# Supporting Information

## Bronsted acid/organic photoredox cooperative catalysis: Easy access to *tri*- and *tetra*-substituted alkenylphosphorus compounds from alcohols and P-H species

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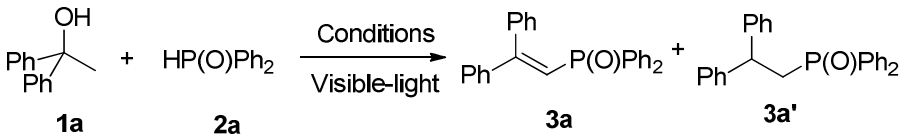
## Contents

# 1. General Information

Unless otherwise noted, all commercially available compounds were used as received. All solvents were purified according to standard procedures. The $^{1}H$ NMR and spectra was recorded at 400MHz, $^{13}C$ NMR was recorded at 101MHz. $^{31}P$ NMR was recorded at 162 MHz. $^{1}H$ and $^{13}C$ NMR Chemical shifts were calibrated to tetramethylsilane as an external reference. Data are reported in the following order: chemical shift (δ) in ppm; multiplicities are indicated s (singlet), d (doublet), t (triplet), dd (doublet of doublets), m (multiplet); coupling constants (*J*) are in Hertz (Hz). The data with an asterisk (*) indicate peaks of the by-products **3'**. IR spectra were recorded on a Thermo Scientific Nicolet iS-5 FT-IR spectrometer and are reported in terms of frequency of absorption ($cm^{-1}$). HRMS were obtained on an IonSpec FT-ICR mass spectrometer with ESI resource. Melting points were measured on a RY-I apparatus and are reported uncorrected. The starting materials **1a**, **2a** purchased from *Energy-chemical Ltd*. *p*-Toluenesulfonic acid purchased from *MERYER CO. LTD*. *tert*-Butyl hydroperoxide was purchased from *Sigma-Aldrich LLC*. Other phosphine oxides **2**[1], ($R_P$)-menthylphosphine oxide [2] and alcohols[3] were readily prepared according to the related literatures. The LEDs were TORNADO (23W), CoolDaylight purchased from *Philips N.V*.

# 2. Screening reaction conditions

**Table 1. Optimization of the Reaction Conditions** [a]




**1a** **2a** **3a** **3a'**

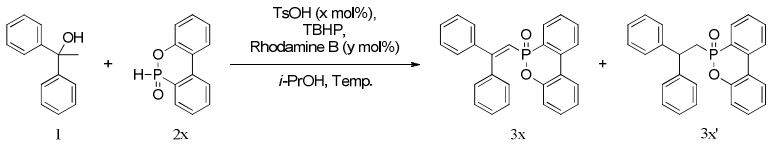
| Entry | Cat.(mol%) | Sol. | [O] | Yield (%) [b] | 3a/3a' [c] |
|---|---|---|---|---|---|
| 1 | TsOH (20), $RhBH^{+}$(2) | *i*-PrOH | air | 11 | 94/6 |
| 2 | TsOH (20), $RhBH^{+}$(2) | *i*-PrOH | $O_2$ | 23 | 91/9 |
| 3 | TsOH (20), $RhBH^{+}$ (2) | *i*-PrOH | $K_2S_2O_8$ | 20 | 79/21 |
| 4 | TsOH (20), $RhBH^{+}$ (2) | *i*-PrOH | DDQ | trace | -/- |
| 5 | TsOH (20), $RhBH^{+}$ (2) | *i*-PrOH | TBHP | 80 (98) | >99/1 |
| 6 | TFA (20), $RhBH^{+}$ (2) | *i*-PrOH | TBHP | 20 | 69/31 |
| 7 | $PhCO_2H$ (20), $RhBH^{+}$ (2) | *i*-PrOH | TBHP | 20 | 69/31 |
| 8 | $HNTf_2$ (20), $RhBH^{+}$ (2) | *i*-PrOH | TBHP | 77 | 98/2 |
| 9 | TsOH (20), Eosin Y (2) | *i*-PrOH | TBHP | 60 | 92/8 |
| 10 | TsOH (20), Eosin B (2) | *i*-PrOH | TBHP | 26 | 97/3 |
| 11 | TsOH (20), Eosin B (2) (alcohol soluble) | *i*-PrOH | TBHP | 32 | 97/3 |
| 12 | TsOH (20), $RhBH^{+}$ (2) | $CH_3CN$ | TBHP | 59 | 79/21 |
| 13 | TsOH (20), $RhBH^{+}$ (2) | DCE | TBHP | 35 | 97/3 |
| 14 | TsOH (20), $RhBH^{+}$ (2) | DMF | TBHP | 25 | 74/26 |
| 15 | TsOH (20), $RhBH^{+}$ (2) | Tol. | TBHP | 10 | 94/6 |
| 16 | TsOH (20), $RhBH^{+}$ (2) | *t*-BuOH | TBHP | 35 | 74/26 |
| 17 | TsOH (20), $RhBH^{+}$ (2) | EtOH | TBHP | 63 | 81/19 |

| | | | | | |
|---|---|---|---|---|---|
| 18 | TsOH (20) | *i*-PrOH | TBHP | 60 | 48/52 |
| 19 | $RhBH^+$ (2) | *i*-PrOH | TBHP | trace | -/- |
| 20 | TsOH (10), $RhBH^+$ (2) | *i*-PrOH | TBHP | 36 | >99/1 |
| 21 | TsOH (20), $RhBH^+$ (1) | *i*-PrOH | TBHP | 83 | 90/10 |
| 22 [d] | TsOH (20), $RhBH^+$ (2) | *i*-PrOH | TBHP | 8 | 96/4 |
| 23 [e] | TsOH (20), $RhBH^+$ (2) | *i*-PrOH | TBHP | 51 | 95/5 |

[a] Experimental conditions see the General method. [b] Isolated yields. [c] The ratio of **3a**/**3a'** was determined by $^{31}P$ NMR. [d] Performed at room temperature. [e] Performed at 50 °C. Result in the parentheses was carried out with 4.0 equivalent (8.0 h later, the second 2.0 equivalent TBHP was then added) of TBHP.

**3a'**was known compounds, while cannot be isolated in this reaction. Thus, we also prepared **3a'** according to the literature [4] and set its data as reference to analysis the ratio between **3a**/**3a'** by NMR. 1H NMR (400 MHz, CDCl3) δ 7.66 – 7.51 (m, 4H), 7.44 – 7.35 (m, 2H), 7.33 – 7.26 (m, 4H), 7.23 – 7.15 (m, 4H), 7.15 – 7.08 (m, 4H), 7.07 – 7.01 (m, 2H), 4.70 (dt, *J* = 11.8, 7.1 Hz, 1H), 3.10 (dd, *J* = 11.0, 7.2 Hz, 2H). $^{13}C$ NMR (101 MHz, $CDCl_3$) δ 143.96 (d, $J_{C-P}$ = 7.2 Hz), 131.39 (d, $J_{C-P}$ = 2.2 Hz), 130.78, 130.68, 128.49, 128.36, 127.91, 126.50, 44.55 (d, $J_{C-P}$ = 2.7 Hz), 36.60 (d, $J_{C-P}$ = 70.4 Hz). $^{31}P$ NMR (162 MHz, Chloroform-d) δ = 30.21.

**Table 2. Optimization of the Reaction Conditions with 2x [a]**

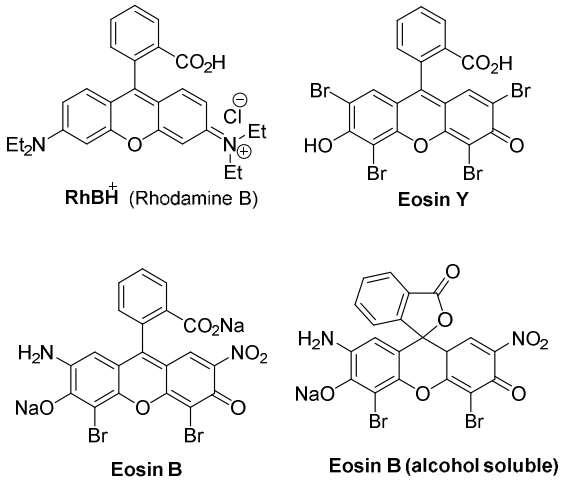



1 2x 3x 3x'

| Entry | x | y | Temp. ($^oC$) | Yield (%) [b] | 3x/3x' [c] |
|---|---|---|---|---|---|
| 1 | 25 | 2 | 80 | 32 | >99/1 |
| 2 | 30 | 2 | 80 | 34 | >99/1 |
| 3 | 20 | 5 | 80 | 34 | >99/1 |
| 4 | 20 | 10 | 80 | 28 | >99/1 |
| 5 | 20 | 2 | 60 | 36 | >99/1 |

[a] Experimental conditions see the General method. [b] Isolated yields. [c] The ratio of **3x/3x'** was determined by $^{31}P$ NMR.

**Figure 1. Structures of Organic Photoredox Catalysts.**




# 3. General Procedure for the substituted alkenylphosphorus compounds.

Alcohol **1** (0.2 mmol), phosphine oxide **2** (0.6 mmol), TsOH 20 mol%, Rhodamine B (2 mol%) and 2 mL $^{i}$PrOH were added into a tube. The reaction was stirred at 80 $^{o}$C under $N_2$ for 30 min. 2 eq. TBHP (~5.5mol/L in decane) was injected into the tube. 8 h later the second 2.0 eq. TBHP was then added. All of the reactions were performed under two white LED (23 W). After complete conversion, volatiles were removed under reduced pressure. The residue was purified *via* PTLC (Petroleum ether (bp: 60-90 $^{o}$C)/ethyl acetate = 2:3) or column chromatography (Petroleum ether (bp: 60-90 $^{o}$C)/ethyl acetate = 1:1) to afford the corresponding products **3a-3aa**. In most examples, pure **3** can be isolated by column chromatography or PTLC. The $R_f$ value of **3** and **3'** almost was same. Thus in few case **3'** and **3** were isolated as a mixture. Then the desired product **3** can also further purified by recrystallization with EtOAc-petroleum ether (60-90 °C). **3'** cannot be isolated from **3**, while the HRMS and $^{31}$P NMR was obtained in this report (for the reactions with lower chemoselectivity).

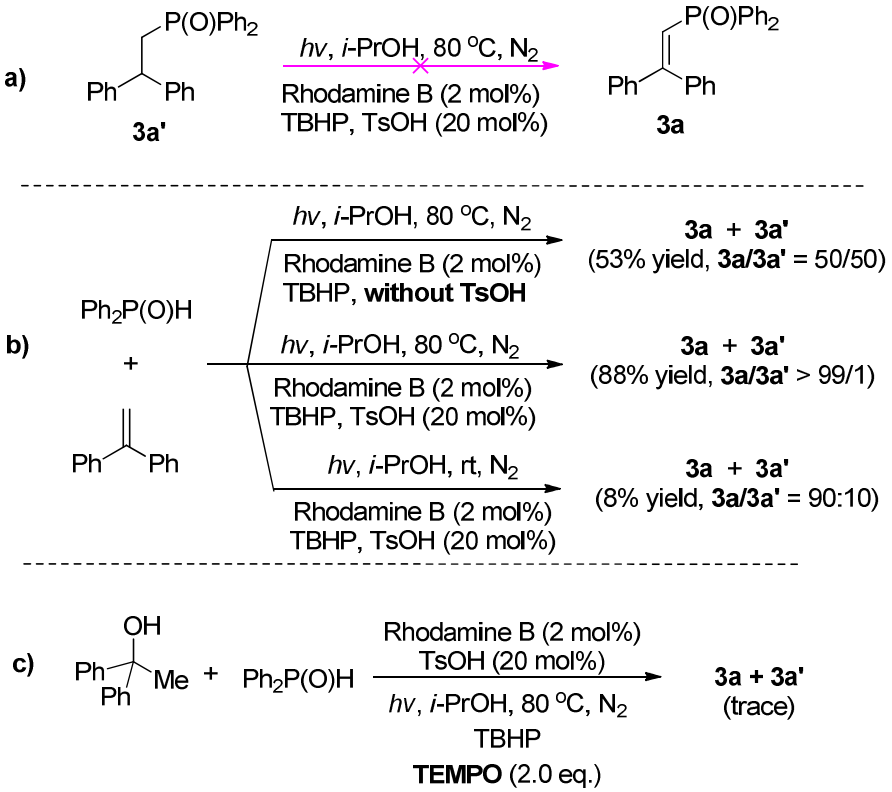
**For gram-scale reaction:** 1,1-diphenylethan-1-ol (0.79 g, 4 mmol), $HP(O)Ph_2$ (2.43 g, 12 mmol), TsOH (0.14 g, 0.8 mmol) and Rhodamine B (0.04 g, 0.08 mmol) were added into a 100 mL round-bottomed flask charged with $N_2$. 40 mL *i*-PrOH was injected into the flask under $N_2$. The reaction mixture was stirred at 80$^{o}$C for 30 min under light irradiating. Then 1.5 mL TBHP (~5.5 M in decane, ~8 mmol) was added dropwise. After stirred for 8 h, the second TBHP (~5.5 M in decane, ~8 mmol) was injected. After complete conversion, volatiles were removed under reduced pressure. The residue was purified *via* column chromatography (Petroleum ether (bp: 60 – 90 $^{o}$C)/EtOAc = 1/1) to afford the corresponding products **3a.** (1.3 g, 3.4 mmol, 85% yield, **3a/3a'** > 99/1).

# 4. Preparation of (2,2-diphenylvinyl)phosphines.

In a 25 mL flask, **3a** (1 mmol) was placed with a magnetic stir bar under $N_2$ atmosphere. Toluene

(6 mL) and $HSiCl_3$ (3 mmol) were then added by a syringe. The reaction mixture was heated at 120 °C in an oil bath for 12h. After cooling, the resulting solution was carefully quenched with 10% aq. NaOH and stirred until excess $HSiCl_3$ was consumed. The resulting mixture was diluted with water and extracted with ethyl acetate (25 mL * 3). The combined organic layer was dried over $Na_2SO_4$ and volatiles were removed in vacuo. The desired phosphine **4** (353.5 mg, 97%) was obtained in an analytically pure form [2b].

# 5. General methods for the control experiments.




a) **3a'** was prepared according to the literature.[4] **3a** (0.2 mmol) was dissolved in 2mL $^i$PrOH, Rhodamine B (2 mol%), TsOH (20 mol%) . The mixture was stirred for 30 min under $N_2$ at 80°C, and 0.4 mmol TBHP was added dropwise. 12 h later volatiles were removed under reduced pressure the crude product was confirmed by $^{31}$P NMR.

b) **Top**: 1,1-Diphenylethylene (0.2 mmol), **2a** (0.6 mmol) and Rhodamine B (2 mol%) was dissolved in 2 mL $^i$PrOH. The mixture was stirred for 30 min under $N_2$ at 80°C, and 0.4 mmol TBHP was added dropwise. 12 h later, the desired product **3a** was obtained by PTLC. **Middle:** 1,1-Diphenylethylene(0.2 mmol), **2a** (0.6 mmol), Rhodamine B (2 mol%) and TsOH (20 mol%) was dissolved in 2 mL $^i$PrOH. The mixture was stirred for 30 min under $N_2$ at 80°C, and 0.4 mmol TBHP was added dropwise. 12 h later, the desired product **3a** was obtained by PTLC. **Bottom**: 1,1-Diphenylethylene (0.2 mmol), **2a**(0.6 mmol), Rhodamine B (2 mol%) and TsOH(20 mol%) was dissolved in 2 mL $^i$PrOH. The mixture was stirred for 30 min under $N_2$ at room temperature, and 0.4 mmol TBHP was added dropwise. 12 h later,

the desired product **3a** was obtained by PTLC.

c) **1a** (0.2 mmol), **2a** (0.6 mmol), Rhodamine B (2 mol%), TsOH(20 mol%) and TEMPO (0.4 mmol) was dissolved in 2 mL $^{i}$PrOH. The mixture was stirred for 30 min under $N_2$ at 80 $^{o}$C, and 0.4 mmol TBHP was added dropwise. After 12h, only a trace amount of **3a** and **3a'** can be detected by NMR.

# 6. Stern-Volmer fluorescence quenching experiments

We investigated the emission and excitation spectra of the photocatalyst Rhodamine B. A solution of Rhodamine B (0.5 mM) in *i*PrOH was chosen as the model. The fluorescence excitation spectrum was obtained with the detection wavelength of 581 nm (Figure 2), and the fluorescence emission spectrum was excited at 571 nm (Figure 3).

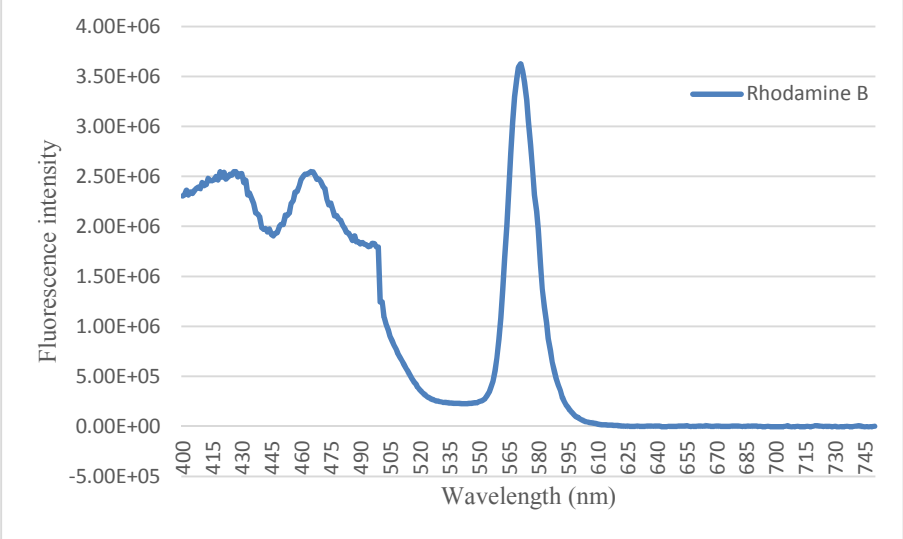



Figure 2. The fluorescence excitation spectrum of Rhodamine B.

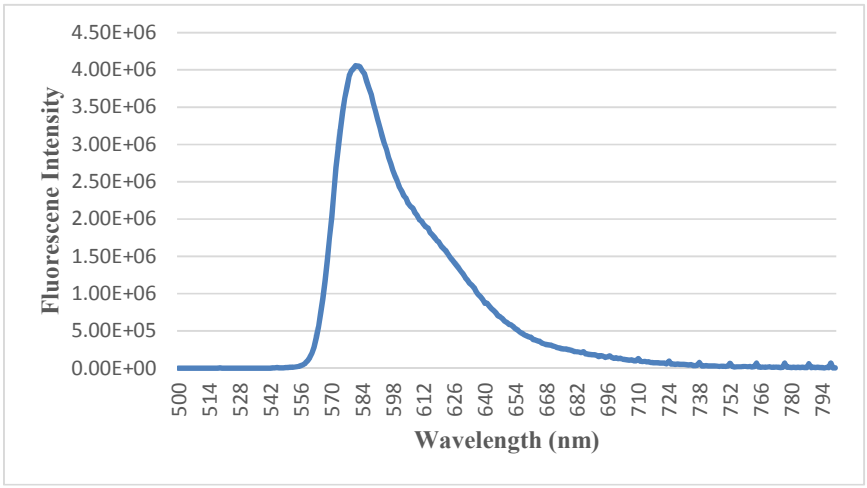



Figure 3. The fluorescence emission spectrum of Rhodamine B excited at 571 nm.

In a typical experiment, appropriate amount of $HP(O)Ph_2$ was added to 3 mL of solution of Rhodamine

B (0.5 mM). And the solution was added to a 1.0 cm quartz cuvette. The emission of the sample was collected (Figure 4). The solution was excited at 571 nm, and the emission intensity at 581 nm was observed (Figure 5).

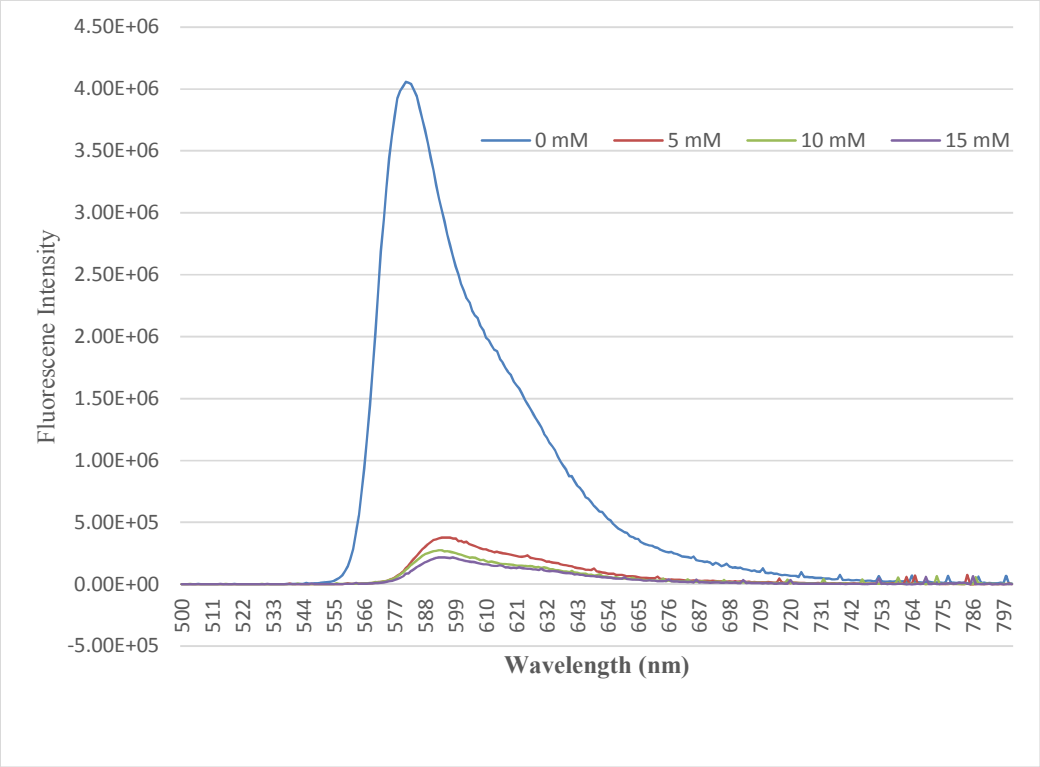



Figure 4. The fluorescence emission spectra of Rhodamine B with different concentration of added $HP(O)Ph_2$ excited at 571 nm.

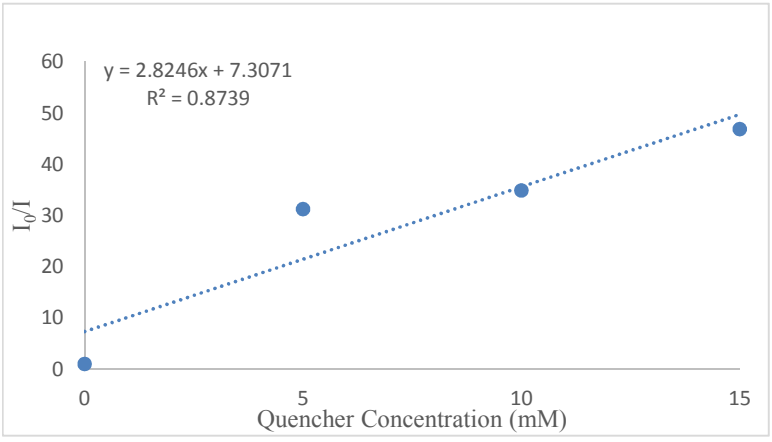
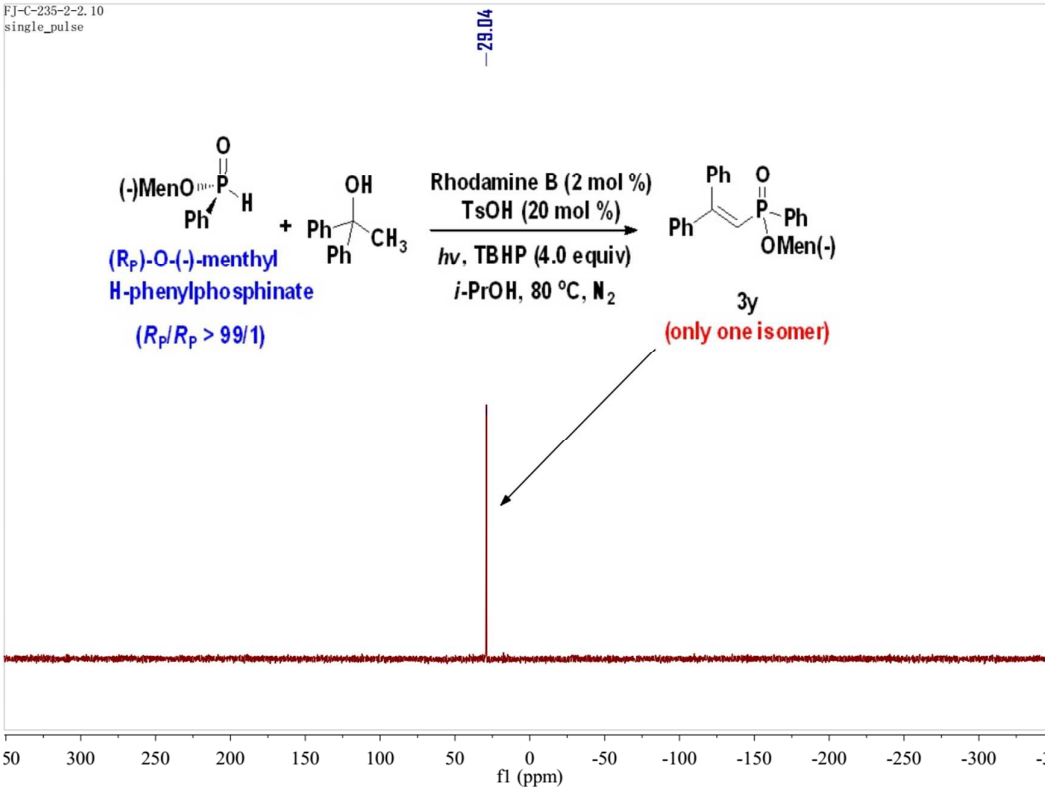



Figure 5. Rhodamine B emission quenching by $HP(O)Ph_2$. Linear quenching is observed.

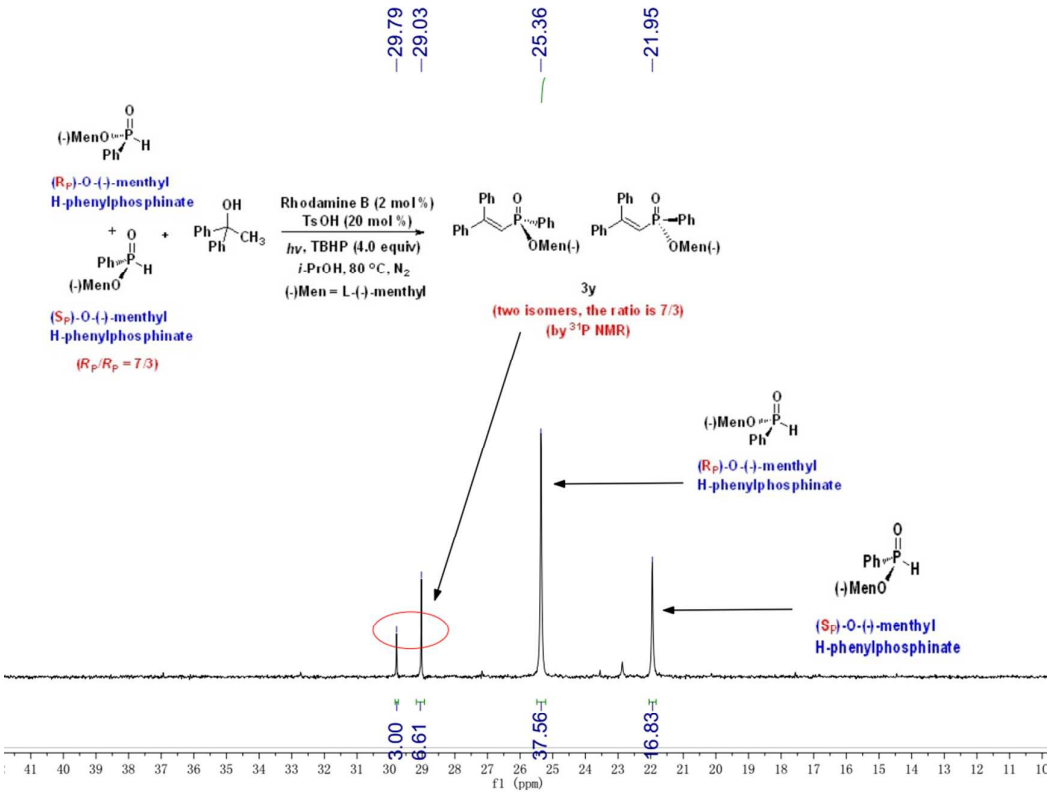
# 7. Determine the configuration of phosphorus atom for 3y.

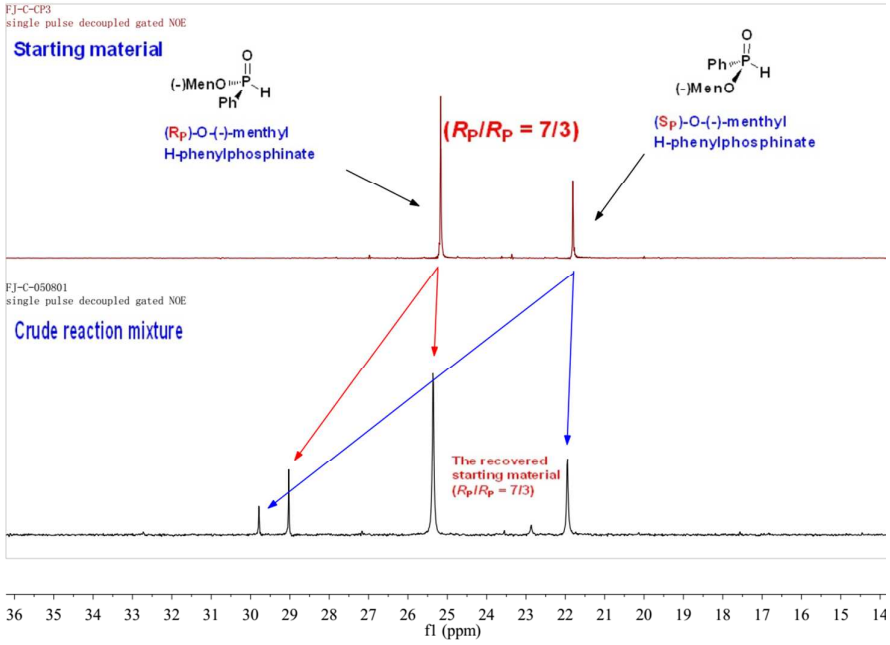
We have tried to confirm the absolute configuration of the phosphorus atoms. In our

original experiment, when ($R_P$)-O-(-)-menthyl H-phenylphosphinate ($R_P/S_P$ > 99/1) was selected as starting material, only one isomer (determined by $^{31}P$ NMR (δ = 29.0 ppm), $^{1}H$ NMR and $^{13}C$ NMR) was detected.



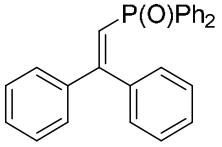

Additionally, when the reaction was conducted by using mixture of O-(-)-menthyl *H*-phenylphosphinate (**$R_P/S_P$ = 7/3**), two isomer can be obviously detected by $^{31}P$ NMR (δ = 29.0 and 29.8, the ratio is also 7/3), $^{1}H$ NMR and $^{13}C$ NMR. Moreover, we also analysis the ratio of the residual O-(-)-menthyl *H*-phenylphosphinate, and the ratio is also $R_P/S_P$ = 7/3. These result revealed that the phosphorus atom in O-(-)-menthyl *H*-phenylphosphinate is stable under the reaction condition. Then we preliminary come to the conclusion that the configuration is retention.


29.79
29.03
25.36
21.95
(-)MenO
Ph
H
(RP)-O-(-)-menthyl
H-phenylphosphinate
Rhodamine B (2 mol %)
TsOH (20 mol %)
hv, TBHP (4.0 equiv)
i-PrOH, 80 °C, N2
(-)Men = L-(-)-menthyl
OMen(-)
(SP)-O-(-)-menthyl
H-phenylphosphinate
(RP/RP = 7/3)
3y
(two isomers, the ratio is 7/3)
(by 31P NMR)
3.00
6.61
37.56
16.83
f1 (ppm)


FJ-C-CP3
single pulse decoupled gated NOE
Starting material
(-)MenO
Ph
H
(RP)-O-(-)-menthyl
H-phenylphosphinate
(RP/RP = 7/3)
(SP)-O-(-)-menthyl
H-phenylphosphinate
FJ-C-050801
single pulse decoupled gated NOE
Crude reaction mixture
The recovered
starting material
(RP/RP = 7/3)
f1 (ppm)

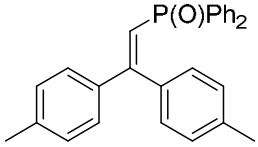
# 8. Analytical Data for All New Compounds

**(2,2-diphenylvinyl)diphenylphosphine oxide (3a)**



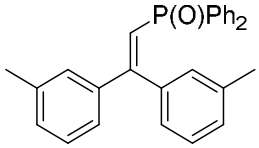

Known compound[5]. Following the general procedure, **3a** was isolated as white solid. Mp: 206-208 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.64 (m, 4H), 7.38 – 7.26 (m, 11H), 7.24 – 7.19 (m, 2H), 7.09 (ddd, $J$ = 14.3, 7.8, 6.1 Hz, 3H), 6.78 (d, $J_{H\text{-}P}$ = 18.1 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 162.06 (d, $J_{C\text{-}P}$ = 2.3 Hz), 141.98 (d, $J_{C\text{-}P}$ = 16.3 Hz), 138.10 (d, $J_{C\text{-}P}$ = 6.7 Hz), 134.47 (d, $J_{C\text{-}P}$ = 105.9 Hz), 131.15 (d, $J_{C\text{-}P}$ = 2.8 Hz), 130.95 (d, $J_{C\text{-}P}$ = 9.4 Hz), 130.40 (d, $J$ = 1.8 Hz), 129.16 (d, $J_{C\text{-}P}$ = 89.3 Hz), 128.46 , 128.41 , 128.38 , 128.29 , 127.67 , 120.66 (d, $J_{C\text{-}P}$ = 103.7 Hz).$^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.31. IR (KBr): 3053.45, 1630.77, 1584.62, 1560.53, 1172.50, 1114.59, 1098.54, 696.44 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{22}OP$ 381.1408, found 381.1408.

**(2,2-di-p-tolylvinyl)diphenylphosphine oxide (3b)**




Following the general procedure. **3b** was isolated as white solid. Mp: 203-205 °C $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.71 – 7.63 (m, 4H), 7.39 – 7.33 (m, 2H), 7.33 – 7.27 (m, 4H), 7.22 (d, $J$ = 8.2 Hz, 2H), 7.11 (dd, $J$ = 8.0, 6.2 Hz, 4H), 6.87 (d, $J$ = 7.8 Hz, 2H), 6.70 (d, $J_{H\text{-}P}$ = 18.5 Hz, 1H), 2.35 (s, 3H), 2.22 (s, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 162.05, 139.29 (d, $J_{C\text{-}P}$ = 16.4 Hz), 139.16 (d, $J_{C\text{-}P}$ = 125.3 Hz), 135.42 (d, $J_{C\text{-}P}$ = 6.9 Hz), 134.75 (d, $J_{C\text{-}P}$ = 105.6 Hz), 131.04, 130.96, 130.35, 129.12, 128.38, 128.31, 128.28, 128.19, 119.01 (d, $J_{C\text{-}P}$ = 104.9 Hz), 21.35 (d, $J_{C\text{-}P}$ = 4.3 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 19.67. IR (KBr): 3022.34, 1610.17, 1580.64, 1553.90, 1275.39, 1181.43, 1115.01, 750.16 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}OP$ 409.1721, found 409.1730. For **3b'** the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 29.86.

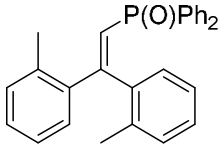
**(2,2-di-m-tolylvinyl)diphenylphosphine oxide (3c)**




Following the general procedure, **3c** was isolated as white solid. Mp: 168-170 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.71 (dd, $J$ = 12.0, 6.7 Hz, 4H), 7.41 – 7.30 (m, 6H), 7.26 – 7.12 (m, 4H), 7.07 – 6.97 (m, 3H), 6.93 (d, $J$ = 7.4 Hz, 1H), 6.77 (d, $J$ = 18.2 Hz, 1H), 2.33 (s, 3H), 2.15 (s, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 162.45 (d, $J_{C\text{-}P}$ = 2.7 Hz), 141.95 (d, $J_{C\text{-}P}$ = 16.3 Hz), 138.17, 138.11, 137.08, 134.58 (d, $J_{C\text{-}P}$ = 105.8 Hz), 131.06 (d, $J_{C\text{-}P}$ = 2.8 Hz), 130.42, 129.66 (d, $J_{C\text{-}P}$ = 264.4 Hz), 129.55 (d, $J_{C\text{-}P}$ = 267.7 Hz), 129.17 (d, $J_{C\text{-}P}$= 51.1 Hz), 127.55 (d, $J_{C\text{-}P}$ = 12.5 Hz), 125.68, 120.31 (d, $J_{C\text{-}P}$ = 104.5 Hz), 21.57, 21.35. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.32. IR (KBr): 3053.93, 2975.64, 2922.81, 1589.27, 1563.49, 1275.38,

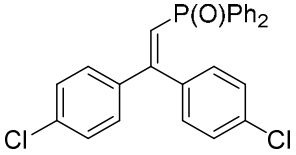
1098.33, 749.38, 560.57 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}OP$ 409.1721, found 409.1729. For **3c'** the $^{31}P$ NMR (162 MHz, $CDCl_3$) δ = 30.18.

**(2,2-di-o-tolylvinyl)diphenylphosphine oxide (3d)**



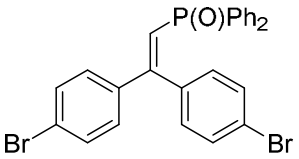

Following the general procedure. The mixture of **3d** and **3d'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate). The pure **3d** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 195-196 °C. $^1H$ NMR (400 MHz, $CDCl_3$) δ 7.66 (dd, *J* = 11.7, 7.4 Hz, 4H), 7.61 (dd, *J* = 7.5, 1.4 Hz, 1H), 7.37 – 7.27 (m, 6H), 7.20 – 7.16 (m, 2H), 7.13 – 7.06 (m, 3H), 7.06 – 7.00 (m, 1H), 6.67 (d, *J* = 7.4 Hz, 1H), 6.62 (d, *J* = 19.9 Hz, 1H), 2.38 (s, 3H), 1.64 (s, 3H). $^{13}C$ NMR (101 MHz, $CDCl_3$) δ 162.40, 141.11 (d, $J_{C-P}$ = 16.1 Hz), 138.17 (d, $J_{C-P}$ = 6.8 Hz), 135.35, 135.04, 132.14, 131.05, 130.86, 130.46 (d, $J_{C-P}$ = 9.3 Hz), 129.59 (d, $J_{C-P}$ = 20.4 Hz), 128.40 (d, $J_{C-P}$= 31.4 Hz), 127.99 (d, $J_{C-P}$ = 11.9 Hz), 125.63 (d, $J_{C-P}$ = 101.4 Hz), 125.24 (d, $J_{C-P}$ = 86.7 Hz), 21.25, 20.01.$^{31}P$ NMR (162 MHz, $CDCl_3$) δ = 17.84. IR (KBr): 3010.68, 1582.84, 1437.11, 1275.36, 1260.64, 1187.13, 1114.89, 749.67 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}OP$ 409.1721, found 409.1726. For **3d'**: the $^{31}P$ NMR (162 MHz, $CDCl_3$) δ = 29.96, the $^1H$ NMR (401 MHz, $CDCl_3$) 5.02 – 4.89 (m, 1H), 2.98 (dd, *J* = 10.7, 7.0 Hz, 2H) was typical data. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{28}OP$ 411.1878, found 411.1888.

**(2,2-bis(4-chlorophenyl)vinyl)diphenylphosphine oxide (3e)**



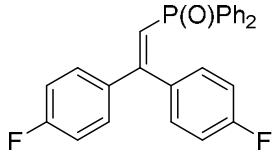

Following the general procedure. The mixture of **3e** and **3e'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate = 1:1). The pure **3e** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 185-186 °C. $^1H$ NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.62 (m, 4H), 7.43 (td, *J* = 7.3, 1.5 Hz, 2H), 7.39 – 7.32 (m, 4H), 7.30 (d, *J* = 8.6 Hz, 2H), 7.25 – 7.11 (m, 4H), 7.06 (d, *J* = 8.6 Hz, 2H), 6.79 (d, *J* = 17.6 Hz, 1H). $^{13}C$ NMR (101 MHz, $CDCl_3$) δ 159.07 (d, $J_{C-P}$ = 2.4 Hz), 139.63 (d, $J_{C-P}$ = 16.0 Hz), 135.89 (d, $J_{C-P}$= 6.8 Hz), 135.33 (d, $J_{C-P}$ = 94.9 Hz), 133.74 (d, $J_{C-P}$ = 106.4 Hz), 131.48 (d, $J_{C-P}$ = 1.4 Hz), 131.28 (d, $J_{C-P}$ = 2.8 Hz), 130.74 (d, $J_{C-P}$ = 9.7 Hz), 129.35, 128.64, 128.38, 128.26, 127.84, 121.67 (d, $J_{C-P}$ = 102.2 Hz). $^{31}P$ NMR (162 MHz, $CDCl_3$) δ19.23. IR (KBr): 3050.10, 1679.40, 1589.99, 1549.35, 1171.31, 1115.61, 1013.49, 751.92 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{20}OPCl_2$ 449.0629, found 449.0630. For **3e'**: the $^{31}P$ NMR (162 MHz, $CDCl_3$) δ = 29.56. the $^1H$ NMR (401 MHz, $CDCl_3$) 4.68* (dt, *J* = 11.0, 7.2 Hz, 1H), 3.02* (dd, *J* = 10.9, 7.3 Hz, 2H) was typical data. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{22}Cl_2OP$ 451.0785, found 451.0786.

