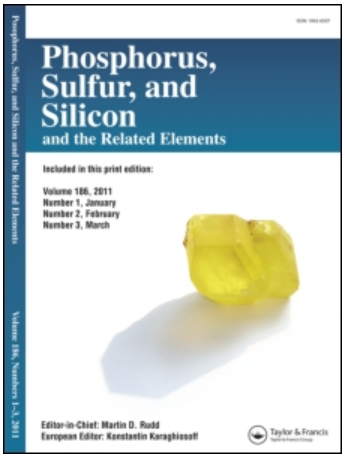

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STUDIES ON ORGANOPHOSPHORUS COMPOUNDS 94. SYNTHESES OF 1-HYDRAZINO- AND 2-HYDRAZINO-ALKYLPHOSPHONIC ACIDS AND DERIVATIVES THEREOF

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STUDIES ON ORGANOPHOSPHORUS COMPOUNDS 94. SYNTHESES OF 1-HYDRAZINO- AND 2-HYDRAZINO-ALKYLPHOSPHONIC ACIDS AND DERIVATIVES THEREOF

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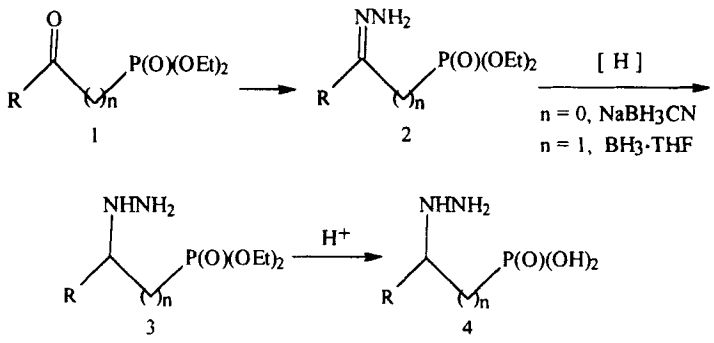
A series of 1-hydrazino- and 2-hydrazino-alkyl (aryl) phosphonic acids and their derivatives were prepared from the corresponding hydrazono compounds by treatment with sodium cyanoborohydride or with the borane-tetrahydrofuran complex, respectively.

Key words: Hydrazino-, hydrazono-alkylphosphonates, sodium cyanoborohydride, borane-tetrahydrofuran complex.

INTRODUCTION

As derivatives of aminoalkylphosphonic acids, hydrazinoalkylphosphonic acids are of considerable interest as compounds with potential biological activity. Addition of dialkyl phosphite to compounds with sp^2 C bearing hydrazono grouping followed by subsequent treatment is one of the general synthetic approach leading to 1-hydrazino-alkylphosphonic acids.[1] Thus Rachon reported the preparation of 1-hydrazino-alkylphosphonic acid based on the addition of diethylphosphite on aldazine followed by acid hydrolysis.[2] Unfortunately, the scope of application of this method is limited to 1-hydrazino-alkylphosphonic acids. Since acid hydrolysis leads to the cleavage of ester linkage, while catalytic hydrogenations usually results in N—N bond splitting, forming 1-aminoalkylphosphonic ester.[3] One of us (Maier),[4] has described a convenient synthesis of the titled compound by dialkylphosphite addition to hydrazone resulting from condensation of formaldehyde with hydrazine in which one of the amino functions was blocked by carbobenzyloxylcarbonyl group which was then removed smoothly by catalytic hydrogenation. This method seems to be a general synthetic route to 1-hydrazino-alkylphosphonic acid. However, other substituted hydrazones are inert to nucleophilic addition of dialkylphosphite.[5]



1, 2, 3, 4, n = 0

R = Me(a), $PhCH_2$(b), *p*-$MeC_6H_4CH_2$(c), *p*-$MeOC_6H_4CH_2$(d), *p*-$FC_6H_4CH_2$(e)

1', 2', 3', 4', n = 1

R = Et(a), *cyc*-Pr(b), $PhCH_2$(c), Ph(d), *p*-$MeC_6H_4CH_2$(e), *p*-$MeOC_6H_4$(f), *p*-MeO,*m*-Br-C_6H_3(g), *p*-FC_6H_4(h), *p*-ClC_6H_4(i), *p*-BrC_6H_4(j), *p*-$NO_2C_6H_4$(k).

RESULTS AND DISCUSSION

In this paper, we wish to report our successful trials on the synthesis of hydrazino alkyl (aryl) phosphonic acids via controlled reduction of corresponding hydrazonoalkyl (aryl) phosphonic acids which are accessible from easily available 1-ketophosphonates[6] and 2-ketophosphonates.[7]

As reported by Haelters,[8] condensation of N-monosubstituted hydrazine with 1-ketophosphonates gave exclusively hydrazone derivatives as expected. Upon reaction of hydrazine or hydrazine hydrate with 1-ketophosphonates, P—C bond cleavage occurred with the formation of acylhydrazine and dialkylphosphite.[9] This reaction involving an addition-elimination process serves as a preparative method for acyl hydrazines. As demonstrated more recently by Akacha,[10] in the presence of glacial acetic acid, 1-ketophosphonates (**1**) gave normal condensation products hydrazono-derivatives (**2**) with hydrazine or hydrazine hydrate.

The 1-hydrazono-alkylphosphonates (**2**) thus obtained were smoothly converted to the corresponding hydrazino-derivatives (**3**) by treatment with excess sodium cyanoborohydride in ethanol in the presence of bromothymol blue as indicator and followed by treatment with *p*-toluene sulfonic acid. It is necessary to point out that diethyl 1-hydrazino-alkylphosphonates (**3**) are air-sensitive oily liquid which turn dark in colour on standing. However, by treatment with excess anhydrous oxalic acid, **3** give colourless crystalline oxalates with sharp melting points. Upon acid hydrolysis, free 1-hydrazino-alkylphosphonic acids (**4**) were obtained as stable crystalline compounds in almost quantitative yield.

