Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Palladium(II)-catalyzed Oxidative C(sp^3)–P Bond Formation via C(sp^3)–H Bond Activation

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I. General remarks

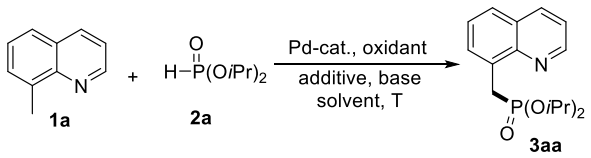
NMR spectra were obtained on a Bruker AMX-600 or Bruker AMX-400. The ^{1}H NMR chemical shifts were measured relative to $CDCl_3$ or DMSO-d_6 as the internal reference ($CDCl_3$: δ = 7.260 ppm; DMSO: δ = 2.500 ppm). The ^{13}C NMR chemical shifts were given using $CDCl_3$ as the internal standard ($CDCl_3$: δ = 77.16 ppm). High-resolution mass spectra (HR-MS) were obtained with a Bruker-impact II (ESI^+).

Unless otherwise noted, all reagents were obtained from commercial suppliers and used without further purification. 8-Methylquinoline **1a**, 8-ethylquinoline **1x,** H-phosphonates **2a-2f**, and diphenylphosphine oxide **2g** were purchased from Adamas-beta®. Substituted 8-methylquinolines **1b-1w** [1-7] and functionalized diarylphosphine oxides **2h-2k** [8] were prepared according to the literatures. All solvents were dried according to standard methods prior to use.

II. Optimization of the reaction conditions.

A Schlenk test tube equipped with a magnetic stir bar was charged with Pd-catalyst, 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv.), oxidant (3.0 equiv.), base (2.0 equiv.), additive and solvent (2.0 mL) under N_2. The resulting mixture was stirred for 10 min at 120 °C, and then diisopropyl phosphite **2a** (0.25 mmol, 1.0 equiv) in solvent (1 mL) was added dropwise via a syringe pump. After addition, the mixture was stirred at 120 °C for indicated time. After cooling to room temperature, the reaction solution was diluted with 20 mL of CH_2Cl_2, then filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3aa**.

Table S1. Optimization of reaction condition.[a]



entry	Pd-cat.	oxidant	base	additive	solvent	Yield (%)
1	**$Pd(OAc)_2$**	**AgOAc**	**NaOAc**	**BQ**	***t*-AmylOH**	**72**
2	$Pd(TFA)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	51

3	$Pd(PPh_3)_4$	AgOAc	NaOAc	BQ	*t*-AmylOH	trace
4	$Pd(dba)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	43
5	$Pd(dppf)Cl_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	26
6	$[RhCp^*Cl]_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	trace
7	-	AgOAc	NaOAc	BQ	*t*-AmylOH	n.d
8	$Pd(OAc)_2$	Ag_2CO_3	NaOAc	BQ	*t*-AmylOH	40
9	$Pd(OAc)_2$	AgTFA	NaOAc	BQ	*t*-AmylOH	21
10	$Pd(OAc)_2$	Ag_2O	NaOAc	BQ	*t*-AmylOH	trace
11	$Pd(OAc)_2$	$Cu(OAc)_2$	NaOAc	BQ	*t*-AmylOH	n.d
12	$Pd(OAc)_2$	$Mn(OAc)_3{\cdot}2H_2O$	NaOAc	BQ	*t*-AmylOH	n.d
13	$Pd(OAc)_2$	$K_2S_2O_8$	NaOAc	BQ	*t*-AmylOH	n.d
14	$Pd(OAc)_2$	-	NaOAc	BQ	*t*-AmylOH	n.d
15	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-BuOH	32
16	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	1,4-dioxane	34
17	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	DMSO	trace
18	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	ethyl glyme	22
19	$Pd(OAc)_2$	AgOAc	NaOAc	1,4-naphthoquinone	*t*-AmylOH	46
20	$Pd(OAc)_2$	AgOAc	NaOAc	1,2,4,5-tetrachlorobenzoquinone	*t*-AmylOH	trace
21	$Pd(OAc)_2$	AgOAc	NaOAc	2,6-ditertbutyl-1,4-benzoquinone	*t*-AmylOH	trace
22	$Pd(OAc)_2$	AgOAc	NaOAc	2,3,5-trimethyl-1,4-benzoquinone	*t*-AmylOH	trace
23	$Pd(OAc)_2$	AgOAc	NaOAc	anthraquinone	*t*-AmylOH	trace
24	$Pd(OAc)_2$	AgOAc	NaOAc	NMMI	*t*-AmylOH	trace
25	$Pd(OAc)_2$	AgOAc	NaOAc	maleic anhydride	*t*-AmylOH	trace
26	$Pd(OAc)_2$	AgOAc	NaOAc	DDQ	*t*-AmylOH	trace
27	$Pd(OAc)_2$	AgOAc	NaOAc	BQ+X-phos (20 mol%)	*t*-AmylOH	trace
28	$Pd(OAc)_2$	AgOAc	NaOAc	BQ+S-phos (20 mol%)	*t*-AmylOH	trace
29	$Pd(OAc)_2$	AgOAc	NaOAc	-	*t*-AmylOH	n.d
30	$Pd(OAc)_2$	AgOAc	NaOAc	BQ (0.2 equiv)	*t*-AmylOH	21
31	$Pd(OAc)_2$	AgOAc	NaOAc	BQ (2 equiv)	*t*-AmylOH	44
32	$Pd(OAc)_2$	AgOAc	NaOAc	BQ (4 equiv)	*t*-AmylOH	43
33	$Pd(OAc)_2$	AgOAc	-	BQ	*t*-AmylOH	n.d
34	$Pd(OAc)_2$	AgOAc	LiOAc	BQ	*t*-AmylOH	52
35	$Pd(OAc)_2$	AgOAc	KOAc	BQ	*t*-AmylOH	28
36	$Pd(OAc)_2$	AgOAc	CsOAc	BQ	*t*-AmylOH	trace
37	$Pd(OAc)_2$	AgOAc	$NaHCO_3$	BQ	*t*-AmylOH	49
38	$Pd(OAc)_2$	AgOAc	PivONa	BQ	*t*-AmylOH	26
39	$Pd(OAc)_2$	AgOAc	PhCOONa	BQ	*t*-AmylOH	46
40	$Pd(OAc)_2$	AgOAc	K_2CO_3	BQ	*t*-AmylOH	trace
41	$Pd(OAc)_2$	AgOAc	K_3PO_4	BQ	*t*-AmylOH	trace
42	$Pd(OAc)_2$	AgOAc	NEt_3	BQ	*t*-AmylOH	trace
43	$Pd(OAc)_2$	AgOAc	DBU	BQ	*t*-AmylOH	trace
44[b]	**$Pd(OAc)_2$**	**AgOAc**	**NaOAc**	**BQ**	***t*-AmylOH**	**71**
45[c]	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	41

46[d]	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	62
47[e]	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	60
48[f]	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	55
49[g]	$Pd(OAc)_2$	AgOAc	NaOAc	BQ	*t*-AmylOH	44

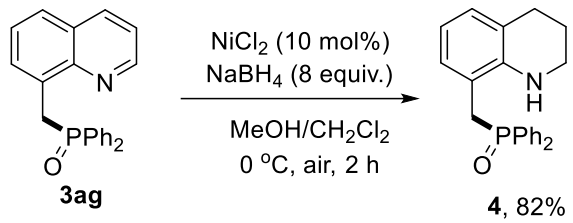
[a] Reaction was carried out using **1a** (0.5 mmol), Pd-cat. (0.025 mmol), base (0.5 mmol), oxidant (0.75 mmol), additive (0.25 mmol) in solvent (2 mL) for 10 hours at 120 °C, and **2a** (0.25 mmol) dissolved in *t*-AmylOH (1 mL) was added dropwise to the reaction mixture over 8 hours. [b] **1a** (0.25 mmol), **2a** (0.75 mmol); [c] feeding time 4 hour, total reaction time 6 hours; [d] feeding time 6 hour, total reaction time 8 hours; [e] feeding time 16 hour, total reaction time 24 hours. [f] 110 °C; [g] 130 °C.

III. General procedure for Pd-catalyzed cross-coupling of 8-methylquinolines 1 with H-phosphonates or diarylphosphine oxides 2.

In a 25 mL rubber-sealed tube, a mixture of 8-methylquinolines **1** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.) and NaOAc (41 mg, 2 equiv) in *t*-AmylOH (2.0 mL) was stirred at 120 °C under N_2 for 10 min. Then H-phosphonates or diarylphosphine oxides **2** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump in 8 h. After addition, the mixture was stirred at the same temperature for another 2 h. After cooling to room temperature, the mixture was filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3**.

IV. Procedure for derivatization reactions of products 3.

a)

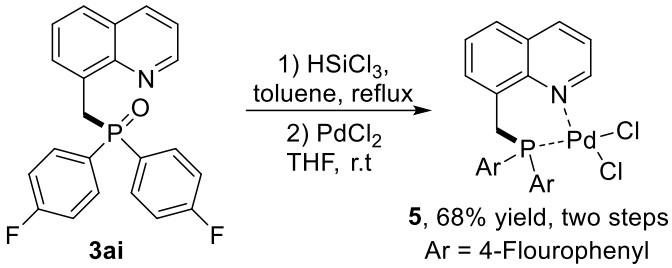


3ag **4**, 82%

To a mixture of **3ag** (0.2 mmol, 68.6 mg) and $NiCl_2$ (10 mol %, 2.6 mg) in MeOH (1.6 mL) and CH_2Cl_2 (0.8 mL), $NaBH_4$ (1.6 mmol, 60.8 mg) was added in portions with stirring at 0 °C for 1 h. After addition, the mixture was stirred at the same temperature for another 1 h. After

the removal of the solvents, the residue was purified by flash column chromatography on silica gel to provide the product **4** as a white solid (57 mg, 82% yield).

b)

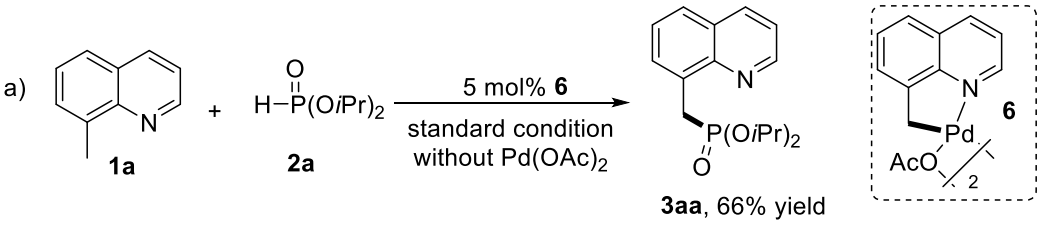


In a 25 mL Schlenk test tube, **3ai** (0.2 mmol, 76 mg) were suspended in anhydrous toluene (2 mL), then NEt_3 (2 mmol, 278 uL) and $HSiCl_3$ (1 mmol, 100 uL) were added by syringe. Subsequently, the mixture was refluxed for 3 h. The mixture was then quenched by saturated sodium bicarbonate solution (1 mL). The aqueous phase was separated and extracted three times with toluene. The combined organic fractions were concentrated in vacuo to give the corresponding phosphine as a white solid. Without further purification, the phosphine was redissolved in anhydrous THF (10 mL), and then $PdCl_2$ (0.2 mmol, 35.5 mg) was added under nitrogen atmosphere. The resulting mixture was stirred at room temperature for 24 h. Finally, the suspension was filtrated. The filter cake was washed with THF and dried in vacuo to give the target palladium complex **5** as a brown solid (73.3 mg, 68% yield over two steps).

V. Mechanism study.

(a) Reaction in Scheme 5a.

a)



1) Preparation of palladacycle **6**:

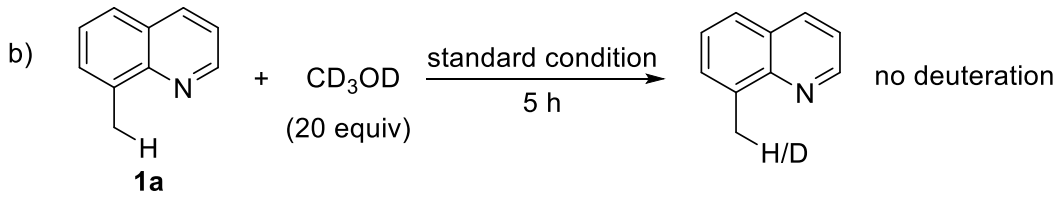
8-Methylquinoline (186 mg, 1.3 mmol) and $Pd(OAc)_2$ (291 mg, 1.3 mmol) were suspended in glacial acetic acid (20 mL). The mixture was refluxed for 1.5 h, and then filtered. Water (150 mL) was added to the filtrate, and the mixture was allowed to sit overnight. The

precipitated product was collected by filtration and recrystallized from CH_2Cl_2/hexane to yield **6** as a bright orange solid.

2）Coupling Reaction between **1a** and **2a** in the presence of intermediate **6:**

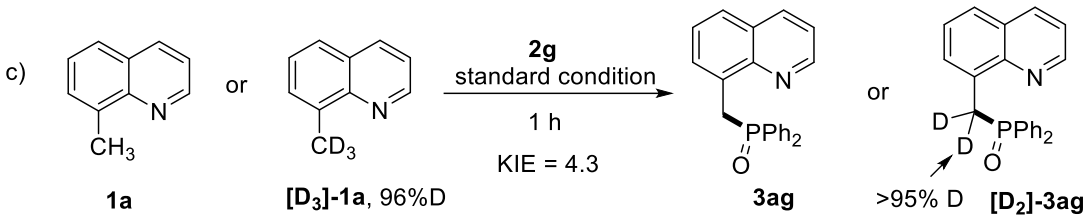
In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), **6** (7.6 mg, 0.0125 mmol, 5 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.) and NaOAc (41 mg, 2 equiv) in *t*-AmylOH (2.0 mL) was stirred at 120 ^oC under N_2 for 10 min. Then **2a** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump in 8 h. After addition, the mixture was stirred at the same temperature for another 2 h. After cooling to room temperature, the mixture was filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3aa** (66% yield).

(b) Reaction in Scheme 5b.

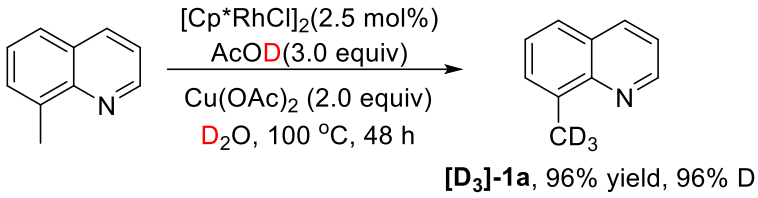


In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.), NaOAc (41 mg, 2 equiv) and CD_3OD (207 uL, 5 mmol, 20 equiv) in *t*-AmylOH (2.0 mL) was stirred at 120 ^oC under N_2 for 5 hours. After cooling to room temperature, the mixture was filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to recover the starting material **1a**, and no deuteration of the methyl C−H bonds was detected via ^1H NMR test.

(c) Reaction in Scheme 5c.



1) Preparation of **[D3]-1a**

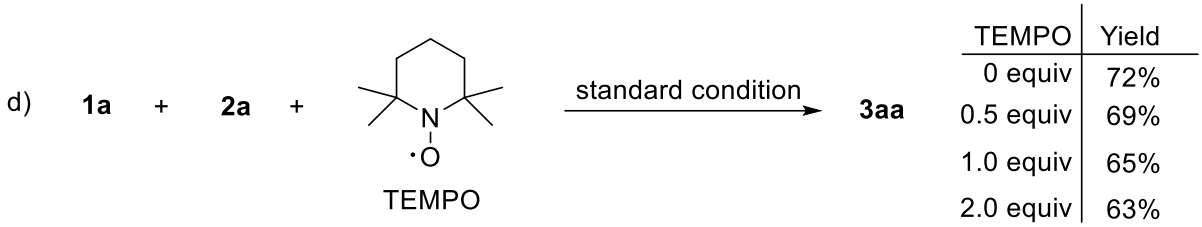


A Schlenk test tube equipped with a magnetic stir bar was charged with 8-methylquinoline (**1a**) (43.0 mg, 0.3 mmol), [RhCp*Cl2]2 (4.6 mg, 0.0075 mmol, 2.5 mol %), AcOD (54.1 mg, 0.9 mmol, 300 mol %), Cu(OAc)2 (109.0 mg, 0.6 mmol, 200 mol %) and D2O (1 mL) under air. The reaction mixture was heated at 100 °C for 20 h. After cooling down, the reaction mixture was extracted with EtOAc (10 mL). The organic layer was dried over MgSO4, and concentrated in vacuo. The residue was purified by flash column chromatography (*n*-hexanes/EtOAc = 10:1) to afford **[D3]-1a** (42.1 mg, 96% D) in 96% yield.

2）Procedure for the parallel KIE experiments

In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** or 8-methylquinoline-*d3* **[D3]-1a** (0.25 mmol, 1.0 equiv), Pd(OAc)2 (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.) and NaOAc (41 mg, 2 equiv) in t-AmylOH (2.0 mL) was stirred at 120 °C under N2 for 10 min. Then diphenylphosphine oxides **2g** (152 mg, 0.75 mmol, 3.0 equiv) in t-AmylOH (1 mL) was added dropwise via an automatic syringe. After one hour, both reactions were rapiddly quenched in ice water. The reactions mixtures were filtered through a celite pad and concentrated under vacuum. The residues were purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3ag** (14.6 mg, 17% yield) and **[D2]-3ag** (3.3 mg, 4% yield).

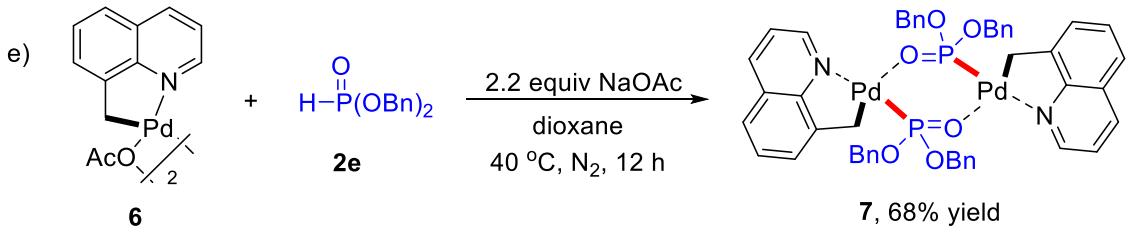
(d) Reaction in Scheme 5d.



TEMPO	Yield
0 equiv	72%
0.5 equiv	69%
1.0 equiv	65%
2.0 equiv	63%

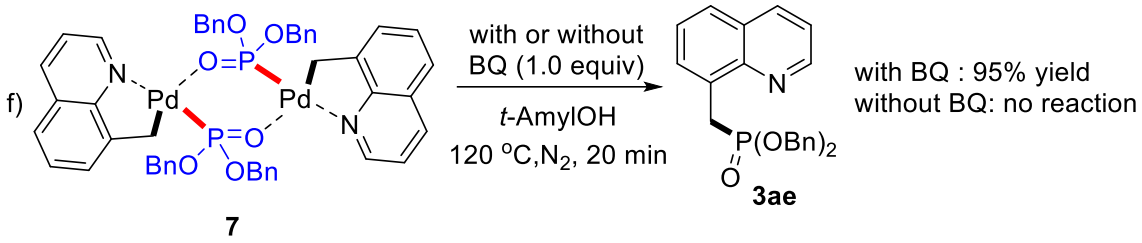
In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.), NaOAc (41 mg, 2 equiv) and 2,2,6,6-tetramethylpiperidine *N*-oxide (indicated equivalents) in *t*-AmylOH (2.0 mL) was stirred at 120 ^{o}C under N_2 for 10 min. Then **2a** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump in 8 h. After addition, the mixture was stirred at the same temperature for another 2 h. After cooling to room temperature, the mixture was filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3aa**.

(e) Reaction in Scheme 5e.



A Schlenk test tube equipped with a magnetic stir bar was charged with palladium complex **6** (64 mg, 0.10 mmol, 1.0 equiv), NaOAc (18 mg, 0.22 mmol, 2.2 equiv), dioxane (2.0 mL) and **2e** (52.4 mg, 0.2 mmol, 2.0 equiv). The reaction was stirred at 40 ℃ for 12 h. After cooling to room temperature, the reaction mixture was filtered through a celite pad and concentrated under vacuum. The residues were purified by column chromatography on silica gel (100-200 mesh) to provide complex **7** (62 mg, 68% yield). Single crystal of **7**, which was suitable for for X-ray crystallographic analysis, was obtained by evaporation from an ethyl ether/chloroform solution.

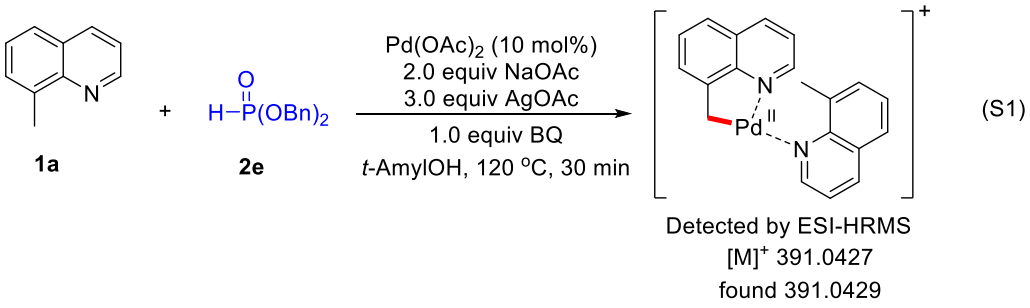
(f) Reaction in Scheme 5f.

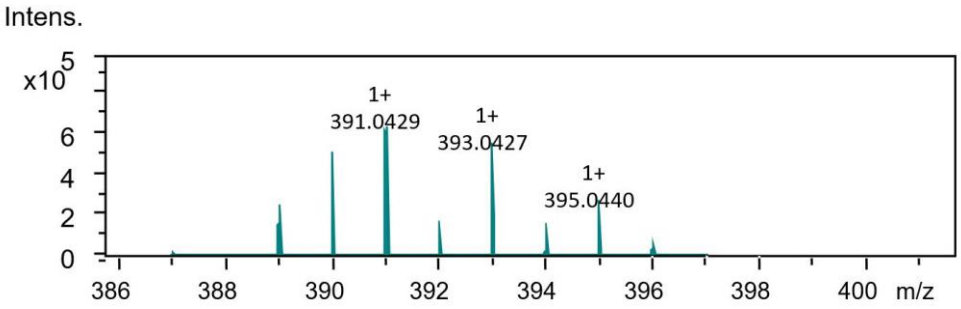


WITH BQ: A Schlenk test tube equipped with a magnetic stir bar was charged with palladium complex **7** (51 mg, 0.10 mmol, 1.0 equiv), BQ (10.8 mg , 0.1 mmol, 1.0 equiv) and t-AmylOH (2 mL) under an N_2 atmosphere. The resulting mixture was heated at 120 ℃ for 20 minutes. After being cooled to ambient temperature, the solvent was removed under reduced pressure and the residue was purified by column chromatography on silica gel to provide the product **3ae** (95% yield).

WITHOUT BQ: A Schlenk test tube equipped with a magnetic stir bar was charged with palladium complex **7** (51 mg, 0.10 mmol, 1.0 equiv) and t-AmylOH (2 mL) under an N_2 atmosphere. The resulting mixture was heated at 120 ℃ for 20 minutes. After being cooled to ambient temperature, the reaction mixture was monitored by TLC and showed that no reaction occurred in the system.

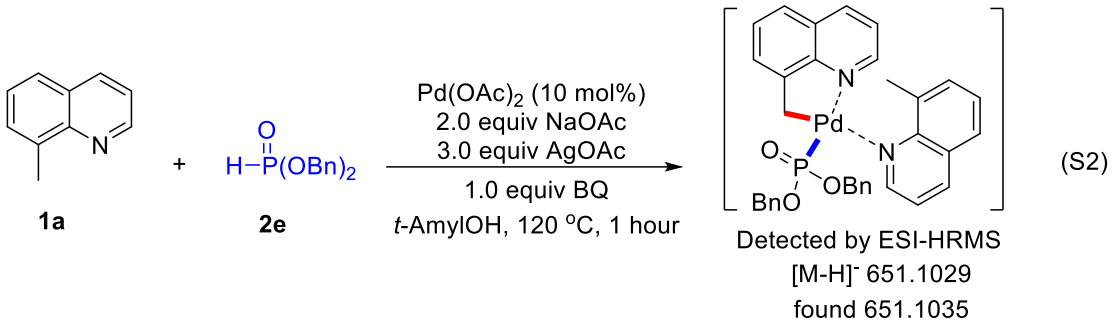
(g) ESI-HRMS analysis

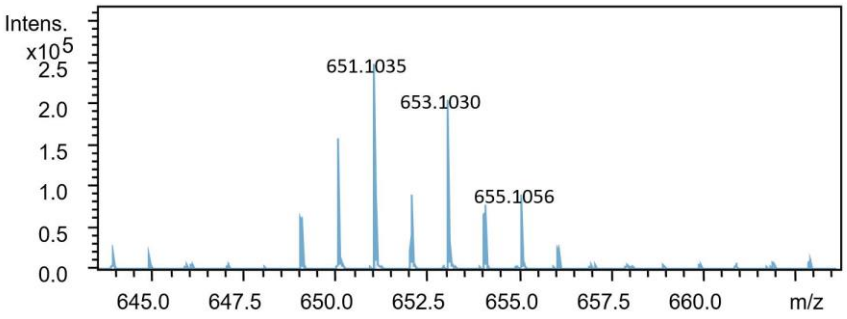




In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone

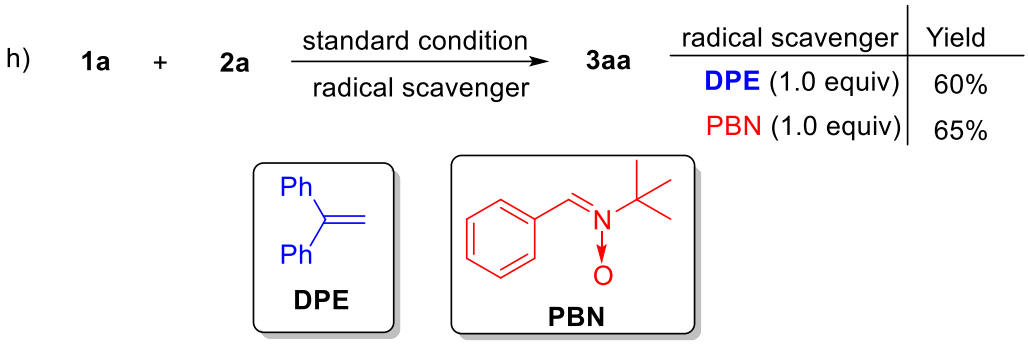
(27 mg, 0.25 mmol, 1.0 equiv.) and NaOAc (41 mg, 2 equiv) in *t*-AmylOH (2.0 mL) was stirred at 120 °C under N_2 for 10 min. Then dibenzyl phosphite **2e** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump. After addition for 30 mins, the reaction mixture was detected by ESI-HRMS. HRMS (ESI): calcd for $C_{20}H_{17}N_2Pd$ $[M]^+$ 391.0427, found 391.0429.





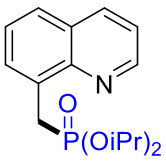
In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.) and NaOAc (41 mg, 2 equiv) in *t*-AmylOH (2.0 mL) was stirred at 120 °C under N_2 for 10 min. Then dibenzyl phosphite **2e** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump. After addition for 1 hour, the reaction mixture was detected by ESI-HRMS. HRMS (ESI): calcd for $C_{34}H_{30}N_2O_3PPd$ $[M-H]^-$ 651.1029, found 651.1035.

(h) Other radical scavengers



In a 25 mL sealed tube, a mixture of 8-methylquinoline **1a** (0.5 mmol, 2.0 equiv), $Pd(OAc)_2$ (5.6 mg, 0.025 mmol, 10 mol%), AgOAc (125 mg, 0.75 mmol, 3.0 equiv.), 1,4-benzoquinone (27 mg, 0.25 mmol, 1.0 equiv.), NaOAc (41 mg, 2 equiv) and DPE (1.0 equivalent) or PBN (1.0 equivalent) in *t*-AmylOH (2.0 mL) was stirred at 120 °C under N_2 for 10 min. Then **2a** (0.25 mmol, 1.0 equiv) in *t*-AmylOH (1 mL) was added dropwise via a syringe pump in 8 h. After addition, the mixture was stirred at the same temperature for another 2 h. After cooling to room temperature, the mixture was filtered through a celite pad and concentrated under vacuum. The residue was purified by column chromatography on silica gel (100-200 mesh) to provide the desired product **3aa**.

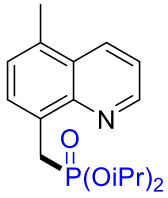
VI. Experimental data for the described substances.



Diisopropyl (quinolin-8-ylmethyl)phosphonate (3aa)

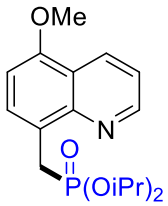
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3aa** as brown oil (55 mg, 72% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.92 (d, *J* = 2.4 Hz, 1H), 8.12 (d, *J* = 8.4 Hz, 1H), 7.88–7.89 (m, 1H), 7.70 (d, *J* = 7.8 Hz, 1H), 7.50 (t, *J* =7.2 Hz, 1H), 7.38 (dd, *J* = 8.4, 4.2 Hz, 1H), 4.56-4.62 (m, *J* = 2H), 4.00 (d, *J* = 22.8 Hz, 2H), 1.22 (d, *J* = 6.0 Hz, 6H), 1.01 (d, *J* = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.6, 146.8 (d, *J* = 7.5 Hz), 136.3, 131.5 (d, *J* = 7.5 Hz), 130.8 (d, *J* = 6.0 Hz), 128.5 (d, *J* = 3.0 Hz), 126.9 (d, *J* = 3.0 Hz), 126.3 (d, *J* = 4.5 Hz), 121.1, 70.5 (d, *J* = 7.5 Hz), 28.2 (d, *J* =

139.5 Hz), 24.0 (dd, *J* = 61.5, 4.5 Hz) ppm. ^{31}P NMR (162 MHz, $CDCl_3$) δ 25.71 ppm. HRMS (ESI^+): calcd for $C_{16}H_{23}NO_3P$ $[M+H]^+$ 308.1416, found 308.1411.



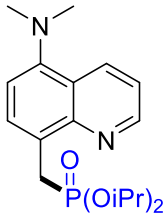
Diisopropyl ((5-methylquinolin-8-yl)methyl)phosphonate (3ba)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ba** as yellow oil (62 mg, 77% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.93 (d, *J* = 2.4 Hz, 1H), 8.30 (d, *J* = 8.4 Hz, 1H), 7.77 (dd, *J* = 7.2, 3.0 Hz, 1H), 7.40-7.42 (m, 1H), 7.34 (d, *J* = 7.2 Hz, 1H), 4.58 - 4.63 (m, 2H), 3.96 (d, *J* = 22.2 Hz, 2H), 2.66 (s, 3H), 1.23 (d, *J* = 6.0 Hz, 6H), 1.04 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.0, 147.0 (d, *J* = 6.0 Hz), 133.5 (d, *J* = 4.5 Hz), 132.7, 130.4 (d, *J* = 6.0 Hz),129.4 (d, *J* = 9.0 Hz), 127.9 (d, *J* = 1.5 Hz), 126.9 (d, *J* = 4.5 Hz), 120.6, 70.5 (d, *J* = 7.5 Hz), 28.2 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 58.5, 6.0 Hz), 18.7 ppm. HRMS (ESI^+): calcd for $C_{17}H_{25}NO_3P$ $[M+H]^+$ 322.1572, found 322.1567.



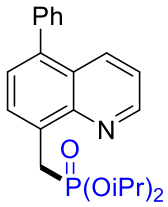
Diisopropyl ((5-methoxyquinolin-8-yl)methyl)phosphonate (3ca)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ca** as brown oil (63 mg, 75% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.92 (dd, *J* = 4.2, 1.2 Hz, 1H), 8.57 (dd, *J* = 8.4, 1H), 7.79 (dd, *J* = 7.8, 3.6 Hz, 1H), 7.36 (dd, *J* = 8.4, 4.2 Hz, 1H), 6.84 (d, *J* = 8.4 Hz, 1H), 4.64 – 4.53 (m, 2H), 3.98 (s, 3H), 3.89 (d, *J* = 21.6 Hz, 2H), 1.22 (d, *J* = 6.6 Hz, 6H), 1.02 (d, *J* = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 154.2 (d, *J* = 3.0 Hz), 149.6, 146.9, 131.2, 130.7, 122.7, 121.0, 120.1, 104.3 (d, *J* = 3.0 Hz), 70.4 (d, *J* = 7.5 Hz), 55.8, 27.6 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 57, 4.5 Hz) ppm. HRMS (ESI^+): calcd for $C_{17}H_{25}NO_4P$ $[M+H]^+$ 338.1521, found 338.1516.



