

Supporting information

Photo-induced phosphorylation/cyclization of *N*-homoallyl and *N*-allyl aldehyde hydrazones to access phosphorylated tetrahydropyridazines and dihydropyrazoles

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Table of Contents

1. General Considerations	S2
2. General Synthetic Procedures	S2
3. Mechanism Studies	S3
4. Characterization Data for the Products	S8
5. References	S24
6. Copies of the ¹H NMR and ¹³C NMR Spectra	S25

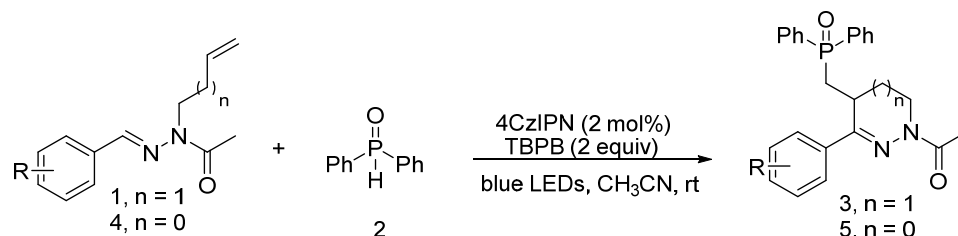
1. General Considerations

General Information: Unless otherwise noted, all chemicals were purchased from Energy Chemical or Bidepharmatech and used without further purification. All reactions were monitored by Thin Layer Chromatography (TLC) using silica gel F254 plates. Column chromatography was performed using EM Silica gel 60 (300-400 mesh). ^1H NMR and ^{13}C NMR spectra were recorded at ambient temperature on a Bruker-Avance 400 MHz NMR spectrometer (101 MHz for ^{13}C). NMR experiments are reported in δ units, parts per million (ppm), and were referenced to CDCl_3 (δ 7.26 or 77.0) as the internal standard. The coupling constants J are given in Hz. High-resolution mass spectra (HRMS) were recorded on a TOF LC/MS equipped with electrospray ionization (ESI) probe operating in positive ion mode. Emission intensities were recorded using a FS5 spectrophotometer.

2. General Synthetic Procedures

All *N*-homoallyl and *N*-allyl aldehyde hydrazones (**1a-1u**, **4a-4p**) were prepared according to the previous reports.¹

General procedure for the synthesis of Compounds **3** and **5**:



The mixture of (*E*)-*N*-homoallyl-*N'*-benzylideneacetohydrazide **1** or (*E*)-*N*-allyl-*N'*-benzylideneacetohydrazide **4** (0.2 mmol), phosphine oxide **2** (0.4 mmol, 2 equiv), 4CzIPN (2 mol%, 3.2 mg), TBPB (0.4 mmol, 77.7 mg) and MeCN (2 mL) were added to a Schlenk tube. The tube was evacuated and backfilled with nitrogen (repeated five times) and then sealed. The mixture was stirred at room temperature under 460-465 nm blue LEDs for 16 hours. Then, the solvent was evaporated under reduced pressure, and the residue was purified by silica gel flash column chromatography (eluent: petroleum ether/ethyl acetate) to obtain the product **3** or **5**.

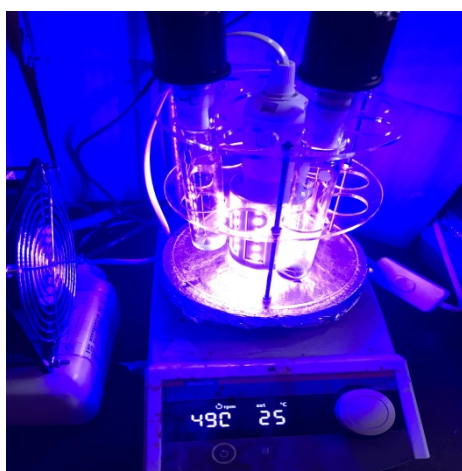


Figure S1. Photoreactor used in this work (20 W blue LED)

The Light Source and the Material of the Irradiation Vessel:

The photochemical reaction was carried out under visible light irradiation by a 20W 460-465 nm blue LED at room temperature. This blue LED was purchased from taobao (link: https://shop358870690.taobao.com/?spm=pc_detail.27183998.202202.3.6d807dd6mNb2jH). The blue LED's energy peak wavelength is 465 nm, the peak width at half-height is 18.6 nm, and irradiance@20 W is 26.92 mW/cm². The reaction vessel is a borosilicate glass tube. The distance between the tube and lamp is about 1cm, and no filter is applied.

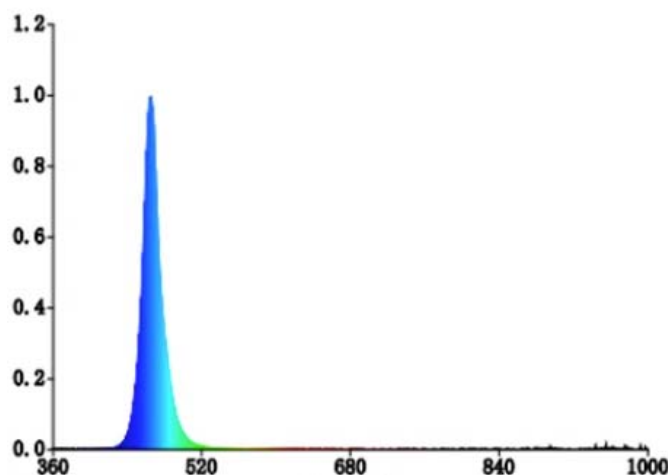
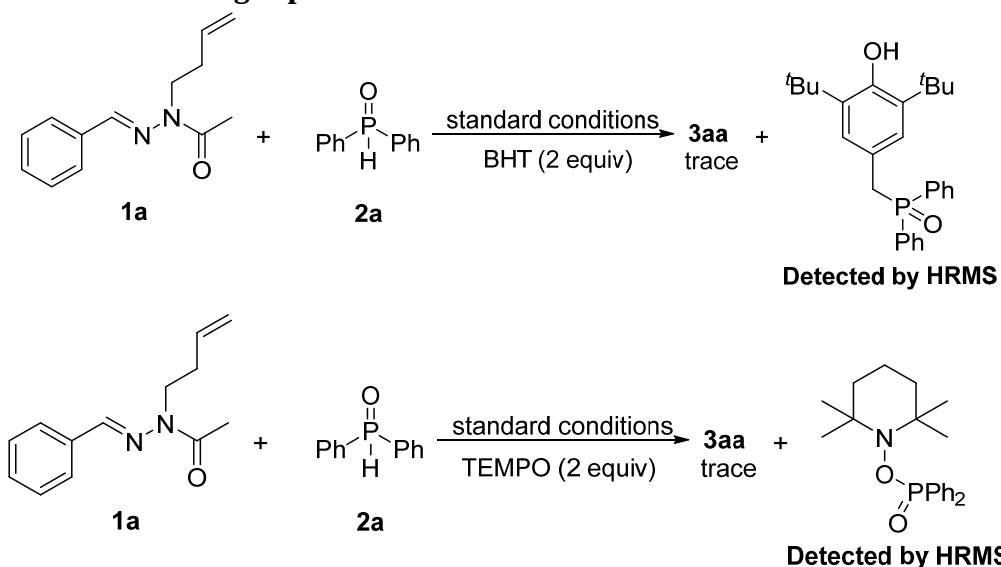


Figure S2. The spectral distribution of 20 W 460-465 nm blue LED

3. Mechanism Studies

3.1 Radical inhibiting experiments:



Under standard conditions, radical inhibitor BHT (0.4 mmol, 88.1 mg, 2 equiv) or TEMPO (0.4 mmol, 62.5 mg, 2 equiv) was added, the mixture was stirred at room temperature under 460-465 nm blue LEDs for 16 hours. Then, the mixture was detected by HRMS.

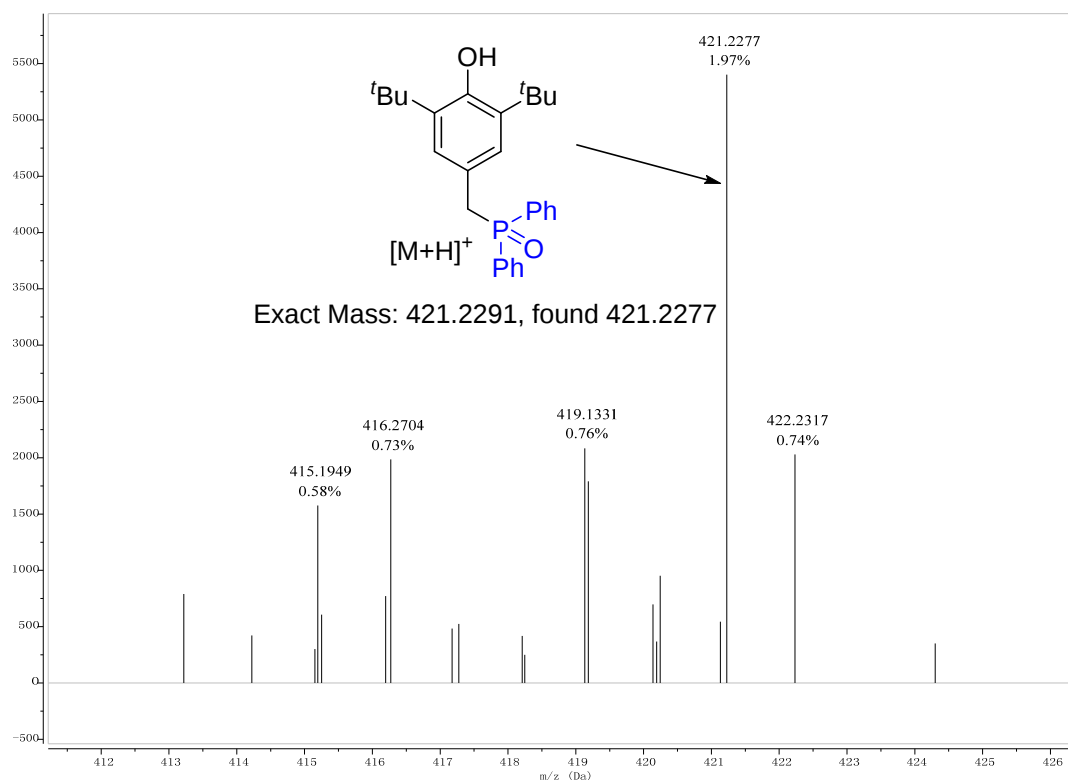


Figure S3. The HRMS spectrum for the radical-trapping experiment with BHT.

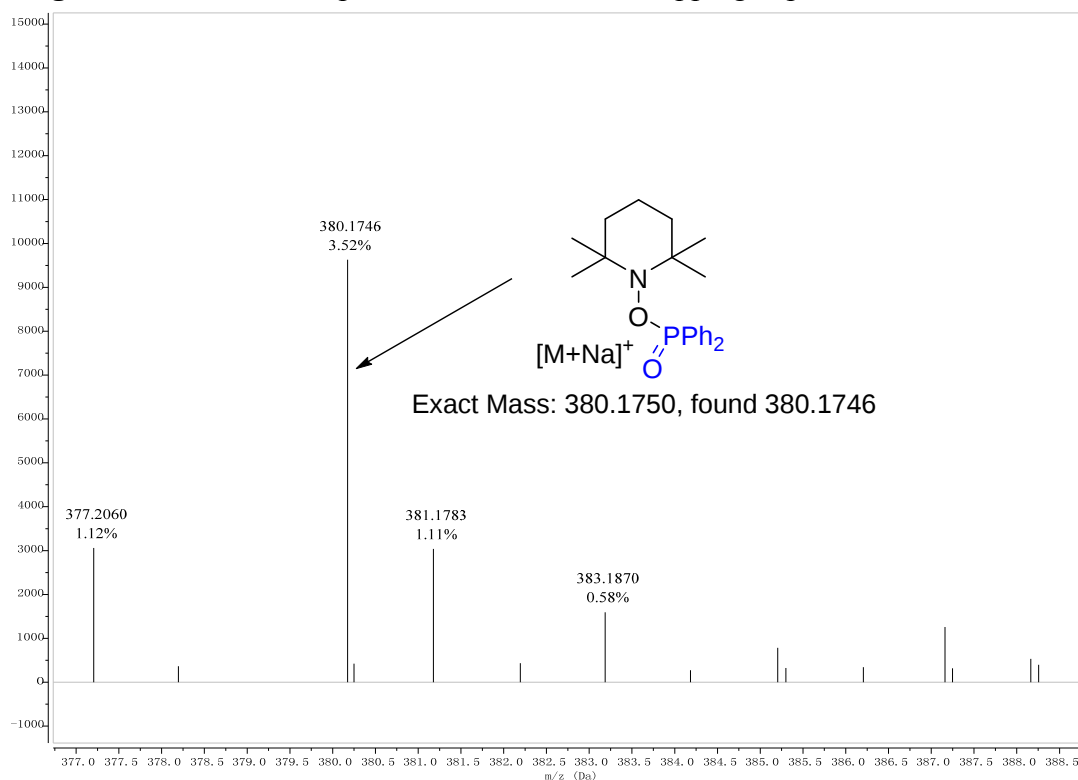


Figure S4. The HRMS spectrum for the radical-trapping experiment with TEMPO.

3.2 Fluorescence quenching experiments

Fluorescence quenching experiments were measured on an FS5 spectrophotometer with a 4 mL quartz cuvette ($d = 1$ cm) with a cap. CH_3CN was degassed by N_2 bubbling for 30 minutes before using. 4CzIPN was excited at 255 nm and the emission spectrum $\lambda_{\text{max}} = 560$ nm was recorded. In a typical experiment, the emission spectrum of a 5×10^{-3} M solution of 4CzIPN with different concentrations of quencher in degassed CH_3CN in 10 mm path length quartz cuvette was collected after degassing with a stream of N_2 for 5 minutes. The concentrations of the quencher stock solution were 0 M, 2.97×10^{-5} M, 5.93×10^{-5} M, 8.87×10^{-5} M, 1.18×10^{-4} M, 1.47×10^{-4} M in MeCN, respectively. Linear regression of I_0/I against concentration is done in Origin 2018 (Figure S6).

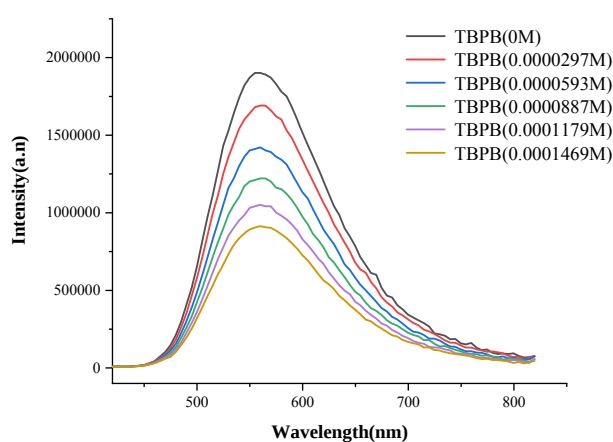


Figure S5. Fluorescence quenching of the excited 4CzIPN with different concentrations of TBPB.

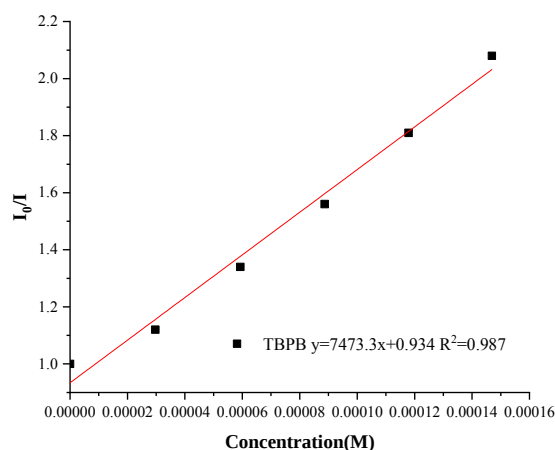


Figure S6. Stern-Volmer quenching studies of the excited 4CzIPN with TBPB

3.3 Quantum yield measurement

Determination of the photon flux: The photon flux of the spectrophotometer was determined by standard ferrioxalate actinometry.² A 0.006 M solution of ferrioxalate

was prepared by dissolving 294.5 mg of potassium ferrioxalate hydrate in 100 mL of 0.05 M H₂SO₄. A buffered solution of phenanthroline was prepared by dissolving 50.4 mg of phenanthroline and 11.1 mg of NaOAc in 50 mL of 0.5 M H₂SO₄. Both solutions were stored in the dark.

To determine the photon flux of the spectrophotometer, the ferrioxalate solution ($V = 2.5$ mL) was irradiated for 20.0 seconds (t_I) with the 20W 460-465 nm blue LEDs. After irradiation, 0.44 mL of the phenanthroline solution was added and was shielded with aluminum foil. The solution was then allowed to rest for 1 h to allow the ferrous ions to coordinate to the phenanthroline completely. The absorbance of the solution was measured at 510 nm. A non-irradiated sample was also prepared and the absorbance at 510 nm measured. Conversion was calculated using eq 1.

$$\text{Mol } \text{Fe}^{2+} = (V \cdot \Delta A) / (l \cdot \varepsilon) \quad (1)$$

Where V is the total volume (0.00294 L) of the solution after addition of phenanthroline, ΔA is the difference in absorbance at 510 nm between the irradiated and non-irradiated solutions, l is the path length (1.000 cm), and ε is the molar absorptivity at 510 nm (11,100 L mol⁻¹ cm⁻¹). The photon flux can be calculated using eq 2.

$$\text{Photon flux} = (\text{mol } \text{Fe}^{2+}) / (\Phi(\text{Fe}^{2+}) \cdot t_I \cdot f) \quad (2)$$

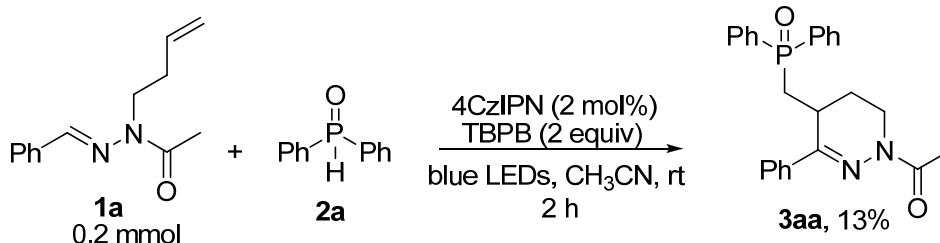
$$\text{Photon flux} = (V \cdot \Delta A) / (l \cdot \varepsilon \cdot \Phi(\text{Fe}^{2+}) \cdot t_I \cdot f) = 0.00294 \cdot 0.2109 / (1 \text{ cm} \cdot 11,100 \text{ L mol}^{-1} \text{ cm}^{-1} \cdot 1.13 \cdot 20 \text{ s} \cdot 0.48) = 5.14 \times 10^{-9} \text{ einsteins s}^{-1}.$$

Where $\Phi(\text{Fe}^{2+})$ is the quantum yield for the ferrioxalate actinometer (1.13 for a 0.006 M solution at $\lambda = 460$ nm), t_I is the time (20.0 s), and f is the fraction of light absorbed at $\lambda = 460$ nm by the ferrioxalate actinometer. The f value is calculated using eq 3 where A is the absorbance of the ferrioxalate solution at 460 nm. An absorption spectrum gave a value of 0.2834 at 460 nm, indicating that the fraction of absorbed light (f) is 0.48.

$$f = 1 - 10^{-A} \quad (3)$$

Determination of quantum yield: The reaction sample (0.1 mmol scale) was prepared following the general procedure and was irradiated with 20W 460-465 nm blue LEDs for 2 h (t_2). Product **3aa** was obtained in 13% yield. The quantum yield was determined using eq 4.

$$\Phi = \text{mol product} / (\text{Photo flux} \cdot t_2 \cdot f') \quad (4)$$



The mixture of **1a** (0.2 mmol), **2a** (0.4 mmol), 4CzIPN (2 mol%), TBPB (0.4 mmol) and MeCN (2 mL) were added to a Schlenk tube. The tube was evacuated and backfilled with nitrogen (repeated five times) and then sealed. The mixture was stirred at room temperature under 460-465 nm blue LEDs for 2 hours. The product **3aa** was obtained in 13% yield.

$$\Phi = \text{mol product} / (\text{Photo flux} * t_2 * f') = (2 * 10^{-4} \text{ mol} * 13\%) / (5.14 \times 10^{-9} \text{ einsteins s}^{-1} * 7200 \text{ s} * 1) = 0.70$$

The photon flux is $5.14 \times 10^{-9} \text{ einsteins s}^{-1}$, t_2 is the reaction time (7,200 s). f' is the fraction of incident light absorbed by the catalyst ($f' > 0.99$).

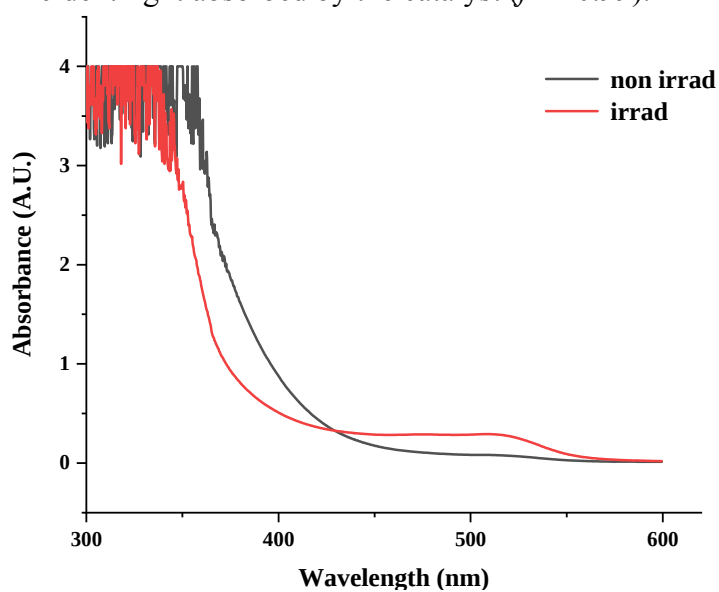
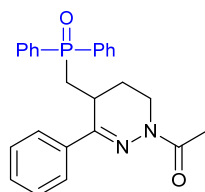
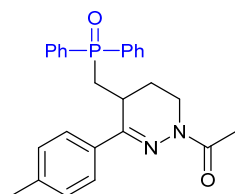


Figure S7. Absorbance of the ferrioxalate actinometer solution

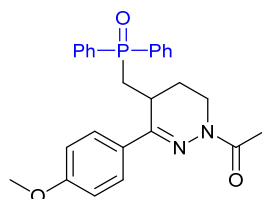
4. Characterization Data for the Products



1-(4-((Diphenylphosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3aa, 58.3 mg, 70%), white solid, mp 291-292 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.67-7.62 (m, 4H), 7.51-7.47 (m, 1H), 7.44-7.34 (m, 7H), 7.24-7.14 (m, 3H), 4.27-4.23 (m, 1H), 3.41-3.34 (m, 1H), 3.17-3.09 (m, 1H), 2.38-2.23 (m, 6H), 1.78-1.68 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 148.1 (d, $J_{\text{C-P}} = 13.1$ Hz), 135.3, 133.6, 132.64, 132.59, 132.2 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.6, 131.1 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.3, 129.0 (d, $J_{\text{C-P}} = 2.0$ Hz), 128.8 (d, $J_{\text{C-P}} = 1.0$ Hz), 128.7, 125.8, 34.6, 31.1 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.7 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.6, 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{25}\text{N}_2\text{O}_2\text{P}$ 417.1726; found 417.1729.

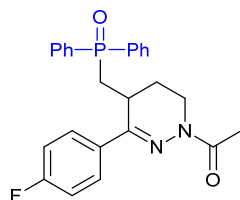


1-(4-((Diphenylphosphoryl)methyl)-3-(p-tolyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ba, 60.3 mg, 67%), white solid, mp 290-291 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.77-7.72 (m, 4H), 7.62-7.58 (m, 1H), 7.56-7.45 (m, 5H), 7.36 (d, $J = 8.3$ Hz, 2H), 7.08 (d, $J = 8.0$ Hz, 2H), 4.37-4.32 (m, 1H), 3.48-3.42 (m, 1H), 3.24-3.16 (m, 1H), 2.46-2.30 (m, 9H), 1.87-1.78 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 148.3 (d, $J_{\text{C-P}} = 13.1$ Hz), 139.5, 133.7, 132.7, 132.6, 132.21, 132.18, 132.15, 131.7, 131.1 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.4, 129.0 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.8 (d, $J_{\text{C-P}} = 4.0$ Hz), 125.8, 34.6, 31.1 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.8 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.6, 21.4, 21.3. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{26}\text{H}_{27}\text{N}_2\text{O}_2\text{P}$ 431.1883; found 431.1883.

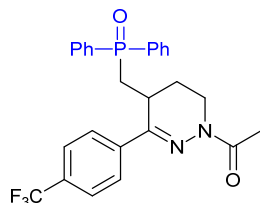


1-(4-((Diphenylphosphoryl)methyl)-3-(4-methoxyphenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ca, 64.3 mg, 72%), white solid, mp 295-297 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.76-7.70 (m, 4H), 7.60-7.55 (m, 1H), 7.52-7.40 (m, 7H), 6.79-6.76 (m, 2H), 4.35-4.29 (m, 1H), 3.80 (s, 3H), 3.47-3.41 (m, 1H), 3.21-3.13 (m, 1H), 2.41-2.37 (m, 5H), 2.30-2.25 (m, 1H), 1.84-1.75 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.3, 160.5, 148.1 (d, $J_{\text{C-P}} = 14.1$ Hz), 133.6, 132.7 (d, $J_{\text{C-P}} = 17.2$ Hz), 132.2 (d, $J_{\text{C-P}} = 2.0$ Hz), 132.1 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.8, 131.0 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 5.1$ Hz), 128.9 (d, $J_{\text{C-P}} = 5.1$ Hz), 127.8, 127.3, 114.0, 55.4, 34.5, 31.2 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.6 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.7, 21.4. HRMS

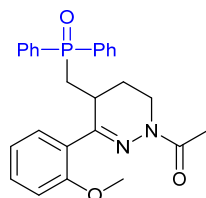
(ESI) m/z : $[M+H]^+$ calcd for $C_{26}H_{27}N_2O_3P$ 447.1832, found 447.1828.



1-(4-((Diphenylphosphoryl)methyl)-3-(4-fluorophenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3da, 42.6 mg, 49%), white solid, mp 284-285 °C; 1H NMR (400 MHz, $CDCl_3$) δ 7.77-7.70 (m, 4H), 7.62-7.44 (m, 8H), 6.98-6.93 (m, 2H), 4.38-4.33 (m, 1H), 3.49-3.42 (m, 1H), 3.23-3.15 (m, 1H), 2.45-2.26 (m, 6H), 1.87-1.77 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.4, 163.4 (d, J_{C-F} = 248.1 Hz), 147.2 (d, J_{C-P} = 12.9 Hz), 133.4, 132.7, 132.4, 132.3 (d, J_{C-P} = 2.9 Hz), 132.3 (d, J_{C-P} = 2.8 Hz), 131.7, 131.4 (d, J_{C-F} = 3.2 Hz), 131.0 (d, J_{C-P} = 9.4 Hz), 130.5 (d, J_{C-P} = 9.5 Hz), 129.0 (d, J_{C-P} = 3.8 Hz), 128.9 (d, J_{C-P} = 3.7 Hz), 127.7 (d, J_{C-F} = 8.1 Hz), 115.6 (d, J_{C-F} = 21.6 Hz), 34.5, 31.2 (d, J_{C-P} = 68.5 Hz), 24.7 (d, J_{C-P} = 2.5 Hz), 21.7, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{25}H_{24}FN_2O_2P$ 435.1632, found 435.1630.

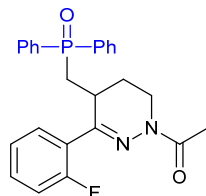


1-(4-((Diphenylphosphoryl)methyl)-3-(4-(trifluoromethyl)phenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ea, 71.7 mg, 74%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.76-7.67 (m, 5H), 7.59-7.44 (m, 10H), 4.37-4.33 (m, 1H), 3.52-3.45 (m, 1H), 3.25-3.17 (m, 1H), 2.44-2.28 (m, 6H), 1.86-1.77 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ , 172.4, 171.1, 146.5 (d, J_{C-P} = 13.1 Hz), 138.7, 133.3, 132.6 (d, J_{C-P} = 2.7 Hz), 132.5, 132.2 (d, J_{C-P} = 2.6 Hz), 131.5, 131.0 (d, J_{C-P} = 9.2 Hz), 130.7, 130.6 (d, J_{C-P} = 1.9 Hz), 130.5 (d, J_{C-P} = 9.5 Hz), 129.0 (d, J_{C-P} = 2.3 Hz), 128.9 (d, J_{C-P} = 2.2 Hz), 123.9 (q, J_{C-F} = 273.1 Hz), 126.0, 125.5 (q, J_{C-F} = 3.9 Hz), 60.4, 34.7, 31.3 (d, J_{C-P} = 68.3 Hz), 24.6 (d, J_{C-P} = 2.5 Hz), 21.6, 21.3, 21.0, 14.2. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{26}H_{24}F_3N_2O_2P$ 485.1600, found 485.1593.

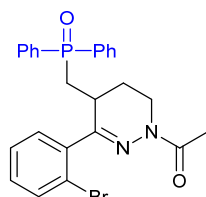


1-(4-((Diphenylphosphoryl)methyl)-3-(2-methoxyphenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3fa, 42.0 mg, 47%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.55-7.50 (m, 2H), 7.44-7.28 (m, 9H), 7.2-7.18 (m, 1H), 6.93 (t, J = 7.4 Hz, 1H), 6.73 (d, J = 8.3 Hz, 1H), 4.00-3.94 (m, 1H), 3.54-3.47 (m, 1H), 3.43-3.34 (m, 4H), 2.28-2.21 (m, 4H), 2.15-2.06 (m, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.4, 157.1, 151.4 (d, J_{C-P} = 15.2 Hz), 134.3, 133.3, 131.7 (d, J_{C-P} = 99.0 Hz), 131.9 (d, J_{C-P} = 3.0 Hz), 131.7 (d, J_{C-P} = 3.0 Hz), 130.9 (d, J_{C-P} = 9.1 Hz), 130.7, 130.4, 130.3 (d, J_{C-P} =

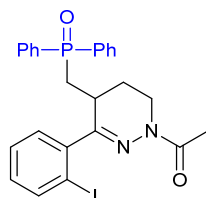
9.1 Hz), 128.8, 128.7 (d, J_{C-P} = 2.0 Hz), 128.6, 126.3, 120.8, 110.9, 55.1, 35.8, 31.3 (d, J_{C-P} = 69.7 Hz), 28.7 (d, J_{C-P} = 2.0 Hz), 22.9, 21.3. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{26}H_{27}N_2O_3P$ 447.1832, found 447.1828.



1-(4-((Diphenylphosphoryl)methyl)-3-(2-fluorophenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ga), 82.5 mg, 95%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.65-7.57 (m, 4H), 7.53-7.39 (m, 6H), 7.35-7.30 (m, 2H), 7.13-7.09 (m, 1H), 7.01-6.96 (m, 1H), 4.06-4.01 (m, 1H), 3.56-3.49 (m, 1H), 3.34-3.25 (m, 1H), 2.33-2.21 (m, 6H), 2.10-2.01 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.4, 160.3 (d, J_{C-F} = 251.0, 147.2 (d, J_{C-P} = 2.4 Hz), 147.1 (d, J_{C-P} = 2.3 Hz), 133.5 (d, J_{C-P} = 99.5 Hz), 132.0 (d, J_{C-P} = 3.7 Hz), 131.9, 130.9, 130.8, 130.7 (d, J_{C-F} = 8.4 Hz), 130.4, 130.3, 128.8 (d, J_{C-P} = 4.1 Hz), 128.7 (d, J_{C-P} = 4.1 Hz), 124.7 (d, J_{C-P} = 12.2 Hz), 124.5 (d, J_{C-F} = 3.5 Hz), 116.3 (d, J_{C-F} = 22.6 Hz), 35.6, 31.5 (d, J_{C-P} = 69.2 Hz), 28.7 (d, J_{C-P} = 2.1 Hz), 28.7 (d, J_{C-P} = 2.1 Hz), 22.7, 21.2. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{25}H_{24}FN_2O_2P$ 435.1632, found 435.1630.

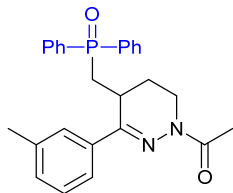


1-(3-(2-Bromophenyl)-4-((diphenylphosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ha), 64.4 mg, 65%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.57-7.48 (m, 3H), 7.43-7.34 (m, 6H), 7.28-7.17 (m, 4H), 7.07-7.05 (m, 1H), 4.04-3.98 (m, 1H), 3.49-3.42 (m, 1H), 3.19-3.10 (m, 1H), 2.21-2.07 (m, 7H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.5, 150.4 (d, J_{C-P} = 14.1 Hz), 138.0, 133.4 (d, J_{C-P} = 100.0 Hz), 132.1 (d, J_{C-P} = 3.0 Hz), 131.9 (d, J_{C-P} = 3.0 Hz), 131.7, 130.8, 130.6 (d, J_{C-P} = 10.1 Hz), 130.3 (d, J_{C-P} = 10.1 Hz), 130.1, 128.9 (d, J_{C-P} = 5.1 Hz), 128.8 (d, J_{C-P} = 5.1 Hz), 127.5, 122.6, 35.5, 30.7 (d, J_{C-P} = 69.7 Hz), 29.4 (d, J_{C-P} = 1.0 Hz), 22.8, 21.3. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{25}H_{24}BrN_2O_2P$ 495.0832, found 495.0817.

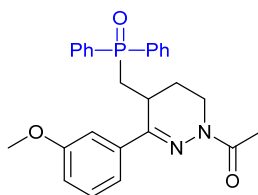


1-(4-((Diphenylphosphoryl)methyl)-3-(2-iodophenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ia), 73.8 mg, 68%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.86-7.84 (m, 1H), 7.63-7.58 (m, 2H), 7.48-7.40 (m, 6H), 7.34-7.29 (m, 3H), 7.09-7.02 (m, 2H), 4.15-4.09 (m, 1H), 3.50-3.43 (m, 1H), 3.19-3.10 (m, 1H), 2.28-2.24 (m, 6H), 2.17-2.09 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.6, 151.8 (d,

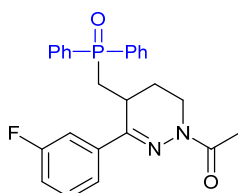
$J_{C-P} = 14.1$ Hz), 141.5, 139.9, 133.4 (d, $J_{C-P} = 99.0$ Hz), 132.1 (d, $J_{C-P} = 2.0$ Hz), 131.9 (d, $J_{C-P} = 3.0$ Hz), 131.7, 130.7 (d, $J_{C-P} = 9.1$ Hz), 130.3 (d, $J_{C-P} = 9.1$ Hz), 130.2, 129.5, 128.9 (d, $J_{C-P} = 4.0$ Hz), 128.8 (d, $J_{C-P} = 4.0$ Hz), 128.2, 97.7, 35.4, 30.4 (d, $J_{C-P} = 69.7$ Hz), 29.6 (d, $J_{C-P} = 2.0$ Hz), 22.9, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{25}H_{24}N_2O_2P$ 543.0693, found 543.0670.



1-(4-((Diphenylphosphoryl)methyl)-3-(m-tolyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ja, 75.7 mg, 88%), white solid, mp 237-238 °C; 1H NMR (400 MHz, $CDCl_3$) δ 7.71-7.65 (m, 4H), 7.57-7.52 (m, 1H), 7.49-7.39 (m, 5H), 7.27 (s, 1H), 7.19-7.16 (m, 1H), 7.13-7.09 (m, 2H), 4.33-4.27 (m, 1H), 3.44-3.36 (m, 1H), 3.22-3.14 (m, 1H), 2.42-2.32 (m, 6H), 2.25 (s, 3H), 1.83-1.74 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.5, 148.5 (d, $J_{C-P} = 14.1$ Hz), 138.3, 135.4, 133.2 (d $J_{C-P} = 98.9$ Hz), 132.5, 132.2, 131.5, 131.1 (d, $J_{C-P} = 9.1$ Hz), 130.5 (d, $J_{C-P} = 10.1$ Hz), 130.2, 128.9 (d, $J_{C-P} = 12.1$ Hz), 128.6, 126.4, 123.1, 34.7, 31.0 (d, $J_{C-P} = 68.7$ Hz), 25.0 (d, $J_{C-P} = 3.0$ Hz), 21.6, 21.6, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{26}H_{27}N_2O_2P$ 431.1883, found 431.1881.

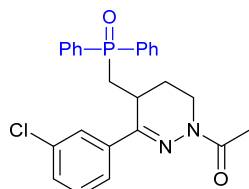


1-(4-((Diphenylphosphoryl)methyl)-3-(3-methoxyphenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ka, 50.9 mg, 57%), white solid, mp 220-222 °C; 1H NMR (400 MHz, $CDCl_3$) δ 7.75-7.70 (m, 4H), 7.58-7.44 (m, 6H), 7.22-7.14 (m, 2H), 6.94-6.87 (m, 2H), 4.35-4.31 (m, 1H), 3.80 (s, 3H), 3.49-3.41 (m, 1H), 3.25-3.17 (m, 1H), 2.41-2.31 (m, 6H), 1.86-1.76 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.4, 159.9, 148.1 (d, $J_{C-P} = 13.1$ Hz), 136.9, 133.6, 132.6 (d, $J_{C-P} = 12.1$ Hz), 132.2, 132.2, 132.2, 131.6, 131.0 (d, $J_{C-P} = 9.1$ Hz), 130.5 (d, $J_{C-P} = 9.1$ Hz), 129.7, 128.9 (d, $J_{C-P} = 12.1$ Hz), 118.2, 115.2, 111.3, 55.3, 34.7, 31.2 (d, $J_{C-P} = 67.7$ Hz), 25.0 (d, $J_{C-P} = 2.0$ Hz), 21.6, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{26}H_{27}N_2O_3P$ 447.1832, found 447.1819.

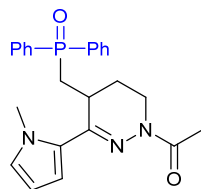


1-(4-((Diphenylphosphoryl)methyl)-3-(3-fluorophenyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3la, 61.7 mg, 71%), white solid, mp 263-264 °C; 1H NMR (400 MHz, $CDCl_3$) δ 7.76-7.70 (m, 4H), 7.61-7.56 (m, 1H), 7.53-7.43 (m, 5H), 7.22-7.14 (m, 3H), 7.02-6.97 (m, 1H), 4.38-4.32 (m, 1H), 3.43-3.35 (m, 1H), 3.24-3.16 (m, 1H),

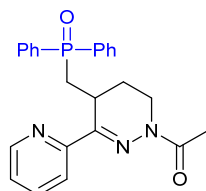
2.45-2.32 (m, 6H), 1.85-1.76 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 163.0 (d, $J_{\text{C-F}} = 246.7$ Hz), 146.9 (d, $J_{\text{C-P}} = 2.8$ Hz), 146.7 (d, $J_{\text{C-F}} = 2.7$ Hz), 137.8 (d, $J_{\text{C-F}} = 7.4$ Hz), 133.0 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.4, 132.3 (d, $J_{\text{C-P}} = 2.7$ Hz), 132.3 (d, $J_{\text{C-P}} = 2.7$ Hz), 131.4, 131.0 (d, $J_{\text{C-P}} = 9.0$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.5$ Hz), 130.2 (d, $J_{\text{C-P}} = 8.2$ Hz), 129.0 (d, $J_{\text{C-P}} = 3.8$ Hz), 128.9 (d, $J_{\text{C-P}} = 3.9$ Hz), 121.4 (d, $J_{\text{C-P}} = 2.9$ Hz), 116.2 (d, $J_{\text{C-F}} = 21.5$ Hz), 112.6 (d, $J_{\text{C-F}} = 23.2$ Hz), 34.7, 31.2 (d, $J_{\text{C-P}} = 68.4$ Hz), 24.8 (d, $J_{\text{C-P}} = 2.4$ Hz), 21.5, 21.5. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{24}\text{FN}_2\text{O}_2\text{P}$ 435.1632, found 435.1629.



