Supporting Information

Electrochemical Synthesis of Phosphorus-Containing Glycines and Peptides via Triarylamine-Catalyzed Dehydrogenative C(sp^3)-P Coupling

Zenghui Ye,*‡[a] Yong Qian, ‡[b] Huaqing Liu,[a] Qiwen Yin,[a] Cuili Lv,[a] Fengzhi Zhang*[a,b]

[a]School of Pharmacy, Hangzhou Medical College, Hangzhou, Zhejiang, 311399, China.

*Corresponding Author: zhangfengzhi@hmc.edu.cn; yezenghui@hmc.edu.cn

[b]College of Pharmaceutical Science, Zhejiang University of Technology, Hangzhou 310014, China.

Table of Contents

1. General Information

All reagents were obtained from commercial suppliers and used without further purification. Yields for all compounds were determined by the column chromatography which was generally performed on silica gel (200-300 mesh) using petroleum ether 40-60 (PE)/EtOAc as eluent, and reactions were monitored by thin layer chromatography (TLC) on a glass pate coated with silica gel with fluorescent indicator (GF254) using UV light. The ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectra were recorded on a Bruker ADNANCE III 400 MHz using $CDCl_3$ as solvent with TMS as internal standard. Chemical shifts are given in ppm (δ) referenced to $CDCl_3$ with 7.26 for ^{1}H and 77.16 for ^{13}C, and to DMSO-d_6 with 2.50 for 1H and 39.52 for ^{13}C. ^{31}P NMR chemical shifts was determined relative to 85% H_3PO_4. Signals are abbreviated as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet, and coupling constants are expressed in hertz. HRMS were recorded on Agilent 6210TOF LC/MS mass spectrometer. LC/MS analysis was conducted on an Agilent Infinity LC/MSD iQ (1260-G6160) instrument.

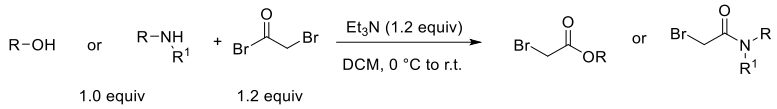
Cyclic voltammograms were obtained on a CHI 600E potentiostat. Electrolysis experiments were performed using DJS-292B or HSPY-600(30 V/100 mA) as DC power supply.

The specific surface area of graphite felt is 1800~2200 m^2/g and the density of graphite felt is 0.143 g/cm^3.

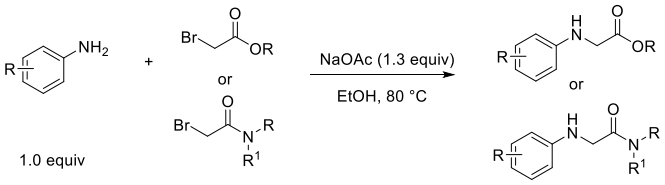
2. Synthesis of Starting Substrates 1 and 2

Esters, amides of *N*-aryl-substituted glycine, phosphine oxide were all prepared according to the previous reports.[1-3]

2.1 General Procedure for the Synthesis of *N*-Aryl Glycine Derivatives



Step-1: To a solution of amine or alcohol (4.0 mmol, 1.0 equiv.) in DCM (15 mL) was added Et_3N (666 μL, 4.8 mmol, 1.2 equiv.). The solution was cooled to 0 °C and a solution of bromoacetyl bromide (415 μL, 4.8 mmol, 1.2 eq) in DCM (5 mL) was added dropwise. The resulting mixture was then allowed to warm up to room temperature and stirred for 2 hours. The resulting solution was quenched with water, then extracted with DCM and the organic layer was dried over Na_2SO_4. After filtration and concentration, the obtained crude intermediate product was used in next step without further purification.

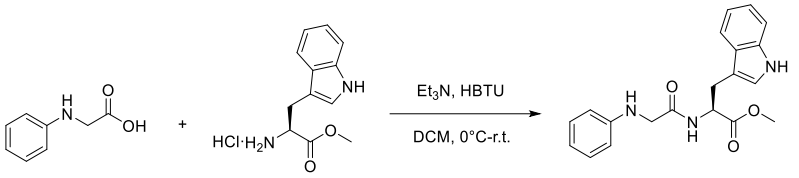


Step-2: A 25 mL round-bottom flask was charged with crude product from step-1, 4-methoxyaniline (369 mg, 3 mmol, 1.0 equiv.), sodium acetate (320 mg, 3.9 mmol, 1.3 equiv.) and EtOH (10 mL). The resulting mixture was stirred at 80 °C until the reaction was completed as indicated by TLC. After cooling to room temperature, EtOH was evaporated, and then water was added. The mixture was extracted with EtOAc and the organic layer was dried over Na_2SO_4. After concentrating in a vacuum rotary evaporator, the crude residue was purified by column chromatography on silica gel to afford the glycine derivatives **1**.

2.2 General Procedure for the Synthesis of *N*-Aryl Glycine Peptides

Dipeptides and polypeptides were all prepared according to previous reports[4, 5]. The general procedure for synthesis of polypeptide for example dipeptide **S1** and tripeptide **S2** was presented.

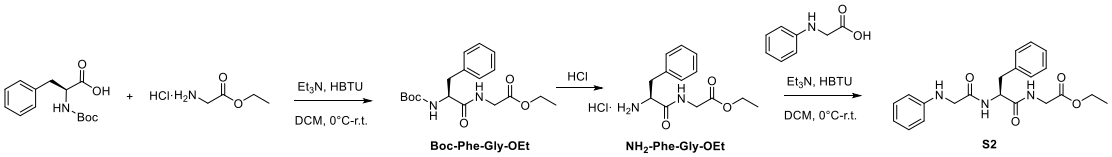
Methyl phenylglycyl-L-tryptophanate (S1)



S1

To a 100 mL round-bottom flask, *N*-phenyl glycine (3.5 mmol, 530 mg) and methyl L-tryptophanate hydrochloride (3.5 mmol, 891 g) were dissolved in 30 mL DCM. At 0 °C, Et_3N (7 mmol, 0.97 mL) was added and stirred for 5 min. HBTU (7 mmol, 2.65 g) was added. The reaction mixture was warmed to room temperature and stirred overnight. Subsequently, water was added to the round-bottom flask. The resulting mixture was extracted with DCM (20 mL x 3), and the combined organic layers were dried over anhydrous Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography and the **S1** was obtained as a pale-yellow solid

Ethyl phenylglycyl-L-phenylalanylglycinate (S2):

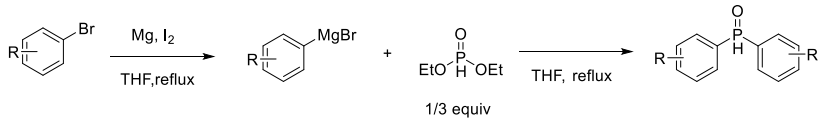


Boc-Phe-Gly-OEt **NH_2-Phe-Gly-OEt** **S2**

Following the general procedure, the reaction of glycine ethyl ester hydrochloride and *N*-(tert-butoxycarbonyl)-L-phenylalanine afforded the dipeptide Boc-Phe-Gly-OEt as a white solid. To a stirred solution of Boc-Phe-Gly-OEt (1 mmol, 350 mg) in dichloromethane (20 mL) was added 1 N HCl (2 mL) and the resultant mixture was stirred for 60 min at room temperature. After completion of the reaction monitored by TLC, the reaction was dried over with Na_2SO_4, filtered and concentrated under reduced pressure The desired product NH_2-Phe-Gly-OEt was afforded as yellow solid, which without further purification and used in next step directly. Following the general procedure, the reaction afforded polypeptide **S2** as a white solid.

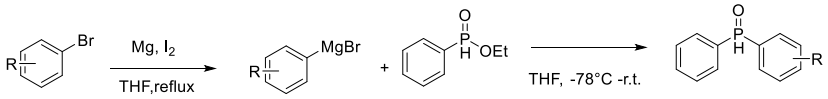
2.3 General Procedure for the Synthesis of Phosphine Oxides 2

General procedure for the synthesis of symmetrical phosphine oxide:



Following the literature procedure[6, 7]: To a 100 mL round bottom flask, aryl bromide (30 mmol, 3 equivalents) was added along with Mg turnings (780 mg, 32 mmol), I_2 (catalytic) and THF (10 mL). The reaction was heated to reflux for 1 hour at which time, the reaction was cooled to room temperature and diethyl phosphite (1.38 g, 10 mmol, 1 equivalent) was added with THF (5 mL). The reaction was once again heated to reflux for one hour. After this time, the mixture was cooled to 0 °C and NH_4Cl (5 mL) was added to quench the reaction. The crude mixture was then extracted with DCM and washed with water (3 x 100 mL). The organic layer was dried over Na_2SO_4 and the solvent was removed under reduced pressure. Purification was performed via silica gel chromatography using PE / isopropanol as the eluent.

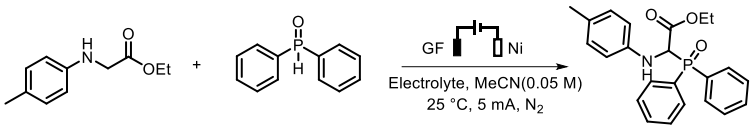
General procedure for the synthesis of unsymmetrical phosphine oxides:



Following the literature procedure[6, 7]: To a 100 mL Schlenk flask, the appropriate Grignard (22.0 mmol, 2.2 equivalents) was added under an atmosphere of dinitrogen. The flask was then placed in a dry ice / acetone (-78 °C) bath. Ethyl phenylphosphinate (1.70 g, 10.0 mmol) was then dissolved in THF (5 mL) and added to the reaction flask slowly. The reaction was then warmed slowly to room temperature and stirred for 2 hours. After this time, the mixture was cooled to 0 °C and NH_4Cl (5 mL) was added to quench the reaction. The crude mixture was then extracted with chloroform and dried over Na_2SO_4 followed by purification via silica gel chromatography using PE / isopropanol as the eluent.

3. Optimization of Conditions

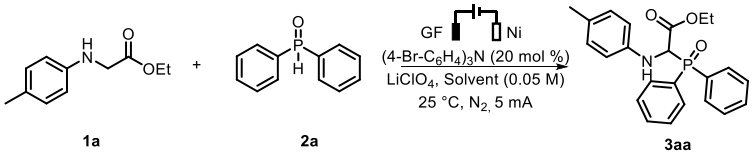
Table S1. Screening of electrolyte [a,b]



Entry	Electrolyte	Yields (%) [b]
1	$LiClO_4$	25
2	$^nBu_4NBF_4$	22
3	$^nBu_4NPF_6$	24
4	$^nBu_4NI$	trace
5	Et_4NBr	23

[a]Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.3 mmol, 1.5 equiv.), MeCN (4.0 mL), electrolyte (0.2 mmol), graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, 5 mA, current/anode volume = 10 mA/cm^3, room temperature, 3 h, Q = 2.8 F·mol^{-1}, under N_2. [b] isolated yield.

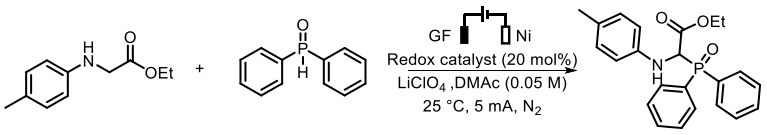
Table S2. Screening of solvent and electricity [a,b]



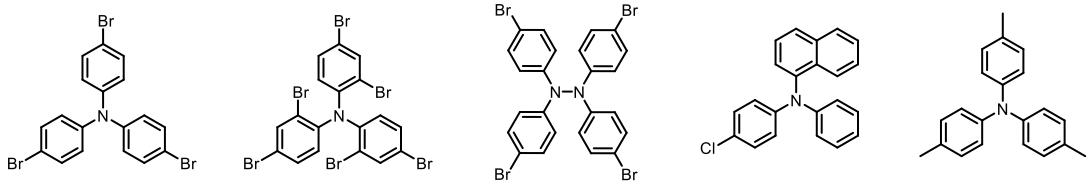
Entry	Solvent	t/h	Q (F/mol)	Yields (%) [b]
1	MeCN	3	2.8	42
2	DCM	8	7.5	NR
3	DMSO	3	2.8	trace
4	NMP	5	4.6	42
5	THF	6	5.6	trace
6	DMF	5.5	5.1	26
7	DMAc	3	2.8	60
8	DMAc	4	3.7	72
9	DMAc	4.5	4.2	72

[a]Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.3 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol), (4-Br-C_6H_4)$_3$N (20 mol %), solvent (4.0 mL), graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, 5 mA, current/anode volume = 10 mA/cm^3, room temperature, Q, under N_2. [b] isolated yield.

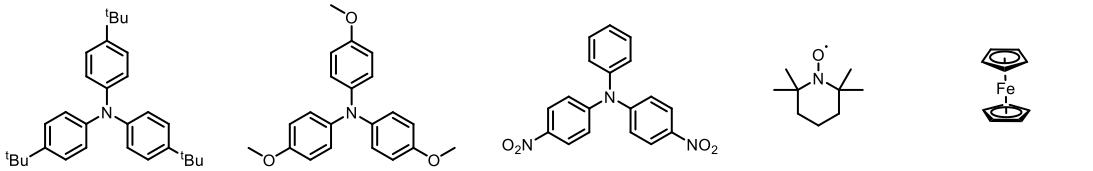
Table S3. Screening of redox mediator [a,b]



1a 2a 3aa



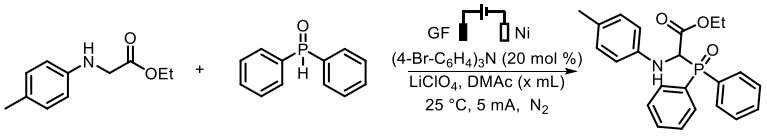
Med 1, 72% **Med 2**, NR **Med 3**, 54% **Med 4**, 62% **Med 5**, 45%



Med 6, 58% **Med 7**, 35% **Med 8**, ND **Med 9**, 51% **Med 10**, messy

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.3 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol), redox mediator (20 mol %), DMAc (4.0 mL), graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, 5 mA, current/anode volume = 10 mA/cm^3, room temperature, 4.5 h, Q = 4.2 F·mol^{-1}, under N_2. [b]isolated yield.

Table S4. Screening of reaction concentration and substrate ratio[a,b]

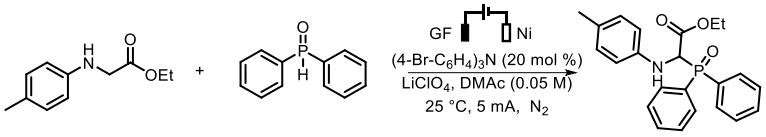


1a 2a 3aa

Entry	1a/mmol	2a/mmol	Solvent/mL	Concentration/ M	Yields (%) [b]
1	0.2	0.3	4	0.05	72
2	0.3	0.45	3	0.1	50
3	0.5	0.75	2.5	0.2	53
4	0.2	0.24	4	0.05	58
5	0.2	0.4	4	0.05	86

[a] Reaction conditions: **1a**, **2a**, (4-Br-C_6H_4)$_3$N (20 mol %), 0.05 M $LiClO_4$ in DMAc, graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, room temperature, 5 mA, current/anode volume = 10 mA/cm^3, Q = 4.2 F·mol^{-1}, under N_2. [b]isolated yield.

Table S5. Screening of electrode materials [a,b]

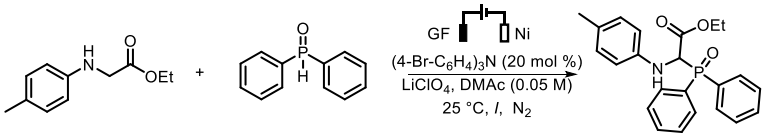


1a 2a 3aa

Entry	Anode	Cathode	Yields (%) [b]
1	graphite felt	nickel foam	72
2	graphite rod	nickel foam	55
3	RVC	nickel foam	71
4	graphite felt	platinum plate	70

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.3 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol), (4-Br-C_6H_4)$_3$N (20 mol %), DMAc (4.0 mL), graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, room temperature, 5 mA, Q = 4.2 F·mol^{-1}, under N_2. [b]isolated yield. graphite rod (ϕ 6 mm) S = 2.166 cm^2, RVC (reticulated vitreous carbon, 10 mm × 10 mm × 5 mm), platinum plate (10 mm × 10 mm × 0.2 mm).

Table S6. Screening of current [a,b]



1a 2a 3aa

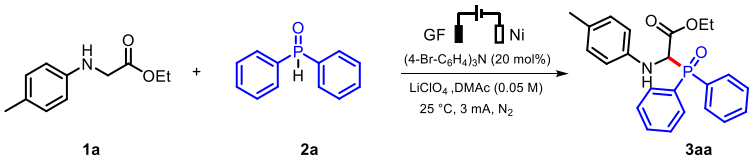
Entry	I/mA	Anode volume (cm^3)	Current/ Anode volume (mA/cm^3)	Time/h	Yields (%) [b]
1	3	0.5	6	7.5	89
2	5	0.5	10	4.5	72
3	10	0.5	20	2.2	47
4	0	0	0	12	NR

[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.3 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol), (4-Br-C_6H_4)$_3$N (20 mol %), DMAc (4.0 mL), graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, room temperature, Q = 4.2 F·mol^{-1}, under N_2. [b]isolated yield.

Notes: Due to the surface area of graphite felt electrode is difficult to calculate, hence, we standardizing this parameter in current/anode volume (mA/cm^3) rather than current density (mA/cm^2). Additionally, the specific surface area of graphite felt is 1800~2200 m^2/g. The specific surface area of graphite felt is 1800~2200 m^2/g and the density of graphite felt is 0.143 g/cm^3.

4. General Procedure for the Synthesis of Phosphorus-containing Glycine and Peptide Derivatives

General procedure A



To a 10 mL Schlenk-tube equipped with a graphite felt (10 mm × 10 mm × 5 mm, anode volume = 0.5 cm^3) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, and a stir bar. The tube was charged with glycine derivatives **1a** (0.20 mmol, 1.0 equiv.), phosphine oxides **2a** (0.30 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol, 1 equiv.), DMAc (4 mL) and then evacuated and backfilled with nitrogen three times. The reaction mixture was stirred and electrolyzed at a constant current of 3 mA (current/anode volume = 6 mA/cm^3) under 25 °C for 7.5 h (4.2 F/mol). After completion of the reaction, the reaction was transferred to a separatory funnel, the electrodes were rinsed with ethyl acetate (5 mL). The aqueous layer was extracted with ethyl acetate (3 × 10 mL). The combined organics were washed successively with water (4 × 10 mL) and brine (10 mL), then dried over anhydrous Na_2SO_4 before being filtered and concentrated via rotary evaporation. The crude oily solid was purified by silica gel chromatography to afford products.

Notes: The triarylamine mediator could be recovered easily through silica flash column chromatography.

Figure S1. Electrolysis setup.

Gram scale synthesis

Procedure for 5 mmol scale synthesis of 3aa: The 5 mmol scale electrolysis of **3aa** was conducted in a 150-mL beaker-type cell with a graphite felt (6.5 cm × 2.7 cm × 0.5 cm, about 4.5 cm immersion depth in solution, anode volume = 6 cm^3) electrode as the anode, a nickel foam (6.5 cm × 2.7 cm × 1.5 mm, about 4.5 cm immersion depth in solution) electrode as the cathode, and a constant current of 23 mA (current/anode volume = 3.8 mA/cm^3, 24.5 h, 4.2 F/mol) under nitrogen atmosphere. The reaction mixture consisted **1a** (965 mg, 5 mmol), **2a** (1.516 g, 7.5 mmol), $(4\text{-Br-Ph})_3N$ (482 mg, 1 mmol), $LiClO_4$ (532 mg, 5 mmol), DMAc (50 mL). Product **3aa** was isolated by column chromatography (PE/EtOAc = 2:1) to afford 1.61 g (4.1 mmol, 82 %) as a white solid. And recovered the mediator $(4\text{-Br-Ph})_3N$ 470 mg (97%).

The green chemistry metrics of this protocol

$$\textit{E-factor} = \frac{\textit{Total mass of wastes}}{\textit{Mass of product}} = \frac{0.966\text{ g} + 1.516\text{ g} + 0.532\text{ g} + 0.482\text{ g} + 46.85\text{ g} - 1.61\text{ g} - 0.467\text{ g}}{1.61\text{ g} + 0.467\text{ g}} = 23.24$$

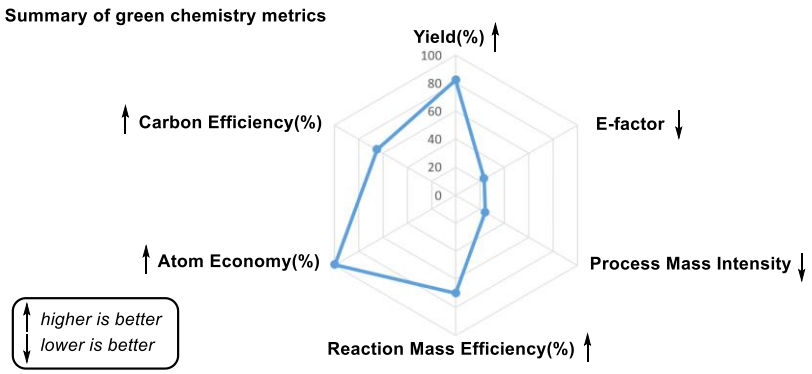
$$\textit{PMI} = \frac{\textit{Total mass of input material in the whole process}}{\textit{Mass of product}} = \frac{0.966\text{ g} + 1.516\text{ g} + 0.532\text{ g} + 0.482\text{ g} + 46.85\text{ g}}{1.61\text{ g} + 0.467\text{ g}} = 24.24$$

$$\textit{RME}\ (\%) = \frac{\textit{Mass of isolated product}}{\textit{Total mass of reactants}} \times 100 = \frac{1.61\text{ g} + 0.467\text{ g}}{0.966\text{ g} + 1.516\text{ g} + 0.482\text{ g}} = 70\%$$

$$\textit{AE}\ (\%) = \frac{\textit{Molecular weight of product}}{\textit{Total molecular weight of reactants}} \times 100 = \frac{393.42}{193.24+202.19} = 99.5\ \%$$

$$\textit{AEt}\ (\%) = \text{AE}\ (\%) \times \text{yield}\ \% = 99.5\ \% \times 82\% = 91.6\ \%$$

$$\textit{CE}\ (\%) = \frac{\textit{Amount of carbon in product}}{\textit{Total amount of carbon}} \times 100 = \frac{4.1 \times 23}{5 \times 11 + 7.5 \times 12} = 65\ \%$$

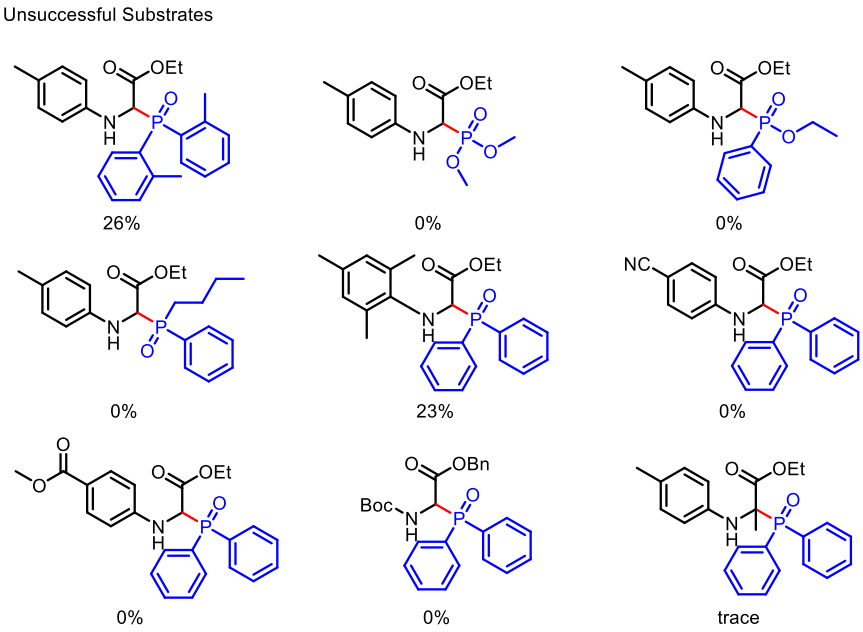


Procedure for 10 mmol scale synthesis of 3la: The 10 mmol scale electrolysis of **3la** was conducted in a 500-mL beaker-type cell with a graphite felt (6.5 cm × 5.5 cm × 0.5 cm, about 5 cm immersion depth in solution, anode volume = 13.75 cm^3) electrode as the anode, a nickel foam (6.5 cm × 5.5 cm × 1.5 mm, about 5 cm immersion depth in solution) electrode as the cathode, and a constant current of 47 mA (current/anode volume = 3.42 mA/cm^3, 24 h, 4.2 F/mol) under nitrogen atmosphere. The reaction mixture consisted **1l** (2.36 g, 10 mmol), **2a** (3.1 g, 15 mmol), $(4\text{-Br-Ph})_3N$ (964 mg, 2 mmol), $LiClO_4$(1.1 g, 10 mmol), DMAc (150 mL). Product **3la** was isolated by column chromatography (DCM/MeOH = 30:1) to afford 1.77 g (45 %) as a yellow solid. And recovered the mediator $(4\text{-Br-Ph})_3N$ 920 mg (95%).

Note: the low reaction yield of **3la** may be due to the precipitation of product **3la** during the reaction, which could decrease the mass transfer efficiency.

Figure S2. Gram scale synthesis electrolysis setup.

5. Unsuccessful Substrates



Scheme S1. Unsuccessful Substrates.

6. Mechanism Investigation

6.1 Cyclic Voltammetry Studies

All the voltammetric experiments were recorded with a CHI 600E potentiostat at room temperature in DMAc. $LiClO_4$ (0.1 M) was used as the supporting electrolyte, a glassy-carbon (GC) (3 mm-diameter, disk-electrode) as the working electrode, Pt wire as the counter electrode. The working electrode potentials were measured versus $Ag/AgNO_3$ reference electrode (internal solution, 0.1 M $AgNO_3$ in DMAc). The redox potential of ferrocene/ferrocenium (Fc/Fc^+) was measured (same experimental conditions) and used to provide an internal reference. The potential values were then adjusted relative to Fc/Fc^+, and electrochemical studies in organic solvents were recorded accordingly. The scan rate was 100 mV s^{-1}.

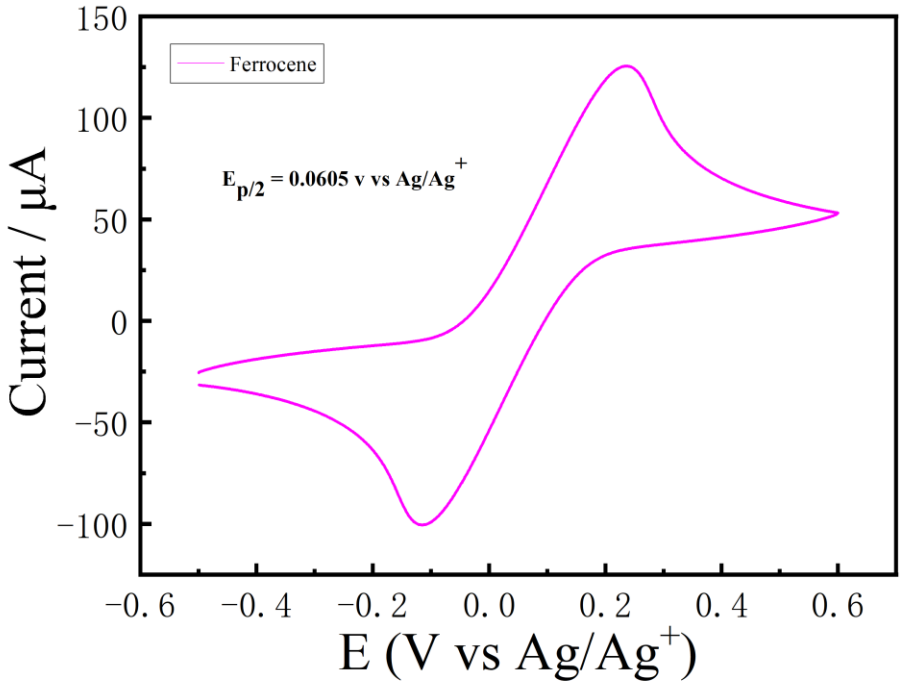


Figure S3. Cyclic voltammograms of 10 mM Ferrocene, DMAc solvent, 0.1 M $LiClO_4$ supporting electrolyte, GC working electrode, 100 mV/s scan rate.

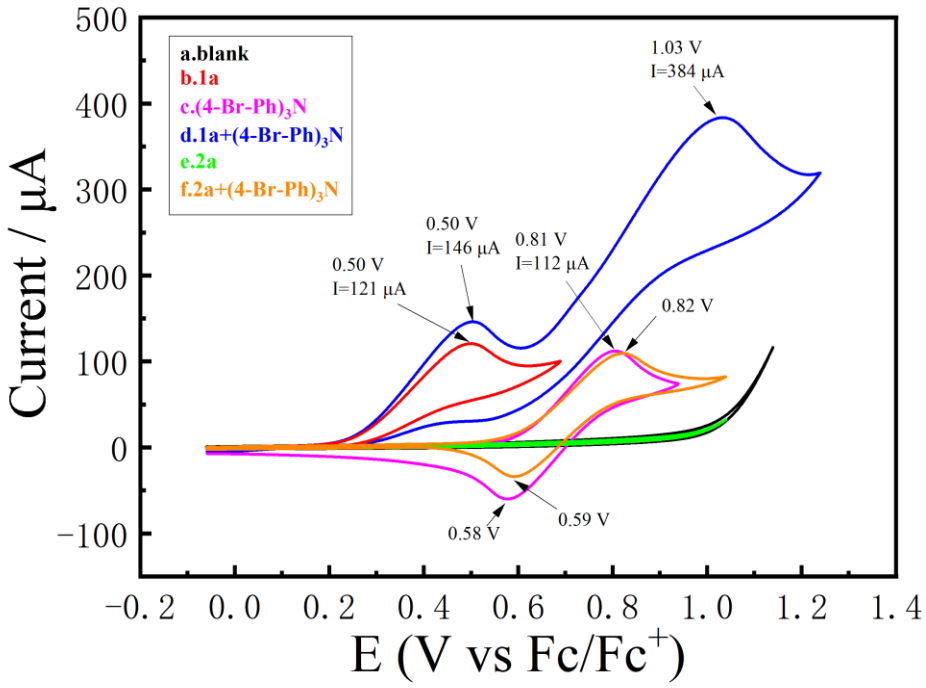


Figure S4. CV analysis on the interaction of **1a, 2a** with $(4\text{-Br-Ph})_3N$ in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

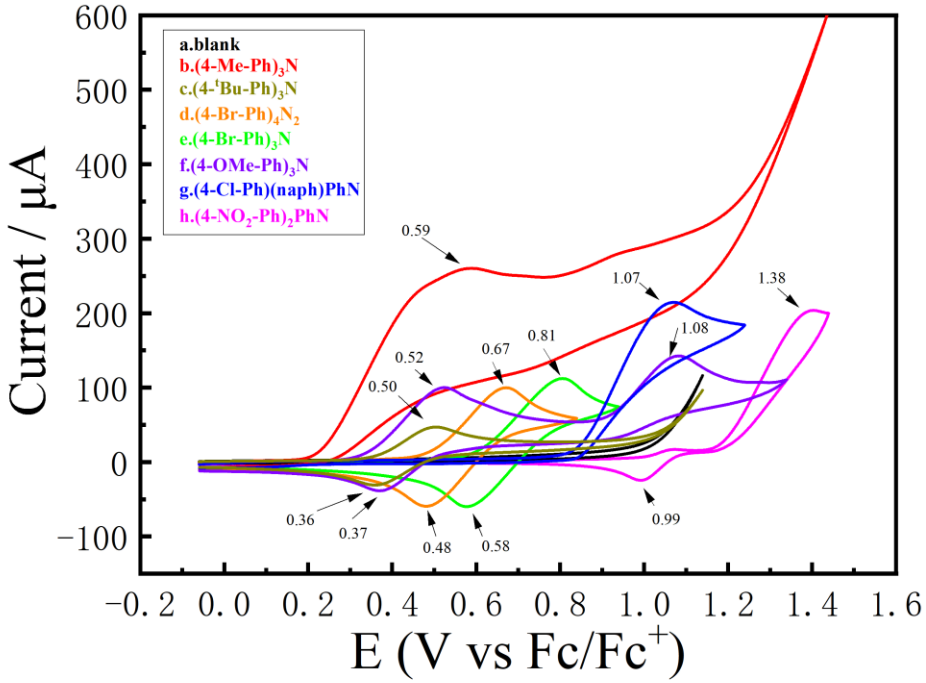
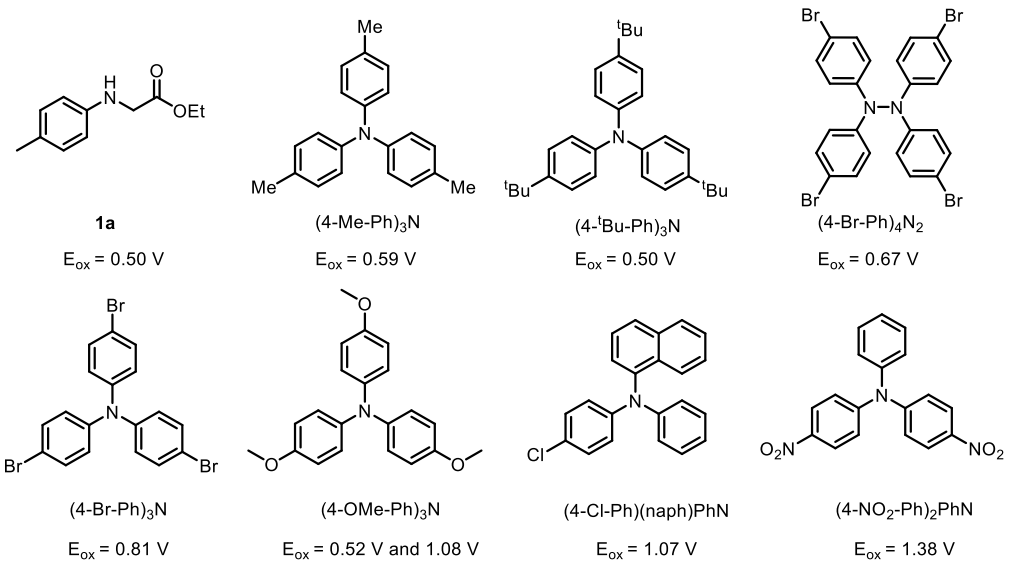


Figure S5. CVs of mediators (10 mM) in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s



Scheme S2. Oxidation potential of 1a and mediators.

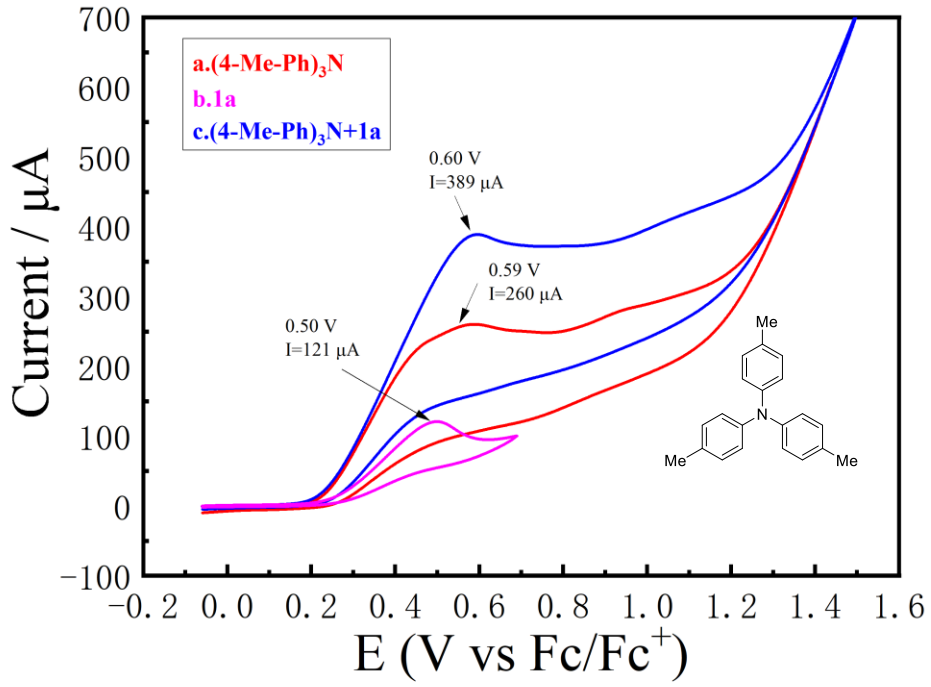


Figure S6. CV analysis on the interaction of **1a** with (4-Me-Ph)$_3$N in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

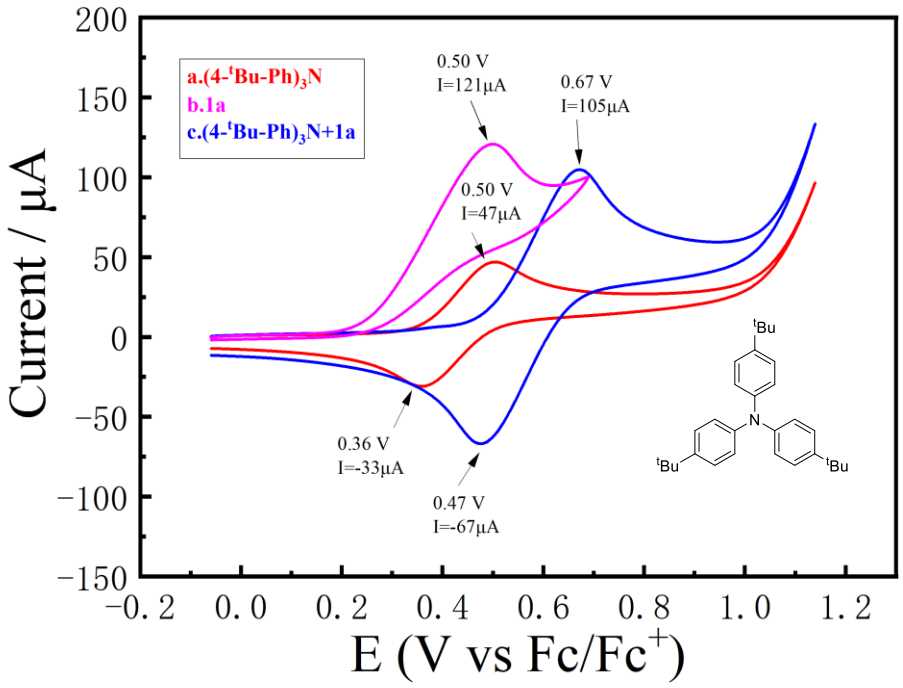


Figure S7. CV analysis on the interaction of **1a** with (4-^{t}Bu-Ph)$_3$N in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

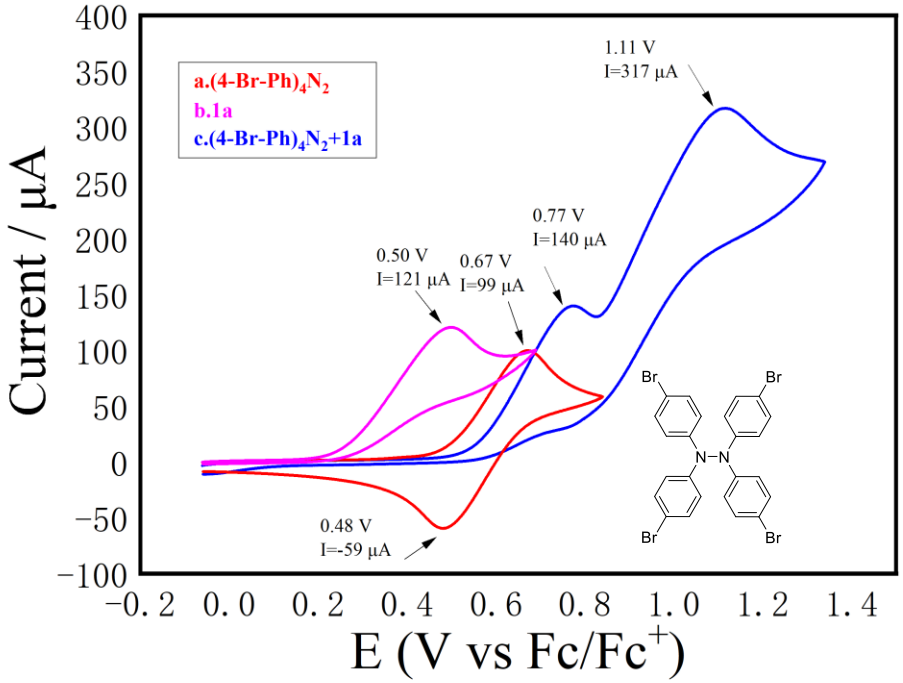


Figure S8. CV analysis on the interaction of **1a** with (4-Br-Ph)$_4$N$_2$ in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

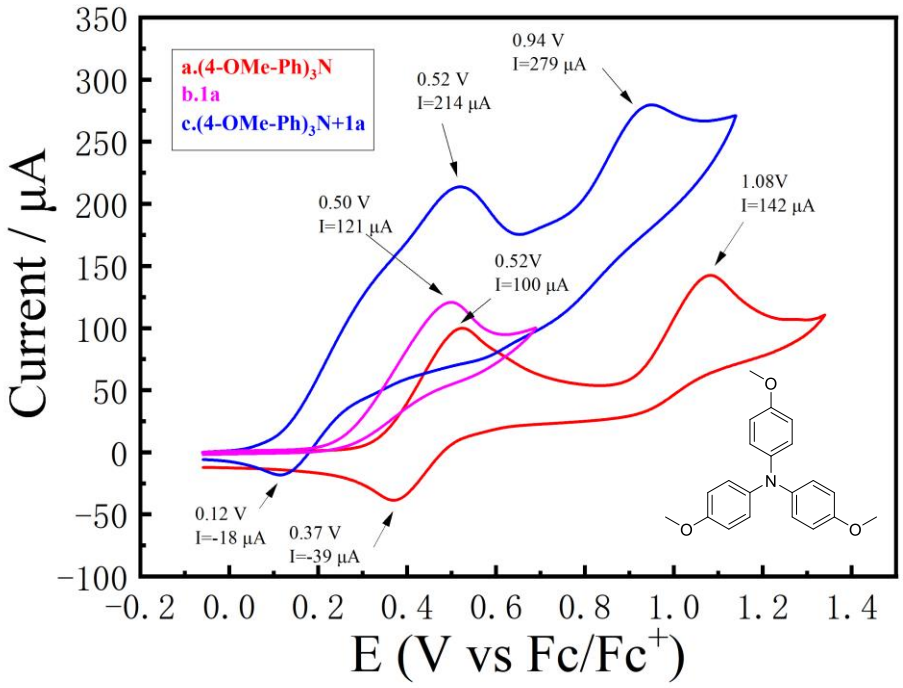


Figure S9. CV analysis on the interaction of **1a** with (4-OMe-Ph)$_3$N in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

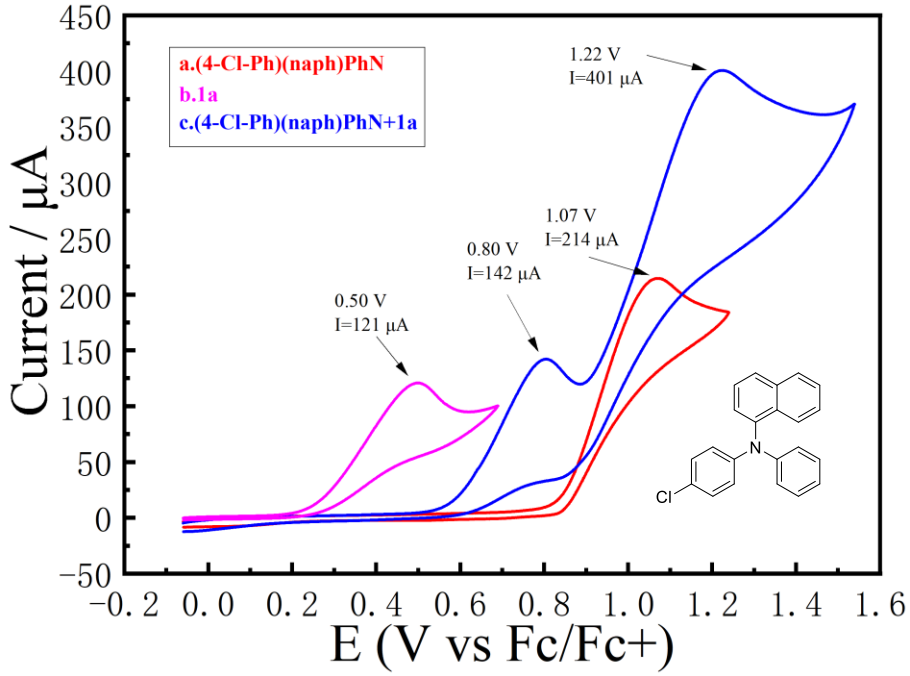


Figure S10. CV analysis on the interaction of **1a** with (4-Cl-Ph)(naph)PhN in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

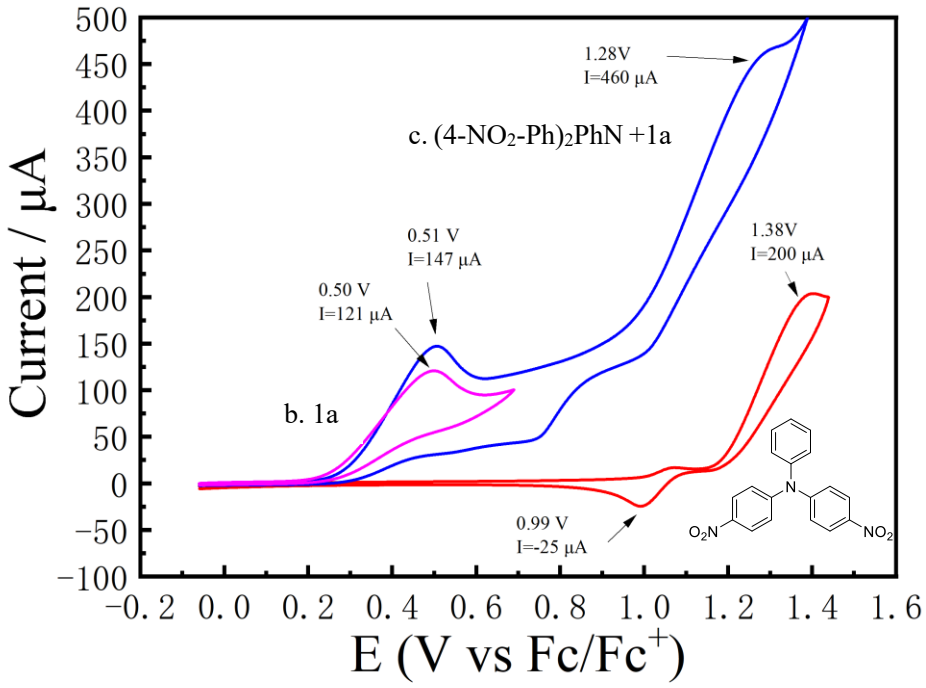


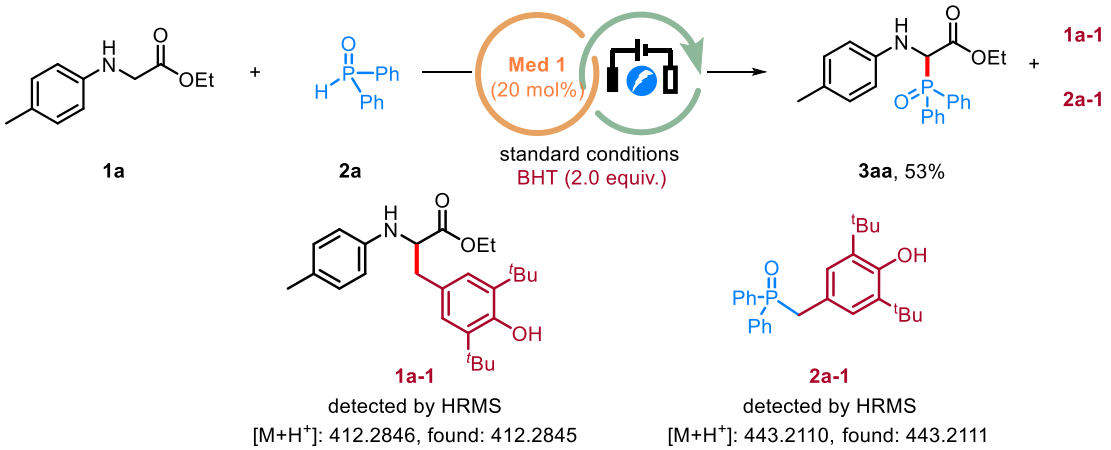
Figure S11. CV analysis on the interaction of **1a** with $(4\text{-}NO_2\text{-}Ph)_2PhN$ in DMAc with $LiClO_4$ (0.1 M) as supporting electrolyte, GC as working electrode and a platinum wire as counter electrode, scan rate = 100 mV/s

According to CVs, $(4\text{-}Me\text{-}Ph)_3N$, $(4\text{-}OMe\text{-}Ph)_3N$, (4-Cl-Ph)(Naph)PhN and $(4\text{-}NO_2\text{-}Ph)_2PhN$ showed the bad reversibility and gave the low yield of desired product. Meanwhile $(4\text{-}^tBu\text{-}Ph)_3N$, $(4\text{-}Br\text{-}Ph)_2N_2$ and $(4\text{-}Br\text{-}Ph)_3N$ shows the good reversibility and provided the moderate to good yield of desired product.

Mediators	reversibility	E_{ox} (V)	Reaction yield (%)
$(4\text{-}Me\text{-}Ph)_3N$	Bad	0.59	45
$(4\text{-}^tBu\text{-}Ph)_3N$	Good	0.50	58
$(4\text{-}Br\text{-}Ph)_2N_2$	Good	0.67	54
$(4\text{-}Br\text{-}Ph)_3N$	Good	0.81	72
$(4\text{-}OMe\text{-}Ph)_3N$	Bad	0.52, 1.08	35
(4-Cl-Ph)(Naph)PhN	Bad	1.07	62
$(4\text{-}NO_2\text{-}Ph)_2PhN$	Bad	1.38	ND

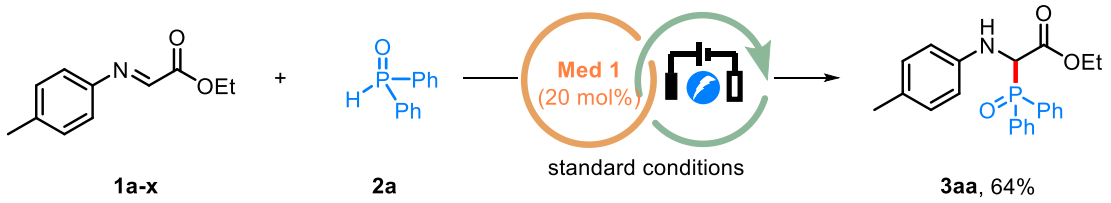
6.2 Control experiments

6.2.1 BHT as radical scavenger



To a 10 mL Schlenk-tube equipped with a graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, and a stir bar. The tube was charged with glycine derivatives **1a** (0.20 mmol, 1.0 equiv.), phosphine oxides **2a** (0.30 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol, 1 equiv.), **BHT** (0.4 mmol, 2 equiv.), DMAc (4 ml) and then evacuated and backfilled with nitrogen three times. The reaction mixture was stirred and electrolyzed at a constant current of 3 mA under 25 °C for 7.5 h (4.2 F/mol). After completion of the reaction, the reaction was transferred to a separatory funnel, the electrodes were rinsed with ethyl acetate (5 mL). The aqueous layer was extracted with ethyl acetate (3 × 10 mL). The combined organics were washed successively with water (4 × 10 mL) and brine (10 mL), then dried over anhydrous Na_2SO_4 before being filtered and concentrated via rotary evaporation. Product **3aa** was isolated by column chromatography (PE/EA= 2:1) to afford 41 mg (53 %) as a white solid. And 1a-1 was detected by HRMS. m/z calc. for $C_{26}H_{37}NO_3$ $[M+H]^+$: 412.2846, found: 412.2845. **2a-1** was detected by HRMS. m/z calc. for $C_{27}H_{33}O_2P$ $[M+Na]^+$: 443.2110, found: 443.2111. This result indicates that free radical intermediates may have been generated during the reaction process.

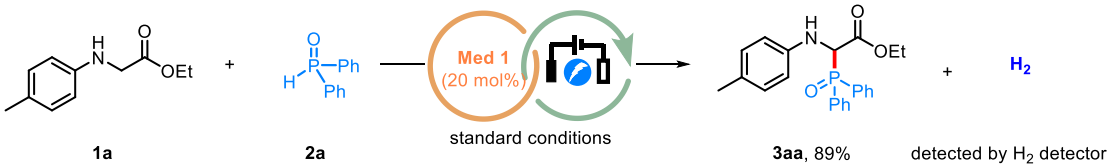
6.2.2 Imine as substrate



To a 10 mL Schlenk-tube equipped with a graphite felt (10 mm × 10 mm × 5 mm) electrode as the anode, a nickel foam (10 mm × 10 mm × 1.5 mm) electrode as the cathode, and a stir bar. The tube was charged with glycine derivatives **1a-x** (0.20 mmol, 1.0 equiv.), phosphine oxides **2a** (0.30 mmol, 1.5 equiv.), $LiClO_4$ (0.2 mmol, 1 equiv.), DMAc (4 ml) and then evacuated and backfilled with nitrogen three times. The reaction mixture was stirred and electrolyzed at a constant current of 3 mA under 25 °C for 7.5 h (4.2 F/mol). After completion of the reaction, the reaction was transferred to a separatory funnel, the electrodes were rinsed with ethyl acetate (5 mL). The aqueous

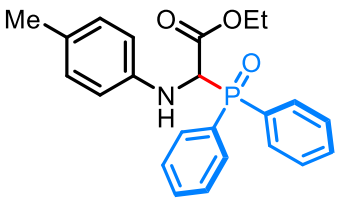
layer was extracted with ethyl acetate (3 × 10 mL). The combined organics were washed successively with water (4 × 10 mL) and brine (10 mL), then dried over anhydrous Na_2SO_4 before being filtered and concentrated via rotary evaporation. Product **3aa** was isolated by column chromatography (PE/EA= 2:1) to afford 51 mg (64 %) as a white solid. This result indicates that ethyl 2-(p-tolylimino)acetate might be the intermediate in this transformation.

