Catalytic hydrophosphorylation of alkyl- and acylhydrazones

E. D. Matveeva, T. A. Podrugina, I. N. Kolesnikova, M. V. Prisyazhnoi, G. G. Karateev, and N. S. Zefirov*

Department of Chemistry, M. V. Lomonosov Moscow State University,
1 Leninskie Gory, 119992 Moscow, Russian Federation.
Fax: +7 (495) 939 0290. E-mail: matveeva@org.chem.msu.ru

N-Boc- and *N*-acylhydrazino phosphonates were obtained for the first time by hydrophosphorylation of the appropriate hydrazones of aliphatic and aromatic aldehydes and heterocyclic and aliphatic ketones in the presence of [tetra(*tert*-butyl)phthalocyanine]aluminum chloride as a catalyst.

Key words: catalysts, hydrazones, phosphorylation, α-hydrazino phosphonates, the Pudovik reaction, [tetra(*tert*-butyl)phthalocyanine]aluminum chloride, phthalocyanines, aluminum complexes.

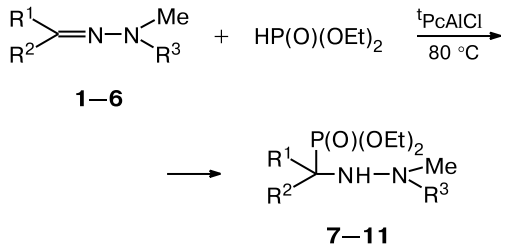
When developing a catalytic method for the synthesis of α-amino phosphonates[1—3] and α-hydrazino phosphonates[4] with [tetra(*tert*-butyl)phthalocyanine]aluminum chloride (^{t}PcAlCl) as a catalyst, we systematically studied the behavior of alkyl- and acylhydrazones of various carbonyl compounds in catalytic hydrophosphorylation. Such reactions produce α-hydrazino phosphonic acids, which often prove to be biologically active.[5]

The use of the Pudovik reaction for hydrophosphorylation of N-substituted hydrazones has been described hitherto in a few papers mainly focusing on variation of the phosphorus component.[6—13] The literature data on hydrophosphorylation of *N*-methyl- and *N*-Boc-hydrazones are lacking; hydrophosphorylation of *N*-acetylhydrazones has been studied only for unsaturated aldehyde derivatives.[6] Moreover, according to the literature data, reactions of *N*,*N*-dimethylhydrazones of aliphatic and aromatic aldehydes,[7] *o*-nitrocinnamaldehyde,[8] and isatin[9] with diethyl phosphite yield no α-hydrazino phosphonates.

$LiClO_4$-catalyzed reactions of aliphatic aldehydes with *N*,*N*-dimethylhydrazine and silylated phosphite afford α-hydrazino phosphonates in good yields;[10] however, aromatic aldehydes remain inert under these conditions. They react with dimethylhydrazine and trimethyl phosphite only in the presence of TMSCl and $LiClO_4$[11] or with tetraalkylammonium salts as catalysts.[12]

We found that hydrophosphorylation of propanal methylhydrazone (**1**) does not occur in such solvents as ether, CH_2Cl_2, DMF, and MeCN; yet this reaction was initiated when the neat hydrazone was heated with a threefold excess of diethyl phosphite (DEP) at 80 °C in the presence of ^{t}PcAlCl. Under these conditions, hydrophosphorylation of methyl- and dimethylhydrazones of cyclohexanone and 3-nitrobenzaldehyde gives the corresponding α-hydrazino phosphonates **7**—**11** in 15—60% yields (Scheme 1, Table 1).

Scheme 1



The best results were achieved in the hydrophosphorylation of propanal methyl- and dimethylhydrazones. The yields of the corresponding α-hydrazino phosphonates **7** and **10** were 60 and 45%, respectively. With cyclohex-

Table 1. Synthesis of α-hydrazino phosphonates **7**—**11** from methyl- and dimethylhydrazones

Hydrazone	Substituents			H : DEP*	*t*/h	Product (yield (%))
	R^1	R^2	R^3			
1	Et	H	H	1 : 3	16	**7** (60)
2	—$(CH_2)_5$—		H	1 : 3	24	**8** (45)
						8 (50**)
3	3-$O_2NC_6H_4$	H	H	1 : 3	70	**9** (30)
4	Et	H	Me	1 : 3	16	**10** (45)
5	—$(CH_2)_5$—		Me	1 : 3	24	**11** (15)
6	3-$O_2NC_6H_4$	H	Me	1 : 6	70	—

* The ratio hydrazone : $HP(O)(OEt)_2$.
** With an equimolar amount of ^{t}PcAlCl.

Published in Russian in *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 2, pp. 409—415, February, 2010.

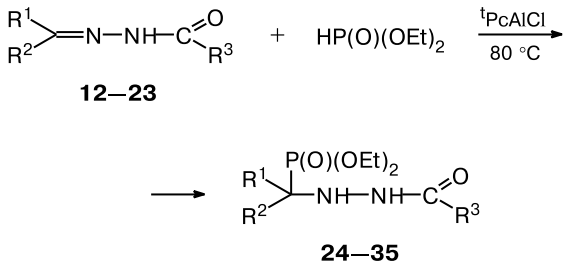
anone methyl- and dimethylhydrazones, the yields of the corresponding α-hydrazino phosphonates **8** and **11** decrease to 45% and 15%, respectively, and the reaction time increases. Prolonged heating of 3-nitrobenzaldehyde *N*-methylhydrazone affords α-hydrazino phosphonate **9** in 30% yield, while 3-nitrobenzaldehyde *N*,*N*-dimethylhydrazone resists hydrophosphorylation under the same conditions.

With cyclohexanone methylhydrazone as an example, we studied the influence of the amount of the catalyst on the yields of the reaction products. We assumed that coordination of the resulting α-hydrazino phosphonate by the central Al atom could blockade the catalyst. However, the reaction in the presence of an equimolar amount of ^{t}PcAlCl gave α-hydrazino phosphonate **8** in 50% yield, which is comparable with its yield for a 5 mol.% charge of the catalyst (45%). Therefore, the moderate yield of product **8** is not related to the elimination of the catalyst from the reaction zone.

Thus, using ^{t}PcAlCl as a catalyst, we effected for the first time the hydrophosphorylation of propanal, 3-nitrobenzaldehyde, and cyclohexanone *N*-methylhydrazones and found that 3-nitrobenzaldehyde dimethylhydrazone cannot be transformed into the corresponding α-hydrazino phosphonate under these conditions.

Hydrophosphorylation of *N*-Boc- and *N*-acetylhydrazones was carried out under the same conditions as for *N*-alkylhydrazones (Scheme 2, Table 2).

Scheme 2



Replacement of alkyl groups by acyl ones (Boc and acetyl) allowed the synthesis of earlier inaccessible α-hydrazino phosphonates from ketone hydrazones. Their yields are appreciably higher than those of the hydrophosphorylation products obtained from methyl- and dimethylhydrazones (see Table 2).

The yields of *N*-acetylhydrazino phosphonates **31**—**35** are comparable with, or higher than, the yields of α-hydrazino phosphonates derived from *N*-Boc-hydrazones (*e.g.*, compounds **31**, **32**). Unlike benzaldehyde *N*-Boc-hydrazone, which is reluctant to catalytic hydrophosphorylation under these conditions, *N*-acetylhydrazone forms the corresponding hydrazino phosphonate **30** in 35% yield. Acetophenone and indanone *N*-acetylhydrazones resist even ^{t}PcAlCl-catalyzed hydrophosphorylation.