1-(3-(3-Chlorophenyl)-4-((diphenylphosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ma, 83.0 mg, 90%), white solid, mp 234-235 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.69-7.63 (m, 4H), 7.55-7.51 (m, 1H), 7.48-7.44 (m, 4H), 7.42-7.37 (m, 2H), 7.23-7.19 (m, 2H), 7.11 (t, $J = 7.9$ Hz, 1H), 4.32-4.26 (m, 1H), 3.34-3.28 (m, 1H), 3.19-3.11 (m, 1H), 2.37-2.26 (m, 6H), 1.79-1.70 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.5, 146.8 (d, $J_{\text{C-P}} = 13.1$ Hz), 137.3, 134.8, 133.0 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 2.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.3, 131.0 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.9, 129.3, 129.1, 129.0, 128.9, 125.9, 124.0, 34.7, 31.1 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.9 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.5, 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{24}\text{ClN}_2\text{O}_2\text{P}$ 451.1337, found 451.1320.

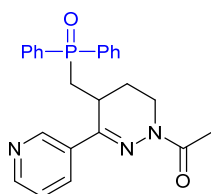


1-(4-((Diphenylphosphoryl)methyl)-3-(1-methyl-1H-pyrrol-2-yl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3na, 49.5 mg, 59%), white solid, mp 296-298 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.78-7.71 (m, 4H), 7.58-7.43 (m, 7H), 6.64 (t, $J = 2.2$ Hz, 1H), 6.01-5.96 (m, 2H), 4.32-4.27 (m, 1H), 3.80 (s, 3H), 3.31-3.18 (m, 2H), 2.54-2.47 (m, 2H), 2.39-2.34 (m, 1H), 2.28 (s, 3H), 1.82-1.74 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 171.7, 144.6 (d, $J_{\text{C-P}} = 13.1$ Hz), 133.3 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.5, 132.2, 132.2, 132.1, 131.5, 131.1 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 128.9 (d, $J_{\text{C-P}} = 3.0$ Hz), 128.8 (d, $J_{\text{C-P}} = 2.0$ Hz), 127.8, 127.6, 112.2, 107.3, 38.5, 34.9, 31.8 (d, $J_{\text{C-P}} = 68.7$ Hz), 26.4 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.9, 21.3. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{26}\text{N}_3\text{O}_2\text{P}$ 420.1835, found 420.1827.

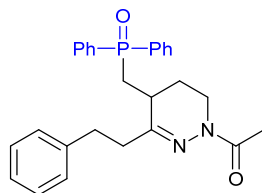


1-(4-((Diphenylphosphoryl)methyl)-3-(pyridin-2-yl)-5,6-dihydropyridazin-1(4H)-

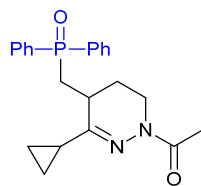
yl)ethan-1-one (30a, 60.1 mg, 72%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 8.45-8.44 (m, 1H), 8.08-8.03 (m, 2H), 7.95 (d, $J = 8.0$ Hz, 1H), 7.72-7.65 (m, 3H), 7.59-7.54 (m, 3H), 7.46-7.38 (m, 3H), 7.25-7.22 (m, 1H), 4.47-4.42 (m, 1H), 3.85-3.77 (m, 1H), 3.37-3.29 (m, 1H), 2.93-2.87 (m, 1H), 2.83-2.78 (m, 1H), 2.41-2.28 (m, 4H), 1.80-1.70 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.3, 153.9, 148.7 (d, $J_{\text{C-P}} = 15.2$ Hz), 148.3, 136.4, 134.4 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.8, 131.7, 131.0, 130.3 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.9, 128.7 (d, $J_{\text{C-P}} = 11.1$ Hz), 128.5 (d, $J_{\text{C-P}} = 12.1$ Hz), 128.2, 123.6, 120.0, 35.3, 30.9 (d, $J_{\text{C-P}} = 68.7$ Hz), 25.2 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.4, 20.8. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{24}\text{N}_3\text{O}_2\text{P}$ 418.1679, found 418.1679.



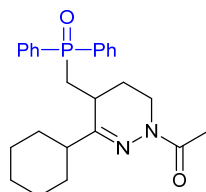
1-(4-((Diphenylphosphoryl)methyl)-3-(pyridin-3-yl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3pa, 30.9 mg, 37%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 8.77 (d, $J = 2.3$ Hz, 1H), 8.54 (d, $J = 4.8$ Hz, 1H), 7.76-7.67 (m, 5H), 7.61-7.57 (m, 1H), 7.53-7.45 (m, 5H), 7.20-7.16 (m, 1H), 4.39-4.33 (m, 1H), 3.46-3.39 (m, 1H), 3.26-3.18 (m, 1H), 2.40-2.28 (m, 6H), 1.87-1.77 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 149.9, 147.5, 145.7 (d, $J_{\text{C-P}} = 13.1$ Hz), 133.3, 133.0, 132.4, 132.4, 132.3, 131.4, 131.1, 130.9 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.1 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.9 (d, $J_{\text{C-P}} = 3.0$ Hz), 123.4, 34.8, 31.3 (d, $J_{\text{C-P}} = 67.7$ Hz), 24.7 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.6, 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{24}\text{N}_3\text{O}_2\text{P}$ 418.1679, found 418.1675.



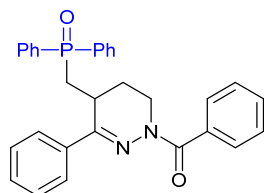
1-(4-((Diphenylphosphoryl)methyl)-3-phenethyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3qa, 72.0 mg, 81%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.69-7.61 (m, 4H), 7.51-7.36 (m, 7H), 7.20-7.16 (m, 2H), 7.13-7.09 (m, 1H), 7.03-7.01 (m, 2H), 4.01-3.96 (m, 1H), 3.15-3.08 (m, 1H), 2.78-2.67 (m, 2H), 2.54-2.48 (m, 1H), 2.46-2.30 (m, 2H), 2.25-2.07 (m, 5H), 1.89-1.83 (m, 1H), 1.67-1.58 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.0, 150.9 (d, $J_{\text{C-P}} = 12.1$ Hz), 141.2, 133.0 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.7, 132.2, 132.2, 132.2, 131.7, 130.8 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.9, 128.9 (d, $J_{\text{C-P}} = 12.1$ Hz), 128.4 (d, $J_{\text{C-P}} = 2.0$ Hz), 126.1, 36.7, 34.9, 32.4, 30.7 (d, $J_{\text{C-P}} = 68.7$ Hz), 28.7 (d, $J_{\text{C-P}} = 3.0$ Hz), 22.5 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.2. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{27}\text{H}_{29}\text{N}_2\text{O}_2\text{P}$ 445.2039, found 445.2043.



1-(3-Cyclopropyl-4-((diphenylphosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ra, 53.3 mg, 70%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.77-7.68 (m, 4H), 7.50-7.40 (m, 6H), 4.01-3.95 (m, 1H), 3.13-3.06 (m, 1H), 2.80-2.72 (m, 1H), 2.68-2.60 (m, 1H), 2.32-2.23 (m, 1H), 2.11 (s, 3H), 1.87-1.81 (m, 1H), 1.71-1.63 (m, 1H), 1.26-1.21 (m, 1H), 0.82-0.77 (m, 1H), 0.73-0.56 (m, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ 171.7, 153.9 (d, $J_{\text{C-P}} = 13.1$ Hz), 133.1 (d, $J_{\text{C-P}} = 99.0$ Hz), 132.9, 132.6, 132.2 (d, $J_{\text{C-P}} = 1.0$ Hz), 132.2 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.9, 130.8 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.9, 129.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 128.9 (d, $J_{\text{C-P}} = 2.0$ Hz), 128.2, 34.9, 31.5 (d, $J_{\text{C-P}} = 69.7$ Hz), 29.7 (d, $J_{\text{C-P}} = 3.0$ Hz), 22.8 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.0, 15.0, 9.0, 6.8. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{22}\text{H}_{25}\text{N}_2\text{O}_2\text{P}$ 381.1726, found 381.1711.

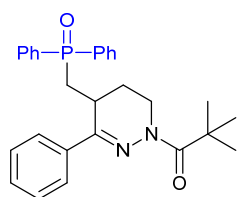


1-(3-Cyclohexyl-4-((diphenylphosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3sa, 62.5 mg, 74%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.80-7.72 (m, 4H), 7.56-7.45 (m, 6H), 4.13-4.06 (m, 1H), 3.16-2.99 (m, 1H), 2.92-2.74 (m, 1H), 2.36-2.20 (m, 5H), 2.06-1.92 (m, 2H), 1.75-1.38 (m, 7H), 1.18-0.92 (m, 4H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.2, 156.3 (d, $J_{\text{C-P}} = 12.1$ Hz), 133.8, 132.8 (d, $J_{\text{C-P}} = 11.1$ Hz), 132.2 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.1 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.9, 130.8 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 43.3, 34.8, 32.1, 31.0 (d, $J_{\text{C-P}} = 69.7$ Hz), 26.4, 26.0 (d, $J_{\text{C-P}} = 7.1$ Hz), 22.5 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.2. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{31}\text{N}_2\text{O}_2\text{P}$ 423.2196, found 423.2191.

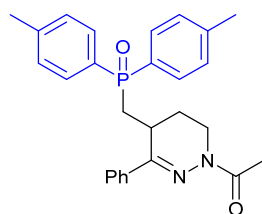


4-((Diphenylphosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl(phenyl)methanone (3ta, 67.0 mg, 70%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.71-7.62 (m, 6H), 7.51-7.30 (m, 9H), 7.21-7.16 (m, 3H), 7.09 (t, $J = 7.5$ Hz, 2H), 4.00-4.35 (m, 1H), 3.49-3.35 (m, 2H), 2.46-2.30 (m, 3H), 1.95-1.85 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 170.5, 148.2 (d, $J_{\text{C-P}} = 14.1$ Hz), 135.1, 134.9, 133.5, 132.6 (d, $J_{\text{C-P}} = 9.1$ Hz), 132.3, 132.3, 132.3, 131.7, 131.1 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.3, 130.0, 129.2, 129.0 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.9 (d, $J_{\text{C-P}} = 5.1$ Hz), 128.6, 127.4, 125.8, 35.7, 31.2 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.6 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.8.

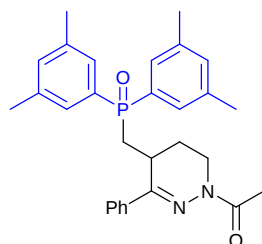
HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{30}H_{27}N_2O_2P$ 479.1883, found 479.1886.



1-(4-((Diphenylphosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)-2,2-dimethylpropan-1-one (3ua), 68.8 mg, 75%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.70-7.62 (m, 4H), 7.55-7.51 (m, 1H), 7.47-7.43 (m, 3H), 7.40-7.35 (m, 4H), 7.20-7.12 (m, 3H), 4.01 (d, $J = 13.7$ Hz, 1H), 3.35-3.27 (m, 2H), 2.39-2.29 (m, 3H), 1.89-1.80 (m, 1H), 1.48 (s, 9H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 135.7, 133.3 (d, $J_{C-P} = 99.0$ Hz), 132.2 (d, $J_{C-P} = 3.0$ Hz), 132.1 (d, $J_{C-P} = 3.0$ Hz), 131.2 (d, $J_{C-P} = 9.1$ Hz), 130.5 (d, $J_{C-P} = 9.1$ Hz), 128.9 (d, $J_{C-P} = 2.0$ Hz), 128.9, 128.8 (d, $J_{C-P} = 3.0$ Hz), 128.5, 125.8, 81.5, 31.3 (d, $J_{C-P} = 68.7$ Hz), 28.3, 24.6, 22.2. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{28}H_{31}N_2O_2P$ 459.2196, found 459.2189.

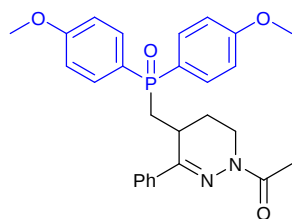


1-(4-((Di-p-tolylphosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ab), 48.1 mg, 54%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.55-7.50 (m, 4H), 7.42-7.40 (m, 2H), 7.26-7.17 (m, 7H), 4.29-4.23 (m, 1H), 3.44-3.36 (m, 1H), 3.17-3.09 (m, 1H), 2.36 (s, 3H), 2.32-2.25 (m, 9H), 1.79-1.69 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.5, 148.3 (d, $J_{C-P} = 13.1$ Hz), 142.7, 142.7, 142.6, 135.4, 131.1 (d, $J_{C-P} = 9.1$ Hz), 130.5 (d, $J_{C-P} = 9.1$ Hz), 129.7 (d, $J_{C-P} = 4.0$ Hz), 129.5 (d, $J_{C-P} = 4.0$ Hz), 129.3, 128.6, 128.6, 125.9, 34.7, 31.3 (d, $J_{C-P} = 68.7$ Hz), 24.8 (d, $J_{C-P} = 2.0$ Hz), 21.7, 21.6, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{27}H_{29}N_2O_2P$ 445.2039, found 445.2026.

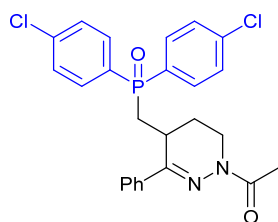


1-(4-((Bis(3,5-dimethylphenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ac), 74.7 mg, 79%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.61 (d, $J = 7.6$ Hz, 2H), 7.52-7.36 (m, 9H), 4.52 (d, $J = 13.9$ Hz, 1H), 3.62-3.56 (m, 1H), 3.45-3.37 (m, 1H), 2.57-2.45 (m, 18H), 2.03-1.93 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.5, 148.4 (d, $J_{C-P} = 7.1$ Hz), 138.7 (d, $J_{C-P} = 6.1$ Hz), 138.6 (d, $J_{C-P} = 5.1$ Hz), 135.5, 133.9, 133.1 (d, $J_{C-P} = 98.0$ Hz), 132.5, 132.2, 131.2, 129.9, 129.2, 128.7, 128.6, 128.6, 128.2, 127.9 (d, $J_{C-P} = 9.1$ Hz), 125.9, 34.7, 30.9 (d, $J_{C-P} = 67.7$ Hz), 24.8 (d, $J_{C-P} = 2.0$ Hz), 21.6, 21.4, 21.4, 21.3. HRMS (ESI) m/z :

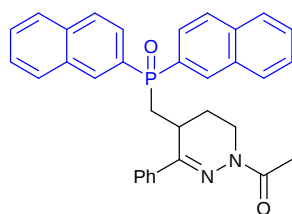
$[M+H]^+$ calcd for $C_{29}H_{33}N_2O_2P$ 473.2352, found 473.2351.



1-(4-((Bis(4-methoxyphenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ad, 45.7 mg, 48%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.58-7.52 (m, 4H), 7.42-7.40 (m, 2H), 7.27-7.18 (m, 3H), 6.94-6.91 (m, 2H), 6.89-6.86 (m, 2H), 4.29-4.24 (m, 1H), 3.79 (s, 3H), 3.74 (s, 3H), 3.41-3.34 (m, 1H), 3.18-3.10 (m, 1H), 2.32-2.22 (m, 6H), 1.79-1.69 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.4, 162.6 (d, J_{C-P} = 3.0 Hz), 162.5 (d, J_{C-P} = 3.0 Hz), 148.4 (d, J_{C-P} = 14.1 Hz), 135.4, 132.9 (d, J_{C-P} = 10.1 Hz), 132.3 (d, J_{C-P} = 11.1 Hz), 129.3, 128.6, 125.9, 125.0, 123.9 (d, J_{C-P} = 2.0 Hz), 122.9, 114.5 (d, J_{C-P} = 4.0 Hz), 114.3 (d, J_{C-P} = 3.0 Hz), 55.4 (d, J_{C-P} = 8.1 Hz), 34.7, 31.5 (d, J_{C-P} = 69.7 Hz), 24.8 (d, J_{C-P} = 3.0 Hz), 21.6, 21.4. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{27}H_{29}N_2O_2P$ 477.1938, found 477.1926.

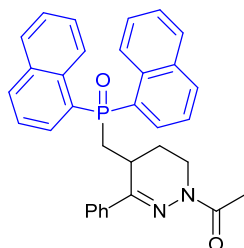


1-(4-((Bis(4-chlorophenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ae, 72.8 mg, 75%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.59-7.53 (m, 4H), 7.43-7.35 (m, 6H), 7.30-7.26 (m, 1H), 7.23-7.19 (m, 2H), 4.32-4.27 (m, 1H), 3.41-3.34 (m, 1H), 3.18-3.10 (m, 1H), 2.36-2.21 (m, 6H), 1.84-1.75 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.5, 147.7 (d, J_{C-P} = 13.1 Hz), 139.1 (d, J_{C-P} = 3.0 Hz), 135.3, 132.4 (d, J_{C-P} = 10.1 Hz), 132.1 (d, J_{C-P} = 12.1 Hz), 131.8 (d, J_{C-P} = 10.1 Hz), 130.7 (d, J_{C-P} = 12.1 Hz), 129.7, 129.5 (d, J_{C-P} = 2.0 Hz), 129.43, 129.36, 129.3, 128.7, 125.8, 34.6, 31.2 (J_{C-P} = 69.7 Hz), 24.7 (d, J_{C-P} = 3.0 Hz), 21.8, 21.3. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{25}H_{23}Cl_2N_2O_2P$ 485.0947, found 485.0937.

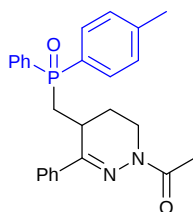


1-(4-((Di(naphthalen-2-yl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3af, 86.8 mg, 84%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 8.38-8.31 (m, 2H), 7.87-7.75 (m, 6H), 7.62-7.46 (m, 6H), 7.38-7.35 (m, 2H), 7.20-7.17 (m, 1H), 7.09-7.05 (m, 2H), 4.31-4.25 (m, 1H), 3.50-3.44 (m, 1H), 3.24-3.16 (m, 1H), 2.57-2.40 (m, 2H), 2.40-2.31 (m, 4H), 1.82-1.72 (m, 1H); ^{13}C

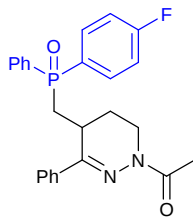
NMR (101 MHz, CDCl₃) δ 172.5, 148.1 (d, J_{C-P} = 14.1 Hz), 135.2, 134.8 (d, J_{C-P} = 2.0 Hz), 134.7 (d, J_{C-P} = 3.0 Hz), 133.3 (d, J_{C-P} = 8.1 Hz), 132.6 (d, J_{C-P} = 9.1 Hz), 130.7, 129.7, 129.5, 129.3, 129.0, 128.9, 128.8, 128.7, 128.6, 128.5, 127.9, 127.3, 125.8, 125.7 (d, J_{C-P} = 10.1 Hz), 125.1 (d, J_{C-P} = 10.1 Hz), 34.7, 31.0 (d, J_{C-P} = 67.7 Hz), 24.9 (d, J_{C-P} = 2.0 Hz), 21.8, 21.4. HRMS (ESI) m/z : [M+Na]⁺ calcd for C₃₃H₂₉N₂NaO₂P 539.1859, found 539.1861.



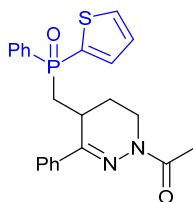
1-(4-((Di(naphthalen-1-yl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ag), 21.7 mg, 21%), colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 8.54-8.46 (m, 2H), 8.11-8.00 (m, 4H), 7.94-7.87 (m, 2H), 7.56-7.32 (m, 8H), 7.24-7.21 (m, 1H), 7.10 (t, J = 7.6 Hz, 2H), 4.31-4.26 (m, 1H), 3.58-3.51 (m, 1H), 3.18-3.10 (m, 1H), 2.90-2.71 (m, 2H), 2.38-2.31 (m, 4H), 1.81-1.71 (m, 1H); ¹³C NMR (101 MHz, CDCl₃) δ 172.5, 148.3 (d, J_{C-P} = 13.1 Hz), 135.2, 134.0 (d, J_{C-P} = 3.0 Hz), 133.9 (d, J_{C-P} = 3.0 Hz), 133.7 (d, J_{C-P} = 3.0 Hz), 133.6 (d, J_{C-P} = 2.0 Hz), 133.4, 133.3, 133.0, 132.9, 131.9 (d, J_{C-P} = 9.1 Hz), 130.1, 129.3, 129.1 (d, J_{C-P} = 4.0 Hz), 128.5, 127.7, 126.7 (d, J_{C-P} = 2.0 Hz), 126.0 (d, J_{C-P} = 5.1 Hz), 125.8, 124.9, 124.7, 124.6, 34.7, 31.0 (d, J_{C-P} = 69.7 Hz), 25.1 (d, J_{C-P} = 2.0 Hz), 21.5, 21.4. HRMS (ESI) m/z : [M+H]⁺ calcd for C₃₃H₂₉N₂O₂P 517.2039, found 517.2037.



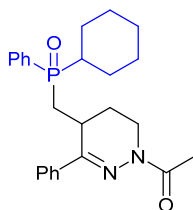
1-(3-Phenyl-4-((phenyl(p-tolyl)phosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ah), 47.4 mg, 55%), colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 7.73-7.69 (m, 2H), 7.63-7.55 (m, 3H), 7.51-7.43 (m, 4H), 7.33-7.24 (m, 5H), 4.35-4.31 (m, 1H), 3.52-3.43 (m, 1H), 3.24-3.17 (m, 1H), 2.43-2.34 (m, 9H), 1.86-1.77 (m, 1H); ¹³C NMR (101 MHz, CDCl₃) δ 172.5, 148.2 (d, J_{C-P} = 13.1 Hz), 142.8 (d, J_{C-P} = 3.0 Hz), 135.4 (d, J_{C-P} = 4.0 Hz), 133.5 (d, J_{C-P} = 9.1 Hz), 132.1, 131.2, 131.1 (d, J_{C-P} = 2.0 Hz), 131.0, 130.6, 130.5 (d, J_{C-P} = 2.0 Hz), 130.4, 129.7 (d, J_{C-P} = 5.1 Hz), 129.6 (d, J_{C-P} = 5.1 Hz), 129.3, 128.9 (d, J_{C-P} = 3.0 Hz), 128.8 (d, J_{C-P} = 3.1 Hz), 128.7 (d, J_{C-P} = 4.0 Hz), 125.8 (d, J_{C-P} = 5.1 Hz), 34.7, 31.5 (d, J_{C-P} = 5.1 Hz), 30.9 (d, J_{C-P} = 5.1 Hz), 24.8 (d, J_{C-P} = 4.0 Hz), 21.6 (d, J_{C-P} = 4.0 Hz), 21.4. HRMS (ESI) m/z : [M+H]⁺ calcd for C₂₆H₂₇N₂O₂P 431.1883, found 431.1872.



1-(4-(((4-Fluorophenyl)(phenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ai), 53.0 mg, 61%), yellow oil; ^1H NMR (400 MHz, CDCl_3) δ 7.69-7.62 (m, 4H), 7.47-7.34 (m, 5H), 7.25-7.05 (m, 5H), 4.32-4.24 (m, 1H), 3.43-3.32 (m, 1H), 3.20-3.10 (m, 1H), 2.39-2.15 (m, 6H), 1.82-1.71 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 165.2 (d, $J_{\text{C-F}} = 255.5$ Hz), 148.1 (d, $J_{\text{C-P}} = 6.1$ Hz), 147.9 (d, $J_{\text{C-P}} = 5.1$ Hz), 135.3 (d, $J_{\text{C-P}} = 4.0$ Hz), 133.7, 133.6 (d, $J_{\text{C-P}} = 2.0$ Hz), 133.5, 133.4, 133.3 (d, $J_{\text{C-P}} = 4.0$ Hz), 133.2, 133.1, 133.0 (d, $J_{\text{C-P}} = 2.0$ Hz), 132.9, 132.4 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.2, 131.2, 131.0 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.6 (d, $J_{\text{C-P}} = 11.1$ Hz), 130.4 (d, $J_{\text{C-F}} = 9.1$ Hz), 129.6, 129.4 (d, $J_{\text{C-P}} = 5.1$ Hz), 129.1 (d, $J_{\text{C-F}} = 3.0$ Hz), 129.0 (d, $J_{\text{C-F}} = 2.0$ Hz), 128.7, 125.8, 116.5, 116.3 (d, $J_{\text{C-P}} = 21.2$ Hz), 116.4 116.3 (d, $J_{\text{C-P}} = 2.0$ Hz), 116.2, 116.1, 34.6, 31.2 (d, $J_{\text{C-P}} = 68.7$ Hz), 24.7 (d, $J_{\text{C-P}} = 3.0$ Hz), 21.7, 21.3. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{24}\text{FN}_2\text{O}_2\text{P}$ 435.1632, found 435.1633.

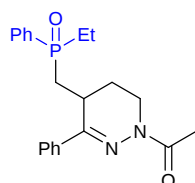


1-(3-Phenyl-4-((phenyl(thiophen-2-yl)phosphoryl)methyl)-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3aj), 53.2 mg, 63%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.82-7.69 (m, 3H), 7.65-7.47 (m, 5H), 7.39-7.30 (m, 3H), 7.26-7.16 (m, 2H), 4.44-4.26 (m, 1H), 3.66-3.35 (m, 1H), 3.32-3.13 (m, 1H), 2.51-2.19 (m, 6H), 1.92-1.77 (m, 1H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.4, 148.0, 147.9 (d, $J_{\text{C-P}} = 3.0$ Hz), 147.7, 135.7 (d, $J_{\text{C-P}} = 10.1$ Hz), 135.4, 135.3, 134.2 (d, $J_{\text{C-P}} = 51.5$ Hz), 133.7 (d, $J_{\text{C-P}} = 4.0$ Hz), 133.6 (d, $J_{\text{C-P}} = 5.0$ Hz), 133.4, 132.9, 132.6, 132.5, 132.4, 131.4, 131.1 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.3 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.3 (d, $J_{\text{C-P}} = 8.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 5.1$ Hz), 128.9 (d, $J_{\text{C-P}} = 5.1$ Hz), 128.7 (d, $J_{\text{C-P}} = 9.1$ Hz), 128.6 (d, $J_{\text{C-P}} = 5.1$ Hz), 125.8 (d, $J_{\text{C-P}} = 7.1$ Hz), 34.7, 33.8 (d, $J_{\text{C-P}} = 12.1$ Hz), 33.1 (d, $J_{\text{C-P}} = 12.1$ Hz), 25.0 (d, $J_{\text{C-P}} = 2.0$ Hz), 24.9 (d, $J_{\text{C-P}} = 2.0$ Hz), 21.7 (d, $J_{\text{C-P}} = 9.1$ Hz), 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{23}\text{H}_{23}\text{N}_2\text{O}_2\text{PS}$ 423.1291, found 423.1293.

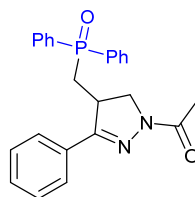


1-(4-((Cyclohexyl(phenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3ak), 27.9 mg, 33%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ

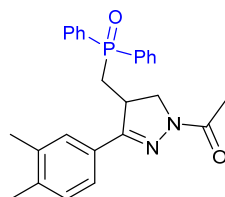
7.70-7.62 (m, 3H), 7.58-7.53 (m, 2H), 7.32-7.28 (m, 1H), 7.25-7.18 (m, 4H), 4.46-4.41 (m, 1H), 3.35-3.27 (m, 1H), 3.08-3.01 (m, 1H), 2.74-2.68 (m, 1H), 2.38 (s, 3H), 2.21-2.11 (m, 1H), 1.95-1.64 (m, 7H), 1.49-1.14 (m, 6H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.5, 148.4 (d, $J_{\text{C-P}} = 13.1$ Hz), 135.5, 132.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.4 (d, $J_{\text{C-P}} = 8.1$ Hz), 130.8, 129.9, 129.2, 128.8 (d, $J_{\text{C-P}} = 11.1$ Hz), 128.5, 125.9, 39.1 (d, $J_{\text{C-P}} = 7.1$ Hz), 34.7, 28.1 (d, $J_{\text{C-P}} = 61.6$ Hz), 26.1 (d, $J_{\text{C-P}} = 13.1$ Hz), 25.7, 25.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 24.83, 24.79, 24.75, 21.8, 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{31}\text{N}_2\text{O}_2\text{P}$ 423.2196, found 423.2192.



1-(4-((Ethyl(phenyl)phosphoryl)methyl)-3-phenyl-5,6-dihydropyridazin-1(4H)-yl)ethan-1-one (3al, 22.1 mg, 30%), colorless oil; ^1H NMR (400 MHz, Chloroform- d) δ 7.73-7.47 (m, 6H), 7.31-7.27 (m, 1H), 7.21-7.17 (m, 3H), 4.48-4.43 (m, 1H), 3.33-3.25 (m, 1H), 3.13-3.05 (m, 1H), 2.71-2.65 (m, 1H), 2.38 (s, 3H), 2.12-1.83 (m, 5H), 1.12-1.06 (m, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.5, 148.1 (d, $J_{\text{C-P}} = 13.1$ Hz), 135.4, 132.2 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.3, 131.0 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.4, 129.2, 129.0 (d, $J_{\text{C-P}} = 11.1$ Hz), 128.5, 125.7, 34.6, 31.1 (d, $J_{\text{C-P}} = 64.6$ Hz), 25.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 23.7 (d, $J_{\text{C-P}} = 70.7$ Hz), 21.9, 21.4, 5.3 (d, $J_{\text{C-P}} = 5.1$ Hz). HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{21}\text{H}_{25}\text{N}_2\text{NaO}_2\text{P}$ 391.1546, found 391.1540.

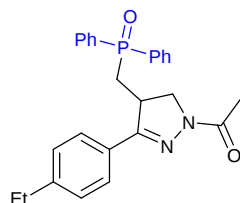


1-(4-((Diphenylphosphoryl)methyl)-3-phenyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5aa, 66.8 mg, 83%), white solid, mp 216-218 $^{\circ}\text{C}$; ^1H NMR (400 MHz, CDCl_3) δ 7.75-7.66 (m, 4H), 7.56-7.41 (m, 8H), 7.33-7.31 (m, 3H), 4.01-3.92 (m, 1H), 3.88-3.73 (m, 2H), 2.55 (t, $J = 14.0$ Hz, 1H), 2.40-2.29 (m, 4H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.4, 157.6 (d, $J_{\text{C-P}} = 13.1$ Hz), 132.4 (d, $J_{\text{C-P}} = 8.1$ Hz), 131.5 (d, $J_{\text{C-P}} = 2.0$ Hz), 130.9 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.7 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.3, 129.6, 129.0, 129.0, 129.0, 128.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 126.9, 50.9, 37.6 (d, $J_{\text{C-P}} = 3.0$ Hz), 32.8 (d, $J_{\text{C-P}} = 68.7$ Hz), 21.5. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{23}\text{N}_2\text{O}_2\text{P}$ 403.1570, found 403.1560.

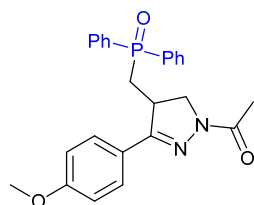


1-(3-(3,4-Dimethylphenyl)-4-((diphenylphosphoryl)methyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ba, 62.9 mg, 73%), white solid, mp 218-219 $^{\circ}\text{C}$; ^1H NMR (400 MHz, CDCl_3) δ 7.71-7.60 (m, 4H), 7.52-7.34 (m, 7H), 7.23-7.20 (m, 1H), 7.04

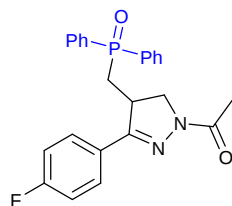
(d, $J = 7.8$ Hz, 1H), 3.90-3.81 (m, 2H), 3.76-3.70 (m, 1H), 2.54-2.48 (m, 1H), 2.33-2.24 (m, 4H), 2.18 (s, 3H), 2.16 (s, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.3, 157.9 (d, $J_{\text{C-P}} = 13.1$ Hz), 139.5, 137.4, 132.7, 132.5, 132.4 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.7, 131.5, 130.9 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.7 (d, $J_{\text{C-P}} = 10.0$ Hz), 130.3, 129.0 (d, $J_{\text{C-P}} = 11.1$ Hz), 127.9, 127.2, 124.5, 50.8, 37.7 (d, $J_{\text{C-P}} = 4.0$ Hz), 32.9 (d, $J_{\text{C-P}} = 68.7$ Hz), 21.6, 19.8 (d, $J_{\text{C-P}} = 2.0$ Hz). HRMS (ESI) m/z : $[\text{M}+\text{Na}]^+$ calcd for $\text{C}_{26}\text{H}_{27}\text{N}_2\text{NaO}_2\text{P}$ 453.1702, found 453.1701.



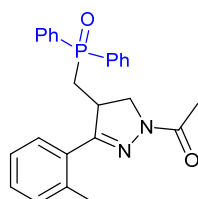
1-(4-((Diphenylphosphoryl)methyl)-3-(4-ethylphenyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ca), 58.5 mg, 68%), white solid, mp 265-267 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.77-7.68 (m, 4H), 7.56-7.43 (m, 8H), 7.17 (d, $J = 8.0$ Hz, 2H), 4.02-3.92 (m, 1H), 3.87-3.83 (m, 1H), 3.79-3.73 (m, 1H), 2.66-2.55 (m, 3H), 2.40-2.31 (m, 4H), 1.20 (t, $J = 7.6$ Hz, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.3, 157.8 (d, $J_{\text{C-P}} = 13.1$ Hz), 146.9, 132.6, 132.4 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.6, 130.9 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.7 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 6.7$ Hz), 128.9 (d, $J_{\text{C-P}} = 6.7$ Hz), 128.6, 127.0, 127.0, 50.8, 37.6 (d, $J_{\text{C-P}} = 3.0$ Hz), 32.9 (d, $J_{\text{C-P}} = 68.7$ Hz), 28.8, 21.5, 15.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{23}\text{N}_2\text{O}_2\text{P}$ 431.1883, found 431.1881.



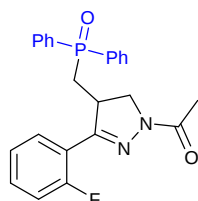
1-(4-((Diphenylphosphoryl)methyl)-3-(4-methoxyphenyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5da), 64.0 mg, 74%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.77-7.69 (m, 4H), 7.58-7.45 (m, 8H), 6.89-6.87 (m, 2H), 4.04-3.94 (m, 1H), 3.81-3.69 (m, 5H), 2.62-2.55 (m, 1H), 2.41-2.31 (m, 4H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.2, 161.2, 157.6 (d, $J_{\text{C-P}} = 12.1$ Hz), 132.7, 132.5 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.2 (d, $J_{\text{C-P}} = 100.0$ Hz), 131.4, 130.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 130.8 (d, $J_{\text{C-P}} = 5.0$ Hz), 129.0 (d, $J_{\text{C-P}} = 10.1$ Hz), 128.6, 122.1, 114.4, 55.4, 50.9, 37.5 (d, $J_{\text{C-P}} = 4.0$ Hz), 33.1 (d, $J_{\text{C-P}} = 68.7$ Hz), 21.5. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{25}\text{N}_2\text{O}_3\text{P}$ 433.1676, found 433.1686.



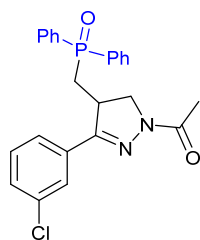
1-(4-((Diphenylphosphoryl)methyl)-3-(4-fluorophenyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ea, 58.9 mg, 70%), white solid, mp 293-294 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.75-7.67 (m, 4H), 7.61-7.43 (m, 8H), 7.05-7.00 (m, 2H), 4.02-3.92 (m, 1H), 3.82-3.70 (m, 2H), 2.56-2.48 (m, 1H), 2.42-2.33 (m, 1H), 2.29 (s, 3H); ¹³C NMR (101 MHz, CDCl₃) δ 169.3, 163.8 (d, *J*_{C-F} = 252.4 Hz), 156.7 (d, *J*_{C-P} = 12.4 Hz), 132.6, 132.5 (d, *J*_{C-P} = 2.8 Hz), 132.4 (d, *J*_{C-P} = 2.7 Hz), 132.2, 131.6, 131.3, 130.8 (d, *J*_{C-P} = 2.5 Hz), 130.7 (d, *J*_{C-P} = 2.8 Hz), 129.1 (d, *J*_{C-F} = 7.2 Hz), 129.0 (d, *J*_{C-P} = 2.8 Hz), 128.9, 125.9 (d, *J*_{C-F} = 3.2 Hz), 116.2 (d, *J*_{C-F} = 21.9 Hz), 51.2, 37.5 (d, *J*_{C-P} = 3.2 Hz), 32.9 (d, *J*_{C-P} = 69.0 Hz), 21.5. HRMS (ESI) *m/z*: [M+H]⁺ calcd for C₂₄H₂₂FN₂O₂P 421.1476, found 421.1481.



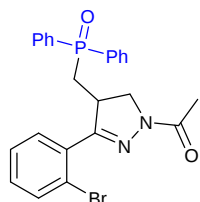
1-(4-((Diphenylphosphoryl)methyl)-3-(o-tolyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5fa, 65.8 mg, 79%), white solid, mp 229-230 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.66-7.59 (m, 4H), 7.50-7.34 (m, 6H), 7.22-7.19 (m, 2H), 7.13-7.05 (m, 2H), 4.01-3.92 (m, 1H), 3.84-3.73 (m, 2H), 2.44-2.37 (m, 4H), 2.30-2.21 (m, 4H); ¹³C NMR (101 MHz, CDCl₃) δ 169.3, 158.2 (d, *J*_{C-P} = 13.1 Hz), 138.4, 132.2 (d, *J*_{C-P} = 100.0 Hz), 132.4 (d, *J*_{C-P} = 3.0 Hz), 132.3 (d, *J*_{C-P} = 3.0 Hz), 132.0, 131.7, 131.3, 130.9 (d, *J*_{C-P} = 9.1 Hz), 130.7 (d, *J*_{C-P} = 9.1 Hz), 129.5, 129.0 (d, *J*_{C-P} = 5.1 Hz), 128.9 (d, *J*_{C-P} = 6.1 Hz), 128.7, 128.5, 126.2, 49.9, 39.8 (d, *J*_{C-P} = 3.0 Hz), 32.8 (d, *J*_{C-P} = 68.7 Hz), 22.5, 21.6. HRMS (ESI) *m/z*: [M+H]⁺ calcd for C₂₅H₂₅N₂O₂P 417.1726, found 417.1714.



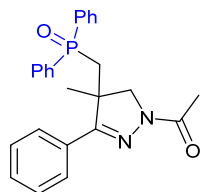
1-(4-((Diphenylphosphoryl)methyl)-3-(2-fluorophenyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ga, 54.7 mg, 65%), colorless oil; ¹H NMR (400 MHz, CDCl₃) δ 7.78-7.66 (m, 5H), 7.55-7.47 (m, 4H), 7.44-7.37 (m, 3H), 7.17 (t, *J* = 7.6 Hz, 1H), 7.10-7.05 (m, 1H), 4.08-3.93 (m, 3H), 2.57-2.51 (m, 1H), 2.37-2.28 (s, 4H); ¹³C NMR (101 MHz, CDCl₃) δ 169.3, 160.4 (d, *J*_{C-F} = 253.6 Hz), 154.5 (d, *J*_{C-P} = 2.8 Hz), 154.3 (d, *J*_{C-P} = 3.0 Hz), 133.3, 132.3, 132.2 (d, *J*_{C-P} = 1.2 Hz), 132.0 (d, *J*_{C-F} = 7.9 Hz), 131.0 (d, *J*_{C-P} = 9.2 Hz), 130.6 (d, *J*_{C-P} = 9.5 Hz), 129.8 (d, *J*_{C-P} = 9.5 Hz), 128.9 (d, *J*_{C-P} = 5.5 Hz), 128.8 (d, *J*_{C-P} = 5.4 Hz), 124.9 (d, *J*_{C-F} = 3.3 Hz), 118.2 (d, *J*_{C-P} = 11.7 Hz), 116.6 (d, *J*_{C-F} = 22.1 Hz), 50.1, 40.5 (d, *J*_{C-P} = 3.3 Hz), 40.5 (d, *J*_{C-P} = 3.0 Hz), 32.5 (d, *J*_{C-P} = 68.9 Hz), 21.5. HRMS (ESI) *m/z*: [M+H]⁺ calcd for C₂₄H₂₂FN₂O₂P 421.1476, found 421.1483.