6.2.3 H_2 detection experiment



Under standard conditions, the model reaction was monitored by a H_2 detector. As the reaction proceeded, the hydrogen production was detected by hydrogen detector. And this result was consistent with Liu's report.[8]

7. Synthesis and Characterization of the Products



Ethyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (3aa)

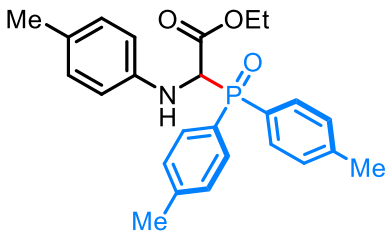
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3aa** was purified by PE/EA (2:1) and obtained as a white solid (70 mg, 89%). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (dddd, *J* = 13.4, 11.8, 7.8, 1.7 Hz, 4H), 7.57 (dtd, *J* = 9.3, 7.4, 1.5 Hz, 2H), 7.52 – 7.45 (m, 4H), 6.98 (d, *J* = 8.1 Hz, 2H), 6.59 (d, *J* = 8.4 Hz, 2H), 4.96 (dd, *J* = 13.6, 10.2 Hz, 1H), 4.69 (dd, *J* = 11.4, 5.4 Hz, 1H), 3.92 (ddq, *J* = 47.0, 10.7, 7.1 Hz, 2H), 2.22 (s, 3H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9 (d, $J_{C\text{-}P}$ = 1.2 Hz), 143.8 (d, $J_{C\text{-}P}$ = 11.3 Hz), 132.6 (t, $J_{C\text{-}P}$ = 3.3 Hz), 131.9, 131.8, 131.7, 131.6, 129.9, 129.0, 128.9, 128.7, 128.6, 128.5, 114.4, 61.9, 58.9(d, $J_{C\text{-}P}$ = 69.3 Hz), 20.5, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.50.

HRMS m/z (ESI) calcd for $C_{23}H_{24}NO_3P$ $[M+H]^+$:394.1572, found 394.1574.



Ethyl 2-(di-p-tolylphosphoryl)-2-(*p*-tolylamino)acetate. (3ab)

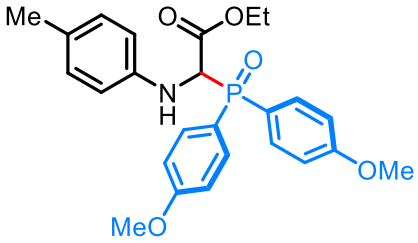
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ab** was purified by PE/EA (3:1) and obtained as a white solid (63 mg, 75%). $\mathbf{R_f}$ = 0.40 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 – 7.68 (m, 4H), 7.28 (dt, *J* = 11.2, 5.6 Hz, 5H), 6.97 (d, *J* = 8.1 Hz, 2H), 6.57 (d, *J* = 8.4 Hz, 2H), 4.91 (dd, *J* = 13.7, 10.2 Hz, 1H), 4.65 (dd, *J* = 10.7, 5.5 Hz, 1H), 3.93 (ddq, *J* = 40.7, 10.7, 7.1 Hz, 2H), 2.39 (d, *J* = 8.1 Hz, 6H), 2.22 (s, 3H), 0.97 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.1, 143.9 (d, $J_{C\text{-}P}$ = 11.3 Hz), 143.2 (d, $J_{C\text{-}P}$ = 2.9 Hz), 143.2 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.9, 131.8, 131.7, 131.6, 129.9, 129.5, 129.4, 129.3, 129.2, 128.8, 127.6, 126.8, 126.6, 125.8, 114.3, 61.8, 59.0 (d, $J_{C\text{-}P}$ = 69.0 Hz), 21.7, 21.7, 20.5, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.92.

HRMS m/z (ESI) calcd for $C_{25}H_{28}NO_3P$ $[M+H]^+$: 422.1885, found 422.1887.



Ethyl 2-(bis(4-methoxyphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ac)

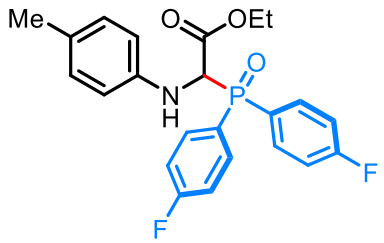
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ac** was purified by PE/EA (2:1) and obtained as a white solid (72 mg, 80%). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (dddd, *J* = 20.3, 11.3, 6.8, 2.0 Hz, 4H), 6.97 (ddt, *J* = 8.7, 7.3, 2.4 Hz, 6H), 6.57 (d, *J* = 8.4 Hz, 2H), 4.88 (d, *J* = 13.9 Hz, 1H), 4.64 (s, 1H), 4.04 – 3.87 (m, 2H), 3.84 (d, *J* = 7.1 Hz, 6H), 2.22 (s, 3H), 1.01 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.2, 163.0 (d, $J_{C\text{-}P}$ = 3.0 Hz), 162.9(d, $J_{C\text{-}P}$ = 3.0 Hz), 143.9 (d, $J_{C\text{-}P}$ = 11.5 Hz), 133.8, 133.7, 133.6, 133.5, 129.9, 128.8, 122.2, 121.1 (d, $J_{C\text{-}P}$ = 3.2 Hz), 120.1, 114.3, 114.3, 114.2 (d, $J_{C\text{-}P}$ = 6.5 Hz), 114.0, 61.8, 59.2 (d, $J_{C\text{-}P}$ = 69.0 Hz), 55.4, 55.4, 20.5, 13.9.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.53.

HRMS m/z (ESI) calcd for $C_{25}H_{28}NO_5P$ $[M+H]^+$: 454.1783, found 454.1784.



Ethyl 2-(bis(4-fluorophenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ad)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ad** was purified by PE/EA (3:1) and obtained as a white solid (65 mg, 76%). $\mathbf{R_f}$ = 0.40 (PE/EA = 3:1);

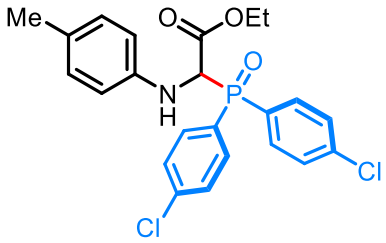
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 – 7.79 (m, 4H), 7.19 (dtd, *J* = 13.3, 8.7, 2.3 Hz, 4H), 6.98 (d, *J* = 8.1 Hz, 2H), 6.57 (d, *J* = 8.4 Hz, 2H), 4.91 (dd, *J* = 13.9, 10.2 Hz, 1H), 4.66 – 4.52 (m, 1H), 4.15 – 3.83 (m, 2H), 2.23 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6, 166.8 (d, *J* = 11.2 Hz), 164.2 (d, *J* = 11.2 Hz), 143.5 (d, *J* = 11.4 Hz), 134.6, 134.5 (d, *J* = 1.9 Hz), 134.4, 134.3 (d, *J* = 2.0 Hz), 134.2, 129.9, 129.4, 126.6, 125.7, 125.5, 124.6, 119.8, 116.5, 116.3 (d, *J* = 3.3 Hz), 116.3, 116.2 (d, *J* = 4.6 Hz), 116.0, 114.5, 62.1, 59.3 (d, *J* = 71.7 Hz), 20.5, 13.9.

^{31}P NMR (162 MHz, $CDCl_3$) δ 27.11.

^{19}F NMR (376 MHz, $CDCl_3$) δ -104.89, -104.92.

HRMS m/z (ESI) calcd for $C_{23}H_{22}F_2NO_3P$ $[M+H]^+$: 430.1383, found 430.1377.



Ethyl 2-(bis(4-chlorophenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ae)

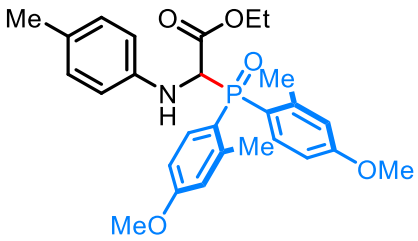
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ae** was purified by PE/EA (3:1) and obtained as a white solid (56.5 mg, 61%). $\mathbf{R_f}$ = 0.30 (PE/EA = 3:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 – 7.71 (m, 4H), 7.47 (ddd, *J* = 13.9, 8.5, 2.6 Hz, 4H), 6.98 (d, *J* = 8.2 Hz, 2H), 6.57 (d, *J* = 8.4 Hz, 2H), 5.00 – 4.82 (m, 1H), 4.58 (d, *J* = 9.1 Hz, 1H), 4.13 – 3.86 (m, 2H), 2.23 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5 (d, $J_{C\text{-}P}$ = 1.5 Hz), 143.4 (d, $J_{C\text{-}P}$ = 11.5 Hz), 139.6 (d, $J_{C\text{-}P}$ = 3.6 Hz), 139.6 (d, $J_{C\text{-}P}$ = 3.6 Hz), 133.2, 133.1, 133.1, 133.0, 130.0, 129.5, 129.3, 129.2 (d, $J_{C\text{-}P}$ = 3.4 Hz), 129.0, 128.8, 128.1, 127.8, 127.1, 114.6, 62.2, 59.1 (d, $J_{C\text{-}P}$ = 72.0 Hz), 20.5, 13.9.

^{31}P NMR (162 MHz, $CDCl_3$) δ 27.38.

HRMS m/z (ESI) calcd for $C_{23}H_{22}Cl_2NO_3P$ $[M+H]^+$: 462.0792, found 462.0791.



Ethyl 2-(bis(4-methoxy-2-methylphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3af)

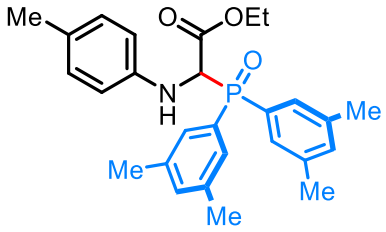
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3af** was purified by PE/EA (1:1) and obtained as a white solid (42 mg, 44%). $\mathbf{R_f}$ = 0.20 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (dd, *J* = 12.9, 8.6 Hz, 1H), 7.59 (dd, *J* = 12.2, 8.3 Hz, 1H), 7.03 (d, *J* = 8.1 Hz, 2H), 6.80 (dt, *J* = 8.8, 2.2 Hz, 1H), 6.73 (dq, *J* = 5.1, 2.4 Hz, 3H), 6.69 – 6.62 (m, 2H), 5.14 – 5.03 (m, 2H), 3.92 – 3.84 (m, 1H), 3.82 (s, 3H), 3.80 (s, 3H), 3.73 – 3.62 (m, 1H), 2.27 (s, 3H), 2.25 (s, 6H), 0.89 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.1 (d, J_{C-P} = 1.8 Hz), 162.7 (d, J_{C-P} = 3.0 Hz), 162.4 (d, J_{C-P} = 2.9 Hz), 145.0 (d, J_{C-P} = 10.3 Hz), 143.9 (d, J_{C-P} = 7.1 Hz), 143.8 (d, J_{C-P} = 7.1 Hz), 135.4 (d, J_{C-P} = 10.9 Hz), 133.5 (d, J_{C-P} = 11.9 Hz), 130.0, 128.5, 122.0, 120.9, 120.7, 119.7, 117.7 (d, J_{C-P} = 12.0 Hz), 117.2 (d, J_{C-P} = 12.0 Hz), 113.8, 111.1 (d, J_{C-P} = 13.3 Hz), 110.8 (d, J_{C-P} = 13.3 Hz), 61.6, 56.6 (d, J_{C-P} = 67.8 Hz), 55.3, 55.2, 21.6 (d, J_{C-P} = 3.9 Hz), 21.4 (d, J_{C-P} = 4.8 Hz), 20.5, 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 30.01.

HRMS m/z (ESI) calcd for $C_{27}H_{32}NO_5P$ $[M+H]^+$: 482.2096, found 482.2097.



Ethyl 2-(bis(3,5-dimethylphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ag)

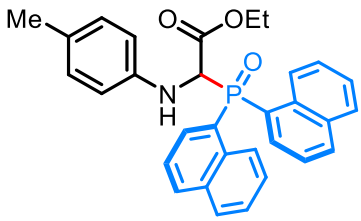
Following the general **procedure A** for 7.5 h (4.2 F/mol), **3ag** was purified by PE/EA (2:1) and obtained as a light yellow solid (45 mg, 51%). $\mathbf{R_f}$ = 0.30 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (dd, *J* = 10.3, 3.6 Hz, 4H), 7.16 (t, *J* = 5.0 Hz, 2H), 6.97 (d, *J* = 8.1 Hz, 2H), 6.59 (d, *J* = 8.5 Hz, 2H), 4.92 (dd, *J* = 13.0, 10.6 Hz, 1H), 4.74 (dd, *J* = 10.6, 5.8 Hz, 1H), 4.00 – 3.77 (m, 2H), 2.33 (d, *J* = 5.5 Hz, 12H), 2.22 (s, 3H), 0.94 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.1 (d, *J* = 1.3 Hz), 144.0 (d, *J* = 11.1 Hz), 138.5, 138.4, 138.3, 138.1, 134.3 (d, *J* = 4.2 Hz), 131.0, 130.5, 129.8, 129.8, 129.5, 129.4, 129.3, 129.2, 129.2, 129.1, 129.0, 128.8, 128.6, 114.3, 61.6, 58.8 (d, *J* = 67.4 Hz), 21.4, 21.3, 20.5, 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 29.37.

HRMS m/z (ESI) calcd for $C_{27}H_{32}NO_3P$ $[M+H]^+$: 450.2198, found 450.2205.



Ethyl 2-(di(naphthalen-1-yl)phosphoryl)-2-(p-tolylamino)acetate. (3ah)

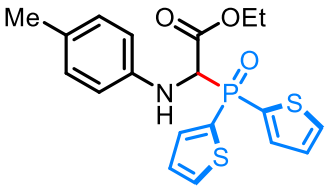
Following the general **procedure A** for 7.5 h (4.2 F/mol), **3ah** was purified by PE/EA (3:1) and obtained as a white solid (93 mg, 94%). $\mathbf{R_f}$ = 0.30 (PE/EA = 3:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.88 – 8.78 (m, 1H), 8.52 (d, *J* = 8.6 Hz, 1H), 8.09 – 7.99 (m, 3H), 7.91 – 7.81 (m, 3H), 7.52 (qd, *J* = 6.3, 5.4, 4.0 Hz, 3H), 7.48 – 7.39 (m, 2H), 7.36 (ddd, *J* = 8.4, 6.9, 1.4 Hz, 1H), 7.01 (d, *J* = 8.2 Hz, 2H), 6.65 (d, *J* = 8.4 Hz, 2H), 5.41 – 5.30 (m, 1H), 5.17 (s, 1H), 3.60 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.17 (dq, *J* = 10.7, 7.1 Hz, 1H), 2.24 (s, 3H), 0.54 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.7 (d, *J* = 2.0 Hz), 143.7 (d, *J* = 11.7 Hz), 134.1, 134.0, 133.9, 133.9 (d, *J* = 3.0 Hz), 133.7 (d, *J* = 3.0 Hz), 133.7, 133.6, 133.5, 133.4, 133.2, 133.1, 132.0, 131.9, 130.0, 129.0, 128.8, 128.7, 127.6, 127.6, 127.5, 126.8 (d, *J* = 6.1 Hz), 126.6 (d, *J* = 5.3 Hz), 126.5 (d, *J* = 4.4 Hz), 124.7 (d, *J* = 4.8 Hz), 124.6 (d, *J* = 4.4 Hz), 114.0, 61.6, 57.9 (d, *J* = 69.3 Hz), 20.5, 13.2.

^{31}P NMR (162 MHz, $CDCl_3$) δ 34.29.

HRMS m/z (ESI) calcd for $C_{31}H_{28}NO_3P$ $[M+H]^+$: 494.1885, found 494.1890.



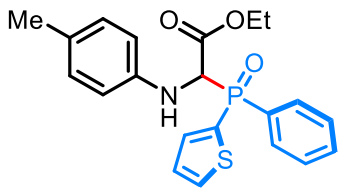
Ethyl 2-(di(thiophen-2-yl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ai) Following the general **procedure A** for 7.5 h (4.2 F/mol), **3ai** was purified by PE/EA (1:1) and obtained as a white solid (46 mg, 57%). $\mathbf{R_f}$ = 0.20 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (ddd, *J* = 7.3, 3.6, 1.1 Hz, 1H), 7.78 (dtd, *J* = 6.1, 4.7, 1.1 Hz, 2H), 7.72 (ddd, *J* = 7.3, 3.7, 1.2 Hz, 1H), 7.22 (dddd, *J* = 10.4, 4.7, 3.6, 2.2 Hz, 2H), 6.99 (d, *J* = 8.3 Hz, 2H), 6.57 (d, *J* = 8.4 Hz, 2H), 4.84 (d, *J* = 16.5 Hz, 1H), 4.49 (s, 1H), 4.14 (q, *J* = 7.1 Hz, 2H), 2.23 (s, 3H), 1.15 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.3 (d, *J* = 2.5 Hz), 143.7 (d, *J* = 11.9 Hz), 137.9 (d, *J* = 10.1 Hz), 137.5 (d, *J* = 10.1 Hz), 135.2 (d, *J* = 4.5 Hz), 134.9 (d, *J* = 4.5 Hz), 129.9, 129.7, 128.4, 128.3, 128.3, 128.2, 115.1, 62.4, 61.5 (d, *J* = 84.1 Hz), 20.5, 14.0.

^{31}P NMR (162 MHz, $CDCl_3$) δ 18.40.

HRMS m/z (ESI) calcd for $C_{19}H_{20}NO_3PS_2[M+H]^+$: 406.0700, found 406.0685.



Ethyl 2-(phenyl(thiophen-2-yl)phosphoryl)-2-(*p*-tolylamino)acetate. (3aj)

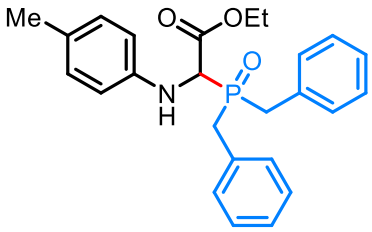
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3aj** was purified by PE/EA (2:1) and obtained as a white solid (59.6 mg, 75%, d.r. = 1.4:1). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 7.98 (ddd, *J* = 12.3, 8.3, 1.4 Hz, 2H), 7.90 (ddd, *J* = 12.2, 8.3, 1.4 Hz, 1H), 7.82 (ddd, *J* = 7.0, 3.7, 1.1 Hz, 1H), 7.77 (td, *J* = 4.6, 1.1 Hz, 1H), 7.74 – 7.70 (m, 1H), 7.60 (tdd, *J* = 9.6, 5.0, 1.6 Hz, 3H), 7.56 – 7.48 (m, 3H), 7.23 (ddd, *J* = 4.8, 3.6, 2.2 Hz, 1H), 7.17 (ddd, *J* = 4.8, 3.6, 2.3 Hz, 1H), 6.99 (d, *J* = 8.4 Hz, 2H), 6.96 (s, 1H), 6.61 (d, *J* = 8.4 Hz, 2H), 6.56 (d, *J* = 8.4 Hz, 1H), 4.92 (s, 1H), 4.84 (s, 1H), 4.15 – 4.05 (m, 1H), 3.95 (dddd, *J* = 17.9, 10.8, 7.2, 3.6 Hz, 2H), 2.24 (s, 3H), 2.22 (s, 2H), 1.13 (t, *J* = 7.2 Hz, 2H), 0.93 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 168.7 (d, *J* = 2.4 Hz), 168.3 (d, *J* = 2.0 Hz), 143.8 (d, *J* = 4.5 Hz), 143.7 (d, *J* = 4.7 Hz), 137.7, 137.6, 137.4, 137.3, 134.9 (d, *J* = 3.4 Hz), 134.7 (d, *J* = 3.4 Hz), 133.0 (d, *J* = 2.9 Hz), 132.9 (d, *J* = 2.9 Hz), 132.0, 131.9, 131.6, 131.5, 130.9, 130.4, 129.9, 129.9, 129.4, 129.3, 128.8, 128.7, 128.6, 128.5, 128.3, 128.2, 128.0, 114.8, 114.7, 62.3, 62.0, 60.6 (d, *J* = 76.5 Hz), 60.5 (d, *J* = 76.5 Hz), 20.5, 20.5, 14.0, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 24.02, 23.21.

HRMS m/z (ESI) calcd for $C_{21}H_{22}NO_3PS[M+H]^+$: 400.1136, found 400.1141.



Ethyl 2-(dibenzylphosphoryl)-2-(*p*-tolylamino)acetate. (3ak)

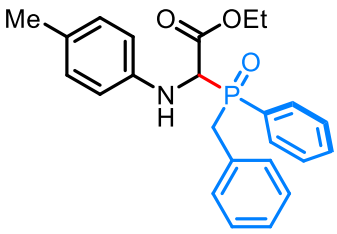
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3aa** was purified by PE/EA (2:1) and obtained as a yellow solid (52 mg, 62%). $\mathbf{R_f}$ = 0.40 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (t, *J* = 7.9 Hz, 3H), 7.33 – 7.27 (m, 5H), 7.23 (dt, *J* = 7.5, 2.0 Hz, 2H), 6.98 (d, *J* = 8.2 Hz, 2H), 6.43 (d, *J* = 8.4 Hz, 2H), 4.53 (s, 1H), 4.36 – 4.29 (m, 1H), 4.23 – 4.11 (m, 2H), 3.45 – 3.30 (m, 2H), 3.29 – 3.15 (m, 2H), 2.24 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.3 (d, *J* = 2.0 Hz), 143.8 (d, *J* = 10.0 Hz), 131.1 (d, *J* = 6.9 Hz), 130.8 (d, *J* = 7.2 Hz), 130.3 (d, *J* = 5.7 Hz), 130.1 (d, *J* = 5.4 Hz), 129.9, 129.1, 129.0, 128.9, 128.7 (d, *J* = 2.6 Hz), 127.4 (t, *J* = 2.7 Hz), 114.2, 62.4, 56.1 (d, *J* = 64.6 Hz), 33.9 (d, *J* = 25.3 Hz), 33.3 (d, *J* = 25.3 Hz), 20.5, 14.2.

^{31}P NMR (162 MHz, $CDCl_3$) δ 44.30.

HRMS m/z (ESI) calcd for $C_{25}H_{28}NO_3P$ $[M+H]^+$: 422.1885, found 422.1884.



Ethyl 2-(benzyl(phenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3al)

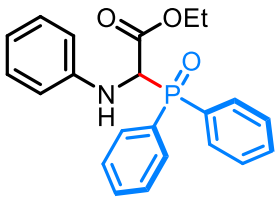
Following the general **procedure A** for 7.5 h (4.2 F/mol), **3al** was purified by PE/EA (2:1) and obtained as a white solid (63 mg, 77%, d.r. = 1.5:1). $\mathbf{R_f}$ = 0.40 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 7.74 – 7.67 (m, 2H), 7.67 – 7.61 (m, 2H), 7.54 (tdd, *J* = 7.1, 3.9, 1.5 Hz, 2H), 7.43 (tdd, *J* = 7.5, 4.1, 2.8 Hz, 3H), 7.21 (d, *J* = 2.6 Hz, 4H), 7.20 (s, 2H), 7.10 (dt, *J* = 6.0, 2.4 Hz, 2H), 7.01 (d, *J* = 8.1 Hz, 2H), 6.97 (d, *J* = 8.1 Hz, 1H), 6.61 (d, *J* = 8.4 Hz, 2H), 6.52 (d, *J* = 8.4 Hz, 1H), 4.83 (s, 1H), 4.65 (d, *J* = 18.7 Hz, 1H), 4.60 (d, *J* = 2.7 Hz, 1H), 4.31 – 4.22 (m, 1H), 4.16 (q, *J* = 7.1 Hz, 2H), 3.86 (q, *J* = 7.1 Hz, 2H), 3.75 – 3.64 (m, 2H), 3.63 – 3.52 (m, 1H), 2.25 (s, 3H), 2.22 (s, 2H), 1.19 (t, *J* = 7.1 Hz, 2H), 0.83 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 169.3 (d, *J* = 1.8 Hz), 168.5 (d, *J* = 1.4 Hz), 144.1 (d, *J* = 10.4 Hz), 143.8 (d, *J* = 10.4 Hz), 132.6 (t, *J* = 1.8 Hz), 131.8, 131.7, 131.5, 131.4, 130.6, 130.5, 130.3, 130.3, 130.2, 130.2, 129.9, 129.9, 129.1, 129.0, 128.9, 128.7, 128.7 (t, *J* = 3.1 Hz), 128.5, 128.3, 128.2, 128.0, 127.8, 127.2 (d, *J* = 3.1 Hz), 127.1 (d, *J* = 3.1 Hz), 114.5, 114.4, 62.3, 61.8, 58.3 (d, *J* = 68.6 Hz), 57.7 (d, *J* = 67.1 Hz), 36.1(d, *J* = 65.2 Hz), 35.0 (d, *J* = 65.2 Hz), 20.5, 20.4, 14.2, 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 36.13, 36.10.

HRMS m/z (ESI) calcd for $C_{24}H_{26}NO_3P$ $[M+H]^+$: 408.1728, found 408.1721.



Ethyl 2-(diphenylphosphoryl)-2-(phenylamino)acetate. (3ba)

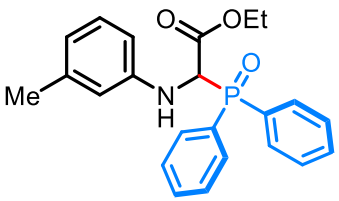
Following the general **procedure A** for 7.5 h (4.2 F/mol), **3ba** was purified by PE/EA (3:1) and obtained as a white solid (67 mg, 88%). $\mathbf{R_f}$ = 0.40 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (dddd, *J* = 11.5, 9.7, 8.3, 1.4 Hz, 4H), 7.5 (dtd, *J* = 9.2, 7.4, 1.5 Hz, 2H), 7.53 – 7.45 (m, 4H), 7.17 (dd, *J* = 8.6, 7.3 Hz, 2H), 6.79 (tt, *J* = 7.4, 1.2 Hz, 1H), 6.69 – 6.62 (m, 2H), 4.99 (d, *J* = 13.3 Hz, 1H), 4.84 (s, 1H), 3.97 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.85 (dq, *J* = 10.8, 7.1 Hz, 1H), 0.94 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.7 (d, *J* = 1.1 Hz), 146.1 (d, *J* = 10.8 Hz), 132.7 (t, *J* = 3.2 Hz), 131.9, 131.8, 131.6, 131.5, 130.7, 129.8, 129.7, 129.4, 128.9, 128.7, 128.6, 128.5, 119.6, 114.2, 61.9, 58.6 (d, *J* = 68.4 Hz), 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.50.

HRMS m/z (ESI) calcd for $C_{22}H_{22}NO_3P$ $[M+H]^+$: 380.1410, found 380.1405.



Ethyl 2-(diphenylphosphoryl)-2-(m-tolylamino)acetate. (3ca)

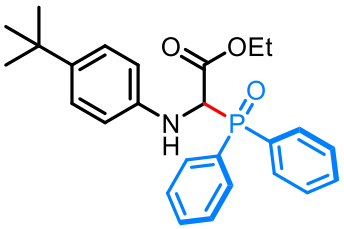
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ca** was purified by PE/EA (2:1) and obtained as a white solid (64 mg, 82%). **R_f** = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 – 7.82 (m, 4H), 7.57 (dtd, *J* = 9.2, 7.4, 1.4 Hz, 2H), 7.53 – 7.42 (m, 4H), 7.05 (td, *J* = 7.5, 1.0 Hz, 1H), 6.61 (d, *J* = 7.5 Hz, 1H), 6.47 (d, *J* = 7.6 Hz, 2H), 4.98 (dd, *J* = 13.3, 9.8 Hz, 1H), 4.77 (t, *J* = 8.0 Hz, 1H), 4.04 – 3.79 (m, 2H), 2.24 (s, 3H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8 (d, *J* = 1.2 Hz), 146.1 (d, *J* = 10.8 Hz), 139.3, 132.7 (t, *J* = 3.3 Hz), 131.9, 131.8, 131.6, 131.5, 130.7, 129.9, 129.7, 129.2, 128.8, 128.7, 128.6, 128.5, 120.5, 115.1, 111.2, 61.9, 58.5 (d, *J* = 68.6 Hz), 21.6, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.48.

HRMS m/z (ESI) calcd for $C_{23}H_{24}NO_3P$ $[M+H]^+$: 394.1572, found 394.1581.



Ethyl 2-((4-(tert-butyl)phenyl)amino)-2-(diphenylphosphoryl)acetate. (3da)

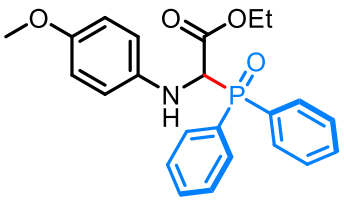
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3da** was purified by PE/EA (2:1) and obtained as a light yellow solid (63 mg, 73%). **R_f** = 0.30 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.84 (m, 4H), 7.61 – 7.53 (m, 2H), 7.51 – 7.45 (m, 4H), 7.19 (d, *J* = 8.6 Hz, 2H), 6.61 (d, *J* = 8.6 Hz, 2H), 4.97 (dd, *J* = 13.4, 10.5 Hz, 1H), 4.73 (dd, *J* = 10.6, 5.4 Hz, 1H), 3.92 (ddq, *J* = 48.7, 10.7, 7.1 Hz, 2H), 1.25 (s, 9H), 0.95 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.9, 143.7 (d, *J* = 11.3 Hz), 142.4, 132.6 (t, *J* = 3.0 Hz), 131.9, 131.8, 131.8, 131.8, 131.7, 131.6, 130.8, 130.0, 129.8, 129.0, 128.8, 128.7, 128.6, 128.5, 126.2, 114.0, 61.9, 58.8 (d, *J* = 69.2 Hz), 34.0, 31.5, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.47.

HRMS m/z (ESI) calcd for $C_{26}H_{30}NO_3P$ $[M+H]^+$: 436.2041, found 436.2033.



Ethyl 2-(diphenylphosphoryl)-2-((4-methoxyphenyl)amino)acetate. (3ea)

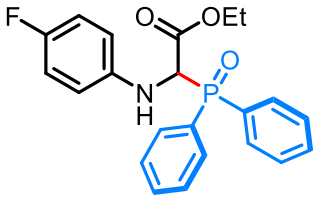
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ea** was purified by PE/EA (2:1) and obtained as a light yellow solid (65 mg, 80%). $\mathbf{R_f}$ = 0.30 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (dddd, *J* = 17.3, 11.9, 8.3, 1.4 Hz, 4H), 7.57 (qd, *J* = 7.4, 3.6 Hz, 2H), 7.49 (qd, *J* = 5.6, 5.0, 3.5 Hz, 4H), 6.75 (d, *J* = 8.9 Hz, 2H), 6.63 (d, *J* = 8.9 Hz, 2H), 4.91 (dd, *J* = 13.7, 8.6 Hz, 1H), 4.55 (s, 1H), 3.93 (ddq, *J* = 41.2, 10.8, 7.1 Hz, 2H), 3.72 (s, 3H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.0 (d, *J* = 1.4 Hz), 153.5, 140.0 (d, *J* = 11.8 Hz), 132.6 (t, *J* = 2.9 Hz), 131.9, 131.8, 131.7, 131.6, 130.8, 130.7, 130.0, 129.7, 129.0, 128.9, 128.8, 128.7, 128.6, 128.5, 115.8, 114.8, 61.9, 59.7 (d, *J* = 69.4 Hz), 55.6, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.41.

HRMS m/z (ESI) calcd for $C_{23}H_{24}NO_4P$ $[M+H]^+$: 410.1521, found 410.1527.



Ethyl 2-(diphenylphosphoryl)-2-((4-fluorophenyl)amino)acetate. (3fa)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **3fa** was purified by PE/EA (3:1) and obtained as a white solid (51.5 mg, 65%). $\mathbf{R_f}$ = 0.20 (PE/EA = 3:1);

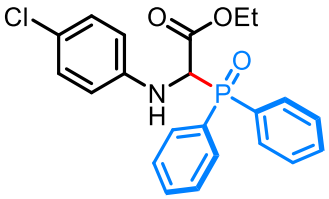
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (dtd, *J* = 11.8, 7.8, 7.3, 1.4 Hz, 4H), 7.58 (tt, *J* = 7.2, 3.6 Hz, 2H), 7.50 (tdd, *J* = 7.2, 5.4, 3.3 Hz, 4H), 6.87 (t, *J* = 8.7 Hz, 2H), 6.64 – 6.57 (m, 2H), 4.90 (dd, *J* = 13.1, 9.9 Hz, 1H), 4.80 – 4.70 (m, 1H), 4.00 – 3.79 (m, 2H), 0.93 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.7 (d, *J* = 1.3 Hz), 156.9 (d, *J* = 237.8 Hz), 142.4 (d, *J* = 11.0 Hz), 132.7 (t, *J* = 3.3 Hz), 131.9, 131.8, 131.6, 131.5, 130.7, 129.7, 129.7, 128.9, 128.8, 128.7, 128.6, 128.5, 116.0, 115.8, 115.4, 115.3, 62.0, 59.3 (d, *J* = 68.1 Hz), 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.49.

^{19}F NMR (376 MHz, $CDCl_3$) δ -125.22.

HRMS m/z (ESI) calcd for $C_{22}H_{21}FNO_3P$ $[M+H]^+$: 398.1321, found 398.1314.



Ethyl 2-((4-chlorophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ga)

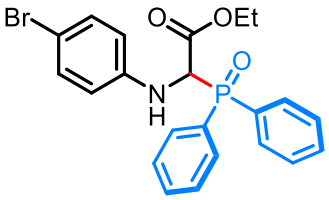
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ga** was purified by PE/EA (2:1) and obtained as a white solid (56.5 mg, 68%). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.81 (m, 4H), 7.59 (qd, *J* = 7.2, 1.5 Hz, 2H), 7.54 – 7.45 (m, 4H), 7.11 (d, *J* = 8.8 Hz, 2H), 6.58 (d, *J* = 8.8 Hz, 2H), 4.98 – 4.84 (m, 2H), 3.89 (ddq, *J* = 51.3, 10.7, 7.1 Hz, 2H), 0.93 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.5, 144.7 (d, *J* = 10.6 Hz), 132.8 (t, *J* = 3.4 Hz), 131.9, 131.8, 131.5, 131.4, 130.6, 129.6 (d, *J* = 2.5 Hz), 129.2, 129.0, 128.8, 128.6, 128.5, 124.3, 115.2, 62.0, 58.6 (d, *J* = 67.3 Hz), 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.50.

HRMS m/z (ESI) calcd for $C_{22}H_{21}ClNO_3P$ $[M+H]^+$: 414.1026, found 414.1026.



Ethyl 2-((4-bromophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ha)

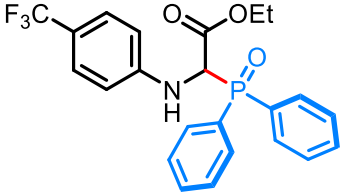
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ha** was purified by PE/EA (2:1) and obtained as a white solid (59 mg, 65%). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (dddd, *J* = 11.7, 8.6, 3.2, 1.6 Hz, 4H), 7.63 – 7.54 (m, 2H), 7.49 (ddtd, *J* = 7.7, 6.0, 4.1, 1.6 Hz, 4H), 7.26 – 7.22 (m, 2H), 6.59 – 6.48 (m, 2H), 4.91 (d, *J* = 8.9 Hz, 2H), 3.89 (ddq, *J* = 52.2, 10.7, 7.1 Hz, 2H), 0.93 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.4, 145.2 (d, *J* = 10.4 Hz), 132.8 (t, *J* = 3.2 Hz), 132.5, 132.1, 131.9, 131.8, 131.5, 131.4, 130.6, 129.6, 129.0, 128.8, 128.7, 128.7, 128.6, 128.5, 115.7, 111.4, 62.1, 58.5 (d, *J* = 68.2 Hz), 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.55.

HRMS m/z (ESI) calcd for $C_{22}H_{21}BrNO_3P$ $[M+H]^+$: 458.0520, found 458.0500.



Ethyl 2-(diphenylphosphoryl)-2-((4-(trifluoromethyl)phenyl)amino)acetate. (3ia)

Following the general **procedure A** for 7.5 h (4.2 F/mol), **3aa** was purified by PE/EA (2:1) and obtained as a white solid (51.5 mg, 58%). $\mathbf{R_f}$ = 0.20 (PE/EA = 2:1);

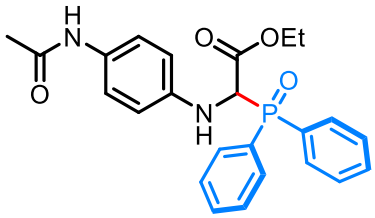
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (tdd, *J* = 7.2, 3.7, 2.3 Hz, 4H), 7.64 – 7.56 (m, 2H), 7.50 (ddt, *J* = 10.6, 5.2, 1.8 Hz, 4H), 7.40 (d, *J* = 8.5 Hz, 2H), 6.68 (d, *J* = 8.5 Hz, 2H), 5.29 (dd, *J* = 9.7, 6.3 Hz, 1H), 5.00 (dd, *J* = 12.6, 9.7 Hz, 1H), 3.95 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.85 – 3.74 (m, 1H), 0.91 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.2, 148.8 (d, *J* = 9.8 Hz), 132.9 (t, *J* = 3.2 Hz), 132.5 (d, *J* = 2.9 Hz), 131.9, 131.9, 131.8, 131.8, 131.4, 131.3, 130.5, 129.5, 129.3, 129.0, 128.9, 128.7, 128.6, 128.3, 126.7 (d, *J* = 3.8 Hz), 125.9, 123.2, 121.2, 120.9, 113.3, 62.1, 58.0 (d, *J* = 66.2 Hz), 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.60.

^{19}F NMR (376 MHz, $CDCl_3$) δ -61.36.

HRMS m/z (ESI) calcd for $C_{23}H_{21}F_3NO_3P$ $[M+H]^+$: 448.1284, found 448.1296.



Ethyl 2-((4-acetamidophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ja)

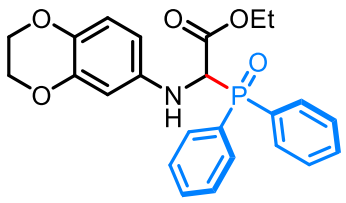
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ja** was purified by DCM/MeOH (50:1) and obtained as a yellow solid (52.6 mg, 61%). $\mathbf{R_f}$ = 0.40 (DCM/MeOH = 30:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.79 (m, 5H), 7.58 (dtd, *J* = 9.2, 7.4, 1.7 Hz, 2H), 7.49 (qd, *J* = 7.5, 2.6 Hz, 4H), 7.32 – 7.26 (m, 2H), 6.57 (d, *J* = 8.7 Hz, 2H), 4.95 (dd, *J* = 13.4, 8.9 Hz, 1H), 4.74 (s, 1H), 3.95 (dq, *J* = 10.7, 7.1 Hz, 1H), 3.81 (dq, *J* = 10.7, 7.1 Hz, 1H), 2.10 (s, 3H), 0.91 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8 (d, *J* = 1.3 Hz), 168.5, 142.8 (d, *J* = 11.3 Hz), 132.8 (t, *J* = 2.3 Hz), 131.9, 131.8, 131.6, 131.5, 130.6, 129.7, 129.6, 128.9, 128.8, 128.7, 128.5, 122.0, 114.5, 62.0, 58.8 (d, *J* = 69.0 Hz), 24.2, 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.84.

HRMS m/z (ESI) calcd for $C_{24}H_{25}N_2O_4P$ $[M+H]^+$: 437.1625, found 437.1626.



Ethyl 2-((2,3-dihydrobenzo[b][1,4]dioxin-6-yl)amino)-2-(diphenylphosphoryl)acetate. (3ka)

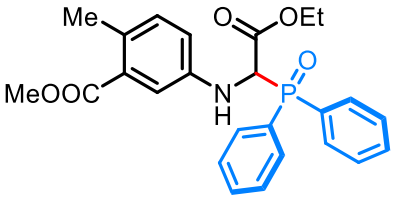
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ka** was purified by PE/EA (1:1) and obtained as a white solid (66.5 mg, 76%). $\mathbf{R_f}$ = 0.10 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (dddd, *J* = 15.5, 11.8, 8.3, 1.4 Hz, 4H), 7.57 (dtd, *J* = 9.0, 7.3, 1.5 Hz, 2H), 7.49 (qd, *J* = 7.5, 3.3 Hz, 4H), 6.71 – 6.64 (m, 1H), 6.21 (s, 1H), 6.19 (d, *J* = 2.8 Hz, 1H), 4.87 (dd, *J* = 13.7, 7.3 Hz, 1H), 4.55 (s, 1H), 4.23 – 4.11 (m, 4H), 3.93 (ddq, *J* = 46.0, 10.7, 7.1 Hz, 2H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8 (d, *J* = 1.5 Hz), 144.0, 140.8 (d, *J* = 12.0 Hz), 137.2, 132.6 (t, *J* = 3.0 Hz), 131.9, 131.8, 131.8, 131.7, 131.6, 130.8, 130.7, 130.0, 129.7, 129.0, 129.0, 128.9, 128.8, 128.7, 128.6, 128.5, 117.8, 108.1, 103.3, 64.6, 64.1, 61.9, 59.3 (d, *J* = 69.5 Hz), 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.55.

HRMS m/z (ESI) calcd for $C_{24}H_{24}NO_5P$ $[M+H]^+$: 438.1465, found 438.1464.



Methyl 5-((1-(diphenylphosphoryl)-2-ethoxy-2-oxoethyl)amino)-2-methylbenzoate. (3la)

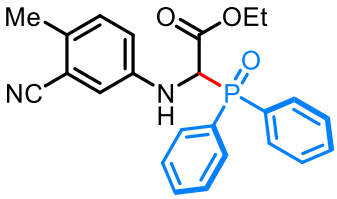
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3la** was purified by PE/EA (2:1) and obtained as a white solid (36 mg, 40%). **R_f** = 0.20 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (dddt, *J* = 11.9, 10.3, 6.9, 1.4 Hz, 4H), 7.58 (dtd, *J* = 8.7, 7.1, 1.5 Hz, 2H), 7.54 – 7.45 (m, 4H), 7.20 (d, *J* = 2.7 Hz, 1H), 7.04 (d, *J* = 8.3 Hz, 1H), 6.73 (dd, *J* = 8.3, 2.7 Hz, 1H), 4.99 (dd, *J* = 13.2, 10.1 Hz, 1H), 4.84 (dd, *J* = 10.7, 5.5 Hz, 1H), 3.99 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.85 (s, 3H), 3.84 (dq, *J* = 10.8, 7.1 Hz, 1H), 2.45 (s, 3H), 0.95 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.6 (d, *J* = 1.1 Hz), 168.0, 144.0 (d, *J* = 11.0 Hz), 132.7 (t, *J* = 3.0 Hz), 132.6, 131.9, 131.8, 131.6, 131.5, 131.1, 130.6, 130.0, 129.7, 129.6, 128.9, 128.7, 128.6, 128.5, 118.2, 115.7, 62.0, 58.7 (d, *J* = 68.4 Hz), 51.8, 20.8, 13.8.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.42.

HRMS m/z (ESI) calcd for $C_{25}H_{26}NO_5P$ $[M+H]^+$: 452.1621, found 452.1631.



Ethyl 2-((3-cyano-4-methylphenyl)amino)-2-(diphenylphosphoryl)acetate. (3ma)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **3ma** was purified by PE/EA (1:1) and obtained as a white solid (32 mg, 38%). **R_f** = 0.10 (PE/EA = 2:1);

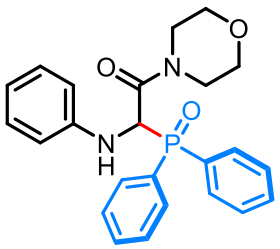
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (dddd, *J* = 12.0, 8.4, 4.3, 1.4 Hz, 4H), 7.59 (td, *J* = 7.4, 1.6 Hz, 2H), 7.55 – 7.47 (m, 4H), 7.08 (d, *J* = 8.4 Hz, 1H), 6.81 (dd, *J* = 8.4, 2.7 Hz, 1H), 6.77 (d, *J* = 2.6

Hz, 1H), 5.05 (dd, *J* = 10.0, 5.8 Hz, 1H), 4.91 (dd, *J* = 12.6, 9.7 Hz, 1H), 3.95 (dq, *J* = 10.7, 7.1 Hz, 1H), 3.80 (dq, *J* = 10.8, 7.1 Hz, 1H), 2.39 (s, 3H), 0.91 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.2, 144.3 (d, *J* = 10.2 Hz), 132.9 (t, *J* = 3.4 Hz), 132.6, 131.9, 131.8, 131.5, 131.4, 131.2, 130.5, 129.5, 129.4, 129.0, 128.9, 128.7, 128.6, 128.4, 119.4, 118.3, 116.1, 113.1, 62.2, 58.3 (d, *J* = 66.7 Hz), 19.4, 13.7.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.55.

HRMS m/z (ESI) calcd for $C_{24}H_{23}N_2O_3P$ $[M+H]^+$: 419.1519, found 419.1525.



2-(diphenylphosphoryl)-1-morpholino-2-(phenylamino)ethan-1-one. (3na)

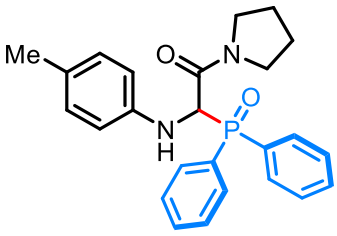
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3na** was purified by PE/EA (1:2) and obtained as a white solid (60 mg, 72%). **R_f** = 0.40 (PE/EA = 1:2);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.00 (m, 2H), 7.91 – 7.81 (m, 2H), 7.57 (tt, *J* = 7.3, 1.9 Hz, 2H), 7.52 – 7.42 (m, 4H), 7.13 (dd, *J* = 8.5, 7.3 Hz, 2H), 6.79 (t, *J* = 7.3 Hz, 1H), 6.58 (d, *J* = 7.9 Hz, 2H), 5.22 (dd, *J* = 15.0, 9.0 Hz, 1H), 4.71 (dd, *J* = 9.1, 3.1 Hz, 1H), 3.86 (ddd, *J* = 12.8, 5.5, 2.9 Hz, 1H), 3.76 (dtd, *J* = 10.7, 7.7, 3.4 Hz, 2H), 3.70 – 3.62 (m, 1H), 3.55 (dddd, *J* = 20.4, 13.0, 7.1, 2.9 Hz, 3H), 3.37 (ddd, *J* = 13.5, 7.4, 3.7 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 166.2 (d, *J* = 1.8 Hz), 146.4 (d, *J* = 10.2 Hz), 132.6 (t, *J* = 2.8 Hz), 132.1, 132.0, 132.0, 131.9, 130.8, 130.1, 129.8, 129.4, 128.8, 128.7, 128.6, 119.9, 114.8, 66.7, 66.6, 57.9 (d, *J* = 75.9 Hz), 46.6, 43.2.

^{31}P NMR (162 MHz, $CDCl_3$) δ 27.64.

HRMS m/z (ESI) calcd for $C_{24}H_{25}N_2O_3P$ $[M+H]^+$: 421.1676, found 421.1682.



2-(diphenylphosphoryl)-1-(pyrrolidin-1-yl)-2-(*p*-tolylamino)ethan-1-one. (3oa)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **3oa** was purified by PE/EA (1:2) and obtained as a white solid (55 mg, 66%). **R_f** = 0.10 (PE/EA = 1:1);

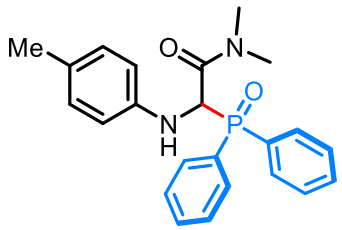
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 – 8.01 (m, 2H), 7.87 (ddd, *J* = 11.6, 7.0, 1.6 Hz, 2H), 7.60 – 7.52 (m, 2H), 7.48 (dq, *J* = 7.1, 3.6 Hz, 4H), 6.95 (d, *J* = 8.1 Hz, 2H), 6.53 (d, *J* = 8.4 Hz, 2H), 5.04

(dd, *J* = 15.6, 8.2 Hz, 1H), 4.52 (d, *J* = 9.7 Hz, 1H), 3.86 (dt, *J* = 9.8, 6.4 Hz, 1H), 3.48 (dt, *J* = 9.7, 6.5 Hz, 1H), 3.45 – 3.34 (m, 2H), 2.21 (s, 3H), 1.90 – 1.65 (m, 4H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 165.8 (d, *J* = 2.2 Hz), 144.3 (d, *J* = 11.2 Hz), 132.4 (d, *J* = 2.8 Hz), 132.3, 132.2, 131.9, 131.8, 131.4, 130.5, 130.4, 129.8, 129.5, 129.0, 128.7, 128.6, 128.5, 128.4, 115.0, 59.9 (d, *J* = 75.1 Hz), 46.9, 46.5, 25.9, 23.9, 20.4.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.36.

HRMS m/z (ESI) calcd for $C_{25}H_{27}N_2O_2P$ $[M+H]^+$: 419.1883, found 419.1883.



2-(diphenylphosphoryl)-N,N-dimethyl-2-(*p*-tolylamino)acetamide. (3pa)

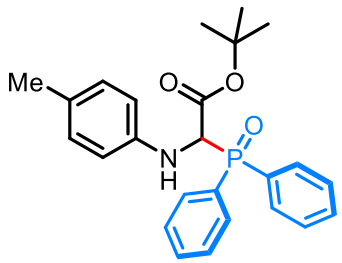
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3pa** was purified by PE/EA (1:1) and obtained as a white solid (48 mg, 61%). **R_f** = 0.15 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (ddt, *J* = 11.0, 7.0, 1.4 Hz, 2H), 7.84 (ddd, *J* = 11.5, 8.3, 1.4 Hz, 2H), 7.59 – 7.53 (m, 2H), 7.51 – 7.45 (m, 4H), 6.94 (d, *J* = 8.2 Hz, 2H), 6.51 (d, *J* = 8.4 Hz, 2H), 5.22 (dd, *J* = 15.6, 8.4 Hz, 1H), 4.46 (d, *J* = 9.8 Hz, 1H), 3.17 (s, 3H), 2.94 (d, *J* = 1.2 Hz, 3H), 2.21 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 167.5 (d, *J* = 2.1 Hz), 144.4 (d, *J* = 11.8 Hz), 132.4, 132.4, 132.3, 131.9, 131.8, 131.5, 130.5, 130.3, 129.9, 129.3, 128.7, 128.6, 128.4, 128.3, 115.3, 58.1 (d, *J* = 76.8 Hz), 37.8, 36.5, 20.5.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.04.

HRMS m/z (ESI) calcd for $C_{23}H_{25}N_2O_2P$ $[M+H]^+$: 393.1726, found 393.1729.



Tert-butyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (3qa)

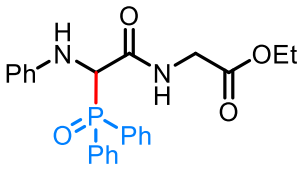
Following the **general procedure A** for 7.5 h (4.2 F/mol), **3qa** was purified by PE/EA (2:1) and obtained as a white solid (62 mg, 74%). **R_f** = 0.30 (PE/EA = 2:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 – 7.81 (m, 4H), 7.62 – 7.52 (m, 2H), 7.51 – 7.42 (m, 4H), 6.97 (d, *J* = 8.2 Hz, 2H), 6.58 (d, *J* = 8.5 Hz, 2H), 4.86 (d, *J* = 13.0 Hz, 1H), 4.74 (s, 1H), 2.22 (s, 3H), 1.14 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 167.5 (d, *J* = 1.1 Hz), 144.0 (d, *J* = 11.1 Hz), 132.5 (d, *J* = 2.8 Hz), 132.4 (d, *J* = 2.8 Hz), 132.1, 132.0, 131.5, 131.4, 129.7, 128.7 (d, *J* = 3.6 Hz), 128.6, 128.6, 128.4, 114.3, 82.9, 59.1 (d, *J* = 70.5 Hz), 27.5, 20.4.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.58.

HRMS m/z (ESI) calcd for $C_{25}H_{28}NO_3P$ $[M+H]^+$: 422.1880, found 422.1889.



Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)glycinate. (4a)

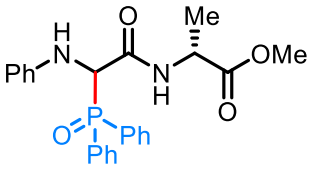
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4a** was purified by PE/EA (1:1) and obtained as a white solid (56 mg, 64%). **R_f** = 0.20 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (ddd, *J* = 11.9, 8.4, 1.4 Hz, 2H), 7.81 (ddd, *J* = 12.0, 8.3, 1.4 Hz, 2H), 7.75 (s, 1H), 7.53 – 7.47 (m, 4H), 7.41 (td, *J* = 7.6, 3.4 Hz, 2H), 7.14 (dd, *J* = 8.6, 7.3 Hz, 2H), 6.83 – 6.76 (m, 1H), 6.69 – 6.64 (m, 2H), 5.32 (dd, *J* = 9.7, 5.0 Hz, 1H), 4.75 (dd, *J* = 14.9, 4.3 Hz, 1H), 4.08 (q, *J* = 7.1 Hz, 2H), 3.81 (dd, *J* = 18.0, 5.5 Hz, 1H), 3.64 (dd, *J* = 18.0, 5.6 Hz, 1H), 1.17 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.8, 168.4, 146.8 (d, *J* = 8.7 Hz), 132.7 (d, *J* = 2.6 Hz), 132.6 (d, *J* = 3.0 Hz), 132.5 (d, *J* = 2.9 Hz), 132.0 (d, *J* = 9.6 Hz), 131.7 (d, *J* = 9.6 Hz), 130.7 (d, *J* = 11.5 Hz), 130.3, 129.8, 129.3, 129.0, 128.9, 128.9, 128.8, 128.7, 128.3 (d, *J* = 12.4 Hz), 119.9, 114.7, 61.4, 60.6 (d, *J* = 65.5 Hz), 41.3, 14.0.

^{31}P NMR (162 MHz, $CDCl_3$) δ 30.35.

HRMS m/z (ESI) calcd for $C_{24}H_{25}N_2O_4P$ $[M+H]^+$: 437.1625, found 437.1633.



Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-D-alaninate. (4b)

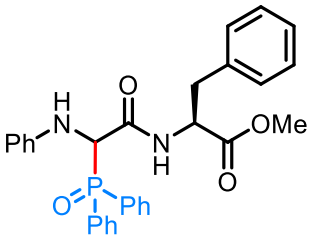
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4b** was purified by PE/EA (1:1) and obtained as a yellow oil (48 mg, 55%, d.r. = 1:1). **R_f** = 0.20 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 8.18 – 8.04 (m, 4H), 7.86 – 7.75 (m, 4H), 7.59 (tt, *J* = 7.3, 1.5 Hz, 2H), 7.52 (dddd, *J* = 9.5, 7.7, 5.9, 2.5 Hz, 6H), 7.41 (dtd, *J* = 15.1, 7.7, 3.3 Hz, 4H), 7.15 (ddd, *J* = 13.0, 8.5, 7.3 Hz, 4H), 6.81 (dt, *J* = 10.8, 7.4 Hz, 2H), 6.69 (d, *J* = 7.7 Hz, 2H), 6.61 (d, *J* = 7.4 Hz, 2H), 5.37 (dd, *J* = 10.8, 3.8 Hz, 1H), 5.32 (dd, *J* = 9.7, 4.4 Hz, 1H), 4.67 (ddd, *J* = 15.3, 11.5, 4.0 Hz, 2H), 4.21 (qt, *J* = 7.2, 3.5 Hz, 2H), 3.64 (s, 3H), 3.59 (s, 3H), 1.22 (d, *J* = 7.1 Hz, 3H), 0.98 (d, *J* = 7.3 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 172.28, 172.18, 168.00, 167.38, 147.00 (d, *J* = 5.4 Hz), 146.92 (d, *J* = 5.1 Hz), 132.71 (t, *J* = 2.1 Hz), 132.58 (d, *J* = 2.8 Hz), 132.44 (d, *J* = 2.8 Hz), 132.16 (d, *J* = 6.3 Hz), 132.06 (d, *J* = 6.3 Hz), 131.82 (d, *J* = 9.1 Hz), 131.73 (d, *J* = 9.1 Hz), 130.52, 130.41, 129.94, 129.88, 129.50, 129.40, 129.25, 128.93, 128.90, 128.87, 128.80 (d, *J* = 2.6 Hz), 128.38 (d, *J* = 1.3 Hz), 128.26 (d, *J* = 1.3 Hz), 120.14, 119.92, 114.89, 114.63, 61.17 (d, *J* = 8.3 Hz), 60.52 (d, *J* = 11.1 Hz), 52.40, 52.31, 48.22, 48.07, 18.11, 17.38.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 29.95, 29.33.