Table 2. Hydrophosphorylation of N-Boc- and N-acetylhydrazones

Hydrazone	Substituents			H : DEP*	*t*/h	Product (yield (%))
	R^1	R^2	R^3			
12	Et	H	OBu^t	1 : 3	8	**24** (60)
13	Me	Me	OBu^t	1 : 3	11	**25** (65)
14	$-(CH_2)_4$		OBu^t	1 : 6	32	**26** (52)
15	$-(CH_2)_5-$		OBu^t	1 : 3	8	**27** (70)
16	$-(CH_2)_6-$		OBu^t	1 : 3	17	**28** (60)
						28 (40**)
17	$-(CH_2)_2NBoc(CH_2)_2-$		OBu^t	1 : 6	8	**29** (90)
18	*cyclo*-C_3H_5	Me	OBu^t	1 : 6	90	**30** (55)
19	Me	Me	Me	1 : 3	6	**31** (85)
						31 (60*)
20	$-(CH_2)_5-$		Me	1 : 3	1.5	**32** (85)
21	$-(CH_2)_2NBoc(CH_2)_2-$		Me	1 : 6	6	**33** (88)
22	*cyclo*-C_3H_5	Me	Me	1 : 6	60	**34** (55)
23	Ph	H	Me	1 : 6	40	**35** (35)

* The ratio hydrazone : $HP(O)(OEt)_2$.
** The reaction was carried out without a catalyst.

We found that, in contrast to *N*-methyl- and *N*,*N*-dimethylhydrazones, *N*-acetyl- and *N*-Boc-hydrazones can be hydrophosphorylated in excess diethyl phosphite in the absence of a solvent or a catalyst.

The advantage of the catalytic version of the reaction was illustrated with cycloheptanone *N*-Boc-hydrazone and acetone *N*-acetylhydrazone as examples. As expected, the yields of hydrazino phosphonates **28** and **31** in the catalytic reaction are substantially higher than those in noncatalytic hydrophosphorylation (see Table 2).

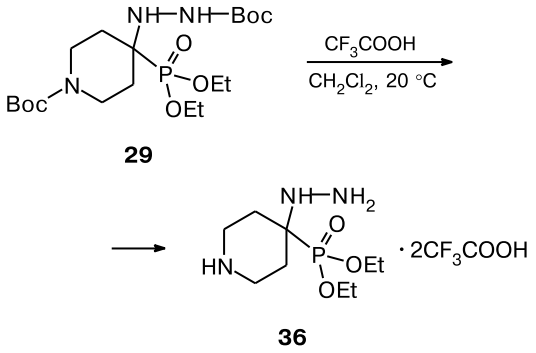
It should be noted that the *N*-Boc-hydrazino phosphonates obtained are of particular interest because Boc-protection can easily be removed under the action of an acid to give the corresponding α-hydrazino phosphonates with a free hydrazine group. The latter compounds are labile and easily decompose when stored.

With α-hydrazino phosphonate **29** as an example, we eliminated both Boc-protecting groups under the action of trifluoroacetic acid and obtained α-hydrazino phosphonate trifluoroacetate **36** (Scheme 3), which is a bioisostere of the ligand to the GABA-receptor[14] (GABA is gamma-aminobutyric acid).

The structures of α-hydrazino phosphonates **7**—**11** and **24**—**36** were confirmed by IR and ^{1}H, ^{13}C, and ^{31}P NMR spectroscopy and their compositions, by elemental analysis or mass spectrometry.

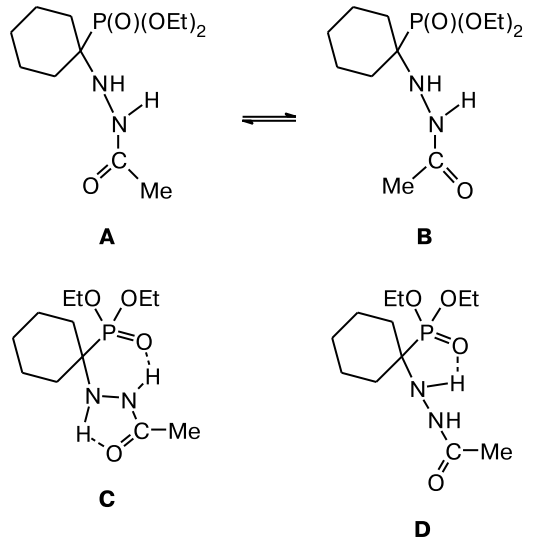
The IR spectra of all α-hydrazino phosphonates **7**—**11** and **24**—**36** show absorption bands at 1230—1280 (P=O) and 3260—3390 cm^{-1} (N—H). For compounds **24**—**36**, the intense broadened bands at 1640—1695 cm^{-1} are due to the carbonyl group. The ^{31}P NMR spectra of α-hydrazino phosphonates **7**—**11** and **24**—**36**, the signals for

Scheme 3



the P atoms appear at δ 20—31. The proposed structures of α-hydrazino phosphonates **7**—**11** and **24**—**36** agree with their ^{1}H and ^{13}C NMR spectra (see Ref. 2).

In the NMR spectra of α-acetylhydrazino phosphonates **31**—**35**, some signals are doubled. For instance, their ^{31}P NMR spectra contain two signals for the P atom with intensity ratios of 4 : 1 for **31**—**34** and 1 : 9 for **35**. This doubling can be attributed to either equilibrium between *cis*- and *trans*-rotamers[15] (structures **A** and **B**) with respect to the hydrazide fragment or intramolecular hydrogen bonding giving rise to two cyclic structures **C** and **D**.



In the ^{1}H and ^{13}C NMR spectra, the signals for the CH_3 protons of the acetyl fragment appear at δ 1.8—2.07. They are two singlets with intensity ratios of 4 : 1 for **31**—**34** and 9 : 1 for **35**, which correlate with the ^{31}P NMR data. The signal for the α-C atom in the ^{13}C NMR spectra of α-acetylhydrazino phosphonates **31**—**35** appears as two doublets at δ 55.20—63.25 ($^{1}J_{C,P}$ = 142.0—162.3 Hz); the signal for the carbonyl C atom appears as two singlets at δ 165—175.

IR spectroscopy revealed intramolecular hydrogen bonding in α-acetylhydrazino phosphonates. We recorded the IR spectra of 1-(*N*-acetylhydrazino)cyclohexylphosphonate **32** in CCl_4 for fourfold and 40-fold dilutions. The absorption bands of the phosphoryl (1260 cm^{-1}) and bound NH groups (3340 cm^{-1}) did not change in intensity or frequency, which suggests intramolecular hydrogen bonding.

To sum up, we found the conditions for the synthesis of earlier unknown hydrazino phosphonates. Using ^{t}PcAlCl as a catalyst, we hydrophosphorylated *N*,*N*-dimethyl-, *N*-methyl-, *N*-Boc-, and *N*-acetylhydrazones. The scope of this reaction was determined.