**(2,2-bis(4-bromophenyl)vinyl)diphenylphosphine oxide (3f)**



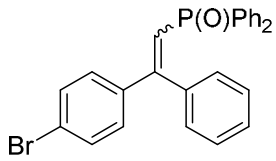

Following the general procedure, **3f** was isolated as white solid, Mp: 190-192 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.63 (m, 4H), 7.49 – 7.40 (m, 4H), 7.35 (td, $J$ = 7.5, 2.8 Hz, 4H), 7.25 – 7.13 (m, 4H), 7.11 – 7.03 (m, 2H), 6.81 (d, $J$ = 17.6 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 159.27, 140.16 (d, $J_{C\text{-}P}$ = 16.3 Hz), 136.43 (d, $J_{C\text{-}P}$ = 6.6 Hz), 133.86 (d, $J_{C\text{-}P}$= 106.3 Hz), 131.89, 131.80, 131.47, 130.98, 130.32 (d, $J_{C\text{-}P}$ = 113.4 Hz), 128.57, 128.45, 124.35, 123.44, 121.93 (d, $J_{C\text{-}P}$ = 102.1 Hz) $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.29. IR (KBr): 3005.76, 1589.45, 1454.25, 1275.38, 1260.64, 1115.81, 1009.88, 749.87 cm$^{-1}$. HRMS (ESI/[M+H]$^{+}$) Calcd. for: $C_{26}H_{20}OPBr_2$ 536.9619, found 536.9614.

**(2,2-bis(4-fluorophenyl)vinyl)diphenylphosphine oxide (3g)**




Following the general procedure. **3g** was isolated as white solid, Mp: 163-165 °C., $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.64 (m, 4H), 7.42 – 7.37 (m, 2H), 7.37 – 7.31 (m, 4H), 7.31 – 7.26 (m, 2H), 7.24 – 7.19 (m, 2H), 7.02 (t, $J$ = 8.6 Hz, 2H), 6.78 (t, $J$ = 8.7 Hz, 2H), 6.74 (d, $J$ = 17.8 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 164.44 (d, $J_{C\text{-}F}$ = 71.3 Hz), 161.95 (d, $J_{C\text{-}F}$ = 69.8 Hz), 159.54 (d, $J_{C\text{-}P}$ = 2.3 Hz), 137.69 (dd, $J$ = 16.2, 3.2 Hz), 134.00 (d, $J$ = 106.3 Hz), 133.78 (dd, $J$ = 6.8, 3.2 Hz), 132.16 (d, $J_{C\text{-}P}$ = 8.2 Hz), 131.18 (d, $J_{C\text{-}P}$ = 2.5 Hz), 130.72 (d, $J_{C\text{-}P}$ = 9.6 Hz), 130.03 (d, $J_{C\text{-}P}$ = 8.5 Hz), 128.27 (d, $J_{C\text{-}P}$ = 12.0 Hz), 120.80 (d, $J_{C\text{-}P}$ = 103.0 Hz), 115.40 (d, $J_{C\text{-}P}$ = 21.7 Hz), 114.59 (d, $J_{C\text{-}P}$ = 21.7 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.21. IR (KBr): 3055.29, 1585.76, 1570.56, 1182.08, 1115.91, 1014.04, 695.50 cm$^{-1}$. HRMS (ESI/[M+H]$^{+}$) Calcd. for: $C_{26}H_{20}OPF_2$ 417.1220, found 417.1229.

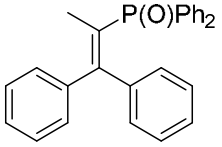
**(2-(4-bromophenyl)-2-phenylvinyl)diphenylphosphine oxide (3h)**




Following the general procedure. The mixture of **3h** and **3h'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate = 1:1). The pure **3h** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 178-180 °C. **3h-1**: $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.62 (m, 4H), 7.47 – 7.39 (m, 2H), 7.39 – 7.28 (m, 9H), 7.15 (dd, $J$ = 52.3, 7.9 Hz, 4H), 6.82 (d, $J$ = 17.6 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 160.61, 141.30 (d, $J_{C\text{-}P}$ = 15.9 Hz), 137.00 (d, $J_{C\text{-}P}$ = 6.9 Hz), 134.17 (d, $J_{C\text{-}P}$ = 106.0 Hz), 131.99, 131.37 (d, $J_{C\text{-}P}$ = 2.0 Hz), 131.03, 130.93, 130.85, 129.88, 128.57 (d, $J_{C\text{-}P}$ = 7.7 Hz), 128.35 (d, $J_{C\text{-}P}$= 13.2 Hz), 123.21, 121.36 (d, $J_{C\text{-}P}$ = 102.8 Hz). **3h-2**: $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.59 (m, 4H), 7.48 – 7.43 (m, 2H), 7.41 – 7.35 (m, 2H), 7.35 – 7.29 (m, 4H), 7.23 – 7.14 (m, 5H), 7.12 – 7.06 (m, 2H), 6.77 (d, $J$ = 17.6 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 160.57 , 140.79 (d, $J_{C\text{-}P}$ = 16.4 Hz), 137.45 (d, $J_{C\text{-}P}$ = 6.7 Hz), 134.10 (d, $J_{C\text{-}P}$ = 106.1 Hz),

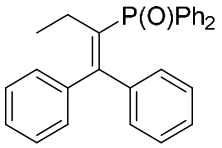
131.20 (d, $J_{C-P}$ = 68.4 Hz), 131.13 (d, $J_{C-P}$ = 2.8 Hz), 130.27 (d, $J_{C-P}$ = 100.4 Hz), 130.21 (d, $J_{C-P}$ = 1.2 Hz), 129.13 (d, $J_{C-P}$ = 118.7 Hz), 128.81 , 128.27 (d, $J_{C-P}$ = 12.1 Hz), 127.69 , 125.75 (d, $J_{C-P}$ = 366.5 Hz), 121.14 (d, $J_{C-P}$ = 103.3 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.18. IR (KBr): 2975.69, 2927.80, 1638.59, 1483.39, 1275.20, 1179.81, 1090.40, 749.70 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{21}BrOP$ 459.0513, found 459.0514. For **3h'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 29.84*. the $^1$H NMR (401 MHz, $CDCl_3$) 4.72-4.62* (m, 1H), 3.12 – 3.01* (m, 2H) was typical data. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{23}OPBr$ 461.0670, found 461.0665.

## (1,1-diphenylprop-1-en-2-yl)diphenylphosphine oxide (3i)



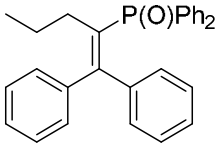

Following the general procedure. The mixture of **3i** and **3i'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate = 1:1). The pure **3i** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 172-174 °C. $^1$H NMR (400 MHz, $CDCl_3$) δ 7.87 – 7.56 (m, 4H), 7.38 – 7.24 (m, 9H), 7.20 – 7.08 (m, 4H), 6.95 – 6.87 (m, 3H), 1.89 (d, $J$ = 13.3 Hz, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 157.70 (d, $J_{C-P}$ = 8.8 Hz), 142.38 (d, $J_{C-P}$ = 15.0 Hz), 140.83 (d, $J_{C-P}$ = 7.6 Hz), 134.45 , 133.43 , 131.08 (d, $J_{C-P}$ = 9.2 Hz), 130.73 (d, $J_{C-P}$ = 2.6 Hz), 130.24 (d, $J_{C-P}$ = 1.8 Hz), 128.37 (d, $J_{C-P}$= 130.4 Hz), 128.22 , 128.12 , 128.01 , 127.33 , 127.16 (d, $J_{C-P}$ = 95.9 Hz), 21.51 (d, $J_{C-P}$ = 12.5 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ27.75. IR (KBr): 2976.21, 2925.59, 1639.18, 1438.28, 1275.38, 1172.99, 1093.48, 750.00 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{27}H_{24}OP$ 395.1565, found 395.1566. For **3i'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 30.52*. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{27}H_{26}OP$ 397.1721, found 397.1730.

## (1,1-diphenylbut-1-en-2-yl)diphenylphosphine oxide (3j)



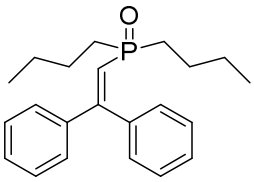

Following the general procedure. The mixture of **3j** and **3j'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate = 1:1). The pure **3j** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 217-219 °C. $^1$H NMR (400 MHz, $CDCl_3$) δ 7.76 – 7.60 (m, 4H), 7.37 – 7.24 (m, 9H), 7.23 – 7.07 (m, 4H), 6.95 – 6.84 (m, 3H), 2.36 (dq, $J$ = 16.6, 7.3 Hz, 2H), 0.86 (t, $J$ = 7.4 Hz, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 157.91 (d, $J_{C-P}$ = 9.3 Hz), 142.62 (d, $J_{C-P}$ = 15.4 Hz), 140.98 (d, $J_{C-P}$ = 7.7 Hz), 135.26 , 134.39 (d, $J_{C-P}$ = 101.6 Hz), 134.34 , 131.18 (d, $J_{C-P}$ = 9.1 Hz), 130.62 (d, $J_{C-P}$ = 2.8 Hz), 129.98 , 128.34 , 128.33 , 128.01 , 127.59 (d, $J_{C-P}$ = 60.2 Hz), 127.49 (d, $J_{C-P}$ = 9.1 Hz), 26.42 (d, $J_{C-P}$ = 11.7 Hz), 14.83 (d, $J_{C-P}$ = 2.1 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 27.21. IR (KBr): 3054.91, 2975.57, 2928.15, 1639.06, 1488.58, 1275.97, 1175.97, 1094.12, 699.53 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}OP$ 409.1721, found 409.1732. For **3j'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 30.50*, HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{28}OP$ 411.1878, found 411.1875.

**(1,1-diphenylpent-1-en-2-yl)diphenylphosphine oxide (3k)**



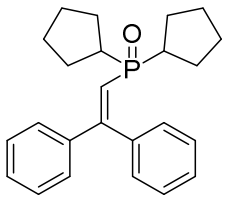

Following the general procedure. The mixture of **3k** and **3k'** was isolated by column chromatography (Petroleum ether (bp: 60-90 $^{o}$C)/ethyl acetate = 1:1). The pure **3k** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 172-174 $^{o}$C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.74 – 7.64 (m, 4H), 7.37 – 7.23 (m, 9H), 7.22 – 7.09 (m, 4H), 6.94 – 6.83 (m, 3H), 2.34 – 2.23 (m, 2H), 1.36 (dq, $J$ = 14.8, 7.3 Hz, 2H), 0.54 (t, $J$ = 7.3 Hz, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 158.52 (d, $J_{C\text{-}P}$ = 9.2 Hz), 142.86 (d, $J_{C\text{-}P}$ = 15.6 Hz), 141.23 (d, $J_{C\text{-}P}$ = 7.9 Hz), 134.58 (d, $J_{C\text{-}P}$ = 101.6 Hz), 133.54 (d, $J_{C\text{-}P}$ = 92.9 Hz), 131.27 (d, $J_{C\text{-}P}$ = 9.1 Hz), 130.68 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.32 (d, $J_{C\text{-}P}$ = 1.4 Hz), 128.71 (d, $J_{C\text{-}P}$ = 0.8 Hz), 128.40 , 128.09 , 127.97 , 127.65 (d, $J_{C\text{-}P}$ = 13.5 Hz), 127.39 , 35.35 (d, $J_{C\text{-}P}$ = 11.6 Hz), 23.46 (d, $J_{C\text{-}P}$ = 2.4 Hz), 13.91. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 26.70. IR (KBr): 3054.42, 2974.44, 2928.66, 1437.54, 1180.97, 1095.68, 699.29 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{29}H_{28}OP$ 423.1878, found 423.1872. For **3j'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 30.50$^{*}$, HRMS$^{*}$ (ESI/$[M+H]^+$) Calcd. for: $C_{29}H_{30}OP$ 425.2034, found 425.2035.

**dibutyl(2,2-diphenylvinyl)phosphine oxide (3l)**




Following the general procedure. **3l** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.35 (m, 5H), 7.35 – 7.26 (m, 5H), 6.31 (d, $J$ = 13.3 Hz, 1H), 1.54 – 1.40 (m, 8H), 1.28 (dq, $J$ = 13.6, 6.8 Hz, 4H), 0.85 (t, $J$ = 7.3 Hz, 6H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 158.32 (d, $J_{C\text{-}P}$ = 2.4 Hz), 141.57 (d, $J_{C\text{-}P}$ = 15.3 Hz), 138.81 (d, $J_{C\text{-}P}$ = 5.7 Hz), 129.73 (d, $J_{C\text{-}P}$ = 1.3 Hz), 129.23, 128.89, 128.37, 128.18, 127.90, 120.50 (d, $J_{C\text{-}P}$ = 91.5 Hz), 29.19 (d, $J_{C\text{-}P}$ = 69.9 Hz), 24.12 (d, $J_{C\text{-}P}$ = 15.1 Hz), 23.87 (d, $J_{C\text{-}P}$ = 3.7 Hz), 13.59. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 38.95. IR (KBr): 2975.07, 2928.76, 1639.25, 1444.09, 1275.37, 1260.72, 1157.76, 1090.11, 750.00 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{22}H_{30}OP$ 341.2034, found 341.2030.

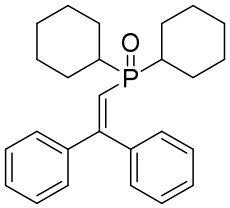
**dicyclopentyl(2,2-diphenylvinyl)phosphine oxide (3m)**




Following the general procedure. **3m** was isolated as white solid. Mp: 148-150 $^{o}$C, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.29 (m, 8H), 7.28 – 7.24 (m, 2H), 6.21 (d, $J$ = 15.4 Hz, 1H), 1.90 – 1.75 (m, 10H), 1.68 (dqd, $J$ = 10.2, 5.3, 2.2 Hz, 4H), 1.53 (tq, $J$ = 7.8, 3.8 Hz, 4H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 158.70, 142.61 (d, $J_{C\text{-}P}$ = 14.5 Hz), 138.88 (d, $J_{C\text{-}P}$ = 5.3 Hz), 129.84 (d, $J_{C\text{-}P}$ = 1.2 Hz), 129.05, 128.57,

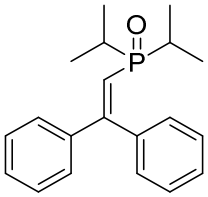
128.41, 127.96, 127.79, 120.27 (d, $J_{C-P}$ = 88.1 Hz), 38.80 (d, $J_{C-P}$ = 72.6 Hz), 27.54 (d, $J_{C-P}$ = 1.5 Hz), 26.71 (d, $J_{C-P}$ = 9.6 Hz), 26.45 (d, $J_{C-P}$ = 1.4 Hz), 26.29 (d, $J_{C-P}$ = 9.4 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 43.62. IR (KBr): 3056.95, 2946.21, 2864.18, 1589.25, 1490.32, 1442.96, 1168.73, 1073.94, 1031.88, 755.99 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{24}H_{30}OP$ 365.2034, found 365.2025.

**dicyclohexyl(2,2-diphenylvinyl)phosphine oxide (3n)**



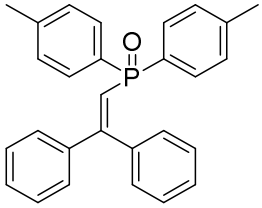
Following the general procedure **3n** was isolated as white solid. Mp: 134-136 $^{o}$C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.30 (m, 8H), 7.26 (dd, $J$ = 7.7, 2.0 Hz, 2H), 6.00 (d, $J_{H-P}$ = 19.2 Hz, 1H), 1.92 – 1.79 (m, 8H), 1.72 – 1.61 (m, 4H), 1.47 – 1.33 (m, 4H), 1.24 – 1.17 (m, 6H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 160.85, 142.91 (d, $J_{C-P}$ = 14.5 Hz), 138.51 (d, $J_{C-P}$ = 5.3 Hz), 130.03 (d, $J_{C-P}$ = 1.4 Hz), 129.08, 128.42, 128.40, 127.94, 127.58, 117.36 (d, $J_{C-P}$ = 84.8 Hz), 36.89 (d, $J_{C-P}$ = 69.8 Hz), 26.66 (d, $J_{C-P}$ = 30.6 Hz), 26.66 (d, $J_{C-P}$ = 5.3 Hz), 26.25 (d, $J_{C-P}$ = 2.9 Hz), 26.05 (d, $J_{C-P}$ = 1.4 Hz), 25.31 (d, $J_{C-P}$ = 3.0 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 42.87. IR (KBr): 3054.55, 3022.59, 2926.29, 2851.00, 1681.96, 1588.64, 1568.54, 1444.73, 1275.06, 1176.02, 763.47 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{34}OP$ 393.2347, found 393.2345.

**(2,2-diphenylvinyl)diisopropylphosphine oxide (3o)**



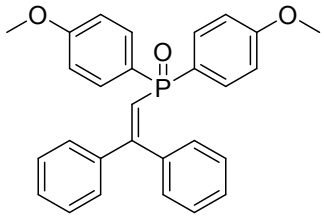
Following the general procedure **3o** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.28 (m, 8H), 7.26 – 7.22 (m, 2H), 6.01 (d, $J$ = 19.6 Hz, 1H), 2.01 – 1.86 (m, 2H), 1.16 (td, $J$ = 15.5, 7.2 Hz, 12H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.61, 143.01 (d, $J_{C-P}$ = 14.5 Hz), 138.45, 130.14, 129.13, 128.52, 128.43, 127.97, 127.56, 116.72 (d, $J_{C-P}$ = 84.8 Hz), 26.86 (d, $J_{C-P}$ = 69.5 Hz), 16.17 (d, $J_{C-P}$ = 95.9 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 47.55. IR (KBr): 3055.77, 2956.37, 2928.23, 2867.44, 1588.49, 1570.91, 1490.43, 1257.98, 1176.64, 1072.84, 695.66 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{20}H_{26}OP$ 313.1721, found 313.1715.

**(2,2-diphenylvinyl)di-p-tolylphosphine oxide (3p)**



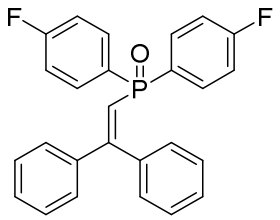
Following the general procedure. The mixture of **3p** and **3p'** was isolated by column chromatography (Petroleum ether (bp: 60-90 $^{o}$C)/ethyl acetate = 1:1). The pure **3p** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 168-169 $^{o}$C, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.55 (ddt, *J* = 11.6, 8.0, 1.5 Hz, 4H), 7.36 – 7.30 (m, 5H), 7.21 (dt, *J* = 8.4, 1.6 Hz, 2H), 7.11 (tt, *J* = 8.5, 6.2 Hz, 7H), 6.75 (d, *J* = 18.0 Hz, 1H), 2.32 (s, 6H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.35 (d, $J_{C-P}$ = 2.3 Hz), 142.18 (d, $J_{C-P}$ = 15.9 Hz), 141.41, 138.18 (d, $J_{C-P}$ = 6.7 Hz), 131.39 (d, $J_{C-P}$ = 108.3 Hz), 130.95 (d, $J_{C-P}$ = 9.7 Hz), 130.36 (d, $J_{C-P}$ = 1.4 Hz), 129.07 (d, $J_{C-P}$ = 12.2 Hz), 128.98 (d, $J_{C-P}$ = 92.5 Hz), 128.38 (d, $J_{C-P}$ = 4.7 Hz), 127.57, 121.11 (d, $J_{C-P}$ = 103.1 Hz), 21.59 (d, $J_{C-P}$ = 1.4 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.85. IR (KBr): 2977.30, 1601.37, 1560.53, 1275.43, 1260.55, 1179.19, 1099.01, 750.13 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}OP$ 409.1721, found 409.1725. For **3p'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 31.52*, the $^{1}$H NMR (401 MHz, $CDCl_3$) 4.17-4.07* (m, 1H), 3.07* (dd, *J* = 11.1, 7.1 Hz, 2H) was typical data. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{28}OP$ 411.1878, found 411.1881.

**(2,2-diphenylvinyl)bis(4-methoxyphenyl)phosphine oxide (3q)**



Following the general procedure, **3q** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.57 (ddd, *J* = 11.2, 8.7, 2.0 Hz, 4H), 7.38 – 7.28 (m, 5H), 7.23 – 7.19 (m, 2H), 7.16 – 7.07 (m, 3H), 6.82 (dt, *J* = 8.8, 2.3 Hz, 4H), 6.75 (d, *J* = 17.7 Hz, 1H), 3.78 (s, 6H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.80 (d, $J_{C-P}$ = 2.9 Hz), 142.21 (d, $J_{C-P}$ = 15.9 Hz), 138.16 (d, $J_{C-P}$ = 6.3 Hz), 132.75 (d, $J_{C-P}$ = 11.0 Hz), 130.35 (d, $J_{C-P}$ = 1.2 Hz), 128.96 (d, $J_{C-P}$ = 87.1 Hz), 128.31, 128.00 (d, $J_{C-P}$ = 79.5 Hz), 126.01 (d, $J_{C-P}$ = 112.3 Hz), 121.49 (d, $J_{C-P}$ = 103.9 Hz), 113.91 (d, $J_{C-P}$ = 13.0 Hz), 55.35. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.61. IR (KBr): 3056.26, 2930.94, 2837.12, 1596.43, 1568.57, 1292.26, 1252.42, 1116.55, 802.31, 697.85 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}O_3P$ 441.1620, found 441.1624. For **3q'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 31.26*. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{28}O_3P$ 443.1776, found 443.1771.

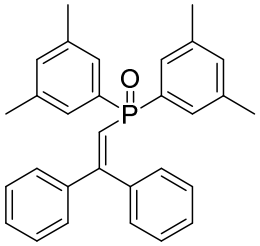
**(2,2-diphenylvinyl)bis(4-fluorophenyl)phosphine oxide (3r)**



Following the general procedure. The mixture of **3r** and **3r'** was isolated by column chromatography (Petroleum ether (bp: 60-90 $^{o}$C)/ethyl acetate = 1:1). The pure **3r** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C) as white solid. Mp: 165-167 $^{o}$C, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.69

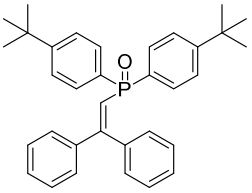
– 7.59 (m, 4H), 7.32 (dddd, $J$ = 18.2, 8.3, 6.0, 2.4 Hz, 5H), 7.22 – 7.13 (m, 3H), 7.09 (ddd, $J$ = 8.4, 6.3, 1.6 Hz, 2H), 6.99 (tt, $J$ = 8.7, 1.8 Hz, 4H), 6.72 (d, $J$ = 18.2 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 165.86 (d, $J_{C\text{-}F}$ = 3.4 Hz), 163.35 (d, $J_{C\text{-}F}$ = 3.4 Hz), 162.59 (d, $J_{C\text{-}P}$ = 2.8 Hz), 141.61 (d, $J_{C\text{-}P}$ = 16.5 Hz), 137.93 (d, $J_{C\text{-}P}$ = 7.0 Hz), 133.29 (dd, $J$ = 10.8, 8.7 Hz), 130.33 (d, $J_{C\text{-}P}$ = 1.4 Hz), 130.15 (dd, $J$ = 109.1, 3.4 Hz), 129.38 (d, $J_{C\text{-}P}$ = 91.0 Hz), 128.52, 128.34, 127.75, 120.09 (d, $J_{C\text{-}P}$ = 105.6 Hz), 115.73 (dd, $J_{C\text{-}P}$ = 21.4, 13.2 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 18.05. IR (KBr): 2956.11, 2921.82, 1591.17, 1497.30, 1275.33, 1260.55, 1184.44, 1114.32, 764.17 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{20}OPF_2$ 417.1220, found 417.1218. For **3r'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 28.66*. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{22}OPF_2$ 419.1376, found 419.1374.

**bis(3,5-dimethylphenyl)(2,2-diphenylvinyl)phosphine oxide (3s)**



Following the general procedure. **3s** was isolated as colorless sticky oil, $^1$H NMR (400 MHz, $CDCl_3$) δ 7.31 (t, $J$ = 2.3 Hz, 5H), 7.26 (d, $J$ = 12.3 Hz, 4H), 7.19 (dt, $J$ = 8.1, 1.7 Hz, 2H), 7.10 (pd, $J$ = 6.7, 1.8 Hz, 3H), 6.97 (s, 2H), 6.75 (d, $J$ = 17.6 Hz, 1H), 2.25 (s, 12H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.02, 142.10 (d, $J_{C\text{-}P}$ = 15.8 Hz), 138.21 (d, $J_{C\text{-}P}$ = 6.0 Hz), 137.88 (d, $J_{C\text{-}P}$ = 12.6 Hz), 134.14 (d, $J_{C\text{-}P}$ = 105.1 Hz), 132.88 (d, $J_{C\text{-}P}$ = 2.3 Hz), 130.26, 129.43, 129.28 (d, $J_{C\text{-}P}$ = 10.5 Hz), 128.61 (d, $J_{C\text{-}P}$ = 9.4 Hz), 128.40, 128.34, 127.43, 121.11 (d, $J_{C\text{-}P}$ = 102.5 Hz), 21.34.$^{31}$P NMR (162 MHz, $CDCl_3$) δ 20.28. IR (KBr): 2919.57, 2857.89, 1600.73, 1585.97, 1274.80, 1260.87, 1182.87, 750.75 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{30}H_{30}OP$ 437.2034, found 437.2039. For **3s'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 31.89*. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{30}H_{32}OP$ 439.2191, found 439.2198.

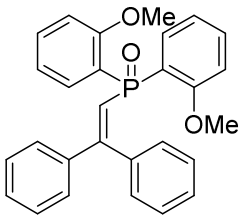
**bis(4-(tert-butyl)phenyl)(2,2-diphenylvinyl)phosphine oxide (3t)**



Following the general procedure. The mixture of **3t** and **3t'** was isolated by column chromatography (Petroleum ether (bp: 60-90 °C)/ethyl acetate = 1:1). The pure **3t** was obtained by recrystallization with EtOAc-petroleum ether (60-90 °C). Mp: 231-233 °C, $^1$H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.56 (m, 4H), 7.31 (td, $J$ = 5.0, 2.1 Hz, 9H), 7.20 – 7.14 (m, 2H), 7.11 – 7.00 (m, 3H), 6.80 (d, $J$ = 17.0 Hz, 1H),. 1.27 (s, 18H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.11 (d, $J_{C\text{-}P}$ = 2.4 Hz), 154.24 (d, $J_{C\text{-}P}$ = 2.9 Hz), 131.69, 130.94, 130.85, 130.62, 130.39 (d, $J_{C\text{-}P}$ = 1.4 Hz), 129.40, 128.43, 128.38, 128.33, 127.53, 125.26 (d, $J_{C\text{-}P}$ = 12.1 Hz), 121.68 (d, $J_{C\text{-}P}$ = 103.5 Hz), 34.91, 31.17. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.30. IR (KBr): 3056.83, 2962.82, 2904.47, 2876.18, 1598.62, 1530.37, 1493.90, 1392.61, 1267.15, 1188.46, 1092.17, 1015.98, 761.44 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{38}OP$ 493.2660, found

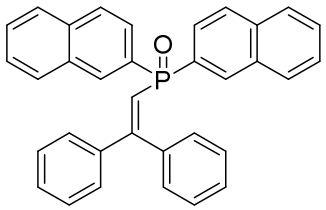
493.2667. For **3t'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 29.53*, the $^{1}$H NMR (401 MHz, $CDCl_3$) 4.75 – 4.66* (m, 1H), 3.06* (dd, *J* = 11.0, 7.2 Hz, 2H) was typical data. HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{40}OP$ 495.2817, found 495.2821.

**(2,2-diphenylvinyl)bis(2-methoxyphenyl)phosphine oxide (3u)**



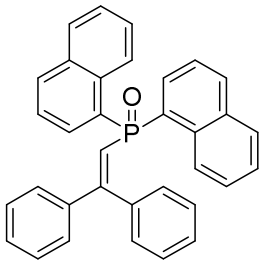

Following the general procedure, **3u** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.44 (dd, *J* = 14.0, 7.6 Hz, 2H), 7.36 (t, *J* = 7.9 Hz, 2H), 7.29 (p, *J* = 3.0 Hz, 5H), 7.18 (dt, *J* = 8.1, 1.9 Hz, 2H), 7.13 – 7.02 (m, 4H), 6.84 (dt, *J* = 21.6, 7.1 Hz, 4H), 3.73 (s, 6H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 160.62, 157.40 (d, $J_{C-P}$ = 2.4 Hz), 143.32 (d, $J_{C-P}$= 17.8 Hz), 138.54 (d, $J_{C-P}$ = 7.2 Hz), 134.29 (d, $J_{C-P}$ = 7.7 Hz), 133.08 (d, $J_{C-P}$ = 2.0 Hz), 130.20, 128.67, 128.34, 128.24, 128.11, 123.10, 122.01, 121.52 (d, $J_{C-P}$ = 108.5 Hz), 120.54 (d, $J_{C-P}$ = 12.0 Hz), 110.82 (d, $J_{C-P}$ = 6.6 Hz), 55.69. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 18.59. IR (KBr): 3058.06, 2936.70, 2836.18, 1589.06, 1477.34, 1275.81, 1179.94, 1073.89, 756.06 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{26}O_3P$ 441.1620, found 441.1611. For **3u'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 25.87*, HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{28}H_{28}O_3P$ 443.1776, found 443.1779.

**(2,2-diphenylvinyl)di(naphthalen-2-yl)phosphine oxide (3v)**



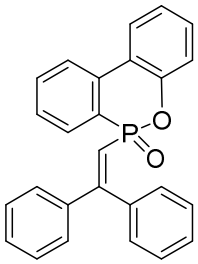

Following the general procedure **3v** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 8.32 (d, *J* = 13.7 Hz, 2H), 7.86 – 7.80 (m, 2H), 7.79 – 7.74 (m, 4H), 7.70 (ddt, *J* = 10.0, 8.4, 1.7 Hz, 2H), 7.55 – 7.45 (m, 4H), 7.35 (qt, *J* = 7.8, 2.0 Hz, 5H), 7.24 (dt, *J* = 7.2, 1.9 Hz, 2H), 7.01 – 6.88 (m, 4H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 162.23 (d, $J_{C-P}$ = 2.4 Hz), 141.89 (d, $J_{C-P}$ = 16.1 Hz), 138.00 (d, $J_{C-P}$ = 6.7 Hz), 134.41 (d, $J_{C-P}$ = 2.4 Hz), 133.06 (d, $J_{C-P}$ = 8.6 Hz), 132.66, 131.50 (d, $J_{C-P}$ = 106.4 Hz), 130.30 (d, $J_{C-P}$ = 1.4 Hz), 129.69, 128.90, 128.71, 128.51, 128.42, 128.24 (d, $J_{C-P}$ = 11.7 Hz), 127.91, 127.78, 127.48, 126.75, 125.98 (d, $J_{C-P}$ = 10.6 Hz), 120.36 (d, $J_{C-P}$ = 104.3 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 19.73. IR (KBr): 3053.53, 2925.86, 2853.05, 1675.23, 1587.34, 1490.97, 1342.31, 1272.96, 1180.26, 1086.15, 1029.71, 750.13 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{26}OP$ 481.1721, found 481.1726. For **3v'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 30.93*, HRMS* (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{28}OP$ 483.1878, found 483.1873.

**(2,2-diphenylvinyl)di(naphthalen-1-yl)phosphine oxide (3w)**



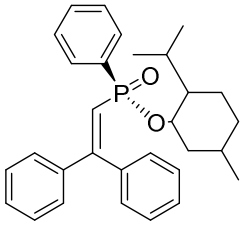
Following the general procedure, **3w** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, CDCl3) δ 8.63 – 8.50 (m, 2H), 7.90 – 7.81 (m, 4H), 7.76 (dd, *J* = 15.5, 7.1 Hz, 2H), 7.46 (dd, *J* = 6.4, 3.2 Hz, 4H), 7.32 – 7.17 (m, 7H), 7.11 (d, *J* = 19.2 Hz, 1H), 6.97 (ddd, *J* = 9.3, 6.4, 2.2 Hz, 1H), 6.86 (d, *J* = 7.3 Hz, 4H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 160.48 (d, $J_{C\text{-}P}$ = 2.7 Hz), 142.17 (d, $J_{C\text{-}P}$ = 16.4 Hz), 137.87 (d, $J_{C\text{-}P}$ = 6.8 Hz), 133.99 (d, $J_{C\text{-}P}$ = 10.5 Hz), 133.84 (d, $J_{C\text{-}P}$ = 9.2 Hz), 133.22 (d, $J_{C\text{-}P}$ = 8.6 Hz), 132.77 (d, $J_{C\text{-}P}$ = 2.9 Hz), 129.72 (d, $J_{C\text{-}P}$= 1.4 Hz), 129.43 (d, $J_{C\text{-}P}$ = 104.1 Hz), 129.33, 129.04 (d, $J_{C\text{-}P}$ = 1.6 Hz), 128.39, 128.32, 127.52 (d, $J_{C\text{-}P}$ = 5.2 Hz), 127.09, 127.03, 126.21, 124.80 (d, $J_{C\text{-}P}$ = 14.0 Hz), 122.16 (d, $J_{C\text{-}P}$ = 102.6 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 23.39. IR (KBr): 3055.33, 2926.68, 2853.53, 2359.68, 1675.57, 1618.71, 1587.83, 1505.82, 1264.68, 1175.95, 1076.46, 773.42 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{26}OP$ 481.1721, found 481.1723. For **3w'**: the $^{31}$P NMR (162 MHz, $CDCl_3$) δ = 32.76$^*$, HRMS$^*$ (ESI/$[M+H]^+$) Calcd. for: $C_{34}H_{28}OP$ 483.1878, found 483.1874.

**6-(2,2-diphenylvinyl)dibenzo[c,e][1,2]oxaphosphinine 6-oxide (3x)**



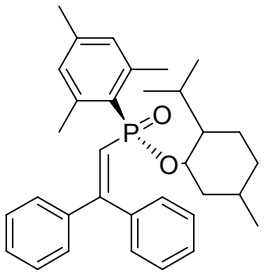
Following the general procedure. **3x** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.47 (m, 4H), 7.35 – 7.22 (m, 5H), 7.22 – 7.16 (m, 2H), 7.16 – 7.11 (m, 2H), 7.11 – 7.07 (m, 2H), 7.07 – 7.02 (m, 2H), 6.96 (d, *J* = 8.1 Hz, 1H), 6.52 (d, *J* = 15.8 Hz, 1H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 161.68 (d, $J_{C\text{-}P}$ = 5.5 Hz), 149.09 (d, $J_{C\text{-}P}$ = 7.9 Hz), 140.83 (d, $J_{C\text{-}P}$ = 19.3 Hz), 137.95 (d, $J_{C\text{-}P}$= 7.6 Hz), 135.49 (d, $J_{C\text{-}P}$ = 6.8 Hz), 132.65 (d, $J_{C\text{-}P}$ = 2.5 Hz), 130.65 (d, $J_{C\text{-}P}$ = 10.7 Hz), 130.08 (d, $J_{C\text{-}P}$ = 42.6 Hz), 129.68, 128.60, 128.44, 128.19, 128.14, 128.01, 127.87, 125.93 (d, $J_{C\text{-}P}$ = 129.9 Hz), 124.62 (d, $J_{C\text{-}P}$ = 54.6 Hz), 123.39 (d, $J_{C\text{-}P}$ = 9.8 Hz), 122.51 (d, $J_{C\text{-}P}$= 11.6 Hz), 120.49 (d, $J_{C\text{-}P}$ = 6.6 Hz), 117.83 (d, $J_{C\text{-}P}$ = 140.9 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ 23.71. IR (KBr): 3058.08, 2924.24, 16781.46, 1583.66, 1489.18, 1476.04, 1236.55, 1203.62, 1079.54, 1029.98, 755.75 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{20}O_2P$ 395.1201, found 395.1205.

**2-isopropyl-5-methylcyclohexyl (2,2-diphenylvinyl)(phenyl)phosphinate (3y)**



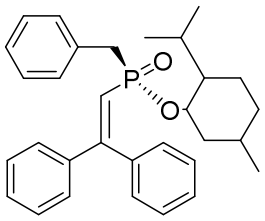
Following the general procedure, 3y was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.47 – 7.39 (m, 2H), 7.32 – 7.24 (m, 6H), 7.19 – 7.12 (m, 3H), 7.12 – 7.02 (m, 4H), 6.56 (d, $J$ = 11.0 Hz, 1H), 4.26 – 4.16 (m, 1H), 2.38 – 2.27 (m, 1H), 1.69 – 1.53 (m, 3H), 1.40 – 1.30 (m, 1H), 1.27 – 1.17 (m, 1H), 0.96 (d, $J$ = 7.0 Hz, 3H), 0.93 (s, 1H), 0.91 – 0.85 (m, 4H), 0.79 (t, $J$ = 12.1 Hz, 1H), 0.70 (d, $J$ = 6.6 Hz, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 159.77 (d, $J_{C\text{-}P}$ = 8.0 Hz), 141.60 (d, $J_{C\text{-}P}$= 19.1 Hz), 138.27 (d, $J_{C\text{-}P}$ = 7.1 Hz), 133.86 (d, $J_{C\text{-}P}$ = 134.8 Hz), 131.44 (d, $J_{C\text{-}P}$ = 10.5 Hz), 131.13 (d, $J_{C\text{-}P}$ = 2.9 Hz), 130.08, 129.29, 128.34, 128.20, 128.05, 127.72, 127.58, 120.96 (d, $J_{C\text{-}P}$ = 143.1 Hz), 76.21 (d, $J_{C\text{-}P}$ = 6.7 Hz), 48.97 (d, $J_{C\text{-}P}$ = 5.6 Hz), 43.21, 34.18, 31.51, 25.83, 22.99, 22.02, 21.34, 16.00. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 28.95. IR (KBr): 2924.68, 1605.74, 1444.44, 1384.60, 1275.30, 1260.41, 1220.88, 1076.54, 1009.53, 750.83 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{30}H_{36}O_2P$ 459.2453, found 459.2455.

**2-isopropyl-5-methylcyclohexyl (2,2-diphenylvinyl)(mesityl)phosphinate (3z)**



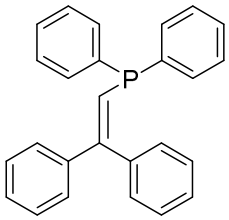
Following the general procedure, **3aa** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.31 – 7.27 (m, 3H), 7.25 (d, $J$ = 1.4 Hz, 2H), 7.10 – 7.05 (m, 1H), 7.04 – 6.96 (m, 4H), 6.64 – 6.51 (m, 3H), 4.30 – 4.20 (m, 1H), 2.38 (s, 6H), 2.15 (s, 3H), 1.63 (d, $J$ = 15.7 Hz, 4H), 1.25 (d, $J$ = 7.1 Hz, 5H), 0.96 (d, $J$ = 7.0 Hz, 3H), 0.90 (d, $J$ = 5.5 Hz, 3H), 0.70 (d, $J$ = 6.6 Hz, 3H).$^{13}$C NMR (101 MHz, $CDCl_3$) δ 156.40 (d, $J_{C\text{-}P}$ = 8.8 Hz), 142.79 (d, $J_{C\text{-}P}$ = 12.0 Hz), 141.58 (d, $J_{C\text{-}P}$ = 18.6 Hz), 140.69 (d, $J_{C\text{-}P}$ = 2.9 Hz), 138.17 (d, $J_{C\text{-}P}$ = 7.6 Hz), 130.19 (d, $J_{C\text{-}P}$= 13.5 Hz), 129.14 (d, $J_{C\text{-}P}$ = 1.7 Hz), 129.02, 128.36, 127.79, 127.74, 127.45, 126.88 (d, $J_{C\text{-}P}$ = 129.5 Hz), 123.86 (d, $J_{C\text{-}P}$ = 140.7 Hz), 75.65 (d, $J_{C\text{-}P}$ = 6.3 Hz), 48.99 (d, $J_{C\text{-}P}$ = 5.8 Hz), 42.53, 34.26, 31.51, 25.92, 23.53 (d, $J_{C\text{-}P}$ = 3.4 Hz), 23.05, 22.12, 21.35, 21.03 (d, $J_{C\text{-}P}$ = 1.4 Hz), 16.08. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 31.54. IR (KBr): 2953.49, 2924.64, 2853.26, 1683.06, 1605.62, 1444.25, 1275.27, 1181.24, 1076.32, 753.61 $cm^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{33}H_{42}O_2P$ 501.2922, found 501.2923.

**2-isopropyl-5-methylcyclohexyl benzyl(2,2-diphenylvinyl)phosphinate (3aa)**



Following the general procedure, **3z** was isolated as colorless sticky oil, $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.38 (m, 3H), 7.37 – 7.34 (m, 3H), 7.33 – 7.31 (m, 1H), 7.31 – 7.27 (m, 1H), 7.25 – 7.23 (m, 1H), 7.23 – 7.20 (m, 1H), 7.20 – 7.18 (m, 2H), 7.18 – 7.16 (m, 1H), 7.13 – 7.09 (m, 2H), 6.14 (d, $J_{H\text{-}P}$ = 12.0 Hz, 1H), 4.22 – 4.12 (m, 1H), 2.91 – 2.68 (m, 2H), 2.08 – 1.97 (m, 1H), 1.88 – 1.80 (m, 1H), 1.66 – 1.56 (m, 2H), 1.38 – 1.26 (m, 3H), 1.00 – 0.90 (m, 2H), 0.89 (d, $J$ = 7.0 Hz, 3H), 0.80 (d, $J$ = 6.5 Hz, 3H), 0.76 (d, $J$ = 6.9 Hz, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 159.22 (d, $J_{C\text{-}P}$ = 6.2 Hz), 141.99 (d, $J_{C\text{-}P}$ = 18.4 Hz), 138.54 (d, $J_{C\text{-}P}$ = 5.8 Hz), 132.16 (d, $J_{C\text{-}P}$ = 8.2 Hz), 130.19 (d, $J_{C\text{-}P}$ = 1.5 Hz), 130.13, 130.07, 129.14, 128.81, 128.27, 128.14 (d, $J_{C\text{-}P}$ = 2.9 Hz), 128.06, 127.83, 119.56 (d, $J_{C\text{-}P}$ = 128.2 Hz), 76.60 (d, $J_{C\text{-}P}$ = 7.7 Hz), 48.64 (d, $J_{C\text{-}P}$ = 5.8 Hz), 43.55, 38.50 (d, $J_{C\text{-}P}$ = 93.9 Hz), 34.02, 31.43, 25.64, 22.75, 21.88, 21.15, 15.71. $^{31}$P NMR (162 MHz, $CDCl_3$) δ 37.50. IR (KBr): 2953.43, 2924.86, 2867.28, 1588.65, 1493.75, 1275.27, 1011.39, 764.92 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{31}H_{38}O_2P$ 473.2609, found 473.2611.

