Electronic Supplementary Material (ESI) for Chemical Communications.

Supporting Information

A scalable electrochemical dehydrogenative cross-coupling of P(O)H compounds with RSH/ROH

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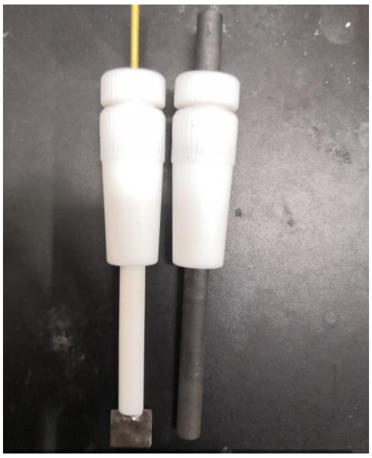
Contents

1. General information

Unless otherwise noted, materials were obtained from commercial suppliers and used without further purification. Reactions were monitored by thin layer chromatography (TLC) using silica gel 60 F-254 plates. The instrument for electrolysis was dual display potentiostat (M8801) (made in China) or ElectraSyn 2.0. Cyclic voltammograms were obtained on a CHI 600E potentiostat. Gas chromatographic analyses were performed on SICT GC-2000Ⅲ gas chromatography instrument with a FID detector. The anode electrode was graphite rod (ϕ 6 mm) and cathodic electrode was platinum plate (15 mm×10 mm×0.1 mm) or the anode electrode and cathode electrode all were platinum electrodes (15 mm×10 mm×0.1 mm). Flash chromatography columns were packed with 200-300 mesh silica gel in petroleum (bp. 60-90 ^{o}C). NMR spectra were measured on a Bruker avanceⅢHD400 (^{1}H at 400 MHz, ^{13}C at 101 MHz, ^{31}P at 162 MHz) magnetic resonance spectrometer. Chemical shifts (δ) are reported in ppm using tetramethylsilane as internal standard (s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, ddd = triplet of doublets, m = multiplet), and coupling constants (J) were reported in Hertz (Hz). ESI-HRMS spectra were recorded on a UPLC of Thermo Q Exactive Focus.

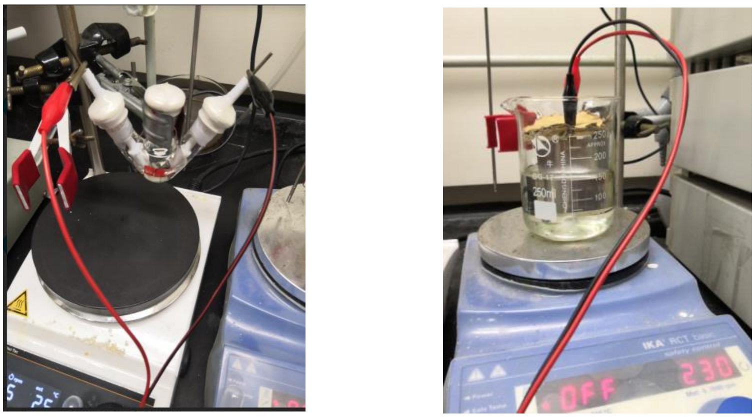
Abbreviations used: GC = graphite rod; RVC = Reticulated Vitreous Carbon; DABCO = 1,4-Diaza[2.2.2]bicyclooctane; NMO = 4-methyl-morpholin4-oxide; NHPI = *N*-Hydroxyphthalimide; Et$_3$N = Triethylamine; DMF = *N*,*N*-Dimethylformamide; DBU = 1,8-diazabicyclo[5.4.0]undec-7-ene; TEMPO = 2,2,6,6-Tetramethyl-1-piperidyloxy.

2. Equipment and experiments pictures

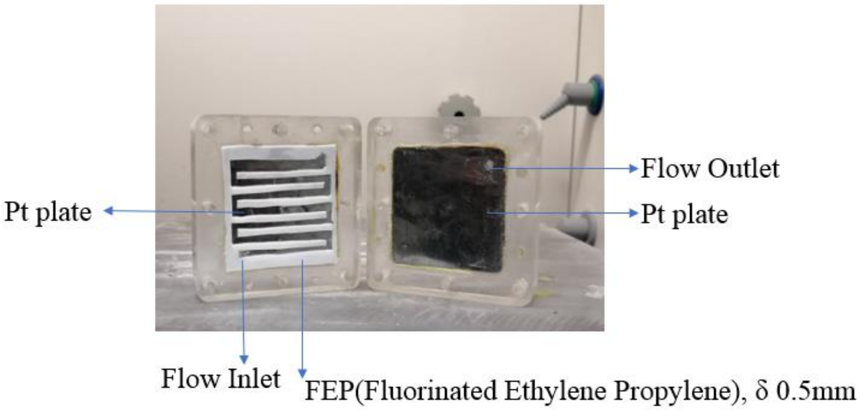


(a) electrodes

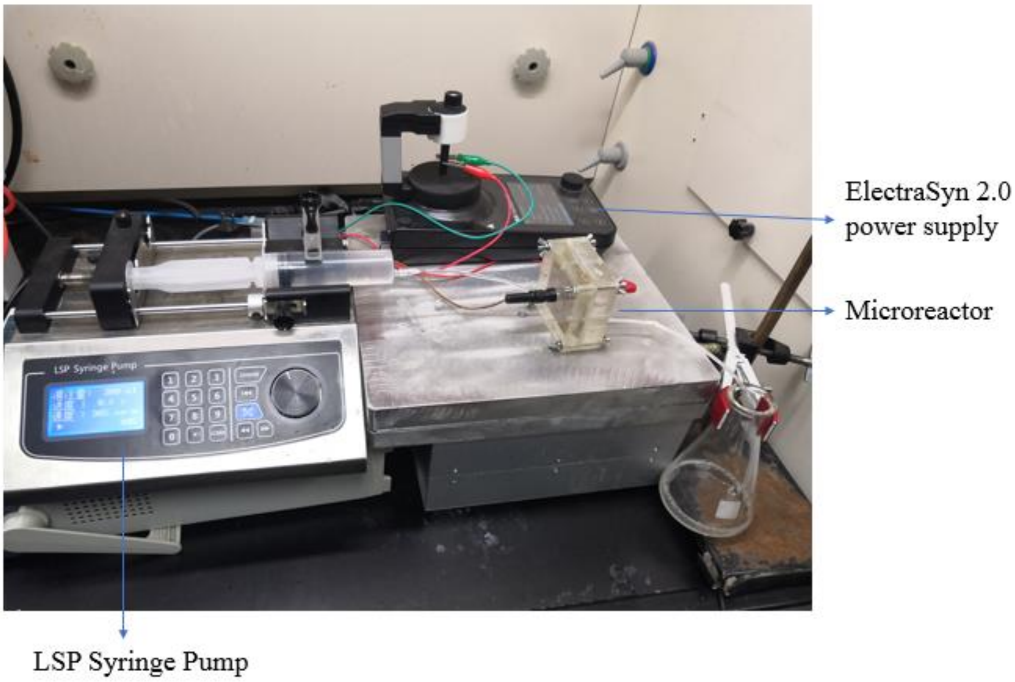
(b) power supply



(c) reaction cell **(d)** gram scale beaker



(e) flow microreactor

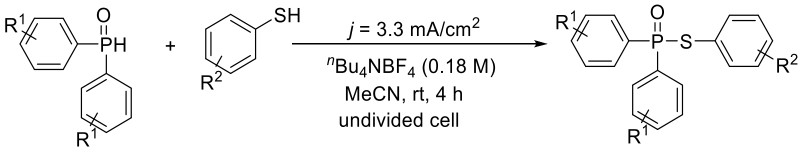


(f) Electrochemical flow setup

Figure S1 Electrolysis setup

3. Experimental procedure

3.1 General procedure for coupling with thiols

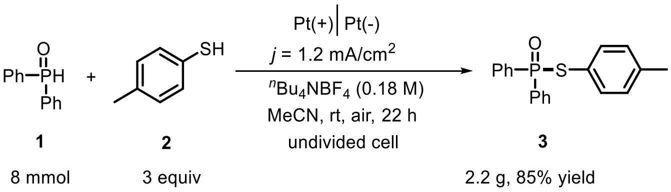


Method A: In an oven-dried undivided three-necked bottle (10 mL) equipped with a stir bar. diphenylphosphine oxide (0.3 mmol), thiol (0.9 mmol), ^{n}Bu$_4$BF$_4$ (0.9 mmol) were dissolved in MeCN (5 mL). The bottle was equipped with platinum plate (15 mm×10 mm×0.1 mm) as the anode and cathode. The resulting mixture was electrolyzed at a constant current mode with a constant current density of 3.3 mA/cm^2 under ambient temperature for corresponding time. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 5 : 1 - 3 : 1) to afford the desired product.

Method B: In an oven-dried undivided three-necked bottle (10 mL) equipped with a stir bar. diphenylphosphine oxide (0.3 mmol), thiol (0.9 mmol), ^{n}Bu$_4$BF$_4$ (0.9 mmol) were dissolved in DMF (5 mL). The bottle was equipped with platinum plate (15 mm×10 mm×0.1 mm) as the anode and cathode. The resulting mixture was electrolyzed at a constant current mode with a constant current density of 3.3 mA/cm^2 under ambient temperature for corresponding time. When the reaction was finished, the solution was extracted with EtOAc (3 × 12 mL) and brine (2 × 12 mL). The combined organic layer was dried with Na$_2$SO$_4$, filtered the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 5 : 1 - 3 : 1) to afford the desired product.

Method C: In an exemplary procedure for the electrolysis with an ElectraSyn 2.0. diphenylphosphine oxide (0.3 mmol), thiol (0.9 mmol), ^{n}Bu$_4$BF$_4$ (0.9 mmol) were added in sequence to a 5 mL ElectraSyn vial with a stirring bar. The screw thread area of the vial was covered with a piece of Parafilm and screwed to finger-tight with the ElectraSyn vial cap equipped with a Pt electrode (anode) and a Pt electrode (cathode). The undivided cell was adapted to the ElectraSyn 2.0 vial holder and electrolysed under a constant current density of 3.3 mA/cm^2 for 4 h. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 5 : 1 - 3 : 1) to afford the desired product.

Procedure for gram scale synthesis:

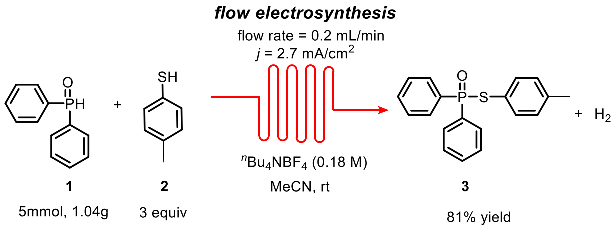


diphenylphosphine oxide (8 mmol, 1.61 g), thiol (24 mmol, 2.98 g), ${}^{n}Bu_4BF_4$ (24 mmol, 7.90 g) were placed in an beaker (250 mL).The beaker was equipped with a stir bar, followed by MeCN (135 mL).Two platinum plate (50 mm×50 mm×0.1 mm) were set up in the beaker. The resulting mixture was electrolyzed at a constant current mode with a constant current density of 1.2 mA/cm^2 under ambient temperature for 22 h. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 3 : 1) to afford the desired product.

Flow chemistry:

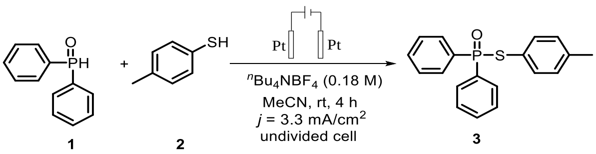
FEP (fluorinated ethylene propylene) with channel 3 mm width; thickness: 0.5 mm; total length of the pipeline of 30.1 cm; volume: 450 μL; exposed electrode surface: 9.57 cm^2. (Figure S1e)

The device comprises a micro-flow electrochemical reactor made out of two bodies (75x75x25 mm, Figure S1), which can be polymer. The bodies have a square space in the centre (50x50 mm^2), where the two-platinum plate (thickness 0.1 mm) electrodes are placed and FEP was sandwiched between two platinum electrodes. The housing of the reactor has a hole in the middle that allows an easy connection of the electrodes to the power supply by a copper wire. This plate also has 2 holes, one for the inlet and one for the outlet of the reaction solution.



The **1** (5 mmol, 1.04g) , **2** (15 mmol, 1.86 g) and ${}^{n}Bu_4BF_4$ (15 mmol, 4.92 g) were dissolved in MeCN (84 mL) and flowed through the electrochemical microreactor (volume = 450 μL) in a flow rate of 0.2 mL/min (Figure S1). A constant current density of 2.7 mA/cm^2 was employed. The solution was concentrated under reduced pressure on a rotary evaporator. The residue was chromatographed through silica gel eluting with petroleum/ethyl ether to give the product.

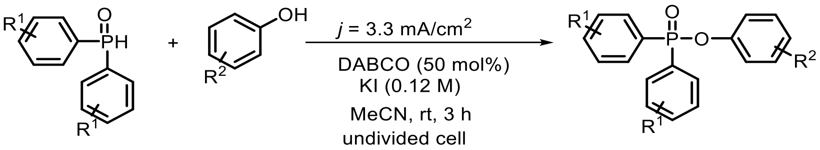
Table S1 Optimization of the reaction conditions[a]



Entry	Deviation from standard conditions	Yield[b] (%)
1	None	84
2[c]	1 equiv thiol	49
3[c]	2 equiv thiol	69
4[c]	3 equiv thiol	76
5	$LiClO_4$ instead of $^nBu_4NBF_4$	62
6	$^nBu_4NPF_6$ instead of $^nBu_4NBF_4$	71
7	MeCN = 4 mL	62
8	MeCN = 7 mL	56
9	DMF instead of MeCN	83
10	MeOH instead of MeCN	49
11	GC (+) | Pt (-) instead of Pt (+) | Pt (-)	58
12	RVC (+) | Pt (-) instead of Pt (+) | Pt (-)	68
13	j = 2.7 mA/cm^2 instead of j = 3.3 mA/cm^2	64
14	j = 4.7 mA/cm^2 instead of j = 3.3 mA/cm^2	56
15	10 mol % Cp_2Fe as additive	58
16	10 mol % $^nBu_4NBr$ as additive	81
17	without current	n.d.

[a] Standard conditions: Pt anode, Pt cathode, **1** (0.3 mmol), **2** (0.9 mmol), ^{n}Bu$_4$NBF$_4$ (0.18 M), MeCN (5.0 mL), rt, constant current = 5 mA (j = 3.3 mA/cm^2), 4 h. [b] Isolated yield. [c] 0.12 M ^{n}Bu$_4$NBF$_4$

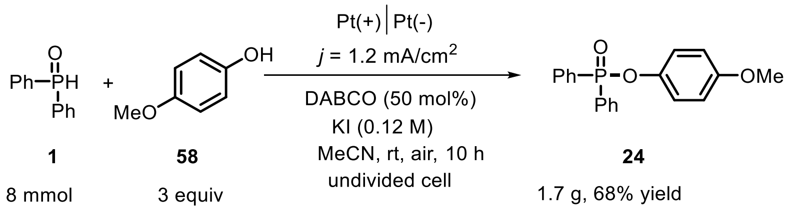
3.2 General procedure for diphenylphosphine oxide with phenol



Method A: In an oven-dried undivided three-necked bottle (10 mL) equipped with a stir bar. diphenylphosphine oxide (0.3 mmol), phenol (0.9 mmol), KI (0.6 mmol), DABCO (0.15 mmol) were dissolved in MeCN (5 mL) and stir for 10 minutes. The bottle was equipped with graphite rod (ϕ 6 mm, about 8 mm immersion depth in solution) as the anode and platinum plate (15 mm×10 mm×0.1 mm) as the cathode. The resulting mixture was electrolyzed at a constant current mode with a constant current density of 3.3 mA/cm^2 under ambient temperature for corresponding time. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 5 : 1 - 1 : 1) to afford the desired product.

Method B: In an exemplary procedure for the electrolysis with an ElectraSyn 2.0. diphenylphosphine oxide (0.3 mmol), phenol (0.9 mmol), KI (0.6 mmol), DABCO (0.15 mmol) were added in sequence to a 5 mL ElectraSyn vial with a stirring bar. The screw thread area of the vial was covered with a piece of Parafilm and screwed to finger-tight with the ElectraSyn vial cap equipped with a graphite electrode (anode) and a Pt electrode (cathode). The undivided cell was adapted to the ElectraSyn 2.0 vial holder and electrolysed under a constant current density of 3.3 mA/cm^2 for 3.5 h. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 5 : 1 - 1 : 1) to afford the desired product.

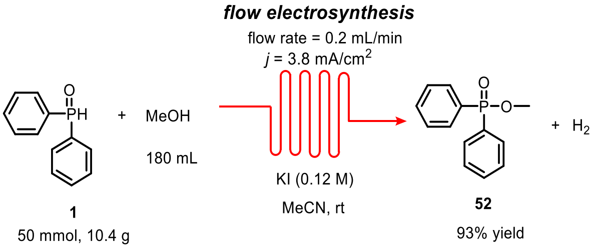
Procedure for gram scale synthesis:



Diphenylphosphine oxide (8 mmol, 1.61g), phenol (24 mmol, 2.98 g), KI (16 mmol, 2.66 g), DABCO (4 mmol, 450 mg) were placed in an beaker (250 mL). The beaker was equipped with a stir bar, followed by MeCN (135 mL) and stir for 20 minutes. Two platinum plate (50 mm×50 mm×0.1 mm) were set up in the beaker. The resulting mixture was electrolyzed at a constant current mode with a constant current density of 1.2 mA/cm^2 under ambient temperature for 10 h. When the reaction was finished, the solvent was removed with a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum : ethyl ether = 3 : 1) to afford the desired product.

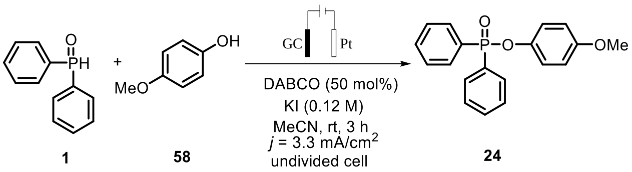
Flow chemistry:

FEP (fluorinated ethylene propylene) with channel 3 mm width; thickness: 0.5 mm:; total length of the pipeline of 30.1 cm; volume: 450 µL; exposed electrode surface: 9.57 cm^2. (Figure S1e)
The device comprises a micro-flow electrochemical reactor made out of two bodies (75x75x25 mm, Figure S1), which can be polymer. The bodies have a square space in the centre (50x50 mm^2), where the two-platinum plate (thickness 0.1 mm) electrodes are placed and FEP was andwiched between two platinum electrodes. The housing of the reactor has a hole in the middle that allows an easy connection of the electrodes to the power supply by a copper wire. This plate also has 2 holes, one for the inlet and one for the outlet of the reaction solution.



The **1** (50 mmol, 10.4 g) and KI (100 mmol, 16.7 g) was dissolved in MeCN/MeOH (4:1, 0.84 L) and flowed through the electrochemical microreactor (volume = 450 µL) in a flow rate of 0.2 mL/min (Figure S1). A constant current density of 3.8 mA/cm^2 was employed. The solution was concentrated under reduced pressure on a rotary evaporator. The residue was chromatographed through silica gel eluting with petroleum/ethyl ether to give the product.

Table S2 Optimization of the reaction conditions[a]



Entry	Deviation from standard conditions	Yield[b] (%)
1	None	78
2[c]	No DABCO	25
3	0.25 equiv DABCO	72
4	1.0 equiv DABCO	68
5	1.5 equiv DABCO	69
6	quinoline instead of DABCO	65
7	NMO instead of DABCO	47
8	NHPI instead of DABCO	n.d.
9[c]	Et_3N instead of DABCO	n.d.
10[c]	DBU instead of DABCO	n.d.
11	^{n}Bu$_4$NI instead of KI	68
12	NaI instead of KI	77
13	NH_4I instead of KI	n.d
14	LiBr instead of KI	n.d
15	^{n}Bu$_4$NBF$_4$ instead of KI	trace
16	Pt (+) ｜ Pt (-) instead of GC (+) ｜ Pt (-)	77
17	C (+) ｜ Pt (-) instead of GC (+) ｜ Pt (-)	71
18	GC (+) ｜ GC (-) instead of GC (+) ｜ Pt (-)	57
19	j = 2.0 mA/cm^2 instead of j = 3.3 mA/cm^2, 4 h	50
20	j = 4.7 mA/cm^2 instead of j = 3.3 mA/cm^2, 2 h 30 min	67
21	2.5 V instead of j = 3.3 mA/cm^2, 2 h 10 min	66
22	without current	n.d.

[a] Standard conditions: GC anode, Pt cathode, **1** (0.3 mmol), **58** (0.9 mmol), DABCO (50 mol%) , KI (0.12 M), MeCN (5.0 mL), rt, constant current = 5 mA (j = 3.3 mA/cm^2), 3 h. [b] Isolated yield. [c] 5 equiv **58**. n.d. = not detected

4. General procedure for cyclic voltammetry (CV)

Cyclic voltammetry was performed in a three-electrode cell connected to a schlenk line at room temperature. The working electrode was a platinum disk electrode, the counter electrode a platinum wire. The reference was an Ag/AgCl electrode submerged in saturated aqueous KCl solution, and separated from reaction by a salt bridge. 10 mL of MeCN containing 0.1 M $^{n}\mathrm{Bu_4NBF_4}$ were poured into the electrochemical cell in all experiments. Concentration: 0.03 M. The scan rate is 0.1 V/s, ranging from 0 V to 2.5 V. The peak potentials vs. Ag/AgCl for used. The obvious oxidation peaks of 4-methylbenzenethiol and 4-methoxyphenol were observed 1.859V , 1.511V respectively.

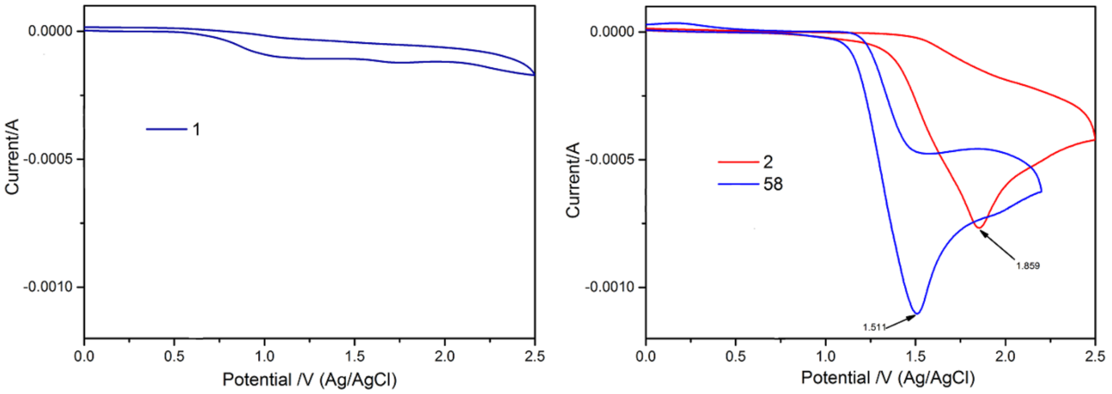
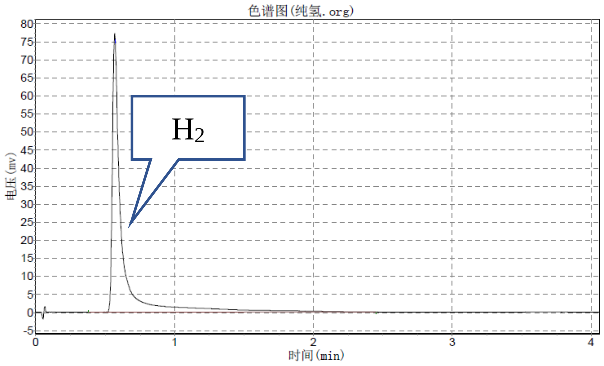


Figure S2 Cyclic voltammertry experiment of reactants

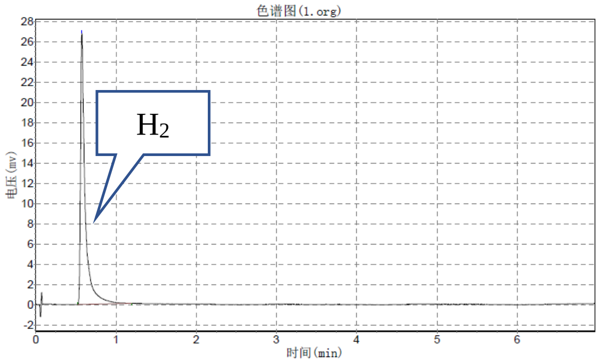
5. Detection of H_2 by GC



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		0.573	76291.617	354313.906	100.0000
总计			76291.617	354313.906	100.0000

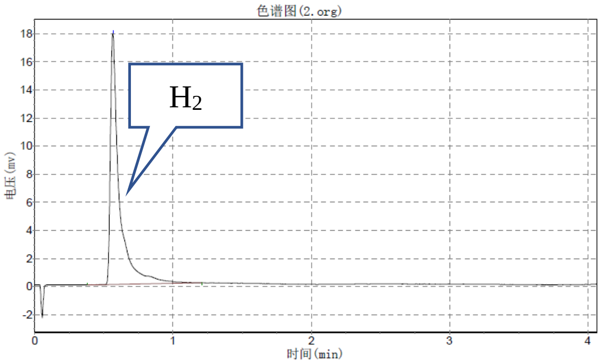
(a) standard hydrogen sample



分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		0.573	26812.145	108501.555	100.0000
总计			26812.145	108501.555	100.0000

(b) P(O)H-SH



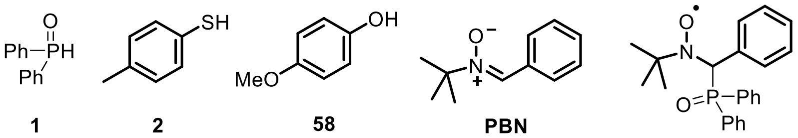
分析结果表

峰号	峰名	保留时间	峰高	峰面积	含量
1		0.563	17893.477	80247.000	100.0000
总计			17893.477	80247.000	100.0000

(c) P(O)H-OH

6. EPR experiments

EPR spectra were recorded at room temperature on a Bruker ESP-300E: Receiver Gain = 1.78 e^{+004}; Phase = 0 deg; Harmoni = 1; Mod. Frequency = 100.000 KHz; Mod. Amplitude = 6.00 G; Center Field = 3360.00 G; Sweep width 90.000 G; Resolution = 2048 points; Conversion Time = 40.00 ms; Time const. = 20.48 ms; Sweep time = 81.92 s; Power = 60.39 mw.



a) PBN + KI + MeCN

b) PBN + KI + **1** + MeCN

c) PBN + KI + **1** + DABCO + MeCN

d) PBN + KI + **1** + **58** + DABCO + MeCN

e) PBN + ^{n}Bu$_4$NBF$_4$ + **1** + MeCN

f) PBN + ^{n}Bu$_4$NBF$_4$ + **1** + **2** + MeCN

EPR study of reaction a:

Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with KI (0.6 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.

EPR study of reaction b:

Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with **1** (0.30 mmol), KI (0.6 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.

EPR study of reaction c:

Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with **1** (0.30 mmol), DABCO (0.15 mmol), KI (0.6 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.

EPR study of reaction d:

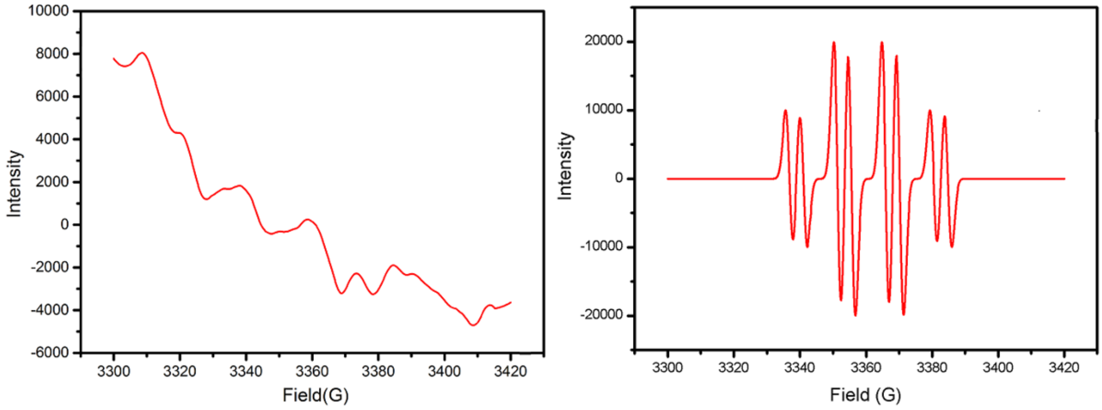
Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with **1** (0.30 mmol), **58** (0.90 mmol), DABCO (0.15 mmol), KI (0.6 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.

EPR study of reaction e:

Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with **1** (0.30 mmol), ^{n}Bu$_4$NBF$_4$ (0.9 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.

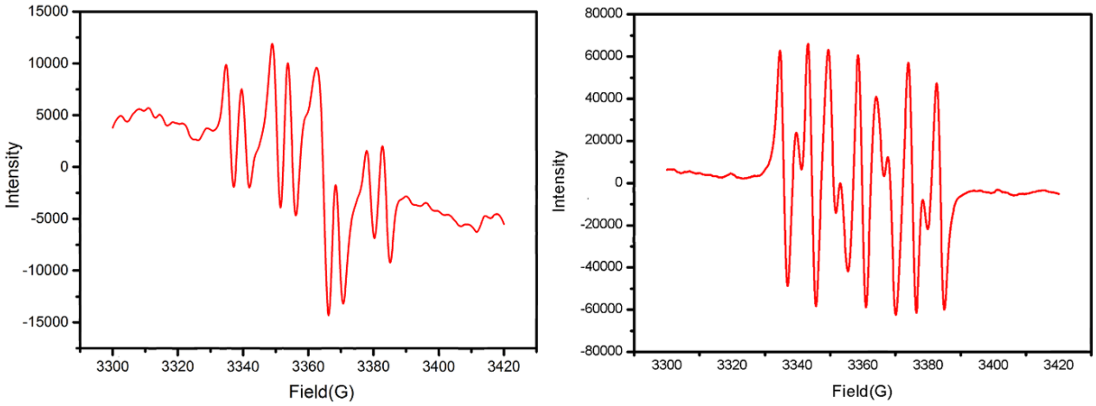
EPR study of reaction f:

Under constant current conditions, a ElectraSyn 2.0 equipped with a stir bar was loaded with **1** (0.30 mmol), **2** (0.90 mmol), $^{n}Bu_4NBF_4$ (0.9 mmol) and PBN (0.30 mmol) in 5.0 mL MeCN was stirred at rt. After 10 mins, the solution sample was taken out into a small tube and analyzed by EPR.



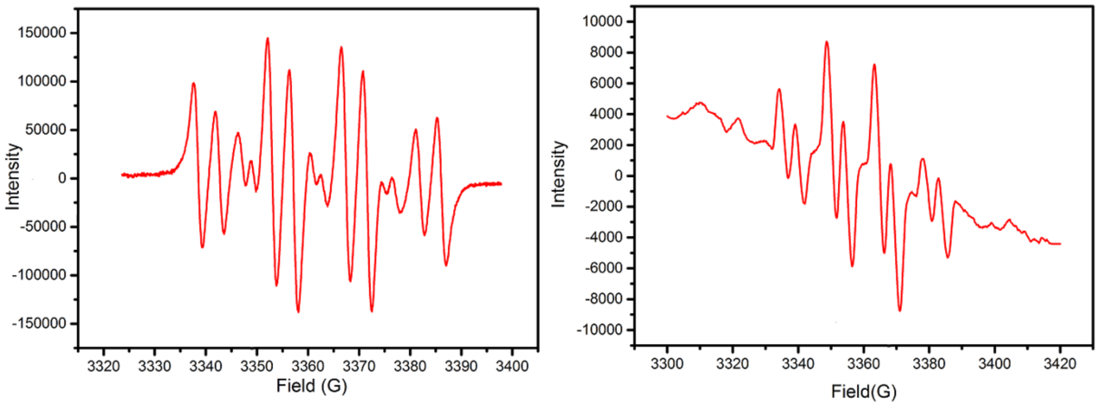
Reaction **a**

Reaction **b**



Reaction **c**

Reaction **d**



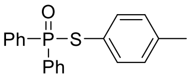
Reaction **e**

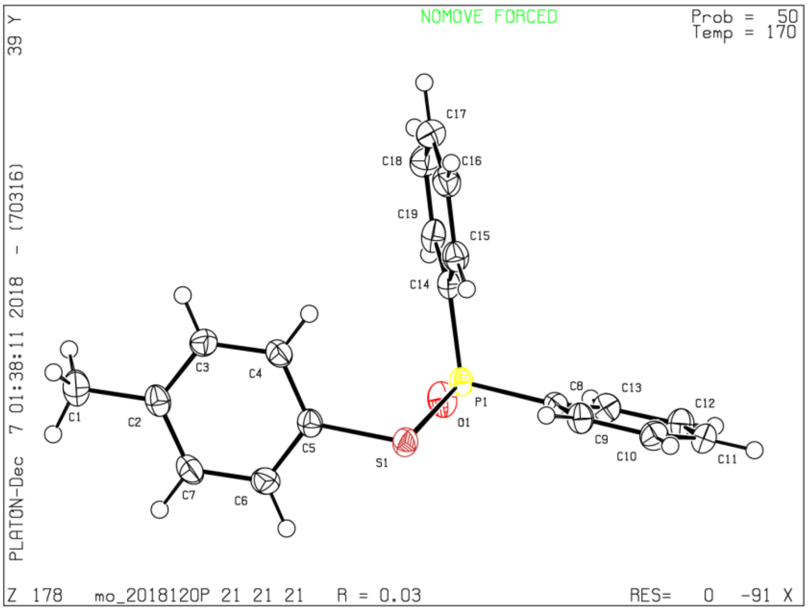
Reaction **f**

Figure S3 EPR experiments pictures

7. X-Ray crystallographic data

X-Ray crystallographic data of 3:





```
Bond precision:   C-C = 0.0036 A          Wavelength=0.71073

Cell:              a=8.5391(4)     b=11.0667(5)     c=16.9456(9)
                   alpha=90        beta=90          gamma=90
Temperature:       170 K

                  Calculated                Reported
Volume            1601.35(13)               1601.35(13)
Space group       P 21 21 21                P 21 21 21
Hall group        P 2ac 2ab                 P 2ac 2ab
Moiety formula    C19 H17 O P S             ?
Sum formula       C19 H17 O P S             C19 H17 O P S
Mr                324.36                    324.35
Dx,g cm-3         1.345                     1.345
Z                 4                         4
Mu (mm-1)         0.301                     0.301
F000              680.0                     680.0
F000'             681.13
h,k,lmax          11,14,22                  11,14,22
Nref              3980[ 2276]               3962
Tmin,Tmax         0.897,0.973               0.588,0.746
Tmin'             0.887

Correction method= # Reported T Limits: Tmin=0.588 Tmax=0.746
AbsCorr = MULTI-SCAN

Data completeness= 1.74/1.00       Theta(max)= 28.296

R(reflections)= 0.0332( 3457)      wR2(reflections)= 0.0885( 3962)

S = 1.008                  Npar= 200
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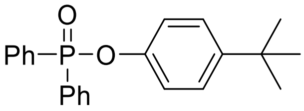
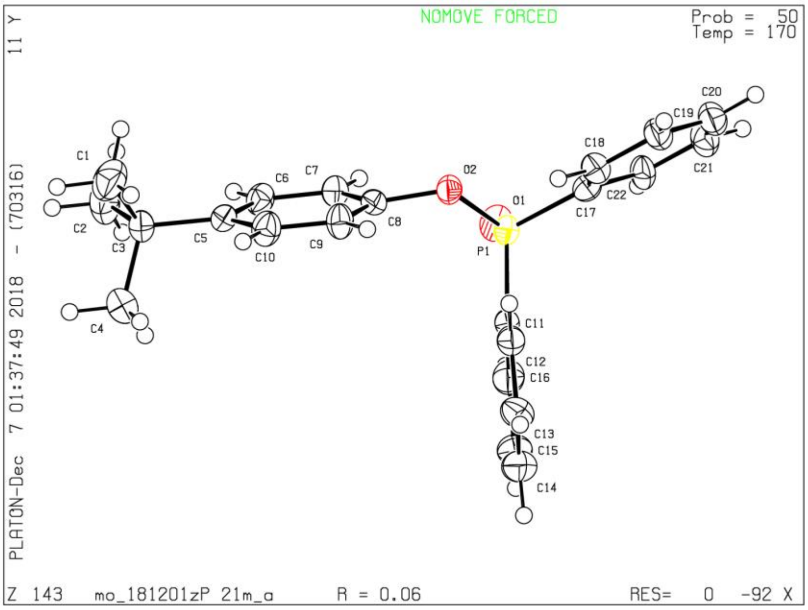
X-Ray crystallographic data of 28:





```
Bond precision:  C-C = 0.0075 A          Wavelength=0.71073

Cell:            a=8.9390(15)     b=11.3093(18)      c=9.5031(17)
                 alpha=90         beta=100.362(5)    gamma=90
Temperature:     170 K

                 Calculated                 Reported
Volume           945.0(3)                   945.0(3)
Space group      P 21                       P 21
Hall group       P 2yb                      P 2yb
Moiety formula   C22 H23 O2 P               ?
Sum formula      C22 H23 O2 P               C22 H23 O2 P
Mr               350.37                     350.37
Dx,g cm-3        1.231                      1.231
Z                2                          2
Mu (mm-1)        0.157                      0.157
F000             372.0                      372.0
F000'            372.35
h,k,lmax         11,15,12                   11,15,12
Nref             4716[ 2473]                4654
Tmin,Tmax        0.910,0.954                0.510,0.746
Tmin'            0.910

Correction method= # Reported T Limits: Tmin=0.510 Tmax=0.746
AbsCorr = MULTI-SCAN

Data completeness= 1.88/0.99       Theta(max)= 28.382

R(reflections)= 0.0572( 3416)      wR2(reflections)= 0.1624( 4654)

S = 1.003                  Npar= 229
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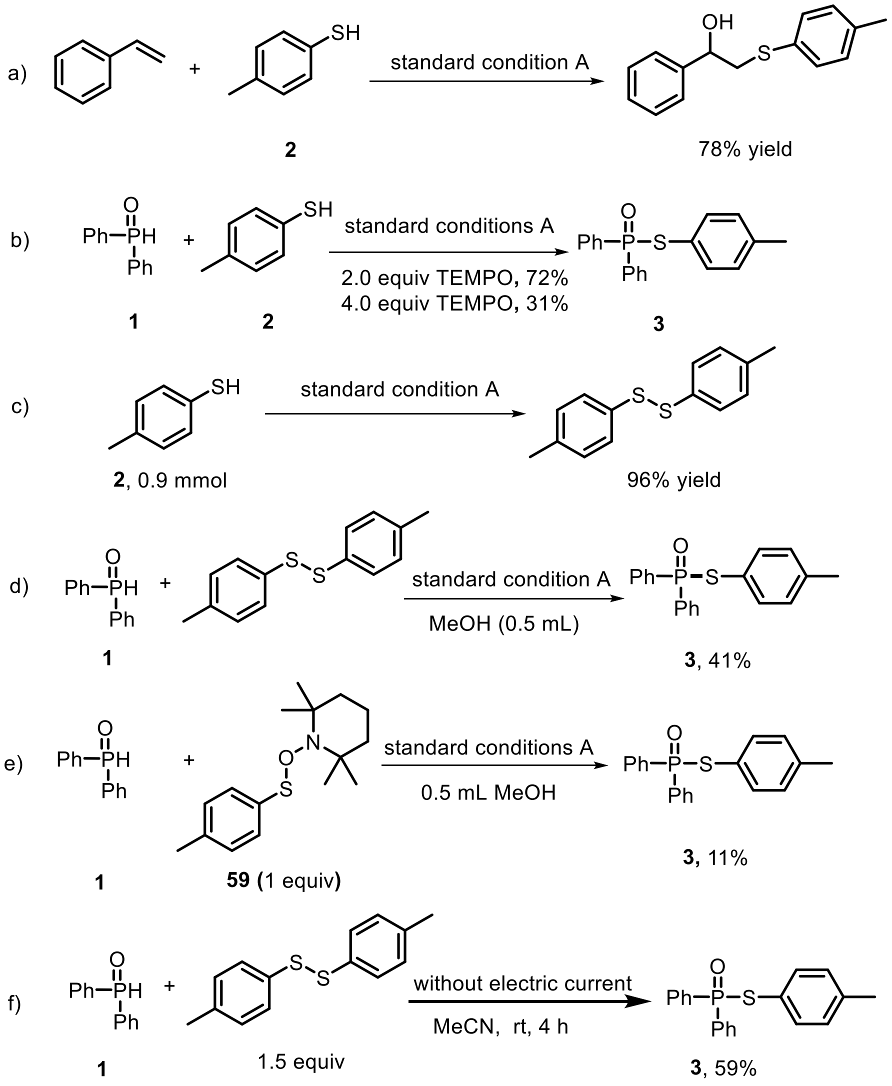
8. Mechanistic studies



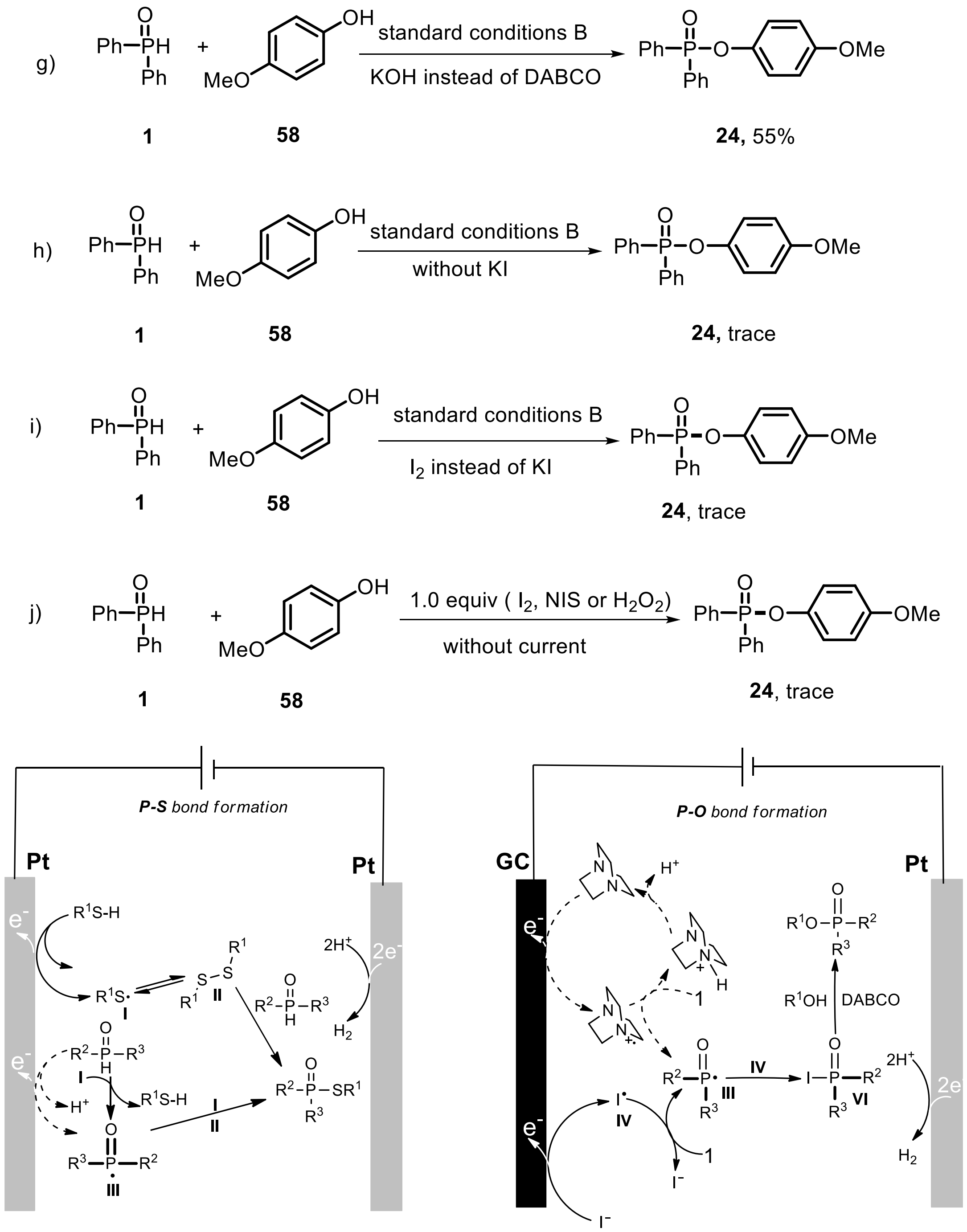
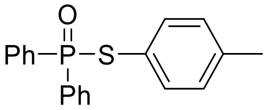


Figure S4 Mechanistic studies experiments

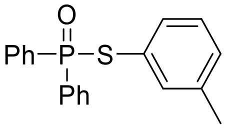
To shine light on the mechanism of this electrochemical dehydrogenative cross-coupling reaction, several control experiments were conducted. For the P-O bond formation, lower yields of the P-S coupling product **3** were obtained by adding 2.0 equiv. or 4.0 equiv. of TEMPO under the standard condition A (72% and 31% yields were obtained, respectively; equation b). The disulfide was obtained in 96% yield without substrate **1** under the standard conditions (equation c). These results suggested that thiyl radical intermediates were involved in the catalytic cycle. When disulphide was subjected to the standard conditions with adding methanol as a proton source, the coupling product

3 was obtained in 41% yield (equation d), suggesting that the disulphide was one of the intermediates of this transformation. Furthermore, the radical trapping product **59** could react with **1** under the standard condition to afford the product **3** in 11% yield (equation e), indicating that the sulfur radical could be regenerated by the homolytic cleavage of the S-O bond of **59**. To our surprise, we found that the diphenylphosphine oxide **1** could react with disulfide to give 59% yield of the product **3** without an electric current (equation f). For the P-O bond formation, the reaction worked well and the coupling product **24** was obtained in 55% yield, when using KOH instead of DABCO as base. Moreover, only trace product was obtained in absence of KI under the standard condition, indicating that the KI was essential for this reaction. Different from the previous report, only trace amount of product was obtained, when using I_2 instead of KI, suggesting that the I_2 was not involved in the catalytic cycle. No desired product was obtained, when the chemical oxidants such as I_2, NIS, H_2O_2 were adding to the reaction without electricity. Based on the EPR results we have observed, we considered that the phosphorus radicals could generated from the P(O)H compounds by anode oxidation directly or by a HAT process with sulfur radicals (SI-6; experiments **a-f**). The signal of phosphorus radicals was observed without 4-methylbenzenethiol **2** under the standard condition, which suggested that the phosphorus radicals could generated by anode oxidation directly under electric current (SI-6; experiment **e**). So, according to the results we observed and previous literature reports, several alternative mechanisms were also proposed (Figure S4), such as the mechanisms including the phosphorus radicals generated from the P(O)H compounds by anode oxidation directly or DABCO working as a hydrogen atom transfer (HAT) reagent in the reaction.

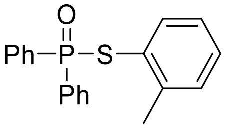
9. Characterization data



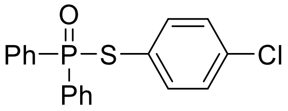
S-(p-tolyl) diphenylphosphinothioate (3)[1]. Yield = 84%; white solid; Mp: 117-119 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.90 – 7.79 (m, 4H), 7.54 – 7.47 (m, 2H), 7.47 – 7.39 (m, 4H), 7.32 (dd, *J* = 8.1, 1.6 Hz, 2H), 7.00 (d, *J* = 8.1 Hz, 2H), 2.24 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 142.92, 142.80, 139.22, 139.20, 135.40, 135.37, 133.19, 132.29, 132.26, 132.13, 131.71, 131.61, 130.00, 129.98, 128.60, 128.47, 122.27, 122.22, 21.18. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.39. **HRMS** (ESI) calcd for $C_{19}H_{18}OPS$ $(M+H)^+$: 325.0810, found: 325.0808



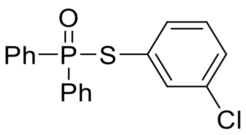
S-(m-tolyl) diphenylphosphinothioate (4)[1]. Yield = 66%; white solid; Mp: 96-98 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89 – 7.80 (m, 4H), 7.52-7.48(m, 2H), 7.48 – 7.37 (m, 4H), 7.23 (dd, *J* = 8.3, 0.9 Hz, 2H), 7.12 – 7.00 (m, 2H), 2.21 (s, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.33. **HRMS** (ESI) calcd for $C_{19}H_{18}OPS$ $(M+H)^+$: 325.0810, found: 325.0812



S-(o-tolyl) diphenylphosphinothioate (5)[1]. Yield = 73%; white solid; Mp: 72-74 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.87 – 7.76 (m, 4H), 7.53 – 7.39 (m, 7H), 7.19 – 7.09 (m, 2H), 7.04 – 6.97 (m, 1H), 2.34 (s, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.01. **HRMS** (ESI) calcd for $C_{19}H_{18}OPS$ $(M+H)^+$: 325.0810, found: 325.0815

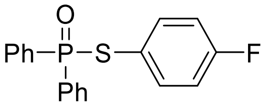


S-(4-chlorophenyl) diphenylphosphinothioate (6)[1]. Yield = 80%; white solid; Mp: 108-110 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 – 7.79 (m, 4H), 7.57 – 7.50 (m, 2H), 7.49 – 7.42 (m, 4H), 7.38 (dd, *J* = 8.5, 1.6 Hz, 2H), 7.21 – 7.14 (m, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.55. **HRMS** (ESI) calcd for $C_{18}H_{15}ClOPS$ $(M+H)^+$: 345.0264, found: 345.0262

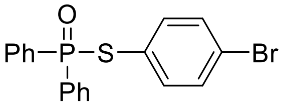


S-(3-chlorophenyl) diphenylphosphinothioate (7)[2]. Yield = 78%; white solid; 185-187 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.90 – 7.80 (m, 4H), 7.58 – 7.51 (m, 2H), 7.48-7.44 (m, 4H), 7.39 (d, *J*

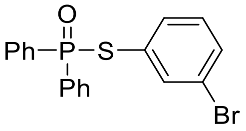
= 6.8 Hz, 2H), 7.26 – 7.19 (m, 1H), 7.14 (t, *J* = 8.2 Hz, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.69. **HRMS** (ESI) calcd for $C_{18}H_{15}ClOPS$ $(M+H)^+$: 325.0264, found: 325.0269



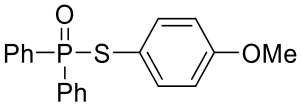
S-(4-fluorophenyl) diphenylphosphinothioate (8)[1]. Yield = 66%; white solid; Mp: 109-111 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 – 7.79 (m, 4H), 7.56 – 7.49 (m, 2H), 7.49 – 7.37 (m, 6H), 6.90 (t, *J* = 8.6 Hz, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.56. **HRMS** (ESI) calcd for $C_{18}H_{15}FOPS(M+H)^+$: 329.0560, found: 329.0557



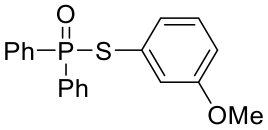
S-(4-bromophenyl) diphenylphosphinothioate (9)[1]. Yield = 86%; white solid; Mp: 107-109 °C; **^{1}H NMR** (400 MHz, CDCl3) δ 7.88 – 7.79 (m, 4H), 7.57 – 7.50 (m, 2H), 7.50 – 7.42 (m, 4H), 7.36 – 7.28 (m, 4H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.48. **HRMS** (ESI) calcd for $C_{18}H_{15}BrOPS$ $(M+H)^+$: 388.9759, found: 388.9765



S-(3-bromophenyl) diphenylphosphinothioate (10)[3]. Yield = 66%; white solid; Mp: 190-192 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89 – 7.79 (m, 4H), 7.52 -7.51(m, 3H), 7.49-7.43 (m, 5H), 7.37 (d, *J* = 7.8 Hz, 1H), 7.08 (t, *J* = 7.9 Hz, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.75. **HRMS** (ESI) calcd for $C_{18}H_{15}BrOPS$ $(M+H)^+$: 388.9759, found: 388.9759

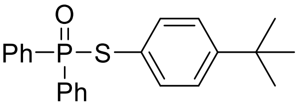


S-(4-methoxyphenyl) diphenylphosphinothioate (11)[1]. Yield = 70%; white solid; Mp: 137-139 °C; **^{1}H NMR (**400 MHz, $CDCl_3$) δ 7.90 – 7.79 (m, 4H), 7.54 – 7.47 (m, 2H), 7.47 – 7.38 (m, 4H), 7.37 – 7.30 (m, 2H), 6.72 (d, *J* = 8.8 Hz, 2H), 3.71 (s, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.38. **HRMS** (ESI) calcd for $C_{19}H_{18}O_2PS$ $(M+H)^+$: 341.0760, found: 341.0762

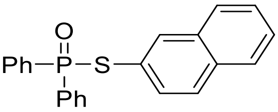


S-(3-methoxyphenyl) diphenylphosphinothioate (12)[1]. Yield = 75%; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 – 7.79 (m, 4H), 7.56 – 7.47 (m, 2H), 7.48 – 7.36 (m, 4H), 7.10 (t, *J* = 7.9 Hz, 1H), 7.04 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.00 – 6.94 (m, 1H), 6.82 – 6.75 (m, 1H), 3.66 (s, 3H). **^{31}P NMR**

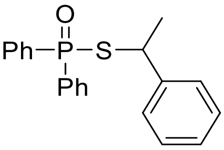
(162 MHz, $CDCl_3$) δ = 41.41.**HRMS** (ESI) calcd for $C_{19}H_{18}O_2PS$ $(M+H)^+$: 341.0760, found: 341.0762



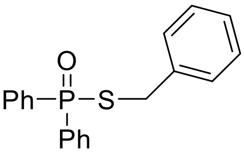
S-(4-(tert-butyl)phenyl) diphenylphosphinothioate (13)[1]. Yield = 75%; white solid; Mp: 124-126 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.87-7.81 (m, 4H), 7.54 – 7.47 (m, 2H), 7.43-7.41 (m, 4H), 7.35 (dd, *J* = 8.5, 1.7 Hz, 2H), 7.24 – 7.18 (m, 2H), 1.23 (s, 9H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.58. **HRMS** (ESI) calcd for $C_{22}H_{24}OPS$ $(M+H)^+$: 367.1280, found: 367.1281



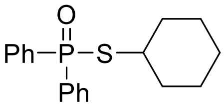
S-(naphthalen-2-yl) diphenylphosphinothioate (14)[1]. Yield = 47%; white solid; Mp: 106-108 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.99 (s, 1H), 7.92 – 7.84 (m, 4H), 7.76 – 7.67 (m, 2H), 7.66 (d, *J* = 8.6 Hz, 1H), 7.52 – 7.47 (m, 3H), 7.43 (m, *J* = 9.8, 4.9, 1.7 Hz, 6H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.49. **HRMS** (ESI) calcd for $C_{22}H_{18}OPS$ $(M+H)^+$: 361.0810, found: 361.0813



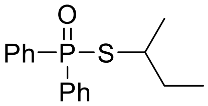
S-(1-phenylethyl) diphenylphosphinothioate (15). Yield = 67%; colorless oil; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 – 7.71 (m, 4H), 7.53 – 7.47 (m, 1H), 7.47 – 7.40 (m, 3H), 7.36-7.33 (m, 2H), 7.21 – 7.10 (m, 5H), 4.50-4.46 (m, 1H), 1.73 (d, *J* = 7.1 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 143.08, 143.04, 134.55, 133.49, 133.28, 132.29, 132.26, 132.22, 132.08, 132.05, 131.94, 131.83, 131.22, 131.12, 128.68, 128.55, 128.51, 128.42, 127.39, 127.02, 77.43, 77.11, 76.80, 44.49, 44.47, 24.95, 24.91. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 41.82. **HRMS** (ESI) calcd for $C_{20}H_{20}OPS$ $(M+H)^+$: 339.0967, found: 339.0966



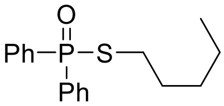
S-benzyl diphenylphosphinothioate (16)[1]. Yield = 62%; white solid; Mp: 88-90 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91 – 7.83 (m, 4H), 7.56 – 7.49 (m, 2H), 7.49 – 7.41 (m, 4H), 7.25 – 7.13 (m, 5H), 4.02 (d, *J* = 9.2 Hz, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 42.81. **HRMS** (ESI) calcd for $C_{19}H_{18}OPS$ $(M+H)^+$: 325.0810, found: 325.0815



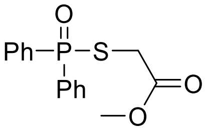
S-cyclohexyl diphenylphosphinothioate (17)[1]. Yield = 90%; white solid; Mp: 87-89 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.92 – 7.83 (m, 4H), 7.57 – 7.39 (m, 6H), 3.33-3.25 (m, 1H), 1.94 (dd, *J* = 9.7, 4.1 Hz, 2H), 1.71 – 1.58 (m, 2H), 1.60 – 1.40 (m, 3H), 1.33 – 1.20 (m, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 42.02. **HRMS** (ESI) calcd for $C_{18}H_{22}OPS$ (M+H)$^+$: 317.1123, found: 317.1122



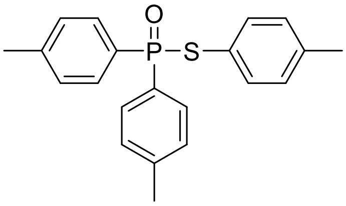
S-(sec-butyl) diphenylphosphinothioate (18). Yield = 80%; colorless oil; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.93 – 7.84 (m, 4H), 7.55 – 7.42 (m, 6H), 3.29-3.22 (m, 1H), 1.76 – 1.54 (m, 2H), 1.34 (d, *J* = 6.9 Hz, 3H), 0.92 (t, *J* = 7.4 Hz, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 134.66, 134.41, 133.59, 133.35, 132.14, 132.12, 131.58, 131.48, 131.37, 128.63, 128.50, 77.42, 77.10, 76.79, 43.24, 43.22, 31.67, 31.62, 23.23, 23.19, 11.06. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 41.90. **HRMS** (ESI) calcd for $C_{16}H_{20}OPS$ (M+H)$^+$: 291.0967, found: 291.0972



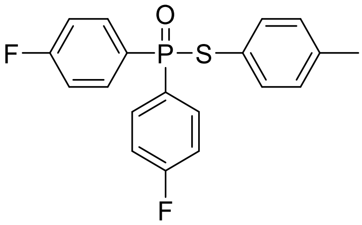
S-pentyl diphenylphosphinothioate (19). Yield = 84%; colorless oil; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.93 – 7.84 (m, 4H), 7.57 – 7.51 (m, 2H), 7.51 – 7.44 (m, 4H), 2.82-2.76 (m, 2H), 1.68 – 1.55 (m, 2H), 1.31 – 1.22 (m, 4H), 0.83 (t, *J* = 7.2 Hz, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 134.02, 132.95, 132.25, 132.22, 131.54, 131.43, 128.71, 128.58, 30.73, 30.27, 30.22, 29.28, 29.26, 22.04, 13.87. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 43.11. **HRMS** (ESI) calcd for $C_{17}H_{22}OPS$ (M+H)$^+$: 305.1123, found: 305.1123



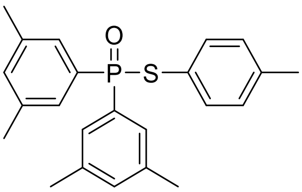
methyl 2-((diphenylphosphoryl)thio)acetate (20). Yield = 84%; colorless oil; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.92 – 7.84 (m, 4H), 7.60 – 7.54 (m, 2H), 7.53 – 7.46 (m, 4H), 3.62 (d, *J* = 10.9 Hz, 2H), 3.54 (s, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 169.12, 169.07, 132.80, 132.72, 132.69, 131.73, 131.64, 131.54, 128.85, 128.72, 77.44, 77.13, 76.81, 52.68, 30.09. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 42.98. **HRMS** (ESI) calcd for $C_{15}H_{16}O_3PS$ (M+H)$^+$: 307.0552, found: 307.0547