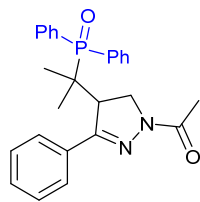
1-(3-(3-Chlorophenyl)-4-((diphenylphosphoryl)methyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ha), 78.6 mg, 90%), white solid, mp 255-256 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.73-7.62 (m, 4H), 7.52-7.38 (m, 8H), 7.29-7.20 (m, 2H), 3.92-3.74 (m, 3H), 2.51-2.44 (m, 1H), 2.36-2.27 (m, 4H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.5, 156.2 (d, $J_{\text{C-P}} = 13.1$ Hz), 135.0, 132.5 (d, $J_{\text{C-P}} = 4.0$ Hz), 132.4, 131.8 (d, $J_{\text{C-P}} = 10.1$ Hz), 131.6, 131.5, 130.9 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.7 (d, $J_{\text{C-P}} = 10.1$ Hz), 130.3 (d, $J_{\text{C-P}} = 17.2$ Hz), 129.1 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 8.1$ Hz), 126.7, 125.1, 51.2, 37.6 (d, $J_{\text{C-P}} = 3.0$ Hz), 32.8 (d, $J_{\text{C-P}} = 69.7$ Hz), 21.5. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{22}\text{ClN}_2\text{O}_2\text{P}$ 437.1180, found 437.1175.



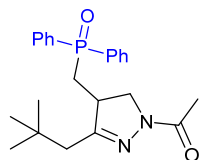
1-(3-(2-Bromophenyl)-4-((diphenylphosphoryl)methyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ia), 63.5 mg, 66%), white solid, mp 290-291 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.64-7.54 (m, 5H), 7.49-7.19 (m, 10H), 4.20-4.11 (m, 1H), 4.03 (t, $J = 11.9$ Hz, 1H), 3.84-3.79 (m, 1H), 2.35-2.20 (m, 5H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.4, 158.0 (d, $J_{\text{C-P}} = 15.2$ Hz), 134.0, 133.0, 132.3 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.0, 131.4, 131.4, 131.2, 131.0 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.6 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.8 (d, $J_{\text{C-P}} = 4.0$ Hz), 127.8, 122.0, 50.3, 40.8 (d, $J_{\text{C-P}} = 3.0$ Hz), 32.1 (d, $J_{\text{C-P}} = 69.7$ Hz), 21.6. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{22}\text{BrN}_2\text{O}_2\text{P}$ 481.0675, found 481.0673.



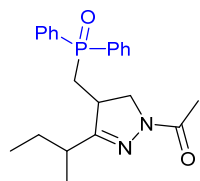
1-(4-((Diphenylphosphoryl)methyl)-4-methyl-3-phenyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ja), 74.1 mg, 89%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.81-7.76 (m, 2H), 7.69-7.60 (m, 4H), 7.51-7.36 (m, 9H), 4.34 (d, $J = 12.5$ Hz, 1H), 3.79 (d, $J = 12.5$ Hz, 1H), 2.95-2.88 (m, 1H), 2.70-2.64 (m, 1H), 2.31 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ 169.3, 159.7 (d, $J_{\text{C-P}} = 11.1$ Hz), 134.3, 133.7, 133.3, 132.7, 132.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 130.5 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.8, 129.0, 128.9, 128.8, 128.8, 128.7, 127.3, 58.1, 49.3 (d, $J_{\text{C-P}} = 4.0$ Hz), 37.1 (d, $J_{\text{C-P}} = 68.7$ Hz), 25.9 (d, $J_{\text{C-P}} = 5.1$ Hz), 21.4. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{25}\text{H}_{25}\text{N}_2\text{O}_2\text{P}$ 417.1726, found 417.1715.



1-(4-(2-(Diphenylphosphoryl)propan-2-yl)-3-phenyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ka), 72.3 mg, 84%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.91-7.86 (m, 2H), 7.81-7.75 (m, 2H), 7.52-7.45 (m, 6H), 7.39-7.32 (m, 5H), 4.22-4.13 (m, 1H), 3.80-3.73 (m, 1H), 2.81-2.76 (m, 1H), 2.26 (s, 3H), 1.43 (s, 3H), 1.28-1.26 (m, 4H); ^{13}C NMR (101 MHz, CDCl_3) δ 172.0, 156.3 (d, $J_{\text{C-P}} = 6.1$ Hz), 137.5, 134.0 (d, $J_{\text{C-P}} = 97.0$ Hz), 132.7, 132.1 (d, $J_{\text{C-P}} = 2.0$ Hz), 132.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.0 (d, $J_{\text{C-P}} = 9.1$ Hz), 130.6 (d, $J_{\text{C-P}} = 9.1$ Hz), 129.9, 129.0, 128.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 128.2 (d, $J_{\text{C-P}} = 6.1$ Hz), 127.9, 40.7, 40.0, 38.0, 37.0 (d, $J_{\text{C-P}} = 3.0$ Hz), 28.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 24.9 (d, $J_{\text{C-P}} = 4.0$ Hz), 21.3. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{26}\text{H}_{27}\text{N}_2\text{O}_2\text{P}$ 431.1883, found 431.1877.

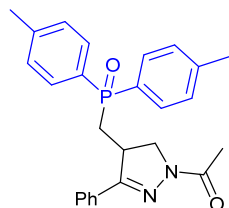


1-(4-((Diphenylphosphoryl)methyl)-3-neopentyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5la), 17.4 mg, 22%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.80-7.72 (m, 4H), 7.57-7.49 (m, 6H), 3.77-3.71 (m, 1H), 3.57-3.52 (m, 1H), 3.44-3.37 (m, 1H), 2.59-2.52 (m, 1H), 2.31-2.27 (m, 1H), 2.23 (s, 3H), 2.18-2.01 (m, 2H), 0.95 (s, 9H); ^{13}C NMR (101 MHz, CDCl_3) δ 168.8, 159.7 (d, $J_{\text{C-P}} = 12.1$ Hz), 132.7, 132.6, 132.4 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.3 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.7, 131.6, 130.8 (d, $J_{\text{C-P}} = 1.0$ Hz), 130.7 (d, $J_{\text{C-P}} = 2.0$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 7.1$ Hz), 128.9 (d, $J_{\text{C-P}} = 7.1$ Hz), 128.7 (d, $J_{\text{C-P}} = 12.1$ Hz), 49.3, 42.2 (d, $J_{\text{C-P}} = 3.0$ Hz), 40.7, 31.8 (d, $J_{\text{C-P}} = 69.7$ Hz), 31.8, 21.5. HRMS (ESI) m/z : $[\text{M}+\text{H}]^+$ calcd for $\text{C}_{23}\text{H}_{29}\text{N}_2\text{O}_2\text{P}$ 397.2059, found 397.2061.

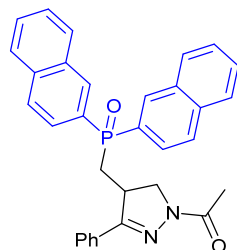


1-(3-(Sec-butyl)-4-((diphenylphosphoryl)methyl)-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ma), 52.0 mg, 68%), colorless oil; ^1H NMR (400 MHz, CDCl_3) δ 7.72-7.62 (m, 4H), 7.51-7.39 (m, 6H), 3.73-3.66 (m, 1H), 3.48-3.31 (m, 1.79H), 2.53-2.37 (m, 1.78H), 2.33-2.20 (m, 1.43H), 2.13 (s, 3H), 1.77-1.66 (m, 0.5H), 1.54-1.36 (m, 1H), 1.31-1.24 (m, 0.5H), 1.10 (d, $J = 6.7$ Hz, 1.49H), 0.98 (d, $J = 7.0$ Hz, 1.5H), 0.86 (t, $J = 7.4$ Hz, 1.5H), 0.76 (t, $J = 7.4$ Hz, 1.5H); ^{13}C NMR (101 MHz, CDCl_3) δ 168.8, 164.9, 164.7, 164.6, 132.7 (d, $J_{\text{C-P}} = 3.0$ Hz), 132.4 (d, $J_{\text{C-P}} = 3.1$ Hz), 132.2 (d, $J_{\text{C-P}} = 3.0$ Hz), 131.8 (d, $J_{\text{C-P}} = 2.0$ Hz), 131.7 (d, $J_{\text{C-P}} = 2.0$ Hz), 130.7 (d, $J_{\text{C-P}} = 3.0$ Hz), 130.6 (d, $J_{\text{C-P}} = 3.0$ Hz), 130.5 (d, $J_{\text{C-P}} = 10.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 12.1$ Hz), 129.0 (d, $J_{\text{C-P}} = 2.0$ Hz), 128.9 (d, $J_{\text{C-P}} = 2.0$ Hz), 128.6 (d, $J_{\text{C-P}} = 12.1$ Hz), 49.9

(d, J_{C-P} = 9.1 Hz), 39.9 (d, J_{C-P} = 4.0 Hz), 39.5 (d, J_{C-P} = 3.0 Hz), 34.3, 33.5, 32.6 (d, J_{C-P} = 5.1 Hz), 31.9 (d, J_{C-P} = 5.1 Hz), 26.9 (d, J_{C-P} = 73.7 Hz), 21.3, 18.4, 16.3, 12.0, 10.8. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{22}H_{27}N_2O_2P$ 383.1883, found 383.1969.



1-(4-((Di-p-tolylphosphoryl)methyl)-3-phenyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ab), 62.0 mg, 72%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 7.59-7.50 (m, 6H), 7.33-7.30 (m, 3H), 7.25-7.19 (m, 4H), 4.04-3.94 (m, 1H), 3.78-3.68 (m, 2H), 2.54-2.47 (m, 1H), 2.32 (d, J = 7.8 Hz, 6H), 2.29-2.22 (s, 4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.2, 169.4, 157.9 (d, J_{C-P} = 13.1 Hz), 142.9 (d, J_{C-P} = 2.0 Hz), 142.8 (d, J_{C-P} = 2.0 Hz), 130.9 (d, J_{C-P} = 4.0 Hz), 130.8 (d, J_{C-P} = 4.0 Hz), 130.2, 129.8, 129.7, 129.7, 129.5, 129.3, 129.0, 128.5, 128.3, 128.2, 127.0, 60.4, 51.0, 37.6 (d, J_{C-P} = 4.0 Hz), 33.1 (d, J_{C-P} = 68.7 Hz), 21.7, 21.5, 21.1, 14.2. HRMS (ESI) m/z : $[M+Na]^+$ calcd for $C_{26}H_{27}N_2O_2P$ 453.1702, found 453.1697.

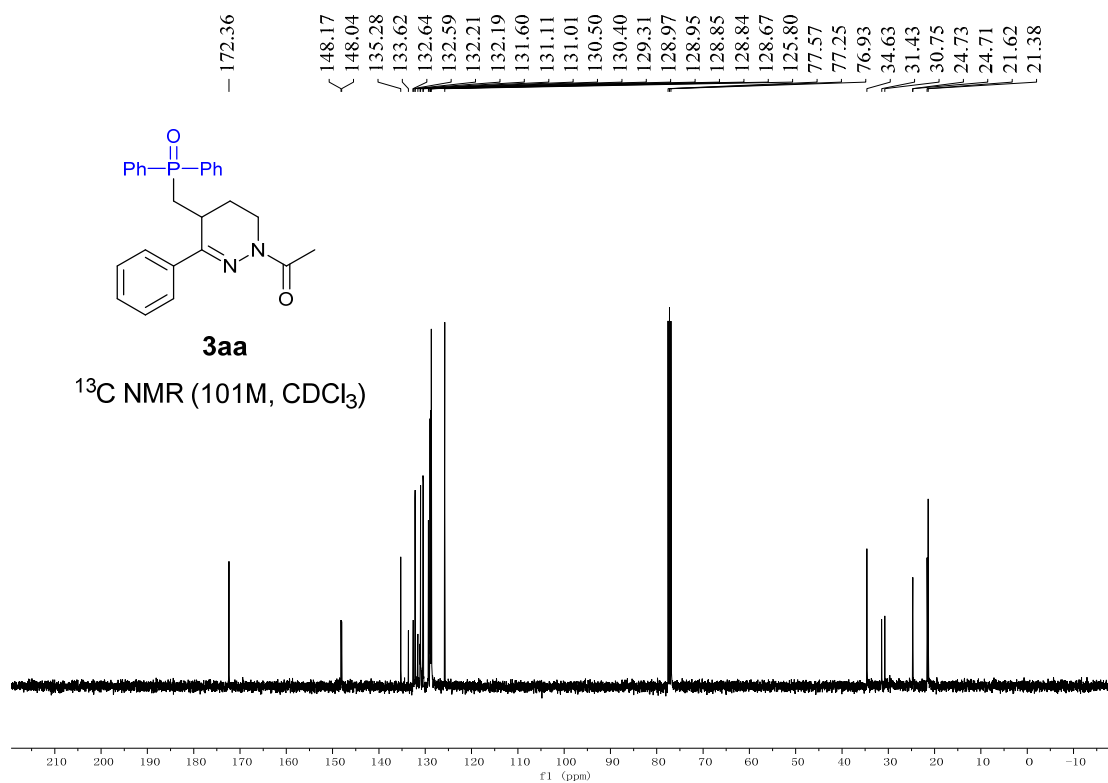
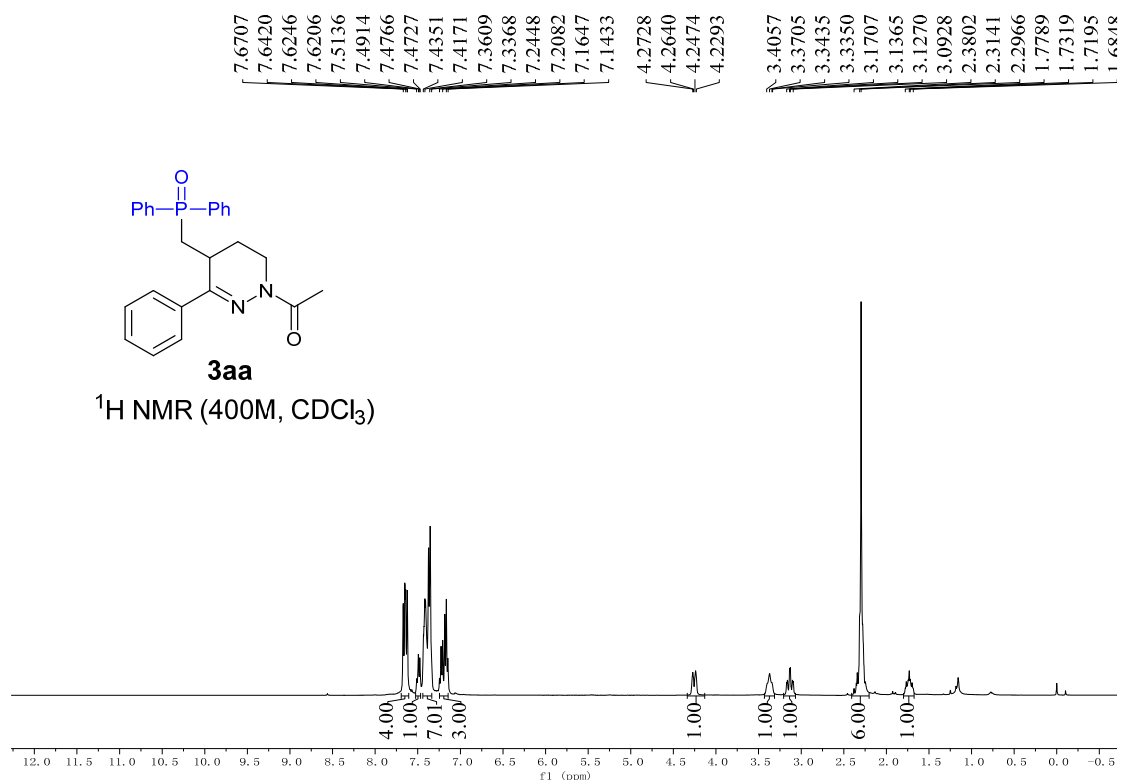


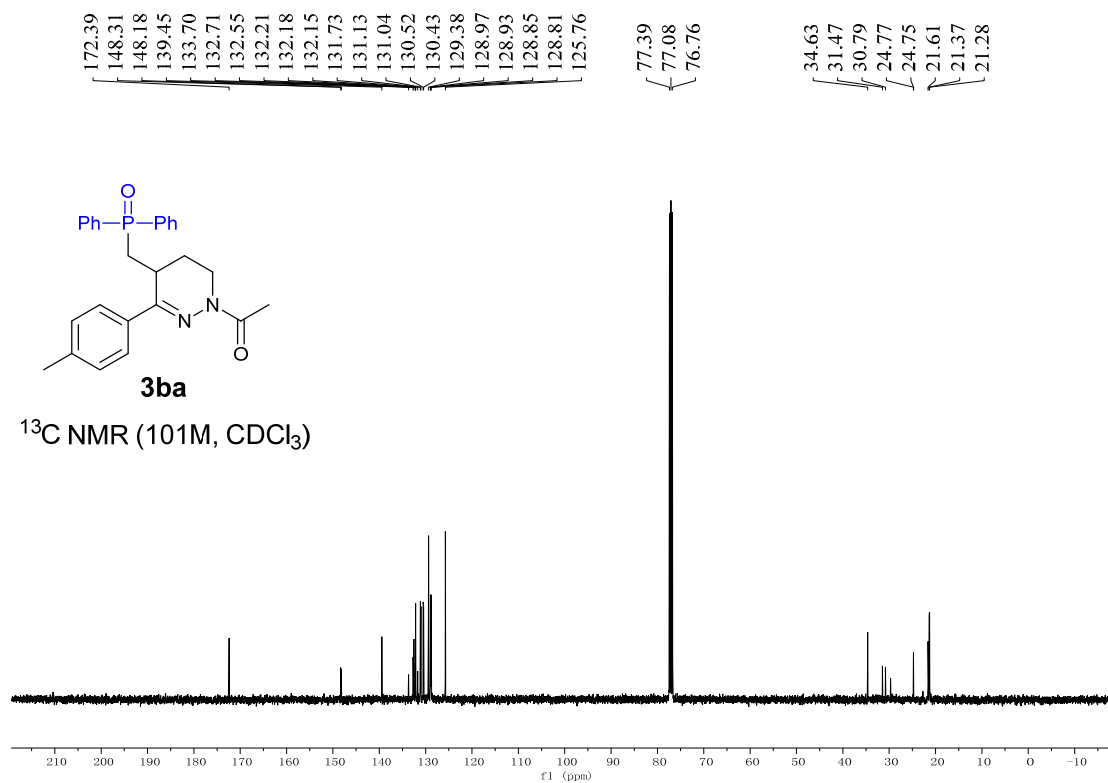
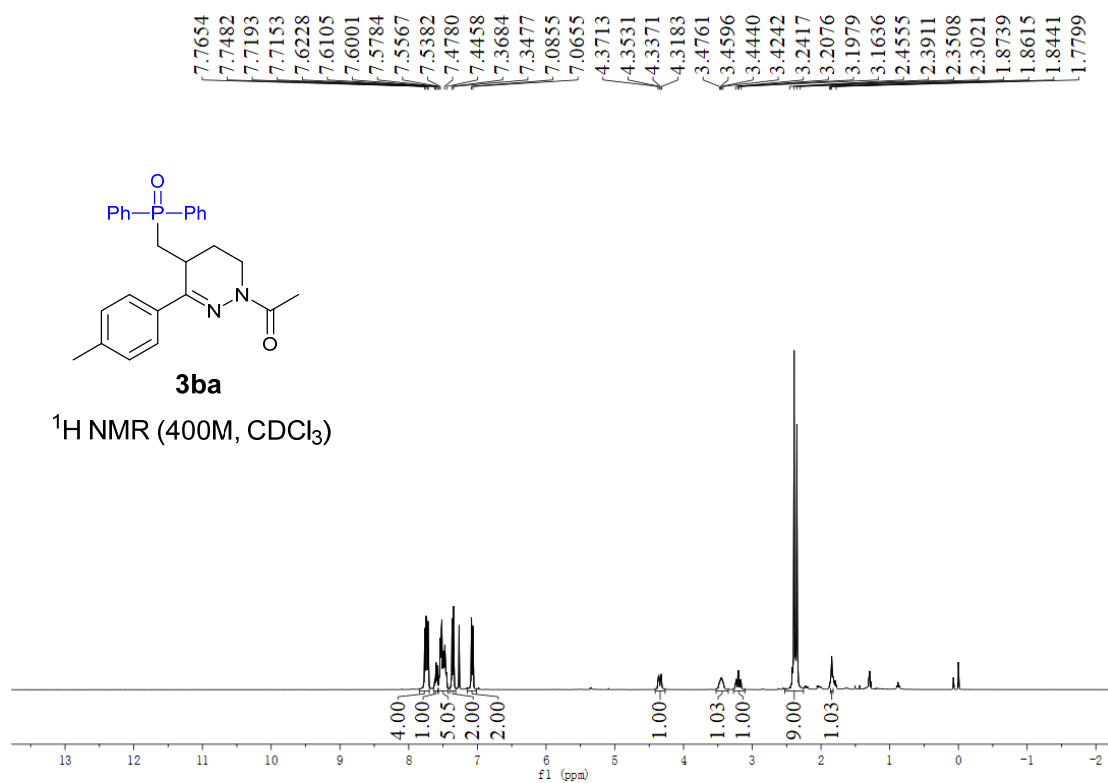
1-(4-((Di(naphthalen-2-yl)phosphoryl)methyl)-3-phenyl-4,5-dihydro-1H-pyrazol-1-yl)ethan-1-one (5ae), 47.2 mg, 47%), colorless oil; 1H NMR (400 MHz, $CDCl_3$) δ 8.49-8.44 (m, 2H), 8.00-7.86 (m, 6H), 7.75-7.56 (m, 8H), 7.40-7.34 (m, 3H), 4.15-3.99 (m, 2H), 3.87-3.82 (m, 1H), 2.84-2.77 (m, 1H), 2.66-2.57 (m, 1H), 2.36 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.2, 169.5, 157.7 (d, J_{C-P} = 13.1 Hz), 134.8 (d, J_{C-P} = 3.0 Hz), 133.3, 133.2, 133.1, 132.6 (d, J_{C-P} = 12.1 Hz), 130.3, 129.7, 129.5 (d, J_{C-P} = 2.0 Hz), 129.1, 129.1, 129.0, 129.0, 128.9, 128.9, 128.8, 128.6 (d, J_{C-P} = 3.0 Hz), 128.5 (d, J_{C-P} = 2.0 Hz), 128.3, 128.0 (d, J_{C-P} = 5.1 Hz), 127.3 (d, J_{C-P} = 6.1 Hz), 127.0, 125.0 (d, J_{C-P} = 10.1 Hz), 125.2 (d, J_{C-P} = 11.1 Hz), 60.4, 51.2, 37.7 (d, J_{C-P} = 3.0 Hz), 32.7 (d, J_{C-P} = 69.7 Hz), 21.6, 21.1, 14.2. HRMS (ESI) m/z : $[M+H]^+$ calcd for $C_{33}H_{27}N_2O_2P$ 503.1885, found 503.1883.

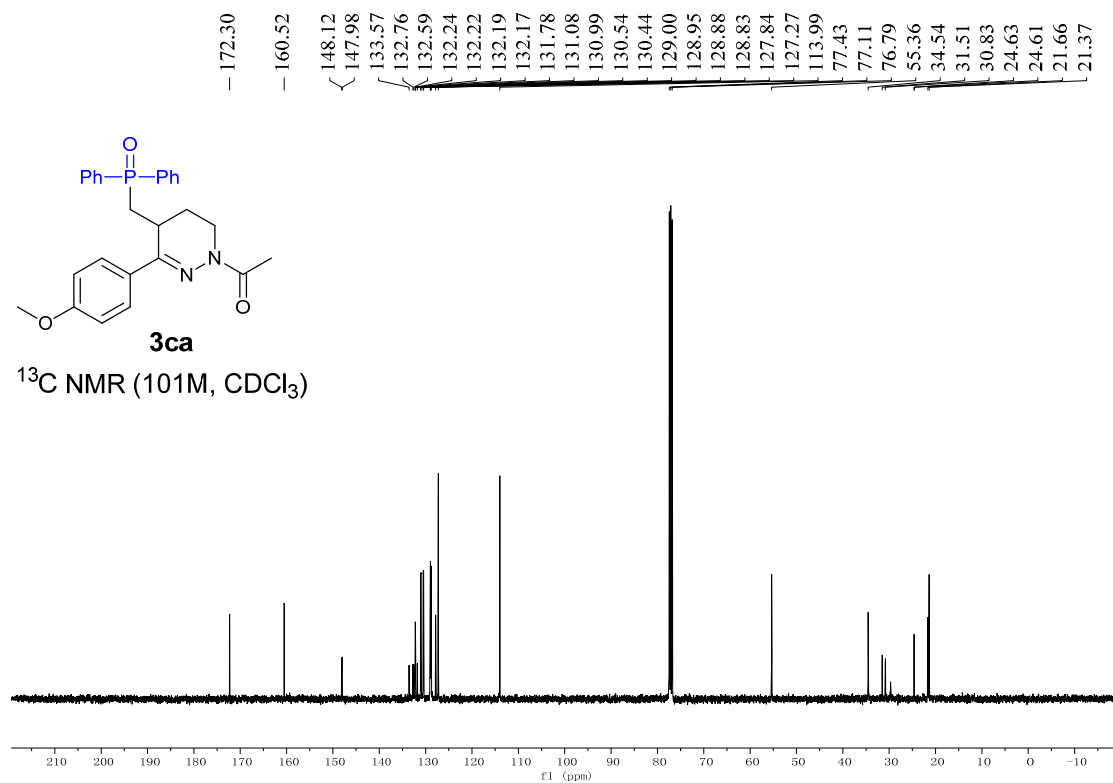
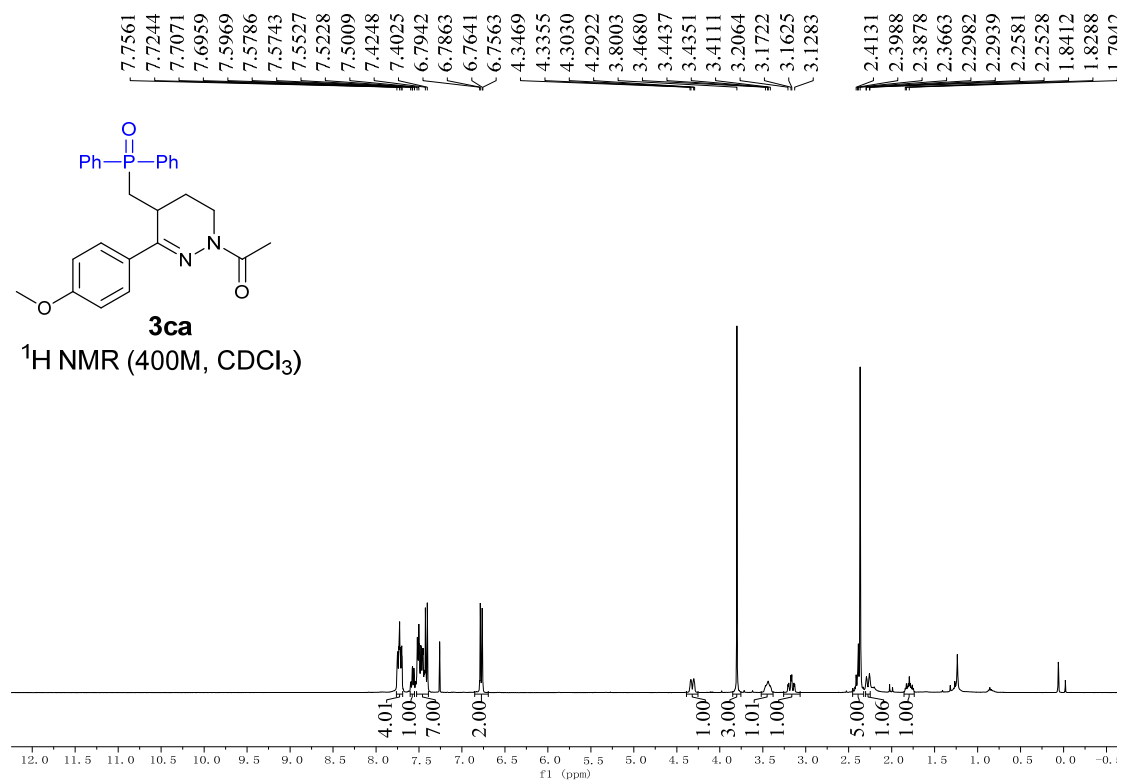
5. References

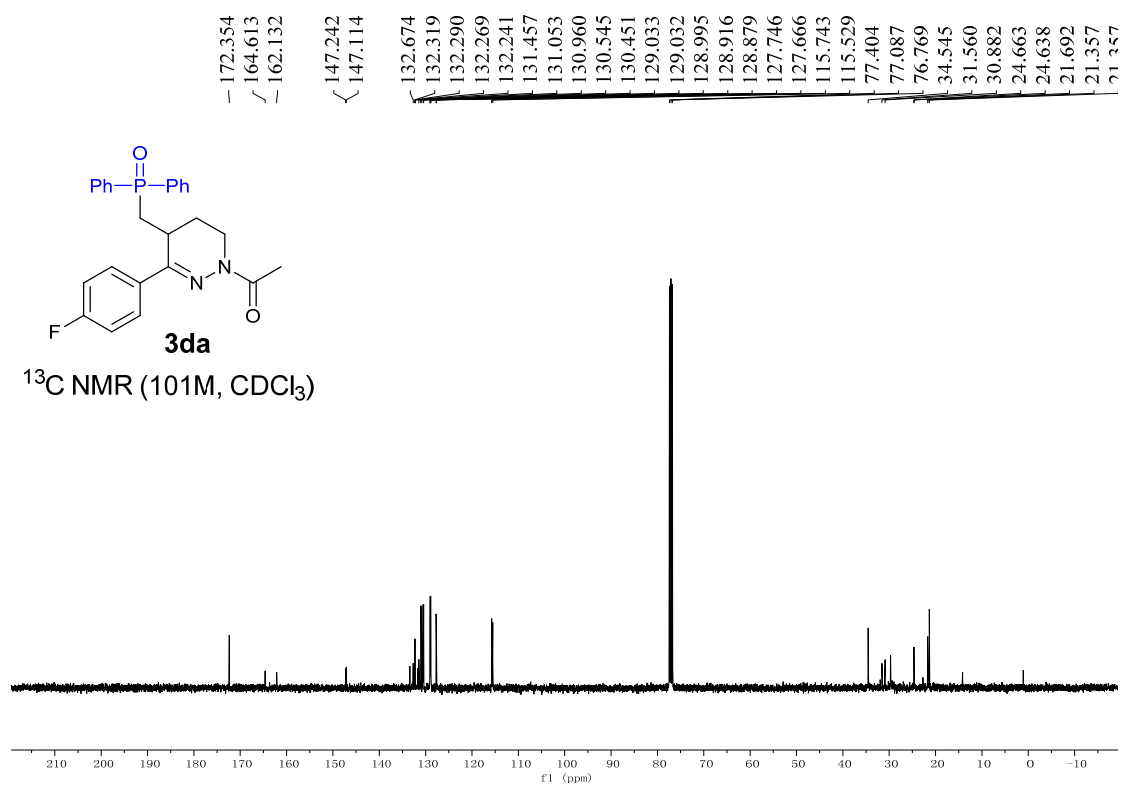
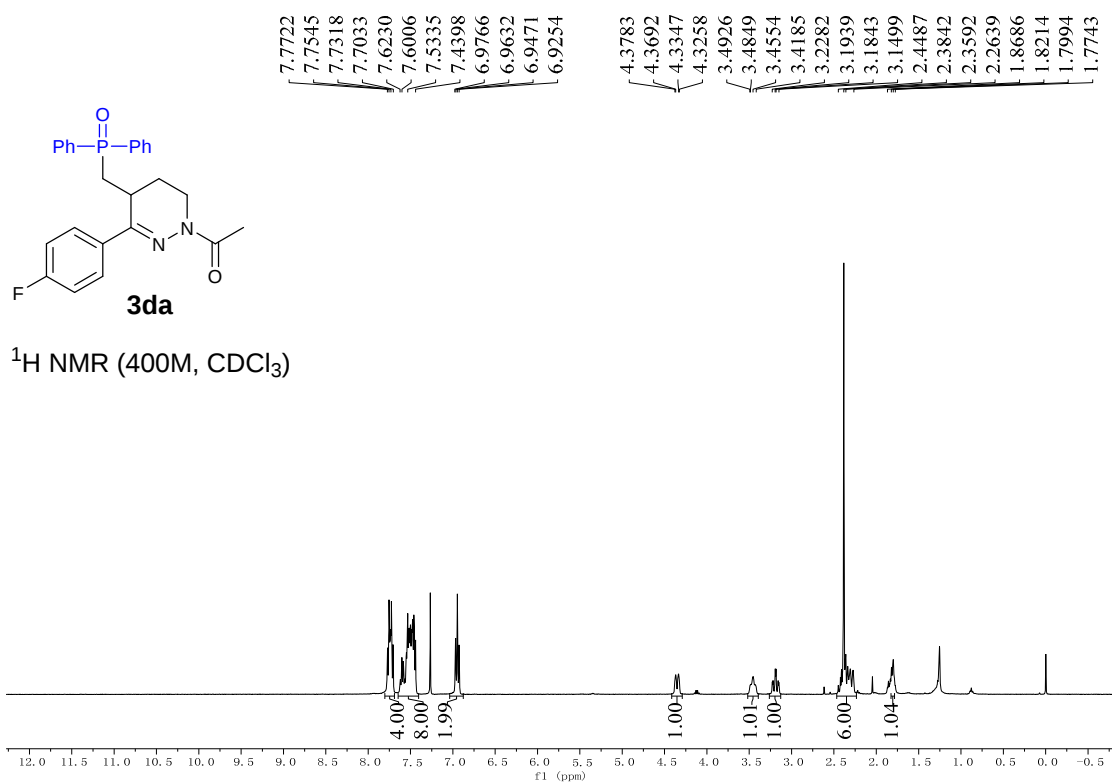
1. Y. Wu, X. Wu, L. Liu, J.-T. Yu and C. Pan, *Org. Lett.*, 2024, **26**, 122.
2. (a) M. A. Cismesia and T. P. Yoon, *Chem. Sci.*, 2015, **6**, 5426. (b) Y. Dong, N. Xiong, Z. Rong and R. Zeng, *Org. Lett.*, 2024, DOI: 10.1021/acs.orglett.4c00410.

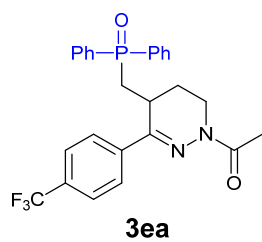
6. Copies of the ^1H NMR and ^{13}C NMR Spectra



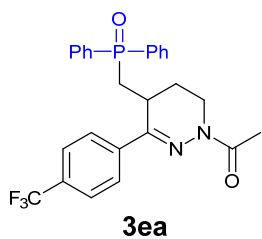
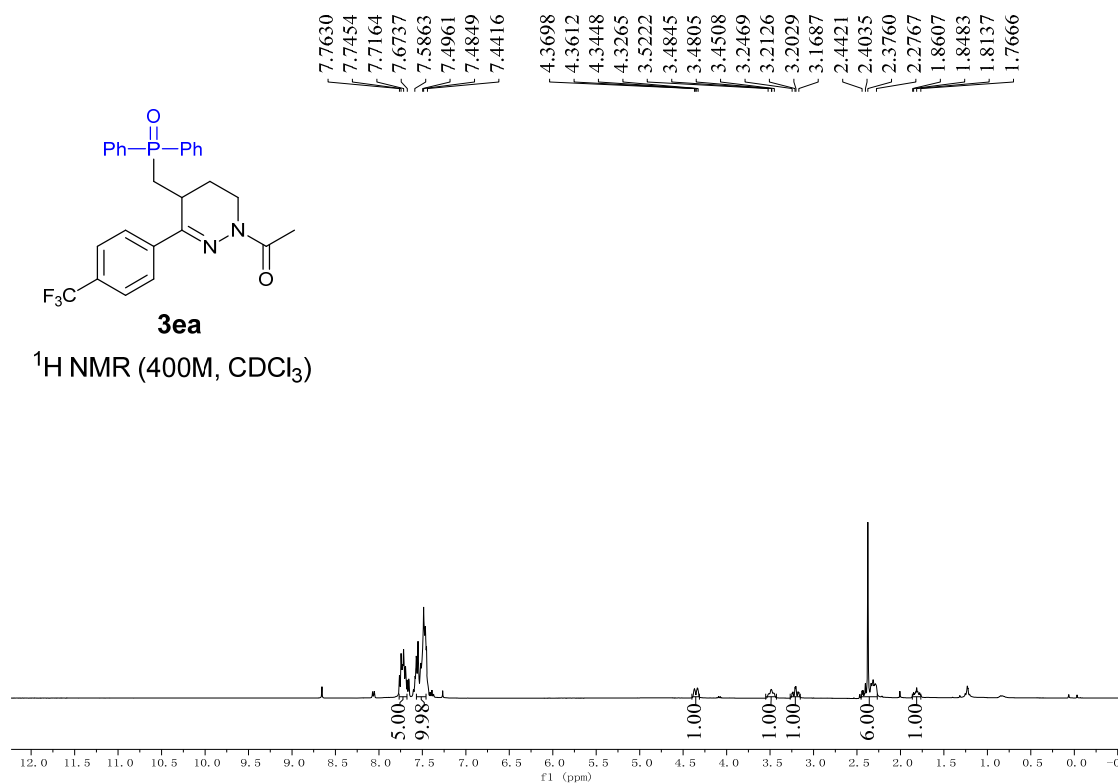