HRMS m/z (ESI) calcd for $C_{24}H_{25}N_2O_4P$ $[M+H]^+$: 437.1625, found 437.1624.



Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalaninate. (4c)

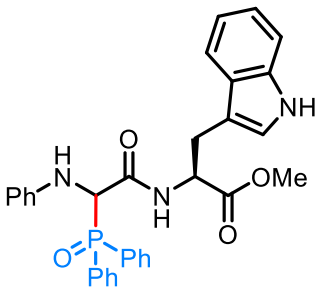
Following the general **procedure A** for 7.5 h (4.2 F/mol), **4c** was purified by PE/EA (1:1) and obtained as a yellow oil (62 mg, 60%, d.r. = 1.2:1). **R_f** = 0.20 (PE/EA = 1:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 8.05 (dddd, *J* = 13.3, 11.9, 8.3, 1.4 Hz, 4H), 7.76 (dtd, *J* = 12.0, 8.4, 1.4 Hz, 4H), 7.61 – 7.53 (m, 3H), 7.53 – 7.44 (m, 6H), 7.38 (ttd, *J* = 7.3, 3.3, 1.9 Hz, 4H), 7.28 – 7.20 (m, 3H), 7.20 – 7.10 (m, 5H), 7.09 – 7.03 (m, 2H), 7.00 – 6.95 (m, 2H), 6.88 – 6.83 (m, 3H), 6.83 – 6.77 (m, 1H), 6.66 – 6.62 (m, 2H), 6.62 – 6.58 (m, 2H), 5.31 (dd, *J* = 10.8, 4.0 Hz, 1H), 5.21 (dd, *J* = 10.3, 4.5 Hz, 1H), 4.67 (t, *J* = 3.9 Hz, 1H), 4.63 (t, *J* = 4.0 Hz, 1H), 4.54 (dt, *J* = 8.5, 6.0 Hz, 1H), 4.46 (q, *J* = 6.8 Hz, 1H), 3.57 (s, 3H), 3.50 (s, 2H), 2.95 – 2.85 (m, 2H), 2.78 – 2.67 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 171.03, 170.70, 168.05, 167.80, 146.88 (d, *J* = 8.4 Hz), 146.72 (d, *J* = 8.4 Hz), 135.70, 135.35, 132.68, 132.57, 132.39, 132.12, 132.03, 131.76, 131.66, 130.63, 130.58, 129.90, 129.72, 129.61, 129.56, 129.34, 129.24, 129.09, 128.93, 128.89, 128.81, 128.71, 128.66, 128.45, 128.32, 128.18, 127.14, 126.99, 120.11, 119.98, 114.88, 114.55, 61.15, 60.90, 60.50, 60.27, 53.42, 52.17, 38.47, 37.69.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 29.79, 29.65.

HRMS m/z (ESI) calcd for $C_{30}H_{29}N_2O_4P$ $[M+H]^+$: 513.1943, found 513.1945.



Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-tryptophanate. (4d)

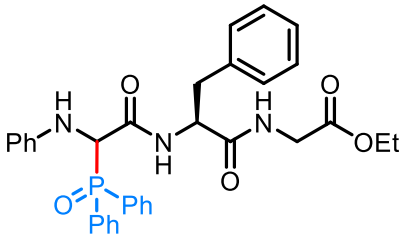
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4d** was purified by PE/EA (1:2) and obtained as a yellow foam solid (46 mg, 42%, d.r. = 1:1). $\mathbf{R_f}$ = 0.30 (PE/EA = 1:2);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 8.39 – 8.30 (m, 1H), 8.06 – 7.98 (m, 3H), 7.93 (ddd, *J* = 11.9, 8.3, 1.3 Hz, 2H), 7.78 (ddd, *J* = 12.0, 8.3, 1.4 Hz, 2H), 7.71 – 7.61 (m, 4H), 7.59 – 7.53 (m, 2H), 7.53 – 7.45 (m, 4H), 7.41 (td, *J* = 7.8, 3.3 Hz, 5H), 7.38 – 7.34 (m, 2H), 7.31 (d, *J* = 8.1 Hz, 1H), 7.27 – 7.20 (m, 5H), 7.18 (dd, *J* = 7.0, 1.1 Hz, 1H), 7.16 – 7.06 (m, 7H), 7.05 – 6.99 (m, 1H), 6.95 (d, *J* = 2.4 Hz, 1H), 6.79 (td, *J* = 7.3, 3.7 Hz, 2H), 6.62 – 6.57 (m, 3H), 6.57 – 6.52 (m, 2H), 5.21 (dd, *J* = 9.6, 4.6 Hz, 1H), 5.14 (dd, *J* = 10.3, 4.7 Hz, 1H), 4.74 – 4.68 (m, 1H), 4.66 (d, *J* = 9.9 Hz, 1H), 4.63 – 4.58 (m, 1H), 4.49 (q, *J* = 6.5 Hz, 1H), 3.49 (s, 3H), 3.49 (s, 3H), 3.22 – 3.06 (m, 2H), 2.99 (qd, *J* = 14.8, 6.0 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 171.52, 171.34, 167.92 (d, J = 1.3 Hz), 167.46 (d, J = 1.3 Hz), 146.79 (d, J = 8.1 Hz), 146.71 (d, J = 8.1 Hz), 136.15, 136.02, 132.70 (d, J = 3.0 Hz), 132.64 (d, J = 3.0 Hz), 132.56 (d, J = 3.0 Hz), 132.47 (d, J = 3.0 Hz), 132.16, 132.07, 131.95, 131.86, 131.75, 131.65, 131.56, 130.50, 130.37, 129.63 (d, J = 2.4 Hz), 129.48, 129.31, 129.21, 128.93 (d, J = 4.7 Hz), 128.81 (d, J = 4.7 Hz), 128.62 (d, J = 2.2 Hz), 128.38 (d, J = 1.8 Hz), 128.26 (d, J = 1.8 Hz), 127.20, 127.13, 123.59, 123.10, 122.18, 121.98, 120.01, 119.81, 119.54, 119.43, 118.54, 118.48, 114.81, 114.55, 111.34, 111.21, 109.49, 109.07, 77.00, 60.98, 60.75, 60.33, 60.09, 52.73 (d, J = 53.4 Hz), 52.27 (d, J = 7.4 Hz), 28.08, 27.36.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 30.43, 29.72.

HRMS m/z (ESI) calcd for $C_{32}H_{30}N_3O_4P$ $[M+H]^+$: 552.2052, found 552.2056.



Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalanylglycinate. (4e)

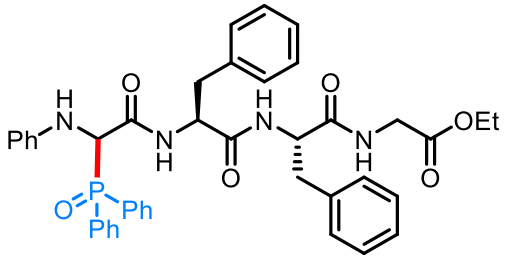
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4e** was purified by DCM/MeOH (30:1) and obtained as a yellow oil (90 mg, 77%, d.r. = 1:1). $\mathbf{R_f}$ = 0.40 (DCM/MeOH = 30:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 8.29 (t, *J* = 5.8 Hz, 1H), 7.94 – 7.74 (m, 10H), 7.68 (dddd, *J* = 13.8, 8.3, 2.8, 1.4 Hz, 5H), 7.57 (ddt, *J* = 9.2, 3.6, 2.6 Hz, 5H), 7.54 – 7.36 (m, 16H), 7.20 – 7.11 (m, 7H), 7.07 (ddd, *J* = 8.4, 5.0, 2.1 Hz, 3H), 7.00 (dd, *J* = 8.2, 6.7 Hz, 2H), 6.89 – 6.74 (m, 4H), 6.50 (dd, *J* = 8.6, 1.1 Hz, 2H), 6.44 (dd, *J* = 8.6, 1.0 Hz, 2H), 4.97 (dd, *J* = 16.5, 9.1 Hz, 1H), 4.76 (tt, *J* = 7.0, 5.4 Hz, 2H), 4.70 – 4.61 (m, 2H), 4.46 (dd, *J* = 9.2, 5.1 Hz, 1H), 4.17 (dq, *J* = 12.8, 7.2 Hz, 4H), 4.06 – 3.81 (m, 4H), 3.19 (dd, *J* = 14.3, 5.2 Hz, 1H), 3.12 – 3.04 (m, 1H), 2.96 (d, *J* = 5.5 Hz, 1H), 2.89 – 2.82 (m, 1H), 1.29 – 1.24 (m, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 171.33, 170.83, 169.63, 169.57, 167.29, 167.07, 146.04 (d, J = 10.5 Hz), 145.79 (d, J = 9.9 Hz), 137.00, 136.08, 133.05 (d, J = 2.7 Hz), 132.92 (d, J = 2.7 Hz), 132.74 (t, J = 2.4 Hz), 132.66 (d, J = 2.7 Hz), 132.38, 132.28, 131.68 (d, J = 3.9 Hz), 131.59 (d, J = 3.2 Hz), 131.46, 131.37, 130.79, 130.67, 129.50, 129.36, 129.33, 129.28, 129.17, 129.02, 128.89, 128.85, 128.78, 128.73, 128.69, 128.66, 128.56, 128.49, 126.68, 120.16, 120.11, 114.94, 113.99, 61.22, 61.15, 60.62 (d, J = 61.9 Hz), 59.22 (d, J = 70.8 Hz), 54.59, 53.76, 41.44, 38.07, 37.14, 35.20, 21.62, 14.20.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 34.39, 31.26.

HRMS m/z (ESI) calcd for $C_{33}H_{34}N_3O_5P$ $[M+H]^+$: 584.2309, found 584.2315.



Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalanyl-L-phenylalanylglycinate. (4f)

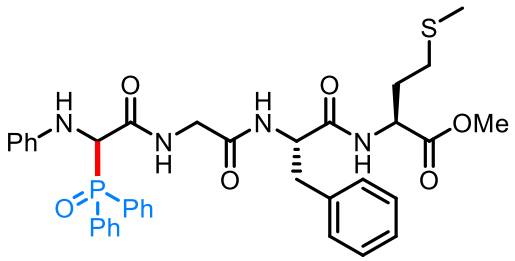
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4f** was purified by DCM/MeOH (30:1) and obtained as a yellow foam solid (58 mg, 40%, d.r. = 1.7:1). **R_f** = 0.30 (DCM/MeOH = 30:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 7.95 – 7.71 (m, 7H), 7.65 – 7.40 (m, 11H), 7.25 – 7.07 (m, 16H), 6.99 – 6.91 (m, 3H), 6.90 – 6.79 (m, 3H), 6.77 – 6.71 (m, 1H), 6.56 – 6.49 (m, 2H), 6.39 – 6.33 (m, 1H), 4.82 – 4.56 (m, 5H), 4.42 (td, *J* = 7.9, 5.7 Hz, 1H), 4.20 – 4.02 (m, 5H), 3.86 – 3.65 (m, 2H), 3.32 – 3.13 (m, 2H), 2.93 – 2.80 (m, 3H), 2.48 (dd, *J* = 14.2, 8.3 Hz, 1H), 1.24 (q, *J* = 7.0 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 171.35, 171.15, 170.61, 170.37, 169.61, 169.33, 168.15, 167.43, 145.98 (d, J = 10.9 Hz), 145.67 (d, J = 9.4 Hz), 137.74, 137.55, 136.10, 135.69, 133.27 (d, J = 2.7 Hz), 133.07 (d, J = 3.0 Hz), 132.93 (d, J = 2.7 Hz), 132.83 (d, J = 2.8 Hz), 132.19, 132.09, 131.58, 131.52, 131.49, 131.46, 131.42, 131.36, 129.97, 129.72, 129.63, 129.59, 129.45, 129.34, 129.21, 129.14, 129.02, 128.99, 128.95, 128.90, 128.86, 128.80, 128.77, 128.73, 128.63, 128.45, 128.38, 128.14, 127.71, 127.05, 126.86, 126.66, 126.54, 120.56, 120.39, 114.58, 113.97, 61.35, 61.23, 60.16, 59.49, 54.95 (d, J = 25.4 Hz), 54.49 (d, J = 95.5 Hz), 41.36, 41.33, 36.89, 36.85, 14.19.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 34.69, 30.25.

HRMS m/z (ESI) calcd for $C_{33}H_{34}N_3O_5P$ $[M+Na]^+$: 753.2812, found 753.2809.



Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)glycyl-L-phenylalanyl-L-methioninate. (4g)

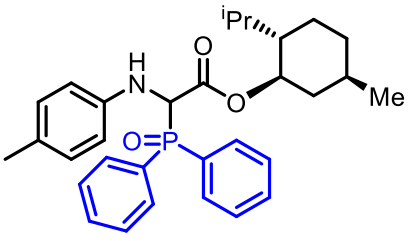
Following the **general procedure A** for 7.5 h (4.2 F/mol), **4g** was purified by DCM/MeOH (30:1) and obtained as a yellow oil (46 mg, 33%, d.r. = 1.2:1). $\mathbf{R_f}$ = 0.30 (DCM/MeOH = 30:1);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 8.27 (d, *J* = 8.3 Hz, 1H), 8.11 (d, *J* = 8.4 Hz, 1H), 7.96 – 7.76 (m, 9H), 7.72 – 7.68 (m, 1H), 7.58 (dddd, *J* = 14.7, 7.1, 4.5, 1.6 Hz, 4H), 7.52 – 7.45 (m, 8H), 7.26 – 7.13 (m, 14H), 6.82 (t, *J* = 7.4 Hz, 2H), 6.64 – 6.55 (m, 4H), 5.05 – 4.98 (m, 1H), 4.97 – 4.93 (m, 2H), 4.74 (ddd, *J* = 15.2, 8.5, 6.4 Hz, 2H), 4.65 (td, *J* = 7.9, 5.0 Hz, 1H), 4.58 (td, *J* = 8.0, 5.1 Hz, 1H), 4.45 (dd, *J* = 7.8, 6.1 Hz, 1H), 4.13 – 4.02 (m, 1H), 3.85 (dd, *J* = 17.1, 6.9 Hz, 1H), 3.78 – 3.68 (m, 2H), 3.68 (s, 3H), 3.65 (s, 3H), 3.24 (ddd, *J* = 14.4, 8.6, 6.0 Hz, 2H), 3.09 (ddd, *J* = 23.7, 14.1, 9.0 Hz, 2H), 2.47 (ddd, *J* = 8.5, 6.7, 1.7 Hz, 2H), 2.39 – 2.31 (m, 2H), 2.15 – 2.07 (m, 1H), 2.05 (s, 1H), 2.02 (s, 3H), 1.97 (s, 3H), 1.96 – 1.88 (m, 1H), 1.80 (dtd, *J* = 14.3, 8.4, 6.1 Hz, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 172.55, 172.43, 171.40, 171.26, 169.14, 168.94, 168.00, 167.81, 146.12(d, J = 4.4 Hz), 146.02(d, J = 3.3 Hz), 137.25, 137.22, 133.13(d, J = 2.9 Hz), 132.97(d, J = 2.5 Hz), 132.92(d, J = 2.8 Hz), 132.83(d, J = 2.7 Hz), 132.20, 132.10, 131.89, 131.80, 131.67, 131.58, 131.49, 131.40, 130.55, 130.45, 130.28, 130.02, 129.57, 129.52, 129.23, 129.20, 129.09, 129.07, 128.97, 128.94, 128.84, 128.82, 128.72, 128.67, 128.48, 128.44, 126.74, 126.68, 120.41, 120.12, 114.72, 114.24, 60.29(d, J = 16.0 Hz), 59.61(d, J = 18.0 Hz), 55.47, 55.28, 52.50, 52.47, 51.60, 51.56, 43.37, 43.19, 38.63, 37.47, 37.30, 31.59, 31.48, 29.93, 29.89, 15.39.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 33.42, 32.47.

HRMS m/z (ESI) calcd for $C_{37}H_{41}N_4O_6PS$ $[M+H]^+$: 701.2557, found 701.2545.



(1R,2S,5R)-2-isopropyl-5-methylcyclohexyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (5a)

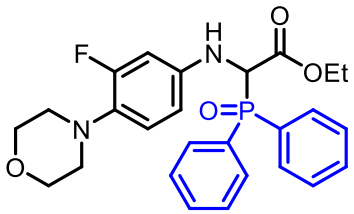
Following the **general procedure A** for 7.5 h (4.2 F/mol), **5a** was purified by PE/EA (3:1) and obtained as a yellow solid (50 mg, 51%, d.r. = 1:1). $\mathbf{R_f}$ = 0.30 (PE/EA = 1:2);

^{1}H NMR (400 MHz, $CDCl_3$) **two isomers** δ 7.99 – 7.81 (m, 8H), 7.61 – 7.42 (m, 12H), 7.09 (d, *J* = 8.0 Hz, 1H), 6.99 – 6.92 (m, 3H), 6.84 (d, *J* = 8.3 Hz, 1H), 6.59 (dd, *J* = 8.2, 5.2 Hz, 3H), 4.96 (dd, *J* = 13.0, 10.7 Hz, 2H), 4.83 (dd, *J* = 11.0, 6.3 Hz, 1H), 4.67 (dd, *J* = 11.4, 5.4 Hz, 1H), 4.58 – 4.40 (m, 2H), 2.22 (s, 5H), 1.76 (pd, *J* = 7.0, 2.6 Hz, 1H), 1.61 – 1.48 (m, 4H), 1.46 – 1.36 (m, 2H), 1.20 (tt, *J* = 11.5, 2.6 Hz, 2H), 1.08 (dddt, *J* = 20.8, 13.8, 11.3, 3.6 Hz, 2H), 0.92 – 0.69 (m, 14H), 0.63 (d, *J* = 6.9 Hz, 1H), 0.54 (dd, *J* = 10.8, 6.9 Hz, 5H), 0.45 (d, *J* = 6.8 Hz, 1H), 0.30 (d, *J* = 6.8 Hz, 2H).

^{13}C NMR (101 MHz, $CDCl_3$) **two isomers** δ 168.52 (d, J = 1.1 Hz), 168.32 (d, J = 1.1 Hz), 144.06 (d, J = 11.9 Hz), 143.85 (d, J = 11.9 Hz), 132.72 (d, J = 2.5 Hz), 132.61 (d, J = 3.0 Hz), 132.55, 132.51, 132.48, 132.46, 132.35 (d, J = 3.5 Hz), 132.26 (d, J = 3.5 Hz), 132.13, 132.07, 132.04, 131.98, 131.64, 131.55, 131.52, 131.48, 131.39, 131.25, 130.70, 130.51, 130.23, 130.02, 129.79, 129.73, 129.53, 129.04, 128.84, 128.79, 128.72, 128.67, 128.63, 128.61, 128.57, 128.51, 128.49, 128.45, 128.39, 119.63, 114.70, 114.16, 76.35, 76.22, 59.43 (d, J = 68.4 Hz), 58.75 (d, J =70.5 Hz), 46.51, 46.21, 40.24, 39.64, 33.97, 31.28, 31.16, 25.86, 24.95, 24.69, 22.85, 22.49, 21.93, 21.86, 20.83, 20.79, 20.46, 20.42, 15.80, 15.18.

^{31}P NMR (162 MHz, $CDCl_3$) **two isomers** δ 28.10, 28.03.

HRMS m/z (ESI) calcd for $C_{30}H_{36}NO_3P$ $[M+Na]^+$: 512.2331 found 512.2332.



Ethyl 2-(diphenylphosphoryl)-2-((3-fluoro-4-morpholinophenyl)amino)acetate. (5b)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **5b** was purified by PE/EA (1:2) and obtained as a yellow solid (46.5 mg, 48%). **R_f** = 0.20 (PE/EA = 1:2);

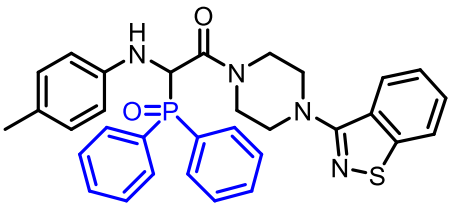
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (dddd, *J* = 11.9, 8.6, 5.3, 1.4 Hz, 4H), 7.58 (ddt, *J* = 6.6, 5.6, 1.7 Hz, 2H), 7.52 – 7.48 (m, 4H), 6.80 (t, *J* = 9.1 Hz, 1H), 6.45 – 6.37 (m, 2H), 4.88 (dd, *J* = 12.8, 10.4 Hz, 1H), 4.79 (dd, *J* = 10.6, 5.3 Hz, 1H), 3.97 (dq, *J* = 10.7, 7.1 Hz, 1H), 3.89 – 3.78 (m, 5H), 2.99 – 2.90 (m, 4H), 0.93 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 168.59, 157.88, 155.44, 132.75 (t, *J* = 3.6 Hz), 132.63 (d, *J* = 3.0 Hz), 131.89, 131.80, 131.56, 131.46, 130.80, 130.68, 130.65, 129.68, 129.63, 129.01, 128.92, 128.88, 128.79, 128.64, 128.52, 120.16 (d, *J* = 3.5 Hz), 109.75 (d, *J* = 3.0 Hz), 103.13, 67.10, 61.99, 58.89 (d, *J* = 67.3 Hz), 51.56, 13.74.

^{31}P NMR (162 MHz, $CDCl_3$) δ 28.40.

^{19}F NMR (376 MHz, $CDCl_3$) δ -121.91.

HRMS m/z (ESI) calcd for $C_{26}H_{28}FN_2O_4P$ $[M+Na]^+$: 505.1663 found 505.1672.



1-(4-(benzo[d]isothiazol-3-yl)piperazin-1-yl)-2-(diphenylphosphoryl)-2-(*p*-tolylamino)ethan-1-one. (5c)

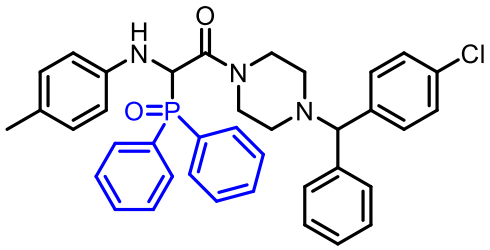
Following the **general procedure A** for 7.5 h (4.2 F/mol), **5c** was purified by PE/EA (1:2) and obtained as a yellow solid (95 mg, 84%). $\mathbf{R_f}$ = 0.20 (PE/EA = 1:2);

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.09 (dd, *J* = 8.2, 5.5 Hz, 2H), 7.94 (td, *J* = 11.4, 6.9 Hz, 4H), 7.68 – 7.53 (m, 7H), 7.47 (t, *J* = 7.6 Hz, 1H), 6.93 (d, *J* = 8.2 Hz, 2H), 6.82 – 6.75 (m, 2H), 5.78 (dd, *J* = 13.7, 10.5 Hz, 1H), 5.28 (dd, *J* = 10.6, 3.2 Hz, 1H), 4.03 (ddd, *J* = 19.1, 10.3, 5.8 Hz, 1H), 3.77 – 3.66 (m, 1H), 3.62 – 3.54 (m, 1H), 3.49 (s, 1H), 3.33 (t, *J* = 5.1 Hz, 3H), 3.29 – 3.19 (m, 1H), 2.16 (s, 3H).

^{13}C NMR (101 MHz, DMSO-d_6) δ 165.96 (d, *J* = 1.9 Hz), 163.12, 152.07, 144.63 (d, *J* = 11.7 Hz), 132.27 (d, *J* = 7.8 Hz), 131.90, 131.83, 131.74, 131.58, 131.49, 131.07, 130.92, 130.09, 129.41, 128.66, 128.54, 128.06, 127.26, 127.10, 124.57, 124.13, 121.19, 114.36, 55.11 (d, *J* = 74.4 Hz), 49.77, 49.71, 45.20, 42.00, 20.12.

^{31}P NMR (162 MHz, DMSO-d_6) δ 27.63.

HRMS m/z (ESI) calcd for $C_{32}H_{31}N_4O_2PS$ $[M+H]^+$: 567.1978 found 567.1973.



1-(4-((4-chlorophenyl)(phenyl)methyl)piperazin-1-yl)-2-(diphenylphosphoryl)-2-(*p*-tolylamino)ethan-1-one. (5d)

Following the **general procedure A** for 7.5 h (4.2 F/mol), **5d** was purified by PE/EA (1:1) and obtained as a light yellow solid (94 mg, 74%). $\mathbf{R_f}$ = 0.40 (DCM/MeOH = 30:1);

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 – 7.91 (m, 2H), 7.79 – 7.70 (m, 2H), 7.45 (tt, *J* = 7.0, 1.5 Hz, 2H), 7.36 (dtd, *J* = 10.8, 7.6, 6.3, 3.1 Hz, 4H), 7.25 (td, *J* = 5.4, 2.6 Hz, 4H), 7.21 – 7.13 (m, 4H), 7.09 (td, *J* = 7.1, 1.8 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 2H), 6.39 (d, *J* = 8.4 Hz, 2H), 5.08 (dd, *J* = 15.4, 9.5 Hz, 1H), 4.44 (dd, *J* = 9.5, 2.6 Hz, 1H), 4.11 (s, 1H), 3.77 (ddd, *J* = 13.1, 6.6, 2.9 Hz, 1H), 3.70 – 3.59 (m, 1H), 3.49 – 3.41 (m, 1H), 3.36 (td, *J* = 7.5, 3.4 Hz, 1H), 2.51 – 2.39 (m, 1H), 2.30 (qd, *J* = 7.1, 3.5 Hz, 1H), 2.26 – 2.16 (m, 2H), 2.12 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.12, 164.77 (t, *J* = 2.1 Hz), 143.23 (d, *J* = 11.1 Hz), 140.69 (d, *J* = 2.9 Hz), 139.87 (d, *J* = 2.1 Hz), 131.65 (d, *J* = 2.8 Hz), 131.33 (t, *J* = 2.8 Hz), 131.14, 131.05, 130.91, 130.83, 130.20, 129.24 (d, *J* = 6.6 Hz), 128.77, 128.28, 128.11, 128.04, 127.72, 127.70, 127.67, 127.65, 127.63, 127.51, 127.46, 127.34, 126.67, 126.28 (d, *J* = 3.1 Hz), 114.03, 74.01, 59.36, 56.91 (d, *J* = 76.7 Hz), 50.52 (d, *J* = 45.6 Hz), 45.35, 41.89, 19.40.

^{31}P NMR (162 MHz, $CDCl_3$) δ 27.53.

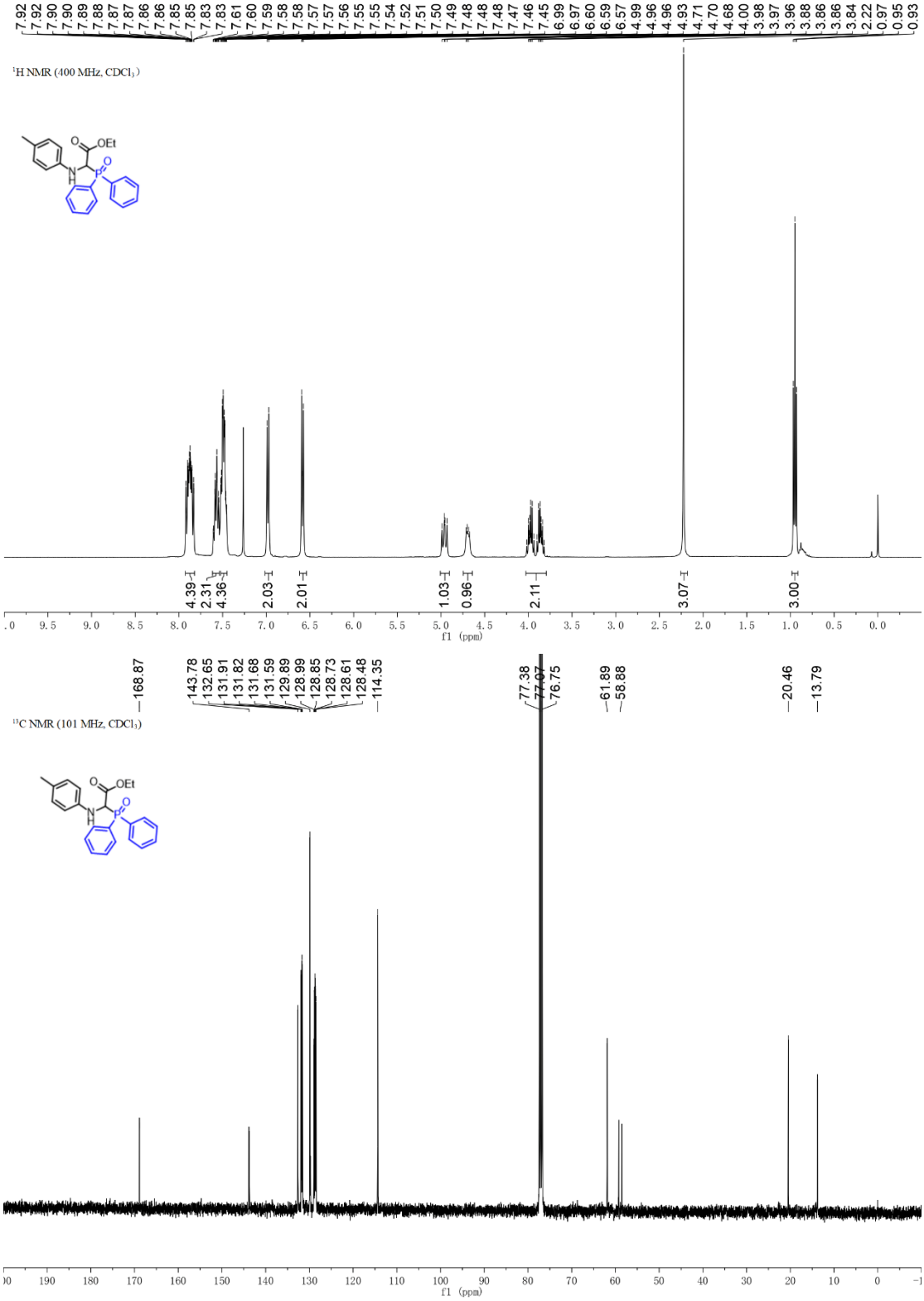
HRMS m/z (ESI) calcd for $C_{38}H_{37}ClN_3O_2P$ $[M+H]^+$: 634.2385 found 634.2398.

8. References

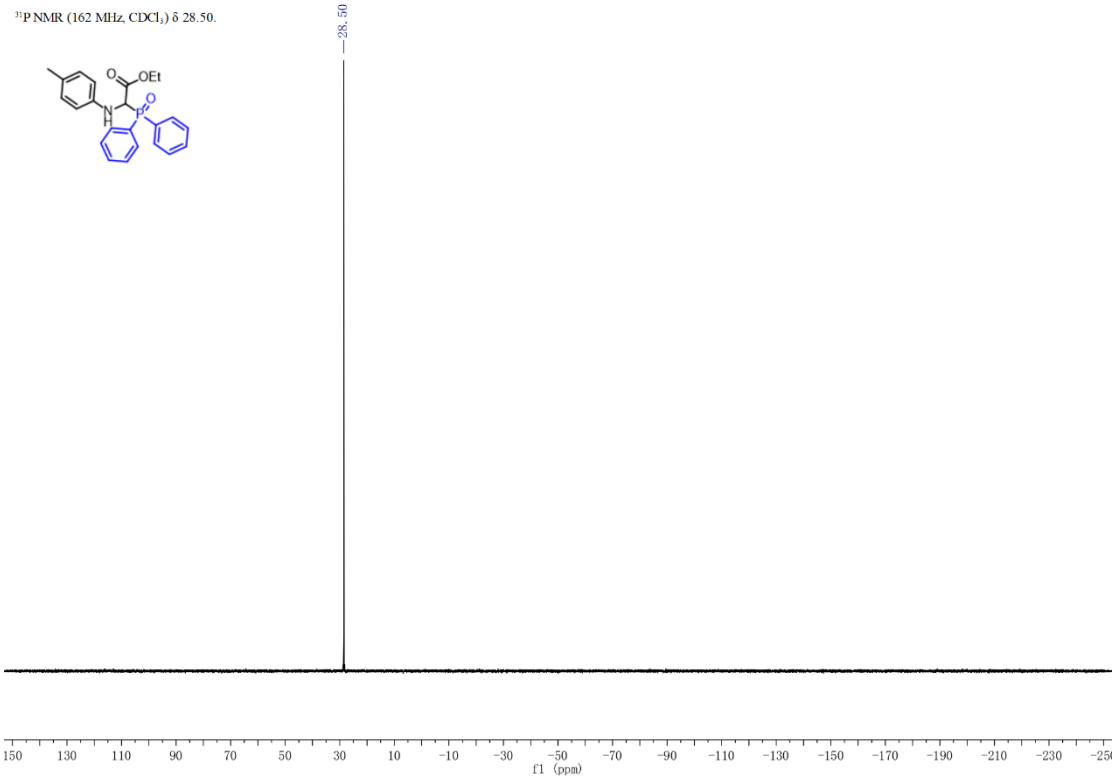
1. J. Xie and Z. Z. Huang, *Angew. Chem. Int. Ed.*, **2010**, *49*, 10181-10185.
2. R. Rohlmann, T. Stopka, H. Richter and O. García Mancheño, *J. Org. Chem*., **2013**, **78**, 6050-6064.
3. S. Yang, H. Hu, J.-H. Li and M. Chen, *ACS Catal.*, **2023**, *13*, 15652-15662.
4. Y. Gao, J. Liu, C. Wei, Y. Li, K. Zhang, L. Song and L. Cai, *Nat Commun.*, **2022**, *13*, 7450.
5. C. Wang, M. Guo, R. Qi, Q. Shang, Q. Liu, S. Wang, L. Zhao, R. Wang and Z. Xu, *Angew. Chem. Int. Ed.*, **2018**, *57*, 15841-15846.
6. C.-K. Li, Z.-K. Tao, A. Shoberu, W. Zhang and J.-P. Zou, *Org. Lett.*, **2022**, *24*, 6083-6087.
7. L. P. Miller, J. A. Vogel, S. Harel, J. M. Krussman and P. R. Melvin, *Org. Lett.*, **2023**, *25*, 1834-1838.
8. R. Wang, J. Wang, Y. Zhang, B. Wang, Y. Xia, F. Xue, W. Jin and C. Liu, *Adv. Synth. Catal*, **2023**, *365*, 900-905.

9. NMR Spectra

Ethyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (3aa)

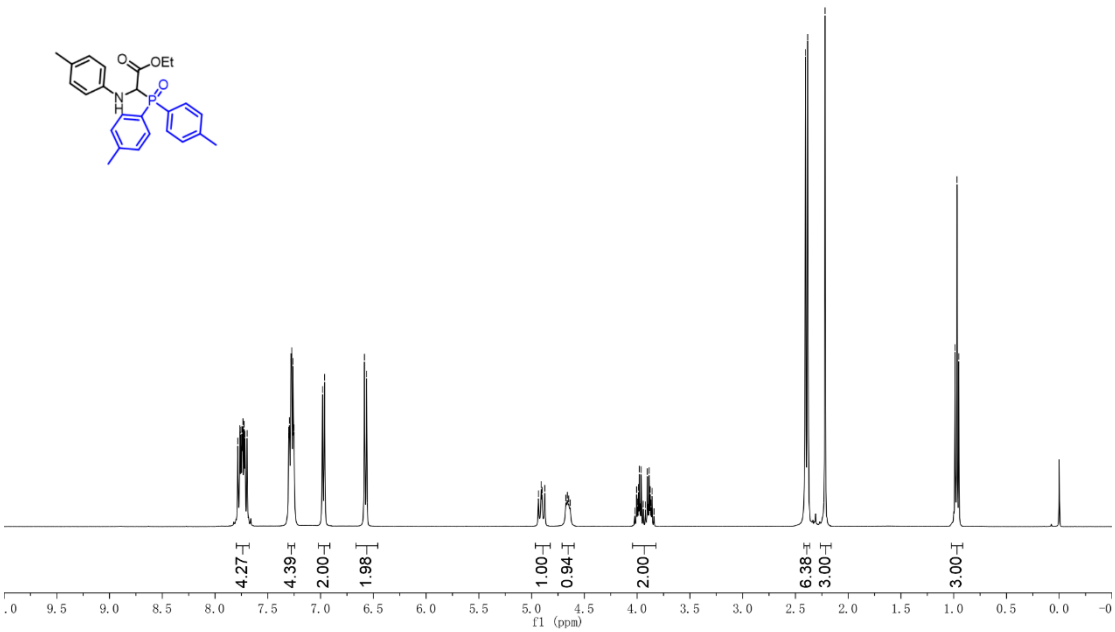


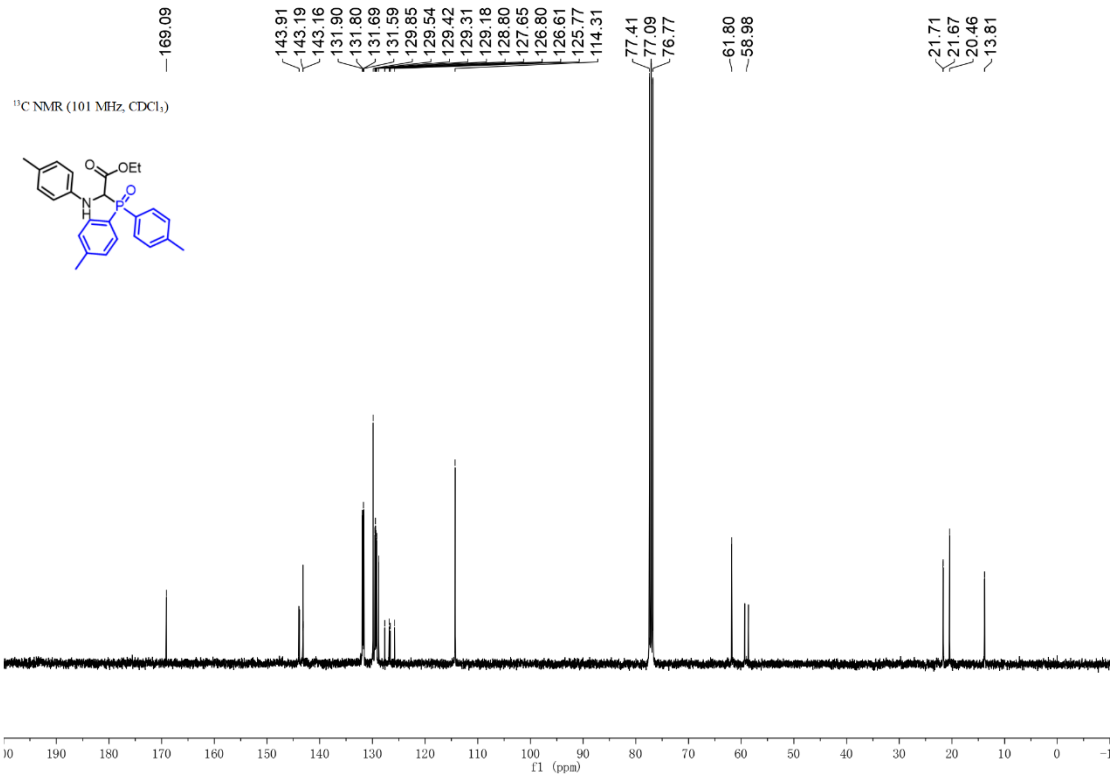
^{31}P NMR (162 MHz, $CDCl_3$) δ 28.50.



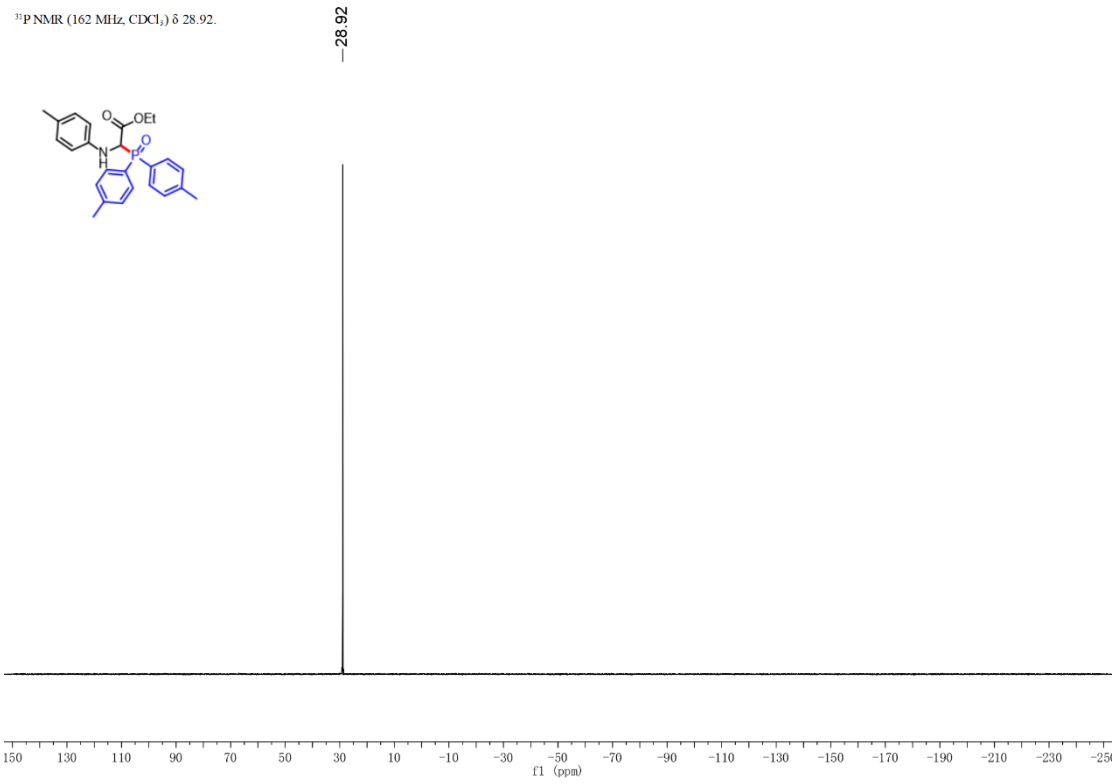
Ethyl 2-(di-*p*-tolylphosphoryl)-2-(*p*-tolylamino)acetate. (3ab)

^{1}H NMR (400 MHz, $CDCl_3$)



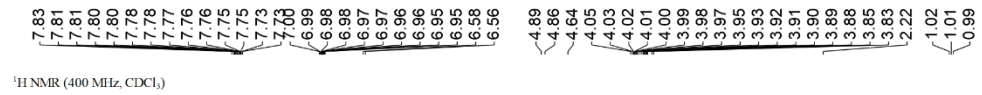


^{13}C NMR (101 MHz, $CDCl_3$)

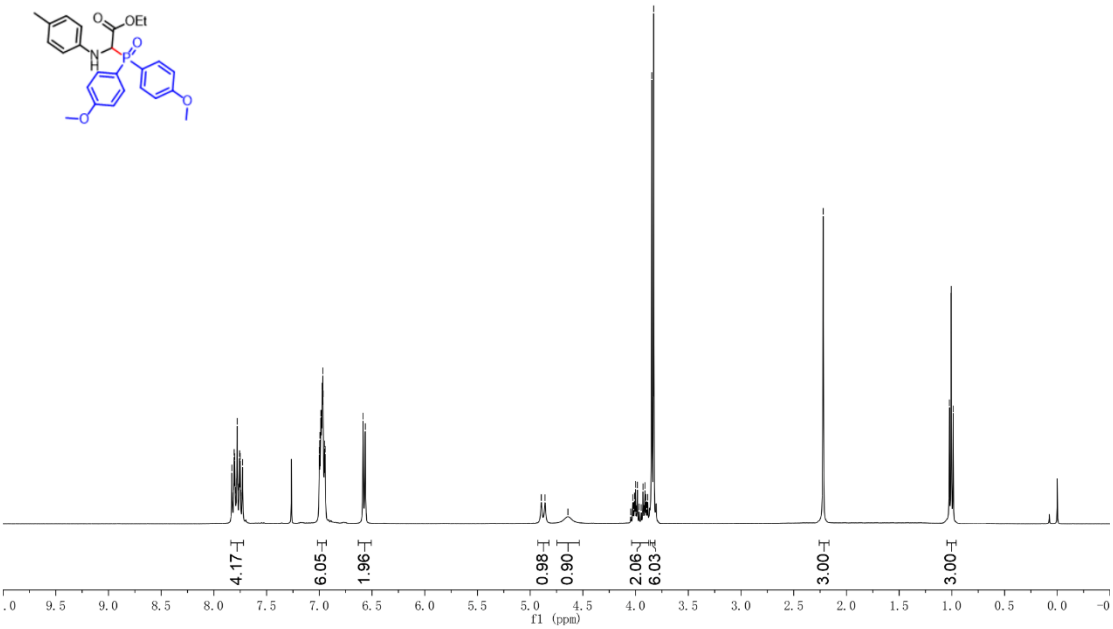


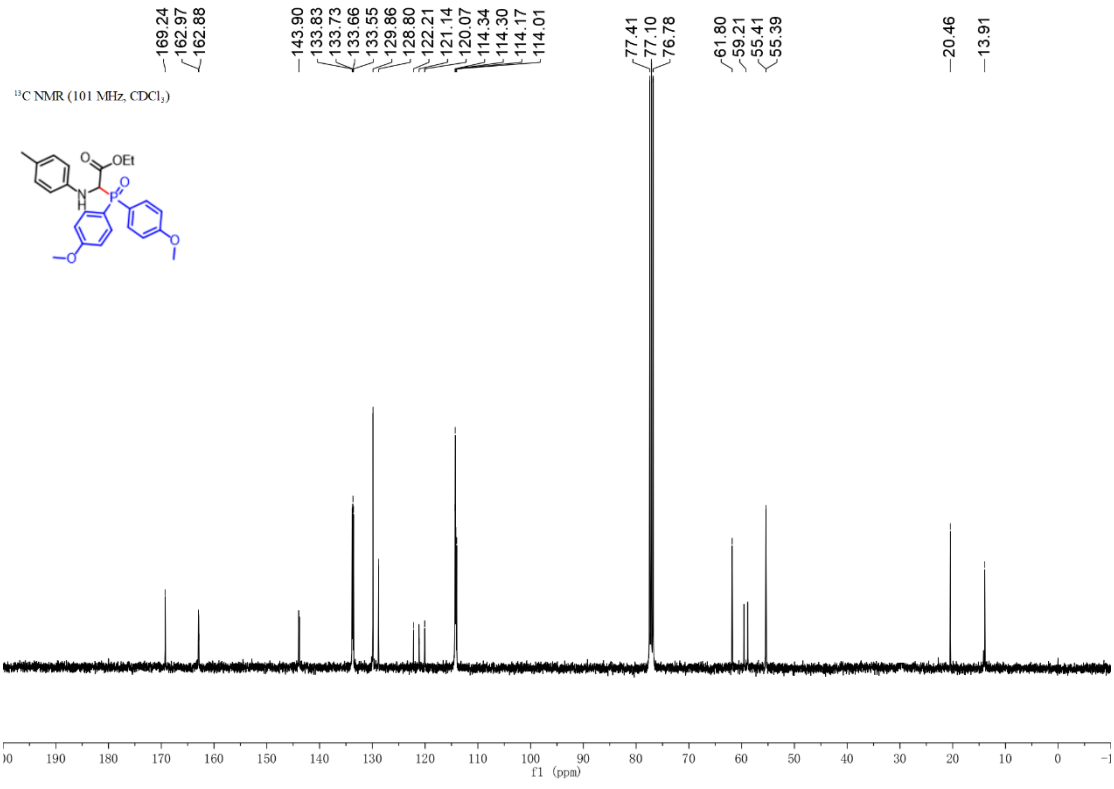
^{31}P NMR (162 MHz, $CDCl_3$) δ 28.92.