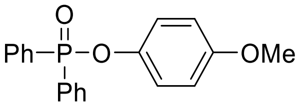
S-(p-tolyl) di-p-tolylphosphinothioate (21)[1]. Yield = 53%; white solid; Mp: 88-90 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.72 (dd, *J* = 12.7, 8.1 Hz, 4H), 7.32 (dd, *J* = 8.1, 1.6 Hz, 2H), 7.25 – 7.17 (m, 4H), 7.00 (d, *J* = 8.2 Hz, 2H), 2.37 (s, 6H), 2.25 (s, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 41.88. **HRMS** (ESI) calcd for $C_{21}H_{22}OPS$ $(M+H)^+$: 353.1123, found: 353.1121



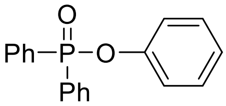
S-(p-tolyl) bis(4-fluorophenyl)phosphinothioate (22)[1]. Yield = 84%; white solid; Mp: 97-99 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.90 – 7.77 (m, 4H), 7.30 (dd, *J* = 8.1, 1.7 Hz, 2H), 7.18 – 7.10 (m, 4H), 7.03 (d, *J* = 8.2 Hz, 2H), 2.27 (s, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 39.23. **HRMS** (ESI) calcd for $C_{19}H_{16}F_2OPS$ $(M+H)^+$: 361.0622, found: 361.0623



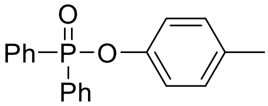
S-(p-tolyl) bis(3,5-dimethylphenyl)phosphinothioate(23)[1]. Yield = 80%; white solid; Mp: 141-143 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.44 (d, *J* = 13.2 Hz, 4H), 7.33 (dd, *J* = 8.1, 1.5 Hz, 2H), 7.10 (s, 2H), 7.00 (d, *J* = 8.0 Hz, 2H), 2.31 (s, 12H), 2.24 (s, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 139.00, 138.98, 138.25, 138.12, 135.41, 135.37, 133.01, 131.96, 129.92, 129.90, 129.23, 129.12, 122.79, 122.74, 77.48, 77.16, 76.84, 21.29, 21.14. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 42.56. **HRMS** (ESI) calcd for $C_{23}H_{26}OPS$ $(M+H)^+$: 381.1436, found:381.1635



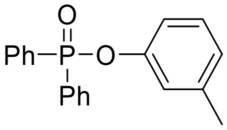
4-methoxyphenyl diphenylphosphinate(24)[4]. Yield = 78%; white solid; Mp: 100-102 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.94 – 7.81 (m, 4H), 7.57 – 7.48 (m, 2H), 7.50 – 7.39 (m, 4H), 7.14 – 7.05 (m, 2H), 6.78 – 6.69 (m, 2H), 3.72 (s, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 156.37, 144.35, 144.26, 132.43, 132.40, 131.90, 131.80, 131.68, 130.31, 128.64, 128.51, 121.68, 121.63, 114.60, 77.38, 77.06, 76.74, 55.53. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 30.55. **HRMS** (ESI) calcd for $C_{19}H_{18}O_3P$ $(M+H)^+$: 325.0988, found:325.0995



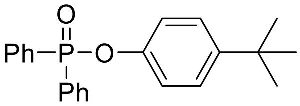
phenyl diphenylphosphinate (25)^{4}. Yield = 54%; white solid; Mp: 134-136 ^{o}C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 – 7.84 (m, 4H), 7.55-7.51 (m, 2H), 7.48-7.43 (m, 4H), 7.27 – 7.17 (m, 4H), 7.07 (t, *J* = 6.9 Hz, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.40. **HRMS** (ESI) calcd for $C_{18}H_{16}O_2P$ $(M+H)^+$: 295.0882, found:295.0882



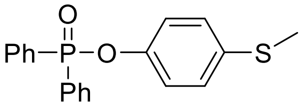
p-tolyl diphenylphosphinate(26)^{4}. Yield = 64%; white solid; Mp: 113-115 ^{o}C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 – 7.82 (m, 4H), 7.51 (dd, *J* = 10.5, 4.3 Hz, 2H), 7.46-7.41(m, 4H), 7.08 (d, *J* = 8.0 Hz, 2H), 7.01 (d, *J* = 8.5 Hz, 2H), 2.23 (s, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.27. **HRMS** (ESI) calcd for $C_{19}H_{18}O_2P$ $(M+H)^+$: 309.1039, found: 309.1044



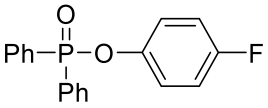
m-tolyl diphenylphosphinate(27)^{4}. Yield = 69%; white solid; Mp: 108-110 ^{o}C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.93 – 7.84 (m, 4H), 7.55 – 7.48 (m, 2H), 7.49 – 7.41 (m, 4H), 7.08 (dd, *J* = 15.6, 7.8 Hz, 2H), 6.97 (d, *J* = 8.2 Hz, 1H), 6.87 (d, *J* = 7.5 Hz, 1H), 2.25 (s, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.17. **HRMS** (ESI) calcd for $C_{19}H_{18}O_2P$ $(M+H)^+$: 309.1039, found: 309.1035



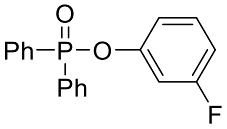
4-(tert-butyl)phenyl diphenylphosphinate(28)^{4}. Yield = 63%; white solid; Mp: 170-172 ^{o}C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.95 – 7.84 (m, 4H), 7.57 – 7.48 (m, 2H), 7.50 – 7.42 (m, 4H), 7.27 – 7.20 (m, 2H), 7.09 (dd, *J* = 8.8, 1.1 Hz, 2H), 1.24 (s, 9H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.22. **HRMS** (ESI) calcd for $C_{22}H_{24}O_2P$ $(M+H)^+$: 351.1508, found: 351.1502



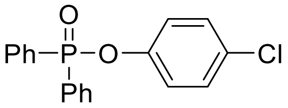
4-(methylthio)phenyl diphenylphosphinate(29). Yield = 65%; white solid; Mp: 106-108 ^{o}C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.92 – 7.84 (m, 4H), 7.57 – 7.50 (m, 2H), 7.51 – 7.41 (m, 4H), 7.13 (s, 4H), 2.40 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 148.73, 148.65, 134.17, 134.16, 132.56, 132.53, 131.86, 131.76, 131.48, 130.11, 128.71, 128.58, 128.39, 121.33, 121.29, 16.56. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.85. **HRMS** (ESI) calcd for $C_{19}H_{18}O_2PS$ $(M+H)^+$: 341.0760, found: 341.0764



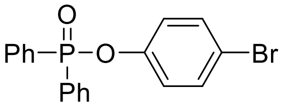
4-fluorophenyl diphenylphosphinate(30)[4] . Yield = 77%; white solid; Mp: 131-133 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.93 – 7.83 (m, 4H), 7.59 – 7.51 (m, 2H), 7.51 – 7.42 (m, 4H), 7.21-7.15 (m,1H), 7.02 (d, *J* = 8.9 Hz, 1H), 7.00 – 6.94 (m, 1H), 6.81-6.76 (m, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.27. **HRMS** (ESI) calcd for $C_{18}H_{15}FO_2P$ $(M+H)^+$: 313.0788, found: 313.0786



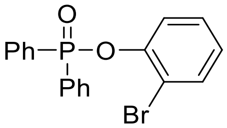
3-fluorophenyl diphenylphosphinate(31). Yield = 81%; white solid; Mp: 130-132 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.98 – 7.80 (m, 4H), 7.59 – 7.51 (m, 2H), 7.51 – 7.42 (m, 4H), 7.21-7.16 (m, 1H), 7.05 – 6.99 (m, 1H), 6.99 – 6.93 (m, 1H), 6.81-6.77(m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 164.17, 161.71, 157.82, 151.82, 151.74, 151.71, 151.63, 138.00, 132.70, 132.67, 131.81, 131.71, 131.23, 130.45, 130.35, 129.86, 128.78, 128.65, 116.57, 116.54, 116.52, 116.49, 111.83, 111.63, 108.94, 108.89, 108.69, 108.64, 77.40, 77.09, 76.77. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.28. **HRMS** (ESI) calcd for $C_{18}H_{15}FO_2P$ $(M+H)^+$: 313.0788, found: 313.0783



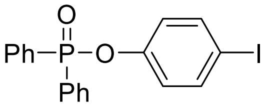
4-chlorophenyl diphenylphosphinate(32)[4]. Yield = 76%; white solid; Mp: 117-119 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.92 – 7.81 (m, 4H), 7.58 – 7.50 (m, 2H), 7.48-7.44 (m, 4H), 7.23 – 7.11 (m, 4H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.31. **HRMS** (ESI) calcd for $C_{18}H_{15}ClO_2P$ $(M+H)^+$: 329.0493, found: 329.0486



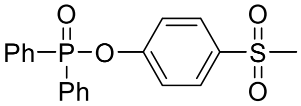
4-bromophenyl diphenylphosphinate(33)[4]. Yield = 73%; white solid; Mp: 115-117 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.93 – 7.81 (m, 4H), 7.58 – 7.50 (m, 2H), 7.50 – 7.43 (m, 4H), 7.36 – 7.30 (m, 2H), 7.09 (dd, *J* = 9.0, 1.2 Hz, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.33. **HRMS** (ESI) calcd for $C_{18}H_{15}BrO_2P$ $(M+H)^+$: 372.9988, found: 372.9979



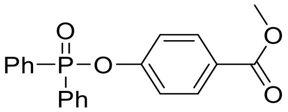
2-bromophenyl diphenylphosphinate(34)[5]. Yield = 71%; white solid; Mp: 102-104 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.05 – 7.94 (m, 4H), 7.62-7.60 (m, 1H), 7.55 – 7.48 (m, 3H), 7.48 – 7.41 (m, 4H), 7.15 (ddd, *J* = 8.3, 7.6, 1.6 Hz, 1H), 6.92 (ddd, *J* = 8.2, 7.5, 1.0 Hz, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.73. **HRMS** (ESI) calcd for $C_{18}H_{15}BrO_2P$ $(M+H)^+$: 372.9988, found: 372.9994



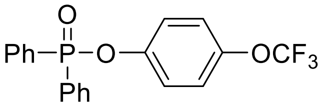
4-iodophenyl diphenylphosphinate(35)[4]. Yield = 75%; white solid; Mp: 140-142 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91 – 7.82 (m, 4H), 7.58 – 7.50 (m, 4H), 7.50 – 7.42 (m, 4H), 7.01 – 6.94 (m, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.25. **HRMS** (ESI) calcd for $C_{18}H_{15}IO_2P$ $(M+H)^+$: 420.9849, found: 420.9846



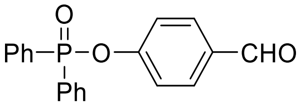
4-(methylsulfonyl)phenyl diphenylphosphinate(36). Yield = 64%; white solid; Mp: 111-113 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.95 – 7.80 (m, 6H), 7.62 – 7.55 (m, 2H), 7.54 – 7.46 (m, 4H), 7.42 (dd, *J* = 8.8, 0.9 Hz, 2H), 3.00 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 155.22, 155.14, 136.53, 133.04, 133.01, 131.75, 131.64, 130.69, 129.57, 129.32, 128.96, 128.82, 121.58, 121.53, 77.43, 77.11, 76.79, 44.60. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 32.55 **HRMS** (ESI) calcd for $C_{19}H_{18}O_4PS$ $(M+H)^+$: 373.0658, found: 373.0663



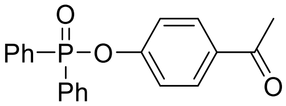
methyl 4-((diphenylphosphoryl)oxy)benzoate(37). Yield = 77%; white solid; Mp: 126-128 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.98 – 7.84 (m, 6H), 7.58 – 7.51 (m, 2H), 7.49-7.45 (m, 4H), 7.29 (dd, *J* = 8.8, 1.0 Hz, 2H), 3.85 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 166.30, 154.79, 154.71, 132.76, 132.73, 131.80, 131.69, 131.52, 131.11, 129.74, 128.81, 128.67, 126.49, 120.56, 120.51, 77.42, 77.10, 76.78, 52.11. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.36. **HRMS** (ESI) calcd for $C_{20}H_{18}O_4P$ $(M+H)^+$: 353.0937, found: 353.0939



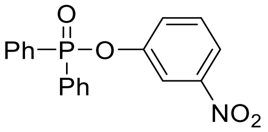
4-(trifluoromethoxy)phenyl diphenylphosphinate(38)[4]. Yield = 70%; white solid; Mp: 58-60 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.95 – 7.81 (m, 4H), 7.59 – 7.51 (m, 2H), 7.51 – 7.43 (m, 4H), 7.25 – 7.17 (m, 2H), 7.09 (d, *J* = 8.9 Hz, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.59. **HRMS** (ESI) calcd for $C_{19}H_{15}F_3O_3P$ $(M+H)^+$:379.0705, found: 379.0711



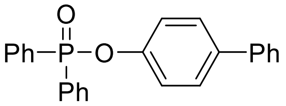
4-formylphenyl diphenylphosphinate(39)[6]. Yield = 46%; white solid; Mp: 98-100 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.89 (s, 1H), 7.94 – 7.86 (m, 4H), 7.79 (d, *J* = 8.6 Hz, 2H), 7.57-7.54 (m, 2H), 7.52 – 7.46 (m, 4H), 7.39 (d, *J* = 8.0 Hz, 2H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.77. **HRMS** (ESI) calcd for $C_{19}H_{16}O_3P$ $(M+H)^+$: 323.0832, found:323.0829



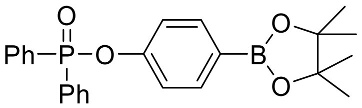
4-acetylphenyl diphenylphosphinate(40)[6]. Yield = 79%; white solid; Mp: 111-113 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.95 – 7.81 (m, 6H), 7.60 – 7.53 (m, 2H), 7.54 – 7.44 (m, 4H), 7.30 (dd, *J* = 8.7, 0.9 Hz, 2H), 2.53 (s, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 31.42. **HRMS** (ESI) calcd for $C_{20}H_{18}O_3P$ (M+H)$^+$: 337.0988, found: 337.0985



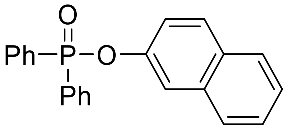
3-nitrophenyl diphenylphosphinate(41)[7]. Yield = 61%; white solid; Mp: 122-124 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 8.01 (dd, *J* = 3.3, 2.2 Hz, 1H), 7.99 – 7.94 (m, 1H), 7.94 – 7.87 (m, 4H), 7.64 -7.62(m, 1H), 7.58-7.56 (m, 2H), 7.54 – 7.47 (m, 4H), 7.43 (t, *J* = 8.2 Hz, 1H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 32.90. **HRMS** (ESI) calcd for $C_{18}H_{15}NO_4P$ (M+H)$^+$: 340.0733, found: 340.0726



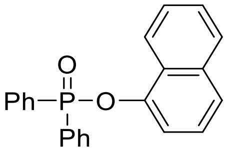
[1,1'-biphenyl]-4-yl diphenylphosphinate(42)[4]. Yield = 62%; white solid; Mp: 152-154 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.92-7.89 (m, 4H), 7.52 (dd, *J* = 7.3, 1.4 Hz, 2H), 7.49 – 7.42 (m, 8H), 7.37 (t, *J* = 7.5 Hz, 2H), 7.31 – 7.24 (m, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 30.79. **HRMS** (ESI) calcd for $C_{24}H_{20}O_2P$ (M+H)$^+$: 371.1195, found: 371.1200



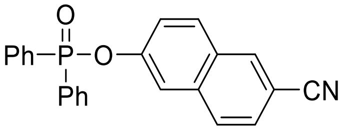
4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl diphenylphosphinate(43). Yield = 41%; white solid; Mp: 117-119 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.93 – 7.83 (m, 4H), 7.69 (d, *J* = 8.4 Hz, 2H), 7.55 – 7.49 (m, 2H), 7.48 – 7.41 (m, 4H), 7.23 (dd, *J* = 8.6, 1.1 Hz, 2H), 1.30 (s, 12H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 153.60, 153.52, 136.50, 132.54, 132.51, 131.87, 131.77, 131.43, 130.05, 128.70, 128.57, 120.02, 119.97, 83.84, 24.86. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 30.42. **HRMS** (ESI) calcd for $C_{24}H_{27}BO_4P$ (M+H)$^+$: 421.1735, found: 421.1728



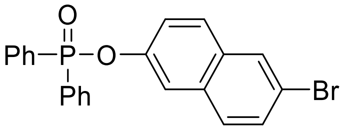
naphthalen-2-yl diphenylphosphinate(44)[4]. Yield = 72%; white solid; Mp: 120-122 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.97 – 7.89 (m, 4H), 7.72 (dd, *J* = 14.3, 6.3 Hz, 4H), 7.55 – 7.48 (m, 2H), 7.48 – 7.41 (m, 5H), 7.40 – 7.34 (m, 2H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 30.75. **HRMS** (ESI) calcd for $C_{22}H_{18}O_2P$ (M+H)$^+$: 345.1039, found: 345.1036



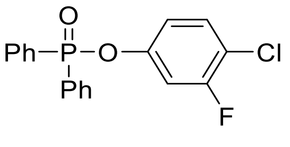
naphthalen-1-yl diphenylphosphinate(45)[4]. Yield = 47%; white solid; Mp: 110-112 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 – 8.18 (m, 1H), 8.02 – 7.89 (m, 4H), 7.79 (dd, *J* = 7.4, 1.8 Hz, 1H), 7.58 – 7.42 (m, 10H), 7.25 (dd, *J* = 9.0, 7.0 Hz, 1H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.86. **HRMS** (ESI) calcd for $C_{22}H_{18}O_2P$ $(M+H)^+$: 345.1039, found: 345.1046



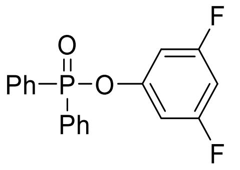
6-cyanonaphthalen-2-yl diphenylphosphinate(46). Yield = 68%; yellow oil ; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.12 (s, 1H), 7.99 – 7.88 (m, 4H), 7.78 (dd, *J* = 10.5, 6.2 Hz, 3H), 7.59 – 7.52 (m, 3H), 7.50-7.46 (m, 5H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 151.16, 151.07, 135.50, 133.80, 132.84, 132.81, 131.82, 131.72, 131.13, 130.49, 129.76, 129.41, 128.87, 128.77, 128.74, 127.10, 122.68, 122.63, 119.10, 117.38, 117.33, 108.72, 77.42, 77.10, 76.78 **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.83. **HRMS** (ESI) calcd for $C_{23}H_{17}NO_2P$ $(M+H)^+$: 370.0991, found: 370.0991



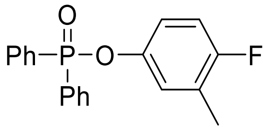
6-bromonaphthalen-2-yl diphenylphosphinate(47). Yield = 63%; white solid; Mp: 119-121 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.98 – 7.85 (m, 5H), 7.66 (s, 1H), 7.61 (d, *J* = 8.9 Hz, 1H), 7.57 – 7.50 (m, 3H), 7.50 – 7.42 (m, 5H), 7.36 (dd, *J* = 8.9, 1.8 Hz, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 148.91, 148.83, 132.69, 132.66, 132.35, 131.87, 131.77, 131.68, 131.34, 129.96, 129.66, 129.15, 128.90, 128.80, 128.66, 121.84, 121.79, 119.13, 117.31, 117.26, 77.41, 77.10, 76.78. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 31.28 **HRMS** (ESI) calcd for $C_{22}H_{17}BrO_2P$ $(M+H)^+$: 423.0144, found: 423.0135



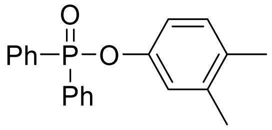
4-chloro-3-fluorophenyl diphenylphosphinate(48). Yield = 81%; white solid; Mp: 99-101 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.93 – 7.79 (m, 4H), 7.60 – 7.52 (m, 2H), 7.53 – 7.43 (m, 4H), 7.25 (dd, *J* = 13.6, 5.0 Hz, 1H), 7.08-7.07 (m, 1H), 7.00-6.97 (m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 159.20, 156.71, 150.09, 149.99, 149.91, 132.95, 132.92, 131.78, 131.68, 130.83, 130.71, 129.33, 128.89, 128.76, 117.48, 117.43, 117.39, 117.18, 117.01, 112.42, 110.19, 110.14, 109.95, 109.90, 104.60, 104.37, 77.43, 77.11, 76.79. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 32.31. **HRMS** (ESI) calcd for $C_{18}H_{15}ClFO_2P$ $(M+H)^+$: 347.0398, found: 347.0440



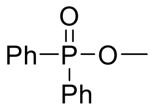
3,5-difluorophenyl diphenylphosphinate(49). Yield = 72%; white solid; Mp: 135-137 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.94 – 7.81 (m, 4H), 7.59-7.54 (m, 2H), 7.53 – 7.45 (m, 4H), 6.82-6.80 (m, 2H), 6.58-6.52 (m, 1H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 164.36, 164.21, 161.89, 161.74, 152.27, 152.19, 132.92, 132.89, 131.77, 131.66, 130.79, 129.42, 128.88, 128.75, 105.07, 105.02, 104.93, 104.86, 104.78, 104.73, 100.82, 100.57, 100.32, 77.39, 77.08, 76.76 **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 32.24. **HRMS** (ESI) calcd for $C_{18}H_{14}F_2O_2P$ $(M+H)^+$: 331.0694, found: 331.0692



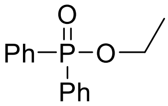
4-fluoro-3-methylphenyl diphenylphosphinate(50). Yield = 57%; white solid; Mp: 102-105 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88-7.84 (m, 4H), 7.58 – 7.50 (m, 2H), 7.50 – 7.42 (m, 4H), 7.05 (dd, *J* = 6.2, 2.7 Hz, 1H), 6.96 – 6.89 (m, 1H), 6.83 (t, *J* = 8.9 Hz, 1H), 2.17 (d, *J* = 1.9 Hz, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 159.28, 156.89, 146.26, 146.18, 132.57, 132.54, 131.85, 131.75, 131.46, 130.08, 128.71, 128.57, 126.31, 126.11, 123.52, 123.47, 123.42, 119.20, 119.16, 119.12, 119.08, 115.72, 115.48, 14.65, 14.62. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 30.91. **HRMS** (ESI) calcd for $C_{19}H_{17}FO_2P$ $(M+H)^+$: 327.0945, found: 327.0942



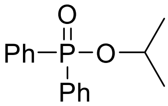
3,4-dimethylphenyl diphenylphosphinate(51). Yield = 41%; white solid; Mp: 112-114 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.89-7.85 (m, 4H), 7.56 – 7.49 (m, 2H), 7.49 – 7.41 (m, 4H), 7.01 (s, 1H), 6.95 (d, *J* = 8.3 Hz, 1H), 6.89 (d, *J* = 8.3 Hz, 1H), 2.15 (d, *J* = 7.4 Hz, 6H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 29.95. **HRMS** (ESI) calcd for $C_{20}H_{20}O_2P$ $(M+H)^+$: 323.1195, found: 323.1200



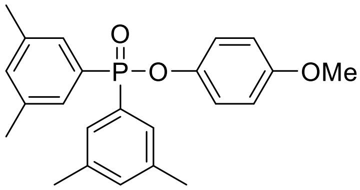
methyl diphenylphosphinate(52)^4. Yield = 91%; colorless oil; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.86 – 7.77 (m, 4H), 7.57 – 7.50 (m, 2H), 7.50 – 7.42 (m, 4H), 3.77 (d, *J* = 11.1 Hz, 3H). **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 33.26.. **HRMS** (ESI) calcd for $C_{13}H_{14}O2P$ $(M+H)^+$: 233.0726, found: 233.0723



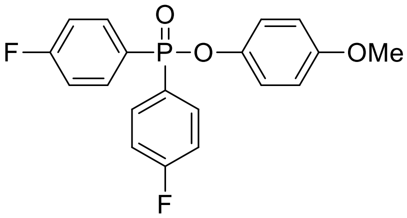
ethyl diphenylphosphinate(53)[4]. Yield = 79%; colorless oil; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.82-7.79 (m, 4H), 7.55 – 7.48 (m, 2H), 7.45 -7.42(m, 4H), 4.11-4.07 (m, 2H), 1.37 (t, *J* = 7.1 Hz, 3H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 31.39. **HRMS** (ESI) calcd for $C_{14}H_{16}O_2P$ (M+H)$^+$: 247.0882, found: 247.0889



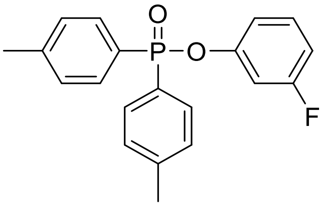
isopropyl diphenylphosphinate(54)[4]. Yield = 40%; white solid; Mp: 101-103 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.86 – 7.77 (m, 4H), 7.50 (m, *J* = 6.4, 2.9, 1.4 Hz, 2H), 7.44-7.41 (m, 4H), 4.71-4.63 (m, 1H), 1.35 (d, *J* = 6.2 Hz, 6H). **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 29.81. **HRMS** (ESI) calcd for $C_{15}H_{18}O_2P$ (M+H)$^+$: 261.1039, found: 261.1039



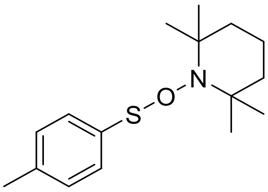
4-methoxyphenyl bis(3,5-dimethylphenyl)phosphinate(55). Yield = 54%; white solid; Mp: 100-103 °C; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.49 (d, *J* = 12.7 Hz, 4H), 7.19 – 7.03 (m, 4H), 6.74 (d, *J* = 8.9 Hz, 2H), 3.71 (s, 3H), 2.33 (s, 12H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 156.26, 144.51, 144.43, 138.30, 138.16, 134.08, 131.62, 130.19, 129.42, 129.32, 121.75, 121.70, 114.55, 77.40, 77.08, 76.76, 55.53, 21.29 **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 31.86. **HRMS** (ESI) calcd for $C_{23}H_{26}O_3P$ (M+H)$^+$: 381.1614, found: 381.1611



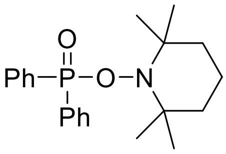
4-methoxyphenyl bis(4-fluorophenyl)phosphinate(56). Yield = 69%; colorless oil ; **^{1}H NMR** (400 MHz, CDCl$_3$) δ 7.90-7.83 (m, 4H), 7.17-7.12 (m, 4H), 7.10 – 7.05 (m, 2H), 6.75 (d, *J* = 9.0 Hz, 2H), 3.72 (s, 3H). **^{13}C NMR** (101 MHz, CDCl$_3$) δ = 166.66, 166.62, 164.13, 164.09, 156.56, 144.01, 143.93, 134.51, 134.42, 134.39, 134.30, 127.51, 127.48, 126.09, 126.06, 121.59, 121.55, 116.28, 116.13, 116.06, 115.92, 114.69, 77.41, 77.09, 76.78, 55.52. **^{31}P NMR** (162 MHz, CDCl$_3$) δ = 28.62. **HRMS** (ESI) calcd for $C_{19}H_{16}F_2O_3P$ (M+H)$^+$: 361.0800, found: 361.0795



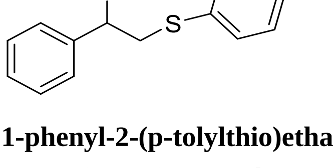
3-fluorophenyl di-p-tolylphosphinate(57). Yield = 30%; colorless oil ; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.75 (dd, *J* = 12.4, 8.1 Hz, 4H), 7.31 – 7.24 (m, 4H), 7.18 -7.15(m, 1H), 7.01 (dd, *J* = 8.3, 0.8 Hz, 1H), 6.96- 6.92(m, 1H), 6.78 -6.75(m, 1H), 2.38 (s, 6H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 164.16, 161.70, 143.24, 143.21, 131.80, 131.69, 130.37, 130.28, 129.49, 129.35, 128.19, 126.79, 77.37, 77.05, 76.74, 21.69 **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 32.40 **HRMS** (ESI) calcd for $C_{20}H_{19}FO_2P$ $(M+H)^+$: 341.1101, found: 341.1096



2,2,6,6-tetramethyl-1-((p-tolylthio)oxy)piperidine(59). Yield = 24%; colorless oil; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.58 – 7.52 (m, 2H), 7.25 (d, *J* = 7.9 Hz, 2H), 2.39 (s, 3H), 1.75 – 1.34 (m, 15H), 0.92 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 147.09, 139.46, 129.27, 125.94, 77.38, 77.07, 76.75, 61.19, 58.75, 43.52, 41.41, 35.35, 32.60, 28.74, 27.96, 26.99, 21.23, 17.30. **HRMS** (ESI) calcd for $C_{16}H_{26}NOS$ $(M+H)^+$: 280.1730, found: 280.1730



2,2,6,6-tetramethylpiperidin-1-yl diphenylphosphinate(60). Yield = 26%; colorless oil; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.91 – 7.80 (m, 4H), 7.53 – 7.37 (m, 6H), 1.31 – 0.88 (m, 18H).**^{13}C NMR** (101 MHz, $CDCl_3$) δ = 134.51, 133.16, 131.68, 131.58, 131.55, 128.35, 128.23, 61.62, 61.60, 40.11, 16.89. **^{31}P NMR** (162 MHz, $CDCl_3$) δ = 33.66. **HRMS** (ESI) calcd for $C_{21}H_{29}NO_2P$ $(M+H)^+$: 358.1930, found: 358.1927



1-phenyl-2-(p-tolylthio)ethan-1-ol. Yield = 78%; colorless oil; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 – 7.23 (m, 7H), 7.13 (d, *J* = 7.9 Hz, 2H), 4.66 (dd, *J* = 9.6, 3.3 Hz, 1H), 3.26 (dd, *J* = 13.8, 3.4 Hz, 1H), 3.02 (dd, *J* = 13.8, 9.7 Hz, 1H), 2.96 (s, 1H), 2.33 (s, 3H). **^{13}C NMR** (101 MHz, $CDCl_3$) δ = 142.18, 137.18, 131.10, 130.90, 130.00, 128.57, 127.96, 125.90, 71.47, 44.85, 21.12. **HRMS** (ESI) calcd for $C_{15}H_{17}OS$ $(M+H)^+$:245.0995, found: 245.0998

10. References

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5. T. Yuan, S. Huang, C. Cai, G. P. Lu, *Org. Biomol. Chem.* **2017**, *16*, 30-33.
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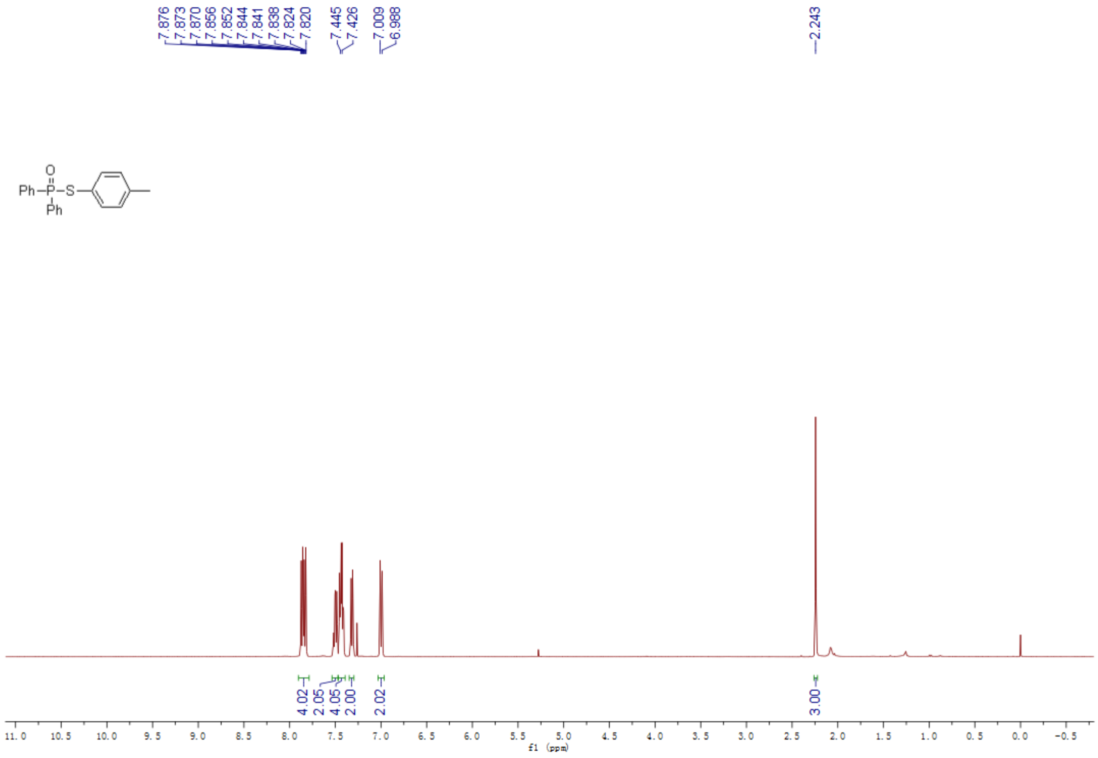
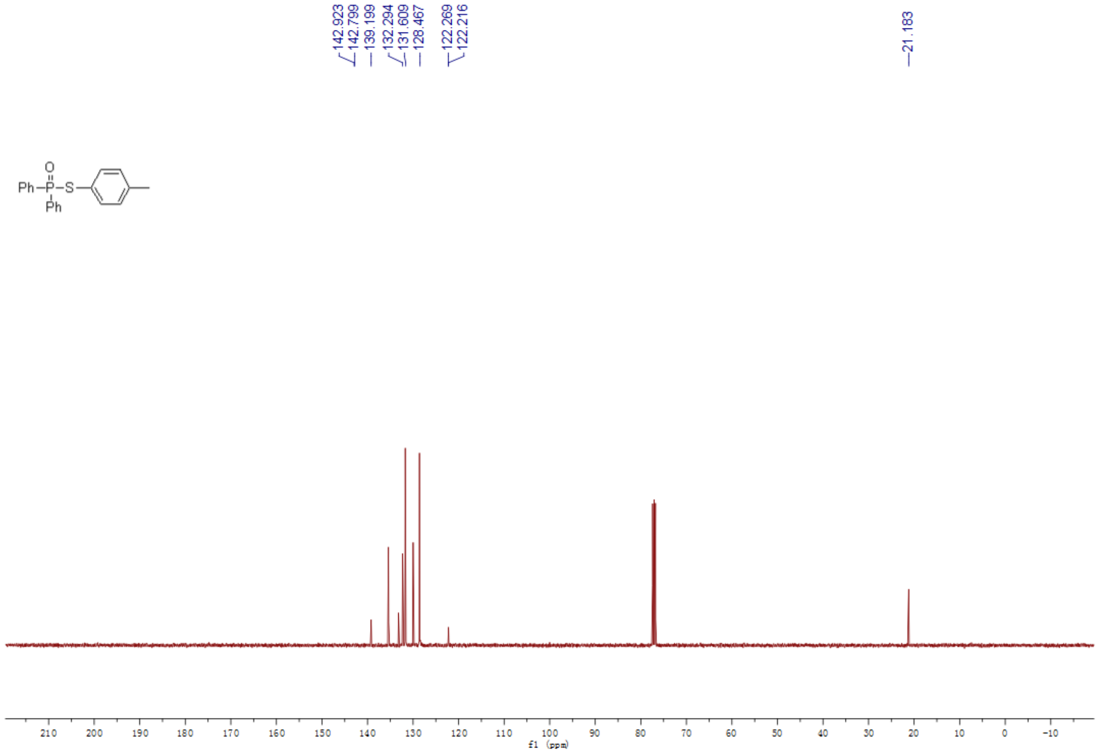
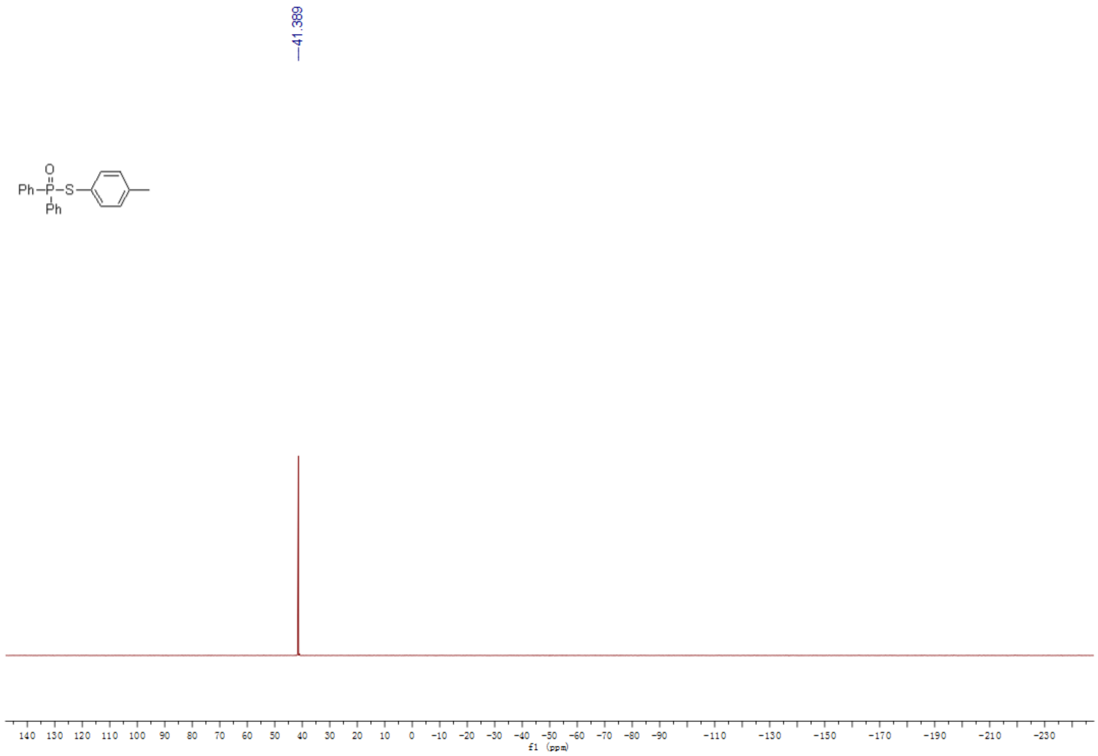
7. B. Xiong, K. Zeng, S. Zhang, Y. Zhou, C.-T. Au, S.-F. Yin, *Tetrahedron* **2015**, 71, 9293-9298.

11. NMR spectra of product



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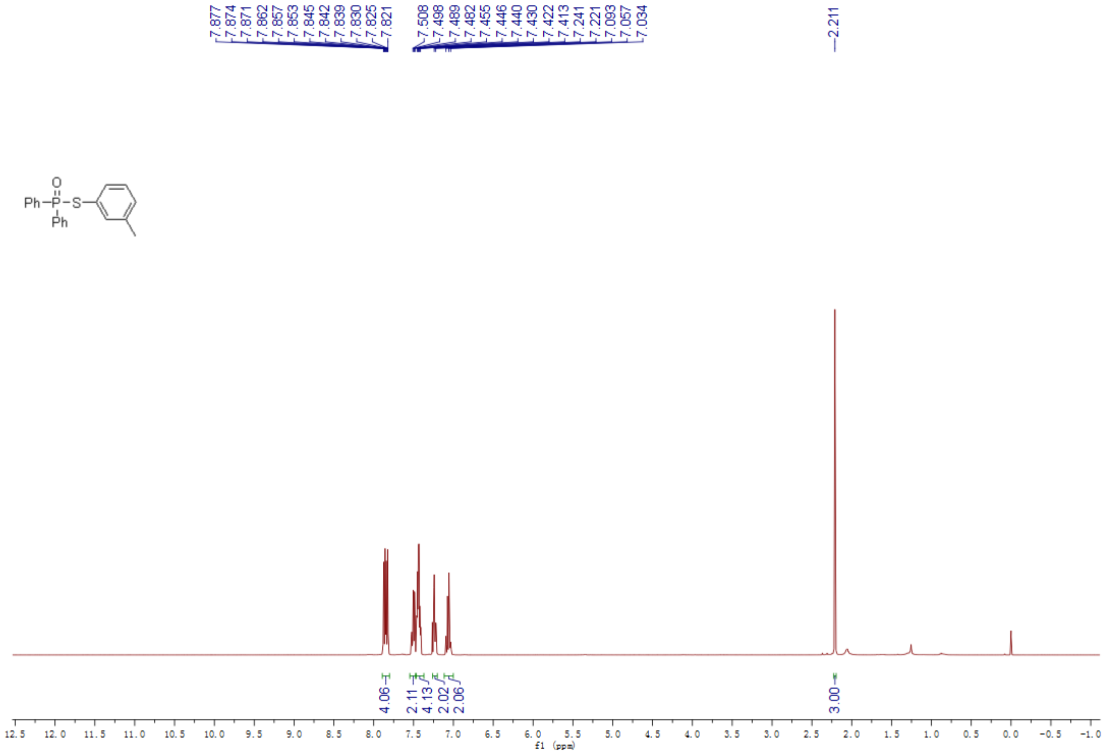
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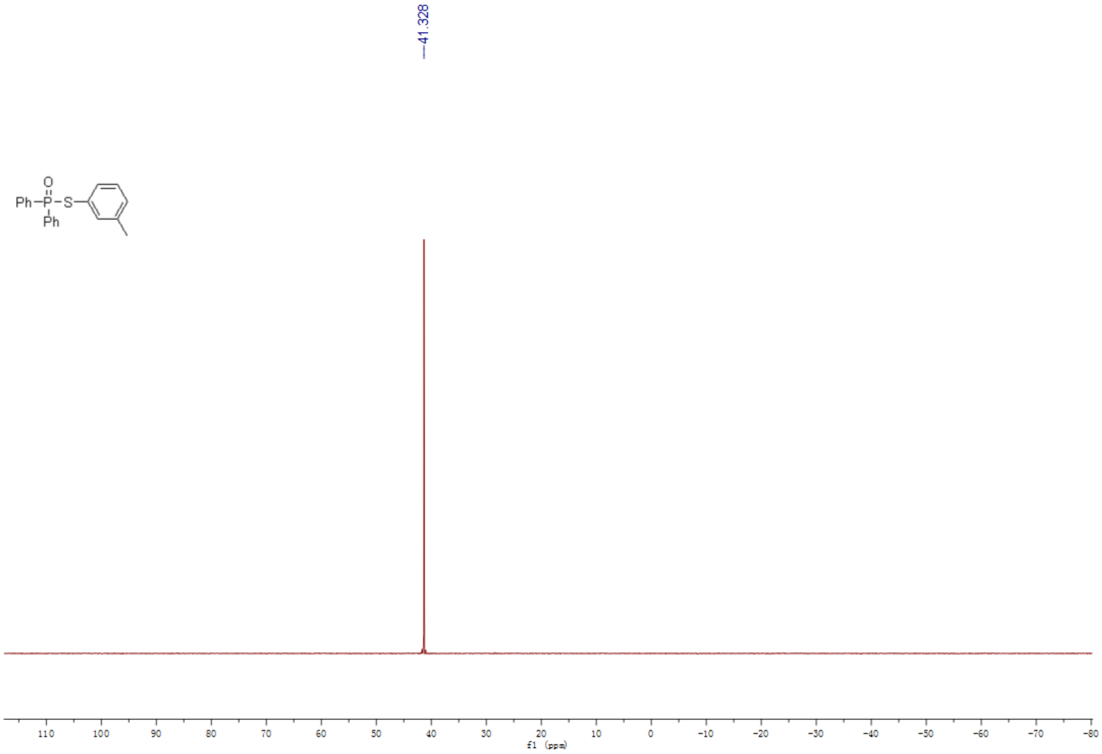
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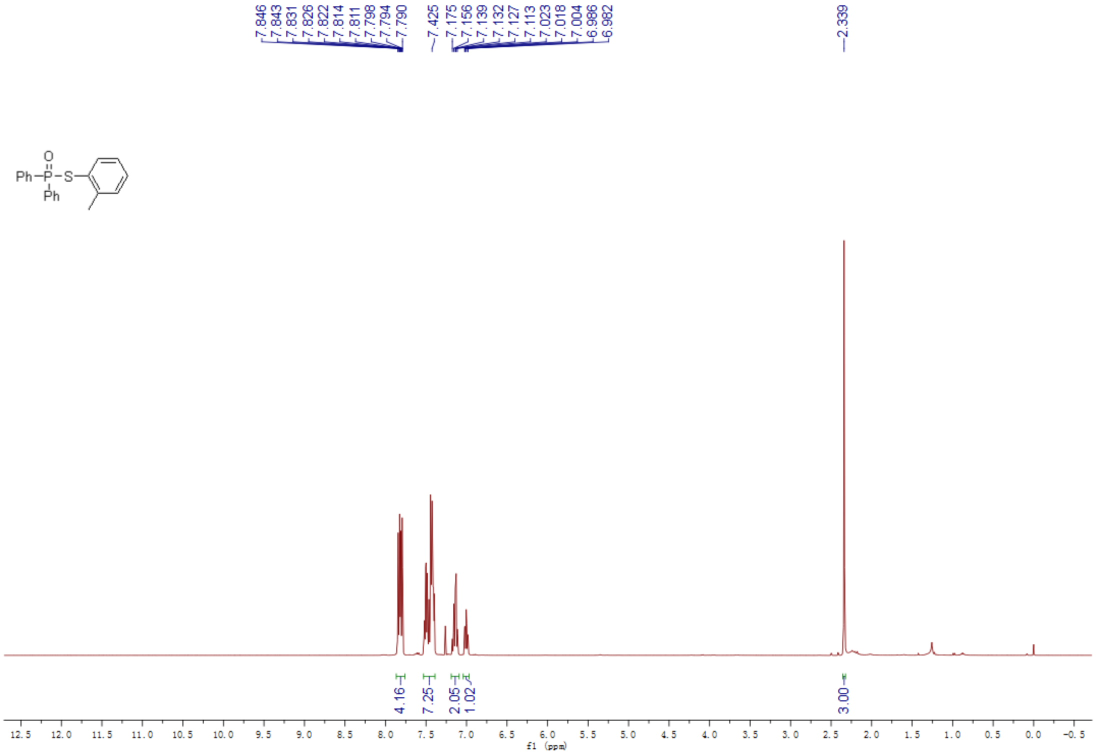
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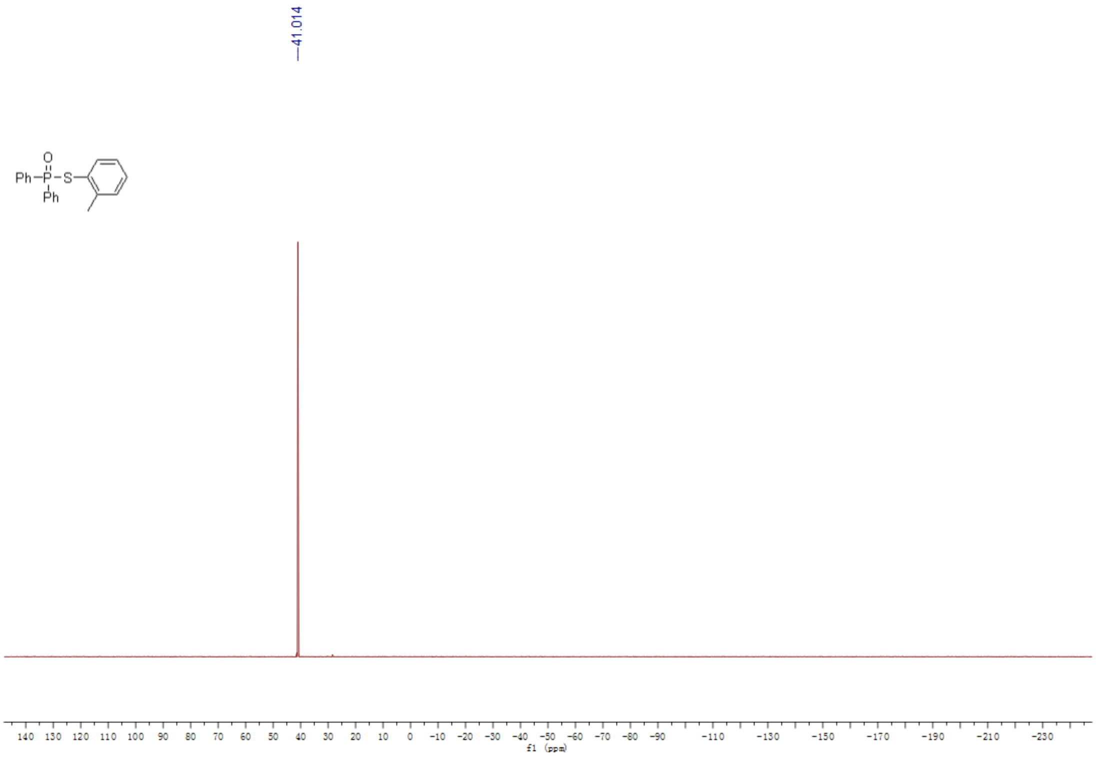
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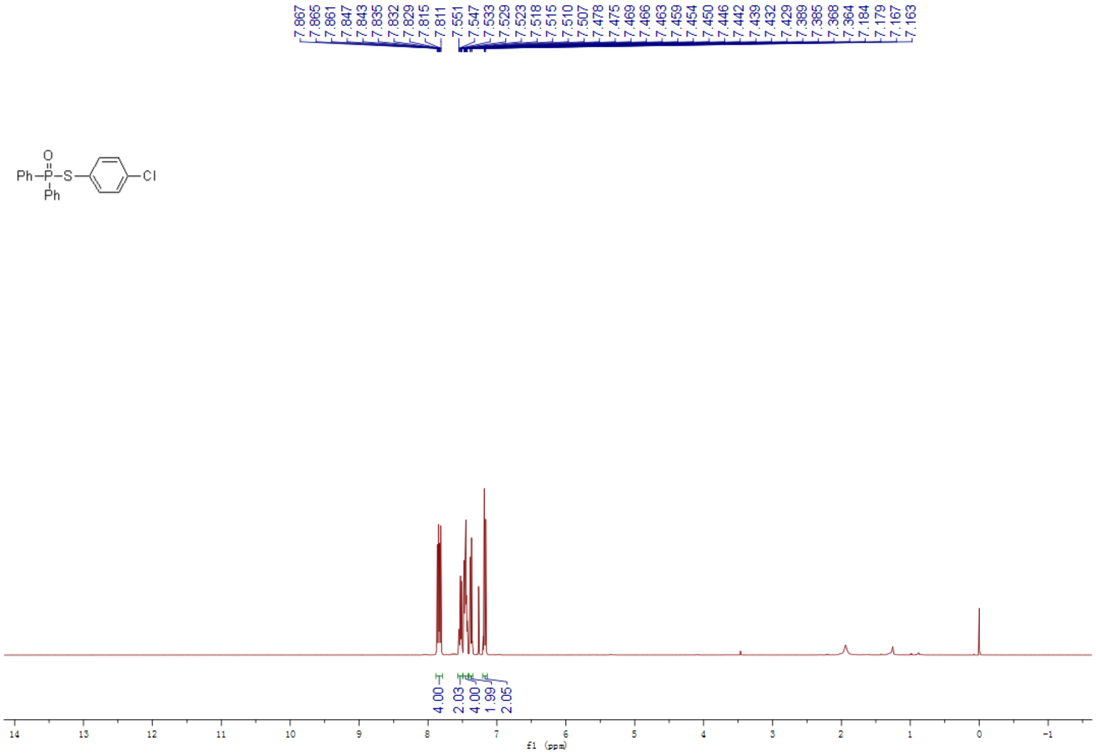
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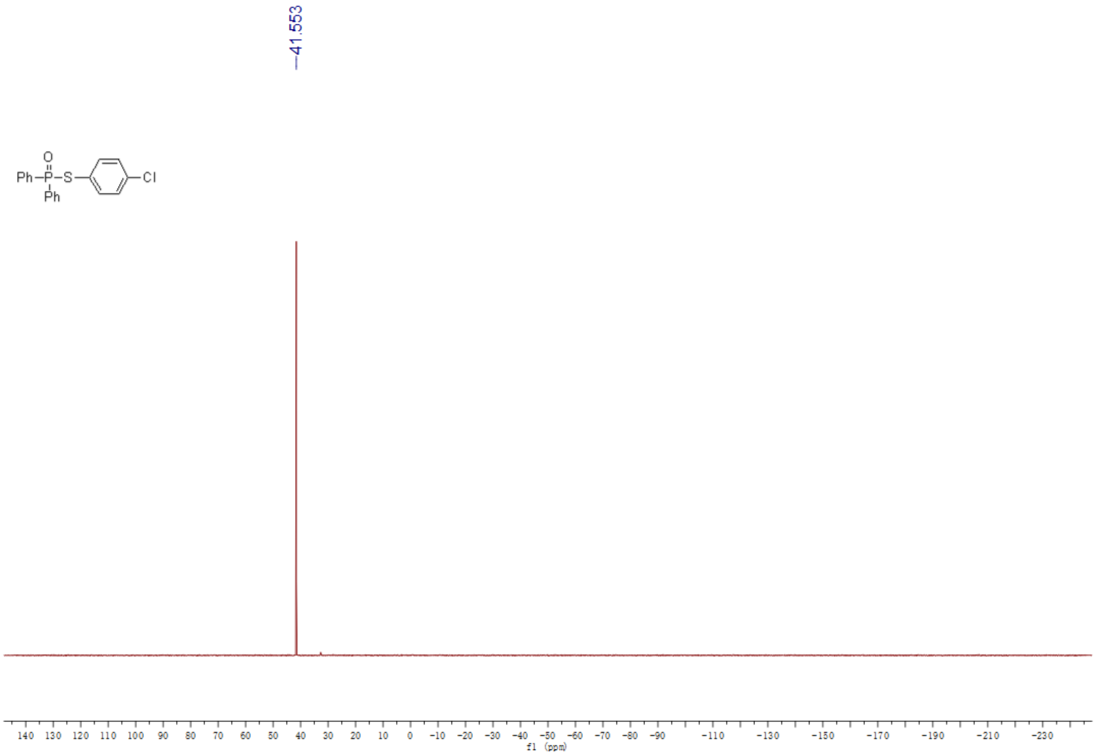

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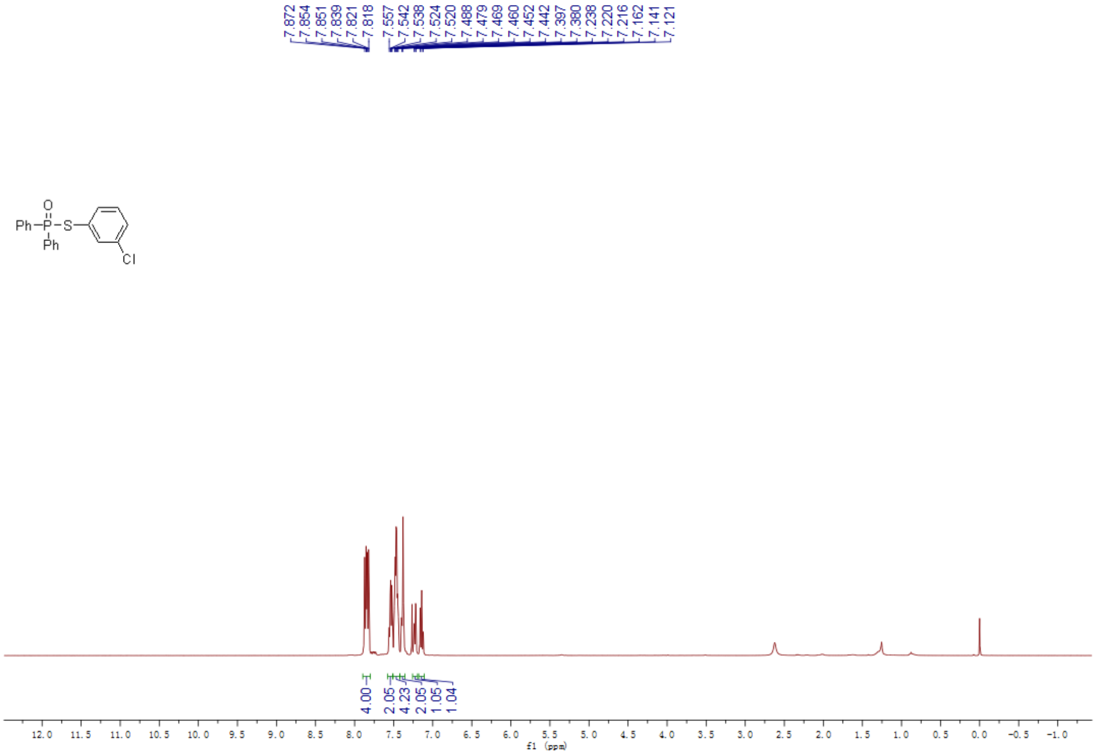