For the preparation of 2-hydrazino-ethylphosphonic acids (**4'**), 2-ketophosphonates (**1'**) were used as starting material. Formation of hydrazono-derivatives (**2'**)

underwent analogously as for the preparation of **2**. **2'** were purified by chromatography with neutral silica gel. Conversion of **2'** to **3'** was achieved by treatment with excess borane-tetrahydrofuran complex. They were also isolated as oxalates. Free 2-hydrazino-ethylphosphonic acids (**4'**) were obtained in good yield by acid hydrolysis of **3'**.

EXPERIMENTAL

Melting points are uncorrected. Infrared spectra were obtained on a Shimadzu IR-440 infrared spectrometer. ^{1}H-NMR spectra were recorded on a 60 MHz Varian EM 360 spectrometer using CCl_4 (for **2'a–k**), D_2O (for **3a–e** and **3'a–k**) or D_2O + NaOH (for **4a–e** and **4'd–j**) as the solvent and TMS as the internal reference. ^{31}P-NMR spectra were taken with a 90 MHz FX-90Q spectrometer using $CDCl_3$ (for **2'a–k**), D_2O (for **3a–e** and **3'a–k**) or D_2O + NaOH (for **4a–e** and **4'd–j**) as the solvent and 85% H_3PO_4 as the external standard. EI-MS was measured on a Finnigen-4021 mass spectrometer, while FAB-MS was measured on a Finnigen MAT 8430 mass spectrometer. Elemental analyses were performed at Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences.

Diethyl-1-hydrazino-alkylphosphonate: *Typical procedure*: Triethylphosphite (8.3 g, 0.05 mol) was added gradually under stirring to acyl chloride (0.05 mol). The addition was controlled so that the reaction temperature was kept under 40°C. After that the reaction mixture was heated to 60–70°C for 1 h, the low boiling fraction was removed on a rotatory evaporator under reduced pressure. The residue thus obtained was dissolved in ethanol (60 mL), transferred to a separating funnel and then added to a mixture prepared from 85% hydrazine hydrate (5.9 g, 0.1 mol N_2H_4), glacial acetic acid (12 mL) and ethanol (120 mL). The reaction mixture was stirred for 12 h at r.t. The solvent was removed under reduced pressure and the residue thus obtained was dissolved in methylene dichloride (100 mL) and washed successively with water (4 × 50 mL) and then saturated brine. After drying overnight with anhydrous Na_2SO_4, it was filtered and evaporated. The 1-hydrazono-alkylphosphonate was obtained as a viscous liquid. The intermediate thus obtained (about 0.04 mol) was dissolved in a mixture of $NaBH_3CN$ (7.6 g, 0.12 mol) and bromothymol blue (50 mg) in ethanol (80 mL) which was placed in a 250 mL three necked flask fixed with stirrer, thermometer and separatory funnel connected to pure nitrogen. An ethanol solution (90 mL) of *p*-toluene sulfonic acid hydrate (23 g, 0.121 mol) was introduced through the separatory funnel. The addition speed was controlled by the colour change of the indicator. After completion of addition, the reaction mixture was stirred for additional 6–8 h. Upon standing for 2 hours the precipitated TsONa was removed by filtration and the filtrate was concentrated and then treated with 10% NaOH. Extraction with methylene dichloride (4 × 50 mL) and washing the organic solution successively with water and then saturated brine (100 mL) followed by drying over anhydrous Na_2SO_4 and removal of the solvent gave a viscous residue. The crystalline oxalate of diethyl 1-hydrazino-alkylphosphonate was obtained by recrystallization from EtOH/Et_2O. It has a sharp melting point.

Diethyl 1-hydrazino-ethylphosphonate (oxalate) (**3a**): mp 102–103°C; IR (KCl, cm^{-1}): 3600–3400 (NH^+), 1600 (C=O), 1230 (P=O), 1020 (P—O—C); ^{1}H-NMR (ppm): 4.4 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.80–3.20 (m, 1H, P—$C\underline{H}CH_3$), 1.74–1.44 (m, 9H, 2 × $OCH_2C\underline{H}_3$ + P—$CHC\underline{H}_3$); ^{31}P-NMR: 24.30 ppm; Analysis: Found: C, 33.19; H, 6.44; N, 9.47; P, 10.45%. Calculated for $C_8H_{19}N_2O_7P$ (286.3): C, 33.56; H, 6.70; N, 9.77; P, 10.82%.

Diethyl 1-hydrazino-1-benzyl-methylphosphonate (oxalate) (**3b**): mp 98–100°C; IR (KCl, cm^{-1}): 3400–3300 (NH^+), 1620 (C=O), 1220 (P=O), 1030 (P—O—C); ^{1}H-NMR (ppm): 7.20 (s, $5H_{arom}$), 4.30 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.50–2.97 (m, 1H, P—$C\underline{H}CH_2$), 2.82 (d, 2H, P—$CHC\underline{H}_2$), 1.05 (t, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.44 ppm; Analysis: Found: C, 45.93; H, 6.19; N, 7.41%. Calculated for $C_{14}H_{23}N_2O_7P$ (362.4): C, 46.36; H, 6.41; N, 7.73%.

Diethyl 1-hydrazino-1-(p-methylbenzyl)-methylphosphonate (oxalate) (**3c**): mp 132–134°C; IR (KCl, cm^{-1}): 3300–3150 (NH^+), 1610 (C=O), 1210 (P=O), 1000 (P—O—C); ^{1}H-NMR (ppm): 7.30 (s, $4H_{arom}$), 4.40–3.50 (m, 5H, 2 × $OC\underline{H}_2CH_3$ + P—$C\underline{H}CH_2$), 3.20–2.70 (m, 2H, P—$CHC\underline{H}_2$), 2.30 (s, 3H, Ph—$C\underline{H}_3$), 1.45–1.10 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.56 ppm; Analysis: Found: C, 45.67; H, 6.44; N, 6.91%. Calculated for $C_{16}H_{26}N_2O_9P$ (421.4): C, 45.60; H, 6.23; N, 6.65%.