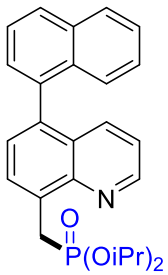
Diisopropyl ((5-(dimethylamino)quinolin-8-yl)methyl)phosphonate (3da)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3da** as yellow oil (46 mg, 53% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.91 (s, 1H), 8.57 (d, *J* = 7.2 Hz, 1H), 7.79 (d, *J* = 4.8 Hz, 1H), 7.38 (dd, *J* = 7.8, 3.6 Hz, 1H), 7.10 (d, *J* = 7.8 Hz, 1H), 4.59 – 4.64 (m, 2H), 3.93 (d, *J* = 22.2 Hz, 2H), 2.87 (s, 6H), 1.23 (d, *J* = 6.0 Hz, 6H), 1.04 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 150.0, 149.0, 133.2, 130.8, 129.6, 125.4, 124.2, 119.9, 114.4, 70.5 (d, *J* = 7.5 Hz), 45.5, 28.0 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 63.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{18}H_{28}N_2O_3P$ $[M+H]^+$ 351.1838, found 351.1832.



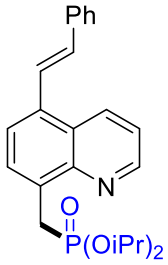
Diisopropyl ((5-phenylquinolin-8-yl)methyl)phosphonate (3ea)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ea** as brown oil (48 mg, 50% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.94 (d, *J* = 2.4 Hz, 1H), 8.23 (d, *J* = 3.0 Hz, 1H), 7.92-7.94 (m, 1H), 7.47-7.51 (m, 3H), 7.44 (d, *J* = 7.2 Hz, 3H), 7.33-7.35 (m, 1H), 4.63 – 4.69 (m, 2H), 4.05 (d, *J* = 22.2 Hz, 2H), 1.27 (d, *J* = 6.0 Hz, 6H), 1.09 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.3, 146.9, 139.6, 139.5 (d, *J* = 3.0 Hz), 134.6, 130.9 (d, *J* = 9.0 Hz), 130.23, 130.18, 128.6, 127.7, 127.0 (d, *J* = 4.5 Hz), 126.9 (d, *J* = 3.0 Hz), 121.0, 70.6 (d, *J* = 6.0 Hz), 28.5 (d, *J* = 139.5 Hz), 24.1 (dd, *J* = 58.5, 6.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{22}H_{27}NO_3P$ $[M+H]^+$ 384.1729, found 384.1723.



Diisopropyl ((5-(naphthalen-1-yl)quinolin-8-yl)methyl)phosphonate (3fa)

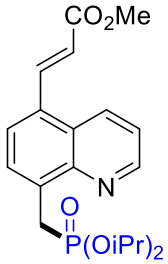
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3fa** as yellow oil (89 mg, 82% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.95 (s, 1H), 8.01-8.03 (m, 1H), 7.96 (t, *J* = 9.0 Hz, 2H), 7.75 (d, *J* = 6.6 Hz, 1H), 7.56-7.60 (m, 2H), 7.45-7.48 (m, 2H), 7.29-7.30 (m, 2H), 7.23 (d, *J* = 4.2 Hz, 1H), 4.69 – 4.74 (m, 2H), 4.08-4.18 (m, 2H), 1.30 (d, *J* = 6.0 Hz, 6H), 1.12 (dd, *J* = 13.2, 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.2, 137.8, 137.0, 135.6, 133.8, 132.9, 131.1, 130.6, 128.5, 128.4, 128.3, 126.4, 126.3, 126.1, 125.5, 121.0, 70.7 (d, *J* = 7.5 Hz), 28.7 (d, *J* = 139.5 Hz), 24.3 (d, *J* = 3.0 Hz), 23.9 (t, *J* = 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{26}H_{29}NO_3P$ $[M+H]^+$ 434.1885, found 434.1877.



Diisopropyl (*E*)-((5-styrylquinolin-8-yl)methyl)phosphonate (3ga)

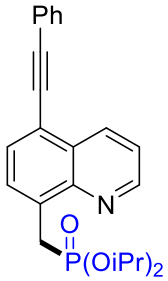
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ga** as yellow oil (69 mg, 68% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.96 (s, 1H), 8.56 (d, *J* = 7.8 Hz, 1H), 7.90 (s, 1H), 7.78 (d, *J* = 18.0 Hz, 2H), 7.59 (d, *J* = 7.8 Hz, 2H), 7.44-7.45 (m, 1H), 7.40 (t, *J* = 7.2 Hz, 2H), 7.31 (t, *J* = 7.2 Hz, 1H), 7.17 (d, *J* = 16.2 Hz, 1H), 4.61-4.66 (m, 2H), 4.03 (d, *J* = 22.2 Hz, 2H), 1.25 (d, *J* = 6.0 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.4, 146.8 (d, *J* = 7.0 Hz), 137.4, 134.3 (d, *J* = 4.0 Hz), 132.6 (d, *J* = 2.0 Hz), 132.4, 131.2 (d, *J* = 9.0 Hz), 130.6 (d, *J* = 6.0 Hz), 129.0, 128.2, 126.9, 126.7 (d, *J* = 2.0 Hz), 124.4 (d, *J* = 2.0 Hz), 123.6 (d, *J* = 4.0 Hz), 120.9, 70.6

(d, *J* = 7.0 Hz), 28.5 (d, *J* = 140.0 Hz), 24.1 (dd, *J* = 38.0, 5.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{24}H_{29}NO_3P$ [M+H] $^+$ 410.1885, found 410.1883.



Methyl (*E*)-3-(8-((diisopropoxyphosphoryl)methyl)quinolin-5-yl)acrylate (3ha)

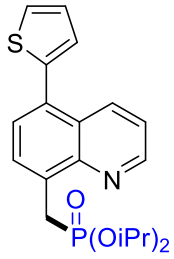
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ha** as yellow oil (52 mg, 53% yield, E/Z = 5:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.98 (d, *J* = 4.2 Hz, 1H), 8.54 (d, *J* = 8.4 Hz, 1H), 8.41 (d, *J* = 16.2 Hz, 1H), 7.89–7.91 (m, 1H), 7.80 (d, *J* = 7.8 Hz, 1H), 7.48-7.50 (m, 1H), 6.54 (d, *J* = 15.6 Hz, 1H), 4.58-4.66 (m, 2H), 4.03 (d, *J* = 22.8 Hz, 2H), 3.84 (s, 3H), 1.23 (d, *J* = 6.6 Hz, 6H), 1.05 (d, *J* = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 167.2, 149.4, 140.1, 134.0 (d, *J* = 9.0 Hz), 132.6, 131.0 (d, *J* = 4.5 Hz), 130.8, 126.8, 125.2 (d, *J* = 4.5 Hz), 121.6, 121.3, 121.1, 70.8 (d, *J* = 6.0 Hz), 52.0, 29.0 (d, *J* = 138.0 Hz), 24.0 (dd, *J* = 51.0, 4.5 Hz) ppm. HRMS (ESI $^+$): calcd for $C_{20}H_{27}NO_5P$ [M+H] $^+$ 392.1627, found 392.1629.



Diisopropyl ((5-(phenylethynyl)quinolin-8-yl)methyl)phosphonate (3ia)

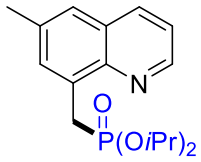
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ia** as pale yellow oil (56 mg, 55% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.99 (s, 1H), 8.74 (d, *J* = 8.4 Hz, 1H), 7.88 (dd, *J* = 7.8, 3.6 Hz, 1H), 7.78 (d, *J* = 7.2 Hz, 1H), 7.63 (dd, *J* = 7.2, 1.8 Hz, 2H), 7.51 (dd, *J* = 7.8, 3.0 Hz, 1H), 7.37-7.42 (m, 3H), 4.60 – 4.66 (m, 2H), 4.03 (d, *J* = 22.2 Hz, 2H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.8, 146.2, 135.2, 132.6 (d, *J* = 7.5 Hz), 131.8, 130.5 (d, *J* = 4.5 Hz), 128.8, 128.6, 123.1, 121.7, 120.2 (d, *J* = 3.0 Hz), 95.0, 86.4, 70.7 (d, *J* = 6.0 Hz),

28.7 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 51.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{24}H_{27}NO_3P$ $[M+H]^+$ 408.1729, found 408.1722.



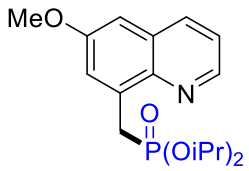
Diisopropyl ((5-(thiophen-2-yl)quinolin-8-yl)methyl)phosphonate (3ja)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ja** as pale yellow oil (39 mg, 40% yield). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.95 (dd, *J* = 4.0, 1.6 Hz, 1H), 8.53 (dd, *J* = 8.4, 2.1 Hz, 1H), 7.90 (dd, *J* = 7.6, 3.6 Hz, 1H), 7.60 (d, *J* = 7.6 Hz, 1H), 7.38-7.45 (m, 2H), 7.17-7.19 (m, 2H), 4.61-4.69 (m, 2H), 4.03 (d, *J* = 22.4 Hz, 2H), 1.26 (d, *J* = 6.4 Hz, 6H), 1.09 (d, *J* = 6.4 Hz, 6H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.5, 146.9 (d, *J* = 7.0 Hz), 140.6, 134.4, 131.8 (d, *J* = 9.0 Hz), 131.6 (d, *J* = 4.0 Hz), 130.1 (d, *J* = 7.0 Hz), 128.1 (d, *J* = 4.0 Hz), 127.8, 127.6, 127.2 (d, *J* = 2.0 Hz), 126.2, 121.3, 70.6 (d, *J* = 6.0 Hz), 28.5 (d, *J* = 139.0 Hz), 24.1 (dd, *J* = 37.0, 5.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{20}H_{25}NO_3PS$ $[M+H]^+$ 390.1293, found 390.1287.



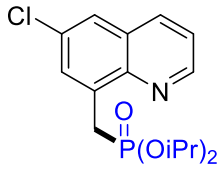
Diisopropyl ((6-methylquinolin-8-yl)methyl)phosphonate (3ka)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ka** as brown oil (44 mg, 55% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.85 (d, *J* = 3.6 Hz, 1H), 8.03 (d, *J* = 8.4 Hz, 1H), 7.73 (s, 1H), 7.47 (s, 1H), 7.33-7.35 (m, 1H), 4.58 – 4.62 (m, 2H), 3.95 (d, *J* = 22.2 Hz, 2H), 2.52 (s, 3H), 1.23 (d, *J* = 6.0 Hz, 6H), 1.03 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 148.7, 145.4 (d, *J* = 6.0 Hz), 136.1 (d, *J* = 4.5 Hz), 135.6, 133.1 (d, *J* = 6.0 Hz), 131.0 (d, *J* = 9.0 Hz), 128.6, 125.8 (d, *J* = 4.5 Hz), 121.1, 70.5 (d, *J* = 7.5 Hz), 28.1 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 64.5, 4.5 Hz), 21.7 ppm. HRMS (ESI$^+$): calcd for $C_{17}H_{25}NO_3P$ $[M+H]^+$ 322.1572, found 322.1566.



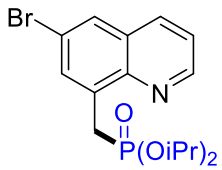
Diisopropyl ((6-methoxyquinolin-8-yl)methyl)phosphonate (3la)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3la** as brown oil (59 mg, 70% yield). ^{1}H NMR (600 MHz, $CDCl_3$) δ: = 8.77 (d, *J* = 3.0 Hz, 1H), 8.01 (d, *J* = 7.8 Hz, 1H), 7.56 (s, 1H), 7.32-7.34 (m, 1H), 6.98 (s, 1H), 460-4.65 (m, 2H), 3.95 (d, *J* = 22.2 Hz, 2H), 3.91 (s, 3H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$) δ 157.3 (d, *J* = 3.0 Hz), 147.1, 143.0 (d, *J* = 7.5 Hz), 135.0, 133.2 (d, *J* = 9.0 Hz), 129.7 (d, *J* = 3.0 Hz), 123.1 (d, *J* = 7.5 Hz), 121.5, 104.7 (d, *J* = 3.0 Hz), 70.6 (d, *J* = 6.0 Hz), 55.6, 28.2 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 57.0, 4.5 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{17}H_{25}NO_4P$ $[M+H]^{+}$ 338.1521, found 338.1515.



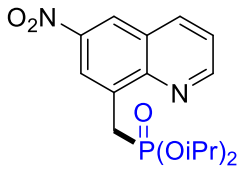
Diisopropyl ((6-chloroquinolin-8-yl)methyl)phosphonate (3ma)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ma** as brown oil (45 mg, 53% yield). ^{1}H NMR (600 MHz, $CDCl_3$) δ: = 8.92 (s, 1H), 8.06 (d, *J* = 7.2 Hz, 1H), 7.82 (s, 1H), 7.70 (s, 1H), 7.42 (s, 1H), 4.63-4.66 (m, 2H), 3.96 (d, *J* = 22.2 Hz, 2H), 1.25 (d, *J* = 4.2 Hz, 6H), 1.09 (d, *J* = 4.2 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.8, 145.2 (d, *J* = 7.5 Hz), 135.4, 134.0 (d, *J* = 9.0 Hz), 132.0 (d, *J* = 4.5 Hz), 131.4 (d, *J* = 7.5 Hz), 129.1 (d, *J* = 1.5 Hz), 125.4 (d, *J* = 4.5 Hz), 122.0, 70.8 (d, *J* = 7.5 Hz), 28.2 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 51.0, 4.5 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{16}H_{22}ClNO_3P$ $[M+H]^{+}$ 342.1026, found 342.1022.



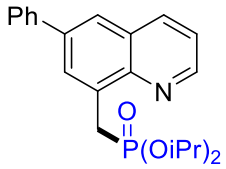
Diisopropyl ((6-bromoquinolin-8-yl)methyl)phosphonate (3na)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3na** as brown oil (43 mg, 45% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.93 (s, 1H), 8.05 (d, *J* = 7.8 Hz, 1H), 7.95 (s, 1H), 7.88 (s, 1H), 7.40-7.43 (m, 1H), 4.63 – 4.67 (m, 2H), 3.96 (dd, *J* = 22.2, 2.4 Hz, 2H), 1.25 (d, *J* = 6.0 Hz, 6H), 1.10 (d, J = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.8, 145.3 (d, *J* = 7.5 Hz), 135.5, 134.1, 134.0 (d, *J* = 6.0 Hz), 129.6 (d, *J* = 3.0 Hz), 128.8 (d, *J* = 3.0 Hz), 122.0, 120.2 (d, *J* = 6.0 Hz), 70.8 (d, *J* = 7.5 Hz), 28.2 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 48.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{16}H_{22}BrNO_3P$ [M+H] $^+$ 386.0521, found 386.0514.



Diisopropyl ((6-nitroquinolin-8-yl)methyl)phosphonate (3oa)

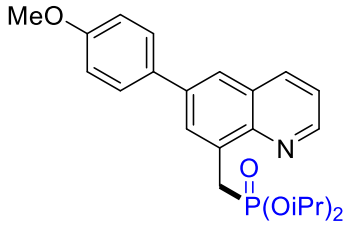
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3oa** as brown oil (39 mg, 44% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 9.10 (d, *J* = 3.6 Hz, 1H), 8.69 (s, 1H), 8.62 (s, 1H), 8.34 (d, *J* = 8.4 Hz, 1H), 7.56-7.58 (m, 1H), 4.66-4.71 (m, 2H), 4.05 (d, *J* = 22.8 Hz, 2H), 1.27 (d, *J* = 6.0 Hz, 6H), 1.16 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 153.0, 148.7 (d, *J* = 6.0 Hz), 145.1 (d, *J* = 5.0 Hz), 138.3, 134.9 (d, *J* = 9.0 Hz), 127.3 (d, *J* = 2.0 Hz), 123.7 (d, *J* = 7.0 Hz), 123.3 (d, *J* = 3.0 Hz), 122.9, 71.0 (d, *J* = 7.0 Hz), 28.7 (d, *J* = 139.0 Hz), 24.0 (dd, *J* = 24.0 Hz, 5.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{16}H_{22}N_2O_5P$ [M+H] $^+$ 353.1266, found 353.1260.



Diisopropyl ((6-phenylquinolin-8-yl)methyl)phosphonate (3pa)

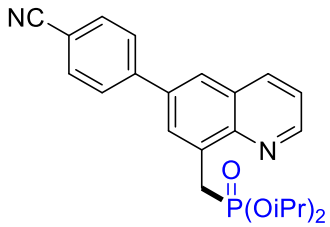
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3pa** as brown oil (71 mg, 74% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.93 (d, *J* = 3.6 Hz, 1H), 8.17-8.20 (m, 2H), 7.91 (s, 1H), 7.74 (d, *J* = 7.8 Hz, 2H), 7.48 (t, *J* = 7.8 Hz, 2H), 7.38-7.42 (m, 2H), 4.62-4.67 (m, 2H), 4.05(d, *J* = 22.2 Hz, 2H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.6, 146.2 (d, *J* = 6.0 Hz),

140.3, 138.9 (d, *J* = 4.5 Hz), 136.5, 132.0 (d, *J* = 9.0 Hz), 130.5 (d, *J* = 7.5 Hz), 129.0, 128.8 (d, *J* = 1.5 Hz), 127.8, 127.6, 124.4 (d, *J* = 3.0 Hz), 121.5, 70.6 (d, *J* = 7.5 Hz), 28.4 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 57.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{22}H_{27}NO_3P$ $[M+H]^+$ 384.1729, found 384.1722.



Diisopropyl ((6-(4-methoxyphenyl)quinolin-8-yl)methyl)phosphonate (3qa)

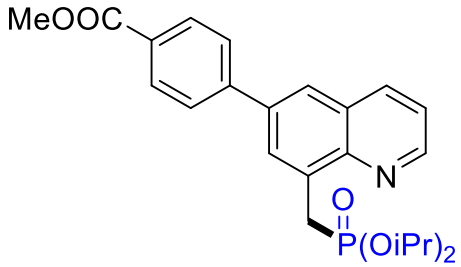
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3qa** as brown oil (52 mg, 50% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.90 (d, *J* = 4.5 Hz, 1H), 8.15-8.17 (m, 2H), 7.85 (s, 1H), 7.68 (d, *J* = 8.4 Hz, 2H), 7.38-7.40 (m, 1H), 7.02 (d, *J* = 9.0 Hz, 2H), 4.61-4.66 (m, 2H), 4.04 (d, *J* = 22.2 Hz, 2H), 3.87 (s, 3H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.05 (d, *J* = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 159.8, 149.1, 145.7, 138.6, 136.6, 132.7, 131.7 (d, *J* = 9.0 Hz), 130.5, 128.9 (d, *J* = 3.0 Hz), 128.6, 123.6 (d, *J* = 3.0 Hz), 121.4, 114.6, 70.6 (d, *J* = 7.5 Hz), 55.5, 28.4 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 57.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{23}H_{29}NO_4P$ $[M+H]^+$ 414.1834, found 414.1821.



Diisopropyl ((6-(4-cyanophenyl)quinolin-8-yl)methyl)phosphonate (3ra)

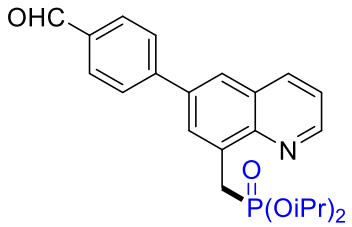
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ra** as yellow solid (65 mg, 64% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.97 (dd, *J* = 3.6, 1.2 Hz, 1H), 8.22 (d, *J* = 8.4 Hz, 1H), 8.18 – 8.19 (m, 1H), 7.93 (s, 1H), 7.84 (d, *J* = 8.4 Hz, 2H), 7.76 (d, *J* = 8.4, 2H),7.45-7.47 (m, 1H), 4.61 – 4.67 (m, 2H), 4.06 (d, *J* = 22.2 Hz, 2H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.05 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 150.2, 146.3, 144.8, 137.0, 136.9 (d, *J* = 4.5 Hz), 132.8, 132.7 (d, *J* = 7.5 Hz), 130.0 (d, *J* = 7.5 Hz), 128.7, 128.2, 125.2 (d, *J* = 4.5 Hz), 121.9, 118.9, 111.6, 70.8 (d, *J* =

6.0 Hz), 28.4 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 52.5, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{23}H_{26}N_2O_3P$ [M+H] $^+$ 409.1681, found 409.1676.



Methyl 4-(8-((diisopropoxyphosphoryl)methyl)quinolin-6-yl)benzoate (3sa)

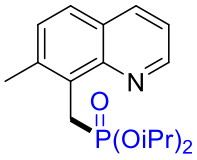
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3sa** as brown oil (60 mg, 54% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.96 (d, *J* = 2.4 Hz, 1H), 8.22 (d, *J* = 7.8 Hz, 2H), 8.14 (d, *J* = 8.4 Hz, 2H), 7.96 (s, 1H), 7.81 (d, *J* = 7.8 Hz, 2H), 7.44-7.46 (m, 1H), 4.62-4.68 (m, 2H), 4.07 (d, *J* = 22.2 Hz, 2H), 3.95 (s, 3H), 1.24 (d, *J* = 6.6 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 167.1, 150.0, 146.5 (d, *J* = 7.5 Hz), 144.8, 137.7 (d, *J* = 4.5 Hz), 136.7, 132.5 (d, *J* = 9.0 Hz), 130.4, 130.2 (d, *J* = 7.5 Hz), 129.5, 128.7, 127.5, 125.0 (d, *J* = 4.5 Hz), 121.7, 70.7 (d, *J* = 7.5 Hz), 52.3, 28.4 (d, *J* = 139.5 Hz), 24.1 (dd, *J* = 54.0, 4.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{24}H_{29}NO_5P$ [M+H] $^+$ 442.1783, found 442.1780.



Diisopropyl ((6-(4-formylphenyl)quinolin-8-yl)methyl)phosphonate (3ta)

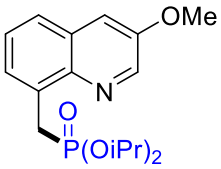
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ta** as brown oil (62 mg, 60% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 10.08 (s, 1H), 8.96 (d, *J* = 2.4 Hz, 1H), 8.21 (d, *J* = 8.4 Hz, 2H), 7.98-8.00 (m, 3H), 7.91 (d, *J* = 7.8 Hz, 2H), 7.44-7.46 (m, 1H), 4.62-4.67 (m, 2H), 4.06 (d, *J* = 22.2 Hz, 2H), 1.25 (d, *J* = 6.0 Hz, 6H), 1.06 (d, *J* = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 192.0, 150.2, 146.6 (d, *J* = 7.5 Hz), 146.3, 137.4 (d, *J* = 4.5 Hz), 136.8, 135.7, 132.6 (d, *J* = 9.0 Hz), 130.5, 130.1 (d, *J* = 6.0 Hz), 128.7, 128.1, 125.3 (d, *J* = 3.0 Hz), 121.8, 70.7 (d, *J* = 7.5 Hz), 28.3 (d, *J* =

139.5 Hz), 24.0 (dd, J = 55.5, 6.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{23}H_{27}NO_4P$ [M+H] $^+$ 412.1678, found 412.1672.



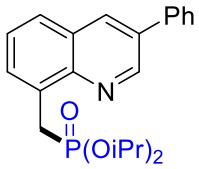
Diisopropyl ((7-methylquinolin-8-yl)methyl)phosphonate (3ua)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ua** as brown oil (24 mg, 30% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.92 (d, J = 3.0 Hz, 1H), 8.08 (d, J = 7.8 Hz, 1H), 7.61 (dd, J = 8.4, 1.8 Hz, 1H), 7.39 (d, J = 8.4 Hz, 1H), 7.32-7.34 (m, 1H), 4.54 – 4.62 (m, 2H), 4.08 (d, J = 23.4 Hz, 2H), 2.67 (d, J = 2.4 Hz, 3H), 1.22 (d, J = 6.0 Hz, 6H), 0.97 (d, J = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.0, 139.5, 136.5, 130.2, 129.1, 126.8, 126.1 (d, J = 4.5 Hz), 120.2, 70.5 (d, J = 7.5 Hz), 27.0 (d, J = 139.5 Hz), 24.0 (dd, J = 78.0, 6.0 Hz), 21.2 ppm. HRMS (ESI$^+$): calcd for $C_{17}H_{25}NO_3P$ [M+H] $^+$ 322.1572, found 322.1570.



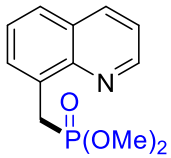
Diisopropyl ((3-methoxyquinolin-8-yl)methyl)phosphonate (3va)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3va** as yellow oil (42 mg, 50% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.68 (d, J = 3.0 Hz, 1H), 7.70-7.72 (m, 1H), 7.62 (d, J = 7.8 Hz, 1H), 7.46 (t, J = 7.8 Hz, 1H), 7.37 (s, 1H), 4.57– 4.63 (m, 2H), 3.96 (d, J = 22.2 Hz, 2H), 3.94 (s, 3H), 1.22 (d, J = 6.0 Hz, 6H), 1.03 (d, J = 6.0 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 153.2, 143.6, 142.0 (d, J = 7.5 Hz), 131.4 (d, J = 7.5 Hz), 129.1 (d, J = 3.0 Hz), 128.2 (d, J = 6.0 Hz), 127.10 (d, J = 4.5 Hz), 125.8 (d, J = 4.5 Hz), 112.6, 70.5 (d, J = 7.5 Hz), 55.6, 28.4 (d, J = 139.5 Hz), 24.0 (dd, J = 60.0, 6.0 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{17}H_{26}NO_4P$ [M+H]$^+$ 338.1521, found 338.1516.



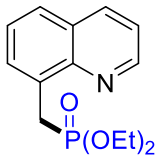
Diisopropyl ((3-phenylquinolin-8-yl)methyl)phosphonate (3wa)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3wa** as brown oil (68 mg, 71% yield).^{1}H NMR (600 MHz, $CDCl_3$): δ = 9.23 (s, 1H), 8.31 (s, 1H), 7.90 (s, 1H), 7.79 (d, *J* = 7.8 Hz, 1H), 7.72 (d, *J* = 7.8 Hz, 2H), 7.56 (d, *J* = 7.2 Hz, 1H), 7.53 (t, *J* = 7.2 Hz, 2H), 7.44 (t, *J* = 7.2 Hz, 1H), 4.62-4.68 (m, 2H), 4.05 (d, *J* = 22.2 Hz, 2H), 1.25 (d, *J* = 6.6 Hz, 6H), 1.07 (d, *J* = 6.6 Hz, 6H) ppm.^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.1, 145.9 (d, *J* = 7.5 Hz), 138.0, 134.0, 133.7, 133.5, 131.5 (d, *J* = 9.0 Hz), 130.7 (d, *J* = 7.5 Hz), 129.3, 128.3 (d, *J* = 3.0 Hz), 128.2, 127.5, 127.1 (d, *J* = 4.5 Hz), 126.8 (d, *J* = 4.5 Hz), 70.6 (d, *J* = 6.0 Hz), 28.4 (d, *J* = 139.5 Hz), 24.0 (dd, *J* = 55.5, 4.5 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{22}H_{27}NO_3P$ [M+H] $^{+}$ 384.1729, found 384.1721.



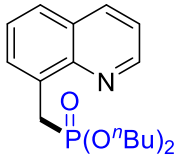
Dimethyl (quinolin-8-ylmethyl)phosphonate (3ab)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/2, v/v) afforded **3ab** as yellow oil (28 mg, 45% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.96 (d, *J* = 3.0 Hz, 1H), 8.18 (d, *J* = 7.8 Hz, 1H), 7.84-7.86 (m, 1H), 7.76 (d, *J* = 8.4 Hz, 1H), 7.54 (t, *J* = 7.8 Hz, 1H), 7.44 (dd, *J* = 7.8, 4.2 Hz, 1H), 4.06 (d, *J* = 22.2 Hz, 2H), 3.67 (d, *J* = 10.8 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.7, 146.6 (d, *J* = 7.5 Hz), 136.5, 130.9 (d, *J* = 6.0 Hz), 130.8, 128.6 (d, *J* = 1.5 Hz), 127.3 (d, *J* = 4.5 Hz), 126.4 (d, *J* = 3.0 Hz), 121.3, 52.9 (d, *J* = 6.0 Hz), 26.6 (d, *J* = 136.5 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{12}H_{15}NO_3P$ [M+H] $^{+}$ 252.0790, found 252.0784.



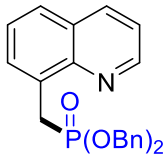
Diethyl (quinolin-8-ylmethyl)phosphonate (3ac)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/2, v/v) afforded **3ac** as yellow oil (32 mg, 46% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.94 (d, *J* = 3.0 Hz, 1H), 8.14 (d, *J* = 8.4 Hz, 1H), 7.85-7.86 (m, 1H), 7.74 (d, *J* = 8.4 Hz, 1H), 7.52 (t, *J* = 7.8 Hz, 1H), 7.39-7.41 (m, 1H), 3.99-4.05 (m, 6H), 1.14 (t, *J* = 6.6 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.7, 146.7 (d, *J* = 7.5 Hz), 136.4, 131.2 (d, *J* = 10.5 Hz), 130.9 (d, *J* = 7.5 Hz), 128.6 (d, *J* = 3.0 Hz), 127.1 (d, *J* = 4.5 Hz), 126.4 (d, *J* = 4.5 Hz), 121.2, 62.1 (d, *J* = 6.0 Hz), 27.4 (d, *J* = 138.0 Hz), 16.4 (d, *J* = 6.0 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{14}H_{19}NO_3P$ $[M+H]^{+}$ 280.1103, found 280.1101.



Dibutyl (quinolin-8-ylmethyl)phosphonate (3ad)

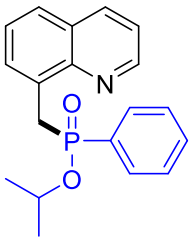
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ad** as brown oil (39 mg, 46% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.93 (d, *J* = 3.0 Hz, 1H), 8.14 (d, *J* = 7.8 Hz, 1H), 7.85 (dd, *J* = 6.6, 3.6 Hz, 1H), 7.73 (d, *J* = 8.4 Hz, 1H), 7.51 (t, *J* = 7.8 Hz, 1H), 7.39-7.41 (m, 1H), 4.03 (d, *J* = 22.2 Hz, 2H), 3.92-3.97 (m, 4H), 1.43-1.48 (m, 4H), 1.19-1.25 (m, 4H), 0.80 (t, *J* = 7.2 Hz, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.6, 146.7 (d, *J* = 7.5 Hz), 136.4, 131.3 (d, *J* = 9.0 Hz), 130.8 (d, *J* = 6.0 Hz), 128.6 (d, *J* = 1.5 Hz), 127.0 (d, *J* = 4.5 Hz), 126.4 (d, *J* = 4.5 Hz), 121.2, 65.8 (d, *J* = 6.0 Hz), 32.6 (d, *J* = 7.5 Hz), 27.2 (d, *J* = 138.0 Hz), 18.7, 13.7 ppm. HRMS (ESI+): calcd for $C_{18}H_{27}NO_3P$ $[M+H]^{+}$ 336.1729, found 336.1724.



Dibenzyl (quinolin-8-ylmethyl)phosphonate (3ae)

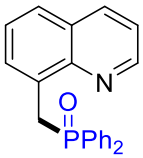
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ae** as brown oil (54 mg, 54% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.87 (d, *J* = 3.0 Hz, 1H), 8.11 (d, *J* = 7.8 Hz, 1H), 7.80-7.82 (m, 1H), 7.72 (d, *J* = 7.8 Hz, 1H), 7.48 (t, *J* = 7.8 Hz, 1H), 7.36 (dd, *J* = 8.4, 4.2 Hz, 1H), 7.24-7.26 (m, 6H), 7.14-7.15 (m, 4H), 4.93-4.99 (m, 4H), 4.12 (d, *J* = 22.2 Hz, 2H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.7, 146.6 (d, *J*

= 7.5 Hz), 136.6 (d, *J* = 6.0 Hz), 136.3, 130.9 (d, *J* = 6.0 Hz), 130.8 (d, *J* = 9.0 Hz), 128.6 (d, *J* = 3.0 Hz), 128.4, 128.2, 127.7, 127.2 (d, *J* = 4.5 Hz), 126.3 (d, *J* = 4.5 Hz), 121.2, 67.5 (d, *J* = 7.5 Hz), 27.7 (d, *J* = 136.5 Hz) ppm. HRMS (ESI$^+$): calcd for $C_{24}H_{23}NO_3P$ [M+H] $^+$ 404.1416, found 404.1411.



