TANDEM ADDITION OF TRIALKYL PHOSPHITES TO α,β - UNSATURATED IMINES: A COMPARISON SILYLATED PHOSPHITES

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General Experimental Methods

All **¹H-NMR** spectra were recorded at room temperature (22°C) using a 300MHz spectrometer with CDCl₃ as a solvent and tetramethylsilane (TMS) as internal standard. **¹³C-NMR** spectra were recorded at 75 MHz and **³¹P-NMR** spectra at 121 MHz. The absolute value of the coupling constants (J) in Hz and assignments of ¹H and ¹³C peaks were determined using COSY, HSQC, HMBC and DEPT experiments. **MS** spectra were measured using a mass spectrometer using electron spray ionisation (ESI, 4000 V). Column chromatography was performed using a glass column with silica gel (particle size 0.035-0.070 mm, pore diameter ca. 6 nm). Solvent systems were determined *via* initial TLC analysis (Merck Kieselgel 60F₂₅₄, precoated 0.25 mm).

General procedure for the synthesis of 3-phosphonyl aminoalkyl phosphonates (PAP's) 6

5 Mmol of an α,β -unsaturated imine **4** is dissolved in 15 mL of absolute ethanol (or methanol in case of TMP) in an oven-dry flask. Under a nitrogen atmosphere, 10 mmol of TEP (or TMP) and 10 mmol of formic acid are added consecutively. When complete conversion is obtained (see Table 1), the solvent is evaporated under reduced pressure. The crude product is dissolved in 25 mL of diethylether and poured into 25 ml of 1 M aqueous HCl. The aqueous phase is washed twice with 15 mL of diethylether, basified by adding 1N NaOH and extracted three times with 20 mL of dichloromethane. The PAP **6** is obtained in satisfactory purity after drying (MgSO_4) and evaporation of the solvent. In order to obtain the PAP's perfectly pure, column chromatography with silica gel as a stationary phase and a mixture of CH_3CN , CH_2Cl_2 and MeOH (80/18/2) as a mobile phase is appropriate.

Product characterization

[3-(Diethoxy-phosphonyl)-3-isopropylamino-1-phenyl-propyl]-phosphonic acid diethyl ester (**6b**)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 38/62).

$^1\text{H-NMR}$ δ (300 MHz, ppm): 0.70 (3H, d, $J = 6.1$ Hz), 0.72 (3H, d, $J = 6.1$ Hz), 0.94 (3H, d, $J = 6.3$ Hz), 0.99 (3H, d, $J = 6.3$ Hz), 1.08 (3H, t, $J = 6.9$ Hz), 1.12 (3H, t, $J = 7.3$ Hz), 1.26-1.36 (18H, multiplet), 1.97-2.53 (4H, multiplet), 2.60 (1H, td, $J = 11.6$ Hz, $J_{\text{HP}} = 2.5$ Hz), 2.71-2.81 (1H, multiplet), 2.86 (1H, septet, $J = 6.3$ Hz), 3.06 (1H, septet x d, $J = 6.3$ Hz, $J_{\text{HP}} = 2.6$ Hz), 3.54-3.79 (2H, multiplet), 2.81-4.21 (16H, multiplet), 7.22-7.41 (10H, multiplet). **$^{13}\text{C-NMR}$ δ (75 MHz, ppm):** 16.2 (CH_3), 16.3 (CH_3), 16.4 (CH_3), 16.46 (CH_3), 16.50 (CH_3), 16.6 (CH_3), 22.2 (CH_3), 22.4 (CH_3), 23.2 (CH_3), 24.1 (CH_3), 30.6 (d, $J_{\text{CP}} = 6.9$ Hz, CH_2), 31.5 (CH_2), 41.0 (dd, $J_{\text{CP}} = 136.7$ Hz, $J_{\text{CP}} = 4.0$ Hz, CH), 41.2 (dd, $J_{\text{CP}} = 136.2$ Hz, $J_{\text{CP}} = 15.0$ Hz, CH), 46.0 (d, $J_{\text{CP}} = 4.0$ Hz, CH), 46.2 (CH), 49.0 (dd, $J_{\text{CP}} = 140.8$ Hz, $J_{\text{CP}} = 17.3$ Hz, CH), 49.6 (dd, $J_{\text{CP}} = 152.9$ Hz, $J_{\text{CP}} = 14.4$ Hz, NCHP, m), 61.71 (CH_2),