Diethyl 1-hydrazino-1-(p-methoxybenzyl)-methylphosphonate (oxalate) (**3d**): mp 138–139°C; IR (KCl, cm^{-1}): 3355–3200 (NH^+), 1610 (C=O), 1205 (P=O), 1005 (P—O—C); ^{1}H-NMR (ppm): 7.00 (d, *J*

= 8 Hz, $2H_{arom}$), 6.80 (d, J = 8 Hz, $2H_{arom}$), 4.25–3.65 (m, 5H, 2 × OCH_2CH_3 + P—$CHCH_2$), 3.55 (s, 3H, OCH_3), 2.84 (dd, 2H, $^3J_{PH}$ = 14.0 Hz, $^2J_{HH}$ = 8.0 Hz, P—$CHCH_2$), 1.20–0.80 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 24.50 ppm; Analysis: Found: C, 43.56; H, 6.31; N, 6.15%. Calculated for $C_{16}H_{26}N_2O_{10}P$ (437.4): C, 43.93; H, 6.00; N, 6.41%.

Diethyl 1-hydrazino-1-(p-fluorobenzyl)-methylphosphonate (oxalate) (**3e**): mp 119–121°C; IR (KCl, cm^{-1}): 3350–3200 (NH^+), 1600 (C=O), 1195 (P=O), 1010 (P—O—C); ^{1}H-NMR (ppm): 7.45–6.75 (m, $4H_{arom}$), 4.40–3.40 (m, 5H, 2 × OCH_2CH_3 + P—$CHCH_2$), 3.30–2.60 (m, 2H, P—$CHCH_2$), 1.40–0.90 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 24.27 ppm; Analysis: Found: C, 42.63; H, 5.35; N, 12.89%. Calculated for $C_{15}H_{23}FN_2O_9P$ (425.4): C, 42.35; H, 5.45; N, 13.17%.

1-hydrazino-alkylphosphonic acid: *Typical procedure*: Diethyl 1-hydrazino-alkylphosphonate (0.01 mol) was dissolved in aqueous hydrochloric acid (8 N, 50 mL) and heated to 90–100°C under vigorous stirring for 12 hours. The residue after evaporation under reduced pressure was dissolved in methanol (60 mL) and then propylene oxide added until the pH of solution approached 6. The solid precipitate was filtered and recrystallized from an appropriate solvent.

1-Hydrazino-ethylphosphonic acid (**4a**): mp 176–178°C (dec.), Lit[2] mp 182–184°C; IR (KCl, cm^{-1}): 3600–2500 (NH, OH), 1130 (P=O), 1010 (P—O—H); ^{1}H-NMR (ppm): 4.10–3.30 (m, 1H, P—$CHCH_3$), 1.90–1.10 (m, 3H, P—$CHCH_3$); ^{31}P-NMR: 27.60 ppm; Analysis: Found: C, 16.88; H, 6.34; N, 19.84; P, 21.95%. Calculated for $C_2H_9N_2O_3P$ (140.1): C, 17.14; H, 6.49; N, 20.00; P, 22.11%.

1-Hydrazino-1-benzyl-methylphosphonic acid (**4b**): mp 204–205.5°C (dec.); IR (KCl, cm^{-1}): 3600–2000 (NH, OH), 1120 (P=O), 1025 (P—O—H); ^{1}H-NMR (ppm): 7.75 (s, $5H_{arom}$), 4.50–4.10 (m, 1H, P—$CHCH_2$), 3.80–3.10 (m, 2H, P—$CHCH_2$); ^{31}P-NMR: 20.72 ppm; Analysis: Found: C, 44.01; H, 6.03; N, 12.97%. Calculated for $C_8H_{13}N_2O_3P$ (216.2): C, 44.44; H, 6.07; N, 12.96%.

1-Hydrazino-1-(p-methylbenzyl)-methylphosphonic acid (**4c**): mp 270–271°C (dec.); IR (KCl, cm^{-1}): 3700–2300 (NH, OH), 1100 (P=O), 1020 (P—O—H); ^{1}H-NMR (ppm): 7.40 (s, $4H_{arom}$), 4.20–3.80 (m, 1H, P—$CHCH_2$), 3.50–3.00 (m, 2H, P—$CHCH_2$), 2.35 (s, 3H, Ph—CH_3); ^{31}P-NMR: 14.55 ppm; Analysis: Found: C, 46.71; H, 6.21; N, 12.08%. Calculated for $C_9H_{15}N_2O_3P$ (230.2): C, 46.96; H, 6.58; N, 12.17%.

1-Hydrazino-1-(p-methoxybenzyl)-methylphosphonic acid (**4d**): mp 220–222°C (dec.); IR (KCl, cm^{-1}): 3600–2000 (NH, OH), 1130 (P=O), 1010 (P—O—H); ^{1}H-NMR (ppm): 7.30 (d, J = 9 Hz, $2H_{arom}$), 6.80 (d, J = 9 Hz, $2H_{arom}$), 3.69 (s, 3H, OCH_3), 3.24 (m, 1H, P-$CHCH_2$), 3.00–2.34 (m, 2H); ^{31}P-NMR: 17.70 ppm; Analysis: Found: C, 43.92; H, 5.89; N, 11.39%. Calculated for $C_9H_{15}N_2O_4P$ (246.2): C, 43.90; H, 6.15; N, 11.38%.

1-Hydrazino-1-(p-fluorobenzyl)-methylphosphonic acid (**4e**): mp 208–209°C (dec.); IR (KCl, cm^{-1}): 3350–3260 (NH, OH), 1125 (P=O), 1020 (P—O—H); ^{1}H-NMR (ppm): 7.65–7.10 (m, $4H_{arom}$), 4.30–3.70 (m, 1H, P—$CHCH_2$), 3.60–2.80 (m, 2H, P—$CHCH_2$); ^{31}P-NMR: 20.41 ppm; Analysis: Found: C, 40.87; H, 5.03; N, 11.62%. Calculated for $C_8H_{12}FN_2O_3P$ (234.2): C, 41.03; H, 5.18; N, 11.96%.