Ethyl 2-(bis(4-methoxyphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ac)

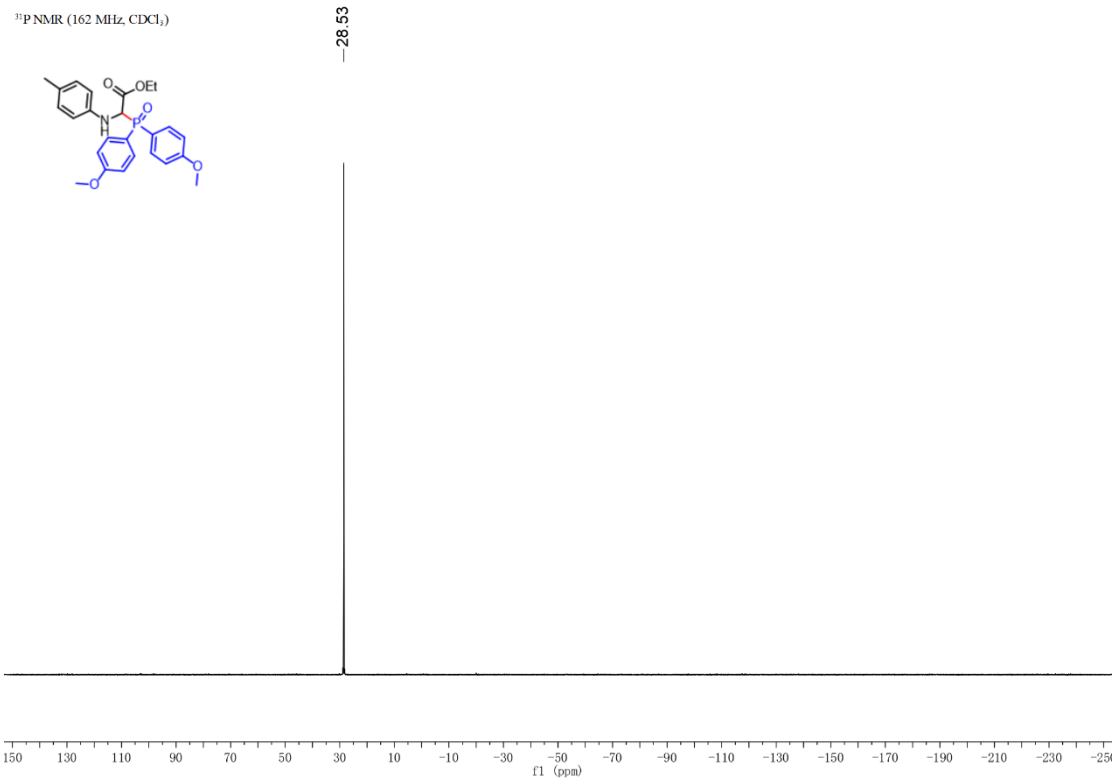


^{1}H NMR (400 MHz, $CDCl_3$)

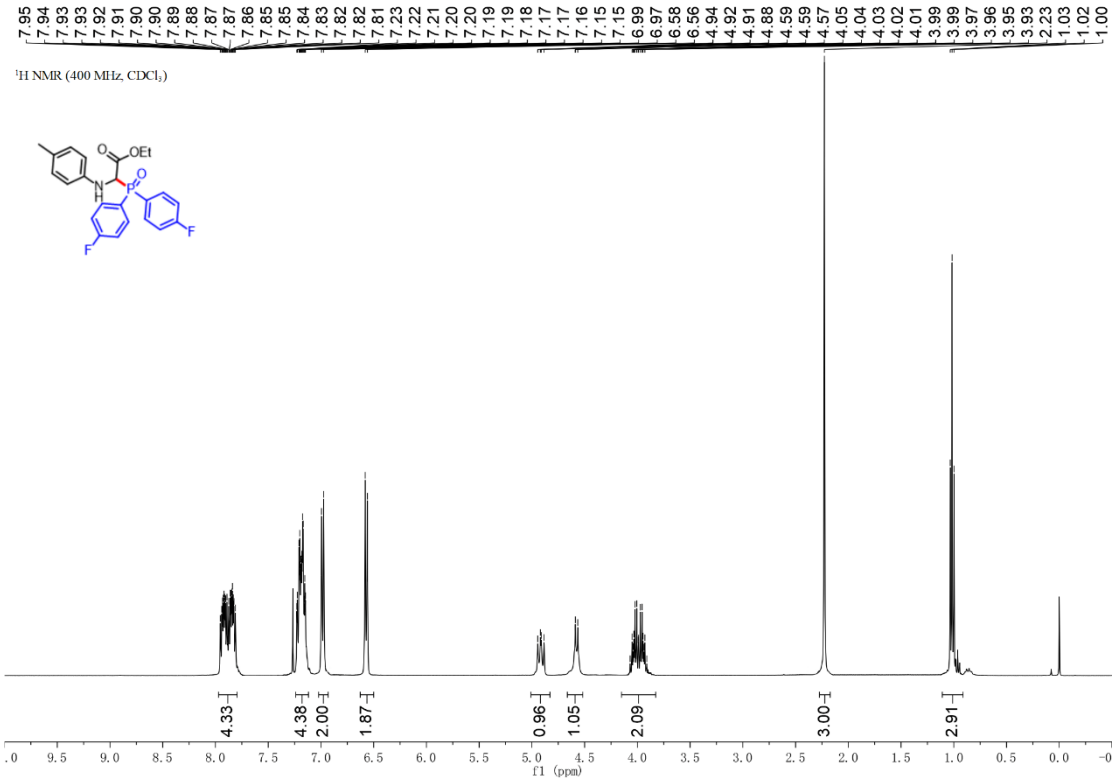


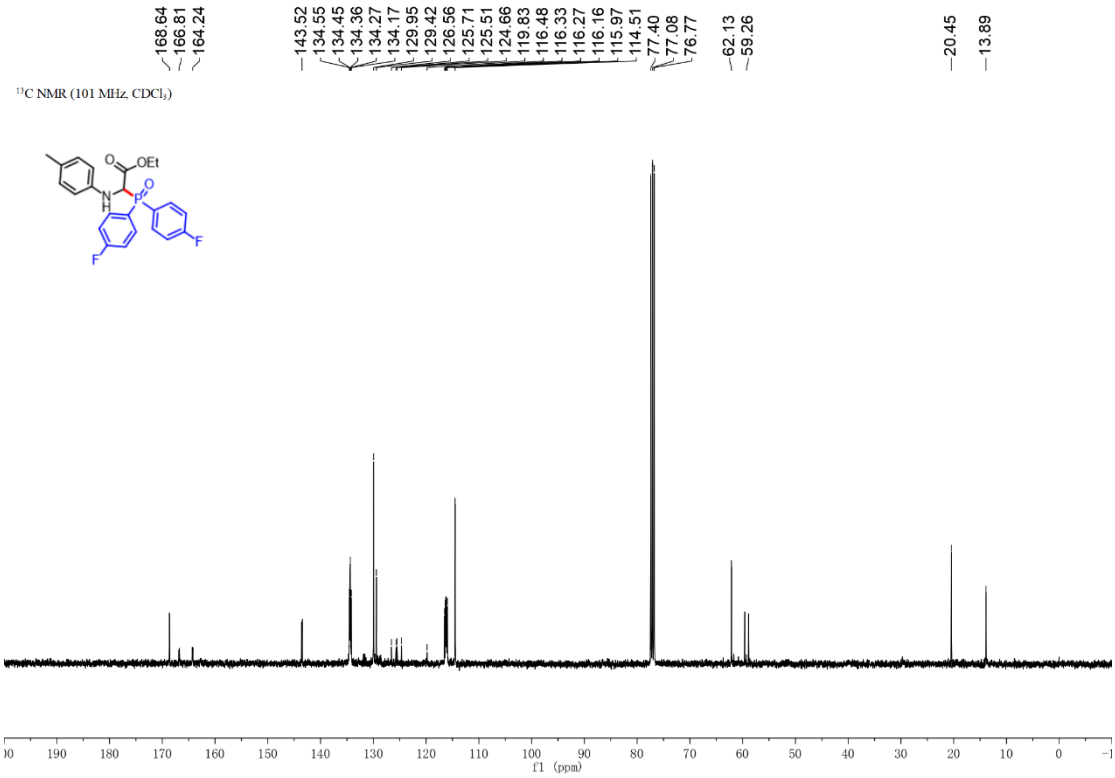


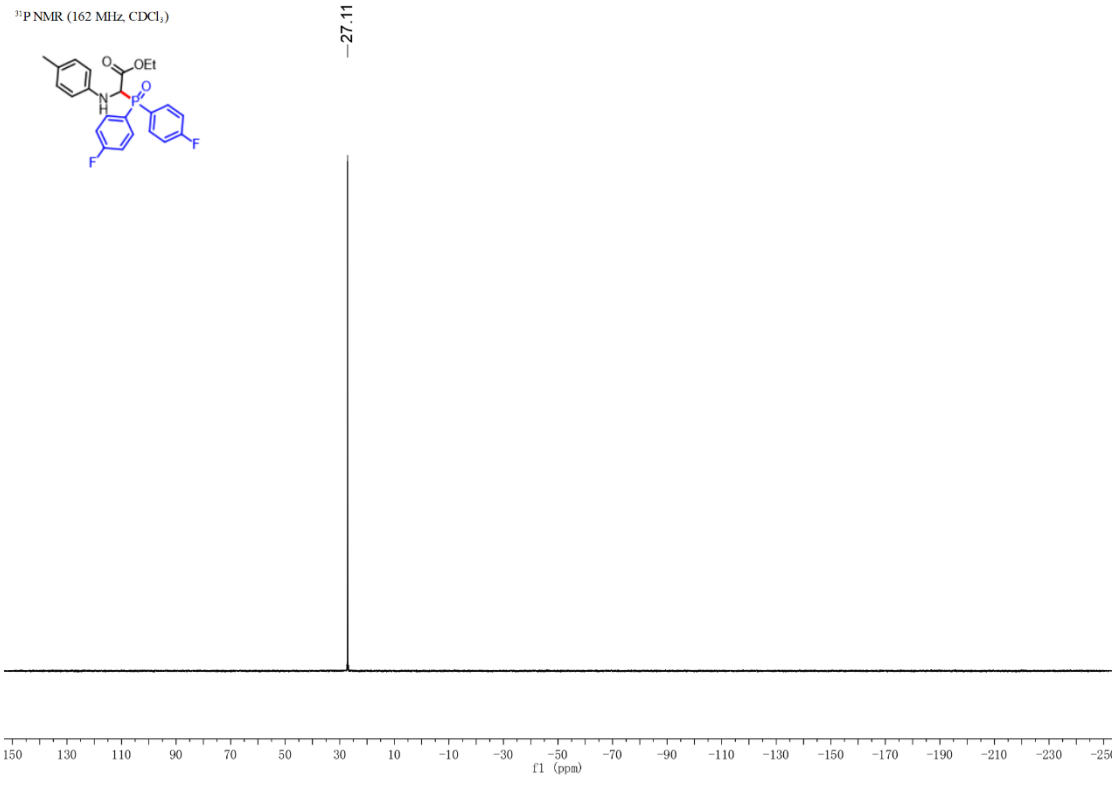
^{13}C NMR (101 MHz, $CDCl_3$)



Ethyl 2-(bis(4-fluorophenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ad)



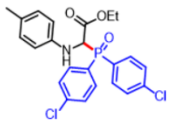

168.64
166.81
164.24
143.52
134.55
134.45
134.36
134.27
134.17
129.95
129.42
126.56
125.71
125.51
124.66
119.83
116.48
116.33
116.27
116.16
115.97
114.51
77.40
77.08
76.77
62.13
59.26
20.45
13.89
^{13}C NMR (101 MHz, $CDCl_3$)
OEt
O
P
O
N
H
F
F
f1 (ppm)

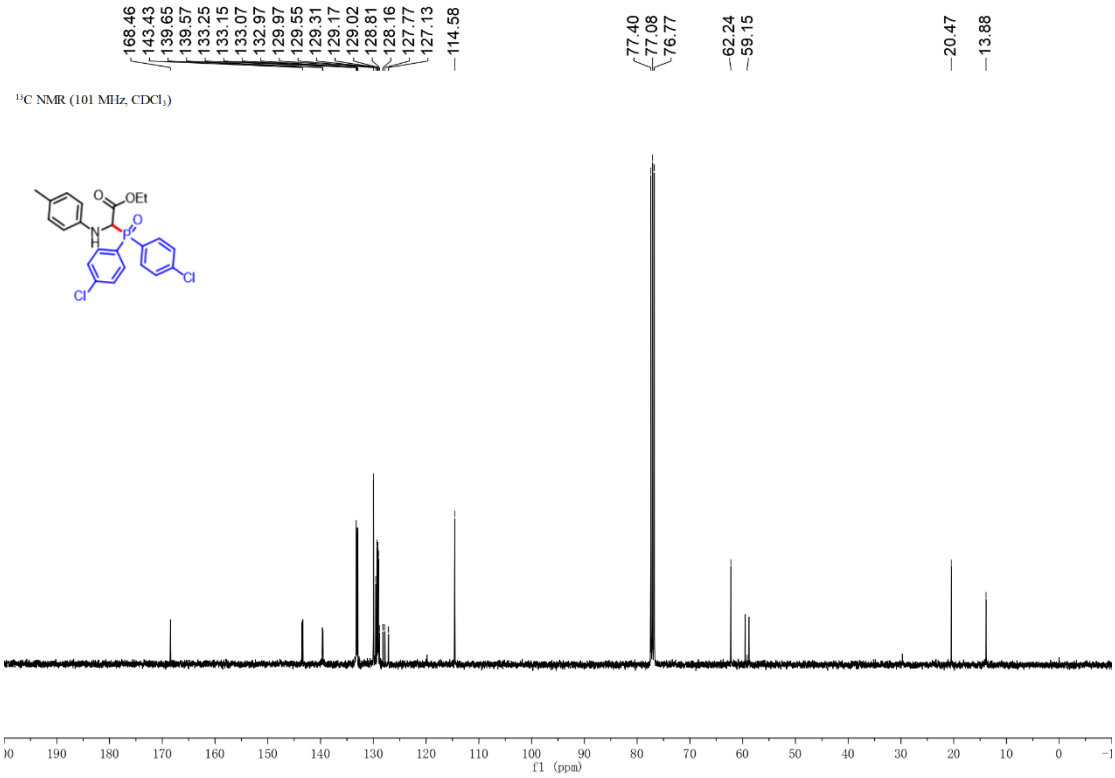

^{31}P NMR (162 MHz, $CDCl_3$)
27.11
OEt
O
P
O
N
H
F
F
f1 (ppm)

^{19}F NMR (376 MHz, $CDCl_3$)

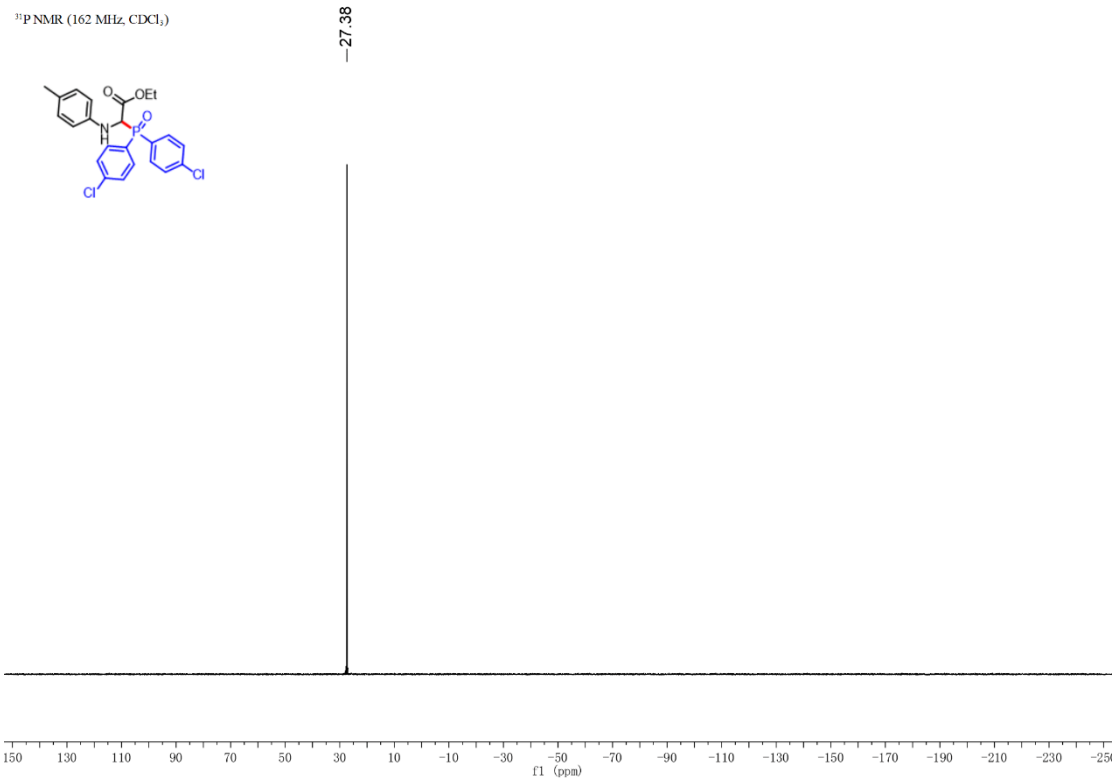
Ethyl 2-(bis(4-chlorophenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ae)

^{1}H NMR (400 MHz, $CDCl_3$)



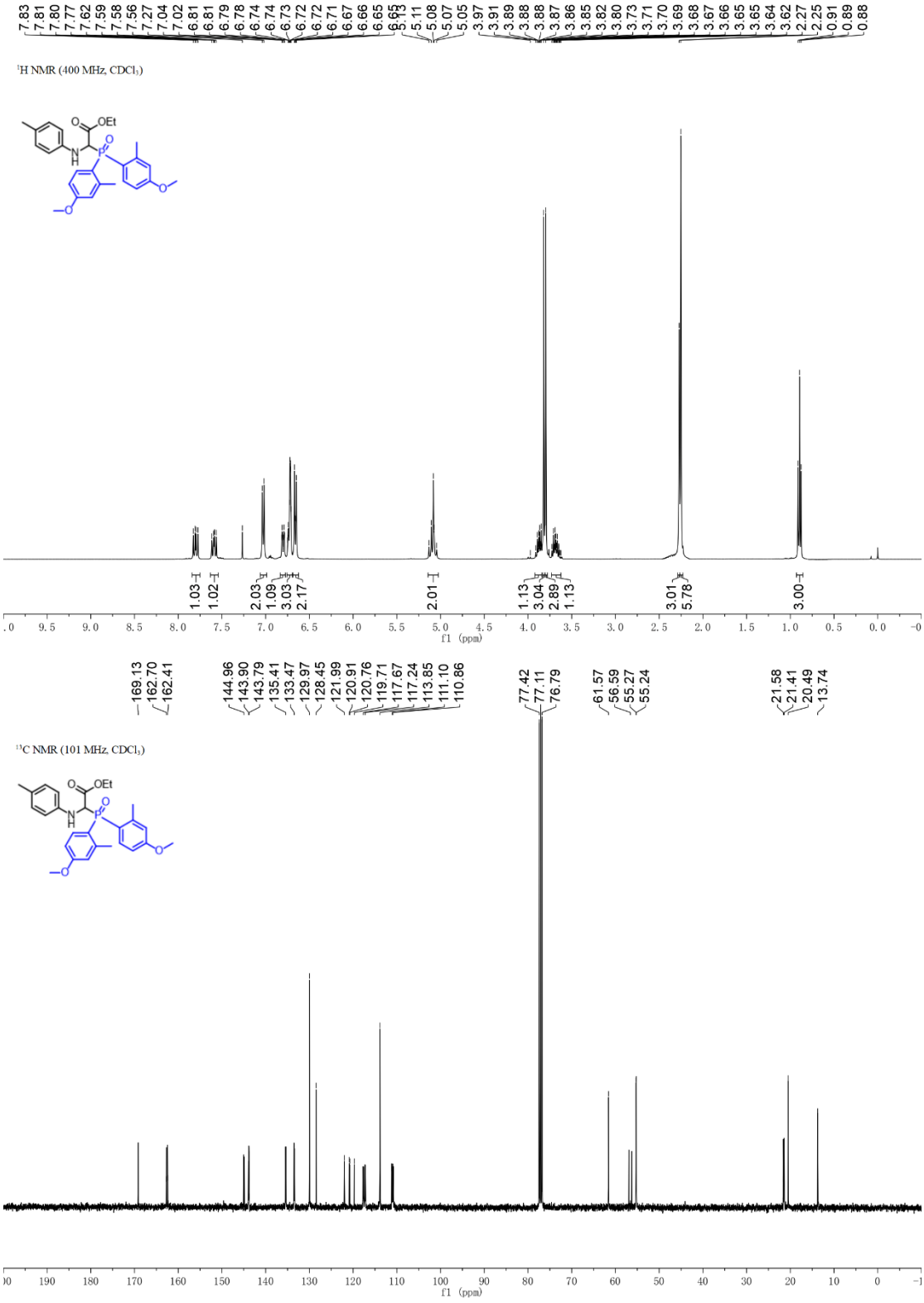


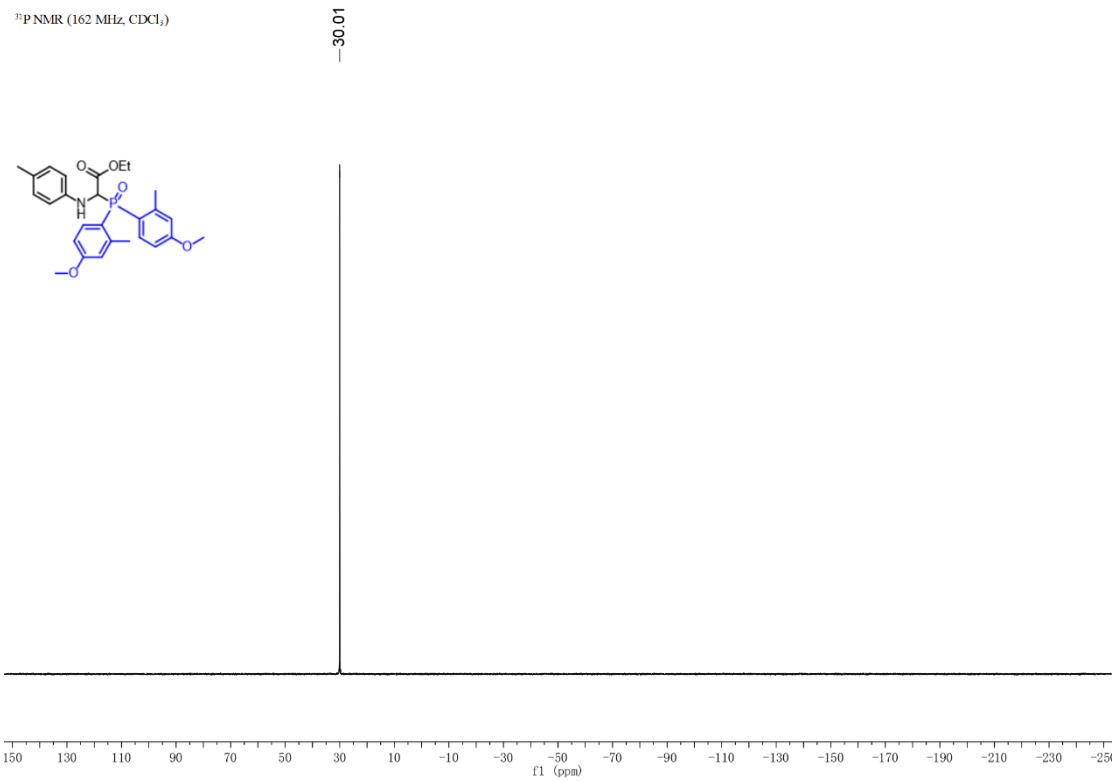
^{13}C NMR (101 MHz, $CDCl_3$)



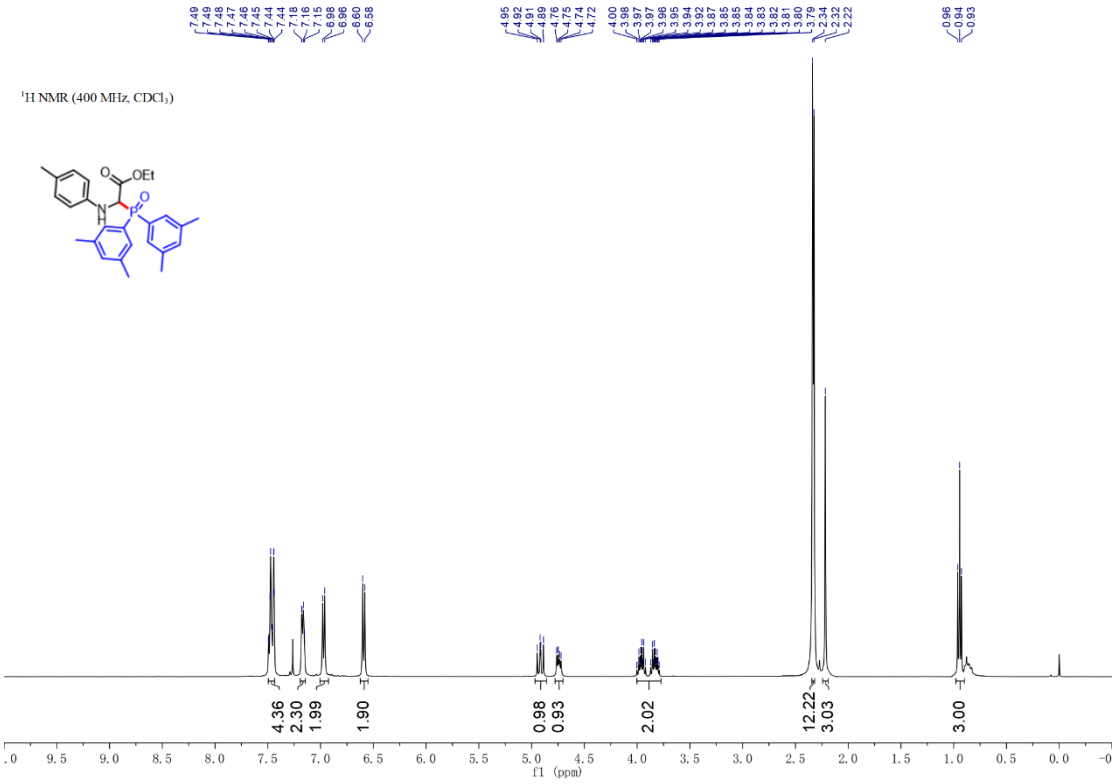
^{31}P NMR (162 MHz, $CDCl_3$)

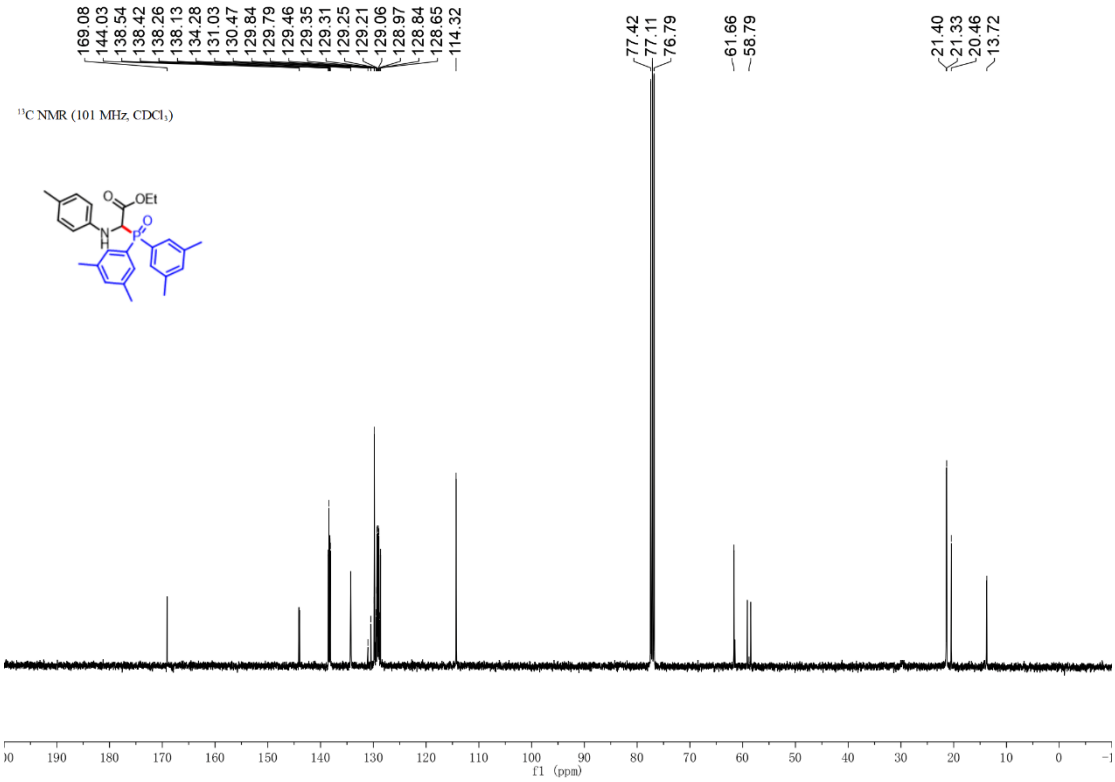
Ethyl 2-(bis(4-methoxy-2-methylphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3af)

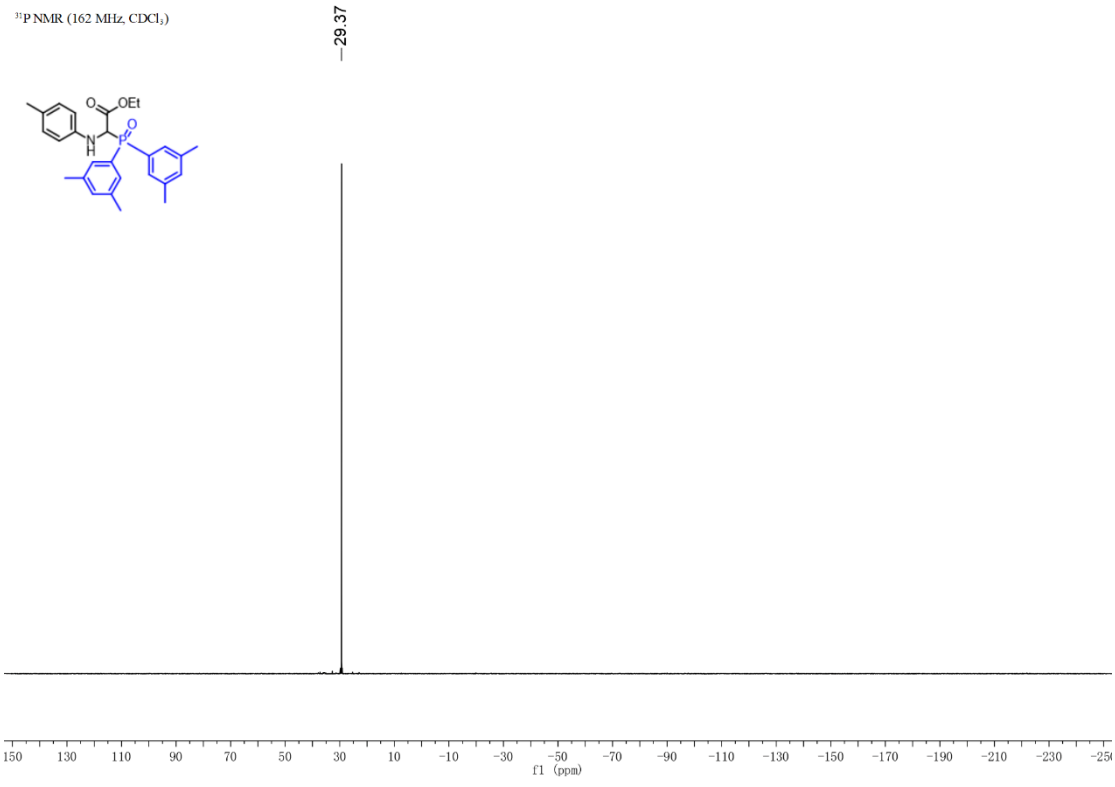




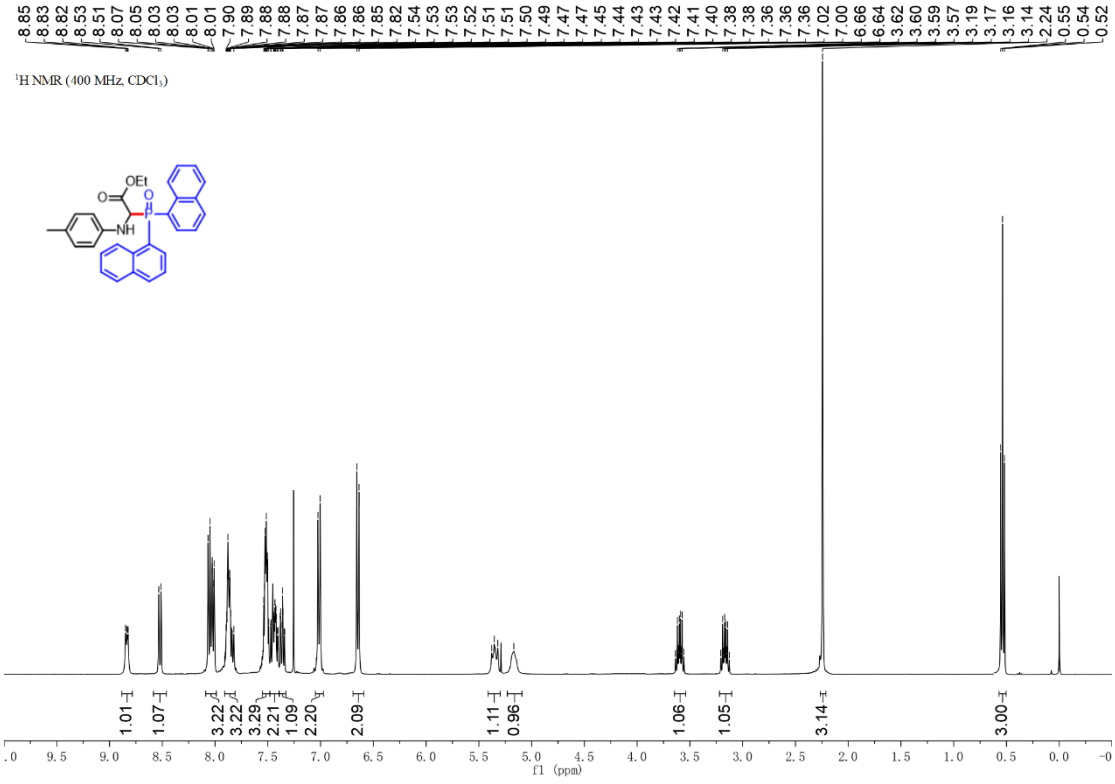
Ethyl 2-(bis(3,5-dimethylphenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ag)

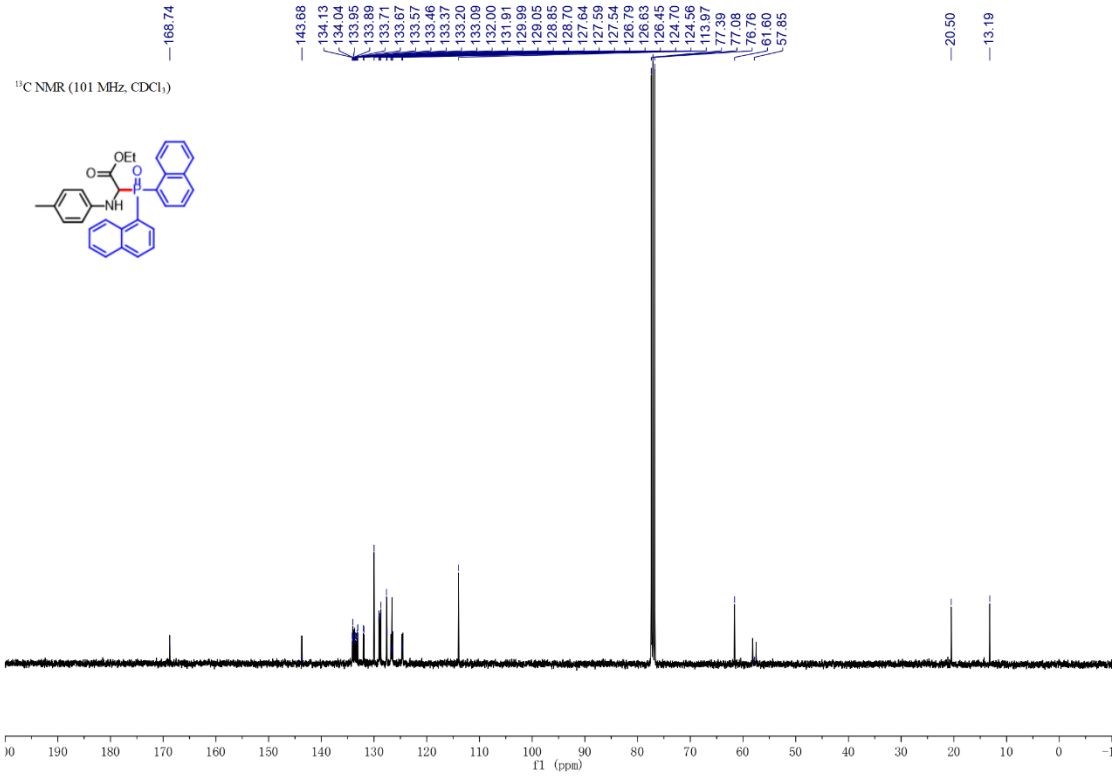


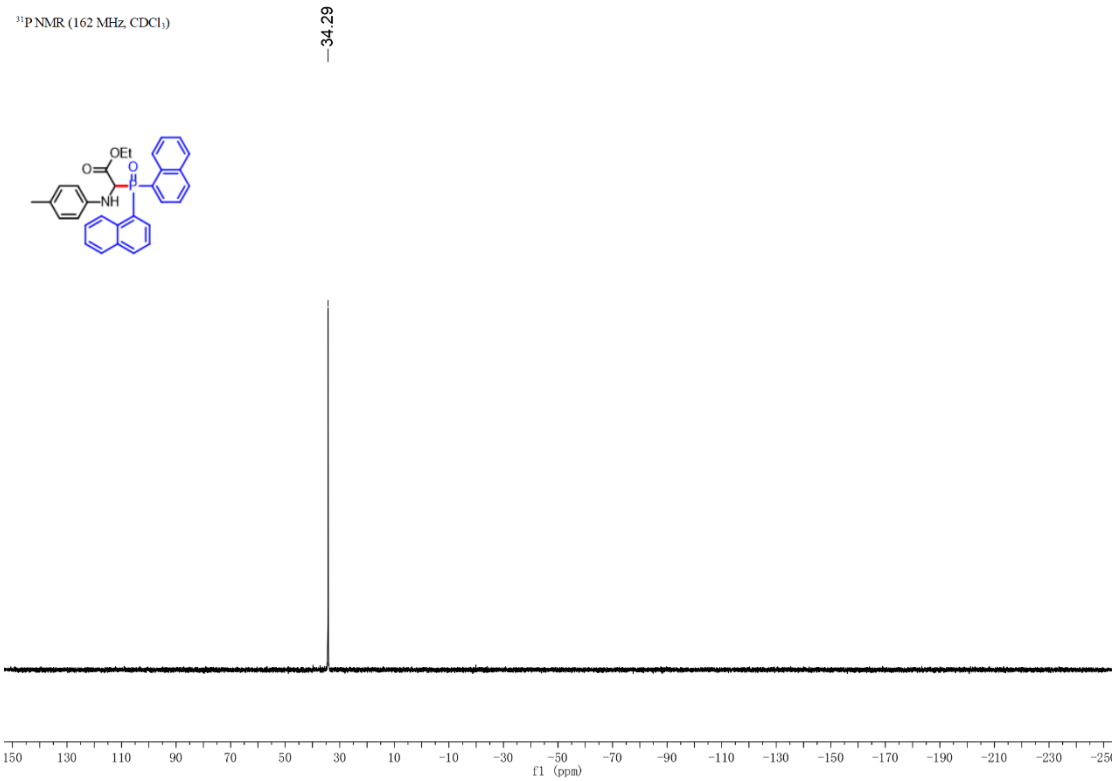

169.08
144.03
138.54
138.42
138.26
138.13
134.28
131.03
130.47
129.84
129.79
129.46
129.35
129.31
129.25
129.21
129.06
128.97
128.84
128.65
114.32
77.42
77.11
76.79
61.66
58.79
21.40
21.33
20.46
13.72
^{13}C NMR (101 MHz, CDCl$_3$)
OEt
O
N
H
P
f1 (ppm)


^{31}P NMR (162 MHz, CDCl$_3$)
29.37
OEt
O
N
H
P
f1 (ppm)

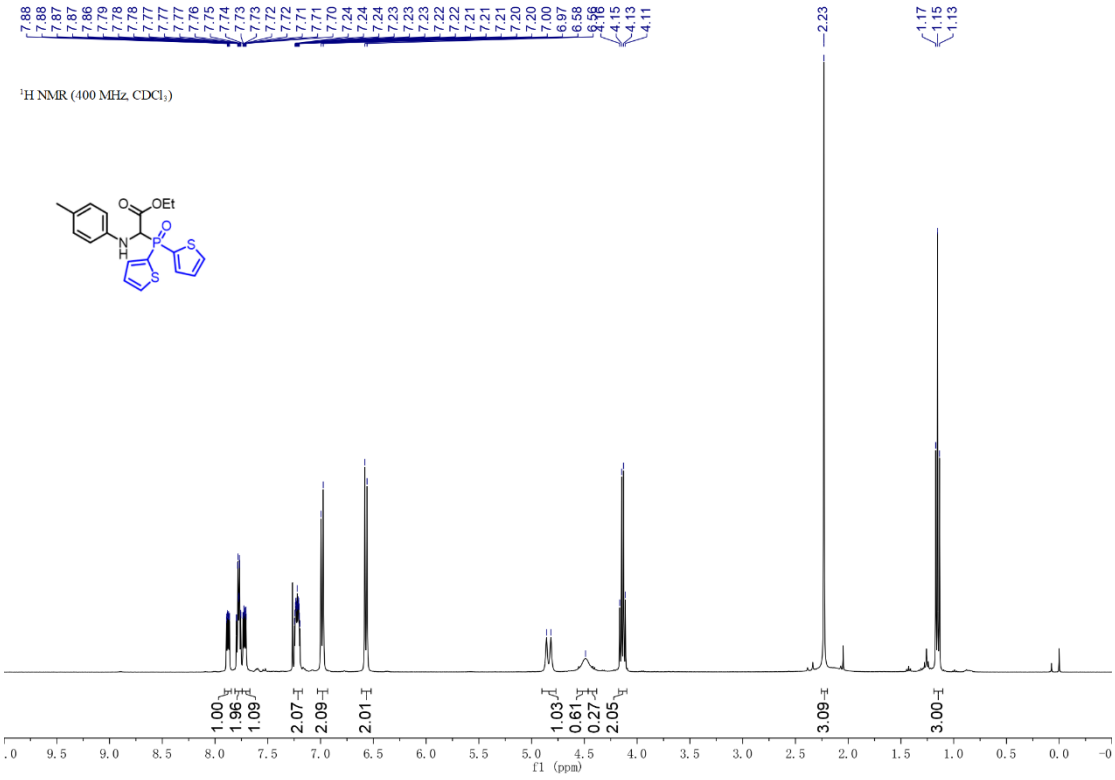
Ethyl 2-(di(naphthalen-1-yl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ah)

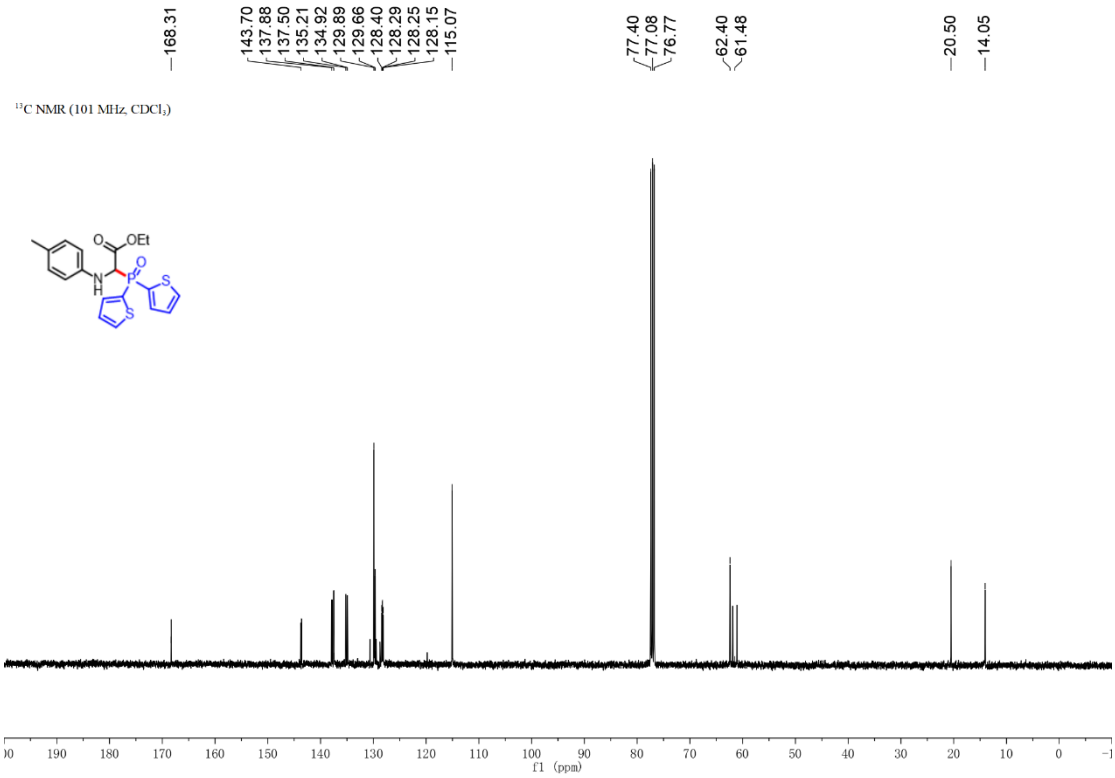


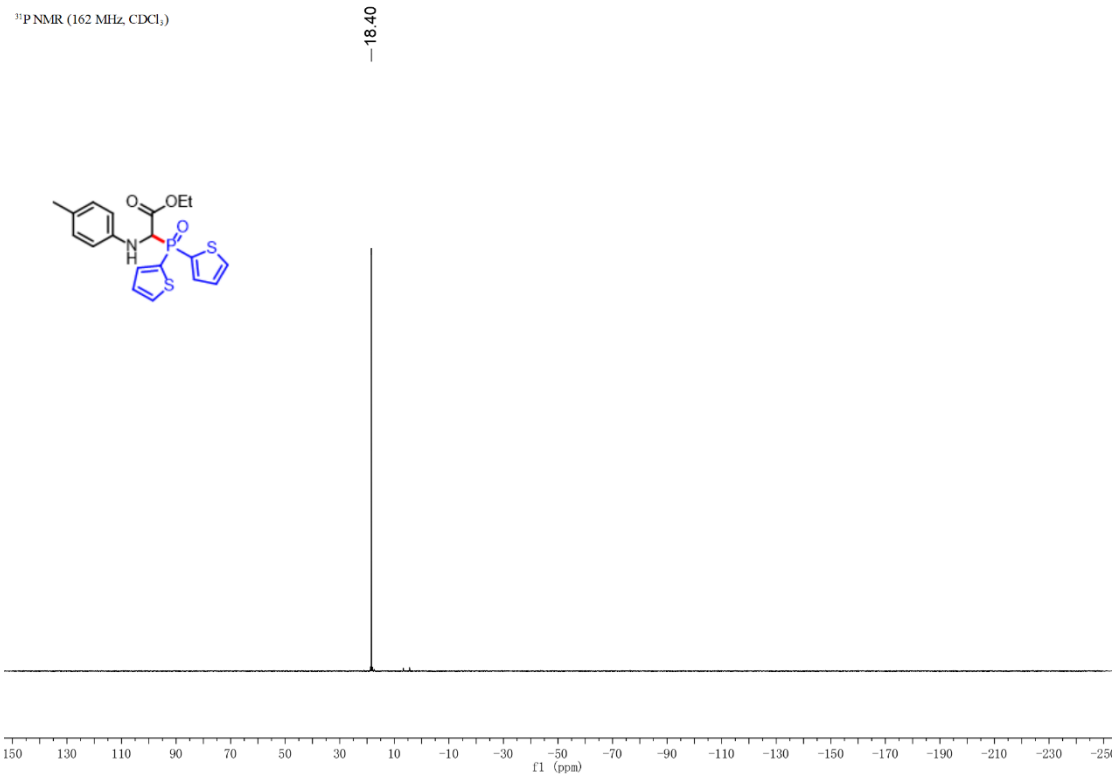




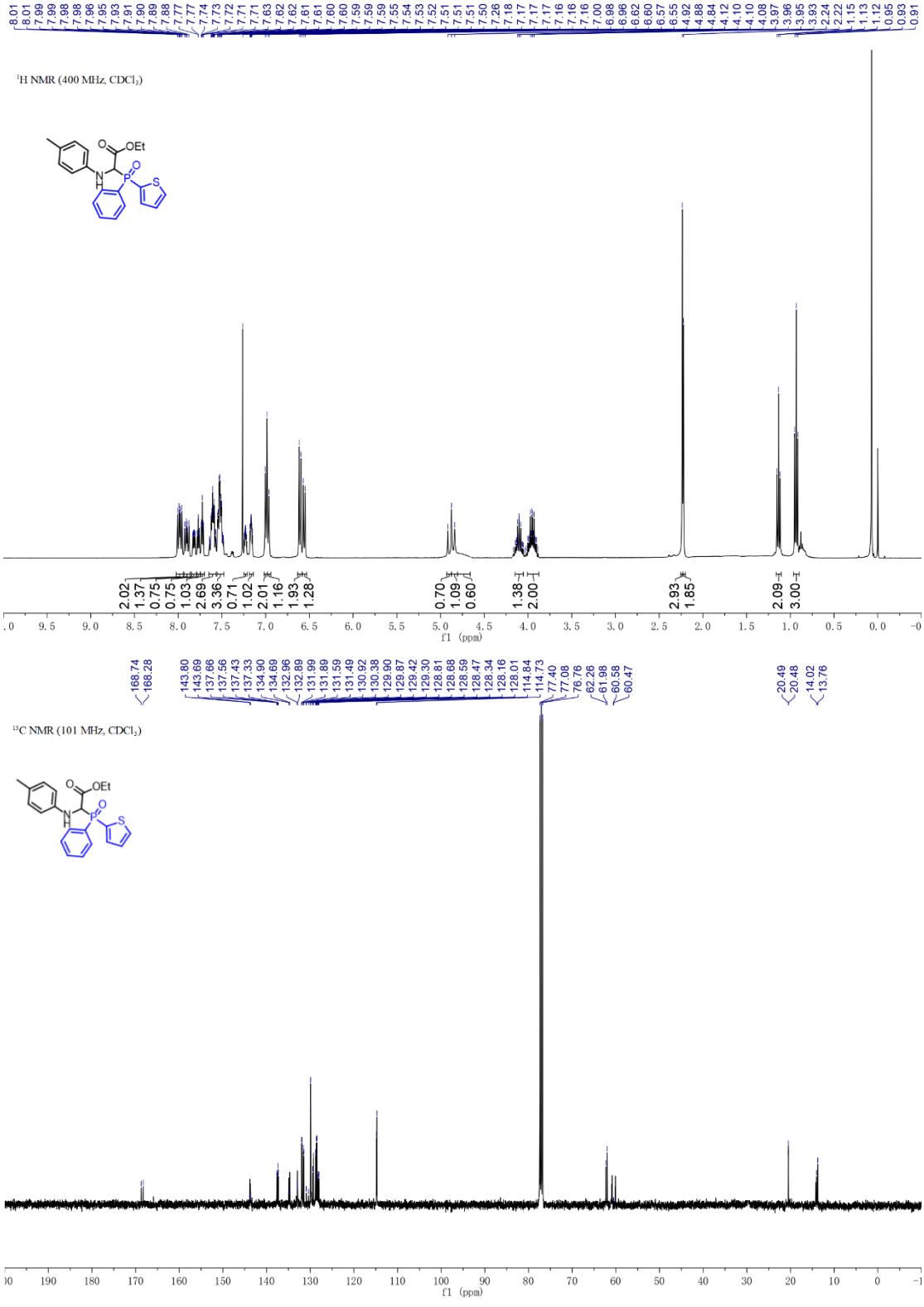
Ethyl 2-(di(thiophen-2-yl)phosphoryl)-2-(*p*-tolylamino)acetate. (3ai)

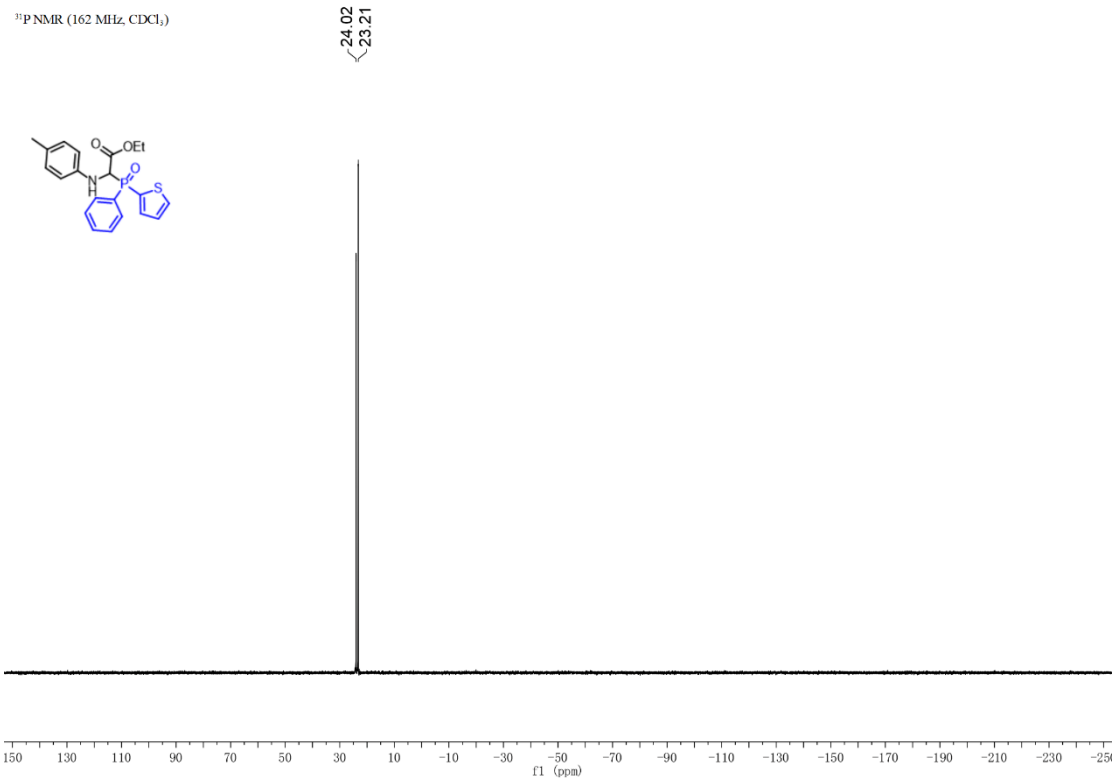



168.31
143.70
137.88
137.50
135.21
134.92
129.89
129.66
128.40
128.29
128.25
128.15
115.07
77.40
77.08
76.77
62.40
61.48
20.50
14.05
13C NMR (101 MHz, CDCl3)
O
OEt
N
H
P
O
S
S
f1 (ppm)

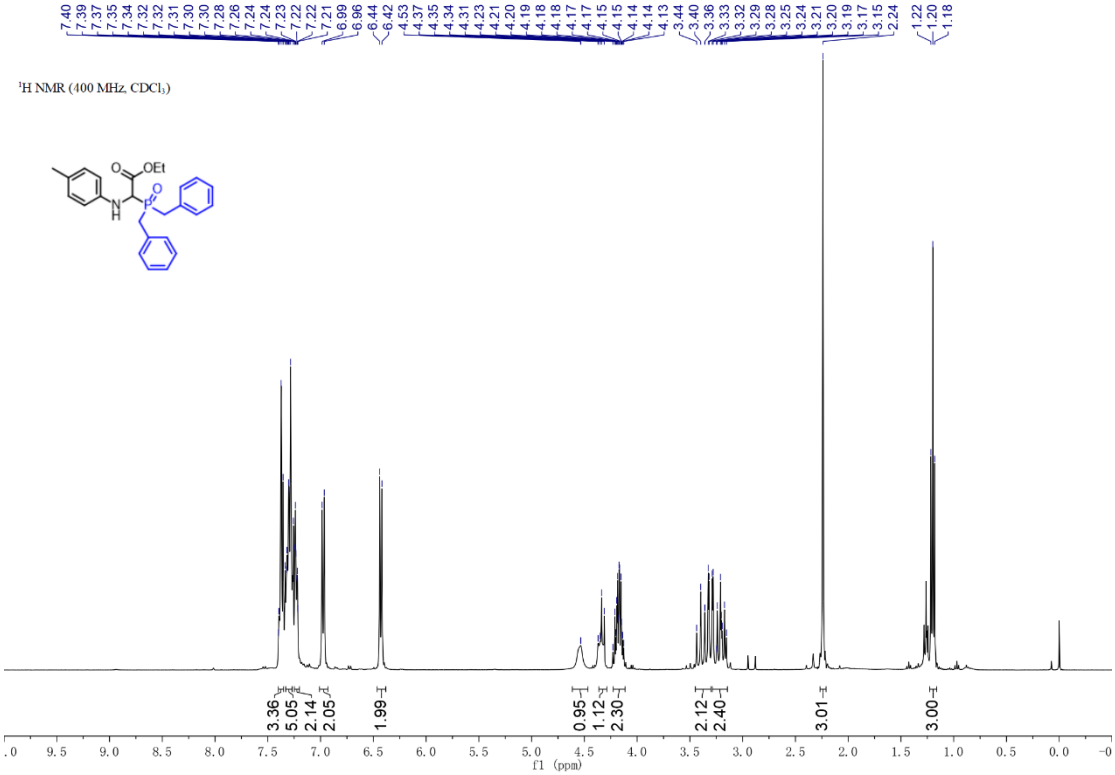

18.40
31P NMR (162 MHz, CDCl3)
O
OEt
N
H
P
O
S
S
f1 (ppm)

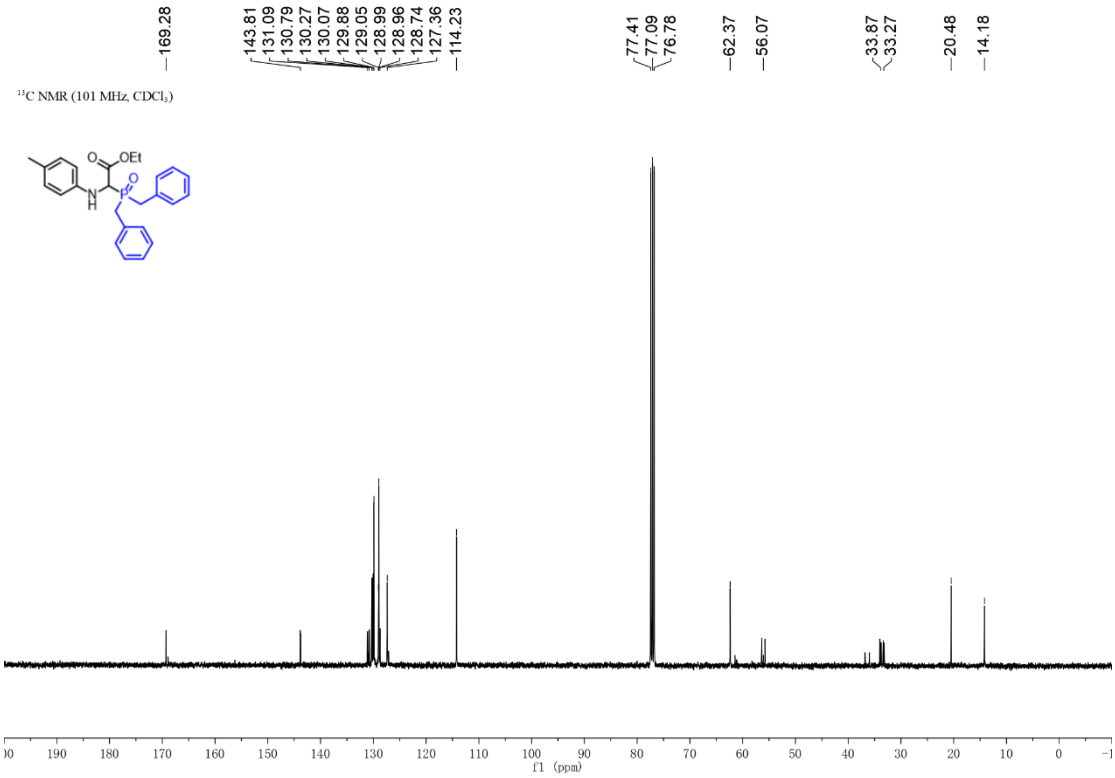
Ethyl 2-(phenyl(thiophen-2-yl)phosphoryl)-2-(*p*-tolylamino)acetate. (3aj)