61.75 (CH₂), 61.81 (CH₂), 61.85 (CH₂), 61.94 (CH₂), 62.37 (CH₂), 62.46 (CH₂), 62.54 (CH₂), 62.58 (CH₂), 62.63 (CH₂), 127.3 (CH), 128.47 (CH), 128.49 (CH), 129.5 (d, J_{CP} = 6.9 Hz, CH), 129.8 (d, J_{CP} = 6.9 Hz, CH), 135.1 (d, J_{CP} = 6.9 Hz, C), 136.1 (d, J_{CP} = 6.9 Hz, C). **³¹P-NMR δ (121 MHz, ppm):** 28.41, 29.94, 29.09 (d, J_{PP} = 9.7 Hz), 29.70 (d, J_{PP} = 9.7 Hz) **IR ν (cm⁻¹):** 3300 (NH), 1243 (P=O), 1047 (br, P-O). **MS m/z:** 312 (65), 450 ([M+H]⁺, 100).

[3-(Diethoxy-phosphonyl)-3-phenylamino-1-phenyl-propyl]-phosphonic acid diethyl ester (6c)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 21/79).

¹H-NMR δ (300 MHz, ppm): 1.03-1.39 (24H, multiplet), 2.11-2.44 (2H, multiplet), 2.55-2.80 (2H, multiplet), 3.40-3.51 (4H, multiplet), 3.67-4.20 (16H, multiplet), 6.34 (2H, d, J = 8.0 Hz), 6.44 (2H, d, J = 8.0 Hz), 6.65-6.72 (2H, multiplet), 7.03-7.13 (4H, multiplet), 7.14-7.33 (10H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 16.3 (CH₃), 16.4 (CH₃), 31.0 (d, J_{CP} = 8.1 Hz, CH₂), 32.0 (CH₂), 40.5 (dd, J_{CP} = 139.6 Hz, J_{CP} = 13.8 Hz, CH), 40.7 (dd, J_{CP} = 145.4 Hz, J_{CP} = 8.1 Hz, CH), 48.4 (dd, J_{CP} = 154.6 Hz, J_{CP} = 16.2 Hz, CH), 49.0 (dd, J_{CP} = 166.1 Hz, J_{CP} = 11.5 Hz, CH), 61.7, 61.8, 61.9, 62.0, 62.1, 62.2, 62.6, 62.7, 62.8, 62.9, 63.0 (CH₂), 113.6 (CH), 113.7 (CH), 118.3 (CH), 118.5 (CH), 127.4 (CH), 127.6 (CH), 128.6 (CH), 128.7 (CH), 129.1 (CH), 129.2 (CH), 129.4 (CH), 129.5 (CH), 129.8 (CH), 129.9 (CH), 134.7 (d, J_{CP} = 6.9 Hz, C), 136.3 (d, J_{CP} = 6.9 Hz, C), 146.4 (d, J_{CP} = 6.9 Hz, C), 146.9 (C). **³¹P-NMR δ (121 MHz, CDCl₃, ppm):** 26.20, 26.29 (d, J_{PP} = 9.7 Hz), 28.60, 29.05 (d, J_{PP} = 9.7 Hz). **IR ν (cm⁻¹):** 3296 (N-H), 1243 (br, P=O), 1027 (br, P-O). **MS m/z:** 484 ([M+H]⁺, 100).

[3-(Dimethoxy-phosphonyl)-3-phenylamino-1-phenyl-propyl]-phosphonic acid dimethyl ester (6d)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 34/66).

¹H-NMR δ (300 MHz, ppm): 2.29 (2H, multiplet), 2.52-2.71 (2H, multiplet), 3.38-3.83 (4H, multiplet), 3.48 (3H, d, J_{HP} = 10.5 Hz), 3.49 (3H, d, J_{HP} = 10.5 Hz), 3.54 (3H, d, J_{HP} = 10.2 Hz), 3.65 (3H, d, J_{HP} = 11.0 Hz), 3.68 (3H, d, J_{HP} = 10.5 Hz), 3.69 (3H, d, J_{HP} = 10.5 Hz), 3.71 (3H, d, J_{HP} = 9.1 Hz), 3.78 (3H, d, J_{HP} = 10.2 Hz), 6.34 (2H, d, J = 8.3 Hz), 6.43 (2H, d, J = 8.3 Hz), 6.46-6.61 (2H, multiplet), 6.78-7.15 (4H, multiplet), 7.16-7.37 (10H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 31.1