Diethyl 2-ethyl-2-hydrazono-ethylphosphonate (**2'a**): To diethyl 2-ethyl-2-oxo-ethyl phosphonate (**1'a**, 4.16 g, 0.02 mol) was added dropwise anhydrous hydrazine (5.0 mL, 0.16 mol) with stirring at r.t. for several minutes, after which acetic acid (11.5 mL, 0.20 mol) was added. A vigorous reaction occurred, and the reaction mixture turned from colorless to pale yellow. The mixture was then stirred at r.t. for 24–32 h to complete the reaction as monitored by TLC. To the resulting residue was added water (100 mL) under stirring. Then the mixture was extracted with methylene dichloride (3 × 30 mL). The combined organic solutions were successively washed with saturated sodium bicarbonate, water and saturated brine and then dried over anhydrous sodium sulfide. Removal of the solvent under reduced pressure gave a crude product which was then purified by chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) to afford **2'a** as a pale yellow sticky oil in 80% yield. IR (film, cm^{-1}): 1680 (C=N), 1255 (P=O), 1040, 960 (P—O—C); ^{1}H-NMR (ppm): 6.20 (s, 2H, NH_2), 4.13 (m, 4H, 2 × OCH_2CH_3), 3.29 (d, 2H, $^2J_{PH}$ = 23.0 Hz, P—CH_2), 2.50 (m, 2H, $^3J_{HH}$ = 7.0 Hz, CH_3CH_2), 1.39 (m, 6H, 2 × OCH_2CH_3), 1.29 (t, 3H, $^3J_{HH}$ = 7.0 Hz, CH_3CH_2); ^{31}P-NMR: 24.0 ppm; EI-MS (M^+): 222; Analysis: Found: C, 43.70; H, 8.29; N, 12.98; P, 13.54%. Calculated for $C_8H_{19}N_2O_3P$ (222.2): C, 43.23; H, 8.62; N, 12.61; P, 13.94%.

Diethyl 2-cyclopropyl-2-hydrazono-ethylphosphonate (**2'b**): Analogous to the preparation of **2'a**, using diethyl 2-cyclopropyl-2-oxo-ethylphosphonate (**1'b**, 4.40 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'b**

was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a pale yellow sticky oil in 80% yield. IR (film, cm^{-1}): 1660 (C=N), 1250 (P=O), 1040, 960 (P—O—C); ^{1}H-NMR (ppm): 6.10 (s, 2H, NH_2), 4.18 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.28 (d, 2H, $^2J_{PH}$ = 23.2 Hz, P—CH_2), 2.00 (m, 1H, CH), 1.33 (m, 6H, 2 × $OCH_2C\underline{H}_3$), 1.07 (m, 4H, CH_2CH_2); ^{31}P-NMR: 24.9 ppm; EI-MS (M^+): 234; Analysis: Found: C, 46.51; H, 8.57; N, 12.24; P, 13.00%. Calculated for $C_9H_{19}N_2O_3P$ (234.2): C, 46.14; H, 8.18; N, 11.96; P, 13.22%.

Diethyl 3-phenyl-2-hydrazono-propylphosphonate (**2'c**): Analogous to the preparation of **2'a**, using diethyl 3-phenyl-2-oxo-propylphosphonate (**1'c**, 5.40 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'c** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a pale yellow sticky oil in 74% yield. IR (film, cm^{-1}): 1700 (C=N), 1250 (P=O), 1030, 960 (P—O—C); ^{1}H-NMR (ppm): 8.13 (s, 2H, NH_2), 7.32 (m, $5H_{arom}$), 4.18 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.50 (d, 2H, $^2J_{PH}$ = 22.8 Hz, P—CH_2), 3.12 (d, 2H, J_{gem} = 10.5 Hz, Ph—$C\underline{H}_2$), 1.33 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.8 ppm; EI-MS (M^+): 284; Analysis: Found: C, 54.46; H, 7.83; N, 9.47; P, 10.77%. Calculated for $C_{13}H_{21}N_2O_3P$ (284.3): C, 54.92; H, 7.45; N, 9.86; P, 10.90%.

Diethyl 2-phenyl-2-hydrazono-ethylphosphonate (**2'd**): Analogous to the preparation of **2'a**, using diethyl 2-phenyl-2-oxo- ethylphosphonate (**1'd**, 5.12 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'd** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 86% yield. IR (film, cm^{-1}): 1610 (C=N), 1240 (P=O), 1030, 960 (P—O—C); ^{1}H-NMR (ppm): 7.66–7.41 (m, $5H_{arom}$), 6.25 (s, 2H, NH_2), 4.09 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.37 (d, 2H, $^2J_{PH}$ = 22.8 Hz, P—CH_2), 1.20 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.4 ppm; EI-MS (M^+ + 1): 271; Analysis: Found: C, 53.71; H, 7.44; N, 10.82; P, 11.09%. Calculated for $C_{12}H_{19}N_2O_3P$ (270.3): C, 53.33; H, 7.09; N, 10.37; P, 11.46%.

Diethyl 2-(p-methylphenyl)-2-hydrazono-ethylphosphonate (**2'e**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-methylphenyl)-2-oxo-ethylphosphonate (**1'e**, 5.40 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'e** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 81% yield. IR (film, cm^{-1}): 1610 (C=N), 1250 (P=O), 1020, 960 (P—O—C): ^{1}H-NMR (ppm): 7.55–7.20 (m, $4H_{arom}$), 6.22 (s, 2H, NH_2), 4.14 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.36 (d, 2H, $^2J_{PH}$ = 22.9 Hz, P—CH_2), 2.36 (s, 3H, Ph—$C\underline{H}_3$), 1.30 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.5 ppm; EI-MS (M^+ − 1): 283; Analysis: Found: C, 54.47; H, 7.80; N, 9.49; P, 10.31%. Calculated for $C_{13}H_{21}N_2O_3P$ (284.3): C, 54.92; H, 7.45; N, 9.86; P, 10.90%.

Diethyl 2-(p-methoxyphenyl)-2-hydrazono-ethylphosphonate (**2'f**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-methoxyphenyl)-2-oxo-ethylphosphonate (**1'f**, 5.72 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'f** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 80% yield. IR (film, cm^{-1}): 1615 (C=N), 1250 (P=O), 1025, 965 (P—O—C); ^{1}H-NMR (ppm): 7.48–7.10 (m, $4H_{arom}$), 6.15 (s, 2H, NH_2), 4.10 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.90 (s, 3H, $OC\underline{H}_3$), 3.36 (d, 2H, $^2J_{PH}$ = 22.8 Hz, P—CH_2), 1.30 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.4 ppm; EI-MS (M^+ + 1): 301; Analysis: Found: C, 51.58; H, 7.46; N, 9.87; P, 9.87%. Calculated for $C_{13}H_{21}N_2O_4P$ (300.3): C, 51.99; H, 7.05; N, 9.33; P, 10.31%.