**(2,2-diphenylvinyl)diphenylphosphane (4)**



Known compound[6]. Following the general procedure, **4** was isolated as white solid, Mp: 121-123 $^{o}$C, $^{1}$H NMR (400 MHz,$CDCl_3$) δ 7.42 (tt, $J$ = 7.3, 2.0 Hz, 4H), 7.33 – 7.28 (m, 7H), 7.28 – 7.23 (m, 7H), 7.22 – 7.18 (m, 2H), 6.86 (d, $J$ = 3.4 Hz, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 157.00 (d, $J_{C\text{-}P}$ = 25.6 Hz), 142.67 (d, $J_{C\text{-}P}$ = 7.3 Hz), 140.51 (d, $J_{C\text{-}P}$ = 10.6 Hz), 140.31 (d, $J_{C\text{-}P}$ = 6.8 Hz), 133.05, 132.86, 130.38 (d, $J_{C\text{-}P}$ = 3.9 Hz), 128.70 (d, $J_{C\text{-}P}$ = 6.6 Hz), 128.52, 128.44, 128.28, 128.24, 128.07, 127.71 (d, $J_{C\text{-}P}$ = 11.1 Hz). $^{31}$P NMR (162 MHz, $CDCl_3$) δ -23.57. IR (KBr): 3059.48, 3042.09, 3011.69, 1955.03, 1883.03, 1812.23, 1582.80, 1441.42, 1272.05, 1180.01, 1075.38, 696.98 cm$^{-1}$. HRMS (ESI/$[M+H]^+$) Calcd. for: $C_{26}H_{22}P$ 365.1459, found 365.1456.

# 9. References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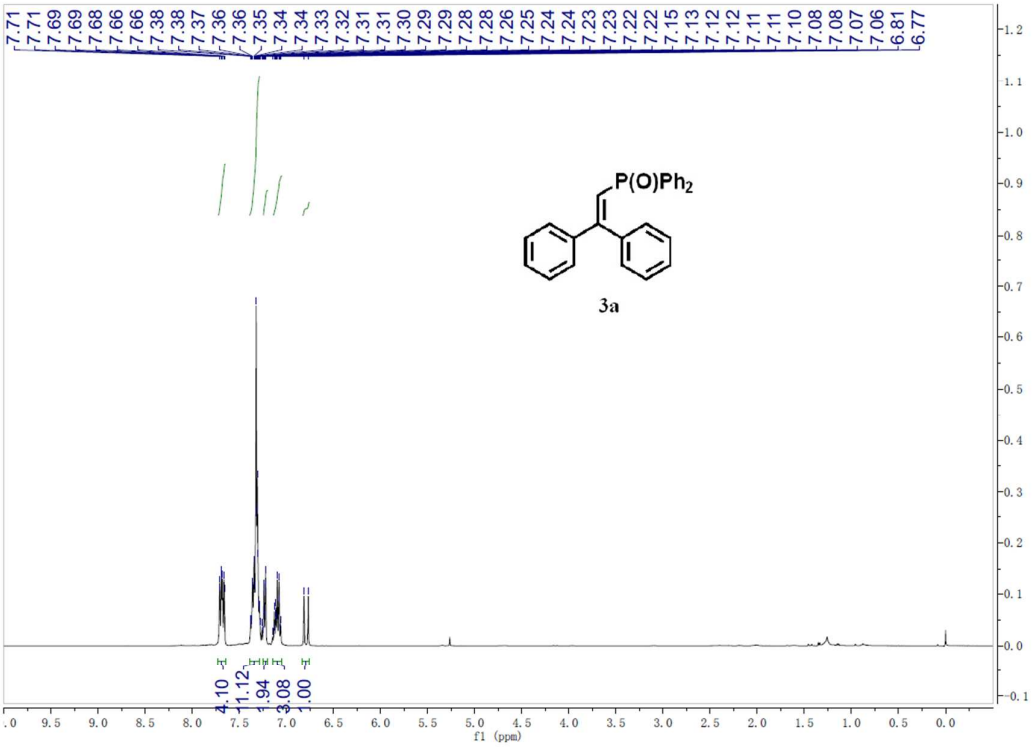
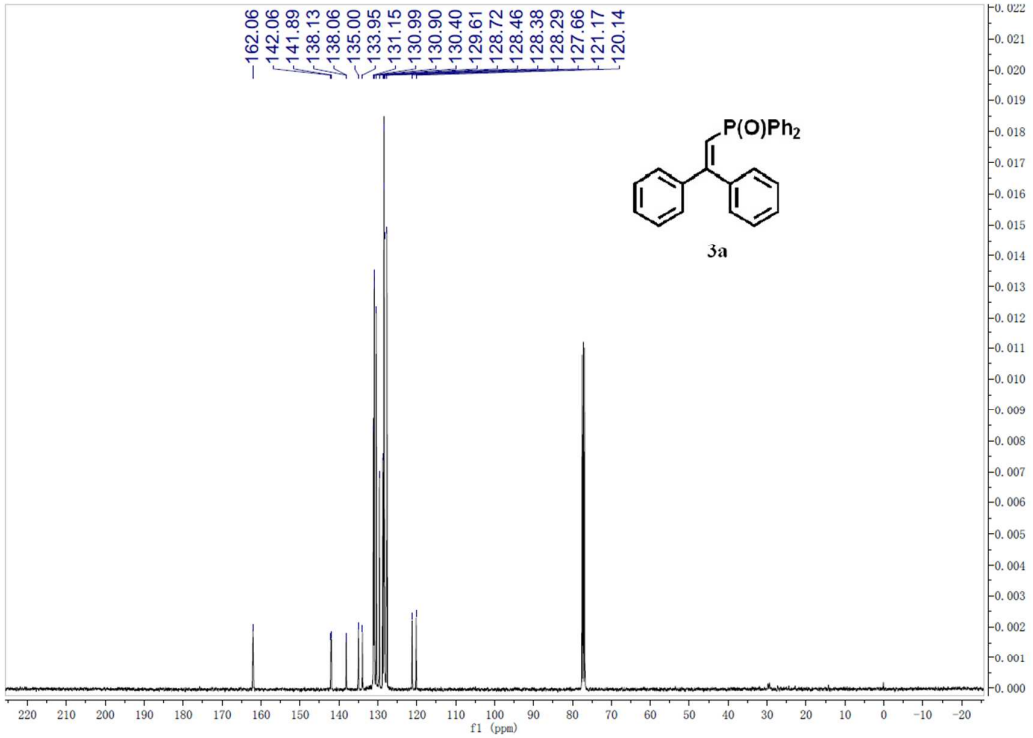
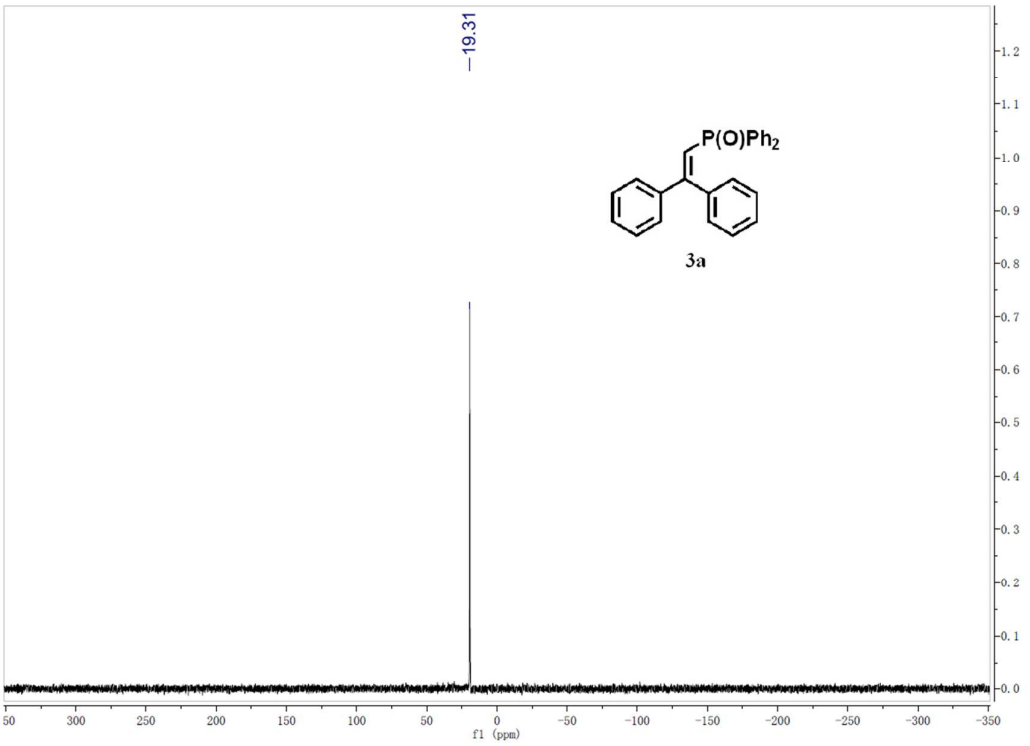
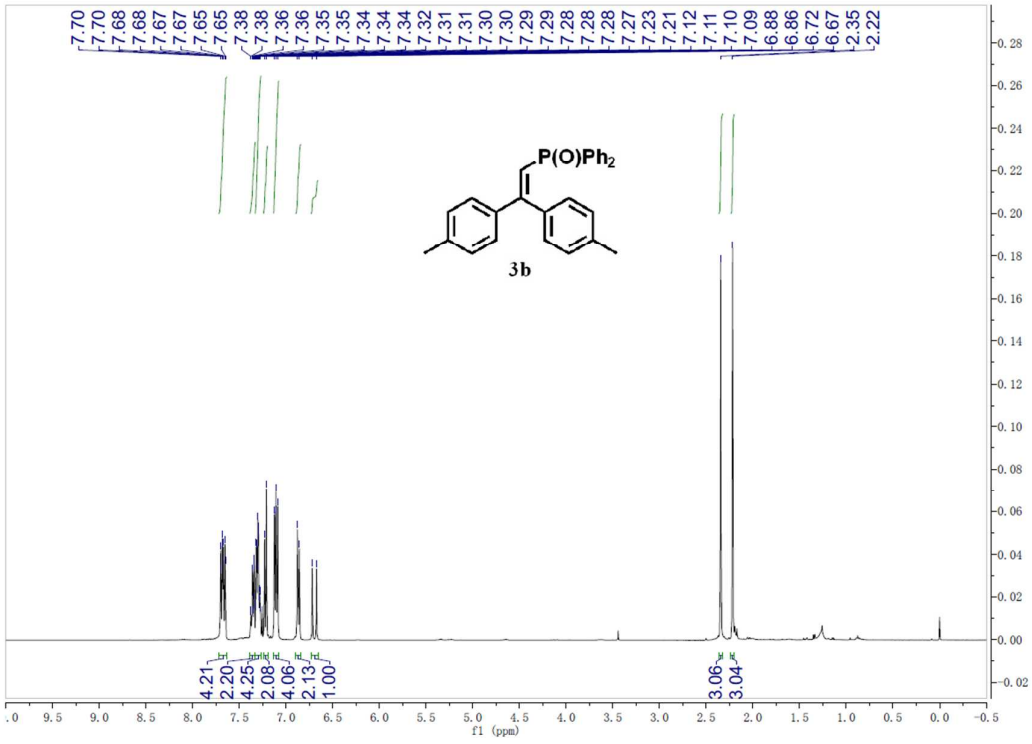
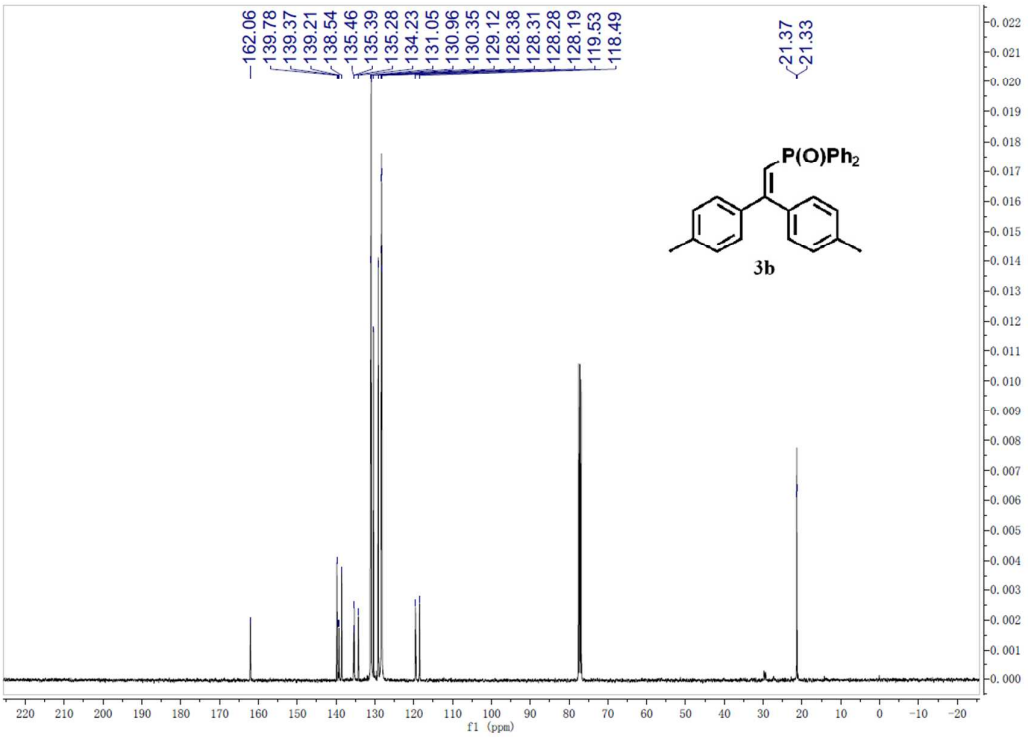
# 10. NMR Spectra for New Compounds

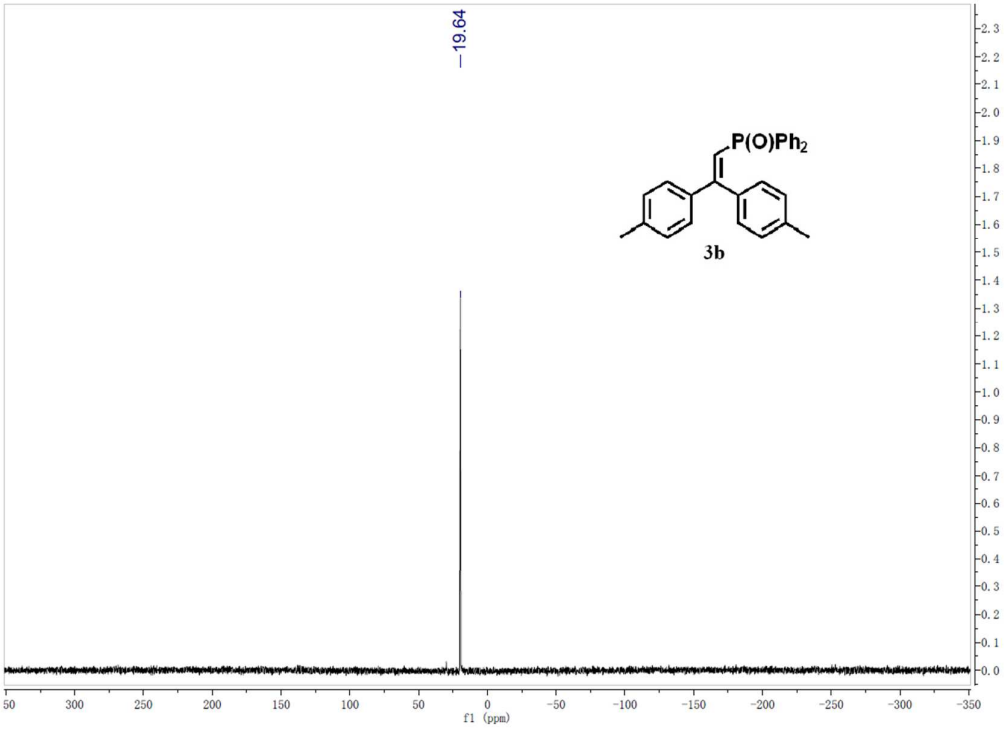


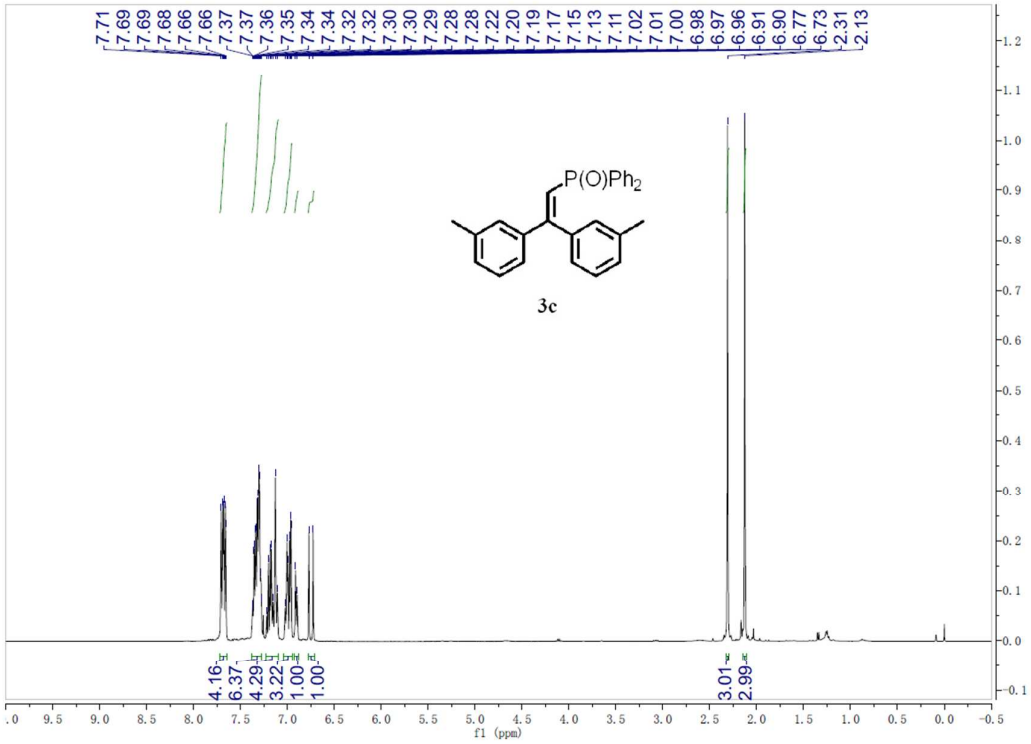



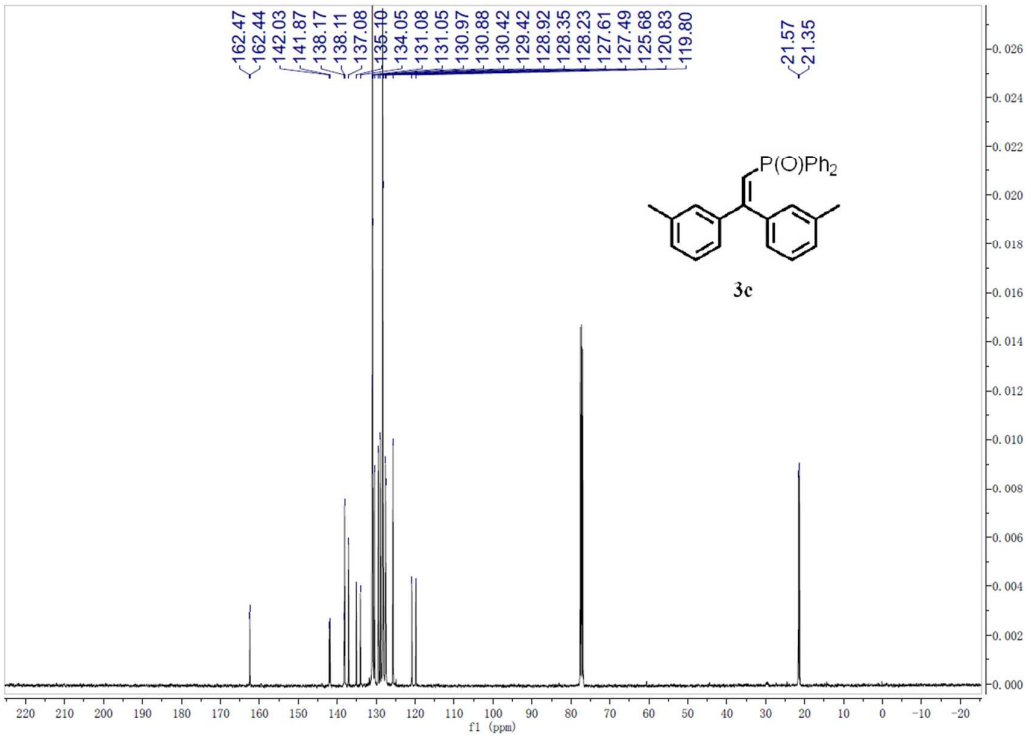

19.31
P(O)Ph2
3a
f1 (ppm)

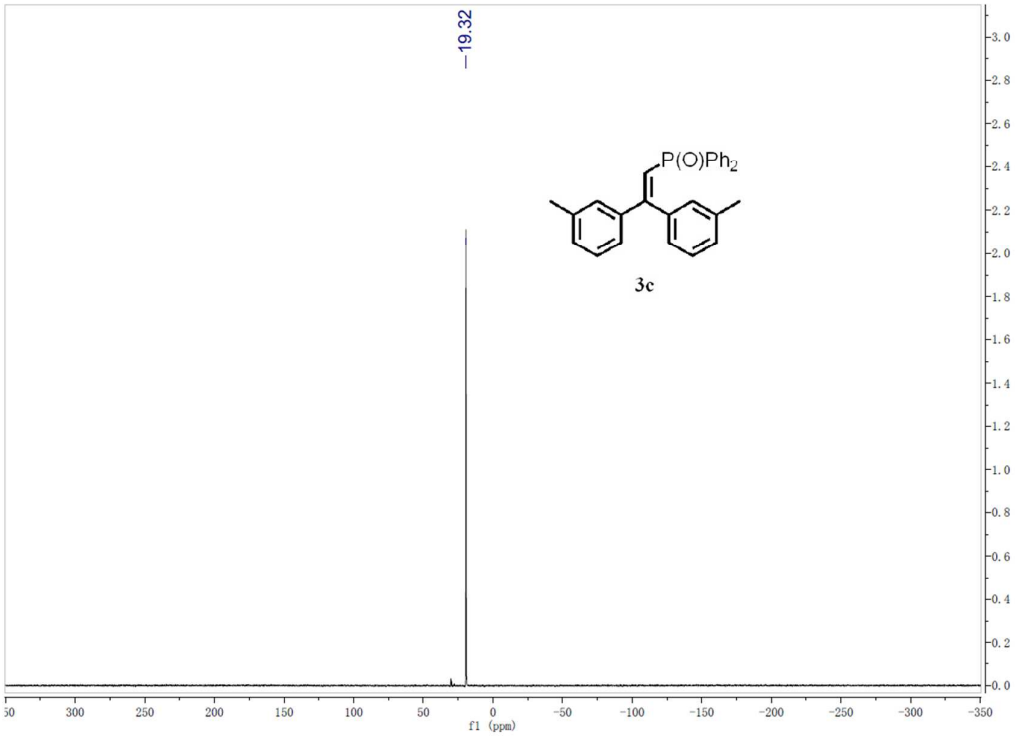

7.70
7.70
7.68
7.68
7.67
7.67
7.65
7.65
7.38
7.38
7.36
7.36
7.35
7.35
7.34
7.34
7.34
7.32
7.31
7.31
7.30
7.30
7.29
7.29
7.28
7.28
7.28
7.27
7.23
7.21
7.12
7.11
7.10
7.09
6.88
6.86
6.72
6.67
2.35
2.22
P(O)Ph2
3b
4.21
2.20
4.25
2.08
4.06
2.13
1.00
3.06
3.04
f1 (ppm)

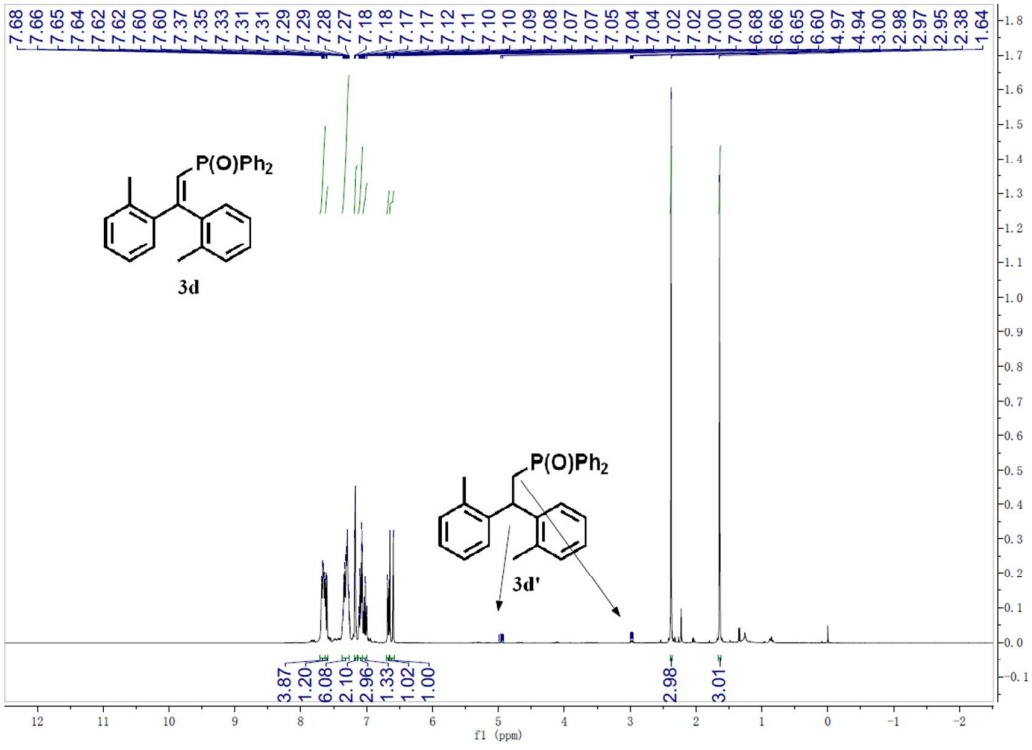

162.06
139.78
139.37
139.21
138.54
135.46
135.39
135.28
134.23
131.05
130.96
130.35
129.12
128.38
128.31
128.28
128.19
119.53
118.49
21.37
21.33
P(O)Ph2
3b
f1 (ppm)

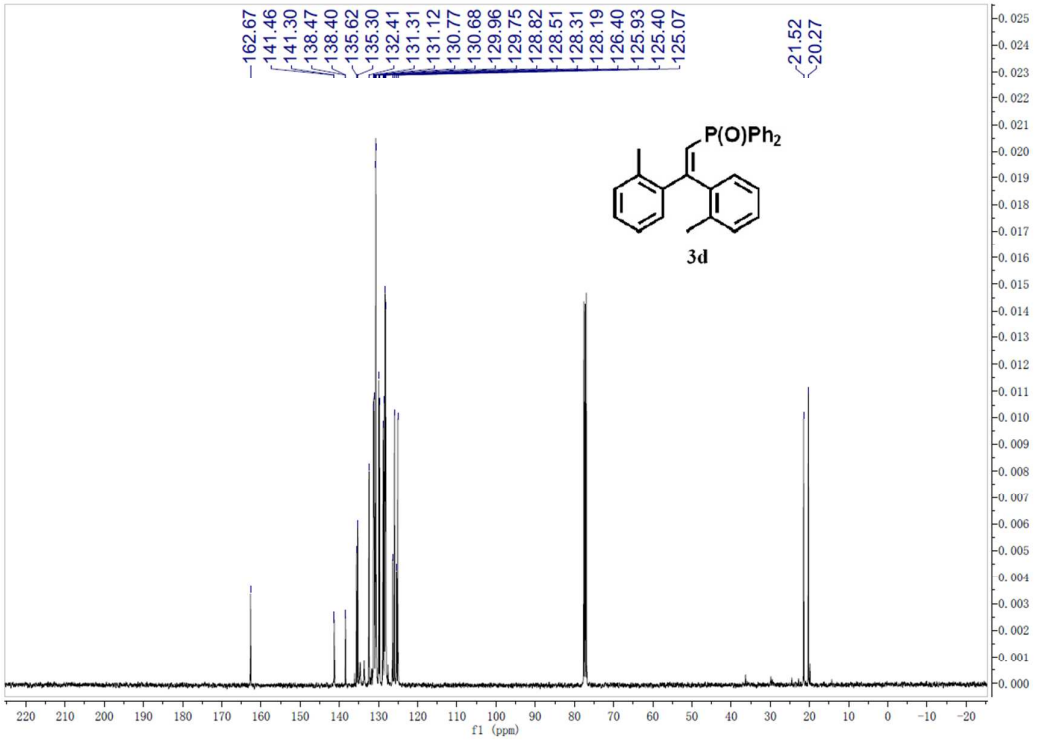

19.64
P(O)Ph2
3b
f1 (ppm)

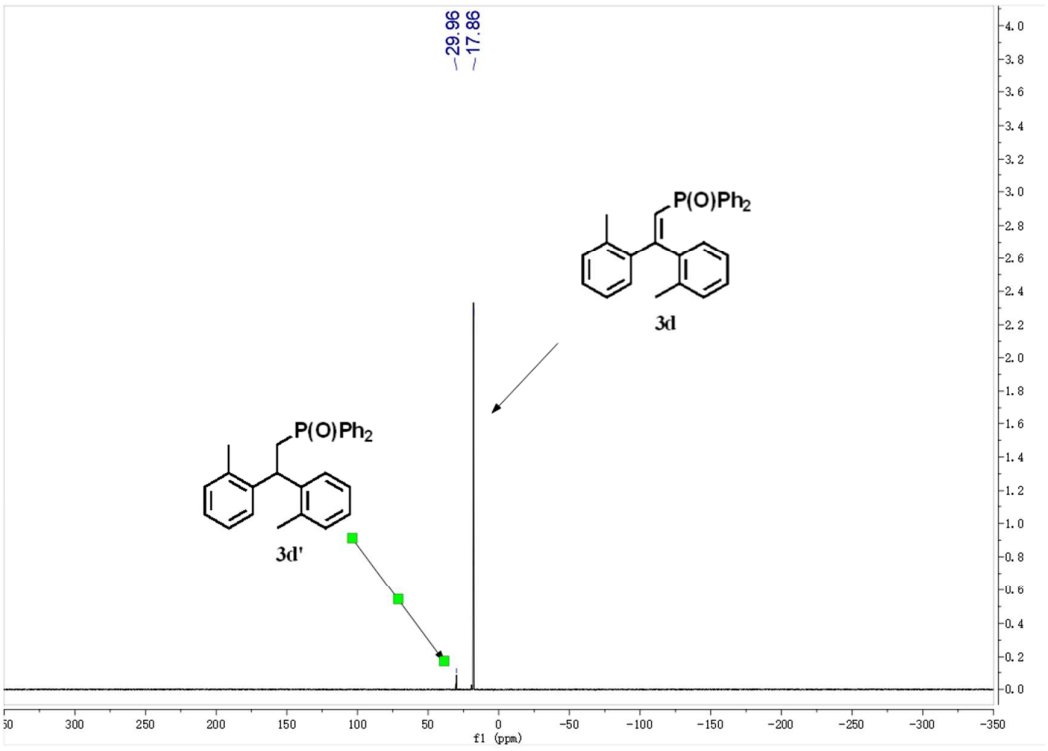

7.71
7.69
7.69
7.68
7.66
7.66
7.37
7.37
7.36
7.35
7.34
7.34
7.32
7.32
7.30
7.30
7.29
7.28
7.28
7.22
7.20
7.19
7.17
7.15
7.13
7.11
7.02
7.01
7.00
6.98
6.97
6.96
6.91
6.90
6.77
6.73
2.31
2.13
P(O)Ph2
3c
4.16
6.37
4.29
3.22
1.00
1.00
3.01
2.99
f1 (ppm)

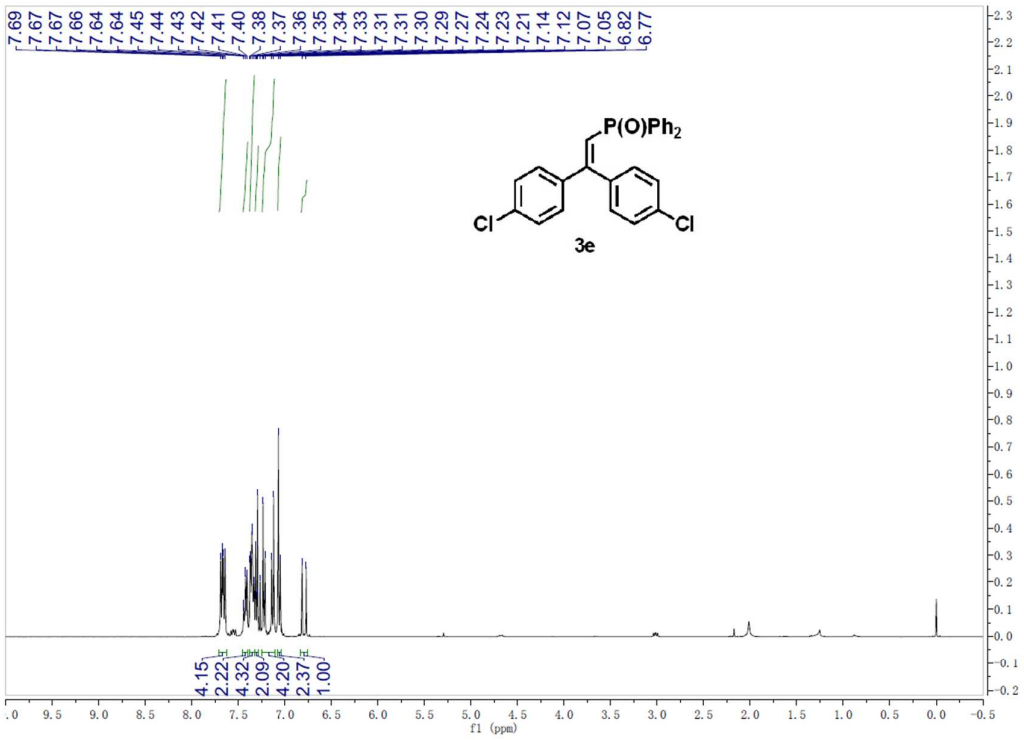

162.47
162.44
142.03
141.87
138.17
138.11
137.08
135.10
134.05
131.08
131.05
130.97
130.88
130.42
129.42
128.92
128.35
128.23
127.61
127.49
125.68
120.83
119.80
21.57
21.35
P(O)Ph2
3c
f1 (ppm)

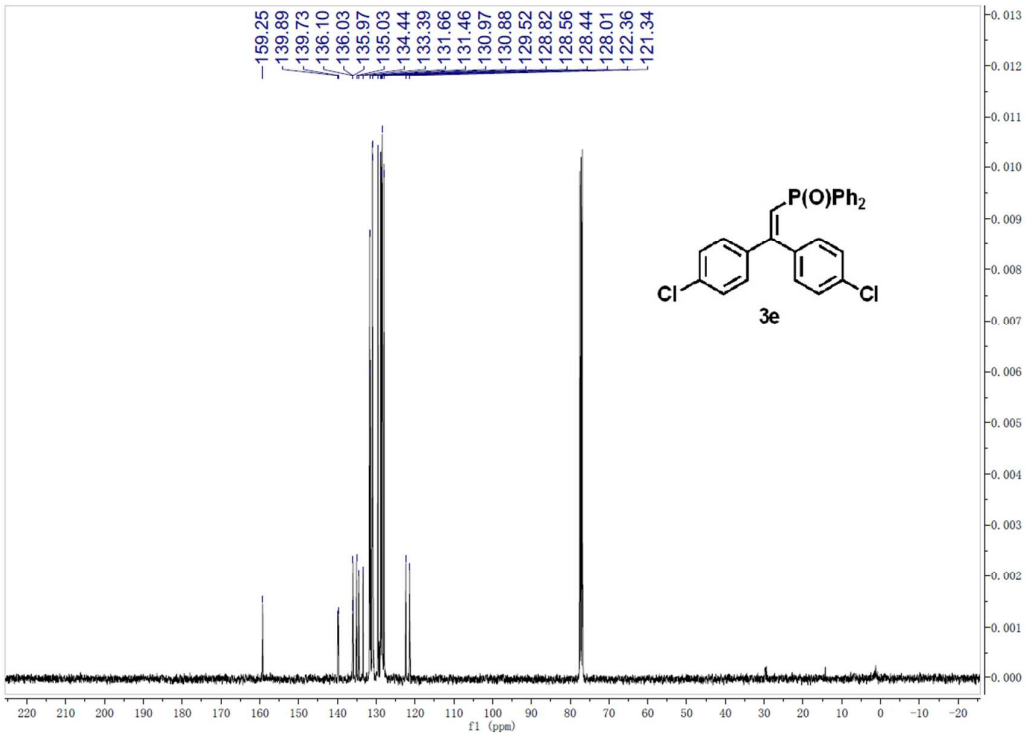

19.32
P(O)Ph2
3c
f1 (ppm)


P(O)Ph2
3d
P(O)Ph2
3d'
3.87
1.20
6.08
2.10
2.96
1.33
1.02
1.00
2.98
3.01
f1 (ppm)


162.67
141.46
141.30
138.47
138.40
135.62
135.30
132.41
131.31
131.12
130.77
130.68
129.96
129.75
128.82
128.51
128.31
128.19
126.40
125.93
125.40
125.07
21.52
20.27
P(O)Ph2
3d
f1 (ppm)


29.96
17.86
P(O)Ph2
3d
P(O)Ph2
3d'
f1 (ppm)


7.69
7.67
7.67
7.66
7.64
7.64
7.45
7.44
7.43
7.42
7.41
7.40
7.38
7.37
7.36
7.35
7.34
7.33
7.31
7.31
7.30
7.29
7.27
7.24
7.23
7.21
7.14
7.12
7.07
7.05
6.82
6.77
P(O)Ph2
Cl
Cl
3e
4.15
2.22
4.32
2.09
4.20
2.37
1.00
f1 (ppm)