Experimental

NMR spectra were recorded on Bruker Avance 400 and Bruker Avance 300 instruments (400.13 (^{1}H), 100.61 (^{13}C), and 161.98 MHz (^{31}P)) in $CDCl_3$ and DMSO-d_6 with $SiMe_4$ as the internal standard (^{1}H, ^{13}C) and with 85% H_3PO_4 as the external standard (^{31}P). IR spectra were recorded on a UR-20 instrument in CCl_4. Elemental analysis was carried out on a Vario-II CHN analyzer. Mass spectra were measured on a Finnigan MAT INCOS 50 quadrupole mass spectrometer (EI, 70 eV, direct inlet probe). Diethyl phosphite (Aldrich) was used as purchased. [Tetra(*tert*-butyl)phthalocyanine]aluminum chloride was prepared according to a known procedure.[16] The course of the reaction was monitored, and the purity of the eluates was checked, by TLC on ALUGRAM SIL G/UV_{254} plates. The products were separated by column chromatography on MN Kieselgel 60 silica gel (0.04—0.063 mm/230—400 mesh ASTM).

Synthesis of substituted hydrazones 1—6 and 12—23 (general procedure). A mixture of a carbonyl compound (3 mmol) and a substituted hydrazine (3 mmol) was refluxed in hexane for 1—3 h. The reaction mixture was concentrated *in vacuo* and the residue was distilled or recrystallized from ethanol to give compounds **1**—**6** and **12**—**23**.

1-Methyl-2-propylidenehydrazine (1). Yield 80%, b.p. 123—124 °C (*cf.* Ref. 17: b.p. 123 °C).

1-Cyclohexylidene-2-methylhydrazine (2). Yield 90%, b.p. 93—95 °C (20 Torr) (*cf.* Ref. 18: b.p. 95 °C (20 Torr)).

1-Methyl-2-[(3-nitrophenyl)methylidene]hydrazine (3). Yield 99%, m.p. 65—66 °C (*cf.* Ref. 18: m.p. 66 °C).

1,1-Dimethyl-2-propylidenehydrazine (4). Yield 75%, b.p. 111—112 °C (*cf.* Ref. 19: b.p. 112 °C).

2-Cyclohexylidene-1,1-dimethylhydrazine (5). Yield 90%, b.p. 68—70 °C (20 Torr) (*cf.* Ref. 20: b.p. 70 °C (20 Torr)).

1,1-Dimethyl-2-[(3-nitrophenyl)methylidene]hydrazine (6). Yield 99%, m.p. 55—56 °C (*cf.* Ref. 21: m.p. 56 °C).

1-*tert*-Butoxycarbonyl-2-(1-methylethylidene)hydrazine (13). Yield 93%, m.p. 103—104 °C (*cf.* Ref. 22: m.p. 100—102 °C).

1-*tert*-Butoxycarbonyl-2-cyclopentylidenehydrazine (14). Yield 82%, m.p. 123—124 °C (*cf.* Ref. 23: m.p. 124—125 °C).

1-*tert*-Butoxycarbonyl-2-cyclohexylidenehydrazine (15). Yield 85%, m.p. 134—135 °C (*cf.* Ref. 23: m.p. 134—135 °C).

1-*tert*-Butoxycarbonyl-2-cycloheptylidenehydrazine (16). Yield 83%, m.p. 122—123 °C (*cf.* Ref. 23: m.p. 121—122 °C).

1-*tert*-Butoxycarbonyl-4-[(*tert*-butoxycarbonyl)hydrazono]-piperidine (17). Yield 94%, m.p. 172—173 °C (*cf.* Ref. 24: m.p. 172—174 °C).

***N*-(1-Methylethylidene)acetohydrazide (19).** Yield 93%, m.p. 133—134 °C (*cf.* Ref. 25: m.p. 134—135 °C).

***N*-Cyclohexylideneacetohydrazide (20).** Yield 88%, m.p. 125—126 °C (*cf.* Ref. 26: m.p. 124 °C).

***N*-(1-Cyclopropylethylidene)acetohydrazide (22).** Yield 87%, m.p. 110—111 °C (*cf.* Ref. 27: m.p. 110—112 °C).

***N*-Benzylideneacetohydrazide (23).** Yield 93%, m.p. 138—140 °C (*cf.* Ref. 28: m.p. 139—141 °C).

1-*tert*-Butoxycarbonyl-2-propylidenehydrazine (12). Yield 87%, m.p. 69—70 °C. ^{1}H NMR ($CDCl_3$), δ: 1.05, 1.11 (both t, 3 H, Me, $^3J_{H,H}$ = 7.6 Hz); 1.46, 1.49 (both s, 9 H, Bu^t); 2.08—2.17, 2.23—2.30 (both m, 2 H, CH_2); 7.17 (br.s, 1 H, NH); 8.01 (s, 1 H, CH=N). ^{13}C NMR ($CDCl_3$), δ: 10.36, 10.86 (both s, Me); 19.78, 25.63 (both s, CH_2); 28.26 (s, Me, Bu^t); 80.78 (s, $\underline{C}Me_3$); 147.71, 148.41 (both s, C=N); 152.77 (s, C=O). IR, ν/cm^{-1}: 1700 (C=N); 1720 (C=O); 3280 (N—H). Found (%): C, 55.61; H, 9.30; N, 16.29. $C_8H_{16}N_2O_2$. Calculated (%): C, 55.79; H, 9.36; N, 16.27.

1-*tert*-Butoxycarbonyl-2-(1-cyclopropylethylidene)hydrazine (18). Yield 90%, m.p. 112—114 °C. ^{1}H NMR ($CDCl_3$), δ: 0.68—0.74 (m, 4 H, 2 CH_2, ring); 1.49, 1.50 (both s, 9 H, Bu^t); 1.60 (s, 3 H, Me) 1.68—1.75 (m, 1 H, CH, ring). ^{13}C NMR ($CDCl_3$), δ: 4.83, 5.25 (both s, CH_2, ring); 9.96, 12.01 (both s, CH, ring); 18.04, 20.25 (both s, Me); 28.27 (s, Me, Bu^t); 80.78 (s, $\underline{C}Me_3$); 152.87 (s, C=O); 153.2 (s, C=N). IR, ν/cm^{-1}: 1630 (C=N); 1690 (C=O); 3250 (N—H). Found (%): C, 60.37; H, 9.36; N, 13.93. $C_{10}H_{18}N_2O_2$. Calculated (%): C, 60.58; H, 9.15; N, 14.13.

4-Acetylhydrazono-1-*tert*-butoxycarbonylpiperidine (21). Yield 89%, m.p. 129—131 °C. ^{1}H NMR ($CDCl_3$), δ: 1.46 (s, 9 H, Bu^t); 2.23 (s, 3 H, Me, Ac); 2.40—2.47 (m, 4 H, $NCH_2C\underline{H}_2$, ring); 3.55 (br.m, 4 H, $NC\underline{H}_2CH_2$, ring); 9.61 (br.s, 1 H, NHAc). ^{13}C NMR, δ: 20.47 (s, Me, Ac); 26.77 (s, $NCH_2\underline{C}H_2$, ring); 28.40 (s, Me, Bu^t); 33.78 (s, $N\underline{C}H_2CH_2$, ring); 80.11 (s, $\underline{C}Me_3$); 151.25 (s, C=O, Boc); 154.60 (s, C=N); 174.24 (s, C=O, Ac). IR, ν/cm^{-1}: 1640 (C=N); 1670, 1690 (C=O); 3240 (N—H). MS, *m/z*: 255 $[M]^+$.