(d, $J = 8.1$ Hz, CH₂), 32.1 (CH₂), 39.9 (dd, $J_{CP} = 139.6$ Hz, $J_{CP} = 13.8$ Hz, CH), 40.2 (dd, $J_{CP} = 137.3$ Hz, $J_{CP} = 8.1$ Hz, CH), 48.1 (dd, $J_{CP} = 154.6$ Hz, $J_{CP} = 16.2$ Hz, CH), 48.6 (dd, $J_{CP} = 155.9$ Hz, $J_{CP} = 11.5$ Hz, CH), 52.6 (d, $J_{CP} = 6.9$ Hz, CH₃), 52.8 (d, $J_{CP} = 6.9$ Hz, CH₃), 53.4 (d, $J_{CP} = 5.8$ Hz, CH₃), 53.5 (d, $J_{CP} = 5.8$ Hz, CH₃), 113.6 (CH), 113.9 (d, $J_{CP} = 10.4$ Hz, CH), 118.1 (CH), 118.5 (CH), 127.6 (CH), 127.69 (CH), 127.74 (CH), 128.56 (CH), 128.59 (CH), 128.7 (CH), 128.8 (CH), 129.0 (CH), 129.2 (CH), 129.25 (CH), 129.28 (CH), 129.33 (CH), 129.4 (CH), 129.5 (CH), 129.57 (CH), 129.63 (CH), 129.7 (CH), 134.17 (d, $J = 6.9$ Hz, C), 135.88 (C), 146.12 (C), 146.63 (C). **³¹P-NMR δ (121 MHz, ppm):** 28.47, 28.74 (d, $J_{PP} = 9.7$ Hz), 30.76, 31.30 (d, $J_{PP} = 9.7$ Hz). **IR ν (cm⁻¹):** 3301 (N-H), 1243 (br, P=O), 1043 (br, P-O). **MS m/z :** 428 ([M+H]⁺, 100), 318 (M⁺-PO(OMe)₂, 10).

[3-Benzylamino-3-(diethoxy-phosphonyl)-1-phenyl-propyl]-phosphonic acid diethyl ester (6e)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 33/67).

¹H-NMR δ (300 MHz, ppm): 1.07 (3H, t, $J = 6.6$ Hz), 1.09 (3H, t, $J = 7.2$ Hz), 1.26-1.36 (18H, multiplet), 2.04-2.48 (4H, multiplet), 2.55 (1H, td, $J = 11.8$ Hz, $J_{HP} = 2.2$ Hz), 2.81-2.94 (1H, multiplet), 3.53-4.19 (22H, multiplet), 7.12-7.36 (20H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 16.2 (CH₃), 16.3 (CH₃), 16.4 (CH₃), 16.46 (CH₃), 16.52 (CH₃), 16.6 (CH₃), 30.68 (d, $J_{CP} = 8.1$ Hz), 31.2 (CH₂), 40.3 (dd, $J_{CP} = 139.6$ Hz, $J_{CP} = 14.4$ Hz), 40.9 (dd, $J_{CP} = 137.3$ Hz, $J_{CP} = 5.8$ Hz), 51.2 (dd, $J_{CP} = 141.9$ Hz, $J_{CP} = 16.2$ Hz), 51.6 (d, $J_{CP} = 8.1$ Hz), 51.7 (dd, $J_{CP} = 150.0$ Hz, $J_{CP} = 13.3$ Hz), 52.0 (CH₂), 61.8 (CH₂), 61.9 (CH₂), 62.0 (CH₂), 62.3 (CH₂), 62.4 (CH₂), 62.5 (CH₂), 62.6 (CH₂), 62.7 (CH₂), 127.0 (CH), 127.1 (CH), 127.28 (CH), 127.31 (CH), 128.2 (CH), 128.37 (CH), 128.42 (CH), 128.56 (CH), 128.59 (CH), 129.35 (CH), 129.44 (CH), 129.5 (CH), 129.6 (CH), 135.1 (d, $J_{CP} = 5.8$ Hz, C), 136.2 (d, $J_{CP} = 6.9$ Hz, C), 139.7 (C), 140.3 (C). **³¹P-NMR δ (121 MHz, ppm):** 28.16, 28.91 (d, $J_{PP} = 9.7$ Hz), 28.99, 29.86 (d, $J_{PP} = 9.7$ Hz). **IR ν (cm⁻¹):** 3306 (NH), 1243 (P=O), 1051, 1026 (P-O). **MS m/z :** 360 (37), 498 ([M+H]⁺, 100).