159.25
139.89
139.73
136.10
136.03
135.97
135.03
134.44
133.39
131.66
131.46
130.97
130.88
129.52
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128.44
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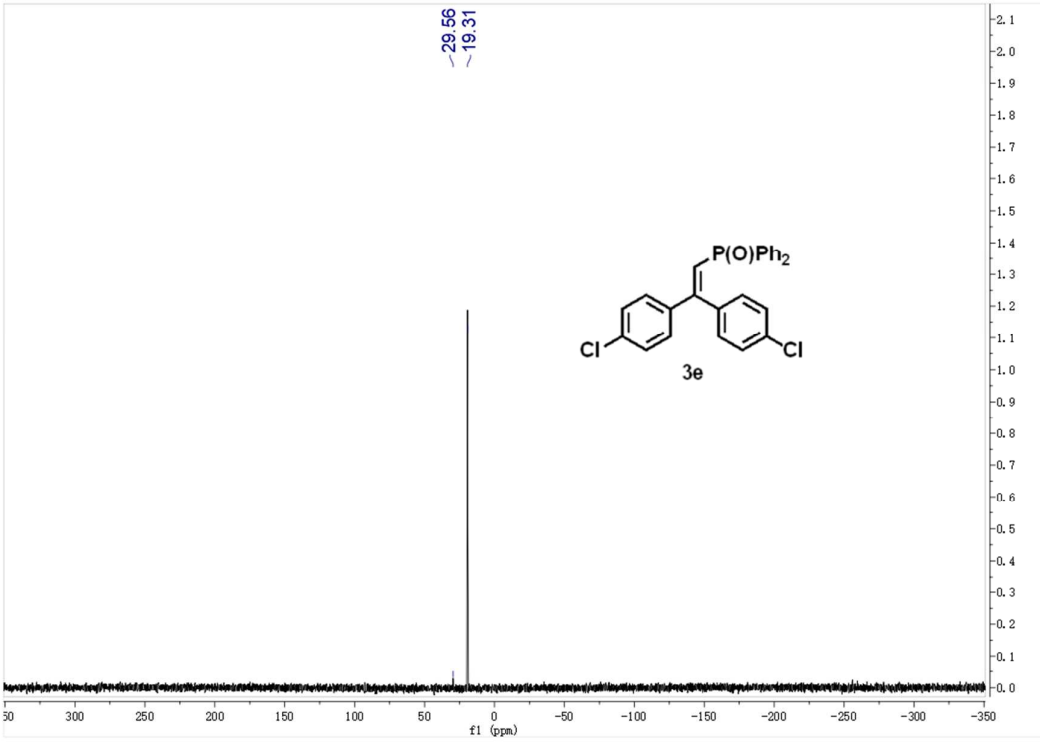
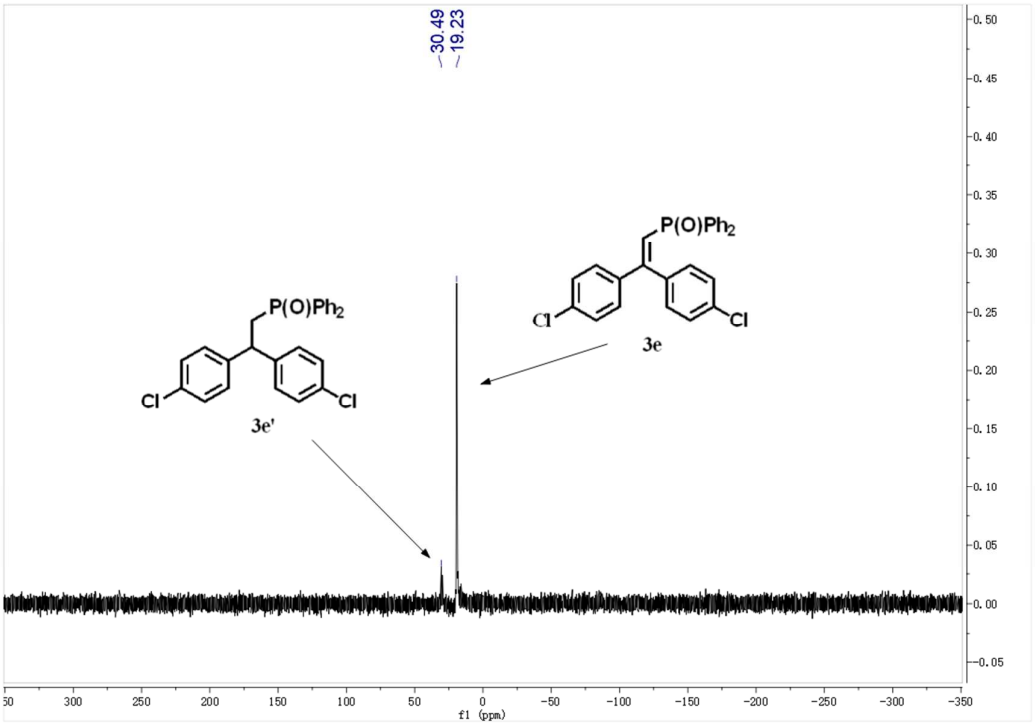
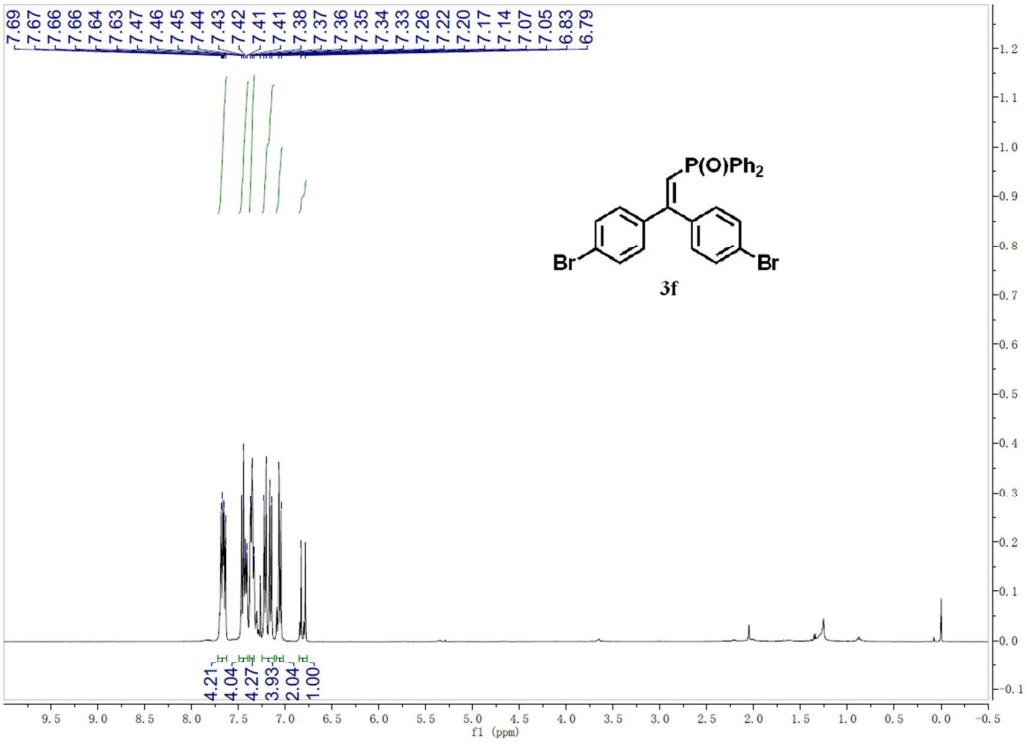
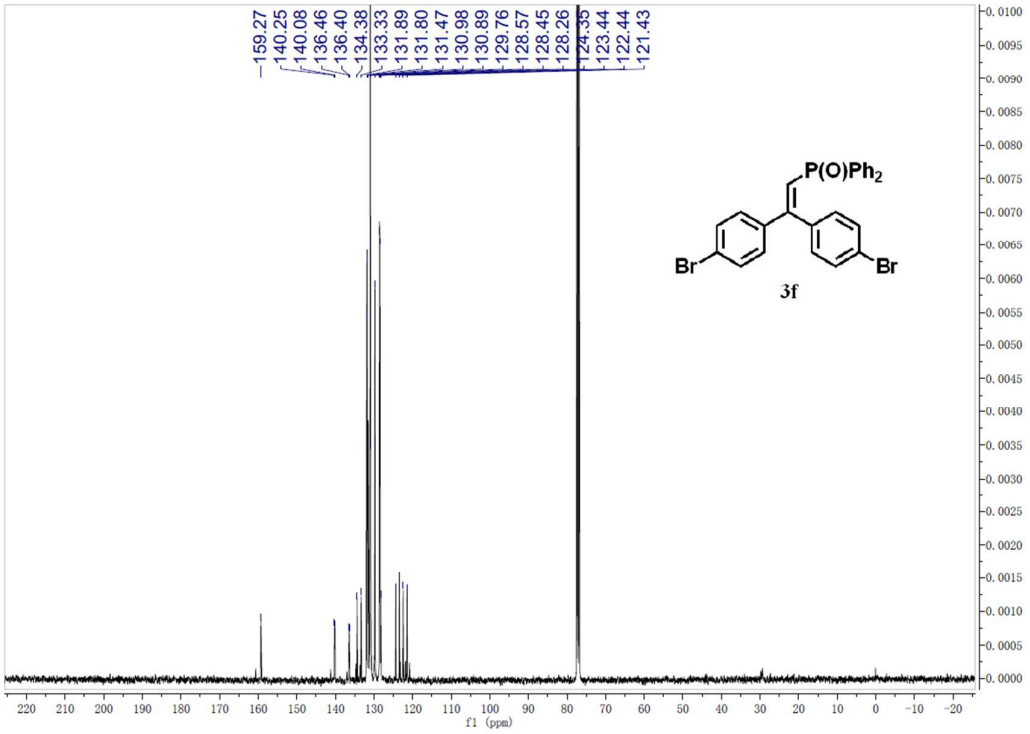
122.36
121.34
P(O)Ph2
Cl
Cl
3e
f1 (ppm)

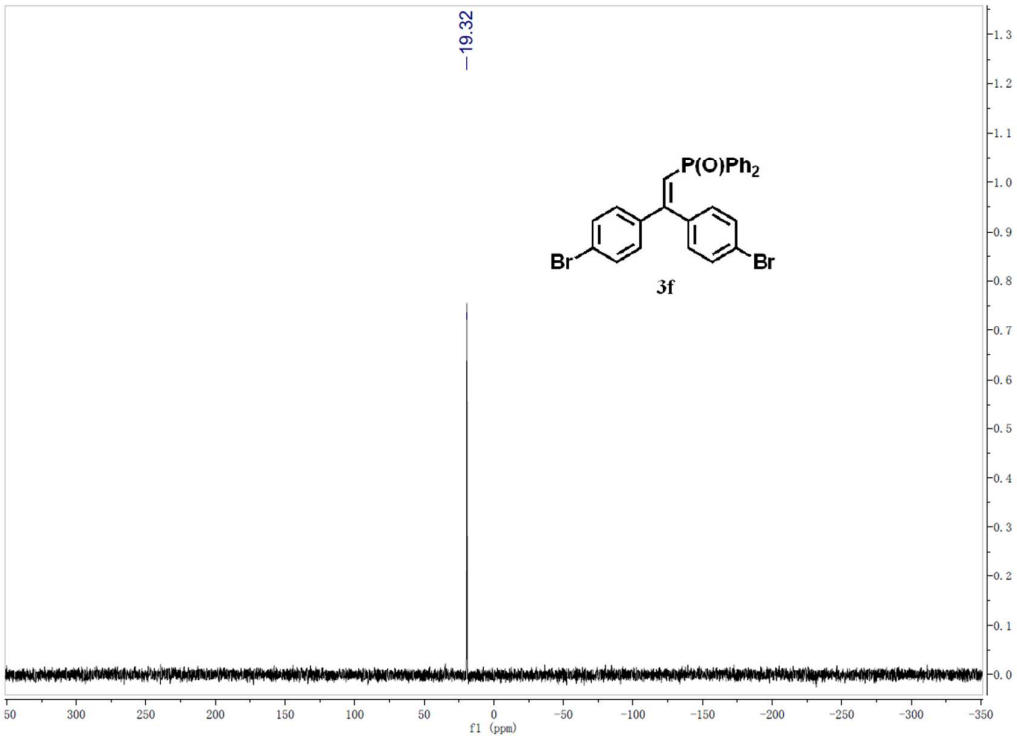


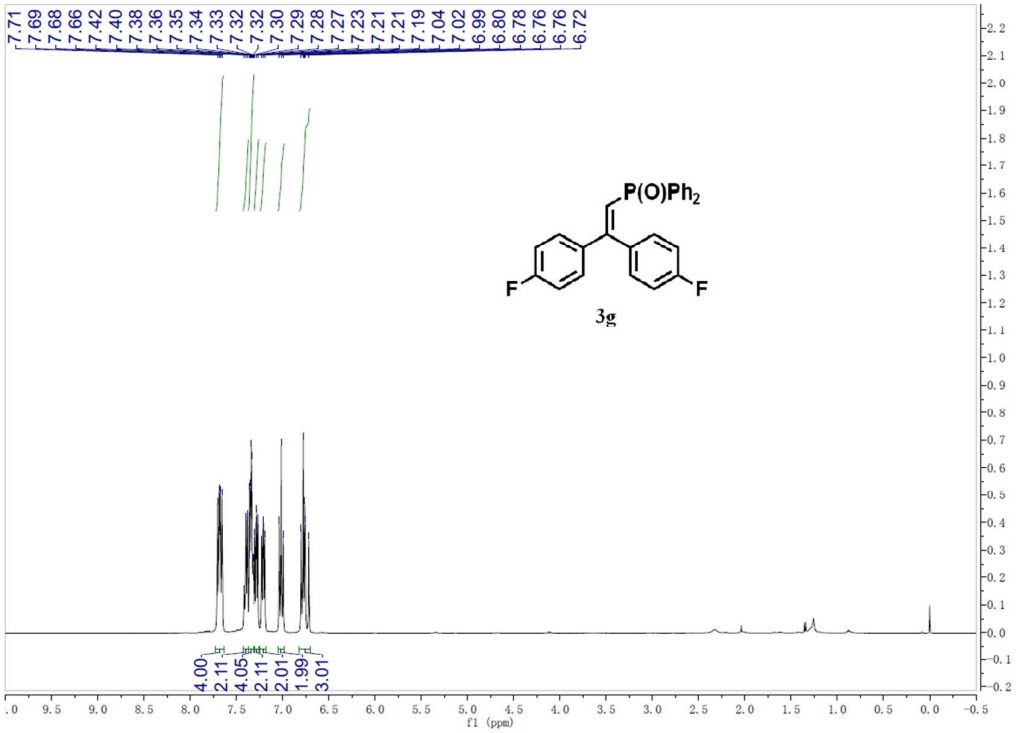



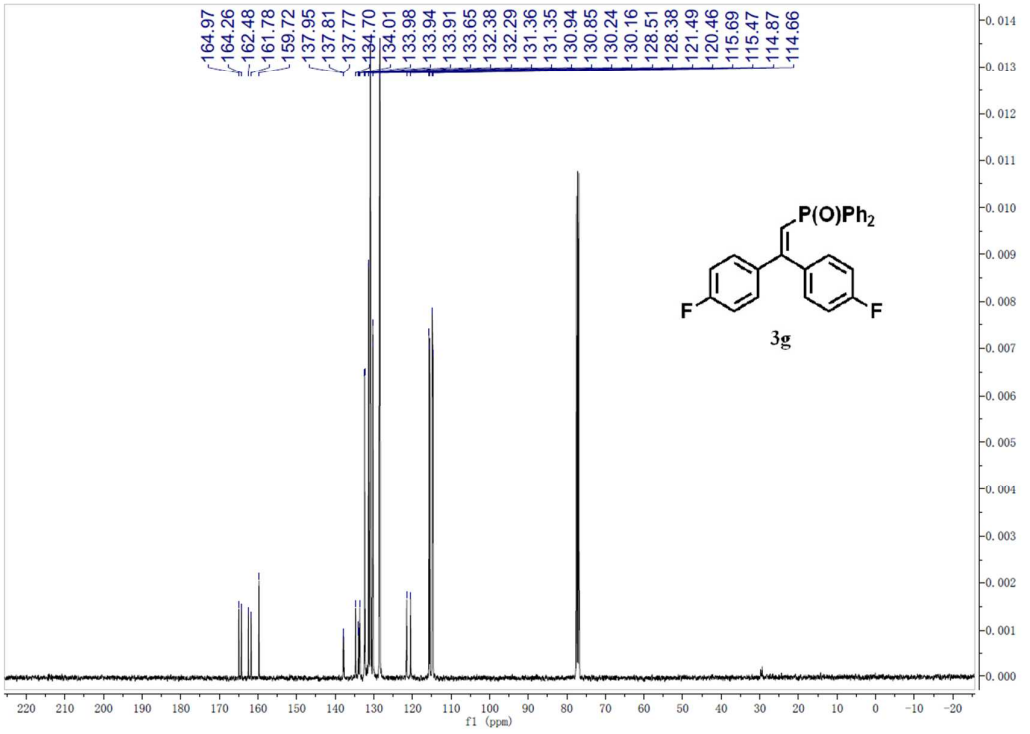

$^{31}$P NMR of crude reaction mixture before isolation (3e and 3e')

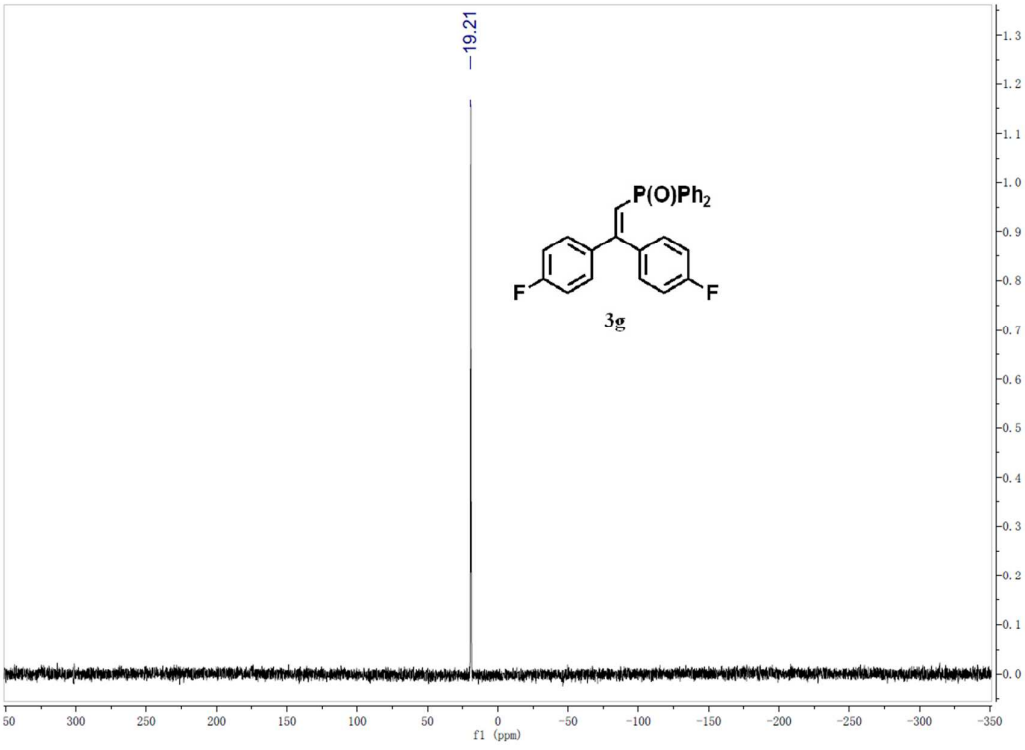

7.69
7.67
7.66
7.66
7.64
7.63
7.47
7.46
7.45
7.44
7.43
7.42
7.41
7.41
7.38
7.37
7.36
7.35
7.34
7.33
7.26
7.22
7.20
7.17
7.14
7.07
7.05
6.83
6.79
P(O)Ph2
Br
Br
3f
4.21
4.04
4.27
3.93
2.04
1.00
f1 (ppm)

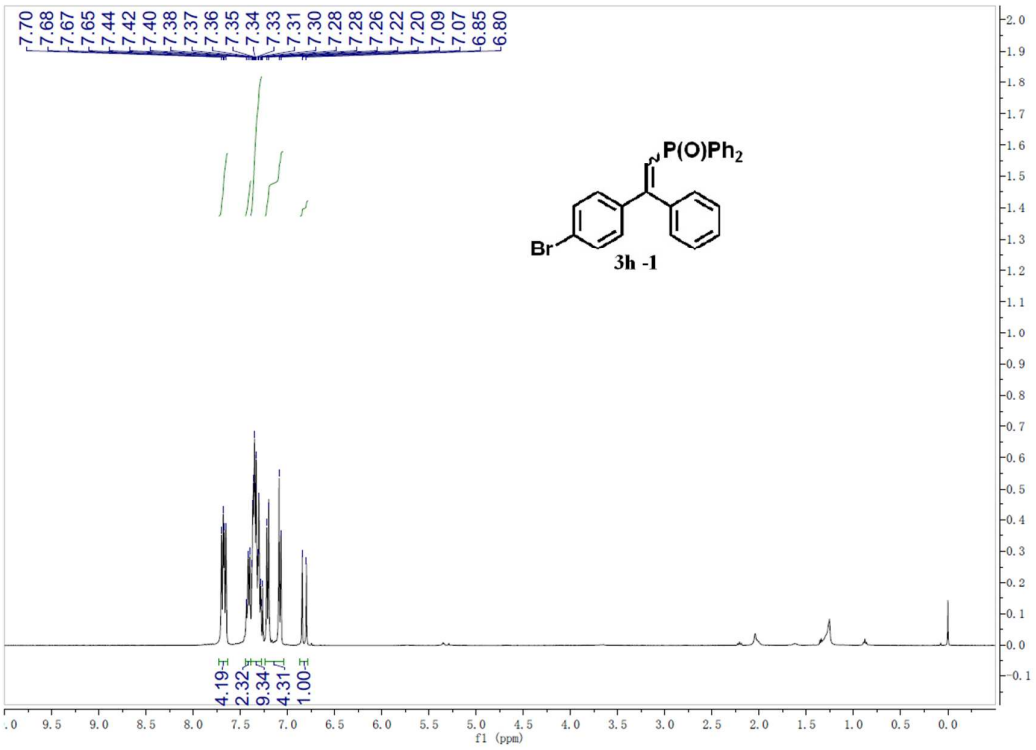

159.27
140.25
140.08
136.46
136.40
134.38
133.33
131.89
131.80
131.47
130.98
130.89
129.76
128.57
128.45
128.26
124.35
123.44
122.44
121.43
P(O)Ph2
Br
Br
3f
f1 (ppm)

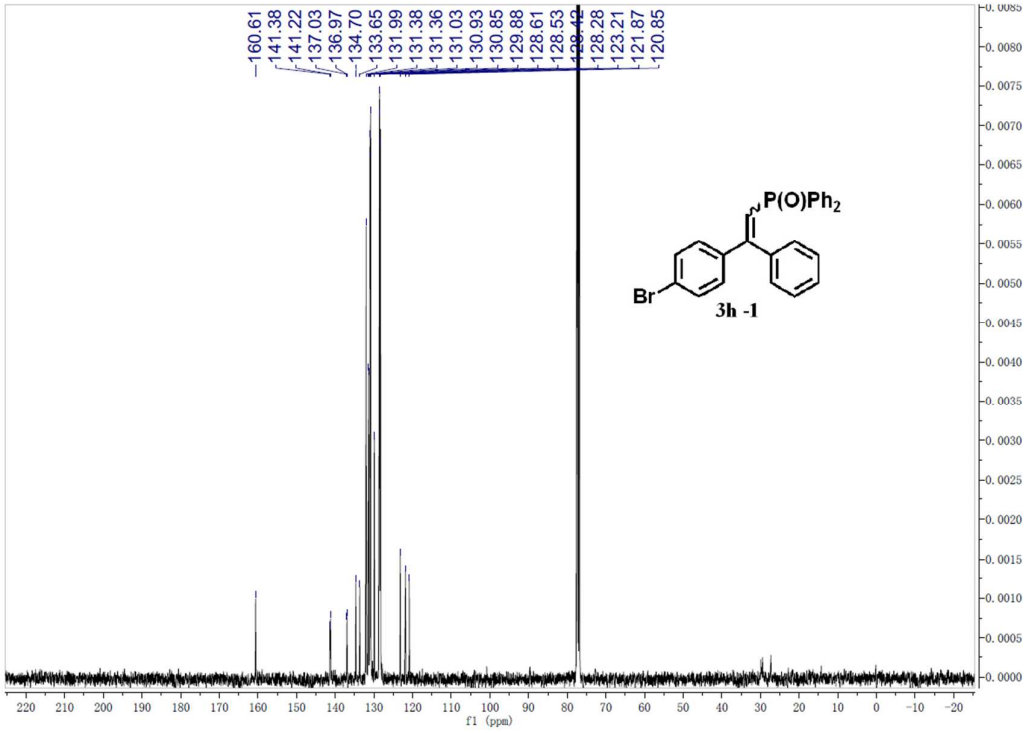

19.32
P(O)Ph2
Br
Br
3f
f1 (ppm)

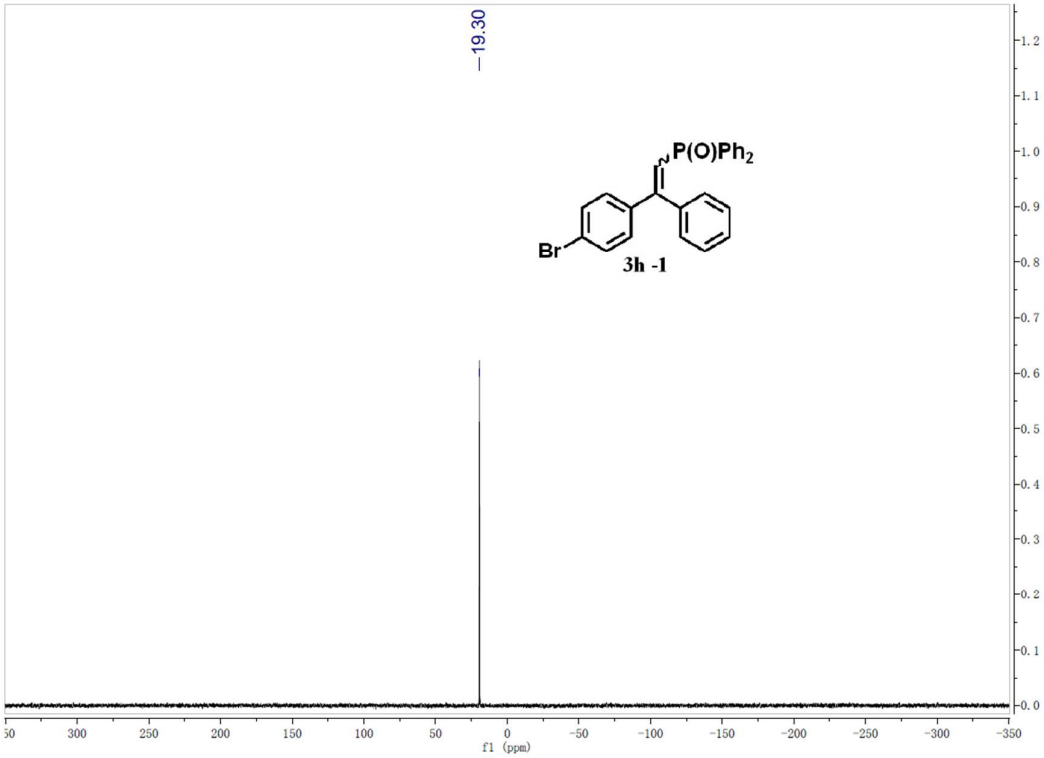

7.71
7.69
7.68
7.66
7.42
7.40
7.38
7.36
7.35
7.34
7.33
7.32
7.32
7.30
7.29
7.28
7.27
7.23
7.21
7.21
7.19
7.04
7.02
6.99
6.80
6.78
6.76
6.76
6.72
P(O)Ph2
F
F
3g
4.00
2.11
4.05
2.11
2.01
1.99
3.01
f1 (ppm)

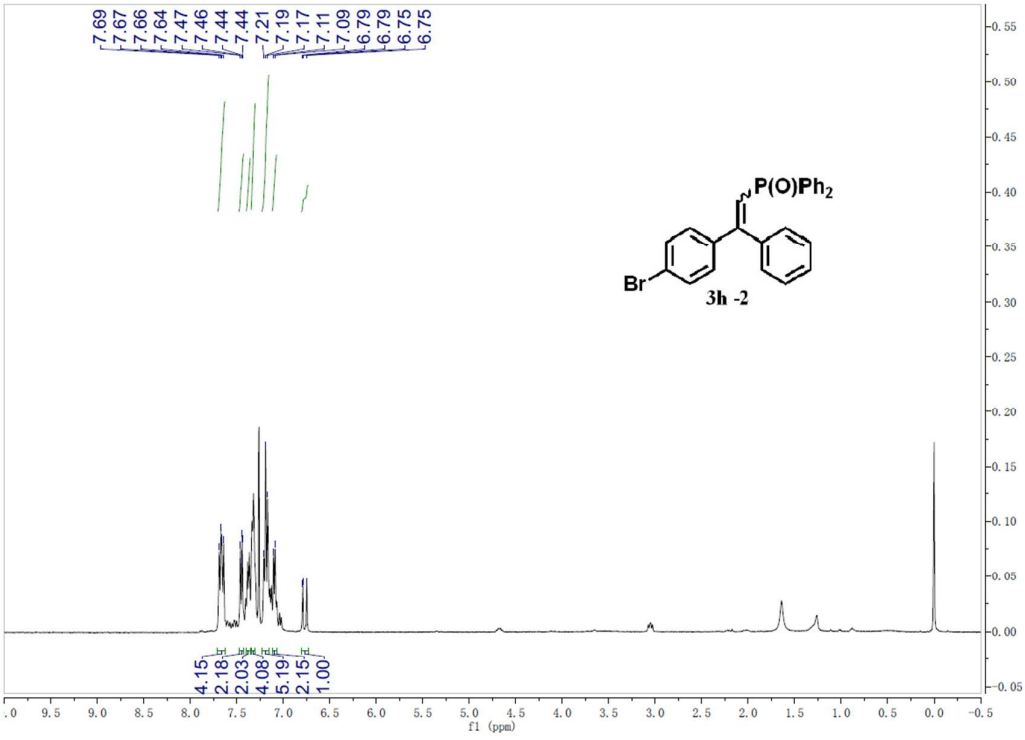

164.97
164.26
162.48
161.78
159.72
137.95
137.81
137.77
134.70
134.01
133.98
133.94
133.91
133.65
132.38
132.29
131.36
131.35
130.94
130.85
130.24
130.16
128.51
128.38
121.49
120.46
115.69
115.47
114.87
114.66
P(O)Ph2
F
F
3g
f1 (ppm)

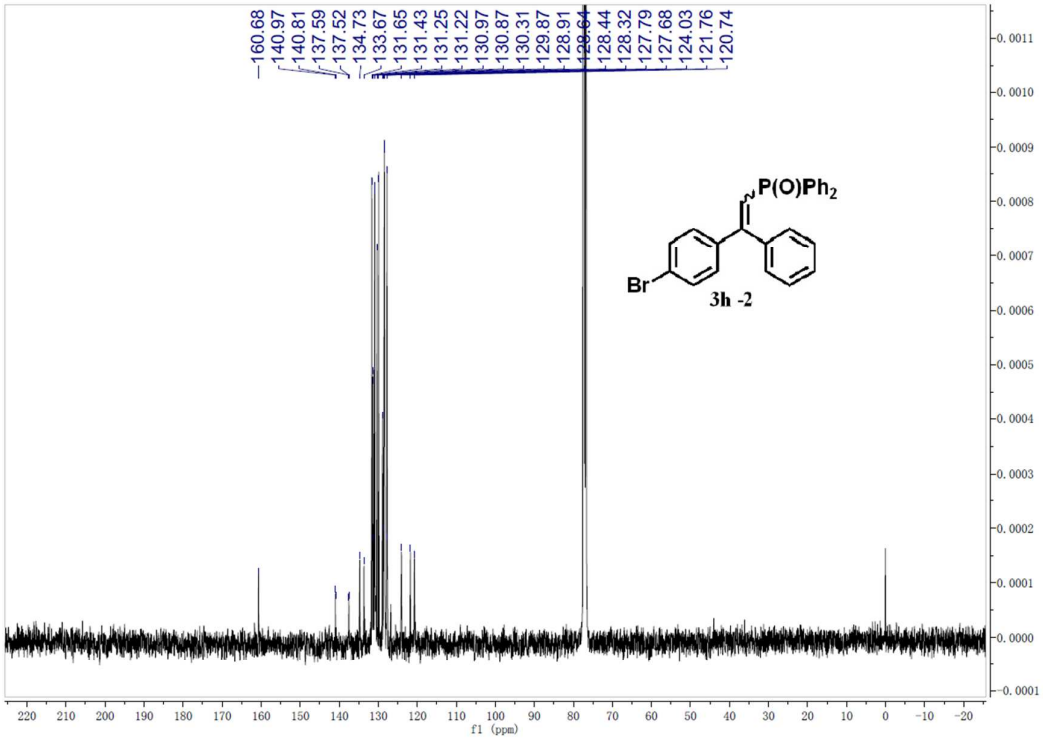

-19.21
P(O)Ph2
F
F
3g
f1 (ppm)

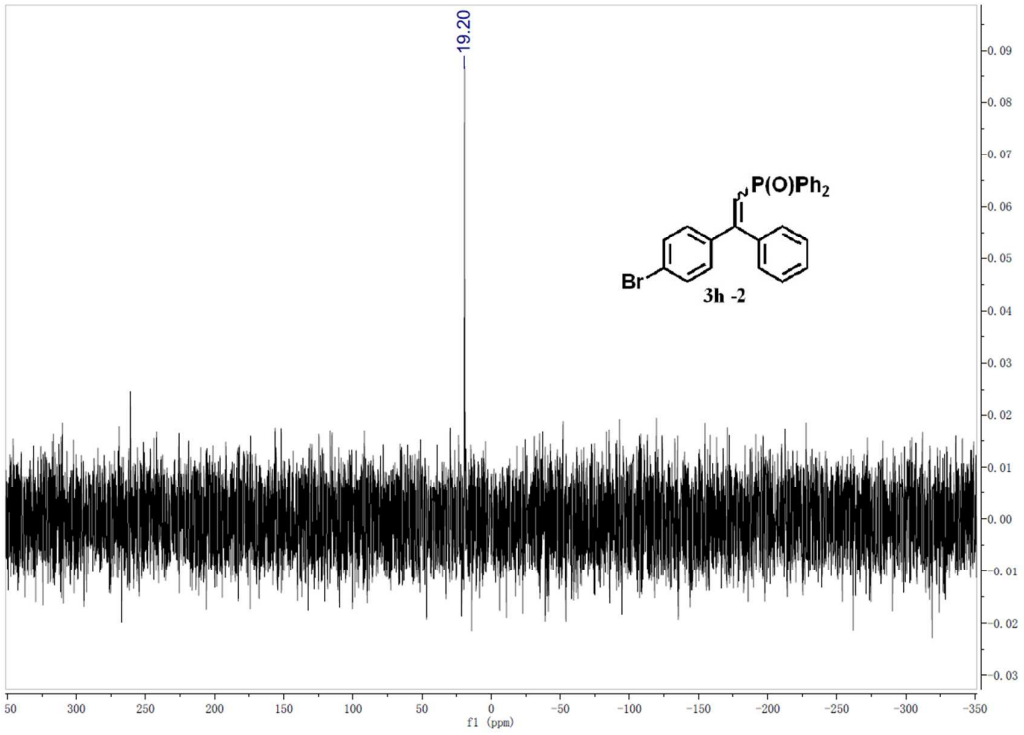

7.70
7.68
7.67
7.65
7.44
7.42
7.40
7.38
7.37
7.36
7.35
7.34
7.33
7.31
7.30
7.28
7.28
7.26
7.22
7.20
7.09
7.07
6.85
6.80
P(O)Ph2
Br
3h -1
4.19
2.32
9.34
4.31
1.00
f1 (ppm)

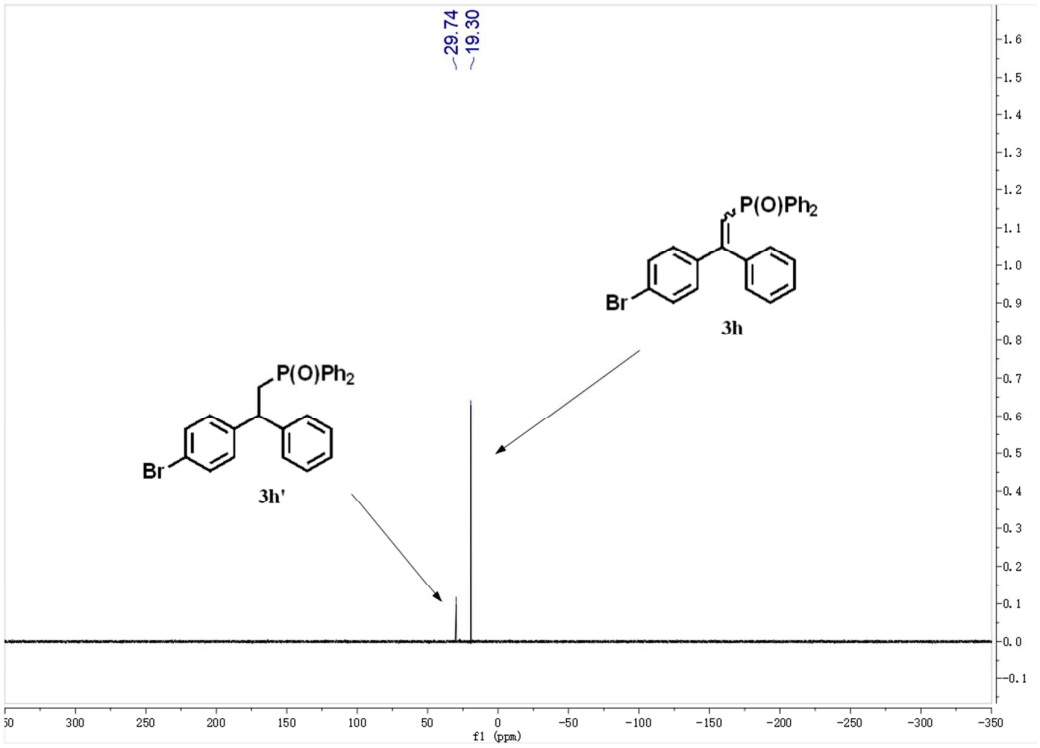

160.61
141.38
141.22
137.03
136.97
134.70
133.65
131.99
131.38
131.36
131.03
130.93
130.85
129.88
128.61
128.53
128.42
128.28
123.21
121.87
120.85
P(O)Ph2
Br
3h -1
f1 (ppm)


19.30
P(O)Ph2
Br
3h -1
f1 (ppm)

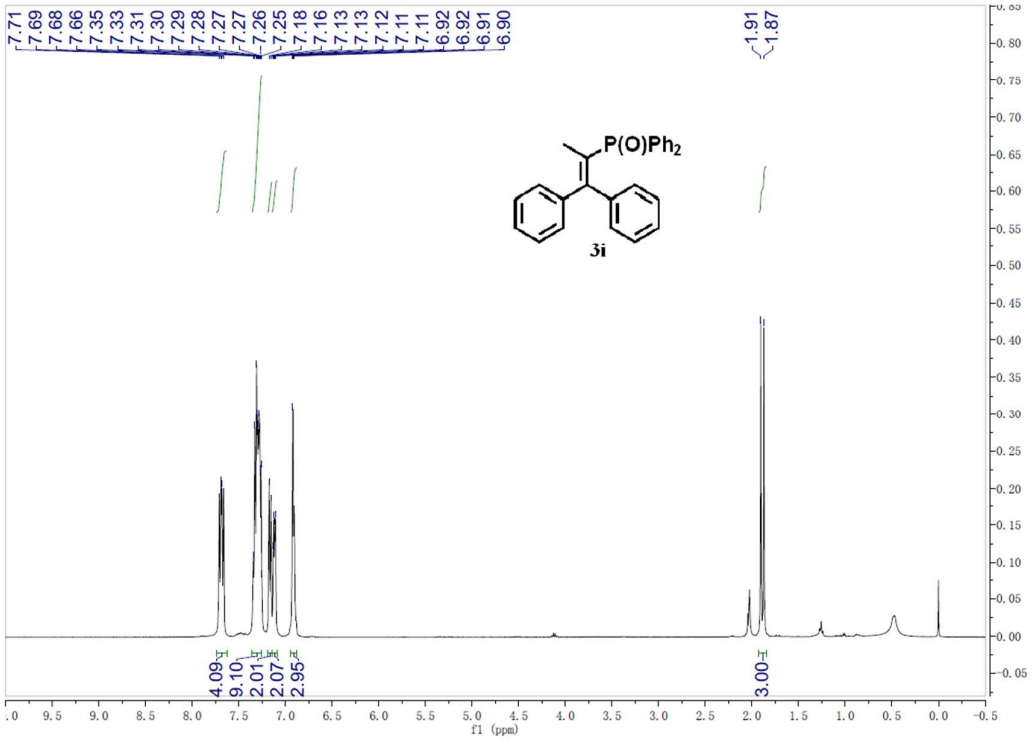

7.69
7.67
7.66
7.64
7.47
7.46
7.44
7.44
7.21
7.19
7.17
7.11
7.09
6.79
6.79
6.75
6.75
P(O)Ph2
Br
3h -2
4.15
2.18
2.03
4.08
5.19
2.15
1.00
f1 (ppm)

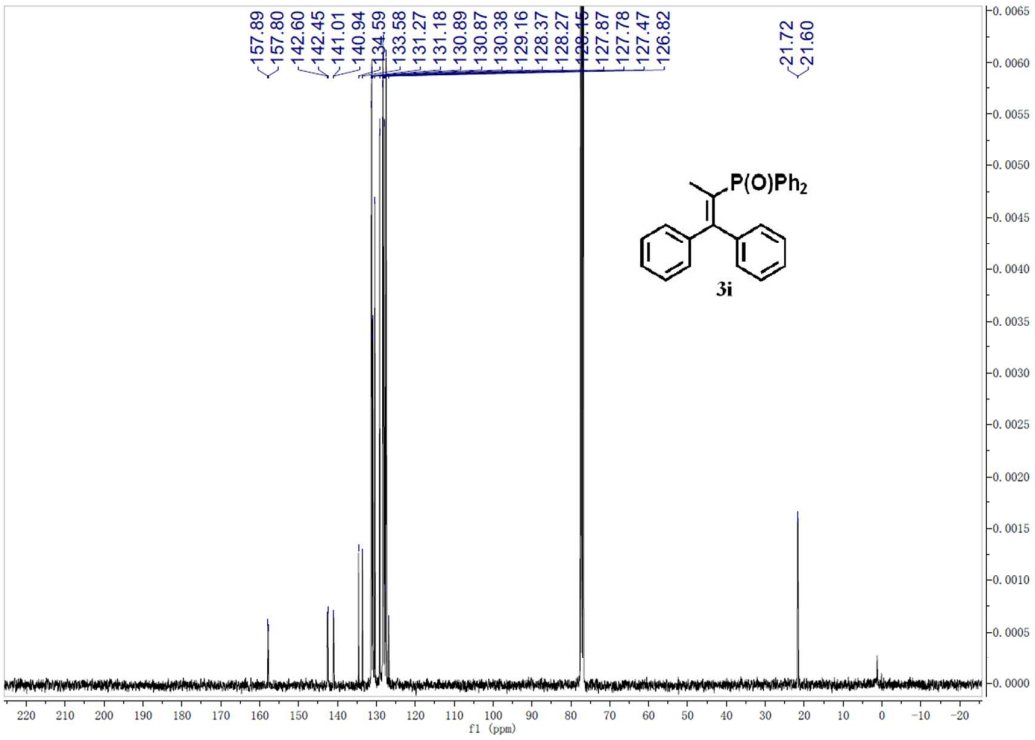

160.68
140.97
140.81
137.59
137.52
134.73
133.67
131.65
131.43
131.25
131.22
130.97
130.87
130.31
129.87
128.91
128.64
128.44
128.32
127.79
127.68
124.03
121.76
120.74
P(O)Ph2
Br
3h -2
f1 (ppm)