Synthesis of α-hydrazino phosphonates 7—11 and 24—35 (general procedure). A mixture of a hydrazone (1 mmol), diethyl phosphite (3—6 mmol), and ^{t}PcAlCl (0.05 mmol) was stirred under argon at 80 °C until the reaction was completed (monitoring by TLC). Then the mixture was diluted with CH_2Cl_2—MeOH (70 : 1, 2 mL) and chromatographed on silica gel (column height 15 cm, column diameter 1.5—2.0 cm). The ratios of the reagents, the reaction times, and the yields of the products are given in Tables 1 and 2.

Diethyl [1-(2-methylhydrazino)propyl]phosphonate (7) was obtained from 1-methyl-2-propylidenehydrazine (**1**). The yield was 60%. ^{1}H NMR ($CDCl_3$), δ: 0.92 (t, 3 H, Me, $^3J_{H,H}$ = 7.3 Hz); 1.29, 1.30 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.52—1.70 (m, 3 H, CH_2, NH); 2.75 (d, 1 H, CH, $^2J_{H,P}$ = 10.3 Hz); 2.84 (s, 3 H, Me, NHMe); 4.06—4.14 (m, 4 H, 2 OCH_2); 5.79 (br.s, 1 H, NH). ^{31}P NMR ($CDCl_3$), δ: 24.44. ^{13}C NMR ($CDCl_3$), δ: 16.27 (d, Me, POEt, $^3J_{C,P}$ = 6.6 Hz); 19.04 (s, Me); 39.84 (s, Me, NHMe); 43.27 (d, CH_2, $^2J_{C,P}$ = 19.7 Hz); 58.44 (d, CH, $^1J_{C,P}$ = 154.6 Hz); 62.31, 62.50 (both d, $POCH_2$, $^2J_{C,P}$ = 5.8 Hz). IR, ν/cm^{-1}: 1260 (P=O); 3260, 3350 (NH). Found (%): C, 42.70; H, 9.31; N, 12.29. $C_8H_{21}N_2O_3P$. Calculated (%): C, 42.85; H, 9.44; N, 12.49. MS, *m/z*: 224 $[M]^+$, 195 $[M - Et]^+$, 166 $[M - Et - Et]^+$, 138 $[P(OH)(OEt)_2]^+$, 87 $[M - P(O)(OEt)_2]^+$.

Diethyl [1-(2-methylhydrazino)cyclohexyl]phosphonate (8) was obtained from 1-cyclohexylidene-2-methylhydrazine (**2**). The yield was 45%. ^{1}H NMR, δ: 1.11—1.27 (m, 2 H, CH_2, ring); 1.32, 1.34 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.0 Hz); 1.40—1.81 (m, 9 H, 4 CH_2, ring, NH); 2.55 (s, 3 H, Me, NHMe); 4.00—4.11 (m, 4 H, 2 OCH_2); 6.01 (br.s, 1 H, NH). ^{31}P NMR ($CDCl_3$), δ: 28.10. ^{13}C NMR ($CDCl_3$), δ: 16.20 (d, Me, POEt, $^3J_{C,P}$ = 6.1 Hz); 23.20 (d, CH_2, ring, $^3J_{C,P}$ = 19.1 Hz); 25.03 (s, CH_2, ring); 30.72 (d, CH_2, ring, $^2J_{C,P}$ = 10.4 Hz); 40.32 (s, Me, NHMe); 62.51, 62.73 (both d, $POCH_2$, $^2J_{C,P}$ = 5.8 Hz); 65.84 (d, C, $^1J_{C,P}$ = = 159.3 Hz). IR, ν/cm^{-1}: 1260 (P=O); 3250, 3340 (NH). Found (%): C, 49.76; H, 9.45; N, 10.40. $C_{11}H_{25}N_2O_3P$. Calculated (%): C, 49.99; H, 9.53; N, 10.60. MS, *m/z*: 264 $[M]^+$, 235 $[M - Et]^+$, 206 $[M - Et - Et]^+$, 138 $[P(OH)(OEt)_2]^+$, 127 $[M - P(O)(OEt)_2]^+$.

Diethyl [(2-methylhydrazino)(3-nitrophenyl)methyl]phosphonate (9) was obtained from 1-methyl-2-[(3-nitrophenyl)-methylidene]hydrazine (**3**). The yield was 30%. ^{1}H NMR ($CDCl_3$), δ: 1.37 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.0 Hz); 1.94 (br.s, 1 H, NH); 3.11 (s, 3 H, Me, NHMe); 3.90 (d, 1 H, CH, $^2J_{H,P}$ = 8.3 Hz); 4.09—4.18 (m, 4 H, 2 OCH_2); 7.21 (br.s, 1 H, NH); 7.46 (dd, 1 H, C(5)H, arom., *J* = 7.8 Hz, *J* = 8.1 Hz); 7.81 (d, 1 H, C(6)H, arom., *J* = 7.8 Hz); 8.03 (d, 1 H, C(4)H, arom., *J* = 8.1 Hz); 8.38 (s, 1 H, C(2)H, arom.). ^{31}P NMR ($CDCl_3$), δ: 22.26. ^{13}C NMR ($CDCl_3$), δ: 16.63 (d, Me, POEt, $^3J_{C,P}$ = 5.4 Hz); 42.14 (s, Me, NHMe); 55.73 (d, CH, $^1J_{C,P}$ = 152.9 Hz); 63.01, 63.20 (both d, $POCH_2$, $^2J_{C,P}$ = 6.9 Hz); 124.87, 125.16, 129.48, 132,04, 136.22, 148.50 (all s, C_{arom}). IR, ν/cm^{-1}: 1250 (N=O, NO_2, P=O); 1600, 1630 (N=O, NO_2); 3260, 3340 (NH). Found (%): C, 45.24; H, 6.30; N, 13.03. $C_{12}H_{20}N_3O_5P$. Calculated (%): C, 45.43; H, 6.35; N, 13.24. MS, *m/z*: 317 $[M]^+$, 288 $[M - Et]^+$, 259 $[M - Et - Et]^+$, 180 $[M - P(O)(OEt)_2]^+$, 138 $[P(OH)(OEt)_2]^+$.

Diethyl [1-(2,2-dimethylhydrazino)propyl]phosphonate (10) was obtained from 1,1-dimethyl-2-propylidenehydrazine (**4**). The yield was 45%. ^{1}H NMR ($CDCl_3$), δ: 1.01 (t, 3 H, Me, *J* = 7.1 Hz); 1.26, 1.28 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.0 Hz); 1.55—1.94 (m, 2 H, CH_2); 2.73 (d, 1 H, CH, $^2J_{H,P}$ = 10.2 Hz); 3.01 (s, 6 H, Me, NMe_2); 3.99—4.13 (m, 4 H, 2 OCH_2). ^{31}P NMR ($CDCl_3$), δ: 24.69. ^{13}C NMR ($CDCl_3$), δ: 16.99 (d, Me, POEt, $^3J_{C,P}$ = 4.8 Hz); 21.39 (s, Me); 43.04 (br.s, CH_2); 47.98 (s, Me, NMe_2); 56.92 (d, CH, $^1J_{C,P}$ = 147.0 Hz); 62.23, 62.76 (both d, $POCH_2$, $^2J_{C,P}$ = 6.8 Hz). IR, ν/cm^{-1}: 1260 (P=O); 3290, 3360 (NH). Found (%): C, 45.20; H, 9.84; N, 11.59. $C_9H_{23}N_2O_3P$. Calculated (%):C, 45.37; H, 9.73; N, 11.76. MS, *m/z*: 238 $[M]^+$, 209 $[M - Et]^+$, 180 $[M - Et - Et]^+$, 138 $[P(OH)(OEt)_2]^+$, 101 $[M - P(O)(OEt)_2]^+$.