Diethyl 2-(p-methoxy-m-bromophenyl)-2-hydrazono-ethylphosphonate (**2'g**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-methoxy-*m*-bromophenyl)-2-oxo-ethylphosphonate (**1'g**, 7.30 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'g** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 85% yield. IR (film, cm^{-1}): 1620 (C=N), 1250 (P=O), 1030, 960 (P—O—C), 650 (C—Br); ^{1}H-NMR (ppm): 8.03–6.92 (m, $3H_{arom}$), 6.00 (s, 2H, NH_2), 4.14 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.93 (s, 3H, $OC\underline{H}_3$), 3.33 (d, 2H, $^2J_{PH}$ = 22.8 Hz, P—CH_2), 1.28 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.3 ppm; EI-MS (M^+ + 1): 380, 382; Analysis: Found: C, 41.60; H, 4.93; N, 7.88; Br, 20.70; P, 8.63%. Calculated for $C_{13}H_{20}BrN_2O_4P$ (379.2): C, 41.17; H, 5.32; N, 7.39; Br, 21.07; P, 8.17%.

Diethyl 2-(p-fluorophenyl)-2-hydrazono-ethylphosphonate (**2'h**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-fluorophenyl)-2-oxo-ethylphosphonate (**1'h**, 5.48 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'h** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether)

as a yellow sticky oil in 79% yield. IR (film, cm^{-1}): 1605 (C=N), 1240 (P=O), 1220, 1150 (C—F), 1030, 960 (P—O—C); ^{1}H-NMR (ppm): 8.29 (s, 2H, NH_2), 8.17–6.92 (m, $4H_{arom}$), 4.07 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.33 (d, 2H, $^2J_{PH}$ = 22.6 Hz, P—CH_2), 1.26 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.7 ppm; EI-MS (M^+): 288; Analysis: Found: C, 49.58; H, 6.67; N, 10.15%. Calculated for $C_{12}H_{18}FN_2O_3P$ (288.3): C, 50.00; H, 6.29; N, 9.72%.

Diethyl 2-(p-chlorophenyl)-2-hydrazono-ethylphosphonate (**2'i**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-chlorophenyl)-2-oxo-ethylphosphonate (**1'i**, 5.81 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'i** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 73% yield. IR (film, cm^{-1}): 1640 (C=N), 1260 (P=O), 1030, 980 (P—O—C), 710 (C—Cl); ^{1}H-NMR (ppm): 7.51–7.18 (m, $4H_{arom}$), 6.15 (s, 2H, NH_2), 4.14 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.34 (d, 2H, $^2J_{PH}$ = 22.6 Hz, P—CH_2), 1.28 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 22.9 ppm; EI-MS (M^+): 304, 306; Analysis: Found: C, 46.93; H, 5.62; N, 9.48; P, 9.73%. Calculated for $C_{12}H_{18}ClN_2O_3P$ (304.7): C, 47.30; H, 5.95; N, 9.20; P, 10.17%.

Diethyl 2-(p-bromophenyl)-2-hydrazono-ethylphosphonate (**2'j**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-bromophenyl)-2-oxo-ethylphosphonate (**1'j**, 6.70 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'j** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 83% yield. IR (film, cm^{-1}): 1650 (C=N), 1230 (P=O), 1020, 960 (P—O—C), 650 (C—Br); ^{1}H-NMR (ppm): 8.15 (s, 2H, NH_2), 8.00–7.45 (m, $4H_{arom}$), 4.15 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.35 (d, 2H, $^2J_{PH}$ = 22.8 Hz, P—CH_2), 1.30 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 24.4 ppm; EI-MS (M^+): 348, 350; Analysis: Found: C, 41.65; H, 5.39; N, 8.39; P, 8.40%. Calculated for $C_{12}H_{18}BrN_2O_3P$ (349.2): C, 41.28; H, 5.20; N, 8.02; P, 8.87%.

Diethyl 2-(p-nitrophenyl)-2-hydrazono-ethylphosphonate (**2'k**): Analogous to the preparation of **2'a**, using diethyl 2-(*p*-nitrophenyl)-2-oxo-ethylphosphonate (**1'k**, 6.02 g, 0.02 mol), anhydrous hydrazine (5.0 mL, 0.16 mol) and acetic acid (11.5 mL, 0.20 mol) for the reaction and followed by similar treatment. **2'k** was obtained by column chromatography with neutral silica gel (1:1 ethyl acetate:petroleum ether) as a yellow sticky oil in 74% yield. IR (film, cm^{-1}): 1620 (C=N), 1550, 1330 (N=O), 1250 (P=O), 1040, 970 (P—O—C); ^{1}H-NMR (ppm): 8.09–7.55 (m, $4H_{arom}$), 6.20 (s, 2H, NH_2), 4.10 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.33 (d, 2H, $^2J_{PH}$ = 22.4 Hz, P—CH_2), 1.25 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 23.7 ppm; EI-MS (M^+): 315; Analysis: Found: C, 45.27; H, 5.49; N, 13.71; P, 9.24%. Calculated for $C_{12}H_{18}N_3O_5P$ (315.3): C, 45.71; H, 5.75; N, 13.33; P, 9.82%.