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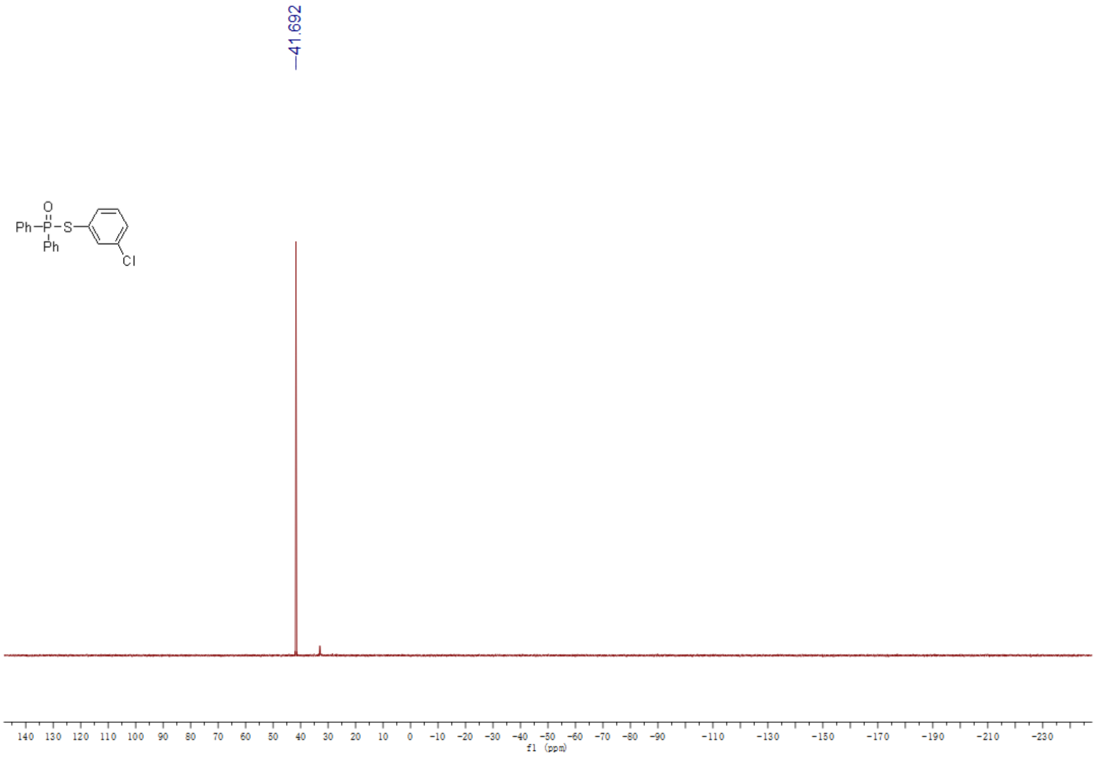
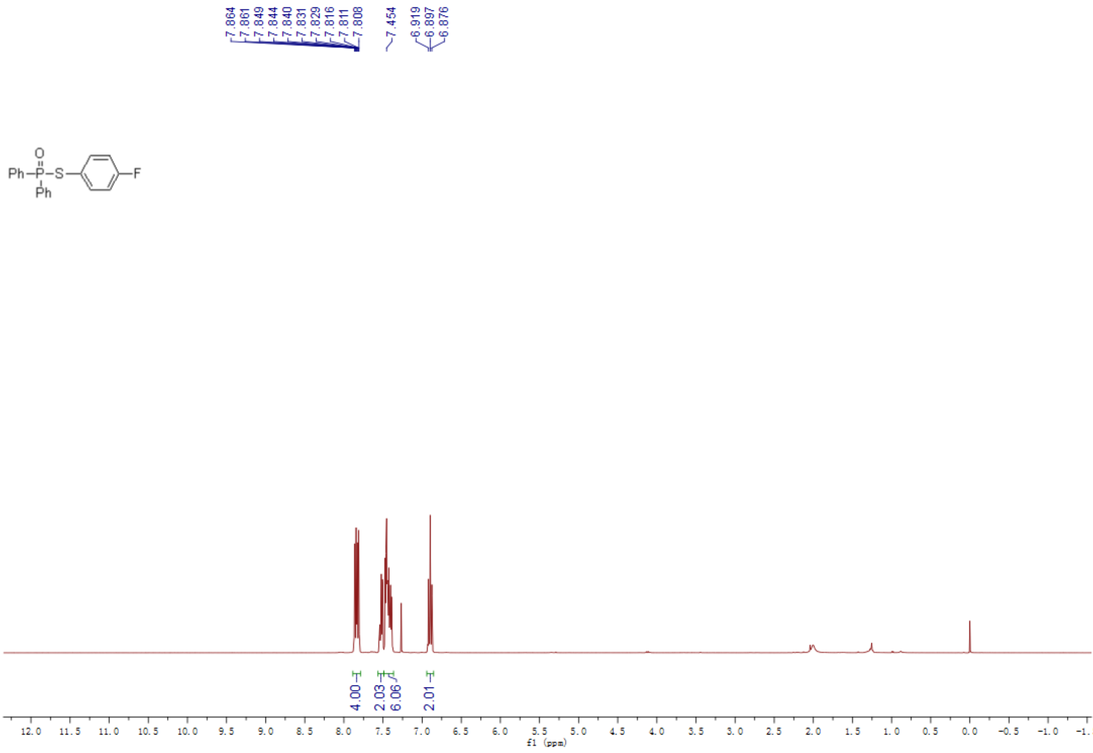
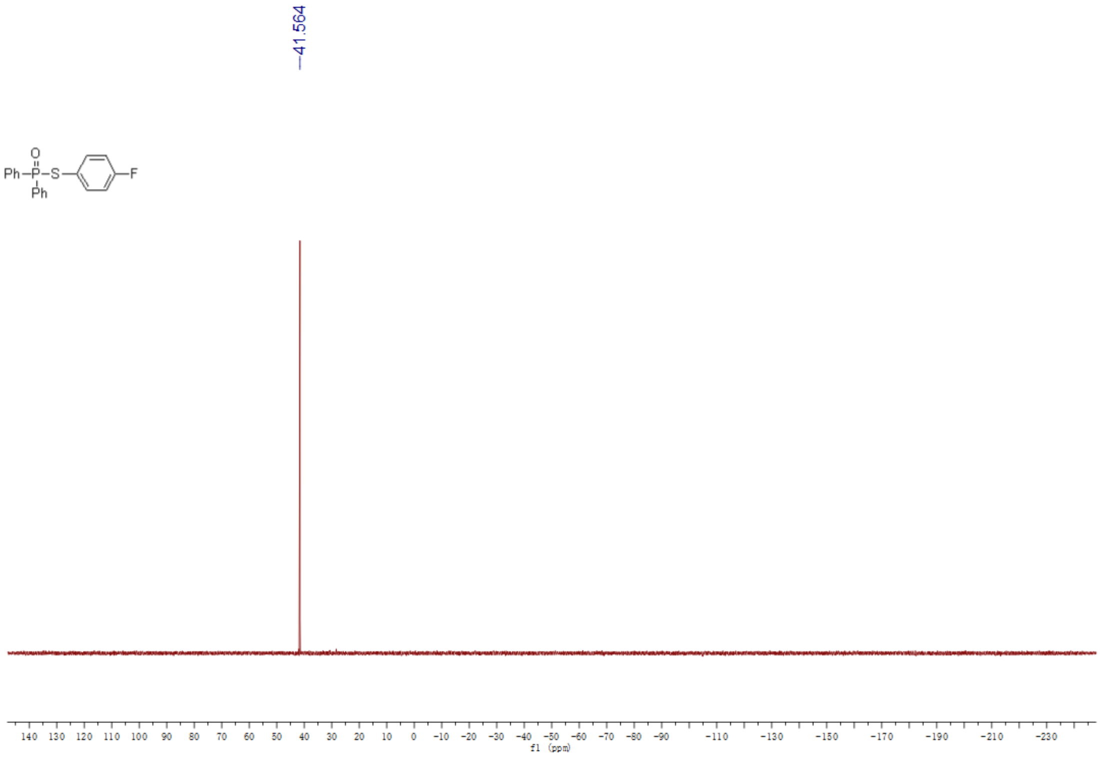
7.818
7.557
7.542
7.538
7.524
7.520
7.488
7.479
7.469
7.460
7.452
7.442
7.397
7.380
7.238
7.220
7.216
7.162
7.141
7.121
Ph
O
P
S
Cl
Ph
4.00
2.05
4.23
2.05
1.05
1.04
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)

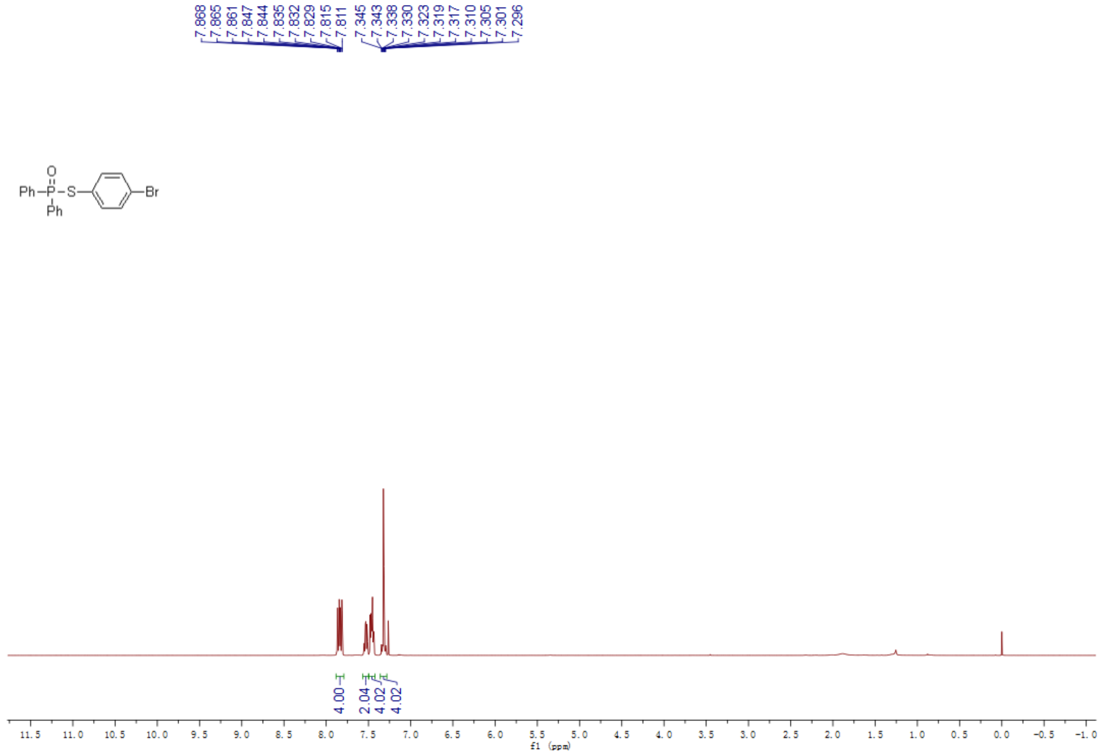


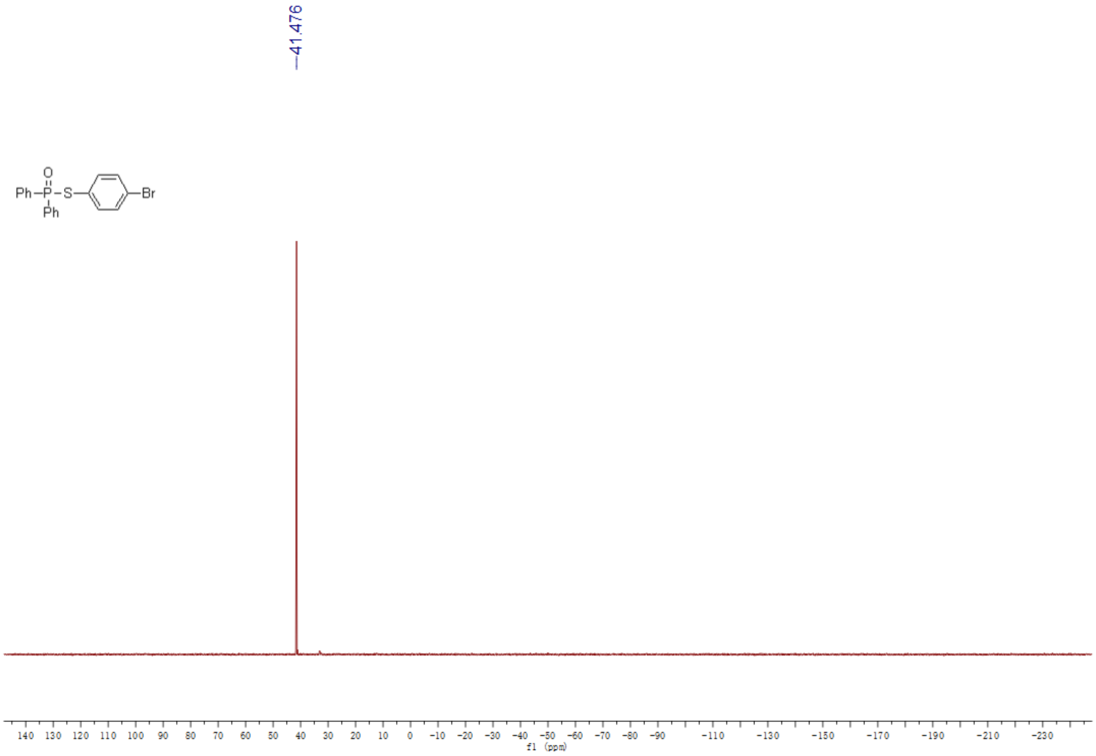
—41.692
Ph
P
O
S
Ph
Cl
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

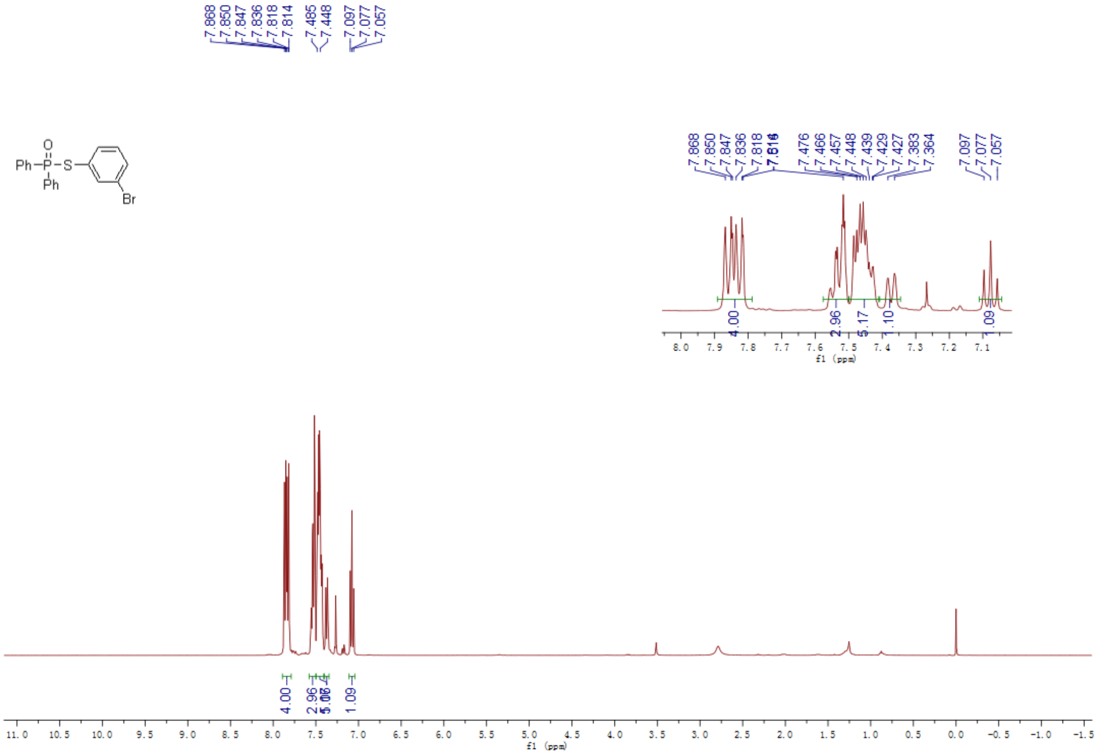


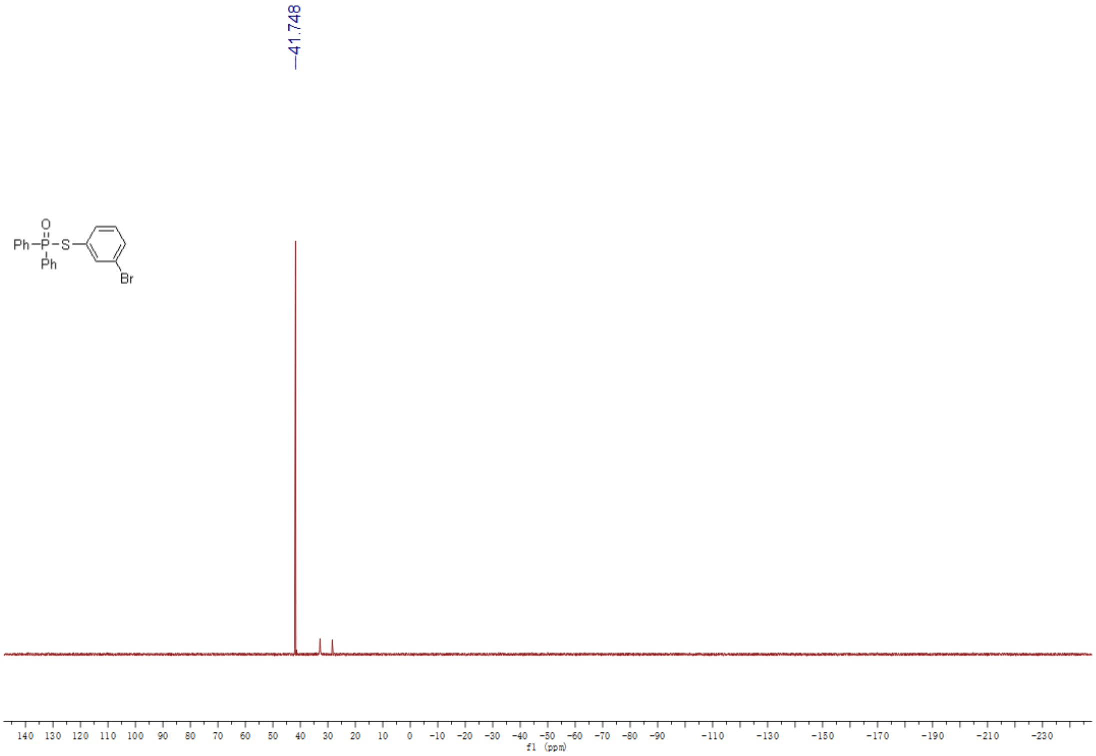
7.864
7.861
7.849
7.844
7.840
7.831
7.829
7.816
7.811
7.808
7.454
6.919
6.897
6.876
Ph
P
O
S
Ph
F
4.00
2.03
6.06
2.01
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0 −1.5
f1 (ppm)

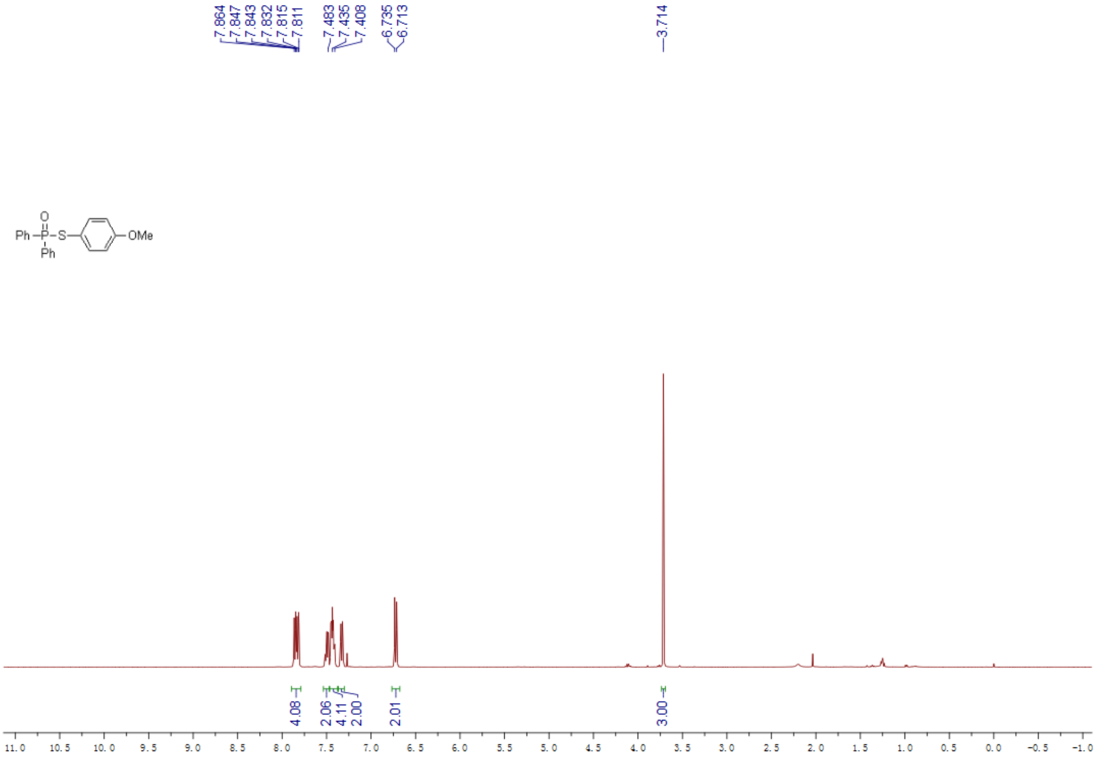

41.564
O
Ph–P–S
Ph
F
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

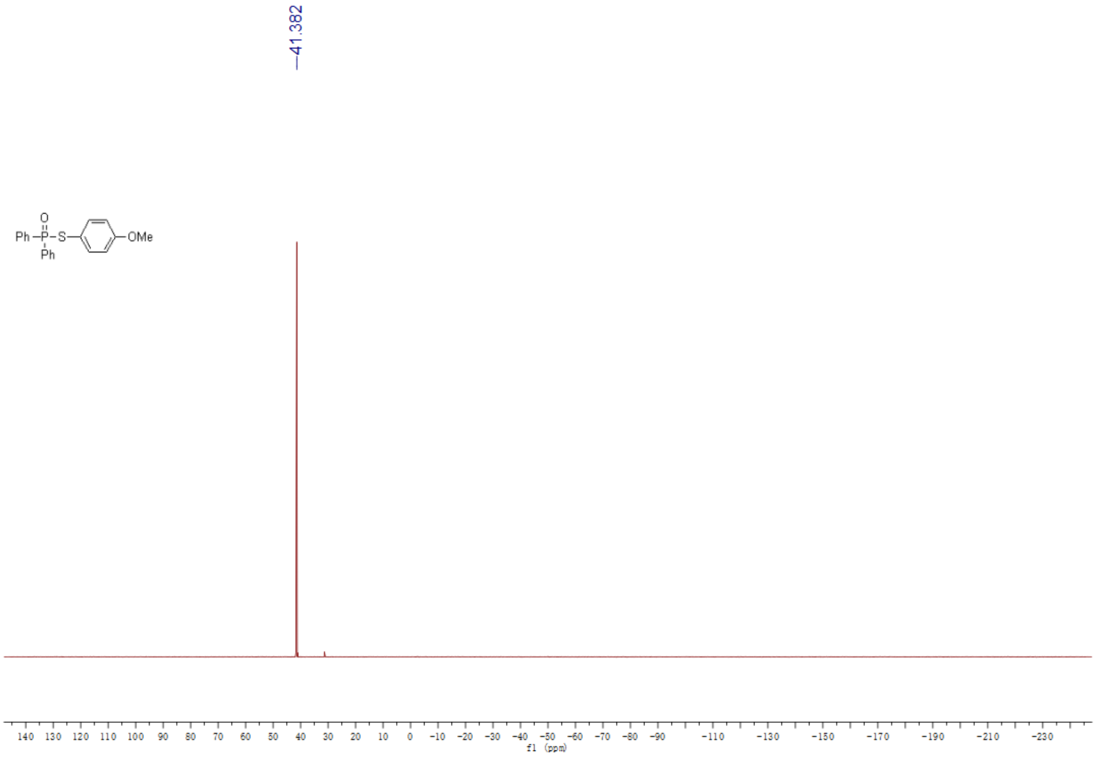

7.868
7.865
7.861
7.847
7.844
7.835
7.832
7.829
7.815
7.811
7.345
7.343
7.338
7.330
7.323
7.319
7.317
7.310
7.305
7.301
7.296
O
Ph–P–S
Ph
Br
4.00
2.04
4.02
4.02
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)

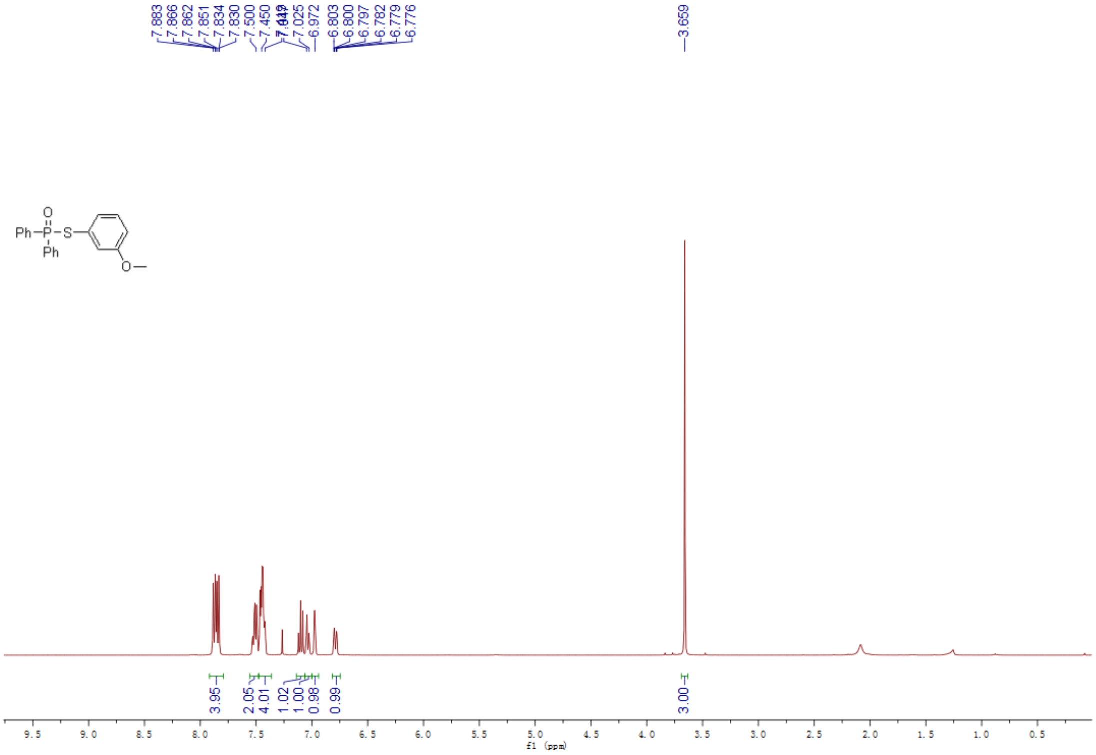

41.476
Ph
O
P
S
Ph
Br
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

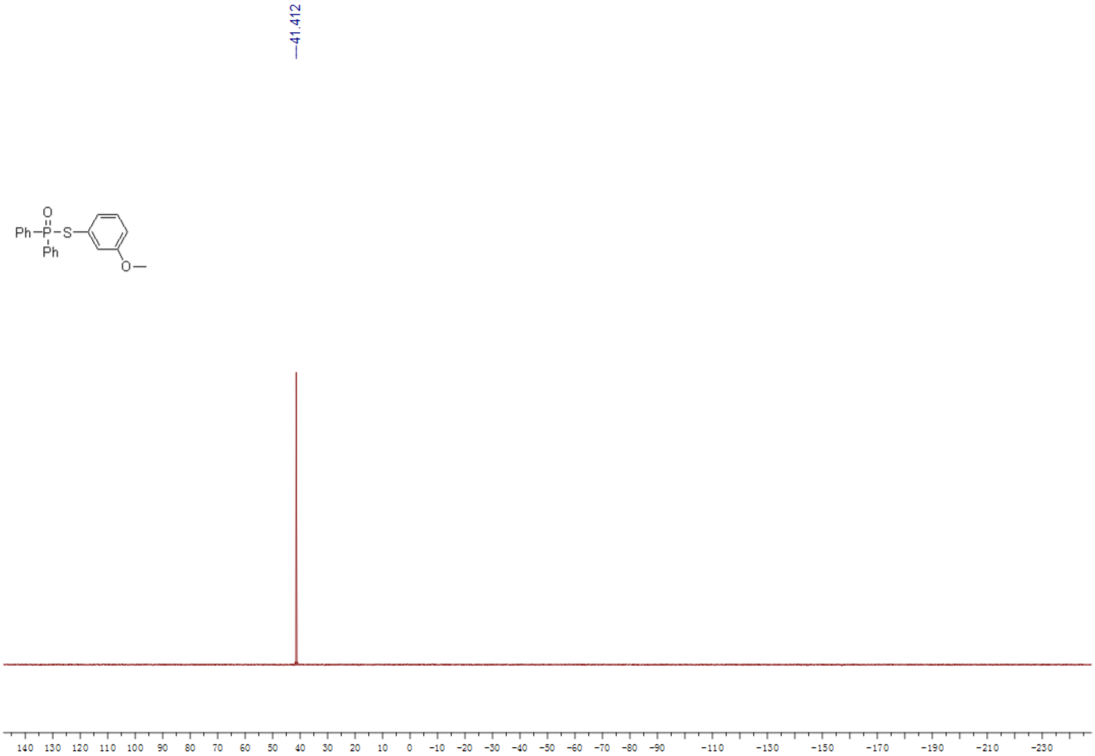

7.868
7.850
7.847
7.836
7.818
7.814
7.485
7.448
7.097
7.077
7.057
Ph
O
P
S
Ph
Br
7.868
7.850
7.847
7.836
7.818
7.816
7.814
7.476
7.466
7.457
7.448
7.439
7.429
7.427
7.383
7.364
7.097
7.077
7.057
4.00
2.96
5.17
1.10
1.09
8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1
f1 (ppm)
4.00
2.96
5.06
1.14
1.09
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 −0.5 −1.0 −1.5
f1 (ppm)

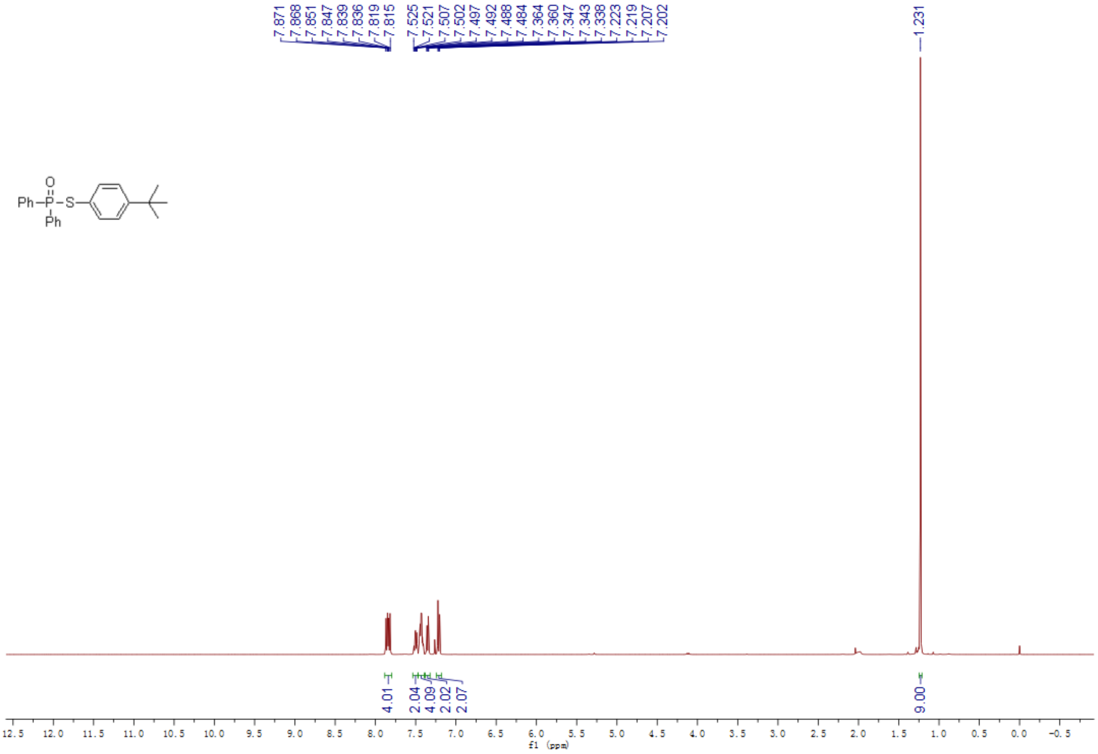

41.748
Ph
O
P
S
Ph
Br
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

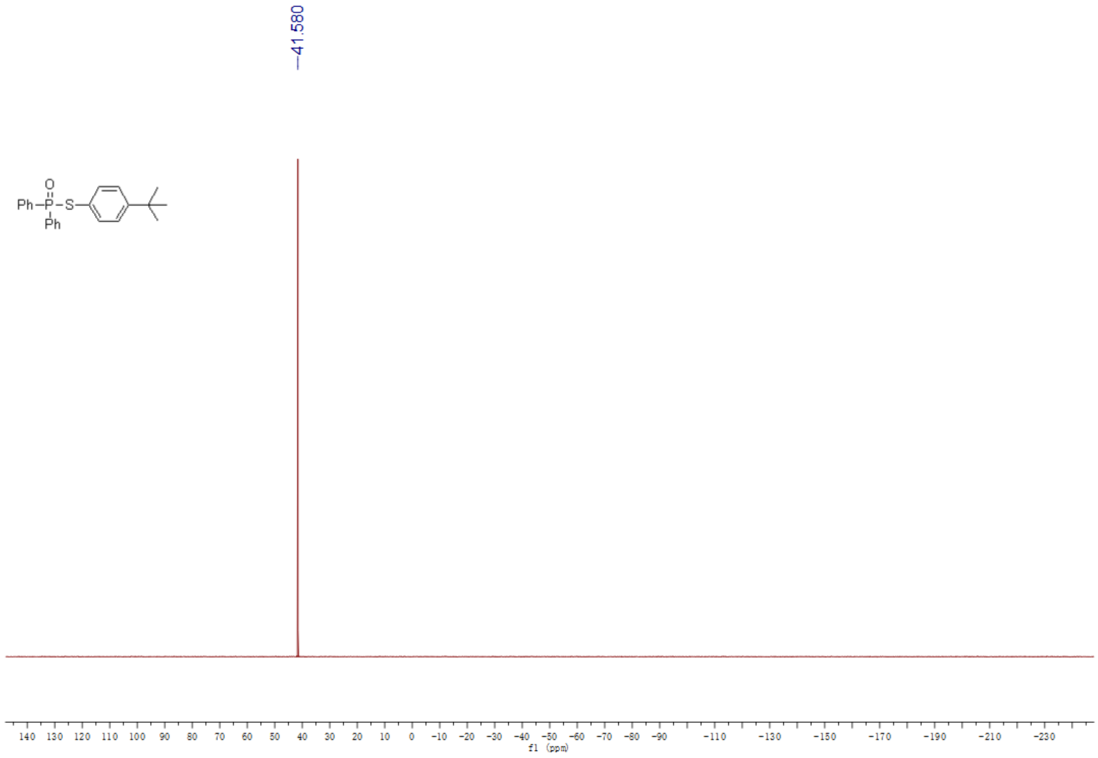

7.864
7.847
7.843
7.832
7.815
7.811
7.483
7.435
7.408
6.735
6.713
3.714
Ph
O
P
S
Ph
OMe
4.08
2.06
4.11
2.00
2.01
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0

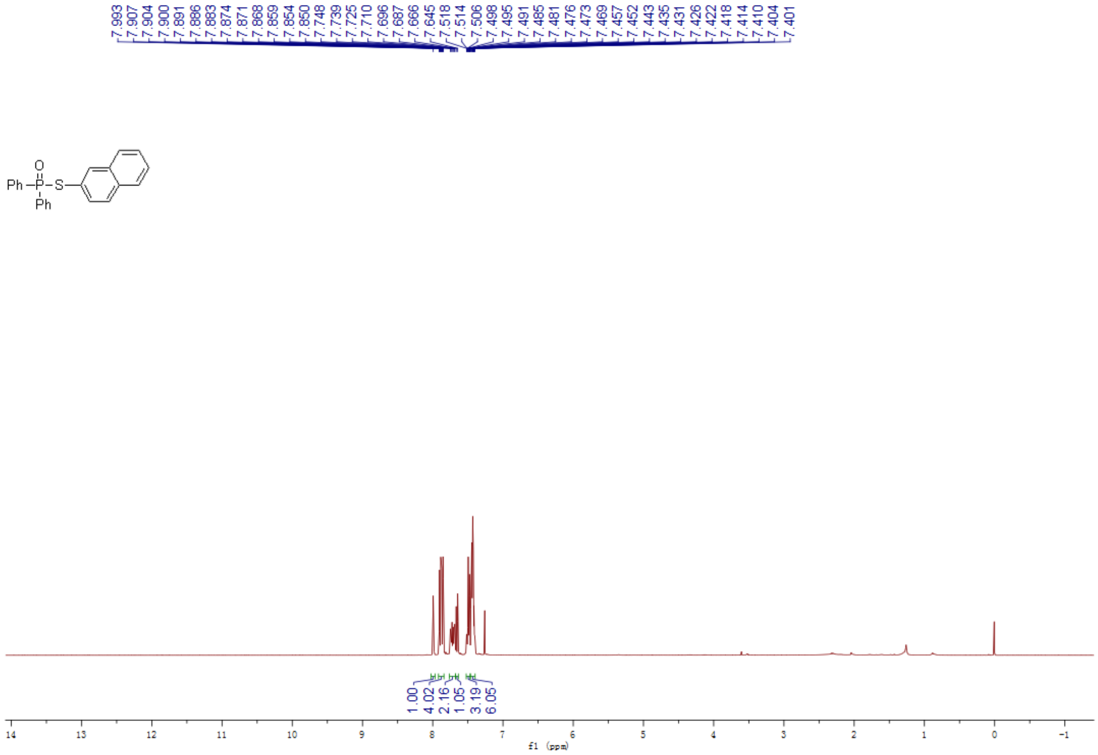

41.382
Ph
O
P
S
Ph
OMe
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

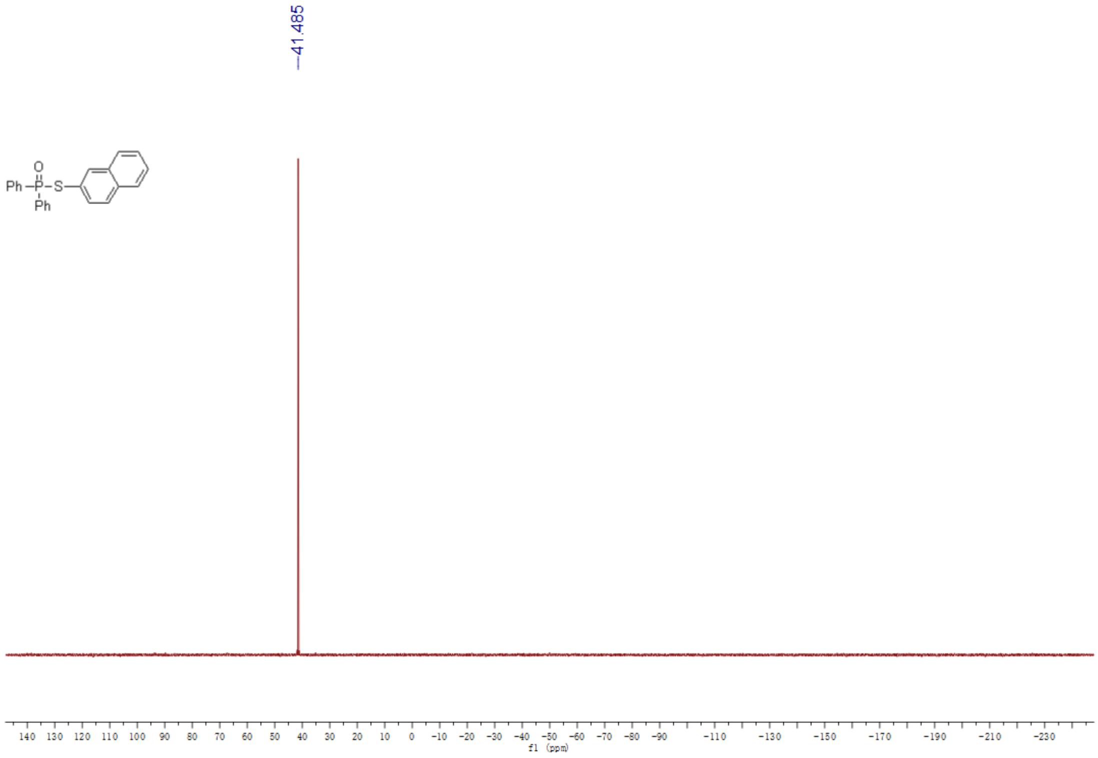

7.883
7.866
7.862
7.851
7.834
7.830
7.500
7.450
7.449
7.025
6.972
6.803
6.800
6.797
6.782
6.779
6.776
3.659
Ph
O
P
S
Ph
O
3.95
2.05
4.01
1.02
1.00
0.98
0.99
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


41.412
Ph
P
O
S
Ph
O
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230

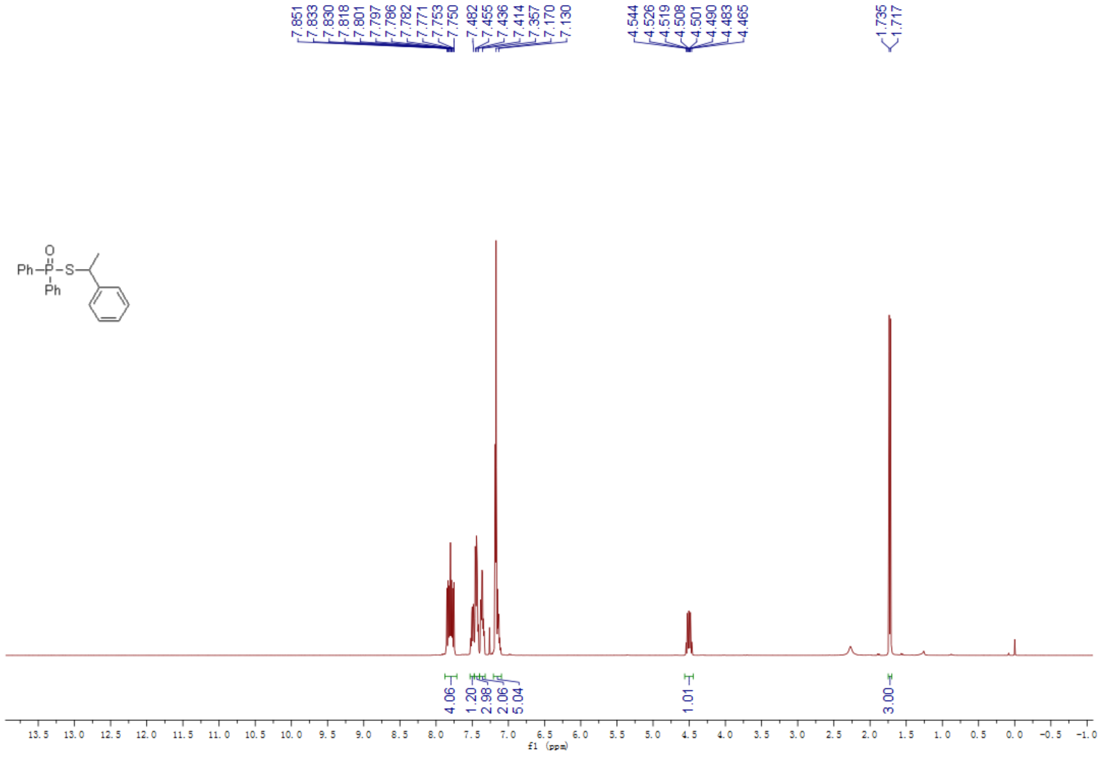

7.871
7.868
7.851
7.847
7.839
7.836
7.819
7.815
7.525
7.521
7.507
7.502
7.497
7.492
7.488
7.484
7.364
7.360
7.347
7.343
7.338
7.223
7.219
7.207
7.202
1.231
Ph
P
O
S
Ph
4.01
2.04
4.09
2.02
2.07
9.00
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)


41.580
O
Ph
P
S
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

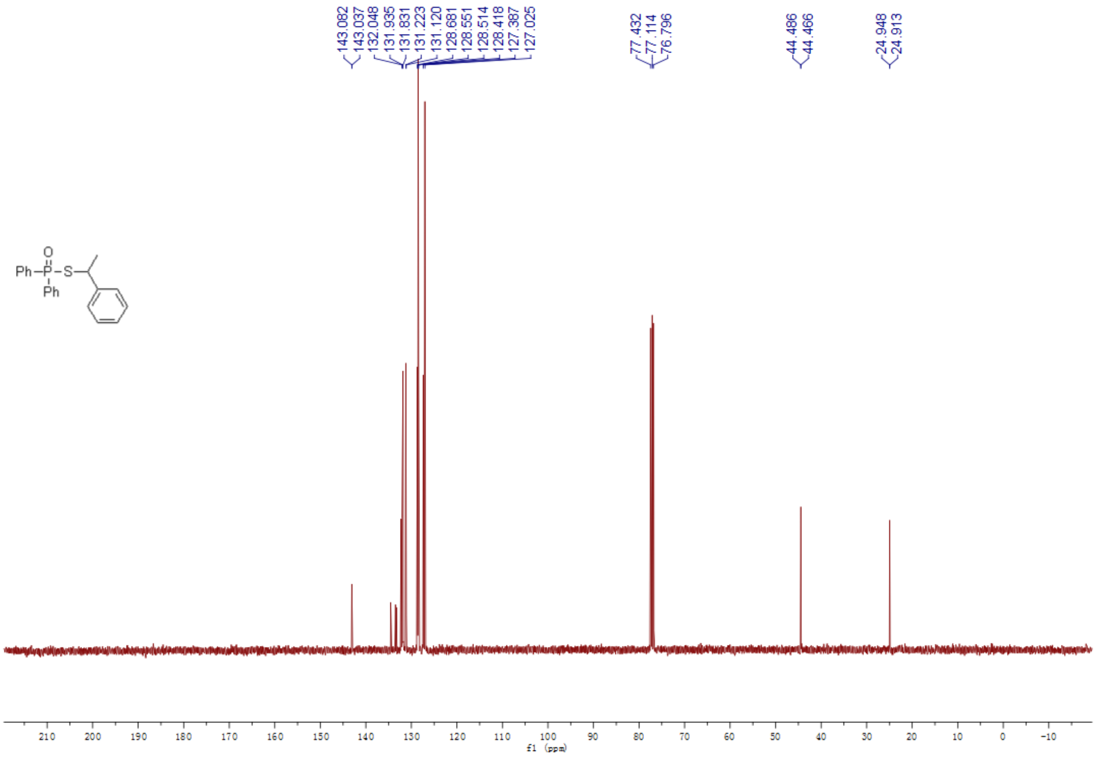

7.993
7.907
7.904
7.900
7.891
7.886
7.883
7.874
7.871
7.868
7.859
7.854
7.850
7.748
7.739
7.725
7.710
7.696
7.687
7.666
7.645
7.518
7.514
7.506
7.498
7.495
7.491
7.485
7.481
7.476
7.473
7.469
7.457
7.452
7.443
7.435
7.431
7.426
7.422
7.418
7.414
7.410
7.404
7.401
O
Ph
P
S
Ph
1.00
4.02
2.16
1.05
3.19
6.05
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

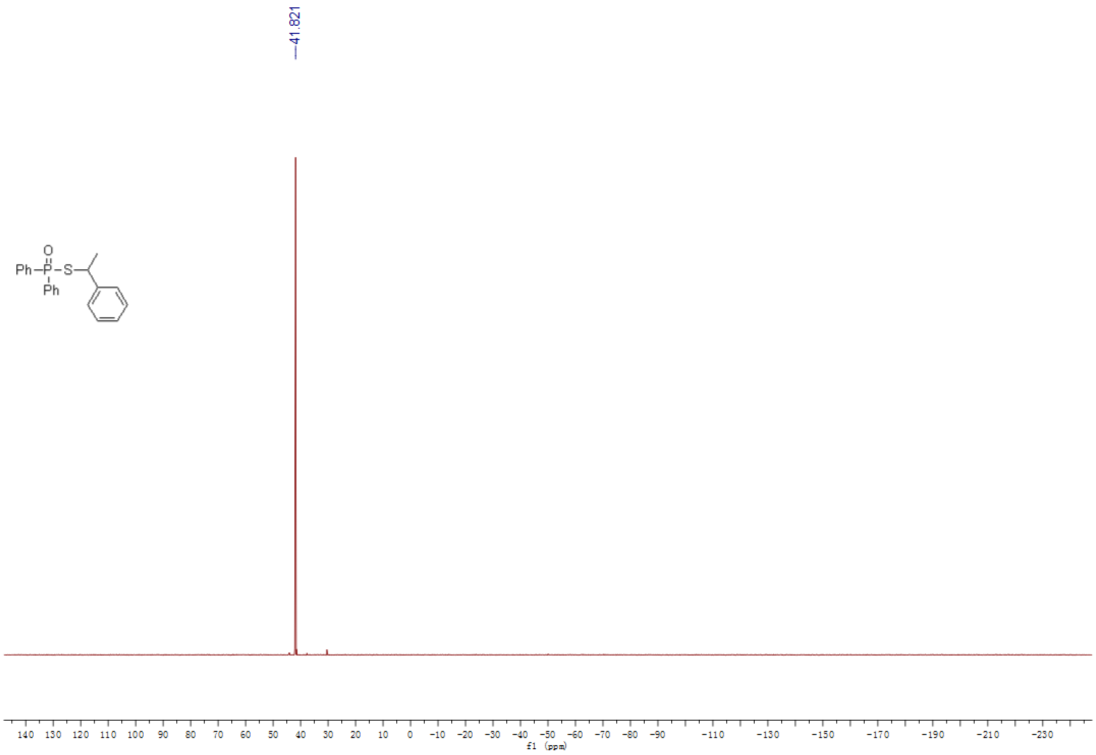


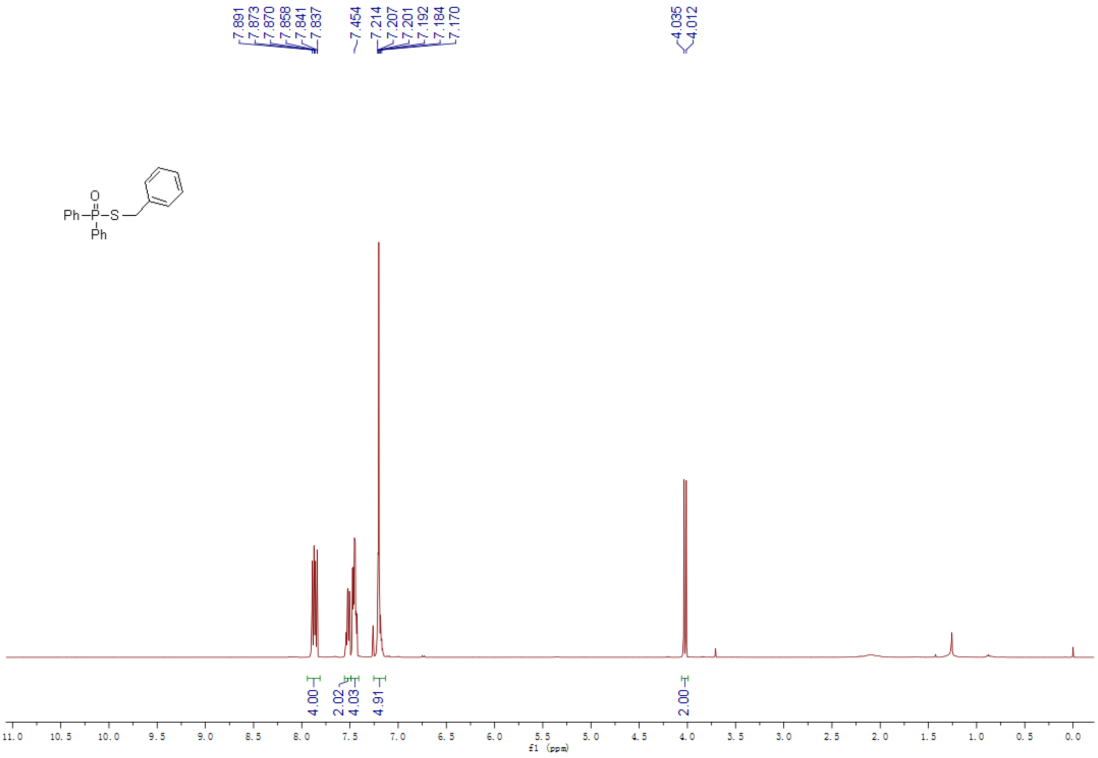
41.485
Ph
O
P
S
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

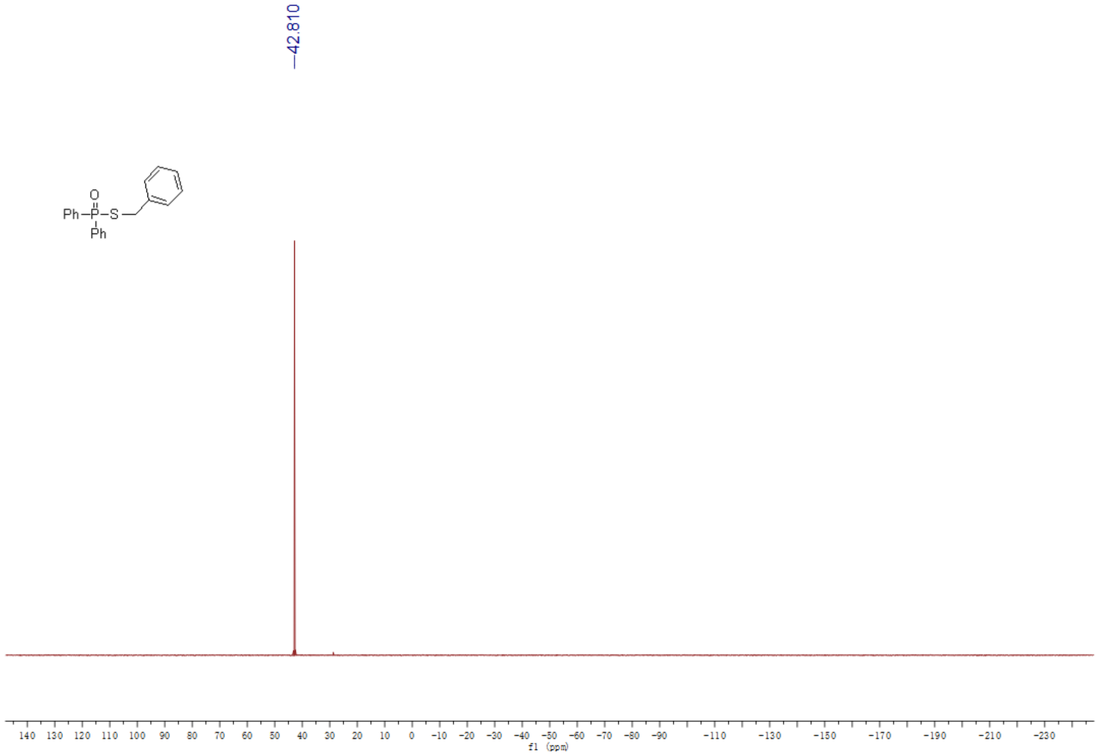


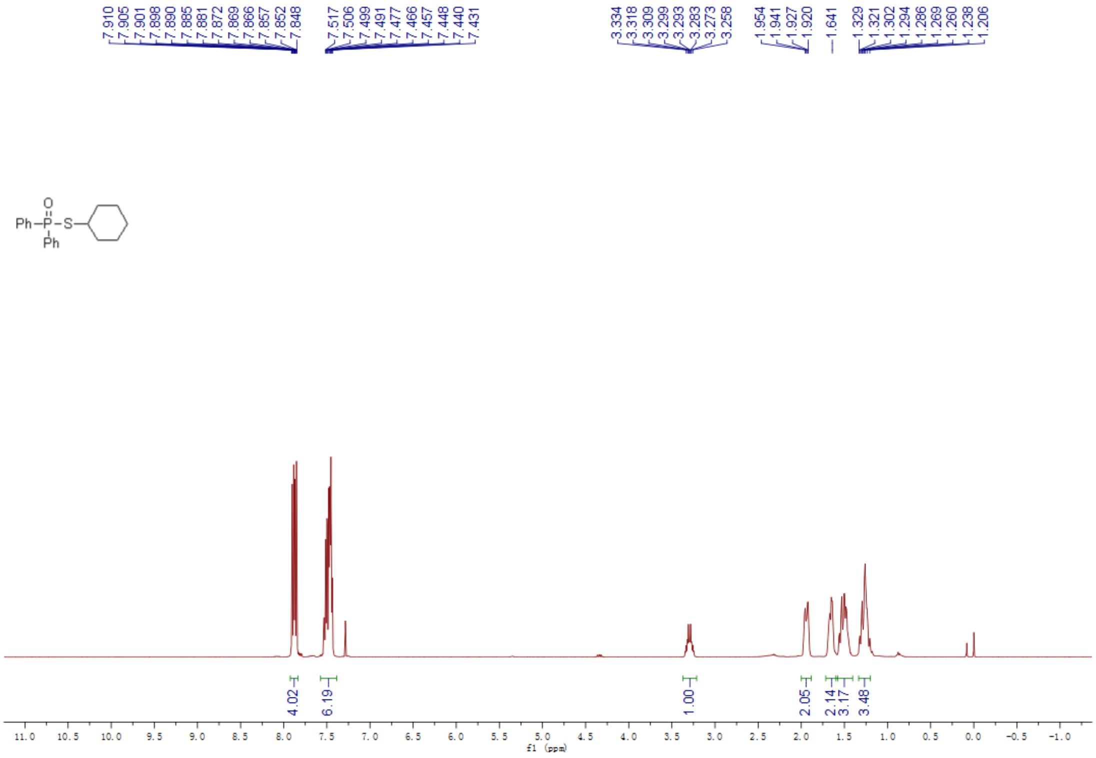
7.851
7.833
7.830
7.818
7.801
7.797
7.786
7.782
7.771
7.753
7.750
7.482
7.455
7.436
7.414
7.357
7.170
7.130
4.544
4.526
4.519
4.508
4.501
4.490
4.483
4.465
1.735
1.717
Ph
O
P
S
Ph
4.06
1.20
2.98
2.06
5.04
1.01
3.00
13.5 13.0 12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)

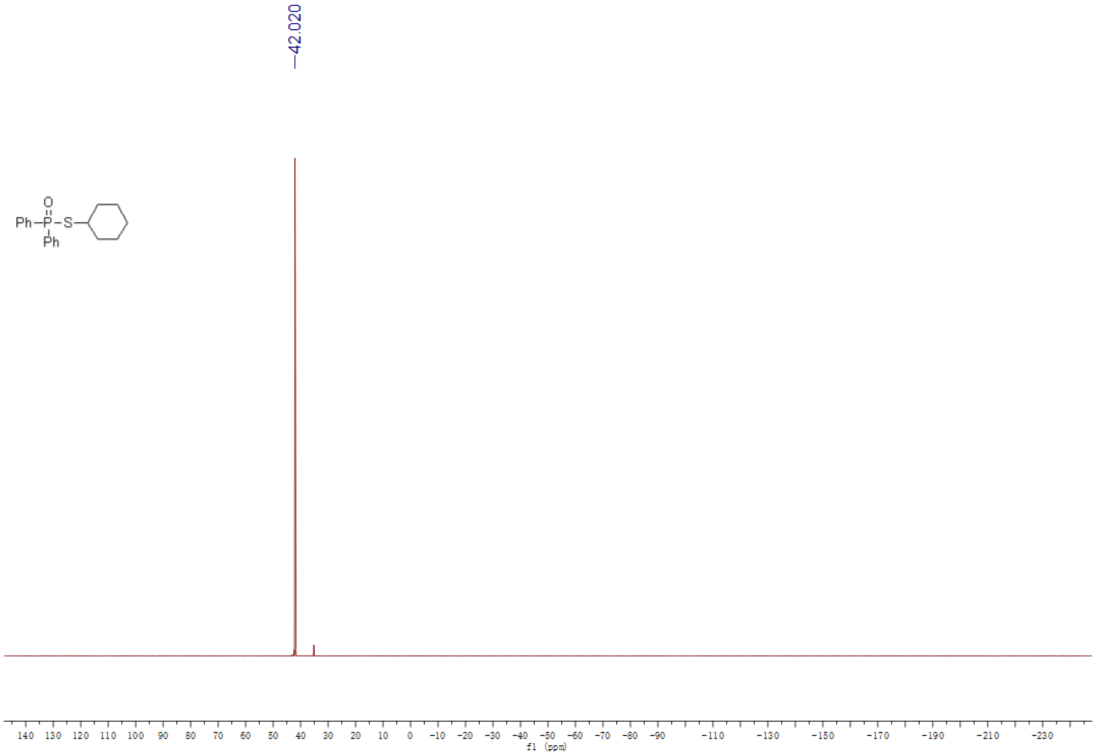

143.082
143.037
132.048
131.935
131.831
131.223
131.120
128.681
128.551
128.514
128.418
127.387
127.025
77.432
77.114
76.796
44.486
44.466
24.948
24.913
O
Ph
P
S
Ph
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