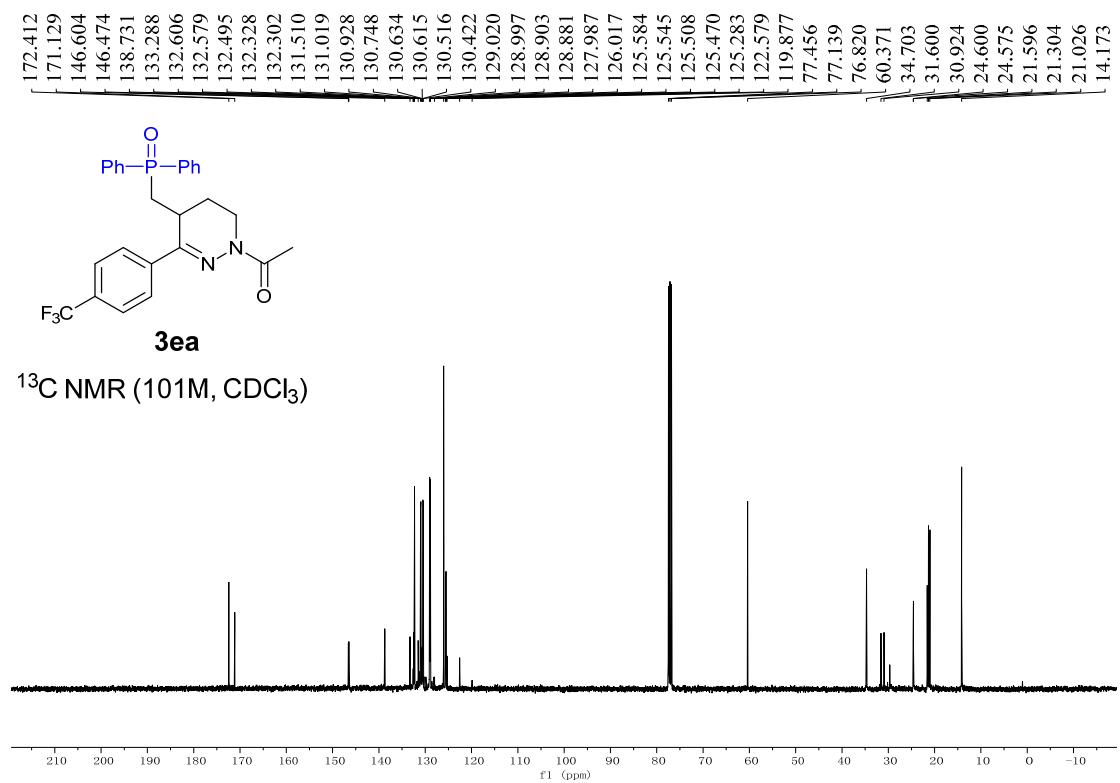


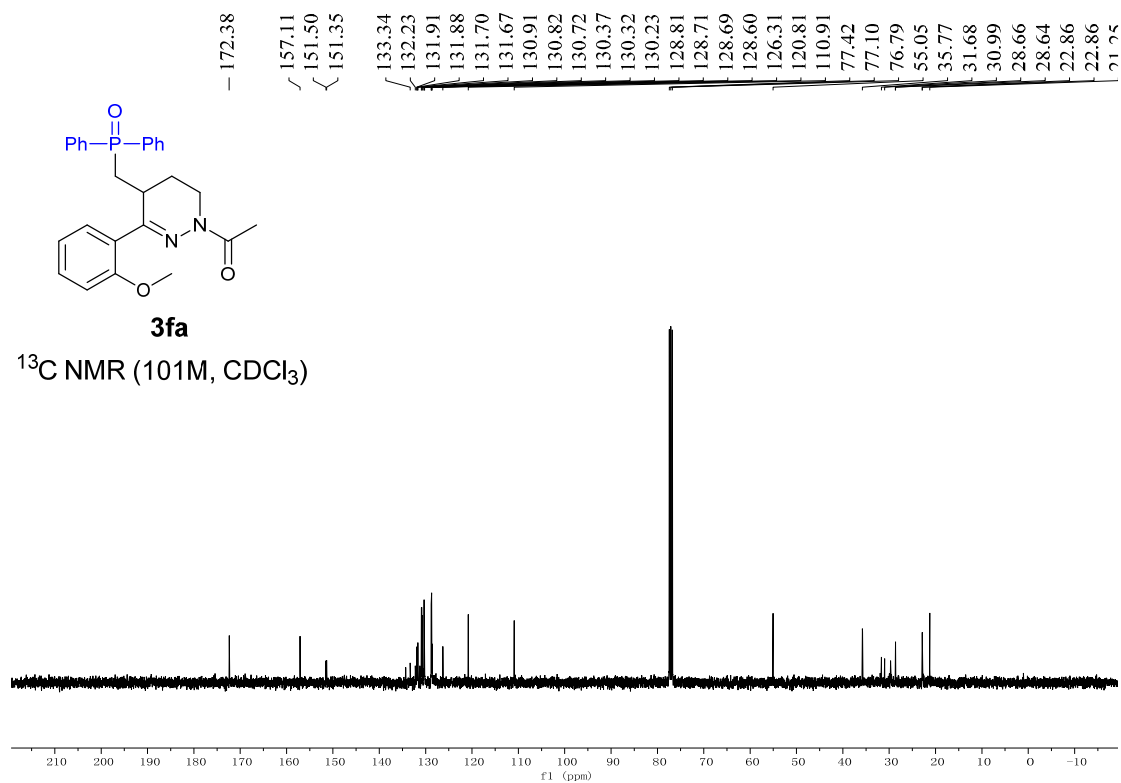
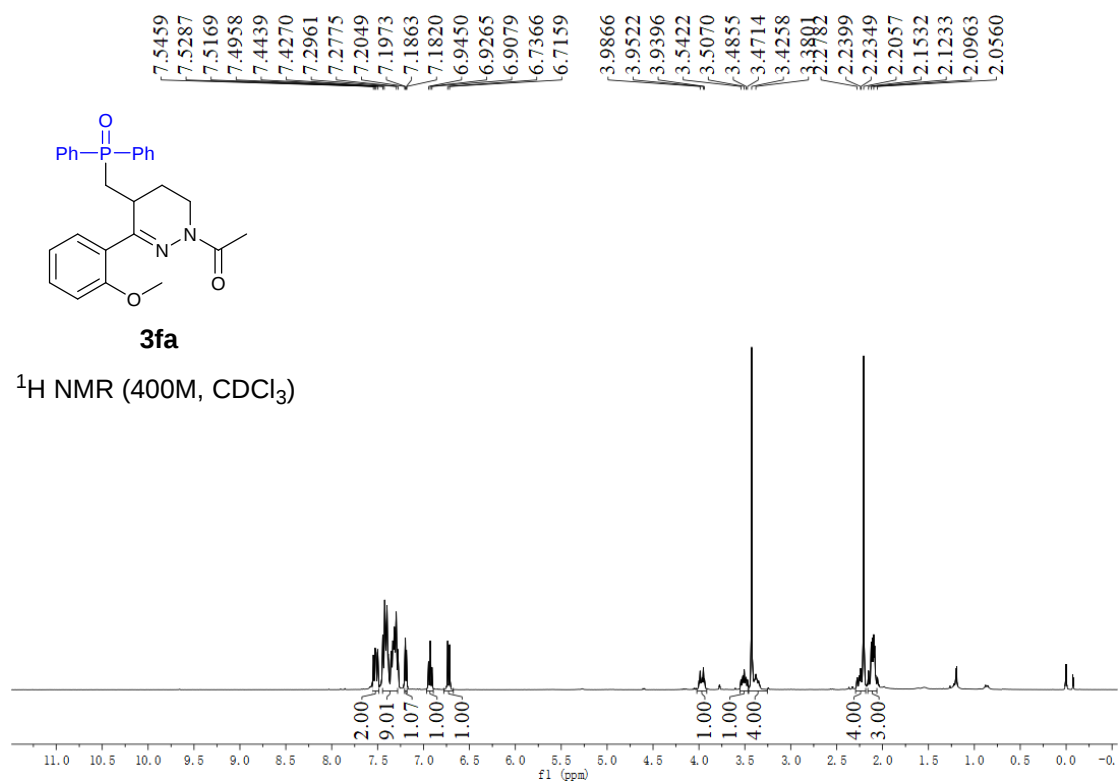


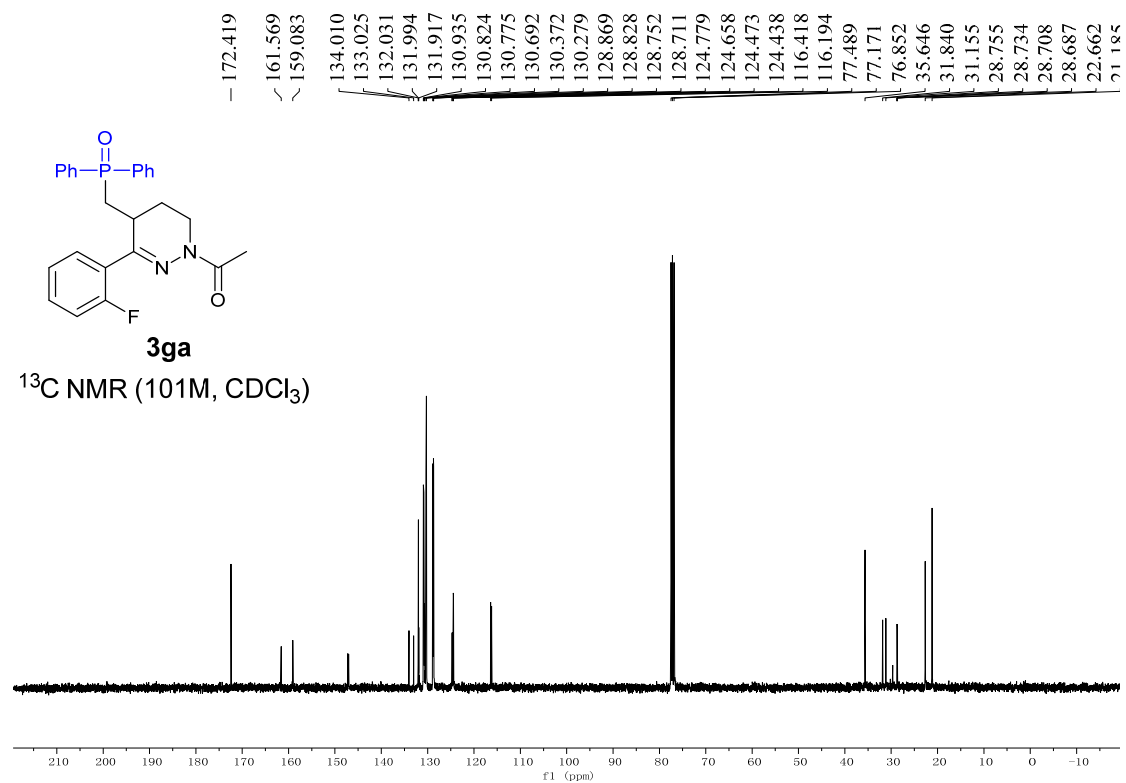
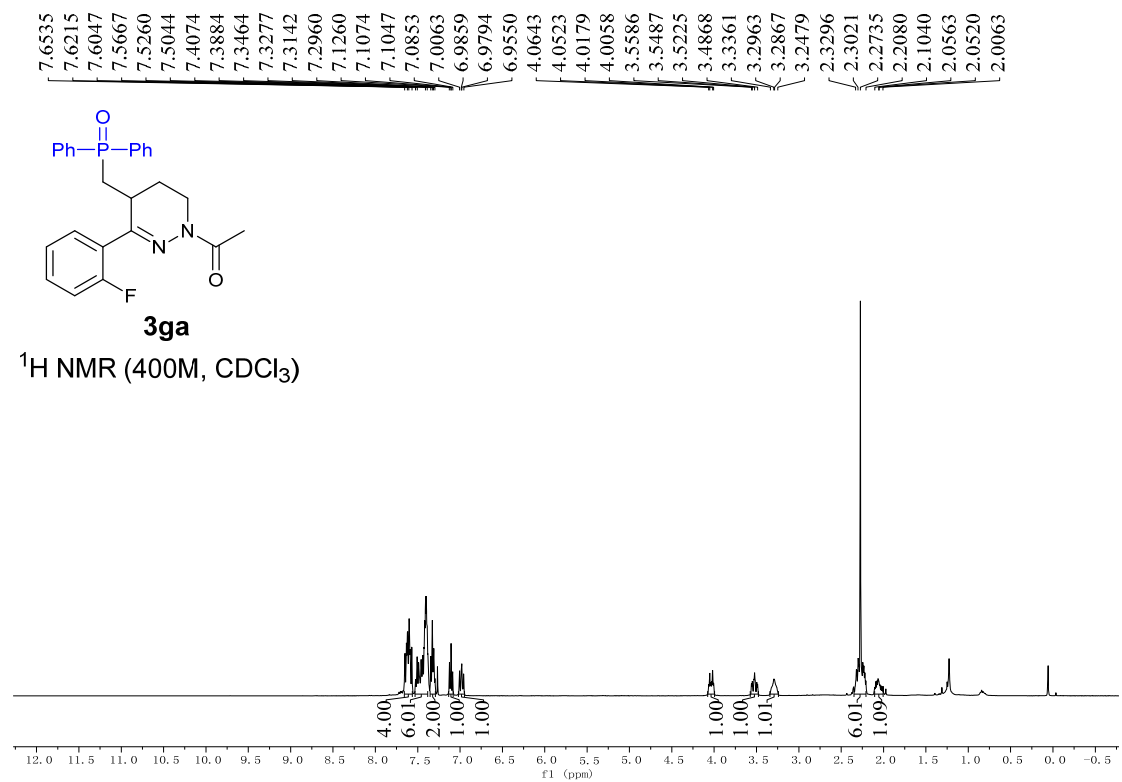
^1H NMR (400M, CDCl_3)

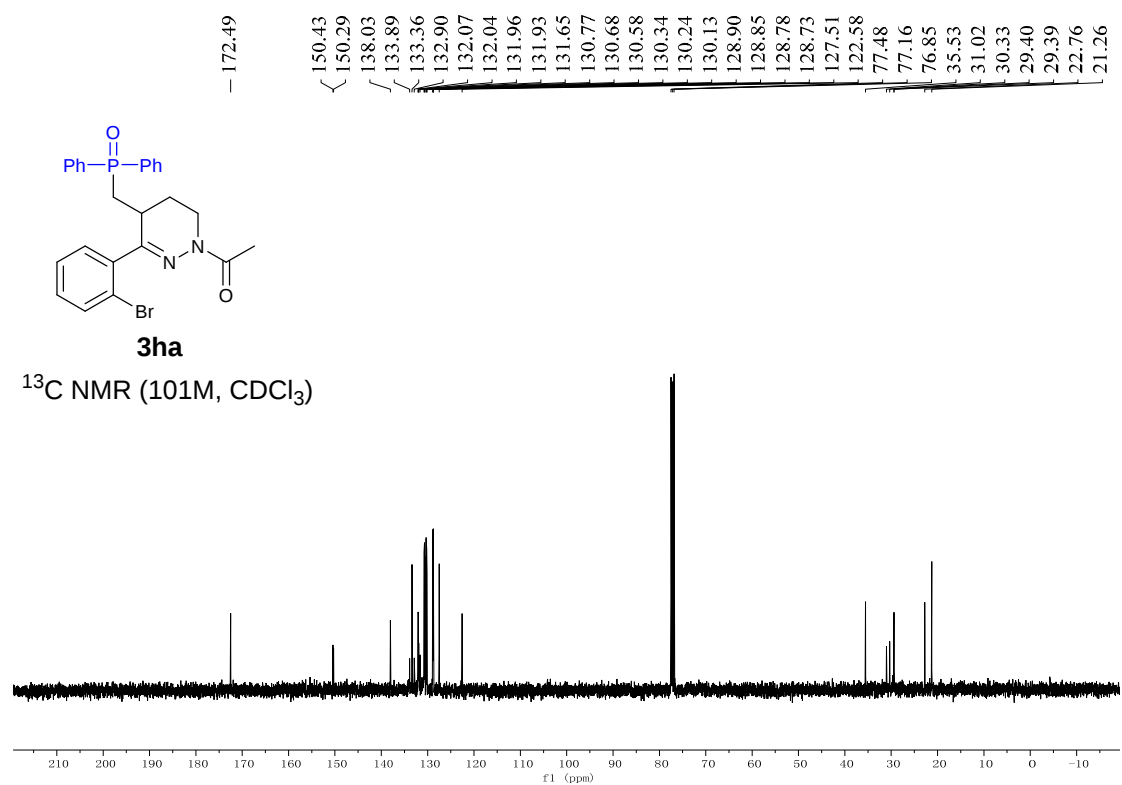
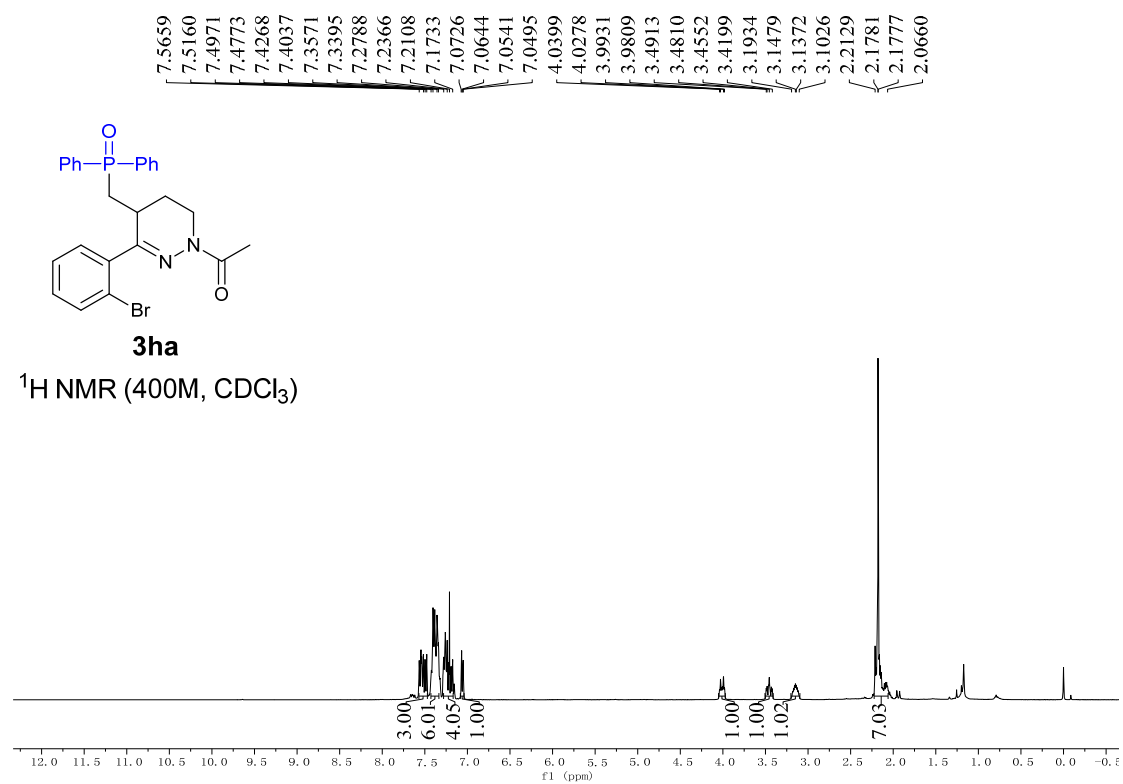


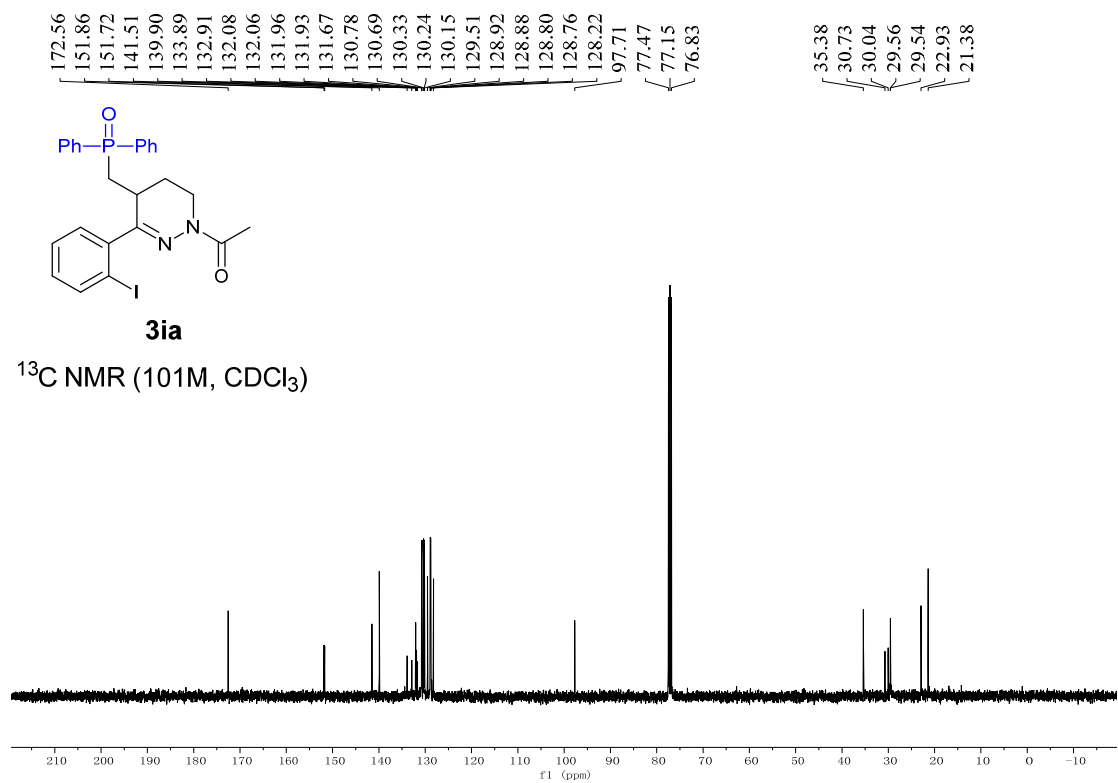
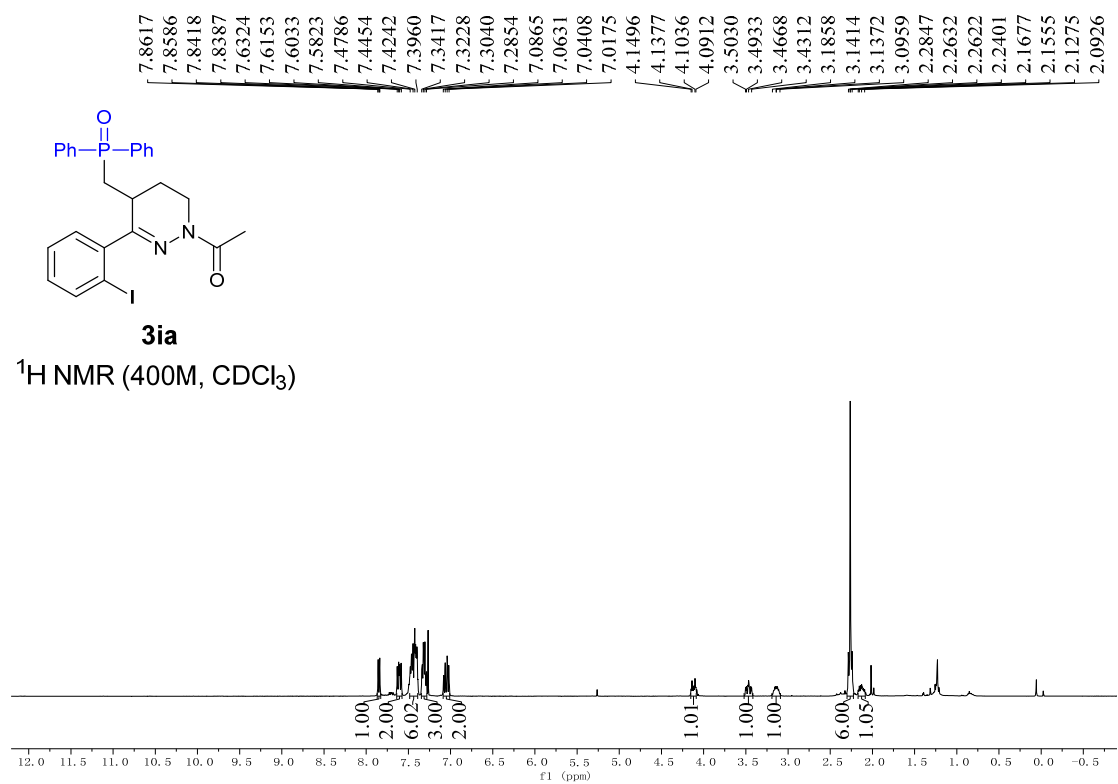
^{13}C NMR (101M, CDCl_3)

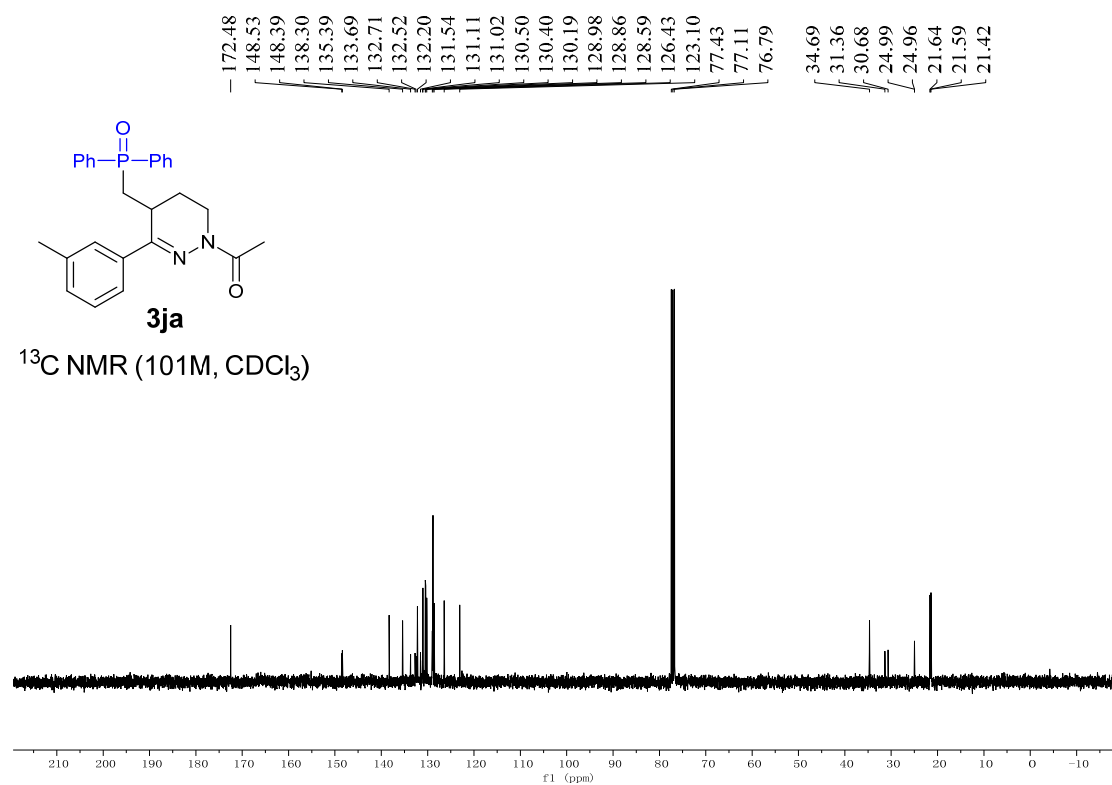
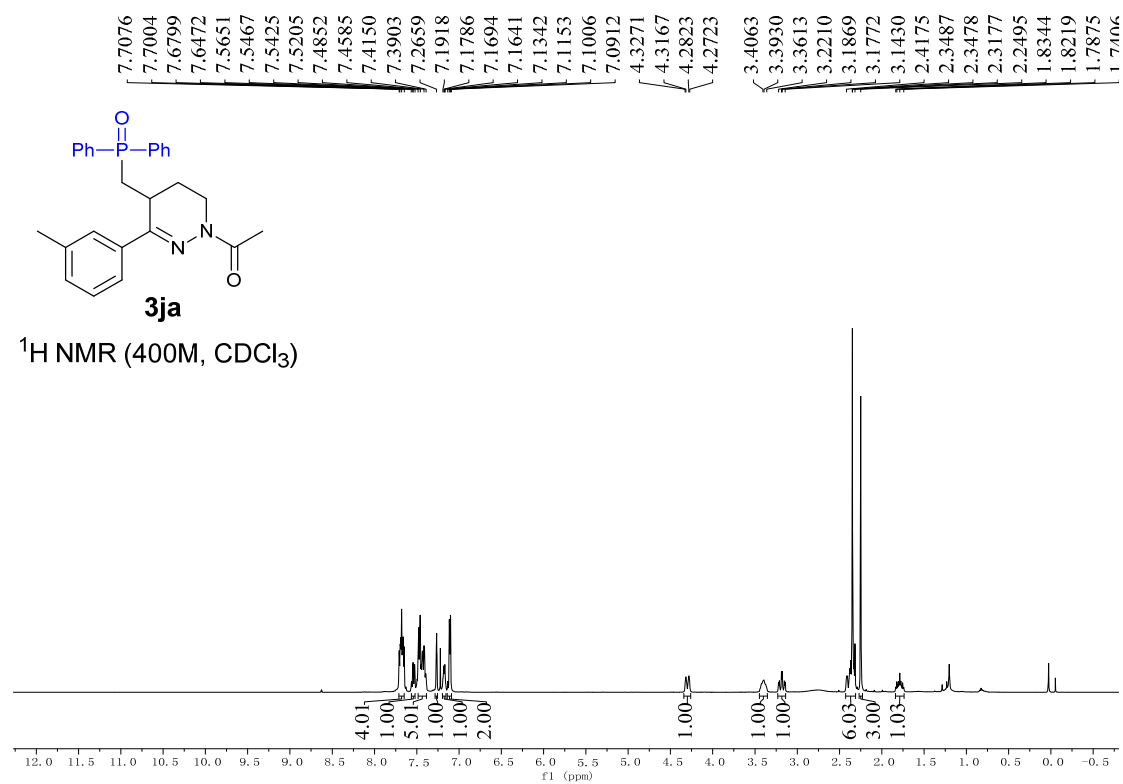


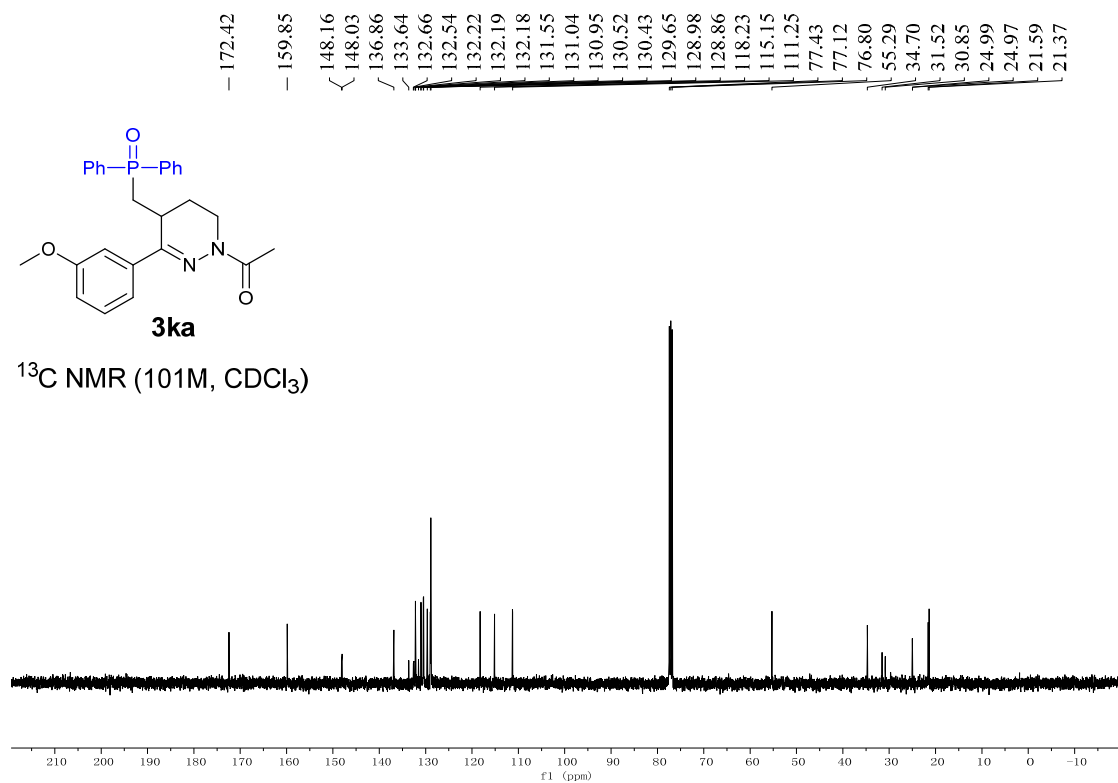
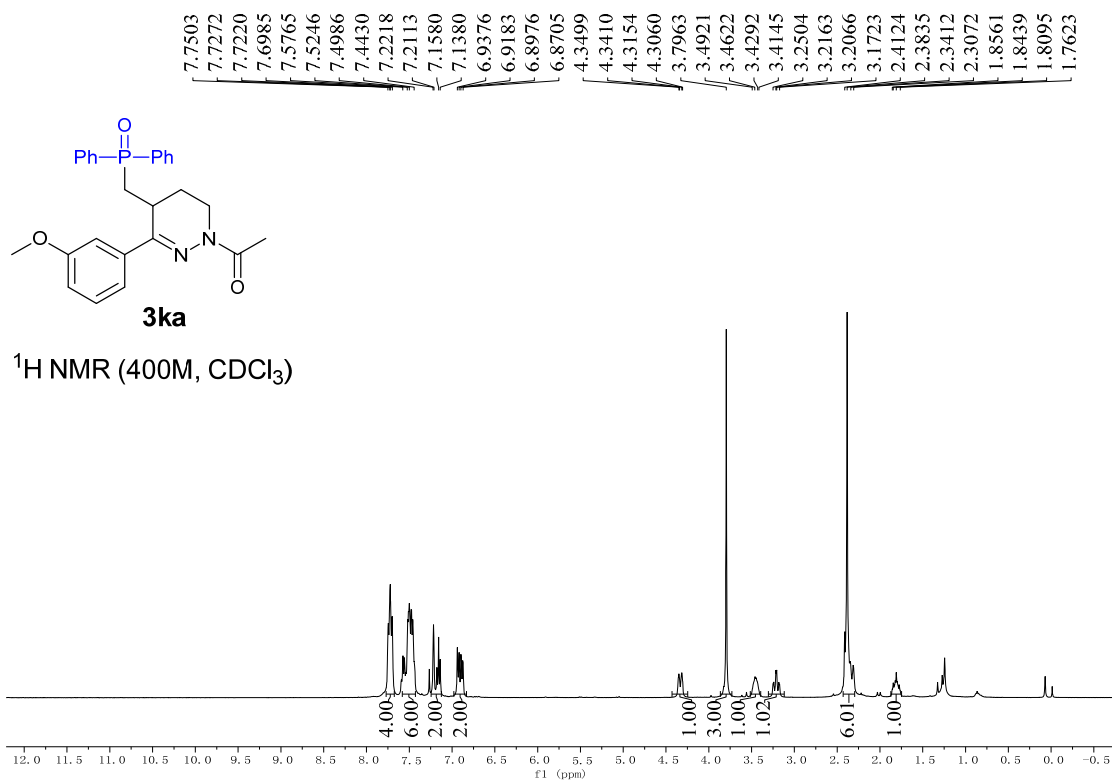














3la

¹H NMR (400M, CDCl₃)

Chemical structure of **3la** is shown above the spectrum. The structure is a 1,2,3,4-tetrahydropyridine derivative with a diphenylphosphoryl group and an acetamide group.

Chemical structure of **3la** is shown above the spectrum. The structure is a 1,2,3,4-tetrahydropyridine derivative with a diphenylphosphoryl group and an acetamide group.

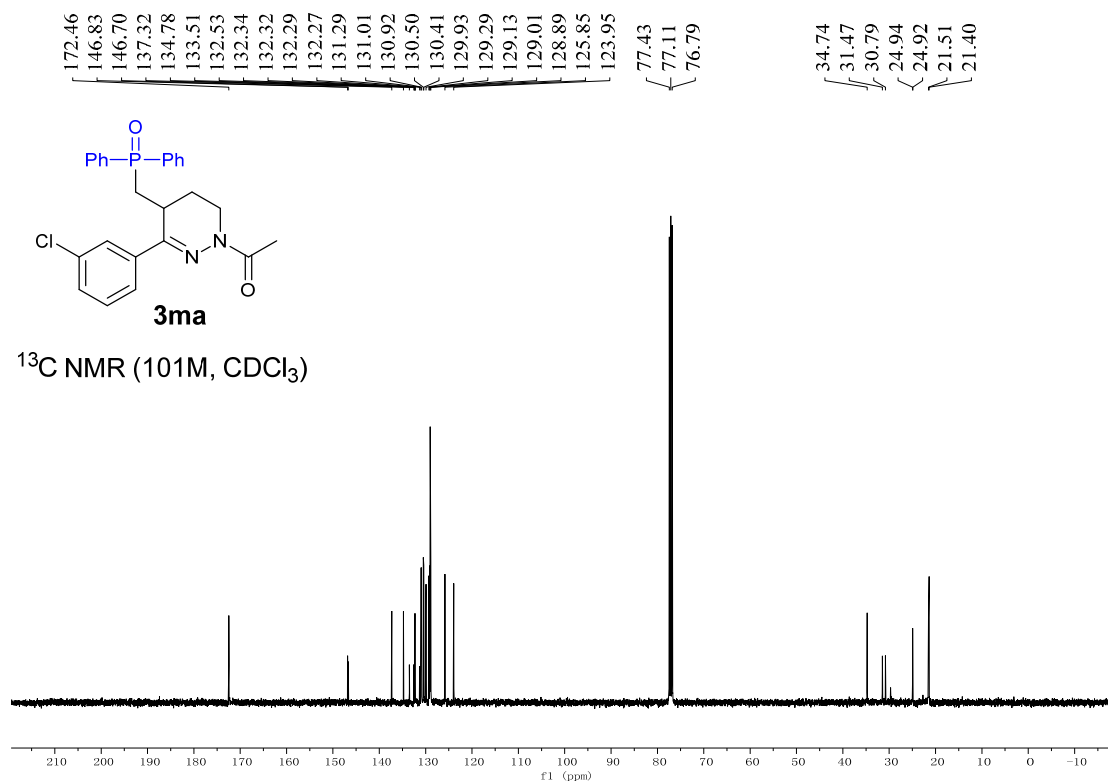
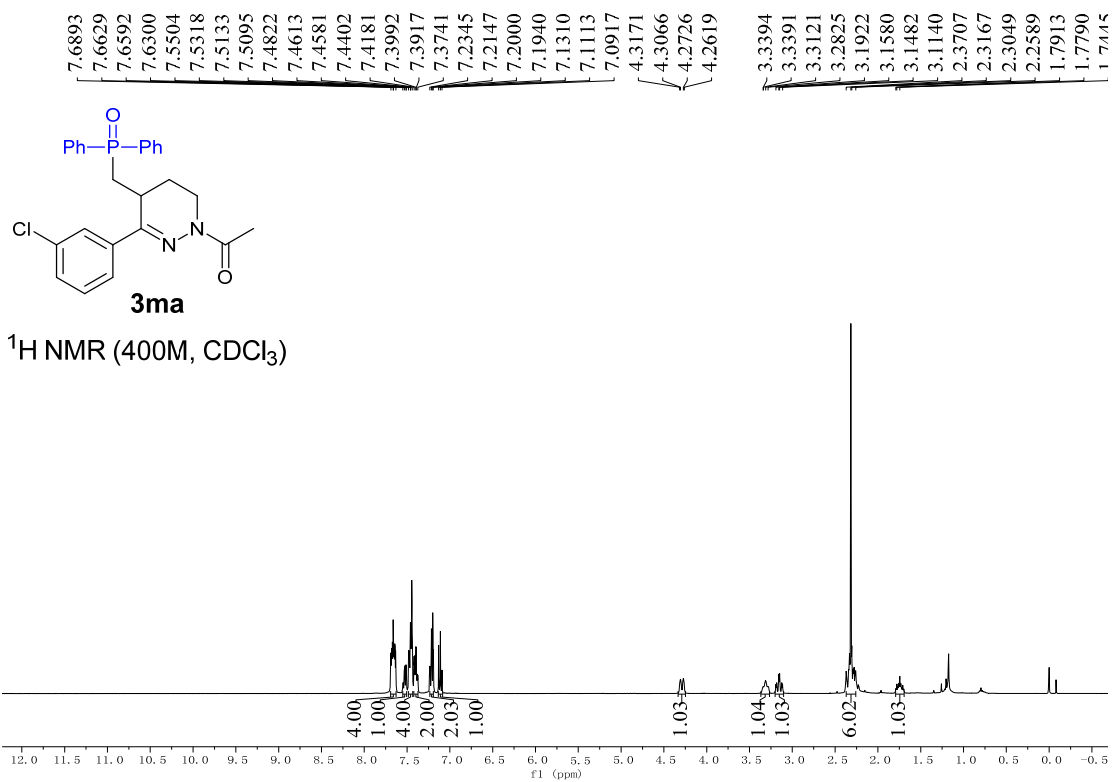