Isopropyl phenyl(quinolin-8-ylmethyl)phosphinate (3af)

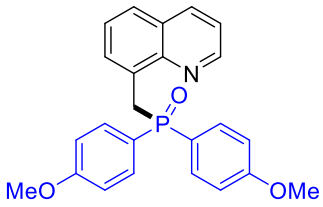
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3af** as brown oil (41 mg, 51% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.70 (d, *J* = 3.6 Hz, 1H), 8.02 (d, *J* = 8.4 Hz, 1H), 7.79 (d, *J* = 3.6 Hz, 1H), 7.61-7.66 (m, 3H), 7.45 (t, *J* = 7.8 Hz, 1H), 7.34 (t, *J* = 7.2 Hz, 1H), 7.23-7.27 (m, 3H), 4.52-4.57 (m, 1H), 4.06-4.25 (m, 2H), 1.22 (d, *J* = 6.0 Hz, 3H), 1.13 (d, *J* = 6.0 Hz, 3H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.2, 146.6 (d, *J* = 6.0 Hz), 136.1, 132.0 (d, *J* = 9.0 Hz), 131.8 [d (132.24, 131.40), *J* = 126.0 Hz], 131.7 (d, *J* = 3.0 Hz), 131.2 (d, *J* = 7.5 Hz), 130.8 (d, *J* = 6.0 Hz), 128.3 (d, *J* = 3.0 Hz), 127.9 (d, *J* = 13.5 Hz), 126.8 (d, *J* = 3.0 Hz), 126.2 (d, *J* = 4.5 Hz), 120.8, 69.9 (d, *J* = 6.0 Hz), 32.1 (d, *J* = 96.0 Hz), 24.3 (dd, *J* = 51.0, 4.5 Hz) ppm. ^{31}P NMR (162 MHz, $CDCl_3$) δ 39.84 ppm. HRMS (ESI$^+$): calcd for $C_{19}H_{21}NO_2P$ [M+H] $^+$ 326.1310, found 326.1304.



Diphenyl(quinolin-8-ylmethyl)phosphine oxide (3ag)

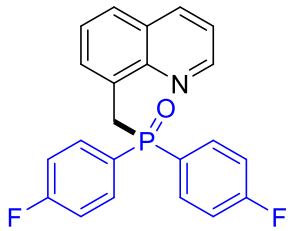
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ag** as brown oil (51 mg, 60% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.76 (t, *J* = 1.8 Hz, 1H), 8.02-8.04 (m, 2H), 7.76-7.79 (m, 4H), 7.65 (d, *J* = 7.8 Hz, 1H), 7.47 (t, *J* = 7.8 Hz, 1H), 7.39 (t, *J* = 7.2 Hz, 2H), 7.28-7.33 (m, 5H), 4.56 (d, *J* = 13.8 Hz, 2H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$) δ 149.2, 146.5 (d, *J* = 6.0 Hz), 136.3, 133.1 [d (133.41, 132.76), *J* = 97.5 Hz], 131.6 (d, *J* = 3.0 Hz), 131.32, 131.3 [d (131.34, 131.28), *J* = 9.0 Hz), 130.8 (d, *J* =

7.5 Hz), 128.4 (d, *J* = 1.5 Hz), 128.3 (d, *J* = 12.0 Hz), 127.0 (d, *J* = 1.5 Hz), 126.5 (d, *J* = 3.0 Hz), 120.9, 31.0 (d, *J* = 67.5 Hz) ppm. ^{31}P NMR (162 MHz, $CDCl_3$) δ 31.63 ppm. HRMS (ESI^+): calcd for $C_{22}H_{19}NOP$ $[M+H]^+$ 344.1204, found 344.1198.



Bis(4-methoxyphenyl)(quinolin-8-ylmethyl)phosphine oxide (3ah)

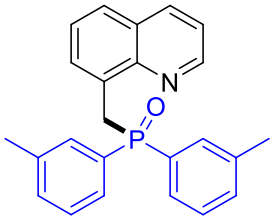
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/3, v/v) afforded **3ah** as pale yellow oil (71 mg, 70% yield). ^{1}H NMR (600 MHz, DMSO-d_6): δ = 8.85 (d, *J* = 2.4 Hz, 1H), 8.29 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 7.8 Hz, 1H), 7.64-7.67 (m, 5H), 7.45-7.49 (m, 2H), 6.97 (d, *J* = 8.4 Hz, 4H), 4.49 (d, *J* = 13.8 Hz, 2H), 3.75 (s, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 162.2 (d, *J* = 3.0 Hz), 149.1, 146.6 (d, *J* = 6.0 Hz), 136.3, 133.1 (d, *J* = 10.5 Hz), 131.3 (d, *J* = 6.0 Hz), 128.4, 126.8 (d, *J* = 3.0 Hz), 126.5 (d, *J* = 3.0 Hz), 125.1, 124.4, 120.8, 113.9 (d, *J* = 13.5 Hz), 55.4, 31.4 (d, *J* = 69.0 Hz) ppm. HRMS (ESI^+): calcd for $C_{24}H_{23}NO_3P$ $[M+H]^+$ 404.1416, found 404.1413.



Bis(4-fluorophenyl)(quinolin-8-ylmethyl)phosphine oxide (3ai)

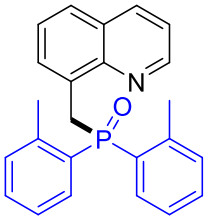
Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ai** as brown oil (76 mg, 80% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.75 (dd, *J* = 3.6 Hz, 1.2 Hz, 1H), 8.05 (d, *J* = 7.8 Hz, 1H), 8.00 (d, *J* = 5.4 Hz, 1H), 7.73 – 7.77 (m, 4H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 1H), 7.30-7.32 (m, 1H), 6.99-7.02 (m, 4H), 4.52 (d, *J* = 14.4 Hz, 2H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 165.0 [dd (165.85, 165.83, 164.18, 164.16), *J* = 250.5, 3.0 Hz)], 149.2, 146.3 (d, *J* = 6.0 Hz), 136.4, 133.7 (dd, *J* = 10.5, 9.0 Hz), 131.4 (d, *J* = 4.5 Hz), 130.3 (d, *J* = 7.5 Hz), 129.1 (d, *J* = 3.0 Hz), 128.4, 127.2 (d, *J* = 3.0 Hz), 126.6 (d, *J* = 3.0 Hz), 121.0, 115.7 (dd, *J* = 21.0, 12.0 Hz), 31.3 (d, *J* = 69.0 Hz)

ppm. ^{19}F NMR (376 MHz, $CDCl_3$) δ: −107.2 ppm. HRMS (ESI^+): calcd for $C_{22}H_{17}F_2NOP$ $[M+H]^+$ 380.1016, found 380.1008.



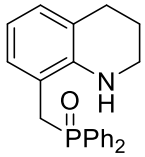
(Quinolin-8-ylmethyl)di-*m*-tolylphosphine oxide (3aj)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3aj** as brown oil (65 mg, 70% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.80 (d, *J* = 3.0 Hz, 1H), 8.07 (s, 2H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.62 (d, *J* = 11.4 Hz, 2H), 7.57 – 7.60 (m, 2H), 7.50 (t, *J* = 6.6 Hz, 1H), 7.34 (s, 1H), 7.17-7.22 (m, 4H), 4.56 (d, *J* = 14.4 Hz, 2H), 2.26 (s, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.1, 146.6 (d, *J* = 6.0 Hz), 138.1 (d, *J* = 12.0 Hz), 136.4, 133.0 [d (133.29, 132.63), *J* = 99.0 Hz], 132.3 (d, *J* = 3.0 Hz), 131.8 (d, *J* = 9.0 Hz), 131.4 (d, *J* = 6.0 Hz), 131.0 (d, *J* = 7.5 Hz), 128.4, 128.3 (d, *J* = 10.5 Hz), 128.2 (d, *J* = 12.0 Hz), 126.9 (d, *J* = 3.0 Hz), 126.6 (d, *J* = 3.0 Hz), 120.9, 31.0 (d, *J* = 67.5 Hz), 21.4 ppm. HRMS (ESI^+): calcd for $C_{24}H_{23}NOP$ $[M+H]^+$ 372.1517, found 372.1518.



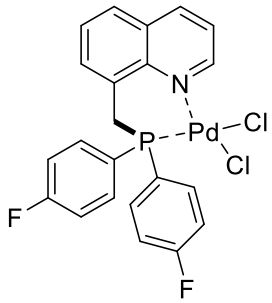
(Quinolin-8-ylmethyl)di-*o*-tolylphosphine oxide (3ak)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 1/1, v/v) afforded **3ak** as yellow oil (48 mg, 52% yield).^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.65 (dd, *J* = 3.6, 1.2 Hz, 1H), 8.01-8.05 (m, 2H), 7.74 (dd, *J* = 12.6, 7.8 Hz, 2H), 7.65 (d, *J* = 7.8 Hz, 1H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.24-7.27 (m, 3H), 7.11 (t, *J* = 7.2 Hz, 2H), 7.03-7.05 (m, 2H), 4.63 (d, *J* = 14.4 Hz, 2H), 2.25 (s, 6H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 149.0, 146.7 (d, *J* = 6.0 Hz), 142.2 (d, *J* = 7.5 Hz), 136.2, 132.2 (d, *J* = 10.5 Hz), 131.9 (d, *J* = 6.0 Hz), 131.6 (d, *J* = 10.5 Hz), 131.5 (d, *J* = 3.0 Hz), 130.9 (d, *J* = 6.0 Hz), 128.3, 126.8 (d, *J* = 3.0 Hz), 126.4 (d, *J* = 3.0 Hz), 125.3 (d, *J* = 12.0 Hz), 120.8, 30.4 (d, *J* = 67.5 Hz), 21.3 (d, *J* = 4.5 Hz) ppm. HRMS (ESI^+): calcd for $C_{24}H_{23}NOP$ $[M+H]^+$ 372.1517, found 372.1510.



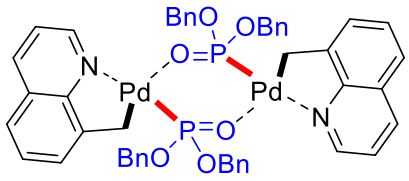
Diphenyl((1,2,3,4-tetrahydroquinolin-8-yl)methyl)phosphine oxide (4)

Purification via silica gel column chromatography (petroleum ether/ethyl acetate = 3/1, v/v) afforded **4** as a white solid (57 mg, 82% yield). M.p. :135-137 ºC; ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.71-7.74 (m, 4H), 7.51 (t, *J* = 7.2 Hz, 2H), 7.45 (t, *J* = 7.2 Hz, 4H), 6.79 (d, *J* = 7.2 Hz, 1H), 6.44 (d, *J* = 7.2 Hz, 1H), 6.37 (t, *J* = 7.2 Hz, 1H), 5.71 (bs, 1H), 3.59 (d, *J* = 12.6 Hz, 2H), 3.33 (t, *J* = 5.4 Hz, 2H), 2.75 (t, *J* = 6.0 Hz, 2H), 1.85-1.89 (m, 2H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 145.1 (d, *J* = 3.0 Hz), 132.4 [d (132.69, 132.04), *J* = 97.5 Hz], 132.0 (d, *J* = 3.0 Hz), 131.2 (d, *J* = 9.0 Hz), 129.6 (d, *J* = 6.0 Hz), 128.7 (d, *J* = 10.5 Hz), 128.6 (d, *J* = 3.0 Hz), 123.5 (d, *J* = 3.0 Hz),117.1 (d, *J* = 9.0 Hz), 116.7 (d, *J* = 1.5 Hz), 42.6, 35.4 (d, J = 67.5 Hz), 27.9, 22.0 ppm. HRMS (ESI^{+}): calcd for $C_{22}H_{23}NOP$ $[M+H]^{+}$ 348.1517, found 348.1511.



Palladium complex **5**

^{1}H NMR (600 MHz, DMSO): δ = 9.72 (s, 1H), 8.72 (d, *J* = 7.8 Hz, 1H), 8.06 (d, *J* = 7.8 Hz, 1H), 7.97 (d, *J* = 7.2 Hz, 1H), 7.82-7.87 (m, 4H), 7.76 (dd, *J* = 7.8, 5.4 Hz, 1H), 7.68 (t, *J* = 7.2 Hz, 1H), 7.34 (t, *J* = 8.4 Hz, 4H), 4.80 (d, *J* = 16.8 Hz, 2H). ^{13}C NMR (150 MHz, DMSO) δ = 164.3 [d (165.12, 163.45), *J* = 250.5 Hz], 156.3, 142.1, 140.6, 135.8 (dd, *J* = 12.0, 9.0 Hz), 135.3 (d, *J* = 10.5 Hz), 130.0, 129.5, 127.6, 127.4, 122.3 (d, *J* = 63.0 Hz), 121.9, 116.2 (dd, *J* = 22.5, 13.5 Hz), 26.0 (d, *J* = 33.0 Hz). HRMS (ESI^{+}): calcd for $C_{22}H_{16}ClF_2NPPd$ $[M-Cl]^{+}$ 503.9712, found 503.9721.



Palladium complex **7**

Purification via silica gel column chromatography (dichloromethane / methanol = 20/1, v/v) afforded **7** as a pale yellow solid (62 mg, 68% yield). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.88 (s, 2H), 8.23 (d, *J* = 7.8 Hz, 2H), 7.60 (t, *J* = 7.2 Hz, 4H), 7.46-7.49 (m, 10H), 7.25-7.29 (m, 10H), 7.20 (t, *J* = 7.2 Hz, 4H), 5.31-5.42 (m, 8H), 3.37 (s, 4H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 151.0, 149.8, 148.1, 139.3 (d, *J* = 3.0 Hz), 137.8 (d, *J* = 6.0 Hz), 129.3, 128.9, 128.2 (d, *J* = 4.5 Hz), 127.8 (d, *J* = 3.0 Hz), 127.5 (d, *J* = 3.0 Hz),127.2 (d, *J* = 4.5 Hz), 123.3 (d, *J* = 6.0 Hz), 121.1, 64.8 (d, *J* = 3.0 Hz), 19.6 (d, *J* = 6.0 Hz) ppm. HRMS (ESI^{+}): calcd for $C_{48}H_{45}N_2O_6P_2Pd_2$ $[M+H]^+$ 1019.0823, found 1019.0830.

VII. References

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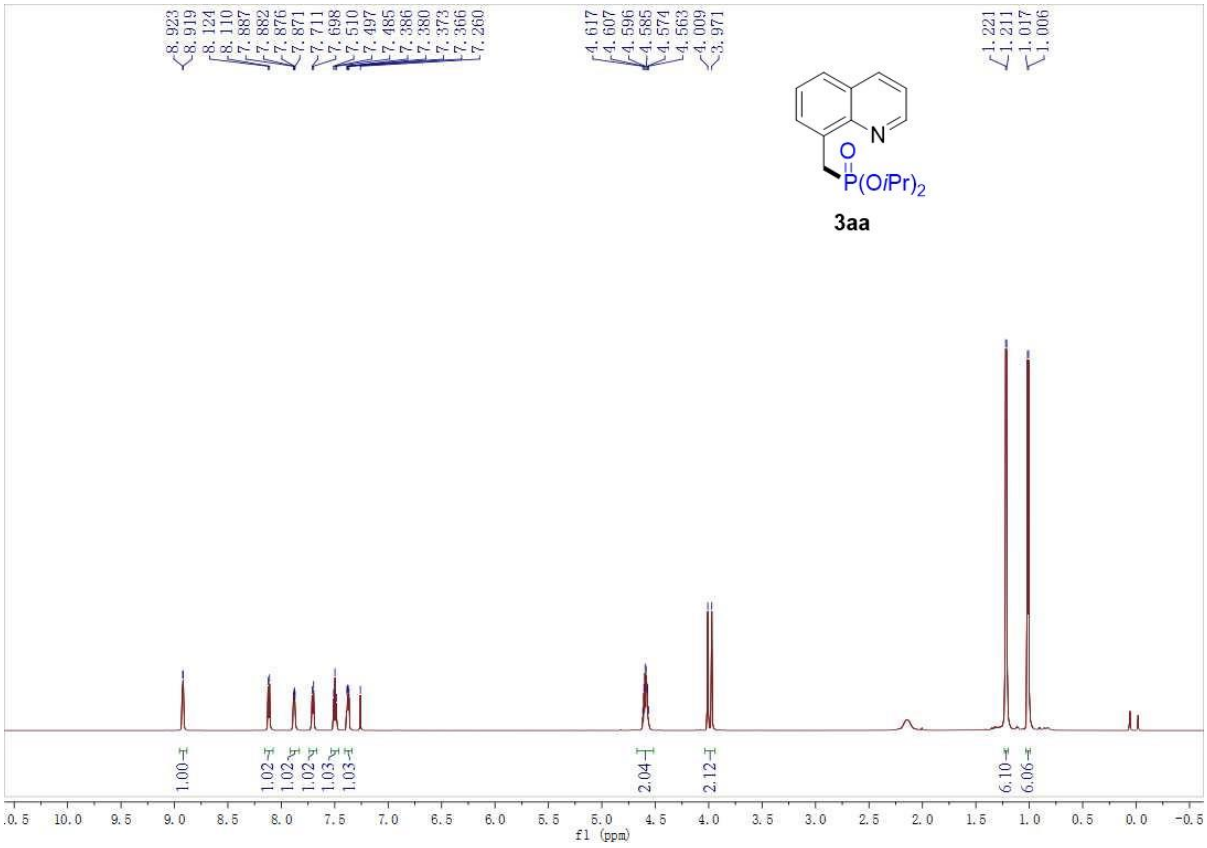
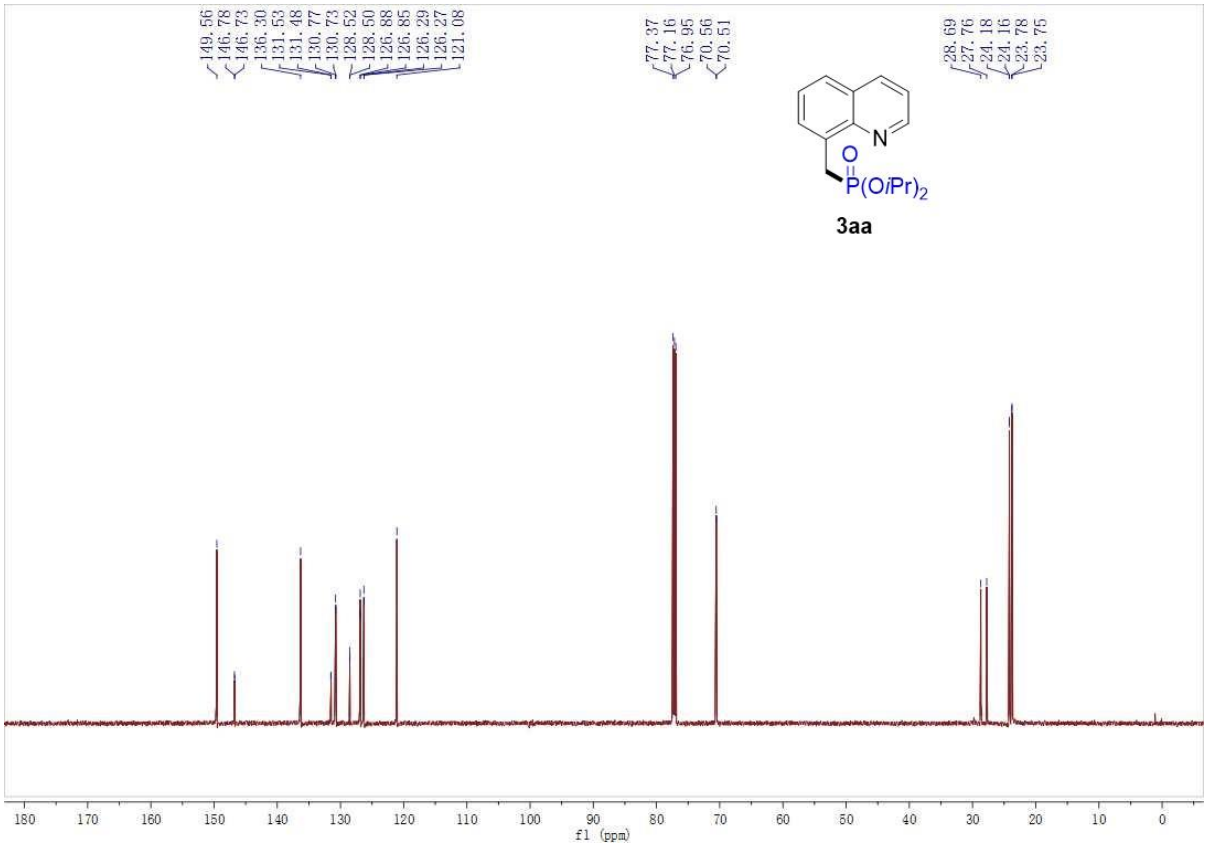
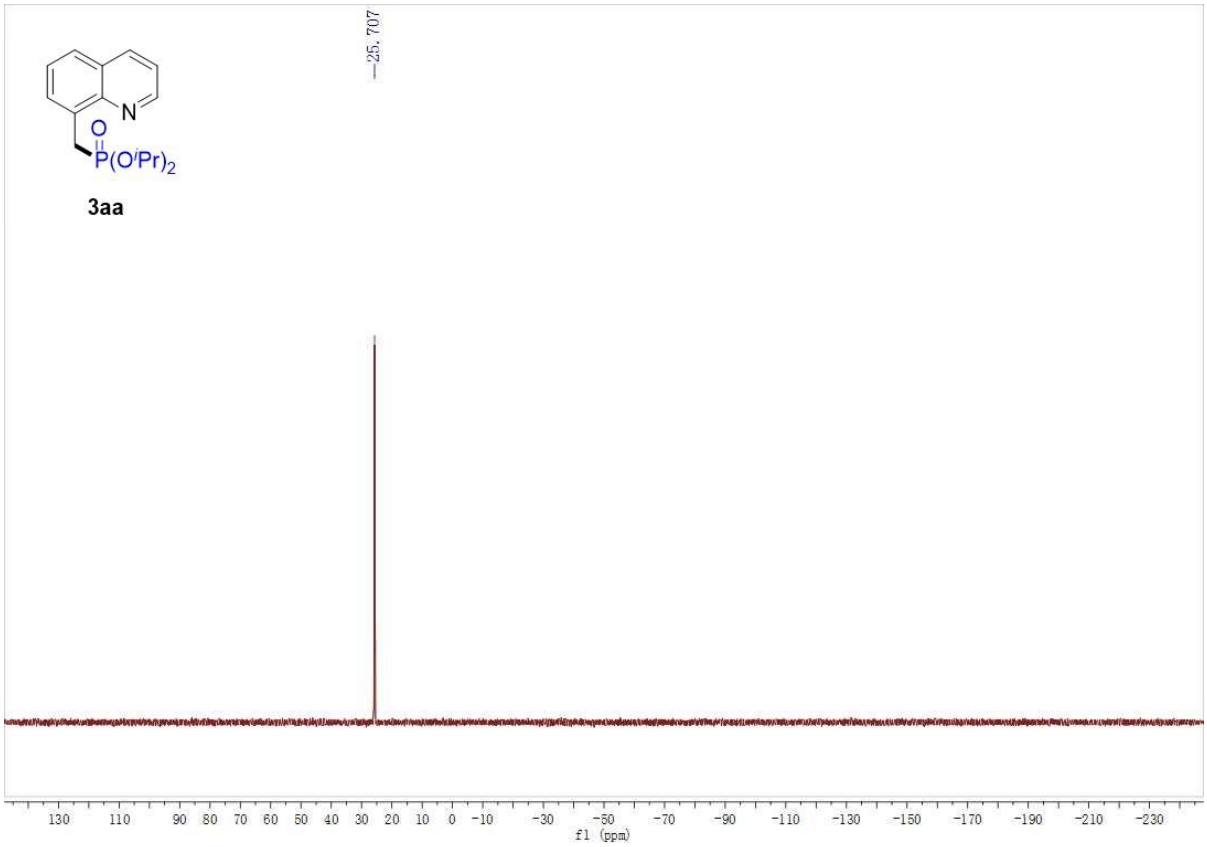
VIII. Copies of NMR spectra