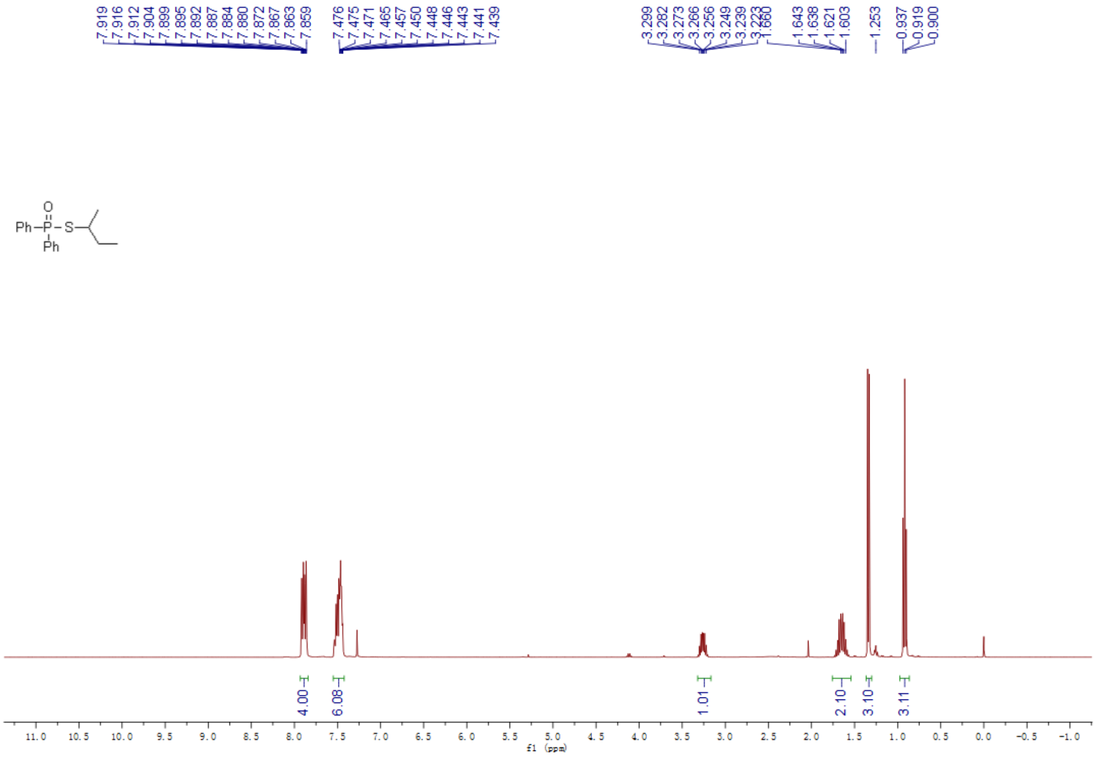

41.821
O
Ph
P
S
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

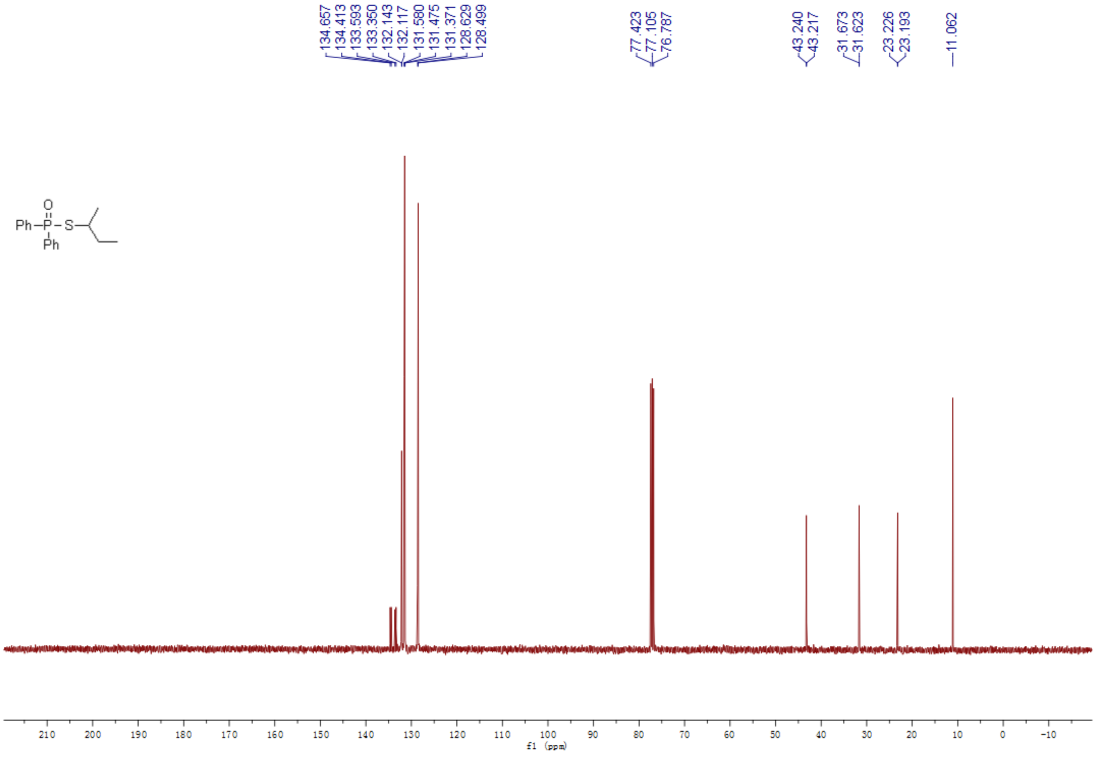

7.891
7.873
7.870
7.858
7.841
7.837
7.454
7.214
7.207
7.201
7.192
7.184
7.170
4.035
4.012
Ph
O
P
S
Ph
4.00
2.02
4.03
4.91
2.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

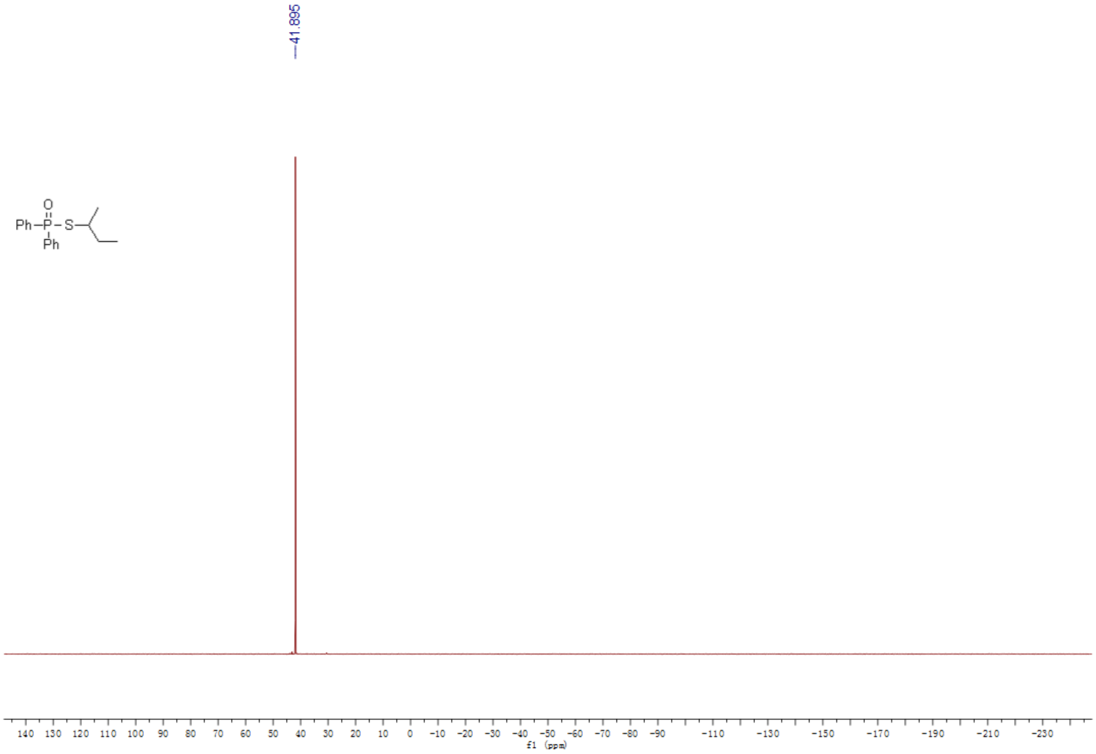

42.810
Ph
O
P
S
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

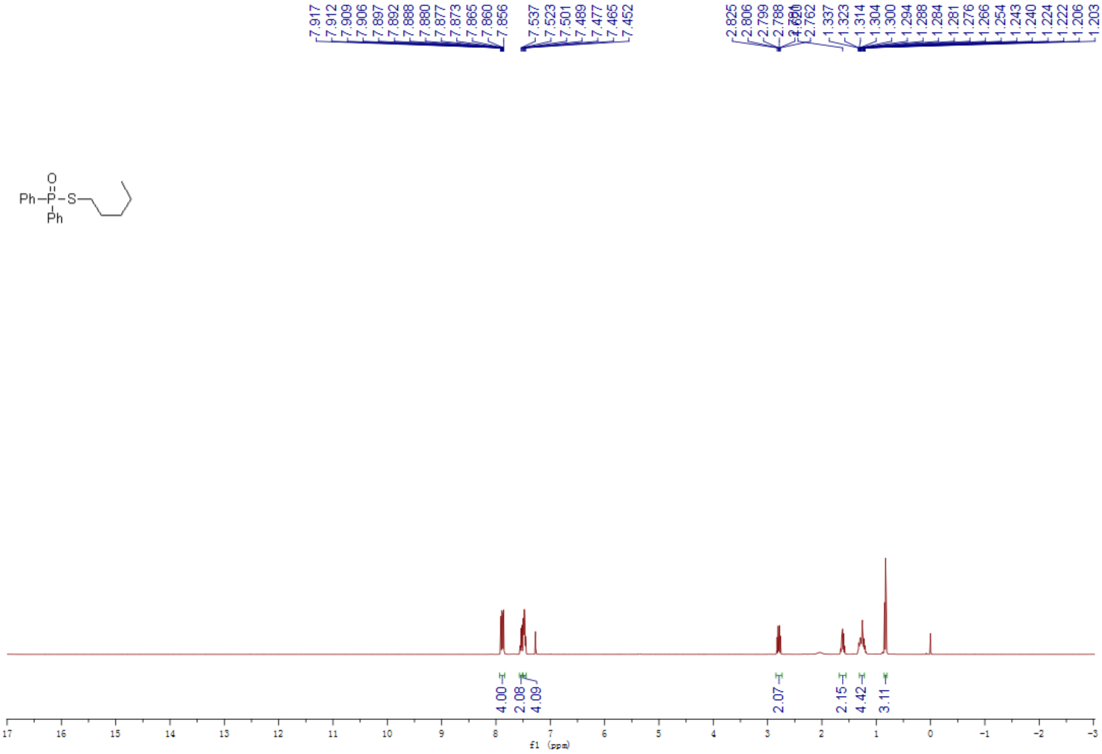

7.910
7.905
7.901
7.898
7.890
7.885
7.881
7.872
7.869
7.866
7.857
7.852
7.848
7.517
7.506
7.499
7.491
7.477
7.466
7.457
7.448
7.440
7.431
3.334
3.318
3.309
3.299
3.293
3.283
3.273
3.258
1.954
1.941
1.927
1.920
1.641
1.329
1.321
1.302
1.294
1.286
1.269
1.260
1.238
1.206
O
Ph
P
S
Ph
4.02
6.19
1.00
2.05
2.14
3.17
3.48
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
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
-0.5
-1.0
f1 (ppm)

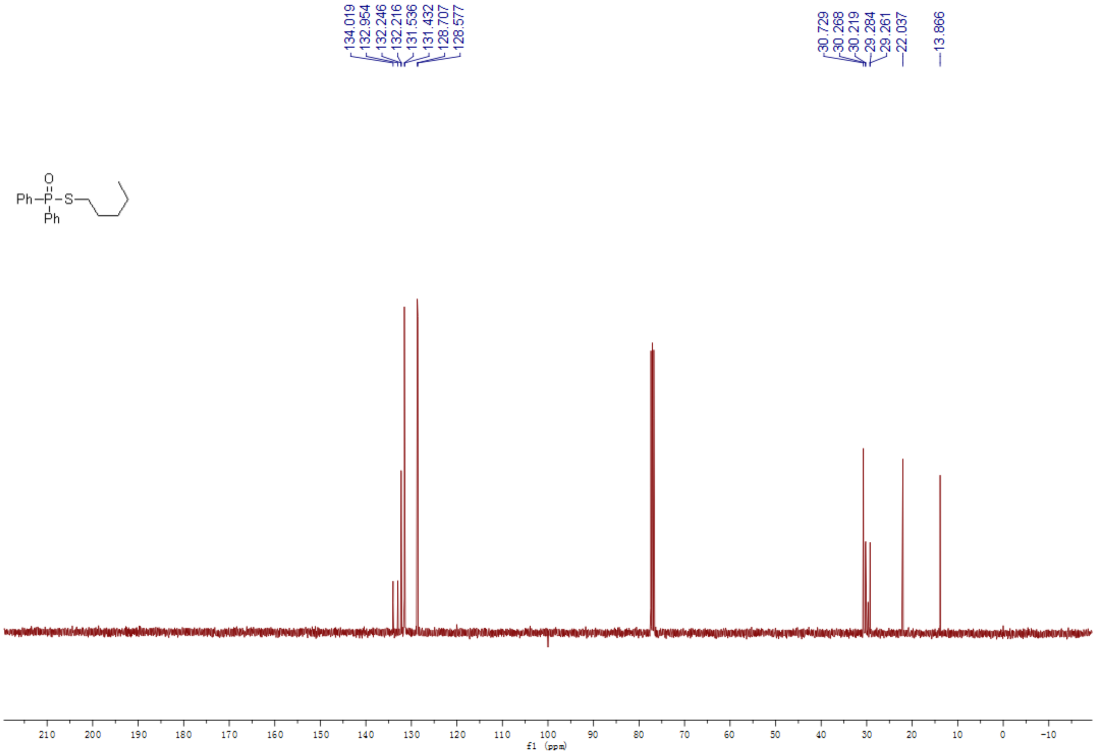

42.020
O
Ph
P
S
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

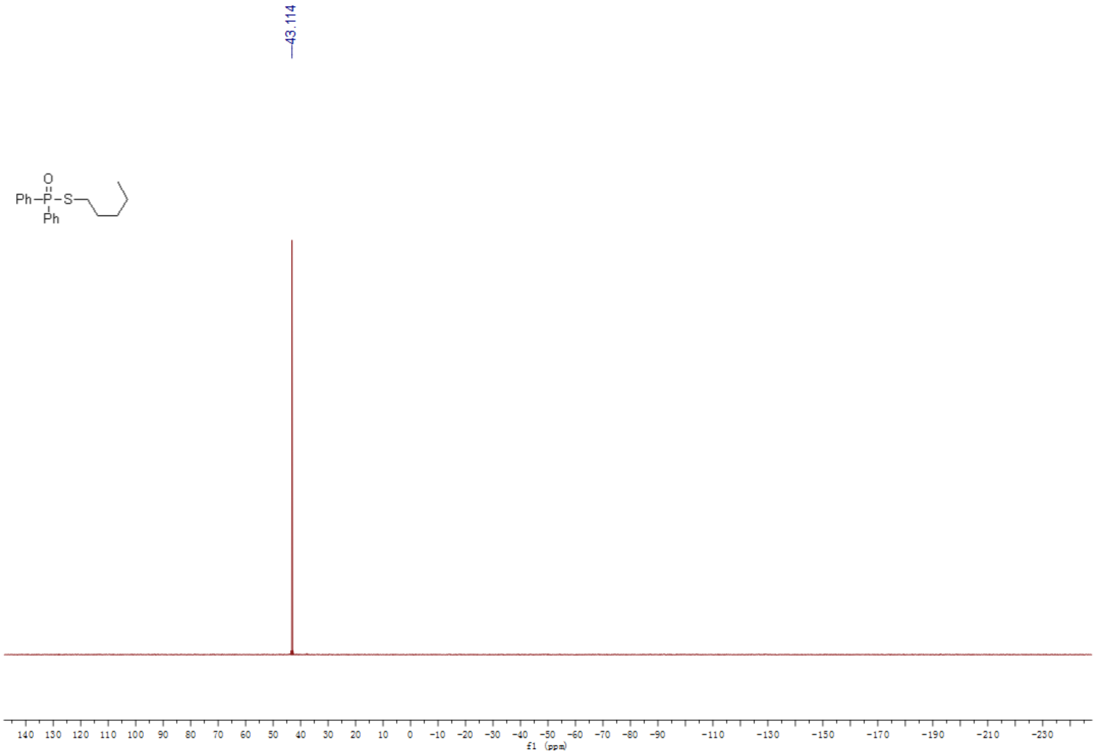

7.919
7.916
7.912
7.904
7.899
7.895
7.892
7.887
7.884
7.880
7.872
7.867
7.863
7.859
7.476
7.475
7.471
7.465
7.457
7.450
7.448
7.446
7.443
7.441
7.439
3.299
3.282
3.273
3.266
3.256
3.249
3.239
3.223
1.660
1.643
1.638
1.621
1.603
1.253
0.937
0.919
0.900
Ph
O
P
S
Ph
4.00
6.08
1.01
2.10
3.10
3.11
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
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
-0.5
-1.0
f1 (ppm)

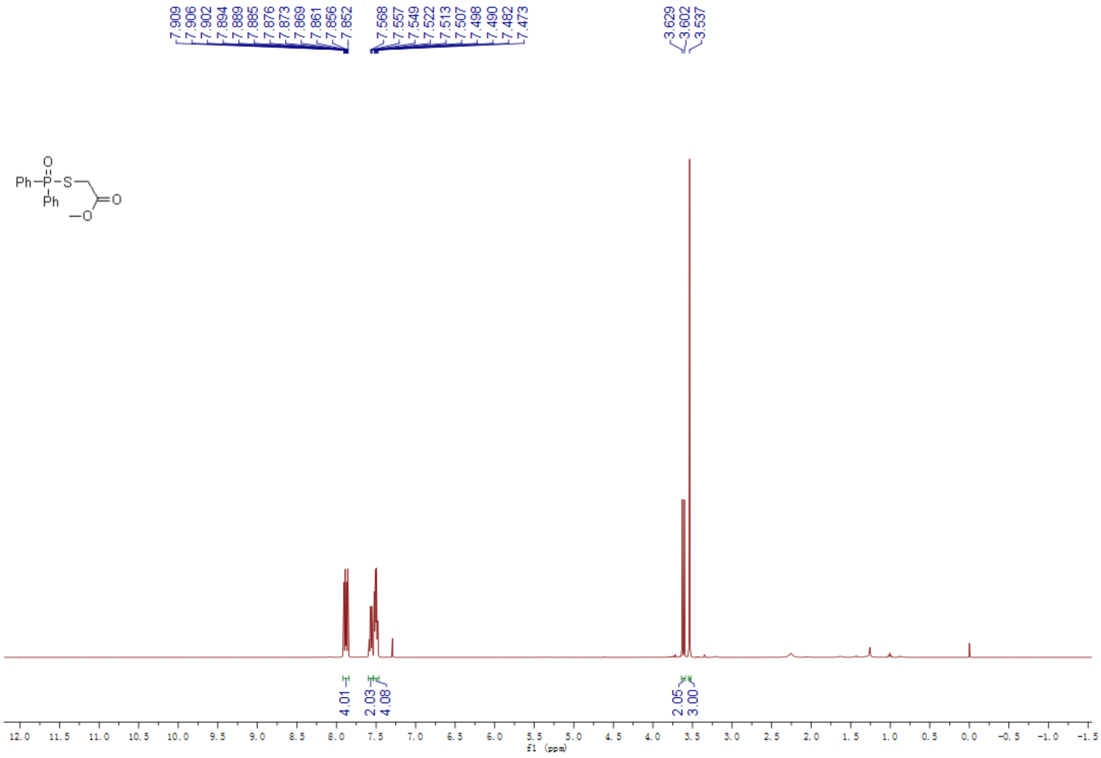

134.657
134.413
133.593
133.350
132.143
132.117
131.580
131.475
131.371
128.629
128.499
77.423
77.105
76.787
43.240
43.217
31.673
31.623
23.226
23.193
11.062
Ph
O
P
S
Ph
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

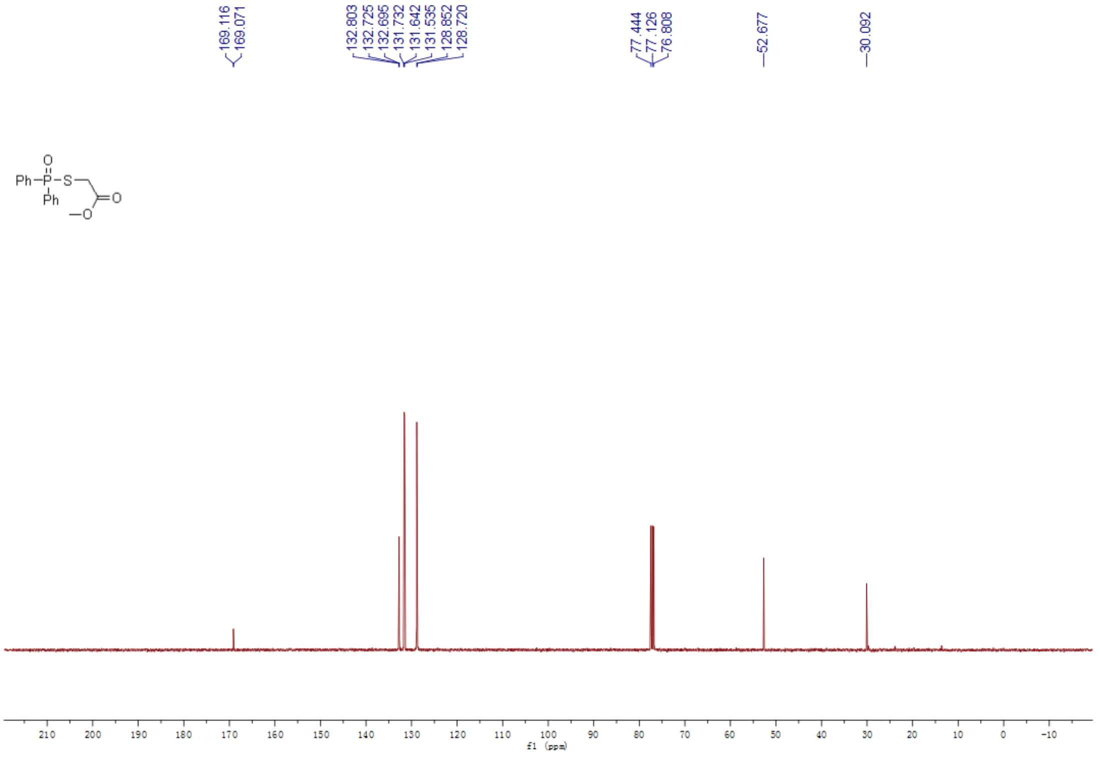

41.895
O
Ph
P
S
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

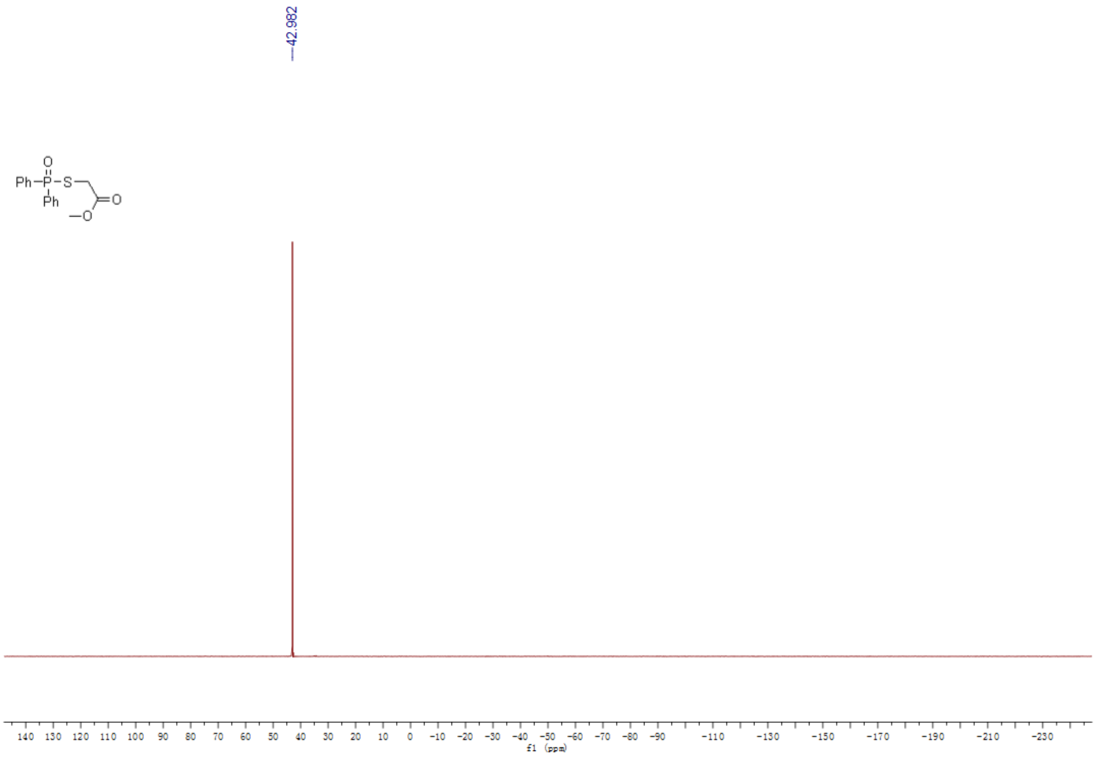

7.917
7.912
7.909
7.906
7.897
7.892
7.888
7.880
7.877
7.873
7.865
7.860
7.856
7.537
7.523
7.501
7.489
7.477
7.465
7.452
2.825
2.806
2.799
2.788
1.620
2.762
1.337
1.323
1.314
1.304
1.300
1.294
1.288
1.284
1.281
1.276
1.266
1.254
1.243
1.240
1.224
1.222
1.206
1.203
O
Ph
P
S
Ph
4.00
2.08
4.09
2.07
2.15
4.42
3.11
17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 −1 −2 −3
f1 (ppm)

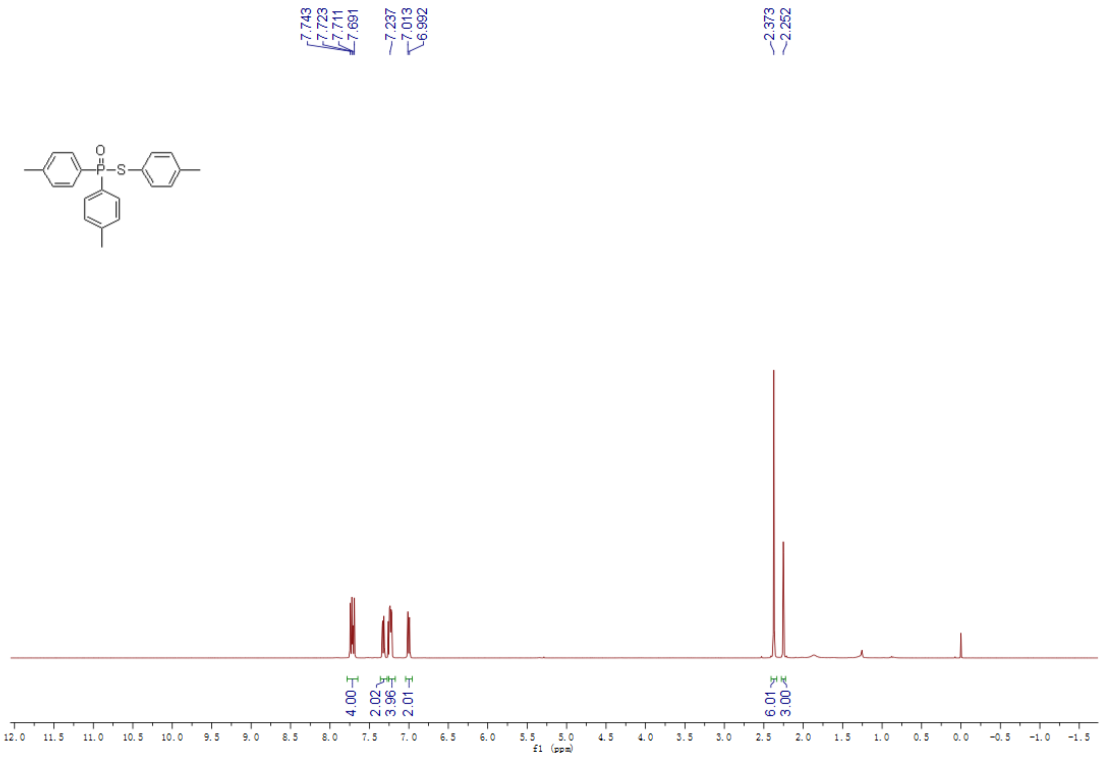

134.019
132.954
132.246
132.216
131.536
131.432
128.707
128.577
30.729
30.268
30.219
29.284
29.261
22.037
13.866
Ph
P
O
S
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

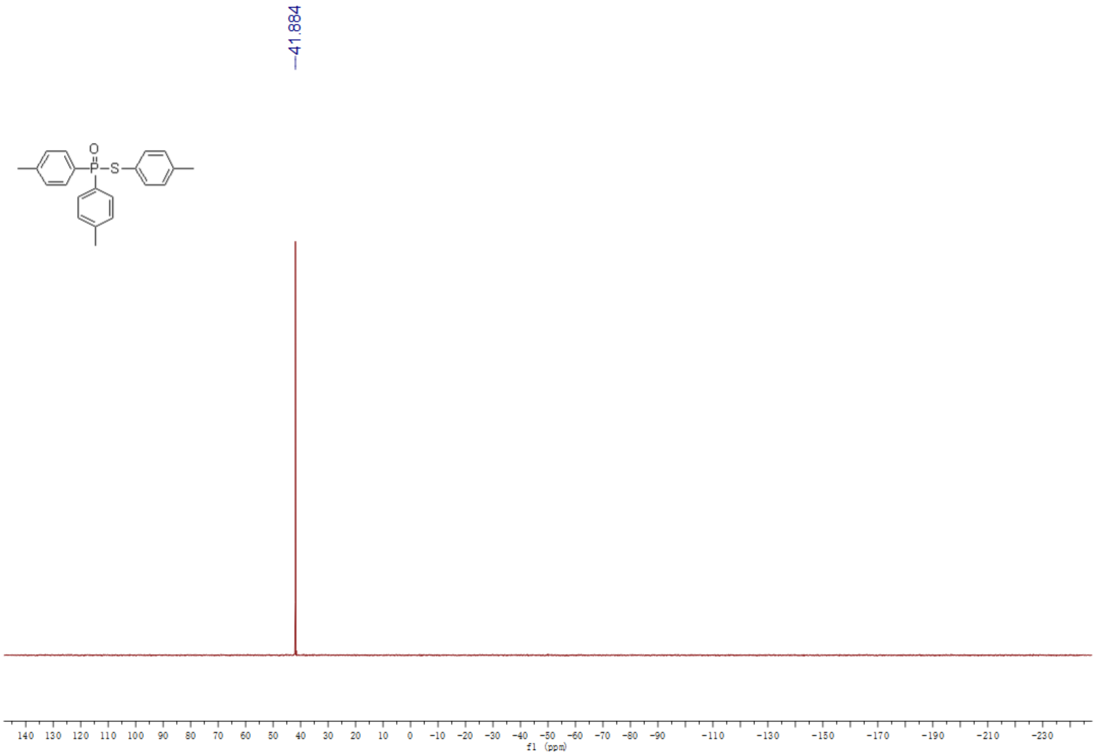

43.114
Ph
P
O
S
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

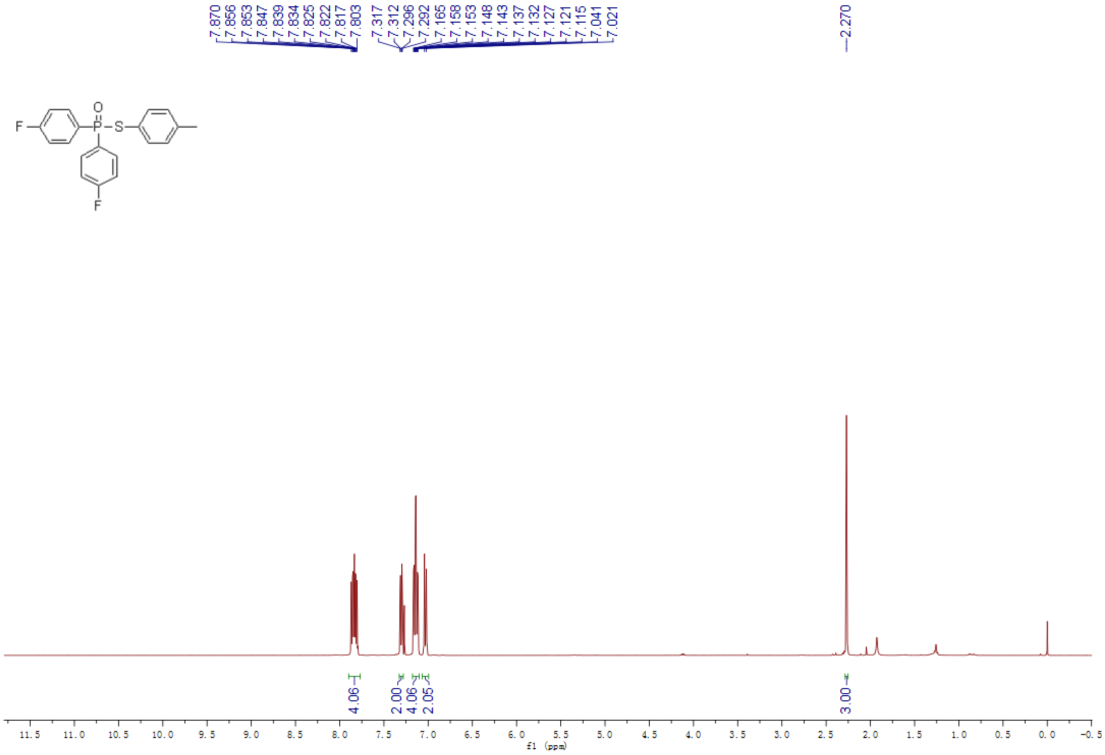

7.909
7.906
7.902
7.894
7.889
7.885
7.876
7.873
7.869
7.861
7.856
7.852
7.568
7.557
7.549
7.522
7.513
7.507
7.498
7.490
7.482
7.473
3.629
3.602
3.537
Ph
P
O
S
Ph
O
O
4.01
2.03
4.08
2.05
3.00
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5
f1 (ppm)

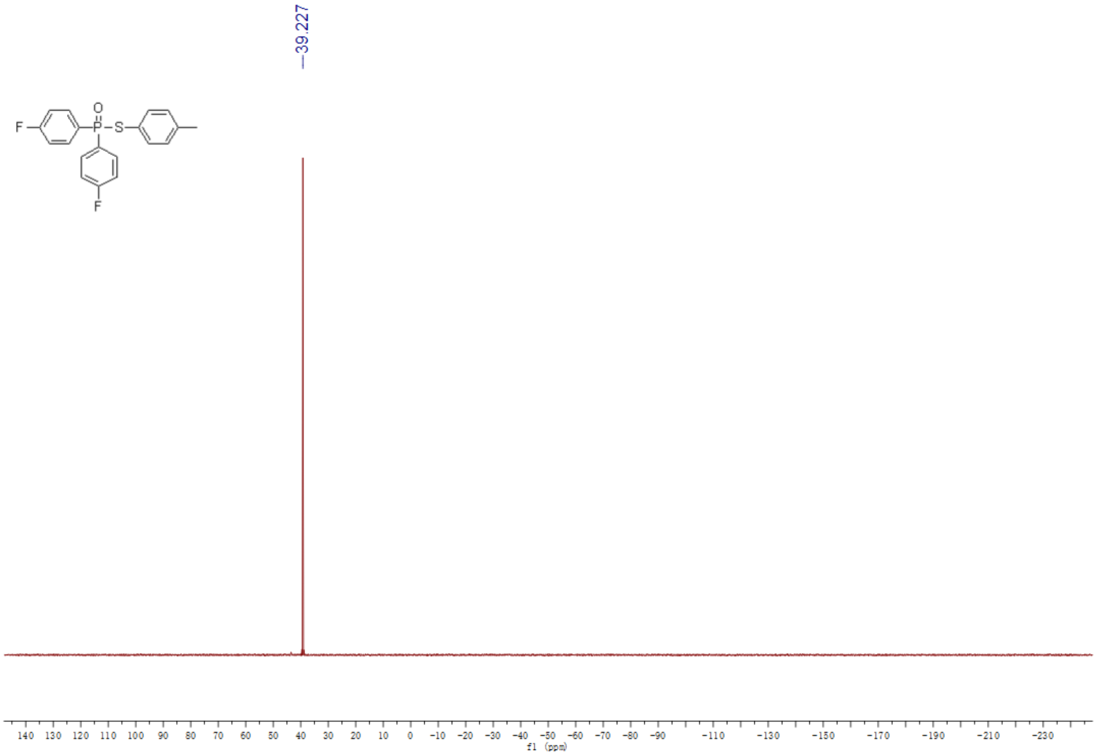

169.116
169.071
132.803
132.725
132.695
131.732
131.642
131.535
128.852
128.720
77.444
77.126
76.808
52.677
30.092
Ph
P
O
S
Ph
O
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

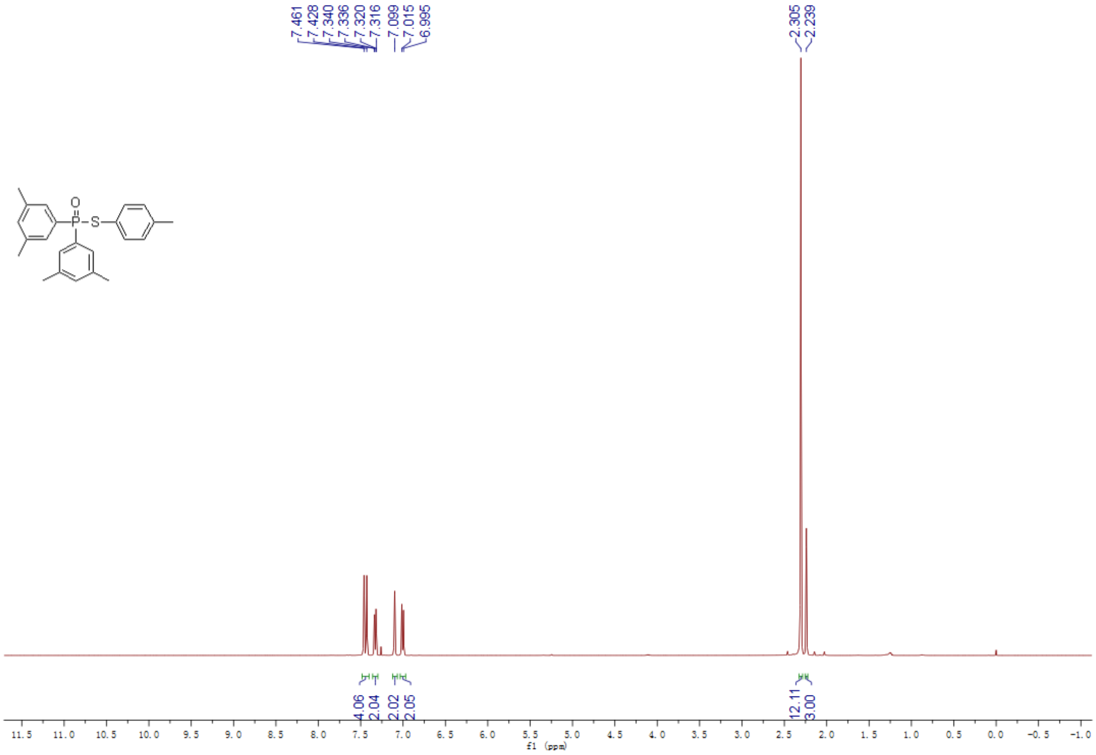

42.982
Ph–P(=O)(Ph)–S–CH2–C(=O)–O–CH3
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

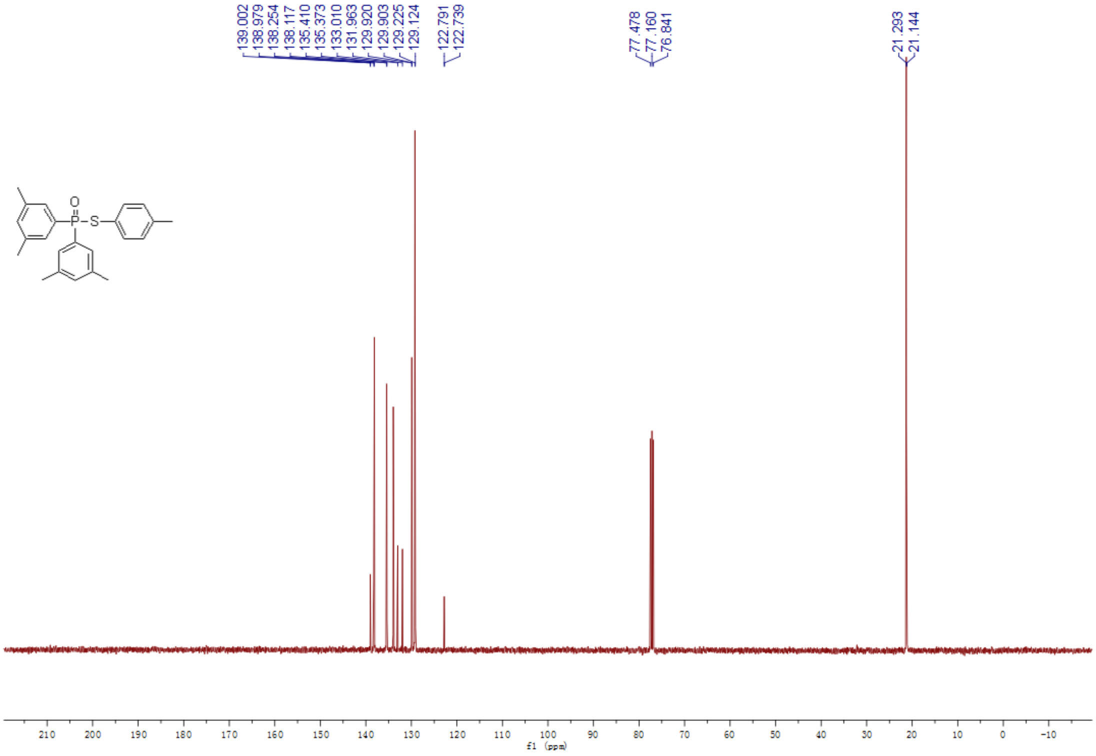

7.743
7.723
7.711
7.691
7.237
7.013
6.992
2.373
2.252
O
P
S
4.00
2.02
3.96
2.01
6.01
3.00
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0 −1.5
f1 (ppm)

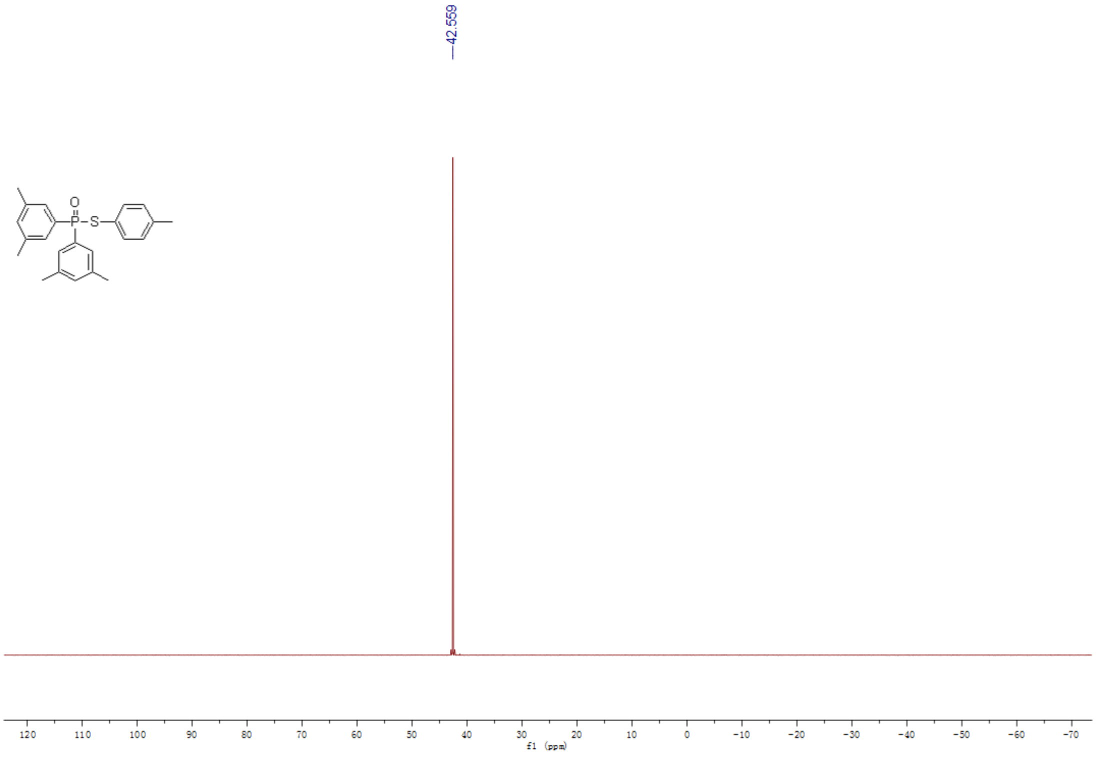

41.884
O
P
S
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

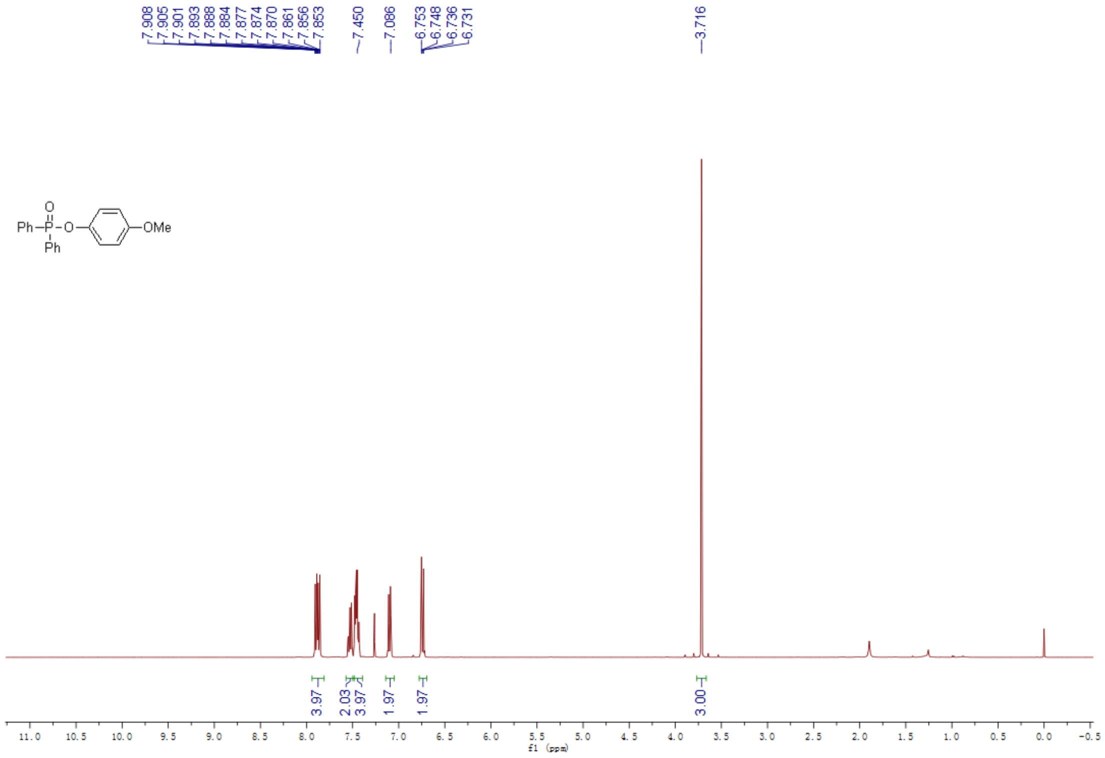

7.870
7.856
7.853
7.847
7.839
7.834
7.825
7.822
7.817
7.803
7.317
7.312
7.296
7.292
7.165
7.158
7.153
7.148
7.143
7.137
7.132
7.127
7.121
7.115
7.041
7.021
2.270
F
O
P
S
F
4.06
2.00
4.06
2.05
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

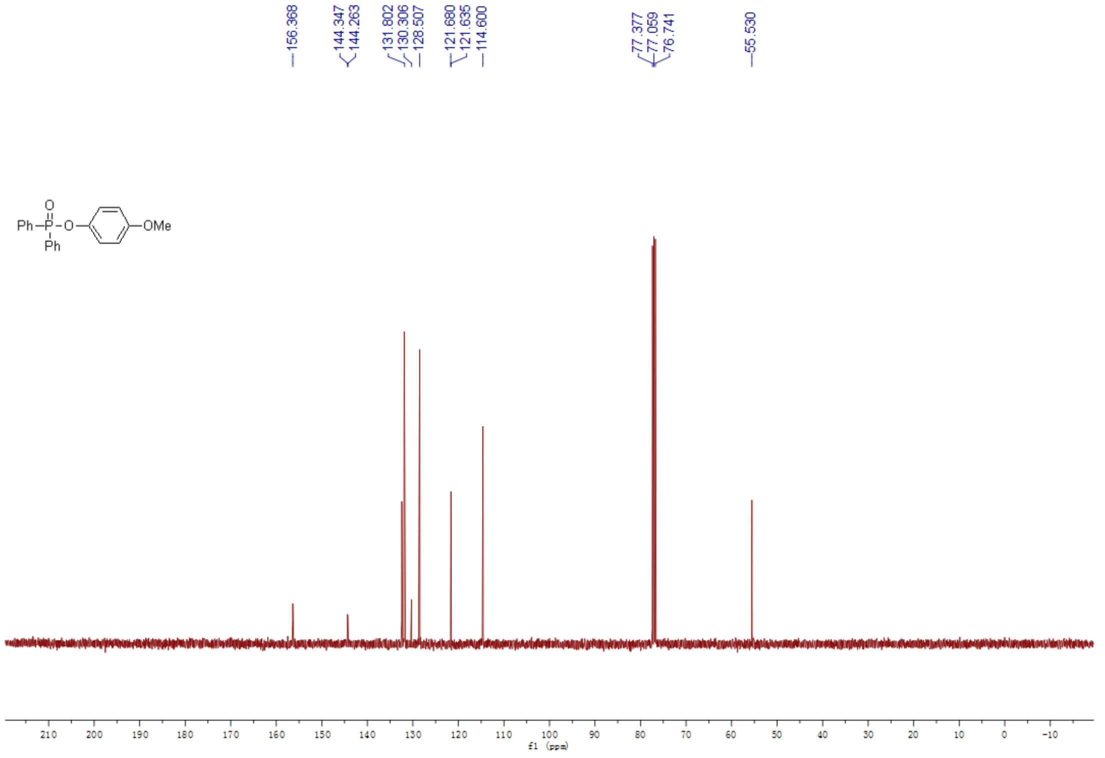

39.227
F
O
P
S
F
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

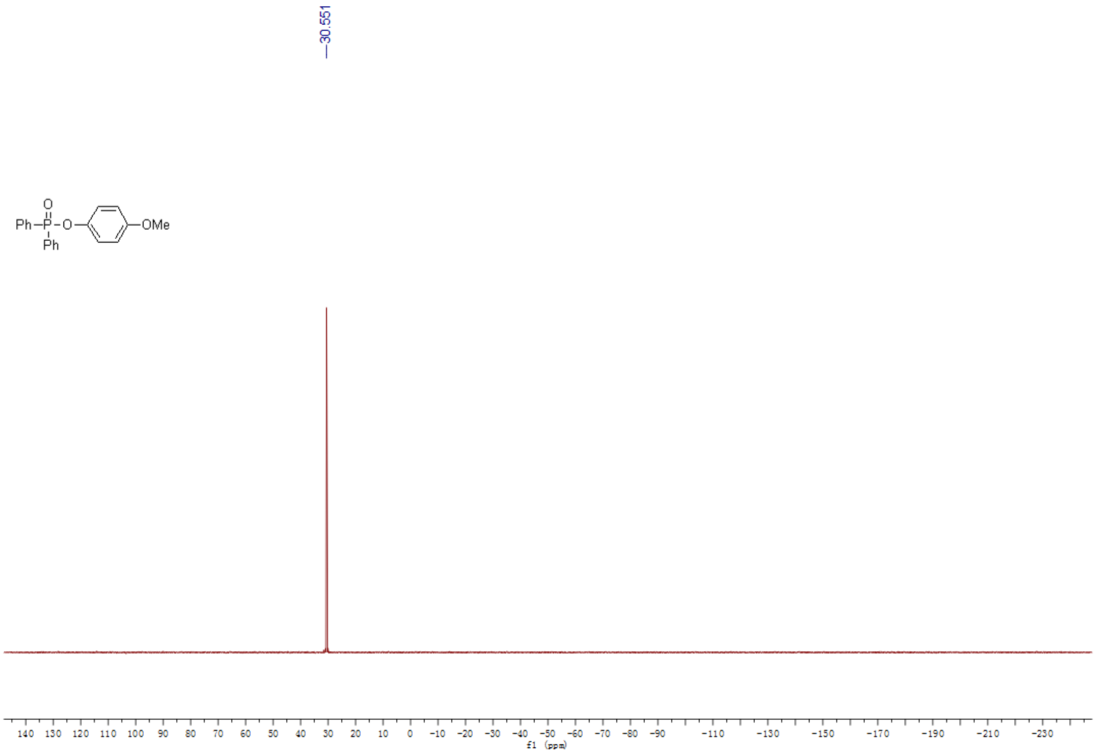

7.461
7.428
7.340
7.336
7.320
7.316
7.099
7.015
6.995
2.305
2.239
O
P
S
4.06
2.04
2.02
2.05
12.11
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)

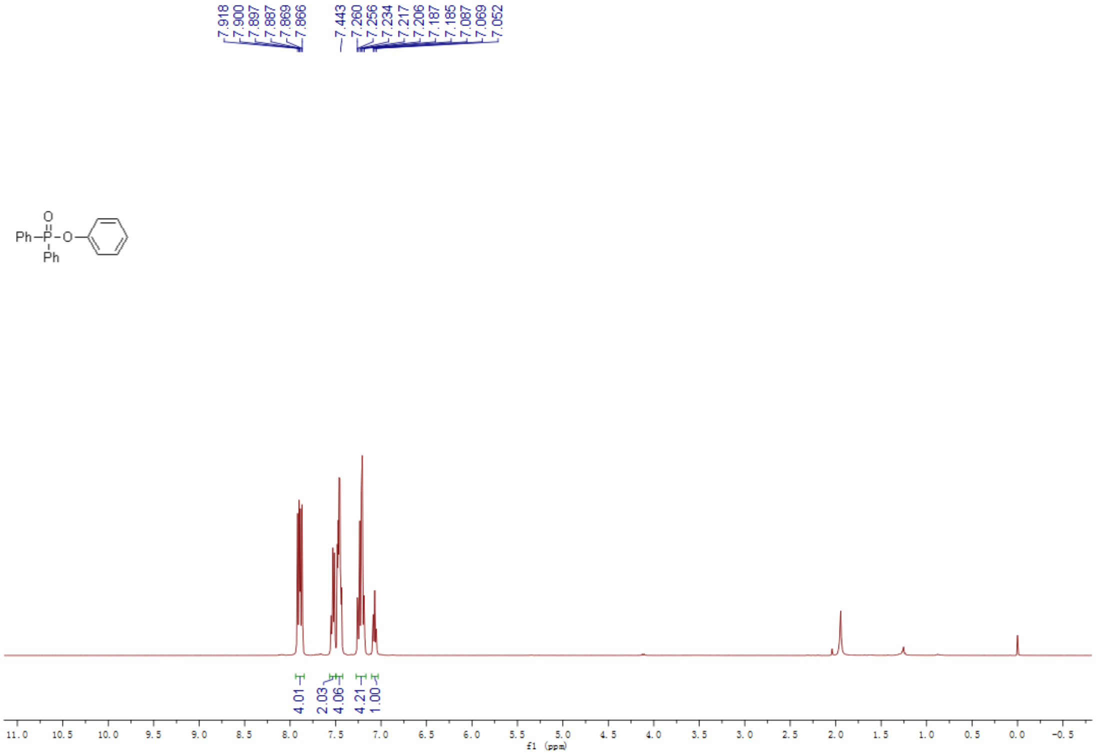

139.002
138.979
138.254
138.117
135.410
135.373
133.010
131.963
129.920
129.903
129.225
129.124
122.791
122.739
77.478
77.160
76.841
21.293
21.144
O
P
S
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

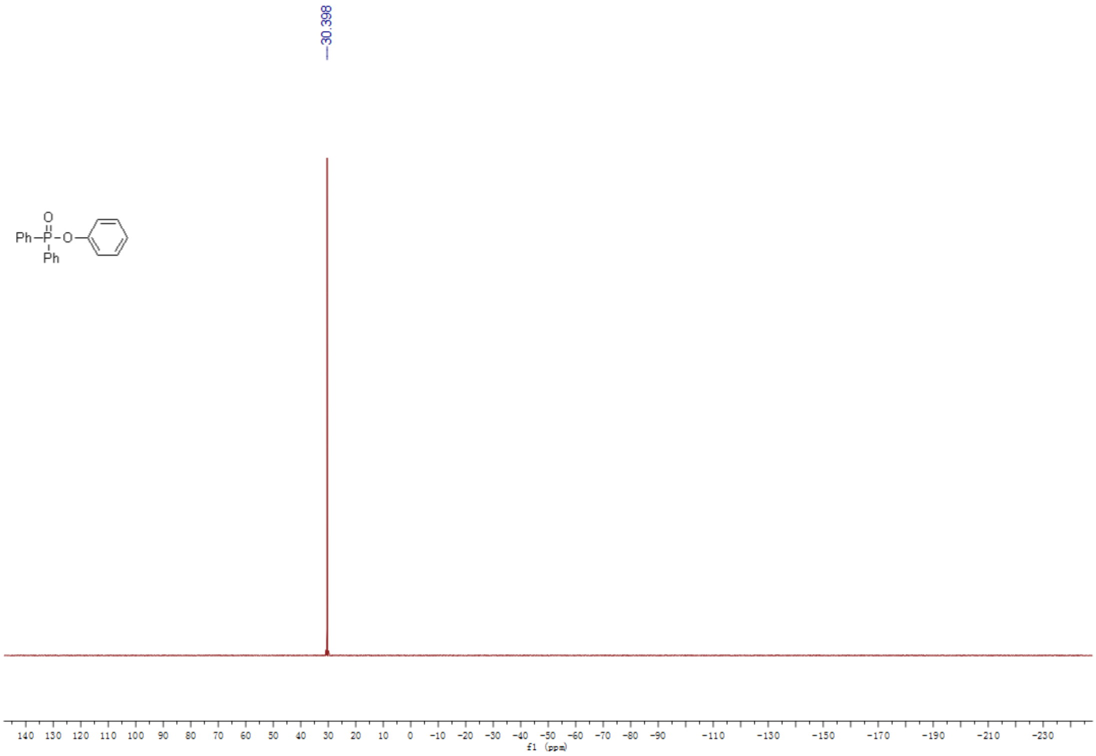

42.559
O
P
S
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
f1 (ppm)

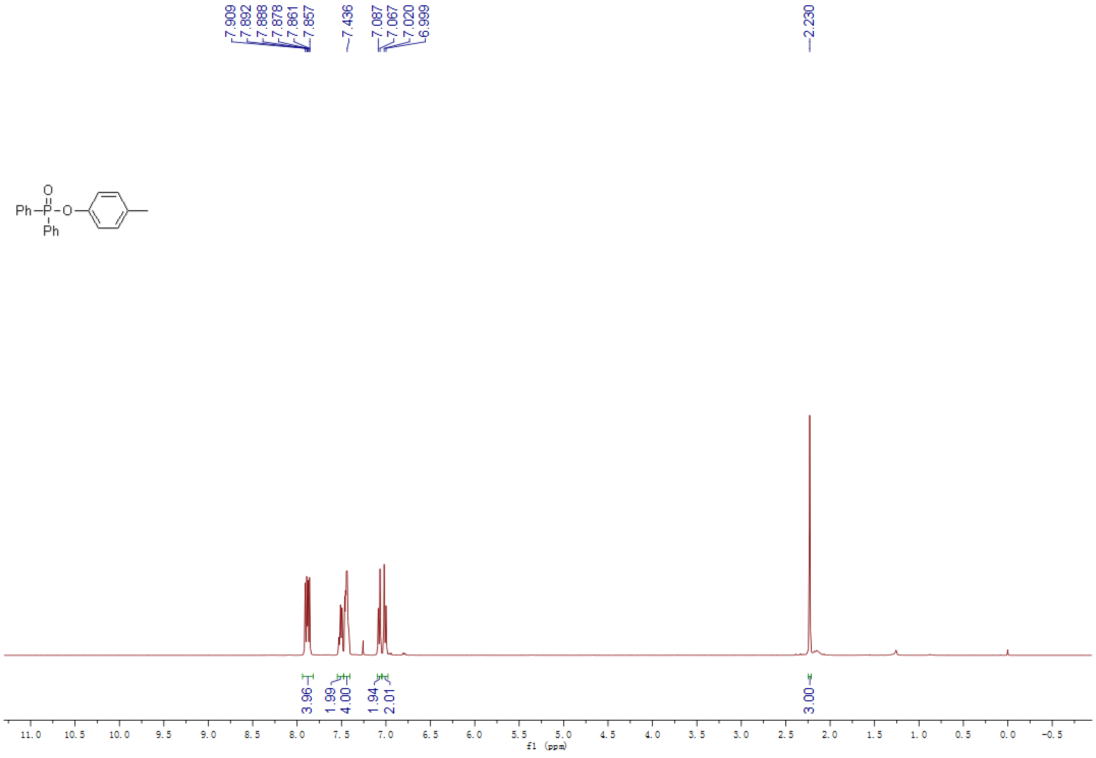

7.908
7.905
7.901
7.893
7.888
7.884
7.877
7.874
7.870
7.861
7.856
7.853
7.450
7.086
6.753
6.748
6.736
6.731
3.716
Ph–P(=O)–O–C6H4–OMe
Ph
3.97
2.03
3.97
1.97
1.97
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