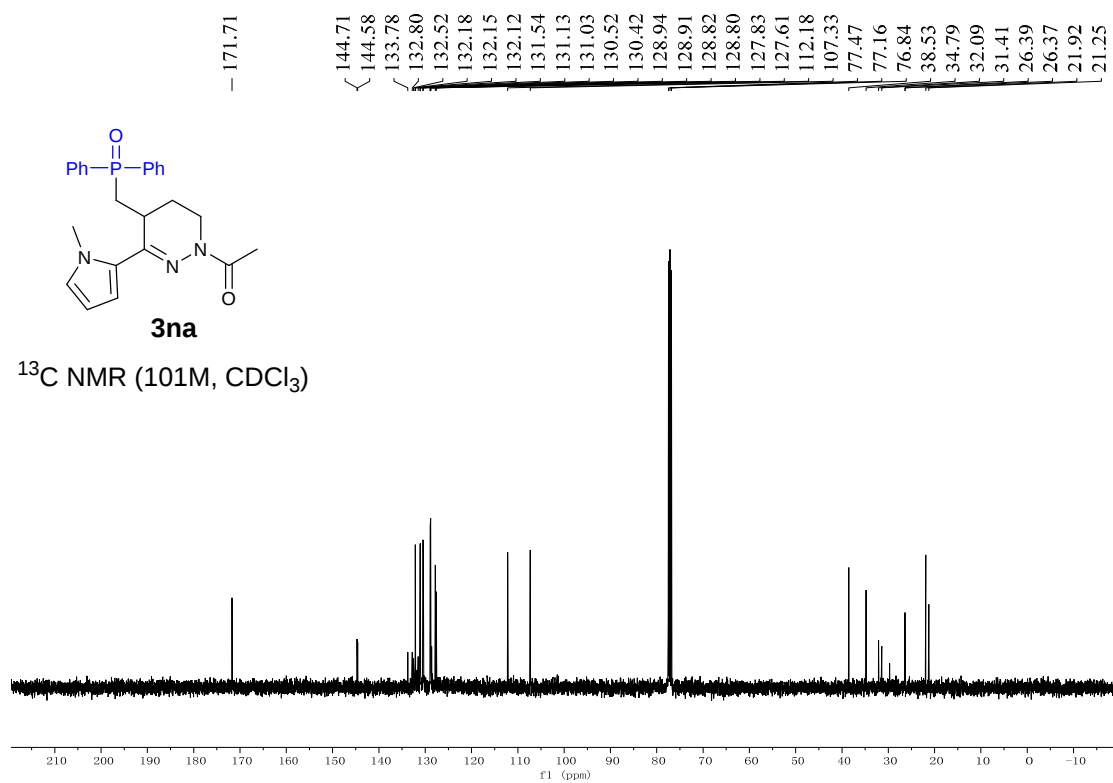
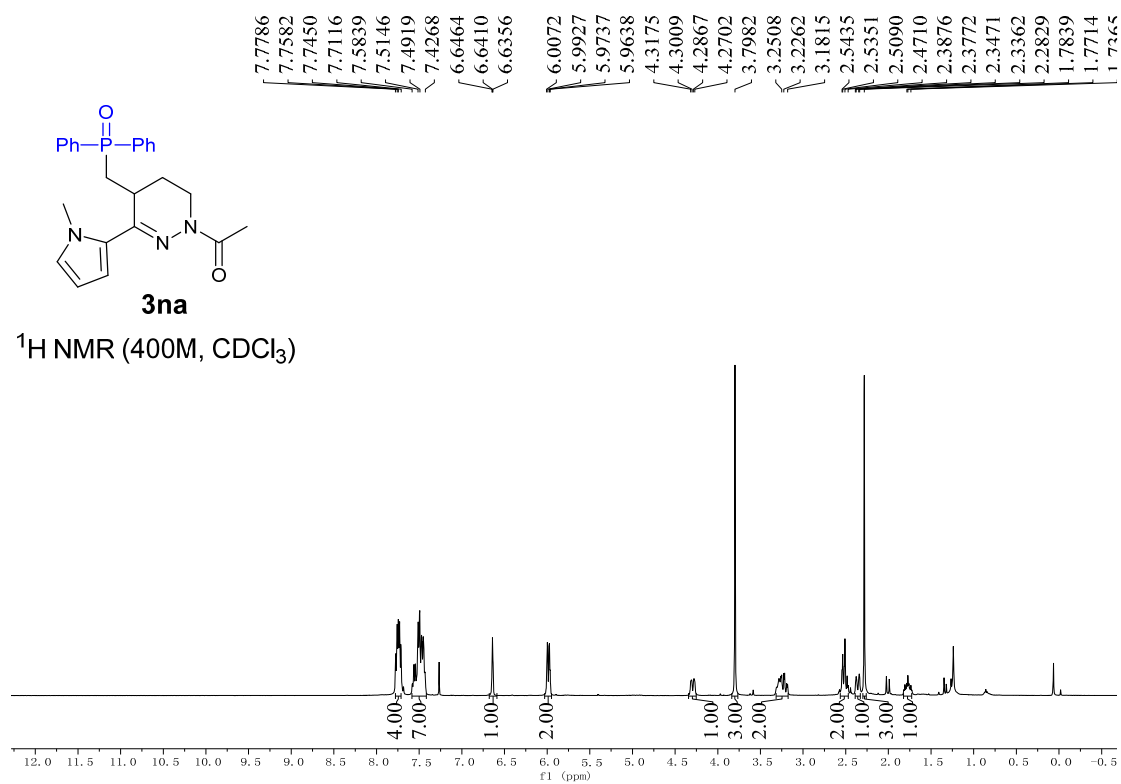
3la

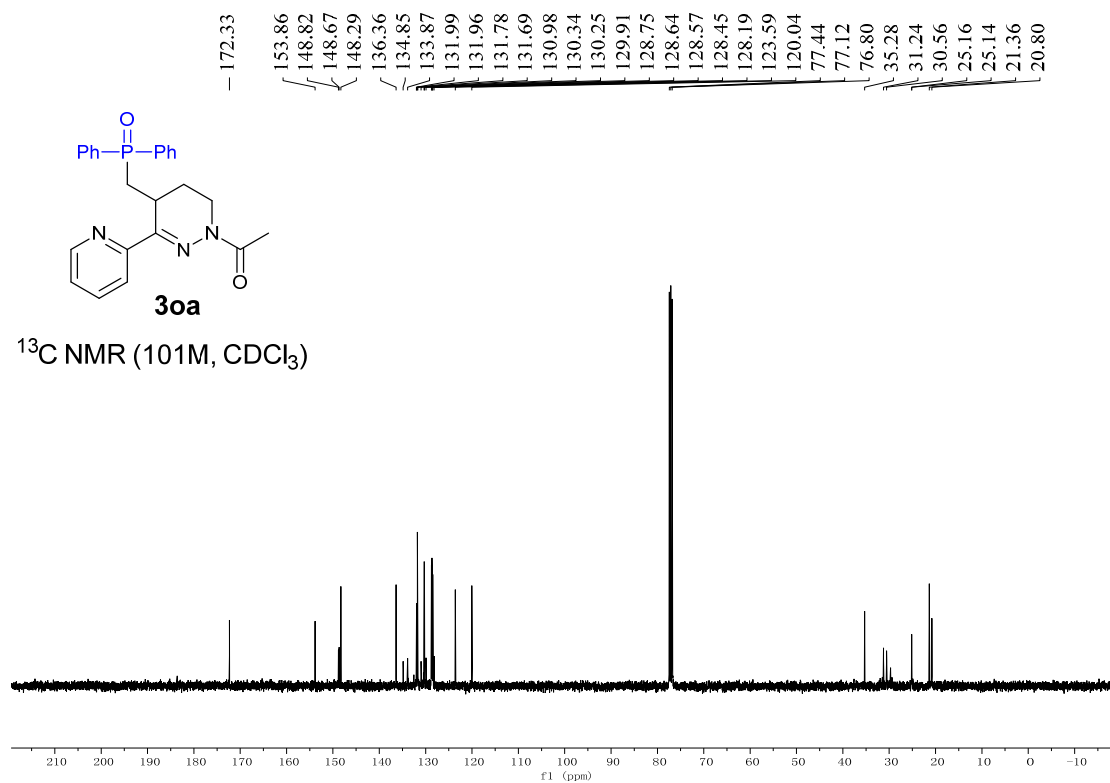
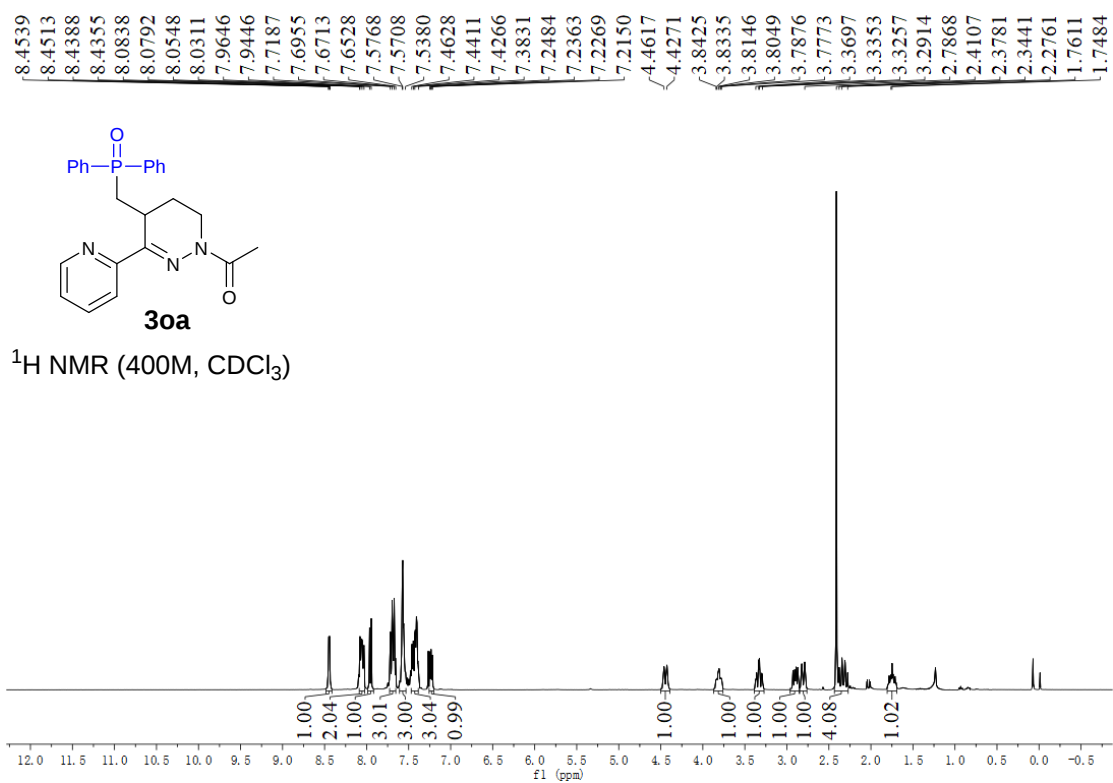
¹³C NMR (101M, CDCl₃)

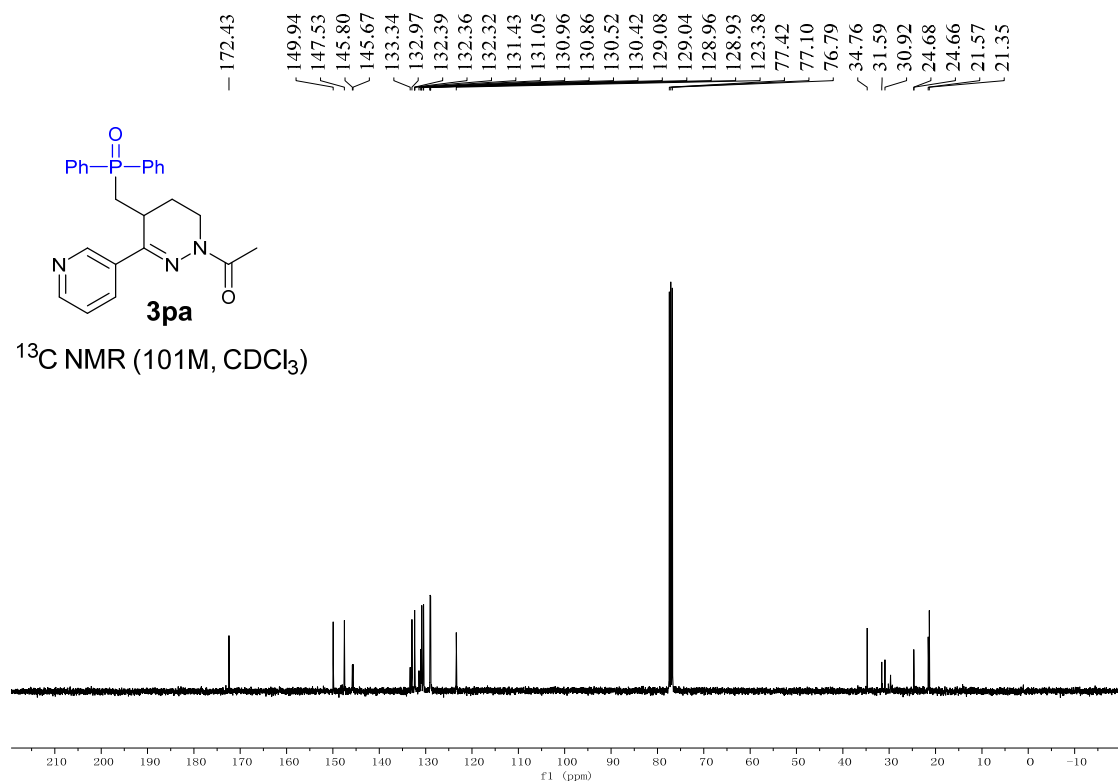
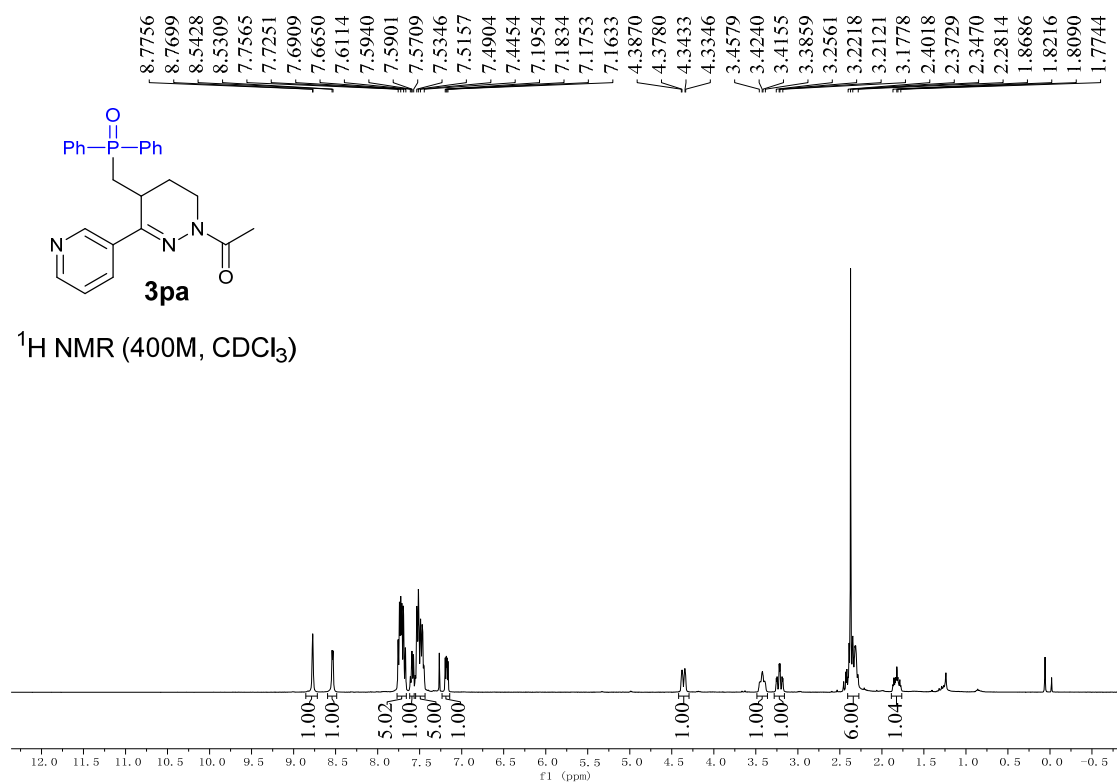
Chemical structure of **3la**: CC(=O)N1CC[C@H](C1=Cc2ccc(F)cc2)CP(=O)(c3ccccc3)c4ccccc4

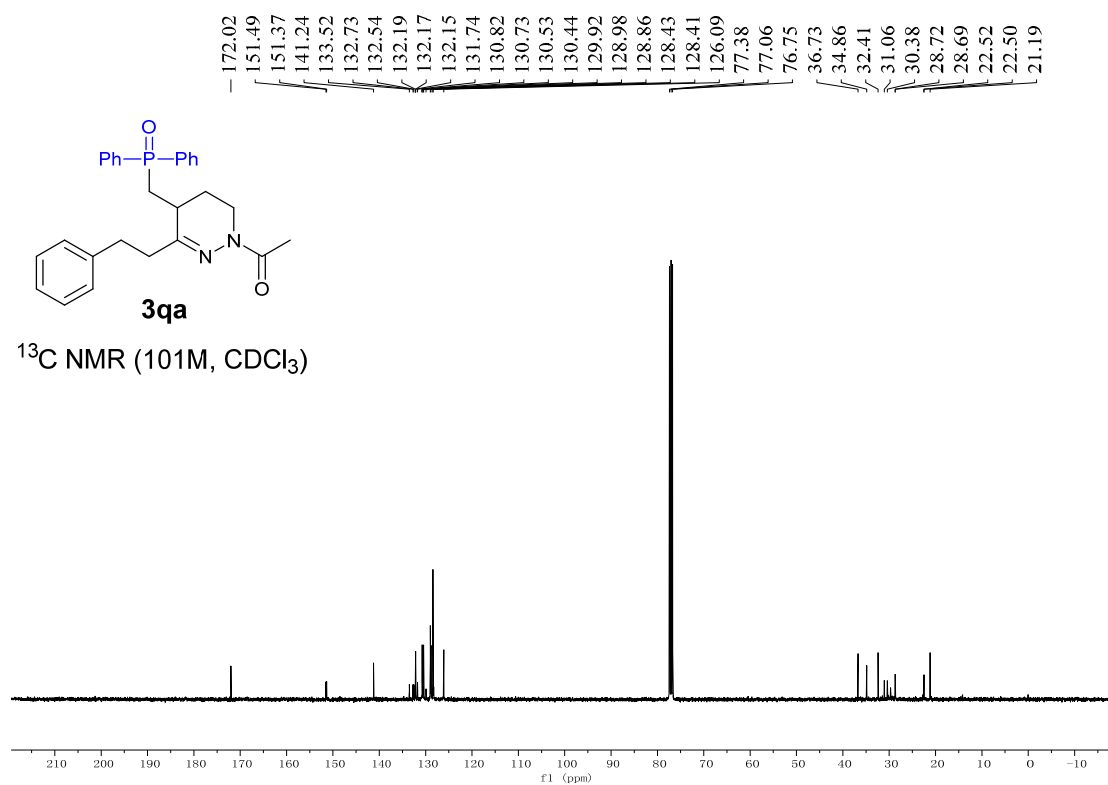
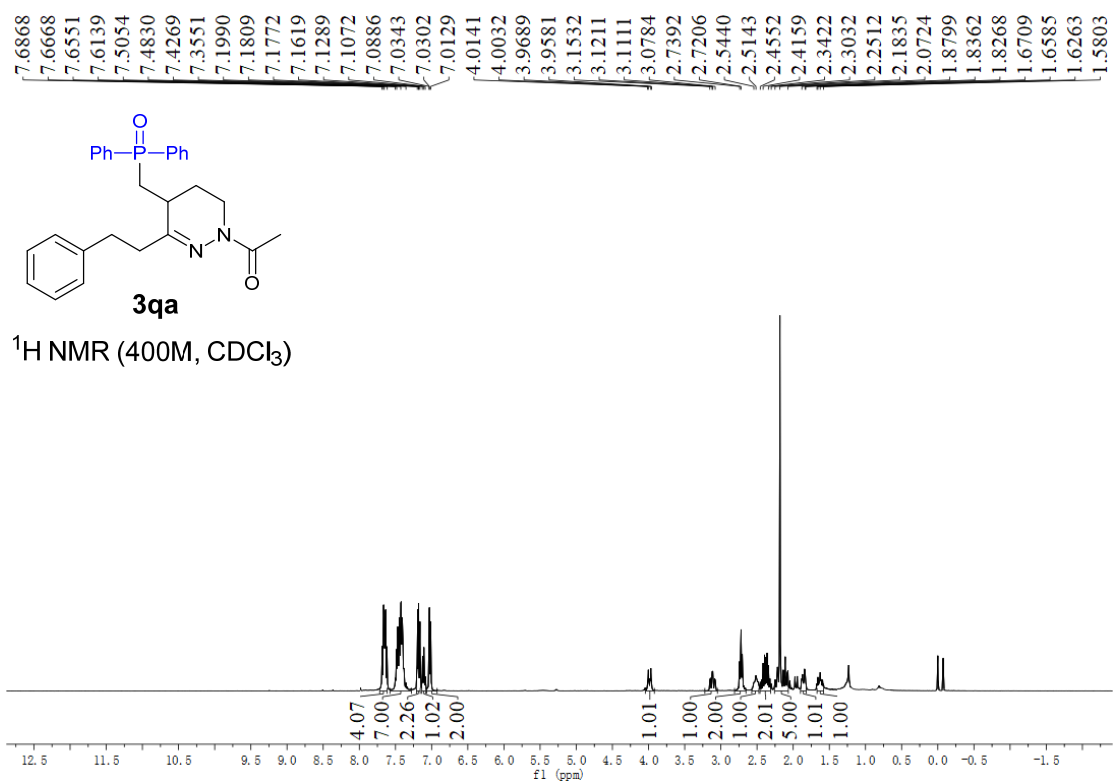
¹³C NMR peaks (ppm): 172.413, 164.195, 161.752, 146.874, 146.846, 146.740, 146.713, 137.798, 137.725, 133.512, 132.530, 132.408, 132.334, 132.307, 132.286, 132.259, 131.424, 131.055, 130.966, 130.515, 130.421, 130.221, 130.140, 129.044, 129.006, 128.928, 128.889, 121.401, 121.372, 116.330, 116.117, 112.709, 112.479, 77.448, 77.130, 76.812, 34.691, 31.518, 30.841, 24.841, 24.817, 21.502, 21.367.

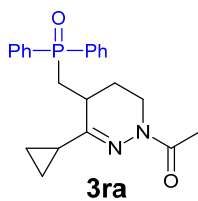
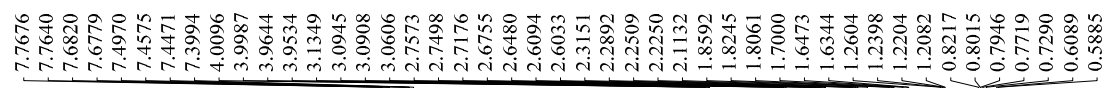




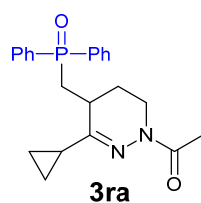
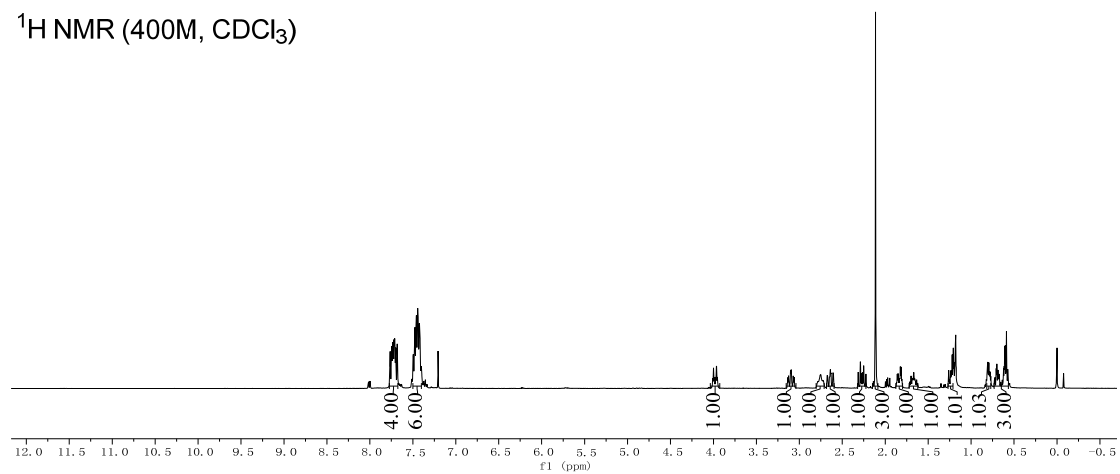




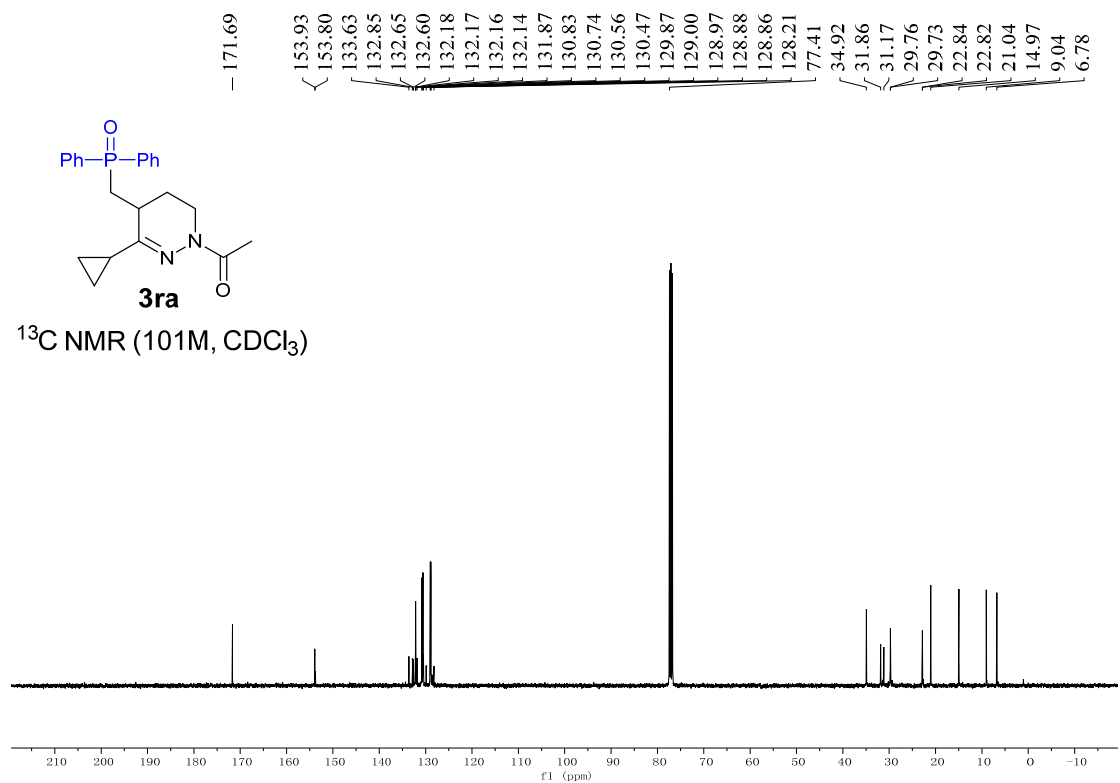


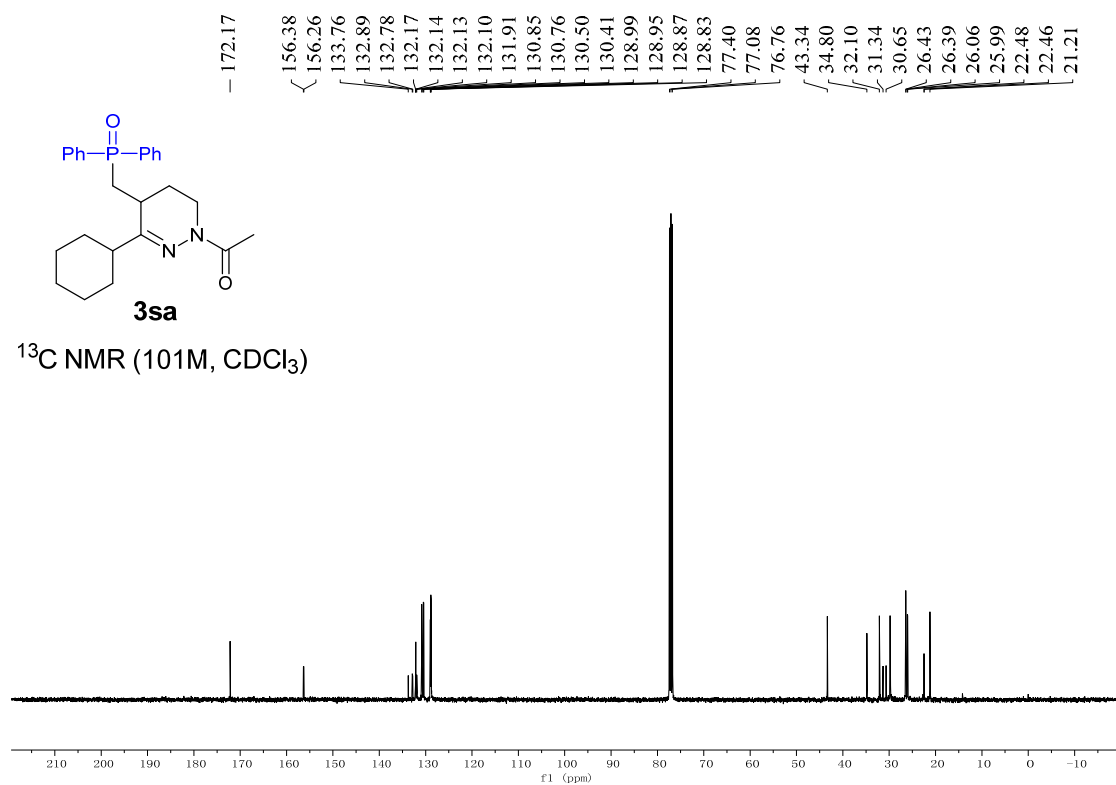
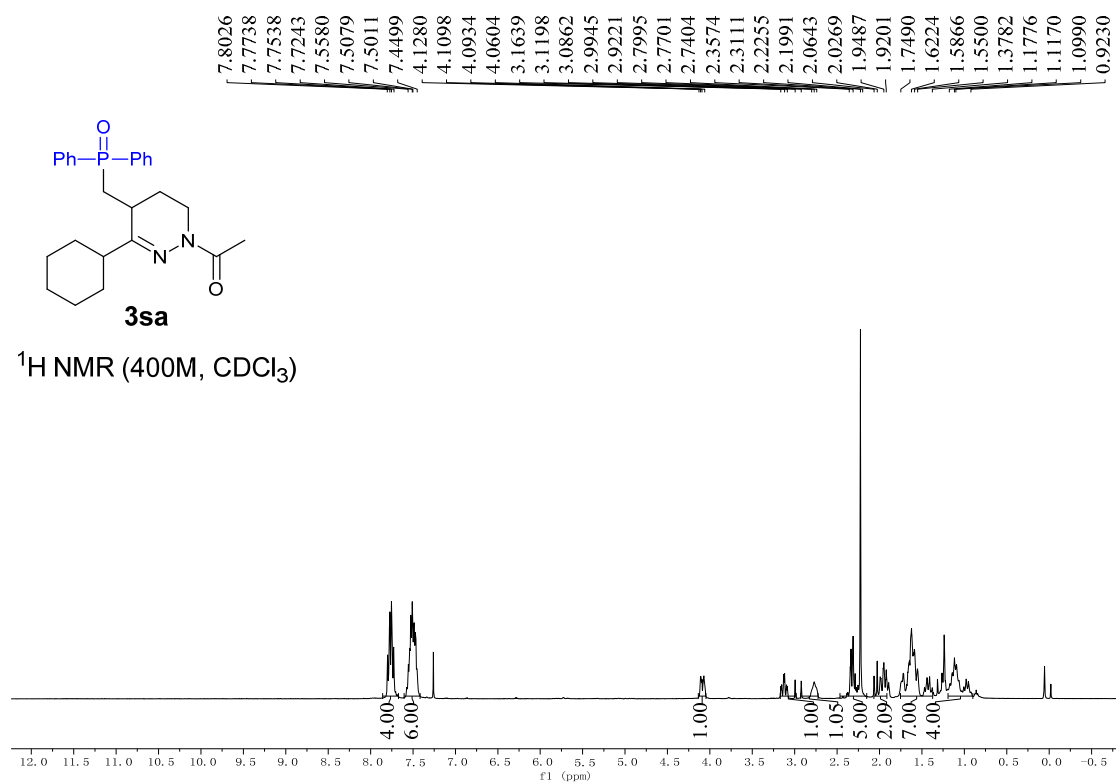


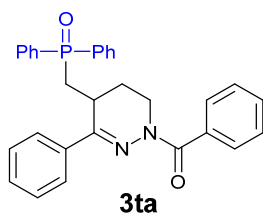
^1H NMR (400M, CDCl_3)



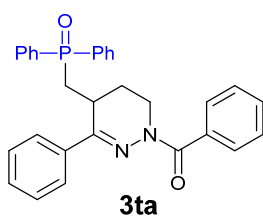
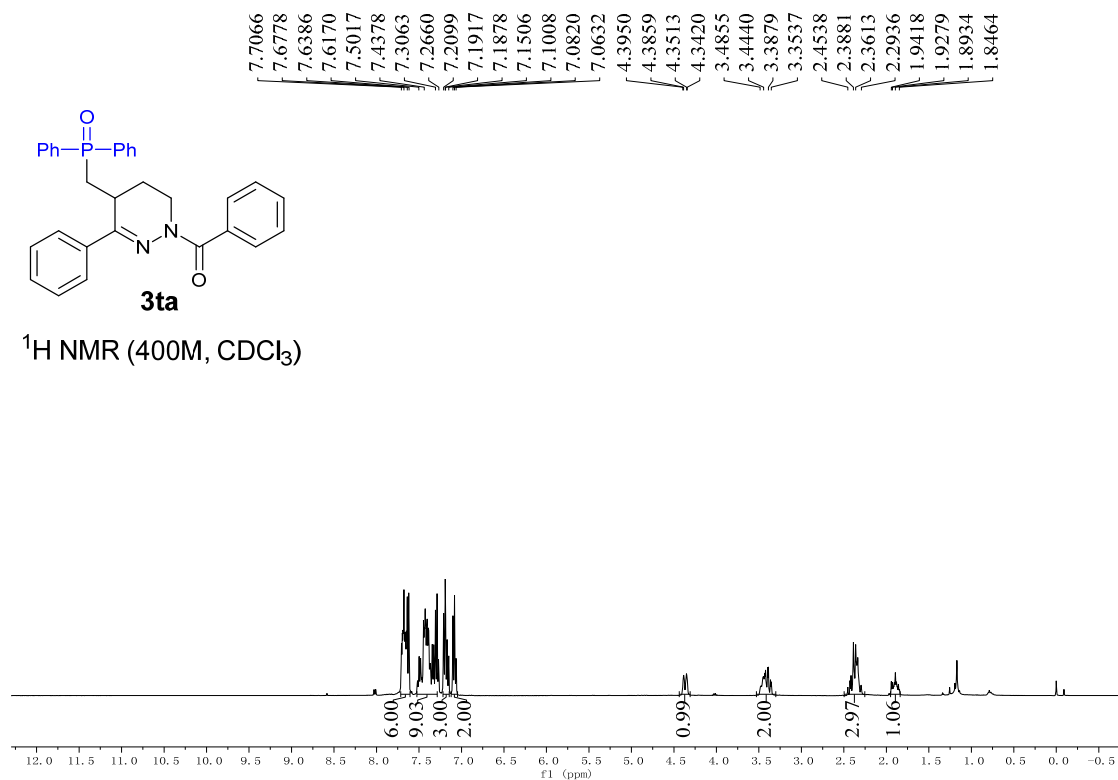
^{13}C NMR (101M, CDCl_3)



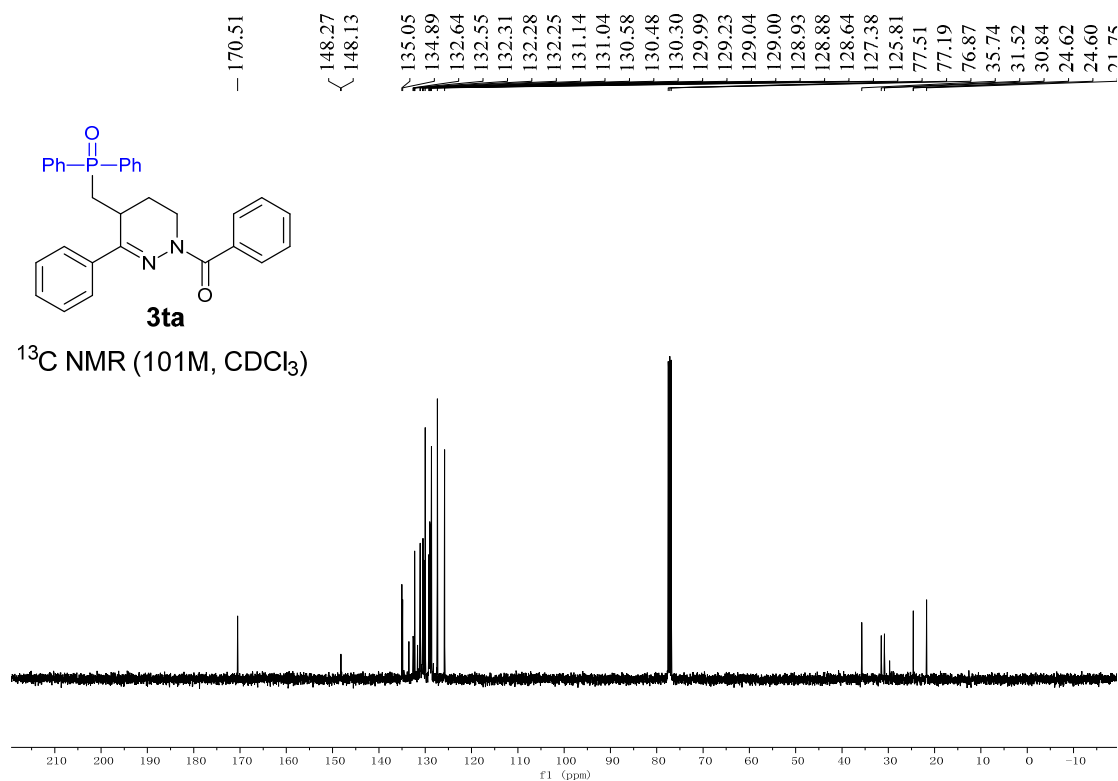


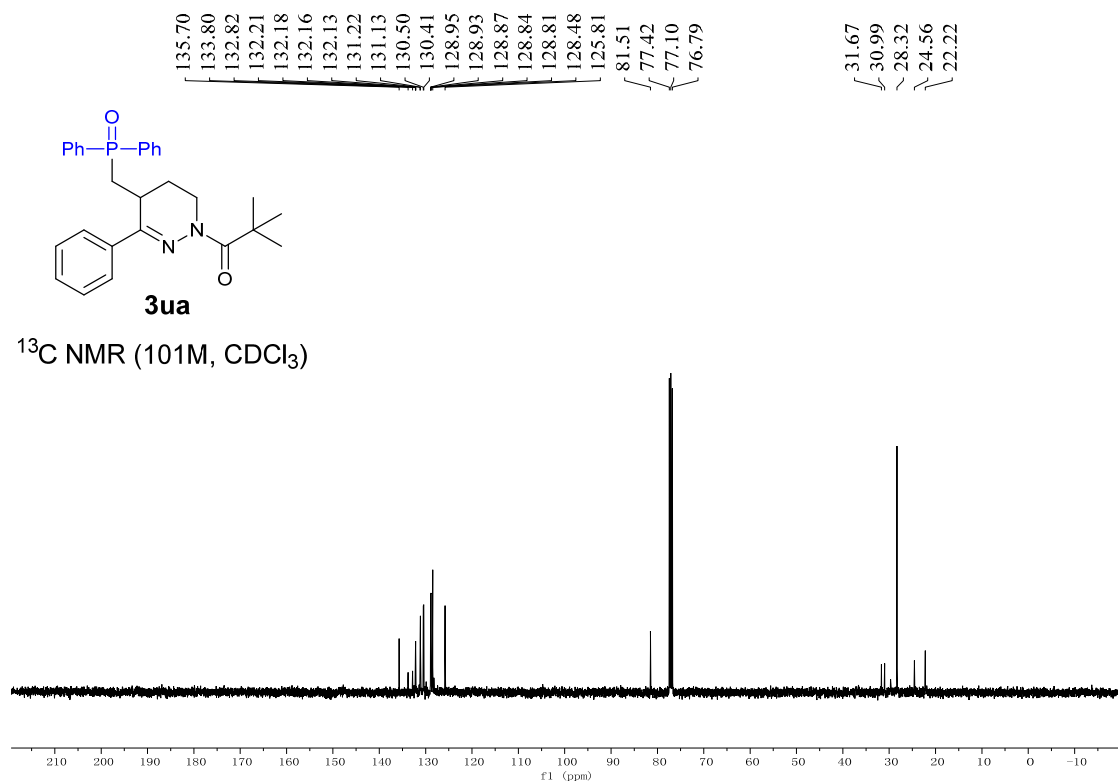
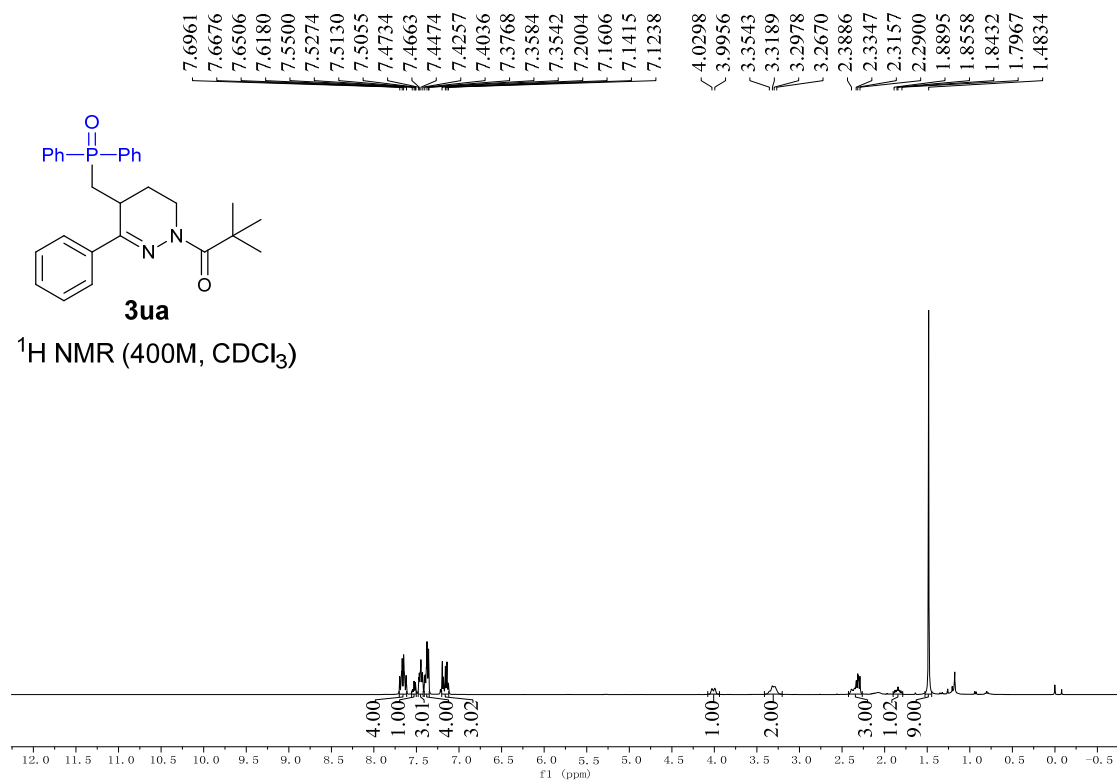