Diethyl 2-ethyl-2-hydrazino-ethylphosphonate (oxalate) (**3'a**): To a solution of diethyl 2-ethyl-2-hydrazono-ethylphosphonate (**2'a**, 1.11 g, 0.005 mol) in anhydrous tetrahydrofuran (20 mL) was added dropwise a borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol, prepared according to the known method[11]) with stirring at −5°C under nitrogen for 1–2 h. The addition should be controlled in such a rate that the reaction temperature does not exceed 0°C. After additional 8–10 h stirring at that temperature, the resulting solution was allowed to warm slowly to room temperature. The mixture was then stirred at r.t. for another 18–24 h to complete the reaction as monitored by TLC. After that the mixture was cooled to 0°C and the excess borane-tetrahydrofuran was destroyed with careful dropwise-addition of cold hydrochloric acid (6 M, 10 mL). Water (50 mL) was added and the resulting mixture was extracted with methylene dichloride (3 × 10 mL). The organic layer was discarded. The aqueous layer was carefully neutralized with aq. sodium bicarbonate and then extracted with methylene dichloride (3 × 20 mL). The combined organic solutions were successively washed with water and saturated brine then dried over anhydrous sodium sulfate. Removal of the solvent under reduced pressure afforded a yellowish sticky oil. To a solution of this sticky oil (0.40 g, 0.0018 mol) in absolute ether (10 mL) was added dropwise 10 mL of an ethereal solution of anhydrous oxalic acid (0.5 g, 0.0055 mol). The resulting mixture was then set aside at r.t. until white crystals precipitated (for ca. 24–48 h). They were collected, washed with anhydrous ether and dried. Recrystallization from ethyl alcohol-ether afforded colorless crystals **3'a** in 53% yield. mp 104–105°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1690 (C=O), 1260 (P=O), 1050, 960 (P—O—C); ^{1}H-NMR (ppm): 4.37 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—$CH_2C\underline{H}$), 4.14 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 2.53 (m, 2H, $^3J_{HH}$ = 7.0 Hz, $CH_3C\underline{H}_2$), 2.74, 2.40 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.6 Hz, P—$C\underline{H}_2CH$), 1.38 (m, 6H, 2 × $OCH_2C\underline{H}_3$), 1.28 (t, 3H, $^3J_{HH}$ = 7.0 Hz, $C\underline{H}_3CH_2$); ^{31}P-NMR: 28.3 ppm; FAB-MS ($M^+ - 1$): 358; Analysis: Found: C, 36.52; H, 6.54; N, 7.69; P, 8.31%. Calculated for $C_{11}H_{24}N_2O_9P$ (359.3): C, 36.77; H, 6.73; N, 7.80; P, 8.62%.

Diethyl 2-cyclopropyl-2-hydrazino-ethylphosphonate (oxalate) (**3'b**): Analogous to the preparation of **3'a**, using diethyl 2-cyclopropyl-2-hydrazono-ethylphosphonate (**2'b**, 1.17 g, 0.005 mol), borane-tet-

rahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'b** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 55% yield. mp 128.5–129.5°C; IR (KCl, cm^{-1}): 3250 (NH^+), 1775 (C=O), 1245 (P=O), 1040, 950 (P—O—C); ^{1}H-NMR (ppm): 4.39 (m, 1H, $^3J_{HH}$ = 7.5 Hz, P—$CH_2C\underline{H}$), 4.10 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 2.77, 2.43 (dd, 2H, $^2J_{PH}$ = 20.2 Hz, $^3J_{HH}$ = 7.5 Hz, P—$C\underline{H}_2CH$), 2.00 (m, 1H, CH), 1.34 (m, 6H, 2 × $OCH_2C\underline{H}_3$), 1.05 (m, 4H, CH_2CH_2); ^{31}P-NMR: 28.2 ppm; FAB-MS (M^+ − 1): 370; Analysis: Found: C, 40.03; H, 6.27; N, 7.40; P, 8.51%. Calculated for $C_{12}H_{24}N_2O_9P$ (371.3): C, 38.81; H, 6.51; N, 7.55; P, 8.34%.

Diethyl 3-phenyl-2-hydrazino-propylphosphonate (oxalate) (**3'c**): Analogous to the preparation of **3'a**, using diethyl 3-phenyl-2-hydrazono-propylphosphonate (**2'c**, 1.42 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'c** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 46% yield. mp 110–111°C; IR (KCl, cm^{-1}): 3300 (NH^+), 1730 (C=O), 1245 (P=O), 1050, 960 (P—O—C); ^{1}H-NMR (ppm): 7.43 (m, $5H_{arom}$), 4.41 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—$CH_2C\underline{H}$), 4.11 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 3.10 (d, 2H, J_{gem} = 10.0 Hz, Ph—$C\underline{H}_2$), 2.75, 2.42 (dd, 2H, $^2J_{PH}$ = 20.8 Hz, $^3J_{HH}$ = 7.6 Hz, P—$C\underline{H}_2CH$), 1.29 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 27.7 ppm; FAB-MS (M^+ − 1): 420; Analysis: Found: C, 45.97; H, 6.00; N, 6.48; P, 7.48%. Calculated for $C_{16}H_{26}N_2O_9P$ (421.4): C, 45.60; H, 6.22; N, 6.65; P, 7.35%.

Diethyl 2-phenyl-2-hydrazino-ethylphosphonate (oxalate) (**3'd**): Analogous to the preparation of **3'a**, using diethyl 2-phenyl-2-hydrazono-ethylphosphonate (**2'd**, 1.35 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'd** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 57% yield. mp 123–124°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1730 (C=O), 1220 (P=O), 1040, 970 (P—O—C); ^{1}H-NMR (ppm): 7.92–7.15 (m, $5H_{arom}$), 4.28 (m, 1H, $^3J_{HH}$ = 7.5 Hz, P—$CH_2C\underline{H}$), 4.00 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 2.78, 2.45 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.5 Hz, P—$C\underline{H}_2CH$), 1.20 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 28.2 ppm; FAB-MS (M^+ − 1): 406; Analysis: Found: C, 44.11; H, 6.07; N, 7.02; P, 7.25%. Calculated for $C_{15}H_{24}N_2O_9P$ (407.3): C, 44.23; H, 5.94; N, 6.88; P, 7.60%.