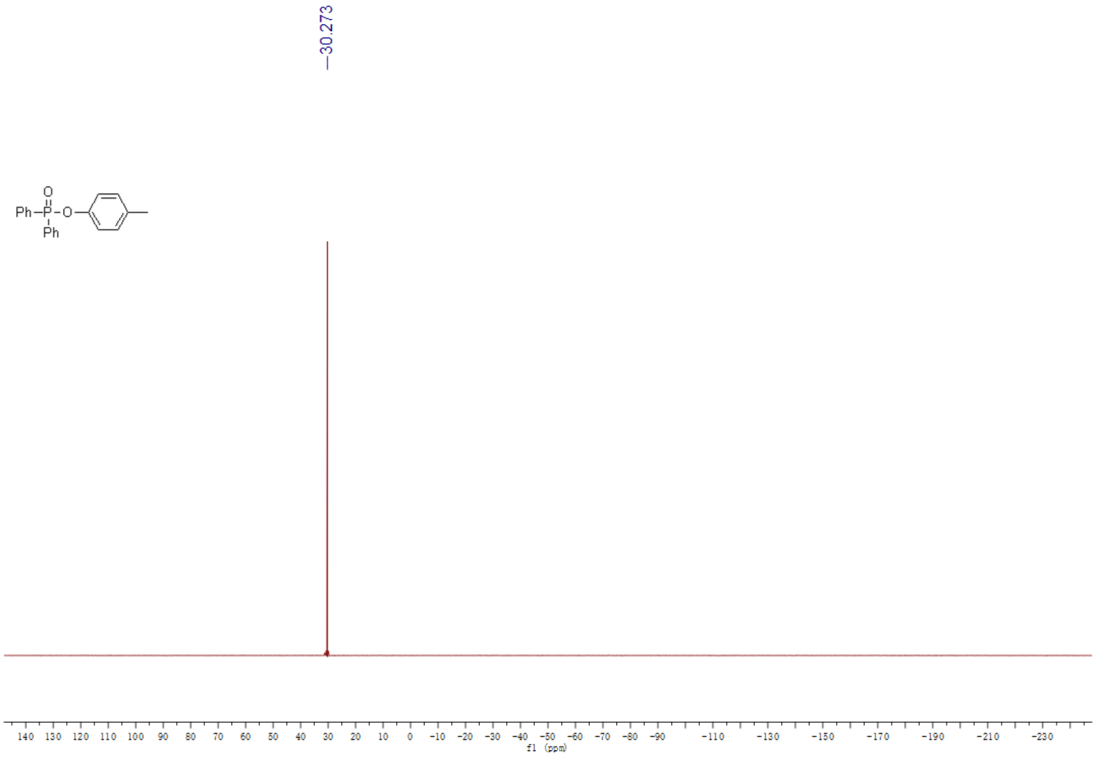

156.368
144.347
144.263
131.802
130.306
128.507
121.680
121.635
114.600
77.377
77.059
76.741
55.530
Ph–P(=O)–O–C6H4–OMe
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

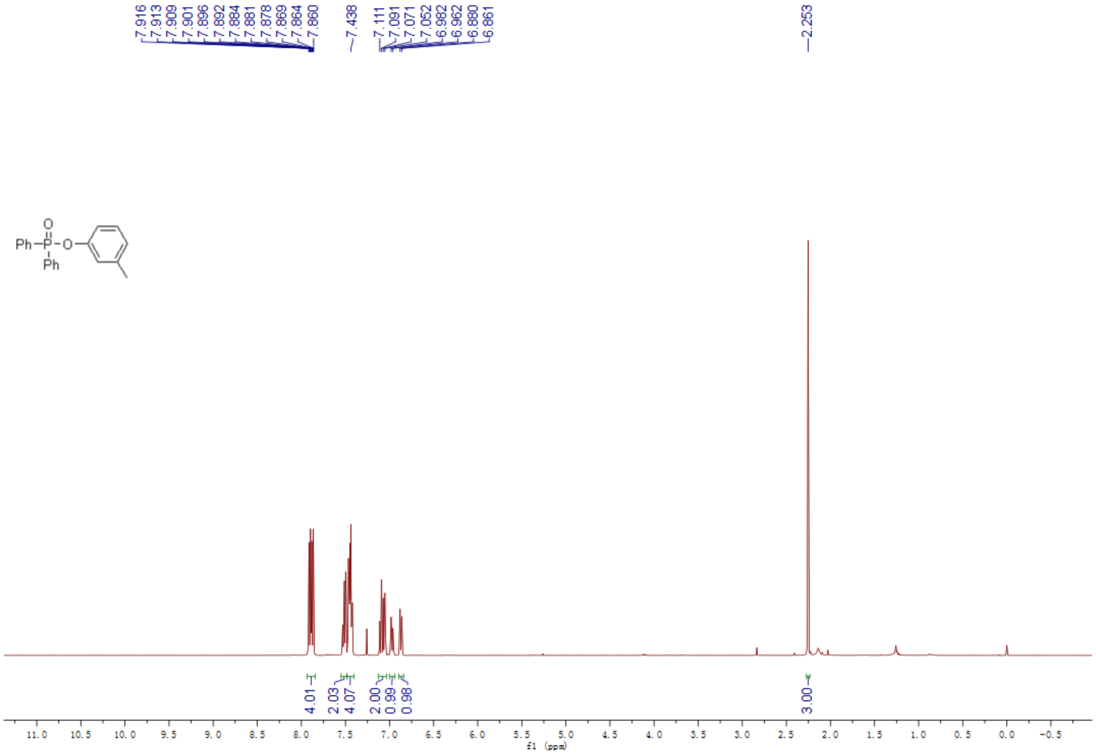

30.551
Ph–P(=O)(Ph)–O–C6H4–OMe
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

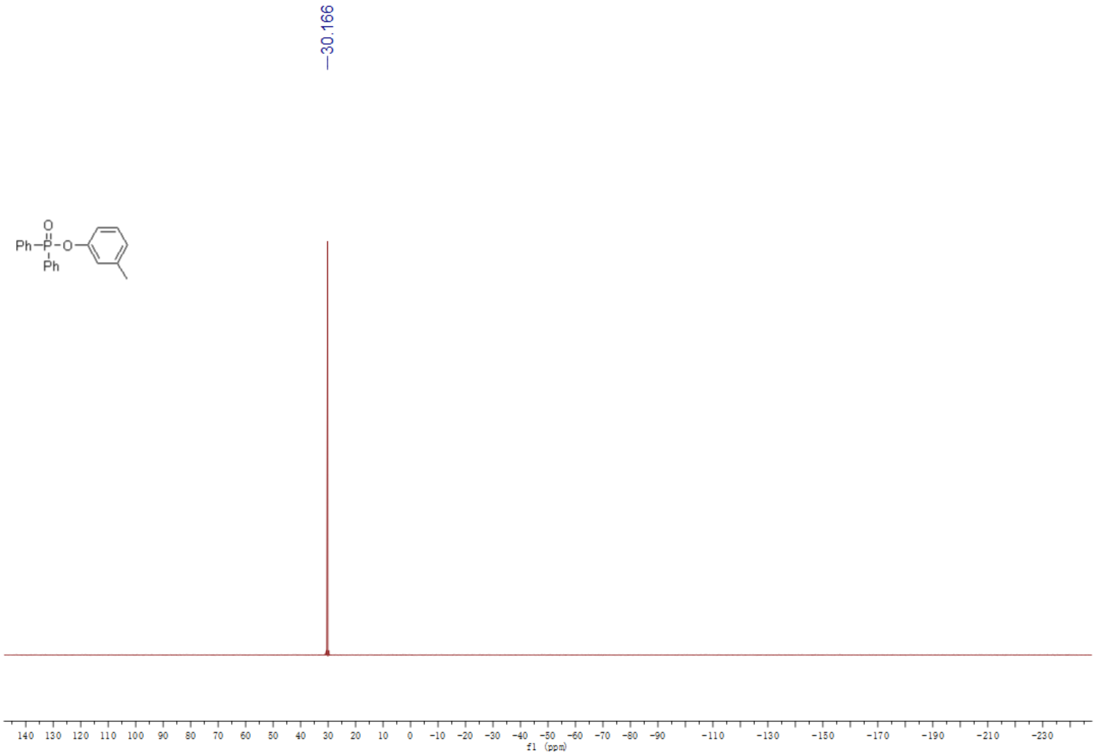

7.918
7.900
7.897
7.887
7.869
7.866
7.443
7.260
7.256
7.234
7.217
7.206
7.187
7.185
7.087
7.069
7.052
Ph–P(=O)(Ph)–O–Ph
4.01
2.03
4.06
4.21
1.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

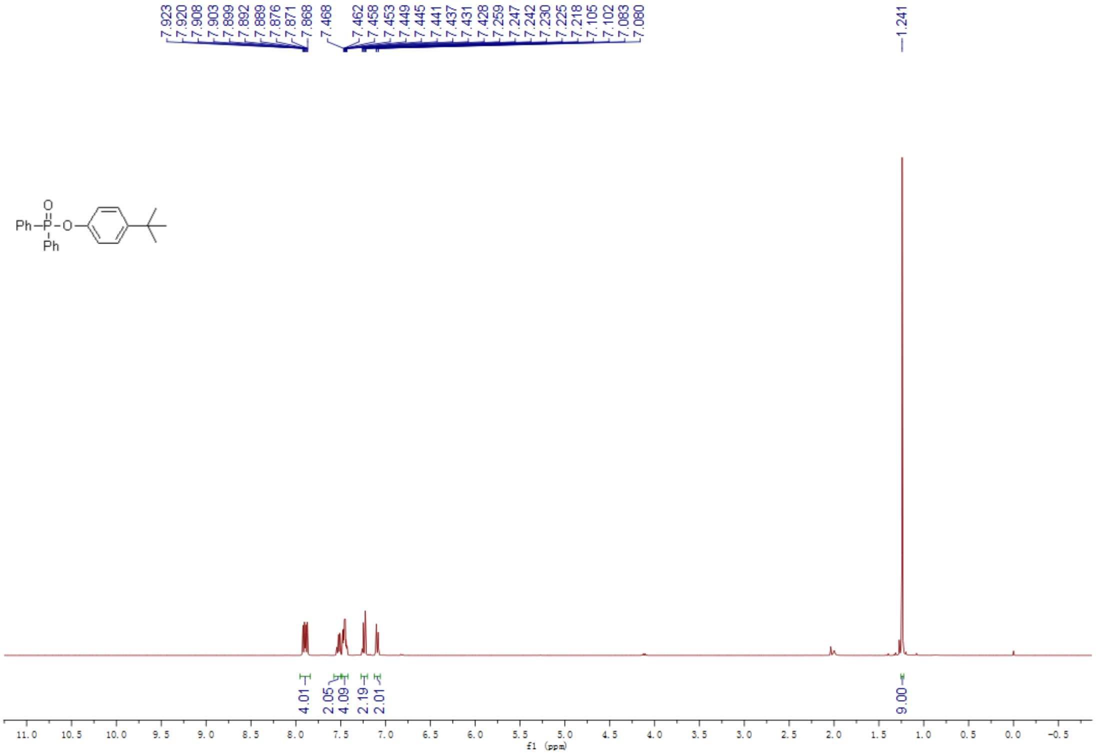

30.398
Ph
O
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

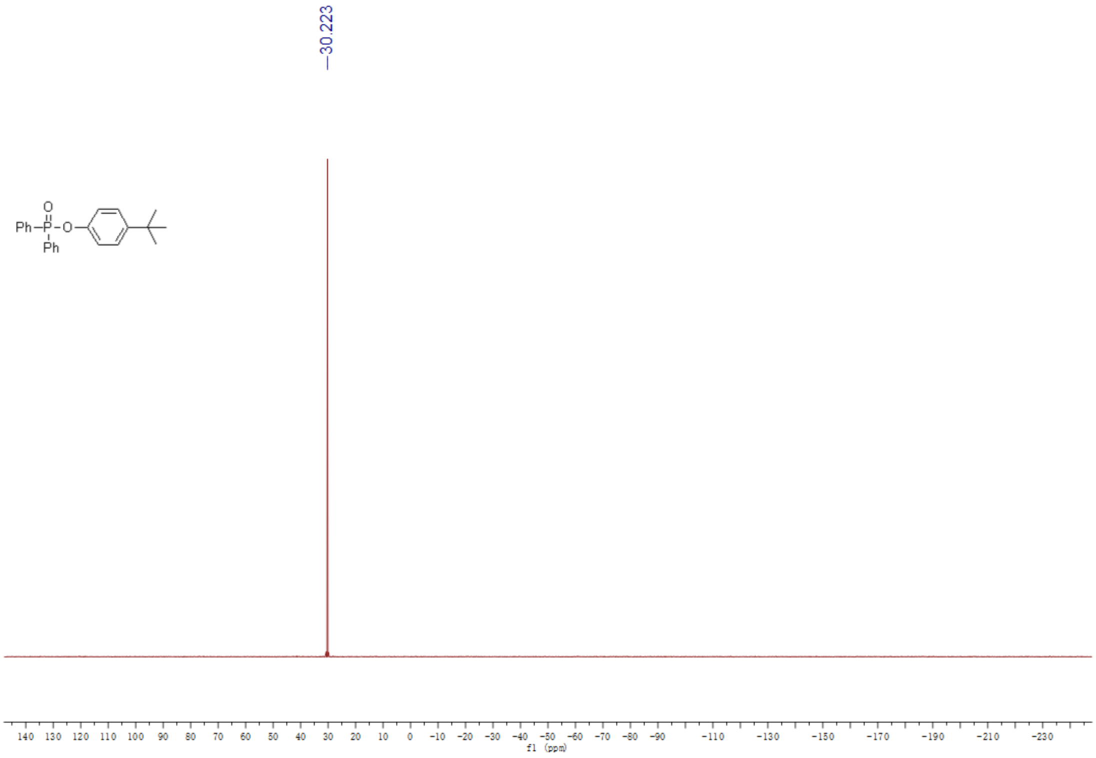

7.909
7.892
7.888
7.878
7.861
7.857
7.436
7.087
7.067
7.020
6.999
2.230
Ph
O
P
O
Ph
3.96
1.99
4.00
1.94
2.01
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

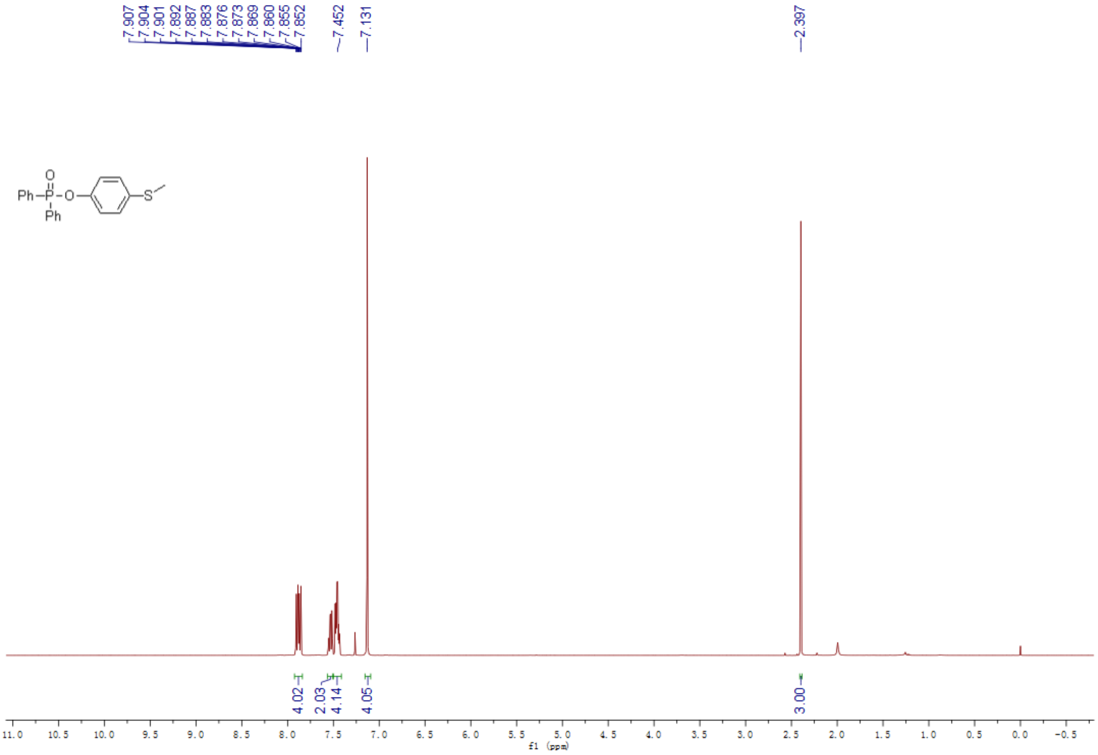

30.273
Ph
O
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

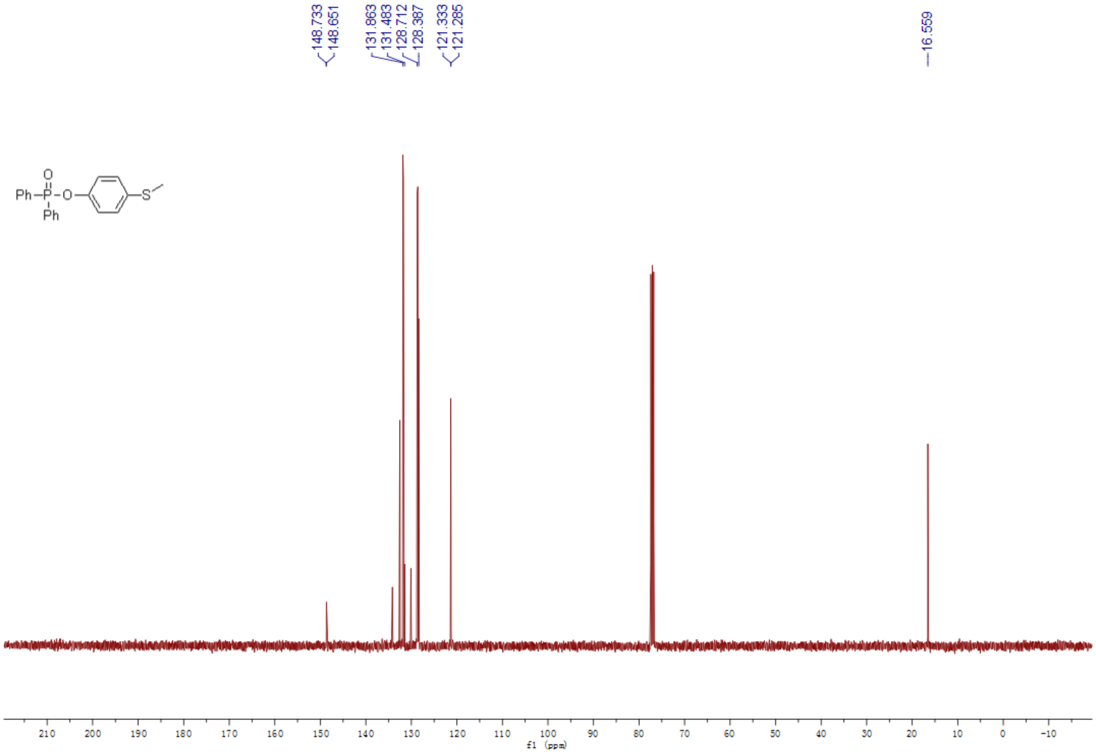

7.916
7.913
7.909
7.901
7.896
7.892
7.884
7.881
7.878
7.869
7.864
7.860
7.438
7.111
7.091
7.071
7.052
6.982
6.962
6.880
6.861
2.253
Ph
O
P
O
Ph
4.01
2.03
4.07
2.00
0.99
0.98
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

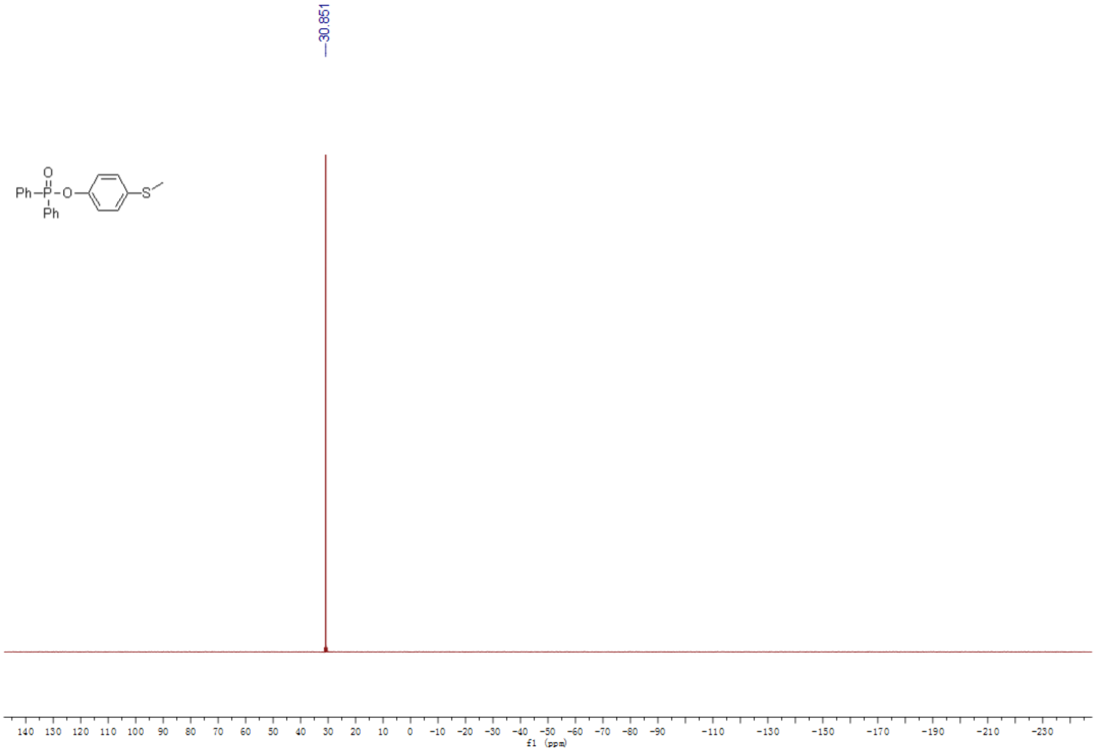

30.166
O
Ph
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

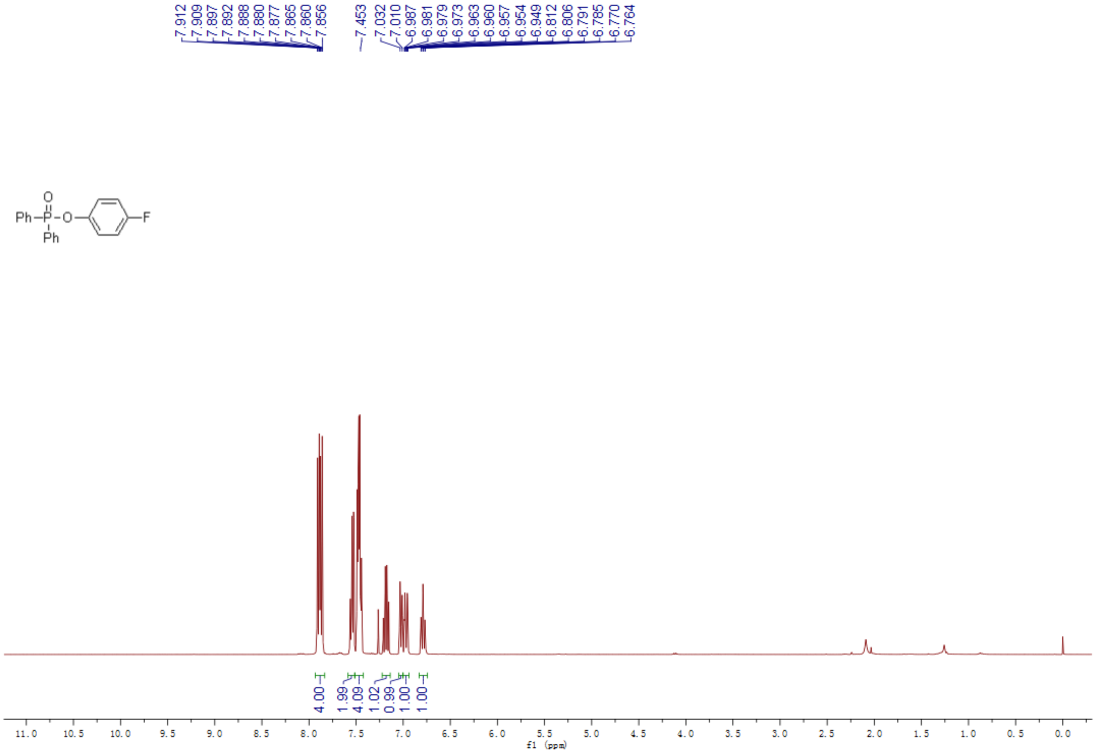

7.923
7.920
7.908
7.903
7.899
7.892
7.889
7.876
7.871
7.868
7.468
7.462
7.458
7.453
7.449
7.445
7.441
7.437
7.431
7.428
7.259
7.247
7.242
7.230
7.225
7.218
7.105
7.102
7.083
7.080
1.241
O
Ph
P
O
Ph
4.01
2.05
4.09
2.19
2.01
9.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

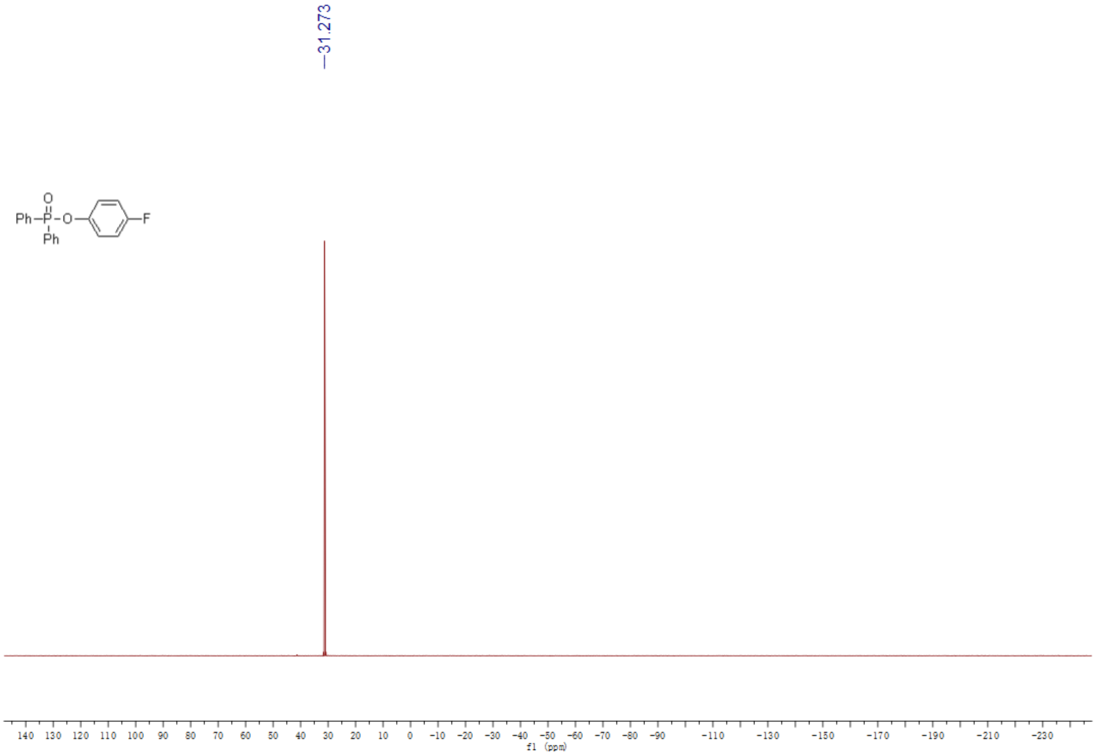

30.223
Ph
O
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

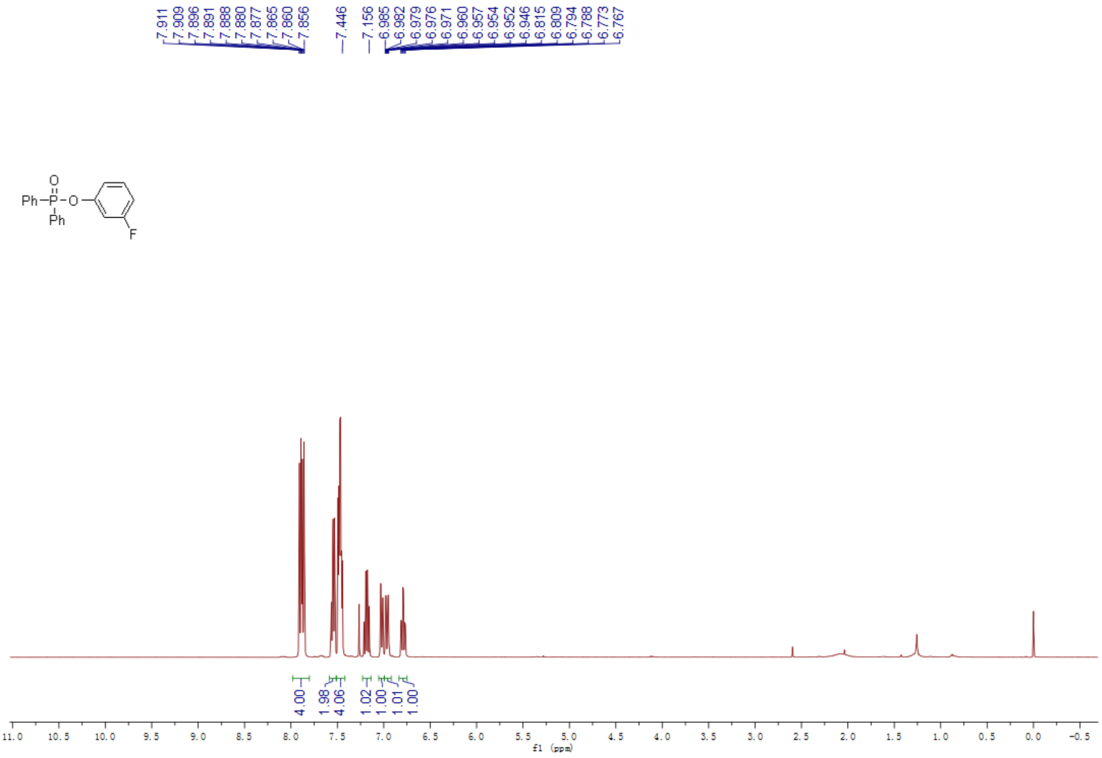

7.907
7.904
7.901
7.892
7.887
7.883
7.876
7.873
7.869
7.860
7.855
7.852
7.452
7.131
2.397
Ph
O
P
O
S
Ph
4.02
2.03
4.14
4.05
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

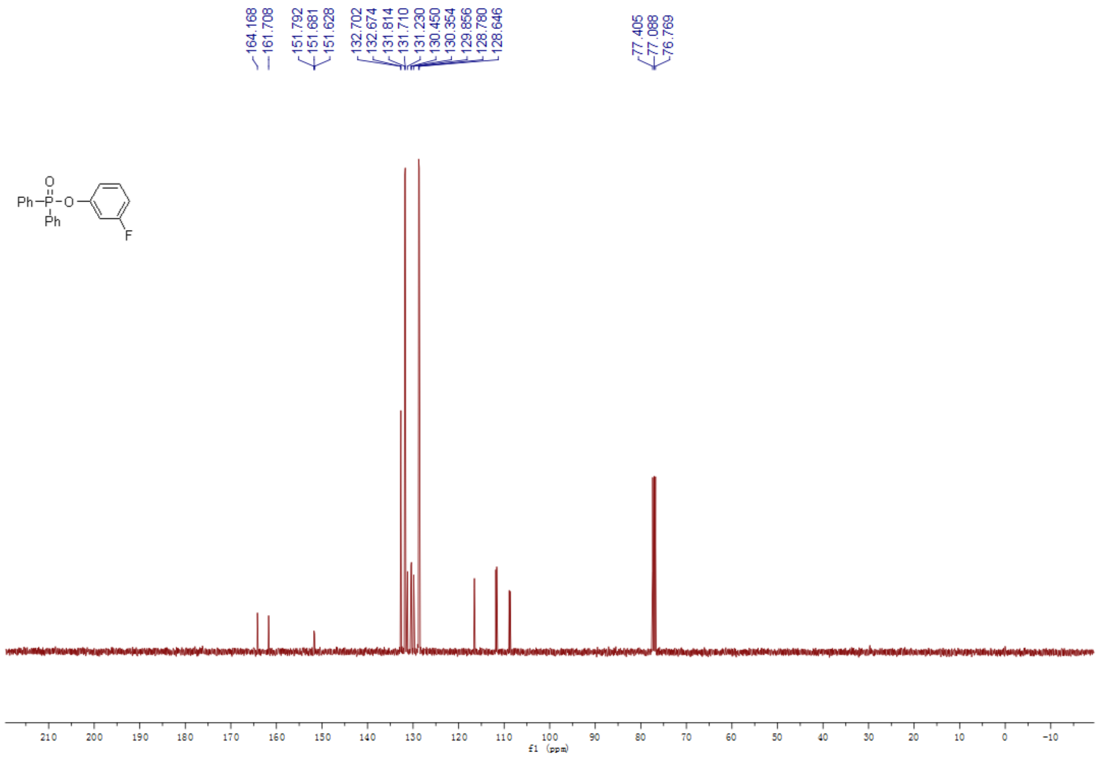

148.733
148.651
131.863
131.483
128.712
128.387
121.333
121.285
16.559
Ph
O
P
O
S
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

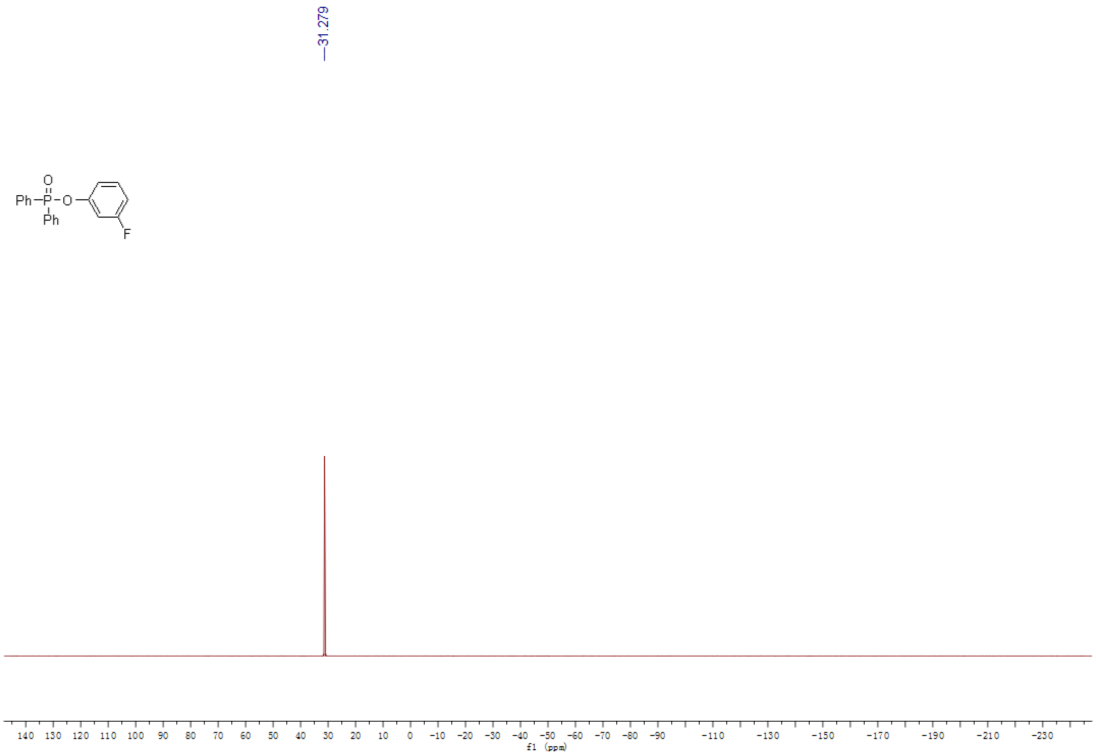

30.851
Ph
O
P
O
S
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

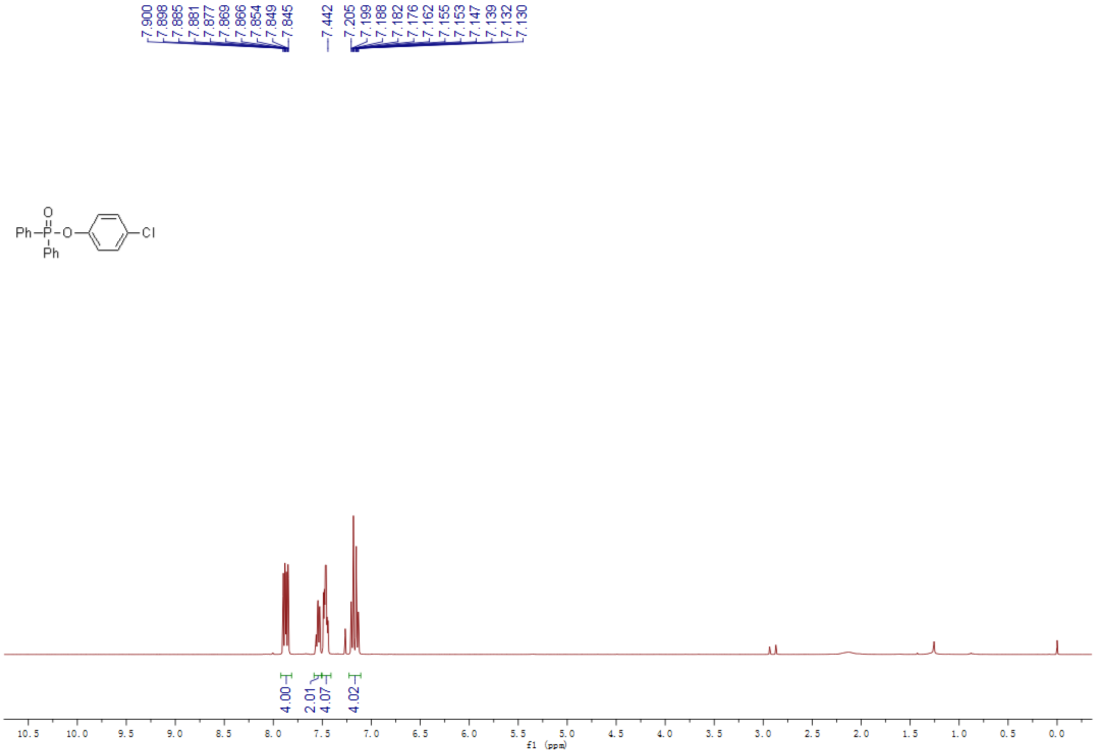

7.912
7.909
7.897
7.892
7.888
7.880
7.877
7.865
7.860
7.856
7.453
7.032
7.010
6.987
6.981
6.979
6.973
6.963
6.960
6.957
6.954
6.949
6.812
6.806
6.791
6.785
6.770
6.764
Ph
O
P
O
F
Ph
4.00
1.99
4.09
1.02
0.99
1.00
1.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

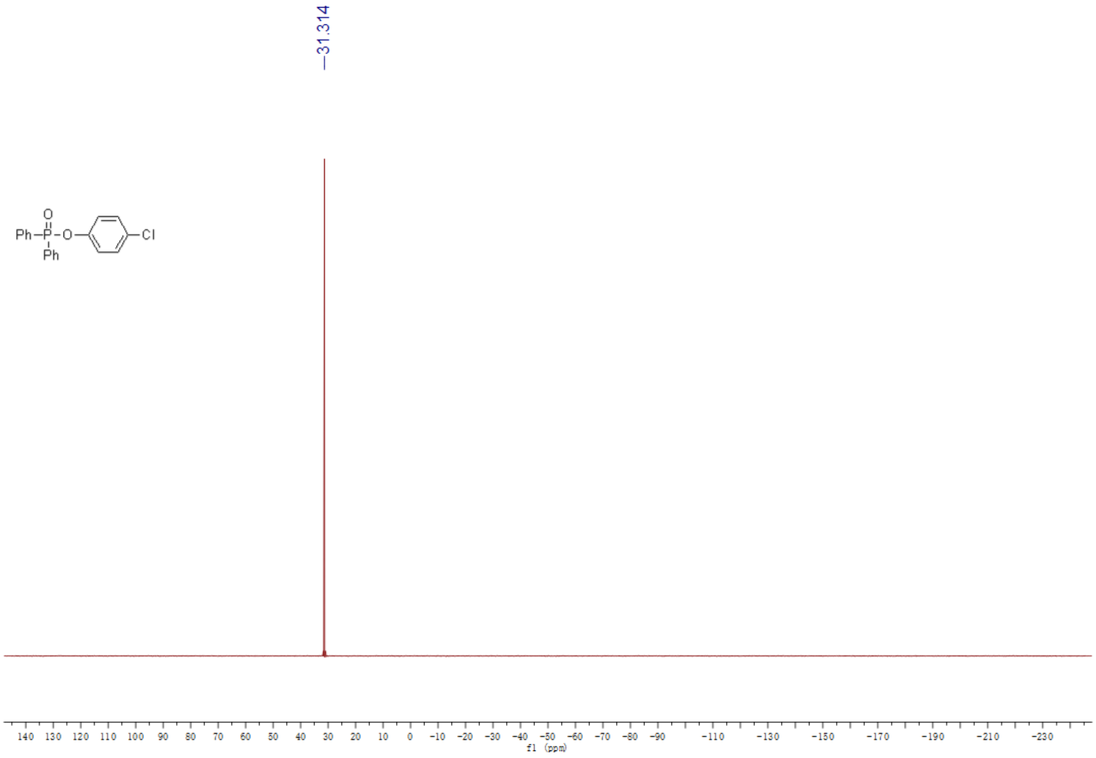

31.273
Ph
O
P
O
F
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


7.911
7.909
7.896
7.891
7.888
7.880
7.877
7.865
7.860
7.856
7.446
7.156
6.985
6.982
6.979
6.976
6.971
6.960
6.957
6.954
6.952
6.946
6.815
6.809
6.794
6.788
6.773
6.767
Ph
O
P
O
Ph
F
4.00
1.98
4.06
1.02
1.00
1.01
1.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
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
-0.5
f1 (ppm)

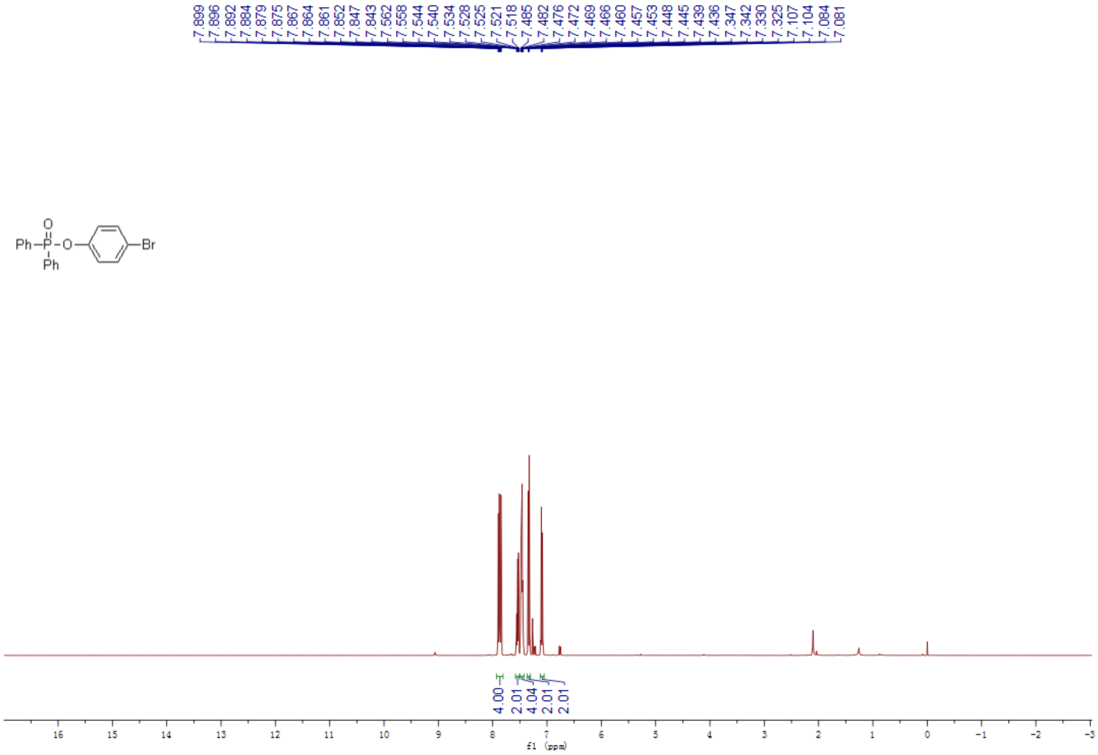

164.168
161.708
151.792
151.681
151.628
132.702
132.674
131.814
131.710
131.230
130.450
130.354
129.856
128.780
128.646
77.405
77.088
76.769
Ph
O
P
O
Ph
F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


31.279
O
Ph
P
O
Ph
F
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

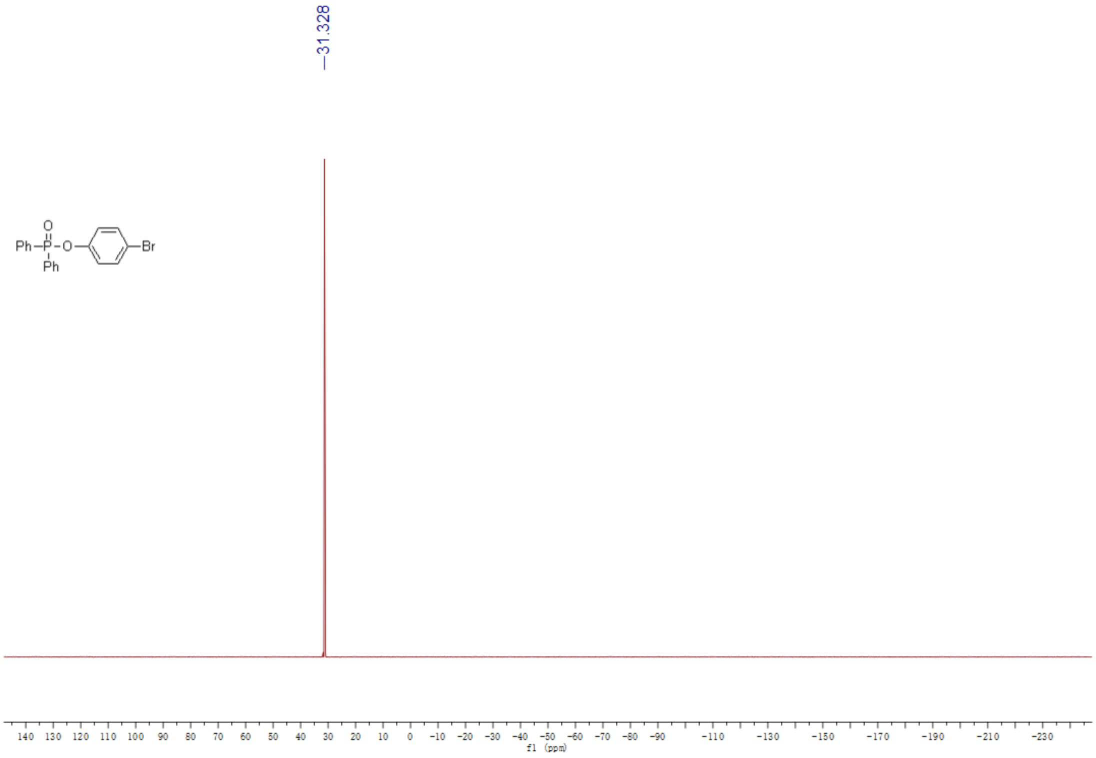

7.900
7.898
7.885
7.881
7.877
7.869
7.866
7.854
7.849
7.845
7.442
7.205
7.199
7.188
7.182
7.176
7.162
7.155
7.153
7.147
7.139
7.132
7.130
O
Ph
P
O
Ph
Cl
4.00
2.01
4.07
4.02
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)



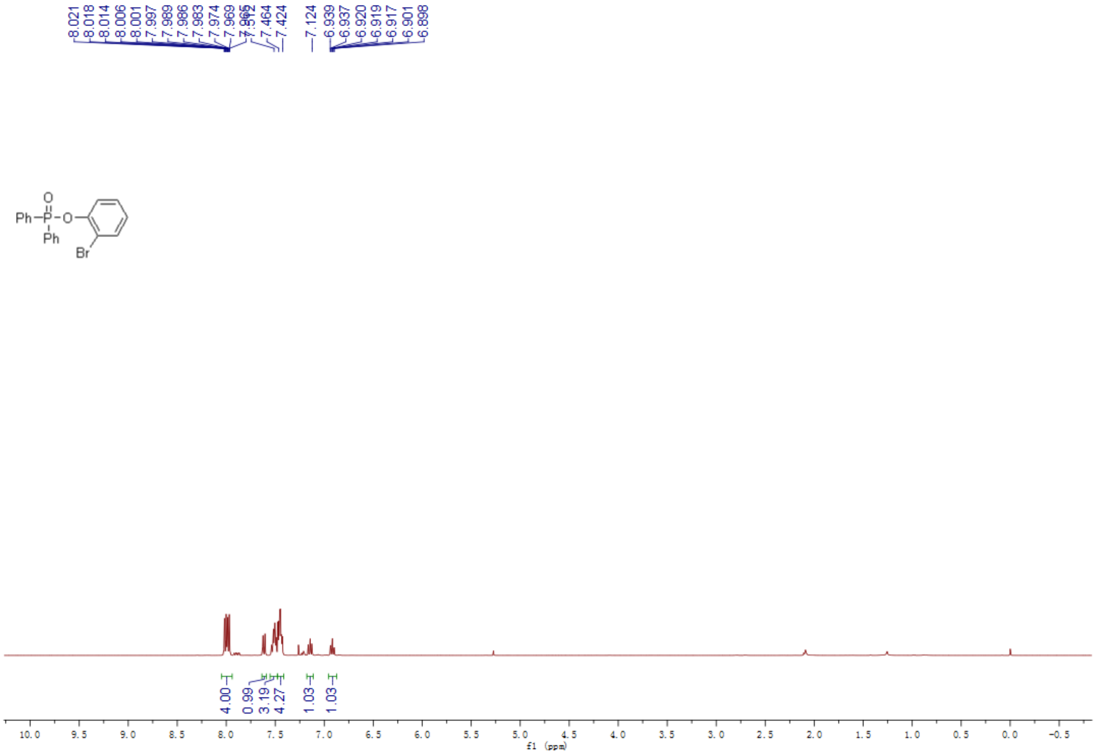
-31.314
Ph
O
P
O
Cl
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)



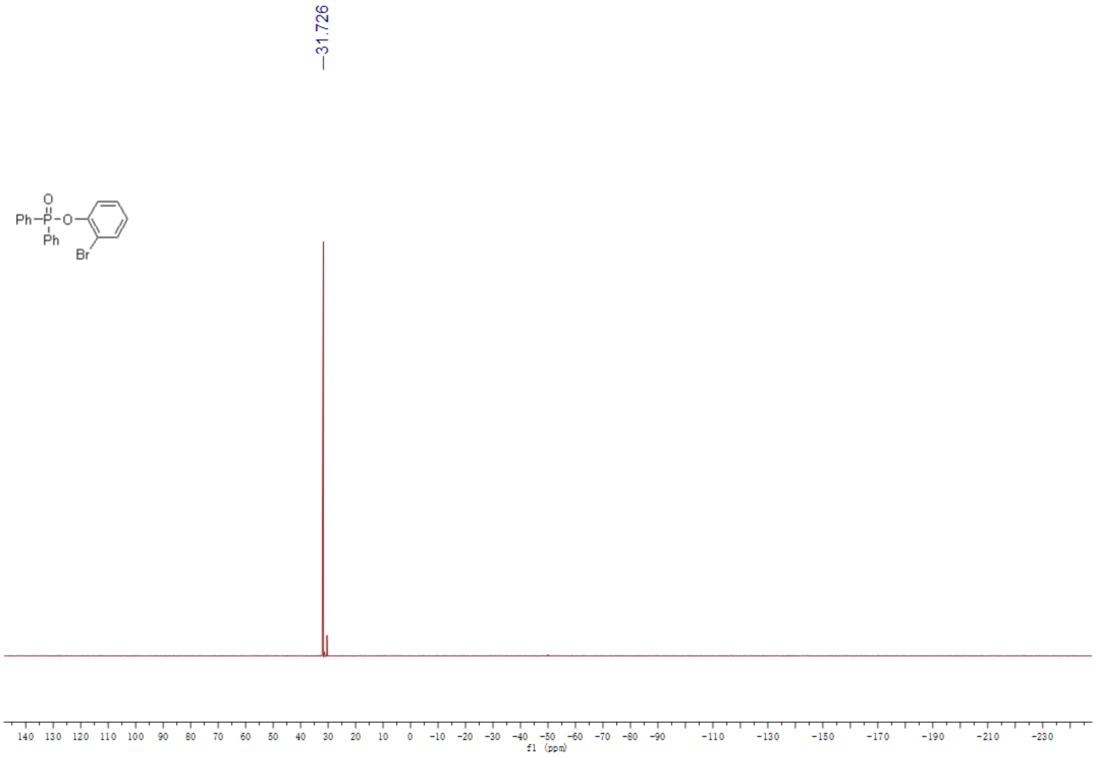
7.899
7.896
7.892
7.884
7.879
7.875
7.867
7.864
7.861
7.852
7.847
7.843
7.562
7.558
7.544
7.540
7.534
7.528
7.525
7.521
7.518
7.485
7.482
7.476
7.472
7.469
7.466
7.460
7.457
7.453
7.448
7.445
7.439
7.436
7.347
7.342
7.330
7.325
7.107
7.104
7.084
7.081
Ph
O
P
O
Br
Ph
4.00
2.01
4.04
2.01
2.01
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

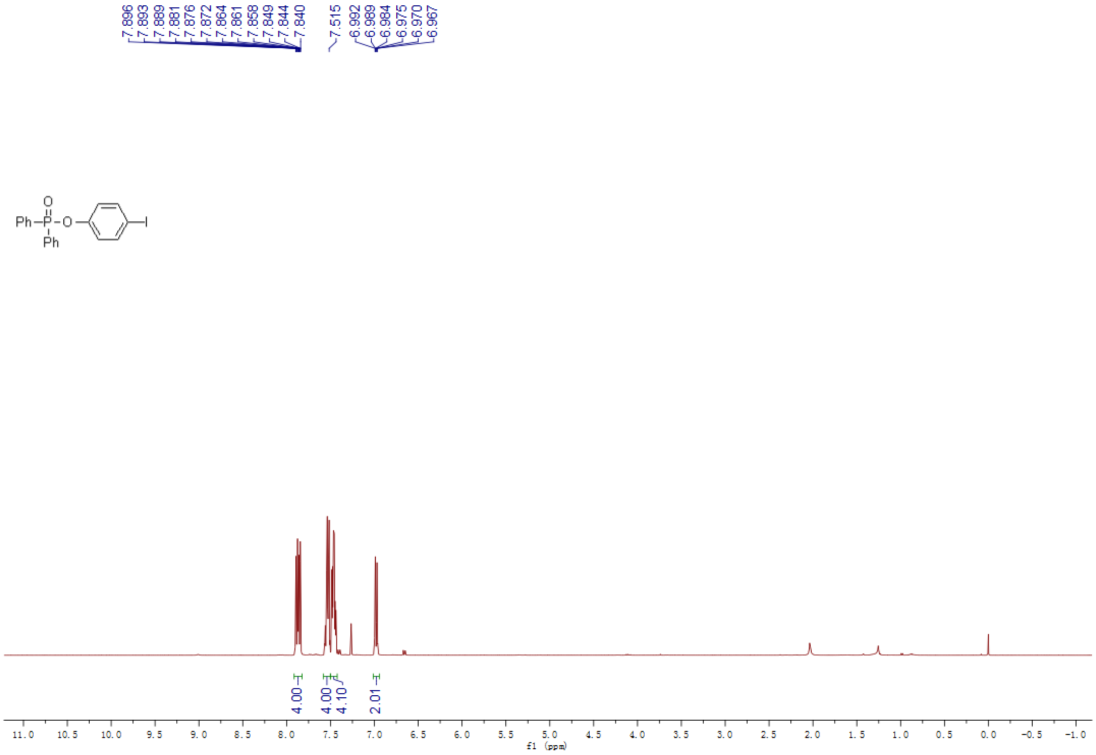


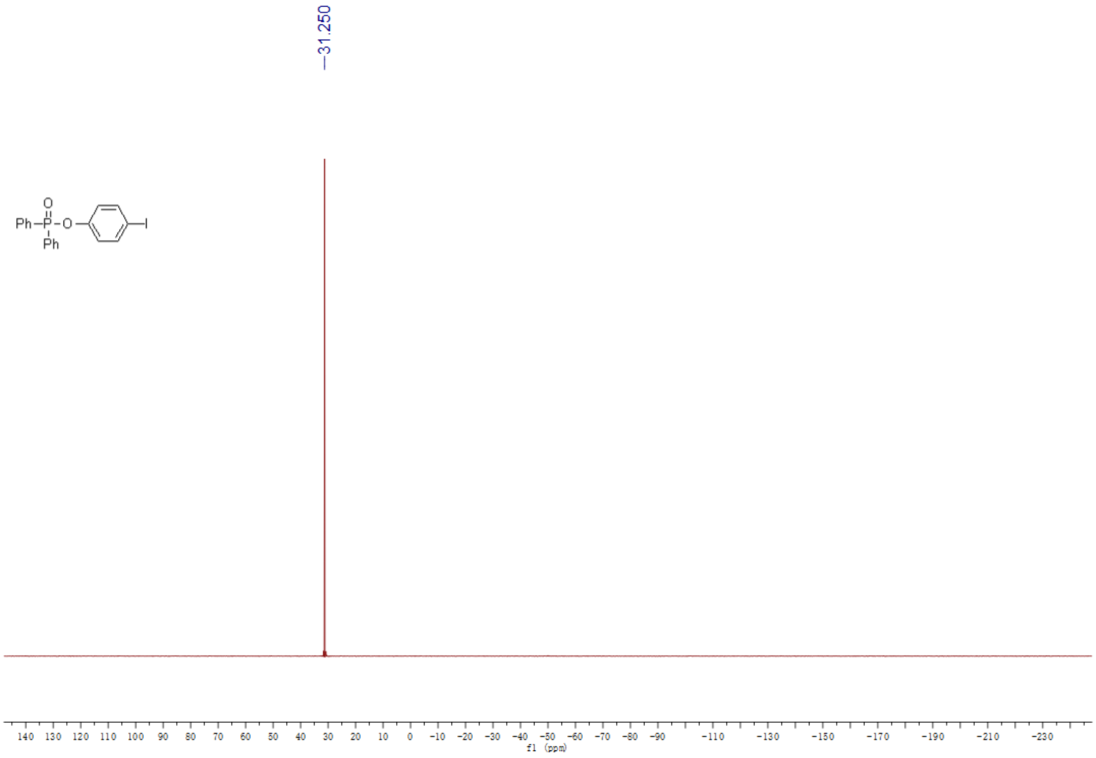
31.328
O
Ph
P
O
Br
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

