Supporting information

A new, efficient and recyclable [Ce(L-Pro)]_{2}(Oxa) as a heterogeneous catalyst used in Kabachnik-Fields reaction.

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1. **Experiment Details**

1.1. **General Procedure**

The catalyst preparation was carried out using dry starting material under pressure. All other reactions were carried out using chemical reagents and solvents without any specific treatment. The respective reactions were monitored by Thin Layer Chromatography (TLC) MACHEREY-NAGEL (SIL G / UV254) and were visualized by fluorescence quenching with UV light at 254 nm. The purification of the compounds was performed by recrystallization solvent using Chloroform / Hexane to 65°C. $^1$H and $^{13}$C NMR spectra were recorded in CDCl$_3$ on Bruker (300 MHz and 75 MHz respectively) spectrometer. $^1$H NMR data are reported as follows: chemical shift ($\delta$, ppm), multiplicity (s = singlet, d = doublet, q = quartet, m = multiplet), coupling constants ($J$) and assignment. The infrared spectra were recorded on FT/IR 4100 type A spectrometer of Jasco. The melting point was measured using DF-3600 of Instrutherm. It is important to mention that all spectral data matched with literature data.

1.2. **Catalyst -Procedure of [Ce(L-Pro)]$_2$(Oxa)**

The cerium catalyst was prepared using L-proline (2.7 mmol) and sodium hydroxide (2.7 mmol) in methanol (10 mL) at room temperature, after 10 minutes then cerium (III) chloride (1.4 mmol) was added. The mixture was stirred at room temperature for 45 minutes, then was added a solution of sodium oxalate (0.1g/mL) as precipitate agent. After completion the reaction was centrifuged, washed with methanol and dried overnight at 40 °C and a pale yellow semi-solid was obtained. The infrared spectra were recorded on FT/IR 4100 type A spectrometer of Jasco. The X-Ray powder diffraction were done at room temperature with CuK$_\alpha$ in a conventional diffractometer. The analysis of Scanning electron microscopy (SEM), were done by a Phenom Pro x model of Anacom Cientifica brand, with an enlargement of 80 to 130,000 times, resolution $\leq$ 14 nm, CCD camera with a zoom of 20 to 135 times.

1.3 **General Procedure of $\alpha$-aminophosphonates**

In a 50 mL round bottle flask was added cerium catalyst (0.02 mmol), benzaldehyde (2.2 mmol), aniline (2.0 mmol) and diphenyl phosphite (2.0 mmol), the mixture was magnetic stirred in toluene (10 mL) at room temperature. The progress of the reaction was monitored by TLC (eluent: EtOAc/hexane, 10:90), until the phosphite and aniline was completely consumed. After the reaction was completed a white solid was formed and then purified by recrystallization (chloroform/hexane) to obtain $\alpha$-aminophosphonates, the catalyst was separated by filtration. All compounds were characterized by $^1$H NMR, $^{13}$C NMR, FT / IR and melting point; all data are summarized as follow.
2. Reaction Optimization

![Chemical Reaction Diagram]

\[
RCHO + R'NH_2 + \text{Ce[(L-Pro)]_2Oxa} \rightarrow R_2NHOPh
\]

\[R= \text{Ph}, 4-	ext{ClPh}, 4-	ext{MePh}, \text{Naphthyl} \]

\[R' = \text{Ph}, 4-	ext{ClPh}, 4-	ext{FPh}, 4-	ext{MePh} \]

2.1. Effects of catalyst

**Table 1** Influence of catalyst loading over the Kabachnik-Fields reaction.\(^a\)

<table>
<thead>
<tr>
<th>Cat (%mol)</th>
<th>Yield (%) (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>2</td>
<td>97</td>
</tr>
</tbody>
</table>

[a] Reaction conditions: benzaldehyde (2.2 mmol), aniline (2.0 mmol) and diphenylphosphite (2.0 mmol) at room temperature  
[b] Yields by recrystallization  
[c] No reaction.