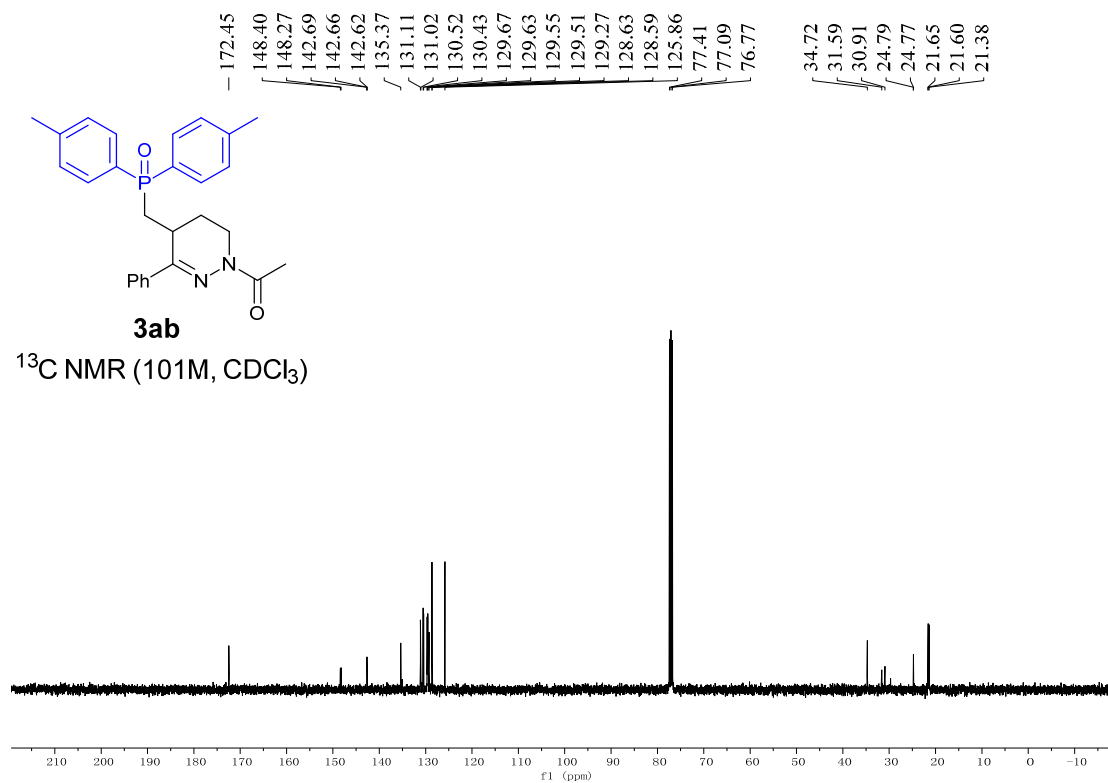
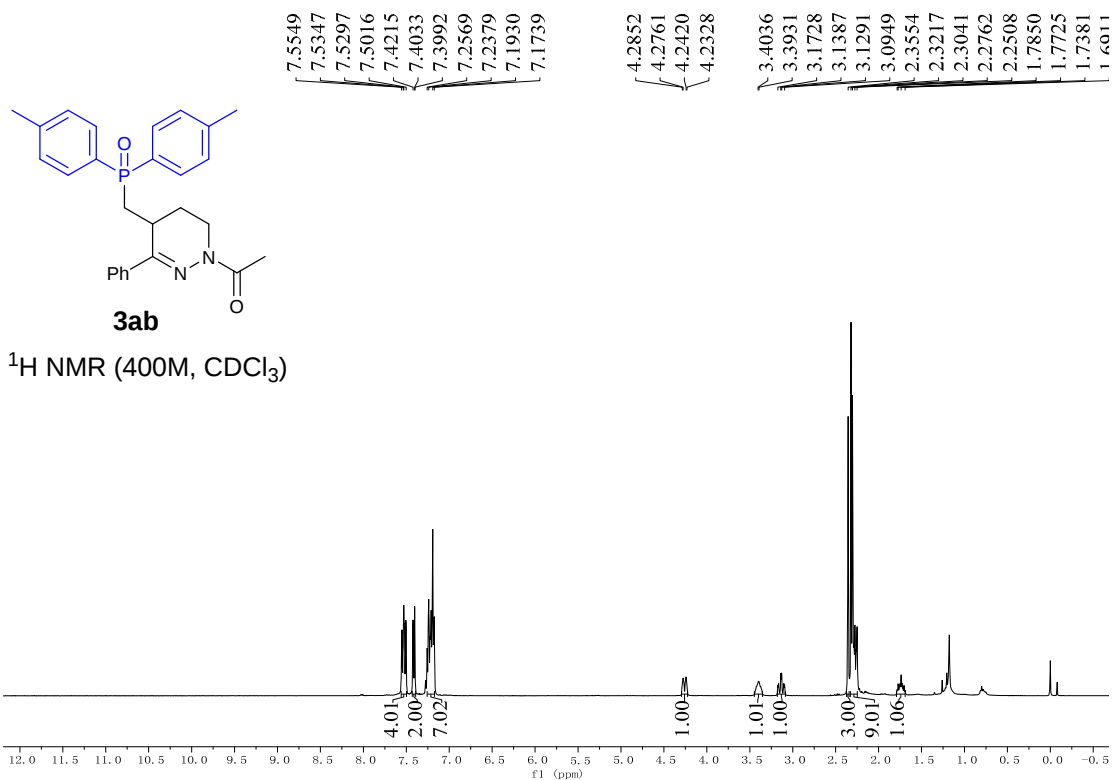
¹H NMR (400M, CDCl₃)

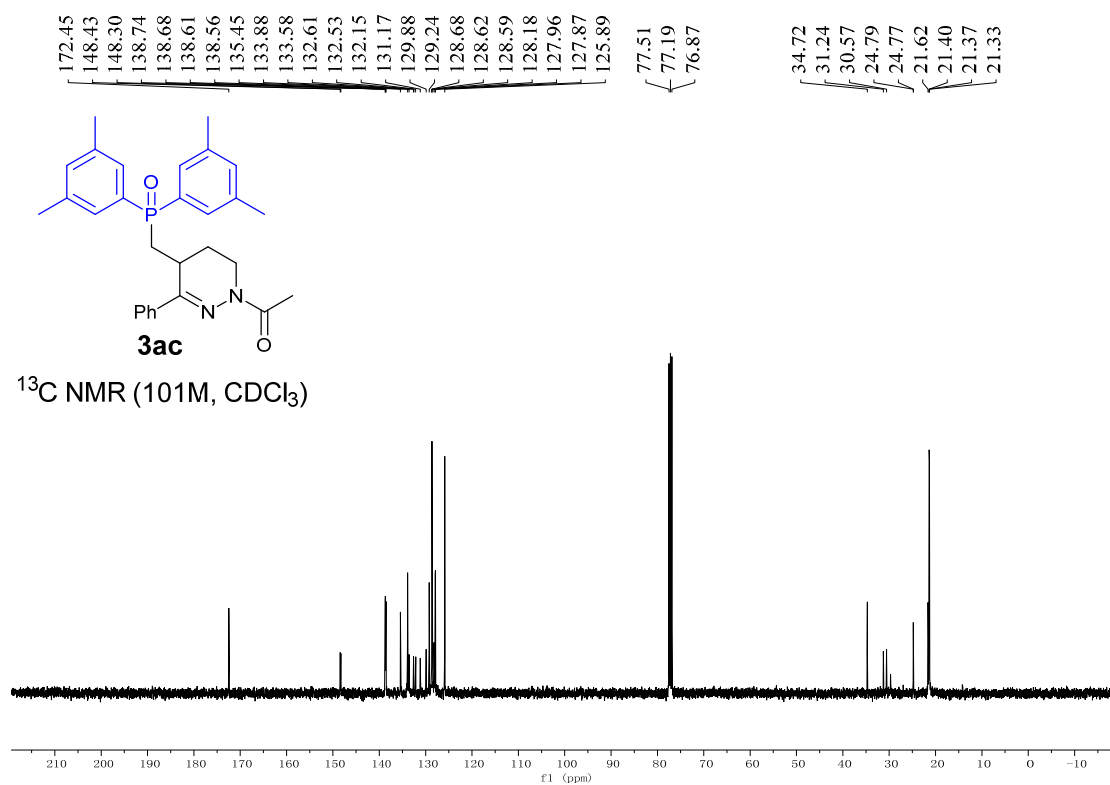
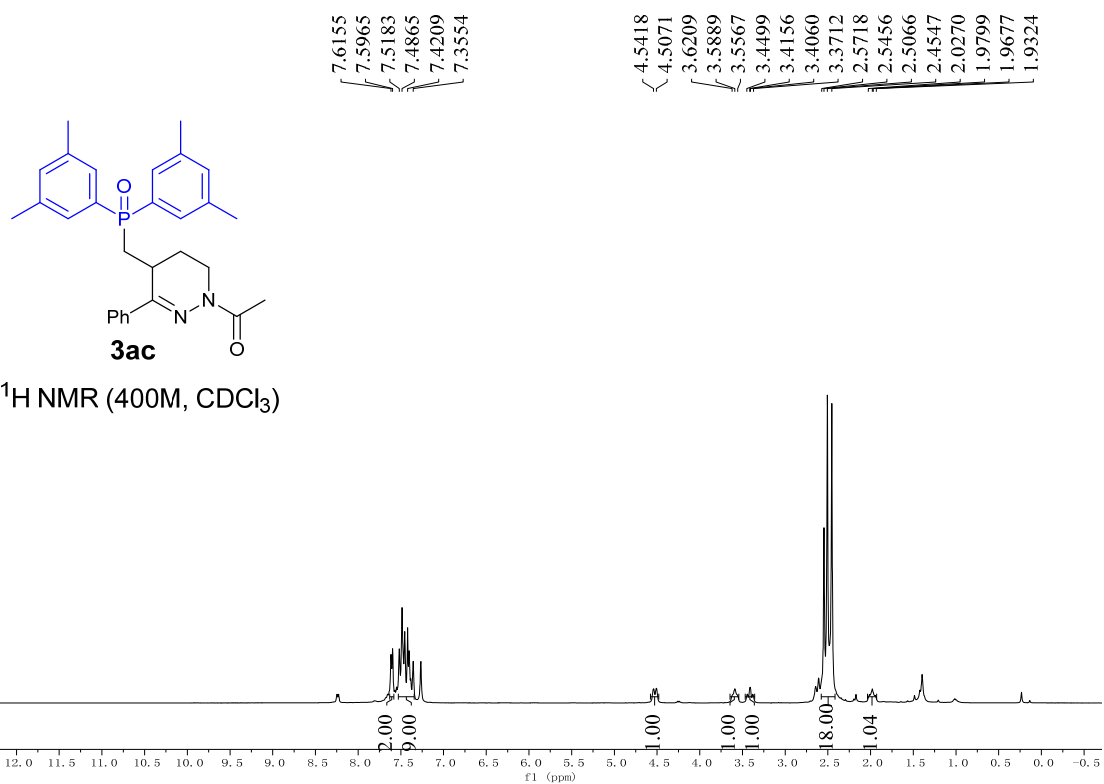


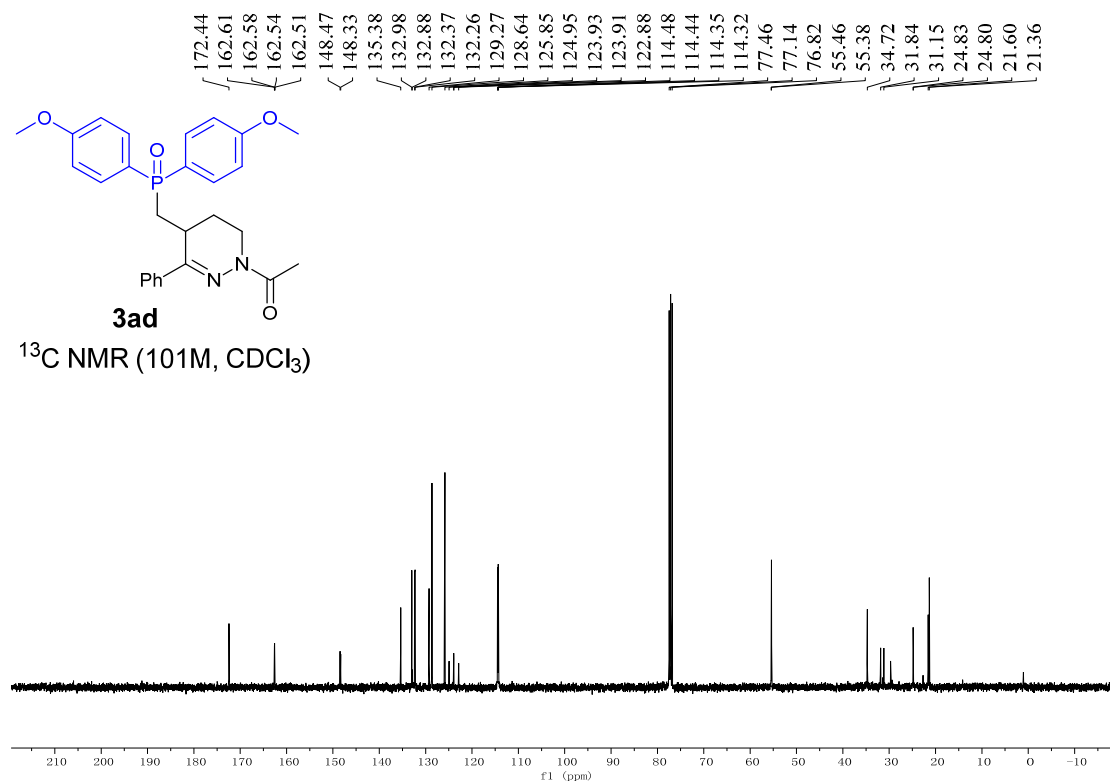
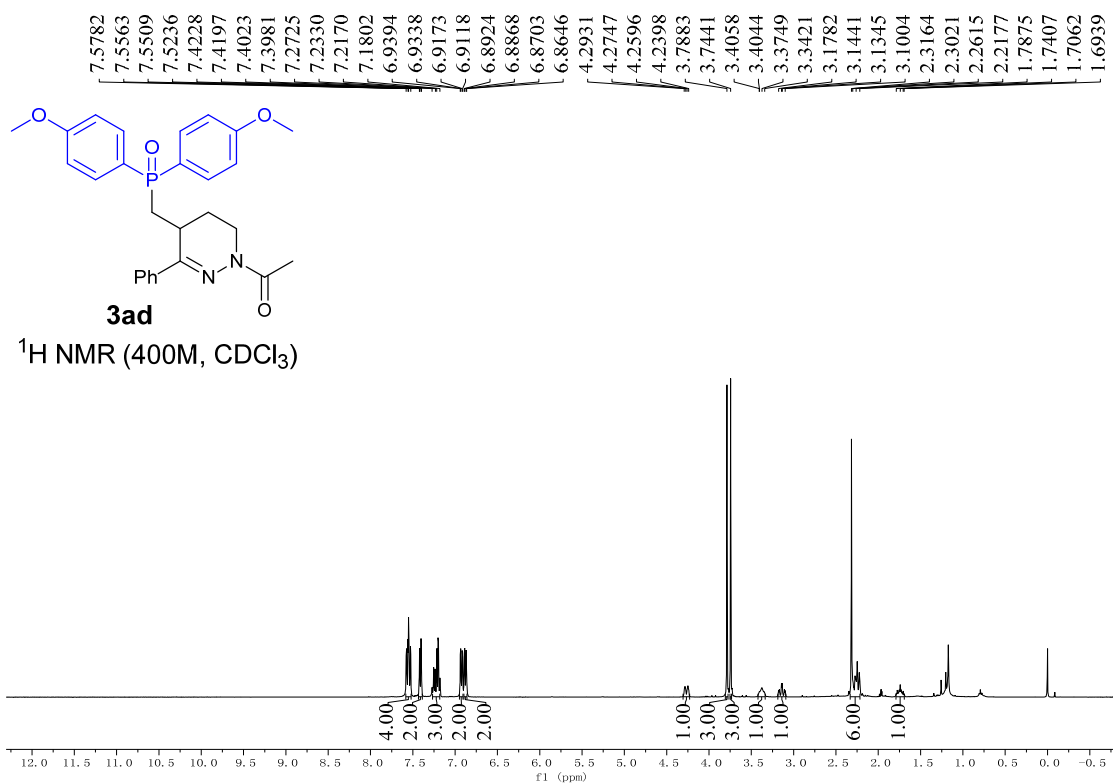
¹³C NMR (101M, CDCl₃)

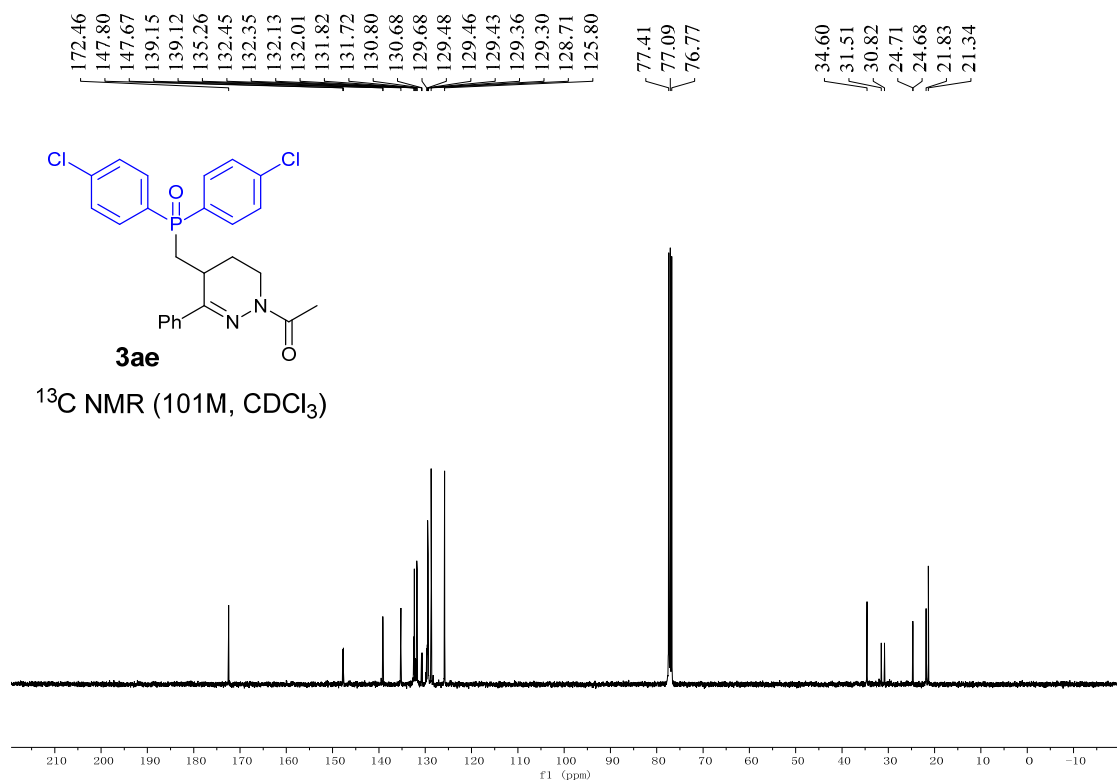
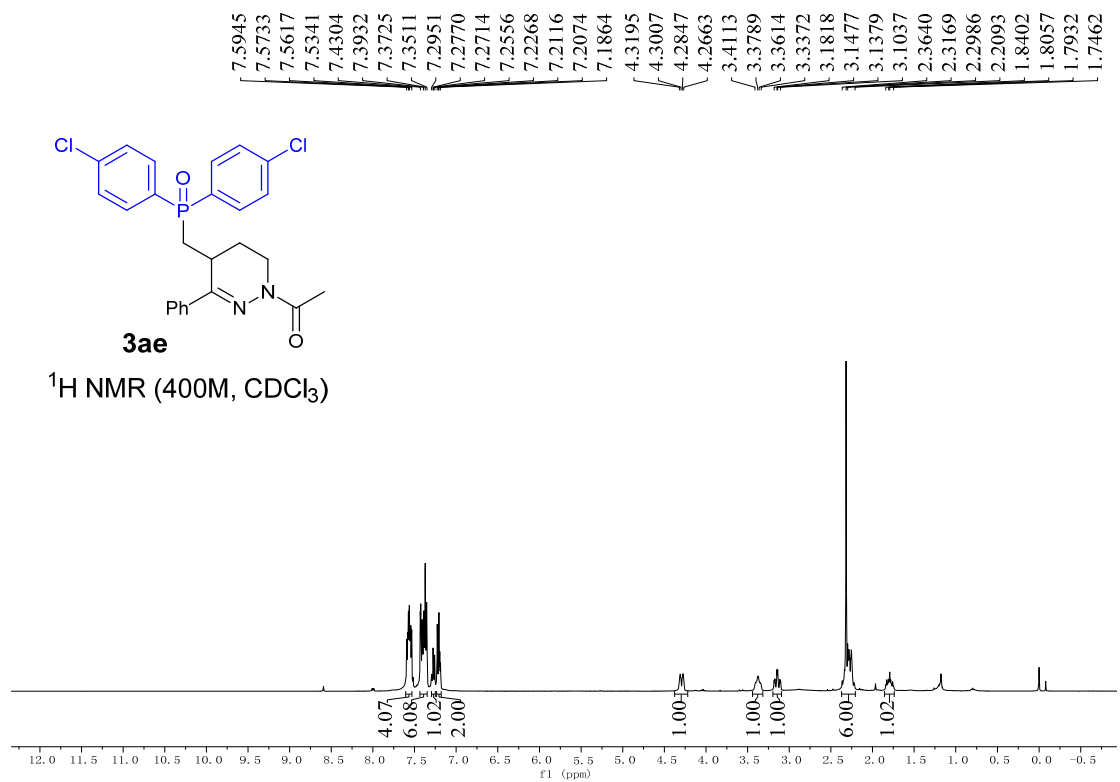


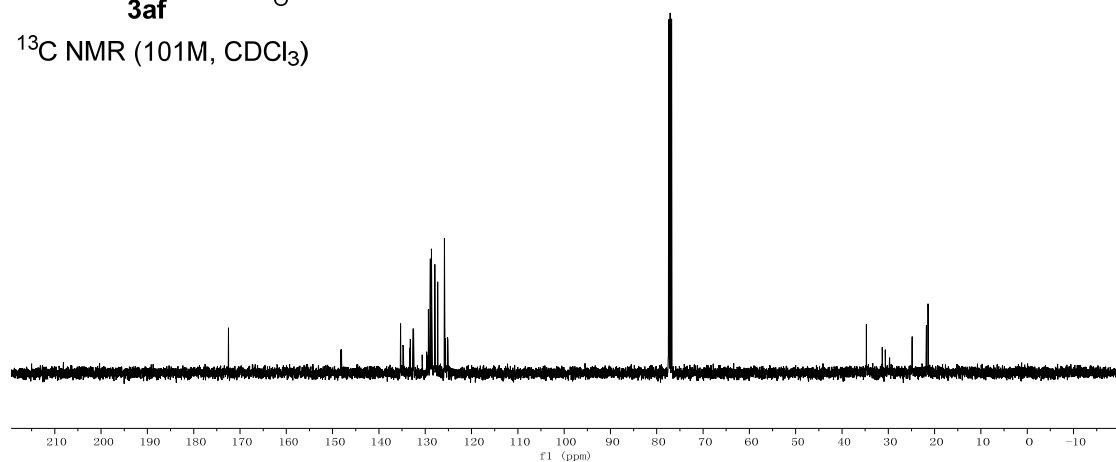
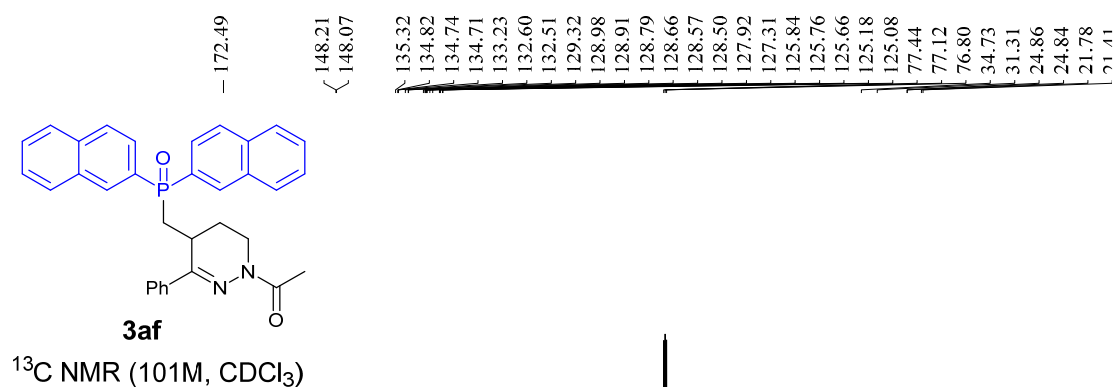
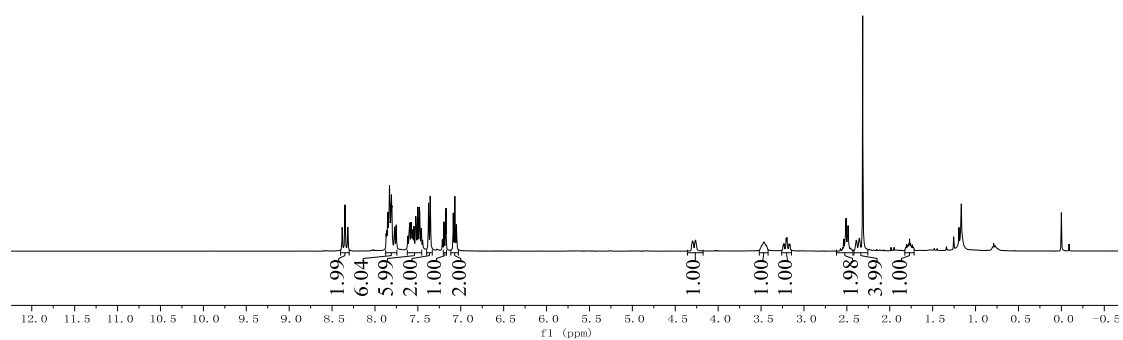
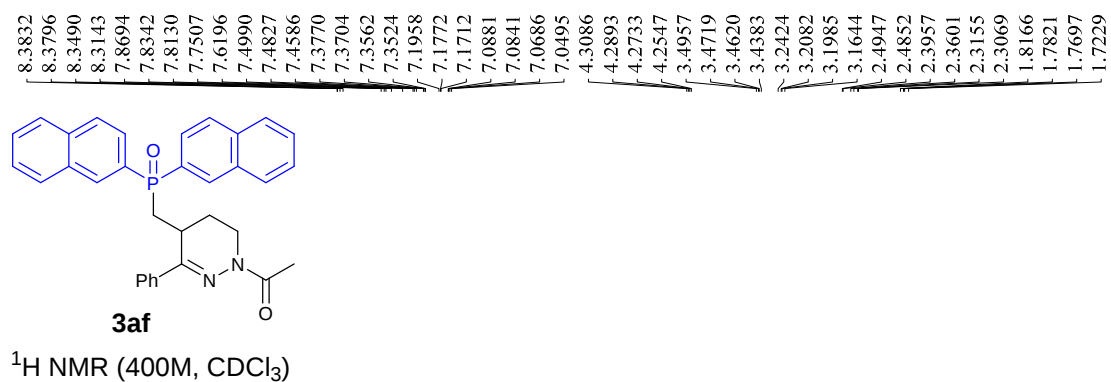


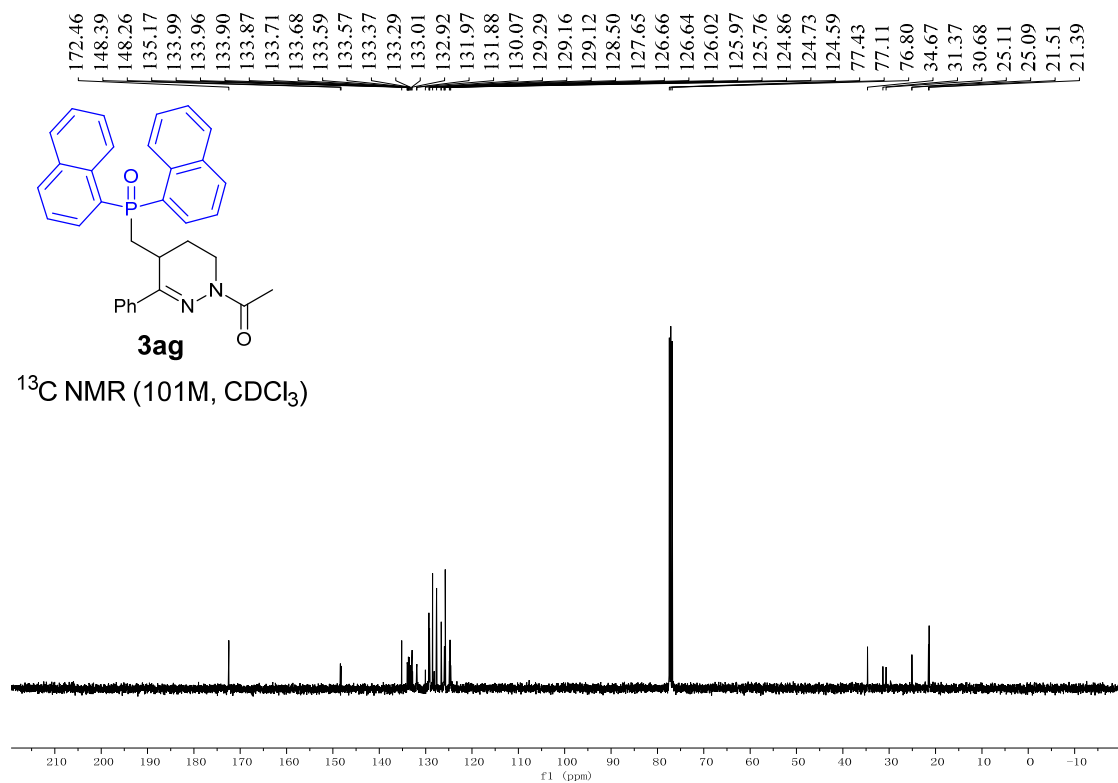
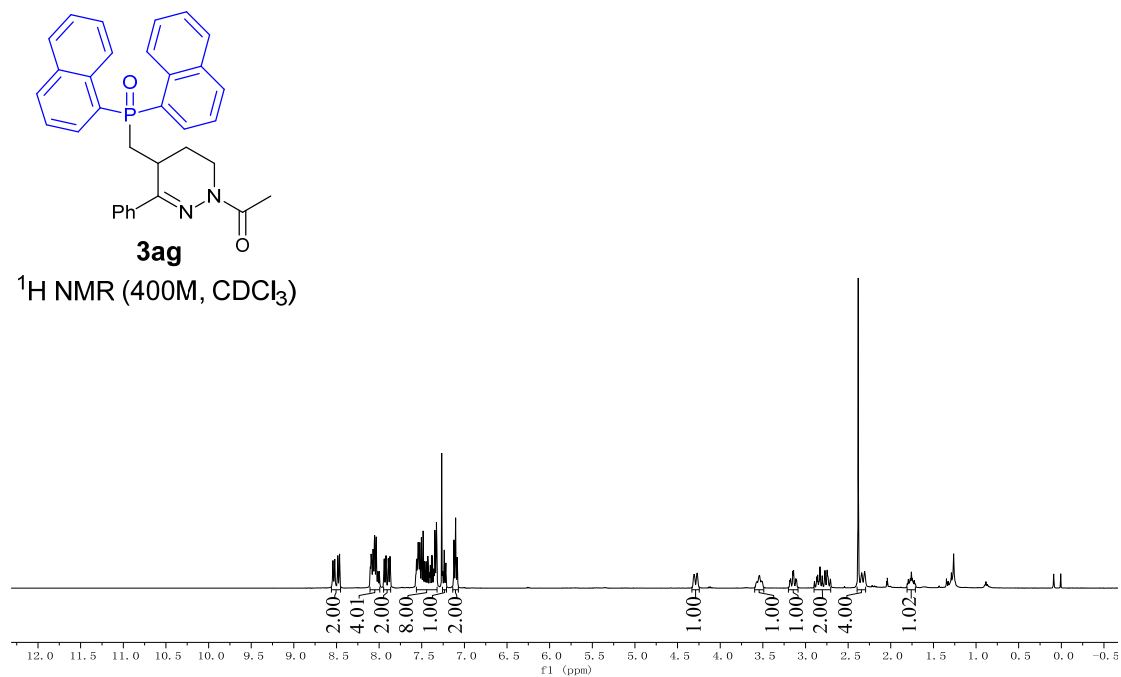
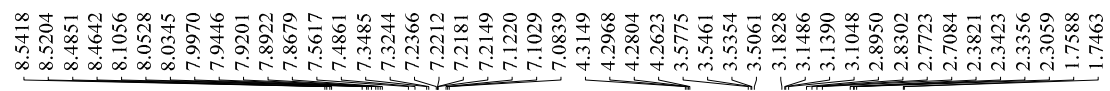


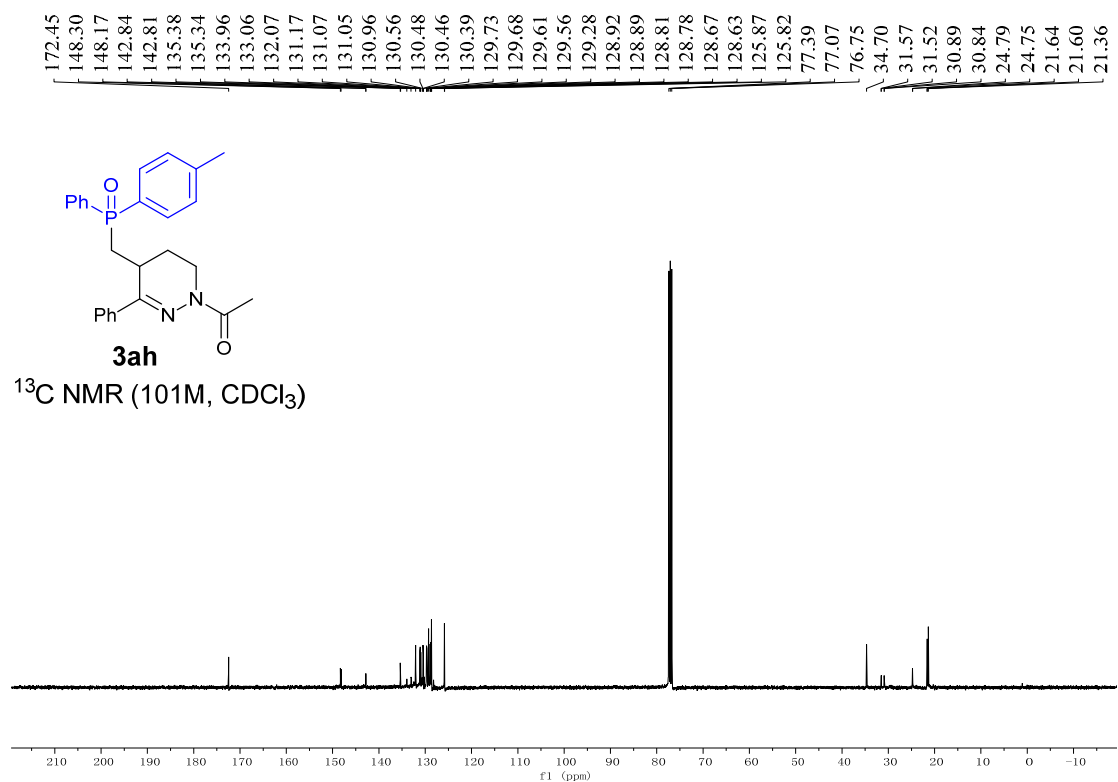
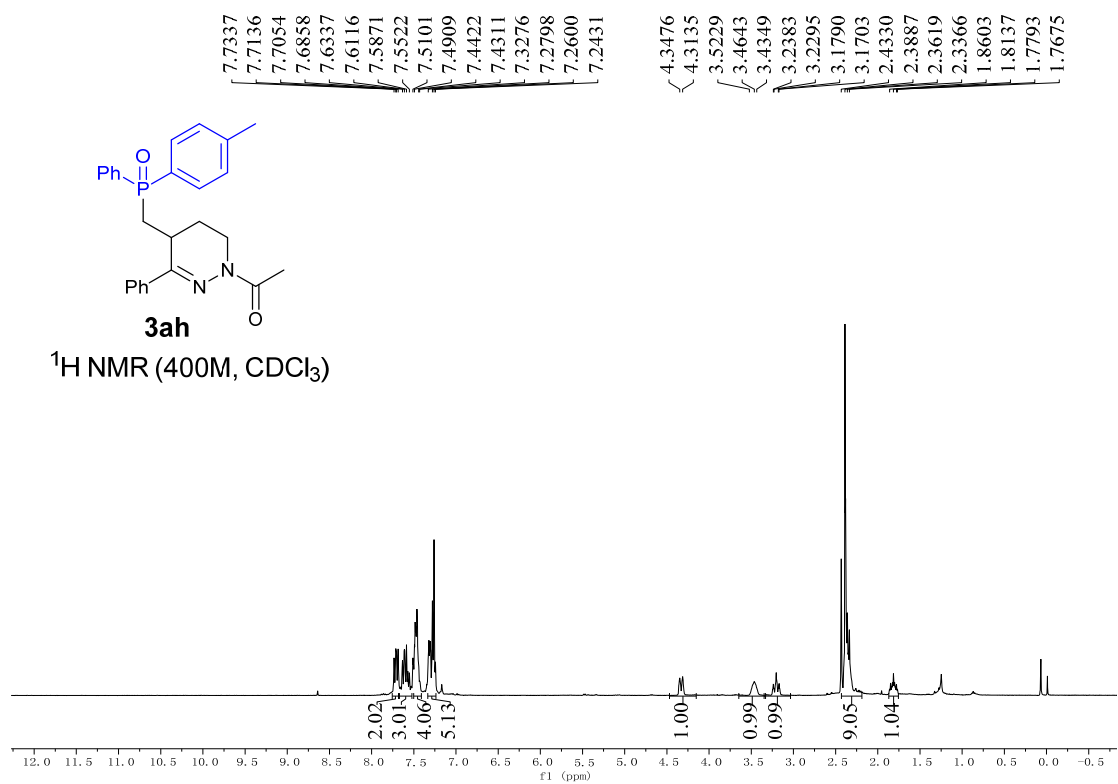