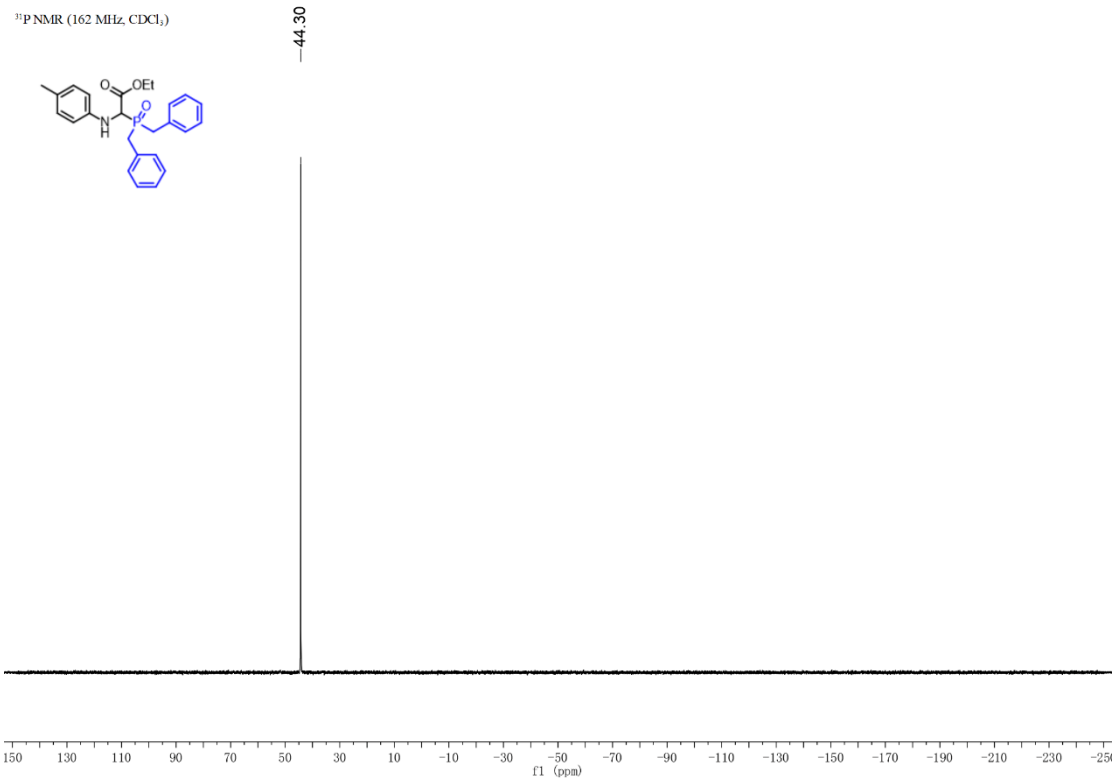




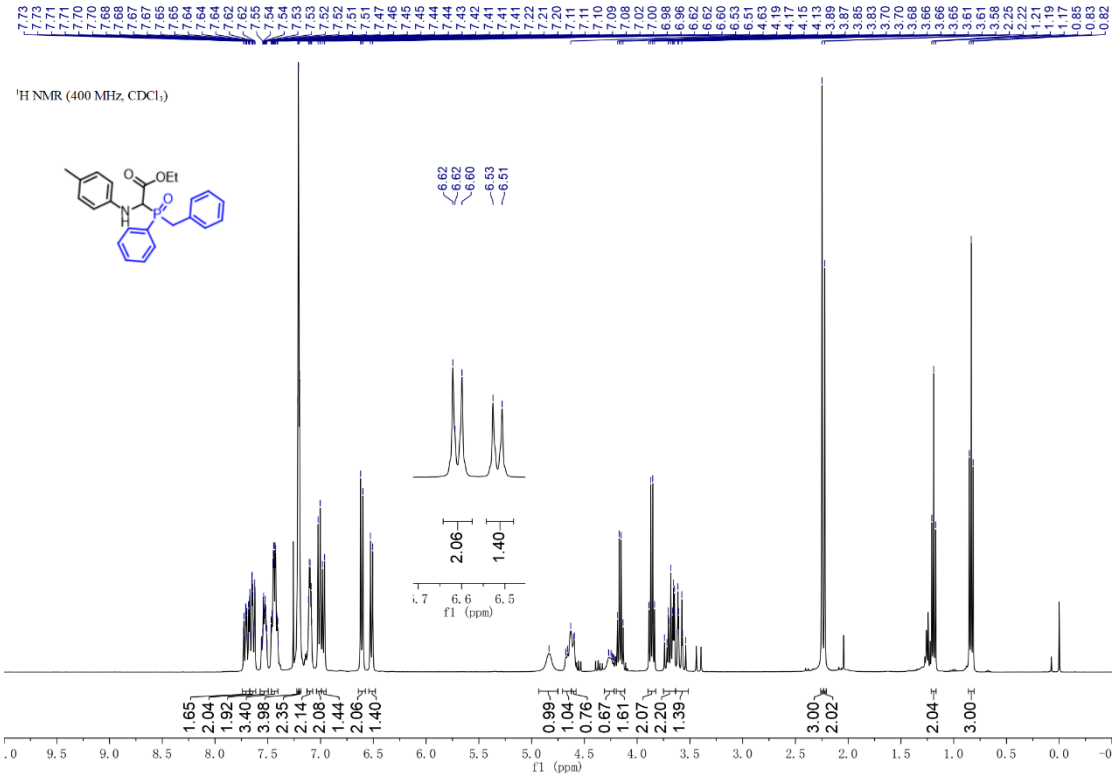
Ethyl 2-(dibenzylphosphoryl)-2-(*p*-tolylamino)acetate. (3ak)

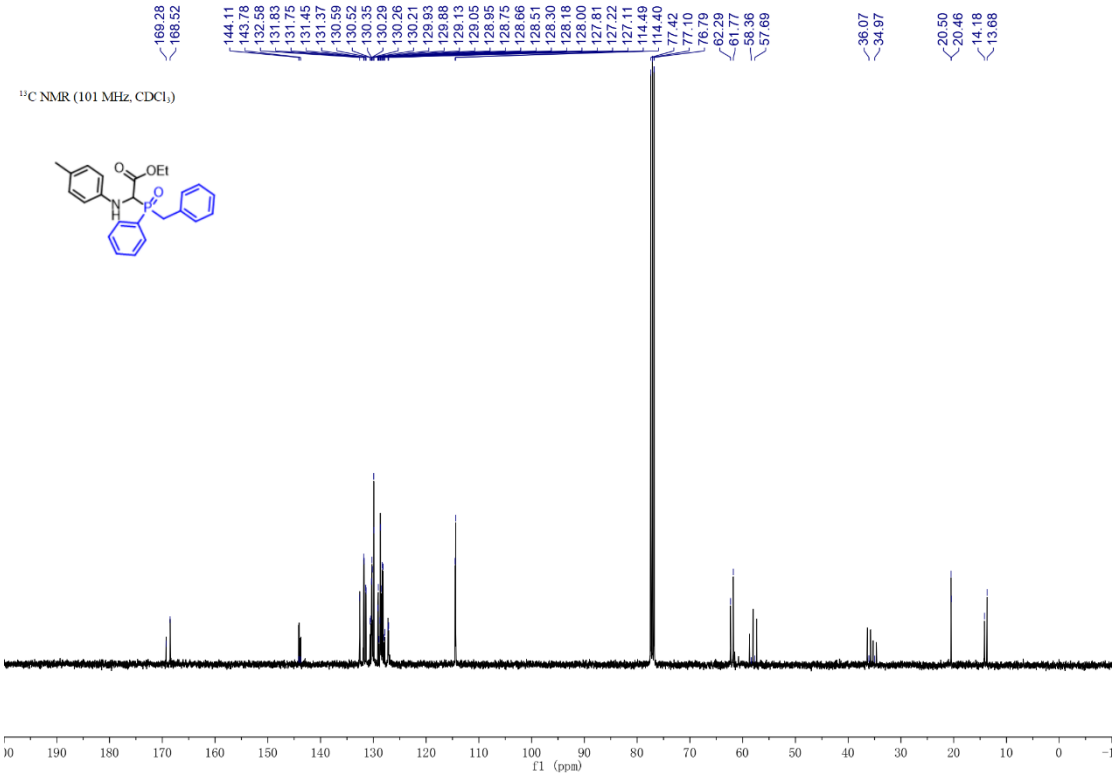


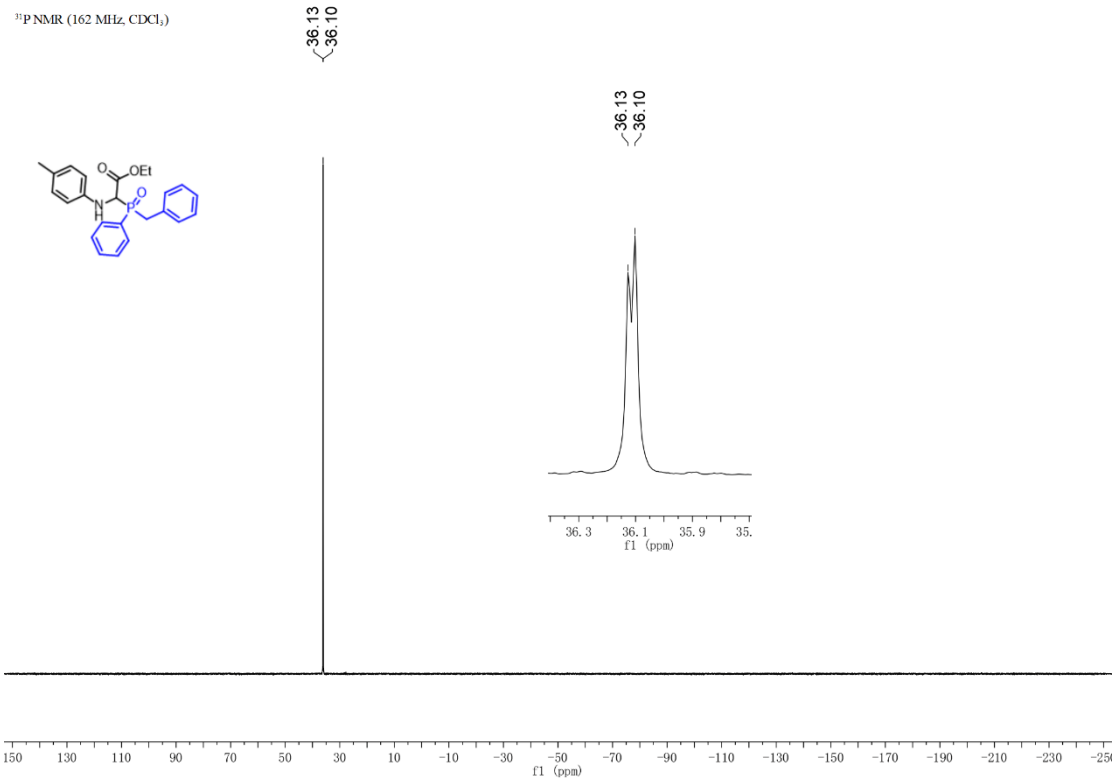

169.28
143.81
131.09
130.79
130.27
130.07
129.88
129.05
128.99
128.96
128.74
127.36
114.23
77.41
77.09
76.78
62.37
56.07
33.87
33.27
20.48
14.18
13C NMR (101 MHz, CDCl3)
OEt
f1 (ppm)


44.30
31P NMR (162 MHz, CDCl3)
OEt
f1 (ppm)

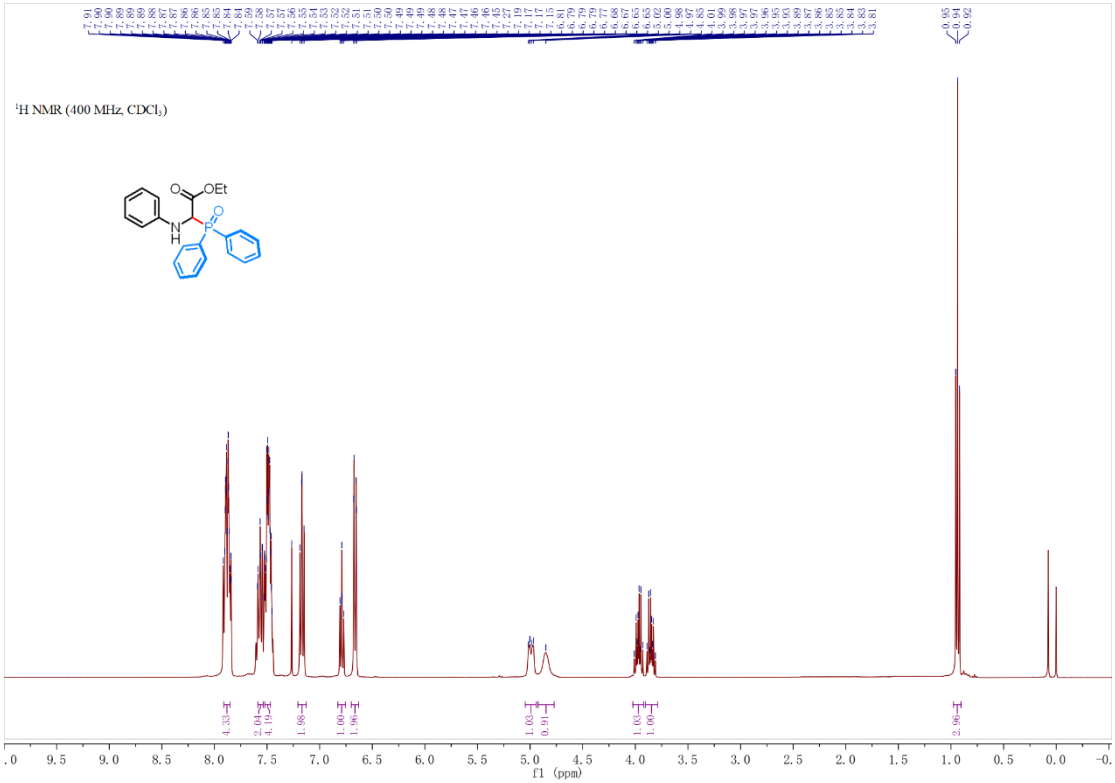
Ethyl 2-(benzyl(phenyl)phosphoryl)-2-(*p*-tolylamino)acetate. (3al)

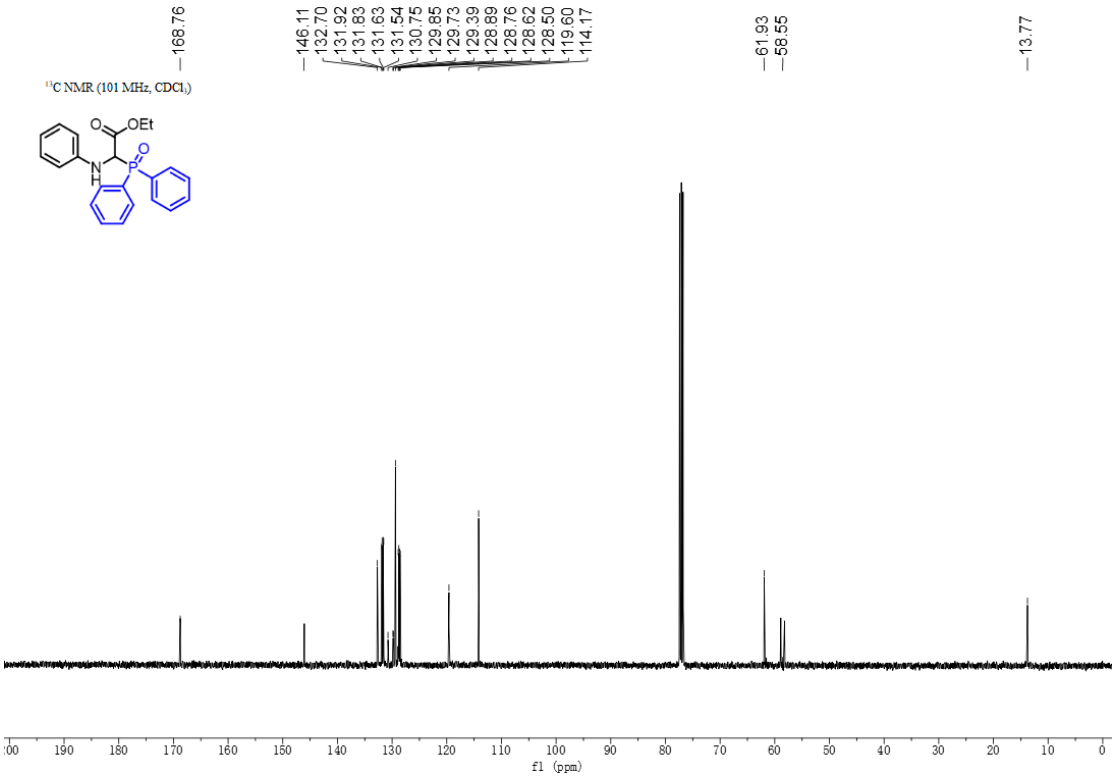


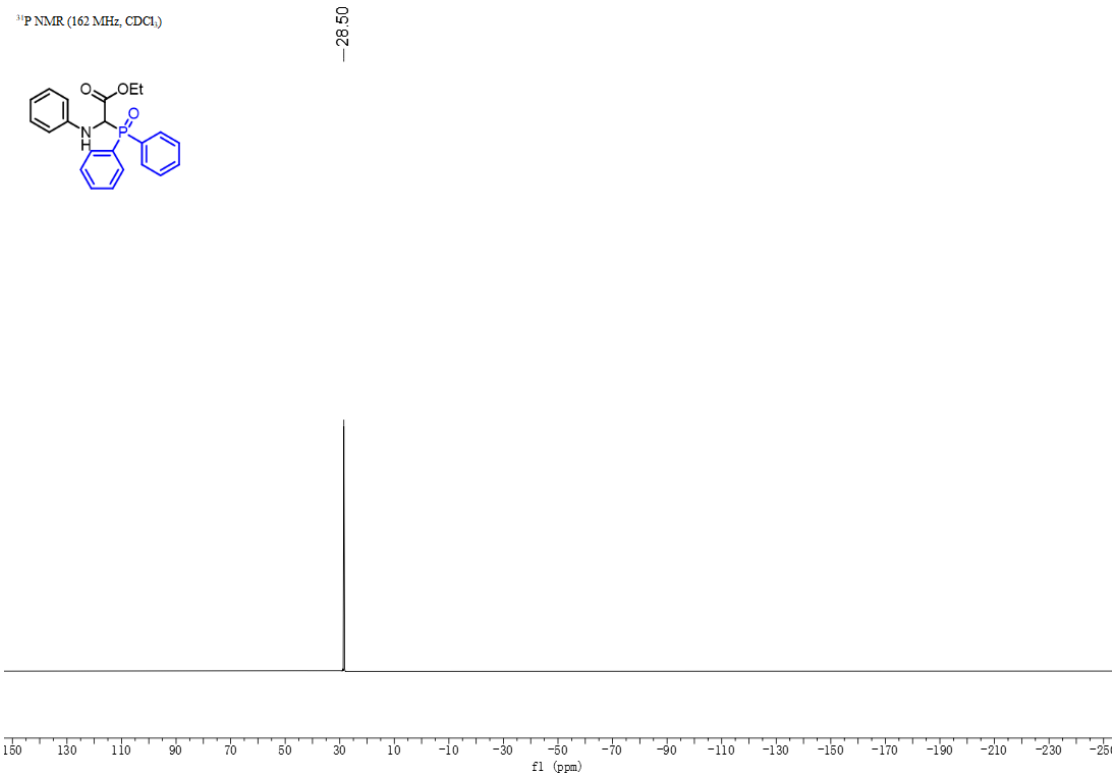




Ethyl 2-(diphenylphosphoryl)-2-(phenylamino)acetate. (3ba)

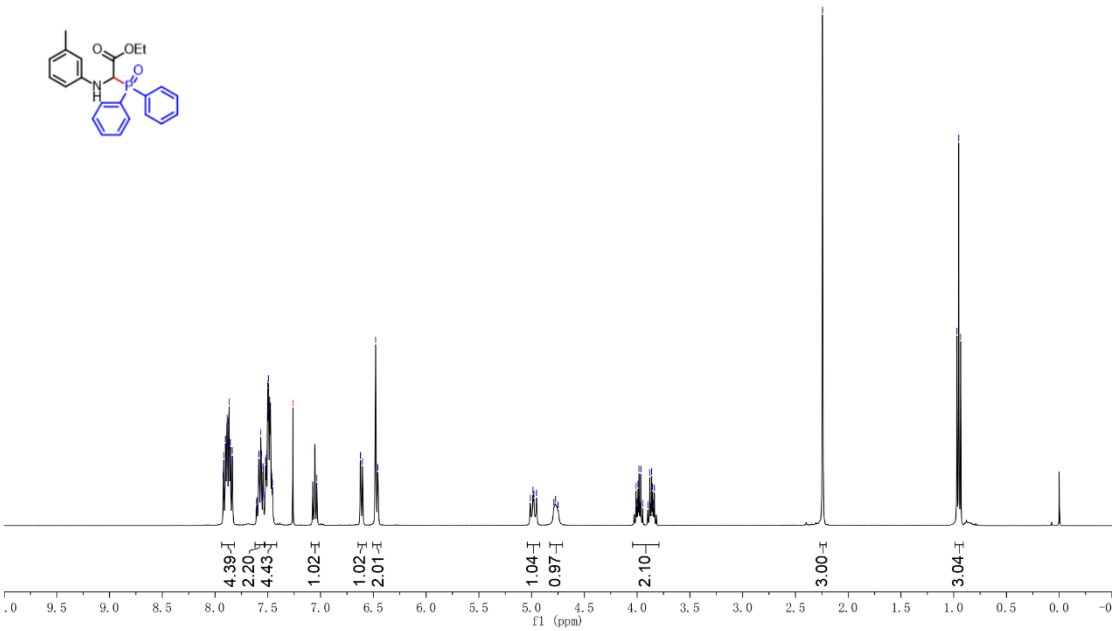


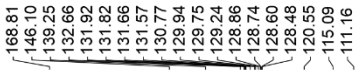

168.76
146.11
132.70
131.92
131.83
131.63
131.54
130.75
129.85
129.73
129.39
128.89
128.76
128.62
128.50
119.60
114.17
61.93
58.55
13.77
^{13}C NMR (101 MHz, CDCl$_3$)
OEt
O
N
H
P
O
f1 (ppm)


28.50
^{31}P NMR (162 MHz, CDCl$_3$)
OEt
O
N
H
P
O
f1 (ppm)

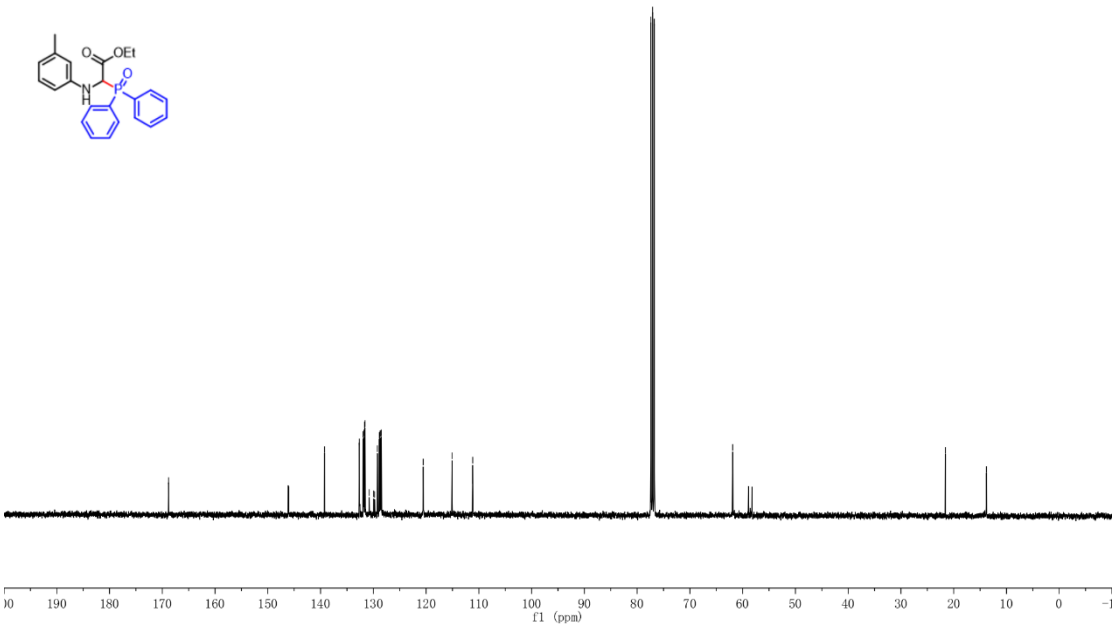
Ethyl 2-(diphenylphosphoryl)-2-(m-tolylamino)acetate. (3ca)

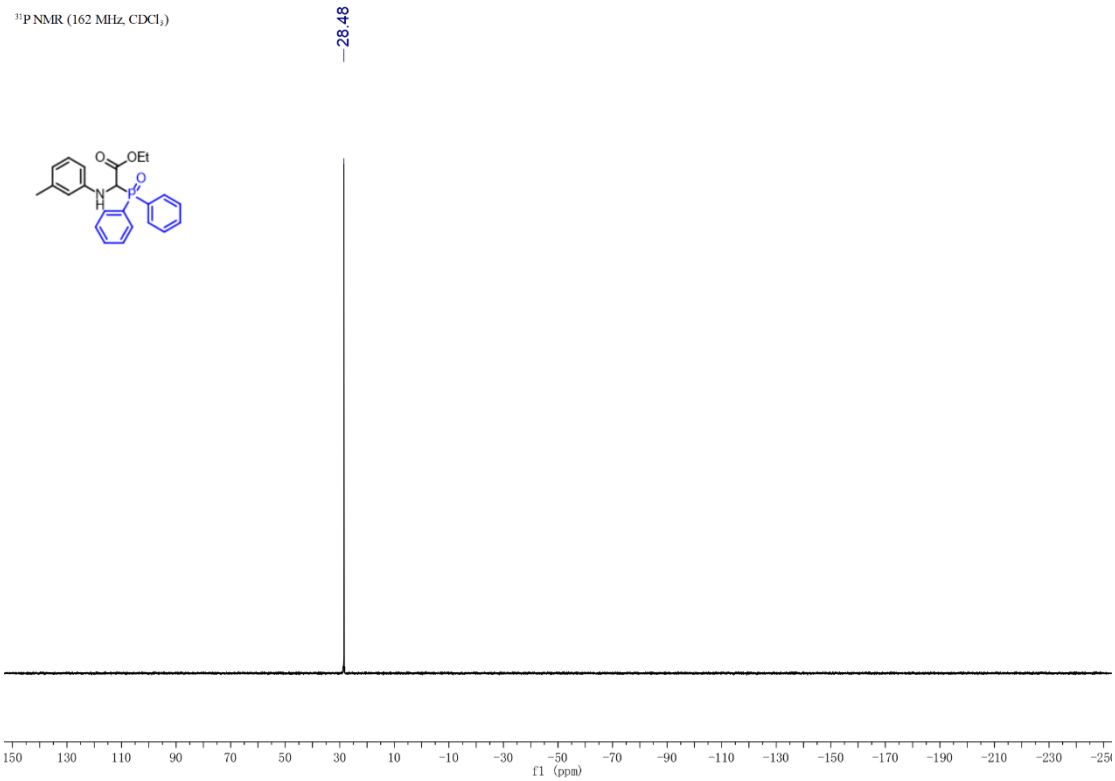
^{1}H NMR (400 MHz, $CDCl_3$)



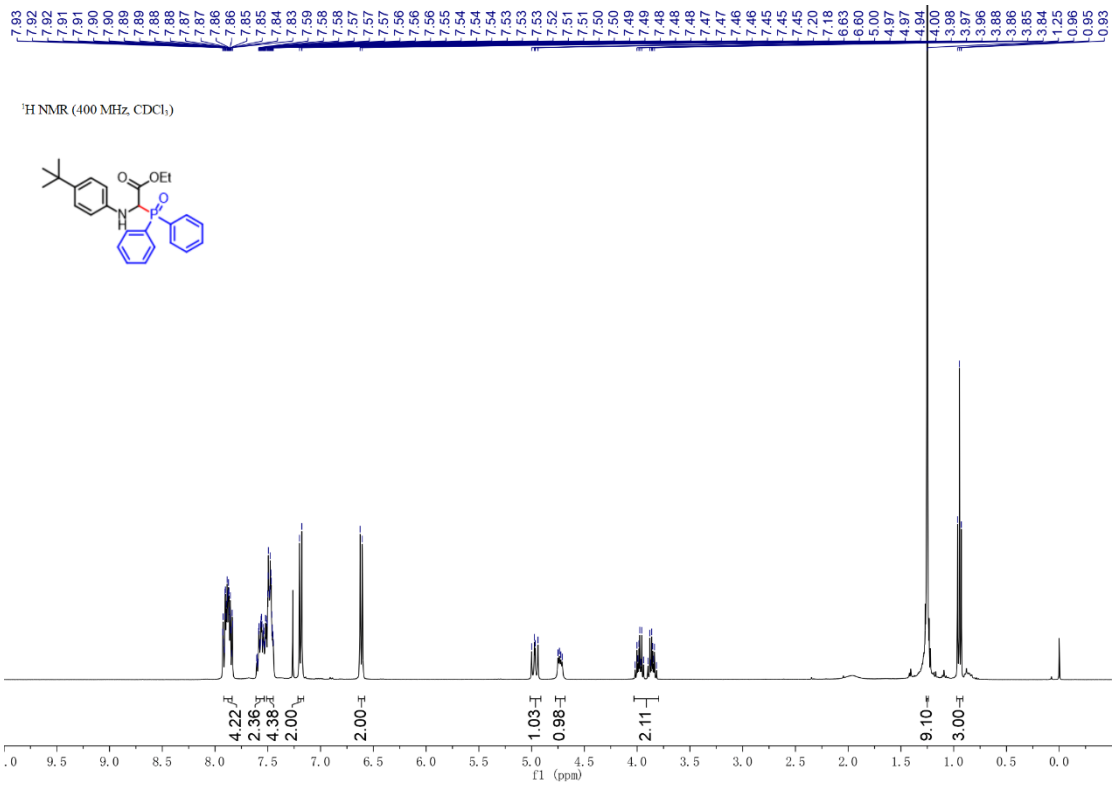


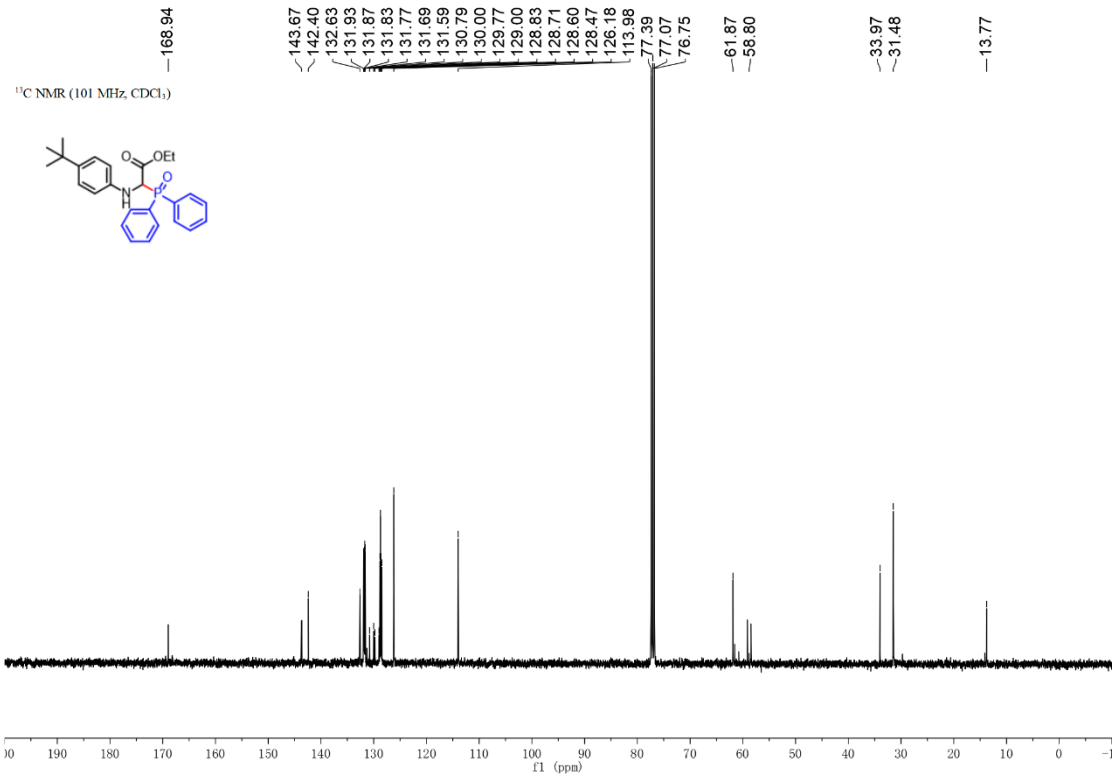
^{13}C NMR (101 MHz, $CDCl_3$)

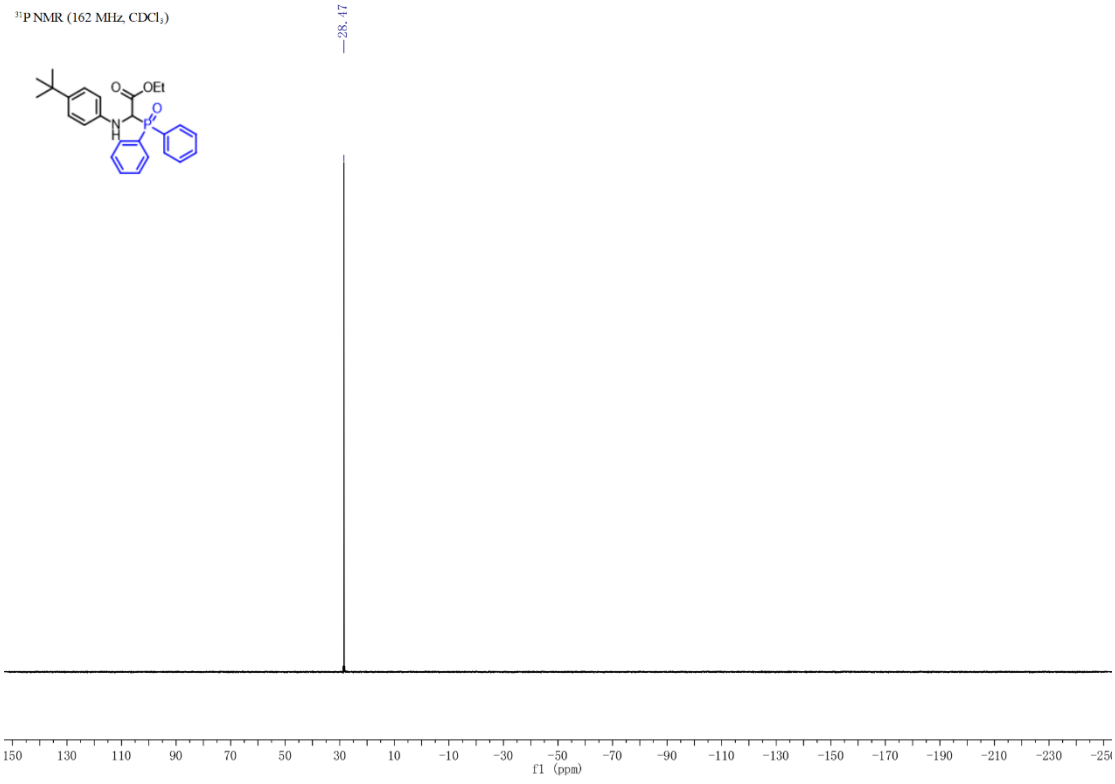




Ethyl 2-((4-(tert-butyl)phenyl)amino)-2-(diphenylphosphoryl)acetate. (3da)

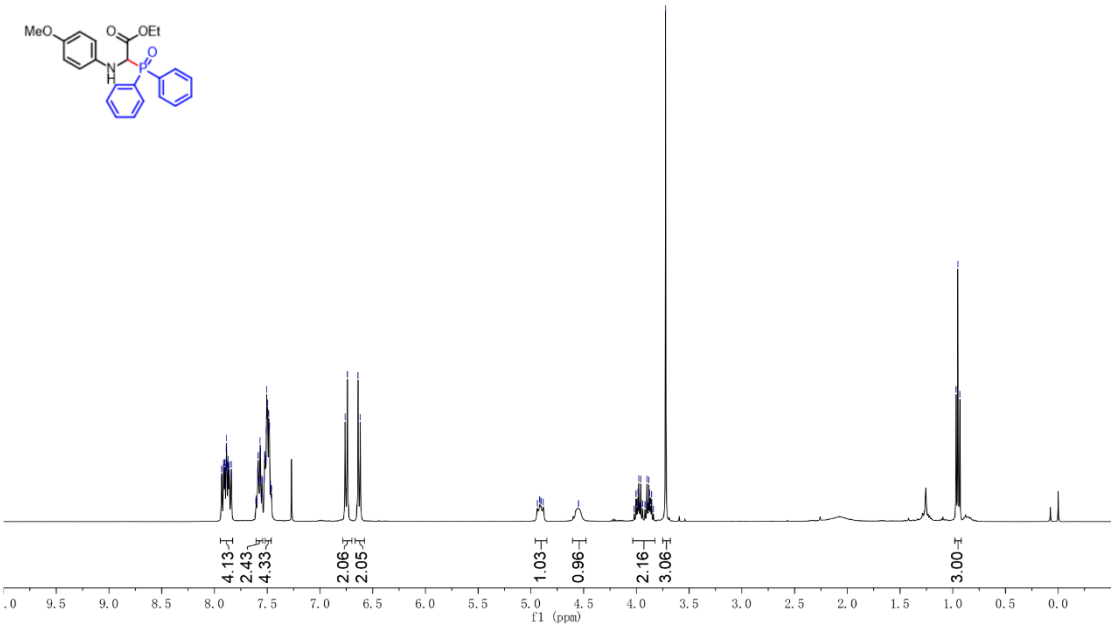


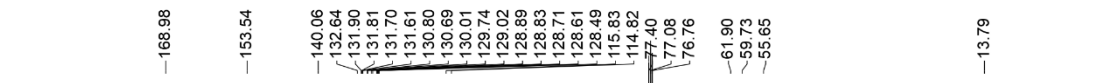

168.94
143.67
142.40
132.63
131.93
131.87
131.83
131.77
131.69
131.59
130.79
130.00
129.77
129.00
128.83
128.71
128.60
128.47
126.18
113.98
77.39
77.07
76.75
61.87
58.80
33.97
31.48
13.77
13C NMR (101 MHz, CDCl3)
OEt
O
O
P
O
N
H
f1 (ppm)


28.47
31P NMR (162 MHz, CDCl3)
OEt
O
O
P
O
N
H
f1 (ppm)

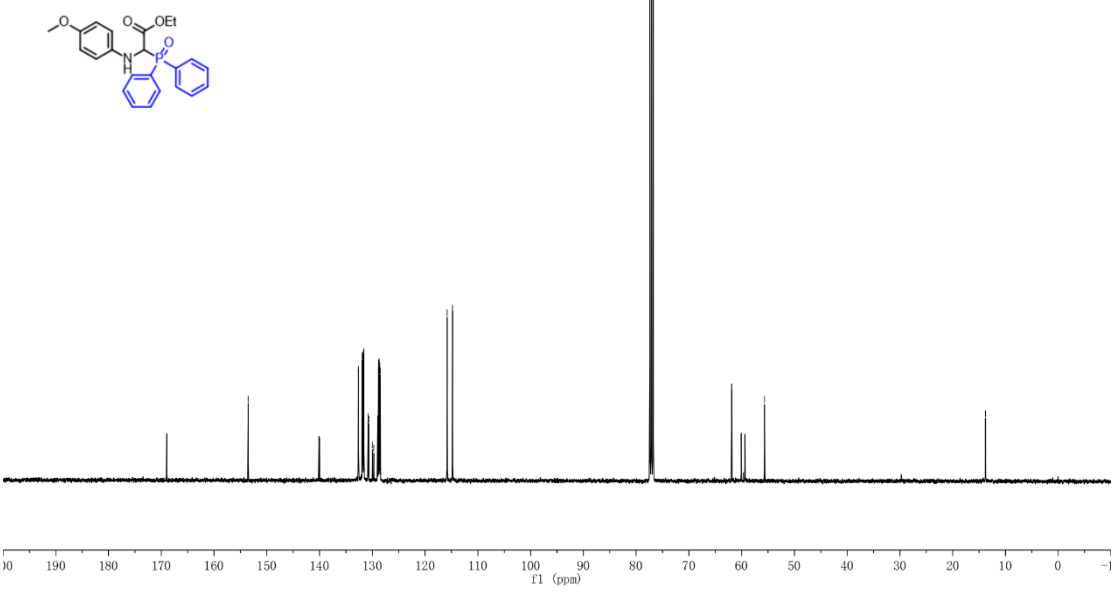
Ethyl 2-(diphenylphosphoryl)-2-((4-methoxyphenyl)amino)acetate. (3ea)

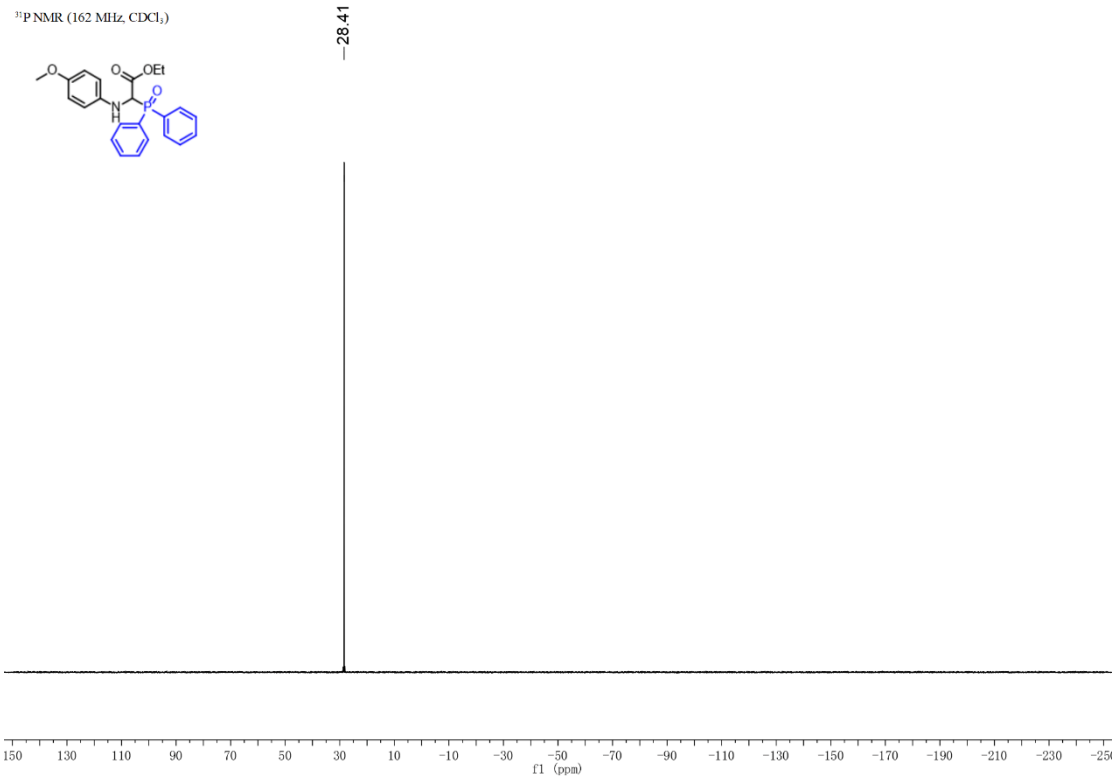
^{1}H NMR (400 MHz, CDCl$_3$)



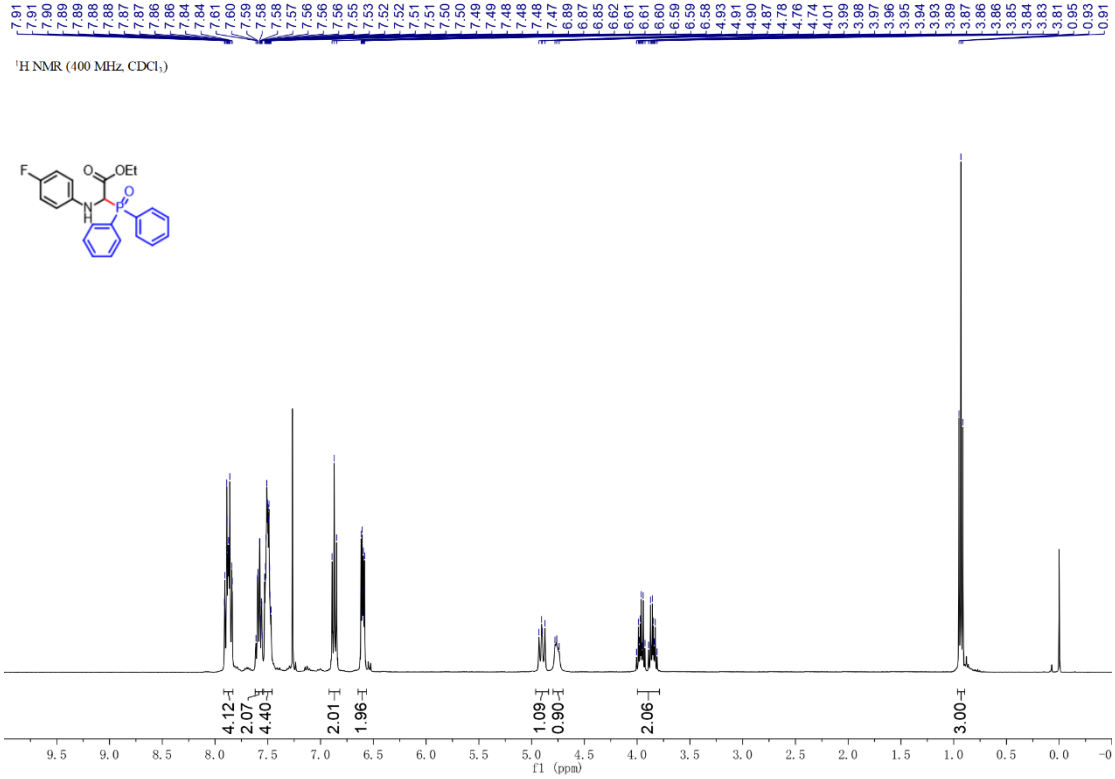


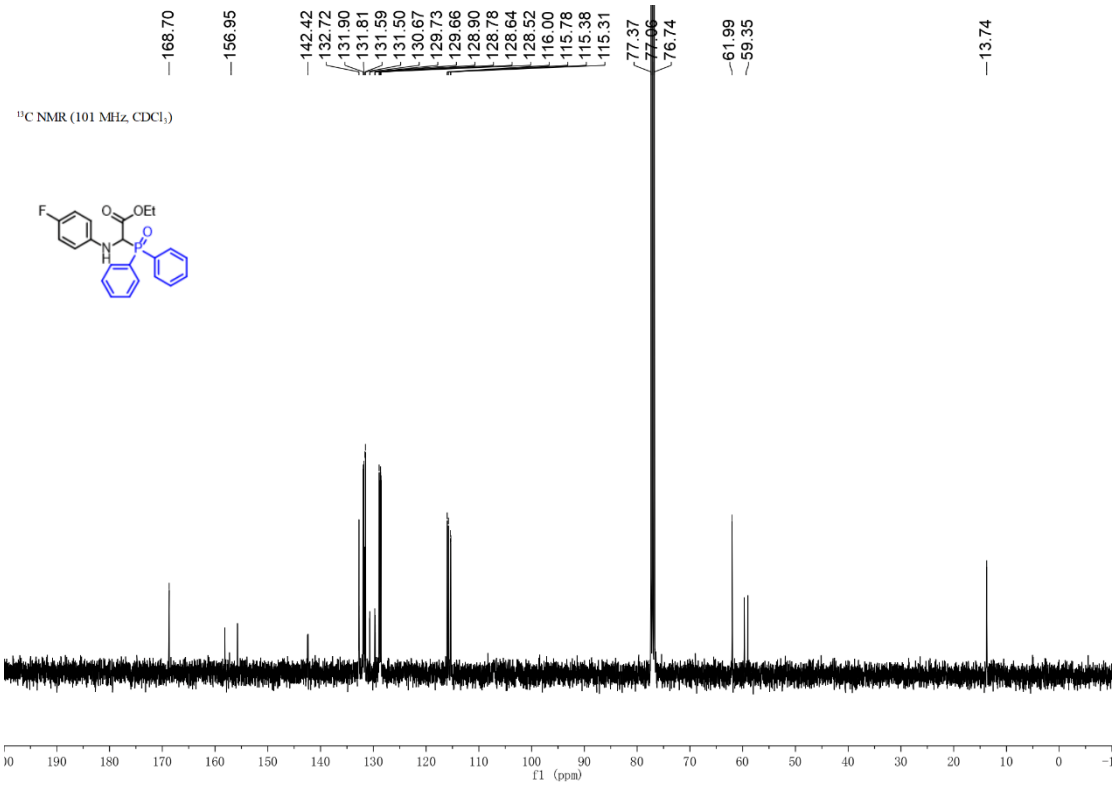
^{13}C NMR (101 MHz, CDCl$_3$)

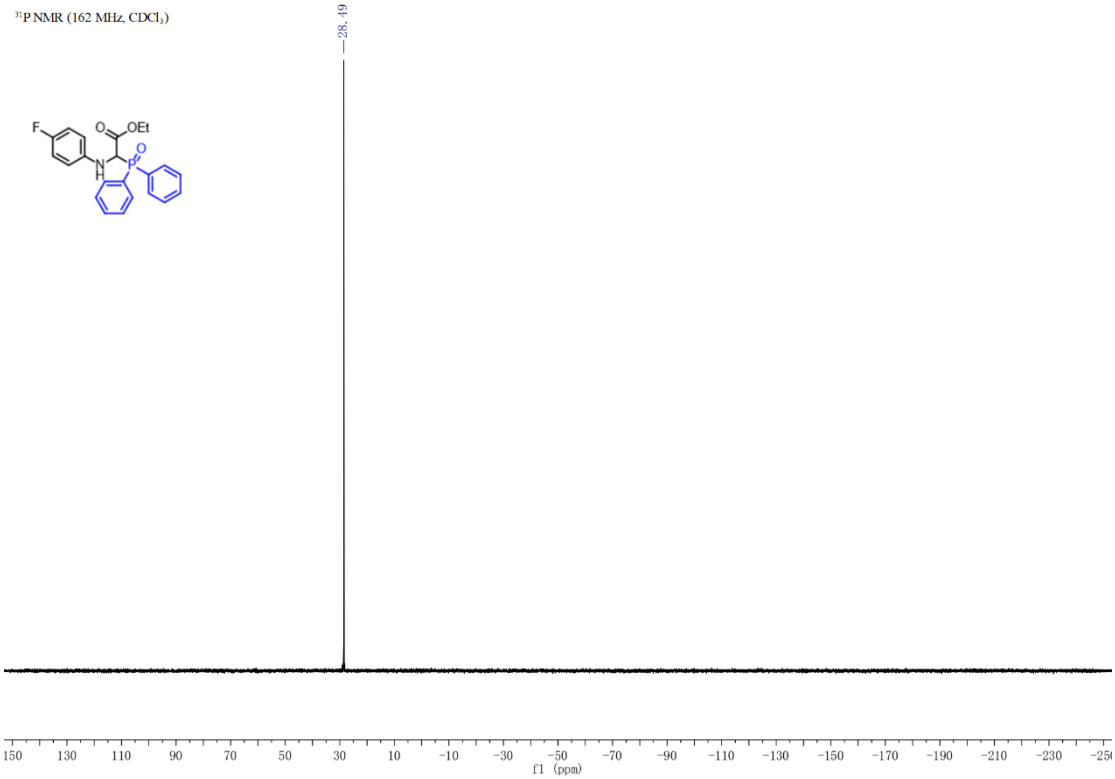




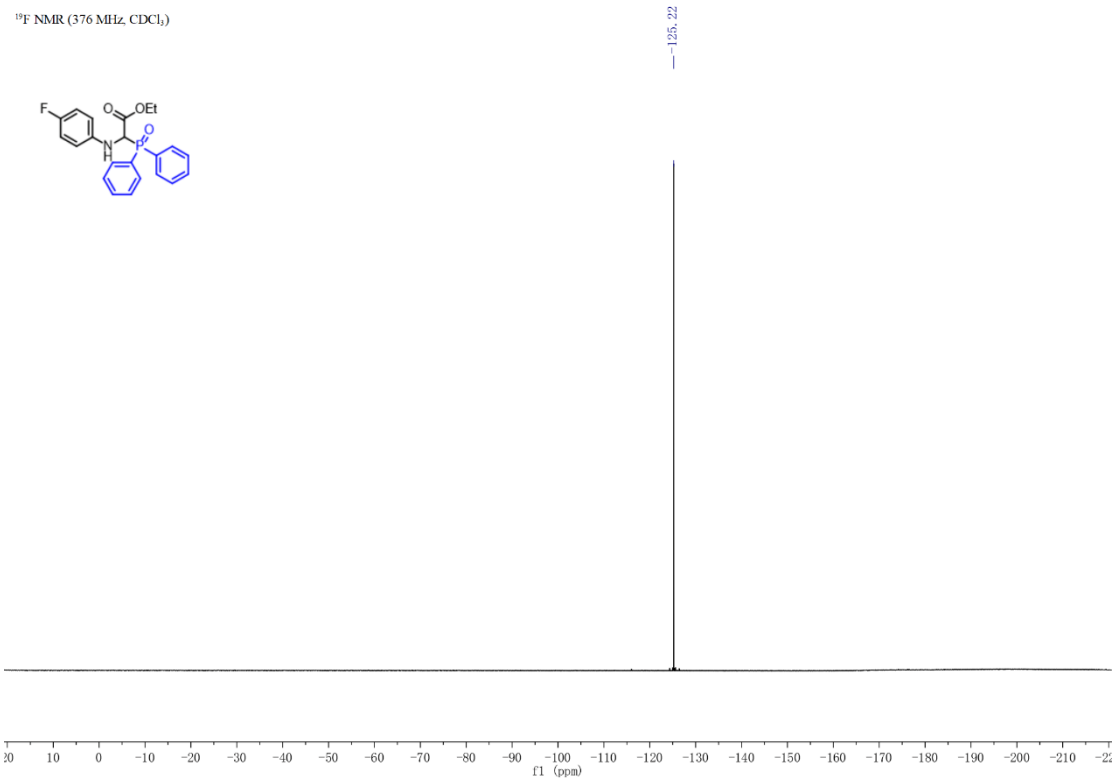
Ethyl 2-(diphenylphosphoryl)-2-((4-fluorophenyl)amino)acetate. (3fa)




168.70
156.95
142.42
132.72
131.90
131.81
131.59
131.50
130.67
129.73
129.66
128.90
128.78
128.64
128.52
116.00
115.78
115.38
115.31
77.37
77.06
76.74
61.99
59.35
13.74
^{13}C NMR (101 MHz, $CDCl_3$)
F
O
OEt
N
H
P
O
f1 (ppm)

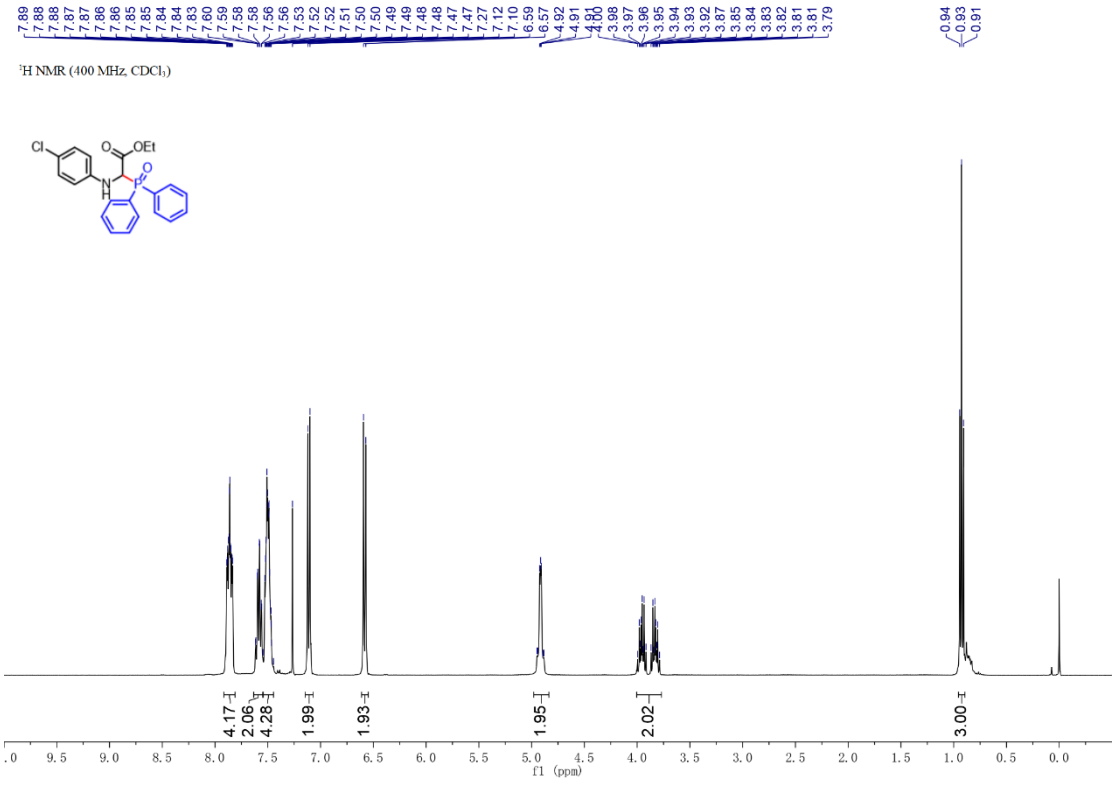

^{31}P NMR (162 MHz, $CDCl_3$)
28.49
F
O
OEt
N
H
P
O
f1 (ppm)