2.2. Solvents effects for the Kabachnik-Fields reaction.

**Table 2** Solvents and yields for the Kabachnik-Fields reaction.\(^a\)

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Time (min)</th>
<th>Yield (%) (^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>10</td>
<td>96</td>
</tr>
<tr>
<td>DCM</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>CH(_3)CN</td>
<td>10</td>
<td>55</td>
</tr>
<tr>
<td>THF</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>No solvent</td>
<td>60</td>
<td>-</td>
</tr>
</tbody>
</table>

[a] Reaction conditions: benzaldehyde (2.2 mmol), aniline (2.0 mmol) and diphenylphosphite (2.0 mmol) and 1 % mol catalyst at room temperature.  
[b] Yield of isolated product.

**Table 3.** Kabachnik-Fields reactions using [Ce(L-Pro)]\(_2\)(Oxa) recyclability.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Yield(^a) (%)</th>
<th>ΔYield (per cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>#2</td>
<td>80</td>
<td>14</td>
</tr>
<tr>
<td>#3</td>
<td>65</td>
<td>15</td>
</tr>
</tbody>
</table>

\(^a\) Yields by recrystallization.
3. Characterization of the Kabachnik-Fields reaction.

**Diphenyl (phenyl(phenylamino)methyl) phosphonate:**

![Chemical structure of Diphenyl (phenyl(phenylamino)methyl) phosphonate](image1)

White solid, PM: 415.13 g/mol. C\textsubscript{25}H\textsubscript{22}NO\textsubscript{3}P. M.p.: 159 °C. IR (KBr) (ν\textsubscript{max} cm\textsuperscript{-1}): 3343 (N-H), 1186.01 (P=O), 762.70 (C-P). \textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): δ ppm 2.14-2.22 (d, J\textsubscript{H-P} = 24.6 Hz, 1H, N-C\textsubscript{H}-P), 3.67-3.89 (m, 4H), 4.10-4.40 (m, 14H), 4.57-4.60 (m, 3H). \textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}): δ ppm 55.01 and 57.06 (d, J\textsubscript{C-P} = 153.3 Hz), 76.66, 77.51, 114.08, 118.918, 120.34, 120.40, 120.70, 120.75, 125.29, 125.46, 125.47, 128.20, 128.28, 128.41, 128.45, 128.47, 128.89, 129.32, 129.68, 129.78, 134.82, 145.97, 150.29.

**Diphenyl ((4-nitrophenyl)(phenylamino)methyl) phosphonate**

![Chemical structure of Diphenyl ((4-nitrophenyl)(phenylamino)methyl) phosphonate](image2)

Yellow solid, MW: 460.12 g/mol. C\textsubscript{25}H\textsubscript{21}N\textsubscript{2}O\textsubscript{5}P. M.p.: 153-155 °C. IR (KBr) (ν\textsubscript{max} cm\textsuperscript{-1}): 3305.39 (N-H), 1182.15 (P=O), 772 (C-P). \textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): δ ppm 5.25-5.36 (d, J = 25,38 Hz, 1H, N-C\textsubscript{H}-P), 6.60-6.68 (m, 2H), 6.75-6.86 (m, 3H), 6.89-7.05 (m, 12H), 7.47-8.50 (m, 3H). \textsuperscript{13}C NMR (75 MHz, CDCl\textsubscript{3}): δ ppm 54.88 and 56.10 (d, J\textsubscript{C-P} = 153.0 Hz), 114.03, 115.41, 119.58, 120.12, 120.16, 120.32, 120.51, 120.54, 123.18, 123.22, 123.48, 123.50, 125.75, 125.87, 129.53, 129.58, 129.96, 129.98, 134.11, 137.53, 137.54, 145.09, 145.21.
Diphenyl ((4-chlorophenyl)(phenylamino)methyl) phosphonate:

Green solid, PM: 449.09 g/mol. C_{25}H_{21}ClNO_3P. M.p: 131-132 °C. IR KBr (ν max cm⁻¹): 3299 (N-H), 1182.15 (P-O), 765.60 (C-P). ¹H NMR (300 MHz, DMSO): δ ppm 5.12-5.20 (d, J = 24.9 Hz, 1H, N-CH-P), 6.64-6.99 (m, 3H), 7.11-7.38 (m, 15H), 7.51-7.57 (m, 2H). ¹³C NMR (75 MHz, CDCl₃): δ ppm 54.40 and 56.45 (d, J P-C = 153.0 Hz), 76.57, 77.42, 113.98, 119.11, 120.20, 120.26, 120.53, 120.58, 125.39, 125.50, 128.97, 129.01, 129.31, 129.39, 129.46, 129.72, 129.77, 133.46, 134.23, 145.43, 145.61, 150.10, 150.12.