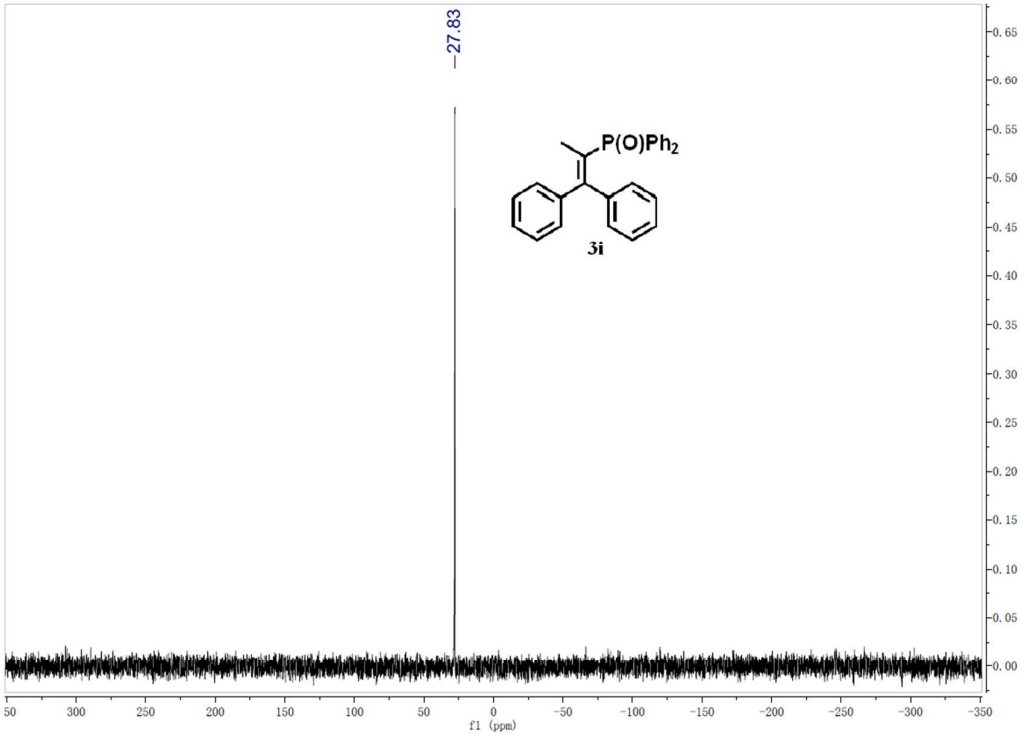

19.20
P(O)Ph2
Br
3h -2
f1 (ppm)

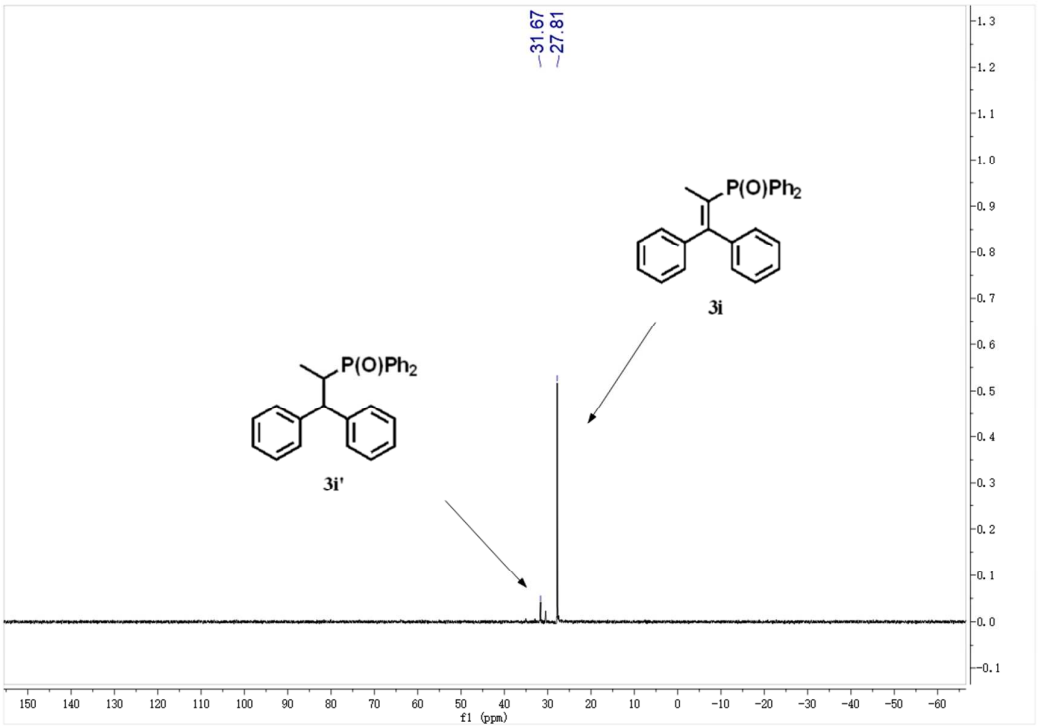



$^{31}$P NMR of crude reaction mixture before isolation (3h and 3h')

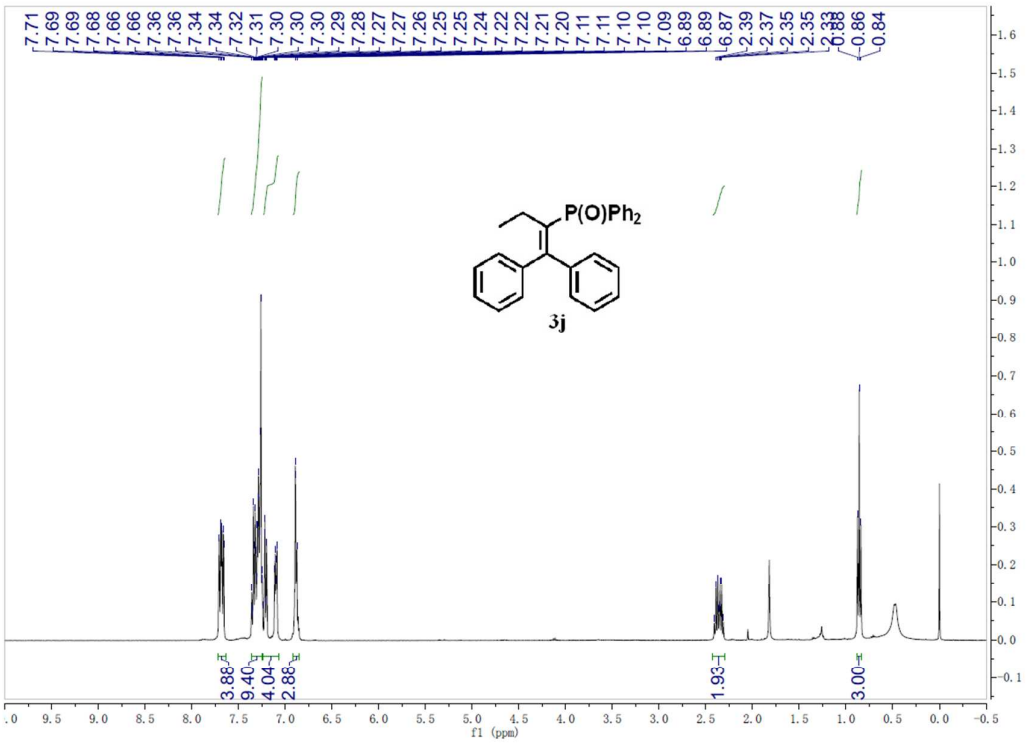


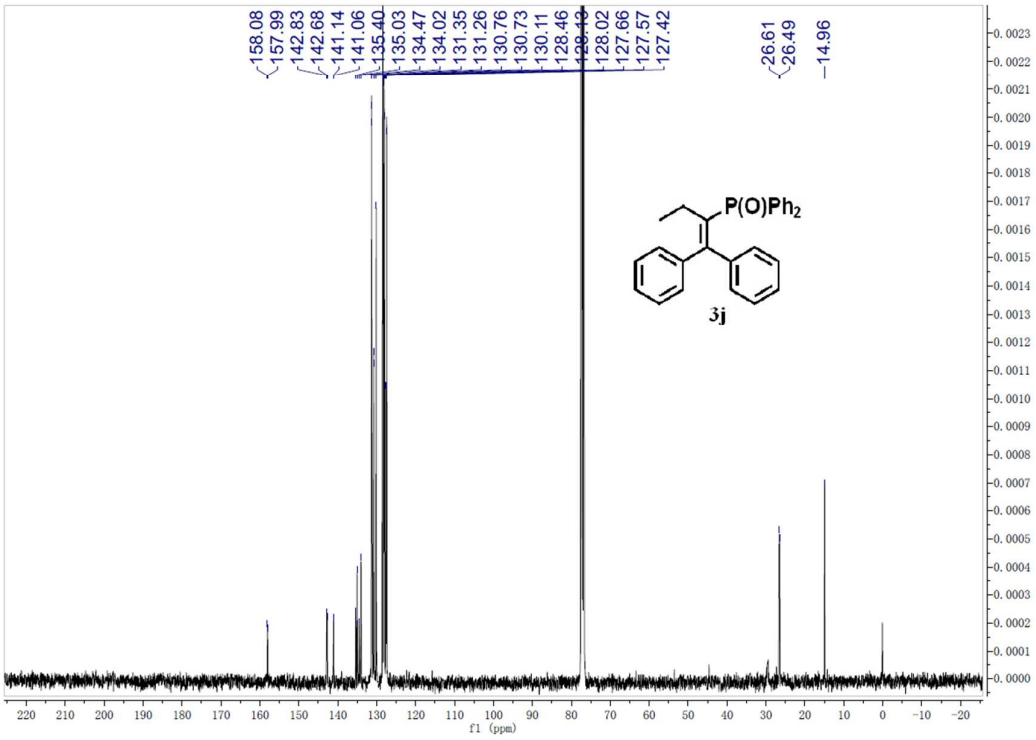

157.89
157.80
142.60
142.45
141.01
140.94
134.59
133.58
131.27
131.18
130.89
130.87
130.38
129.16
128.37
128.27
127.87
127.78
127.47
126.82
21.72
21.60
P(O)Ph2
3i
f1 (ppm)

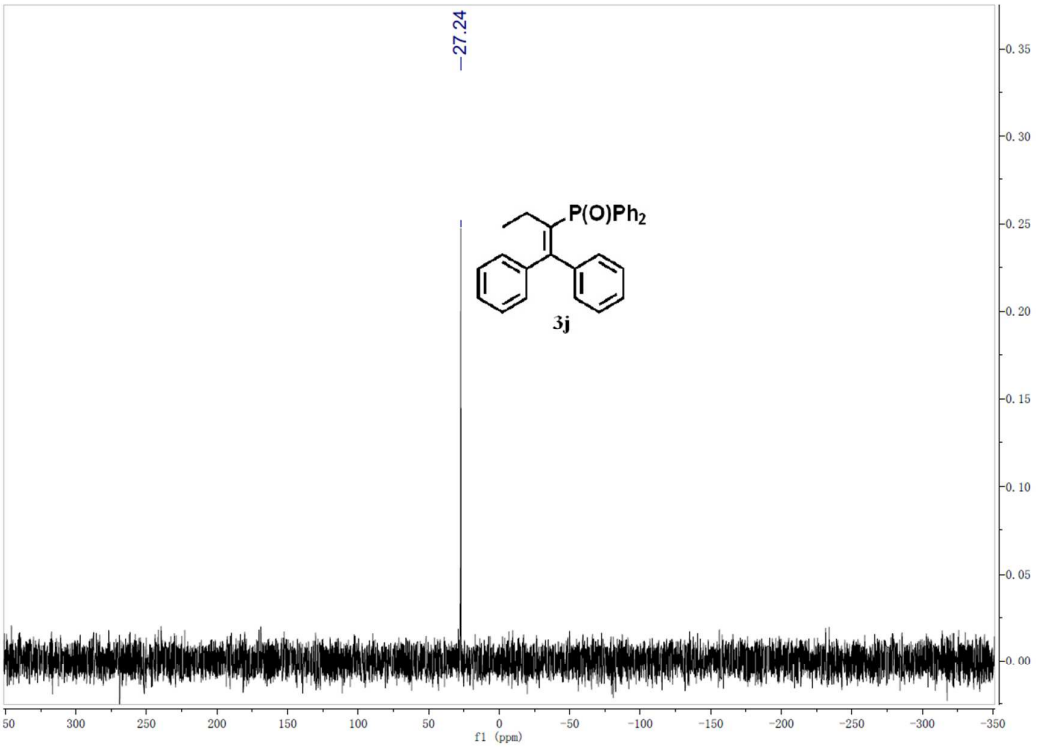

27.83
P(O)Ph2
3i
f1 (ppm)

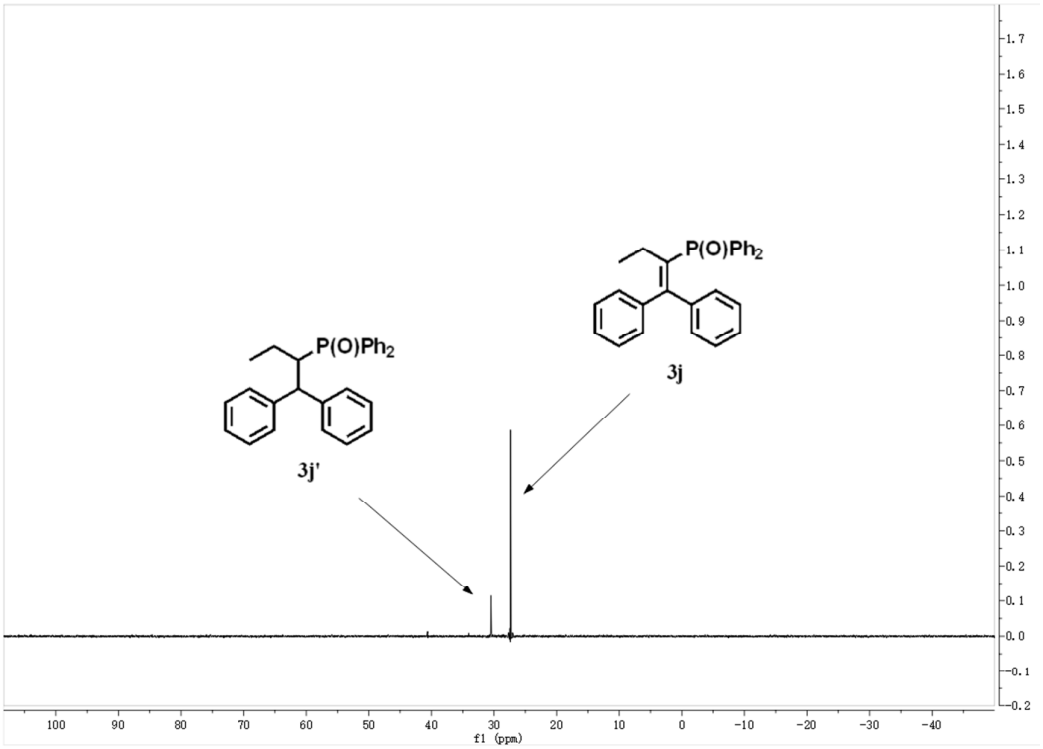



$^{31}$P NMR of crude reaction mixture before isolation (3i and 3i')

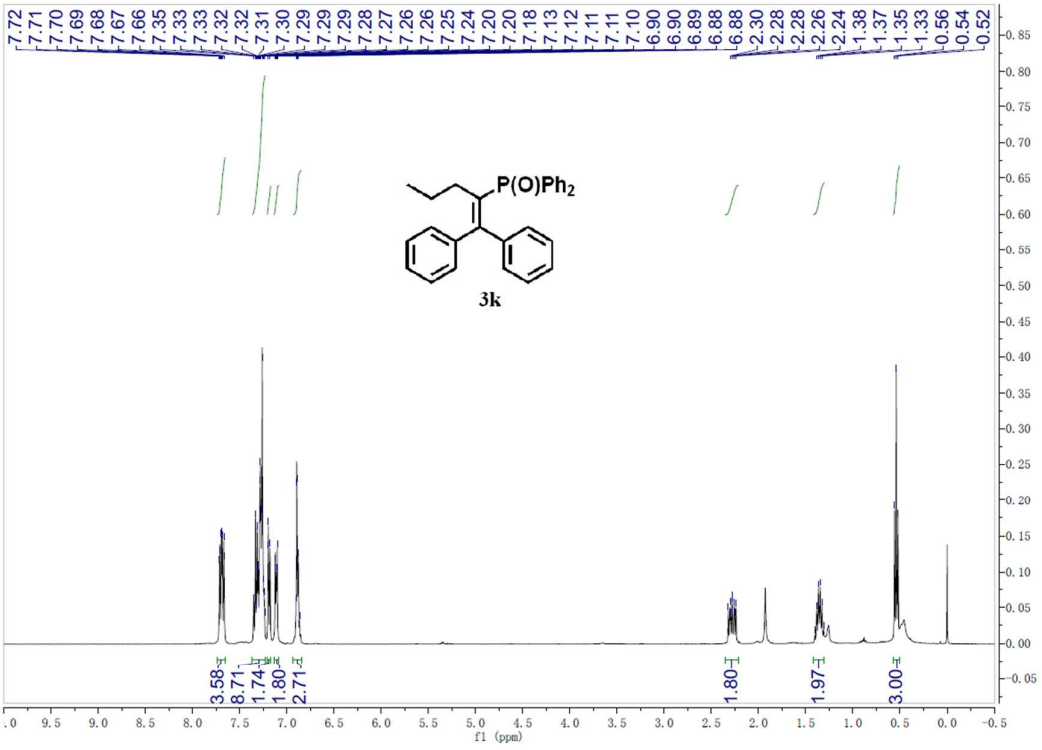


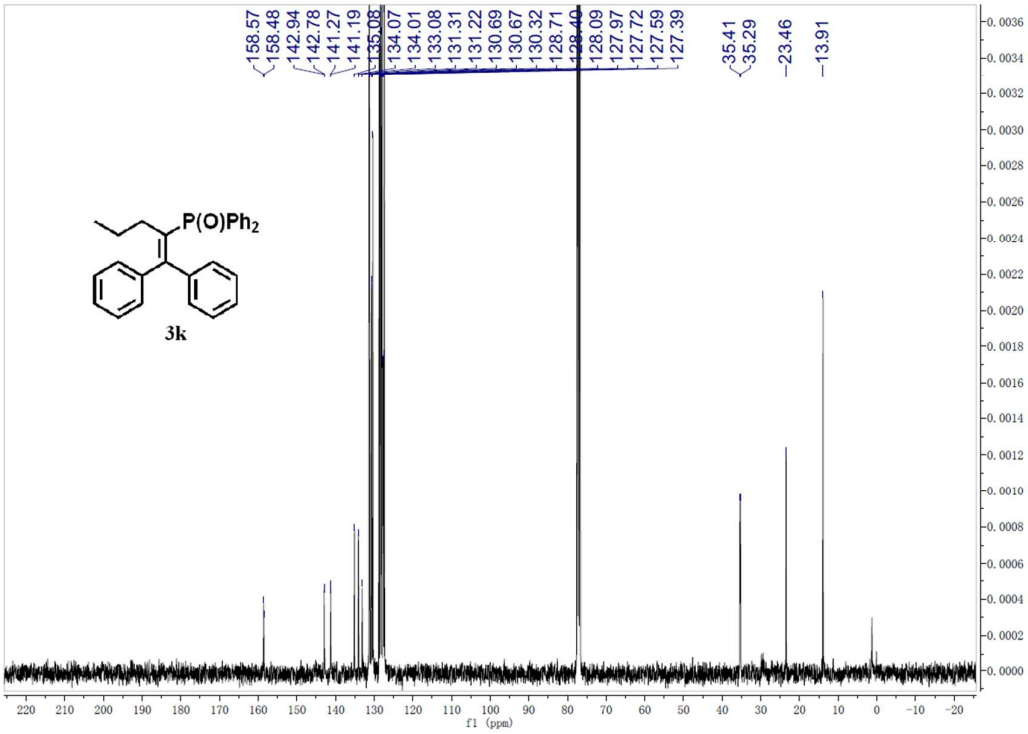

158.08
157.99
142.83
142.68
141.14
141.06
135.40
135.03
134.47
134.02
131.35
131.26
130.76
130.73
130.11
128.46
128.02
127.66
127.57
127.42
26.61
26.49
14.96
P(O)Ph2
3j
f1 (ppm)

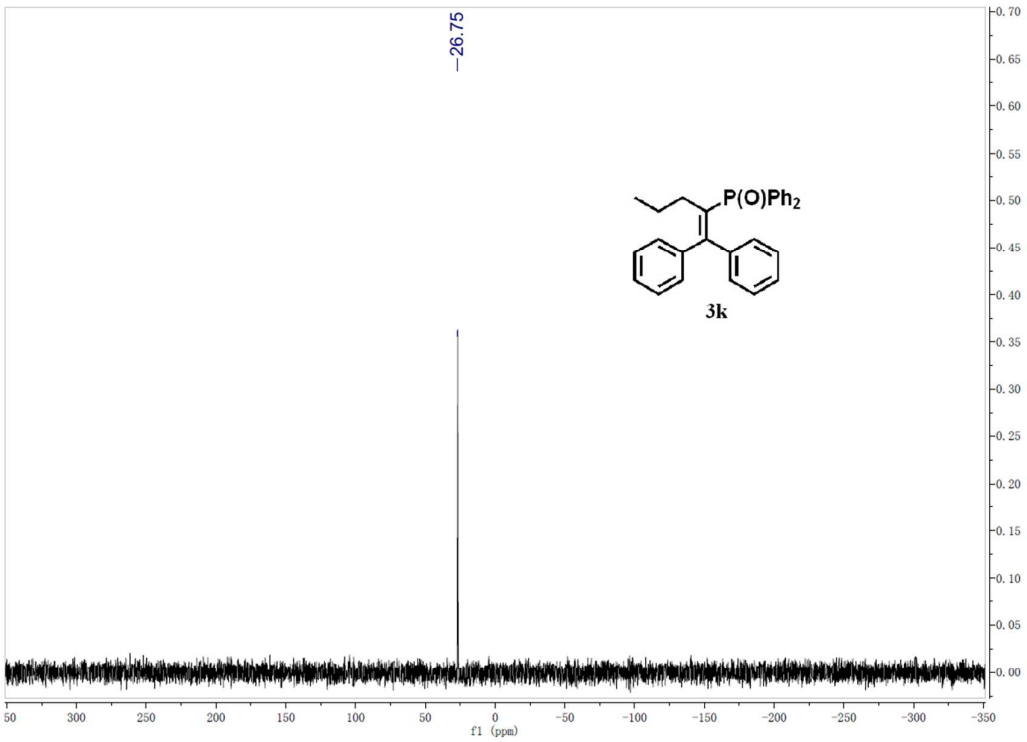

27.24
P(O)Ph2
3j
f1 (ppm)

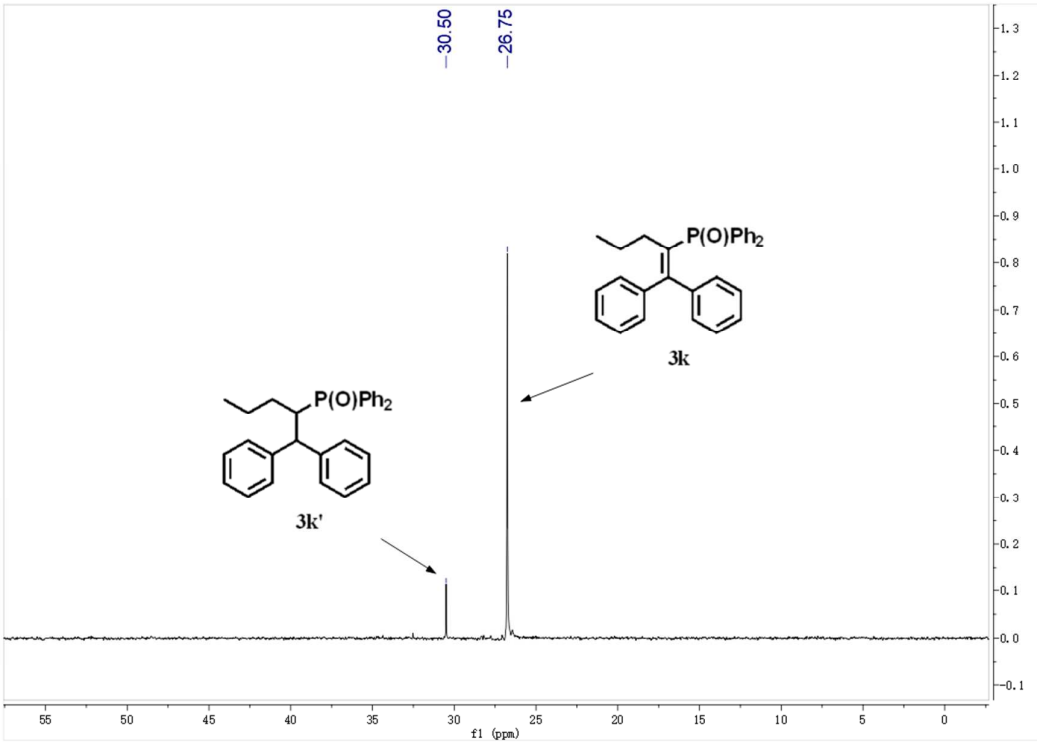



$^{31}$P NMR of crude reaction mixture before isolation (3j and 3j')

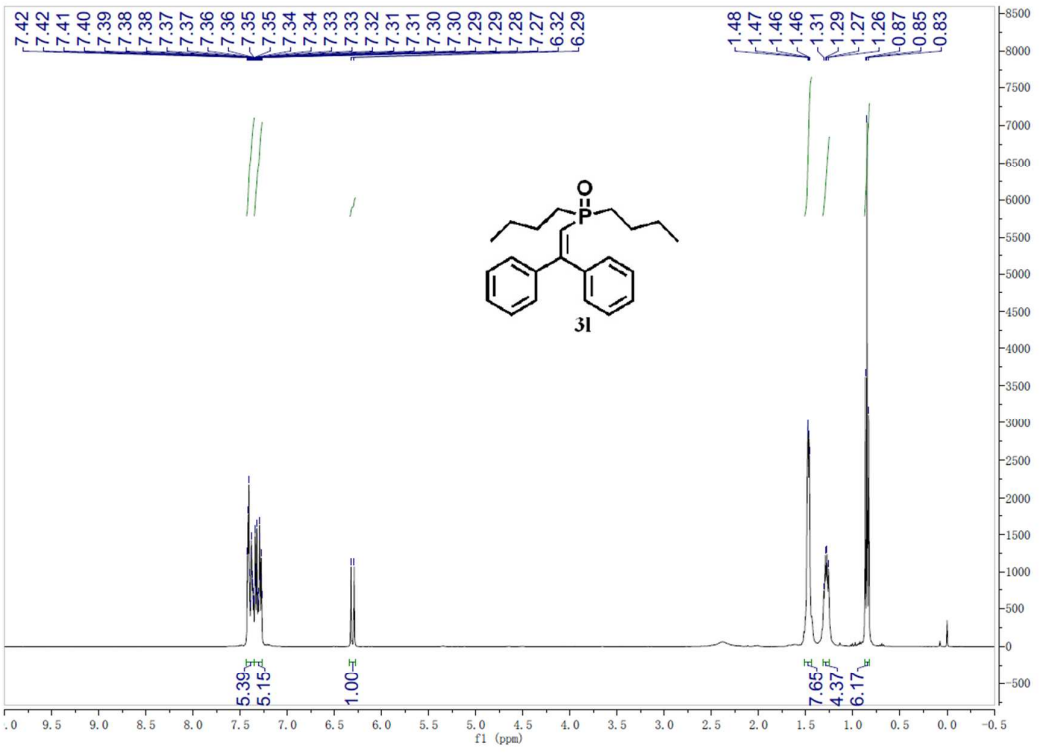


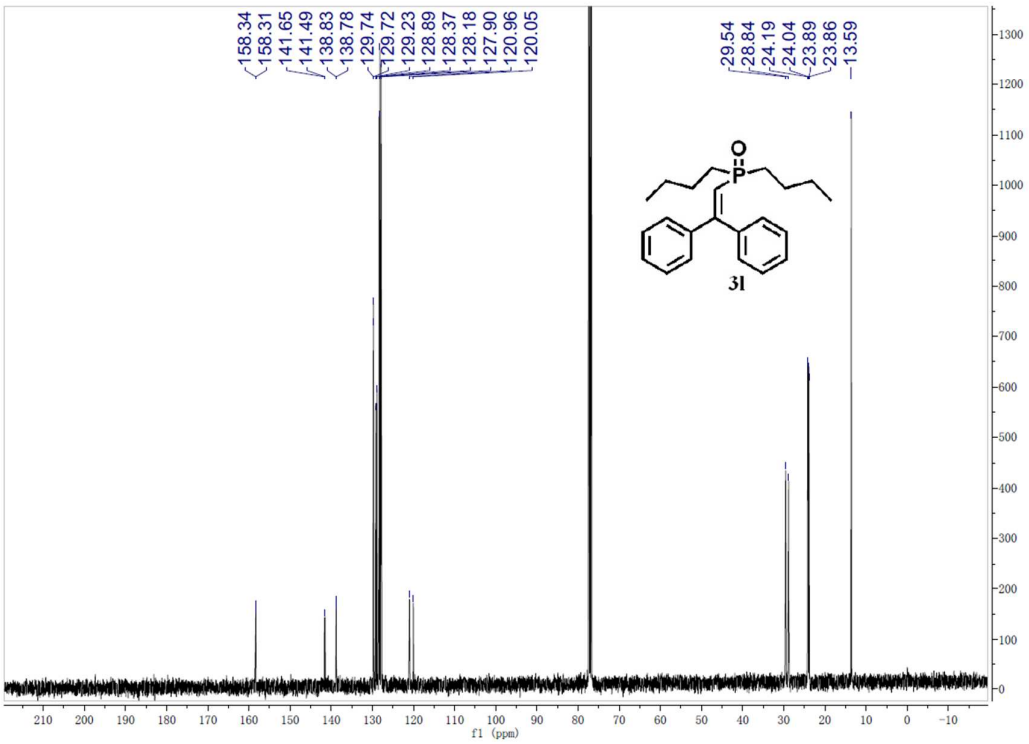

158.57
158.48
142.94
142.78
141.27
141.19
135.08
134.07
134.01
133.08
131.31
131.22
130.69
130.67
130.32
128.71
128.40
128.09
127.97
127.72
127.59
127.39
35.41
35.29
23.46
13.91
P(O)Ph2
3k
f1 (ppm)

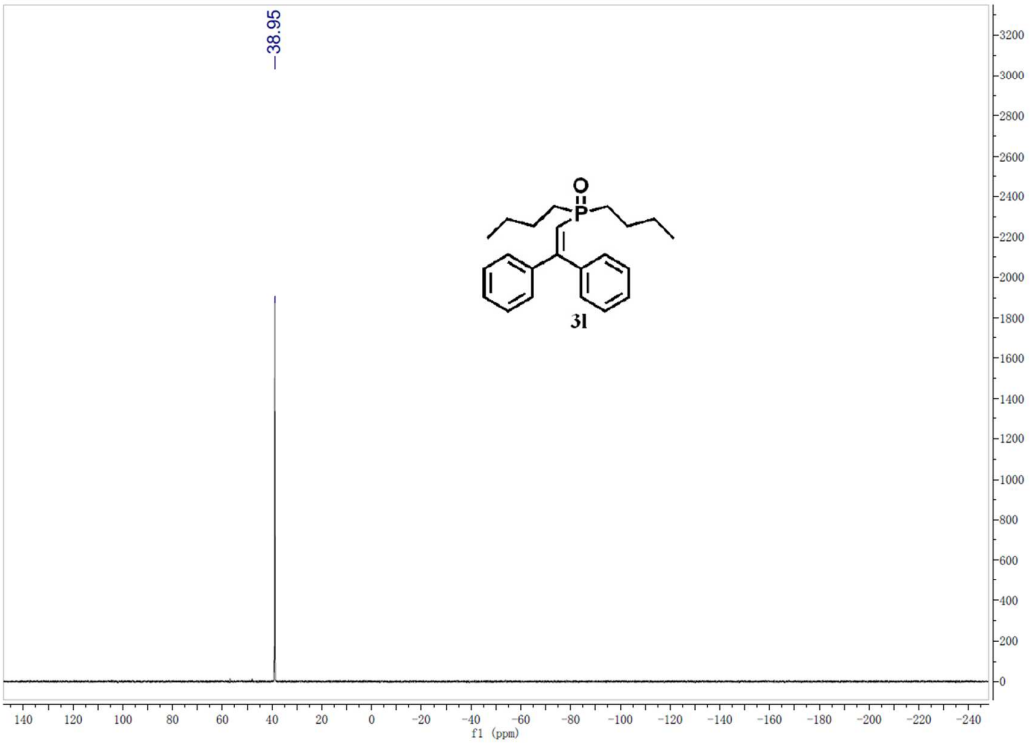

26.75
P(O)Ph2
3k
f1 (ppm)

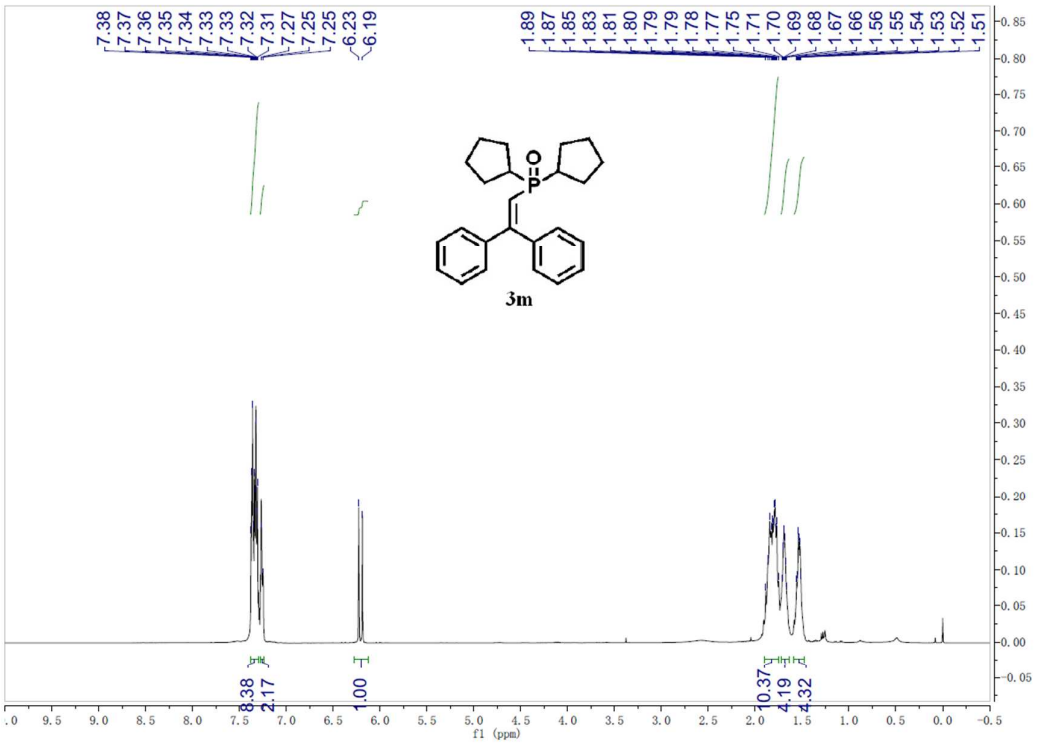


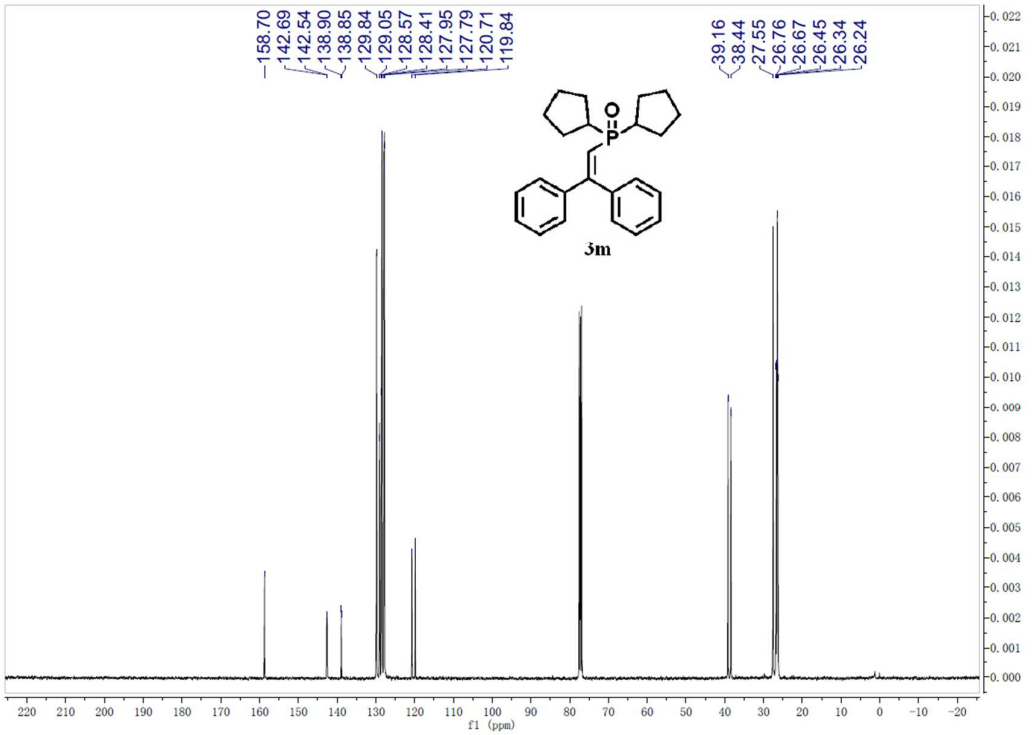

$^{31}$P NMR before recrystallization (3k and 3k')

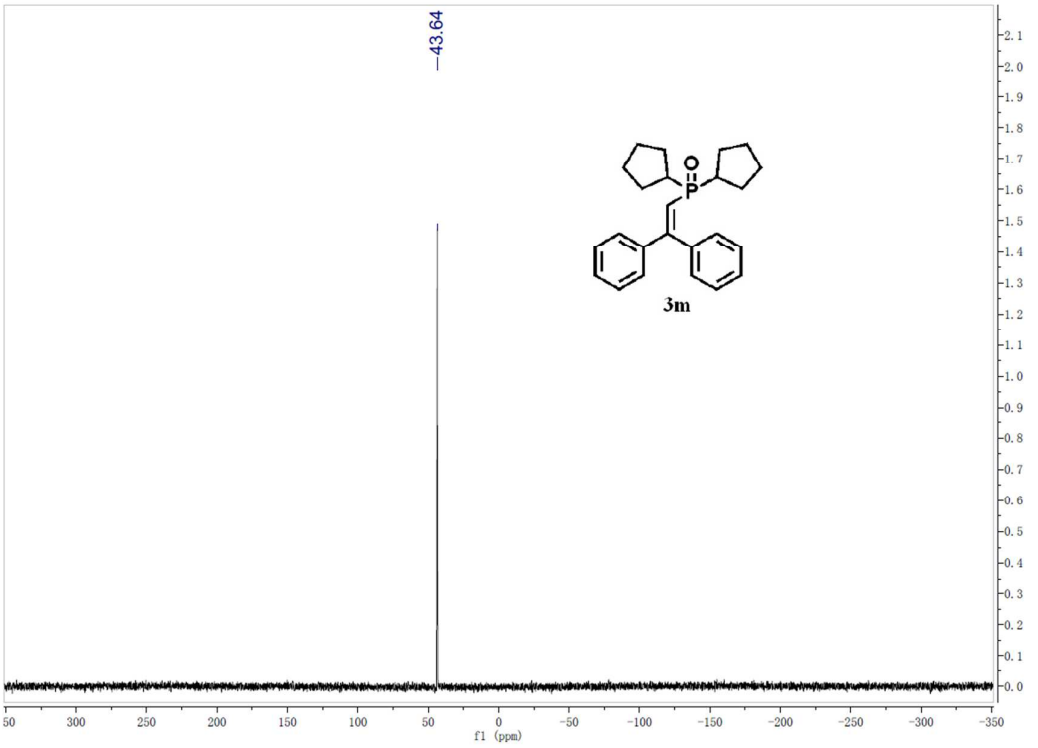


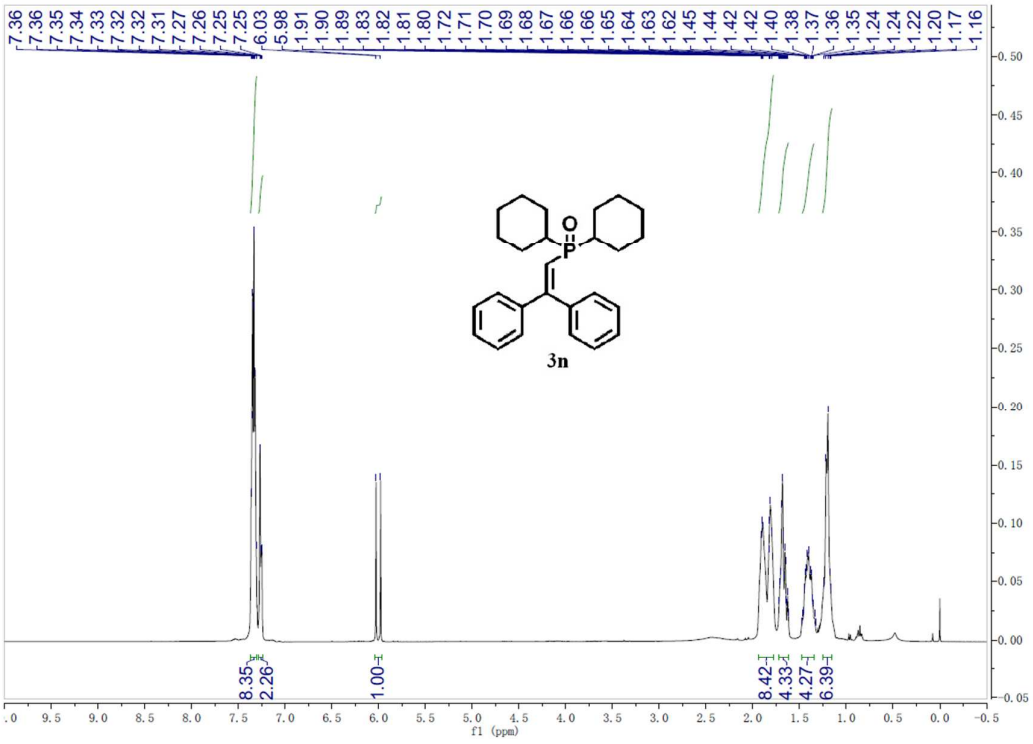

158.34
158.31
141.65
141.49
138.83
138.78
129.74
129.72
129.23
128.89
128.37
128.18
127.90
120.96
120.05
29.54
28.84
24.19
24.04
23.89
23.86
13.59
O
P
3l
f1 (ppm)