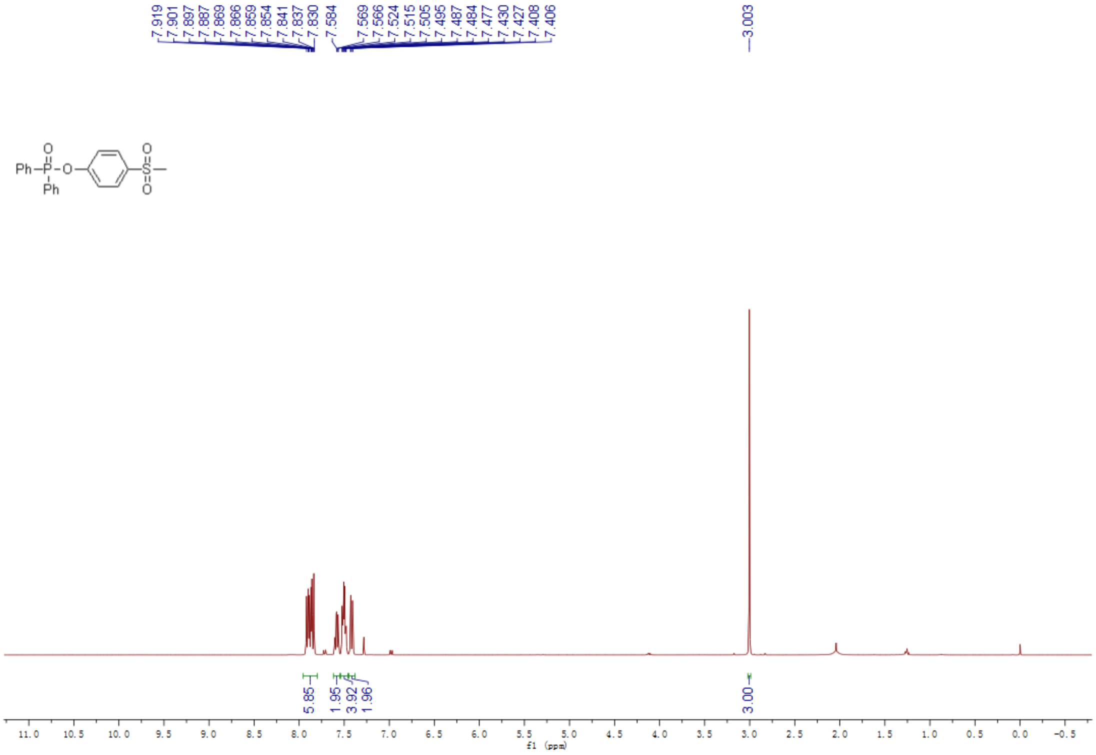


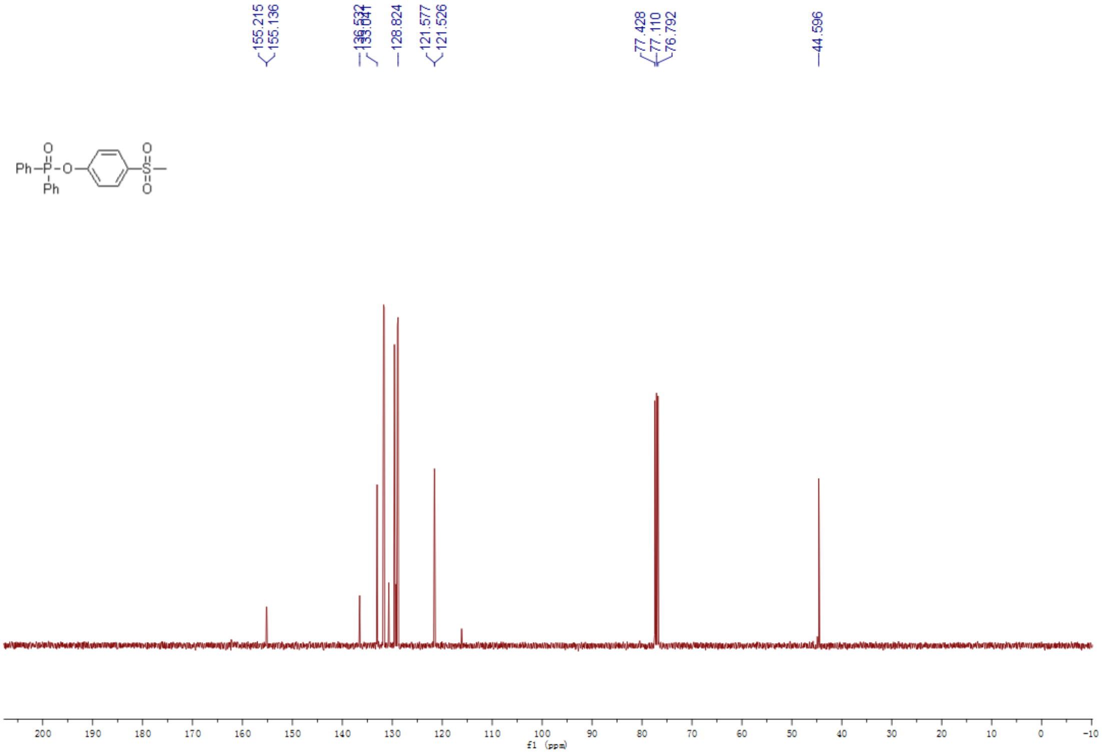
8.021
8.018
8.014
8.006
8.001
7.997
7.989
7.986
7.983
7.974
7.969
7.965
7.512
7.464
7.424
7.124
6.939
6.937
6.920
6.919
6.917
6.901
6.898
O
Ph
P
O
Ph
Br
4.00
0.99
3.19
4.27
1.03
1.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

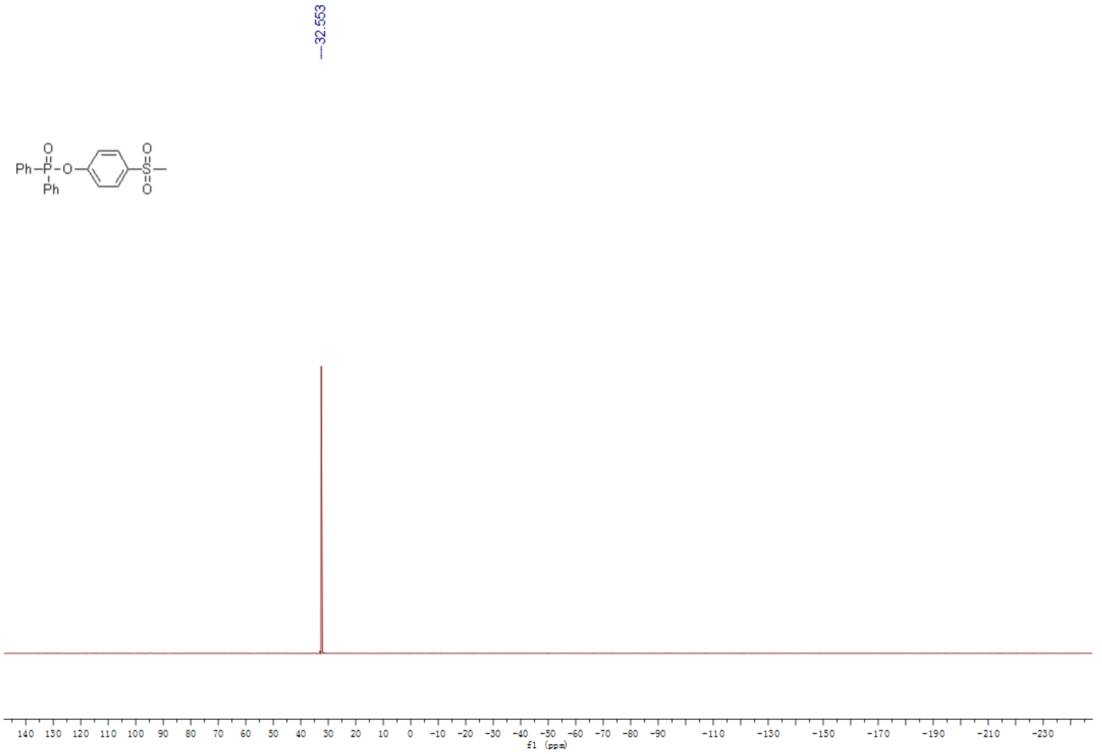

-31.726
Ph
P
O
Ph
O
Br
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

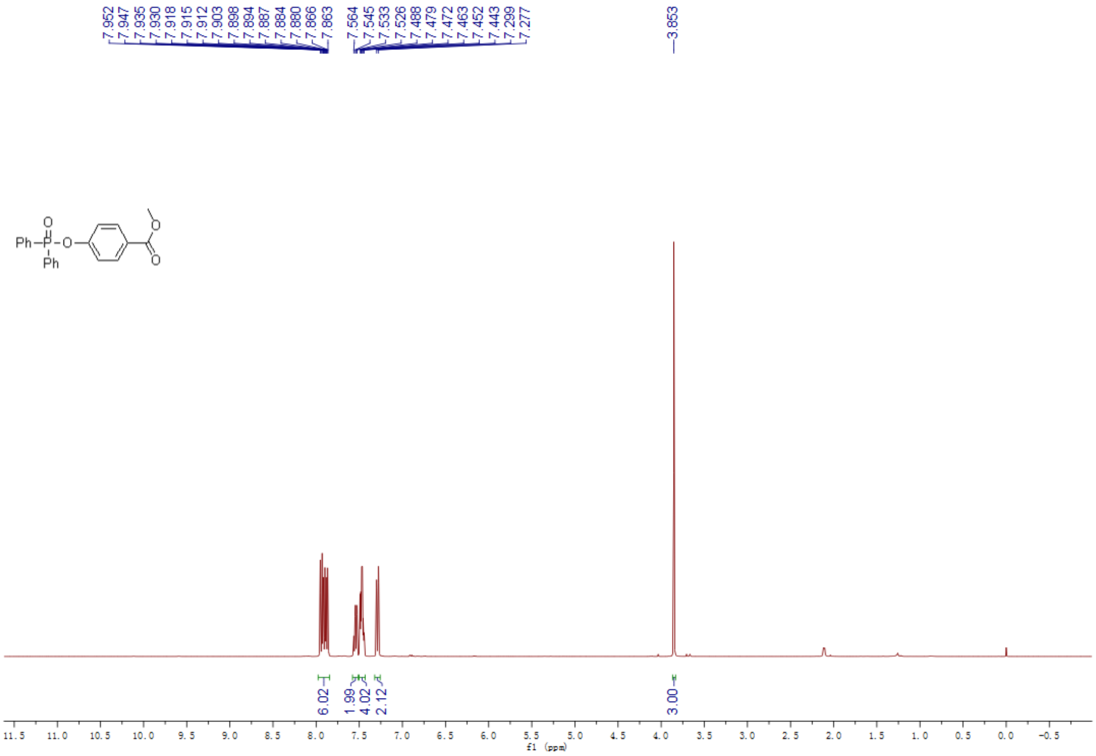

7.896
7.893
7.889
7.881
7.876
7.872
7.864
7.861
7.858
7.849
7.844
7.840
7.515
6.992
6.989
6.984
6.975
6.970
6.967
Ph
P
O
Ph
O
I
4.00
4.00
4.10
2.01
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

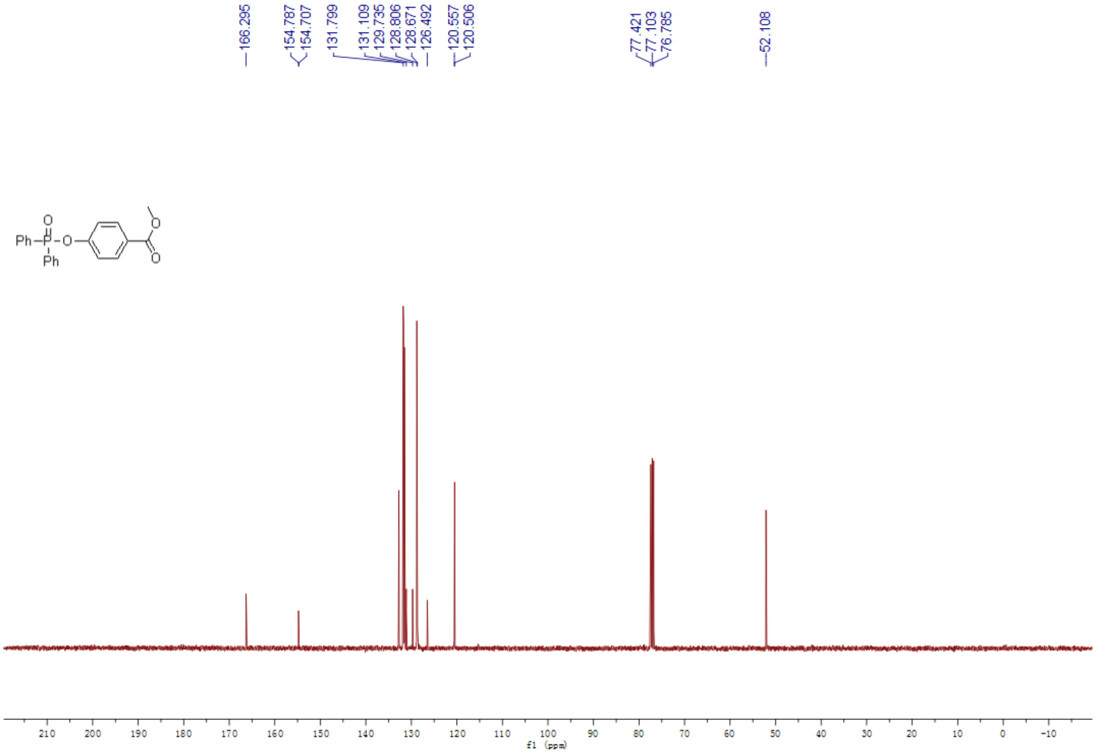

—31.250
Ph–P(O)–O–C6H4–I
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

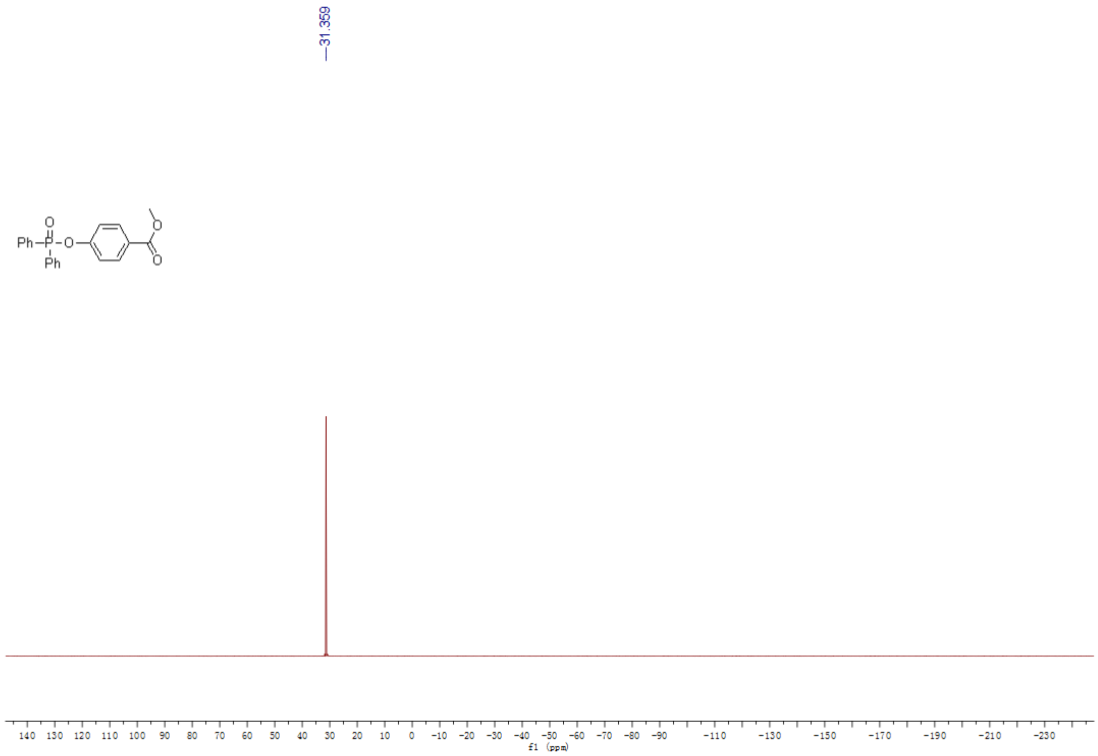

7.919
7.901
7.897
7.887
7.869
7.866
7.859
7.854
7.841
7.837
7.830
7.584
7.569
7.566
7.524
7.515
7.505
7.495
7.487
7.484
7.477
7.430
7.427
7.408
7.406
—3.003
Ph–P(O)–O–C6H4–S(O)2–
Ph
5.85
1.95
3.92
1.96
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)


155.215
155.136
136.532
133.041
128.824
121.577
121.526
77.428
77.110
76.792
44.596
Ph
P
O
O
Ph
S
O
O
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

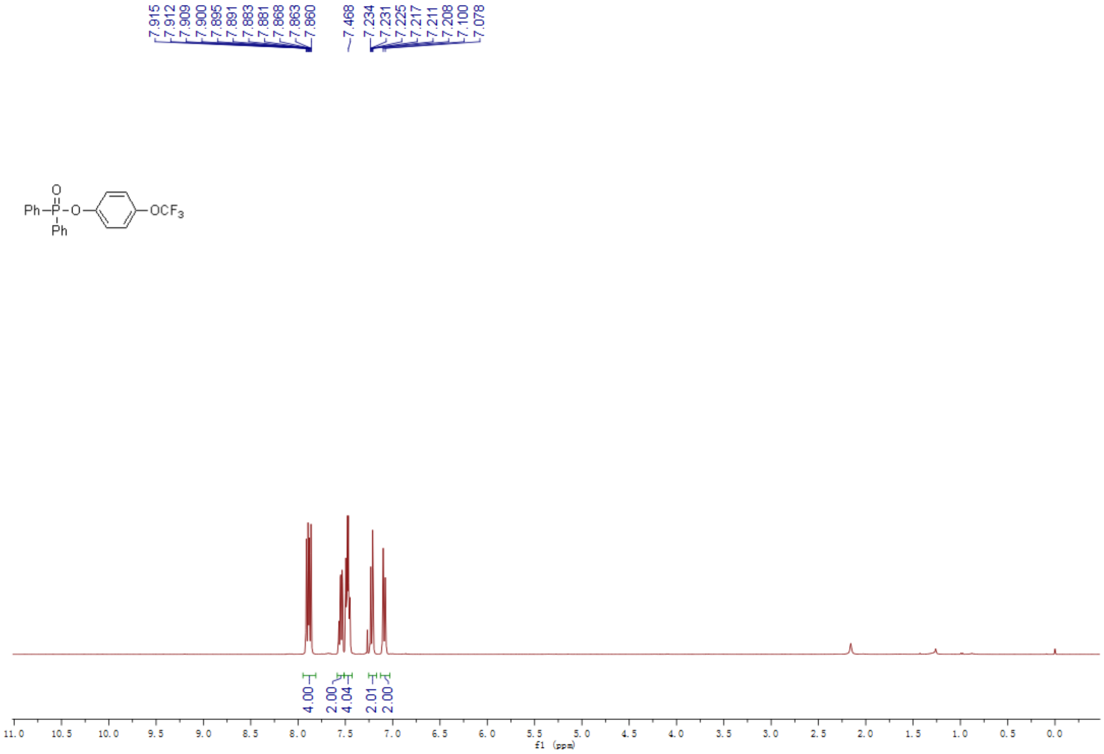

32.553
Ph
P
O
O
Ph
S
O
O
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


7.952
7.947
7.935
7.930
7.918
7.915
7.912
7.903
7.898
7.894
7.887
7.884
7.880
7.866
7.863
7.564
7.545
7.533
7.526
7.488
7.479
7.472
7.463
7.452
7.443
7.299
7.277
3.853
Ph
P
O
O
Ph
O
O
6.02
1.99
4.02
2.12
3.00
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
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
-0.5
f1 (ppm)

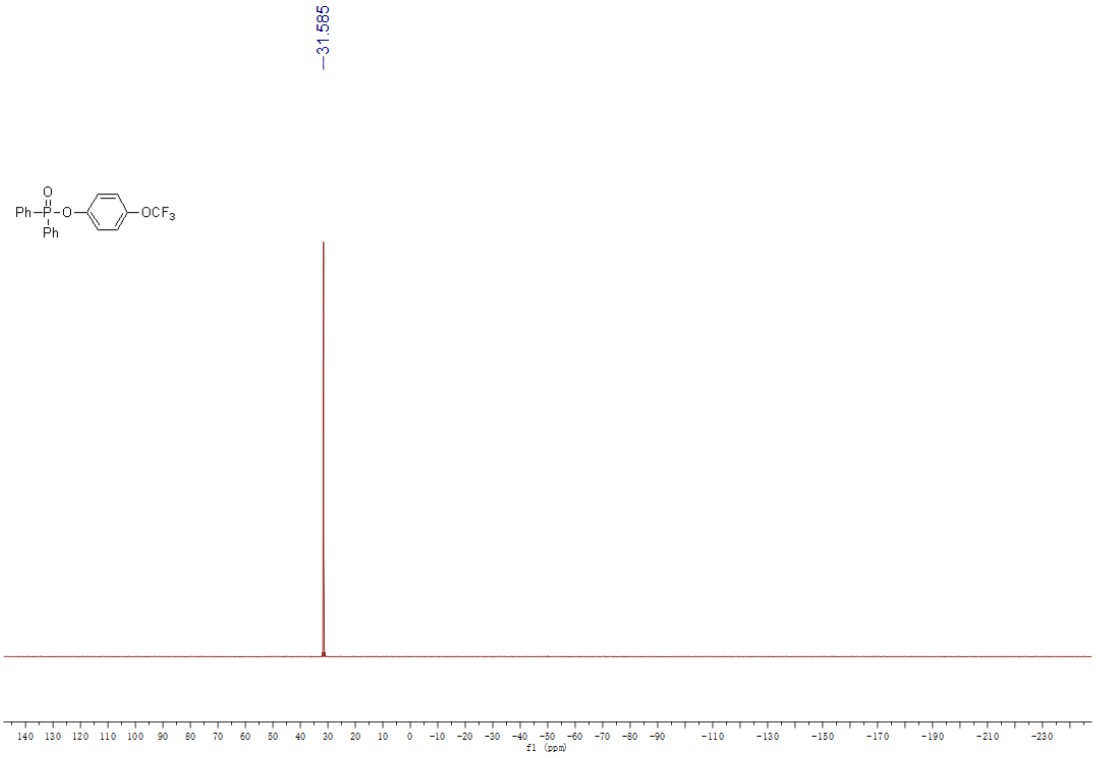

166.295
154.787
154.707
131.799
131.109
129.735
128.806
128.671
126.492
120.557
120.506
77.421
77.103
76.785
52.108
Ph
P
O
O
Ph
O
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



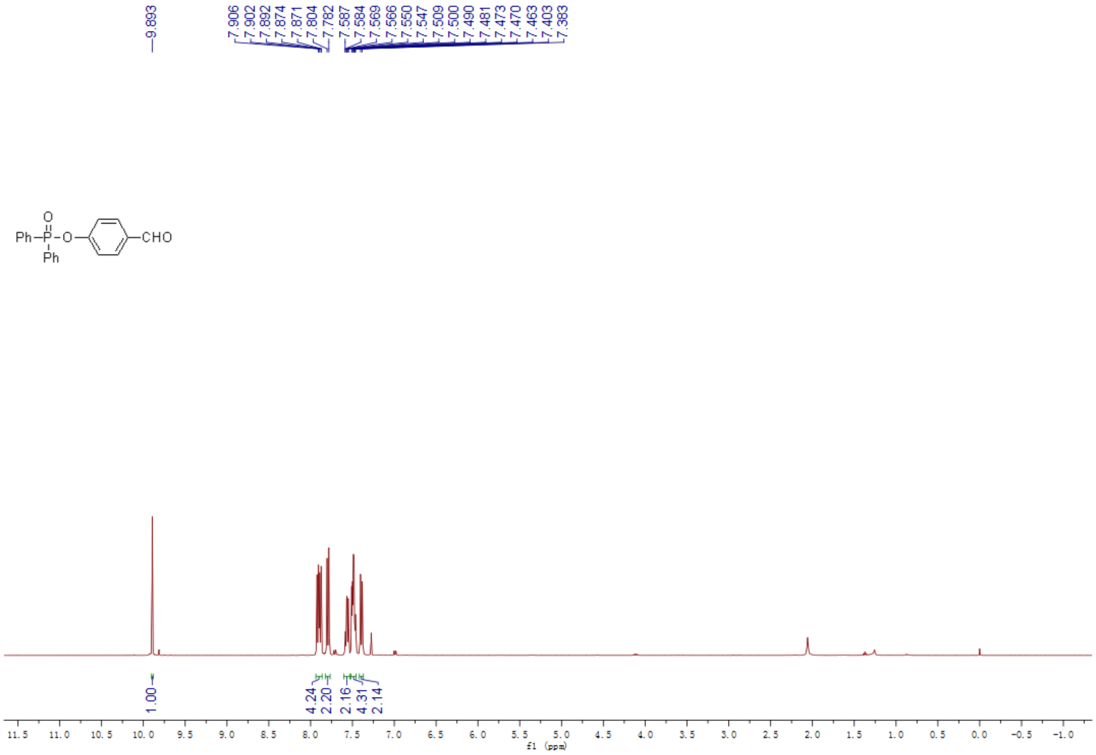
31.359
Ph
P
O
Ph
O
O
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)



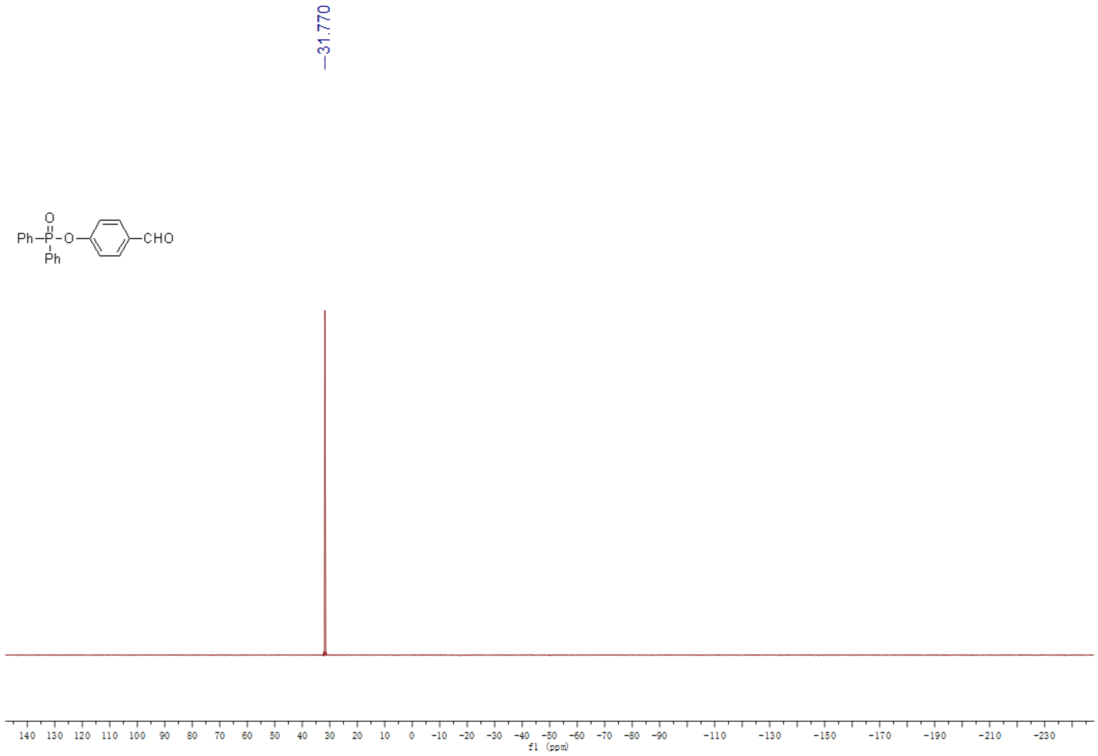
7.915
7.912
7.909
7.900
7.895
7.891
7.883
7.881
7.868
7.863
7.860
7.468
7.234
7.231
7.225
7.217
7.211
7.208
7.100
7.078
Ph
P
O
Ph
O
OCF3
4.00
2.00
4.04
2.01
2.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

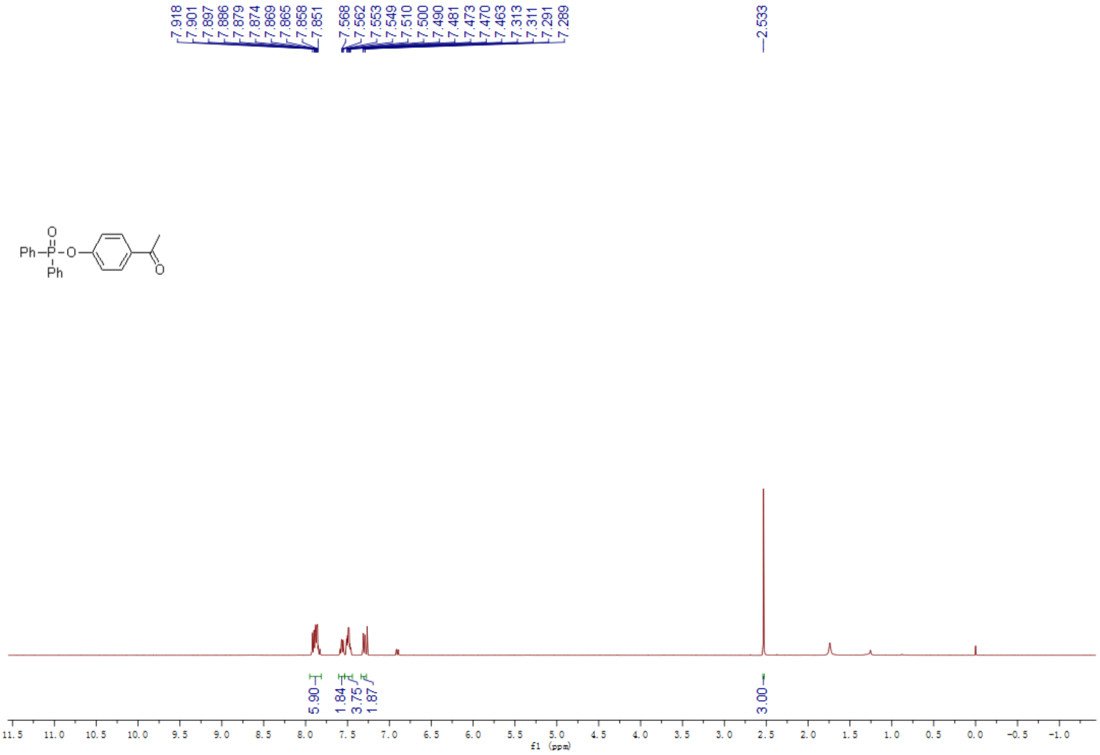


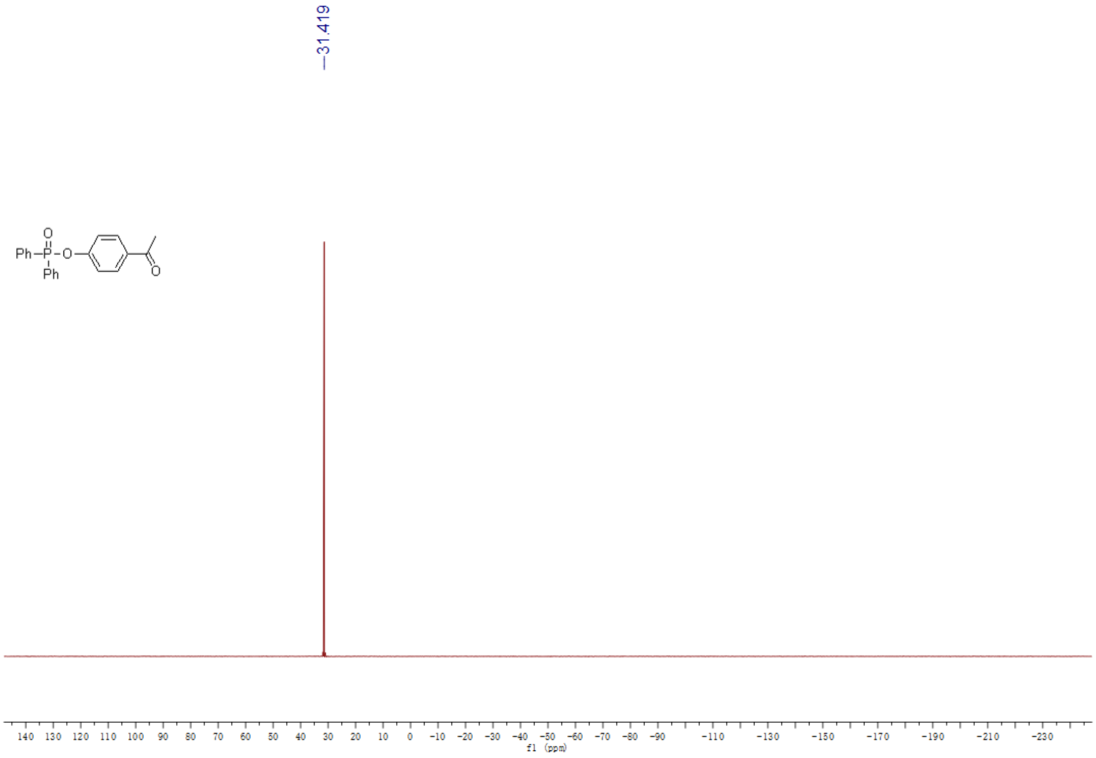
—31.585
O
Ph–P–O–
Ph
–OCF$_3$
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)



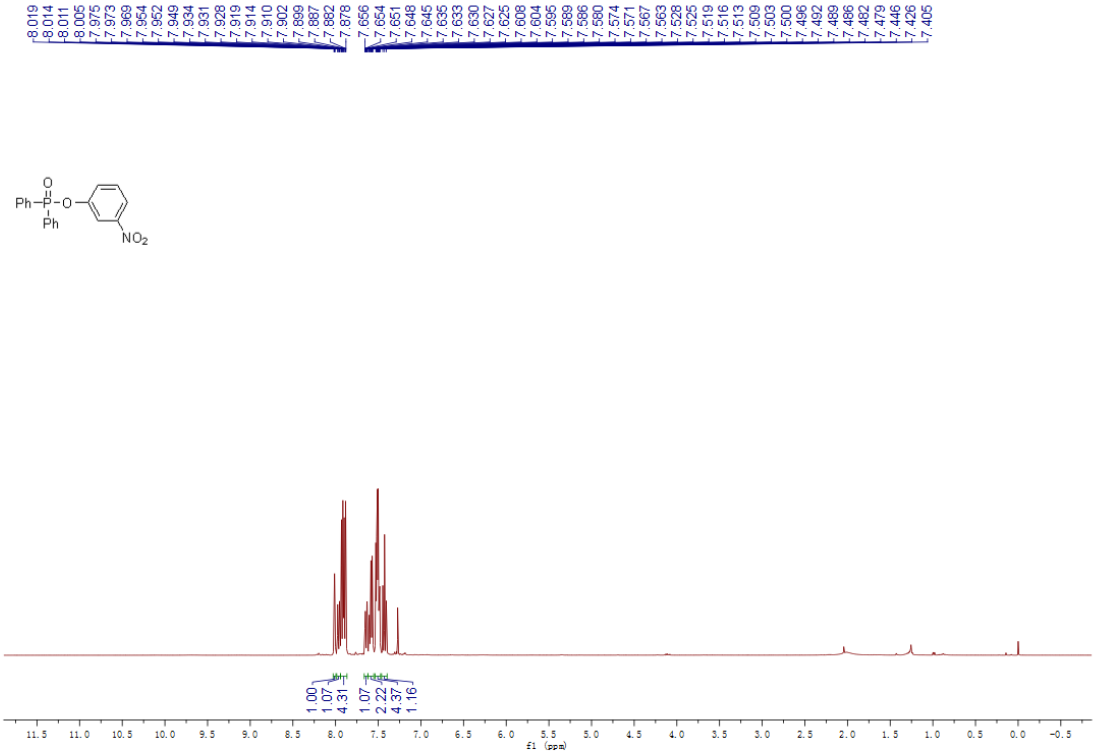
—9.893
7.906
7.902
7.892
7.874
7.871
7.804
7.782
7.587
7.584
7.569
7.566
7.550
7.547
7.509
7.500
7.490
7.481
7.473
7.470
7.463
7.403
7.383
O
Ph–P–O–
Ph
–CHO
1.00
4.24
2.20
2.16
4.31
2.14
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)


31.770
O
Ph
P
O
CHO
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

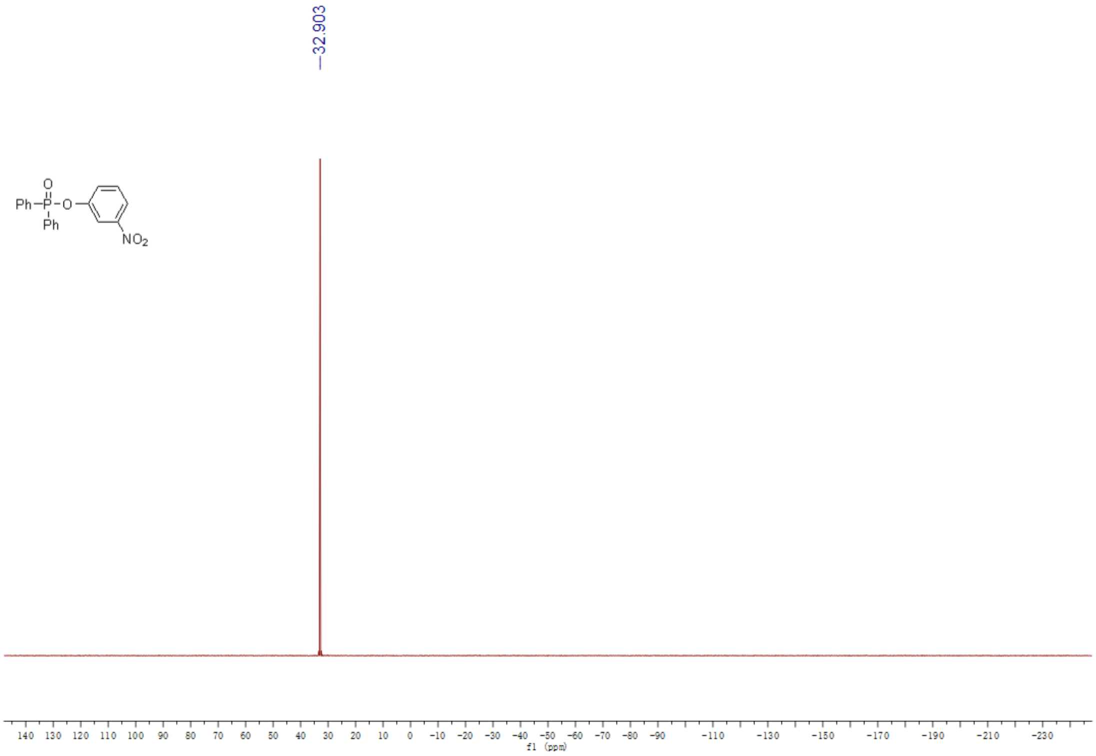

7.918
7.901
7.897
7.886
7.879
7.874
7.869
7.865
7.858
7.851
7.568
7.562
7.553
7.549
7.510
7.500
7.490
7.481
7.473
7.470
7.463
7.313
7.311
7.291
7.289
2.533
O
Ph
P
O
Ph
O
5.90
1.84
3.75
1.87
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)



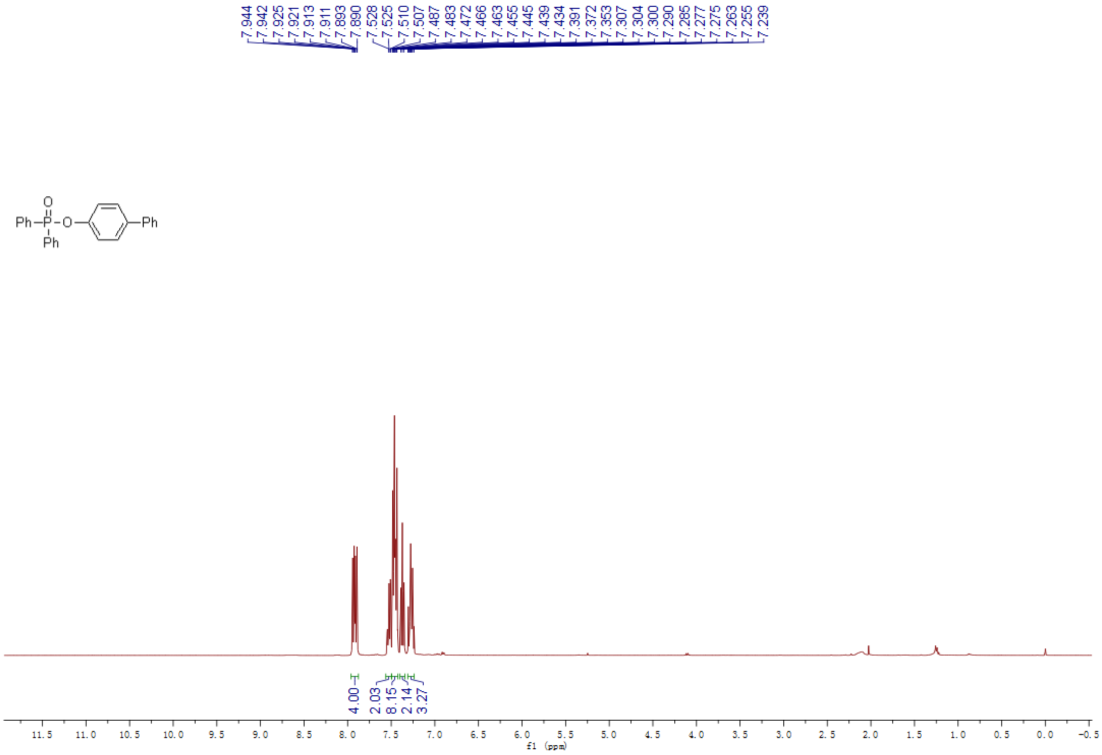
—31.419
Ph
O
P
O
Ph
O
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)



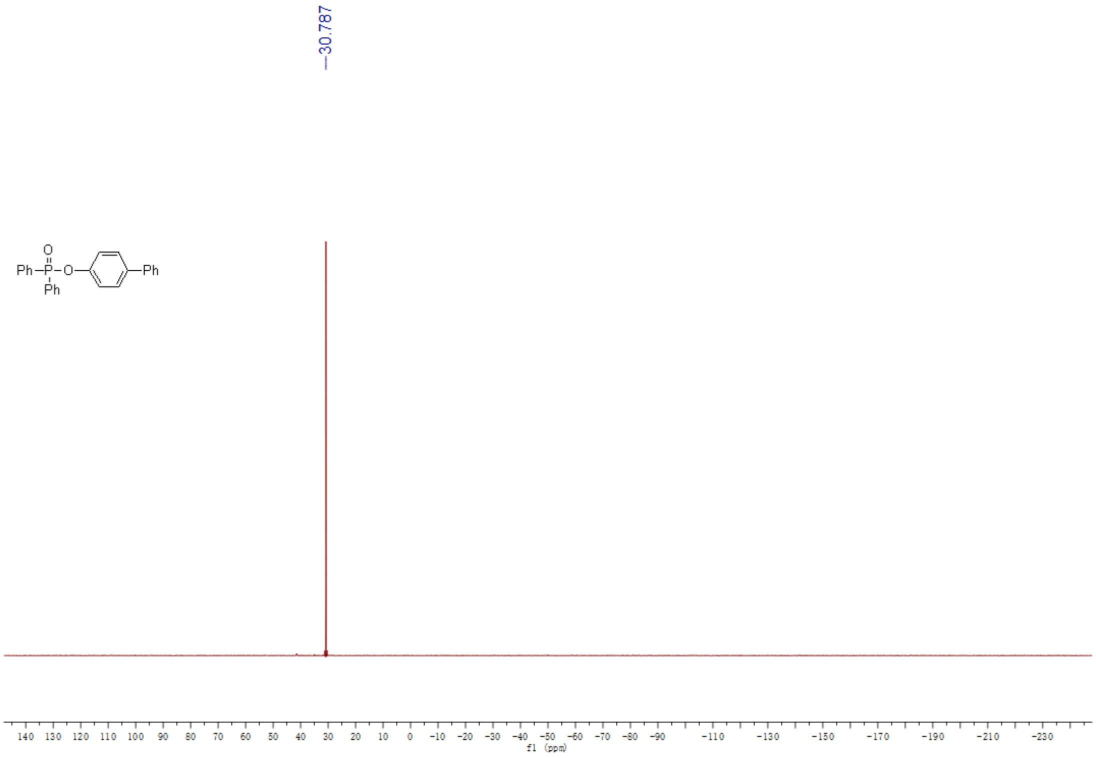
8.019
8.014
8.011
8.005
7.975
7.973
7.969
7.954
7.952
7.949
7.934
7.931
7.928
7.919
7.914
7.910
7.902
7.899
7.887
7.882
7.878
7.656
7.654
7.651
7.648
7.645
7.635
7.633
7.630
7.627
7.625
7.608
7.604
7.595
7.589
7.586
7.580
7.574
7.571
7.567
7.563
7.528
7.525
7.519
7.516
7.513
7.509
7.503
7.500
7.496
7.492
7.489
7.486
7.482
7.479
7.446
7.426
7.405
Ph
O
P
O
Ph
NO$_2$
1.00
1.07
4.31
1.07
2.22
4.37
1.16
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 −0.5
f1 (ppm)

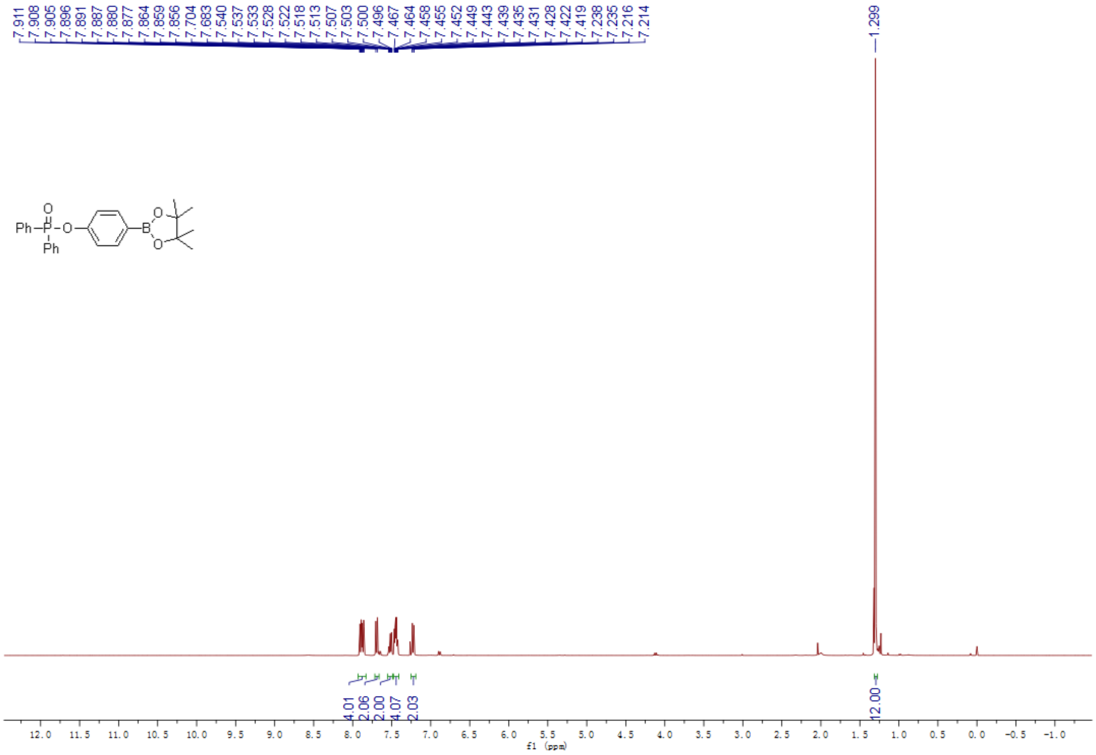


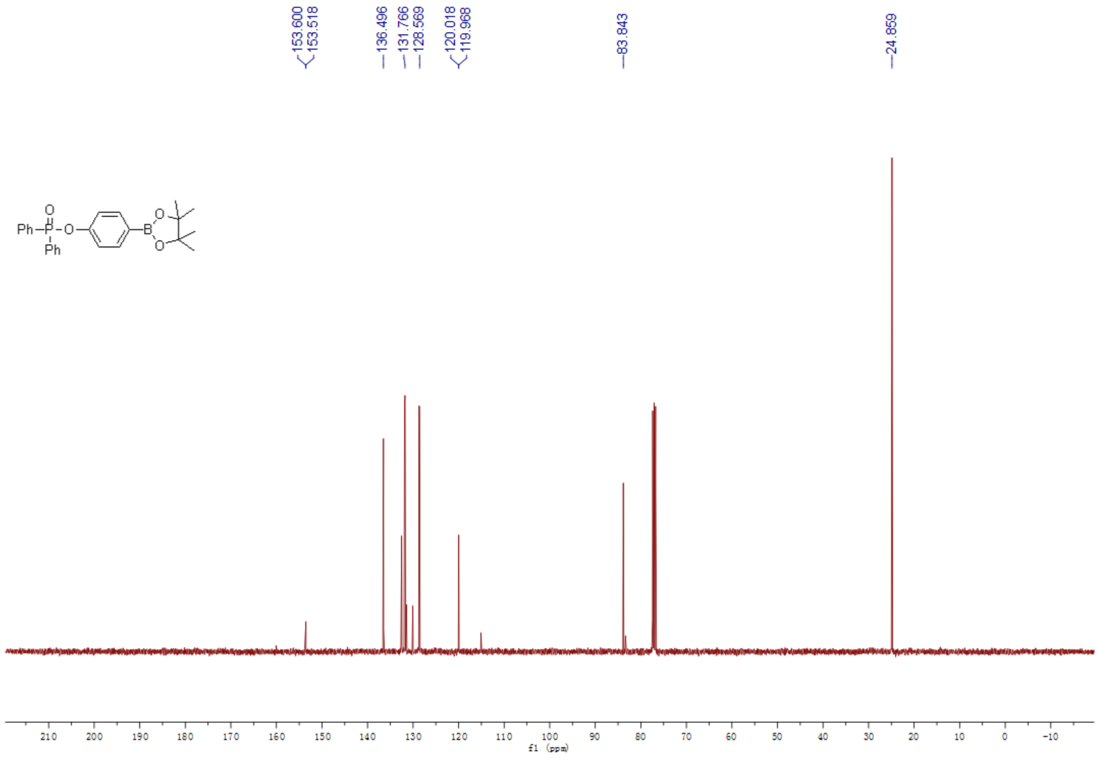
—32.903
O
Ph–P–O
Ph
NO2
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

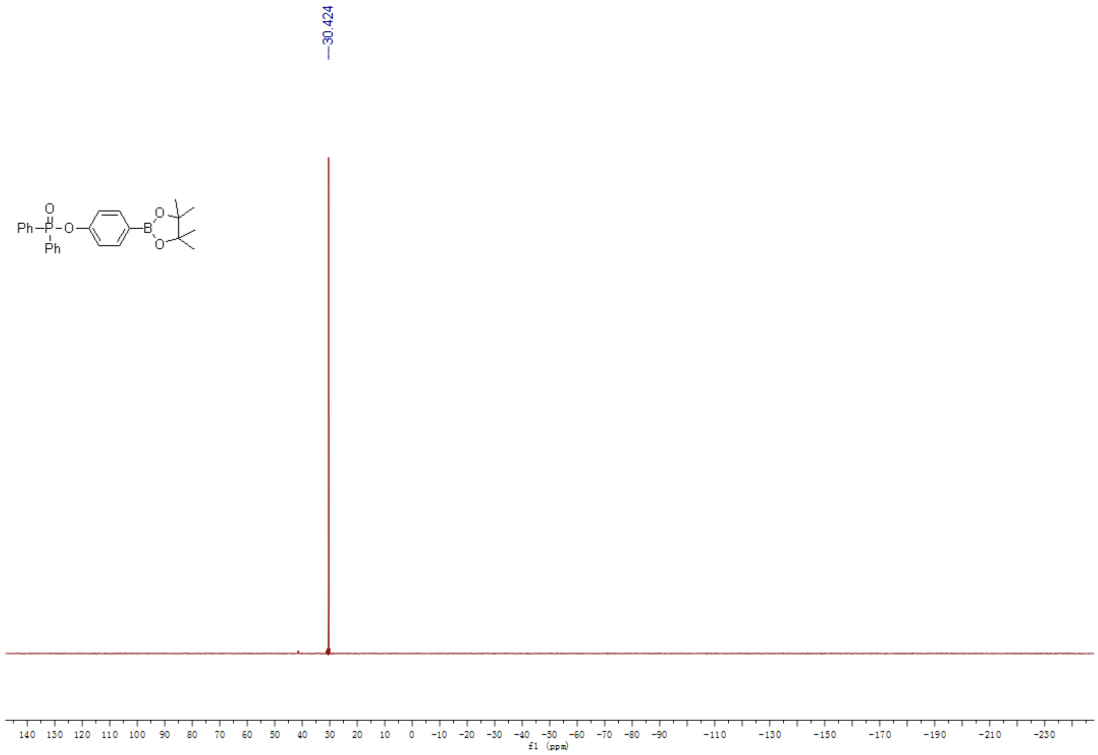


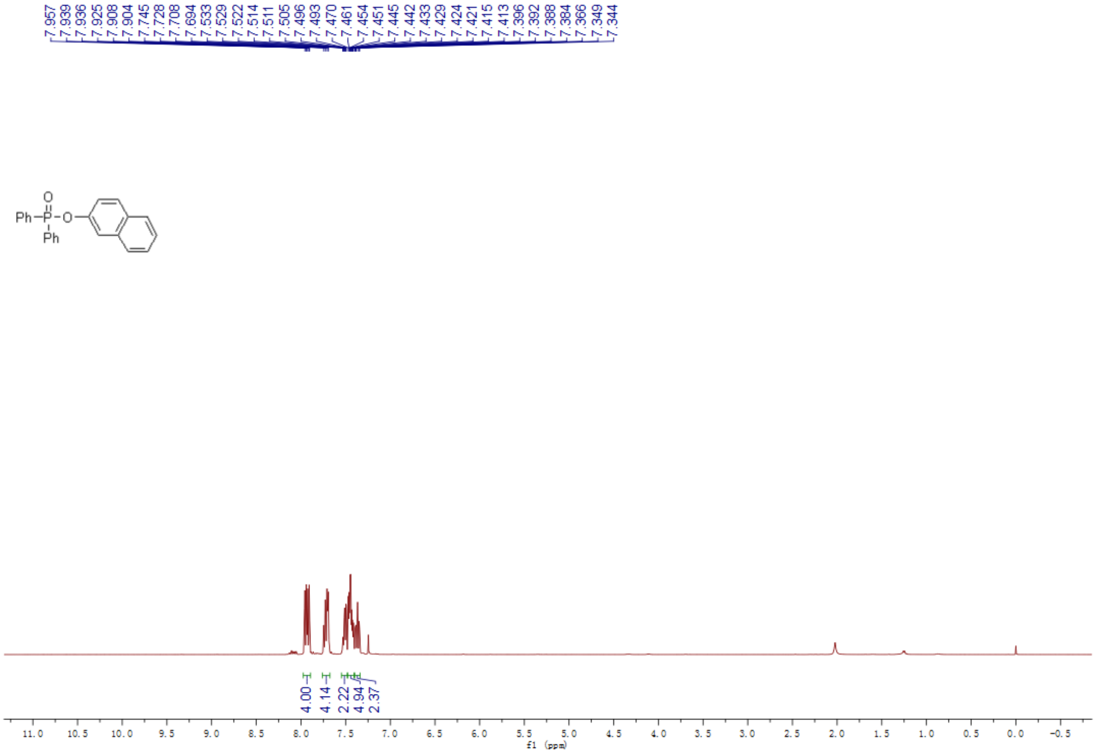
7.944
7.942
7.925
7.921
7.913
7.911
7.893
7.890
7.528
7.525
7.510
7.507
7.487
7.483
7.472
7.466
7.463
7.455
7.445
7.439
7.434
7.391
7.372
7.353
7.307
7.304
7.300
7.290
7.285
7.277
7.275
7.263
7.255
7.239
O
Ph–P–O
Ph
Ph
4.00
2.03
8.15
2.14
3.27
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