Diphenyl ((4-fluorophenyl)(phenylamino)methyl) phosphonate:

Blue solid, PM: 433.12 g/mol. C_{25}H_{19}FNO_3P. M.p: 104-105 °C. IR KBr (ν max cm⁻¹): 3453.29 (N-H), 1284.63 (P-O), 776.80 (C-O). ¹H NMR (300 MHz, CDCl₃): δ ppm 5.19-5.11 (d, J = 24.3 Hz, 1H, N-CH-P), 6.63-6.94 (m, 6H), 7.03-7.33 (m, 12H), 7.52-7.58 (m, 2H). ¹³C NMR (75 MHz, CDCl₃): δ ppm 54.27 and 56.32 (d, J P-C = 153.7 Hz) 76.57, 77.42, 113.98, 115.65, 115.68, 115.94, 115.97, 119.04, 120.19, 120.25, 120.55, 120.60, 125.33, 125.47, 129.30, 129.70, 129.77, 129.81, 129.89, 145.51, 145.71, 150.14, 150.17.
Diphenyl ((4-bromophenyl)(phenylamino)methyl) phosphonate:

Green solid, MW:493.04 g/mol. C_{25}H_{13}BrNO_{3}P. M.p.:138-140 °C. IR KBr (v_{max} cm^{-1}): 3322.75(N-H), 1029.63 (P-O), 765.60 (C-P).^{1}H NMR (300 MHz, CDCl_{3}): δ ppm 5.05-5.24 (d, J = 24.9 Hz, 1H, N-C\_H\_P), 6.59-6.72 (m, 2H), 6.72-6.86 (m, 2H), 6.87-7.00 (m, 2H), 7.06-7.39 (m, 10H), 7.40-7.56 (m, 4H). ^{13}C NMR (75 MHz, CDCl_{3}): δ ppm 54.55 and 56.59 (d, J_{P-C} = 153.55 Hz), 114.07, 115.40, 119.13, 119.22, 120.28, 120.34, 120.62, 120.67, 122.51, 122.56, 125.54, 125.66, 129.40, 129.57, 129.87, 132.01, 132.04, 134.04, 145.50, 145.63, 150.12, 150.18, 150.30.

Diphenyl ((4-methoxyphenyl)(phenylamino)methyl) phosphonate:

Yellow solid, MW:445.14 g/mol. C_{26}H_{24}NO_{4}P. M.p.:141-142 °C. IR KBr (v_{max} cm^{-1}): 3329.0 (N-H), 1252.0 (P-O), 770.4 (C-P).^{1}H NMR (300 MHz, CDCl_{3}): δ ppm 3.80 (s, 3H), 5.08-5.16 (d, J = 24.6 Hz, 1H, N-C\_H\_P), 6.66-6.92 (m, 6H), 7.09-7.33 (m, 11H), 7.45-7.51 (m, 3H). ^{13}C NMR (75 MHz, CDCl_{3}): δ ppm 54.19, 55.16 and 56.26 (d, J_{P-C} = 73.52 Hz), 76.57, 77.42, 113.98, 114.17, 114.20, 118.68, 120.25, 120.31, 120.58, 120.64, 125.11, 125.27, 126.45, 126.47, 129.14, 129.23, 129.31, 129.53, 129.63, 145.76, 145.96, 150.21, 150.23.
Diphenyl (phenylamino)(p-tolyl)methyl phosphonate:

Yellow solid, MW: 429.15 g/mol. C_{26}H_{24}NO_{3}P. Mp: 120-125 °C. IR KBr (ν_{max} cm^{-1}): 3345.01 (N-H), 1215.14 (P=O), 764.63 (C-P).^1\text{H} NMR (300 MHz, CDCl\textsubscript{3}): δ ppm 2.34 (s, 3H), 5.09-5.17 (d, J_{H,P} = 24.6 Hz, 1H, N-C\textsubscript{H}-P), 6.64-6.92 (m, 5H), 7.08-7.32 (m, 12H), 7.42-7.40 (m, 2H). ^{13}\text{C} NMR (75 MHz, CDCl\textsubscript{3}): δ ppm 55.33 and 57.28 (d, J_{P,C} =147.36 Hz), 113.28, 114.25, 115.46, 120.27, 120.31, 120.42, 120.66, 120.78, 125.36, 125.52, 128.20, 128.28, 128.32, 128.45, 128.65, 128.82, 128.86, 129.60, 129.68, 129.77, 129.81, 134.92, 143.48, 143.60.

Diphenyl (3-nitrophenyl)(phenylamino)methyl phosphonate:

Red solid, MW: 460.12 g/mol. C_{25}H_{21}N_{2}O_{5}P. M.p.: 124-126 °C. ^{1}\text{H} NMR (300 MHz, CDCl\textsubscript{3}): δ ppm 5.21 and 5.38 (d, J_{H,P} = 25.9 Hz, 1H, N-C\textsubscript{H}-P), 6.52-6.69 (m, 2H), 6.75-6.94 (m, 3H), 6.96-7.05 (m, 2H), 7.06-7.37 (m, 11H), 7.73-7.83 (m, 2H). ^{13}\text{C} NMR (75 MHz, CDCl\textsubscript{3}): δ ppm 54.83 and 56.83 (d, J_{P,C} =151.22 Hz), 113.92, 114.02, 115.43, 119.25, 119.57, 120.19, 120.25, 120.51, 120.56, 123.97, 124.01, 125.79, 125.88, 128.66, 128.80, 129.06, 129.13, 129.45, 129.51, 129.55, 129.97, 145.23, 145.39.
Diphenyl ((4-(dimethylamino)phenyl)(phenylamino)methyl) phosphonate:

Orange solid MW: 458.18 g/mol. C_{27}H_{27}N_{2}O_{3}P. M.p: 97-98 °C. IR KBr (ν_{max} cm^{-1}): 3399.12 (N-H), 1188.9 (P=O), 772.3 (C-P). ^1H NMR (300 MHz, CDCl$_3$): δ ppm 2.94 (s, 1H), 3.09 (s, 3H), 5.06-5.13 (d, J = 23.7, 1H, N-C$_2$H$_4$-Ph), 6.66-6.94 (m, 6H), 7.10-7.32 (m, 12H), 7.39-7.79 (m, 4H). ^13C NMR (75 MHz, CDCl$_3$): δ ppm 40.54, 54.83 and 56.08 (d, J$_{P-C}$ = 93.7 Hz), 76.82, 77.33, 111.03, 112.75, 112.77, 114.16, 115.52, 118.68, 119.83, 120.52, 120.55, 120.78, 120.82, 125.29, 128.98, 129.03, 129.70, 146.12, 146.24, 150.32, 150.40, 150.47, 150.55, 150.56.

Diphenyl ((phenylamino)(4-(trifluoromethyl) phenyl)methyl) phosphonate:

Green solid. MW: 483.12 g/mol. C_{26}H_{21}F$_3$NO$_3$P. Mp: 118-120 °C. IR KBr (ν_{max} cm^{-1}): 3326.12 (N-H), 1209.63 (P=O), 752.1 (C-P). ^1H NMR (300 MHz, CDCl$_3$): δ ppm 5.18-5.26 (d, J = 24.6, 1H, N-C$_2$H$_4$-Ph), 6.62-6.95 (m, 6H), 7.08-7.33 (m, 10H), 7.55-7.73 (m, 4H). ^13C NMR (75 MHz, CDCl$_3$): δ ppm 55.08 and 56.30 (d, J$_{P-C}$ = 153.17 Hz), 76.74, 77.25, 113.955, 115.31, 119.27, 120.12, 120.16, 120.28, 120.50, 120.53, 125.54, 125.55, 125.66, 125.67, 128.47, 128.51, 129.37, 129.50, 129.76, 129.77, 129.82, 139.03, 145.40, 150.02.
Diphenyl ((phenylamino)(thiophen-2-yl)methyl) phosphate:

Brown solid. MW: 421.09 g/mol. C$_{23}$H$_{20}$NO$_3$PS. Mp: 93-95°C. IR KBr ($v_{max}$ cm$^{-1}$): 3365.1 (N-H), 1277.1 (P=O), 773.3 (C-P). $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ ppm 5.41-5.49 (d, $J$ = 24.4, 1H, N-CH$_2$P), 6.73-6.84 (m, 6H), 6.99-7.33 (m, 16H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ ppm 55.08-56.30 (d, $J_{P-C}$ = 153.17 Hz), 76.745, 77.254, 113.955, 115.318, 119.278, 120.126, 120.160, 120.504, 120.537, 125.543, 125.553, 125.665, 125.676, 128.470, 128.515, 129.373, 129.500, 129.767, 129.774, 129.829, 139.039, 145.406, 150.023.

(3-Phenyl-1-phenylamino-allyl)-phosphonic acid diphenyl ester:

Brown solid. MW: 427.13 g/mol. C$_{26}$H$_{22}$NO$_3$P. Mp: 84-85°C. IR KBr ($v_{max}$ cm$^{-1}$): 3295.75 (N-H), 1213.01 (P=O), 741.97 (C-P). $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ ppm 5.15-5.23 (d, $J_{H-P}$ = 14.1 Hz, 1H, N-CH$_2$P), 5.67 (s, N-H), 6.80-6.89 (m, 5H), 7.08-7.37 (m, 10H), 8.14-8.34 (m, 5H).$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ ppm 76.63 and 77.48 (d, $J_{P-C}$ = 63.90 Hz), 113.21, 115.33, 117.31, 117.70, 119.16, 119.98, 120.73, 121.20, 126.97, 129.45, 129.68, 132.26, 133.25, 133.86, 135.56, 137.21, 137.56, 146.02, 148.43, 155.62.
Diphenyl (((4-nitrophenyl)amino)(phenyl)methyl) phosphonate:

Yellow solid. PM: 460.12 g/mol. C_{25}H_{21}N_{2}O_{5}P. Mp.: 143-145 °C. IR KBr (ν_{max} cm^{-1}): 3328.7 (N-H), 1257.9 (P-O), 770.4 (C-P). \(^{1}\)H NMR (300 MHz, CDCl\(_3\)): δ ppm 5.18-5.26 (d, \(J_{H-P} = 24.5\) Hz, 1H, N-C\(_H\)-P ), 6.59-6.77 (m, 4H), 7.10-7.39 (m, 11H), 7.55-7.58 (m, 3H), 7.98-8.03 (m, 2H). \(^{13}\)C NMR (75 MHz, CDCl\(_3\)): δ ppm 53.45 and 55.51 (d, \(J_{C-P} = 154.5\) Hz), 112.98, 113.10, 115.834, 120.82, 120.87, 121.04, 121.09, 125.91, 125.94, 126.37, 126.97, 128.90, 128.94, 129.10, 129.18, 129.26, 130.40, 135.09, 137.92, 150.30, 150.44, 153.76, 153.91.