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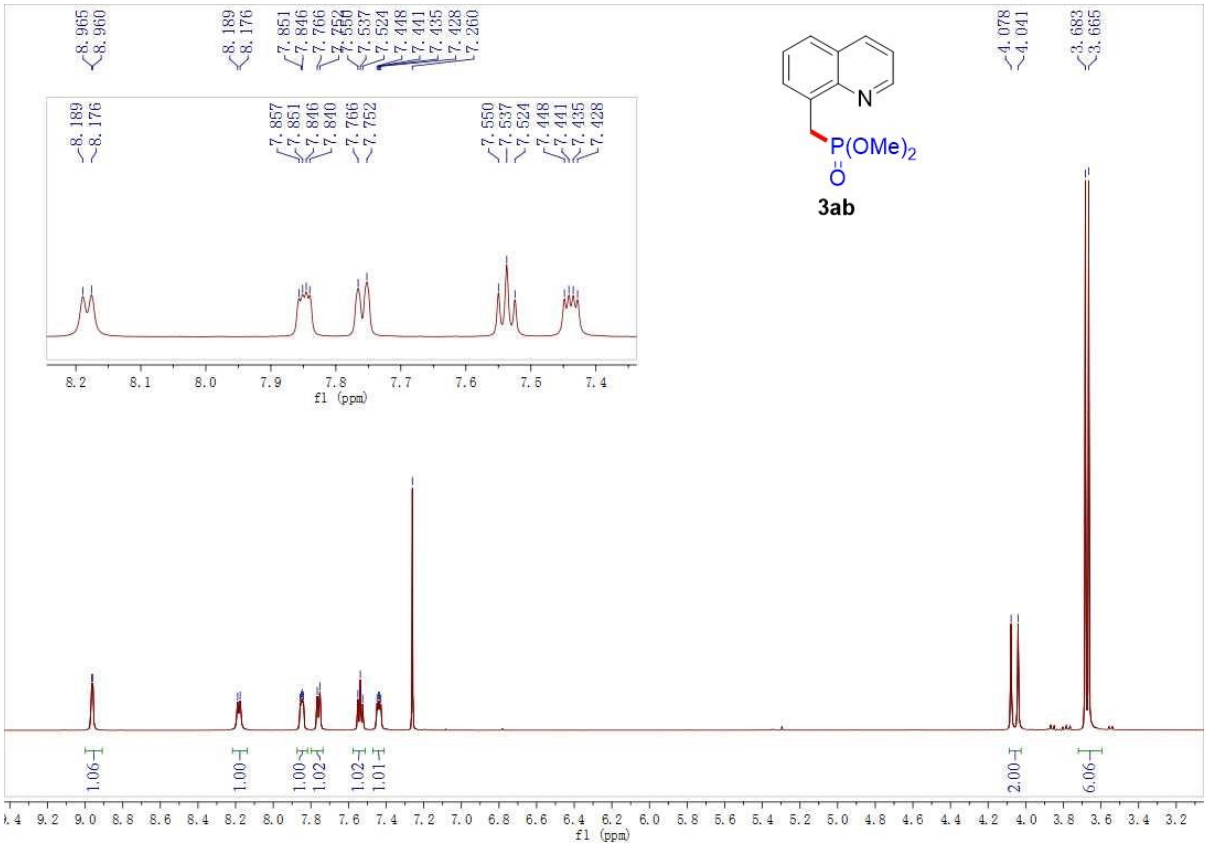
N
O
P(O^{i}Pr)$_2$
3aa
f1 (ppm)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8.960
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7.766
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7.435
7.428
7.260
4.078
4.041
3.683
3.665
N
P(OMe)$_2$
O
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1.00
1.00
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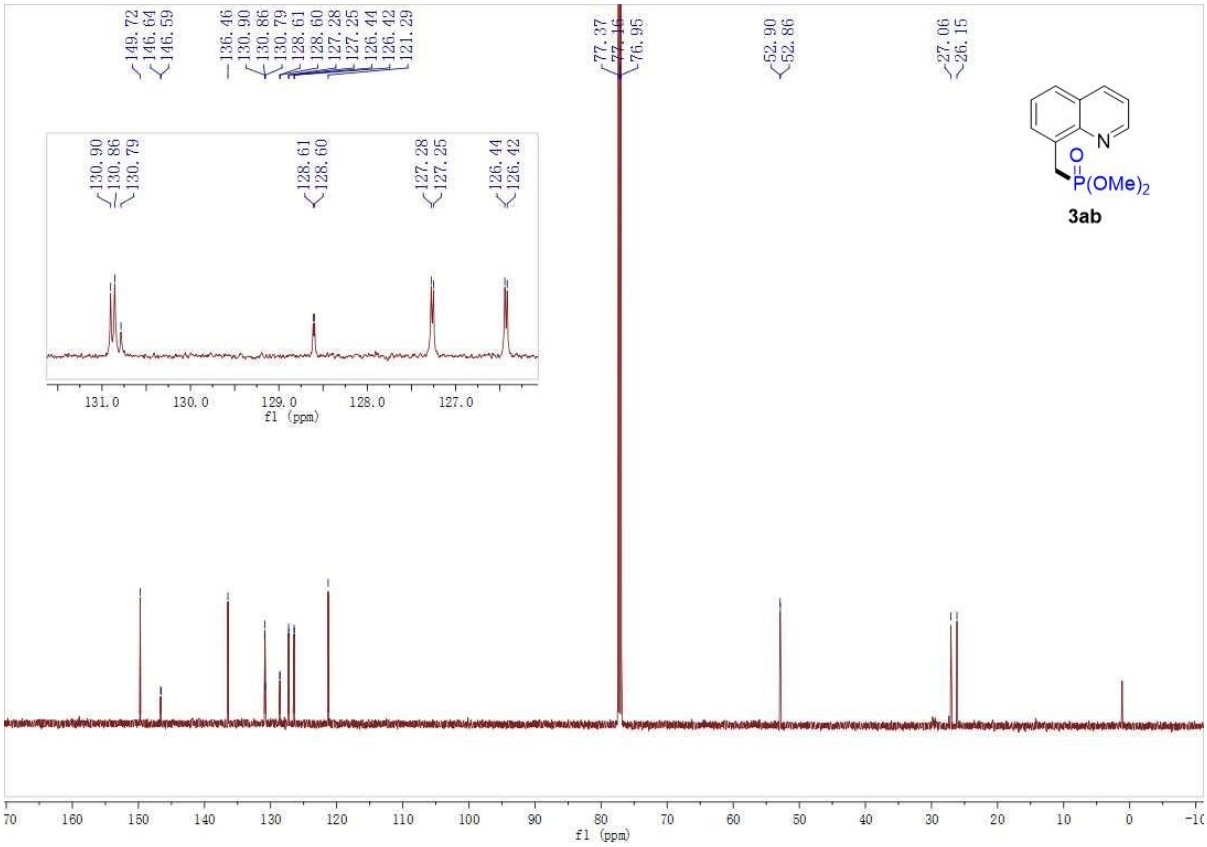
1.02
1.01
2.00
6.06
f1 (ppm)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126.44
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121.29
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77.16
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52.86
27.06
26.15
130.90
130.86
130.79
128.61
128.60
127.28
127.25
126.44
126.42
131.0
130.0
129.0
128.0
127.0
f1 (ppm)
N
O
P(OMe)2
3ab
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160
150
140
130
120
110
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90
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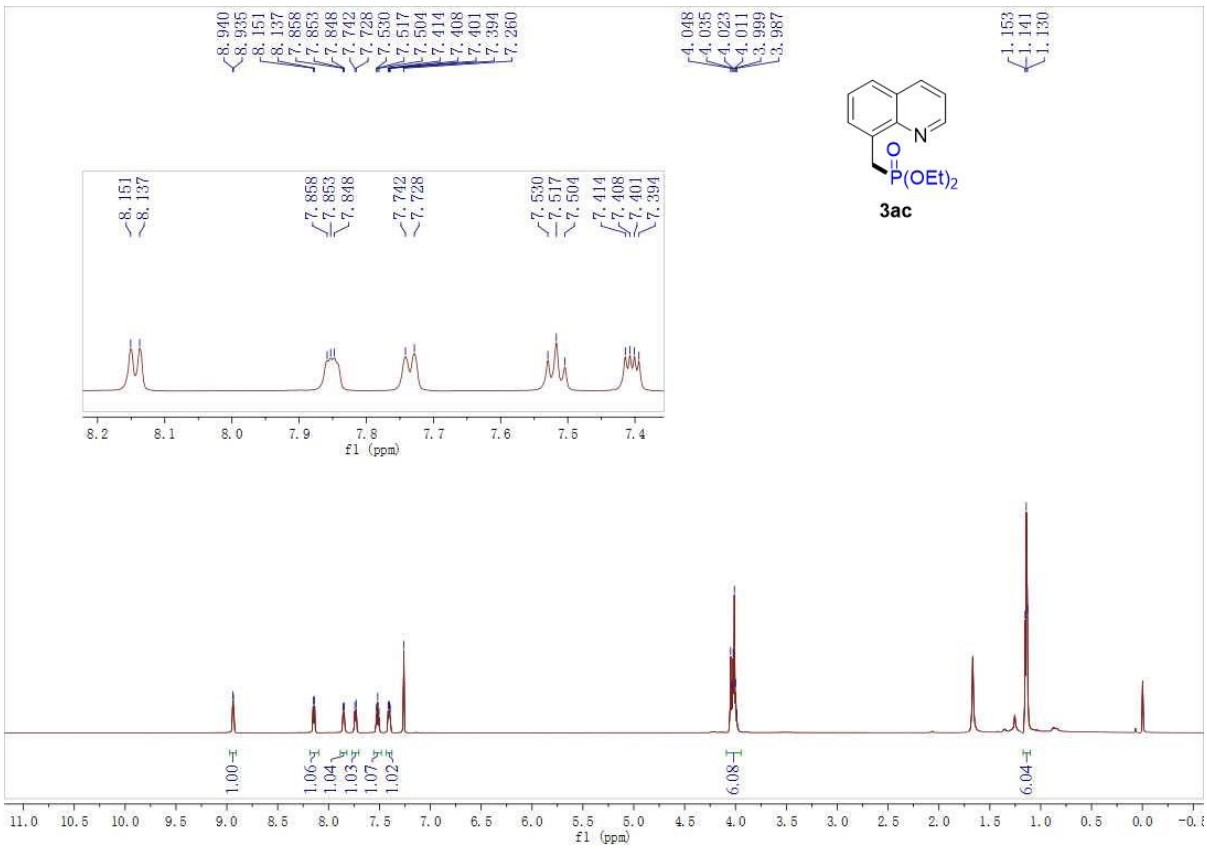
70
60
50
40
30
20
10
0
f1 (ppm)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7.504
7.414
7.408
7.401
7.394
8.2
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7.8
7.7
7.6
7.5
7.4
f1 (ppm)
N
O
P(OEt)2
3ac
1.00
1.06
1.04
1.03
1.07
1.02
6.08
6.04
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6.0
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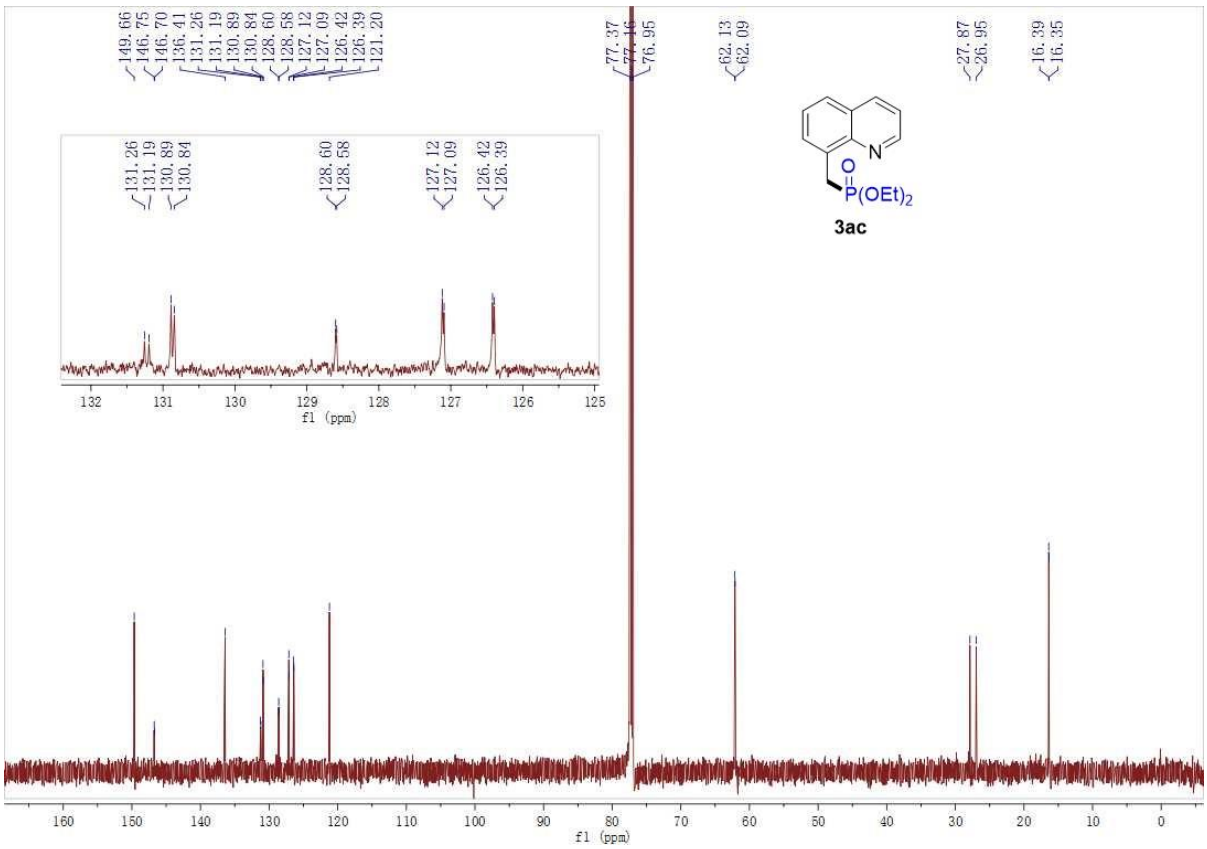
f1 (ppm)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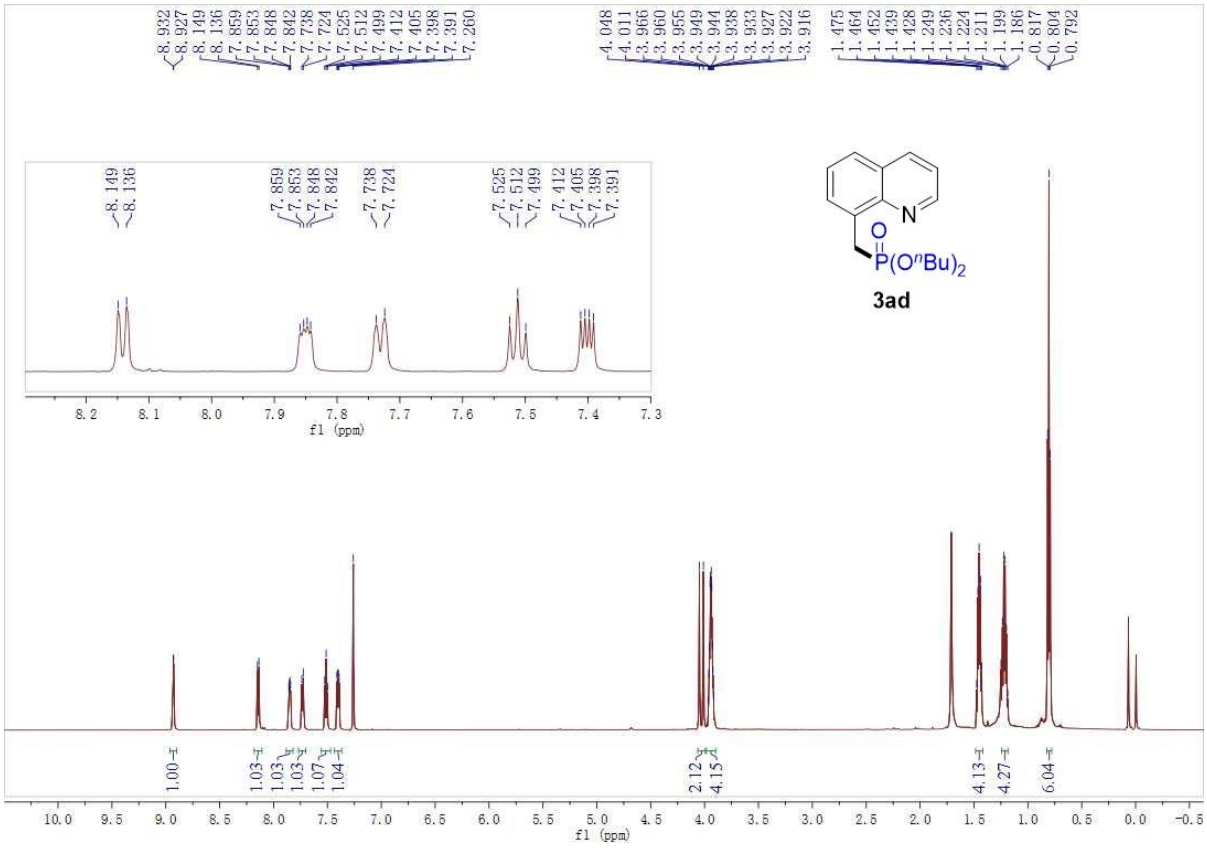
130.84
128.60
128.58
127.12
127.09
126.42
126.39
121.20
77.37
77.16
76.95
62.13
62.09
27.87
26.95
16.39
16.35
131.26
131.19
130.89
130.84
128.60
128.58
127.12
127.09
126.42
126.39
f1 (ppm)
O
P(OEt)2
3ac
f1 (ppm)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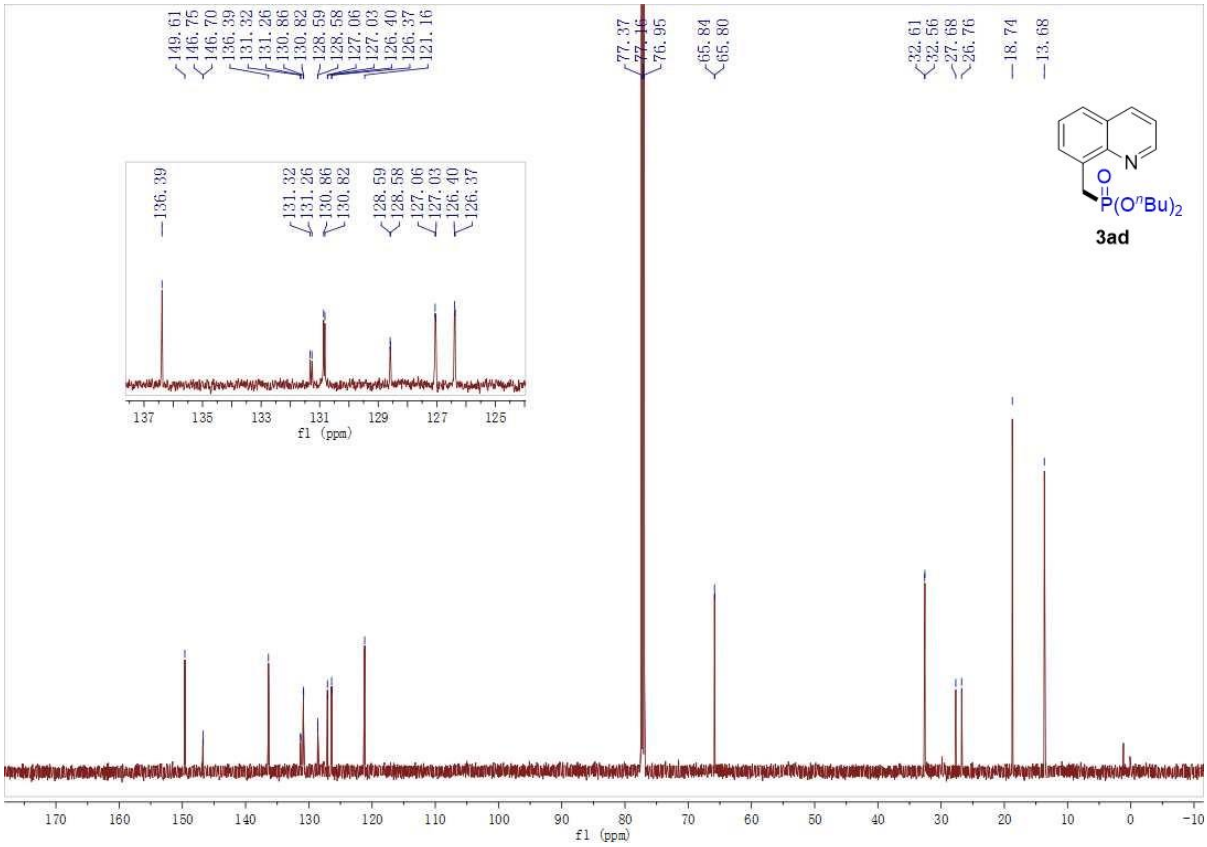
8.927
8.149
8.136
7.859
7.853
7.848
7.842
7.738
7.724
7.525
7.512
7.499
7.412
7.405
7.398
7.391
7.260
4.048
4.011
3.966
3.960
3.955
3.949
3.944
3.938
3.933
3.927
3.922
3.916
1.475
1.464
1.452
1.439
1.428
1.249
1.236
1.224
1.211
1.199
1.186
0.817
0.804
0.792
8.149
8.136
7.859
7.853
7.848
7.842
7.738
7.724
7.525
7.512
7.499
7.412
7.405
7.398
7.391
f1 (ppm)
O
P(OnBu)2
3ad
1.00
1.03
1.03
1.03
1.07
1.04
2.12
4.15
4.13
4.27
6.04
f1 (ppm)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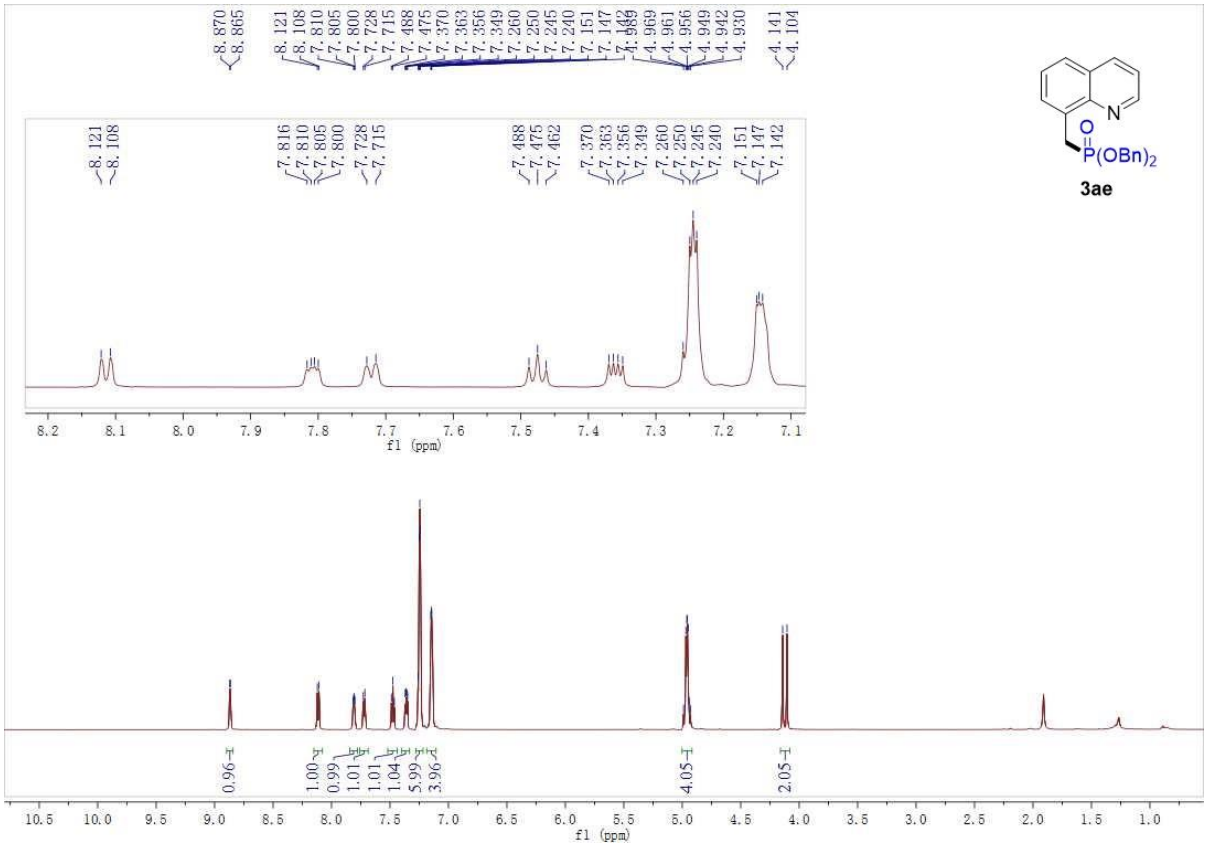
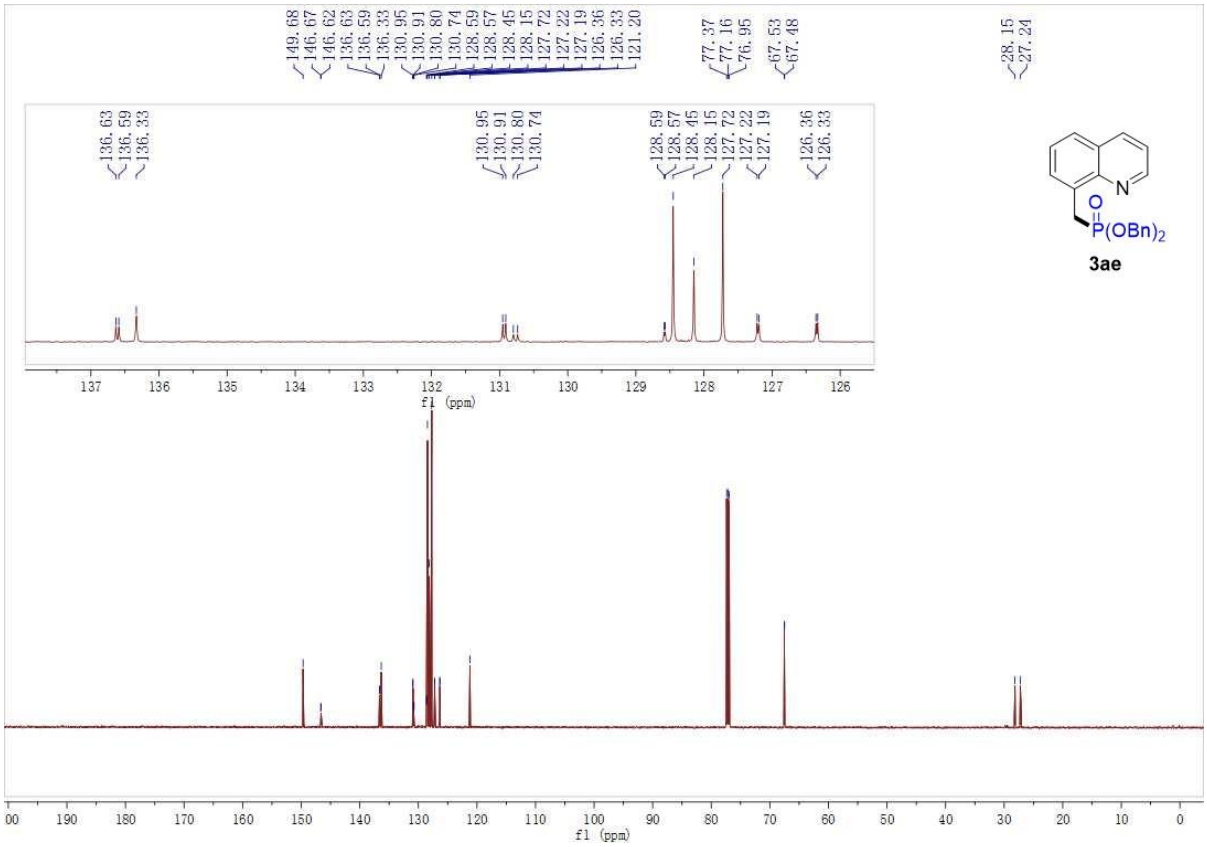
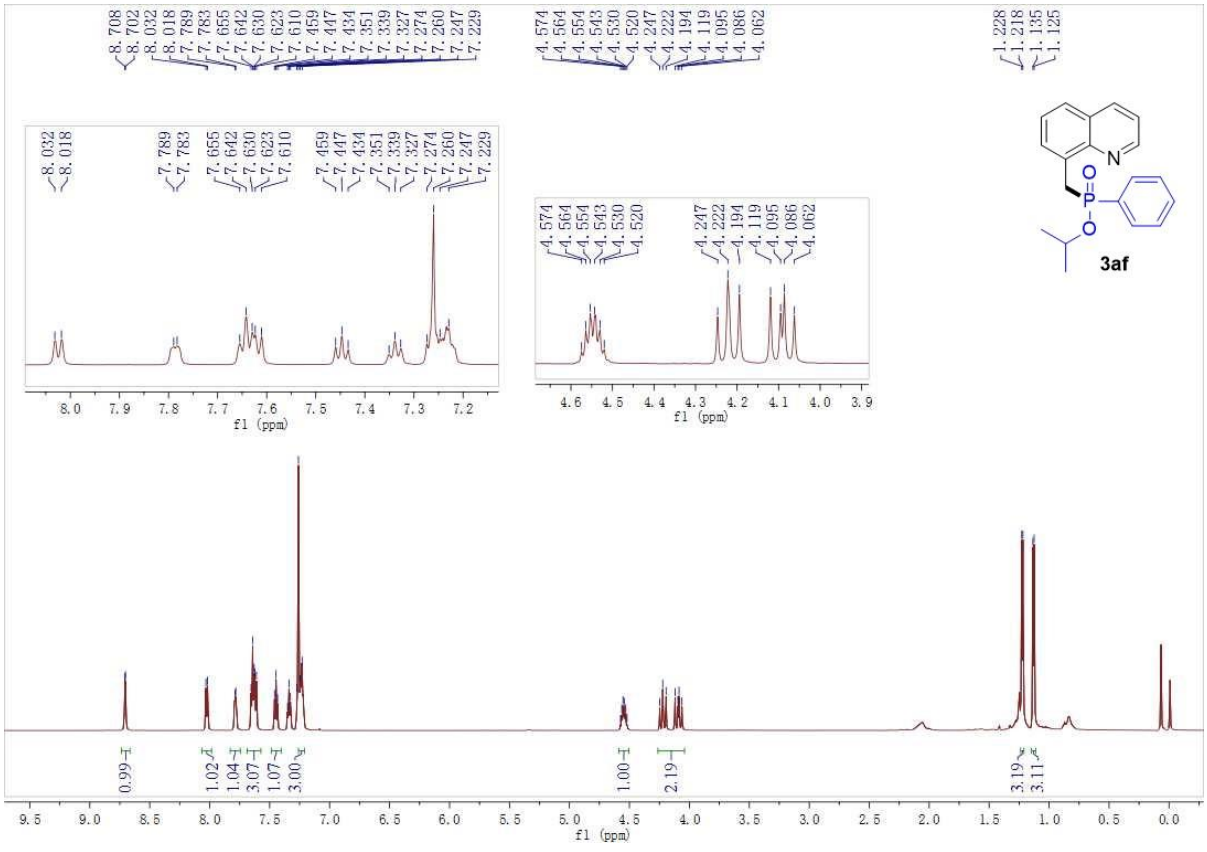
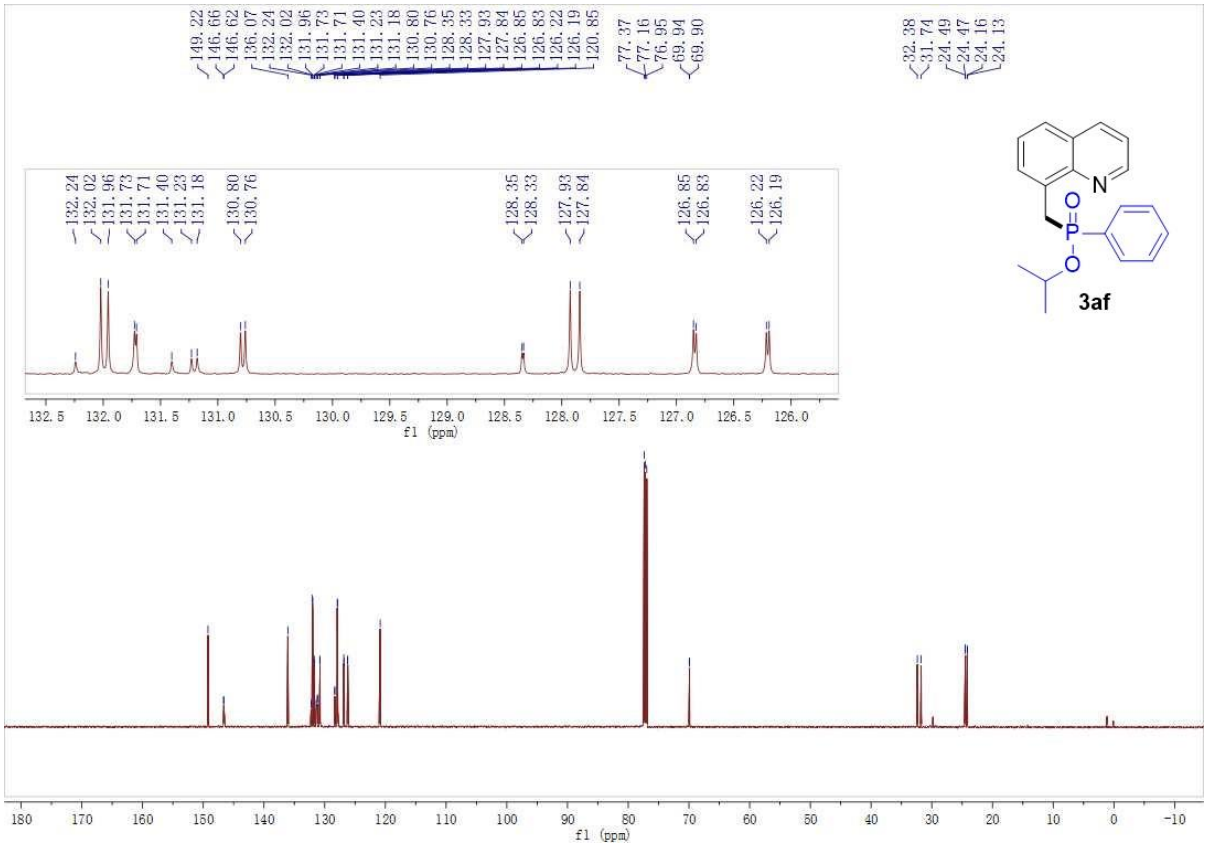
146.75
146.70
136.39
131.32
131.26
130.86
130.82
128.59
128.58
127.06
127.03
126.40
126.37
121.16
77.37
77.16
76.95
65.84
65.80
32.61
32.56
27.68
26.76
18.74
13.68
O
P(O^{n}Bu)$_2$
3ad
f1 (ppm)


8.870
8.865
8.121
8.108
7.810
7.805
7.800
7.728
7.715
7.488
7.475
7.370
7.363
7.356
7.349
7.260
7.250
7.245
7.240
7.151
7.147
4.969
4.961
4.956
4.949
4.942
4.930
4.141
4.104
O
P(OBn)$_2$
3ae
0.96
1.00
0.99
1.01
1.01
1.04
5.99
3.96
4.05
2.05
f1 (ppm)


