P$	388.40	61.85	6.49	61.68	6.52
41	$C_{22}H_{29}N_2O_6P$	448.45	58.92	6.52	58.72	6.59
42	$C_{46}H_{61}N_2O_6P$	768.97	71.85	8.00	71.64	8.07
43	$C_{36}H_{55}N_2O_4P$	610.81	70.79	9.07	70.65	8.94
44	$C_{38}H_{59}N_2O_6P$	670.87	68.03	8.86	67.82	8.74
45	$C_{62}H_{91}N_2O_6P$	991.38	75.12	9.25	74.89	9.03

[a]The compounds **26** and **27** were described earlier in [16,17,22].

Compounds **41** and **42** were synthesized by the same procedure.

*Bis[N-methyl-N-oleoylamino(phenyl)methyl]phosphinic Acid (***43***).* To a cooled (10°C) and stirred mixture of 3.1 g of amine **7**, 5 mL of pyridine, and 30 mL of methylene chloride, 7.7 g of oleoyl chloride in 10 mL of methylene chloride was added. The mixture was heated for 3 h and was left to stand for 12 h. The precipitate was filtered off. The filtrate was diluted with 20 mL of water and heated for 1 h. The solvents were then removed in a vacuum. Twenty milliliters of water 10 mL of hexane and 3 mL of ether were added to the residue, and the mixture was stirred for 0.5 h. Hexane was separated, and water was distilled off in a vacuum of 1 mmHg for 1 h to obtain 4.9 g of acid **43**.

Compounds **44,45** were prepared by the same method.

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