[3-Allylamino-3-(diethoxy-phosphonyl)-1-phenyl-propyl]-phosphonic acid diethyl ester (6f)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 72/28).

¹H-NMR δ (300 MHz, ppm): 1.06-1.36 (12, multiplet), 1.60 (2H, s(br), 2.01-2.28 (2H, multiplet), 2.37-2.55 (3H, multiplet), 2.80 (1H, ddd, $J = 14.0$ Hz, $J = 8.0$ Hz, $J = 5.8$ Hz), 3.00-3.06 (1H, multiplet), 3.14 (1H, dd, $J_{AB} = 13.8$ Hz, $J = 6.3$ Hz), 3.26 (1H, dd, $J_{AP} = 13.8$ Hz, $J = 5.7$ Hz), 3.40-3.47 (1H, multiplet), 3.53-4.18 (18H, multiplet), 4.93-5.16 (4H, multiplet), 5.62-5.84 (2H, multiplet), 7.25-7.39 (10H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 16.2 (CH₃), 16.39 (CH₃), 16.4 (CH₃), 16.5 (CH₃), 16.6 (CH₃), 16.7 (CH₃), 30.6 (d, $J_{CP} = 8.1$ Hz, CH₂), 31.1 (CH₂), 40.3 (dd, $J_{CP} = 138.5$ Hz, $J_{CP} = 13.8$ Hz, CH), 41.0 (dd, $J_{CP} = 137.3$ Hz, $J_{CP} = 5.8$ Hz, CH), 50.2 (d, $J_{CP} = 8.0$ Hz, CH₂), 50.7 (CH₂), 51.0 (dd, $J_{CP} = 152.3$ Hz, $J_{CP} = 16.2$ Hz, CH), 51.7 (dd, $J_{CP} = 151.1$ Hz, $J_{CP} = 13.8$ Hz, CH), 61.9 (CH₂), 62.0 (CH₂), 62.1 (CH₂), 62.4 (CH₂), 62.5 (CH₂), 62.7 (CH₂), 62.9 (CH₂), 115.9 (CH₂), 116.5 (CH₂), 127.4 (CH), 128.0 (CH), 128.6 (CH), 129.45 (CH), 129.53 (CH), 129.65 (CH), 129.74 (CH), 135.1 (d, $J_{CP} = 6.9$ Hz, C), 136.1 (d, $J_{CP} = 6.9$ Hz, C), 136.3 (CH), 136.8 (CH). **³¹P-NMR δ (121 MHz, ppm):** 28.25, 28.98, 29.02 (d, $J_{PP} = 9.7$ Hz), 29.89 (d, $J_{PP} = 9.7$ Hz). **IR ν (cm⁻¹):** 3469 (N-H), 1239 (br, P=O), 1028 (br, P-O). **MS m/z :** 448 ([M+H]⁺, 100), 408 (M⁺-CH₂CH=CH₂+H, 25), 234 (M⁺-CH₂CH=CH₂-PO(OEt)₂, 20).

[3-(Diethoxy-phosphonyl)-3-(*p*-OMe-benzylamino)-1-phenyl-propyl]-phosphonic acid diethyl ester (6g)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 36/64).

¹H-NMR δ (300 MHz, ppm): 1.04-1.11 (6H, ~q), 1.09 (18H, multiplet), 2.06-2.30 (2H, multiplet), 2.32-2.46 (2H, multiplet), 2.54 (1H, td, $J = 12.1$ Hz, $J_{HP} = 2.3$ Hz), 2.74-2.87 (1H, multiplet), 3.49-4.20 (22H, multiplet), 3.78 (3H, s), 3.82 (3H, s), 6.76 (2H, d, $J = 8.5$ Hz), 6.85 (2H, d, $J = 8.8$ Hz), 7.03 (2H, d, $J = 8.8$ Hz), 7.19-7.36 (12H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 16.2 (CH₃), 16.3 (CH₃), 16.4 (CH₃), 16.46 (CH₃), 16.54 (CH₃), 16.6 (CH₃), 30.7 (d, $J_{CP} = 6.9$ Hz, CH₂), 31.1 (CH₂), 40.3 (dd, $J_{CP} = 139.0$ Hz, $J_{CP} = 14.4$ Hz, CH), 40.9 (dd, $J_{CP} = 137.3$ Hz, $J_{CP} = 5.8$ Hz, CH), 50.9 (dd, $J_{CP} = 141.9$ Hz, $J_{CP} = 16.2$ Hz, CH), 50.9 (d, $J_{CP} = 8.1$ Hz, CH₂), 51.4 (CH₂), 51.5 (dd, $J_{CP} = 150.0$ Hz, $J_{CP} = 13.9$ Hz, CH), 55.2 (d, $J_{CP} = 4.6$ Hz, CH₃), 61.8 (CH₂), 61.88 (CH₂), 61.89 (CH₂), 62.3 (CH₂),