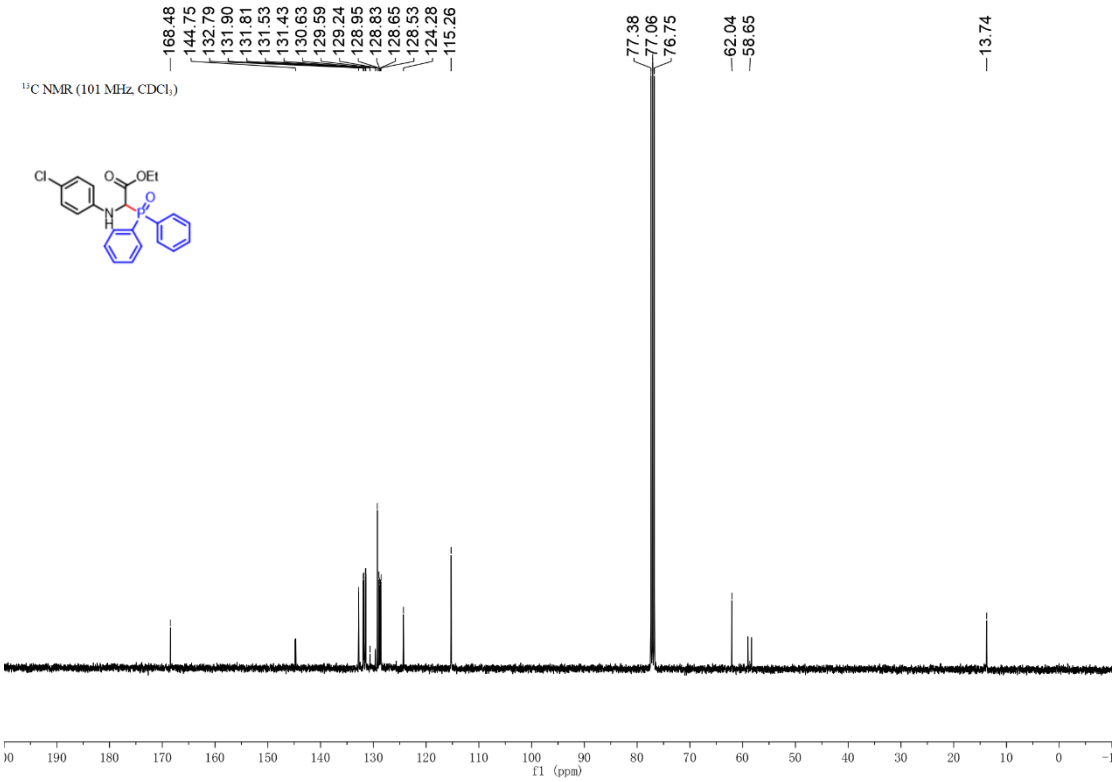
^{19}F NMR (376 MHz, $CDCl_3$)

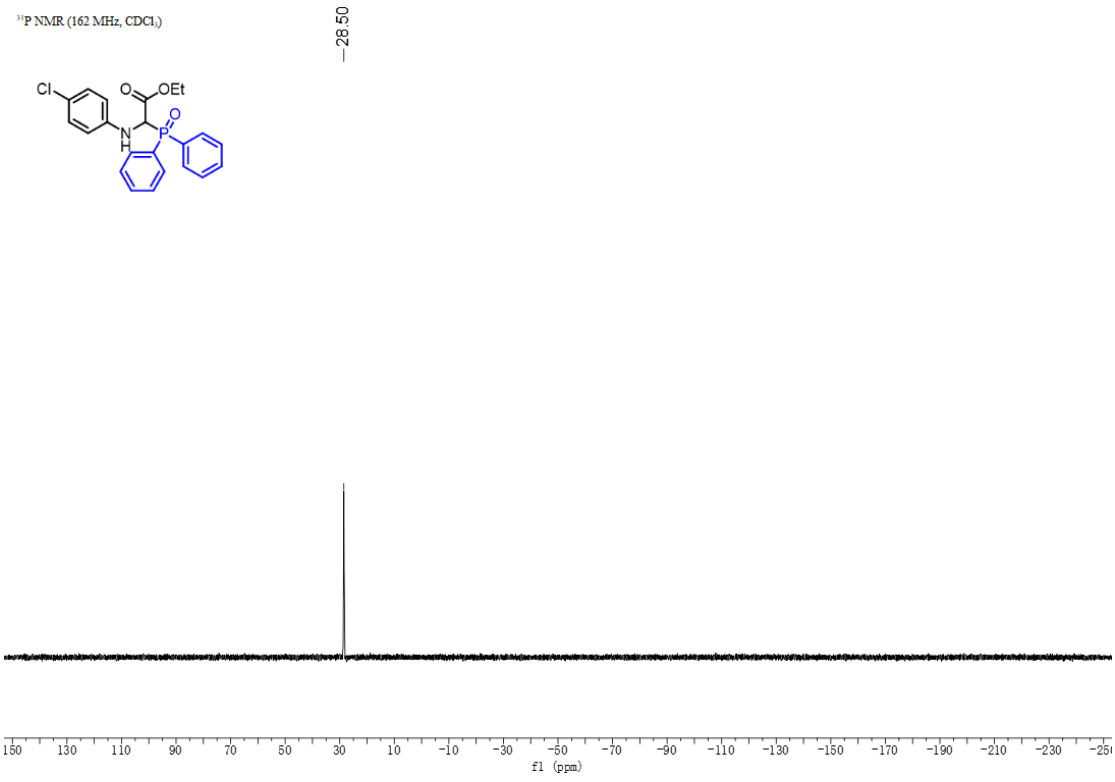


Ethyl 2-((4-chlorophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ga)

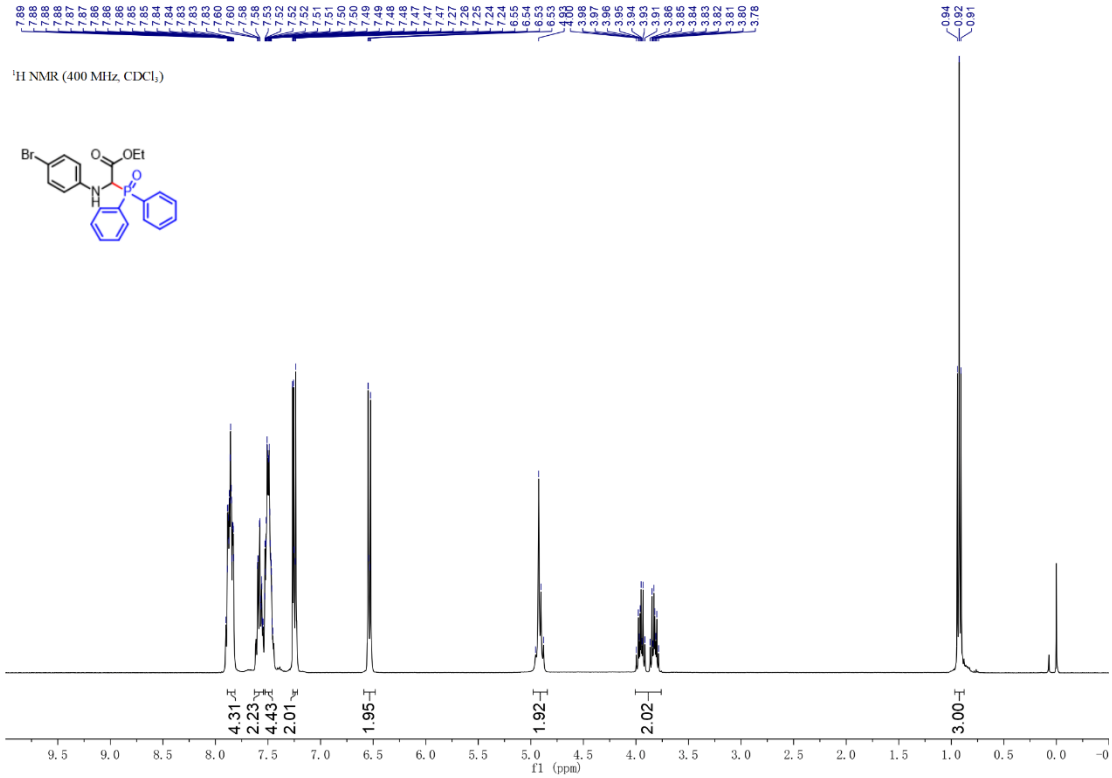
^{1}H NMR (400 MHz, $CDCl_3$)

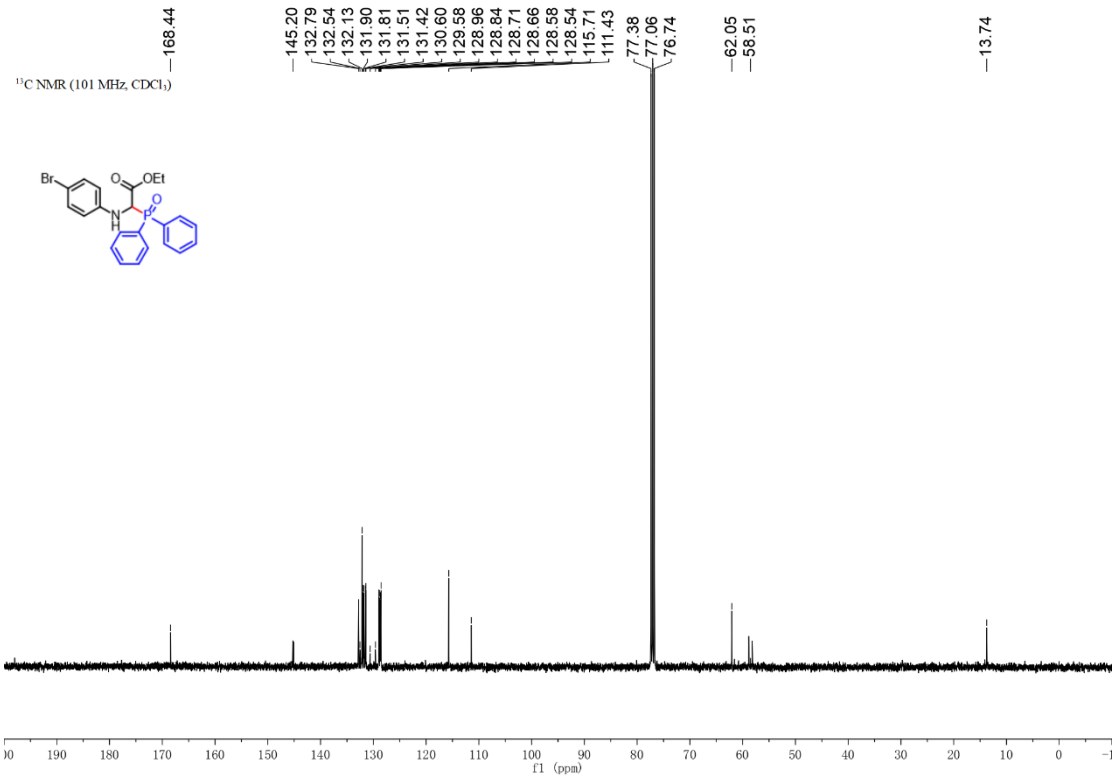


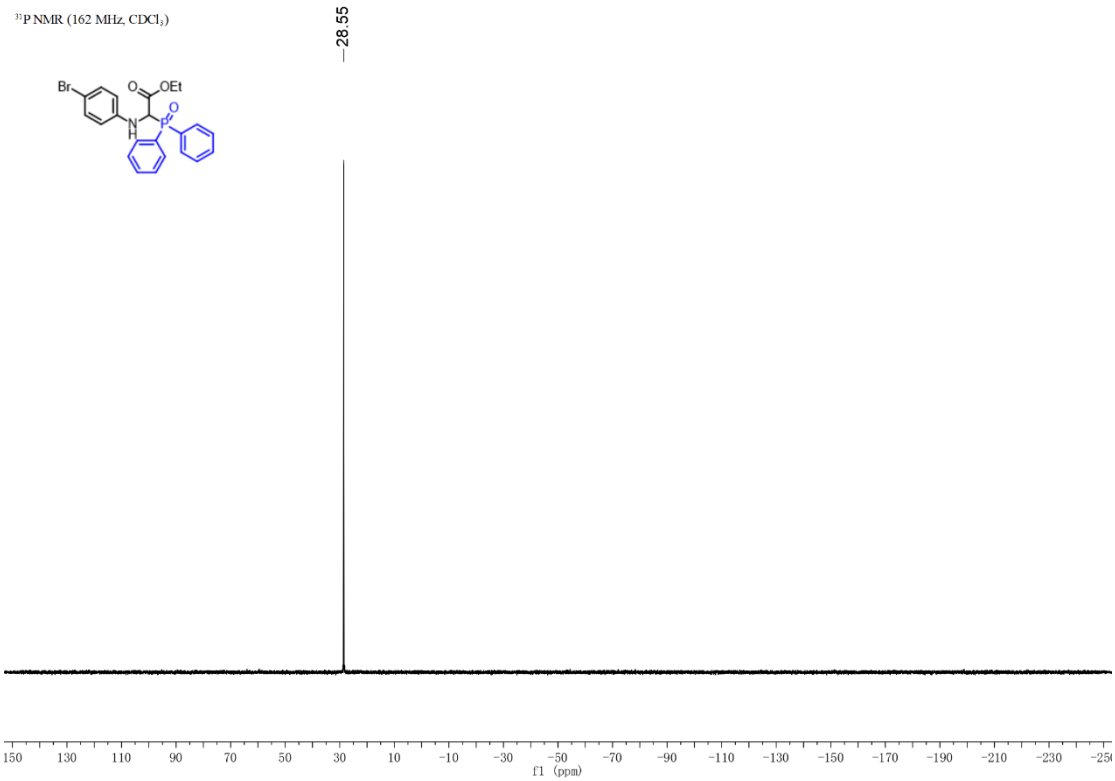

168.48
144.75
132.79
131.90
131.81
131.53
131.43
130.63
129.59
129.24
128.95
128.83
128.65
128.53
124.28
115.26
77.38
77.06
76.75
62.04
58.65
13.74
13C NMR (101 MHz, CDCl3)
Cl
O
OEt
N
H
P
O
f1 (ppm)


28.50
31P NMR (162 MHz, CDCl3)
Cl
O
OEt
N
H
P
O
f1 (ppm)

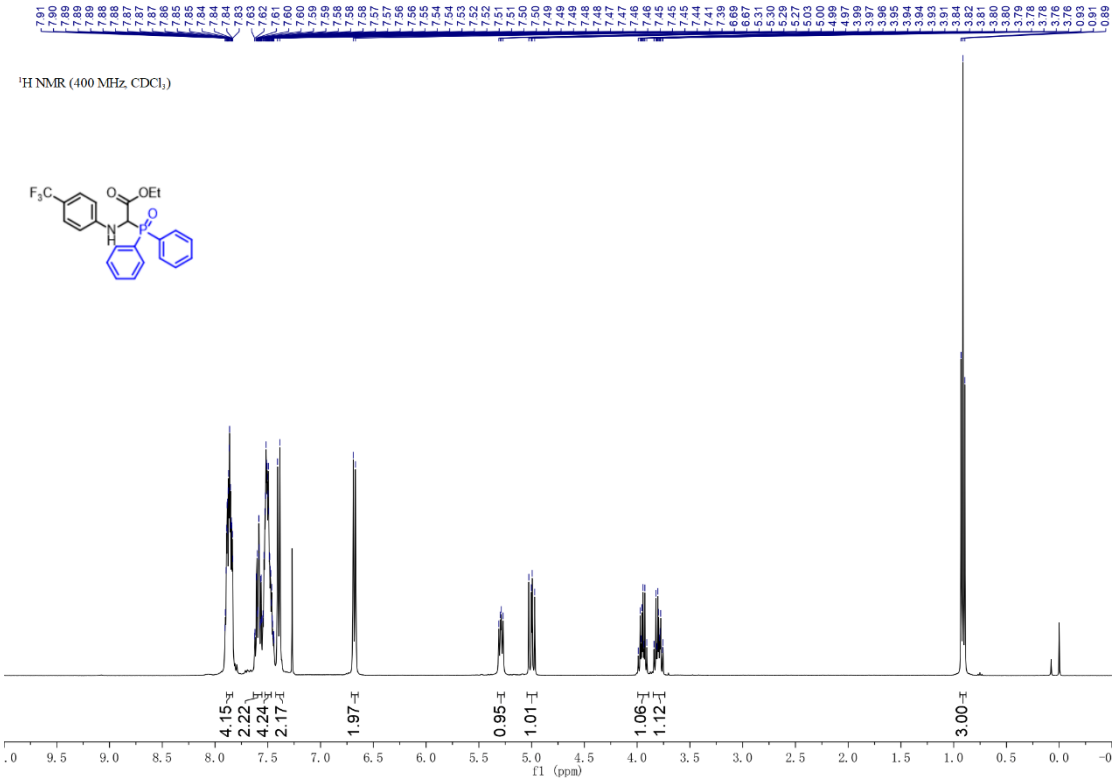
Ethyl 2-((4-bromophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ha)

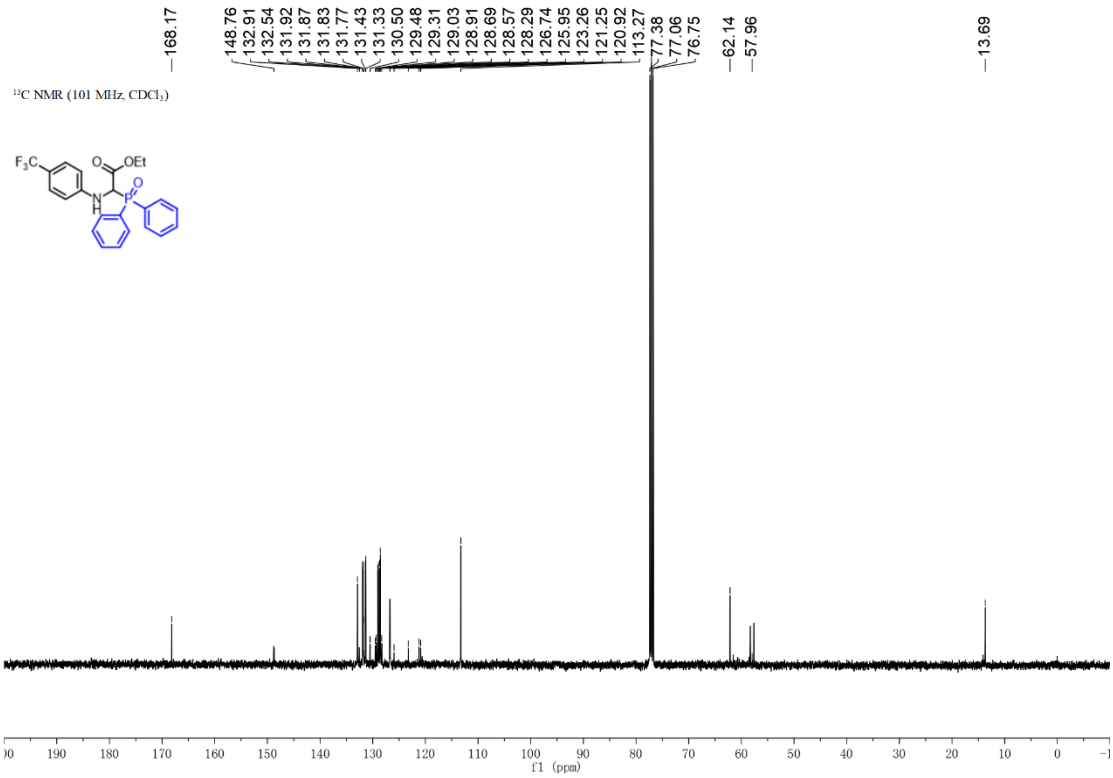


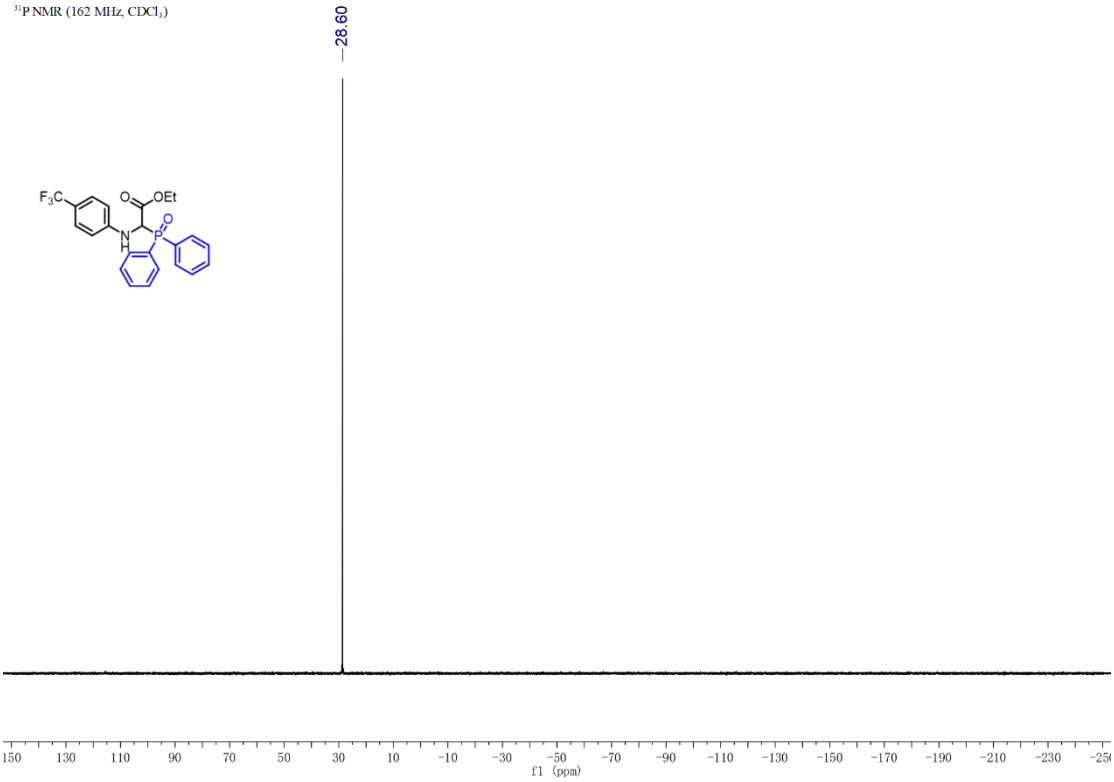


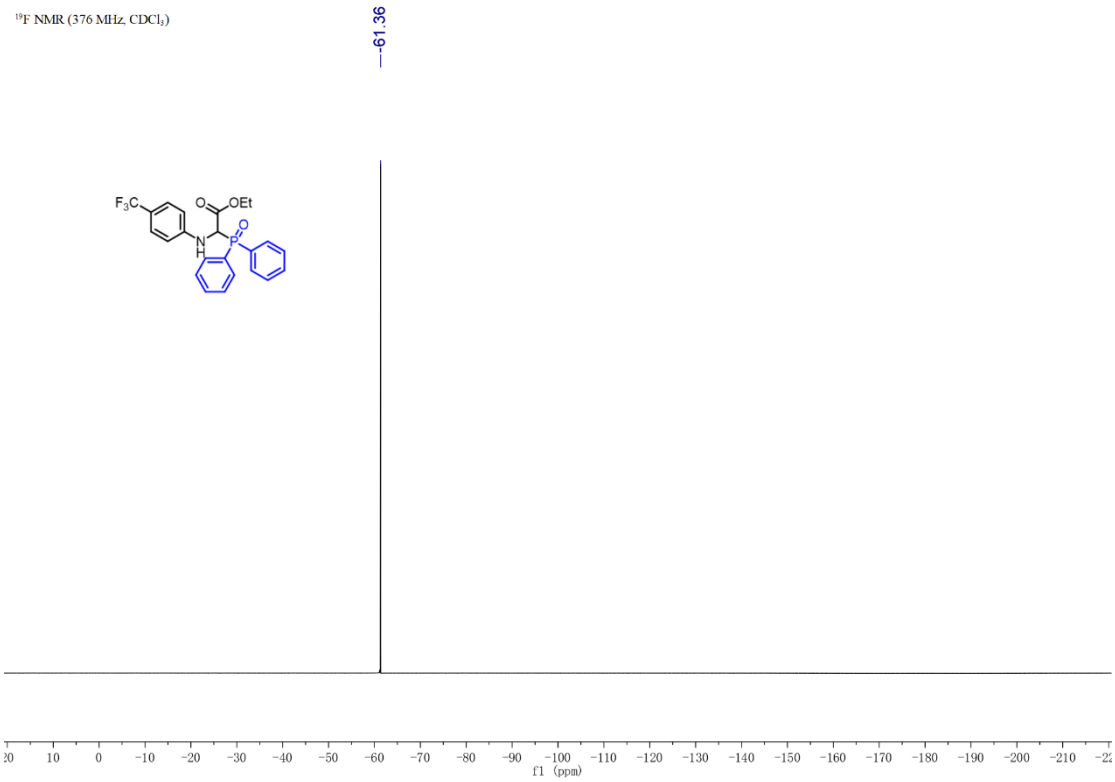


Ethyl 2-(diphenylphosphoryl)-2-((4-(trifluoromethyl)phenyl)amino)acetate. (3ia)

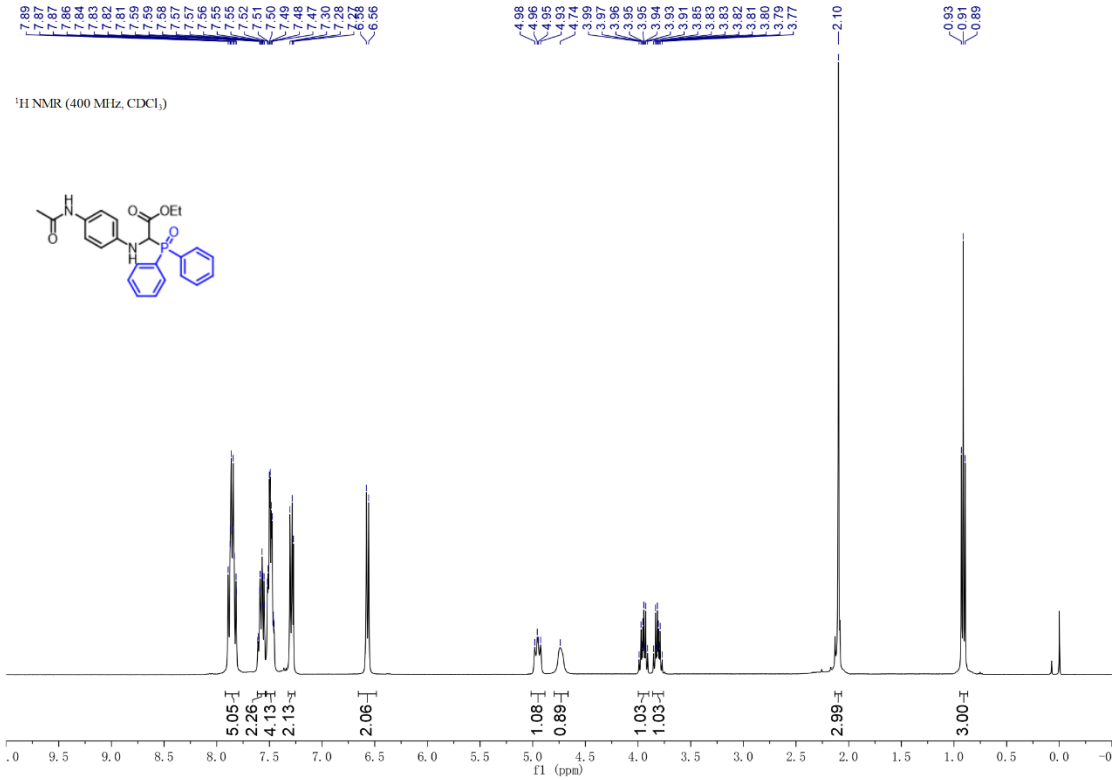


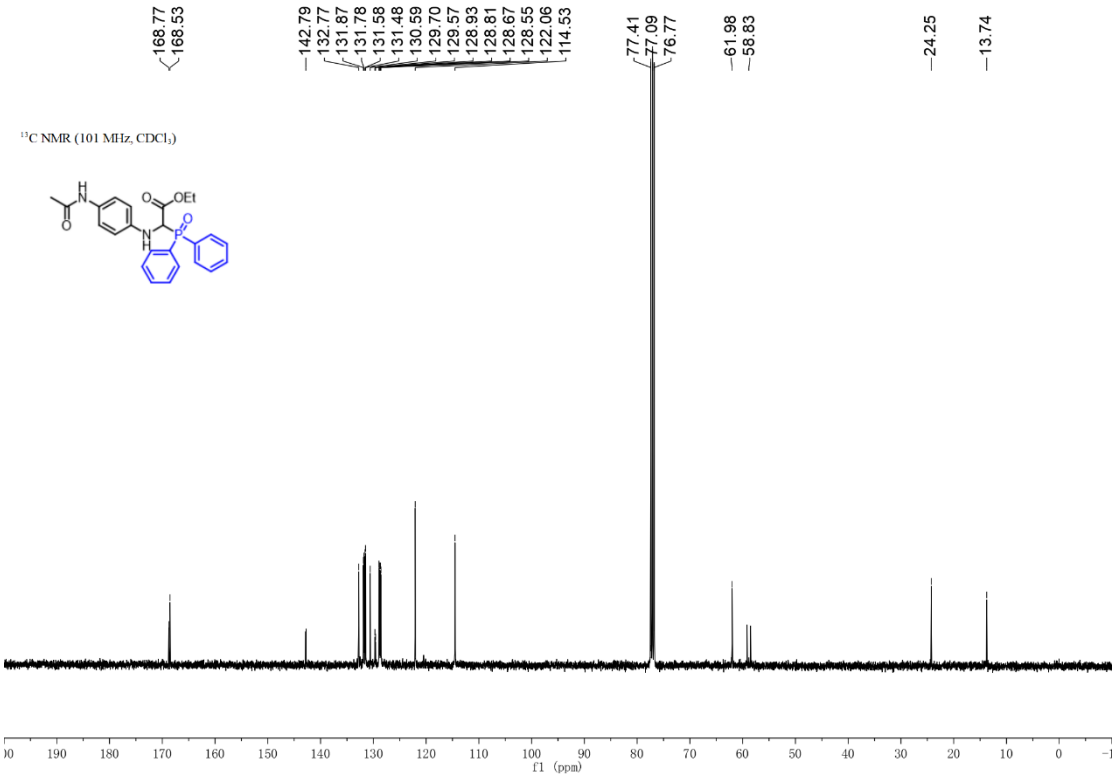

168.17
148.76
132.91
132.54
131.92
131.87
131.83
131.77
131.43
131.33
130.50
129.48
129.31
129.03
128.91
128.69
128.57
128.29
126.74
125.95
123.26
121.25
120.92
113.27
77.38
77.06
76.75
62.14
57.96
13.69
^{13}C NMR (101 MHz, CDCl$_3$)
F$_3$C
O
OEt
N
H
P
O
f1 (ppm)

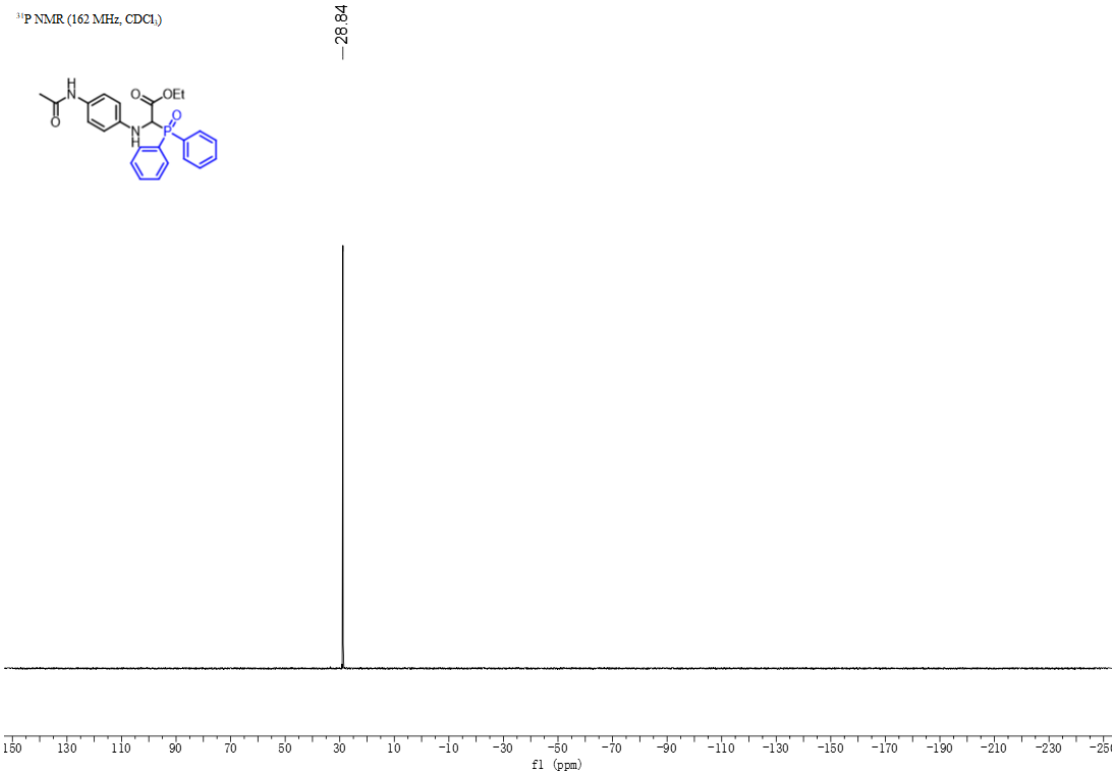

^{31}P NMR (162 MHz, CDCl$_3$)
28.60
F$_3$C
O
OEt
N
H
P
O
f1 (ppm)



Ethyl 2-((4-acetamidophenyl)amino)-2-(diphenylphosphoryl)acetate. (3ja)

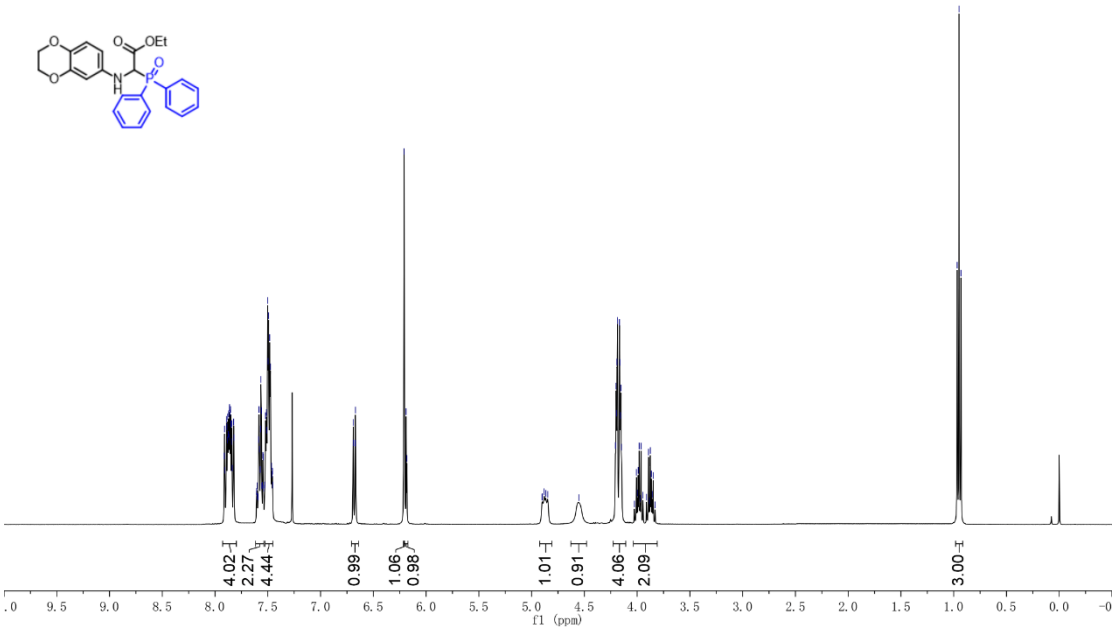



168.77
168.53
142.79
132.77
131.87
131.78
131.58
131.48
130.59
129.70
129.57
128.93
128.81
128.67
128.55
122.06
114.53
77.41
77.09
76.77
61.98
58.83
24.25
13.74
13C NMR (101 MHz, CDCl3)
f1 (ppm)

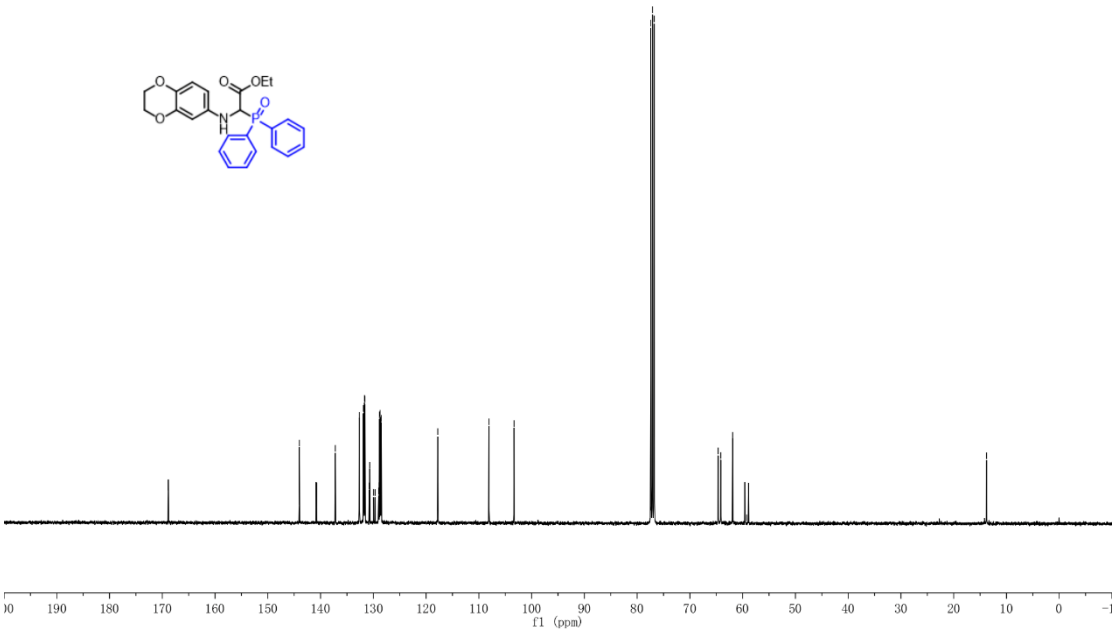

28.84
31P NMR (162 MHz, CDCl3)
f1 (ppm)

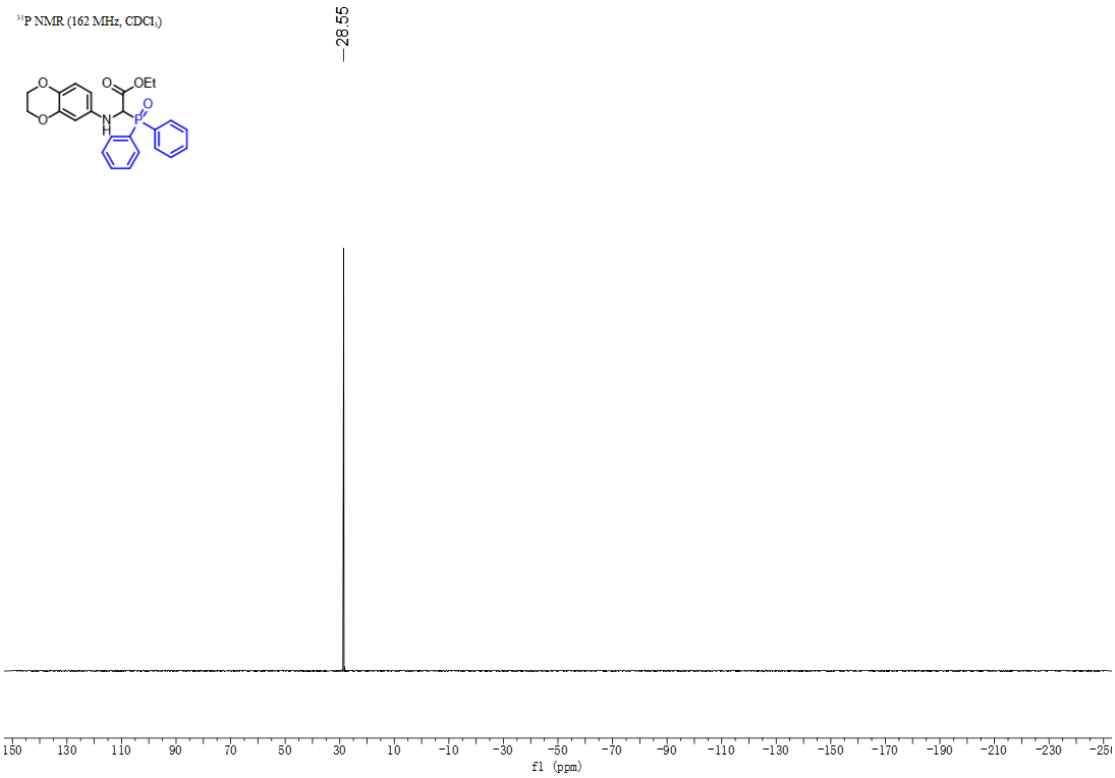
Ethyl 2-((2,3-dihydrobenzo[b][1,4]dioxin-6-yl)amino)-2-(diphenylphosphoryl)acetate. (3ka)

^{1}H NMR (400 MHz, $CDCl_3$)

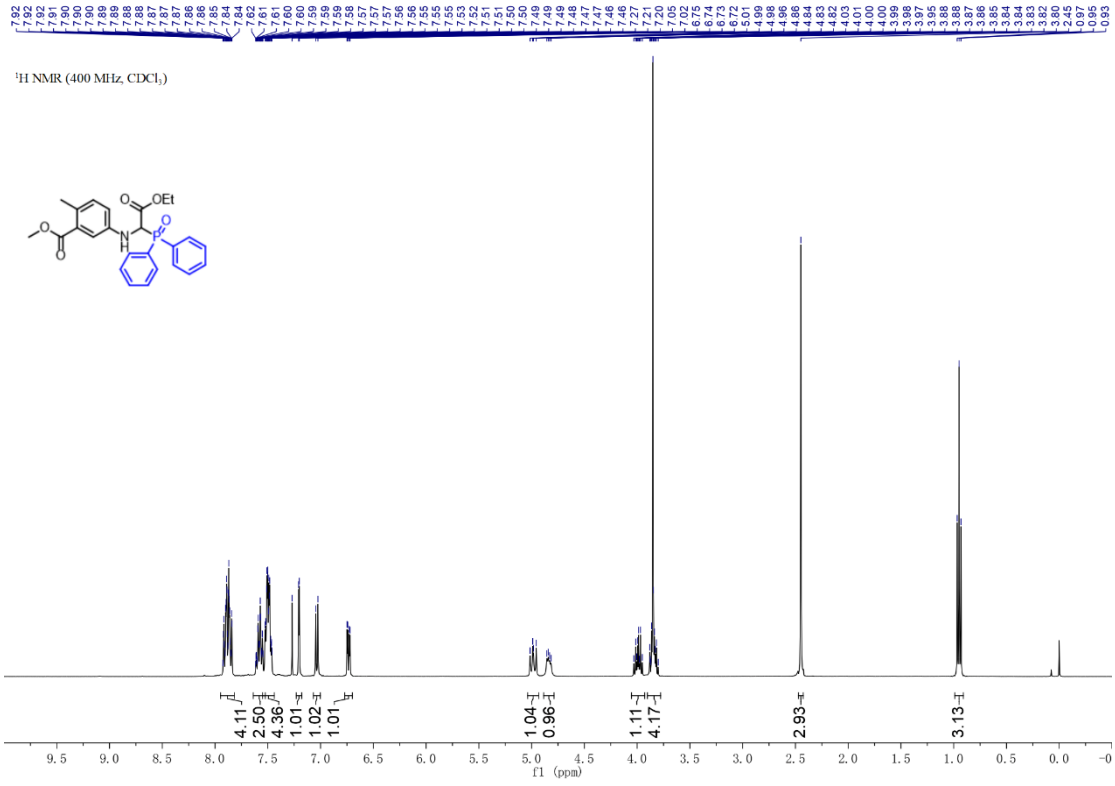


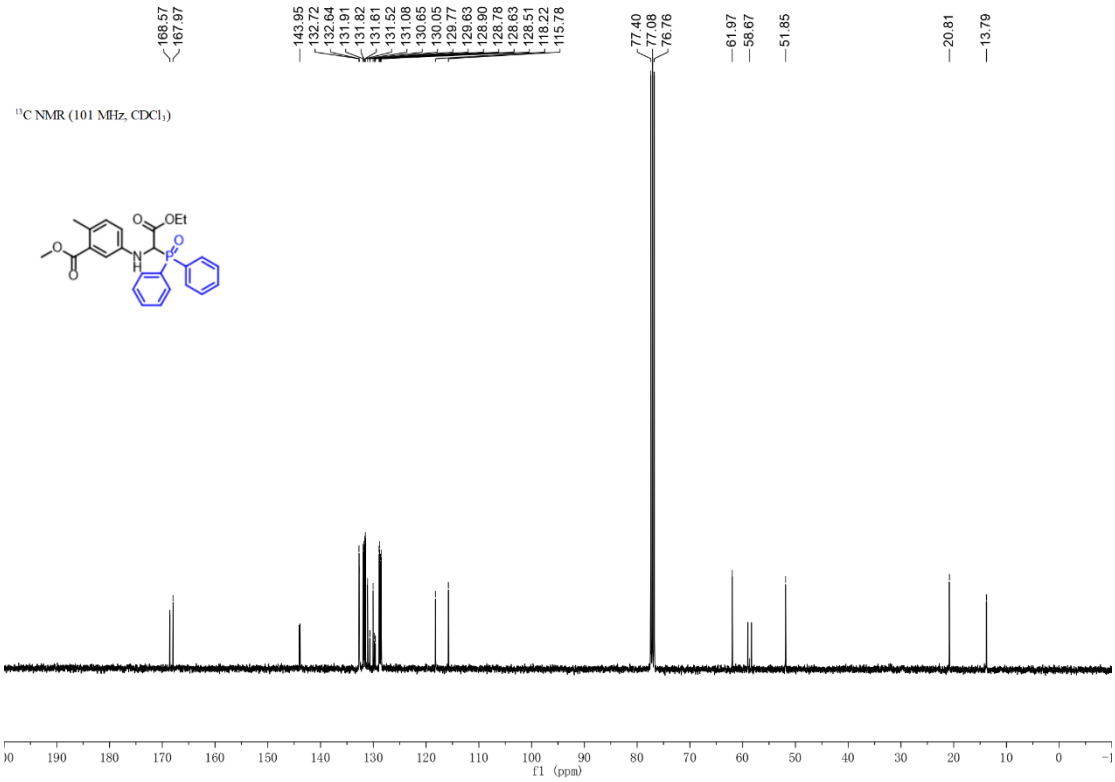
^{13}C NMR (101 MHz, $CDCl_3$)

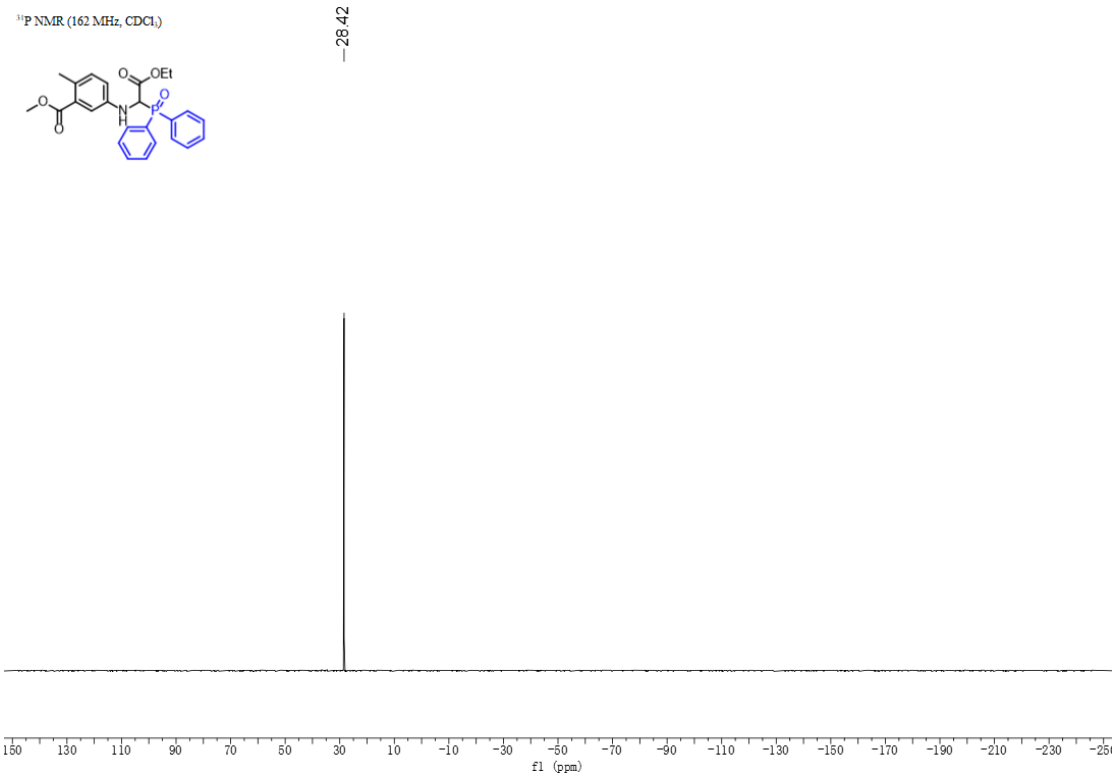




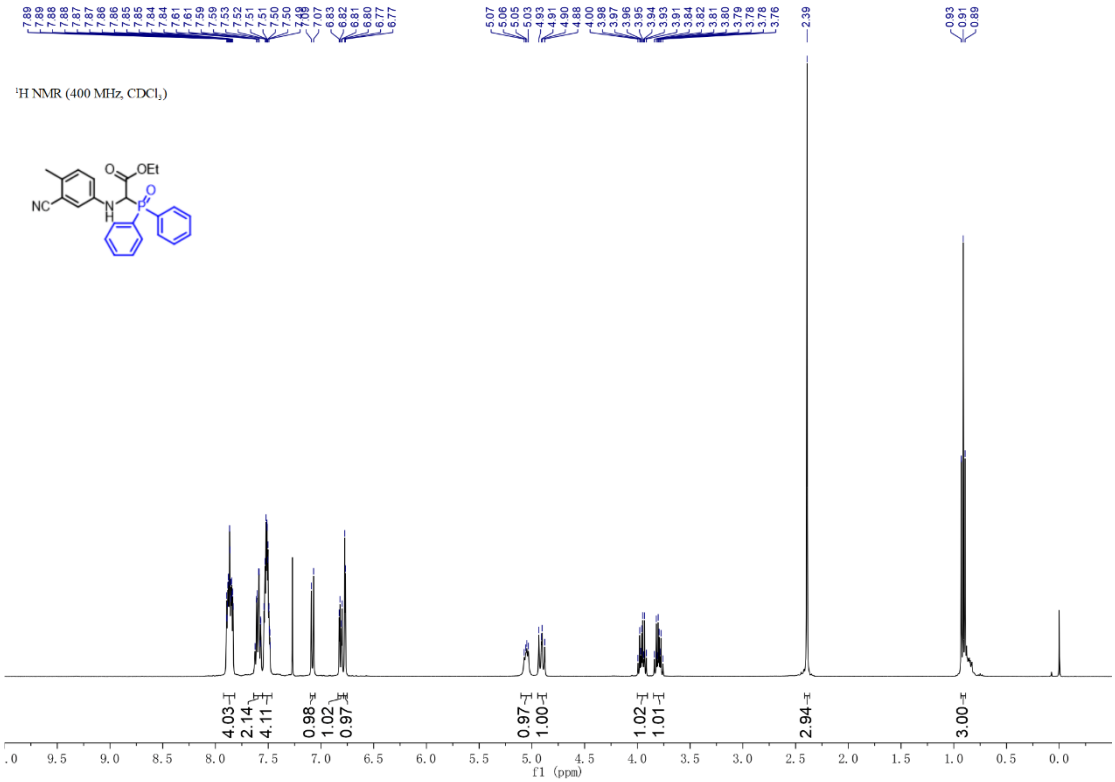
Methyl 5-((1-(diphenylphosphoryl)-2-ethoxy-2-oxoethyl)amino)-2-methylbenzoate. (3la)