Diethyl [1-(2,2-dimethylhydrazino)cyclohexyl]phosphonate (11) was obtained from 2-cyclohexylidene-1,1-dimethylhydrazine (**5**). The yield was 15%. ^{1}H NMR ($CDCl_3$), δ: 1.09—1.26 (m, 2 H, CH_2, ring); 1.27, 1.29 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.0 Hz); 1.35—1.80 (m, 8 H, 4 CH_2, ring); 2.93 (s, 6 H, 2 Me, NMe_2); 4.05—4.16 (m, 4 H, 2 OCH_2). ^{31}P NMR ($CDCl_3$), δ: 28.19. ^{13}C NMR ($CDCl_3$), δ: 16.19 (d, Me, POEt, $^3J_{C,P}$ = 6.1 Hz); 23.01 (d, CH_2, ring, $^3J_{C,P}$ = 19.0 Hz); 25.13 (s, CH_2, ring); 31.61 (d, CH_2, ring, $^2J_{C,P}$ = 10.2 Hz); 45.88 (s, Me, NMe_2); 62.41, 62.63 (both d, $POCH_2$, $^2J_{C,P}$ = 6.4 Hz); 66.74 (d, C, $^1J_{C,P}$ = = 159.1 Hz). IR, ν/cm^{-1}: 1260 (P=O); 3290, 3360 (NH). Found (%): C, 51.54; H, 9.92; N, 9.90. $C_{12}H_{27}N_2O_3P$. Calculated (%):C, 51.78; H, 9.78; N, 10.06. MS, *m/z*: 278 $[M]^+$, 249 $[M - Et]^+$, 220 $[M - Et - Et]^+$, 141 $[M - P(O)(OEt)_2]^+$,138 $[P(OH)(OEt)_2]^+$.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)propyl]phosphonate (24) was obtained from hydrazone **12**. The yield was 60%. ^{1}H NMR ($CDCl_3$), δ: 1.06 (t, 3 H, Me, $^3J_{H,H}$ = 7.5 Hz);

1.27, 1.28 (both t, 3 H each, 2 Me, POEt, $^3J_{H,H}$ = 7.2 Hz); 1.39 (s, 9 H, Bu^t); 1.51—1.62, 1.68—1.82 (both m, 1 H each, CH_2); 3.00—3.06 (m, 1 H, CH); 3.84 (br.s, 1 H, NHNHBoc); 4.06—4.13 (m, 4 H, 2 OCH_2); 6.48 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 26.73. ^{13}C NMR ($CDCl_3$), δ: 11.10 (d, Me; $^3J_{H,P}$ = = 9.7 Hz); 16.50 (br.s, Me, POEt); 21.22 (s, CH_2); 28.34 (s, Me, Bu^t); 59.47 (d, CH, $^1J_{C,P}$ = 155.0 Hz); 61.99, 62.41 (both d, OCH_2, $^2J_{C,P}$ = 7.2 Hz, $^2J_{C,P}$ = 6.4 Hz); 80.45 (s, CMe$_3$); 156.24 (s, C=O). IR, ν/cm^{-1}: 1030, 1070 (P—O—C); 1260 (P=O); 1710 (C=O); 3290 (N—H). Found (%): C, 46.35; H, 8.73; N, 9.15. $C_{12}H_{27}N_2O_5P$. Calculated (%): C, 46.44; H, 8.77; N, 9.03.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)-1-methylethyl]-phosphonate (25) was obtained from hydrazone **13**. The yield was 65%. ^{1}H NMR ($CDCl_3$), δ: 1.22 (d, 6 H, 2 Me, $^3J_{H,P}$ = 15.7 Hz); 1.27 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz, $^3J_{H,H}$ = 7.3 Hz); 1.37 (s, 9 H, Bu^t); 3.90 (br.d, 1 H, NHNHBoc, $^3J_{H,H}$ = 9.6 Hz); 4.06—4.12 (m, 4 H, 2 OCH_2); 6.57 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 29.37. ^{13}C NMR ($CDCl_3$), δ: 16.47 (d, Me, POEt, $^3J_{C,P}$ = 5.1 Hz); 20.75 (s, Me); 28.21 (s, Me, Bu^t); 56.38 (d, CH, $^1J_{C,P}$ = 150.0 Hz); 62.40 (d, OCH_2, $^2J_{C,P}$ = 7.3 Hz); 79.87 (s, CMe$_3$); 156.68 (s, C=O). IR, ν/cm^{-1}: 1040, 1060 (P—O—C); 1260 (P=O); 1740 (C=O); 3260, 3340 (NH). Found (%): C, 46.51; H, 8.64; N, 8.95. $C_{12}H_{27}N_2O_5P$. Calculated (%): C, 46.44; H, 8.77; N, 9.03.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)cyclopentyl]-phosphonate (26) was obtained from hydrazone **14**. The yield was 52%. ^{1}H NMR ($CDCl_3$), δ: 1.29 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.38 (s, 9 H, Bu^t); 1.56—1.73, 1.78—1.91 (both m, 4 H each, ring); 3.73 (br.s, 1 H, NHNHBoc); 4.07—4.15 (m, 4 H, 2 OCH_2); 6.73 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 29.91. ^{13}C NMR ($CDCl_3$), δ: 16.52 (d, Me, POEt, $^3J_{C,P}$ = 5.2 Hz); 24.52 (d, CH_2, ring, $^3J_{C,P}$ = 11.0 Hz); 28.23 (s, Me, Bu^t); 32.20 (d, CH_2, ring, $^2J_{C,P}$ = 4.4 Hz); 62.31 (d, OCH_2, $^2J_{C,P}$ = 7.3 Hz); 66.32 (d, C, $^1J_{C,P}$ = 152.3 Hz); 79.74 (s, CMe$_3$); 156.45 (s, C=O). IR, ν/cm^{-1}: 1040, 1060 (P—O—C); 1255 (P=O); 1740 (C=O); 3290, 3390 (N—H). Found (%): C, 50.17; H, 8.71; N, 8.18. $C_{14}H_{29}N_2O_5P$. Calculated (%): C, 49.99; H, 8.69; N, 8.33.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)cyclohexyl]-phosphonate (27) was obtained from hydrazone **15**. The yield was 70%. ^{1}H NMR ($CDCl_3$), δ: 1.14—1.24 (m, 1 H, ring); 1.30 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz), 1.39—1.43 (m, 1 H, ring); 1.40 (s, 9 H, Bu^t); 1.55—1.63 (m, 3 H, ring); 1.73—1.80 (m, 4 H, ring); 3.77 (br.s, 1 H, NHNHBoc); 4.06—4.15 (m, 4 H, 2 OCH_2); 6.79 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 29.07. ^{13}C NMR ($CDCl_3$), δ: 16.54 (d, Me, POEt, $^3J_{C,P}$ = 5.1 Hz); 19.76 (d, CH_2, ring, $^3J_{C,P}$ = 10.3 Hz); 25.37, 27.60 (both s, CH_2, ring); 28.26 (s, Me, Bu^t); 58.33 (d, C, $^1J_{C,P}$ = 145.6 Hz); 62.31 (d, OCH_2, $^2J_{C,P}$ = 7.4 Hz); 79.65 (s, CMe$_3$); 155.91 (s, C=O). IR, ν/cm^{-1}: 1030, 1050 (P—O—C); 1260 (P=O); 1735 (C=O); 3290 (N—H). Found (%): C, 51.71; H, 8.70; N, 7.88. $C_{15}H_{31}N_2O_5P$. Calculated (%): C, 51.42; H, 8.92; N, 7.99.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)cycloheptyl]-phosphonate (28) was obtained from hydrazone **16**. The yield was 60%. ^{1}H NMR ($CDCl_3$), δ: 1.28, 1.29 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.38 (br.s, 9 H, Bu^t); 1.42—1.58 (m, 6 H, ring), 1.59—1.76 (m, 4 H, ring); 1.59—1.76 (m, 2 H, ring); 3.67 (br.s, 1 H, NHNHBoc); 4.07—4.12 (m, 4 H, 2 OCH_2); 6.74 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 30.74. ^{13}C NMR ($CDCl_3$), δ: 16.47 (d, Me, POEt, $^3J_{C,P}$ = 5.8 Hz); 22.15 (d, CH_2, ring, $^3J_{C,P}$ = 8.8 Hz); 28.25 (s, Me, Bu^t); 30.66, 31.54 (both s, CH_2, ring); 61.81 (d, C, $^1J_{C,P}$ = 141.9 Hz); 62.32 (d, OCH_2, $^2J_{C,P}$ = 8.1 Hz); 79.63 (s, CMe$_3$); 156.31 (s, C=O). IR, ν/cm^{-1}: 1030, 1060 (P—O—C); 1260 (P=O); 1710, 1740 (C=O); 3300, 3390 (N—H). Found (%): C, 52.53; H, 9.00; N, 7.58. $C_{16}H_{33}N_2O_5P$. Calculated (%): C, 52.73; H, 9.13; N, 7.69.