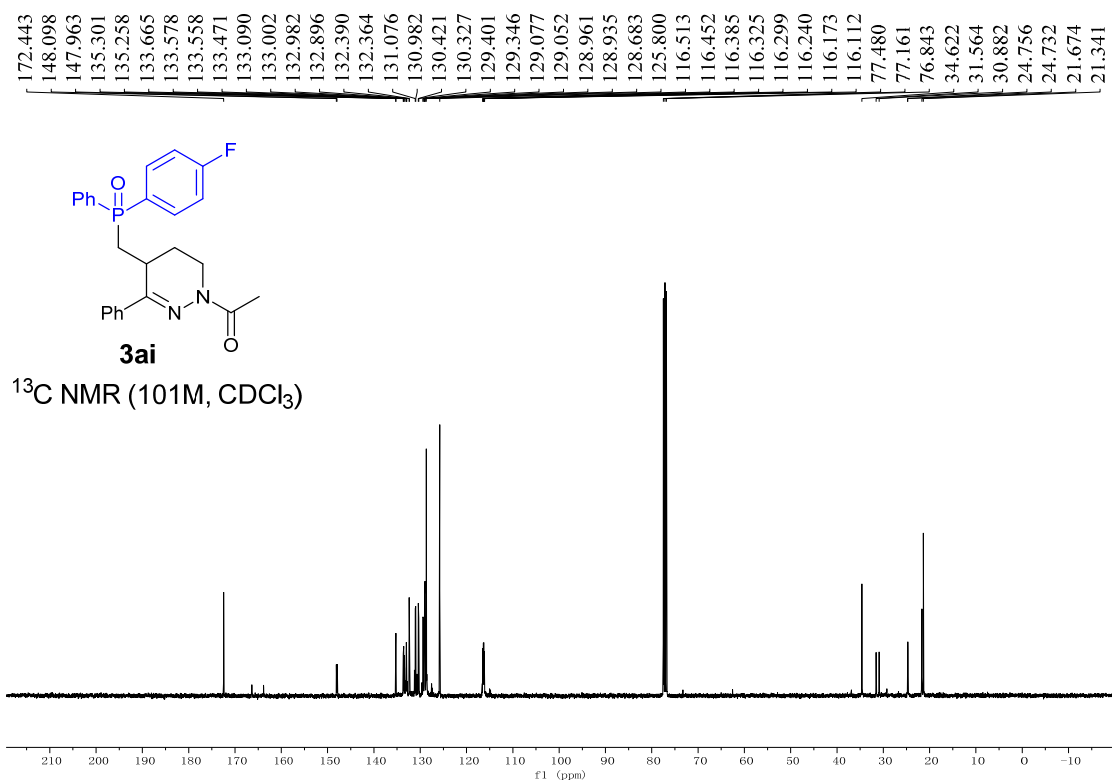
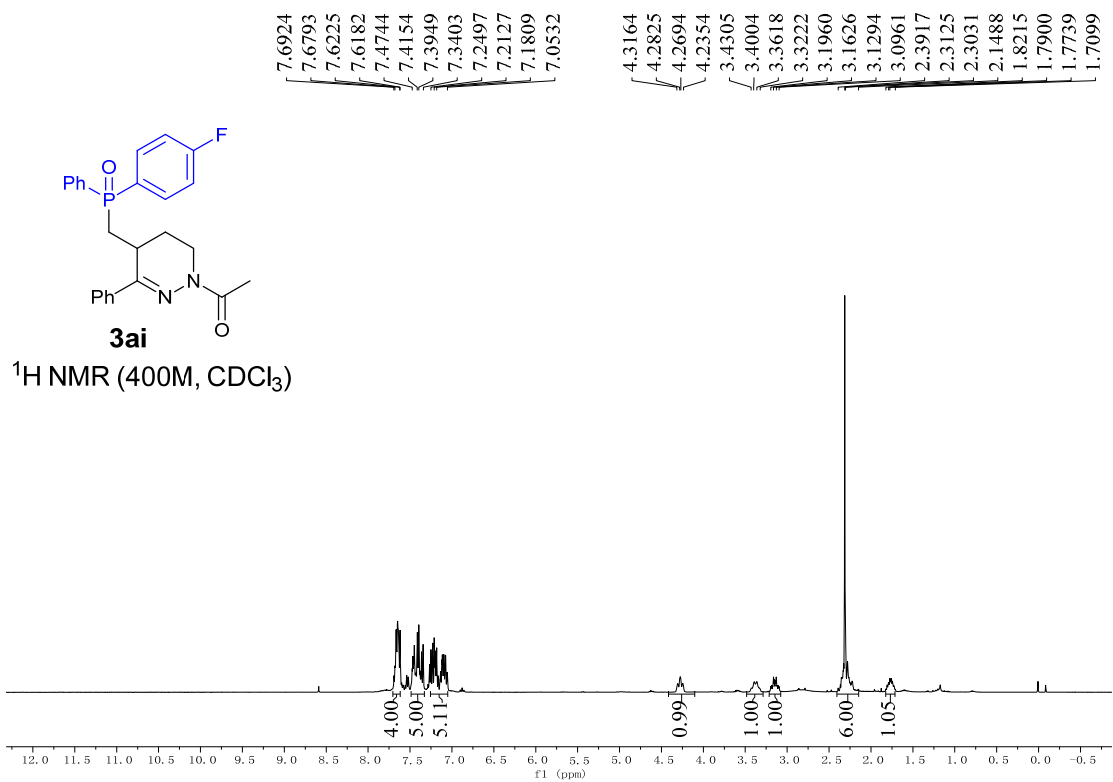


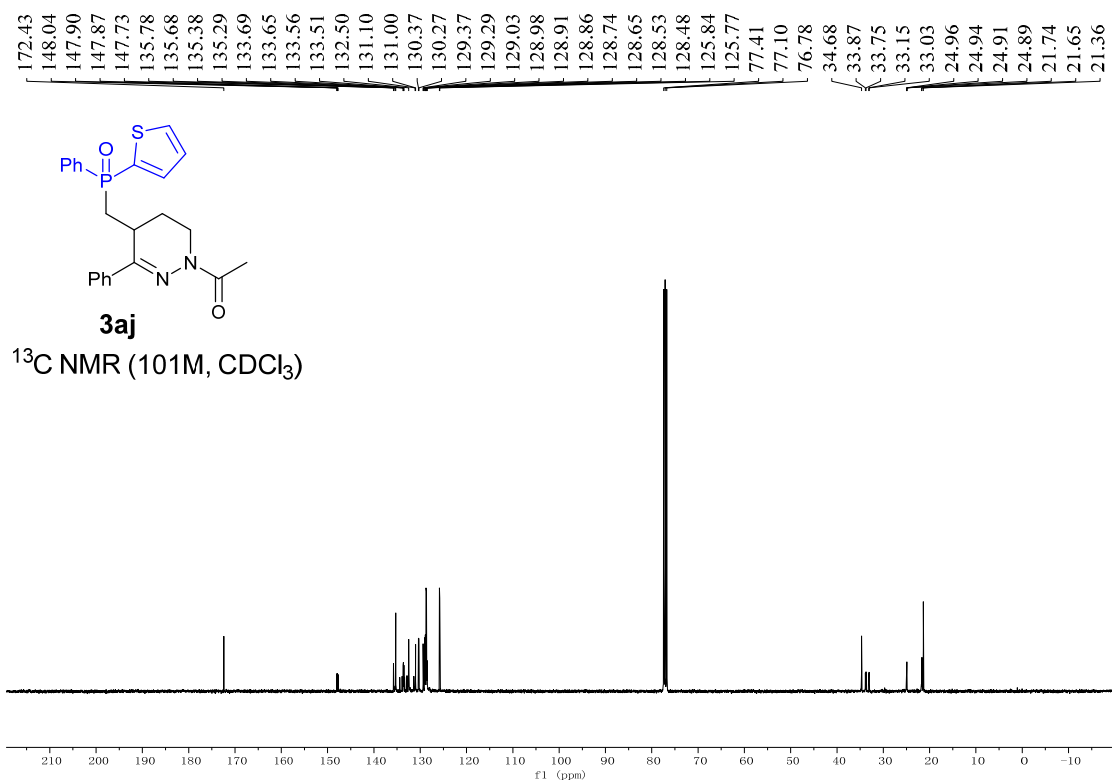
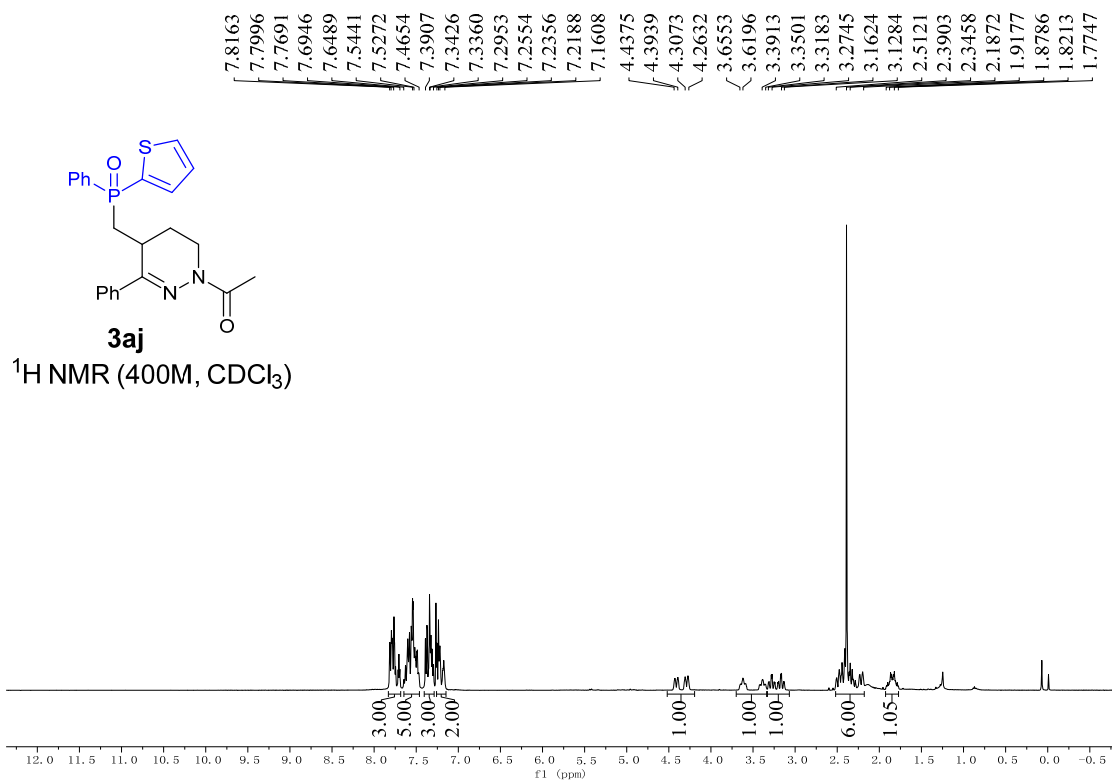


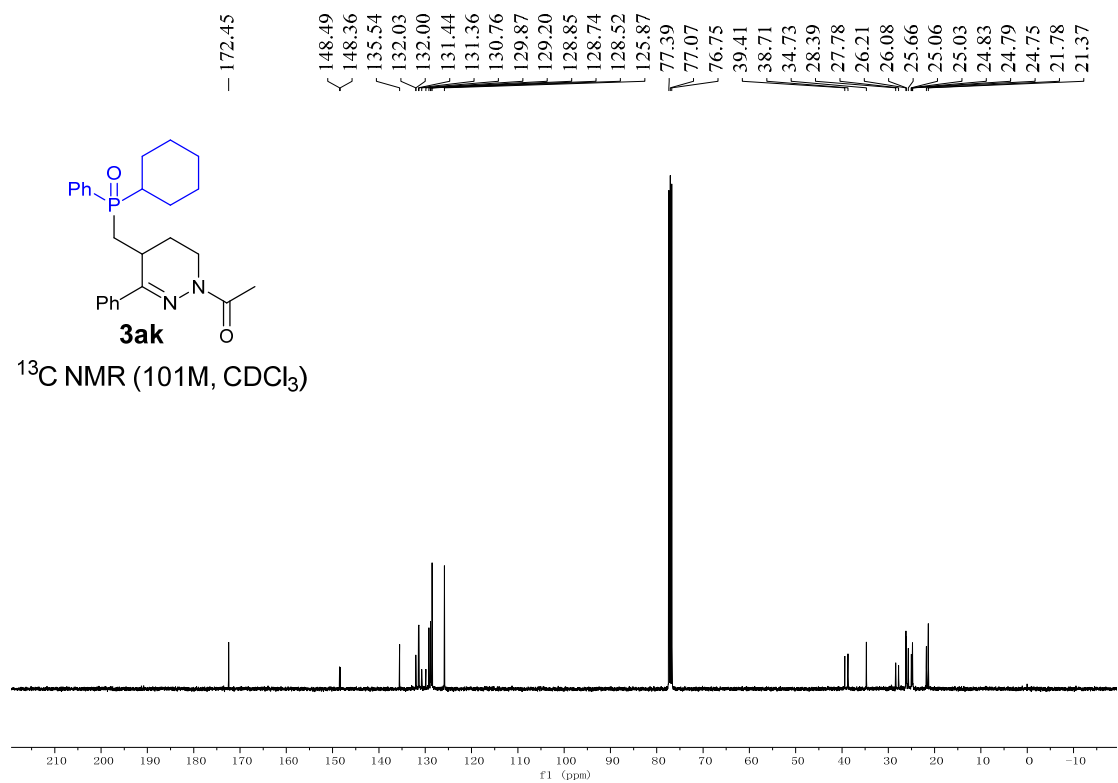
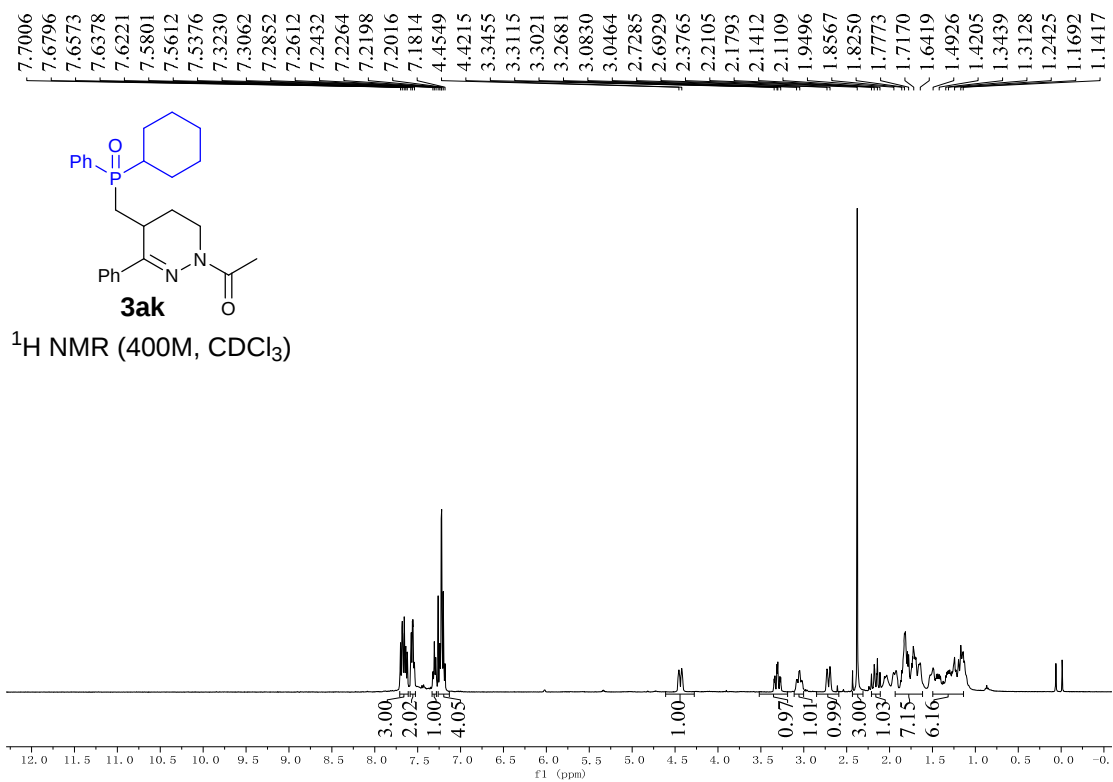


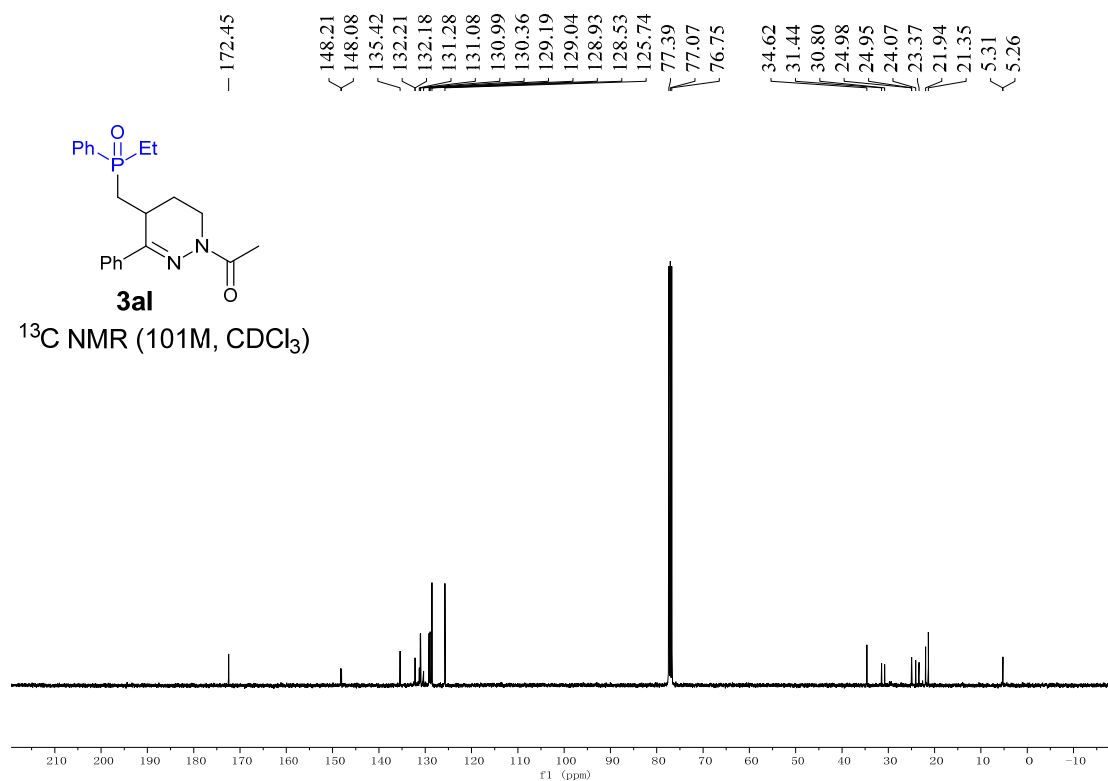
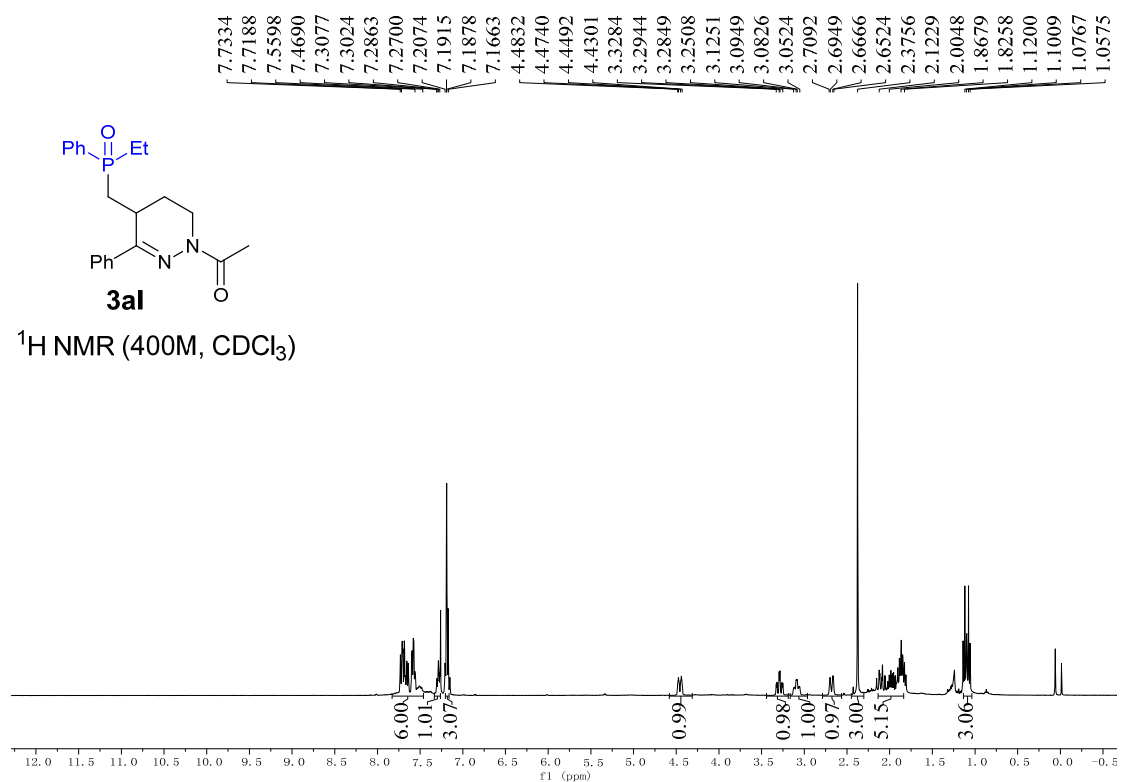


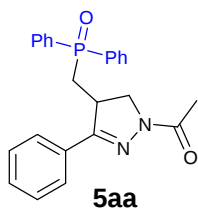




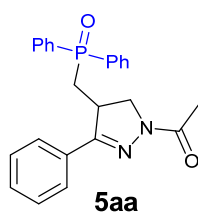
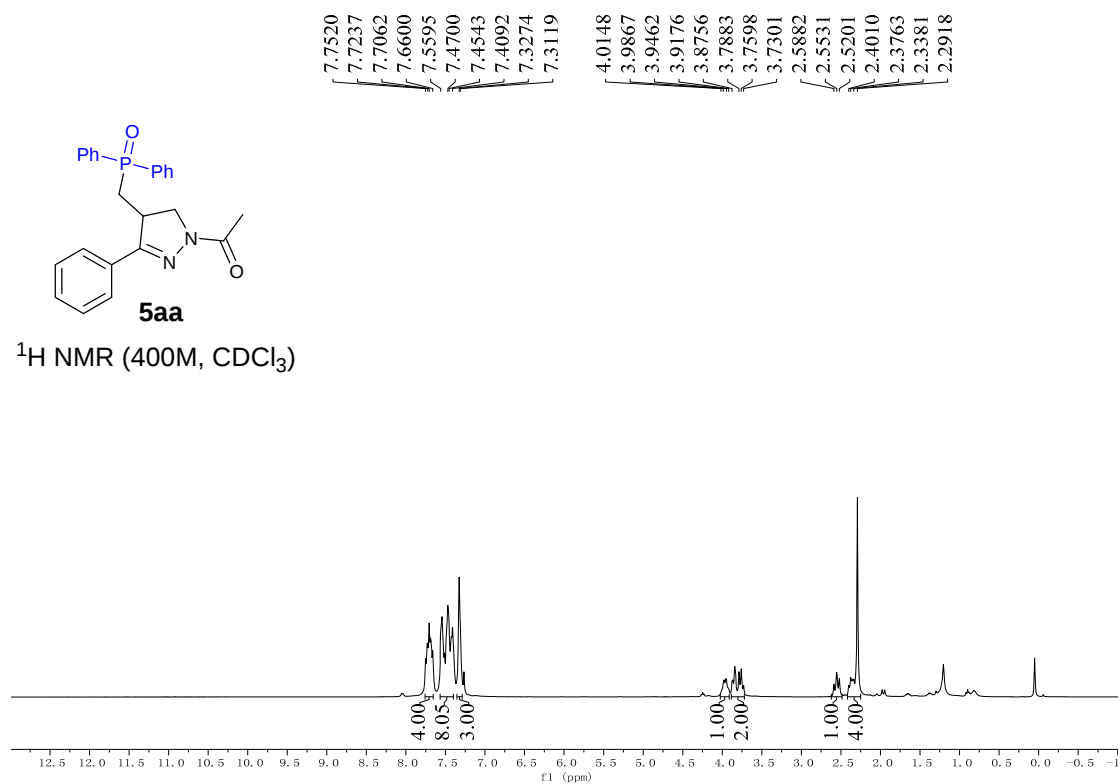




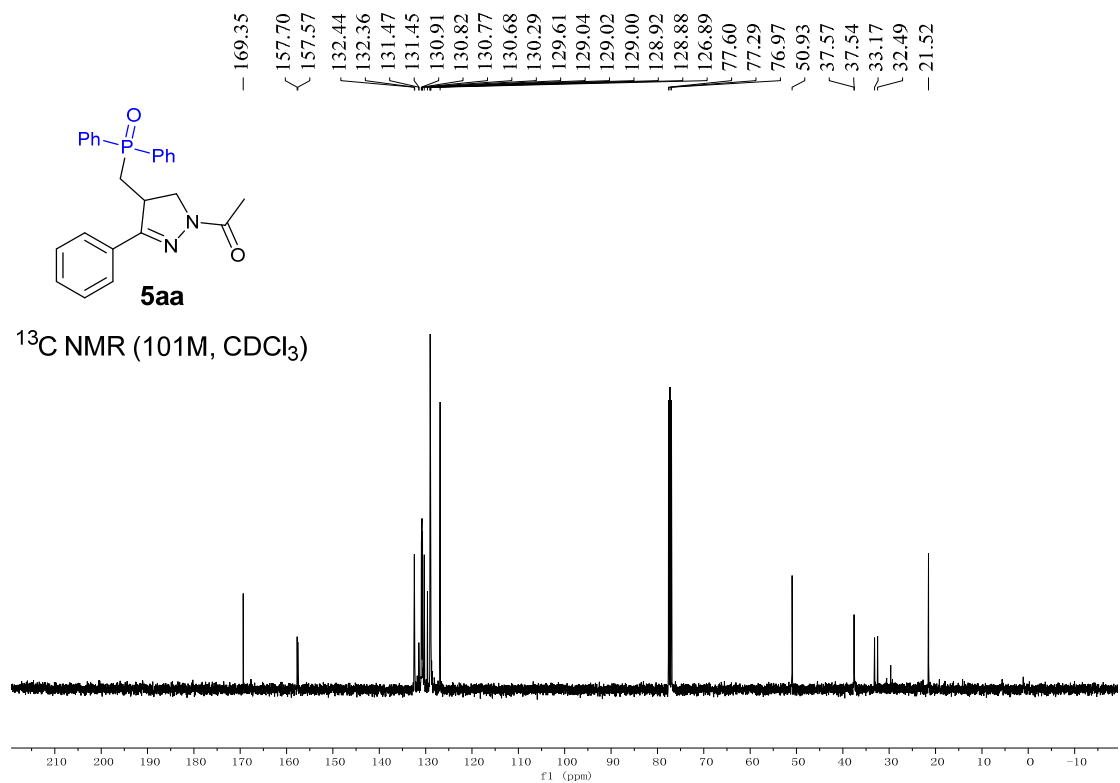


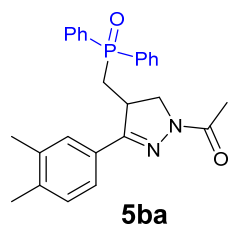


^1H NMR (400M, CDCl_3)

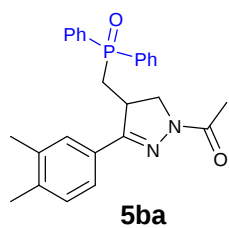
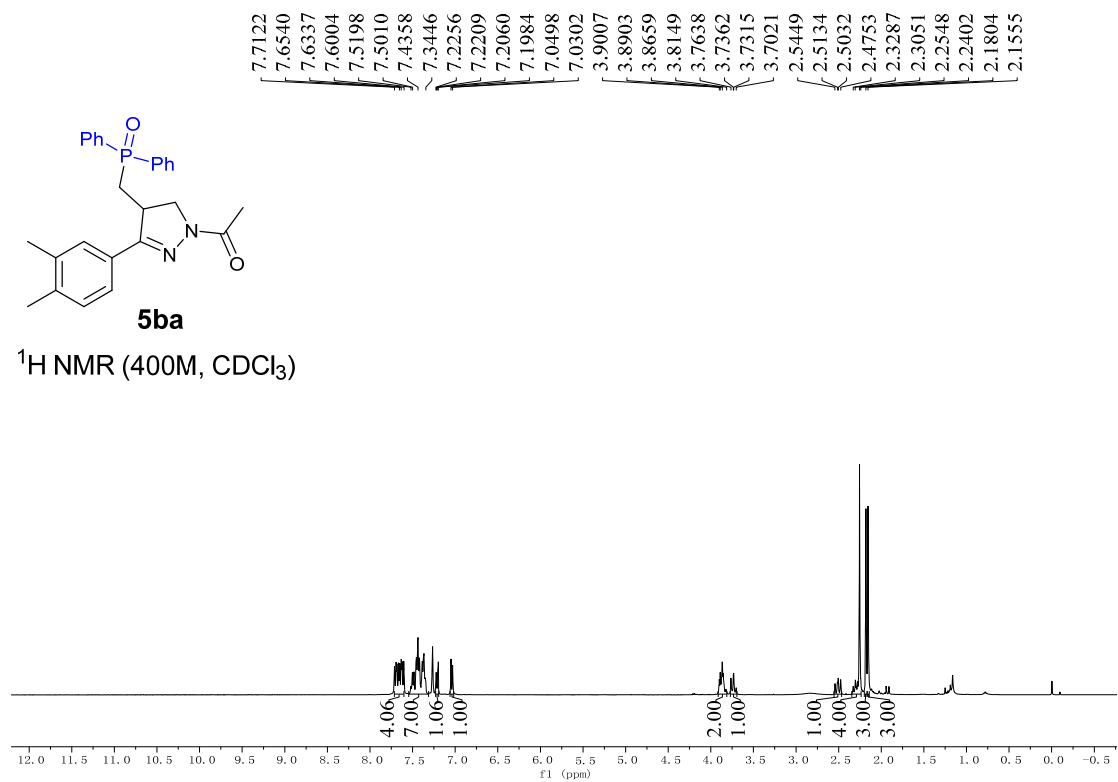


^{13}C NMR (101M, CDCl_3)

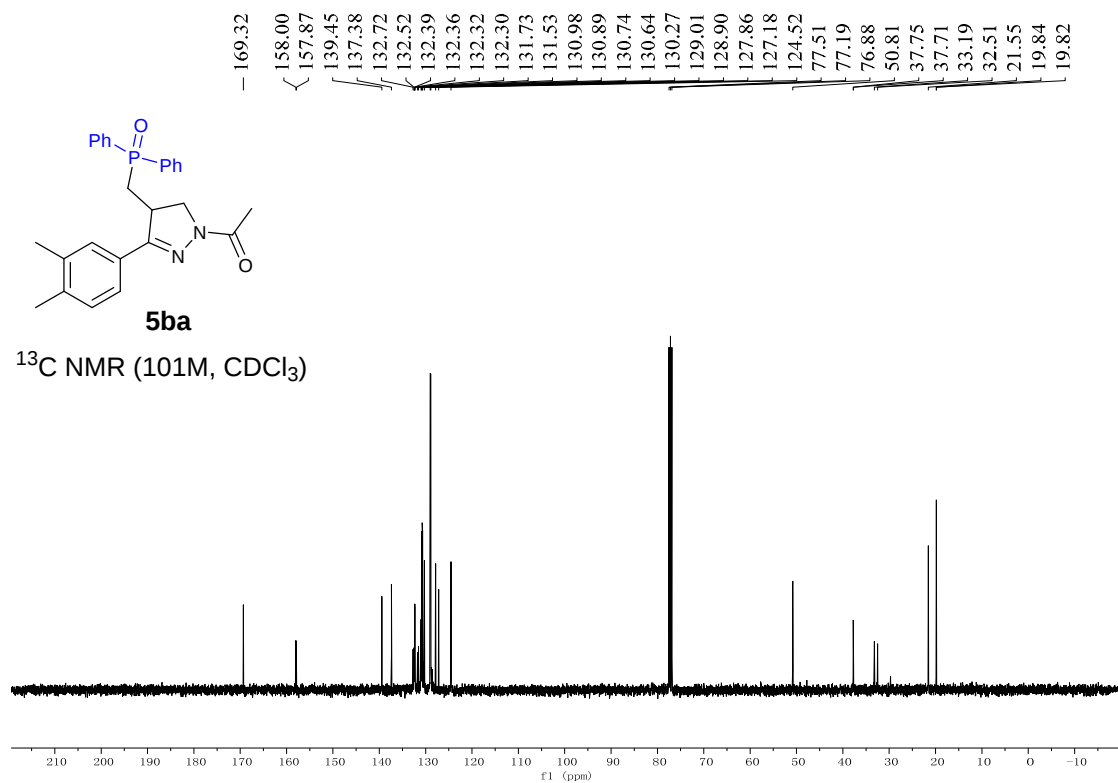


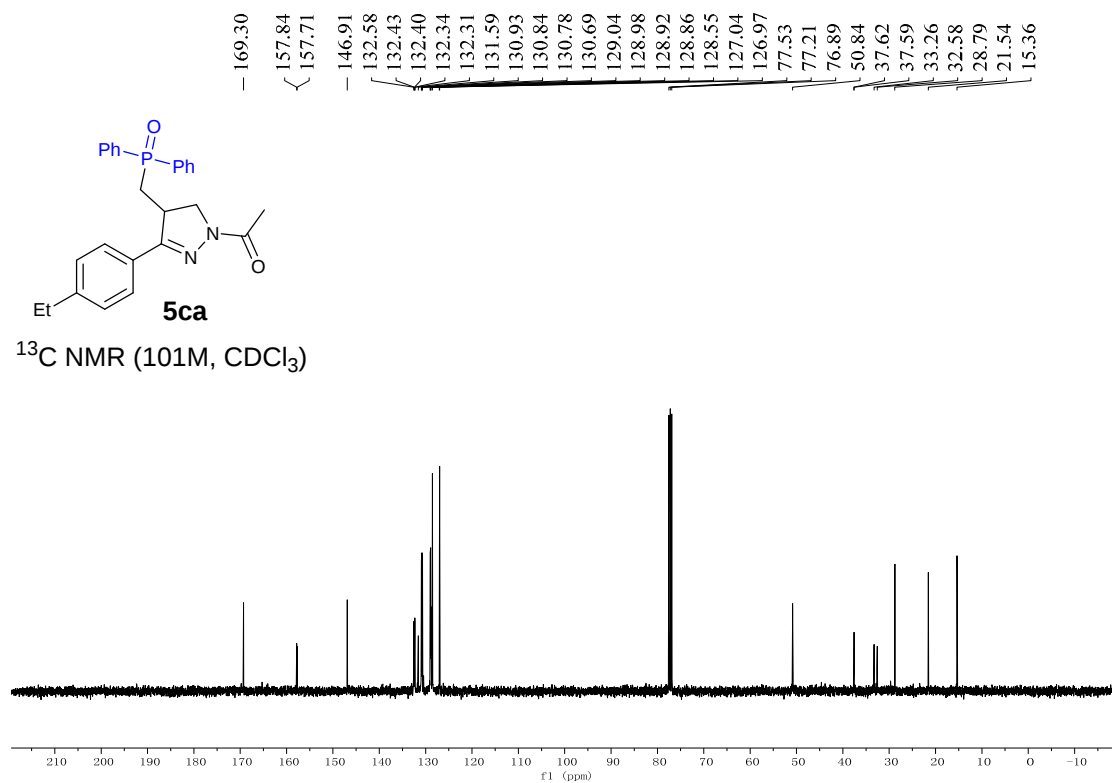
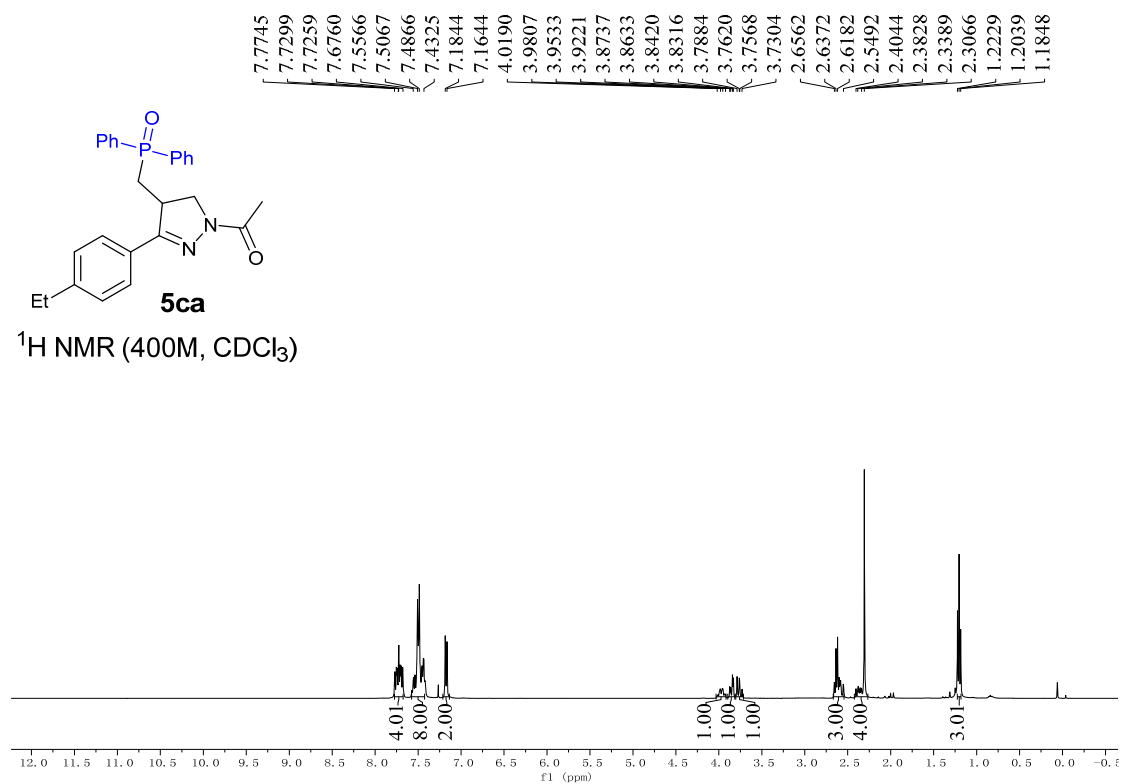


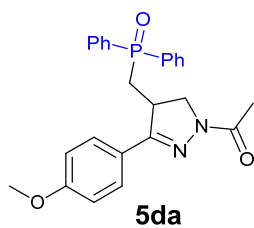
^1H NMR (400M, CDCl_3)



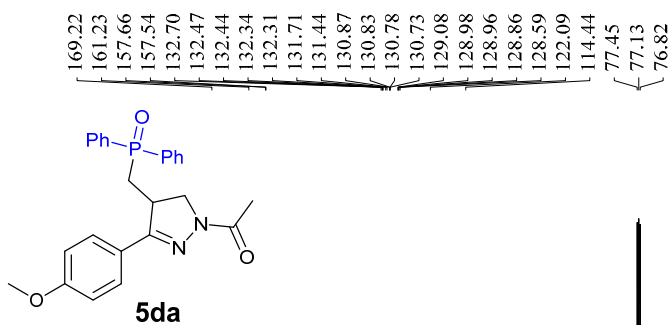
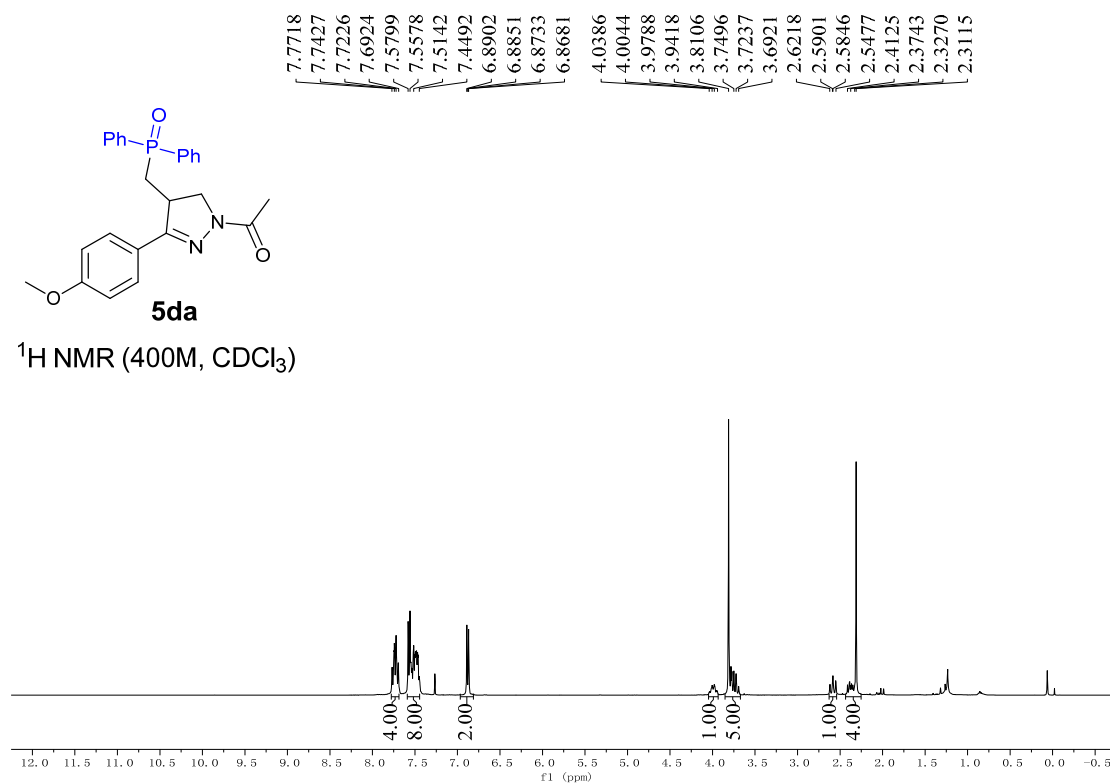
^{13}C NMR (101M, CDCl_3)