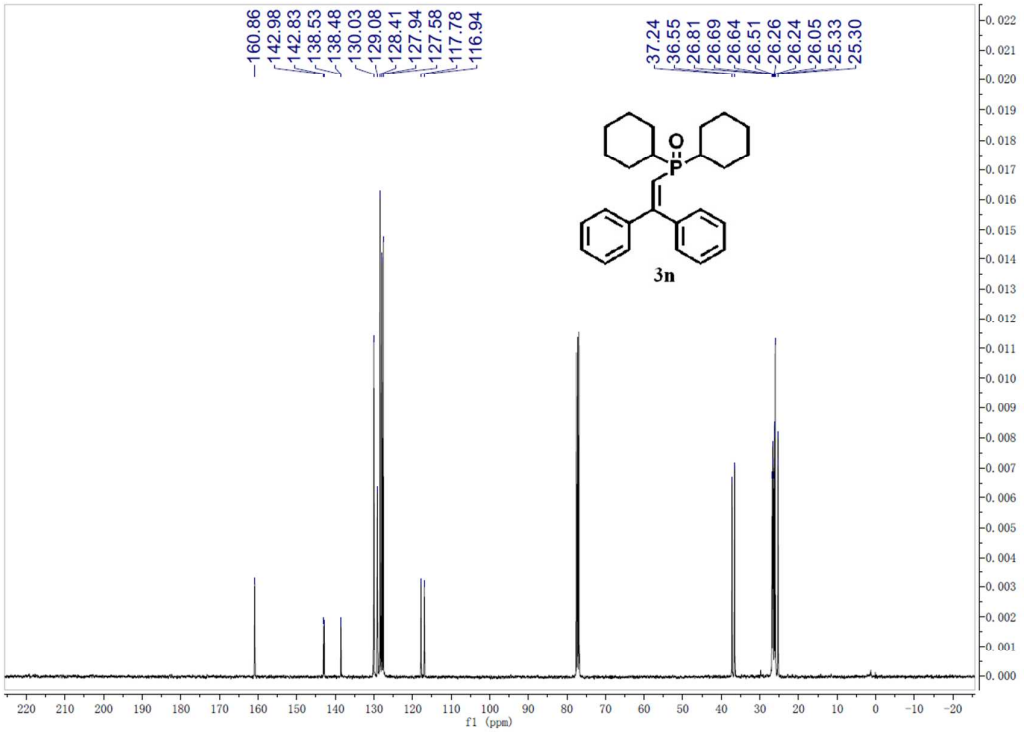

38.95
O
P
3l
f1 (ppm)

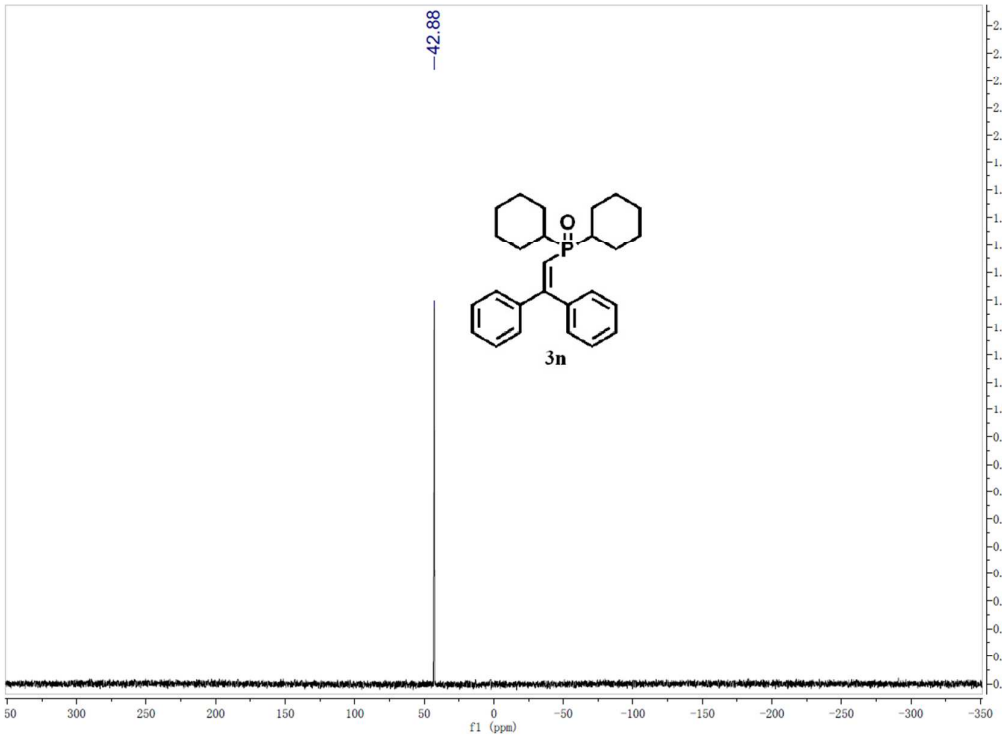

7.38
7.37
7.36
7.35
7.34
7.33
7.33
7.32
7.31
7.27
7.25
7.25
6.23
6.19
1.89
1.87
1.85
1.83
1.81
1.80
1.79
1.79
1.78
1.77
1.75
1.71
1.70
1.69
1.68
1.67
1.66
1.56
1.55
1.54
1.53
1.52
1.51
3m
8.38
2.17
1.00
10.37
4.19
4.32
f1 (ppm)

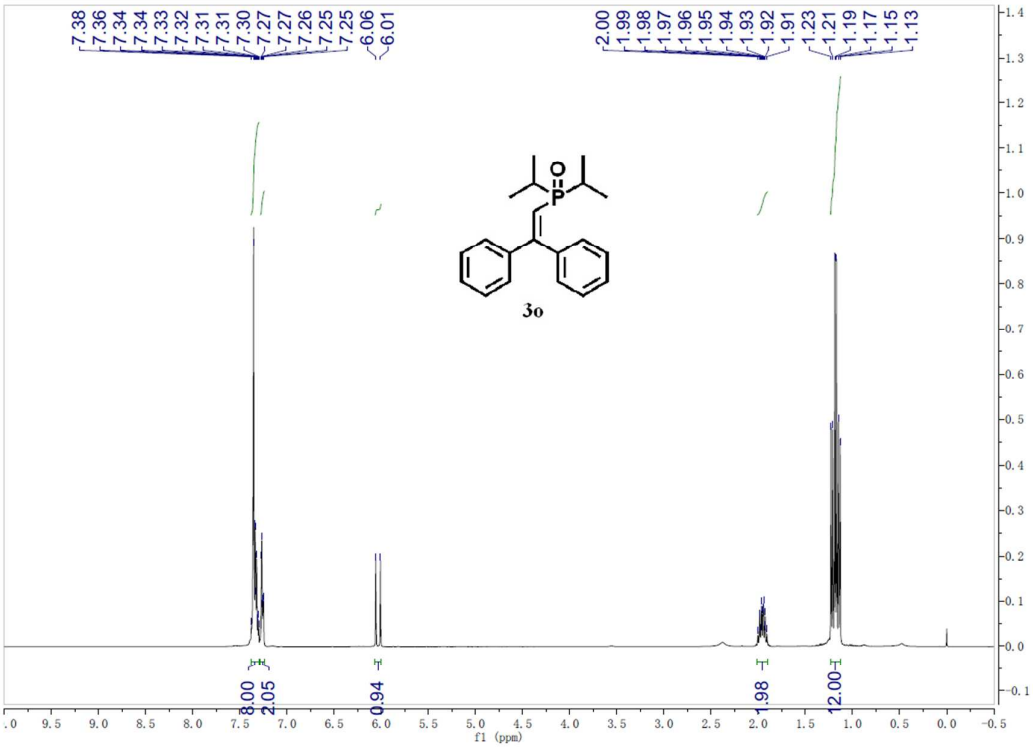

158.70
142.69
142.54
138.90
138.85
129.84
129.05
128.57
128.41
127.95
127.79
120.71
119.84
39.16
38.44
27.55
26.76
26.67
26.45
26.34
26.24
3m
f1 (ppm)

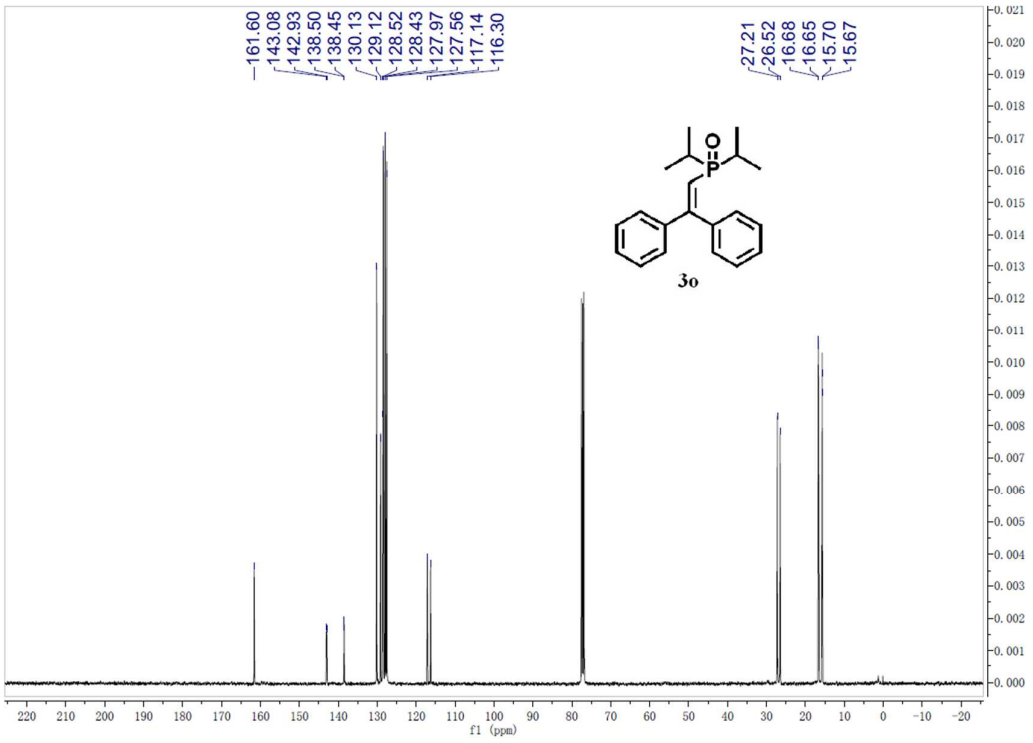

43.64
3m
f1 (ppm)

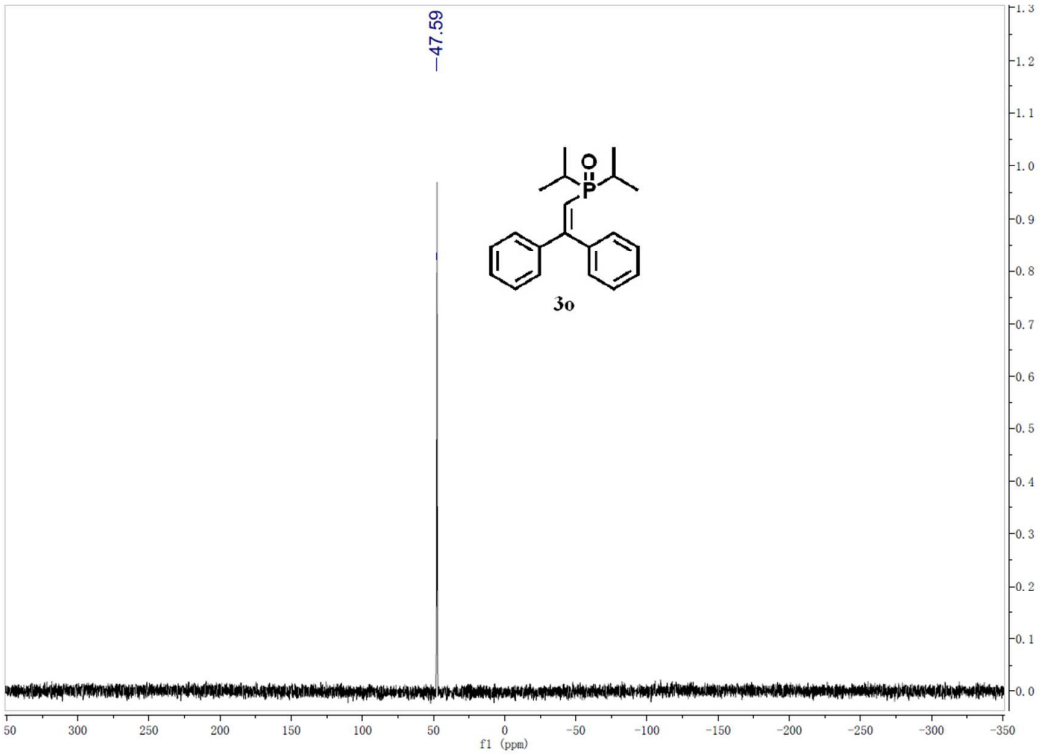

7.36
7.36
7.35
7.34
7.33
7.32
7.32
7.31
7.27
7.26
7.25
7.25
6.03
5.98
1.91
1.90
1.89
1.83
1.82
1.81
1.80
1.72
1.71
1.70
1.69
1.68
1.67
1.66
1.66
1.65
1.64
1.63
1.62
1.45
1.44
1.42
1.42
1.40
1.38
1.37
1.36
1.35
1.24
1.24
1.22
1.20
1.17
1.16
8.35
2.26
1.00
8.42
4.33
4.27
6.39
3n
f1 (ppm)

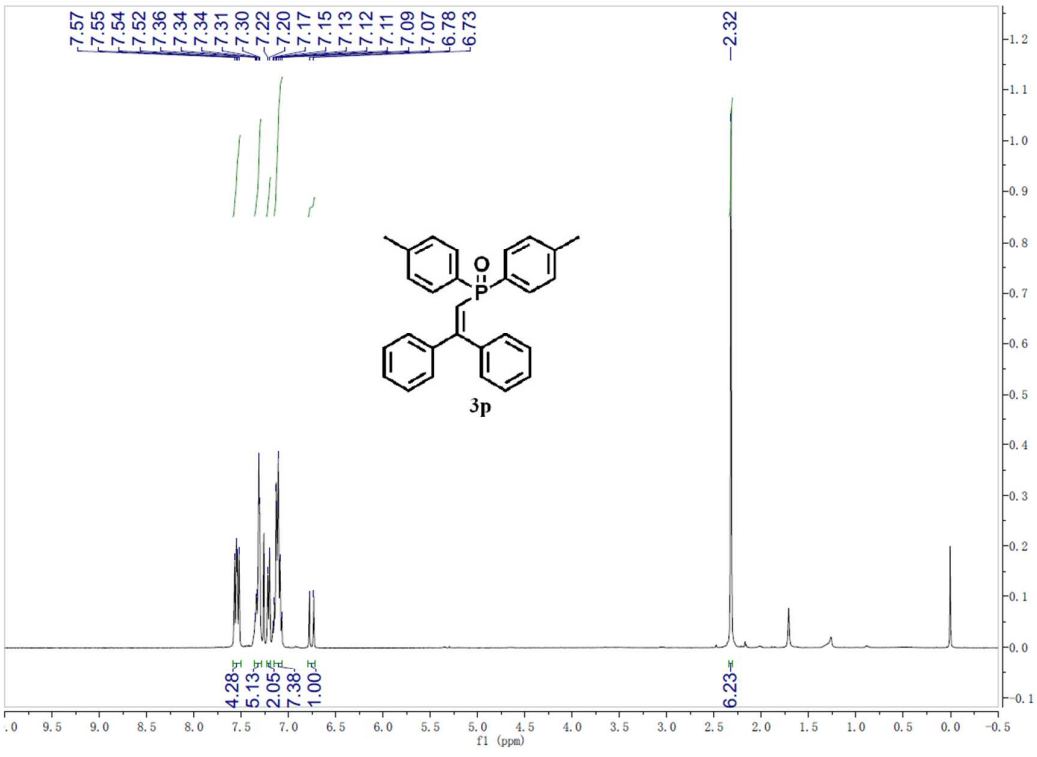

160.86
142.98
142.83
138.53
138.48
130.03
129.08
128.41
127.94
127.58
117.78
116.94
37.24
36.55
26.81
26.69
26.64
26.51
26.26
26.24
26.05
25.33
25.30
3n
f1 (ppm)

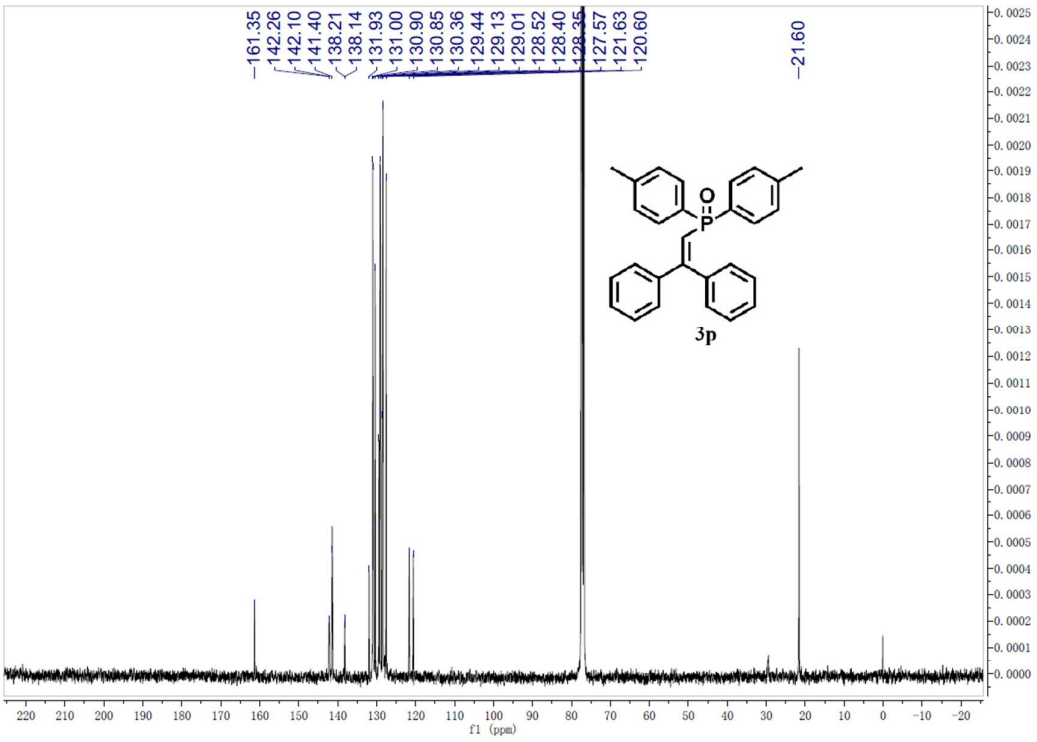

42.88
3n
f1 (ppm)

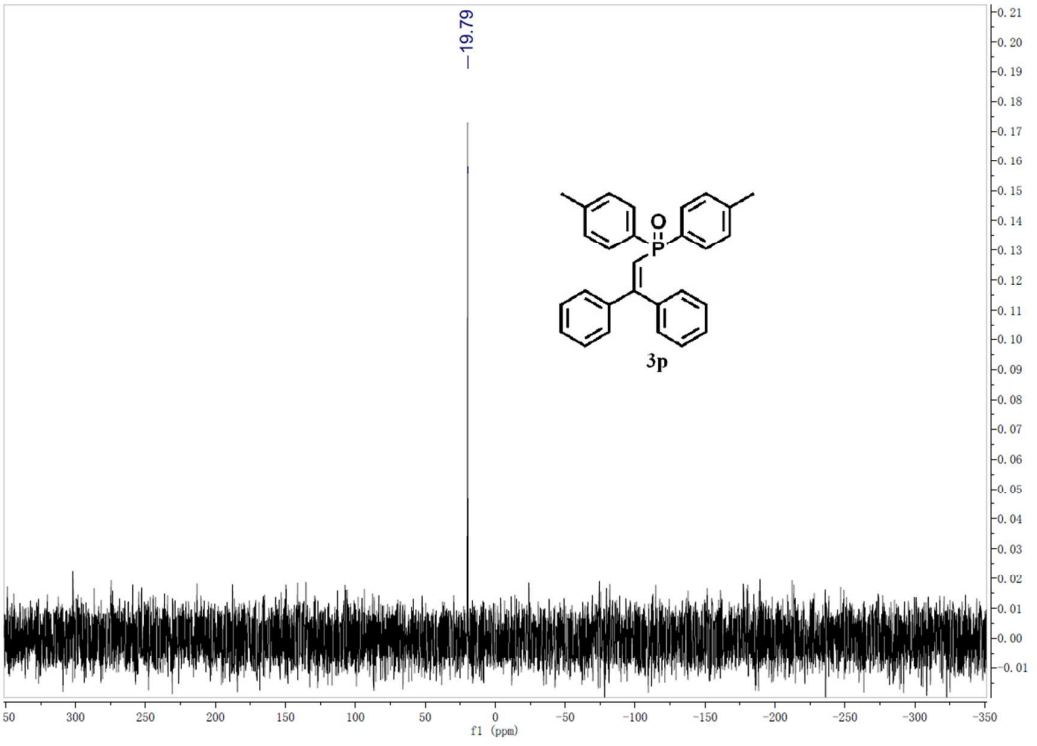

7.38
7.36
7.34
7.34
7.33
7.32
7.31
7.31
7.30
7.27
7.27
7.26
7.25
7.25
6.06
6.01
2.00
1.99
1.98
1.97
1.96
1.95
1.94
1.93
1.92
1.91
1.23
1.21
1.19
1.17
1.15
1.13
3o
8.00
2.05
0.94
1.98
12.00
f1 (ppm)

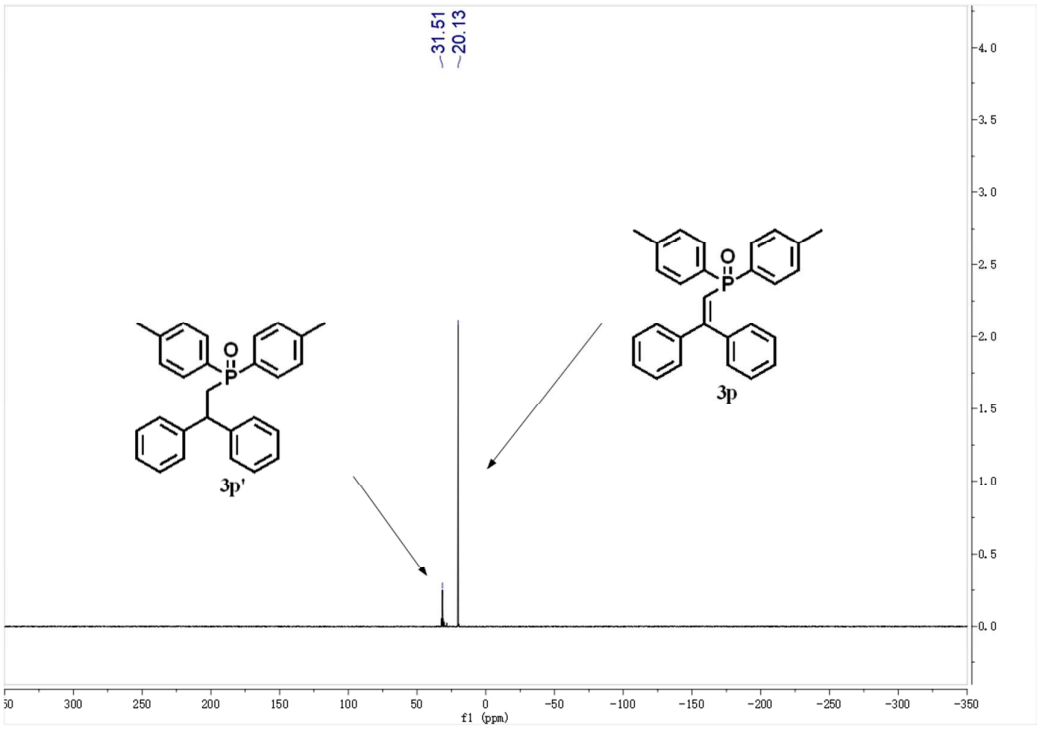

161.60
143.08
142.93
138.50
138.45
130.13
129.12
128.52
128.43
127.97
127.56
117.14
116.30
27.21
26.52
16.68
16.65
15.70
15.67
3o
f1 (ppm)


47.59
3o
f1 (ppm)

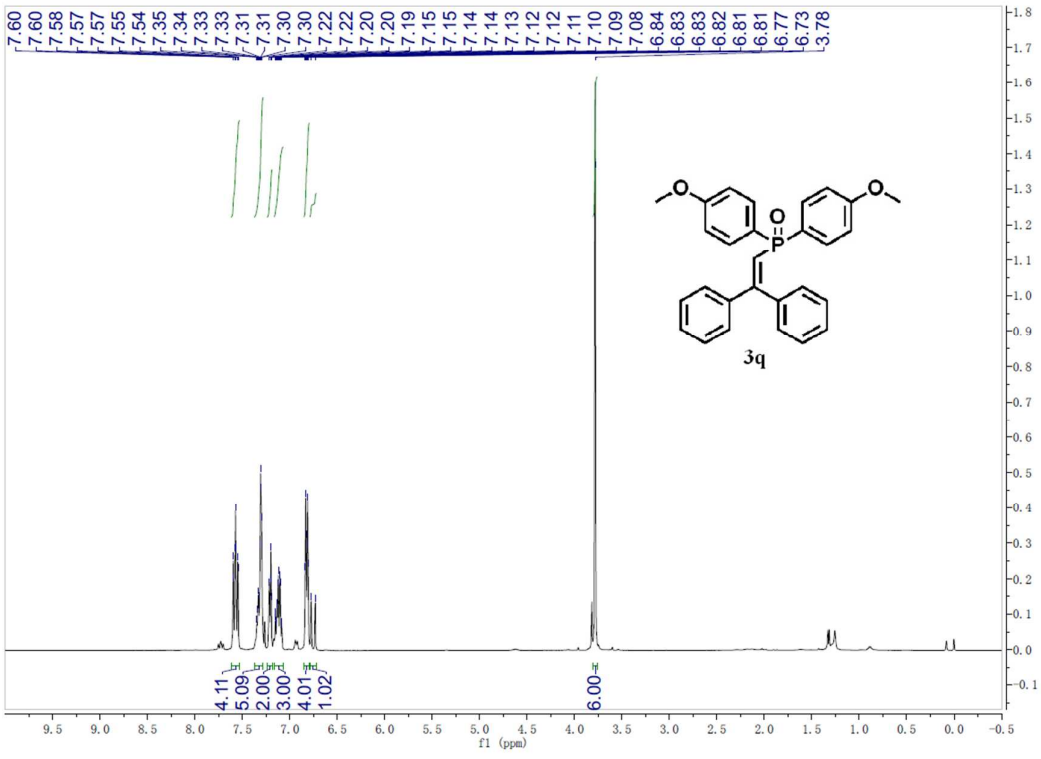

7.57
7.55
7.54
7.52
7.36
7.34
7.34
7.31
7.30
7.22
7.20
7.17
7.15
7.13
7.12
7.11
7.09
7.07
6.78
6.73
2.32
3p
4.28
5.13
2.05
7.38
1.00
6.23
f1 (ppm)

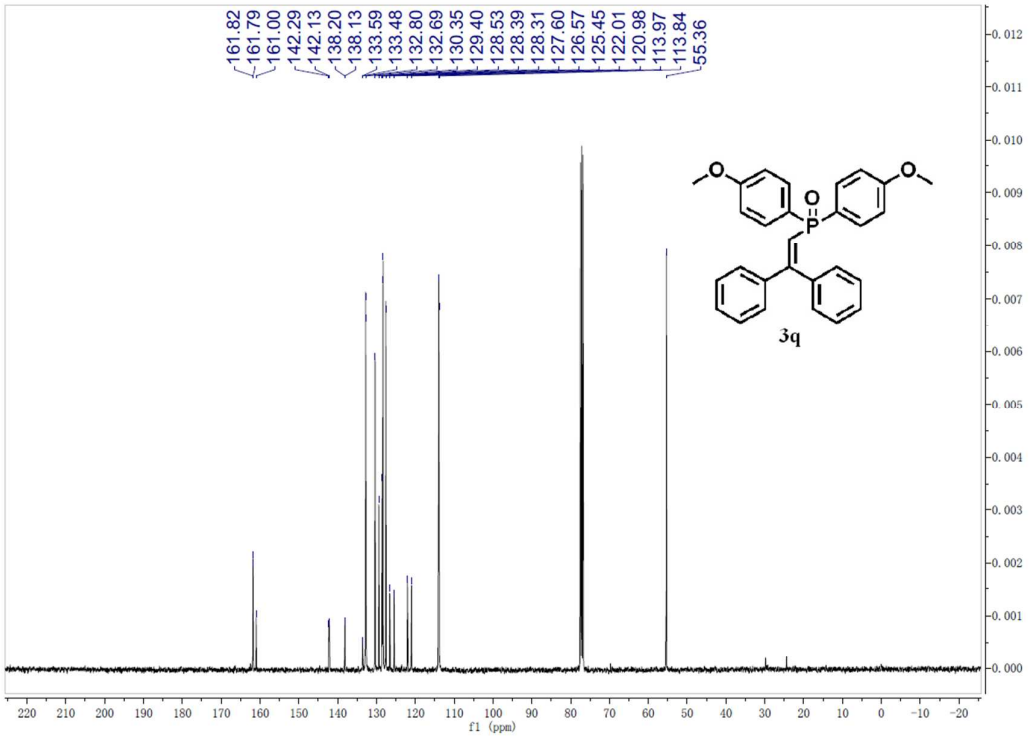

161.35
142.26
142.10
141.40
138.21
138.14
131.93
131.00
130.90
130.85
130.36
129.44
129.13
129.01
128.52
128.40
128.35
127.57
121.63
120.60
21.60
3p
f1 (ppm)

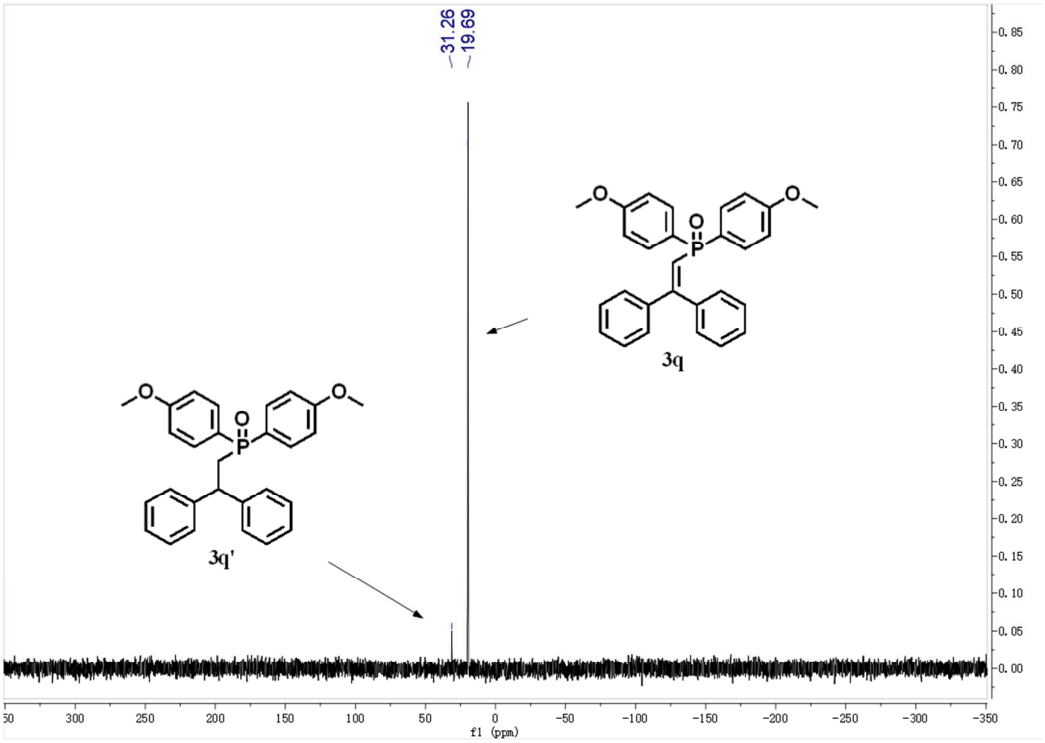

19.79
3p
f1 (ppm)

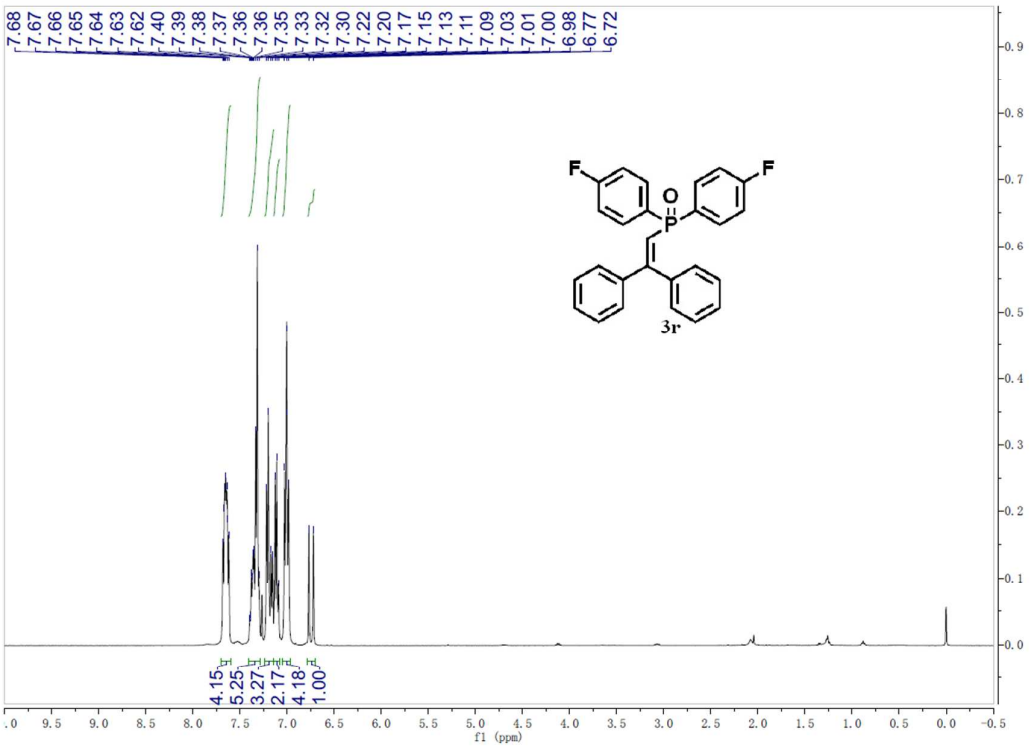


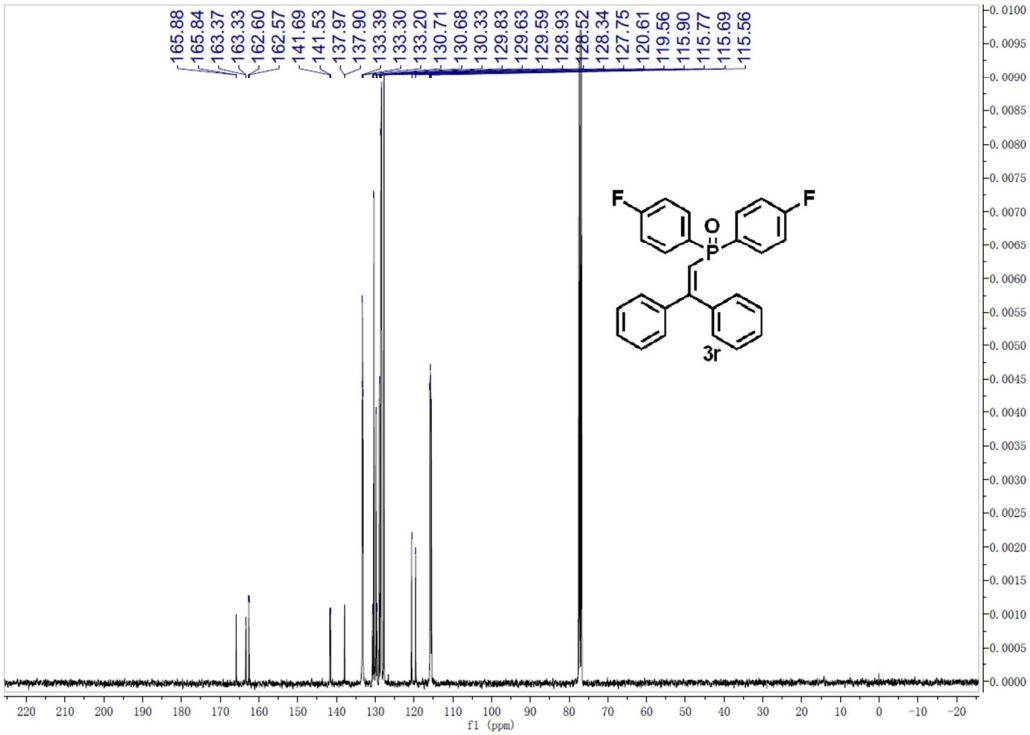

$^{31}$P NMR before recrystallization (3p and 3p')

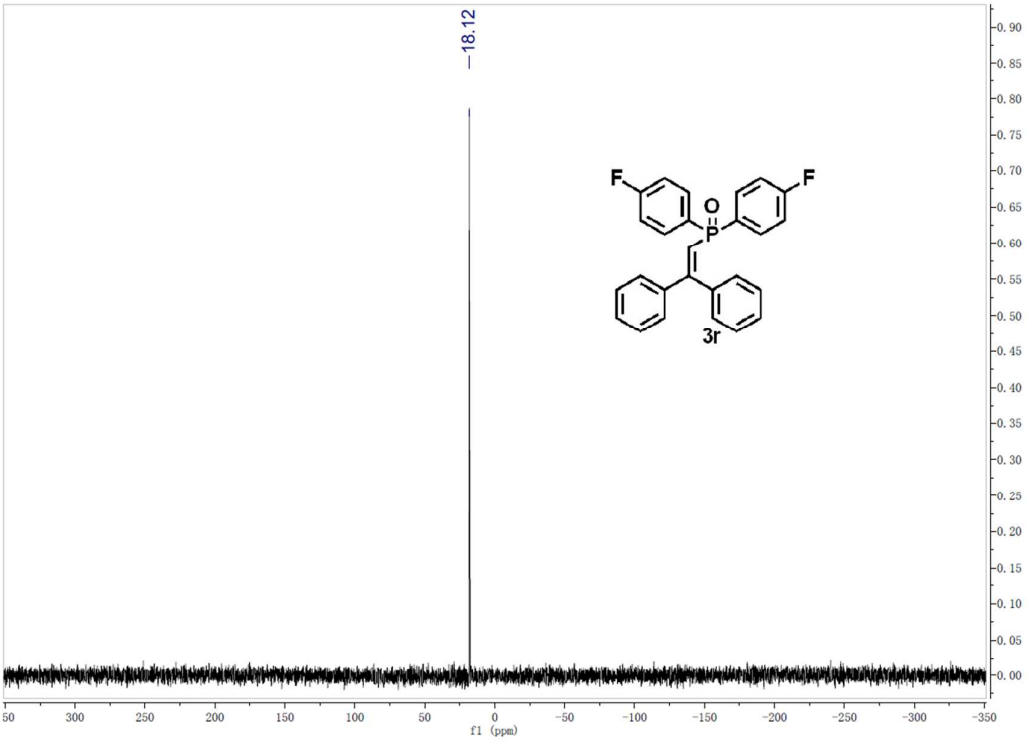


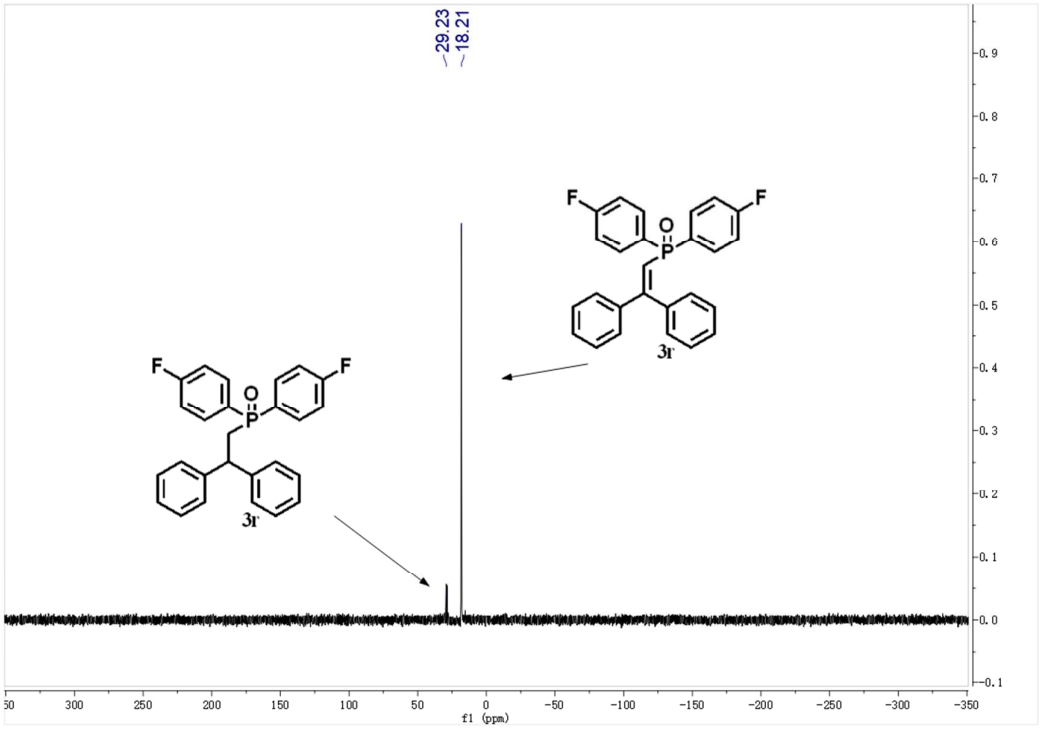

161.82
161.79
161.00
142.29
142.13
138.20
138.13
133.59
133.48
132.80
132.69
130.35
129.40
128.53
128.39
128.31
127.60
126.57
125.45
122.01
120.98
113.97
113.84
55.36
3q
f1 (ppm)