1-*tert*-Butoxycarbonyl-4-(2-*tert*-butoxycarbonylhydrazino)-4-(diethoxyphosphoryl)piperidine (29) was obtained from hydrazone **17**. The yield was 90%. ^{1}H NMR ($CDCl_3$), δ: 1.33 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.42, 1.43 (both s, 18 H, 2 Bu^t); 1.59—1.72, 1.74—1.90 (both m, 2 H each, NCH_2CH_2); 3.23—3.43 (m, 2 H, NCH_2CH_2); 3.70—3.95 (m, 3 H, NCH_2CH_2, NHNH-Boc); 4.10—4.19 (m, 4 H, 2 OCH_2); 6.85 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 27.01. ^{13}C NMR ($CDCl_3$), δ: 16.60 (d, Me, POEt, $^3J_{C,P}$ = 4.0 Hz); 27.51 (s, NCH_2CH_2, ring); 28.35, 28.49 (both s, Me, Bu^t, Boc-N$(CH_2)_2$, BocNH); 37.71, 38.53 (both br.s, NCH_2CH_2, ring); 56.92 (d, C, $^1J_{C,P}$ = 148.6 Hz); 62.69 (d, $POCH_2$, $^2J_{C,P}$ = 7.3 Hz); 79.43, 80.13 (both s, CMe$_3$, Boc-N$(CH_2)_2$, BocNH); 154.75, 156.01 (both s, C=O, Boc-N$(CH_2)_2$, BocNH). IR, ν/cm^{-1}: 1060, 1080 (P—O—C); 1260 (P=O); 1690, 1730 (C=O); 3290, 3320 (N—H). Found (%): C, 50.49; H, 8.32; N, 9.23. $C_{16}H_{33}N_2O_5P$. Calculated (%): C, 50.54; H, 8.48; N, 9.31.

Diethyl [1-(2-*tert*-butoxycarbonylhydrazino)-1-cyclopropylethyl]phosphonate (30) was obtained from hydrazone **18**. The yield was 55%. ^{1}H NMR ($CDCl_3$), δ: 0.40—0.45, 0.47—0.55 (both m, 4 H, CH_2, ring); 0.97, 0.99 (both d, 3 H, Me, $^3J_{H,P}$ = = 16.2 Hz, $^3J_{H,P}$ = 16.1 Hz); 1.12—1.19 (m, 1 H, CH, ring); 1.32—1.37 (m, 6 H, 2 Me, POEt); 1.41, 1.42 (both s, 9 H, Bu^t); 4.01 (br.s, 1 H, NHNHBoc); 4.13—4.23 (m, 4 H, 2 OCH_2); 6.54 (br.s, 1 H, NHNHBoc). ^{31}P NMR ($CDCl_3$), δ: 28.51, 29.63. ^{13}C NMR ($CDCl_3$), δ: 0.15 (d, CH_2, ring, $^3J_{C,P}$ = 8.0 Hz); 1.52 (s, CH_2, ring); 13.78 (br.s, Me, CH, ring); 16.58 (br.s, Me, POEt); 28.33 (s, Me, Bu^t); 58.83 (d, C, $^1J_{C,P}$ = 152.6 Hz); 62.46, 62.74 (both d, OCH_2, $^2J_{C,P}$ = 7.3 Hz); 79.95 (s, CMe$_3$); 156.61 (s, C=O). IR, ν/cm^{-1}: 1040, 1060 (P—O—C); 1260 (P=O); 1720, 1740 (C=O); 3300 (N—H). Found (%): C, 50.24 ; H, 8.85; N, 8.58. $C_{14}H_{29}N_2O_5P$. Calculated (%): C, 49.99; H, 8.69; N, 8.33.

Diethyl [1-(2-acetylhydrazino)-1-methylethyl]phosphonate (31) was obtained from *N*-(1-methylethylidene)acetohydrazide (**19**). The yield was 85%. ^{1}H NMR ($CDCl_3$), δ: 1.28, 1.30 (both d, 6 H, 2 Me, $^3J_{H,P}$ = 15.2 Hz, $^3J_{H,P}$ = 15.7 Hz); 1.34, 1.35 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.0 Hz, $^3J_{H,H}$ = 7.1 Hz); 1.97, 2.08 (both s, 3 H, Me, Ac); 4.13—4.21 (m, 5 H, 2 OCH_2 NHNHAc); 7.83 (br.s, 1 H, NHNHAc). ^{31}P NMR ($CDCl_3$), δ: 28.75, 29.75. ^{13}C NMR ($CDCl_3$), δ: 16.53 (both d, Me, POEt, $^3J_{C,P}$ = 4.1 Hz); 19.59, 21.05 (both s, C(O)CH$_3$); 21.06 (s, Me); 55.89, 56.62 (both d, C, $^1J_{C,P}$ = 143.0 Hz, $^1J_{C,P}$ = 160.6 Hz); 62.69, 62.84 (both d, OCH_2, $^2J_{C,P}$ = 7.3 Hz, $^2J_{C,P}$ = 7.2 Hz); 168.38 175.83 (both s, C=O). IR, ν/cm^{-1}: 1040, 1065 (P—O—C); 1250 (P=O); 1640, 1660 (C=O); 3280 (N—H). Found (%): C, 42.83; H, 8.57; N, 11.13. $C_9H_{21}N_2O_4P$. Calculated (%): C, 42.85; H, 8.39; N, 11.11.