3ae


3af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146.66
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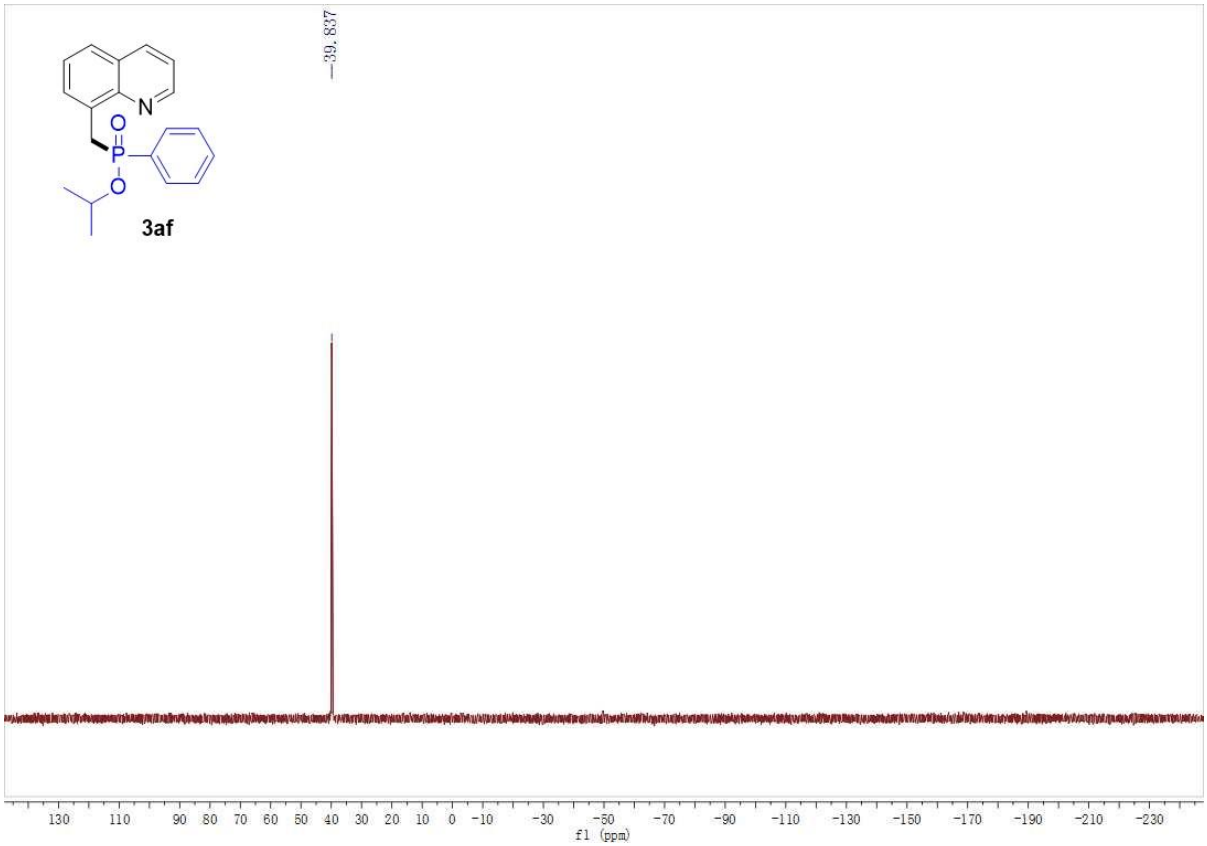
136.07
132.24
132.02
131.96
131.73
131.71
131.40
131.23
131.18
130.80
130.76
128.35
128.33
127.93
127.84
126.85
126.83
126.22
126.19
120.85
77.37
77.16
76.95
69.94
69.90
32.38
31.74
24.49
24.47
24.16
24.13
3af
f1 (ppm)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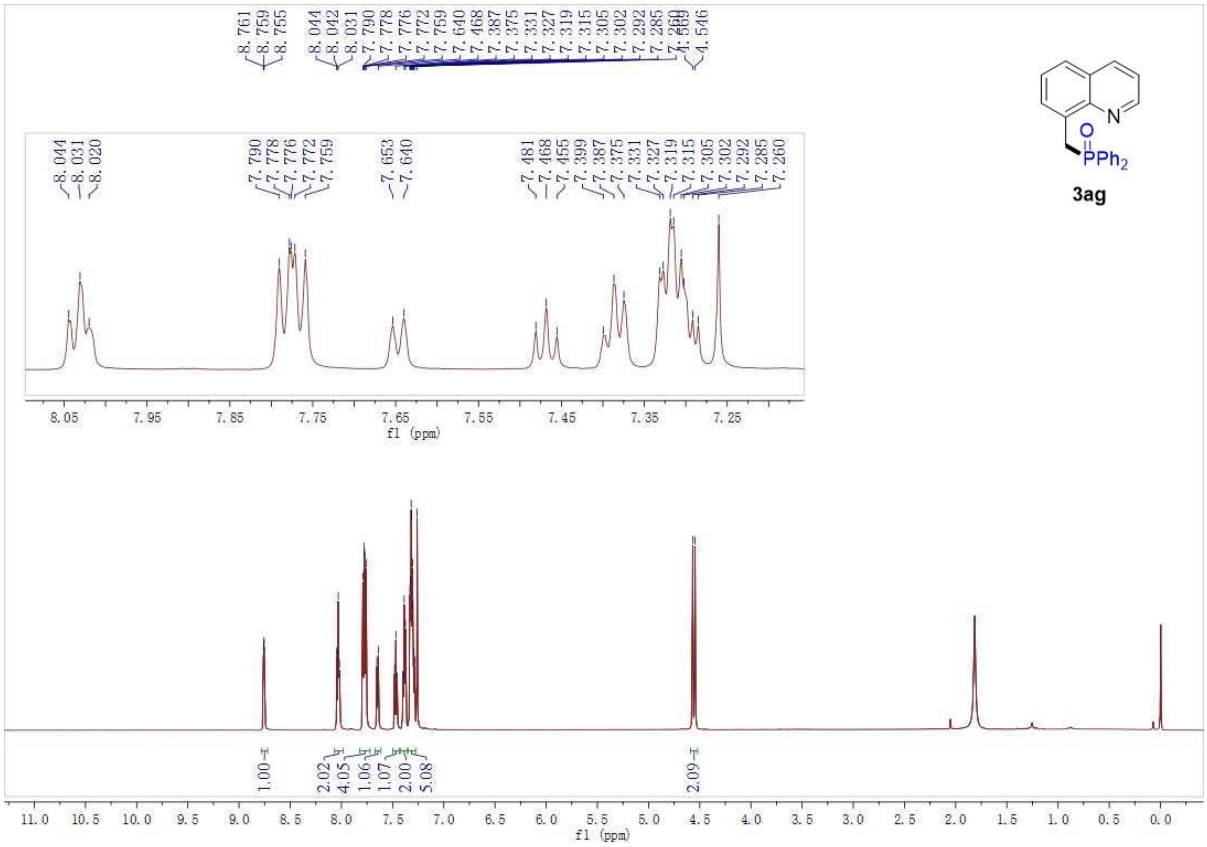
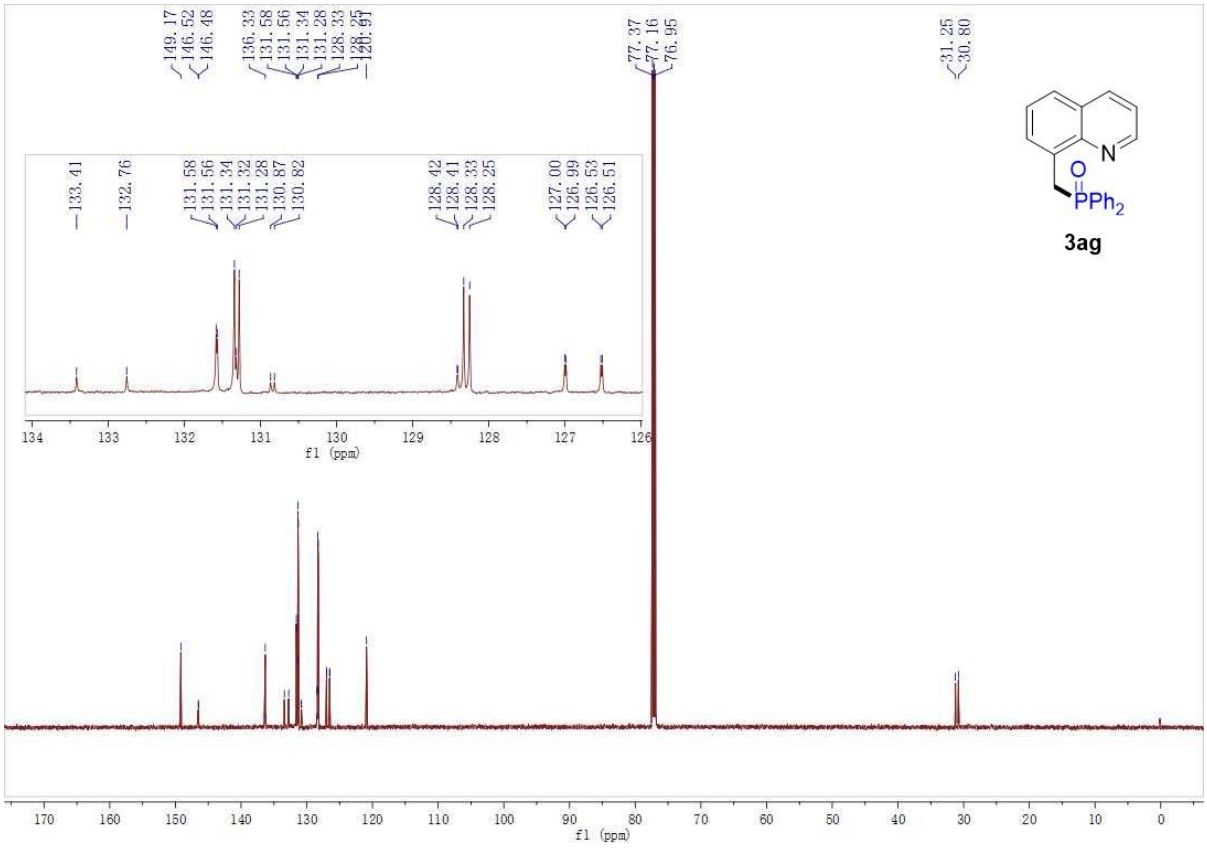
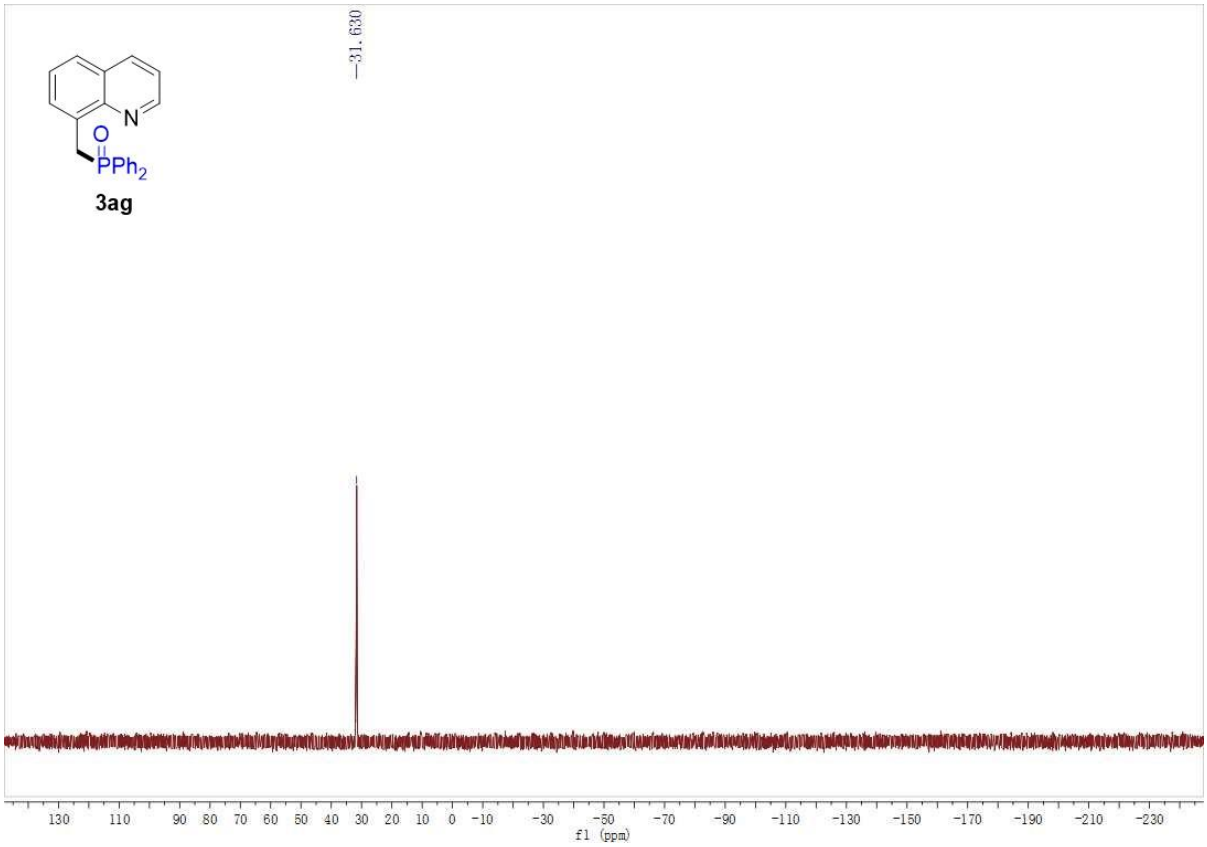
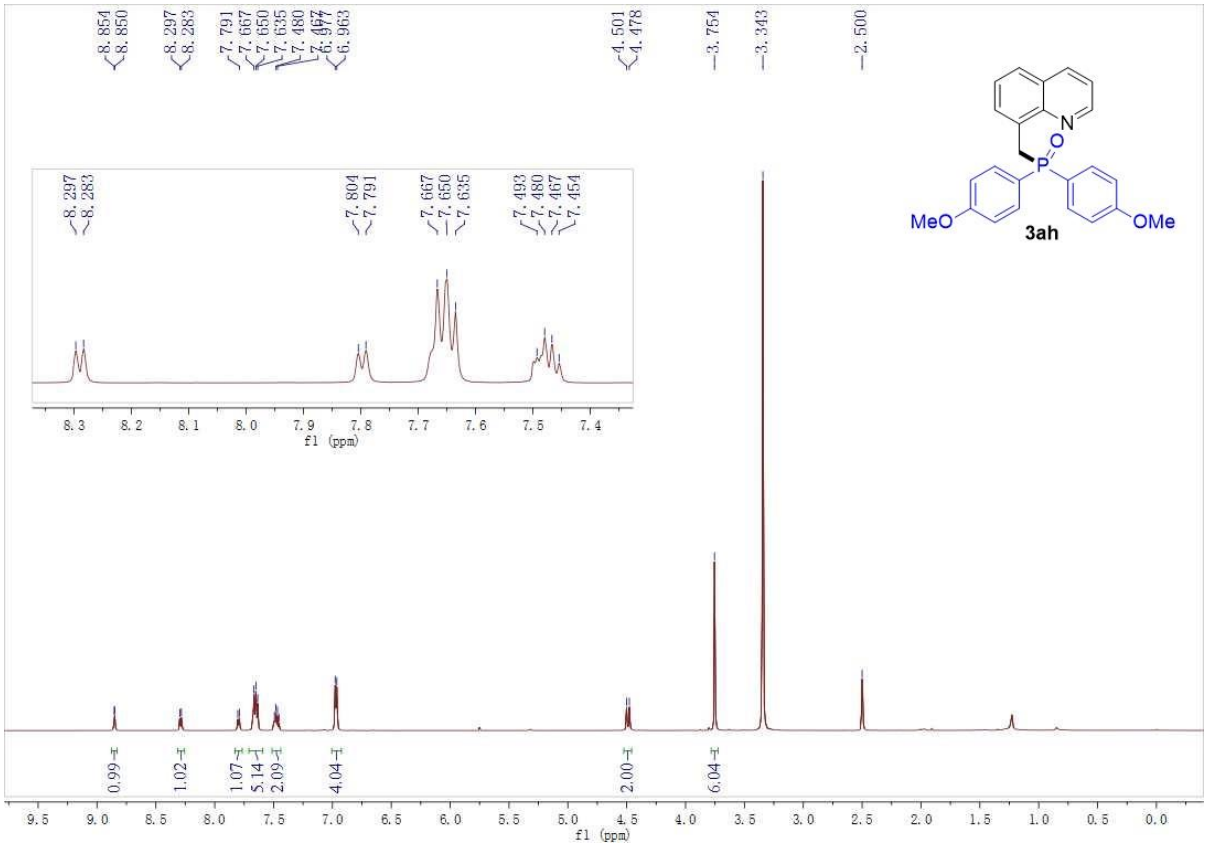
f1 (ppm)


3ag
f1 (ppm)


3ag
f1 (ppm)


31.630
3ag
130 110 90 80 70 60 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)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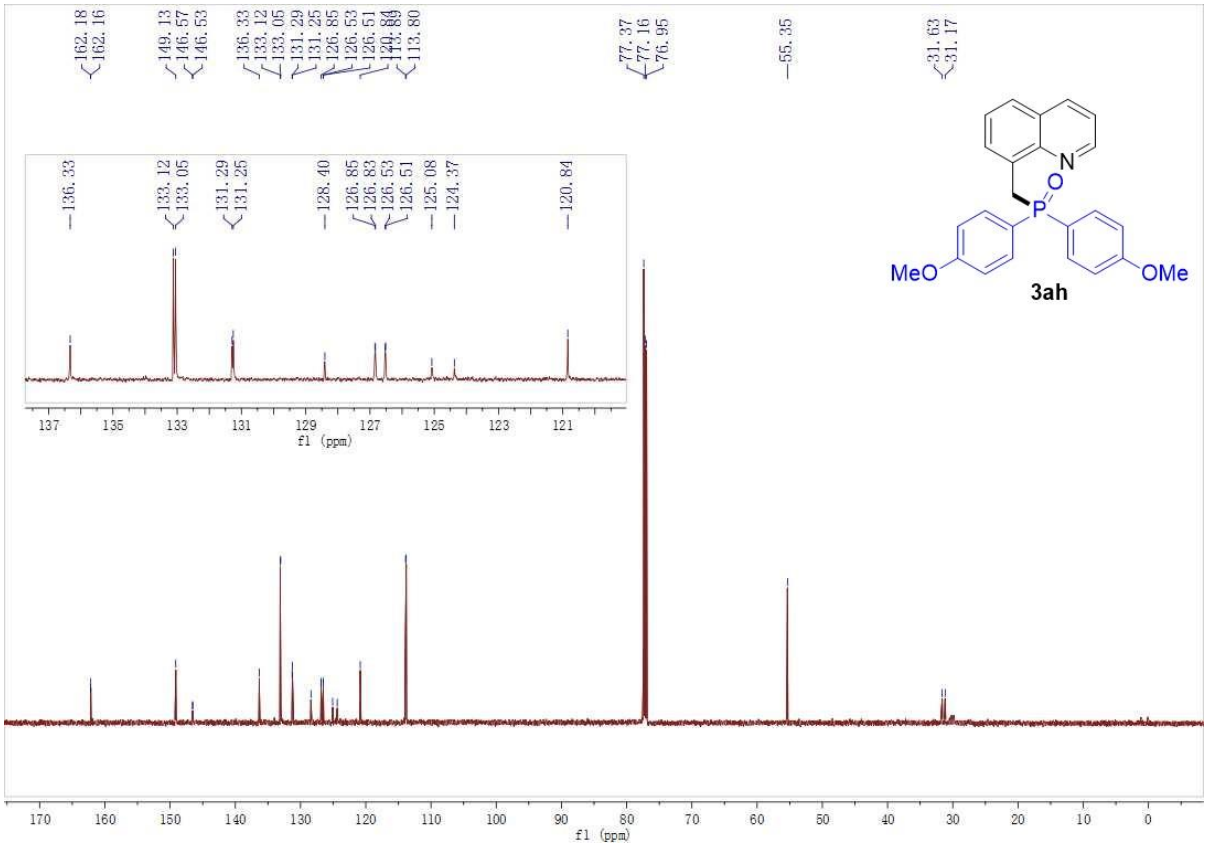
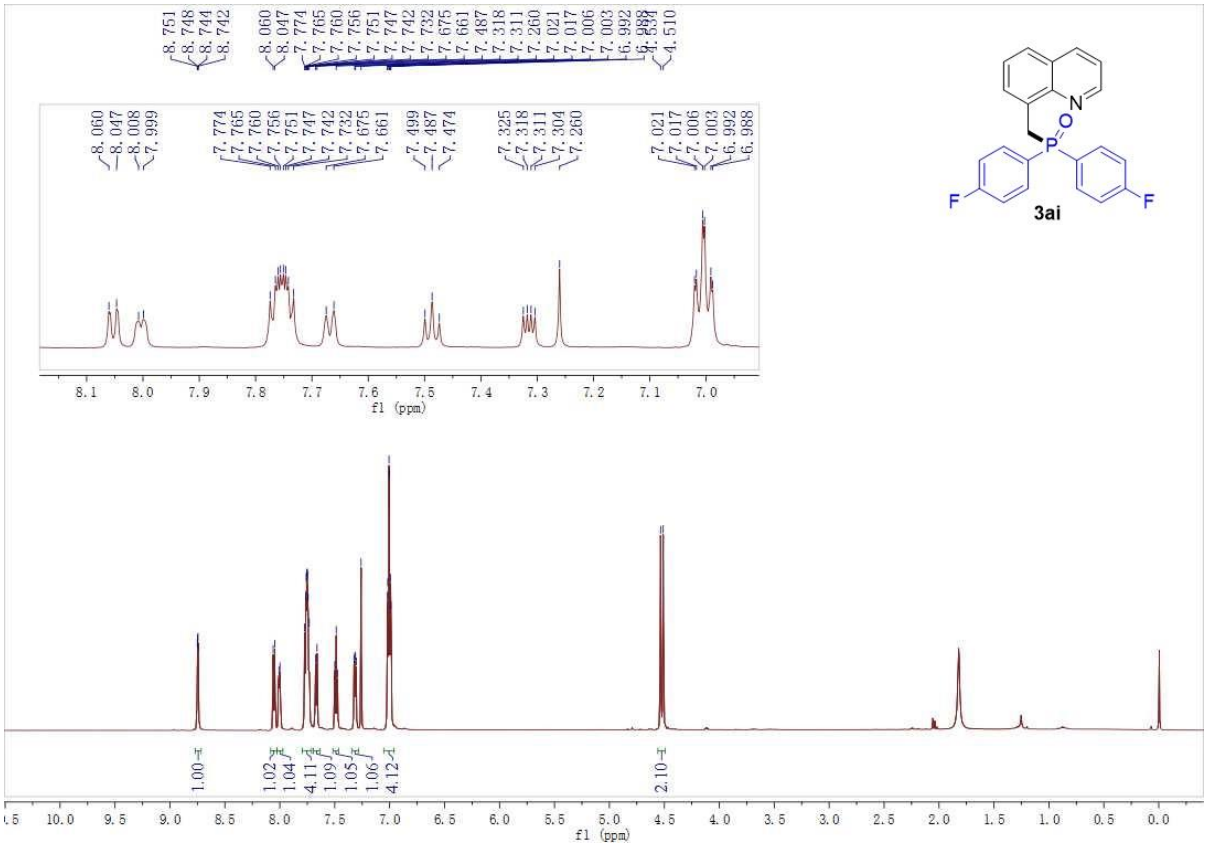
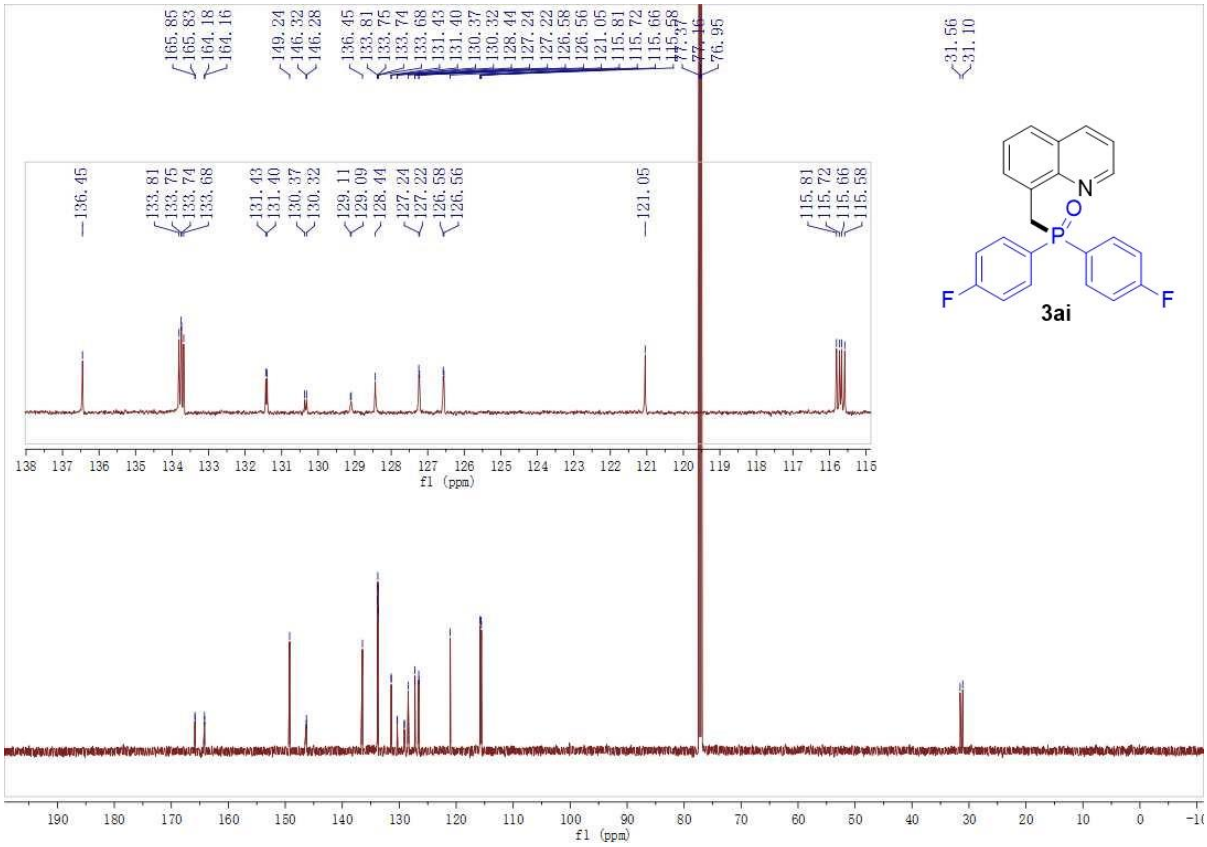
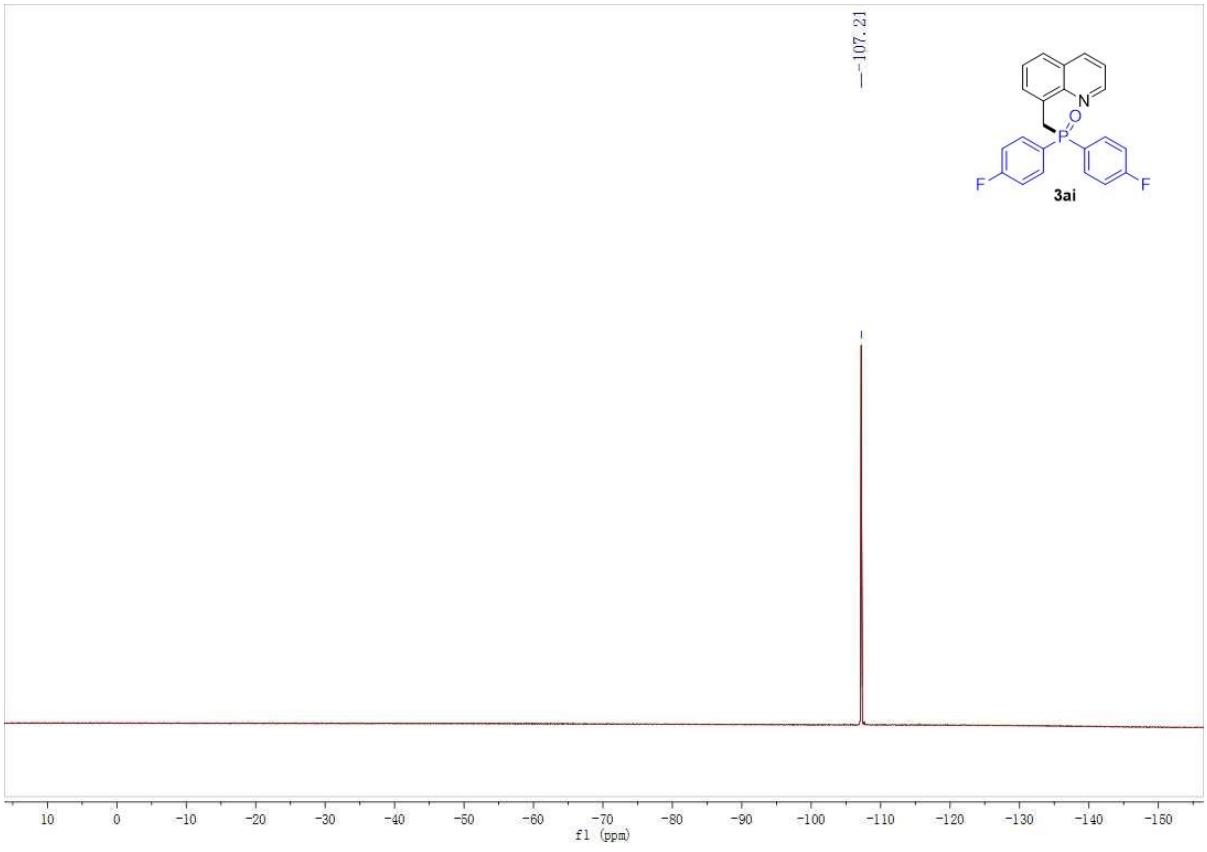
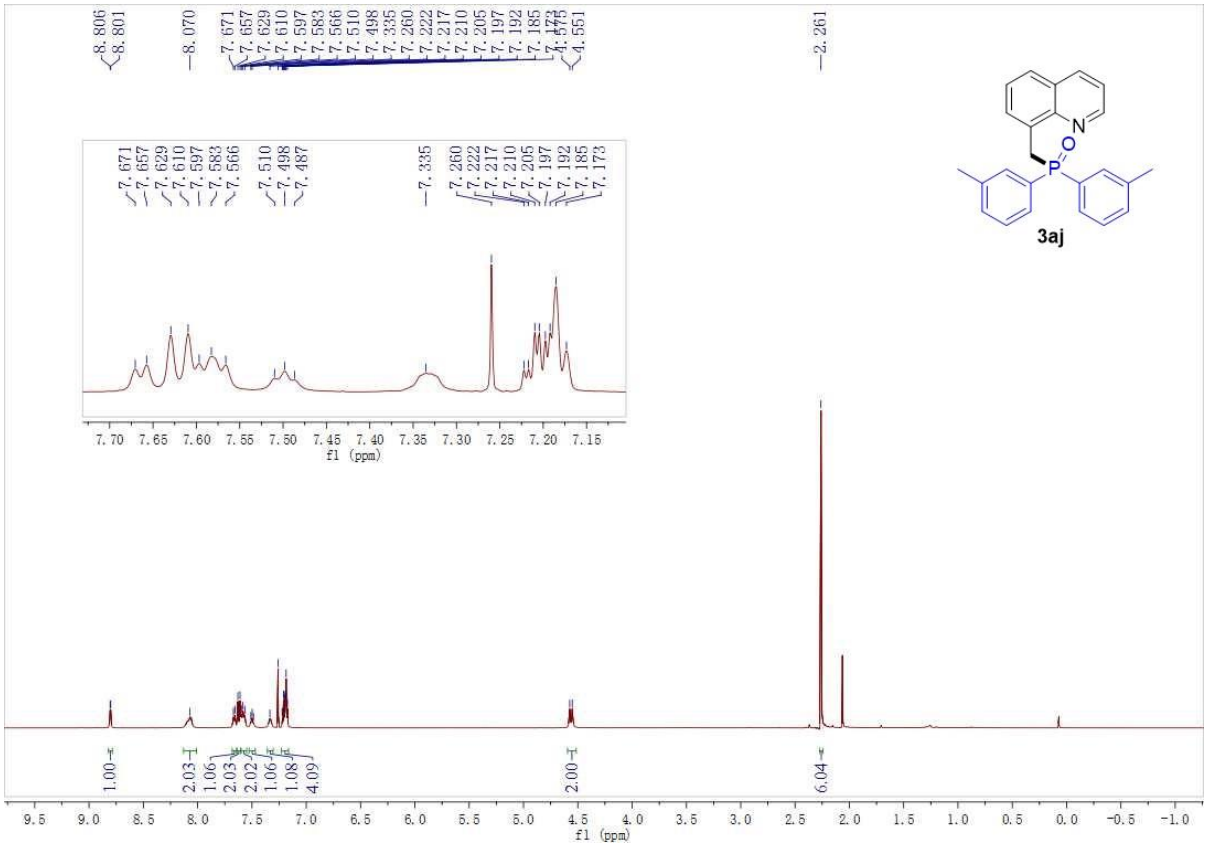
8.850
8.297
8.283
7.791
7.667
7.650
7.635
7.480
6.963
4.501
4.478
3.754
3.343
2.500
3ah
MeO
OMe
0.99
1.02
1.07
5.14
2.09
4.04
2.00
6.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

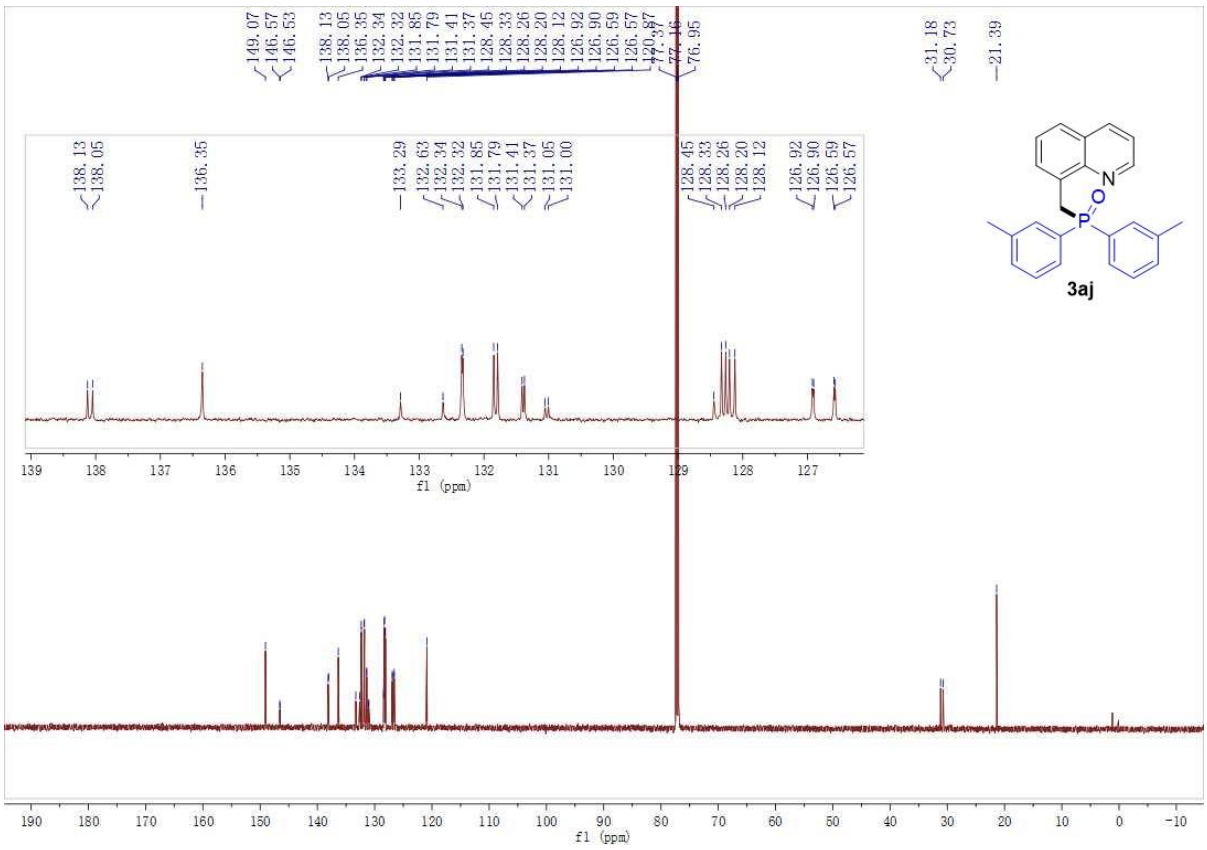

MeO
OMe
3ah
f1 (ppm)


F
F
3ai
f1 (ppm)


165.85
165.83
164.18
164.16
149.24
146.32
146.28
136.45
133.81
133.75
133.74
133.68
131.43
131.40
130.37
130.32
128.44
127.24
127.22
126.58
126.56
121.05
115.81
115.72
115.66
115.58
77.16
76.95
31.56
31.10
f1 (ppm)
3ai