31.26
19.69
3q
3q'
f1 (ppm)

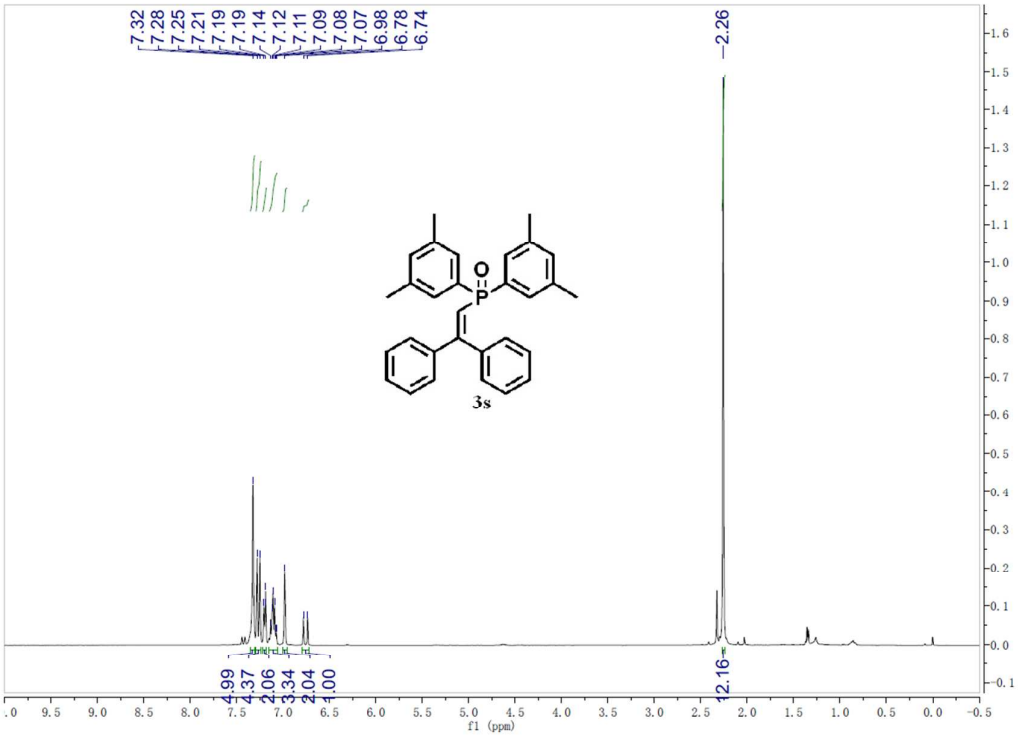

7.68
7.67
7.66
7.65
7.64
7.63
7.62
7.40
7.39
7.38
7.37
7.36
7.36
7.35
7.33
7.32
7.30
7.22
7.20
7.17
7.15
7.13
7.11
7.09
7.03
7.01
7.00
6.98
6.77
6.72
F
O
P
F
3r
4.15
5.25
3.27
2.17
4.18
1.00
f1 (ppm)

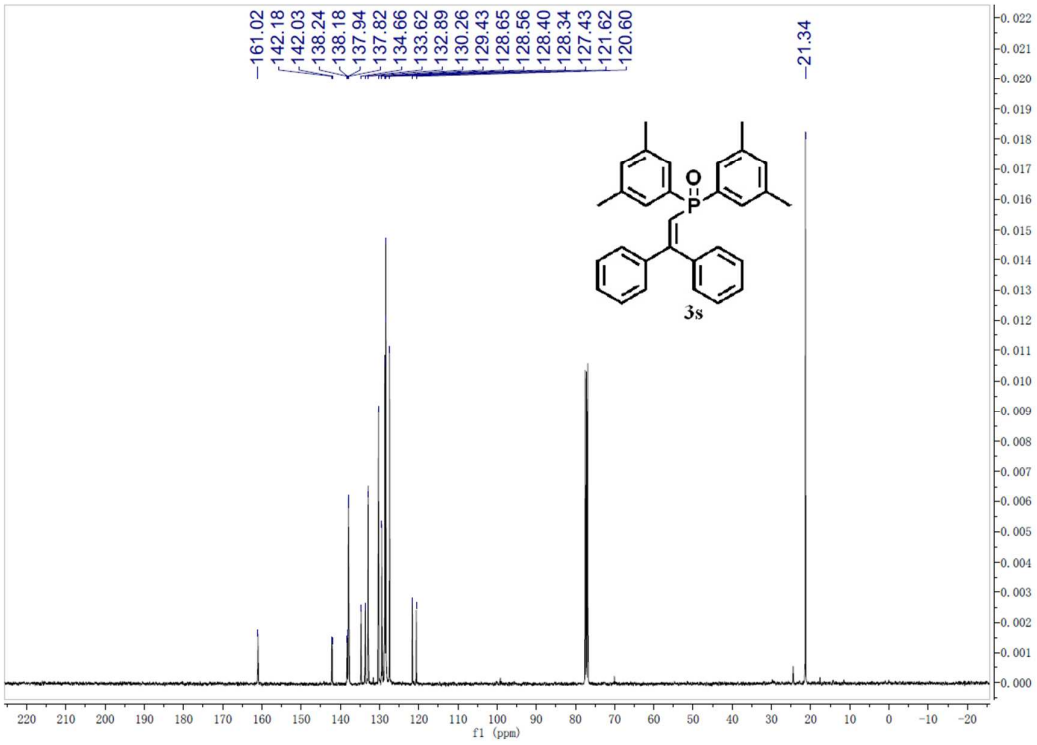

165.88
165.84
163.37
163.33
162.60
162.57
141.69
141.53
137.97
137.90
133.39
133.30
133.20
130.71
130.68
130.33
129.83
129.63
129.59
128.93
128.52
128.34
127.75
120.61
119.56
115.90
115.77
115.69
115.56
F
O
P
F
3r
f1 (ppm)

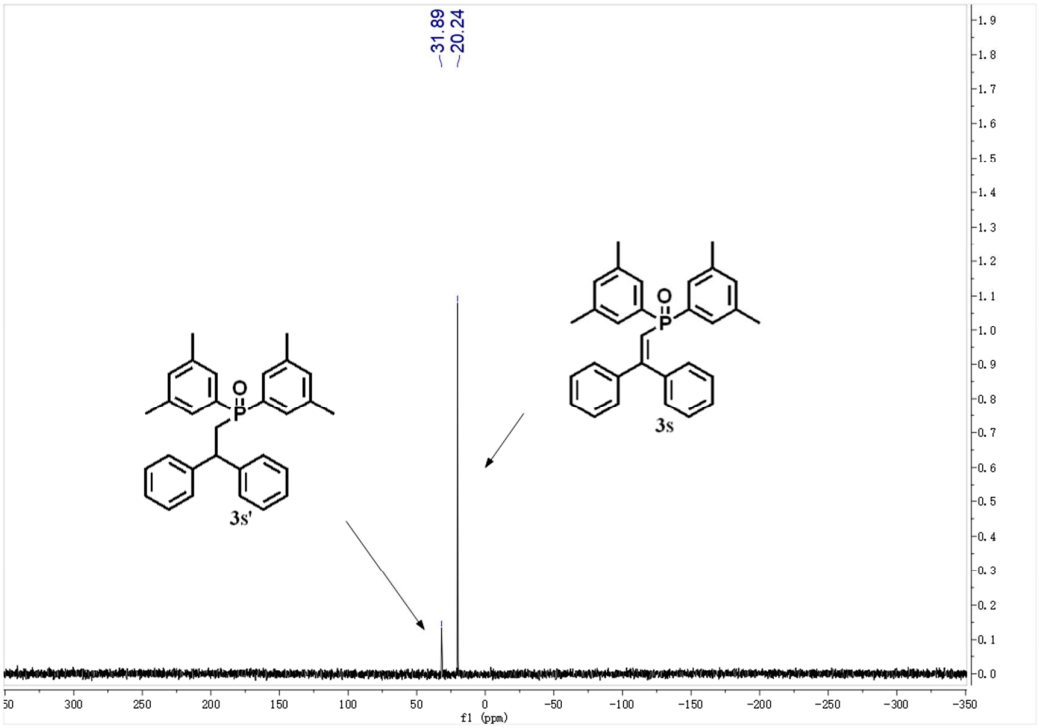


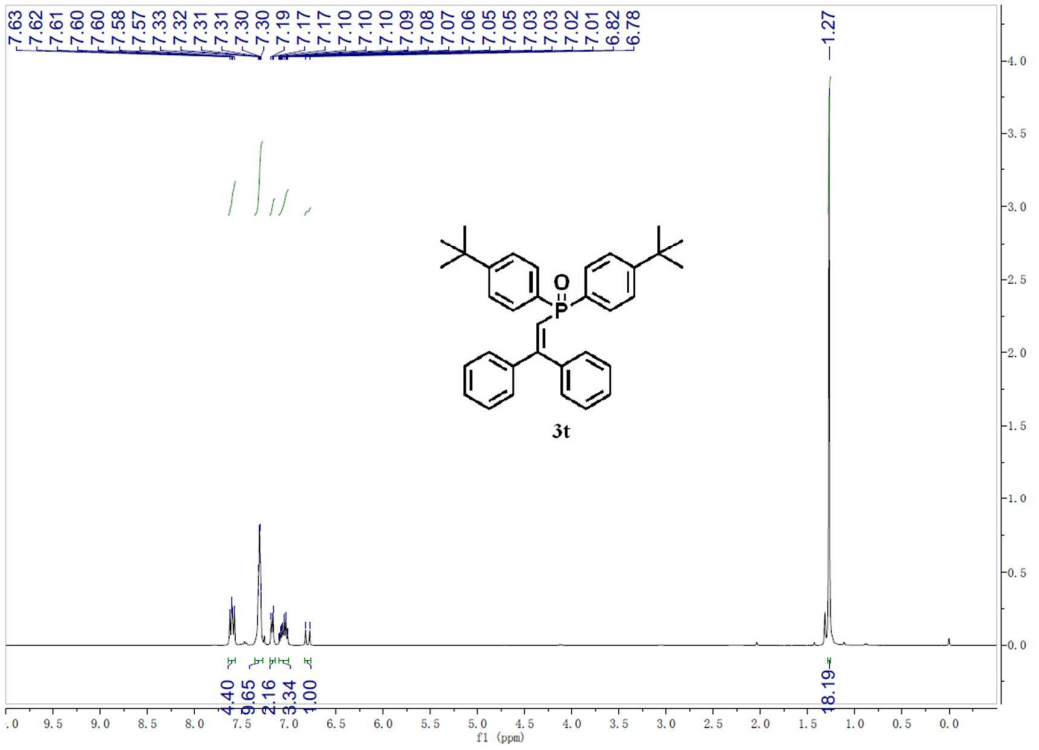



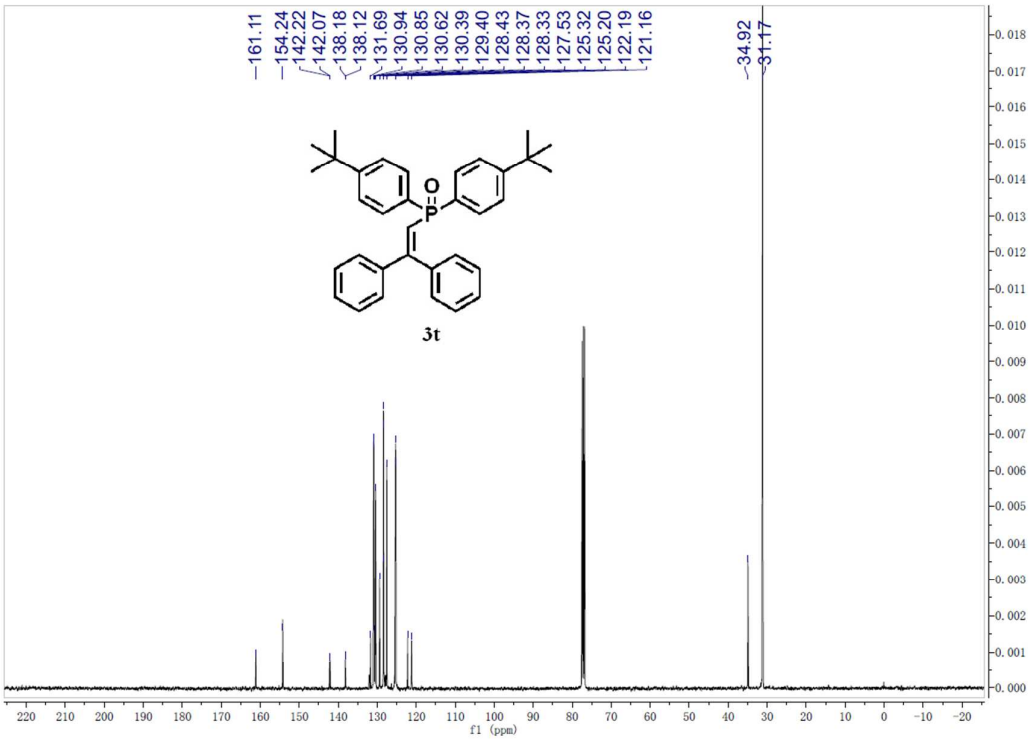

$^{31}$P NMR before recrystallization (3r and 3r')

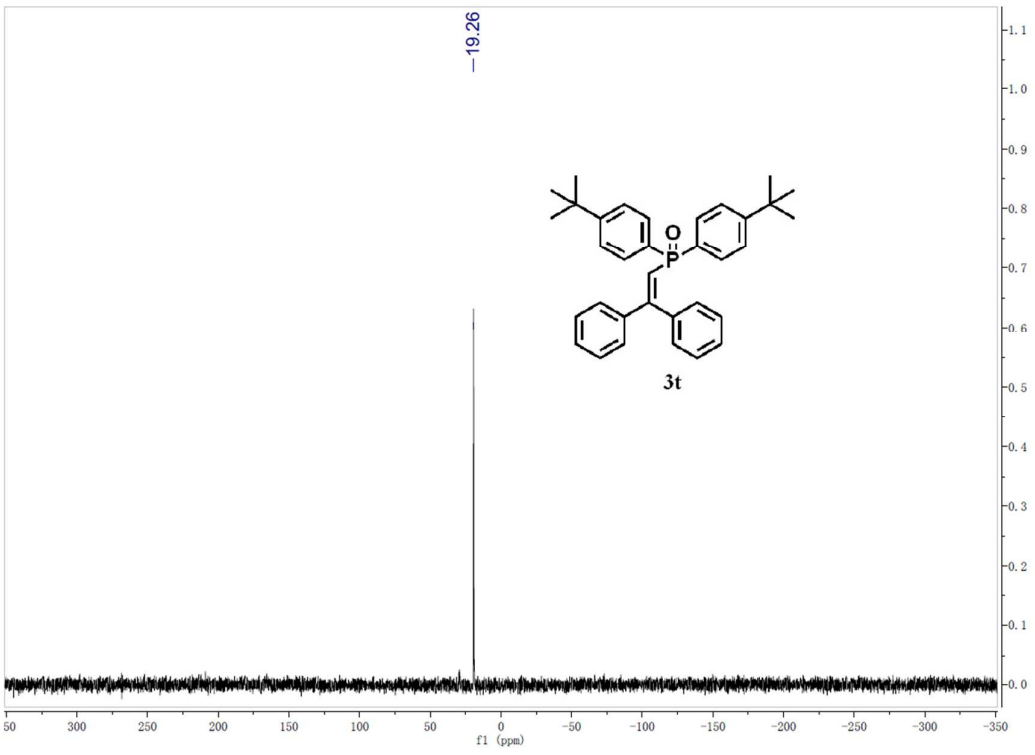

7.32
7.28
7.25
7.21
7.19
7.19
7.14
7.12
7.11
7.09
7.08
7.07
6.98
6.78
6.74
2.26
3s
4.99
4.37
2.06
3.34
2.04
1.00
12.16
f1 (ppm)

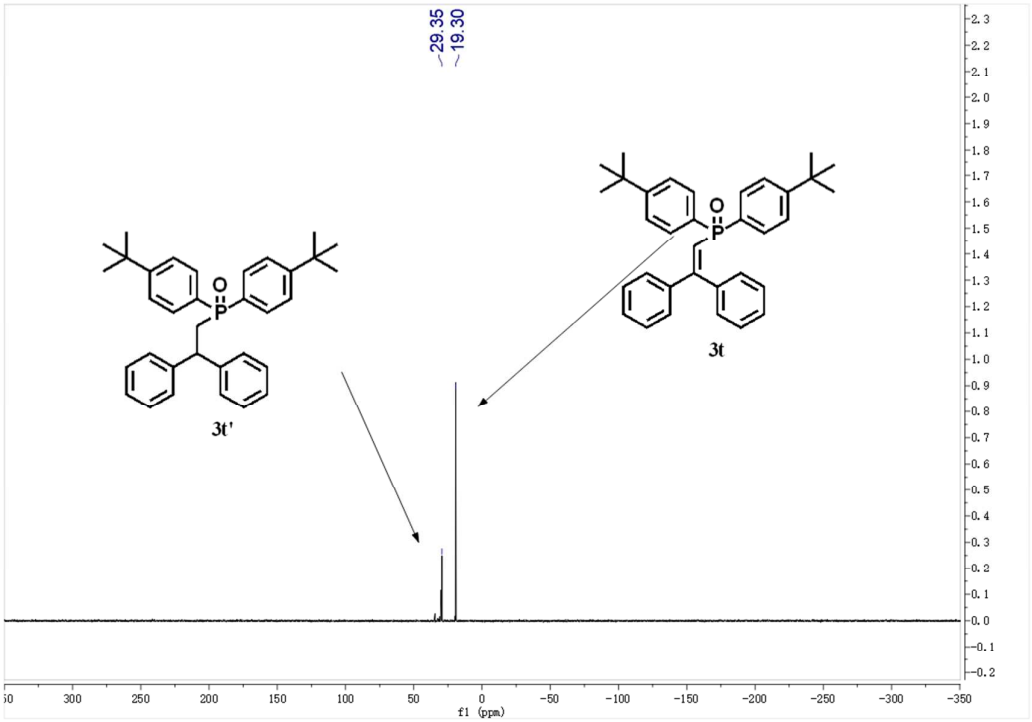

161.02
142.18
142.03
138.24
138.18
137.94
137.82
134.66
133.62
132.89
130.26
129.43
128.65
128.56
128.40
128.34
127.43
121.62
120.60
21.34
3s
f1 (ppm)


31.89
20.24
3s'
3s
f1 (ppm)

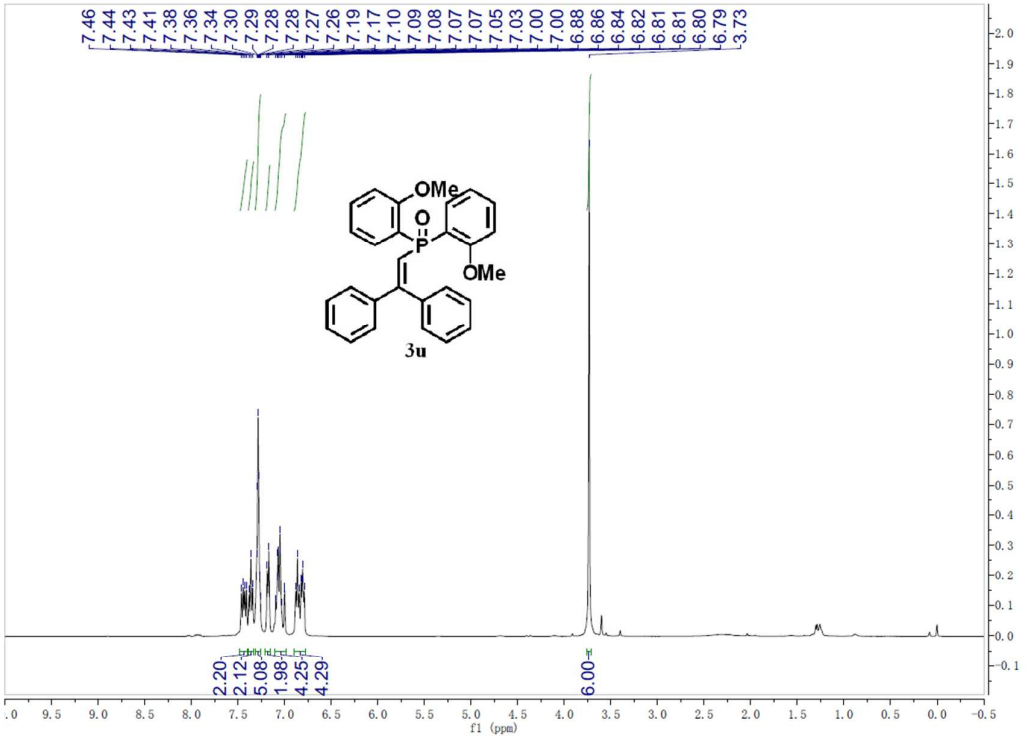

7.63
7.62
7.61
7.60
7.60
7.58
7.57
7.33
7.32
7.31
7.31
7.30
7.30
7.19
7.17
7.17
7.10
7.10
7.10
7.09
7.08
7.07
7.06
7.05
7.05
7.03
7.03
7.02
7.01
6.82
6.78
1.27
3t
4.40
9.65
2.16
3.34
1.00
18.19
f1 (ppm)

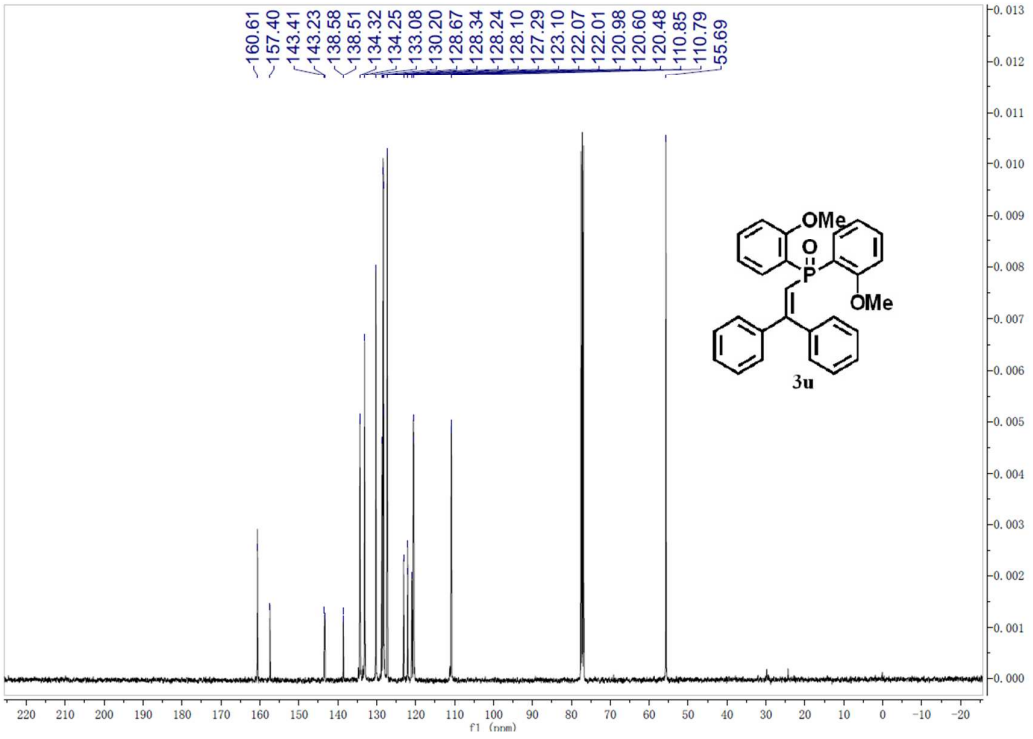

161.11
154.24
142.22
142.07
138.18
138.12
131.69
130.94
130.85
130.62
130.39
129.40
128.43
128.37
128.33
127.53
125.32
125.20
122.19
121.16
34.92
31.17
3t
f1 (ppm)

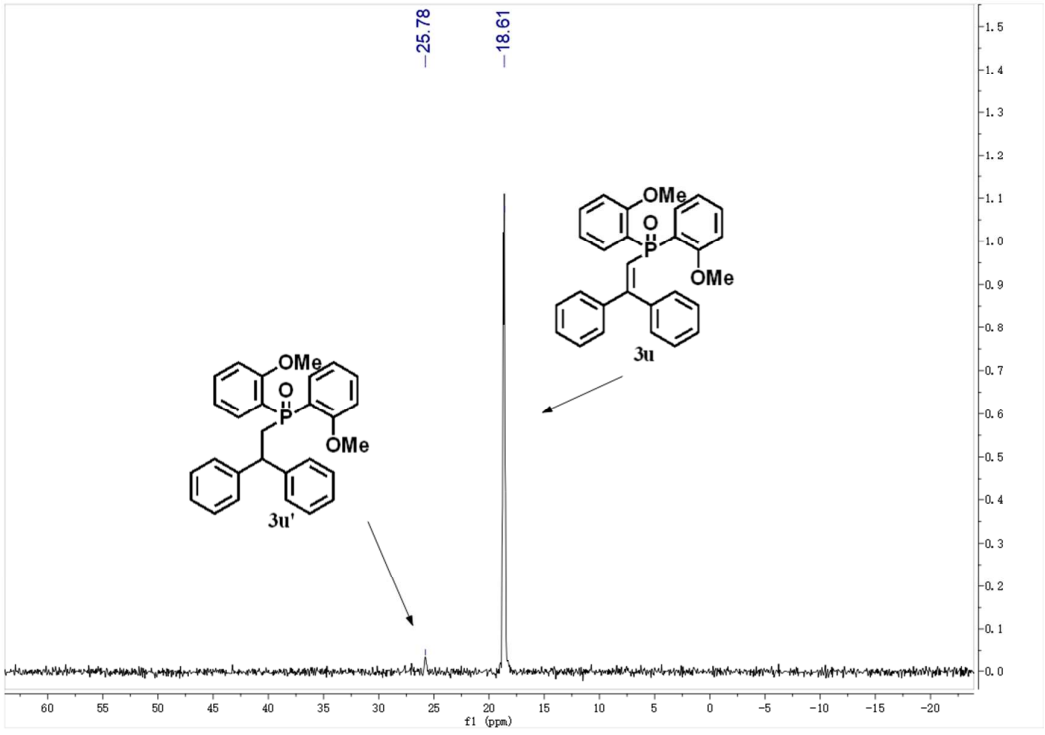

19.26
3t
f1 (ppm)

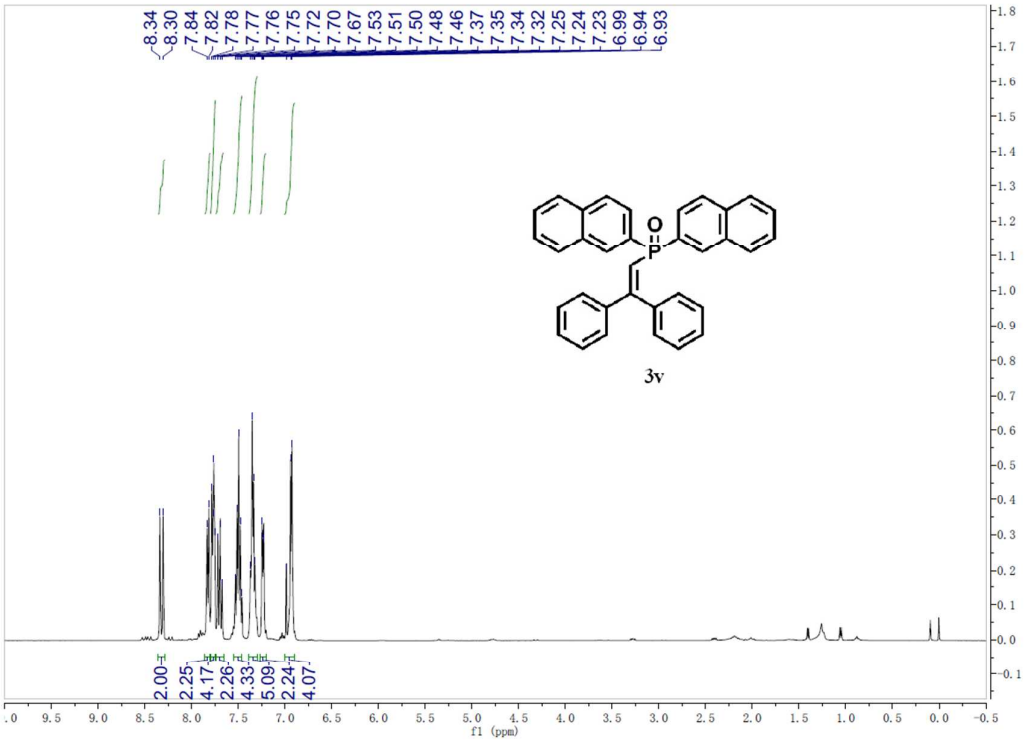


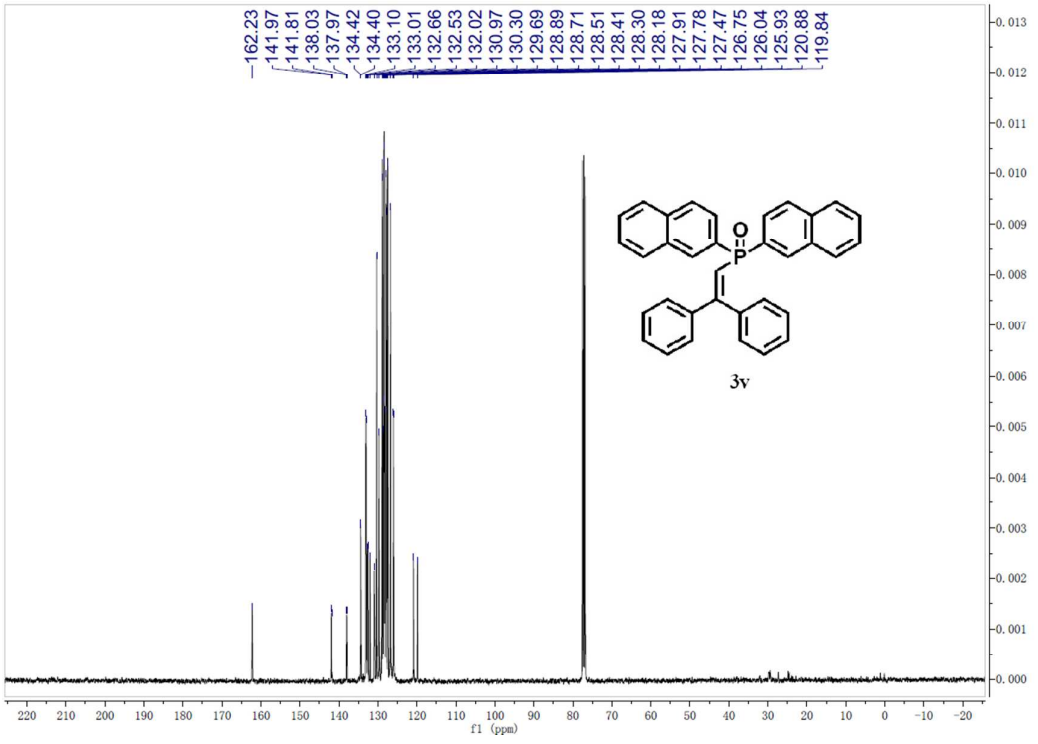

$^{31}$P NMR before recrystallization (3t and 3t')

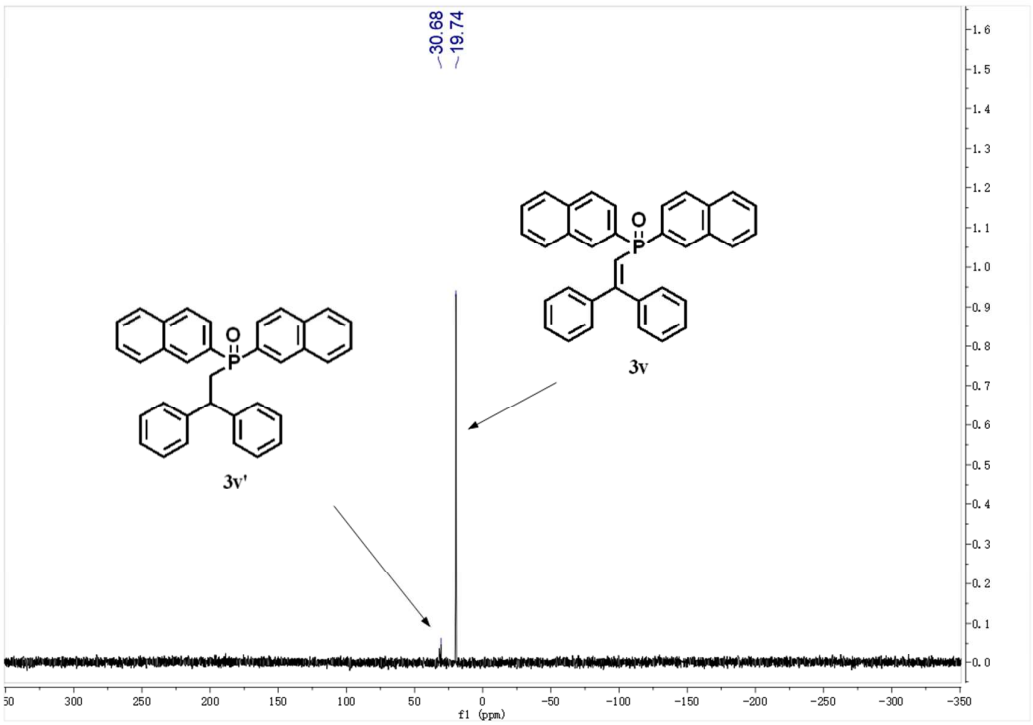


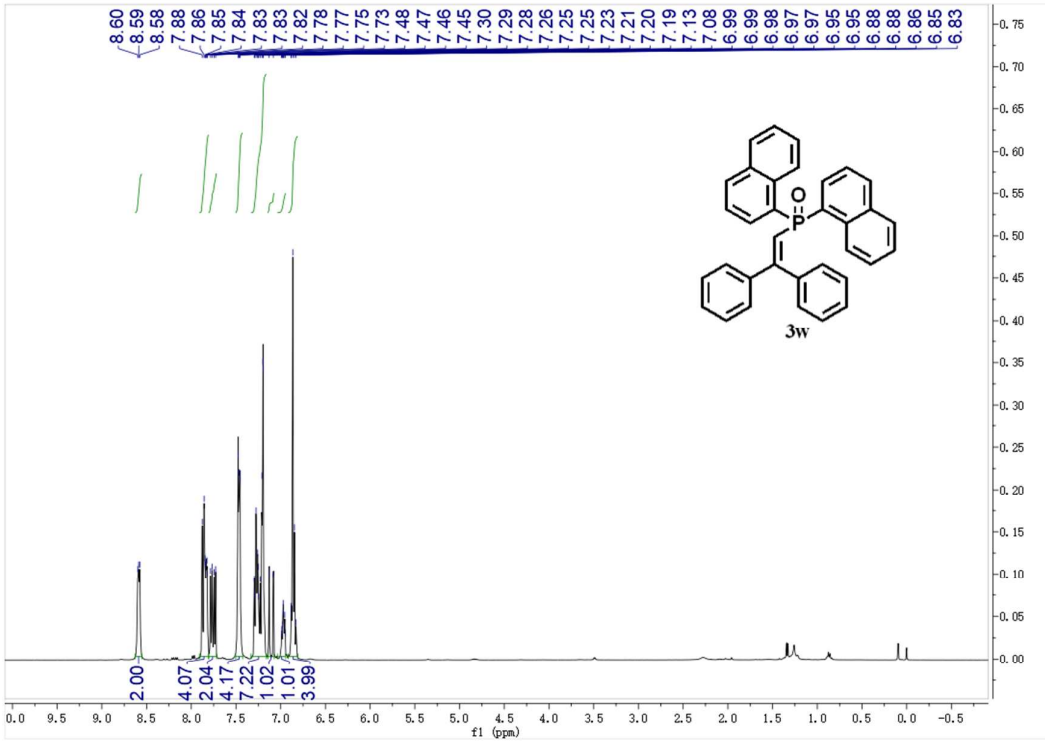

160.61
157.40
143.41
143.23
138.58
138.51
134.32
134.25
133.08
130.20
128.67
128.34
128.24
128.10
127.29
123.10
122.07
122.01
120.98
120.60
120.48
110.85
110.79
55.69
OMe
O
P
OMe
3u
f1 (ppm)

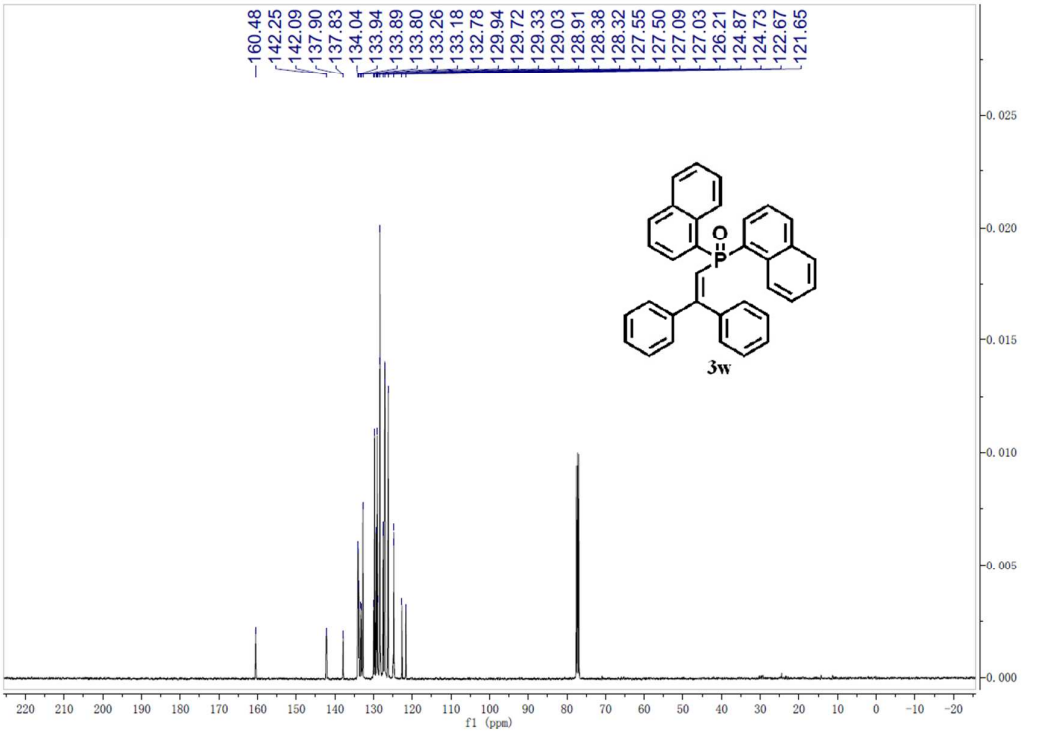

25.78
18.61
OMe
O
P
OMe
3u
3u'
f1 (ppm)

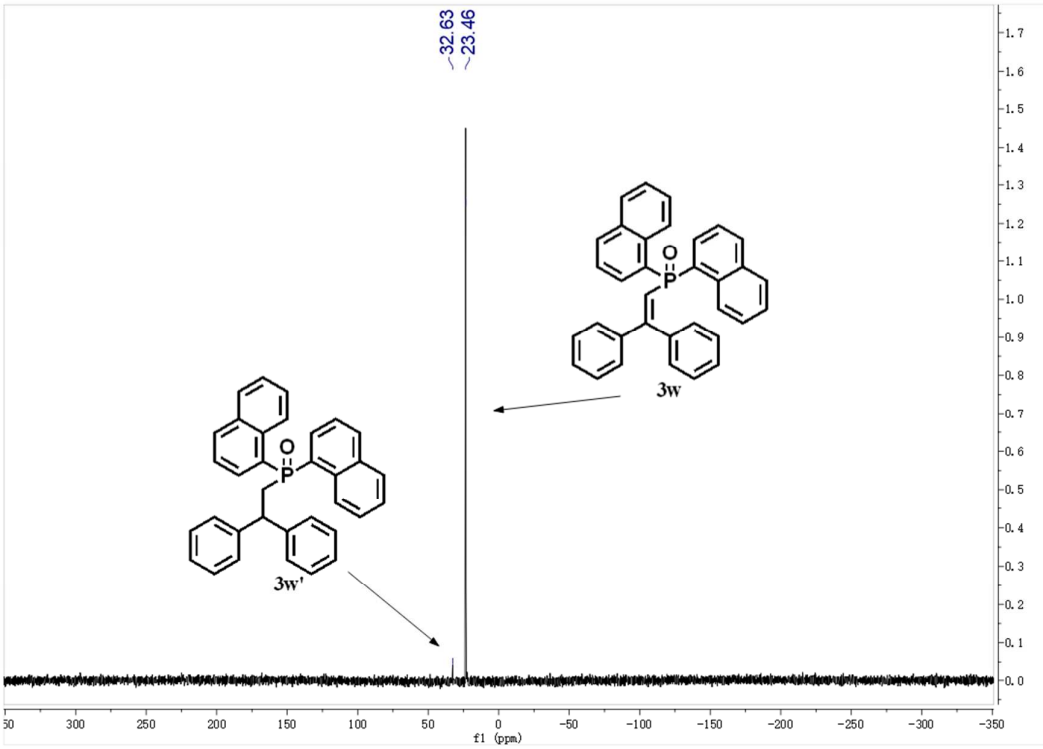

8.34
8.30
7.84
7.82
7.78
7.77
7.76
7.75
7.72
7.70
7.67
7.53
7.51
7.50
7.48
7.46
7.37
7.35
7.34
7.32
7.25
7.24
7.23
6.99
6.94
6.93
3v
2.00
2.25
4.17
2.26
4.33
5.09
2.24
4.07
f1 (ppm)