62.4 (CH₂), 62.5 (CH₂), 62.55 (CH₂), 62.64 (CH₂), 64.4 (CH₂), 113.7 (d, J_{CP} = 9.2 Hz, CH), 113.9 (d, J_{CP} = 6.9 Hz, CH), 127.2 (CH), 128.6 (CH), 129.2 (CH), 129.4 (CH), 129.5 (CH), 129.6 (CH), 129.7 (CH), 129.8 (CH), 131.8 (CH), 132.4 (CH), 135.1 (d, J_{CP} = 6.9 Hz, C), 136.2 (d, J_{CP} = 6.9 Hz, C), 158.6 (C), 158.8 (C). **³¹P-NMR δ (121 MHz, ppm):** 28.27, 29.03, 29.04 (d, J_{PP} = 9.7 Hz), 29.90 (d, J_{PP} = 9.7 Hz). **IR ν (cm⁻¹):** 3452 (NH), 1246 (P=O), 1046 (P-O), 1028 (P-O). **MS m/z:** 528 ([M+H]⁺, 100).

[3-(Diethoxy-phosphonyl)-3-methyl-1-phenylamino-butyl]-phosphonic acid diethyl ester (6h)

¹H-NMR δ (300 MHz, ppm): 1.11 (3H, t, J = 7.0 Hz), 1.17 (3H, d, J = 12.7 Hz), 1.22 (3H, d, J = 12.9 Hz), 1.27 (6H, t, J = 7.2 Hz), 1.30 (3H, t, J = 7.2 Hz), 1.74-1.90 (2H, multiplet), 2.23-2.35 (1H, multiplet), 3.77-3.97 (2H, multiplet), 3.99-4.22 (7H, multiplet), 6.67-6.71 (3H, multiplet), 6.67-6.71 (2H, t, J = 7.9 Hz). **¹³C-NMR δ (75 MHz, ppm):** 16.35 (CH₃), 16.41 (CH₃), 16.46 (CH₃), 16.54 (CH₃), 22.0 (CH₃), 23.5 (d, J_{CP} = 3.5 Hz, CH₃), 34.5 (dd, J_{CP} = 141.2 Hz, J_{CP} = 16.8 Hz, C), 37.6 (d, J_{CP} = 6.9 Hz, CH₂), 47.8 (dd, J_{CP} = 158.6 Hz, J_{CP} = 4.8 Hz, CH), 61.9 (CH₂), 62.0 (CH₂), 62.1 (CH₂), 62.8 (CH₂), 62.9 (CH₂), 113.1 (CH), 117.4 (CH), 129.1 (CH), 146.8 (C). **³¹P-NMR δ (121 MHz, ppm):** 26.38 (d, J_{PP} = 2.2 Hz), 35.83 (d, J_{PP} = 2.2 Hz). **IR ν (cm⁻¹):** 3318 (NH), 1230 (P=O), 1053 (P-O), 1027 (P-O). **MS m/z:** 436 ([M+H]⁺, 100). **Column chromatography:** solvent: CH₃CN/CH₂Cl₂/CH₃OH = 80/18/2; R_f = 0.23 .