-107.21
f1 (ppm)
3ai


8.806
8.801
8.070
7.671
7.657
7.629
7.610
7.597
7.583
7.566
7.510
7.498
7.335
7.260
7.222
7.217
7.210
7.205
7.197
7.192
7.185
7.173
4.551
2.261
3aj
1.00
2.03
1.06
2.03
2.02
1.06
1.08
4.09
2.00
6.04
f1 (ppm)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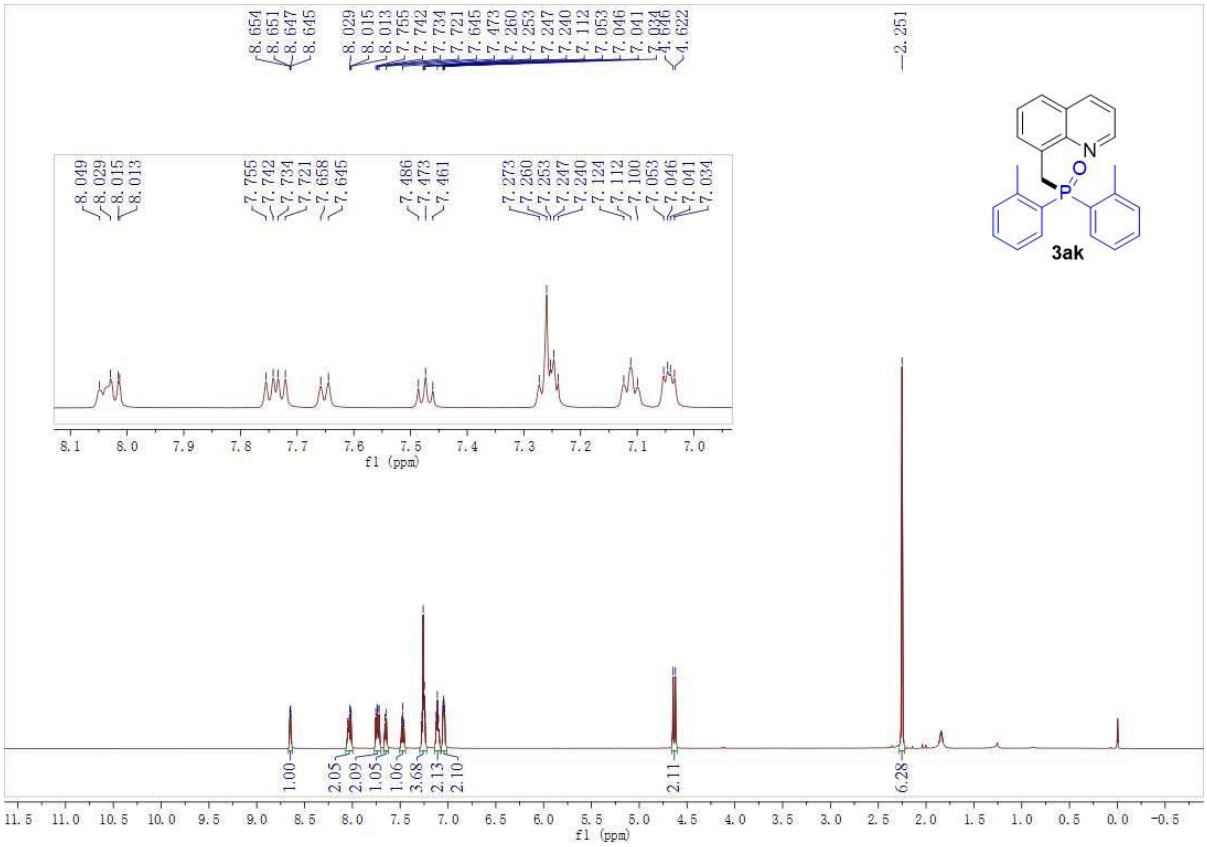
146.57
146.53
138.13
138.05
136.35
132.34
132.32
131.85
131.79
131.41
131.37
128.45
128.33
128.26
128.20
128.12
126.92
126.90
126.59
126.57
77.16
76.95
31.18
30.73
21.39
3aj
f1 (ppm)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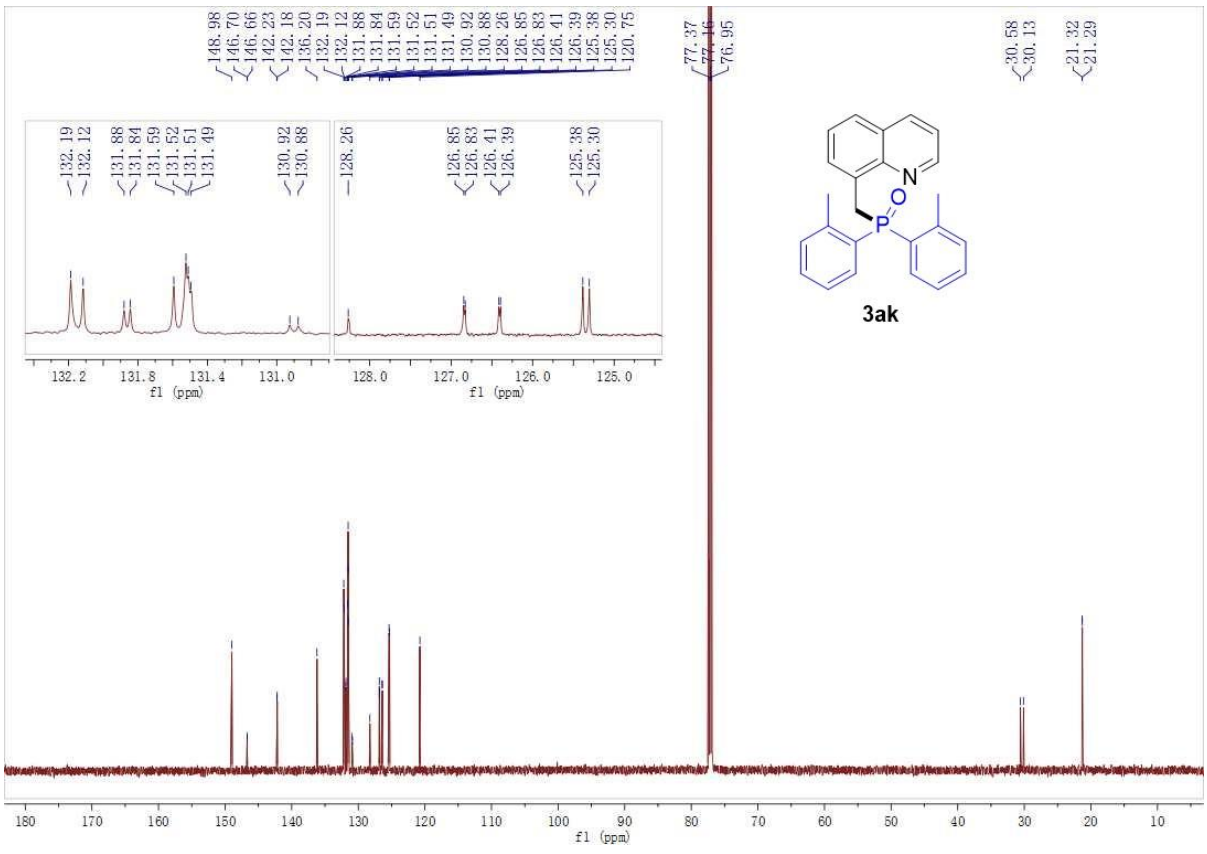
8.651
8.647
8.645
8.029
8.015
8.013
7.755
7.742
7.734
7.721
7.645
7.473
7.260
7.253
7.247
7.240
7.112
7.053
7.046
7.041
7.034
4.622
2.251
3ak
f1 (ppm)
1.00
2.05
2.09
1.05
1.06
3.68
2.13
2.10
2.11
6.28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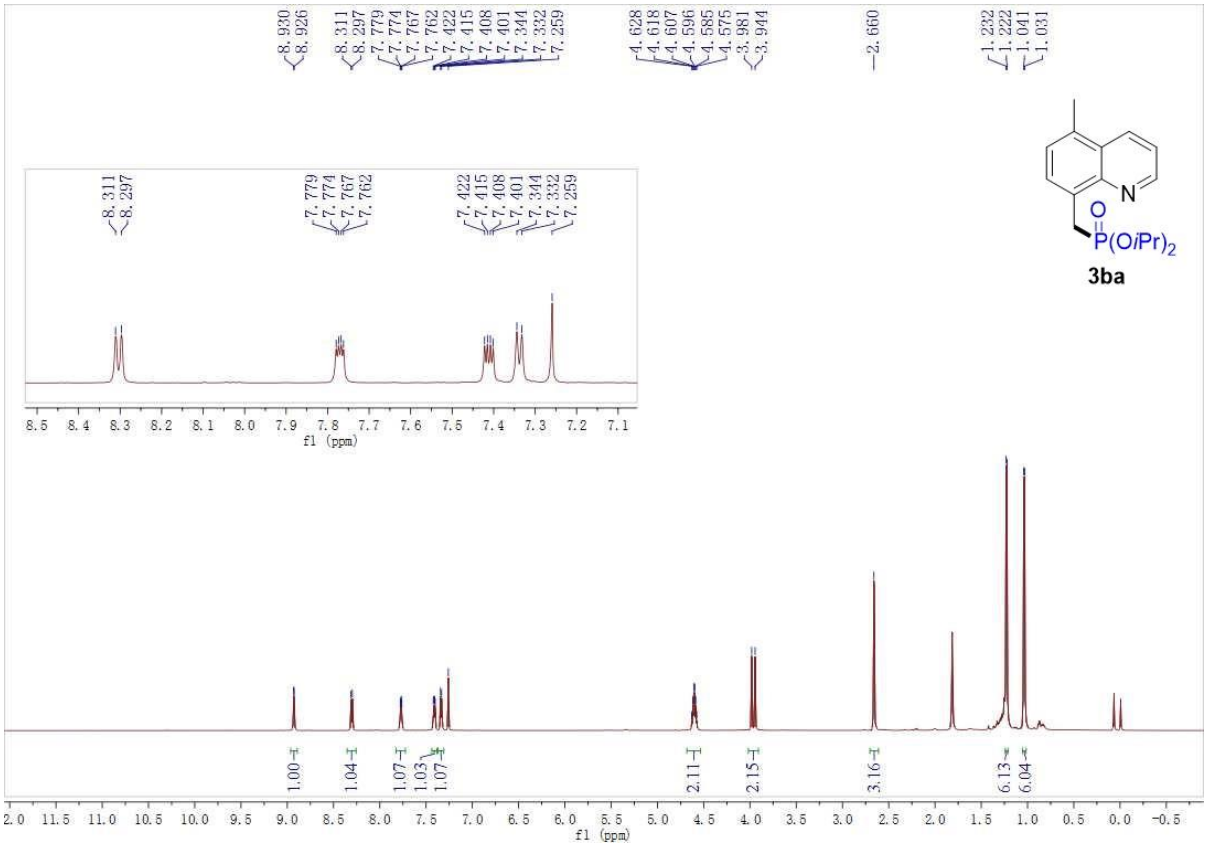
146.70
146.66
142.23
142.18
136.20
132.19
132.12
131.88
131.84
131.59
131.52
131.51
131.49
130.92
130.88
128.26
126.85
126.83
126.41
126.39
125.38
125.30
120.75
77.37
77.16
76.95
30.58
30.13
21.32
21.29
3ak
f1 (ppm)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8.926
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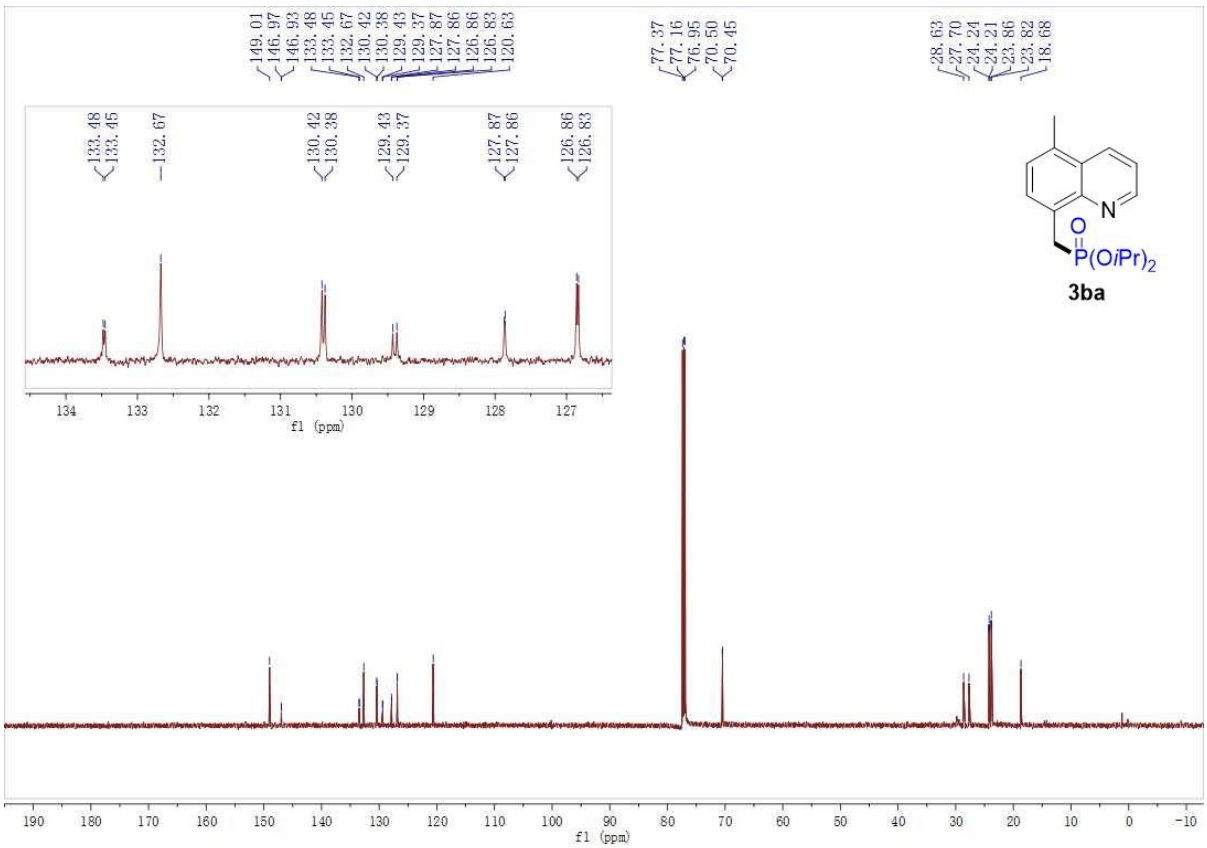
8.297
7.779
7.774
7.767
7.762
7.422
7.415
7.408
7.401
7.344
7.332
7.259
4.628
4.618
4.607
4.596
4.585
4.575
3.981
3.944
2.660
1.232
1.222
1.041
1.031
f1 (ppm)
P(OiPr)2
3ba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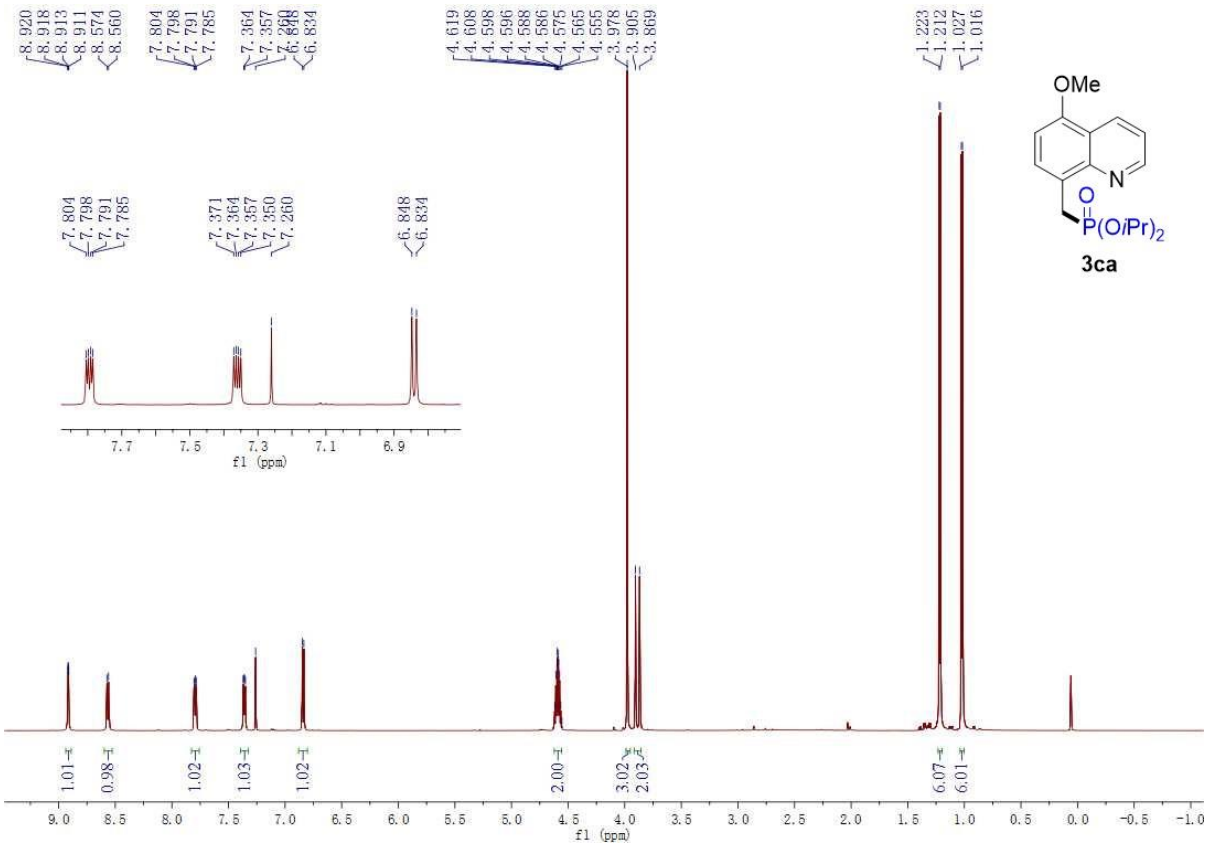
146.97
146.93
133.48
133.45
132.67
130.42
130.38
129.43
129.37
127.87
127.86
126.86
126.83
120.63
77.37
77.16
76.95
70.50
70.45
28.63
27.70
24.24
24.21
23.86
23.82
18.68
f1 (ppm)
P(OiPr)2
3ba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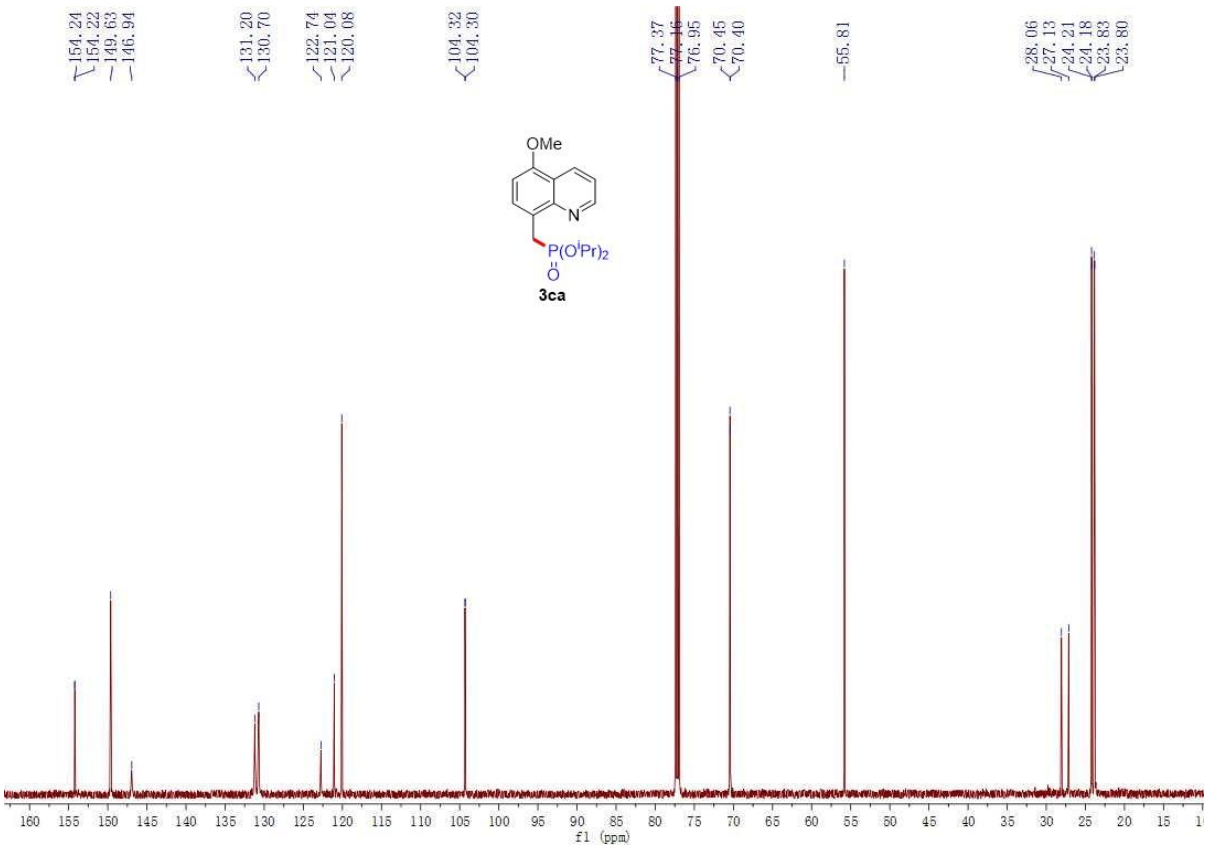
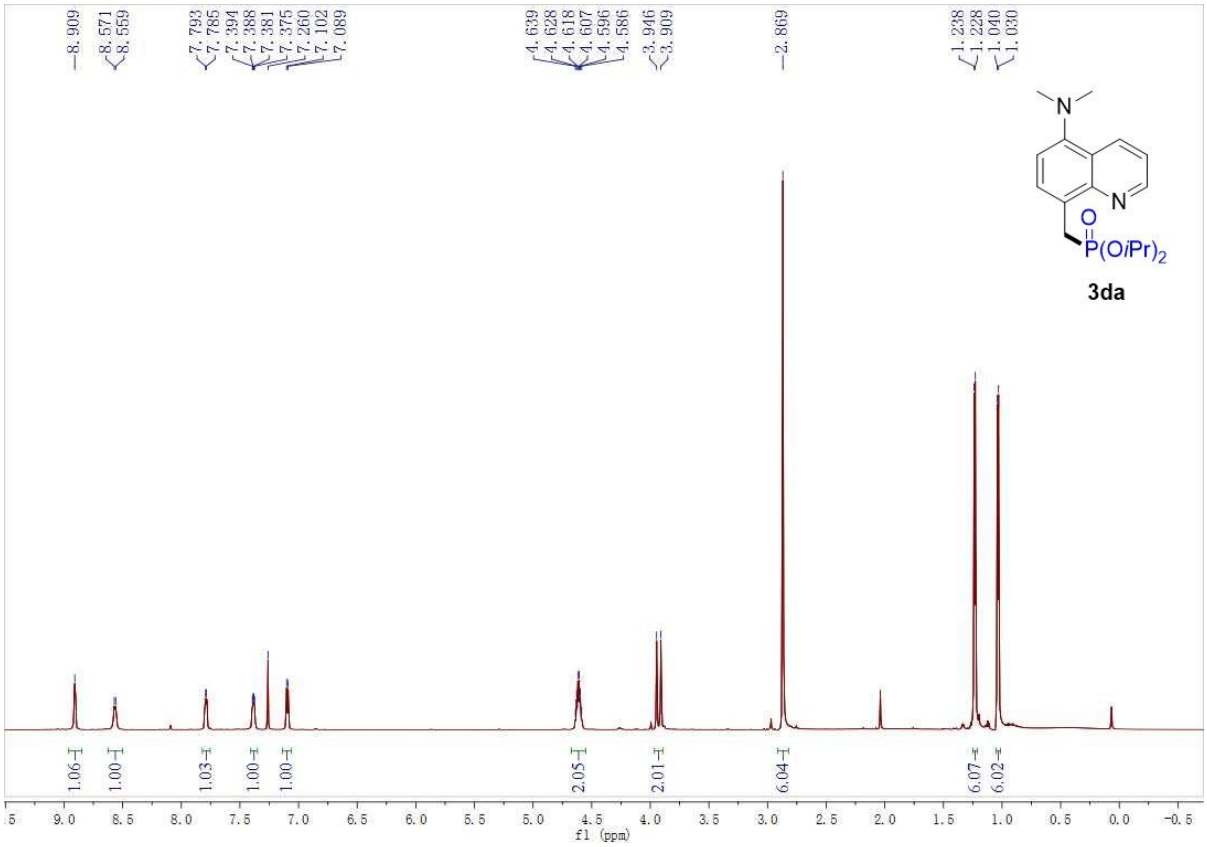
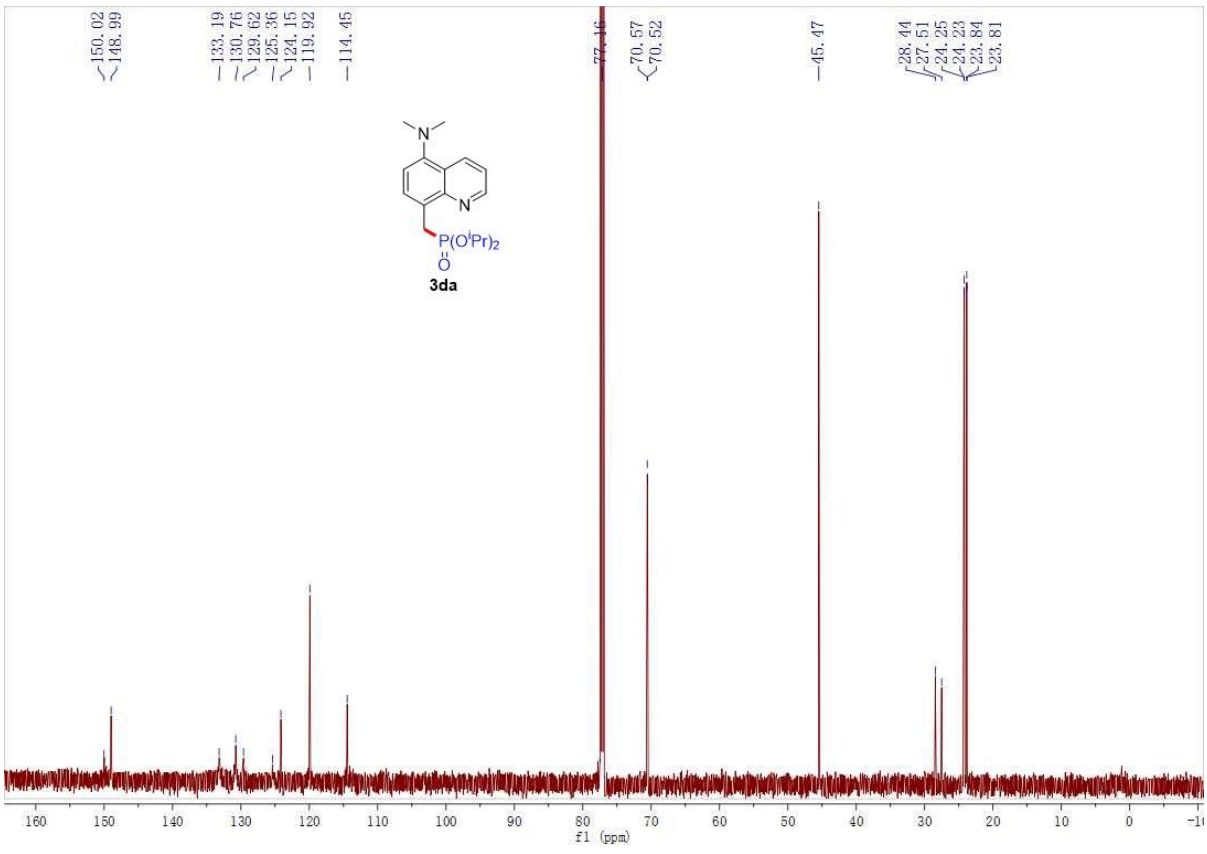
8.918
8.913
8.911
8.574
8.560
7.804
7.798
7.791
7.785
7.364
7.357
6.848
6.834
4.619
4.608
4.598
4.596
4.588
4.586
4.575
4.565
4.555
3.978
3.905
3.869
1.223
1.212
1.027
1.016
OMe
N
O
P(OiPr)2
3ca
f1 (ppm)
1.01
0.98
1.02
1.03
1.02
2.00
3.02
2.03
6.07
6.01


154.24
154.22
149.63
146.94
131.20
130.70
122.74
121.04
120.08
104.32
104.30
77.37
77.16
76.95
70.45
70.40
55.81
28.06
27.13
24.21
24.18
23.83
23.80
OMe
N
P(OiPr)2
O
3ca
f1 (ppm)


8.909
8.571
8.559
7.793
7.785
7.394
7.388
7.381
7.375
7.260
7.102
7.089
4.639
4.628
4.618
4.607
4.596
4.586
3.946
3.909
2.869
1.238
1.228
1.040
1.030
1.06
1.00
1.03
1.00
1.00
2.05
2.01
6.04
6.07
6.02
f1 (ppm)
3da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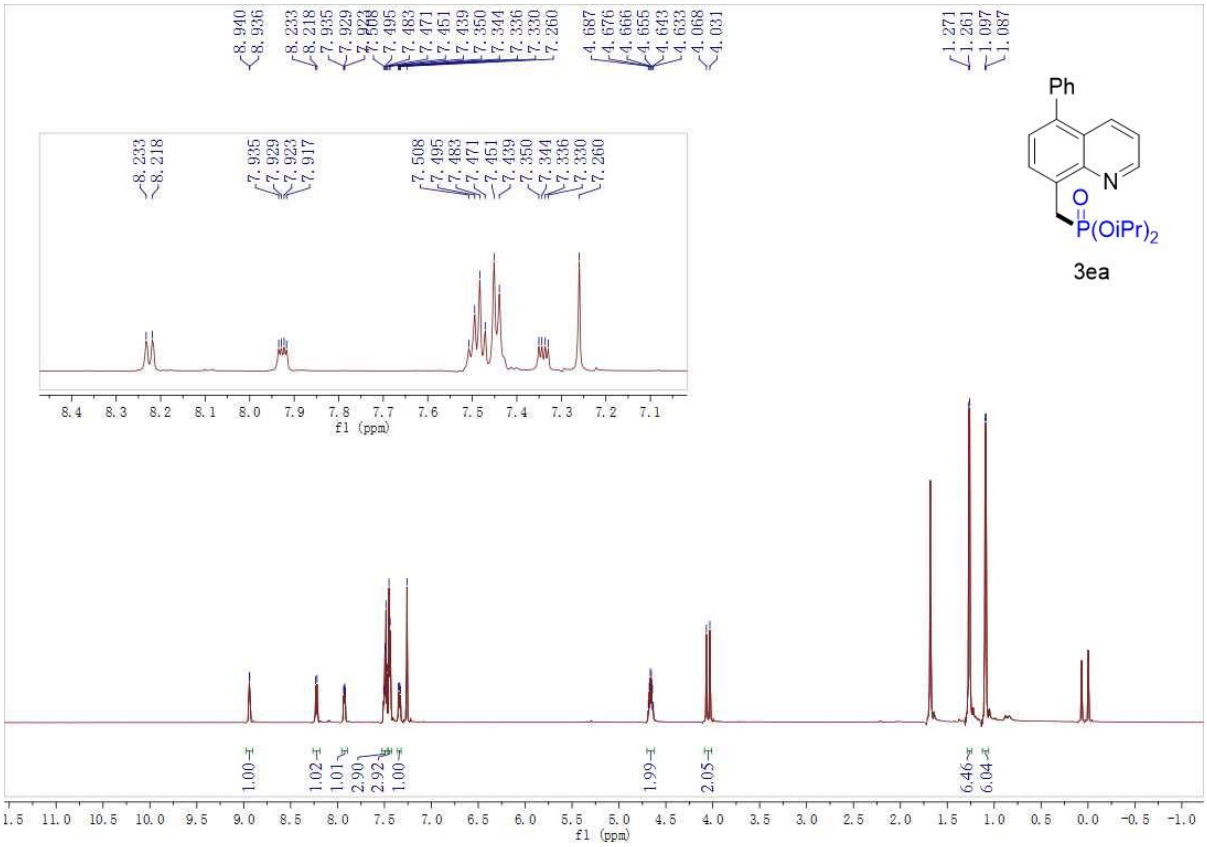
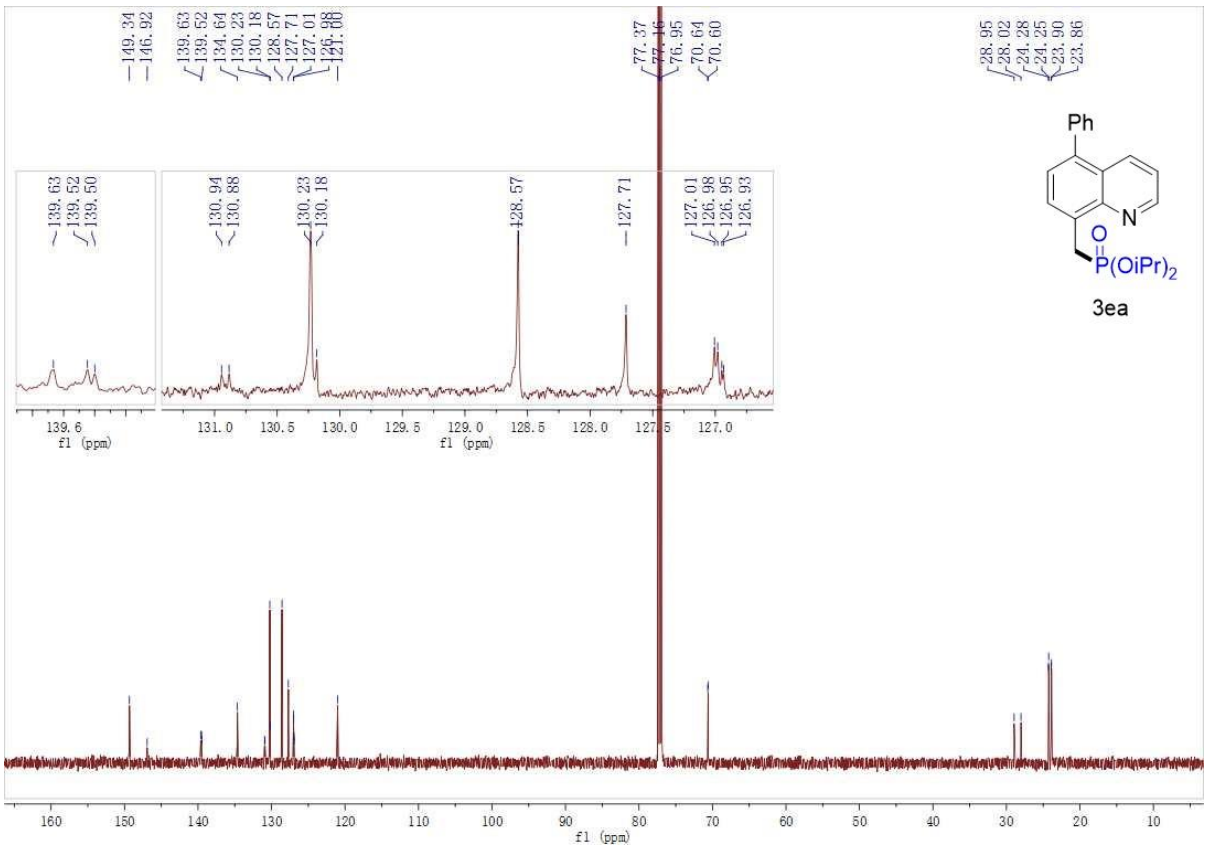
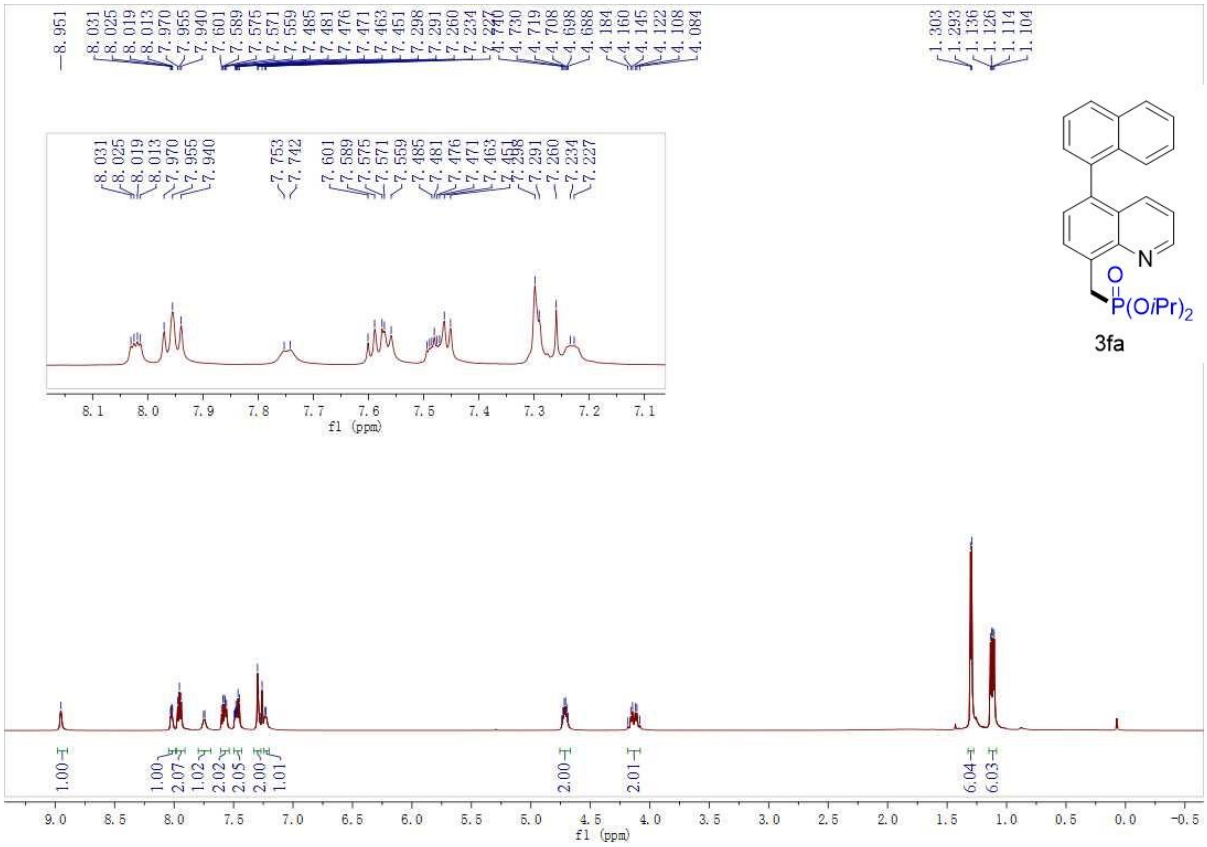
148.99
133.19
130.76
129.62
125.36
124.15
119.92
114.45
77.16
70.57
70.52
45.47
28.44
27.51
24.25
24.23
23.84
23.81
f1 (ppm)
3da