Diethyl 2-(p-methylphenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'e**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-methylphenyl)-2-hydrazono-ethylphosphonate (**2'e**, 1.42 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'e** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 56% yield. mp 125–126°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1760 (C=O), 1220 (P=O), 1030, 960 (P—O—C); ^{1}H-NMR (ppm): 8.13–7.12 (m, $4H_{arom}$), 4.37 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—$CH_2C\underline{H}$), 4.01 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 2.74, 2.41 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.6 Hz, P—$C\underline{H}_2CH$), 2.34 (s, 3H, Ph—$C\underline{H}_3$), 1.30 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 28.1 ppm; FAB-MS (M^+ − 1): 420; Analysis: Found: C, 45.54; H, 5.98; N, 6.79; P, 7.21%. Calculated for $C_{16}H_{26}N_2O_9P$ (421.4): C, 45.60; H, 6.22; N, 6.65; P, 7.35%.

Diethyl 2-(p-methoxyphenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'f**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-methoxyphenyl)-2-hydrazono-ethylphosphonate (**2'f**, 1.50 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'f** was obtained by recrystallization from ethyl alcohol-ether as yellowish crystals in 48% yield. mp 123.5–124.5°C; IR (KCl, cm^{-1}): 3350 (NH^+), 1720 (C=O), 1240 (P=O), 1040, 960 (P—O—C); ^{1}H-NMR (ppm): 8.19–7.28 (m, $4H_{arom}$), 4.39 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—$CH_2C\underline{H}$), 4.14 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 4.12 (s, 3H, $OC\underline{H}_3$), 2.82, 2.48 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.6 Hz, P—$C\underline{H}_2CH$), 1.30 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 28.4 ppm; FAB-MS (M^+ − 1): 436; Analysis: Found: C, 43.71; H, 6.13; N, 6.15; P, 6.90%. Calculated for $C_{16}H_{26}N_2O_{10}P$ (437.4): C, 43.93; H, 5.99; N, 6.41; P, 7.08%.

Diethyl 2-(p-methoxy-m-bromophenyl)-2-hydrazino ethylphosphonate (oxalate) (**3'g**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-methoxy-*m*-bromophenyl)-2-hydrazono-ethylphosphonate (**2'g**, 1.90 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'g** was obtained by recrystallization from ethyl alcohol-ether as yellowish crystals in 50% yield. mp 121–122°C; IR (KCl, cm^{-1}): 3280 (NH^+), 1710 (C=O), 1220 (P=O), 1030, 960 (P—O—C), 570 (C—Br); ^{1}H-NMR (ppm): 8.43–7.35 (m, $3H_{arom}$), 4.41 (m, 1H, $^3J_{HH}$ = 7.4 Hz, P—$CH_2C\underline{H}$), 4.18 (m, 4H, 2 × $OC\underline{H}_2CH_3$), 4.10 (s, 3H, $OC\underline{H}_3$), 2.85, 2.52 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.4 Hz, P—$C\underline{H}_2CH$), 1.20 (m, 6H, 2 × $OCH_2C\underline{H}_3$); ^{31}P-NMR: 28.7 ppm; FAB-MS (M^+ − 1): 514, 516;

Analysis: Found: C, 36.91; H, 4.82; N, 5.33; Br, 15.14; P, 5.78%. Calculated for $C_{16}H_{25}BrN_2O_{10}P$ (516.3): C, 37.22; H, 4.88; N, 5.43; Br, 15.48; P, 6.00%.

Diethyl 2-(p-fluorophenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'h**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-fluorophenyl)-2-hydrazono-ethylphosphonate (**2'h**, 1.44 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'h** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 51% yield. mp 122.5–123.5°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1750 (C=O), 1250 (P=O), 1220, 1150 (C—F), 1040, 960 (P—O—C); ^{1}H-NMR (ppm): 8.23–7.33 (m, $4H_{arom}$), 4.41 (m, 1H, $^3J_{HH}$ = 8.0 Hz, P—CH_2CH), 4.10 (m, 4H, 2 × OCH_2CH_3), 2.81, 2.48 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 8.0 Hz, P—CH_2CH), 1.28 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 28.5 ppm; FAB-MS (M^+ − 1): 424; Analysis: Found: C, 42.52; H, 5.67; N, 6.84%. Calculated for $C_{15}H_{23}FN_2O_9P$ (425.3): C, 42.36; H, 5.45; N, 6.59%.

Diethyl 2-(p-chlorophenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'i**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-chlorophenyl)-2-hydrazono-ethylphosphonate (**2'i**, 1.52 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'i** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 45% yield. mp 106–110°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1720 (C=O), 1220 (P=O), 1030, 970 (P—O—C), 710 (C—Cl); ^{1}H-NMR (ppm): 7.81–7.13 (m, $4H_{arom}$), 4.39 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—CH_2CH), 4.08 (m, 4H, 2 × OCH_2CH_3), 2.73, 2.40 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.6 Hz, P—CH_2CH), 1.30 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 28.3 ppm; FAB-MS (M^+ − 1): 440, 442; Analysis: Found: C, 40.69; H, 5.34; N, 6.69; P, 7.18%. Calculated for $C_{15}H_{23}ClN_2O_9P$ (441.8): C, 40.78; H, 5.25; N, 6.34; P, 7.01%.

Diethyl 2-(p-bromophenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'j**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-bromophenyl)-2-hydrazono-ethylphosphonate (**2'j**, 1.75 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'j** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 58% yield. mp 124–125°C; IR (KCl, cm^{-1}): 3400 (NH^+), 1740 (C=O), 1220 (P=O), 1025, 970 (P—O—C), 660 (C—Br); ^{1}H-NMR (ppm): 7.91–7.19 (m, $4H_{arom}$), 4.41 (m, 1H, $^3J_{HH}$ = 7.5 Hz, P—CH_2CH), 4.10 (m, 4H, 2 × OCH_2CH_3), 2.74, 2.41 (dd, 2H, $^2J_{PH}$ = 20.2 Hz, $^3J_{HH}$ = 7.5 Hz, P—CH_2CH), 1.28 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 27.8 ppm; FAB-MS (M^+ − 1): 484, 486; Analysis: Found: C, 36.86; H, 4.67; N, 5.71; P, 6.00%. Calculated for $C_{15}H_{23}BrN_2O_9P$ (486.2): C, 37.05; H, 4.77; N, 5.76; P, 6.37%.