[1-Benzylamino-3-(diethoxy-phosphonyl)-3-methyl-butyl]-phosphonic acid diethyl ester (6i)

¹H-NMR δ (300 MHz, ppm): 1.22 (3H, d, J_{HP} = 16.8 Hz), 1.24 (3H, d, J_{HP} = 17.1 Hz), 1.33 (12H, ~q, J = 7.2 Hz), 1.63-1.77 (1H, multiplet), 2.07-2.21 (1H, ~q), 3.27 (1H, t, J = 10.4 Hz), 3.85 (1H, d, J = 12.4 Hz), 4.06-4.24 (9H, multiplet), 7.21-7.42 (5H, multiplet). **¹³C-NMR δ (75 MHz, ppm):** 16.5 (CH₃), 16.6 (CH₃), 16.76 (CH₃), 22.2 (d, J_{CP} = 2.3 Hz, CH₃), 22.9 (d, J_{CP} = 2.3 Hz, CH₃), 34.6 (dd, J_{CP} = 140.8 Hz, J_{CP} = 15.0 Hz, C), 37.1 (d, J_{CP} = 3.5 Hz, CH₂), 51.6 (dd, J_{CP} = 147.1 Hz, J_{CP} = 8.7 Hz, CH), 52.4 (CH₂), 61.7 (CH₂), 61.8 (CH₂), 61.9 (CH₂), 62.0 (CH₂), 62.1 (CH₂), 62.6 (CH₂), 126.9 (CH), 128.2 (CH), 128.4 (CH), 140.4 (C). **³¹P-NMR δ (121 MHz, ppm):** 28.84 (d, J_{PP} = 3.7 Hz),

36.26 (d, J_{PP} = 3.0 Hz). **IR ν (cm^{-1}):** 3468 (NH), 1239 (P=O), 1052 (P-O), 1025 (P-O). **MS m/z :** 450 ($[\text{M}+\text{H}]^+$, 100).

[3-Benzylamino-3-(diethoxy-phosphonyl)-1-(2-furyl)-propyl]-phosphonic acid diethyl ester (6j)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 22/78).

$^1\text{H-NMR } \delta$ (300 MHz, ppm): 1.10 (6H, t, J = 7.0 Hz), 1.69-1.33 (18H, multiplet), 2.14-2.35 (2H, multiplet), 2.49-2.68 (2H, multiplet), 3.50-3.79 (4H, multiplet), 3.82-4.17 (16H, multiplet), 6.21 (1H, t, J = 3.2 Hz), 6.26 (1H, t, J = 3.3 Hz), 6.36-6.39 (2H, multiplet), 6.43 (2H, d, J = 8.0 Hz), 6.53 (2H, d, J = 8.3 Hz), 6.67-6.74 (2H, multiplet), 7.07-7.15 (4H, multiplet), 7.39 (2H, br s). **$^{13}\text{C-NMR } \delta$ (75 MHz, ppm):** 16.4 (CH_3), 29.7 (d, J_{CP} = 8.1 Hz, CH_2), 30.4 (d, J_{CP} = 5.8 Hz, CH_2), 34.6 (dd, J_{CP} = 144.2 Hz, J_{CP} = 12.7 Hz, CH), 35.0 (dd, J_{CP} = 141.9 Hz, J_{CP} = 8.1 Hz, CH), 48.8 (dd, J_{CP} = 154.6 Hz, J_{CP} = 13.9 Hz, CH), 49.0 (dd, J_{CP} = 155.2 Hz, J_{CP} = 11.5 Hz, CH), 62.1 (CH_2), 62.3 (CH_2), 62.4 (CH_2), 62.56 (CH_2), 62.64 (CH_2), 62.7 (CH_2), 62.8 (CH_2), 63.0 (CH_2), 63.1 (CH_2), 108.4 (d, J_{CP} = 6.9 Hz, CH), 109.3 (d, J_{CP} = 5.8 Hz, CH), 110.8 (CH), 113.7 (CH), 118.4 (CH), 129.1 (CH), 142.0 (CH), 142.4 (CH), 146.5 (d, J_{CP} = 5.8 Hz, C), 147.1 (C), 148.8 (d, J_{CP} = 9.2 Hz, C), 149.9 (d, J_{CP} = 9.2 Hz, C). **$^{31}\text{P-NMR } \delta$ (121 MHz, CDCl_3 , ppm):** 25.54, 25.91 (d, J_{PP} = 9.7 Hz), 26.03, 26.05 (d, J_{PP} = 9.7 Hz). **IR ν (cm^{-1}):** 3290 (N-H), 1255 (P=O), 1233 (P=O), 1043 (P-O), 1022 (P-O). **MS m/z :** 474 ($[\text{M}+\text{H}]^+$, 100). **Column chromatography:** solvent: $\text{CH}_3\text{CN}/\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH}$ = 80/18/2; R_f = 0.24 and 0.30.