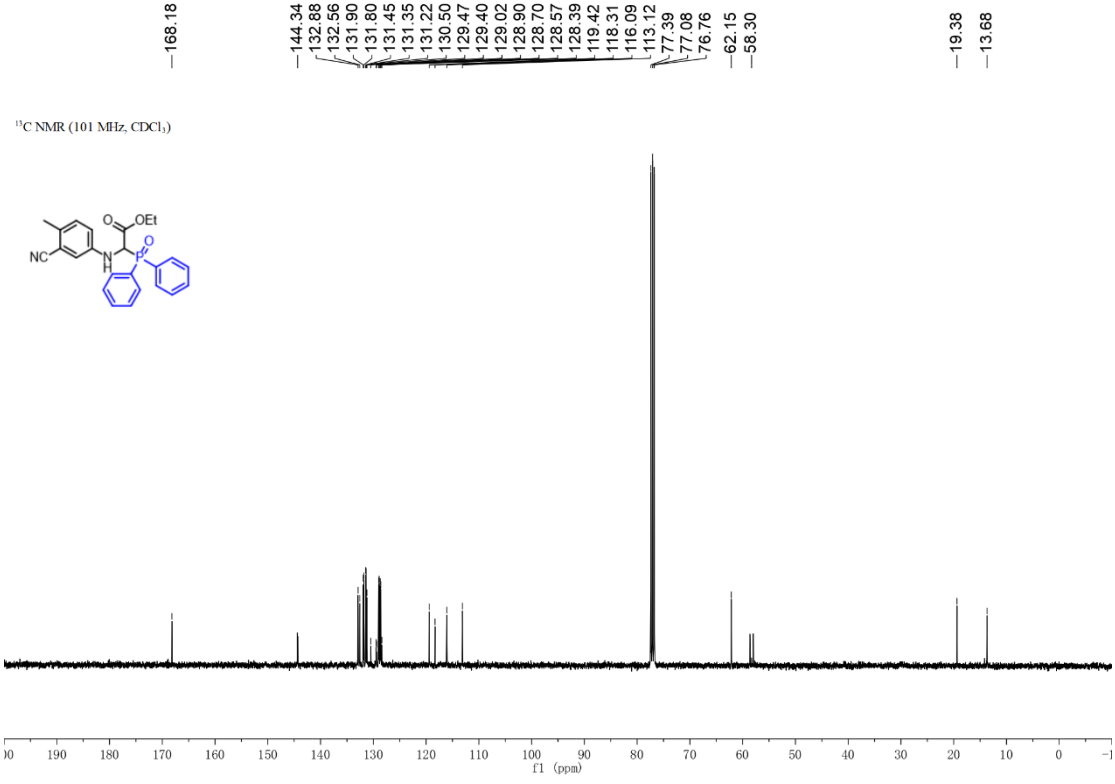



168.57
167.97
143.95
132.72
132.64
131.91
131.82
131.61
131.52
131.08
130.65
130.05
129.77
129.63
128.90
128.78
128.63
128.51
118.22
115.78
77.40
77.08
76.76
61.97
58.67
51.85
20.81
13.79
^{13}C NMR (101 MHz, $CDCl_3$)
f1 (ppm)

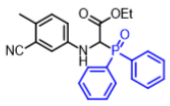

28.42
^{31}P NMR (162 MHz, $CDCl_3$)
f1 (ppm)

Ethyl 2-((3-cyano-4-methylphenyl)amino)-2-(diphenylphosphoryl)acetate. (3ma)



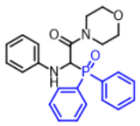


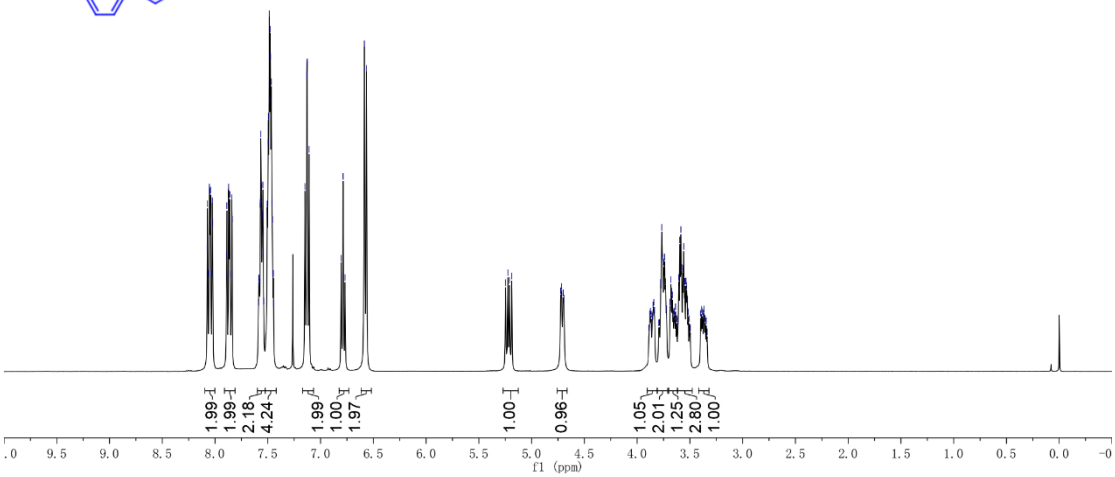
^{31}P NMR (162 MHz, $CDCl_3$)

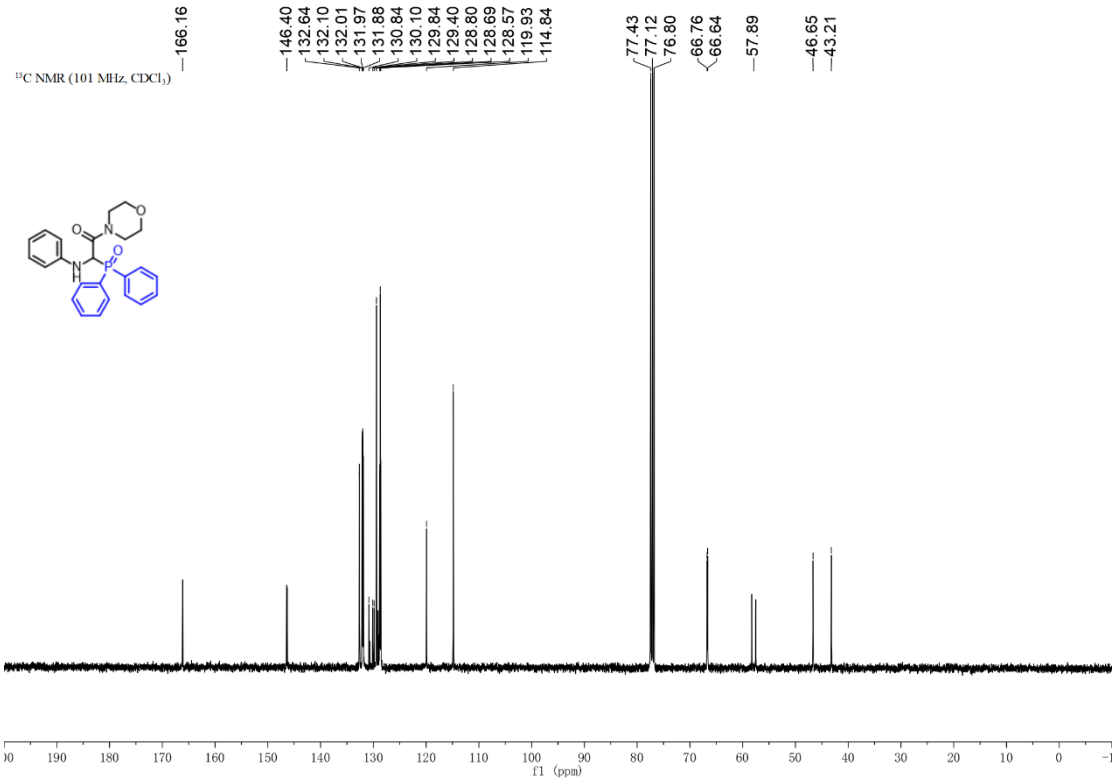


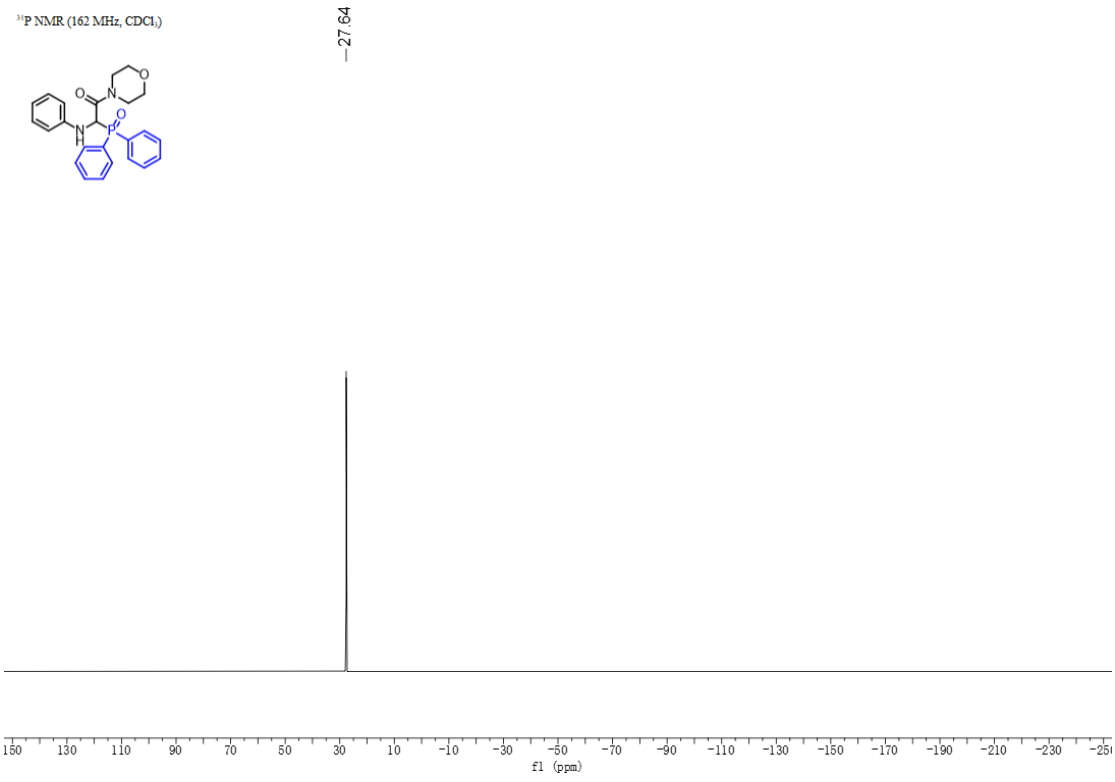
2-(diphenylphosphoryl)-1-morpholino-2-(phenylamino)ethan-1-one. (3na)

^{1}H NMR (400 MHz, $CDCl_3$)

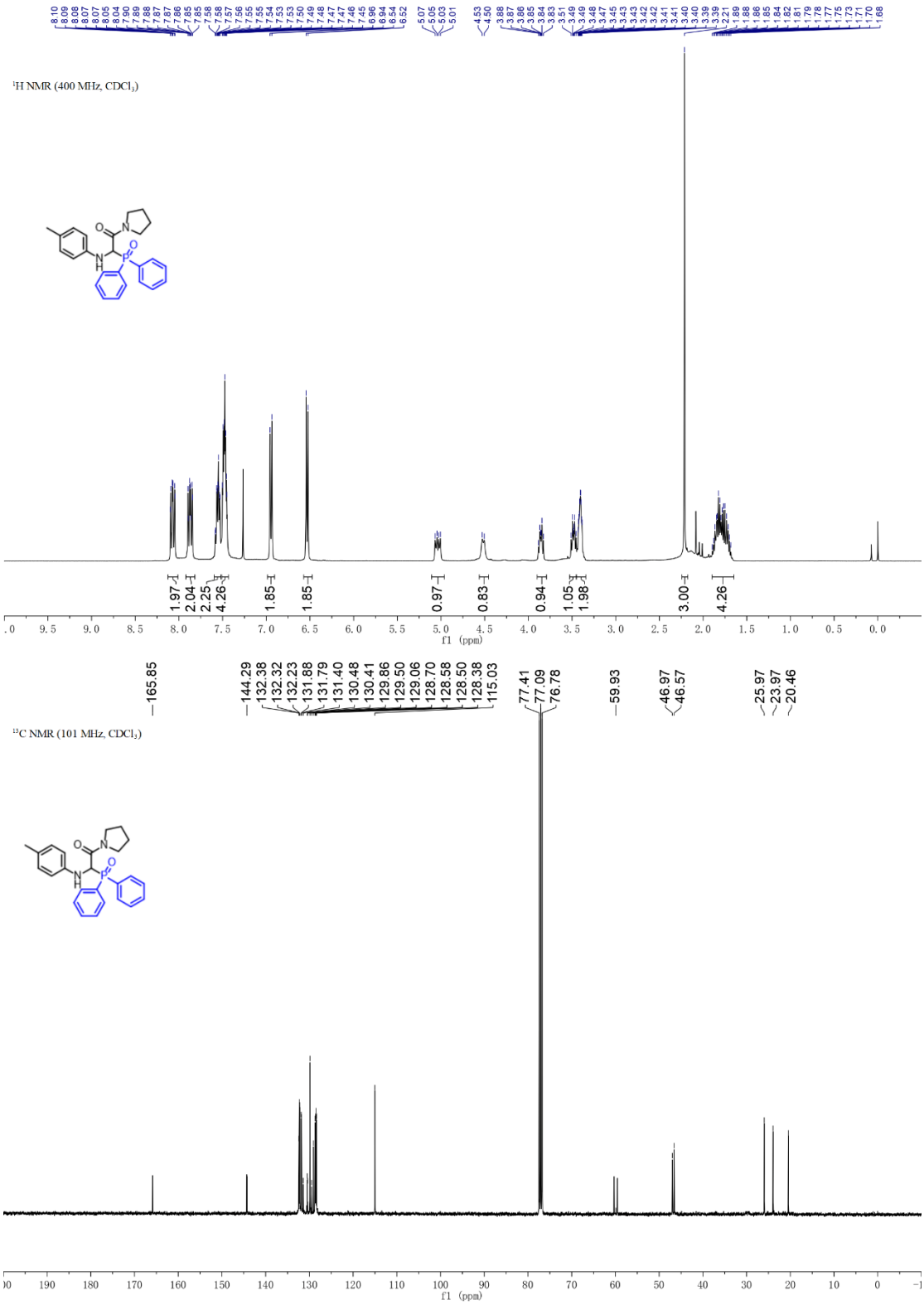


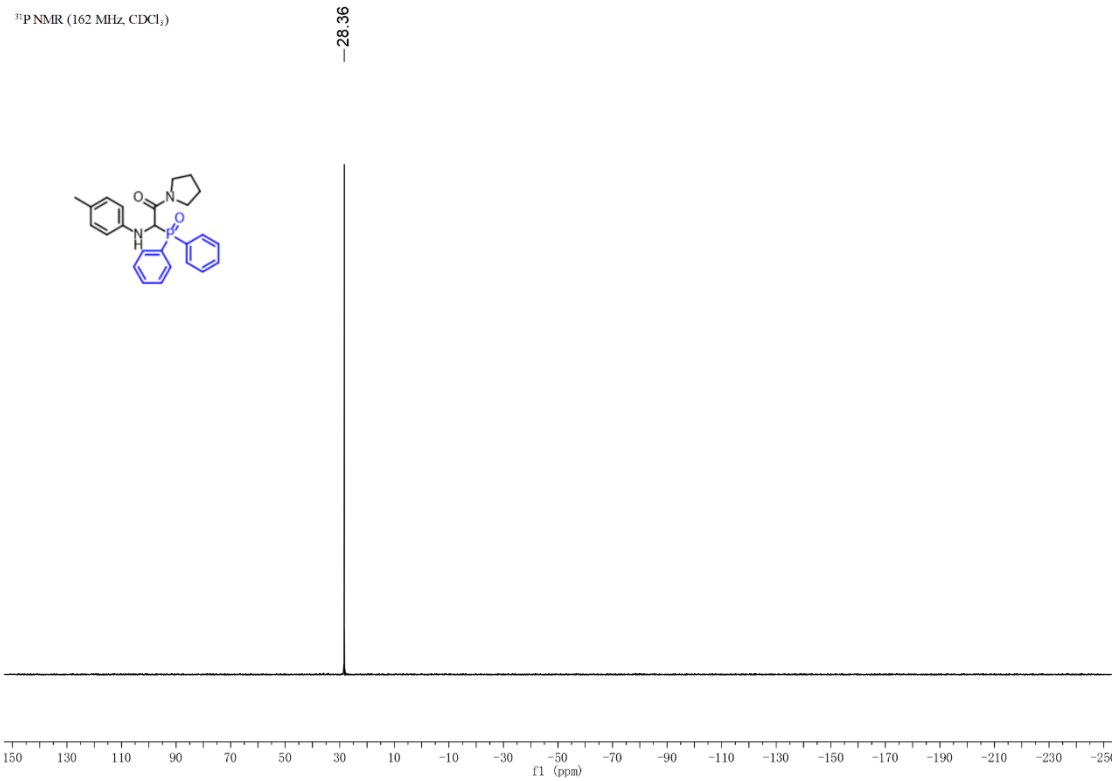



166.16
146.40
132.64
132.10
132.01
131.97
131.88
130.84
130.10
129.84
129.40
128.80
128.69
128.57
119.93
114.84
77.43
77.12
76.80
66.76
66.64
57.89
46.65
43.21
13C NMR (101 MHz, CDCl3)
f1 (ppm)

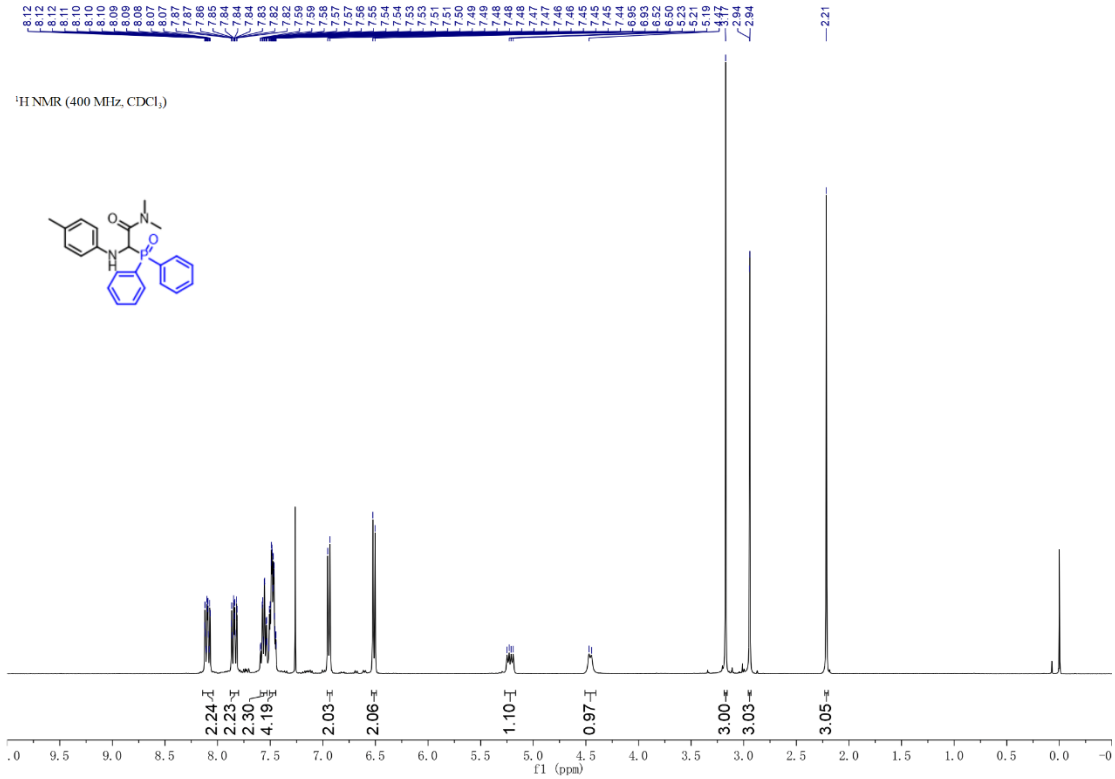

27.64
31P NMR (162 MHz, CDCl3)
f1 (ppm)

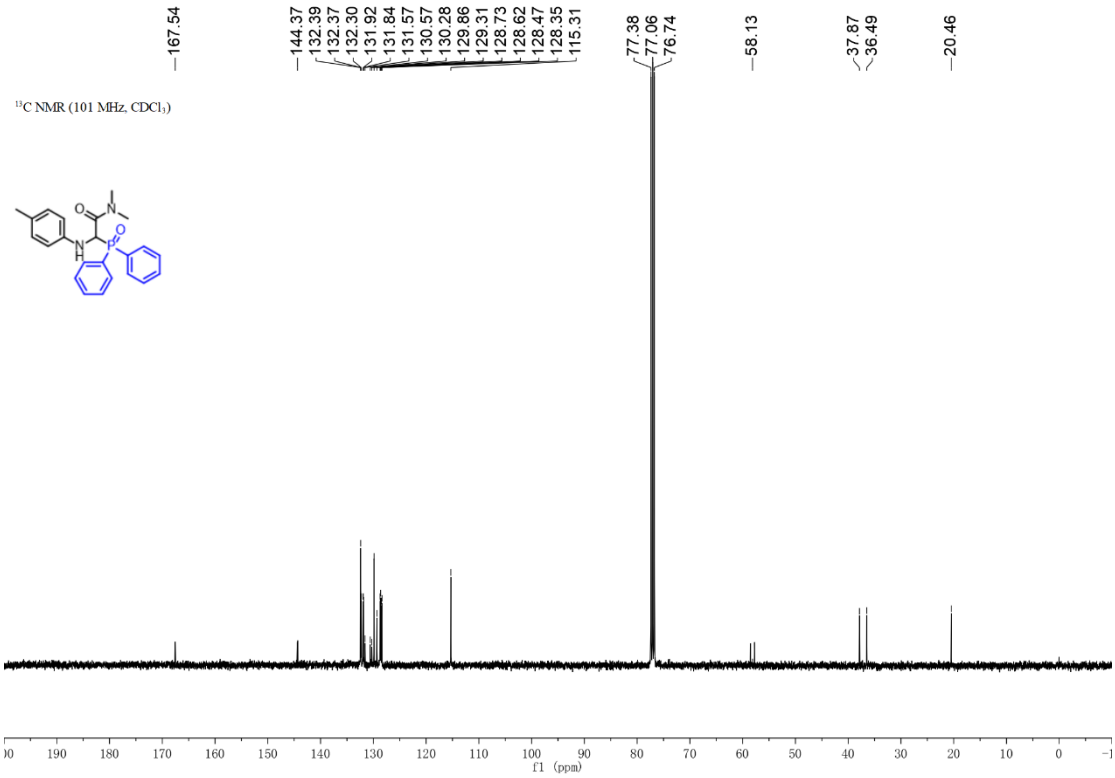
2-(diphenylphosphoryl)-1-(pyrrolidin-1-yl)-2-(*p*-tolylamino)ethan-1-one. (3oa)

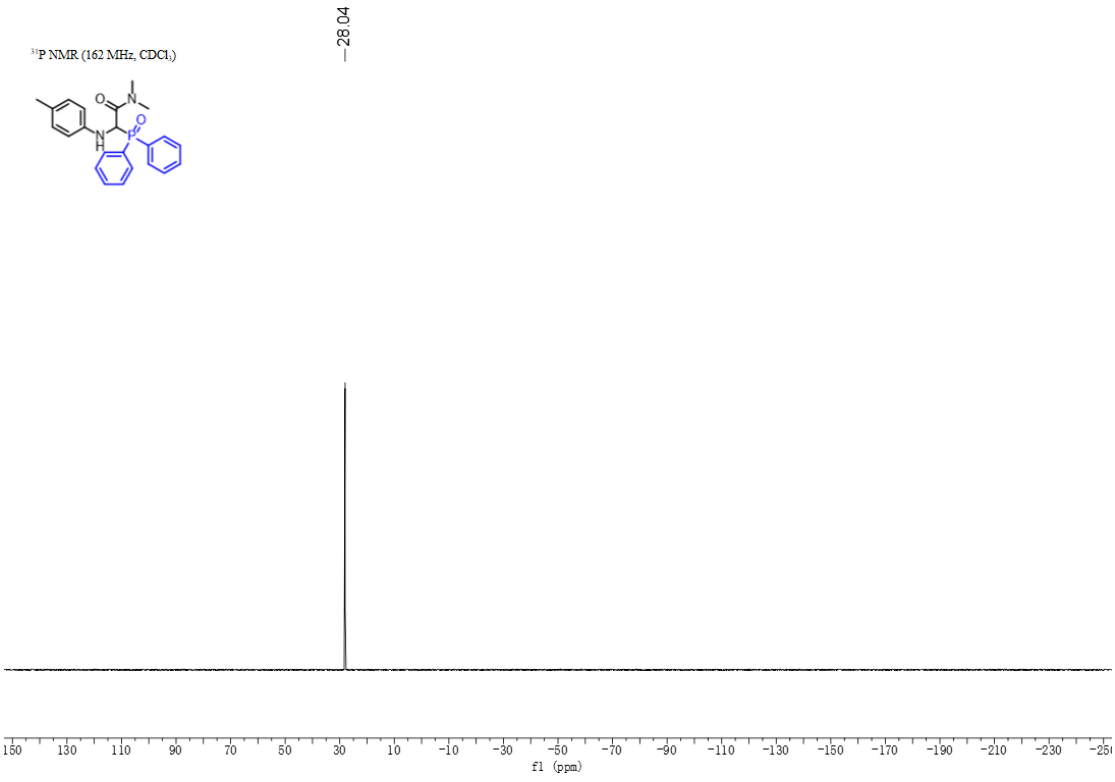




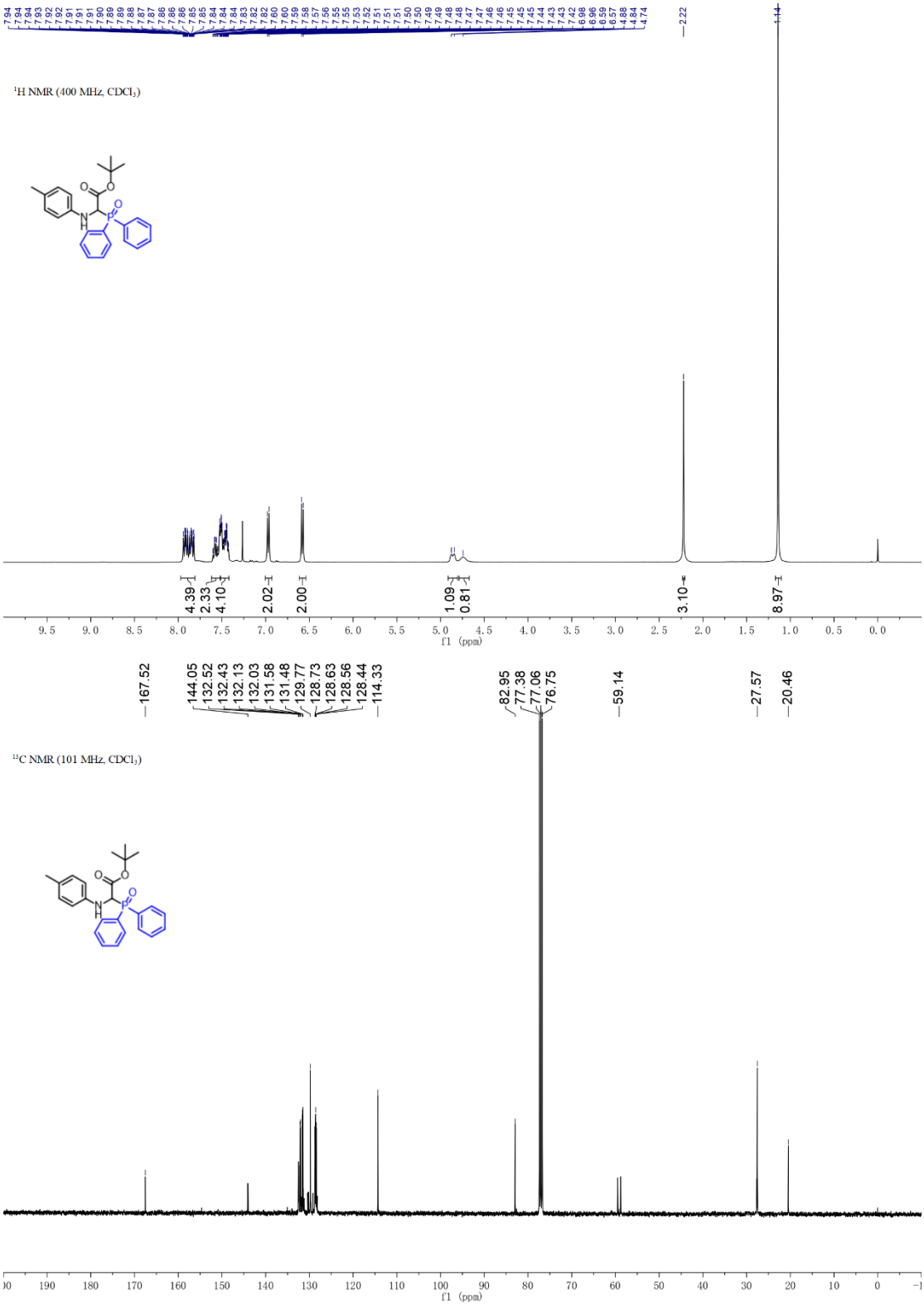
2-(diphenylphosphoryl)-N,N-dimethyl-2-(*p*-tolylamino)acetamide. (3pa)



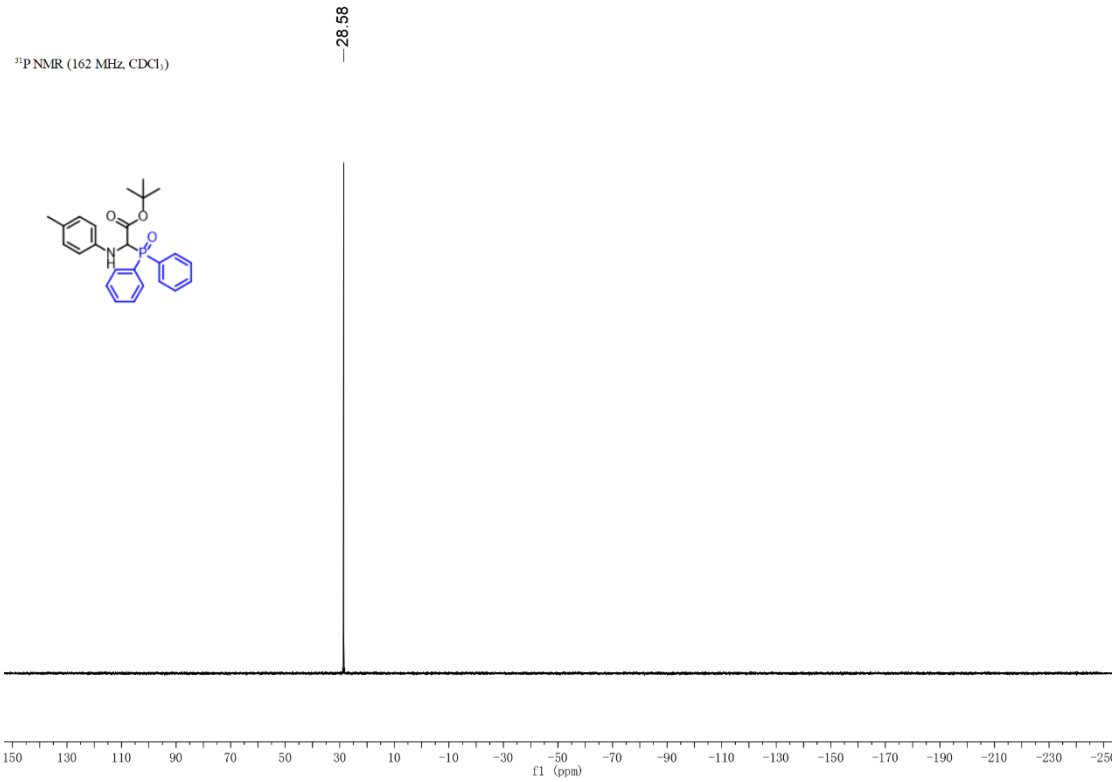

167.54
144.37
132.39
132.37
132.30
131.92
131.84
131.57
130.57
130.28
129.86
129.31
128.73
128.62
128.47
128.35
115.31
77.38
77.06
76.74
58.13
37.87
36.49
20.46
13C NMR (101 MHz, CDCl3)
f1 (ppm)


28.04
31P NMR (162 MHz, CDCl3)
f1 (ppm)

Tert-butyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (3qa)

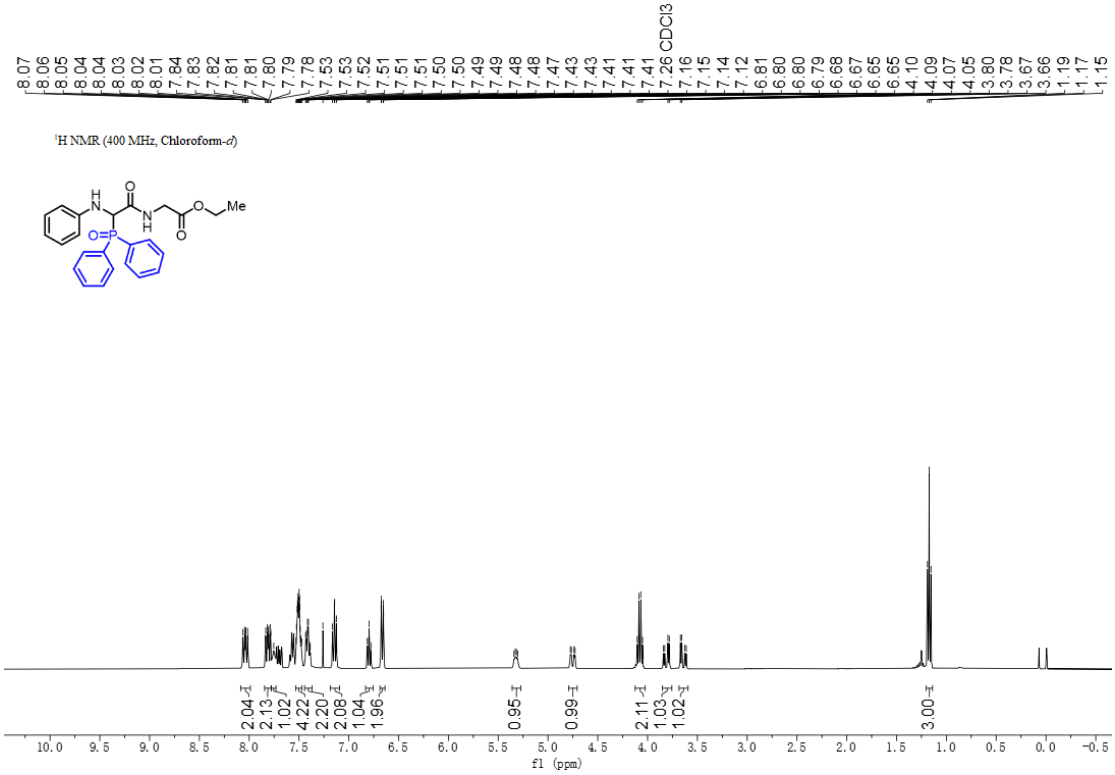


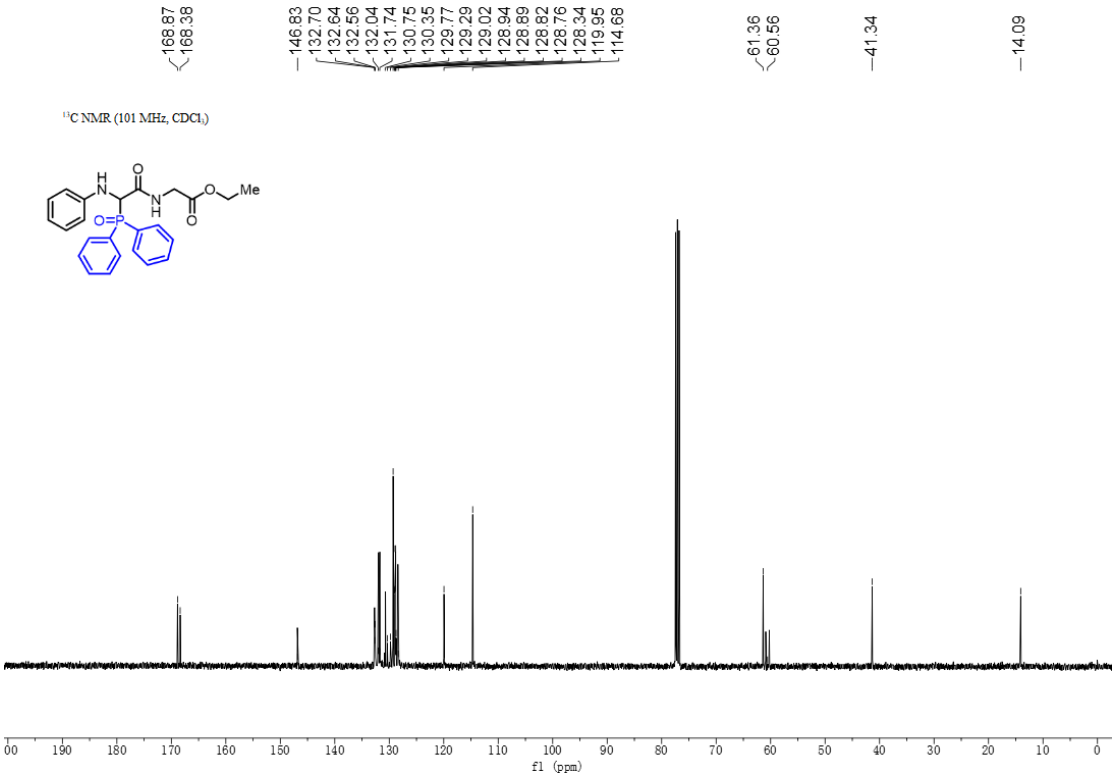
^{31}P NMR (162 MHz, $CDCl_3$)

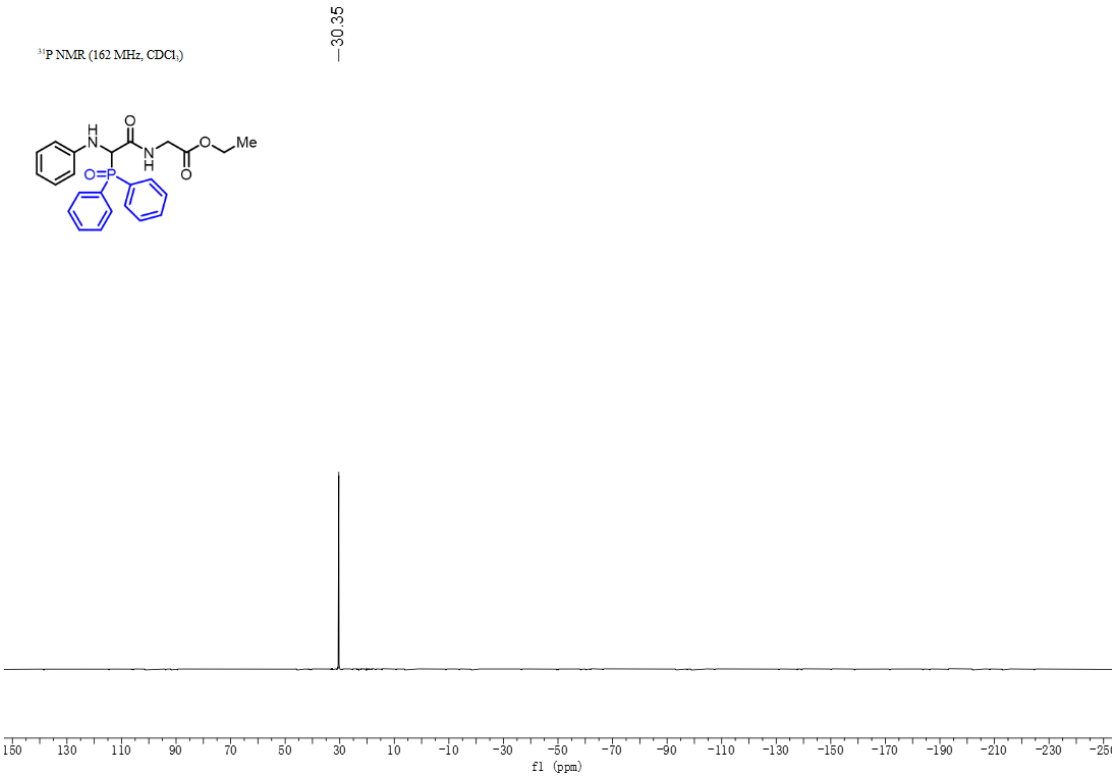


Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)glycinate. (4a)

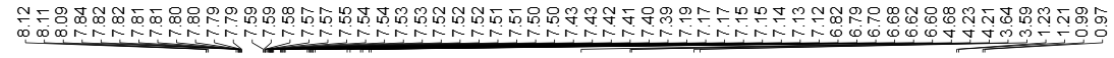
^{1}H NMR (400 MHz, Chloroform-*d*)



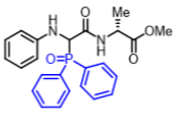

168.87
168.38
146.83
132.70
132.64
132.56
132.04
131.74
130.75
130.35
129.77
129.29
129.02
128.94
128.89
128.82
128.76
128.34
119.95
114.68
61.36
60.56
41.34
14.09
13C NMR (101 MHz, CDCl3)
Me
f1 (ppm)

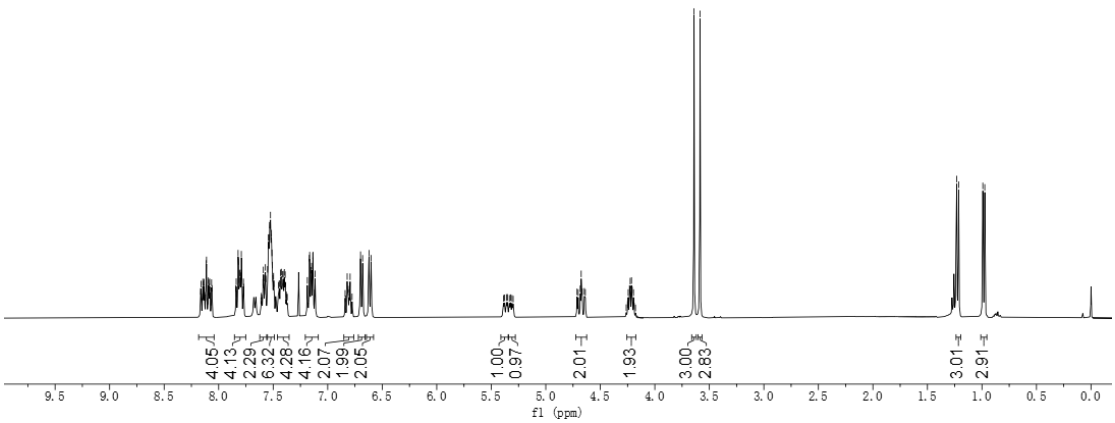

30.35
31P NMR (162 MHz, CDCl3)
Me
f1 (ppm)

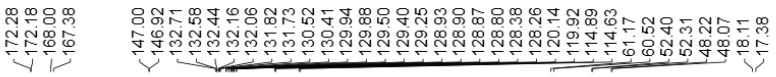
Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-D-alaninate. (4b)



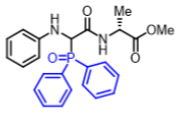
^{1}H NMR (400 MHz, Chloroform-*d*)

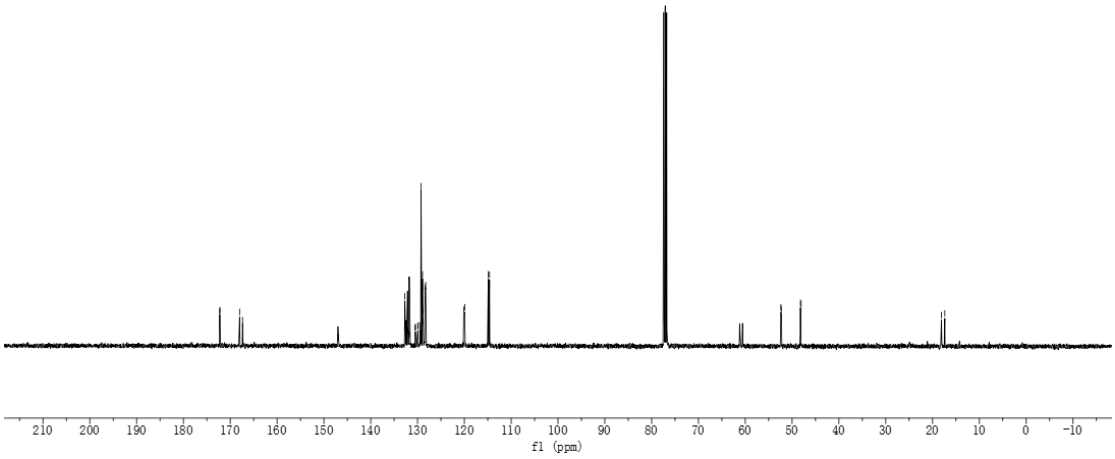


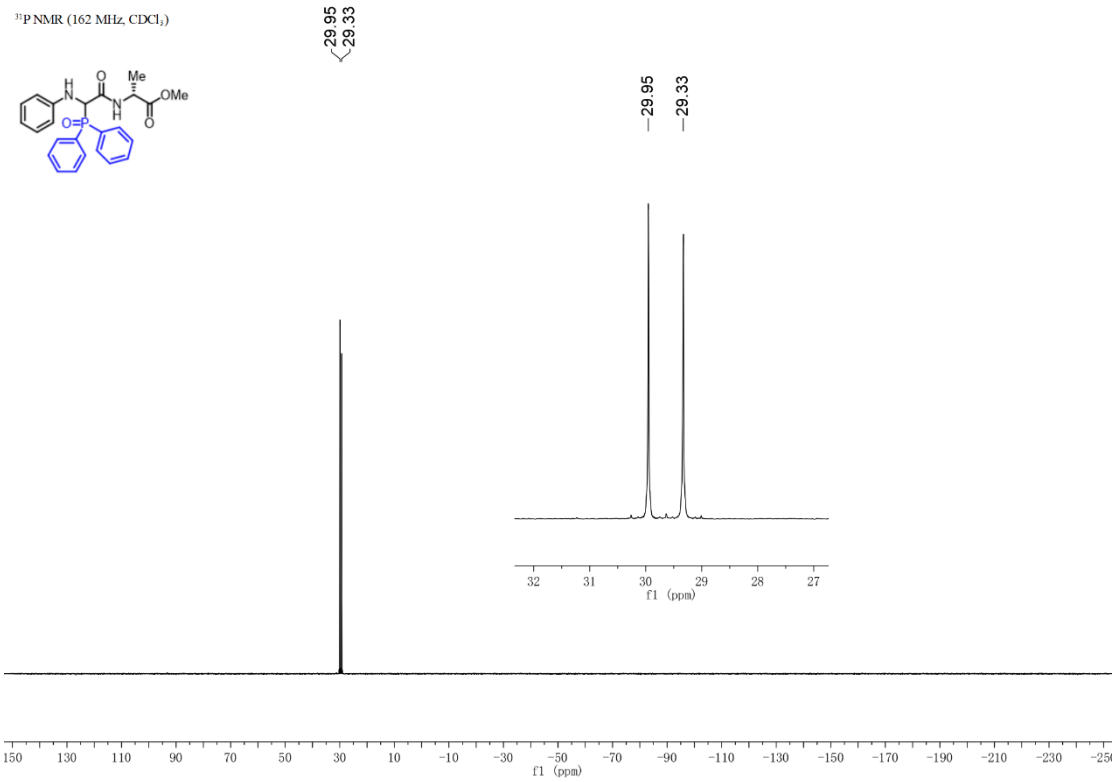




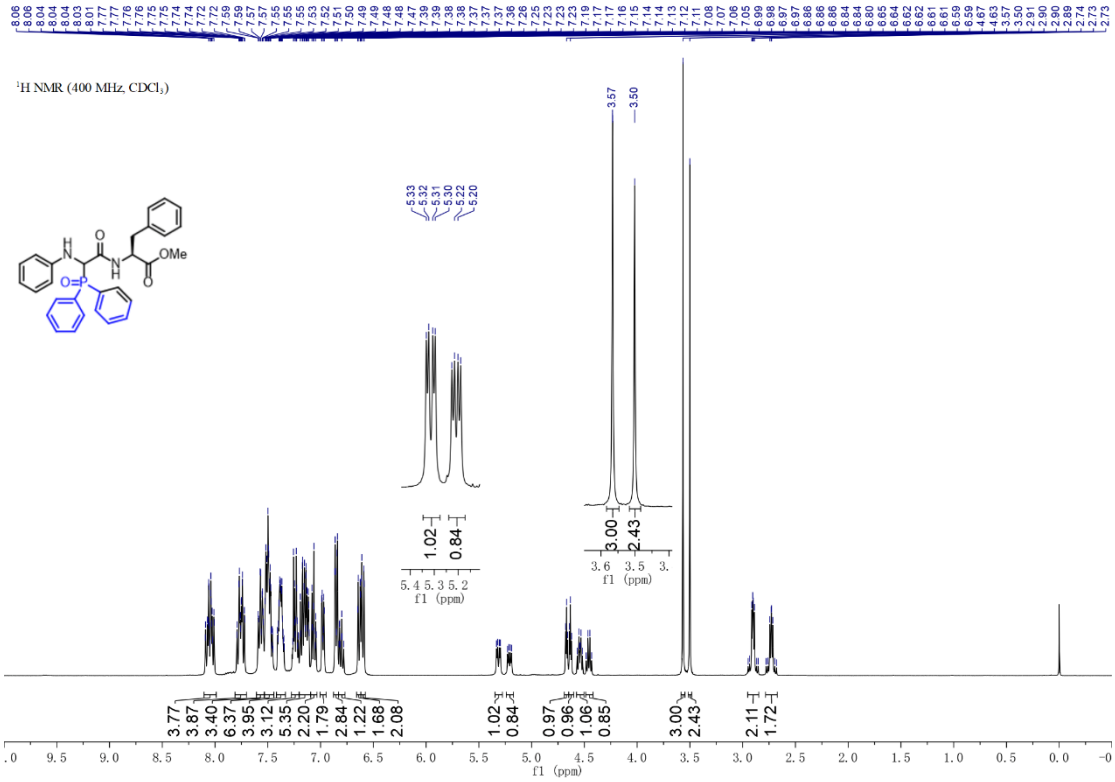
^{13}C NMR (101 MHz, $CDCl_3$)

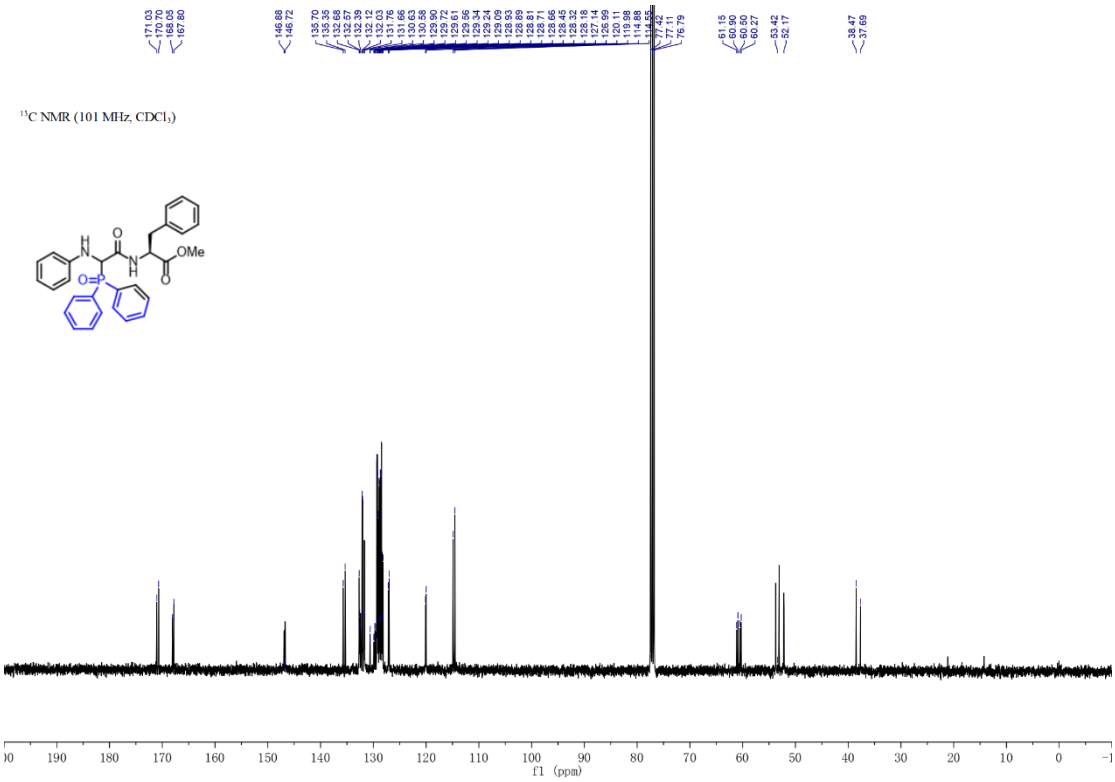


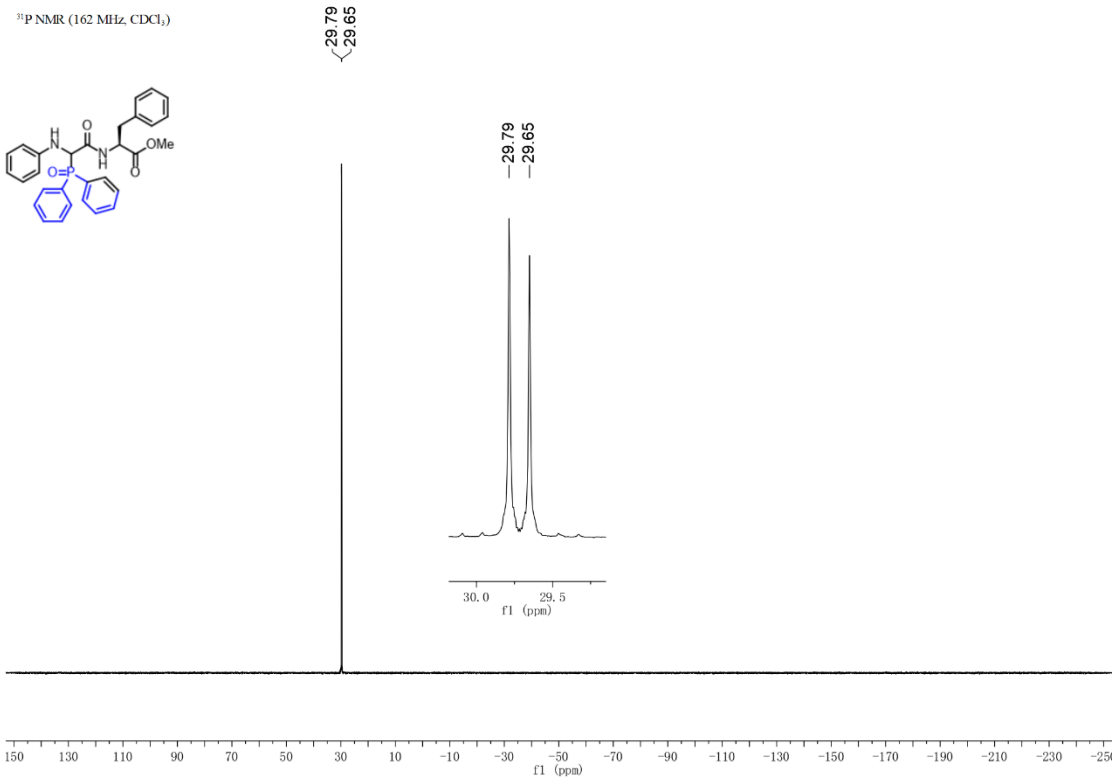




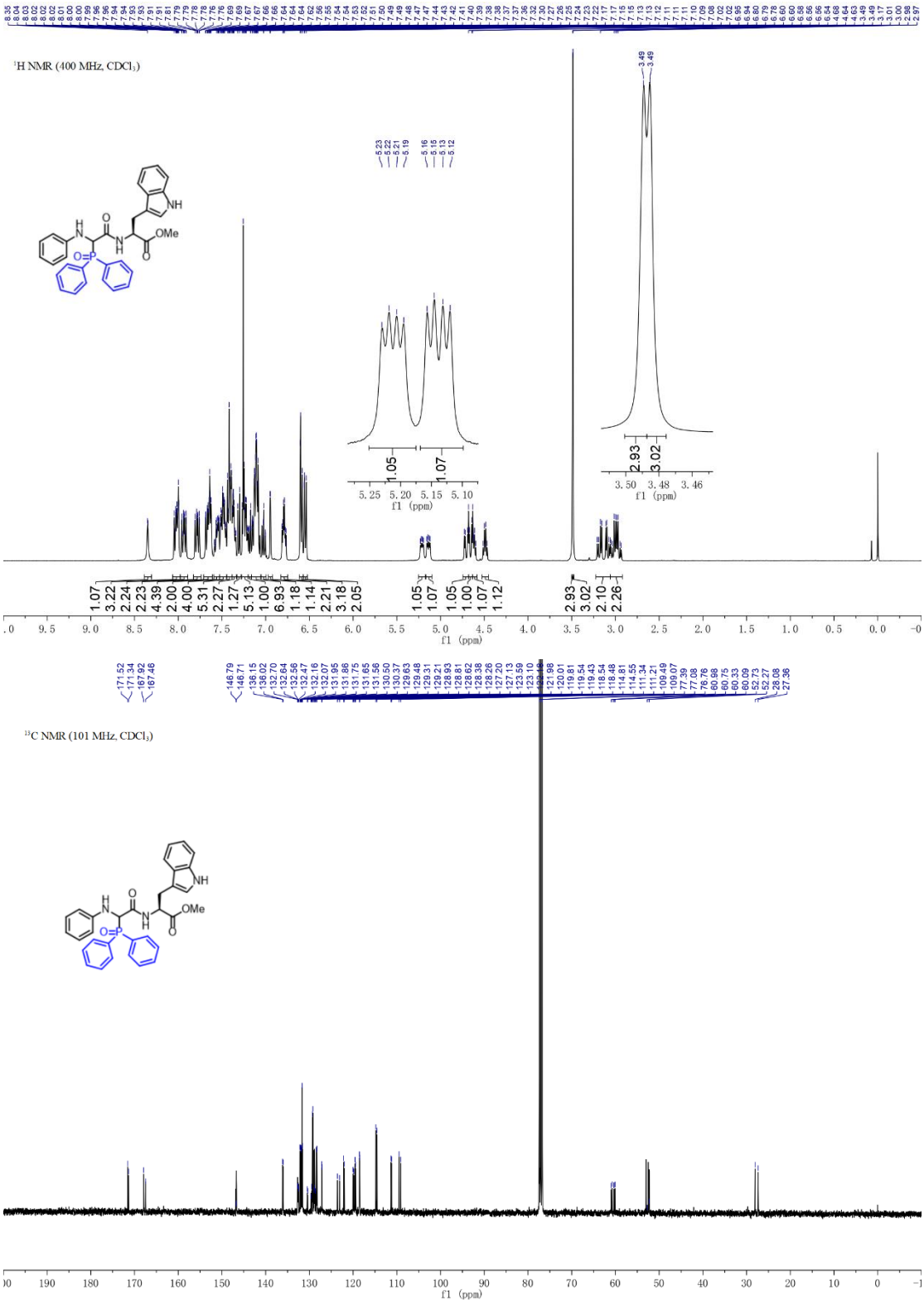
Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalaninate. (4c)