Diethyl [1-(2-acetylhydrazino)cyclohexyl]phosphonate (32) was obtained from *N*-cyclohexylideneacetohydrazide (**20**). The yield was 85%. ^{1}H NMR ($CDCl_3$), δ: 1.04—1.07 (m, 1 H, ring); 1.28, 1.30 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.40—1.89 (m, 9 H, ring); 1.89, 2.12 (both s, 3 H, Me); 4.06—4.15 (m, 4 H, 2 OCH_2); 3.95 (br.s, 1 H, NHNHAc); 8.01 (br.s, 1 H, NHNHAc). ^{31}P NMR ($CDCl_3$), δ: 27.87, 29.19. ^{13}C NMR ($CDCl_3$), δ: 16.39, 16.45 (both d, Me, POEt, $^3J_{C,P}$ = 5.1 Hz);

19.39, 21.11 (both s, C(O)$\underline{C}H_3$); 19.72, 19.99 (both d, CH_2, ring, $^3J_{C,P}$ = 10.9 Hz); 25.01, 27.37 (both s, CH_2, ring); 57.76, 58.35 (both d, C, $^1J_{C,P}$ = 142.0 Hz, $^1J_{C,P}$ = 161.0 Hz), 62.47, 62.66 (both d, OCH_2, $^2J_{C,P}$ = 7.4 Hz); 166.81, 174.99 (both s, C=O). IR, ν/cm^{-1}: 1040, 1070 (P—O—C); 1230 (P=O); 1665 (C=O); 3280 (N—H). Found (%): C, 49.24; H, 8.68; N, 9.35. $C_{12}H_{25}N_2O_4P$. Calculated (%): C, 49.31; H, 8.62; N, 9.58.

4-(2-Acetylhydrazino)-1-*tert*-butoxycarbonyl-4-(diethoxyphosphoryl)piperidine (33) was obtained from hydrazone **21**. The yield was 88%. ^{1}H NMR ($CDCl_3$), δ: 1.33 (t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.42, 1.44 (both s, 9 H, Bu^t); 1.69—1.90 (m, 4 H, C$\underline{H}_2$CH$_2$N); 1.94, 2.15 (both s, 3 H, Me); 3.17—3.30, 3.71—3.90 (both m, 2 H each, $CH_2C\underline{H}_2N$, ring); 4.12—4.20 (m, 4 H, OCH_2); 4.62 (br.s, N$\underline{H}$NHAc); 7.96 (s, NHN$\underline{H}$Ac). ^{31}P NMR ($CDCl_3$), δ: 26.27, 27.24. ^{13}C NMR ($CDCl_3$), δ: 16.55 (d, Me, POEt, $^3J_{C,P}$ = 4.0 Hz); 19.67, 21.29 (both s, C(O)$\underline{C}H_3$); 27.45 (s, $\underline{C}H_2CH_2N$); 28.45 (s, Me, Bu^t); 37.81, 38.50 (both br.s, $CH_2\underline{C}H_2N$); 56.44, 56.99 (both d, C, $^1J_{C,P}$ = 147.0 Hz, $^1J_{C,P}$ = = 160.6 Hz); 63.04 (d, OCH_2, $^2J_{C,P}$ = 7.2 Hz); 79.60, 79.91 (both s, $\underline{C}Me_3$); 154.72 (s, C=O, Boc); 168.03, 174.78 (both s, C=O, Ac). IR, ν/cm^{-1}: 1040, 1060 (P—O—C); 1255 (P=O); 1670, 1685 (C=O); 3280 (N—H). Found (%): C, 48.81; H, 8.18; N, 10.56. $C_{16}H_{32}N_3O_6P$. Calculated (%): C, 48.85; H, 8.20; N, 10.68.

Diethyl [1-(2-acetylhydrazino)-1-cyclopropylethyl]phosphonate (34) was obtained from hydrazone **22**. The yield was 55%. ^{1}H NMR ($CDCl_3$), δ: 0.37—0.54 (m, 4 H, CH_2, ring); 0.89, 0.96 (both d, 3 H, Me, $^3J_{H,P}$ = 16.2 Hz, $^3J_{H,P}$ = 15.9 Hz); 1.14—1.22 (m, 1 H, CH, ring); 1.30, 1.31 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.92, 2.04 (both s, 3 H, Me); 4.07—4.22 (m, 4 H, 2 OCH_2); 4.91 (br.s, 1 H, N$\underline{H}$NHAc); 7.86 (br.s, 1 H, NHN$\underline{H}$Ac). ^{31}P NMR ($CDCl_3$), δ: 27.91, 28.67. ^{13}C NMR ($CDCl_3$), δ: –0.30, 0.33 (both d, CH_2, ring, $^3J_{C,P}$ = 9.6 Hz, $^3J_{C,P}$ = 8.0 Hz); 1.16, 2.03 (both s, CH_2, ring); 13.25, 13.38 (both s, CH_3); 13.54, 14.62 (both s, CH, ring); 16.46, 16.52 (both d, Me, POEt, $^3J_{C,P}$ = 5.6 Hz, $^3J_{C,P}$ = 4.9 Hz); 19.60, 20.97 (both s, C(O)$\underline{C}H_3$); 57.79, 59.15 (both d, C, $^1J_{C,P}$ = 145.3 Hz, $^1J_{C,P}$ = 163.0 Hz); 62.49, 62.44, 63.17 (all d, OCH_2, $^2J_{C,P}$ = = 7.2 Hz); 167.77, 175.84 (both s, C=O). IR, ν/cm^{-1}: 1030, 1065 (P—O—C); 1240 (P=O); 1670 (C=O); 3280 (N—H). Found (%): C, 47.23; H, 8.44; N, 10.23. $C_{11}H_{23}N_2O_4P$. Calculated (%): C, 47.48; H, 8.33; N, 10.07.

Diethyl [(2-acetylhydrazino)(phenyl)methyl]phosphonate (35) was obtained from *N*-benzylideneacetohydrazide **23**. The yield was 35%. ^{1}H NMR ($CDCl_3$), δ: 1.21, 1.25 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.1 Hz); 1.83, 2.09 (both s, 3 H, Me); 3.95—4.07 (m, 4 H, OCH_2); 4.50 (d, 1 H, CH; $^2J_{H,P}$ = 14.4 Hz); 5.27 (br.s, N$\underline{H}$NHAc); 7.30—7.37 (m, 3 H, arom.); 7.43—7.46 (m, 2 H, arom.); 7.60 (br.s, NHN$\underline{H}$Ac). ^{31}P NMR ($CDCl_3$), δ: 20.46, 20.93. ^{13}C NMR ($CDCl_3$), δ: 16.11, 16.29 (both br.s, Me, POEt); 19.62, 20.89 (both s, C(O)$\underline{C}H_3$); 62.25, 62.54 (both d, CH, $^1J_{C,P}$ = 142.9 Hz, $^1J_{C,P}$ = 151.8 Hz); 62.75, 63.32 (both d, $POCH_2$, $^2J_{C,P}$ = 7.2 Hz, $^2J_{C,P}$ = 6.6 Hz); 128.31, 128.44, 128.94 (d, $^3J_{C,P}$ = 5.6 Hz); 133.90 (d, $^2J_{C,P}$ = 7.3 Hz) (C_{arom}); 169.46, 175.36 (both s, C=O). IR, ν/cm^{-1}: 1040, 1055 (P—O—C); 1260 (P=O); 1670 (C=O); 3270 (N—H). Found (%): C, 52.02; H, 7.10; N, 9.50. $C_{13}H_{21}N_2O_4P$. Calculated (%): C, 52.00; H, 7.05; N, 9.33.