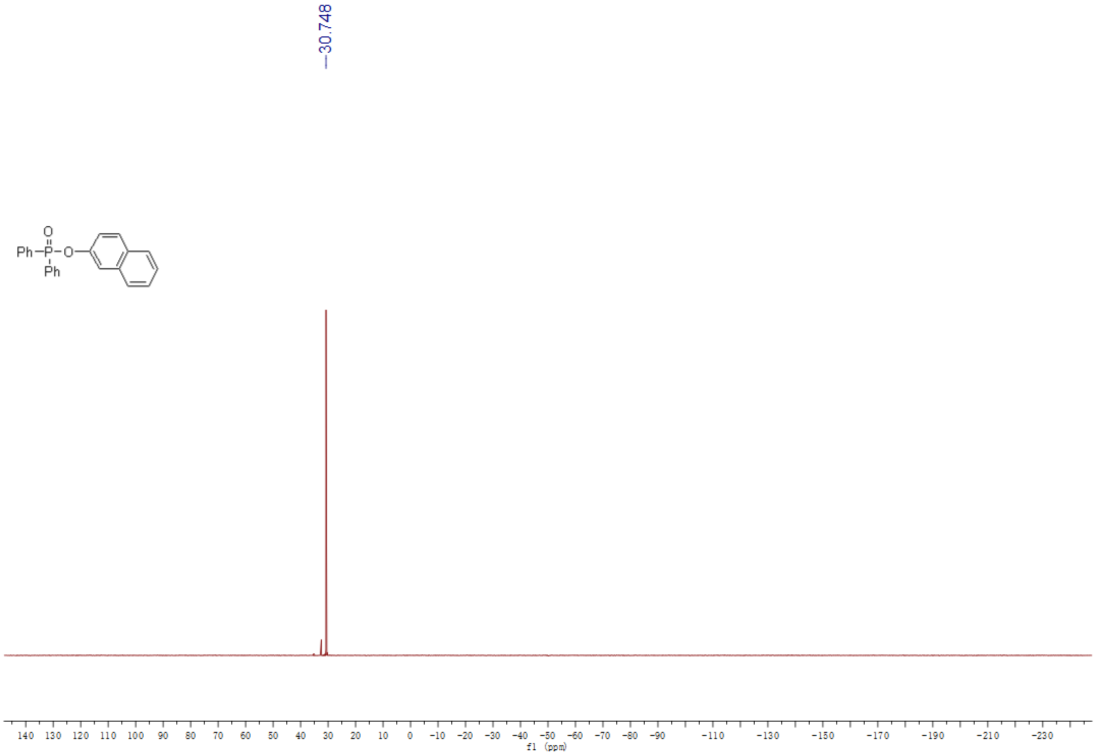

30.787
Ph
P
O
O
Ph
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

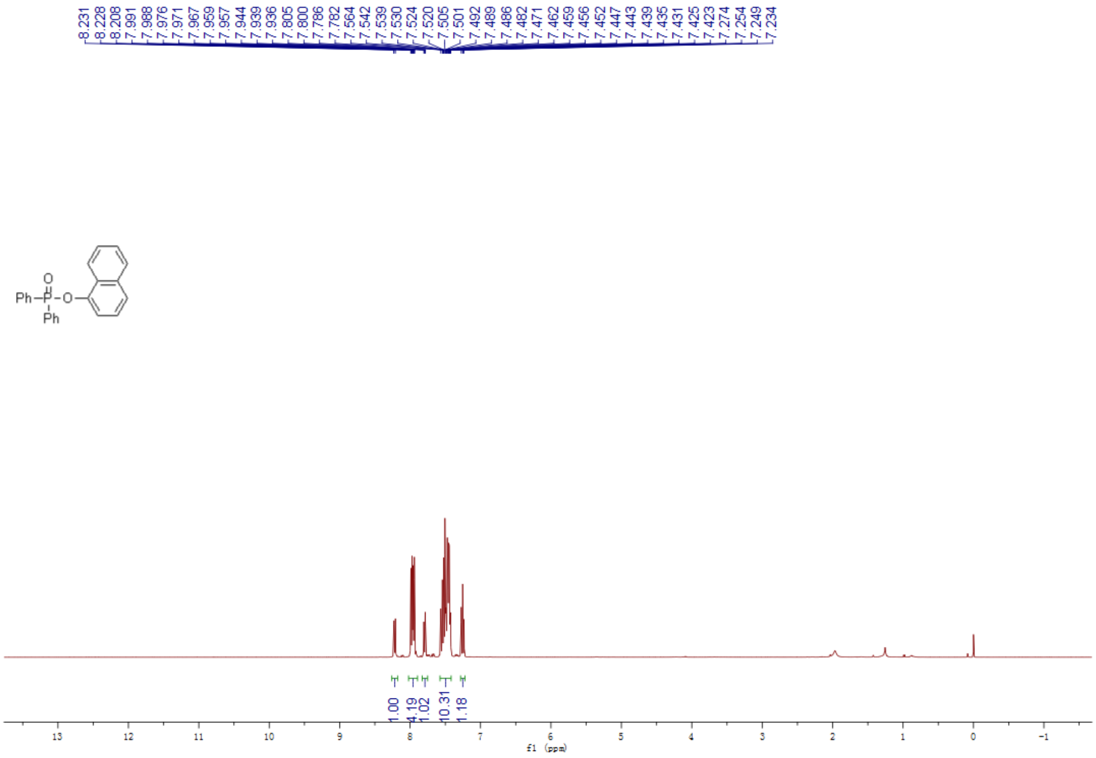

7.911
7.908
7.905
7.896
7.891
7.887
7.880
7.877
7.864
7.859
7.856
7.704
7.683
7.540
7.537
7.533
7.528
7.522
7.518
7.513
7.507
7.503
7.500
7.496
7.467
7.464
7.458
7.455
7.452
7.449
7.443
7.439
7.435
7.431
7.428
7.422
7.419
7.238
7.235
7.216
7.214
1.299
Ph
P
O
O
Ph
B
O
O
4.01
2.06
2.00
4.07
2.03
12.00
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 −0.5 −1.0
f1 (ppm)

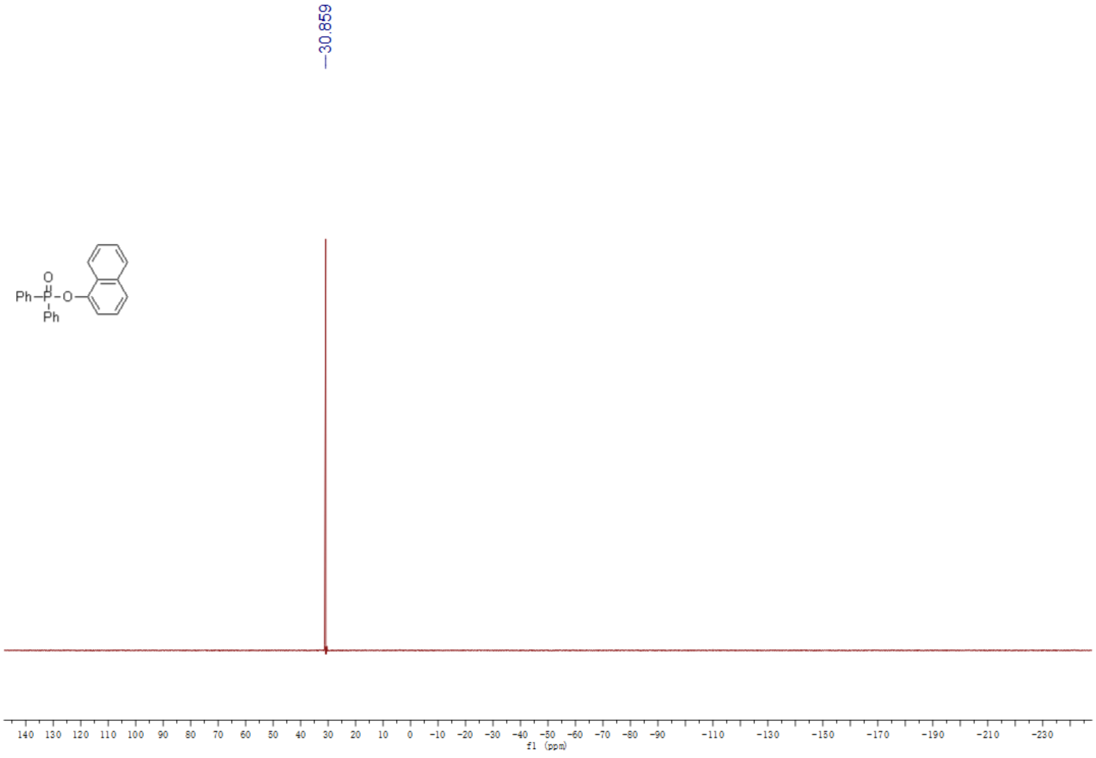

153.600
153.518
136.496
131.766
128.569
120.018
119.968
83.843
24.859
Ph
O
P
O
Ph
B
O
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

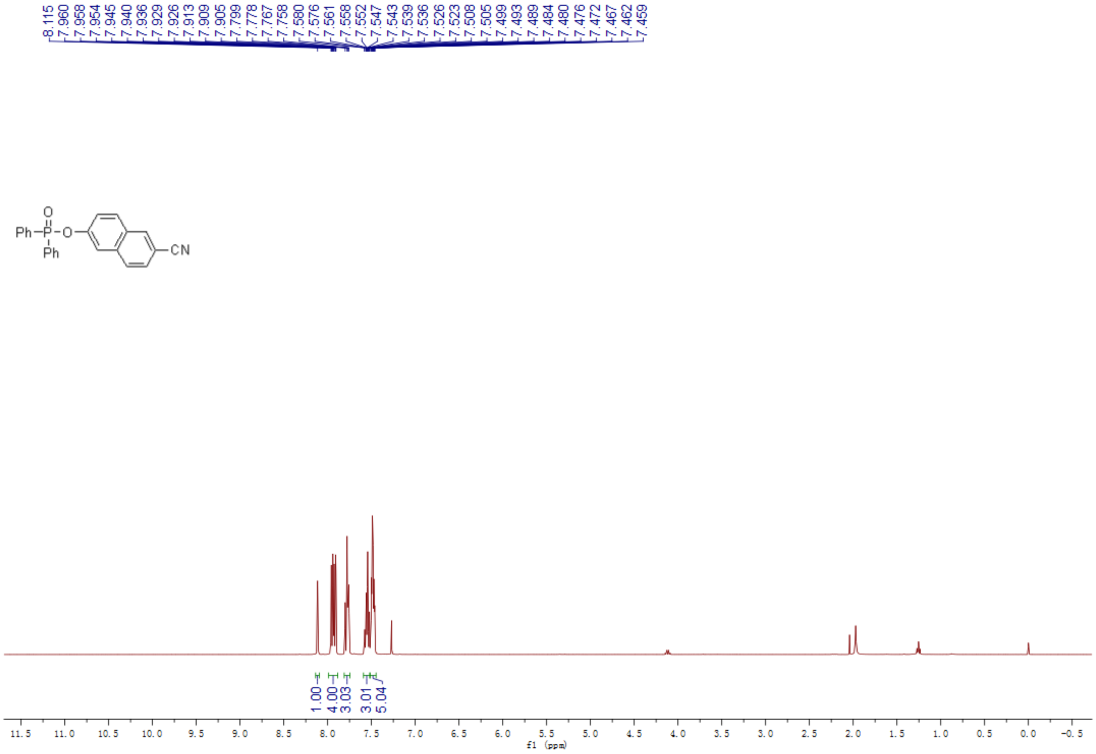

30.424
Ph
O
P
O
Ph
B
O
O
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

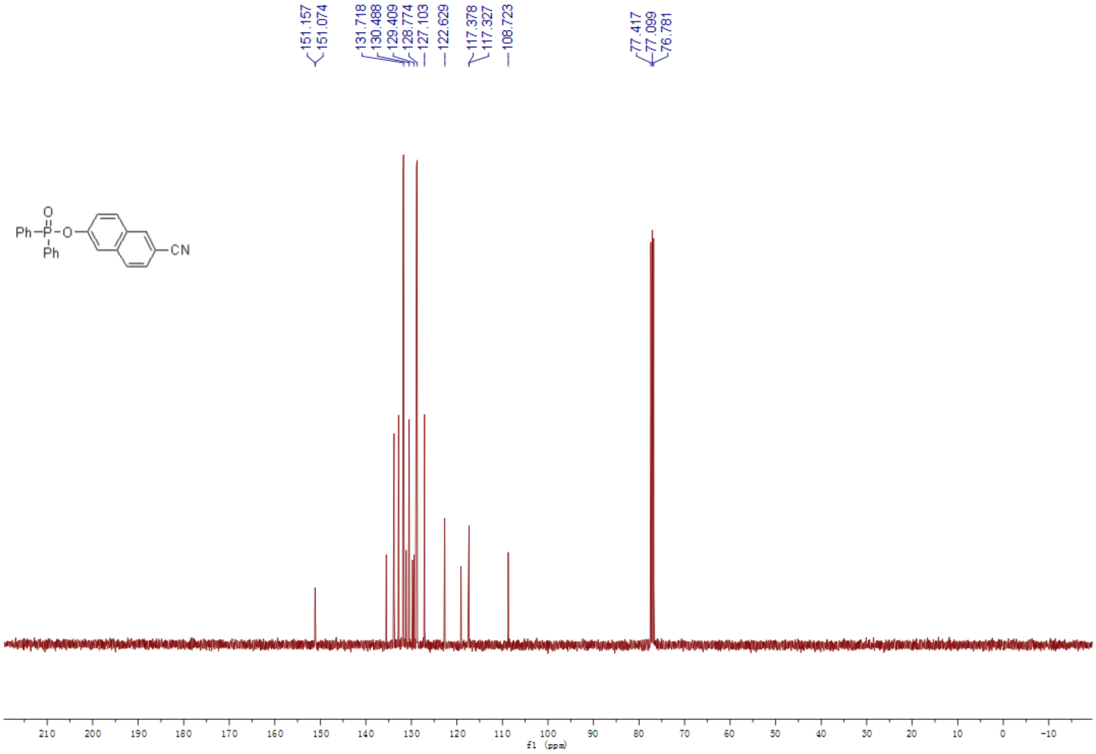

7.957
7.939
7.936
7.925
7.908
7.904
7.745
7.728
7.708
7.694
7.533
7.529
7.522
7.514
7.511
7.505
7.496
7.493
7.470
7.461
7.454
7.451
7.445
7.442
7.433
7.429
7.424
7.421
7.415
7.413
7.396
7.392
7.388
7.384
7.366
7.349
7.344
O
Ph
P
O
Ph
4.00
4.14
2.22
4.94
2.37
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
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
-0.5
f1 (ppm)

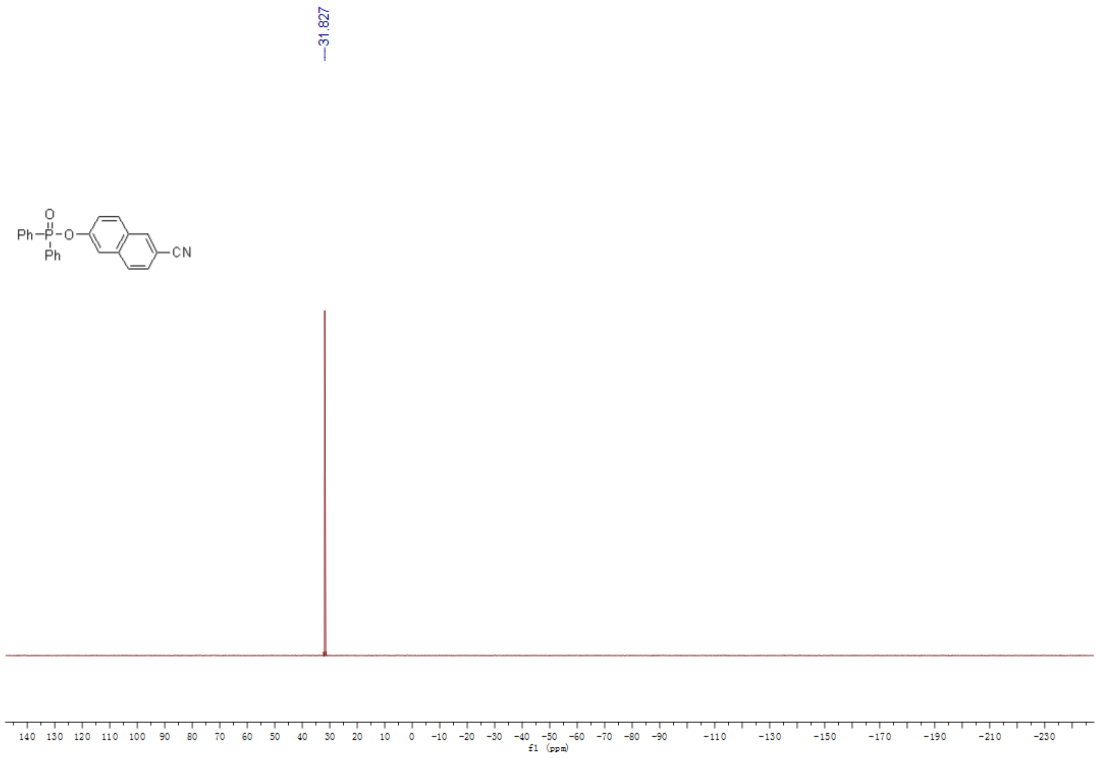

30.748
O
Ph
P
O
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


8.231
8.228
8.208
7.991
7.988
7.976
7.971
7.967
7.959
7.957
7.944
7.939
7.936
7.805
7.800
7.786
7.782
7.564
7.542
7.539
7.530
7.524
7.520
7.505
7.501
7.492
7.489
7.486
7.482
7.471
7.462
7.459
7.456
7.452
7.447
7.443
7.439
7.435
7.431
7.425
7.423
7.274
7.254
7.249
7.234
O
Ph
P
O
Ph
1.00
4.19
1.02
10.31
1.18
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

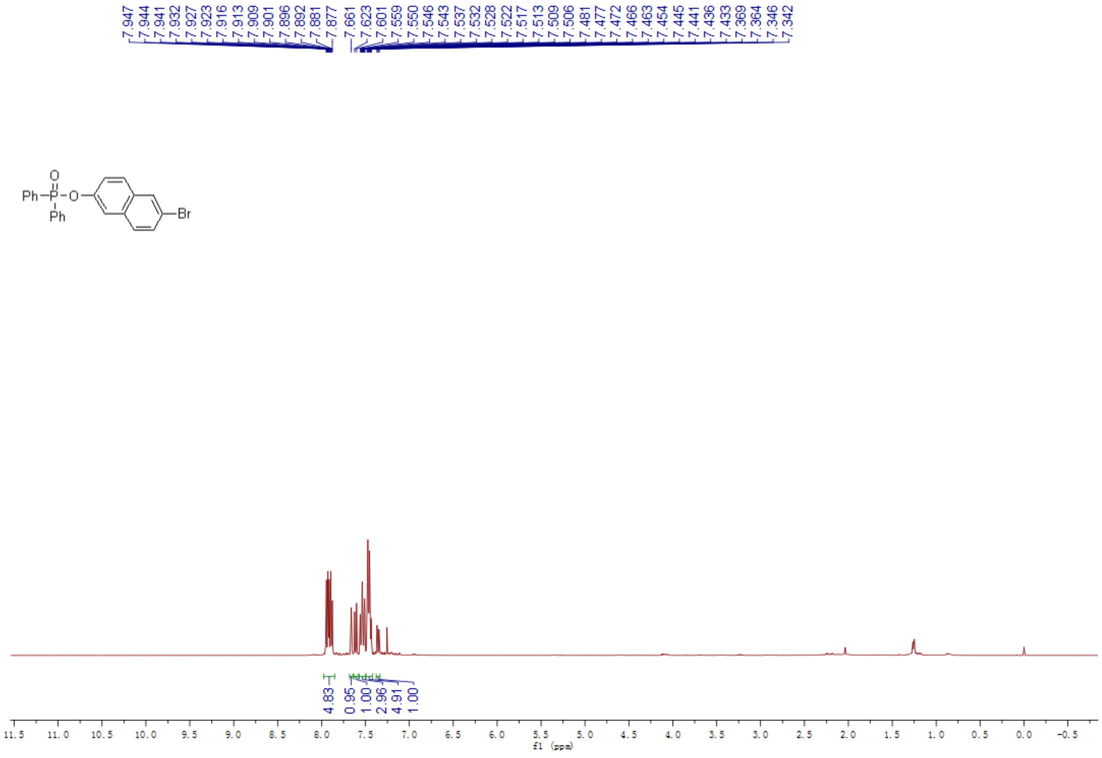

30.859
O
Ph
P
O
Ph
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


8.115
7.960
7.958
7.954
7.945
7.940
7.936
7.929
7.926
7.913
7.909
7.905
7.799
7.778
7.767
7.758
7.580
7.576
7.561
7.558
7.552
7.547
7.543
7.539
7.536
7.526
7.523
7.508
7.505
7.499
7.493
7.489
7.484
7.480
7.476
7.472
7.467
7.462
7.459
O
Ph
P
O
Ph
CN
1.00
4.00
3.03
3.01
5.04
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 -0.5
f1 (ppm)

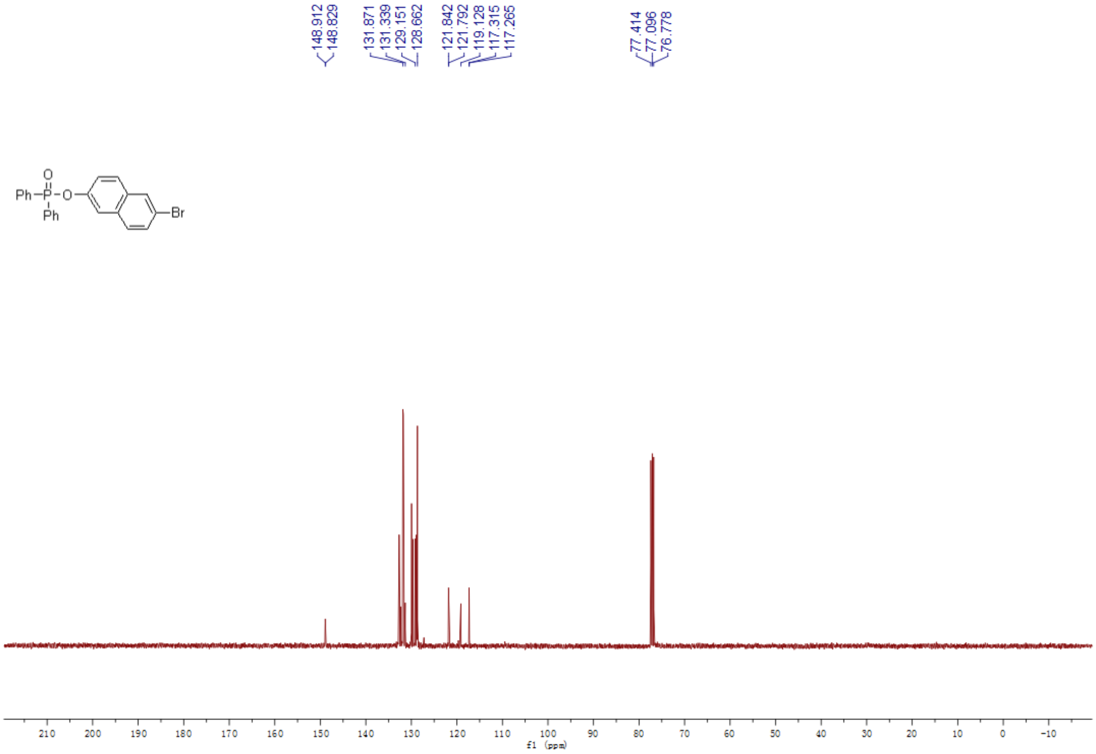

151.157
151.074
131.718
130.488
129.409
128.774
127.103
122.629
117.378
117.327
108.723
77.417
77.099
76.781
O
Ph
P
O
Ph
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

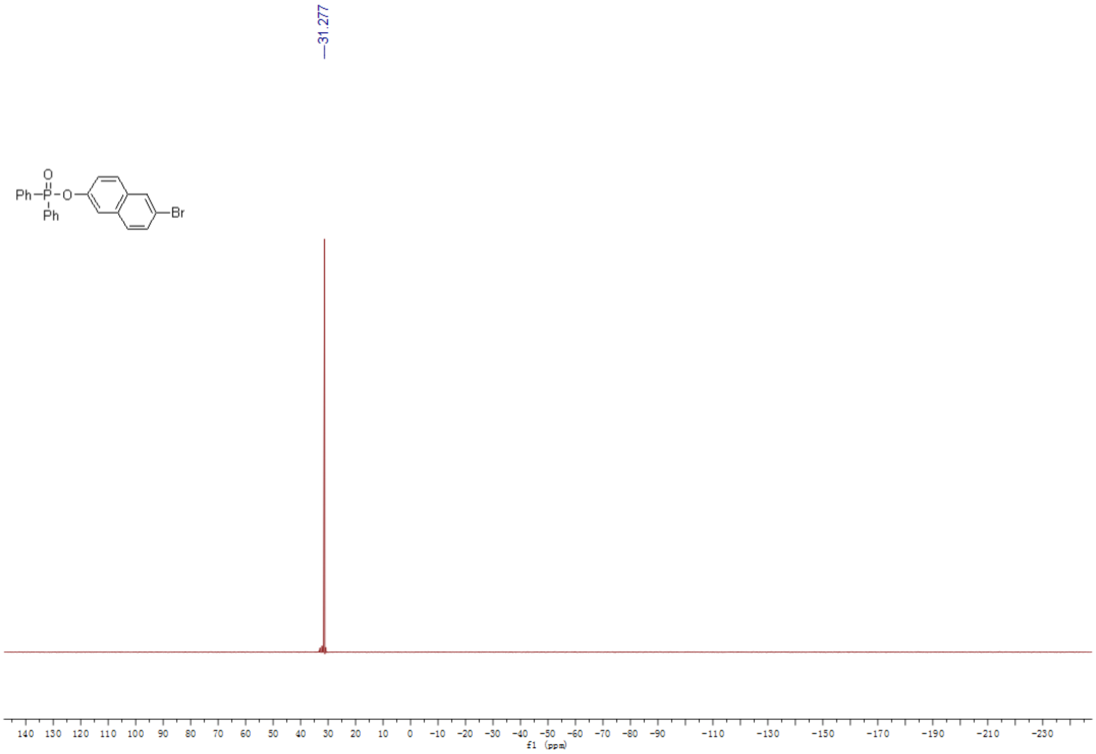


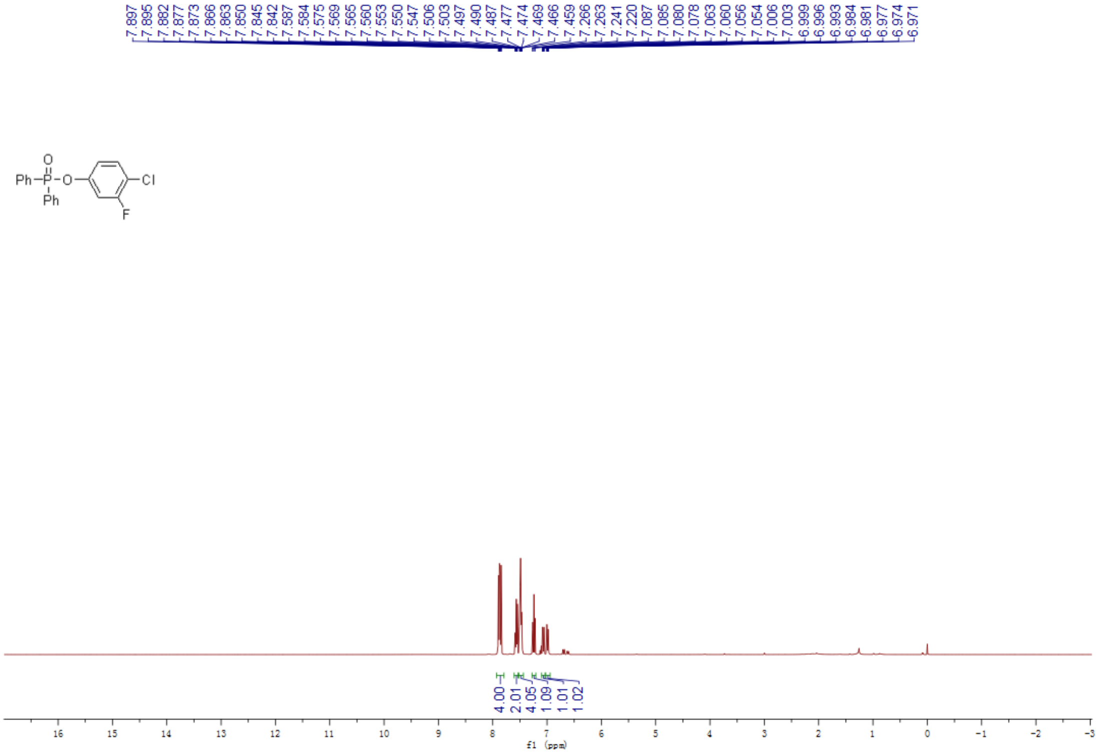
31.827
Ph
O
P
O
Ph
CN
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

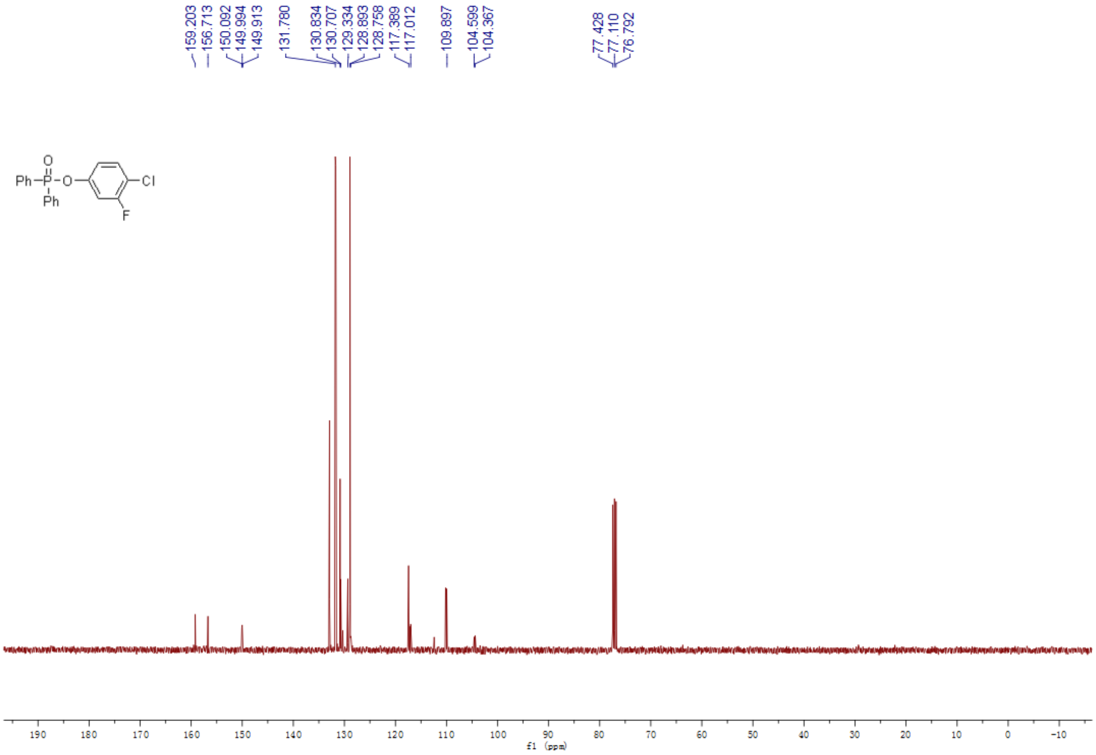


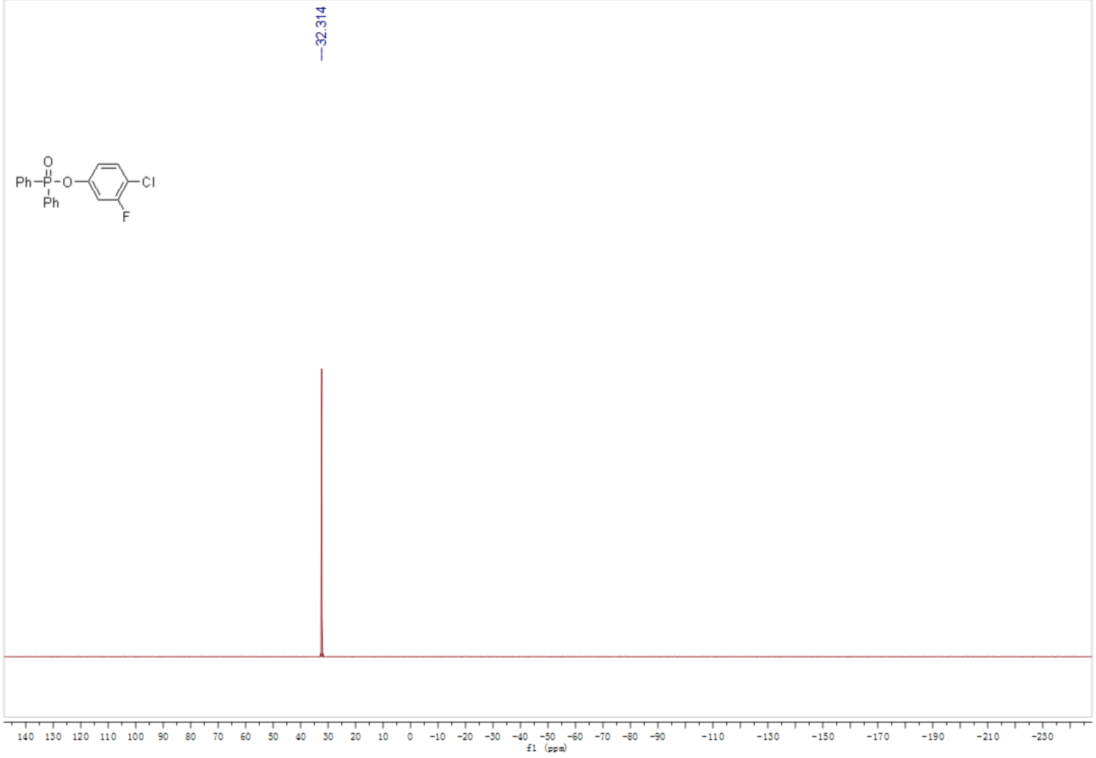
7.947
7.944
7.941
7.932
7.927
7.923
7.916
7.913
7.909
7.901
7.896
7.892
7.881
7.877
7.661
7.623
7.601
7.559
7.550
7.546
7.543
7.537
7.532
7.528
7.522
7.517
7.513
7.509
7.506
7.481
7.477
7.472
7.466
7.463
7.454
7.445
7.441
7.436
7.433
7.369
7.364
7.346
7.342
Ph
O
P
O
Ph
Br
4.83
0.95
1.00
2.96
4.91
1.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 −0.5
f1 (ppm)


148.912
148.829
131.871
131.339
129.151
128.662
121.842
121.792
119.128
117.315
117.265
77.414
77.096
76.778
Ph
P
O
O
Ph
Br
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

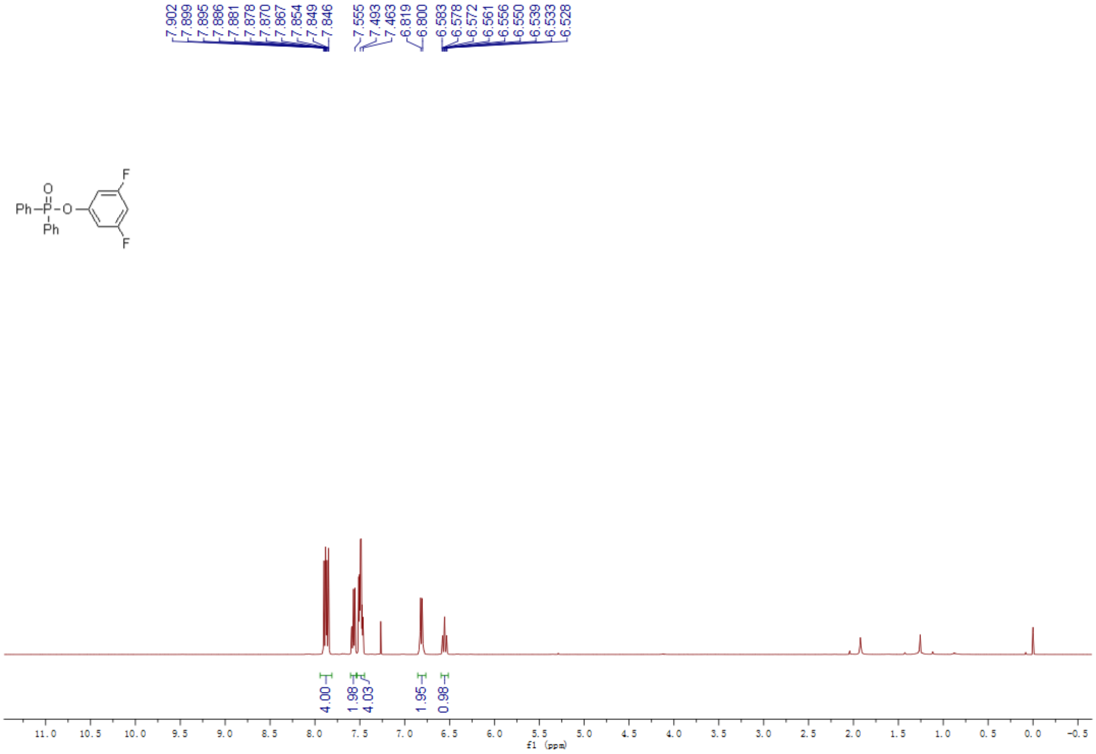

31.277
Ph
P
O
O
Ph
Br
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


7.897
7.895
7.882
7.877
7.873
7.866
7.863
7.850
7.845
7.842
7.587
7.584
7.575
7.569
7.565
7.560
7.553
7.550
7.547
7.506
7.503
7.497
7.490
7.487
7.477
7.474
7.469
7.466
7.459
7.266
7.263
7.241
7.220
7.087
7.085
7.080
7.078
7.063
7.060
7.056
7.054
7.006
7.003
6.999
6.996
6.993
6.984
6.981
6.977
6.974
6.971
Ph
P
O
O
Ph
Cl
F
4.00
2.01
4.05
1.09
1.01
1.02
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

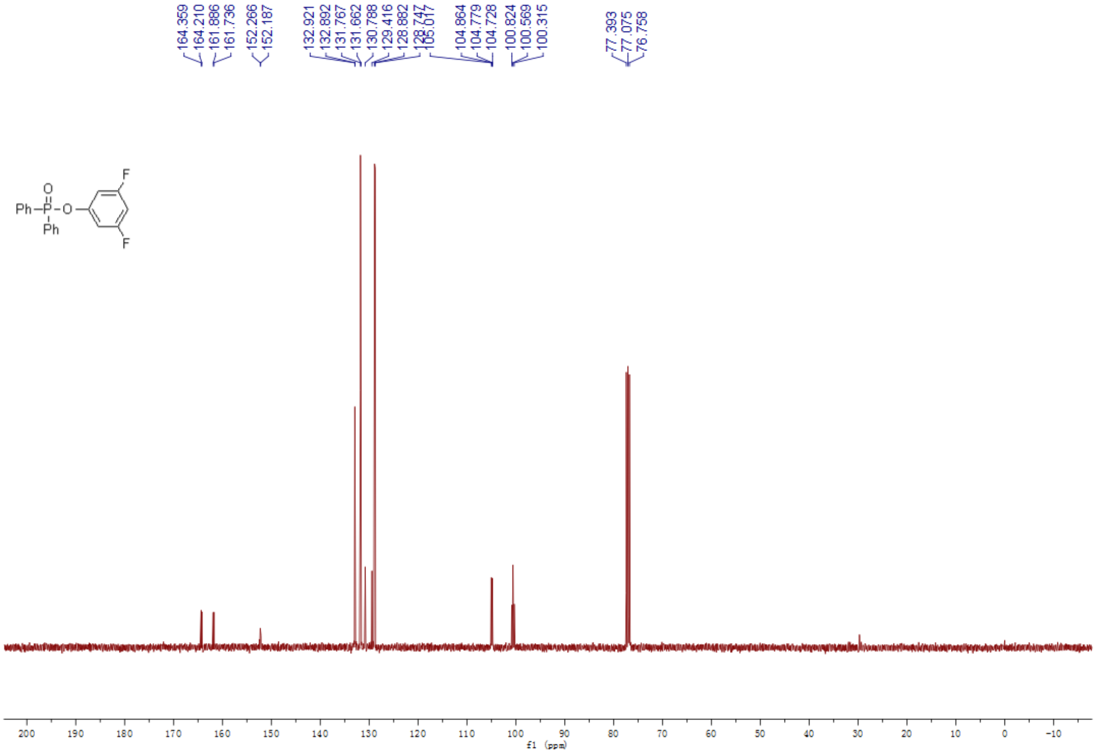

159.203
156.713
150.092
149.994
149.913
131.780
130.834
130.707
129.334
128.893
128.758
117.389
117.012
109.897
104.599
104.367
77.428
77.110
76.792
Ph
P
O
O
Ph
Cl
F
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

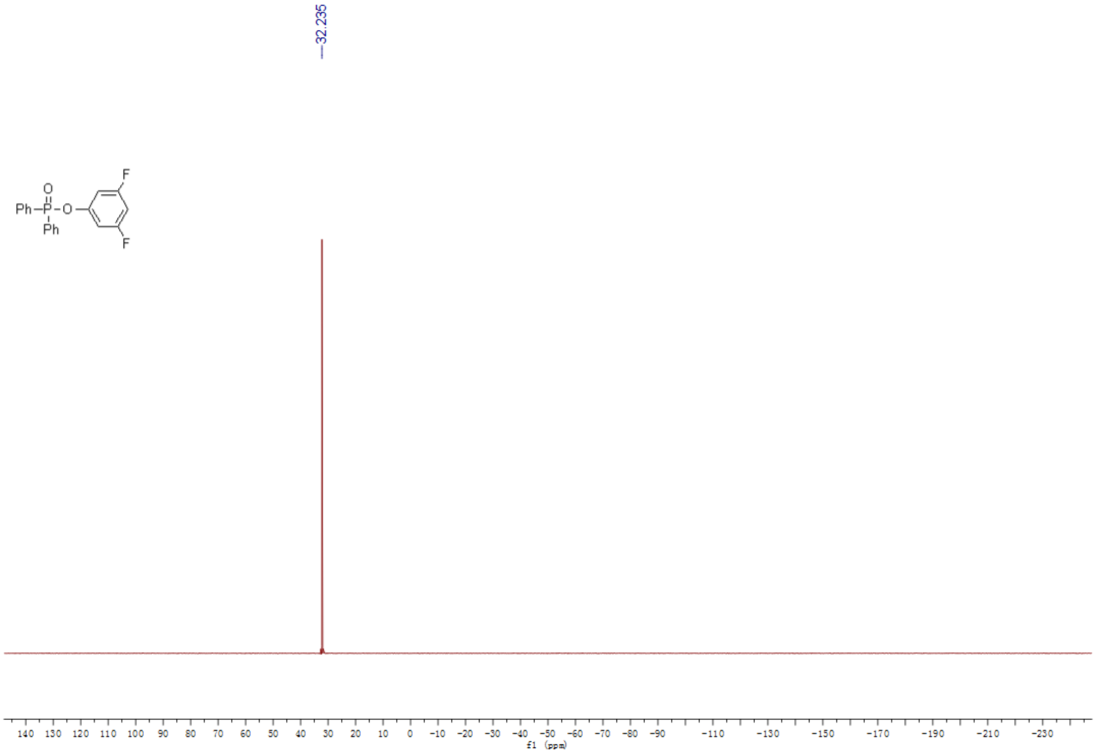


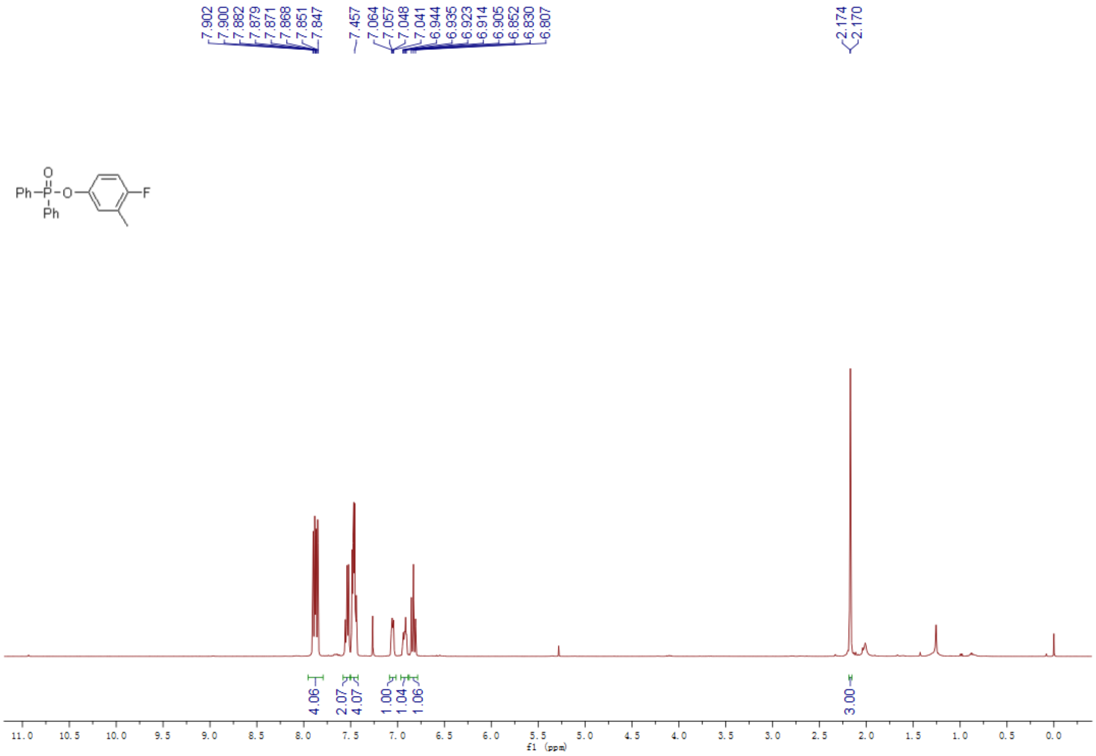
32.314
Ph
O
P
O
Cl
F
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

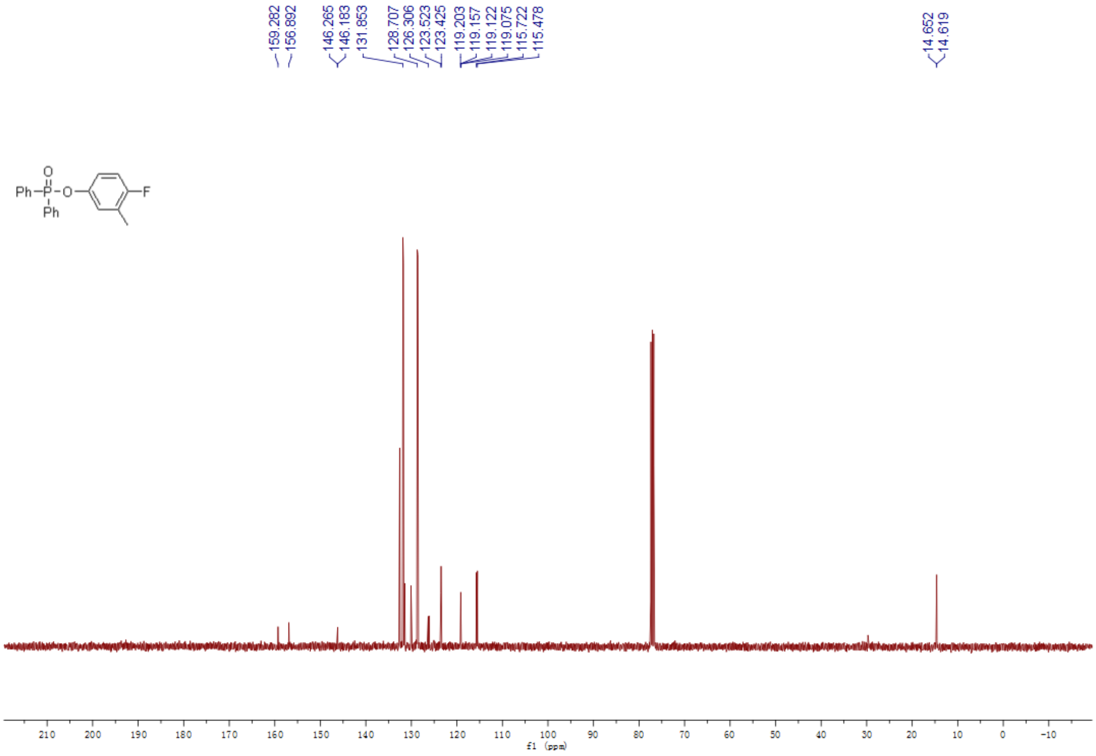


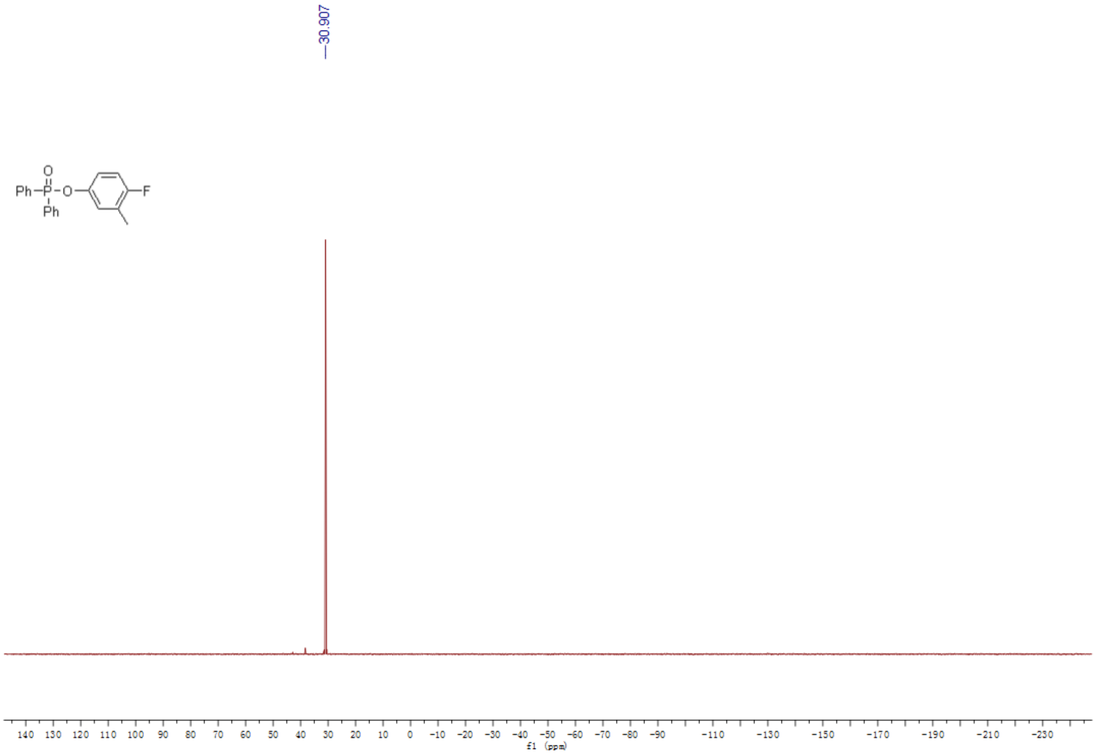
7.902
7.899
7.895
7.886
7.881
7.878
7.870
7.867
7.854
7.849
7.846
7.555
7.493
7.463
6.819
6.800
6.583
6.578
6.572
6.561
6.556
6.550
6.539
6.533
6.528
Ph
O
P
O
F
F
Ph
4.00
1.98
4.03
1.95
0.98
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


164.359
164.210
161.886
161.736
152.266
152.187
132.921
132.892
131.767
131.662
130.788
129.416
128.882
128.747
105.017
104.864
104.779
104.728
100.824
100.569
100.315
77.393
77.075
76.758
Ph
P
O
O
Ph
F
F
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

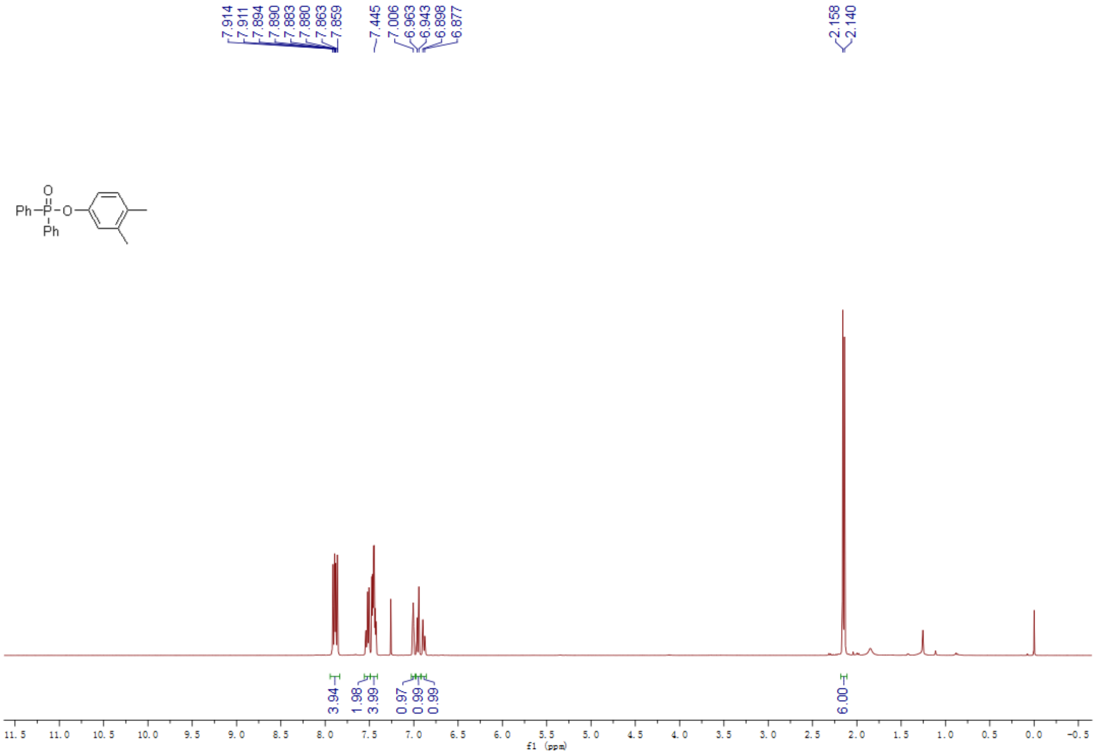

32.235
Ph
P
O
O
Ph
F
F
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)


7.902
7.900
7.882
7.879
7.871
7.868
7.851
7.847
7.457
7.064
7.057
7.048
7.041
6.944
6.935
6.923
6.914
6.905
6.852
6.830
6.807
2.174
2.170
Ph
P
O
O
F
Ph
4.06
2.07
4.07
1.00
1.04
1.06
3.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
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
f1 (ppm)

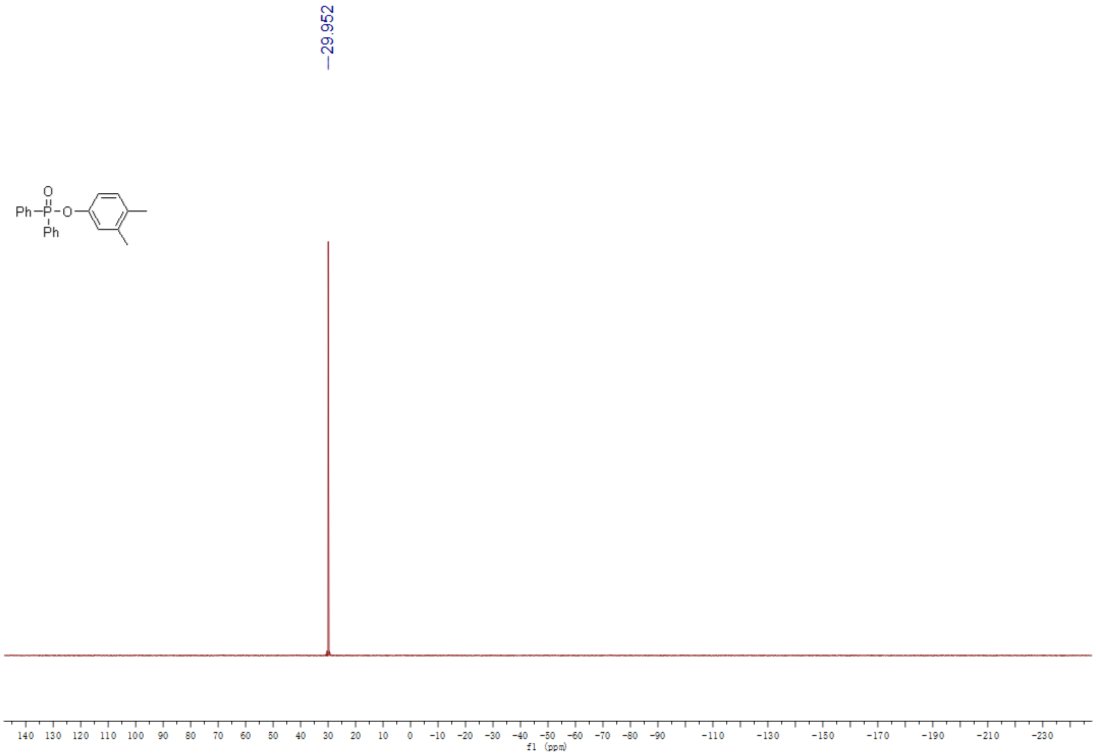

159.282
156.892
146.265
146.183
131.853
128.707
126.306
123.523
123.425
119.203
119.157
119.122
119.075
115.722
115.478
14.652
14.619
Ph
P
O
O
F
Ph
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