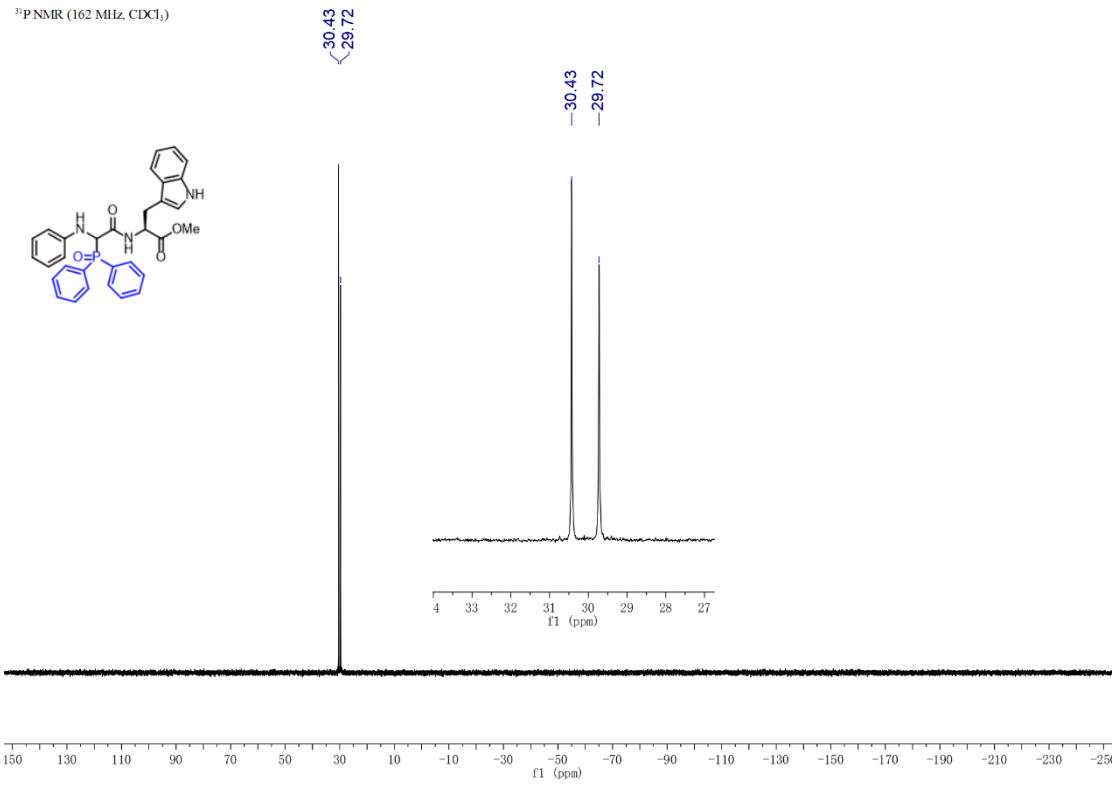



171.03
170.70
169.95
167.80
146.88
146.72
135.70
133.35
132.68
132.57
132.39
132.12
131.93
131.76
131.66
130.63
130.38
129.90
129.72
129.61
129.56
129.34
129.24
129.09
128.93
128.89
128.81
128.71
128.66
128.45
128.32
128.18
127.14
125.99
120.11
119.98
114.88
77.42
77.11
76.79
61.15
60.90
60.65
60.27
53.42
52.17
38.47
37.69
13C NMR (101 MHz, CDCl3)
OMe
f1 (ppm)

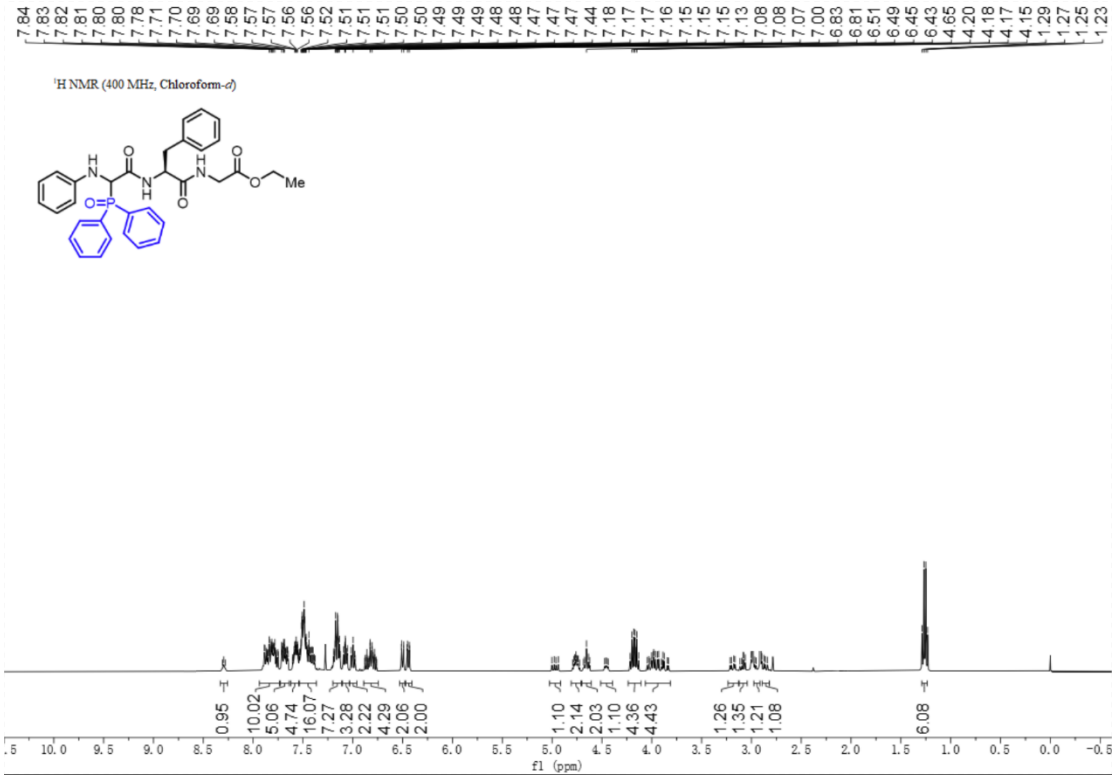

31P NMR (162 MHz, CDCl3)
29.79
29.65
OMe
30.0
29.5
f1 (ppm)
f1 (ppm)

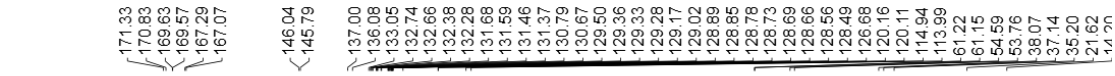
Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-tryptophanate. (4d)



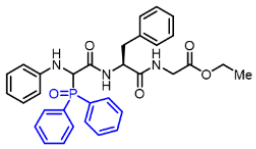


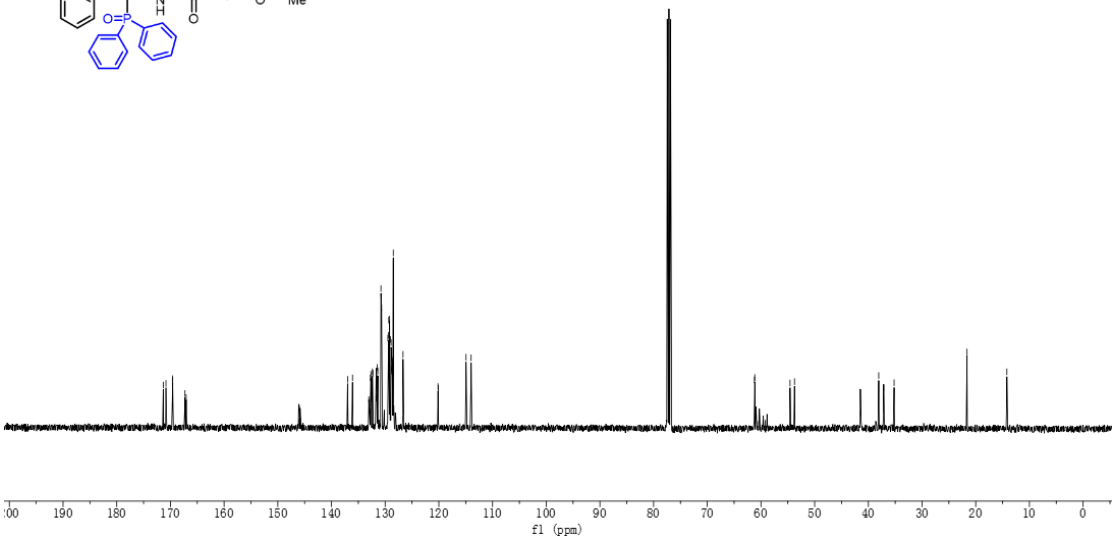
Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalanylglycinate. (4e)



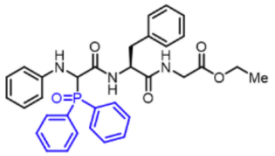


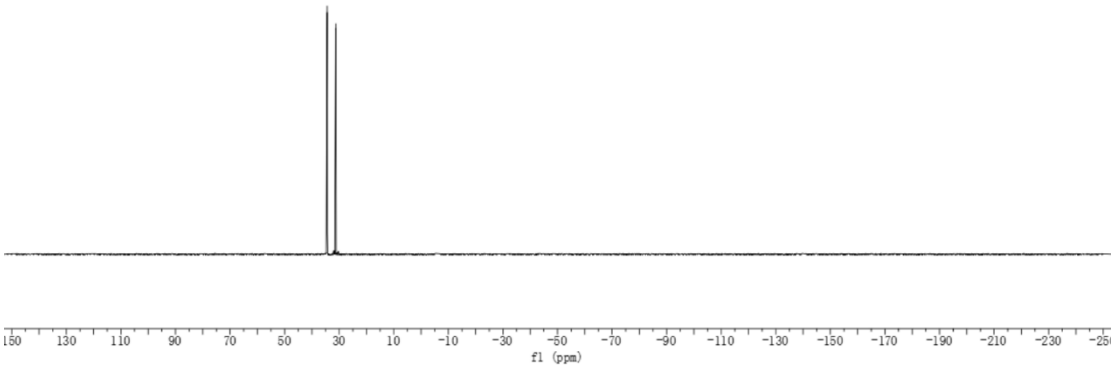
^{13}C NMR (101 MHz, $CDCl_3$)



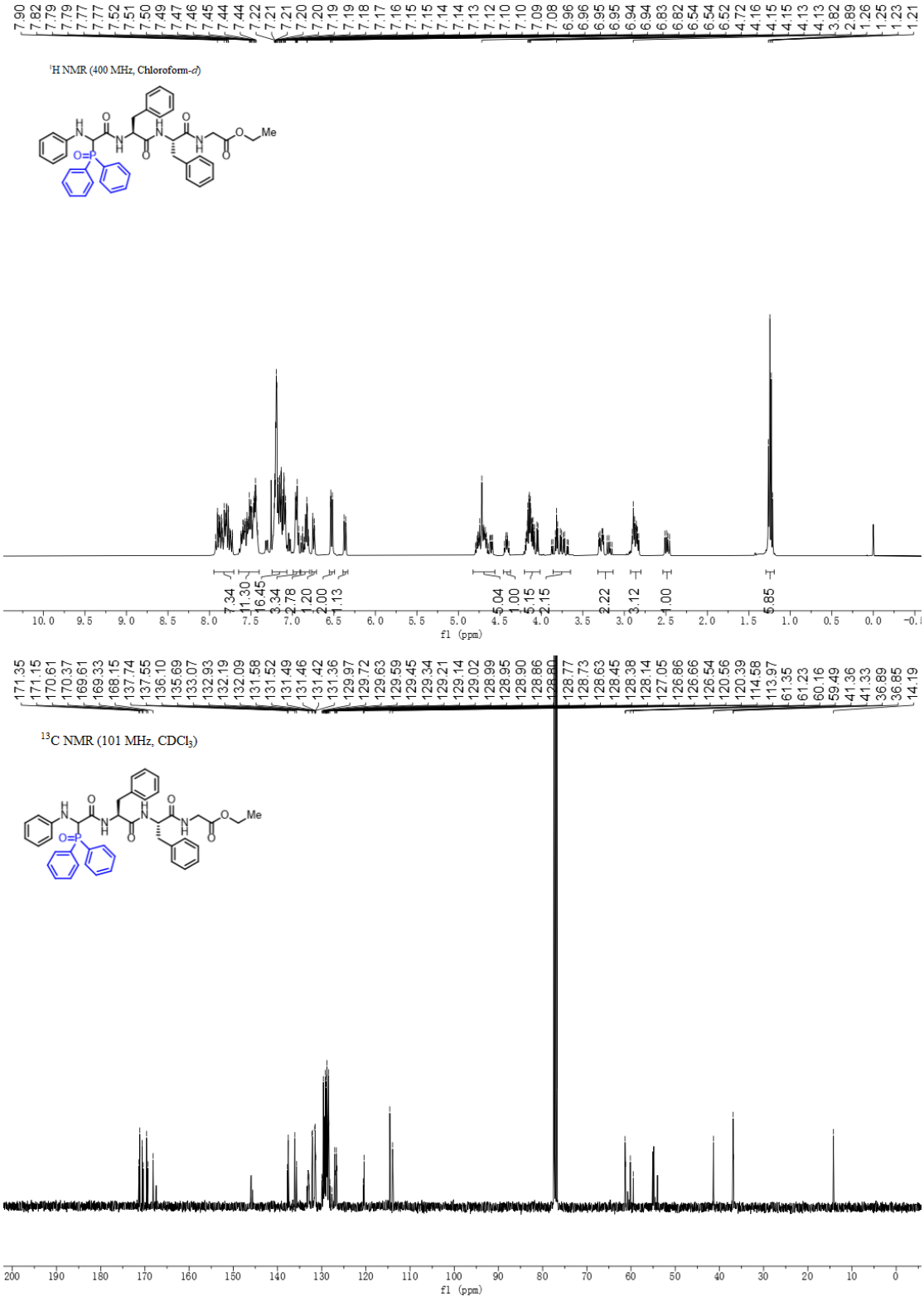


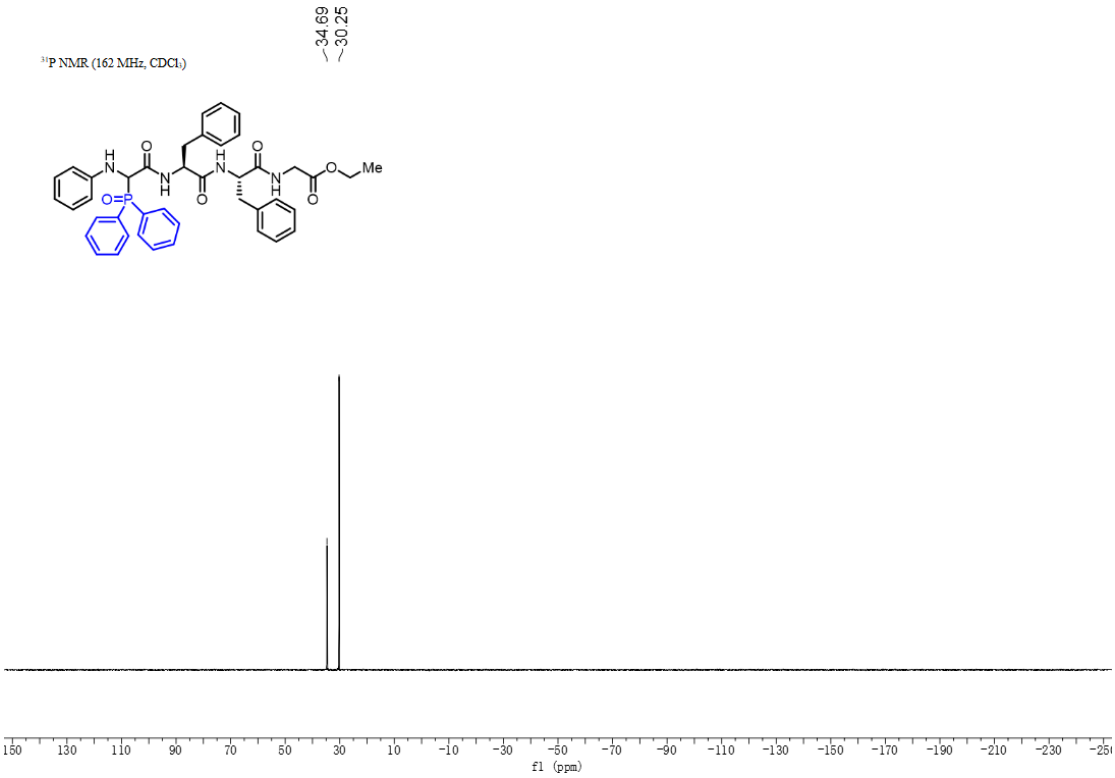
^{31}P NMR (162 MHz, $CDCl_3$)



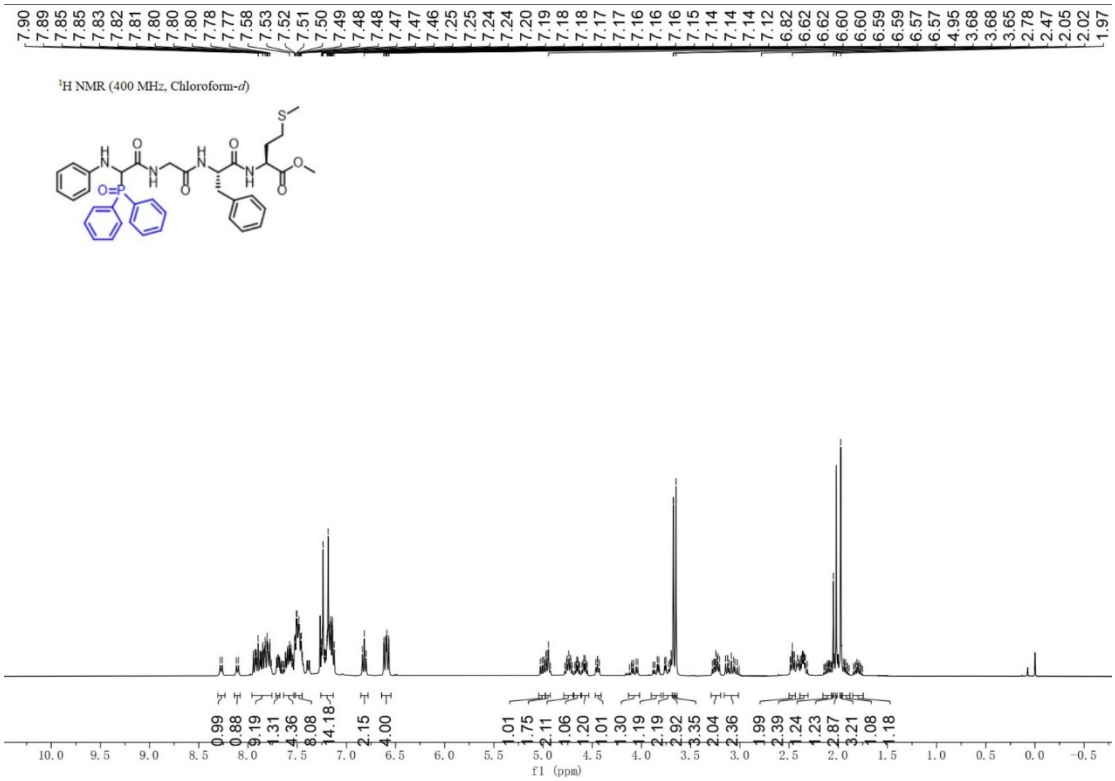


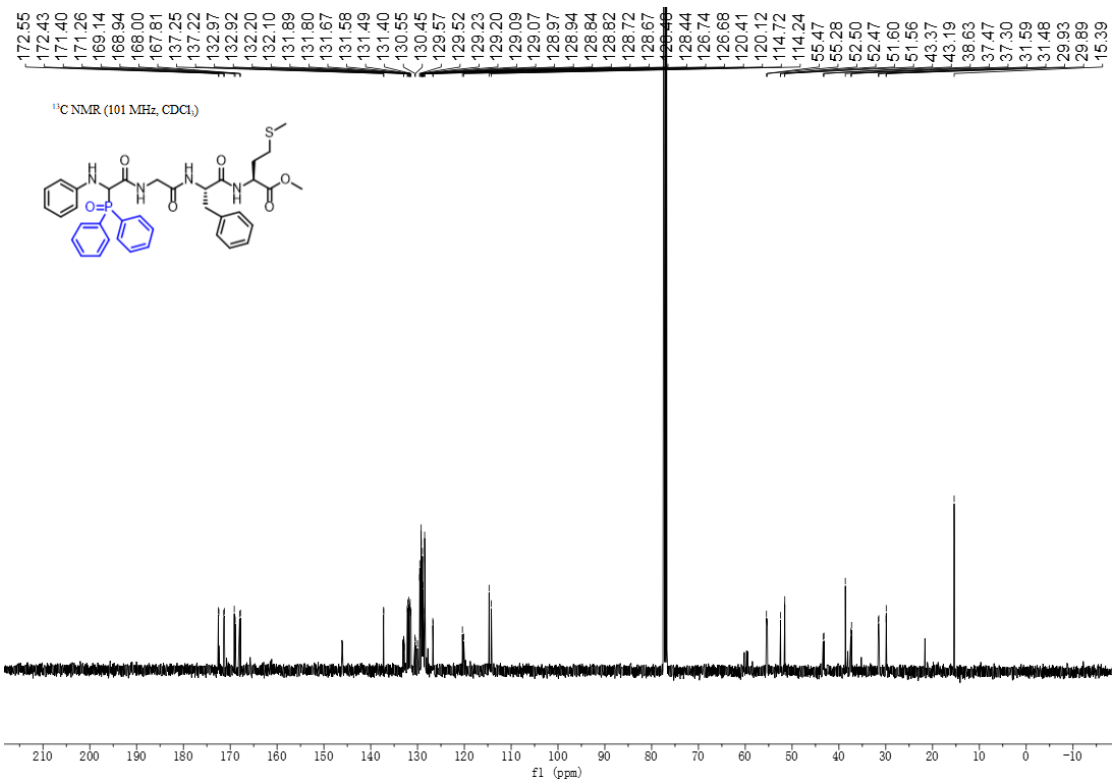
Ethyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)-L-phenylalanyl-L-phenylalanylglycinate. (4f)

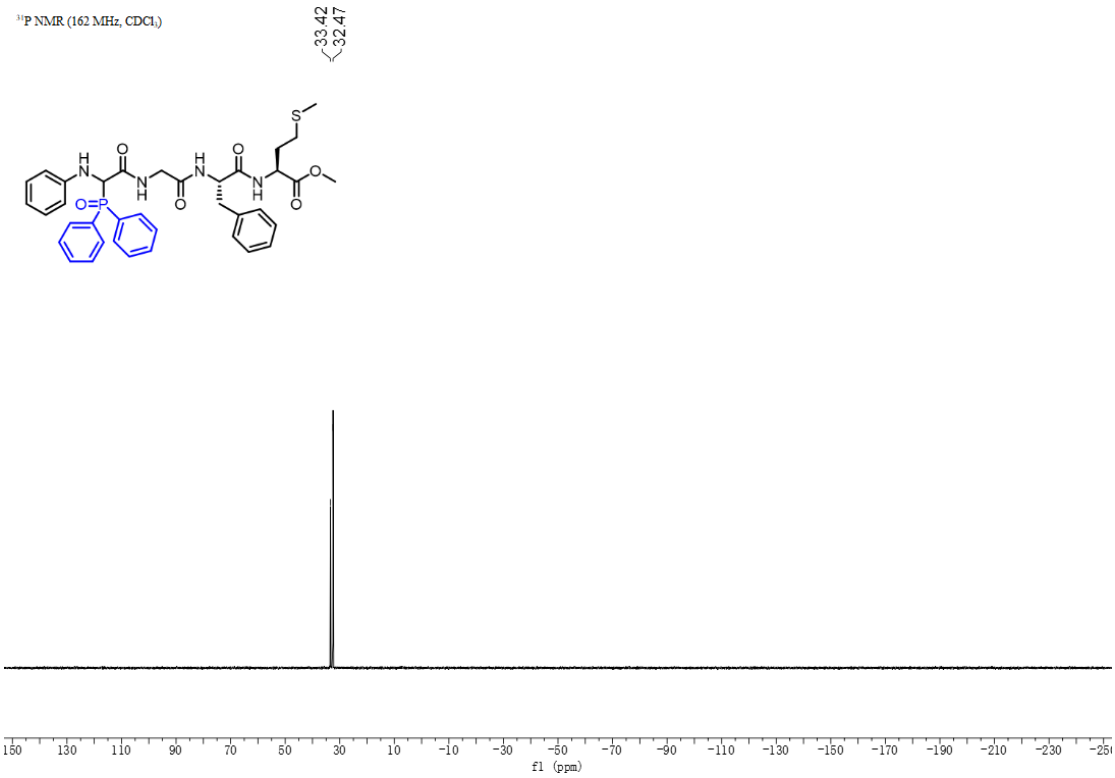




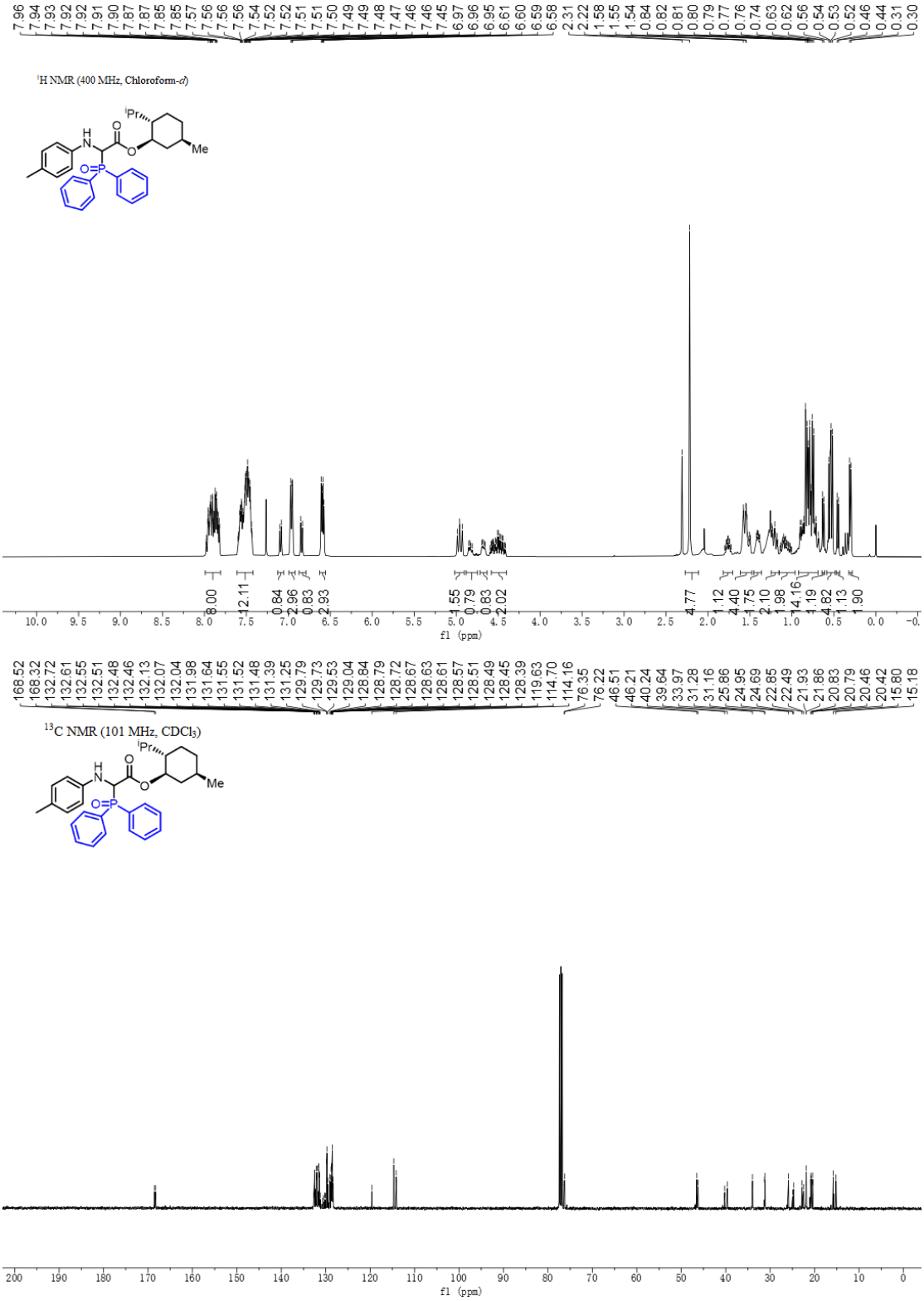
Methyl (2-(diphenylphosphoryl)-2-(phenylamino)acetyl)glycyl-L-phenylalanyl-L-methioninate. (4g)

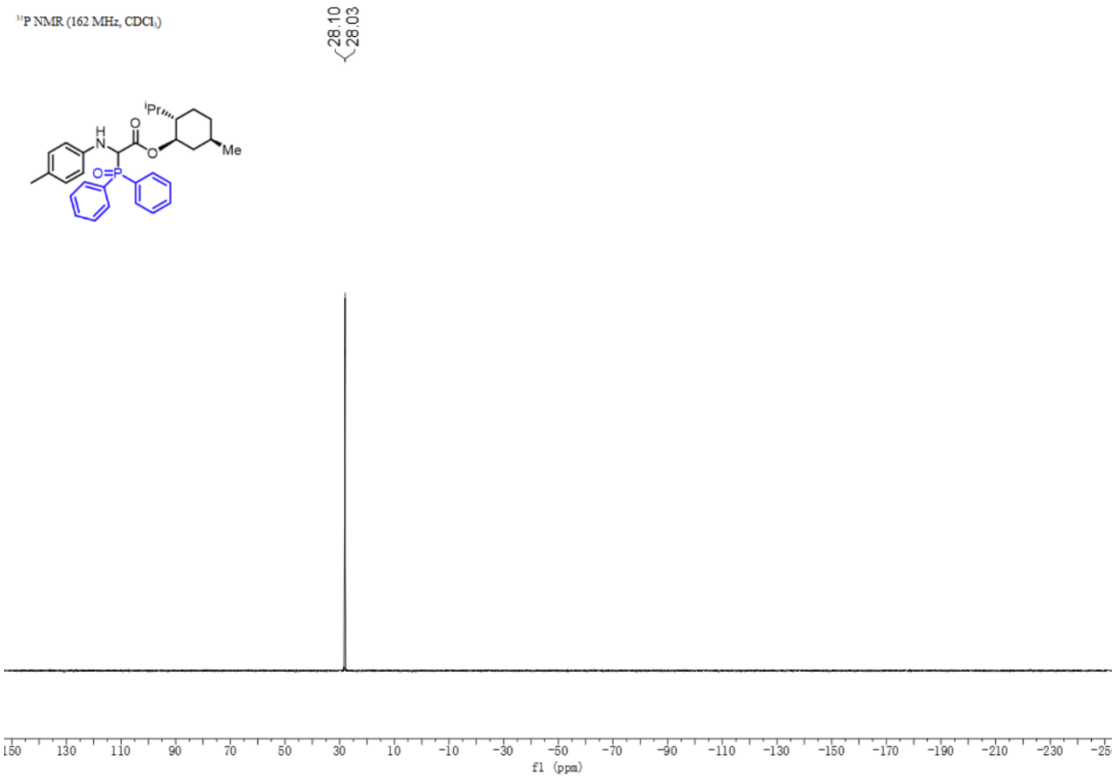



172.55
172.43
171.40
171.26
169.14
168.94
168.00
167.81
137.25
137.22
132.97
132.92
132.20
132.10
131.89
131.80
131.67
131.58
131.49
131.40
130.55
130.45
129.57
129.52
129.23
129.20
129.09
129.07
128.97
128.94
128.84
128.82
128.72
128.67
128.44
126.74
126.68
120.41
120.12
114.72
114.24
55.47
55.28
52.50
52.47
51.60
51.56
43.37
43.19
38.63
37.47
37.30
31.59
31.48
29.93
29.89
15.39
13C NMR (101 MHz, CDCl3)
f1 (ppm)

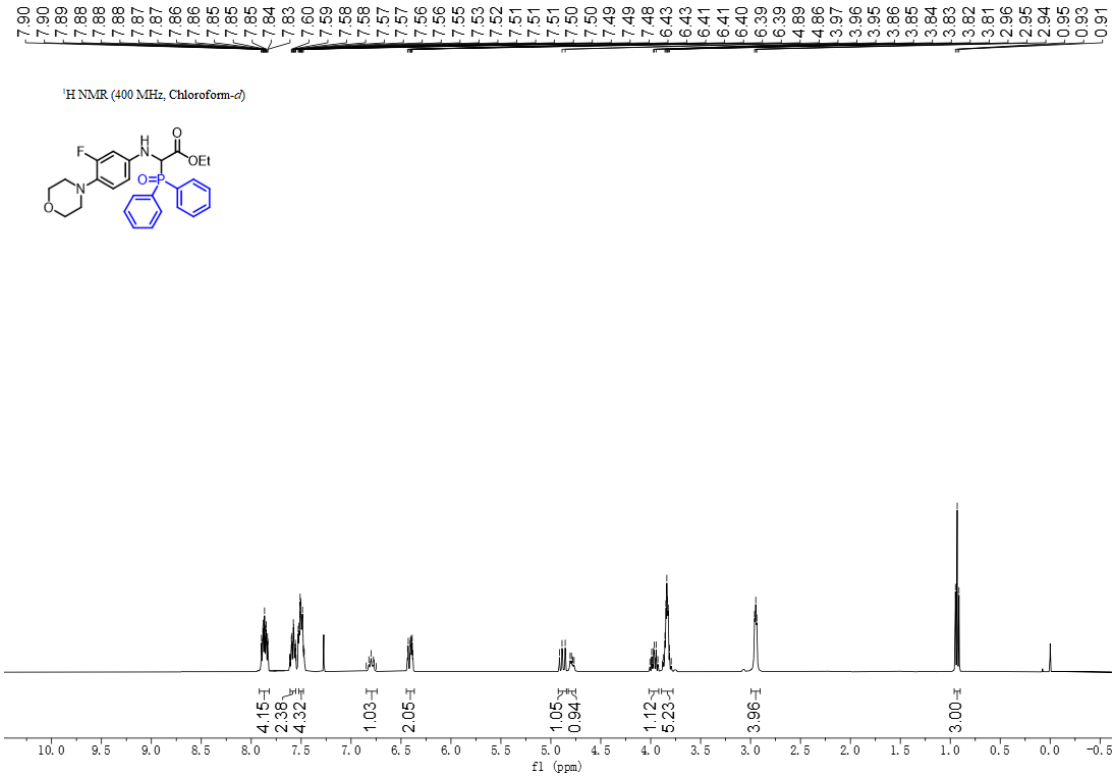

31P NMR (162 MHz, CDCl3)
33.42
32.47
f1 (ppm)

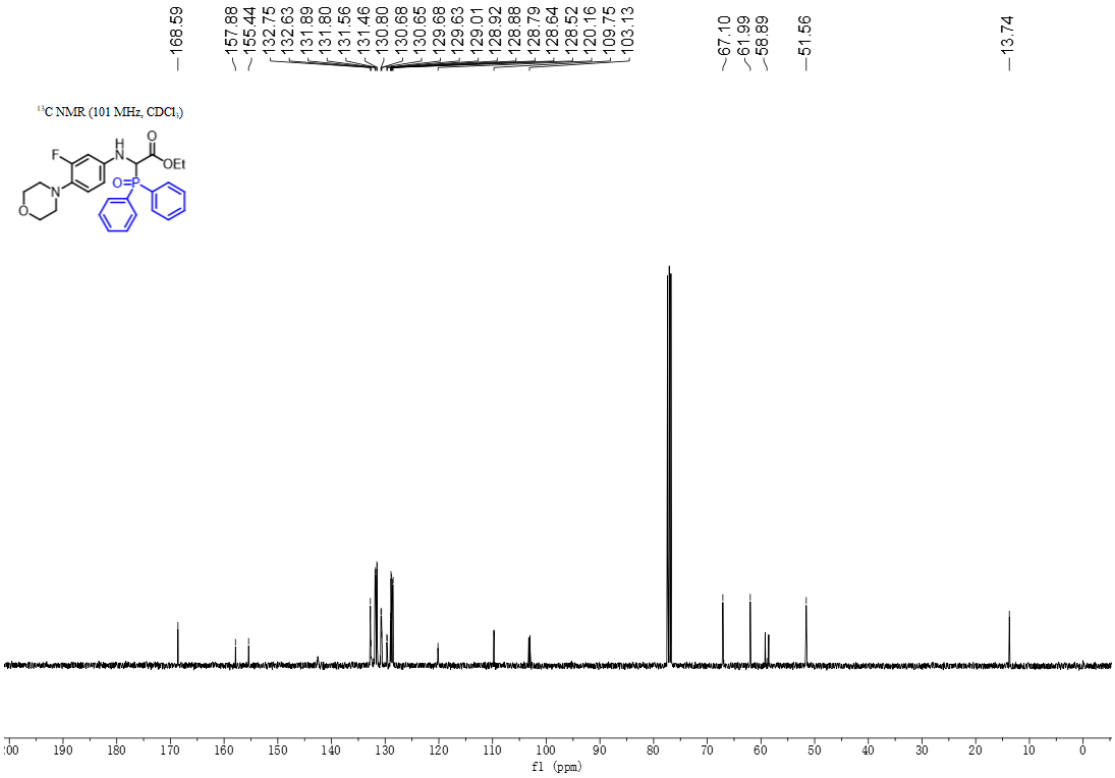
(1R,2S,5R)-2-isopropyl-5-methylcyclohexyl 2-(diphenylphosphoryl)-2-(*p*-tolylamino)acetate. (5a)

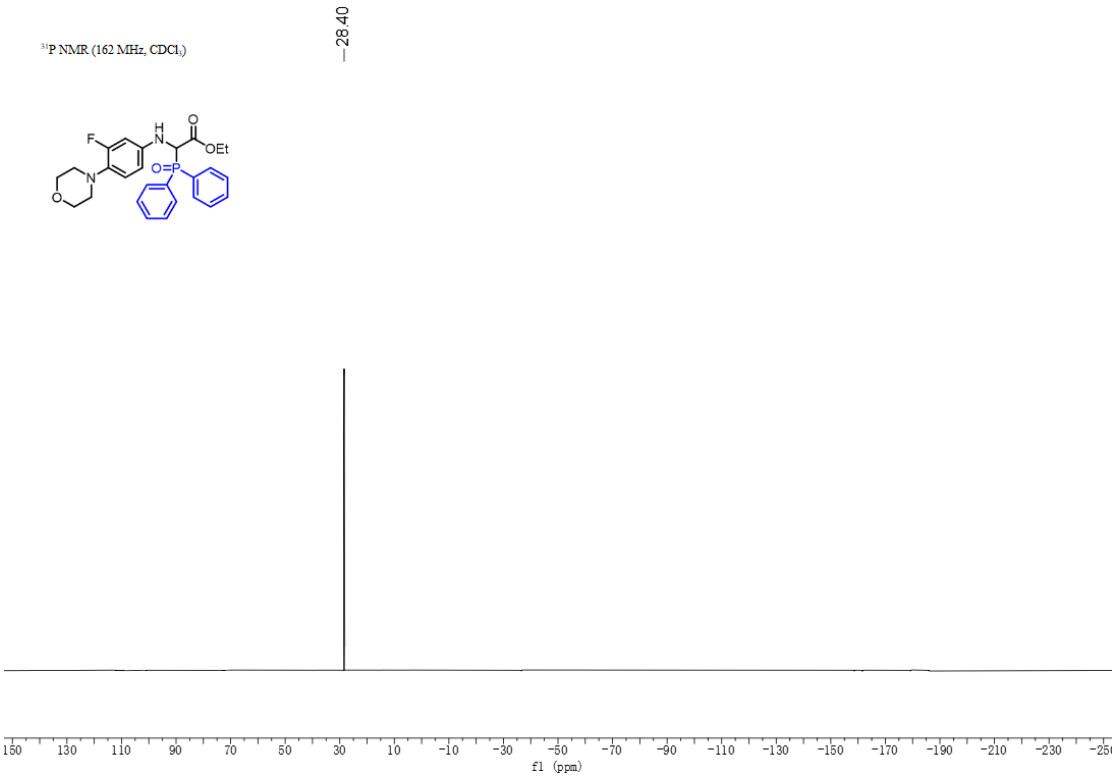




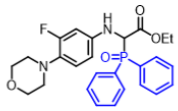
Ethyl2-(diphenylphosphoryl)-2-((3-fluoro-4-morpholinophenyl)amino)acetate. (5b)




168.59
157.88
155.44
132.75
132.63
131.89
131.80
131.56
131.46
130.80
130.68
130.65
129.68
129.63
129.01
128.92
128.88
128.79
128.64
128.52
120.16
109.75
103.13
67.10
61.99
58.89
51.56
13.74
13C NMR (101 MHz, CDCl3)
F
N
H
O
OEt
O=P
N
O
f1 (ppm)

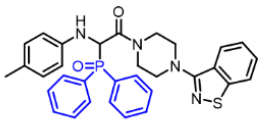

28.40
31P NMR (162 MHz, CDCl3)
F
N
H
O
OEt
O=P
N
O
f1 (ppm)

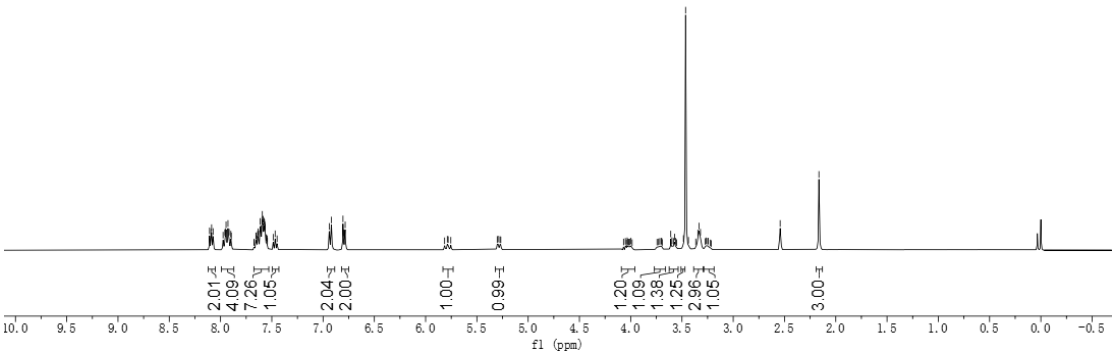
^{19}F NMR (376 MHz, $CDCl_3$)

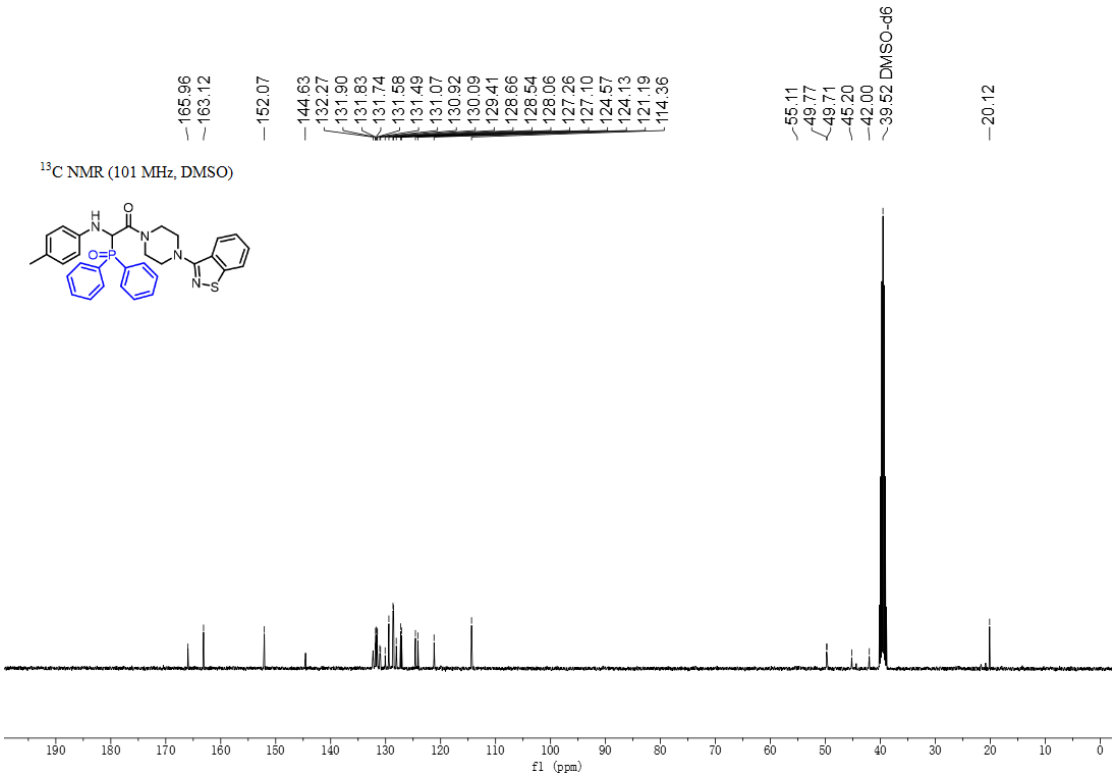


1-(4-(benzo[d]isothiazol-3-yl)piperazin-1-yl)-2-(diphenylphosphoryl)-2-(*p*-tolylamino)ethan-1-one. (5c)

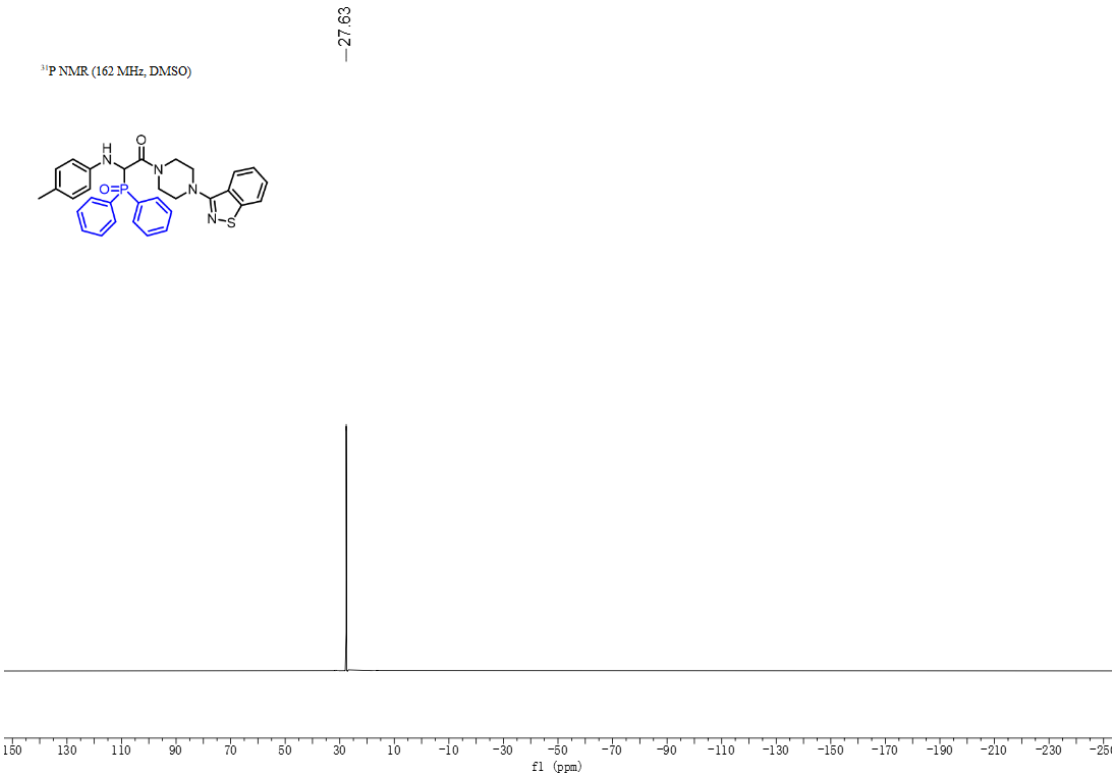
^{1}H NMR (400 MHz, DMSO-d_6)





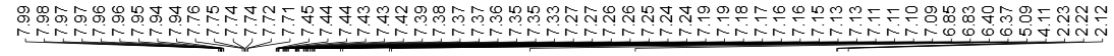


^{13}C NMR (101 MHz, DMSO)

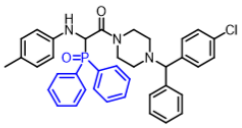


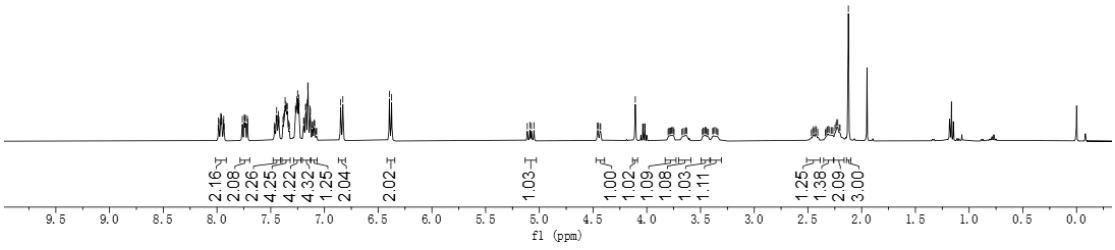
^{31}P NMR (162 MHz, DMSO)

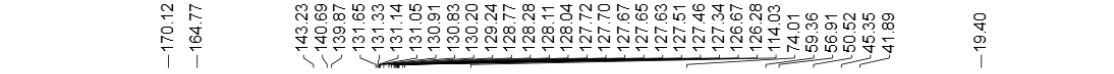
1-(4-((4-chlorophenyl)(phenyl)methyl)piperazin-1-yl)-2-(diphenylphosphoryl)-2-(*p*-tolylamino)ethan-1-one. (5d)



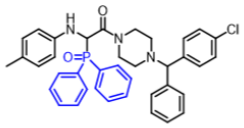
^{1}H NMR (400 MHz, Chloroform-*d*)

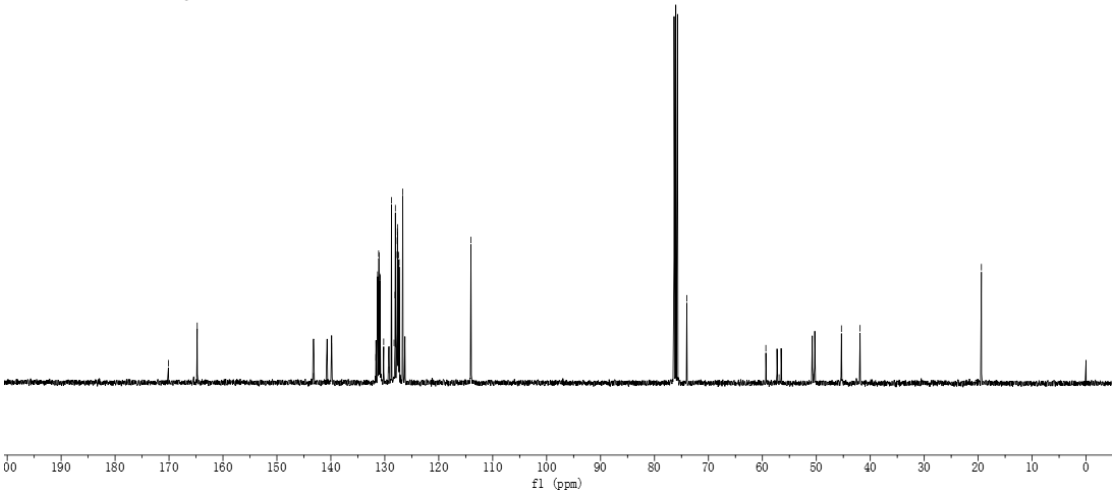




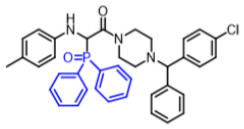


^{13}C NMR (101 MHz, $CDCl_3$)





^{31}P NMR (162 MHz, $CDCl_3$)



27.53