Diethyl 2-(p-nitrophenyl)-2-hydrazino-ethylphosphonate (oxalate) (**3'k**): Analogous to the preparation of **3'a**, using diethyl 2-(*p*-nitrophenyl)-2-hydrazono-ethylphosphonate (**2'k**, 1.58 g, 0.005 mol), borane-tetrahydrofuran solution (2.1 M, 10.0 mL, 0.02 mol), cold hydrochloric acid (6 M, 10 mL) and anhydrous oxalic acid (0.5 g, 0.0055 mol) for the reaction and followed by similar treatment. **3'k** was obtained by recrystallization from ethyl alcohol-ether as colorless crystals in 40% yield. mp 120.5–122°C; IR (KCl, cm^{-1}): 3350 (NH^+), 1720 (C=O), 1540, 1330 (N=O), 1250 (P=O), 1050, 970 (P—O—C); ^{1}H-NMR (ppm): 7.92–7.09 (m, $4H_{arom}$), 4.39 (m, 1H, $^3J_{HH}$ = 7.3 Hz, P—CH_2CH), 4.14 (m, 4H, 2 × OCH_2CH_3), 2.73, 2.40 (dd, 2H, $^2J_{PH}$ = 20.4 Hz, $^3J_{HH}$ = 7.3 Hz, P—CH_2CH), 1.30 (m, 6H, 2 × OCH_2CH_3); ^{31}P-NMR: 27.8 ppm; FAB-MS (M^+ − 1): 451; Analysis: Found: C, 39.61; H, 5.40; N, 9.43; P, 7.03%. Calculated for $C_{15}H_{23}N_3O_{11}P$ (452.3): C, 39.83; H, 5.12; N, 9.29; P, 6.85%.

2-Hydrazino-2-phenyl-ethylphosphonic acid (**4'd**): To **3'd** (0.30 g, 0.0011 mol) was added hydrochloric acid (6 M, 10 mL) with stirring at 80–85°C for 8–12 h. After the reaction was complete as monitored with TLC, the reaction mixture was cooled to room temperature, extracted with methylenedichloride (10 mL) and the organic layer was discarded. The aqueous layer was carefully concentrated under reduced pressure (outer temperature lower than 50°C) to give a yellowish sticky oil. Ethyl alcohol (5 mL) was added to dissolve the oil, and then propylene oxide was added dropwise under stirring and warming, until the solution turned weakly basic (pH = 7–8). The resulting mixture was set aside at room temperature for 24 h. A white powder precipitated. It was collected, washed with cold ethyl alcohol, and dried. Recrystallized from water-ethyl alcohol afforded a white powder **4'd** 0.10 g, in 52% yield. mp 204–206°C (dec.); IR (KCl, cm^{-1}): 3600–2500 (NH, OH), 1180 (P=O), 1040 (P—O—H); ^{1}H-NMR (ppm): 7.97–7.11 (m, $5H_{arom}$), 4.40 (m, 1H, $^3J_{HH}$ = 7.5 Hz, P—CH_2CH), 2.76, 2.44 (dd, 2H, $^2J_{PH}$ = 19.2 Hz, $^3J_{HH}$ = 7.5 Hz, P—CH_2CH); ^{31}P-NMR: 21.8 ppm; FAB-MS (M^+ + 1): 217; Analysis: Found: C, 44.23; H, 6.21; N, 12.88; P, 14.01%. Calculated for $C_8H_{13}N_2O_3P$ (216.2): C, 44.44; H, 6.06; N, 12.96; P, 14.33%.

2-Hydrazino-2-(p-methylphenyl)-ethylphosphonic acid (**4'e**): Analogous to the preparation of **4'd**, using diethyl 2-(*p*-methylphenyl)-2-hydrazino-ethylphosphonate (**3'e**, 0.32 g, 0.0011 mol), hydrochloric acid (6 M, 10 mL) for the reaction and followed by similar treatment. **4'e** was obtained as a white powder in 50% yield. mp 205–206°C (dec.); IR (KCl, cm^{-1}): 3500–2300 (NH, OH), 1180 (P=O), 1030 (P—O—H); ^{1}H-NMR (ppm): 8.04–7.17 (m, $4H_{arom}$), 4.41 (m, 1H, $^3J_{HH}$ = 7.6 Hz, P—CH_2C<u>H</u>), 2.73, 2.41 (dd, 2H, $^2J_{PH}$ = 19.2 Hz, $^3J_{HH}$ = 7.6 Hz, P—C<u>H</u>$_2$CH), 2.30 (s, 3H, Ph—C<u>H</u>$_3$); ^{31}P-NMR: 21.6 ppm; FAB-MS (M^+ + 1): 231; Analysis: Found: C, 46.79; H, 6.74; N, 12.39; P, 13.20%. Calculated for $C_9H_{15}N_2O_3P$ (230.2): C, 46.95; H, 6.57; N, 12.17; P, 13.46%.

2-Hydrazino-2-(p-bromophenyl)-ethylphosphonic acid (**4'j**): Analogous to the preparation of **4'd**, using diethyl 2-(*p*-bromophenyl)-2-hydrazino-ethylphosphonate (**3'j**, 0.39 g, 0.0011 mol), hydrochloric acid (6 M, 10 mL) for the reaction and followed by similar treatment. **4'j** was isolated as a white powder in 49% yield. mp 208–209°C (dec.); IR (KCl, cm^{-1}): 3400–2000 (NH, OH), 1185 (P=O), 1040 (P—O—H); 670 (C—Br); ^{1}H-NMR (ppm): 8.20–7.29 (m, $4H_{arom}$), 4.39 (m, 1H, $^3J_{HH}$ = 7.7 Hz, P—CH_2C<u>H</u>), 2.74, 2.40 (dd, 2H, $^2J_{PH}$ = 20.0 Hz, $^3J_{HH}$ = 7.7 Hz, P—C<u>H</u>$_2$CH); ^{31}P-NMR: 21.8 ppm; FAB-MS (M^+ + 1): 295, 297; Analysis: Found: C, 32.71; H, 4.03; N, 9.38; P, 10.85%. Calculated for $C_8H_{12}BrN_2O_3P$ (295.1): C, 32.56; H, 4.10; N, 9.50; P, 10.50%.

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