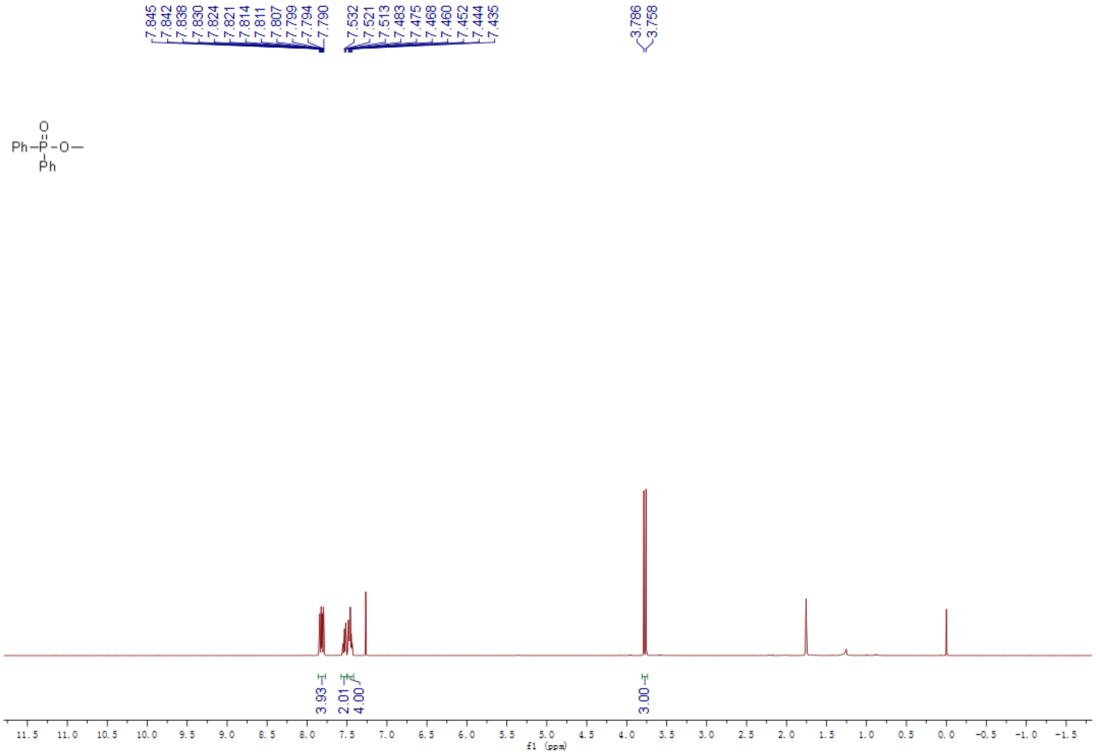


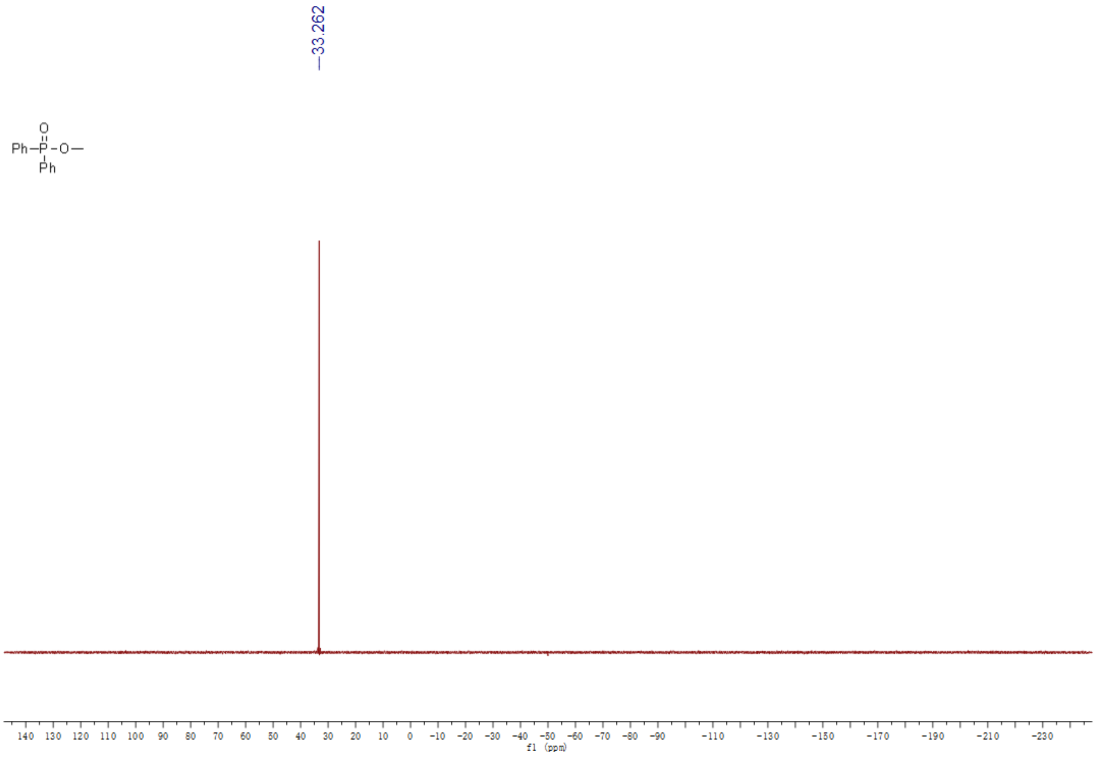
30.907
Ph
O
P
O
F
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

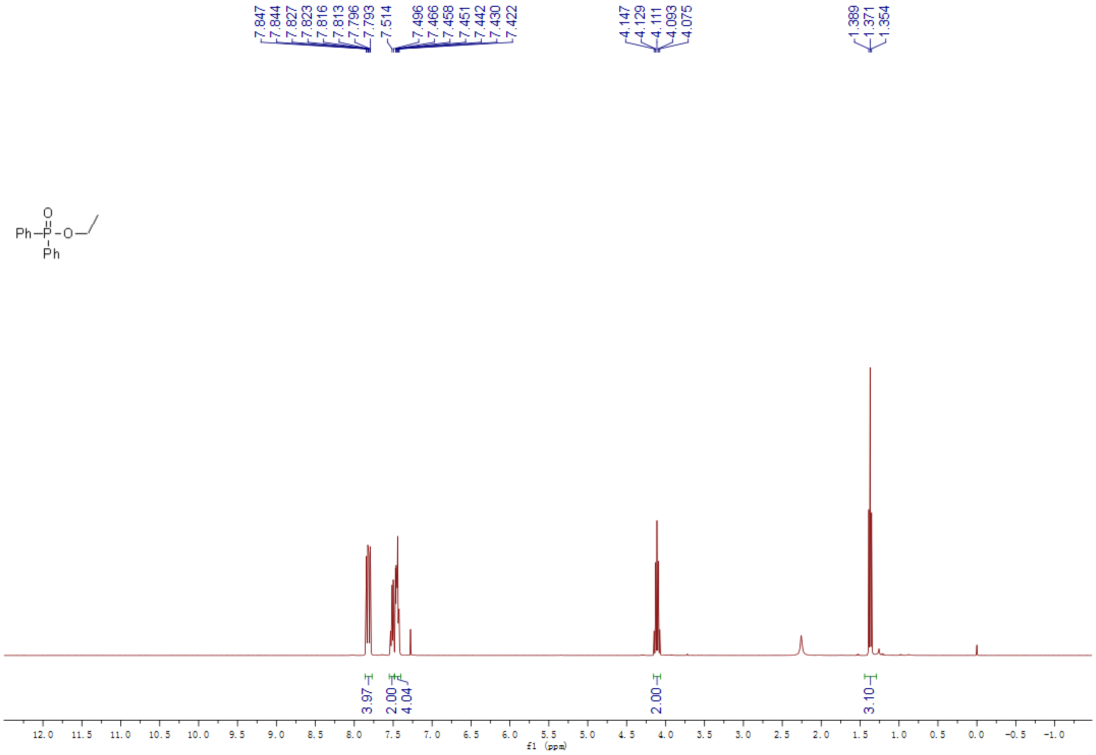


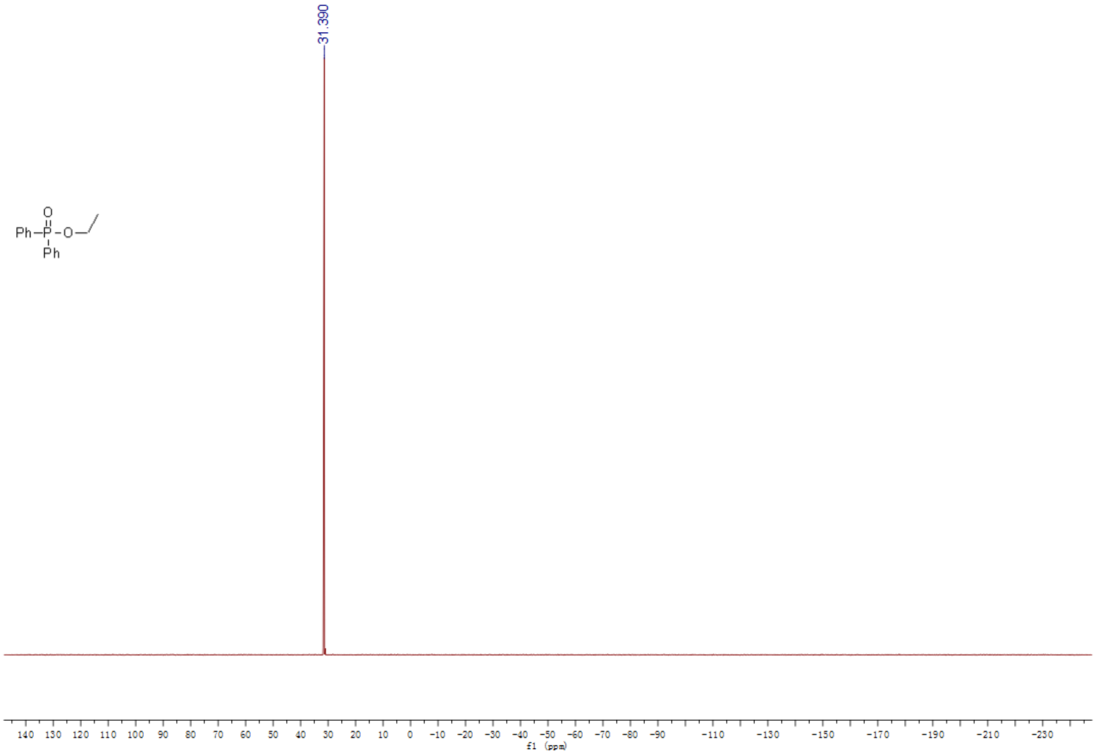
7.914
7.911
7.894
7.890
7.883
7.880
7.863
7.859
7.445
7.006
6.963
6.943
6.898
6.877
2.158
2.140
Ph
O
P
O
Ph
3.94
1.98
3.99
0.97
0.99
0.99
6.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

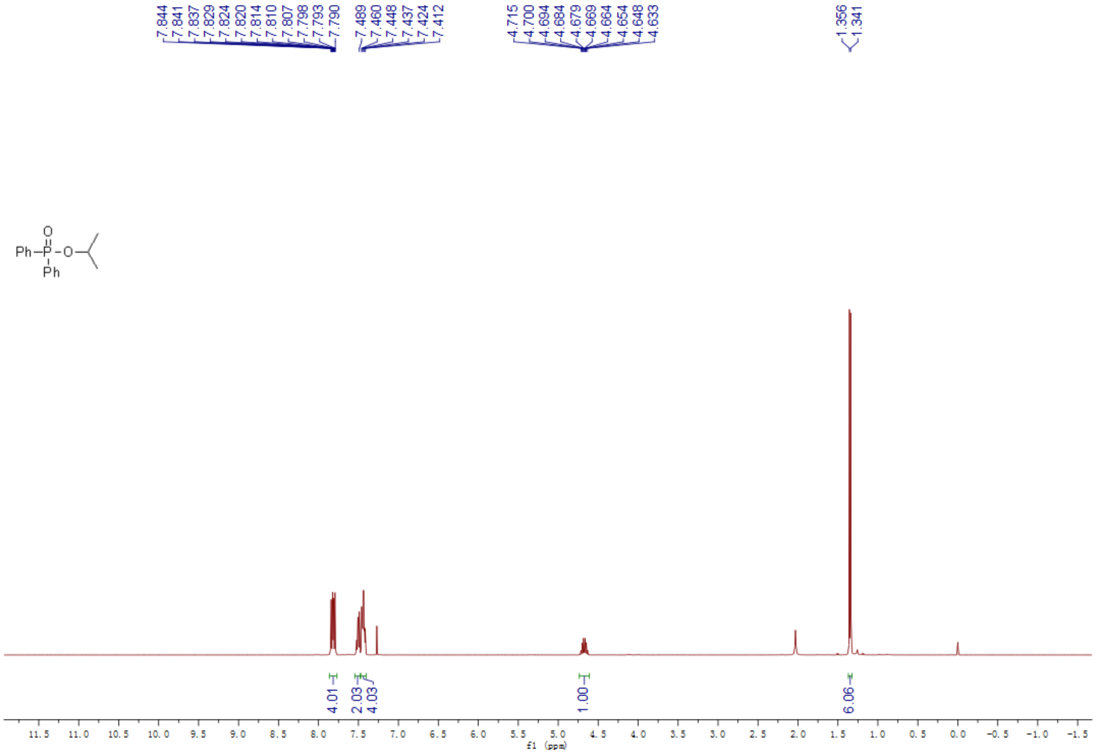

29.952
Ph
O
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

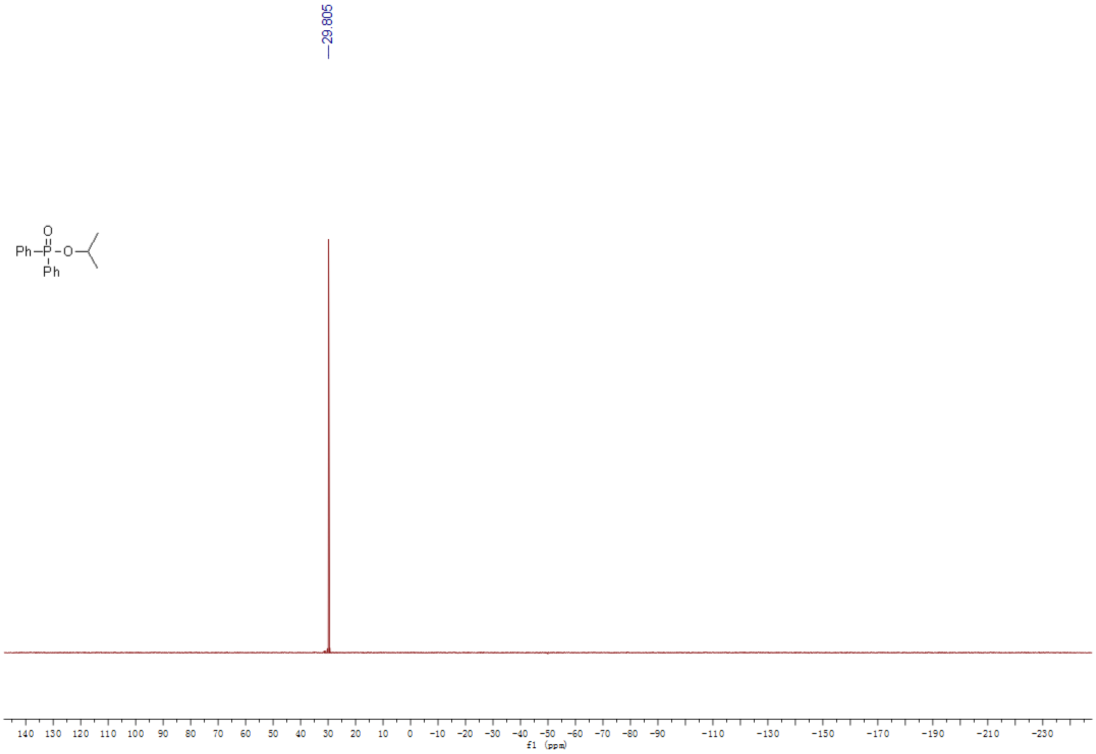

7.845
7.842
7.838
7.830
7.824
7.821
7.814
7.811
7.807
7.799
7.794
7.790
7.532
7.521
7.513
7.483
7.475
7.468
7.460
7.452
7.444
7.435
3.786
3.758
Ph
O
P
O
Ph
3.93
2.01
4.00
3.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0 −1.5
f1 (ppm)


33.262
O
Ph–P–O–
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

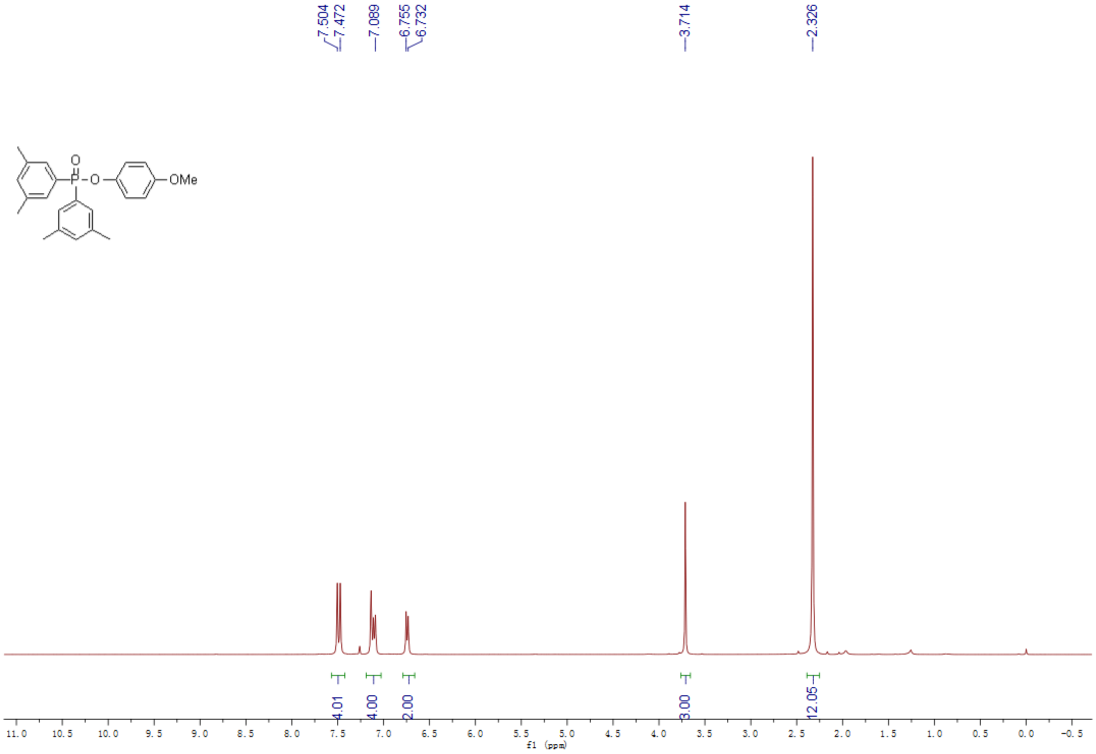

7.847
7.844
7.827
7.823
7.816
7.813
7.796
7.793
7.514
7.496
7.466
7.458
7.451
7.442
7.430
7.422
4.147
4.129
4.111
4.093
4.075
1.389
1.371
1.354
O
Ph–P–O
Ph
3.97
2.00
4.04
2.00
3.10
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0
f1 (ppm)


31.390
O
Ph
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

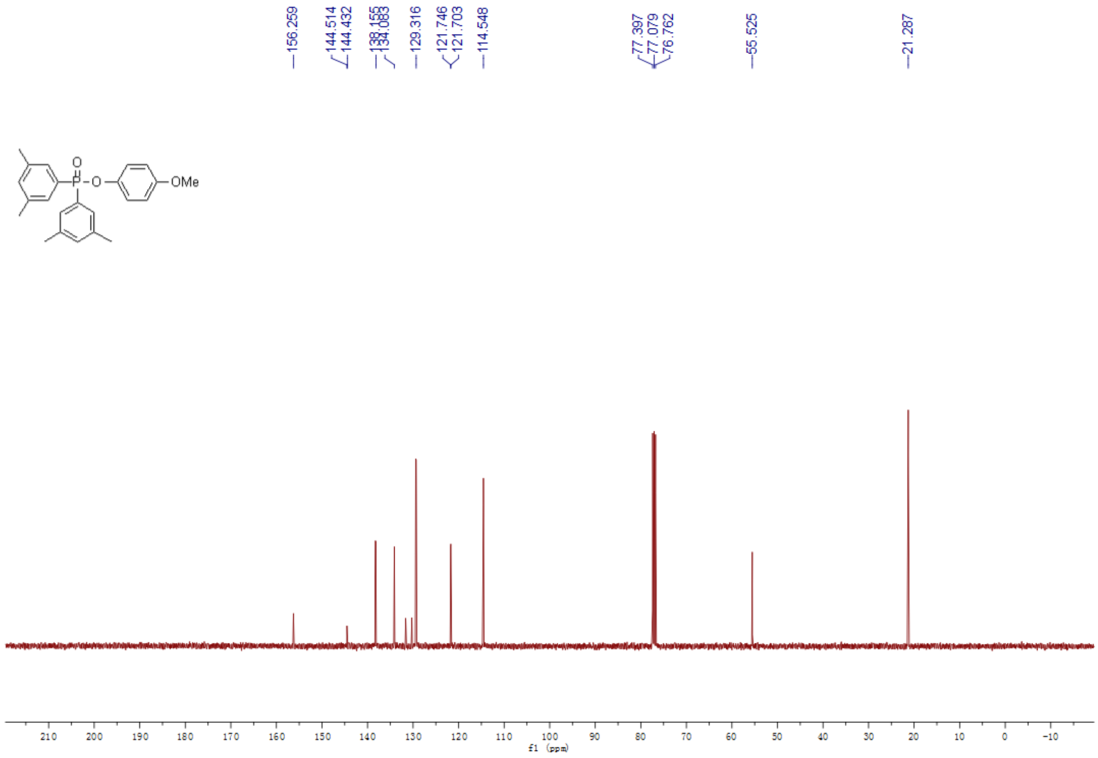

7.844
7.841
7.837
7.829
7.824
7.820
7.814
7.810
7.807
7.798
7.793
7.790
7.489
7.460
7.448
7.437
7.424
7.412
4.715
4.700
4.694
4.684
4.679
4.669
4.664
4.654
4.648
4.633
1.356
1.341
O
Ph
P
O
Ph
4.01
2.03
4.03
1.00
6.06
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5 −1.0 −1.5
f1 (ppm)

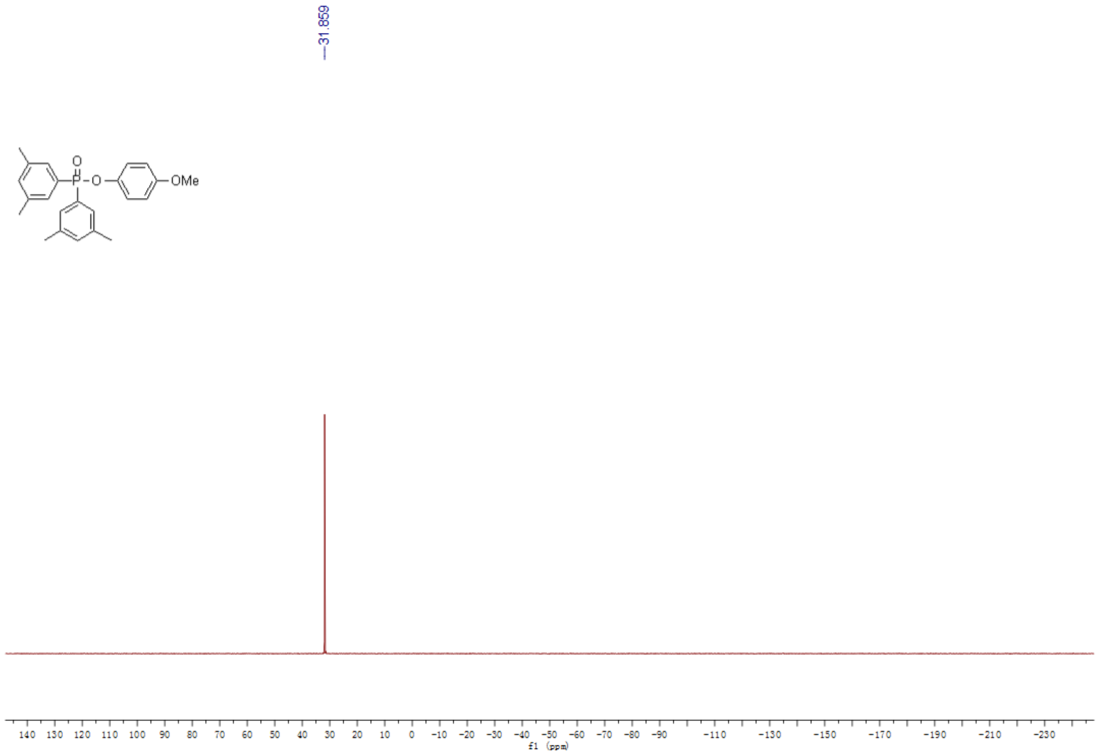


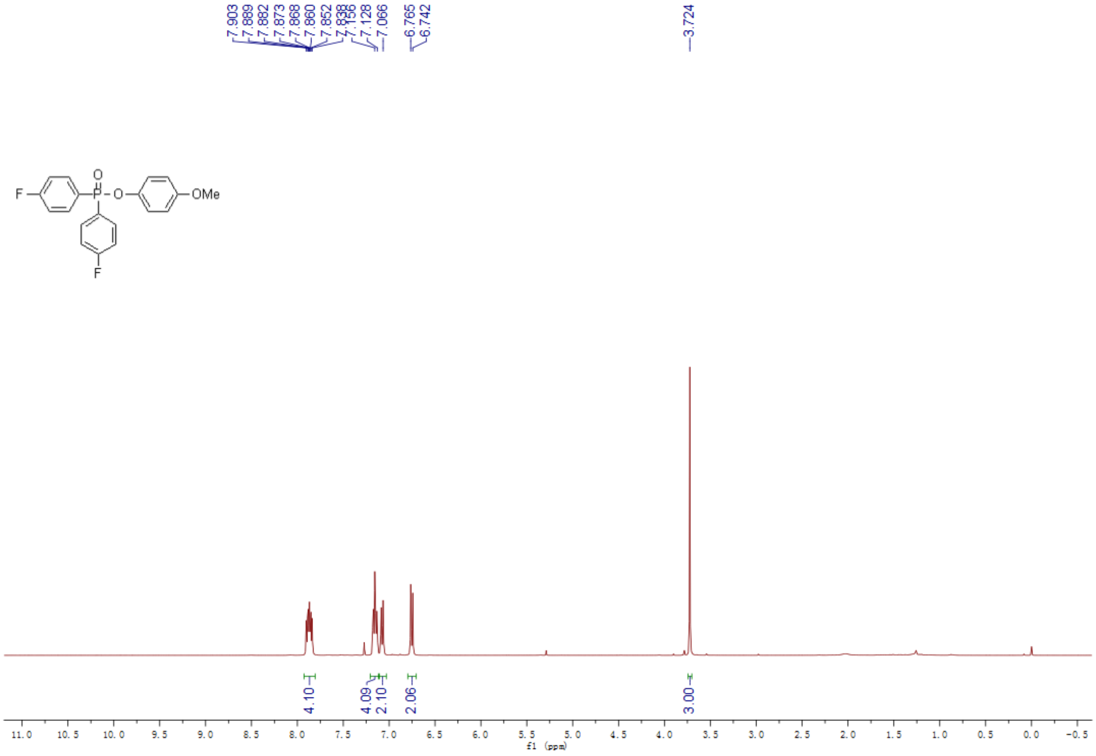
29.805
O
Ph
P
O
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)

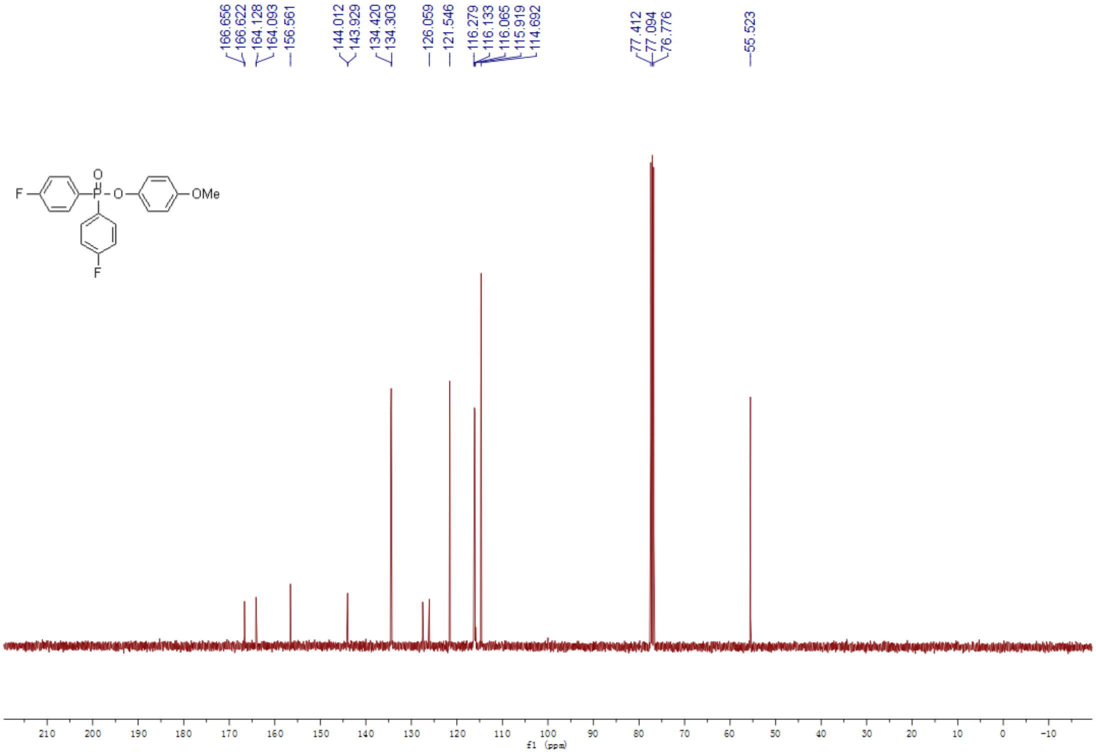


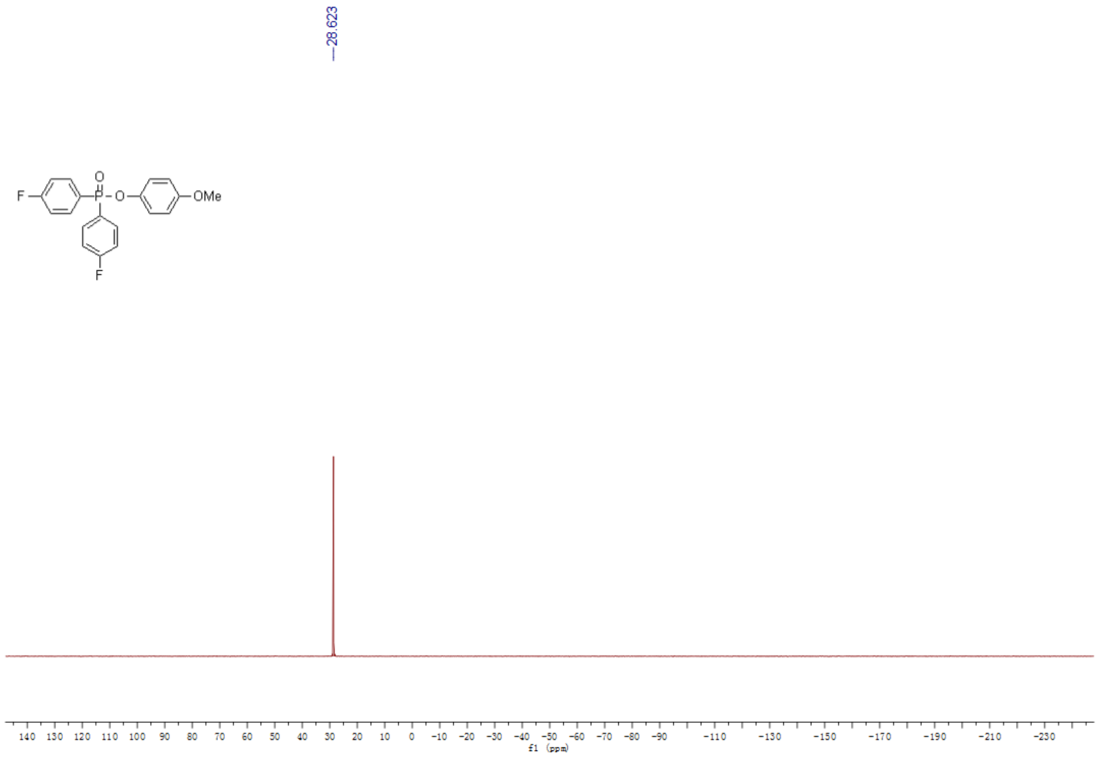
7.504
7.472
7.089
6.755
6.732
3.714
2.326
O
P
O
OMe
4.01
4.00
2.00
3.00
12.05
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 −0.5
f1 (ppm)

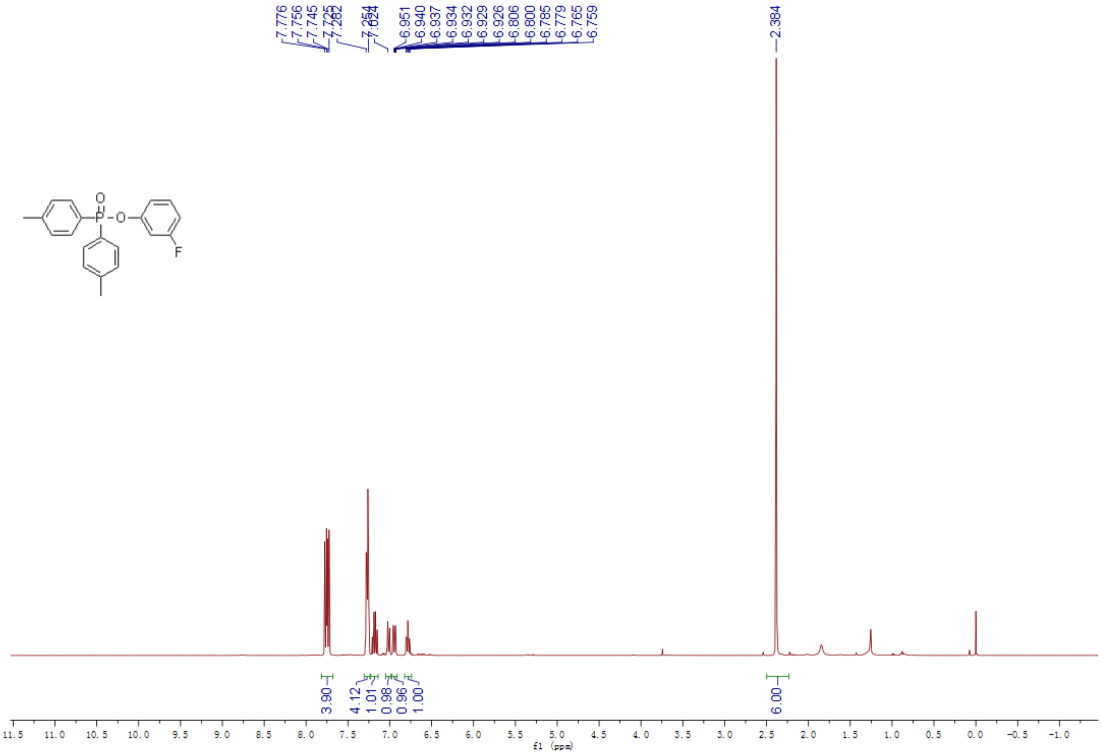

156.259
144.514
144.432
138.155
134.083
129.316
121.746
121.703
114.548
77.397
77.079
76.762
55.525
21.287
O
P
O
OMe
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

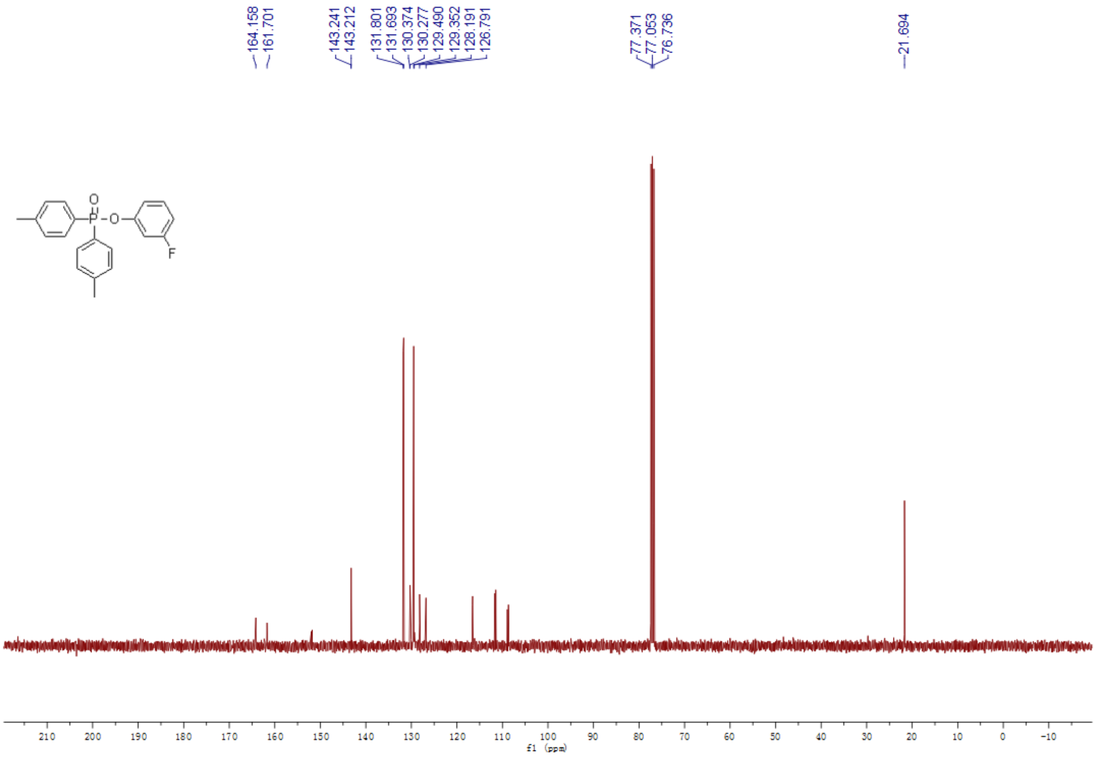

31.859
O
P
O
OMe
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

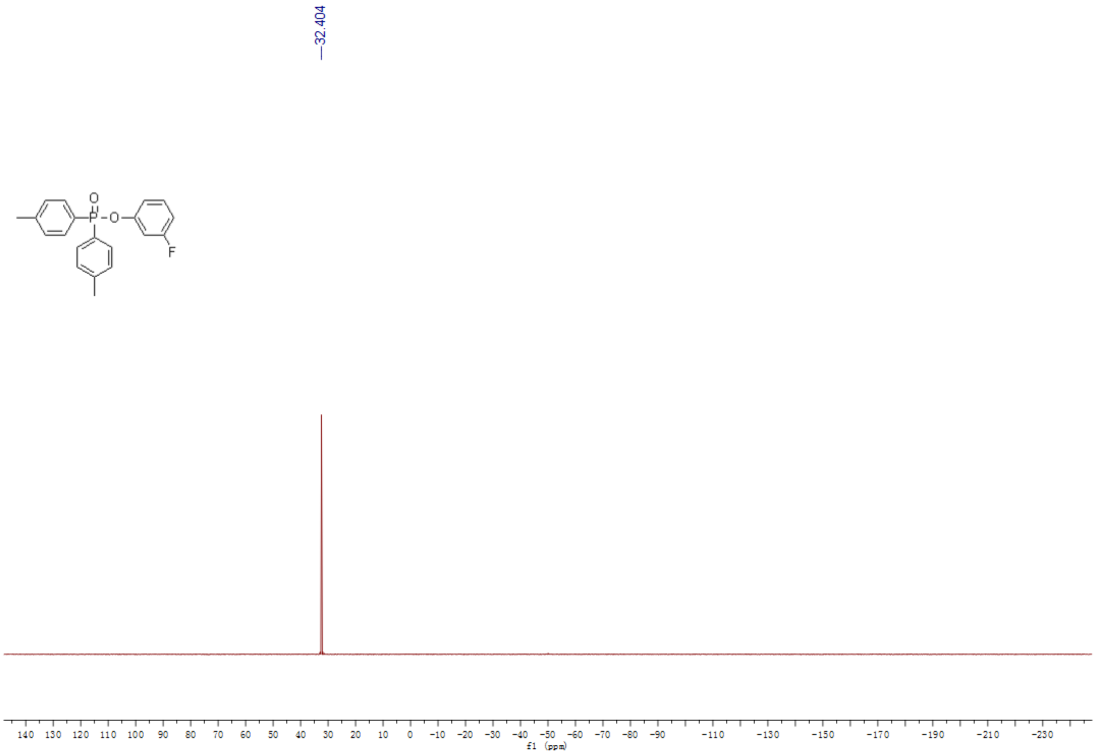

7.903
7.889
7.882
7.873
7.868
7.860
7.852
7.838
7.158
7.128
7.066
6.765
6.742
3.724
F
O
P
O
OMe
F
4.10
4.09
2.10
2.06
3.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

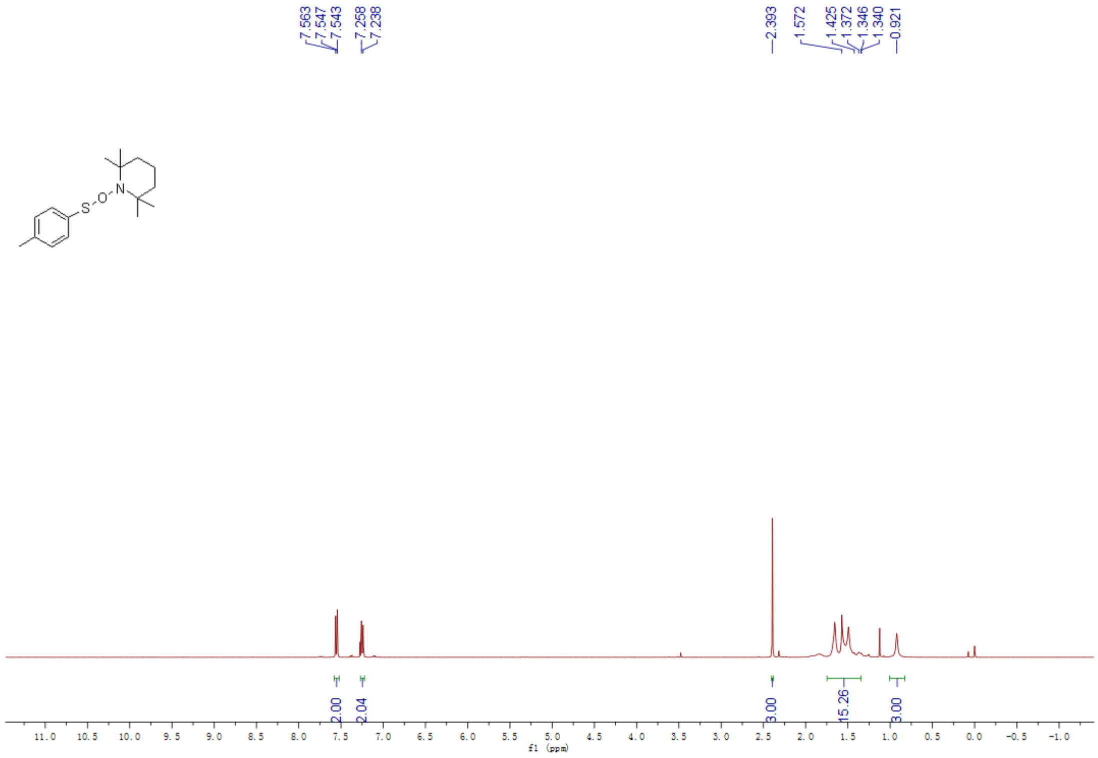

166.656
166.622
164.128
164.093
156.561
144.012
143.929
134.420
134.303
126.059
121.546
116.279
116.133
116.065
115.919
114.692
77.412
77.094
76.776
55.523
F
O
P
O
OMe
F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

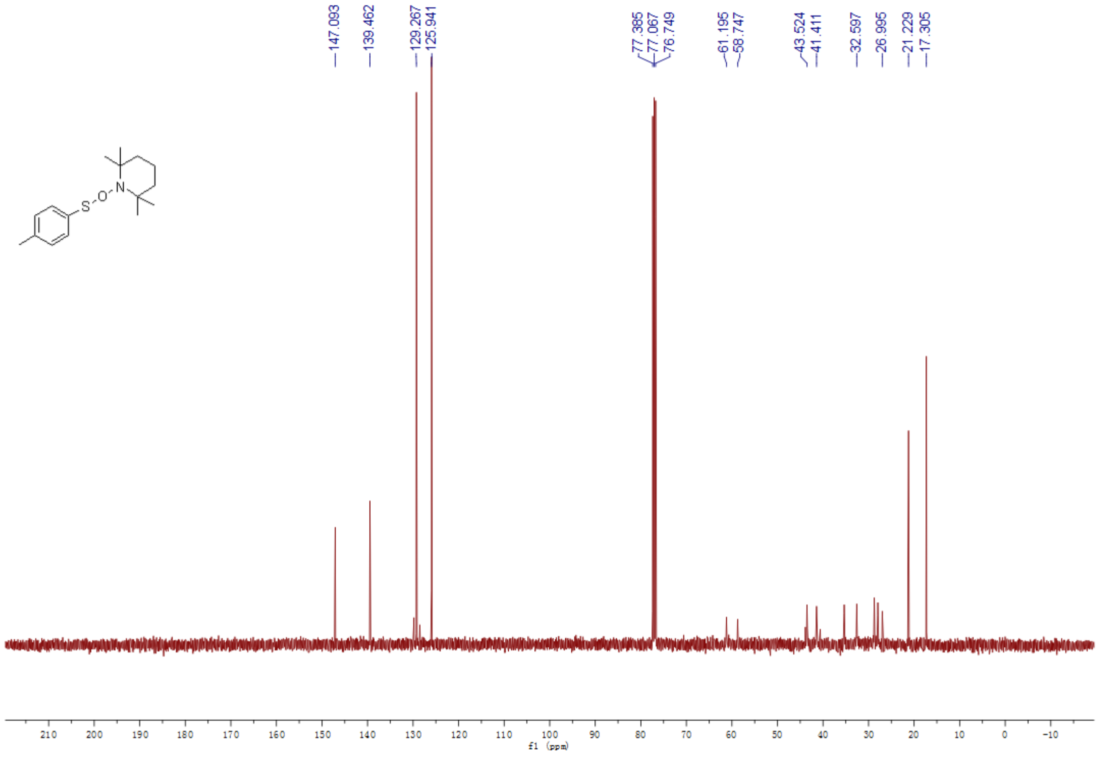

28.623
F
O
P
O
OMe
F
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

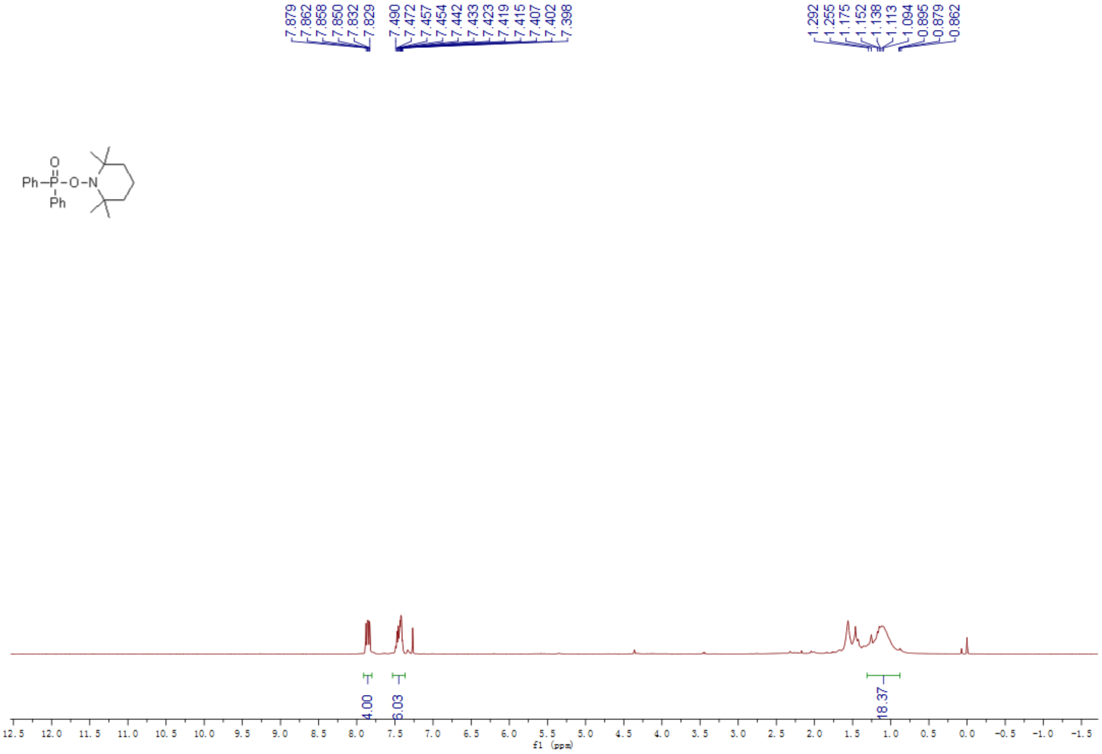

7.776
7.756
7.745
7.725
7.282
7.254
7.024
6.951
6.940
6.937
6.934
6.932
6.929
6.926
6.806
6.800
6.785
6.779
6.765
6.759
2.384
O
P
O
F
3.90
4.12
1.01
0.98
0.96
1.00
6.00
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

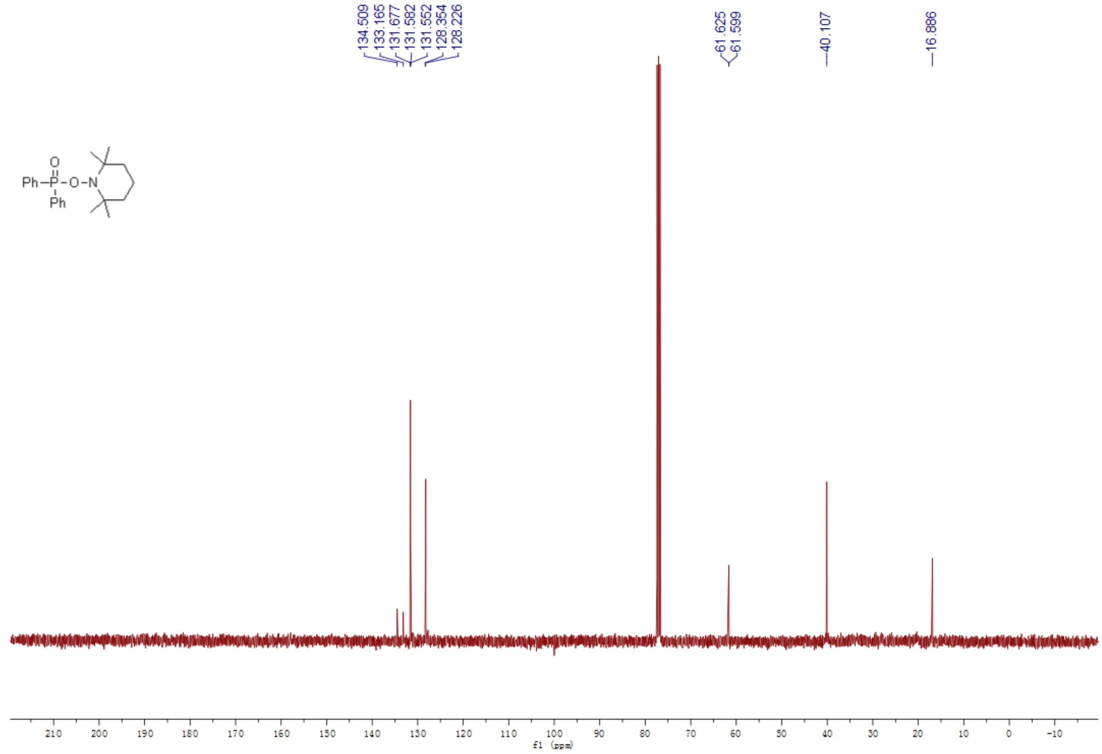

164.158
161.701
143.241
143.212
131.801
131.693
130.374
130.277
129.490
129.352
128.191
126.791
77.371
77.053
76.736
21.694
O
P
O
F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

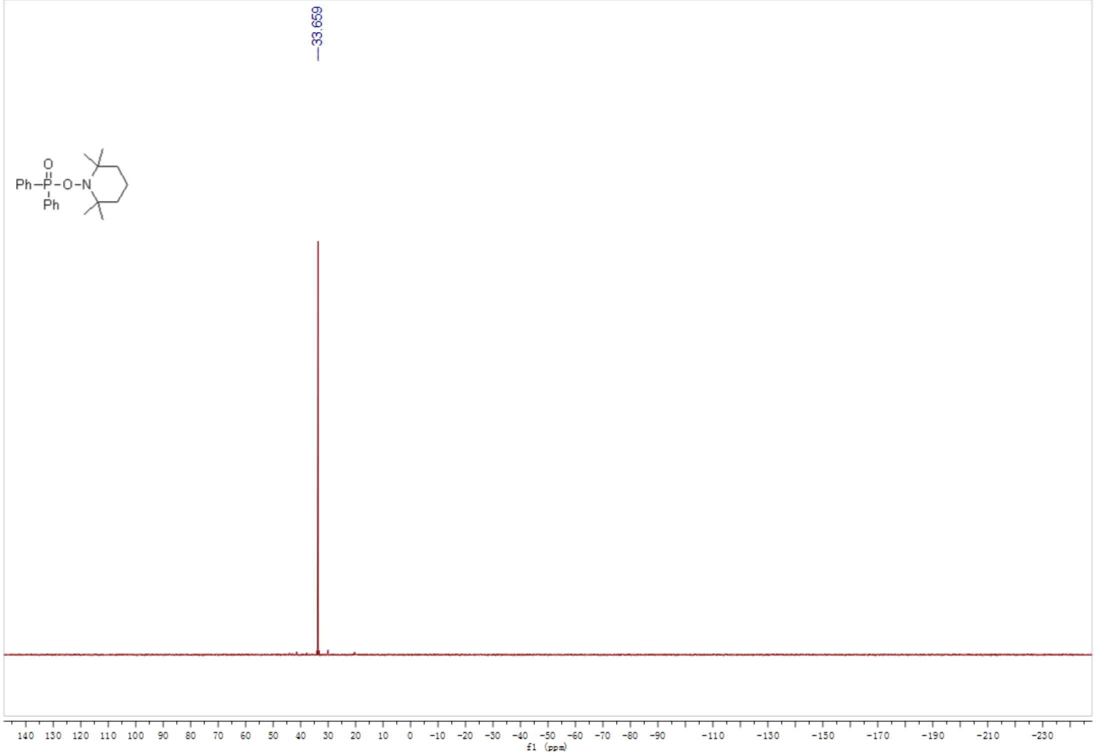

32.404
O
P
O
F
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

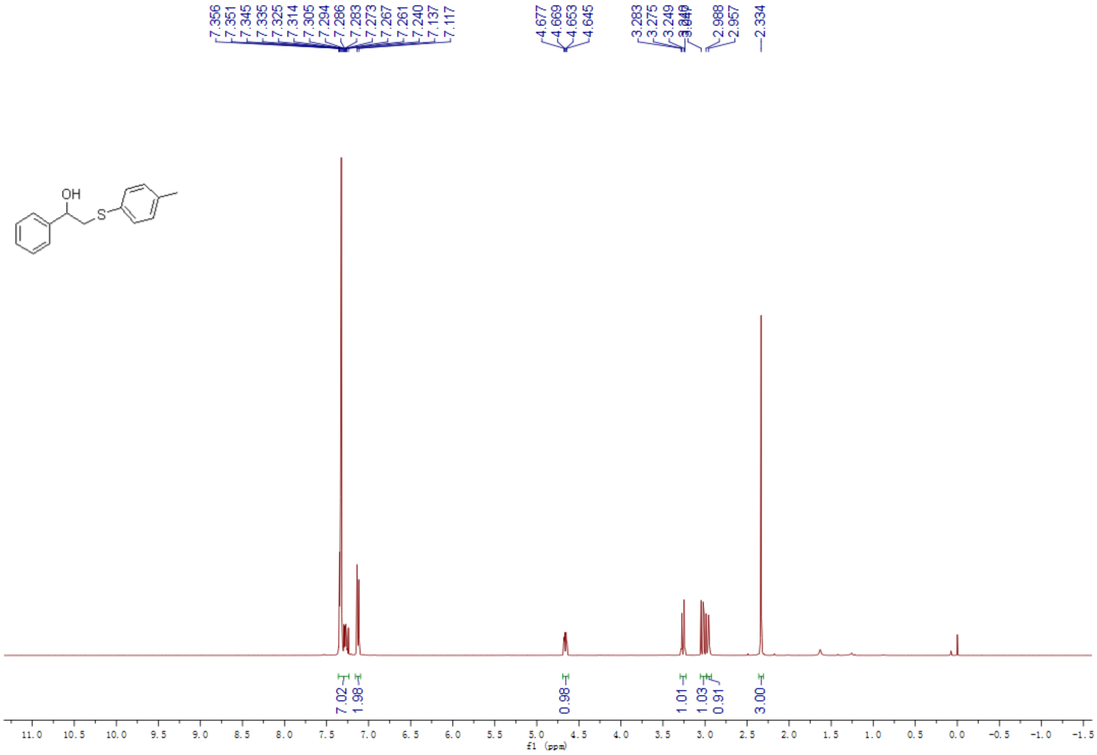

7.563
7.547
7.543
7.258
7.238
2.393
1.572
1.425
1.372
1.346
1.340
0.921
S
O
N
2.00
2.04
3.00
15.26
3.00
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)

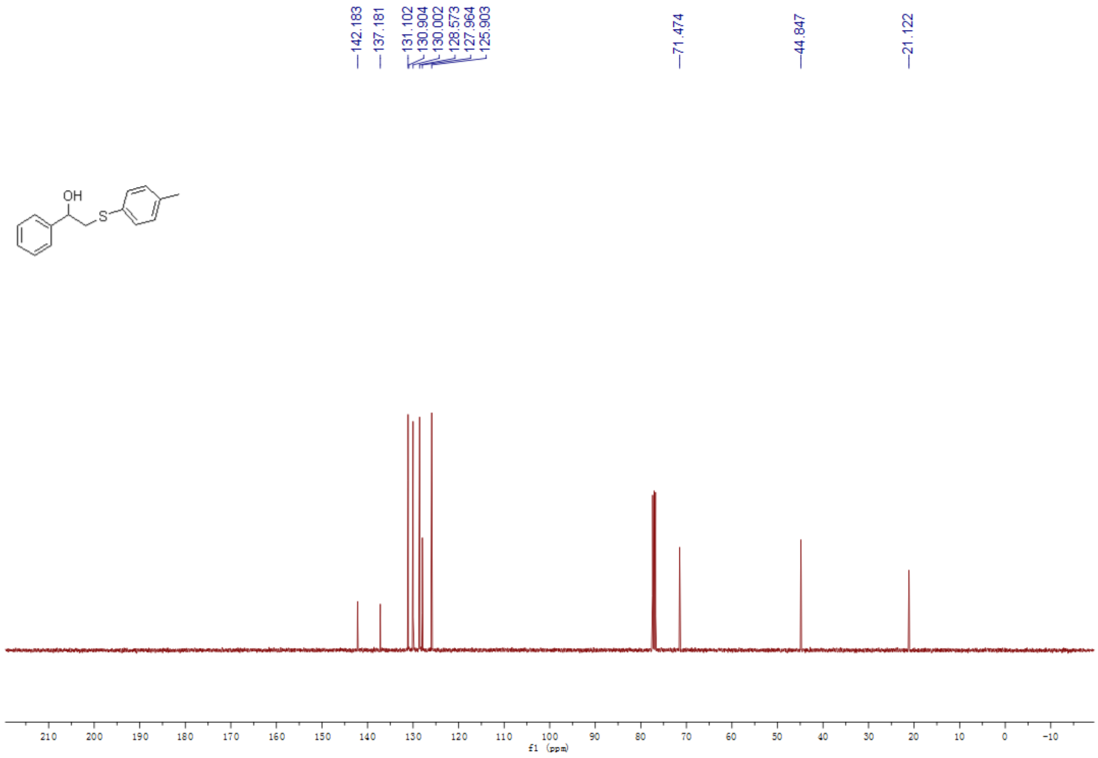

147.093
139.462
129.267
125.941
77.385
77.067
76.749
61.195
58.747
43.524
41.411
32.597
26.995
21.229
17.305
S
O
N
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.879
7.862
7.858
7.850
7.832
7.829
7.490
7.472
7.457
7.454
7.442
7.433
7.423
7.419
7.415
7.407
7.402
7.398
1.292
1.255
1.175
1.152
1.138
1.113
1.094
0.895
0.879
0.862
Ph
P
O
Ph
N
4.00
6.03
18.37
f1 (ppm)


134.509
133.165
131.677
131.582
131.552
128.354
128.226
61.625
61.599
40.107
16.886
Ph
P
O
Ph
N
f1 (ppm)


—33.659
O
Ph–P–O–N
Ph
140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 −10 −20 −30 −40 −50 −60 −70 −80 −90 −110 −130 −150 −170 −190 −210 −230
f1 (ppm)


7.356
7.351
7.345
7.335
7.325
7.314
7.305
7.294
7.286
7.283
7.273
7.267
7.261
7.240
7.137
7.117
4.677
4.669
4.653
4.645
3.283
3.275
3.249
3.240
2.988
2.957
2.334
OH
S
7.02
1.98
0.98
1.01
1.03
0.91
3.00
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 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 −0.5 −1.0 −1.5
f1 (ppm)


142.183
137.181
131.102
130.904
130.002
128.573
127.964
125.903
71.474
44.847
21.122
OH
S
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)