Diphenyl (((4-Chlorophenyl) amino)(phenyl)methyl) phosphonate:

White solid, PM: 449.09. C_{25}H_{21}ClNO_{3}P. Mp:151-152 °C. IR KBr (ν_{max} cm^{-1}): 3336.25 (N-H), 1185.53 (P=O), 775.72 (C-P). \(^{1}\)H NMR (300 MHz, CDCl\(_3\)): δ ppm 3.82-3.90 (d, \(J_{H-P} = 24.6\) Hz, 1H, N-C\(_H\)-P), 5.32-5.64 (m, 4H), 5.84-6.17 (m, 14H), 6.28-6.33 (m, 2H). \(^{13}\)C NMR (75 MHz, CDCl\(_3\)): δ ppm 53.77 and 55.84 (d, \(J_{C-P} = 156.3\) Hz), 115.65, 120.75, 120.81, 121.05, 121.11, 121.18, 125.69, 125.75, 128.48, 128.52, 128.78, 128.81, 128.96, 129.12, 129.20, 130.26, 135.80, 146.33, 146.53, 150.30, 150.43, 150.51, 150.65.
Diphenyl (((4-bromophenyl)amino)(phenyl)methyl) phosphonate:

White solid. PM: 493.04 g/mol. \( \text{C}_{25}\text{H}_{21}\text{BrNO}_3\text{P} \). Mp: 165-167 °C. IR KBr \((v_{\text{max}} \ \text{cm}^{-1})\): 3336.25 (N-H), 1185.53 \((\text{P}=\text{O})\), 775.72 (C-P).\(^1\)H NMR \((300 \ \text{MHz, CDCl}_3\)\): \(\delta\) ppm 5.09-5.18 \((d, J_{\text{H-P}} = 24.6 \ \text{Hz}, 1\text{H, N-CH-P})\), 6.55-6.90 \((m, 4\text{H})\), 7.13-7.45 \((m, 14\text{H})\), 7.55-7.60 \((m, 2\text{H})\).\(^{13}\)C NMR \((75 \ \text{MHz, CDCl}_3\)\): \(\delta\) ppm 55.50 and 57.56 \((d, J_{\text{C-P}} = 154.12 \ \text{Hz})\), 76.57, 77.42, 115.02, 115.12, 115.35, 115.55, 115.84, 120.01, 120.20, 120.26, 120.59, 120.64, 125.32, 125.51, 125.51, 128.19, 128.50, 128.86, 129.62, 129.73, 134.37, 142.12, 150.02.

Diphenyl (((4-iodophenyl)amino)(phenyl)methyl) phosphonate:

Yellow solid. PM: 541.03. \( \text{C}_{25}\text{H}_{21}\text{INO}_3\text{P} \). Mp.: 154-155 °C. IR KBr \((v_{\text{max}} \ \text{cm}^{-1})\): 3339.62 (N-H), 1188.90 \((\text{P}=\text{O})\), 775.726 (C-P).\(^1\)H NMR \((300 \ \text{MHz, CDCl}_3\)\): \(\delta\) ppm 5.05-5.14 \((d, J_{\text{H-P}} = 24.9 \ \text{Hz}, 1\text{H, N-CH-P})\), 6.43-6.46 \((m, 2\text{H})\), 5.82-6.85 \((m, 4\text{H})\), 7.08-7.42 \((m, 12\text{H})\), 7.52-7.55 \((m, 2\text{H})\).\(^{13}\)C NMR \((75 \ \text{MHz, CDCl}_3\)\): \(\delta\) ppm 54.82 and 56.86 \((d, J_{\text{C-P}} = 153.50 \ \text{Hz})\), 115.37, 116.27, 117.39, 120.28, 120.35, 120.64, 120.75, 125.43, 125.63, 128.14, 128.21, 128.61, 128.67, 128.96, 129.06, 129.59, 129.66, 129.89, 134.30, 134.34, 137.88, 145.60.
Diphenyl (((4-methoxyphenyl)amino)(phenyl)methyl) phosphonate:

Light brown solid. PM: 445.14 g/mol. C_{26}H_{24}NO_4P. IR KBr ($\nu_{\text{max}}$ cm$^{-1}$): 3454.8 (N-H), 1186.0 (P=O), 776.2 (C-P).$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ ppm 3.73 (s, 3H), 5.04-5.12 (d, $J_{H,P}$ = 24.3 Hz, 1H, N-C$_{\text{H}}$-$P$), 6.61-6.89 (m, 6H), 7.10-7.40 (m, 12H), 7.54-7.58 (m, 2H).$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ ppm 39.43, 54.15 and 56.22 (d, $J_{C,P}$ = 155.7 Hz), 114.27, 115.01, 120.22, 120.27 120.56, 120.62, 125.06, 125.11, 127.75, 127.79, 128.13, 128.15, 128.62, 128.70, 129.67, 135.74, 140.57, 140.79, 149.82, 149.96, 150.092, 150.22, 151.63.