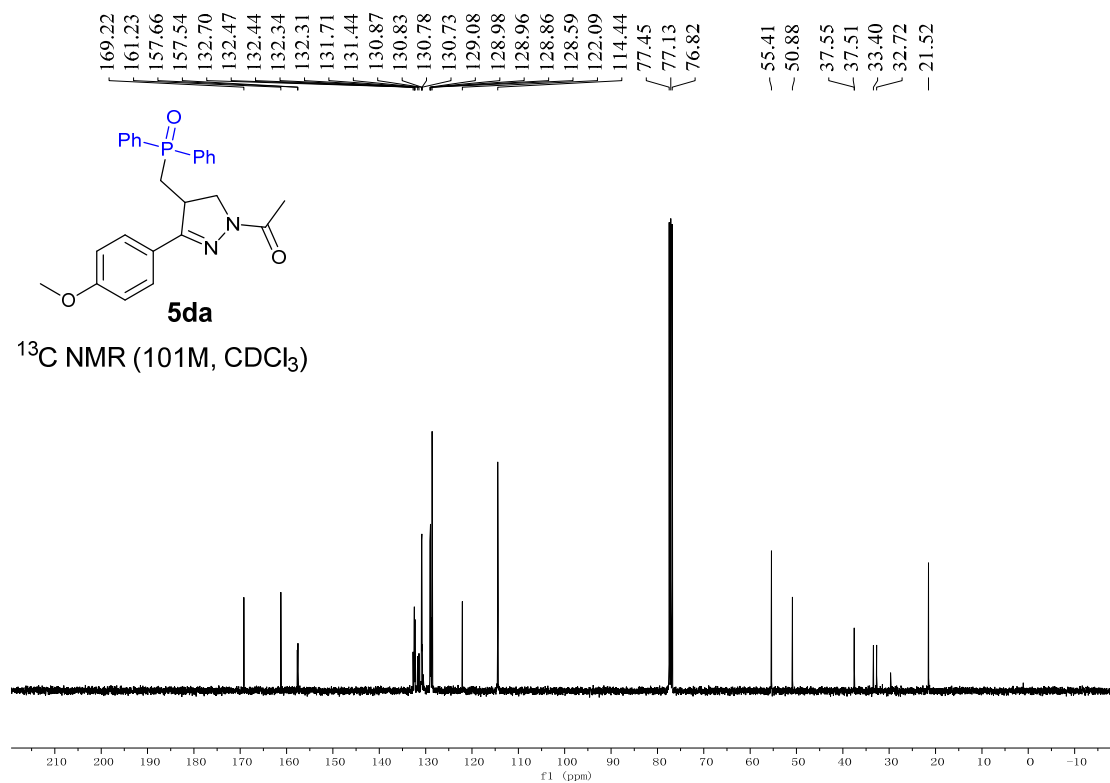


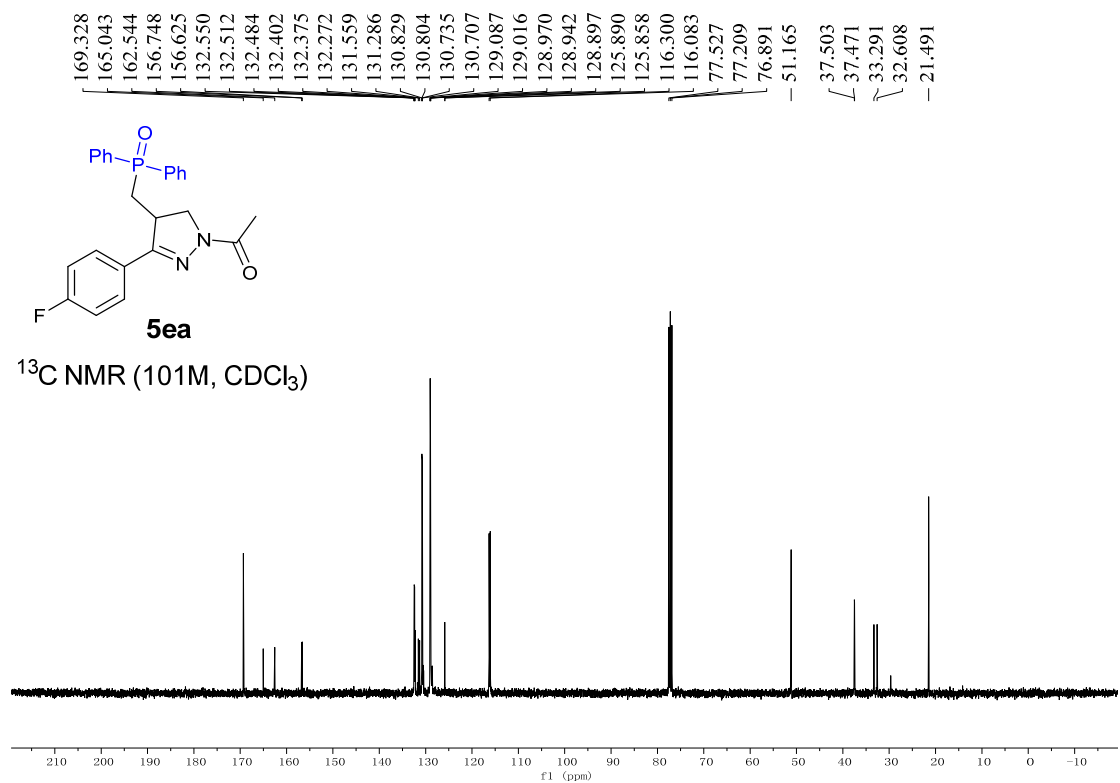
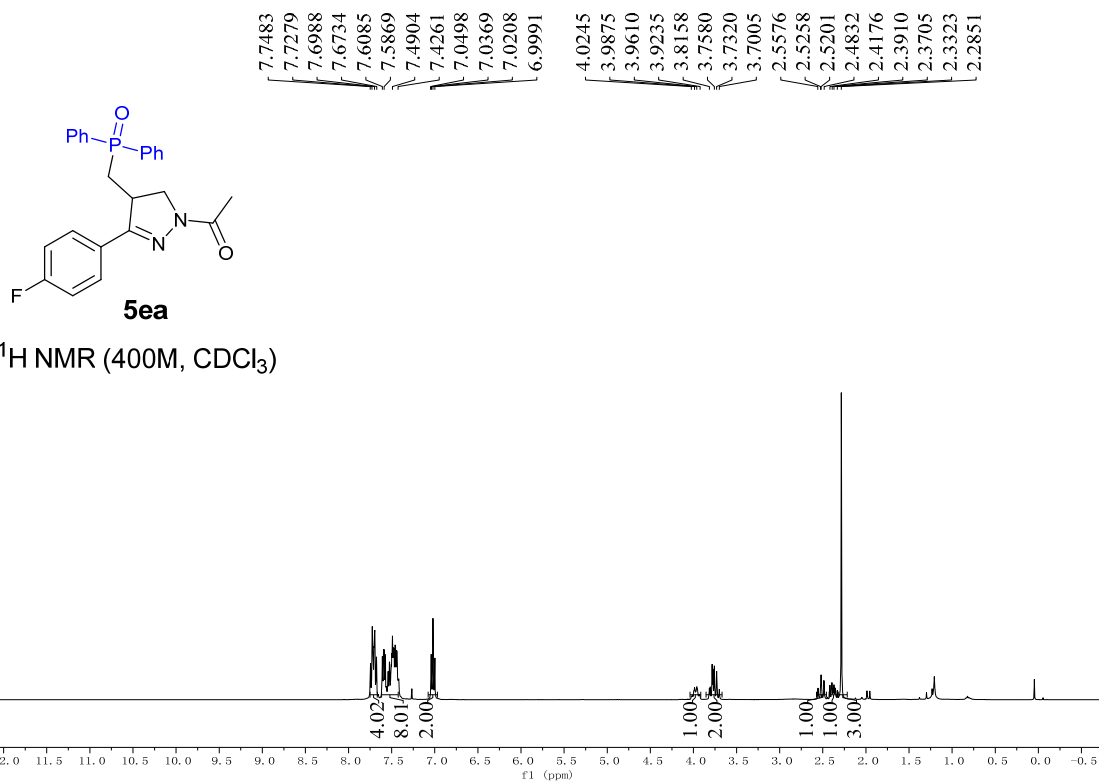


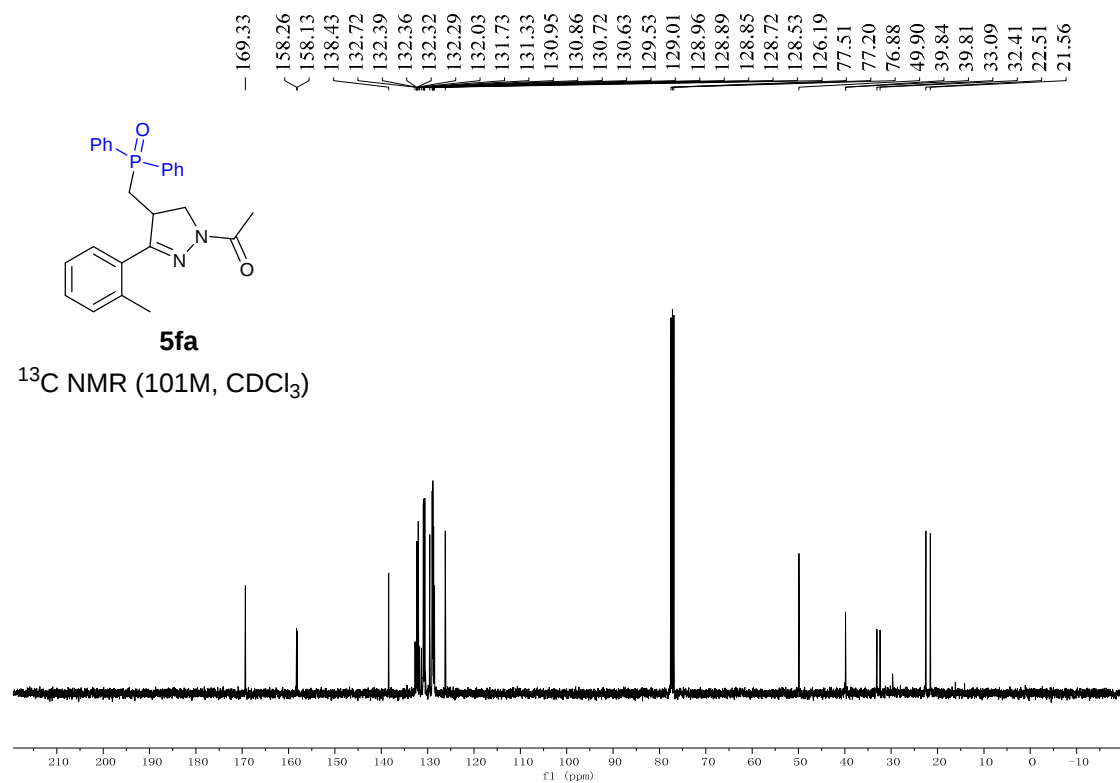
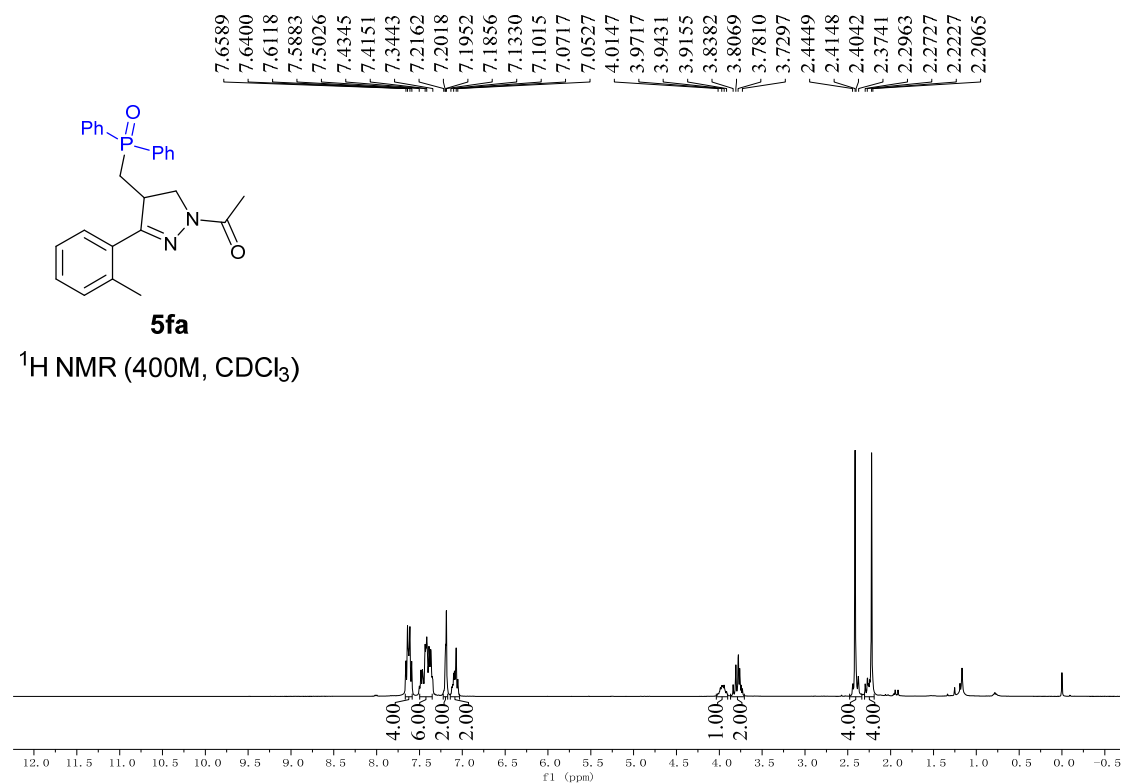
¹H NMR (400M, CDCl₃)

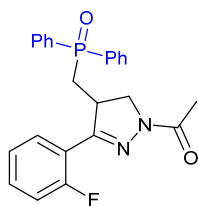


¹³C NMR (101M, CDCl₃)



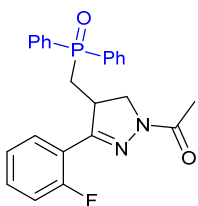
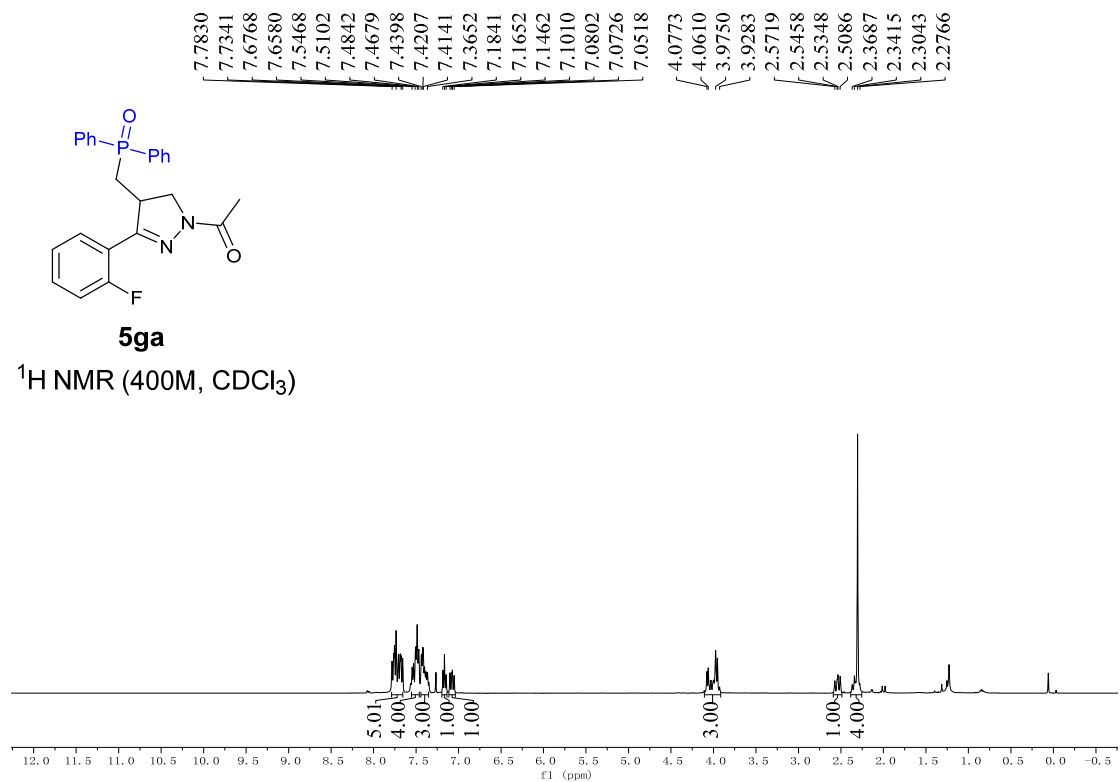






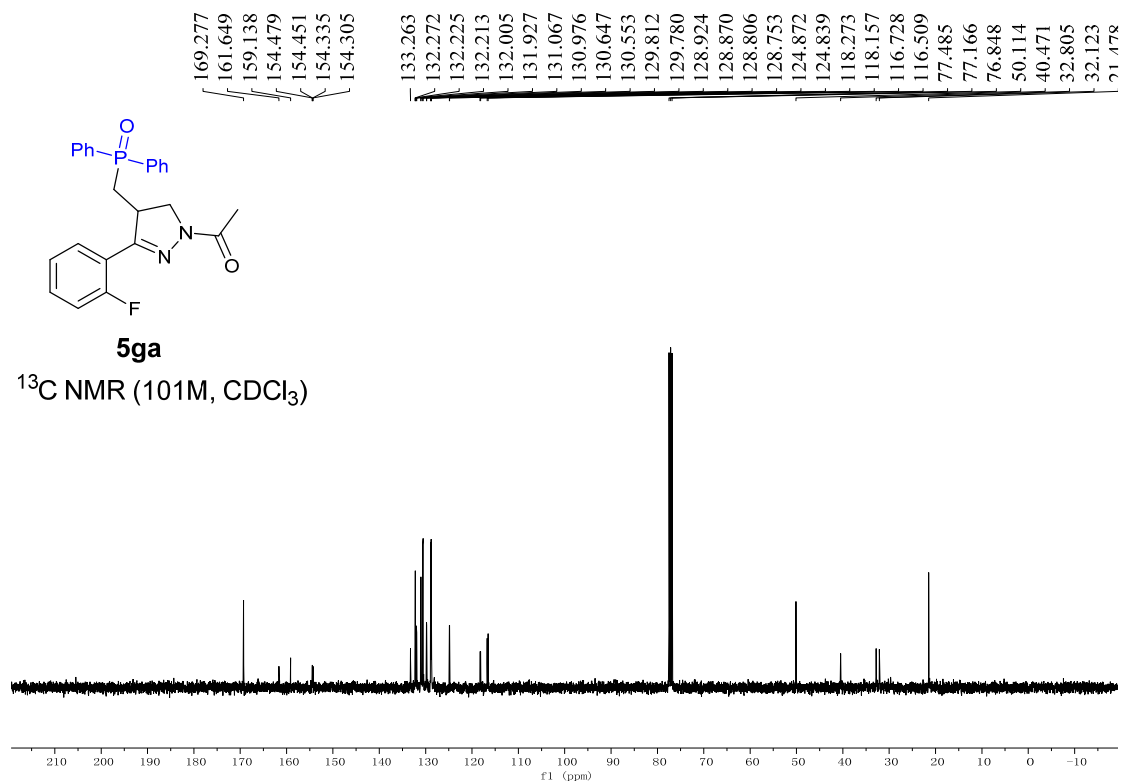
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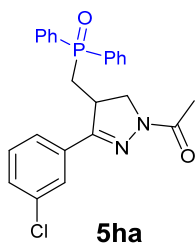
^1H NMR (400M, CDCl_3)



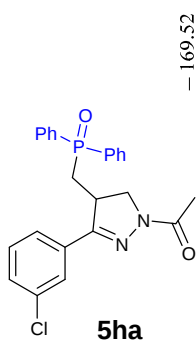
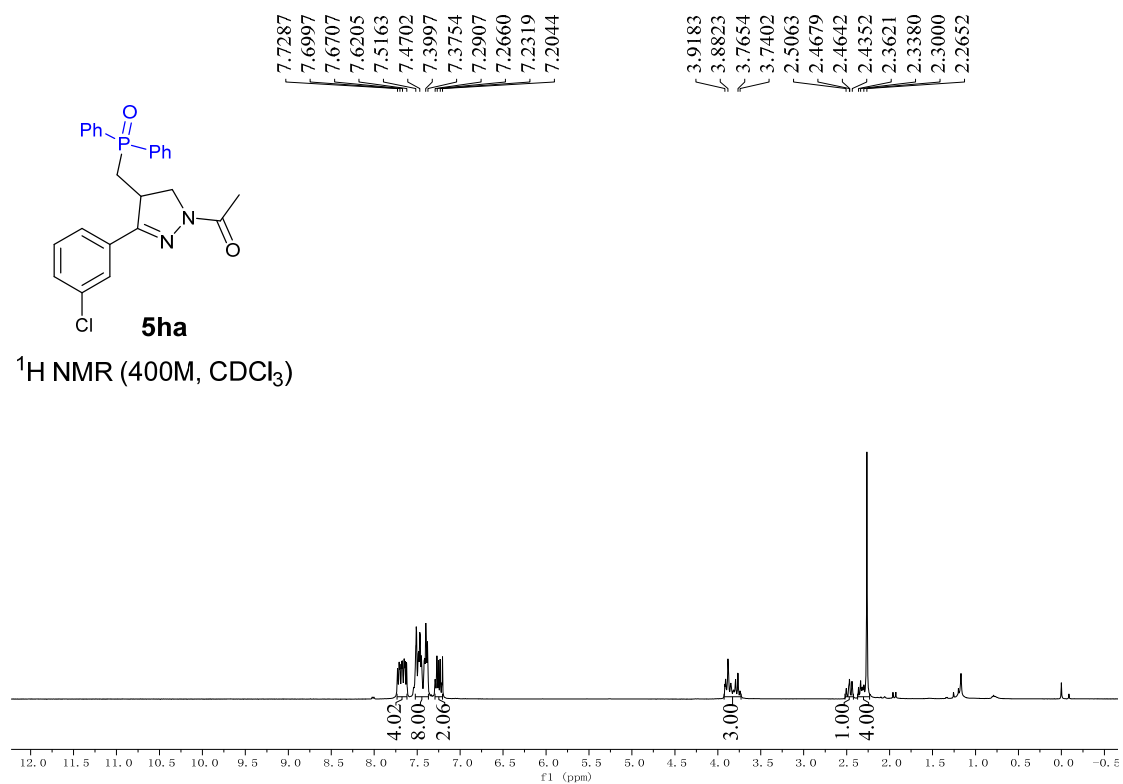
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^{13}C NMR (101M, CDCl_3)

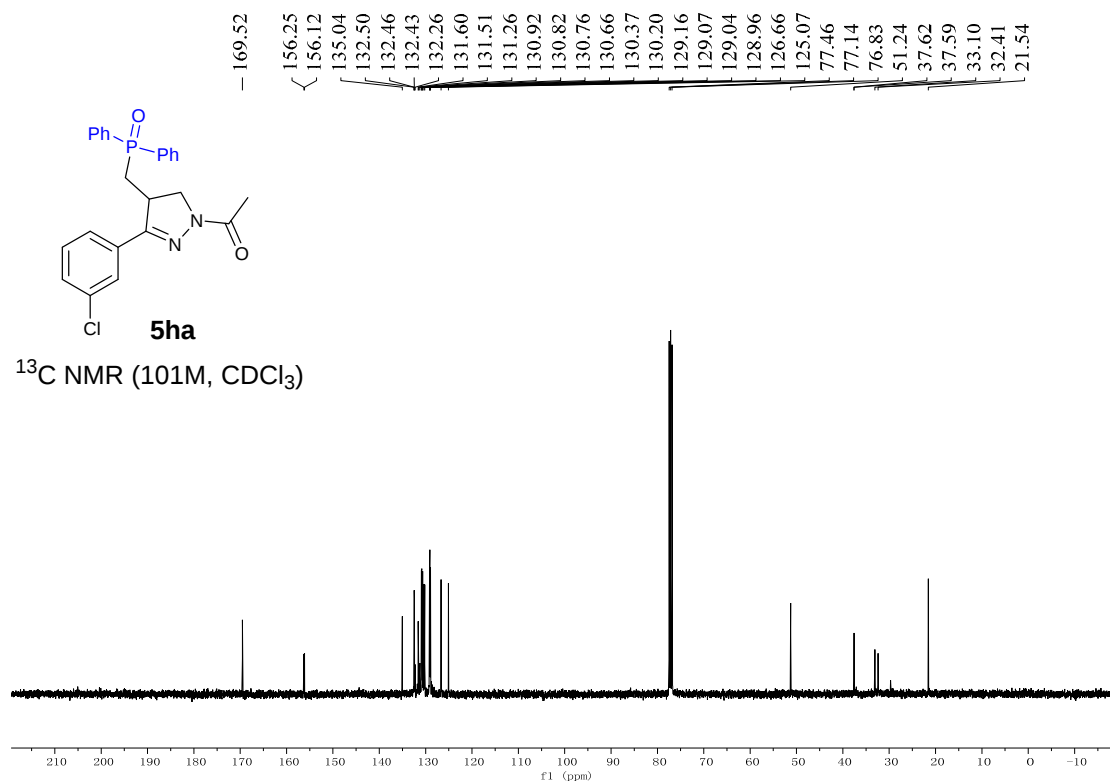


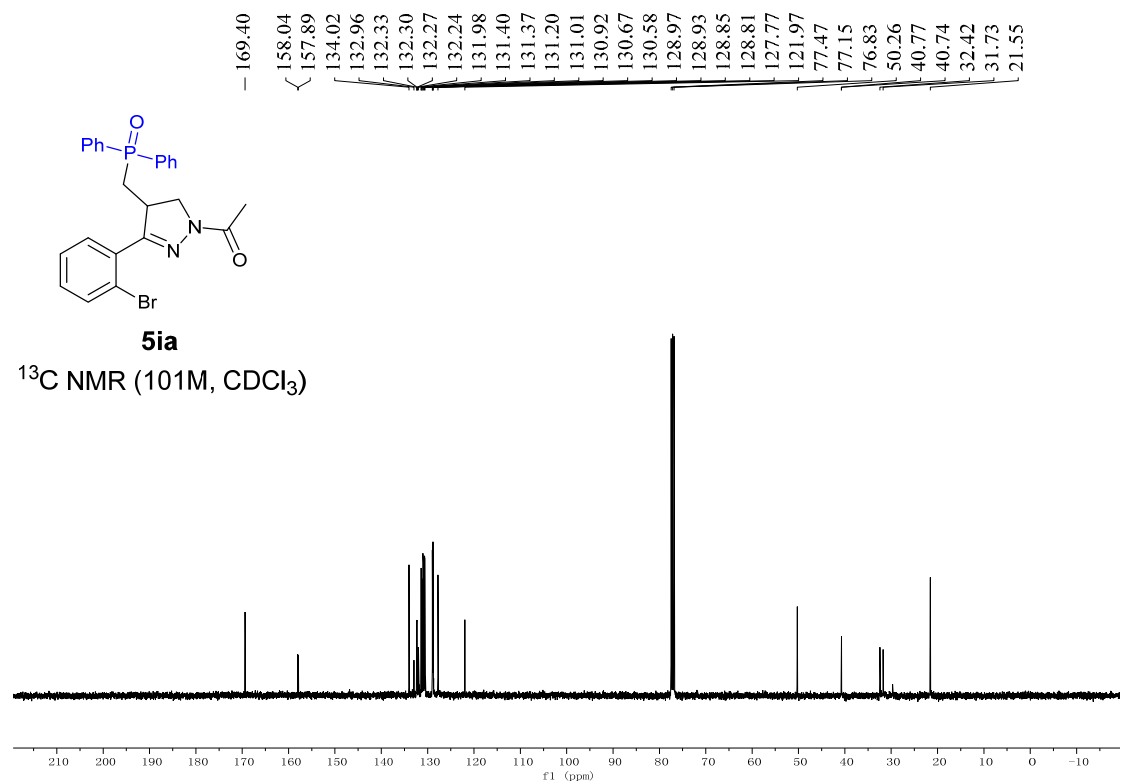
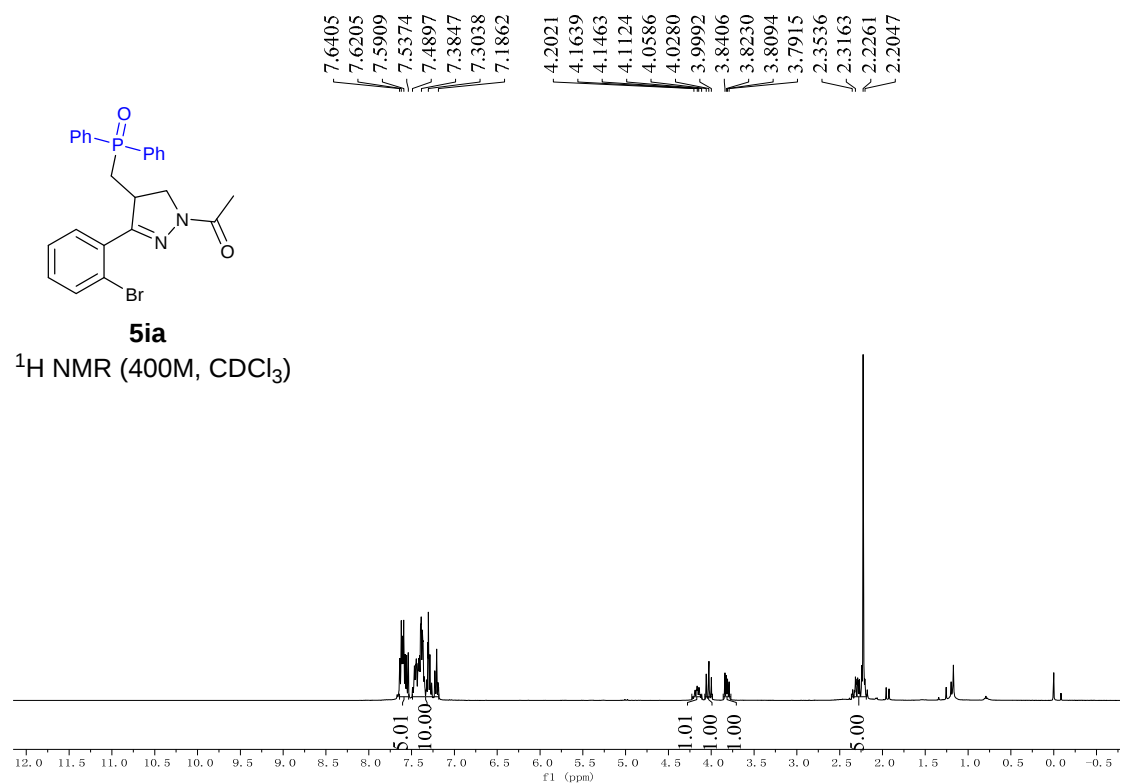


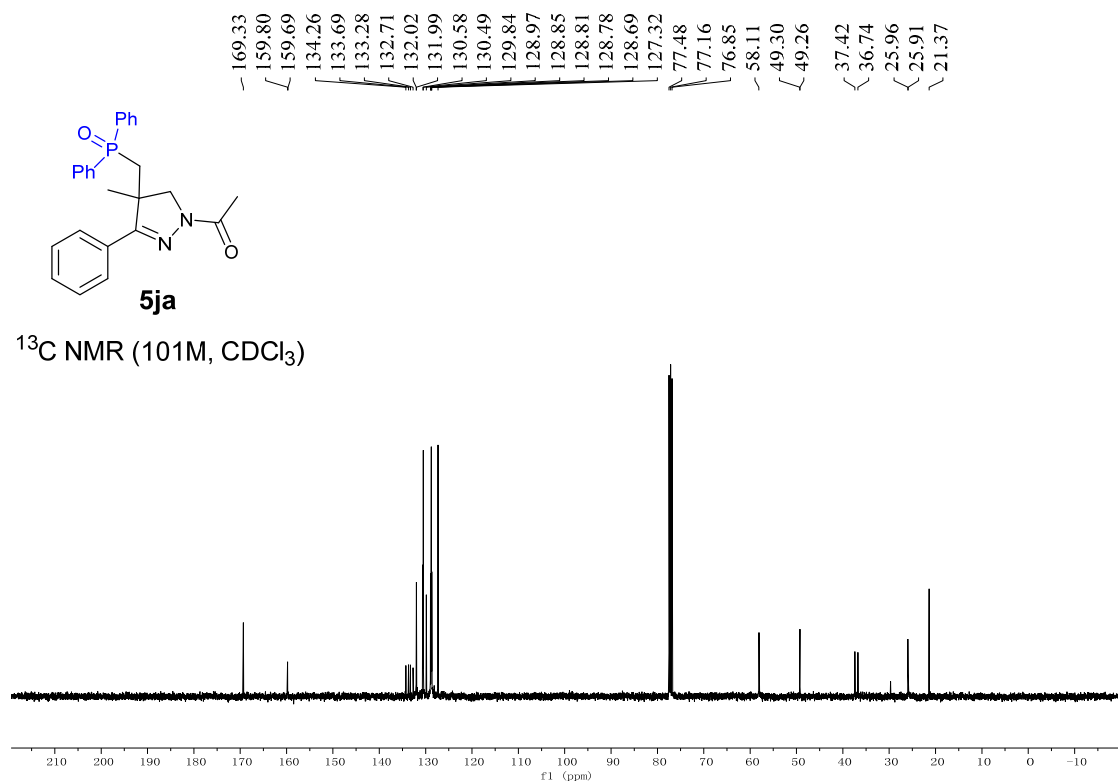
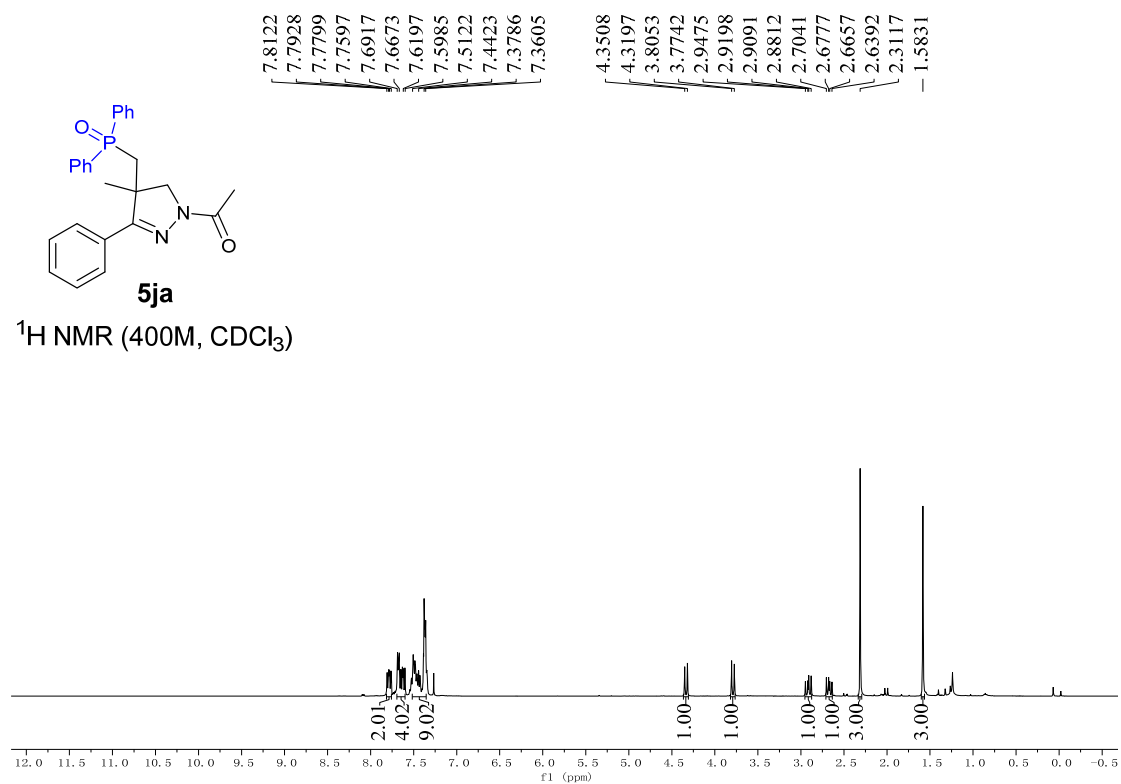
^1H NMR (400M, CDCl_3)

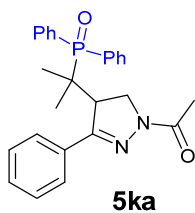


^{13}C NMR (101M, CDCl_3)

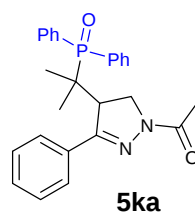
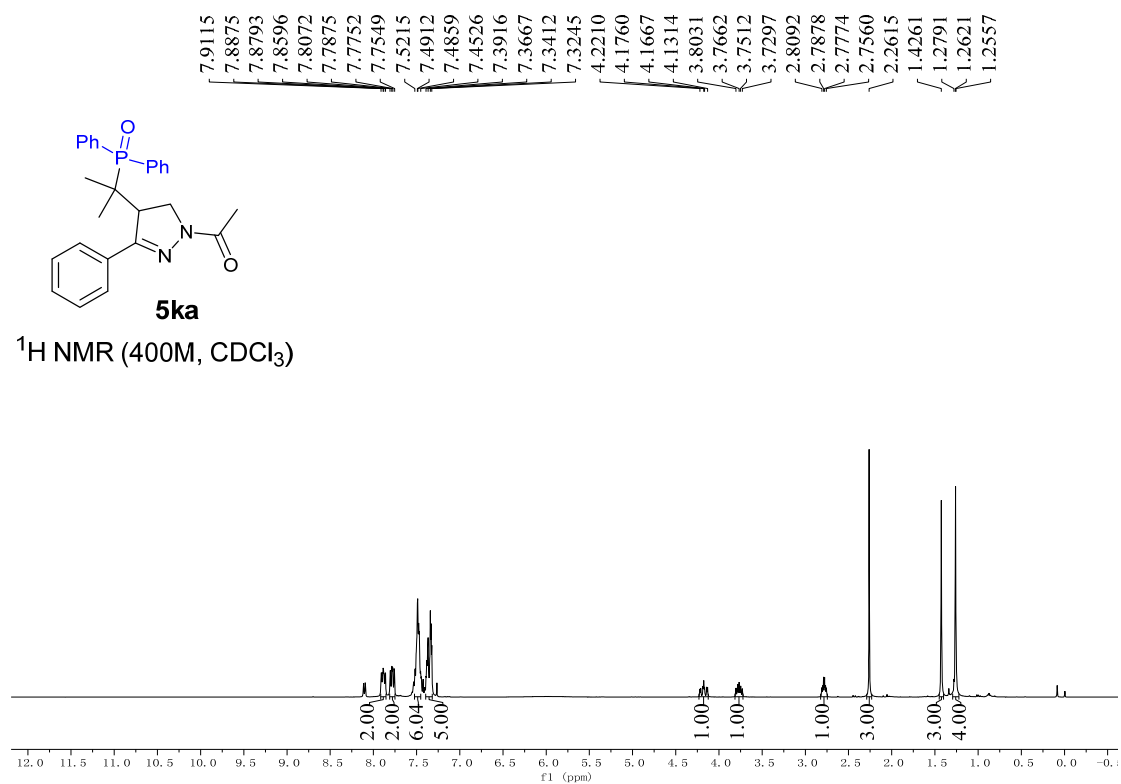








¹H NMR (400M, CDCl₃)



¹³C NMR (101M, CDCl₃)