Diethyl (4-hydrazinopiperidin-4-yl)phosphonate dihydrotrifluoroacetate (36). α-Hydrazino phosphonate **29** (1 mmol) was dissolved in CH_2Cl_2 (5 mL). Then trifluoroacetic acid (5 mL) was added and the reaction mixture was stirred at room temperature for 4 h. The solvent and the trifluoroacetic acid were removed on a rotary evaporator to a constant weight. The yield of salt **36** was 475 mg (99%), a slightly yellowish oil. ^{1}H NMR (DMSO-d_6), δ: 1.20, 1.23 (both t, 6 H, 2 Me, POEt, $^3J_{H,H}$ = 7.2 Hz); 1.85—2.20 (m, 5 H, 2 CH_2, ring, NH); 3.12—3.37 (m, 4 H, 2 CH_2, ring); 4.08, 4.16 (both dq, 4 H, 2 OCH_2, $^3J_{H,P}$ = 8.7 Hz, $^3J_{H,H}$ = 7.2 Hz); 4.62 (br.s, 2 H, NH, ring, NH_2). ^{31}P NMR (DMSO-d_6), δ: 27.27, 28.43. ^{13}C NMR (DMSO-d_6), δ: 18.36, 18.45 (both d, Me, POEt, $^3J_{C,P}$ = 5.7 Hz); 27.02 (s, CH_2, ring); 40.37, 40.85 (both d, CH_2, ring, $^2J_{C,P}$ = 8.0 Hz), 55.63, 57.23 (both d, C, $^1J_{C,P}$ = 150.9 Hz); 67.47, 68.19 (both d, $POCH_2$, $^2J_{C,P}$ = 8.0 Hz). MS, *m/z*: 251 $[M]^+$, 181 $[NH_2—NH=CH—P(O)(OEt)_2]^+$.

This work was financially supported by the Russian Foundation for Basic Research (Project No. 08-03-00611), the Russian Academy of Sciences (Basic Research Programs 1-OKhNM and 9-OKhNM), and the Presidium of the Russian Academy of Sciences (Grant 9P).

References

1. E. D. Matveeva, T. A. Podrugina, E. V. Tishkovskaya, N. S. Zefirov, *Synlett.*, 2003, 2321.
2. E. D. Matveeva, T. A. Podrugina, M. V. Prisyazhnoi, N. S. Zefirov, *Izv. Akad. Nauk, Ser. Khim.*, 2006, 1164 [*Russ. Chem. Bull., Int. Ed.*, 2006, **55**, 1209].
3. N. S. Zefirov, E. D. Matveeva, *ARKIVOC*, 2008, (i), No. 1, 1—17.
4. E. D. Matveeva, T. A. Podrugina, I. N. Kolesnikova, N. S. Zefirov, *Izv. Akad. Nauk, Ser. Khim.*, 2010, 571 [*Russ. Chem. Bull., Int. Ed.*, 2010, **59**, No. 3].
5. P. Diel, L. Maier, Eur. Pat. Appl. EP, 1985, 143 078; *Chem. Abstr.*, 1985, **103**, 215544m.
6. C. Stevens, E. Meenen, K. Masschelein, K. Moonen, A. Blieck, *Synlett.*, 2007, 2549.
7. L. V. Ryapisova, L. B. Kashevarova, S. V. Fridland, I. G. Shaikhiev, *Zh. Obshch. Khim.*, 2000, **70**, 1631 [*Russ. J. Gen. Chem.* (*Engl. Transl.*), 2000, **70**].
8. L. V. Ryapisova, *Fosforilirovannye proizvodnye nesimmetrichnogo dimetilgidrazina: sintez i issledovanie svoistv* [*Phosphorylated Derivatives of Asymmetric Dimethylhydrazine: Synthesis and Study of the Properties*], Ph.D. (Chem.) Thesis, Author´s Abstract, Kazan, 1998, p. 15 (in Russian).
9. L. V. Ryapisova, L. B. Kashevarova, I. G. Shaikhiev, S. V. Fridland, *Zh. Obshch. Khim.*, 1997, **67**, 2061 [*Russ. J. Gen. Chem.* (*Engl. Transl.*), 1997, **67**].
10. A. Heydari, A. Javidan, M. Schaffie, *Tetrahedron Lett.*, 2001, **42**, 8071.
11. A. Heydari, M. Mehrdad, M. Schaffie, M. Abdolrezaie, R. Hajinassirei, *Chem. Lett.*, 2002, **31**, 1146.
12. A. Heydari, A. Arefi, *Catal. Commun.*, 2007, **8**, 1023.
13. C.-L. Lien, C.-T. Hsu, *Int. J. Appl. Sci. Eng.*, 2008, **6**, 11.
14. M. Chebib, G. A. R. Johnston, *J. Med. Chem.*, 2000, **43**, 1427.
15. N. W. Owens, C. Braun, F. Schweizer, *J. Org. Chem.*, 2007, **72**, 4635.
16. S. A. Mikhalenko, S. V. Barkanova, O. L. Lebedev, E. A. Luk´yanets, *Zh. Obshch. Khim.*, 1971, **41**, 2735 [*Russ. J. Gen. Chem.* (*Engl. Transl.*), 1971, **41**].

17. B. V. Ioffe, V. S. Stopskii, Z. I. Sergeeva, *Zh. Org. Khim.*, 1968, **4**, 986 [*J. Org. Chem. USSR* (*Engl. Transl.*), 1968, **4**].
18. R. H. Wiley, G. Irick, *J. Org. Chem.*, 1959, **24**, 1925.
19. G. S. Gol´din, *Zh. Org. Khim.*, 1970, **6**, 754 [*J. Org. Chem. USSR* (*Engl. Transl.*), 1970, **6**].
20. D. Todd, *J. Am. Chem. Soc.*, 1949, **71**, 1356.
21. H. McKennis, J. H. Weatherby, E. P. Dellis, *Anal. Chem.*, 1958, **30**, 499.
22. G. Kaupp, U. Pogodda, J. Schmeyers, *Chem. Ber.*, 1994, **127**, 2249.
23. L. Spialter, D. O´Brien, G. Untereiner, W. Rush, *J. Org. Chem.*, 1965, **30**, 3278.
24. R. McGirk, C. Cyr, W. Ellis, E. White, *J. Org. Chem.*, 1974, **39**, 3851.
25. M. Majchrzak, M. Bekhazi, I. Tse-Sheepy, J. Warkentin, *J. Org. Chem.*, 1989, **54**, 1842.
26. A. Kurtz, C. Niemann, *J. Org. Chem.*, 1961, **26**, 1843.
27. T. V. Troepol´skaya, R. A. Sitdikov, Z. S. Titova, A. P. Stolyarov, Yu. P. Kitaev, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1980, 1280 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.* (*Engl. Transl.*), 1980, **29**].
28. M. Okimoto, T. Chiba, *J. Org. Chem.*, 1990, **55**, 1070.

Received July 16, 2009;
in revised form October 30, 2009