[3-Benzylamino-3-(dimethoxy-phosphonyl)-1-(2-furyl)-propyl]-phosphonic acid dimethyl ester (6k)

The product was obtained as a mixture of two diastereomeric pairs (ratio: 25/75).

$^1\text{H-NMR } \delta$ (300 MHz, ppm): 1.88 (2H, bs), 2.14-2.36 (2H, multiplet), 2.50-2.71 (2H, multiplet), 3.56-3.80 (28H, multiplet), 6.21 (1H, t, J = 3.3 Hz), 6.27 (1H, t, J = 3.3 Hz), 6.37-6.39 (2H, multiplet), 6.44 (2H, d, J = 8.0 Hz), 6.53 (2H, d, J = 8.0 Hz), 6.69-6.79 (2H, multiplet), 7.08-7.18 (4H, multiplet), 7.39-7.42 (2H, multiplet). **$^{13}\text{C-NMR } \delta$ (75 MHz, ppm):** 29.6 (d, J_{CP} = 6.9 Hz, CH_2), 30.2 (d, J_{CP} = 5.8 Hz, CH_2), 33.9 (dd, J_{CP} = 145.4 Hz, J_{CP} = 13.9 Hz, CH), 34.2 (dd, J_{CP} = 141.9 Hz, J_{CP} = 8.1 Hz, CH), 48.3 (dd, J_{CP} = 155.2 Hz, J_{CP} = 14.4 Hz, CH), 48.6 (dd, J_{CP} = 155.2 Hz, J_{CP} = 11.0 Hz, CH), 52.7 (d, J_C = 14.4 Hz, CH), 108.4 (d, J_{CP} = 6.9 Hz, CH), 109.3 (d, J_{CP} = 5.8 Hz, CH), 110.8 (CH), 113.7 (CH), 118.4 (CH), 129.1 (CH), 142.0 (CH), 142.4 (CH), 146.5 (d, J_{CP} = 5.8 Hz, C), 147.1 (C), 148.8 (d, J_{CP} = 9.2 Hz, C), 149.9 (d, J_{CP} = 9.2 Hz, C).

$J_{\text{C-P}} = 6.9 \text{ Hz}$, CH_3), 53.0 (d, $J_{\text{C-P}} = 5.8 \text{ Hz}$, CH_3), 53.3 (d, $J_{\text{C-P}} = 5.8 \text{ Hz}$, CH_3), 53.4 (d, $J_{\text{C-P}} = 5.8 \text{ Hz}$, CH_3), 108.6 (d, $J_{\text{CP}} = 6.9 \text{ Hz}$, CH), 109.6 (d, $J_{\text{CP}} = 6.9 \text{ Hz}$, CH), 110.9 (CH), 113.5 (CH), 118.4 (CH), 129.2 (CH), 142.2 (CH), 142.6 (CH), 146.3 (d, $J_{\text{CP}} = 5.8 \text{ Hz}$, C), 146.9 (C), 148.1 (d, $J_{\text{CP}} = 9.2 \text{ Hz}$, C), 149.4 (d, $J_{\text{CP}} = 10.3 \text{ Hz}$, C). **^{31}P -NMR δ (121 MHz, CDCl_3 , ppm):** 27.84, 28.31 (d, $J_{\text{PP}} = 10.4 \text{ Hz}$), 28.35, 28.47 (d, $J_{\text{PP}} = 10.4 \text{ Hz}$). **IR ν (cm^{-1}):** 3302 (NH), 1242 (P=O), 1043 (P-O). **MS m/z :** 418 ($[\text{M}+\text{H}]^+$, 100). **Column chromatography:** solvent: $\text{CH}_3\text{CN}/\text{CH}_2\text{Cl}_2/\text{CH}_3\text{OH} = 80/18/2$; $R_f = 0.14$ and 0.23 .

^{13}C -NMR spectra of new compounds

*^{13}C -NMR spectrum of compound **6b***

^{13}C -NMR spectrum of compound **6c**

^{13}C -NMR spectrum of compound **6d**

^{13}C -NMR spectrum of compound **6e**

^{13}C -NMR spectrum of compound **6f**

^{13}C -NMR spectrum of compound **6g**

^{13}C -NMR spectrum of compound **6h**

^{13}C -NMR spectrum of compound **6i**

^{13}C -NMR spectrum of compound **6j**

^{13}C -NMR spectrum of compound **6k**