Diphenyl (phenyl($p$-tolylamino)methyl) phosphonate:

White solid. PM: 429.15 g/mol. C_{26}H_{24}NO_3P. Mp: 165-168 $^\circ$C. IR KBr ($\nu_{\text{max}}$ cm$^{-1}$): 3336.2 (N-H), 1185.7 (P=O), 775.7 (C-P).$^1$H NMR (300 MHz, CDCl$_3$): $\delta$ ppm 3.06 (s, 3H), 5.77-5.85 (d, $J_{H,P}$ = 25.2 Hz, 1H, N-C$_{\text{H}}$-$P$), 6.79-7.43 (m, 18H), 7.65-7.68 (m, 2H).$^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ ppm 34.82, 61.26 and 63.41(d, $J_{C,P}$ = 161.4 Hz), 76.57, 77.42, 114.37, 115.36, 118.66, 119.67, 120.46, 120.52, 120.59, 120.65, 125.11, 125.27, 128.35, 128.68, 128.95, 129.07, 129.23, 129.28, 129.54, 129.63, 133.02, 149.86, 149.98.
Diphenyl (((2,6-dimethylphenyl)amino)(phenyl) methyl) phosphonate:

Blue solid. PM: 443.17 g/mol. C_{27}H_{26}NO_{3}P. Mp.: 98-100 °C. IR KBr (ν_{max} cm^{-1}): 3343.4 (N-H), 1213.0 (P=O), 755.4 (C-P).{\textsuperscript{1}}H NMR (300 MHz, CDCl_{3}): δ ppm 2.27 (s, 6H), 4.84-4.92 (d, J_{H-P} = 22.6 Hz, 1H, N-C\textsuperscript{H-P}), 6.72-6.88 (m, 4H), 6.96-7.38 (m, 13H), 7.51-7.55 (m, 2H).{\textsuperscript{13}}C NMR (75 MHz, CDCl_{3}): δ ppm 18.73, 57.98 and 59.96 (d, J_{C-P} = 161.4 Hz), 76.57, 77.42, 115.33, 119.83, 120.24, 120.55, 122.29, 122.78, 125.16, 125.34, 128.25, 128.37, 128.60, 129.05, 129.31, 129.47, 129.68, 131.58, 134.50, 135.397, 135.43, 143.40, 150.01, 156.13.

Figure 1. FTIR spectra for the Diphenyl (phenyl(phenylamino)methyl) phosphonate [A1] in KBr.
4. $^1$H and $^{13}$C NMR spectra analysis

**Figure 2.** $^1$H NMR spectra for the Diphenyl (phenyl(phenylamino)methyl) phosphonate in CDCl$_3$.

**Figure 3.** $^1$H NMR spectra for the Diphenyl (phenyl(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 4. $^1$H NMR spectra for the Diphenyl [(4-nitrophenyl)(phenylamino)methyl] phosphonate in CDCl$_3$.

Figure 5. $^{13}$C NMR spectra for the Diphenyl [(4-nitrophenyl)(phenylamino)methyl] phosphonate in CDCl$_3$. 
Figure 6. $^1$H NMR spectra for the Diphenyl ((4-chlorophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$.

Figure 7. $^1$H NMR spectra for the Diphenyl ((4-chlorophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 8. $^1$H NMR spectra for the Diphenyl ((4-fluorophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$.

Figure 9. $^1$H NMR spectra for the Diphenyl ((4-fluorophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 10. $^1$H NMR spectra for the Diphenyl ((4-bromophenyl)(phenylamino)methyl) phosphonate [A5] in CDCl$_3$.

Figure 11. $^{13}$C NMR spectra for the Diphenyl ((4-bromophenyl)(phenylamino)methyl) phosphonate [A5] in CDCl$_3$. 
Figure 12. $^1$H NMR spectra for the Diphenyl ((4-methoxyphenyl)(phenylamino)methyl) phosphonate in CDCl$_3$.