Ph
N
O
P(OiPr)2
3ea
f1 (ppm)


Ph
N
O
P(OiPr)2
3ea
f1 (ppm)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8.013
7.970
7.955
7.940
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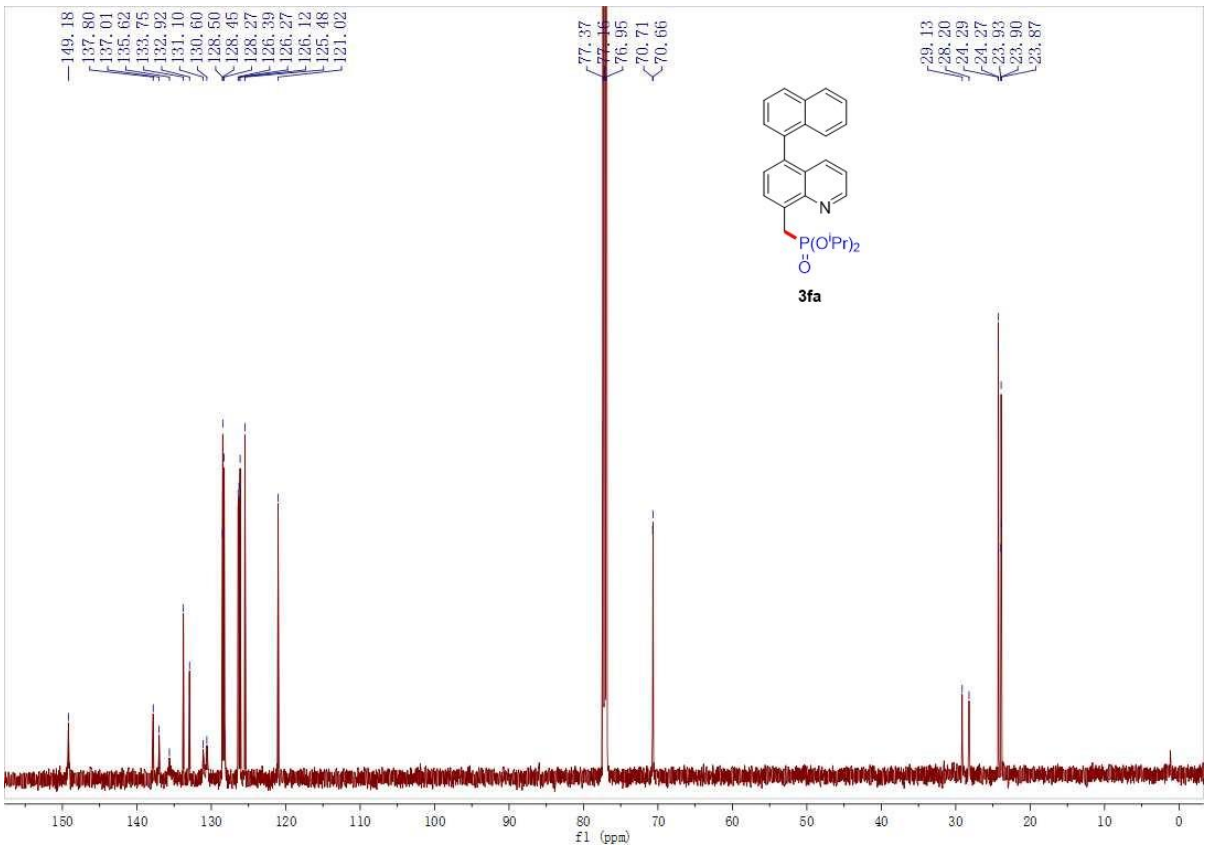
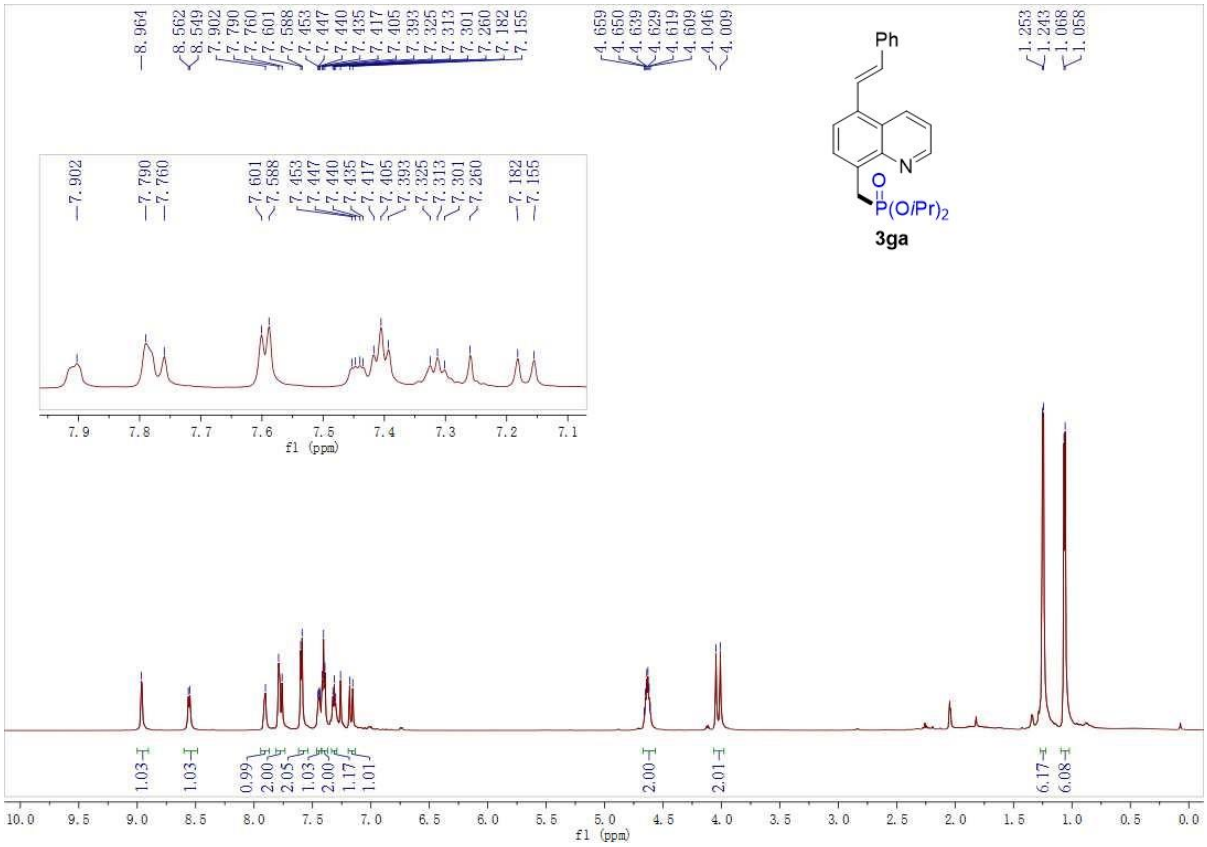
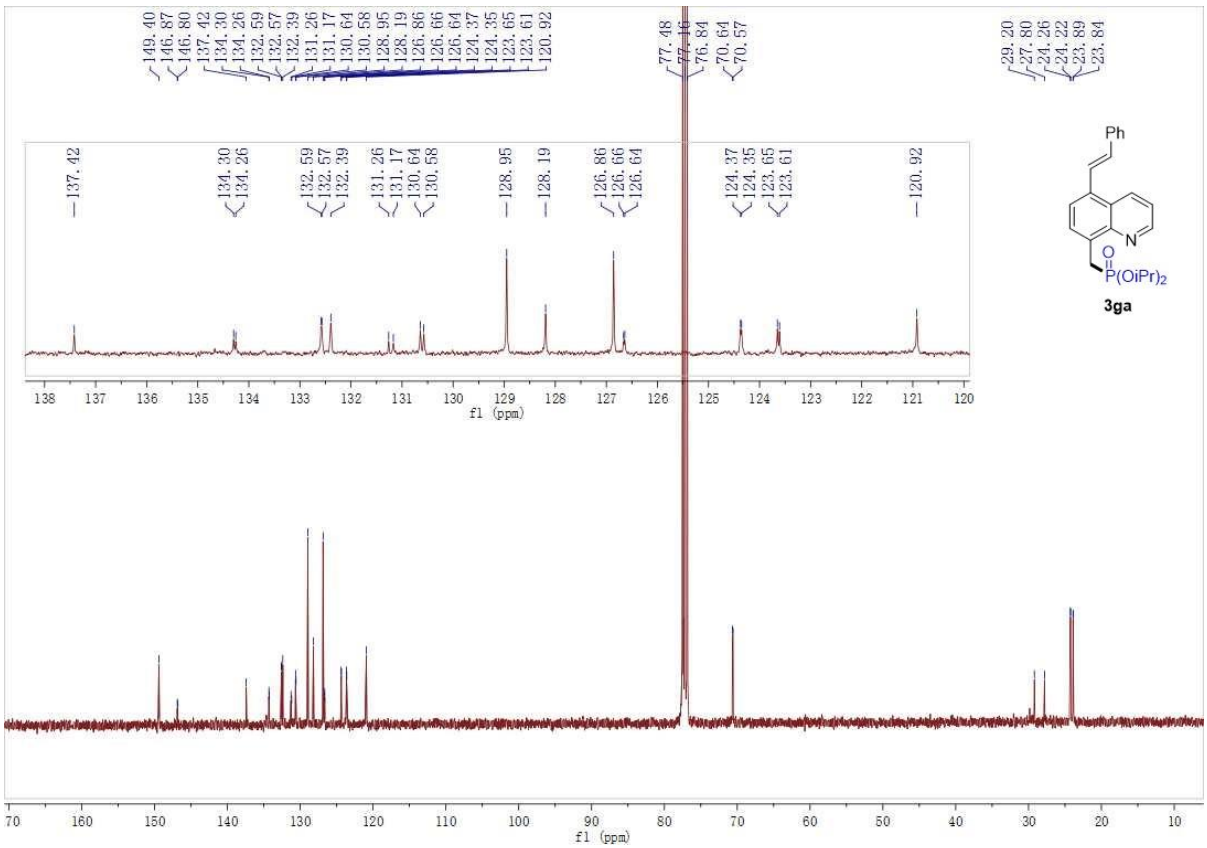
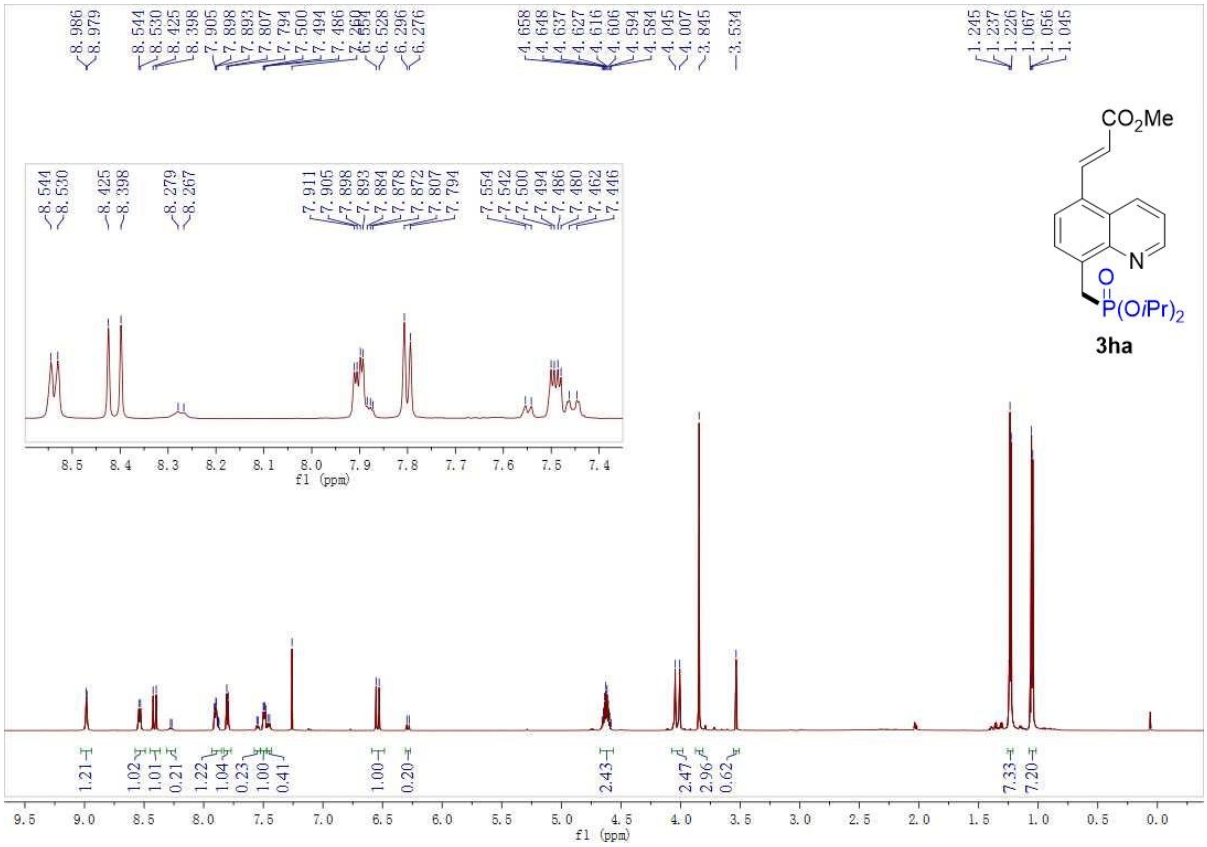
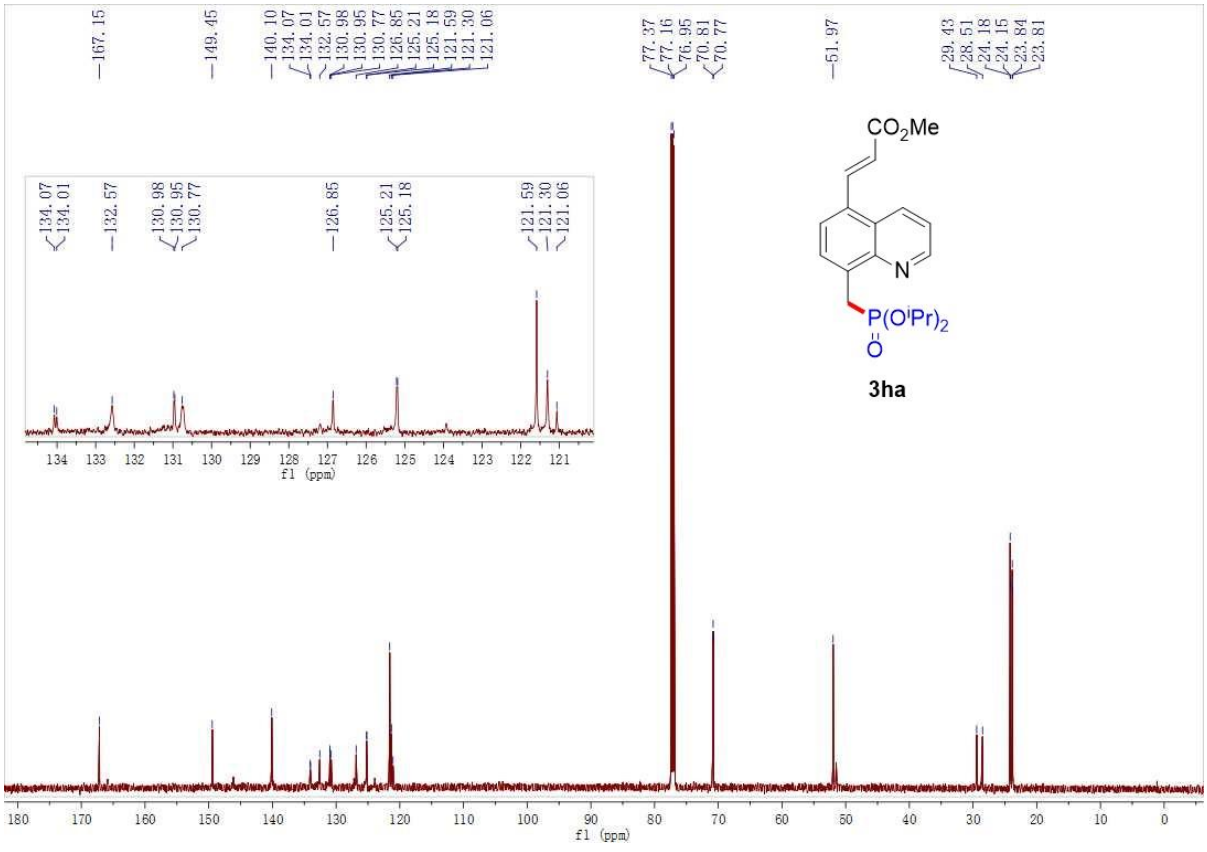
7.589
7.575
7.571
7.559
7.485
7.481
7.476
7.471
7.463
7.451
7.298
7.291
7.260
7.234
7.227
4.730
4.719
4.708
4.698
4.688
4.184
4.160
4.145
4.122
4.108
4.084
1.303
1.293
1.136
1.126
1.114
1.104
7.753
7.742
N
O
P(OiPr)2
3fa
f1 (ppm)
1.00
2.07
1.02
2.02
2.05
2.00
1.01
2.00
2.01
6.04
6.03

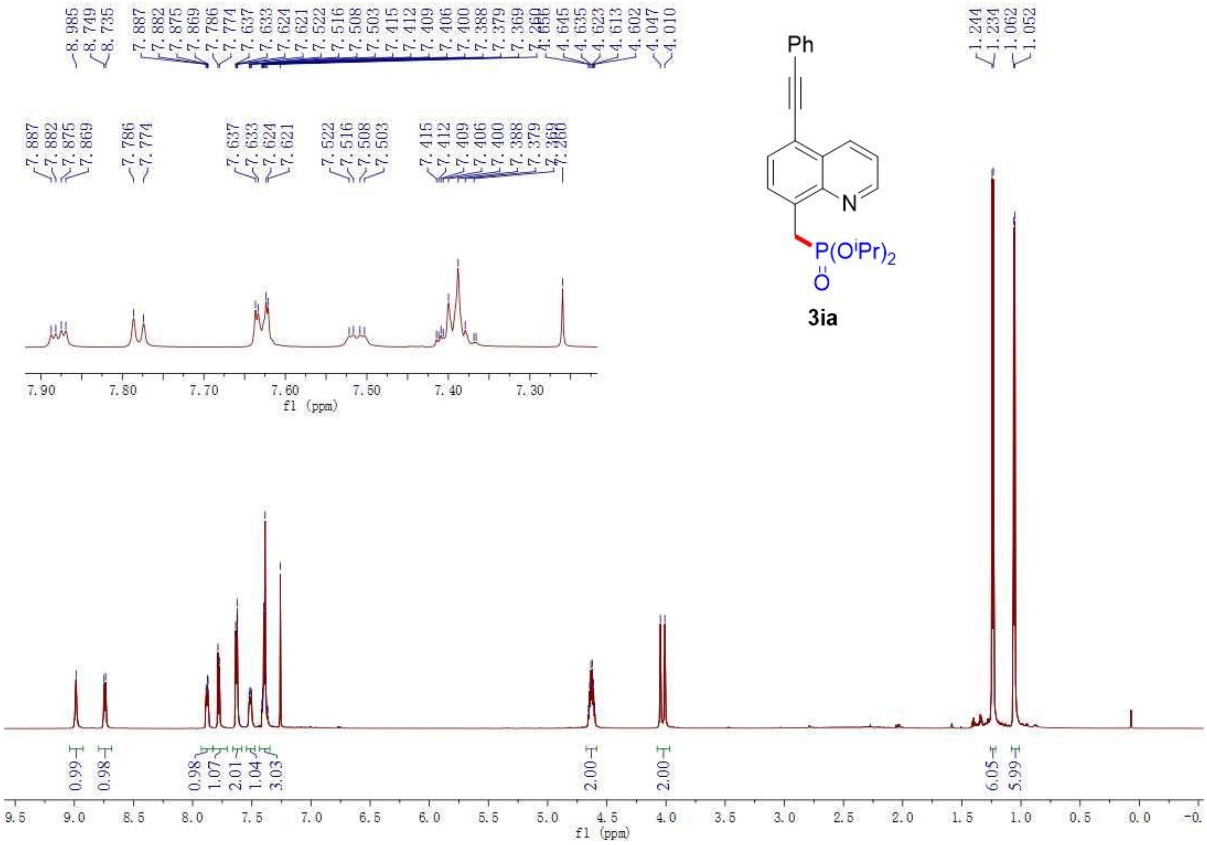

149.18
137.80
137.01
135.62
133.75
132.92
131.10
130.60
128.50
128.45
128.27
126.39
126.27
126.12
125.48
121.02
77.37
77.16
76.95
70.71
70.66
29.13
28.20
24.29
24.27
23.93
23.90
23.87
N
P(OiPr)2
O
3fa
f1 (ppm)

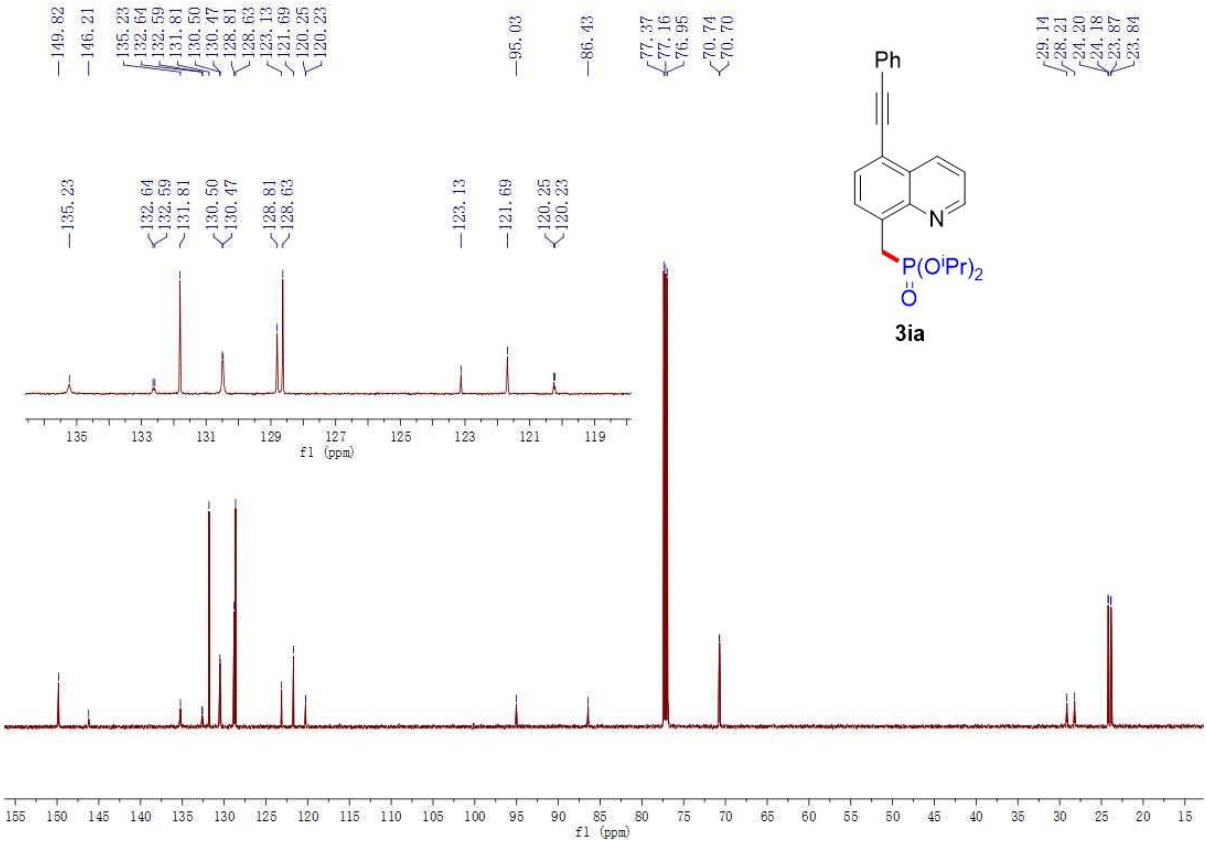

Ph
N
O
P(OiPr)2
3ga
f1 (ppm)

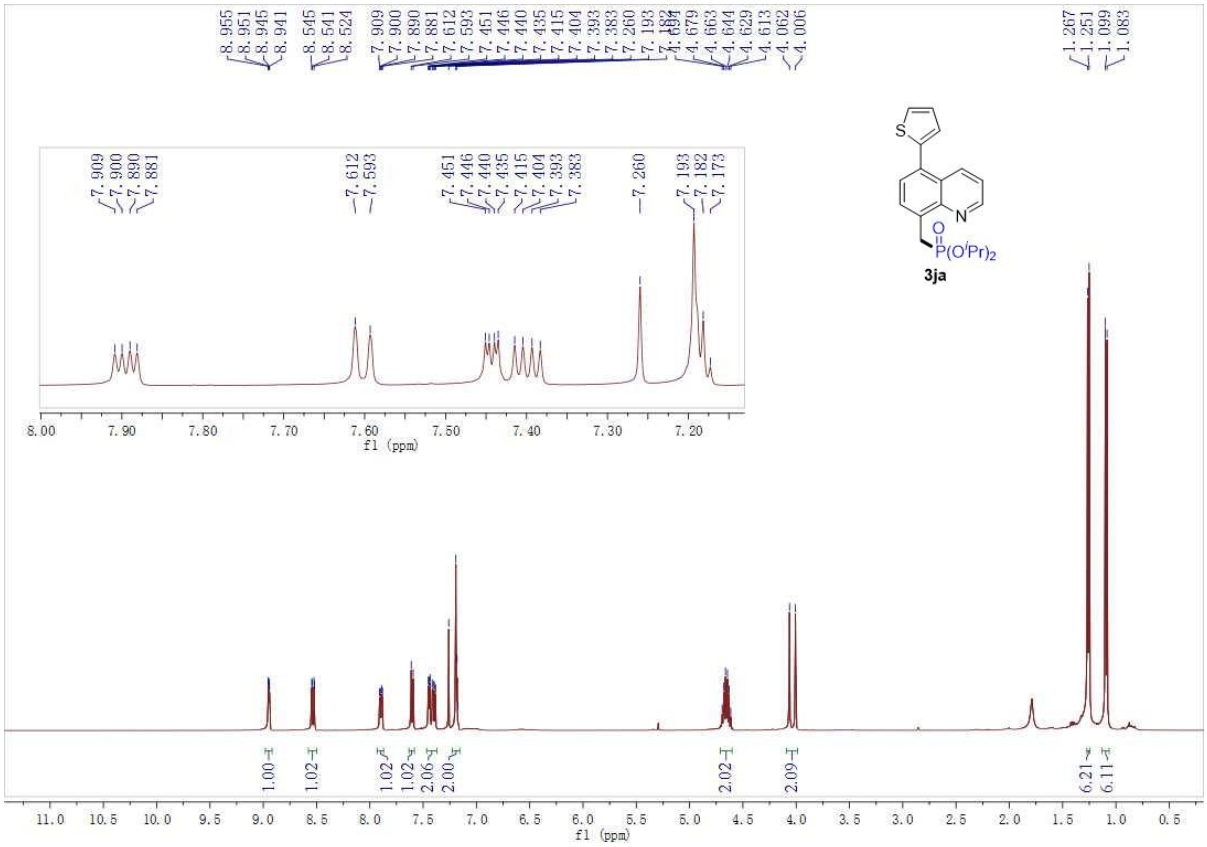

Ph
N
O
P(OiPr)2
3ga
f1 (ppm)


CO2Me
N
O
P(OiPr)2
3ha
f1 (ppm)


CO2Me
N
P(OiPr)2
O
3ha
f1 (ppm)


Ph
N
P(OiPr)2
O
3ia
f1 (ppm)