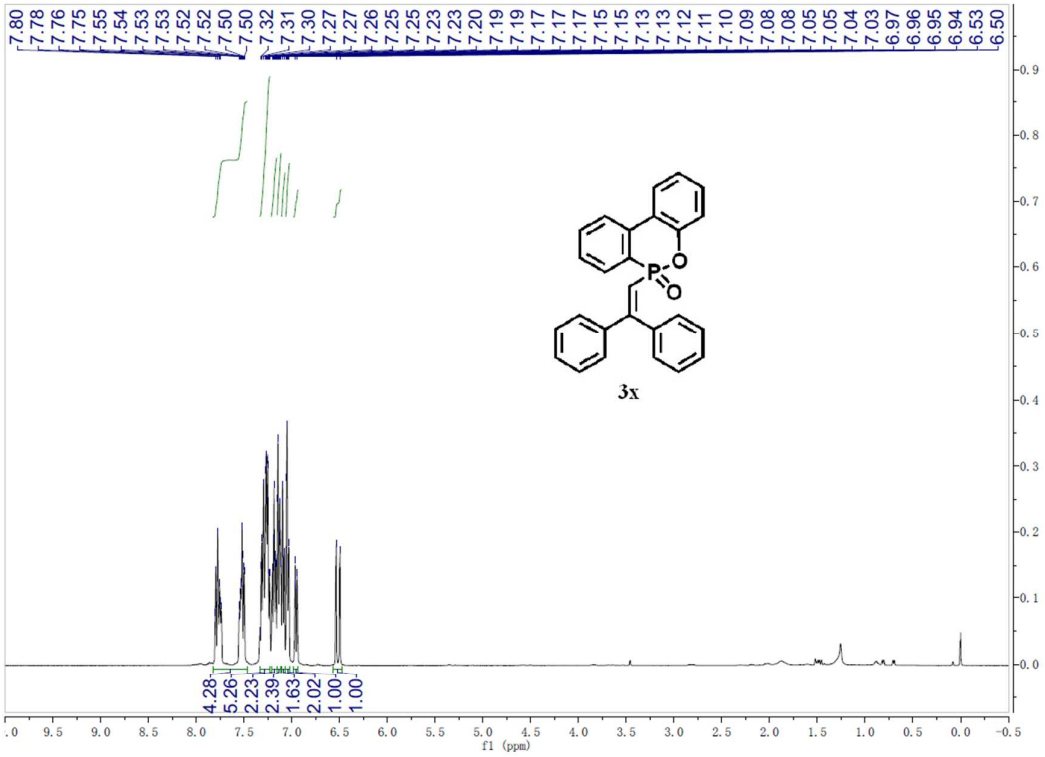

162.23
141.97
141.81
138.03
137.97
134.42
134.40
133.10
133.01
132.66
132.53
132.02
130.97
130.30
129.69
128.89
128.71
128.51
128.41
128.30
128.18
127.91
127.78
127.47
126.75
126.04
125.93
120.88
119.84
3v
f1 (ppm)

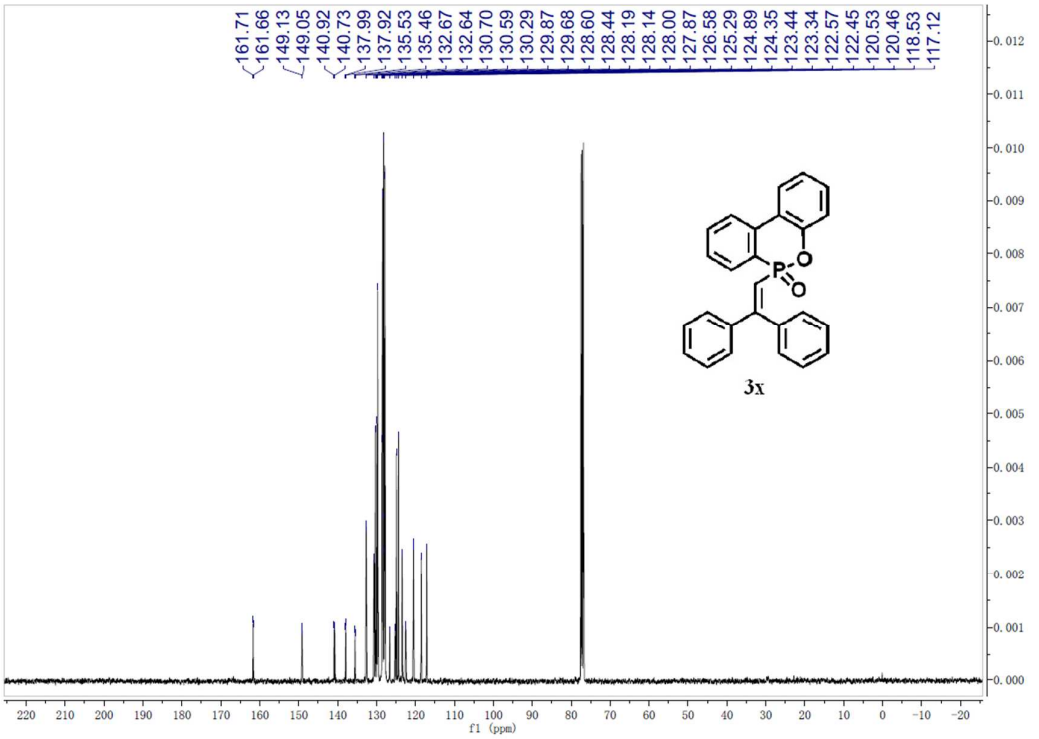

30.68
19.74
3v
3v'
f1 (ppm)

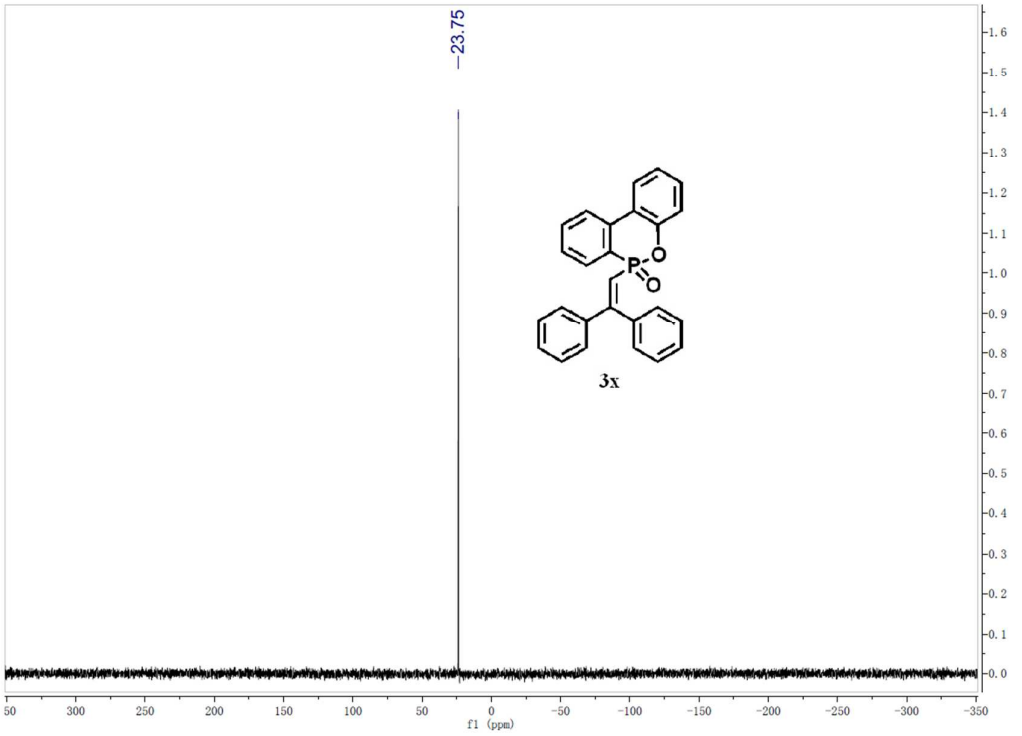

8.60
8.59
8.58
7.88
7.86
7.85
7.84
7.83
7.83
7.82
7.78
7.77
7.75
7.73
7.48
7.47
7.46
7.45
7.30
7.29
7.28
7.26
7.25
7.25
7.23
7.21
7.20
7.19
7.13
7.08
6.99
6.99
6.98
6.97
6.97
6.95
6.95
6.88
6.88
6.86
6.85
6.83
2.00
4.07
2.04
4.17
7.22
1.02
1.01
3.99
3w
f1 (ppm)

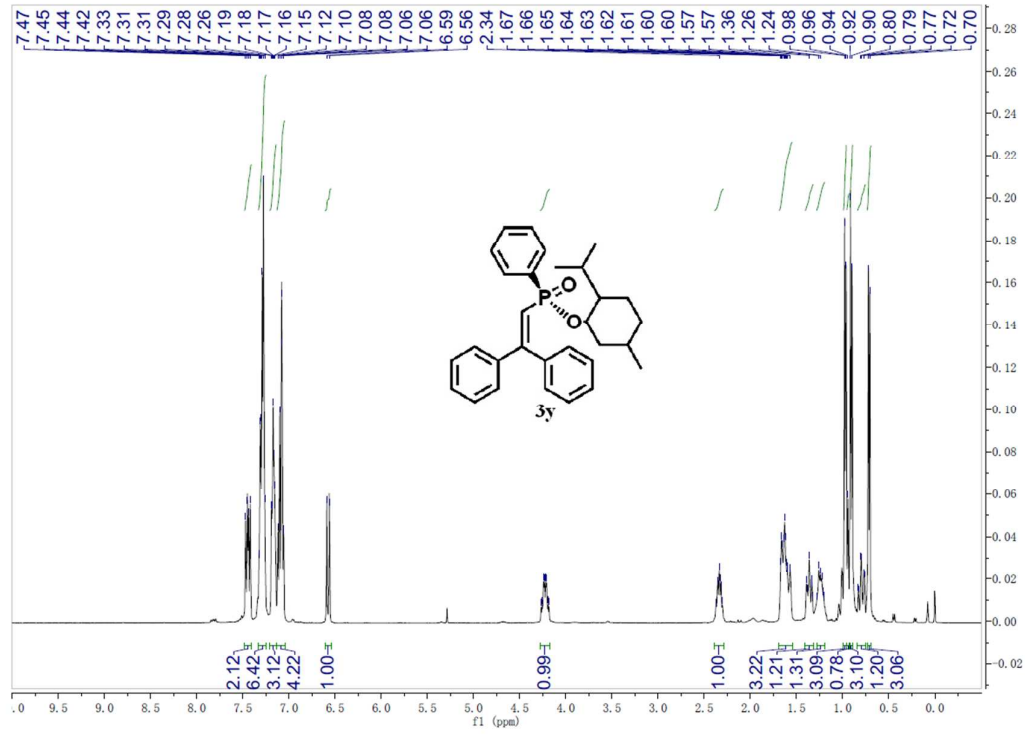

160.48
142.25
142.09
137.90
137.83
134.04
133.94
133.89
133.80
133.26
133.18
132.78
129.94
129.72
129.33
129.03
128.91
128.38
128.32
127.55
127.50
127.09
127.03
126.21
124.87
124.73
122.67
121.65
3w
f1 (ppm)

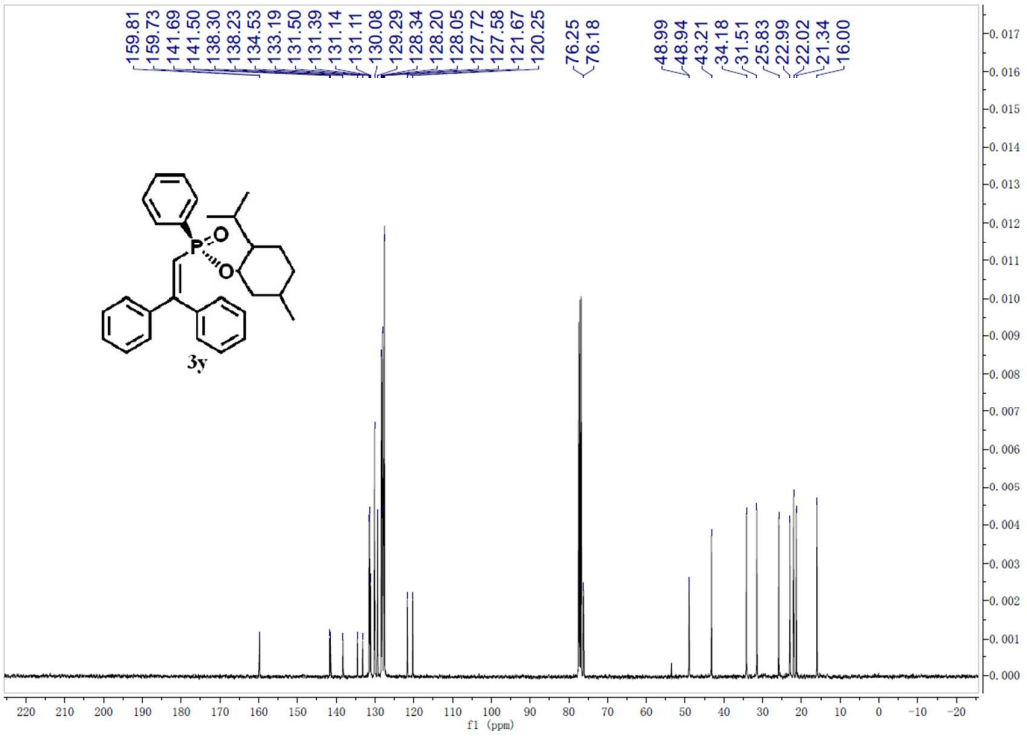

32.63
23.46
3w
3w'
f1 (ppm)

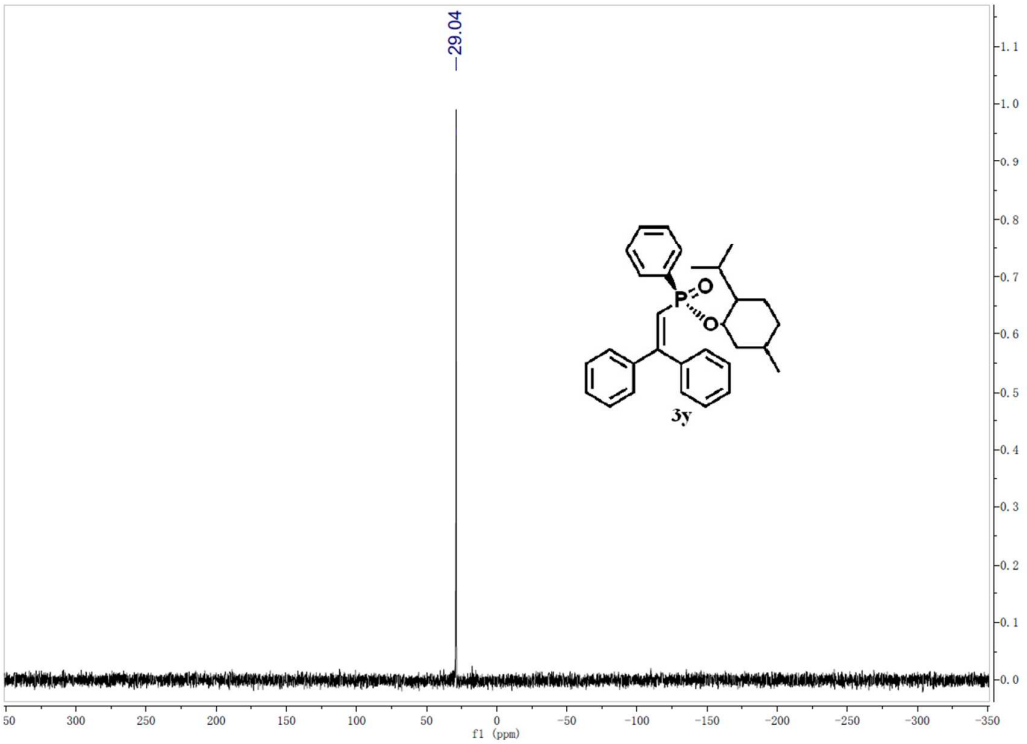

7.80
7.78
7.76
7.75
7.55
7.54
7.53
7.53
7.52
7.52
7.50
7.50
7.32
7.31
7.30
7.27
7.27
7.26
7.25
7.25
7.23
7.23
7.20
7.19
7.19
7.17
7.17
7.17
7.15
7.15
7.13
7.13
7.12
7.11
7.10
7.09
7.08
7.08
7.05
7.05
7.04
7.03
6.97
6.96
6.95
6.94
6.53
6.50
4.28
5.26
2.23
2.39
1.63
2.02
1.00
1.00
f1 (ppm)
3x

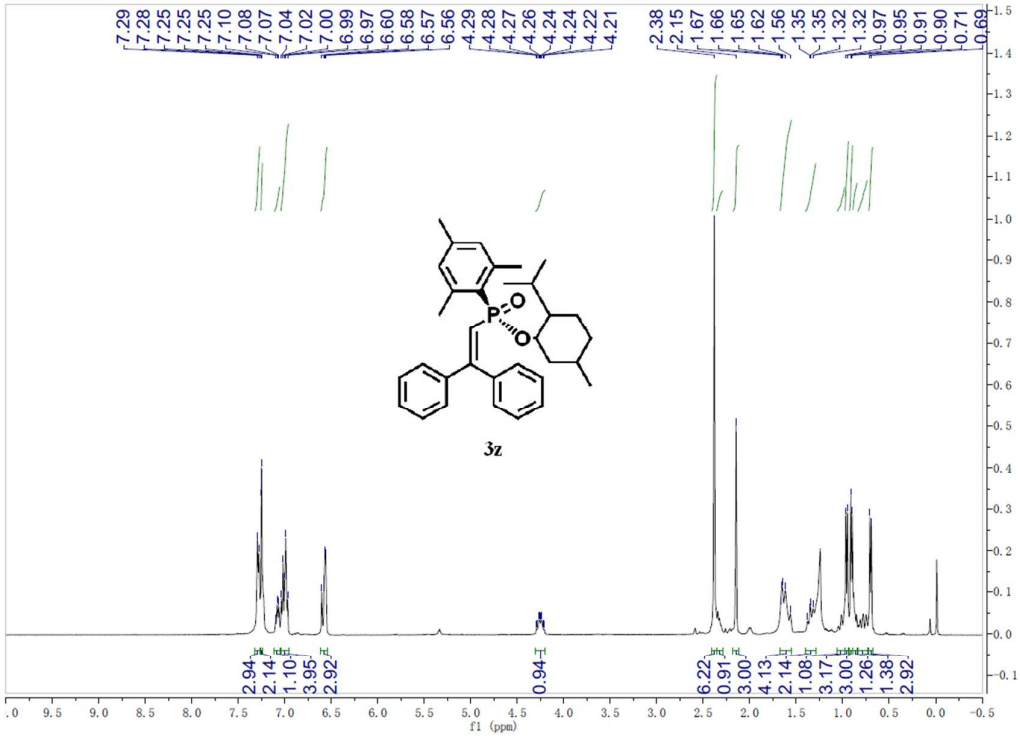

161.71
161.66
149.13
149.05
140.92
140.73
137.99
137.92
135.53
135.46
132.67
132.64
130.70
130.59
130.29
129.87
129.68
128.60
128.44
128.19
128.14
128.00
127.87
126.58
125.29
124.89
124.35
123.44
123.34
122.57
122.45
120.53
120.46
118.53
117.12
f1 (ppm)
3x


23.75
3x
f1 (ppm)

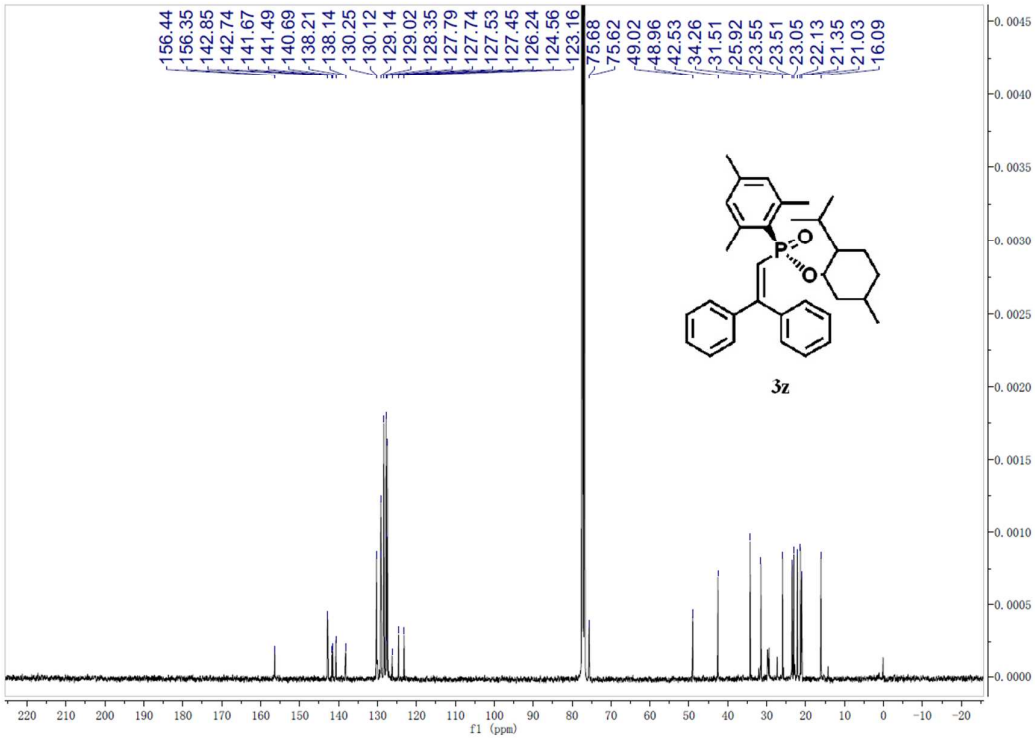

7.47 7.45 7.44 7.42 7.33 7.31 7.31 7.29 7.28 7.26 7.19 7.18 7.17 7.16 7.15 7.12 7.10 7.08 7.08 7.06 7.06 6.59 6.56 2.34 1.67 1.66 1.65 1.64 1.63 1.62 1.61 1.60 1.60 1.57 1.57 1.36 1.26 1.24 0.98 0.96 0.94 0.92 0.90 0.80 0.79 0.77 0.72 0.70
2.12 6.42 3.12 4.22 1.00 0.99 1.00 3.22 1.21 1.31 3.09 0.78 3.10 1.20 3.06
3y
f1 (ppm)


159.81
159.73
141.69
141.50
138.30
138.23
134.53
133.19
131.50
131.39
131.14
131.11
130.08
129.29
128.34
128.20
128.05
127.72
127.58
121.67
120.25
76.25
76.18
48.99
48.94
43.21
34.18
31.51
25.83
22.99
22.02
21.34
16.00
3y
f1 (ppm)

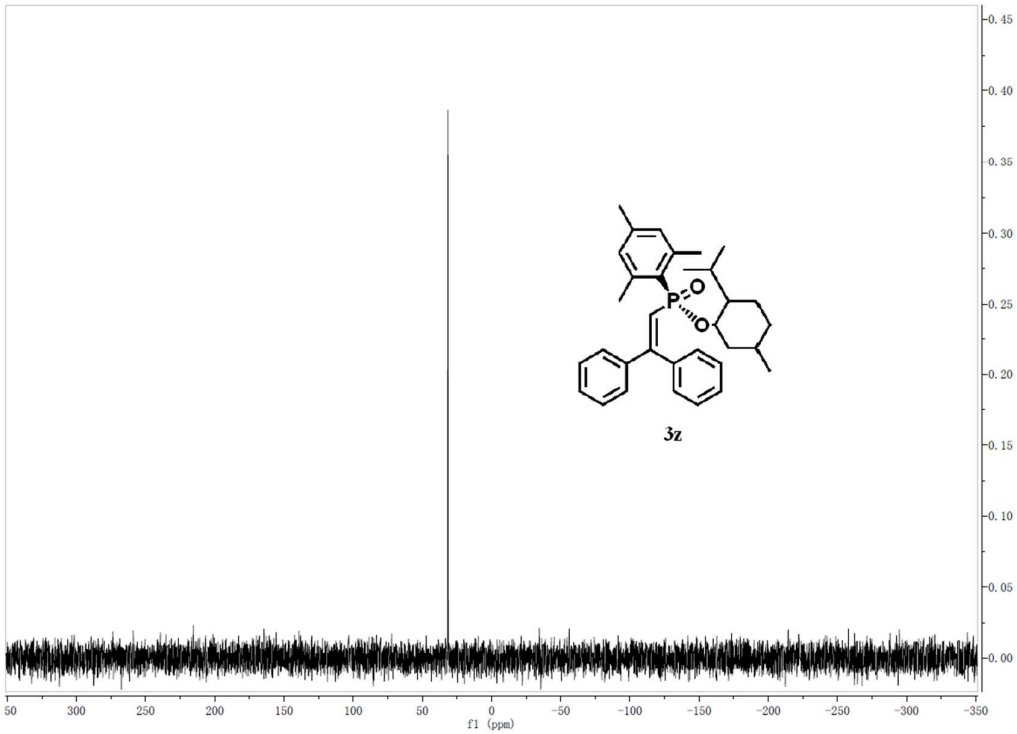

29.04
3y
f1 (ppm)

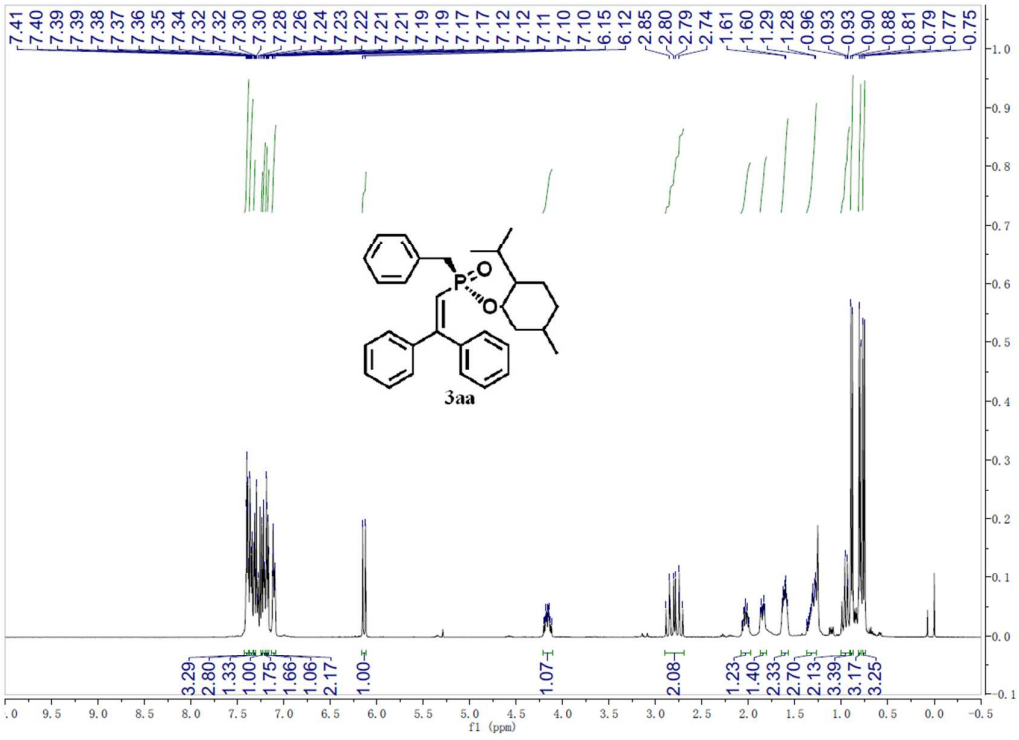

7.29 7.28 7.25 7.25 7.25 7.10 7.08 7.07 7.04 7.02 7.00 6.99 6.97 6.60 6.58 6.57 6.56 4.29 4.28 4.27 4.26 4.24 4.24 4.22 4.21 2.38 2.15 1.67 1.66 1.65 1.62 1.56 1.35 1.35 1.32 1.32 0.97 0.95 0.91 0.90 0.71 0.69
2.94 2.14 1.10 3.95 2.92 0.94 6.22 0.91 3.00 4.13 2.14 1.08 3.17 3.00 1.26 1.38 2.92
f1 (ppm)

*3z*


156.44 156.35 142.85 142.74 141.67 141.49 140.69 138.21 138.14 130.25 130.12 129.14 129.02 128.35 127.79 127.74 127.53 127.45 126.24 124.56 123.16 75.68 75.62 49.02 48.96 42.53 34.26 31.51 25.92 23.55 23.51 23.05 22.13 21.35 21.03 16.09
f1 (ppm)

*3z*


3z
f1 (ppm)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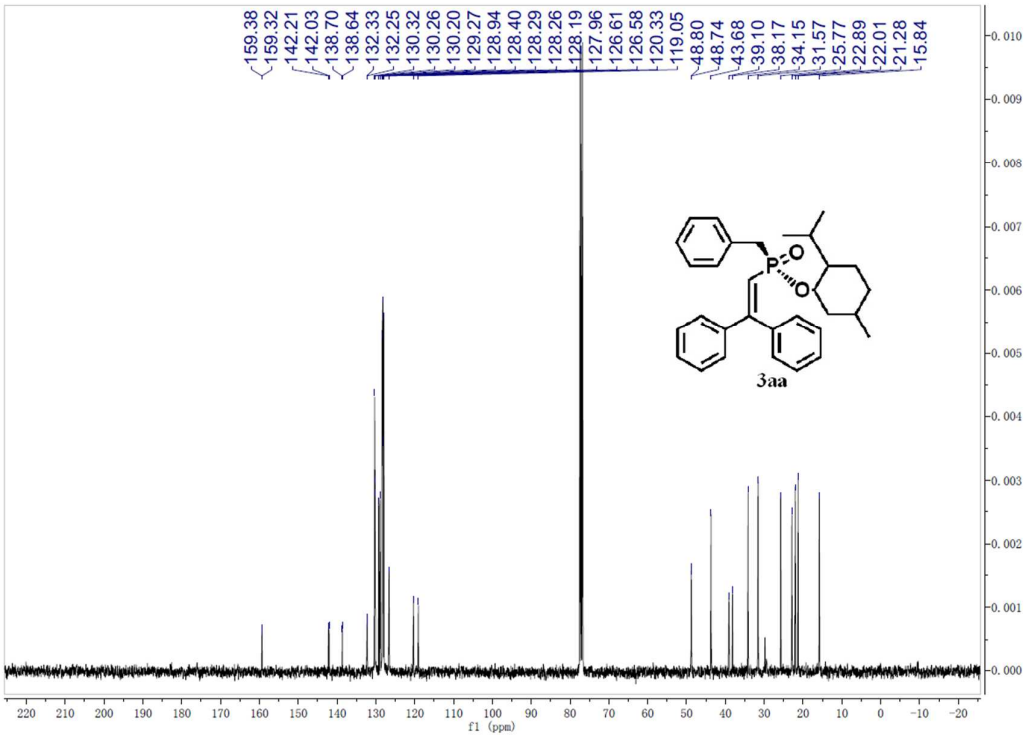
3aa
3.29 2.80 1.33 1.00 1.75 1.66 1.06 2.17 1.00 1.07 2.08 1.23 1.40 2.33 2.70 2.13 3.39 3.17 3.25
f1 (ppm)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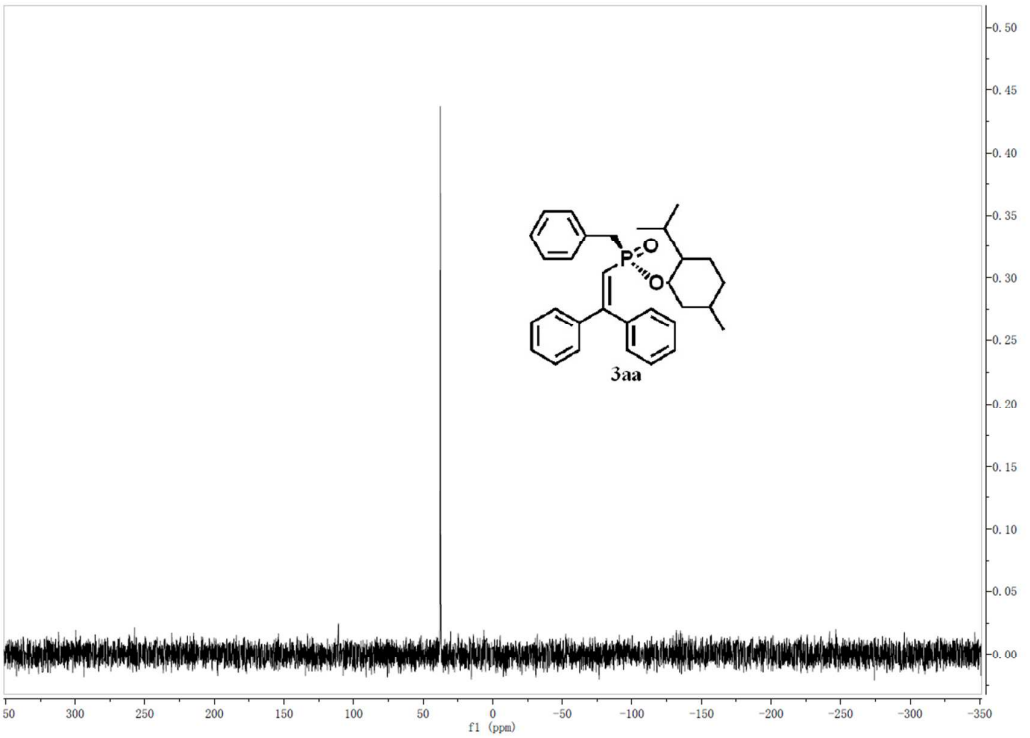
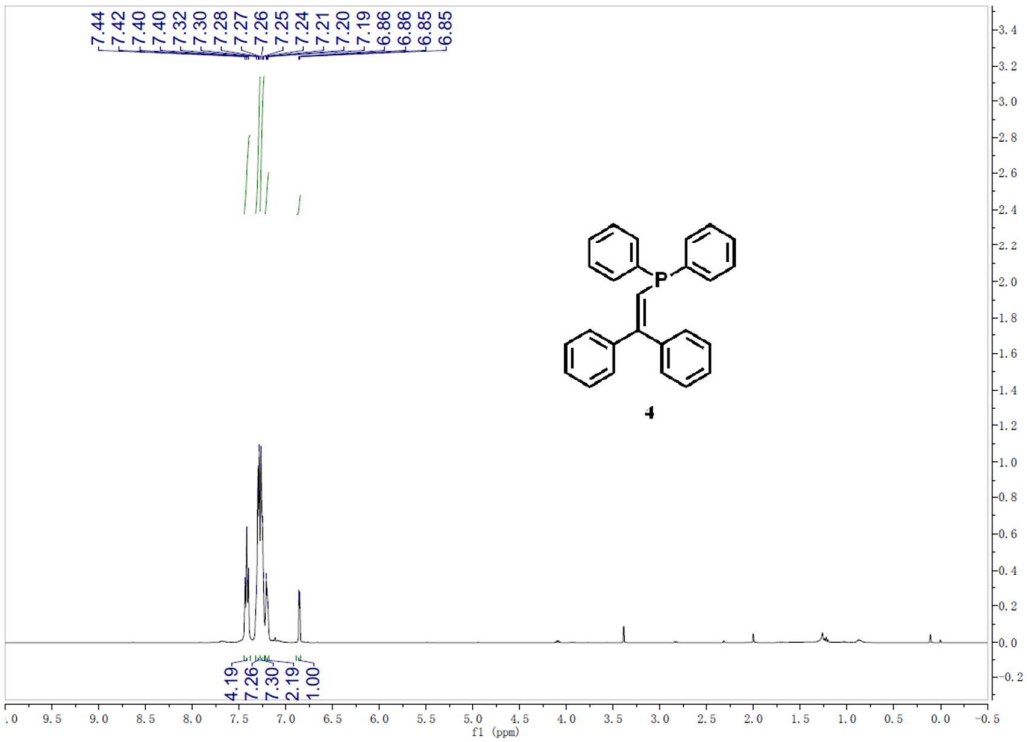
159.32
142.21
142.03
138.70
138.64
132.33
132.25
130.32
130.26
130.20
129.27
128.94
128.40
128.29
128.26
128.19
127.96
126.61
126.58
120.33
119.05
48.80
48.74
43.68
39.10
38.17
34.15
31.57
25.77
22.89
22.01
21.28
15.84
3aa
f1 (ppm)


3aa
f1 (ppm)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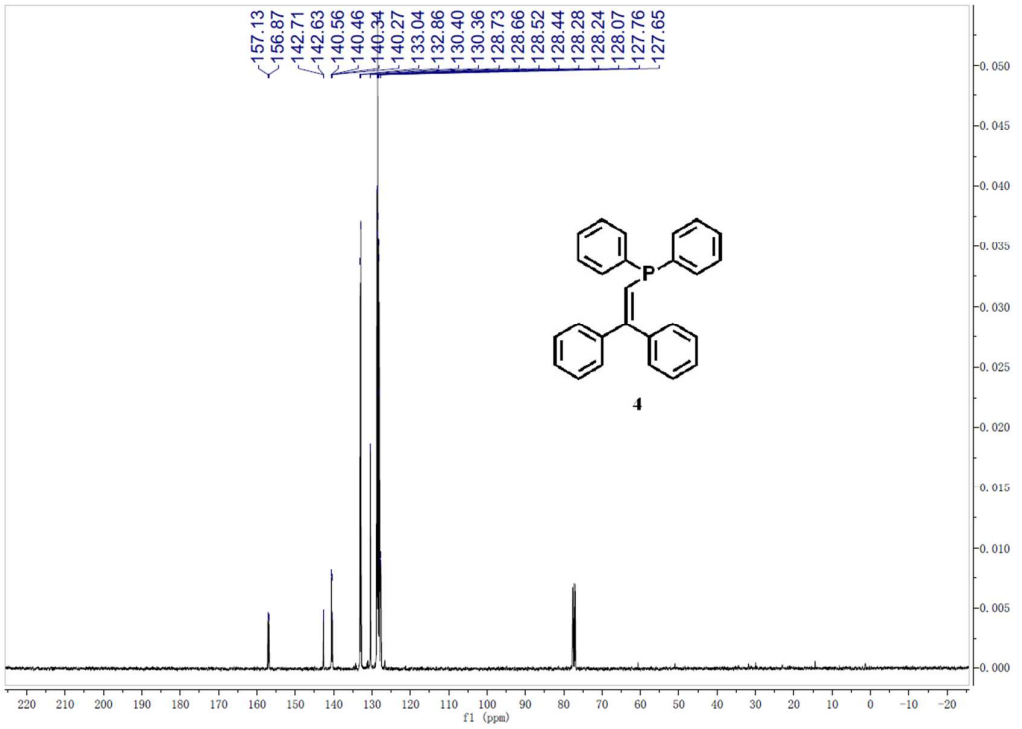
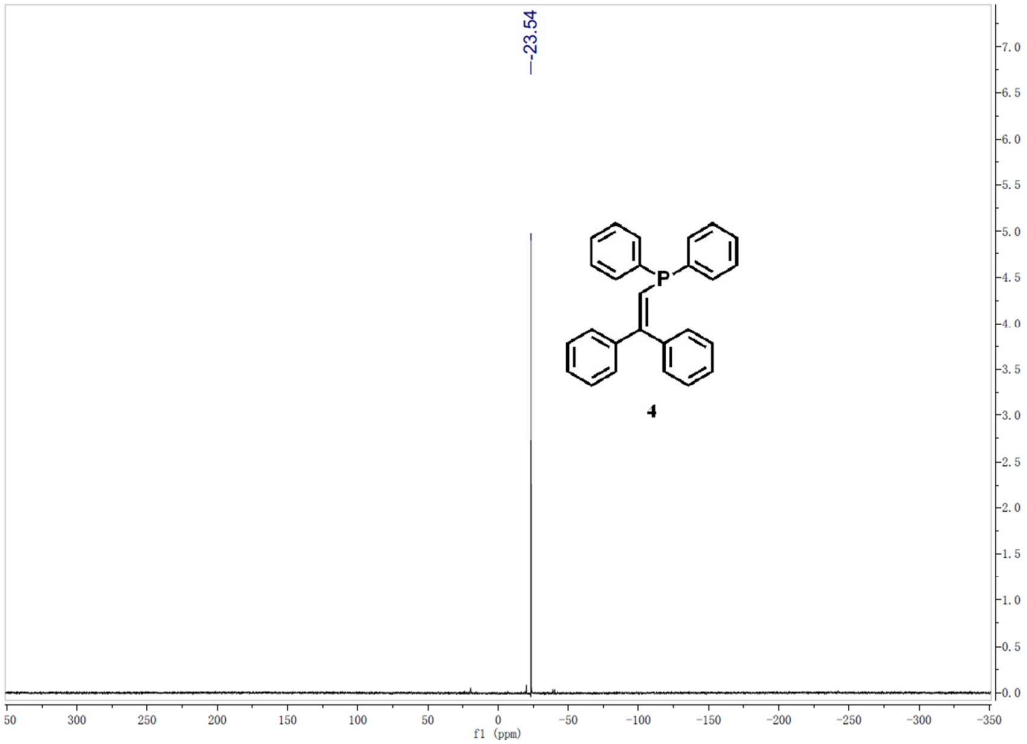
7.42
7.40
7.40
7.32
7.30
7.28
7.27
7.26
7.25
7.24
7.21
7.20
7.19
6.86
6.86
6.85
6.85
4.19
7.26
7.30
2.19
1.00
f1 (ppm)

4


157.13
156.87
142.71
142.63
140.56
140.46
140.34
140.27
133.04
132.86
130.40
130.36
128.73
128.66
128.52
128.44
128.28
128.24
128.07
127.76
127.65
f1 (ppm)

4


-23.54
P
4
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
50
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
f1 (ppm)