Figure 13. $^{13}$C NMR spectra for the Diphenyl ((4-methoxyphenyl)(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 14. $^1$H NMR spectra for the Diphenyl ((3-nitrophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$.

Figure 15. $^{13}$C NMR spectra for the Diphenyl ((3-nitrophenyl)(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 16. $^1$H NMR spectra for the Diphenyl ((phenylamino)(p-tolyl)methyl) phosphonate in CDCl$_3$.

Figure 17. $^1$H NMR spectra for the Diphenyl ((4-(dimethylamino)phenyl)(phenylamino)methyl) phosphonate in CDCl$_3$. 
Figure 18. $^{13}$C NMR spectra for the Diphenyl ([4-(dimethylamino)phenyl](phenylamino)methyl) phosphonate in CDCl$_3$.

Figure 19. $^1$H NMR spectra for the Diphenyl ([4-(dimethylamino)phenyl](phenylamino)methyl) phosphonate in CDCl$_3$. 
**Figure 20.** $^{13}$C NMR spectra for the Diphenyl (phenylamino)(4-(trifluoromethyl) phenyl)methyl) phosphonate in CDCl$_3$.

**Figure 21.** $^1$H NMR spectra for the Diphenyl ((phenylamino)(thiophen-2-yl)methyl) phosphate in CDCl$_3$. 
Figure 22. $^{13}$C NMR spectra for the Diphenyl ((phenylamino)(thiophen-2-yl)methyl) phosphate in CDCl$_3$.

Figure 23. $^1$H NMR spectra for the Diphenyl (((4-nitrophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$. 
Figure 24. $^{13}$C NMR spectra for the Diphenyl (((4-nitrophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$.

Figure 25. $^1$H NMR spectra for the Diphenyl (((4-Chlorophenyl) amino)(phenyl)methyl) phosphonate in CDCl$_3$. 
Figure 26. $^{13}$C NMR spectra for the Diphenyl (((4-Chlorophenyl) amino)(phenyl)methyl) phosphonate in CDCl$_3$.

Figure 27. $^1$H NMR spectra for the Diphenyl (((4-bromophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$. 
Figure 28. $^{13}$C NMR spectra for the Diphenyl (((4-bromophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$.

Figure 29. $^1$H NMR spectra for the Diphenyl (((4-fluorophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$. 
Figure 30. $^{13}$C NMR spectra for the Diphenyl ((4-fluorophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$.

Figure 31. $^1$H NMR spectra for the Diphenyl ((4-iodophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$. 

Diagram 1:

Diagram 2:
Figure 32. $^{13}$C NMR spectra for the Diphenyl (((4-iodophenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$.

Figure 33. $^1$H NMR spectra for the Diphenyl (((4-methoxyphenyl)amino)(phenyl)methyl) phosphonate in DMSO.
Figure 34. $^{13}$C NMR spectra for the Diphenyl (((4-methoxyphenyl)amino)(phenyl)methyl) phosphonate in DMSO.

Figure 35. $^1$H NMR spectra for the Diphenyl (phenyl(p-tolylamino)methyl) phosphonate in CDCl$_3$. 
Figure 36. $^{13}$C NMR spectra for the Diphenyl (phenyl(p-tolylamino)methyl) phosphonate in CDCl$_3$.

Figure 37. $^1$H NMR spectra for the Diphenyl (((2,6-dimethylphenyl)amino)(phenyl)methyl) phosphonate in CDCl$_3$. 
Figure 38. $^{13}$C NMR spectra for the Diphenyl $([2,6$-dimethylphenyl]amino)(phenyl) methyl) phosphonate in CDCl$_3$.

5. Characterization of Ce$[[L$-Pro]$]_2$(Oxa)]

Figure 39. IR for Ce$[[L$-Pro]$]_2$(Oxa)] in KBr spectroscopic.
Figure 40. X-Ray diffraction patterns of [Ce(L-Pro)]₄(Oxa).