Ph
N
P(OiPr)2
O
3ia
f1 (ppm)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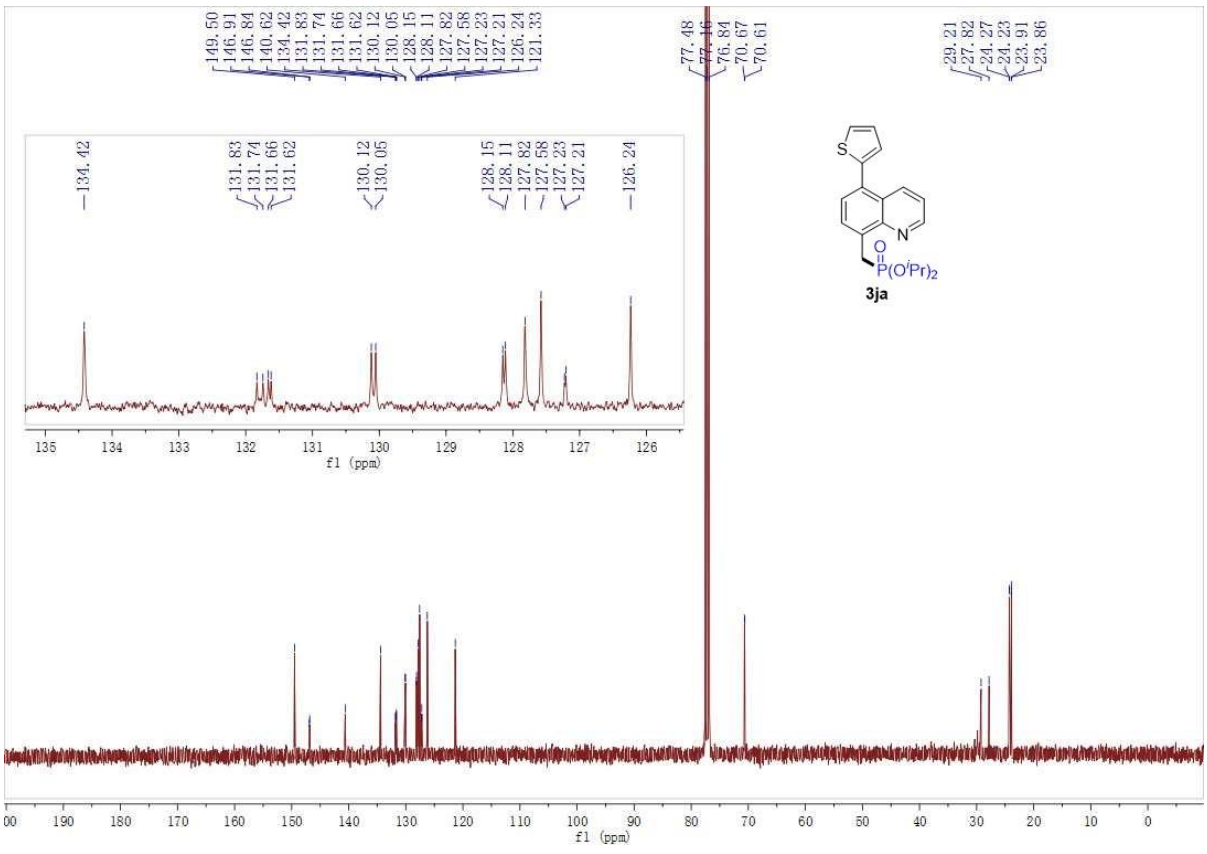
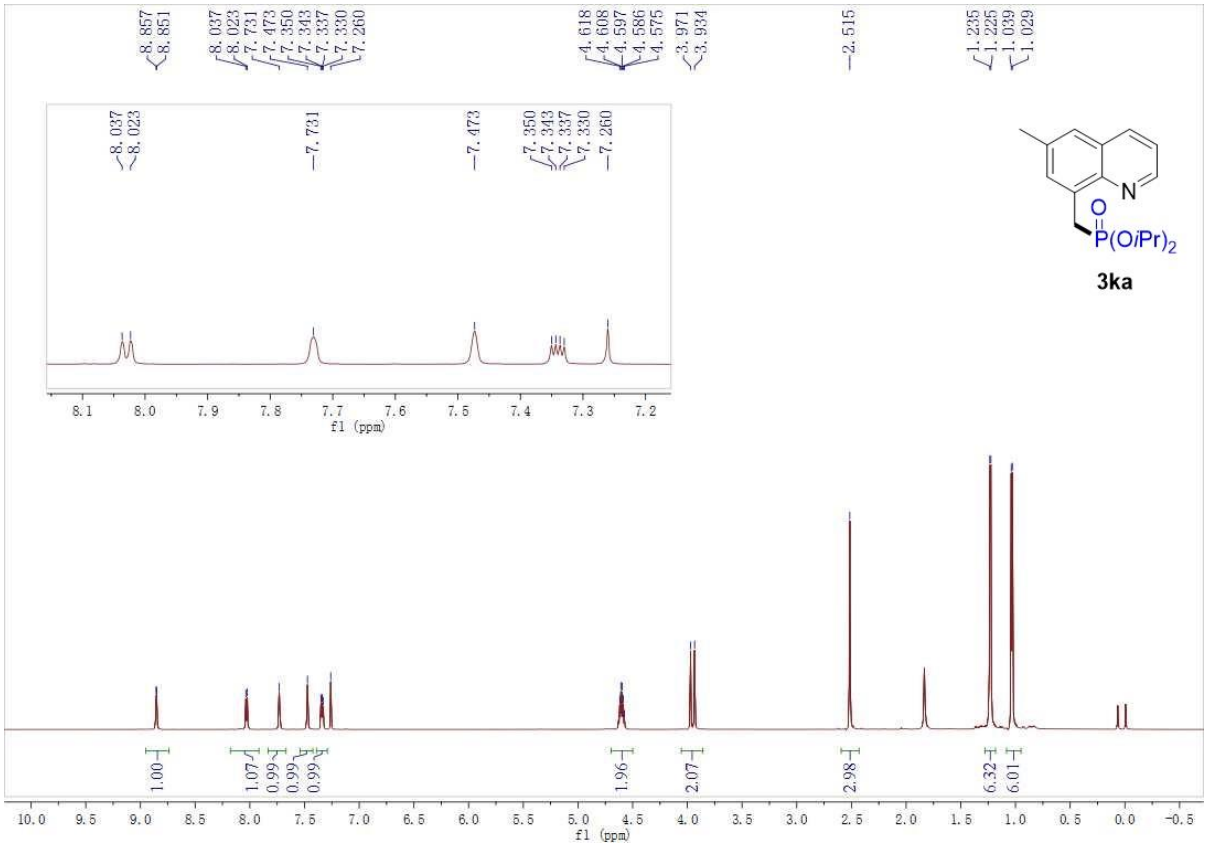
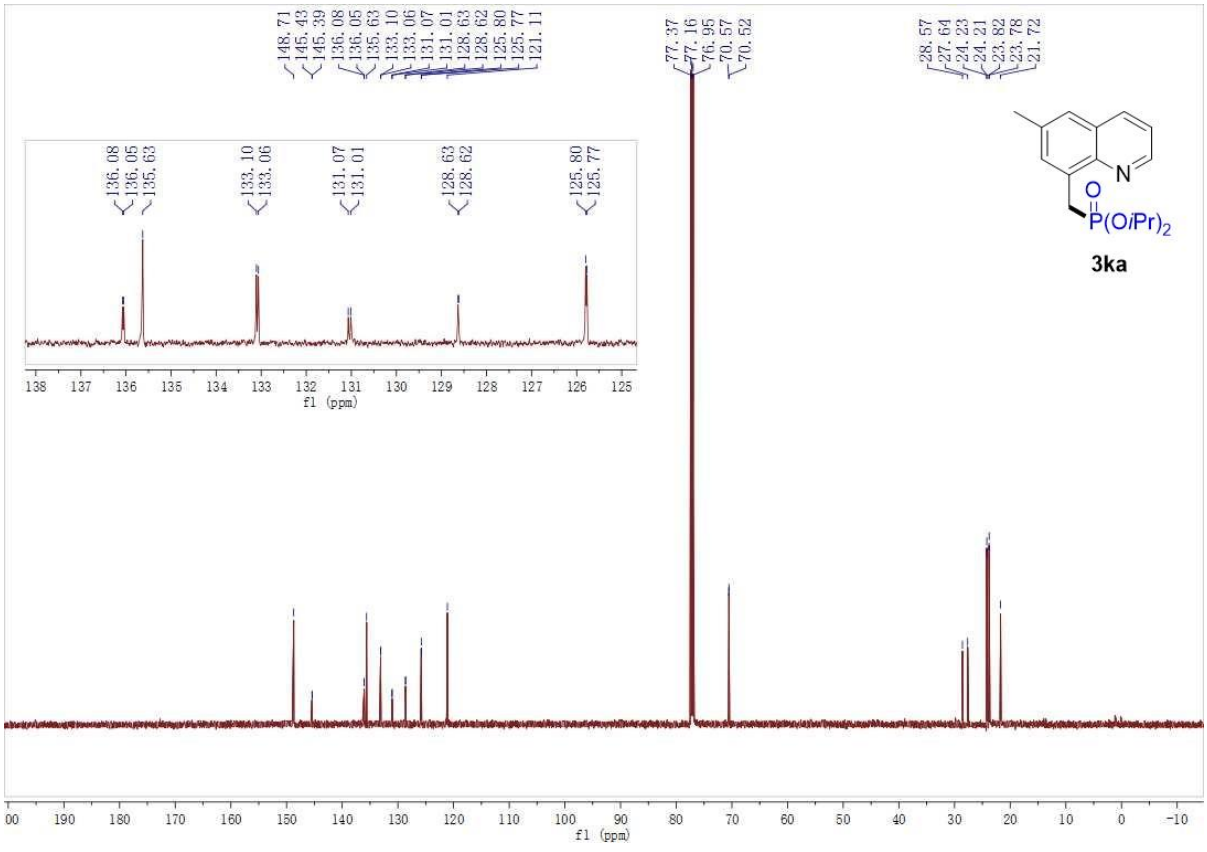
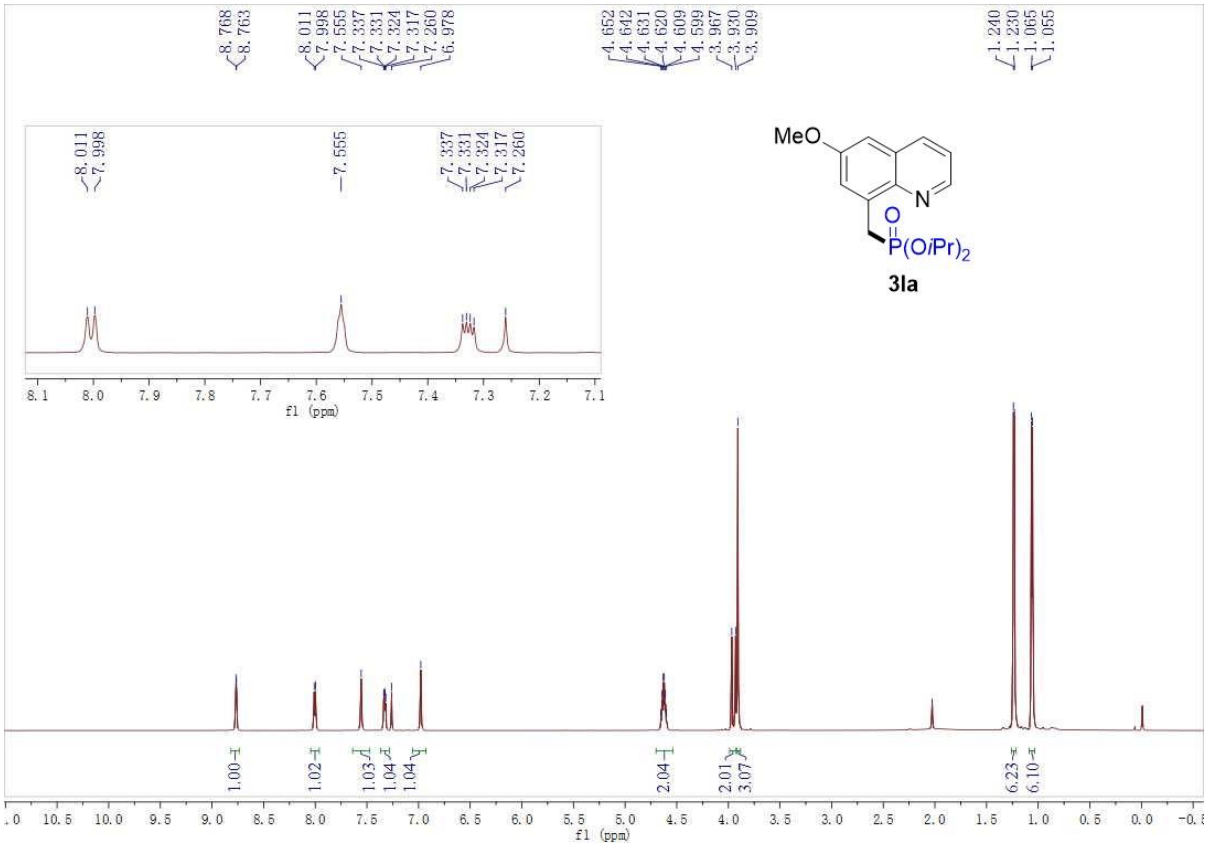
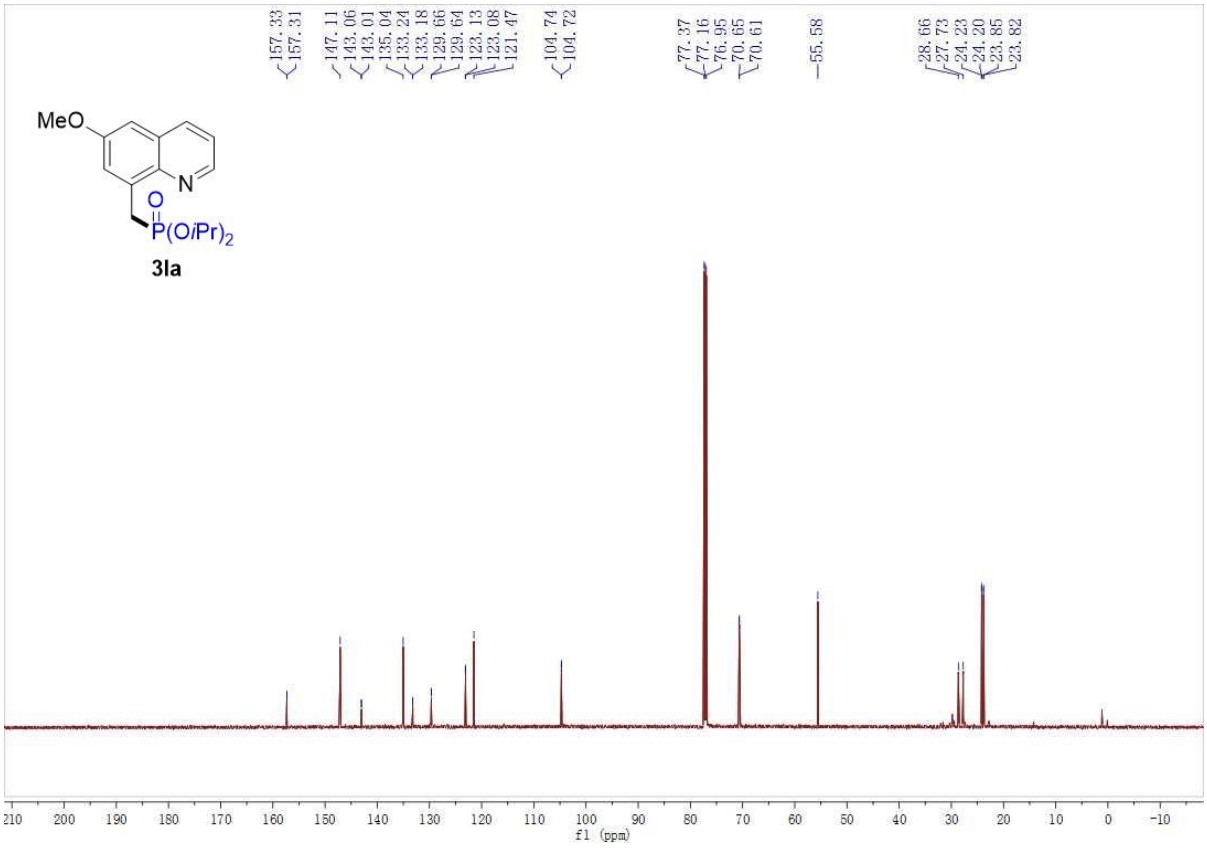
8.951
8.945
8.941
8.545
8.541
8.524
7.909
7.900
7.890
7.881
7.612
7.593
7.451
7.446
7.440
7.435
7.415
7.404
7.393
7.383
7.260
7.193
7.182
7.173
4.679
4.663
4.644
4.629
4.613
4.062
4.006
1.267
1.251
1.099
1.083
S
N
O
P(O'Pr)2
3ja
f1 (ppm)
1.00
1.02
1.02
1.02
2.06
2.00
2.02
2.09
6.21
6.11

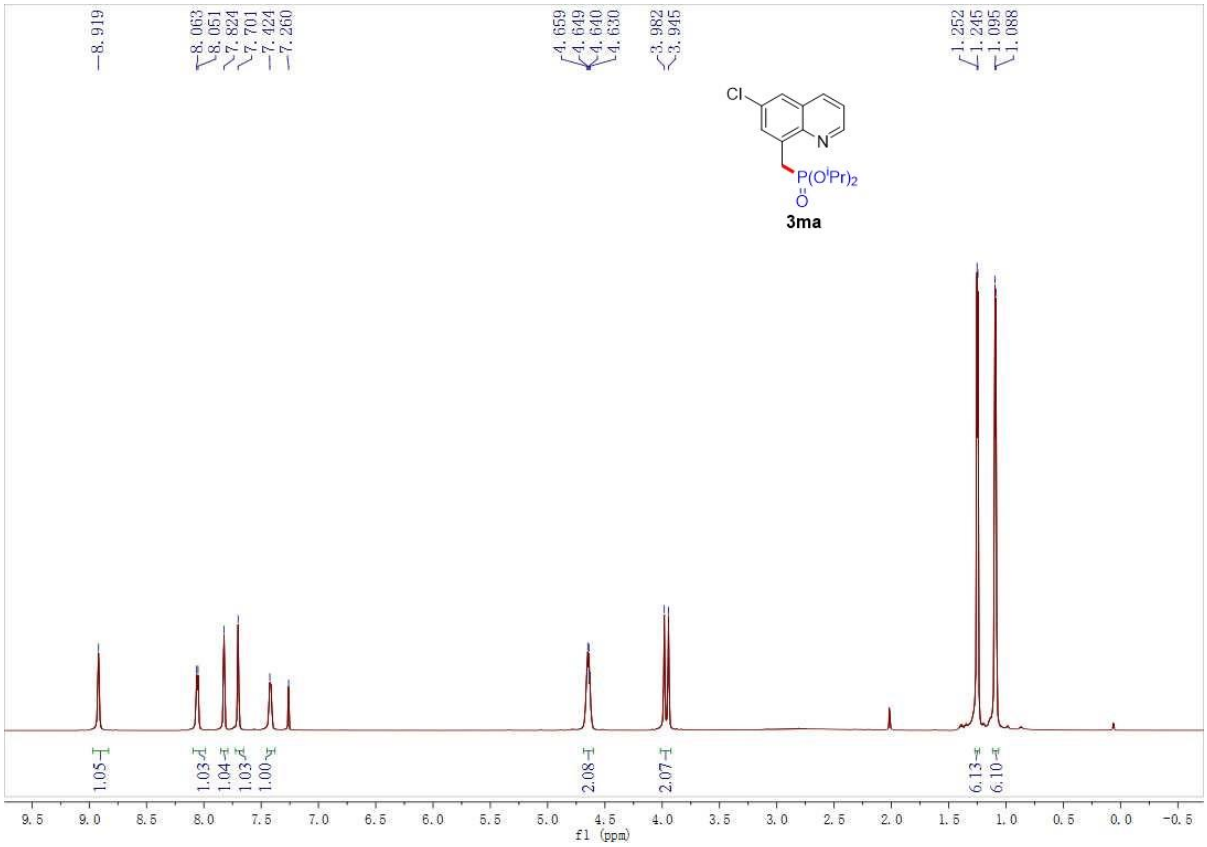

149.50
146.91
146.84
140.62
134.42
131.83
131.74
131.66
131.62
130.12
130.05
128.15
128.11
127.82
127.58
127.23
127.21
126.24
121.33
77.48
77.16
76.84
70.67
70.61
29.21
27.82
24.27
24.23
23.91
23.86
S
N
O
P(O'Pr)2
3ja
f1 (ppm)

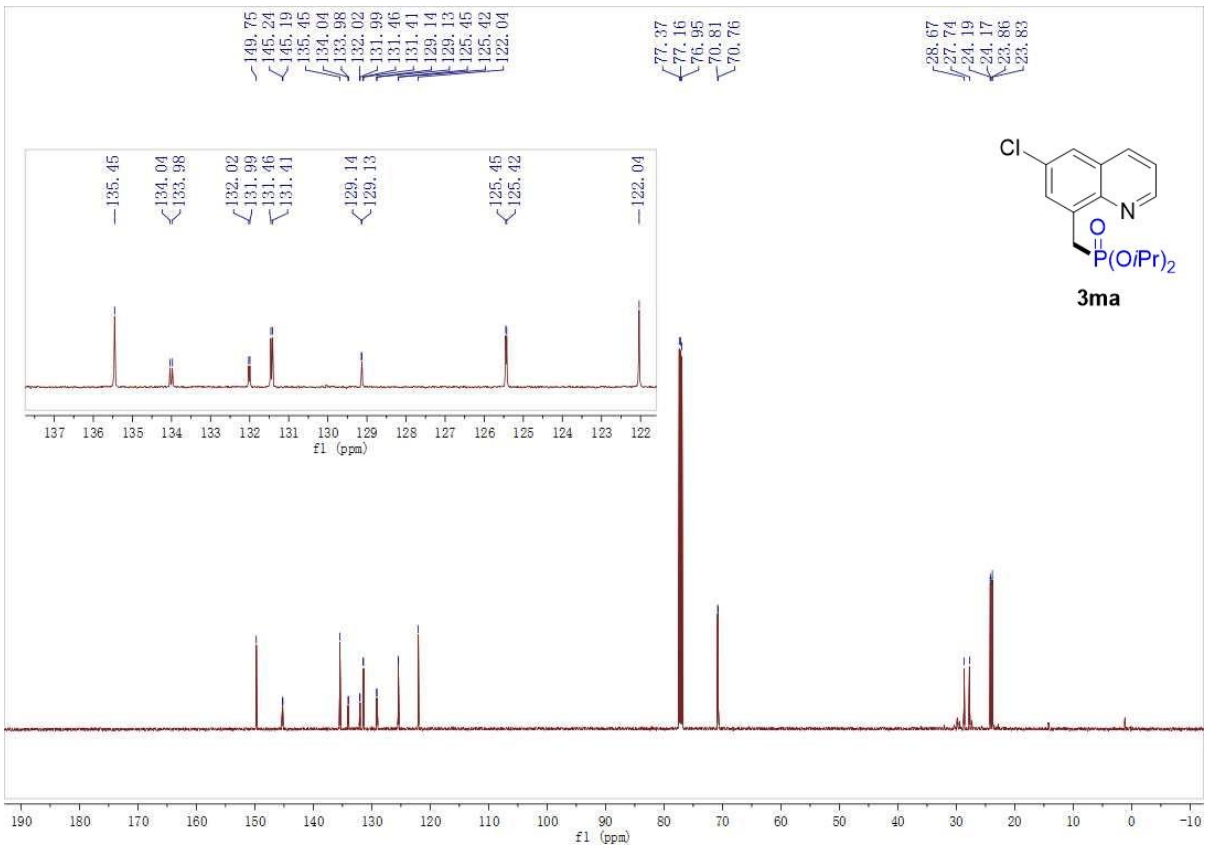

8.857
8.851
8.037
8.023
7.731
7.473
7.350
7.343
7.337
7.330
7.260
4.618
4.608
4.597
4.586
4.575
3.971
3.934
2.515
1.235
1.225
1.039
1.029
1.00
1.07
0.99
0.99
1.96
2.07
2.98
6.32
6.01
f1 (ppm)
P(OiPr)2
3ka

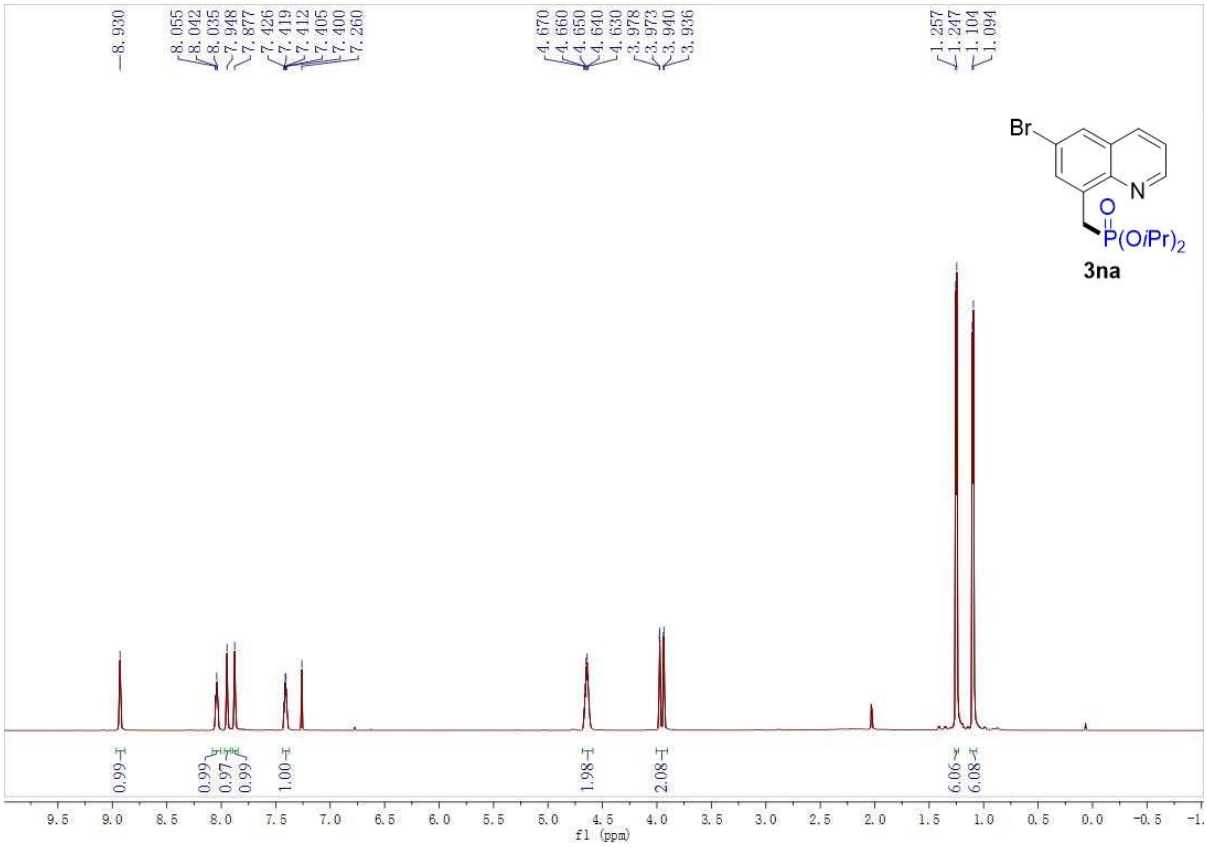

148.71
145.43
145.39
136.08
136.05
135.63
133.10
133.06
131.07
131.01
128.63
128.62
125.80
125.77
121.11
77.37
77.16
76.95
70.57
70.52
28.57
27.64
24.23
24.21
23.82
23.78
21.72
f1 (ppm)
P(OiPr)2
3ka

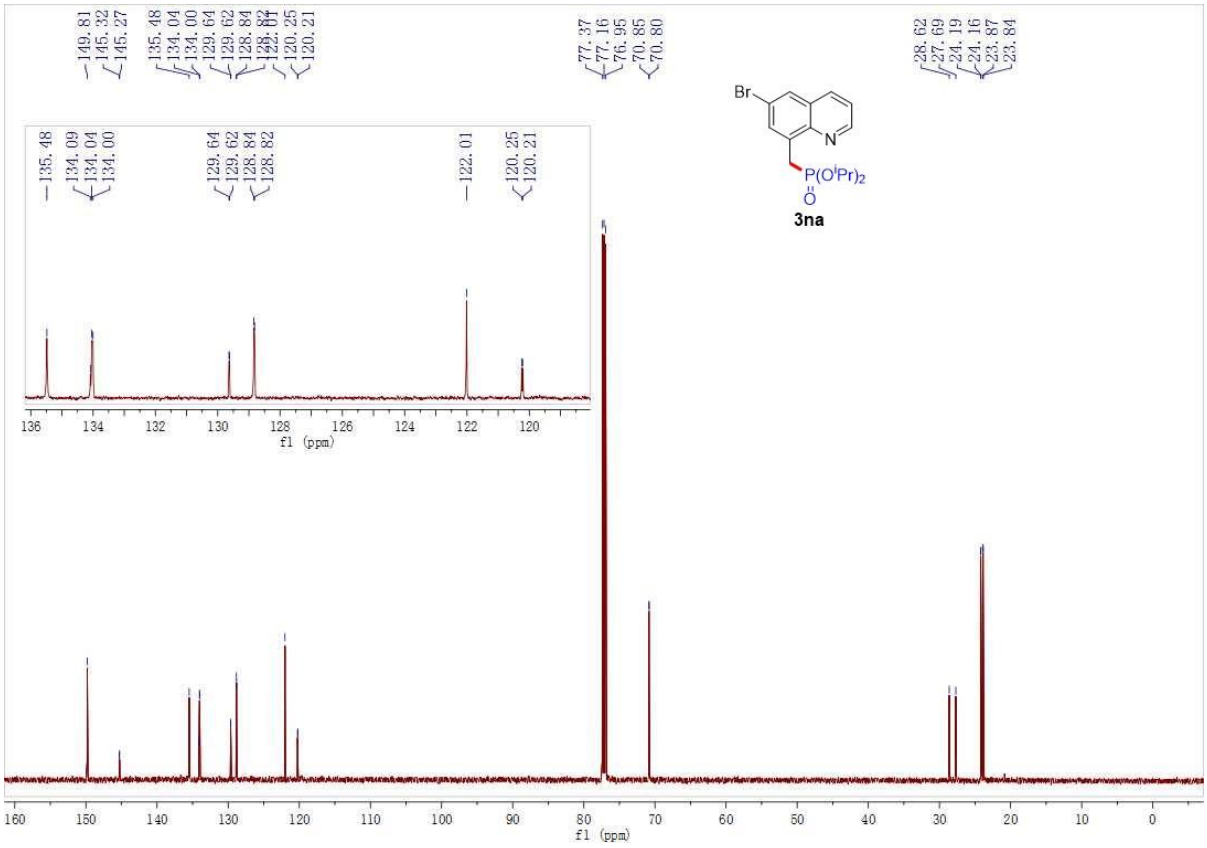

8.768
8.763
8.011
7.998
7.555
7.337
7.331
7.324
7.317
7.260
6.978
4.652
4.642
4.631
4.620
4.609
4.599
3.967
3.930
3.909
1.240
1.230
1.065
1.055
MeO
N
O
P(OiPr)2
3la
f1 (ppm)
1.00
1.02
1.03
1.04
1.04
2.04
2.01
3.07
6.23
6.10


157.33
157.31
147.11
143.06
143.01
135.04
133.24
133.18
129.66
129.64
123.13
123.08
121.47
104.74
104.72
77.37
77.16
76.95
70.65
70.61
55.58
28.66
27.73
24.23
24.20
23.85
23.82
MeO
N
O
P(OiPr)2
3la
f1 (ppm)


8.919
8.063
8.051
7.824
7.701
7.424
7.260
4.659
4.649
4.640
4.630
3.982
3.945
1.252
1.245
1.095
1.088
Cl
N
P(O^{i}Pr)$_2$
O
H
3ma
1.05
1.03
1.04
1.03
1.00
2.08
2.07
6.13
6.10
f1 (ppm)


149.75
145.24
145.19
135.45
134.04
133.98
132.02
131.99
131.46
131.41
129.14
129.13
125.45
125.42
122.04
77.37
77.16
76.95
70.81
70.76
28.67
27.74
24.19
24.17
23.86
23.83
Cl
N
O
P(OiPr)$_2$
3ma
f1 (ppm)


8.930
8.055
8.042
8.035
7.948
7.877
7.426
7.419
7.412
7.405
7.400
7.260
4.670
4.660
4.650
4.640
4.630
3.978
3.973
3.940
3.936
1.257
1.247
1.104
1.094
Br
N
O
P(OiPr)2
3na
0.99
0.99
0.97
0.99
1.00
1.98
2.08
6.06
6.08
f1 (ppm)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145.32
145.27
135.48
134.04
134.00
129.64
129.62
128.84
128.82
122.01
120.25
120.21
77.37
77.16
76.95
70.85
70.80
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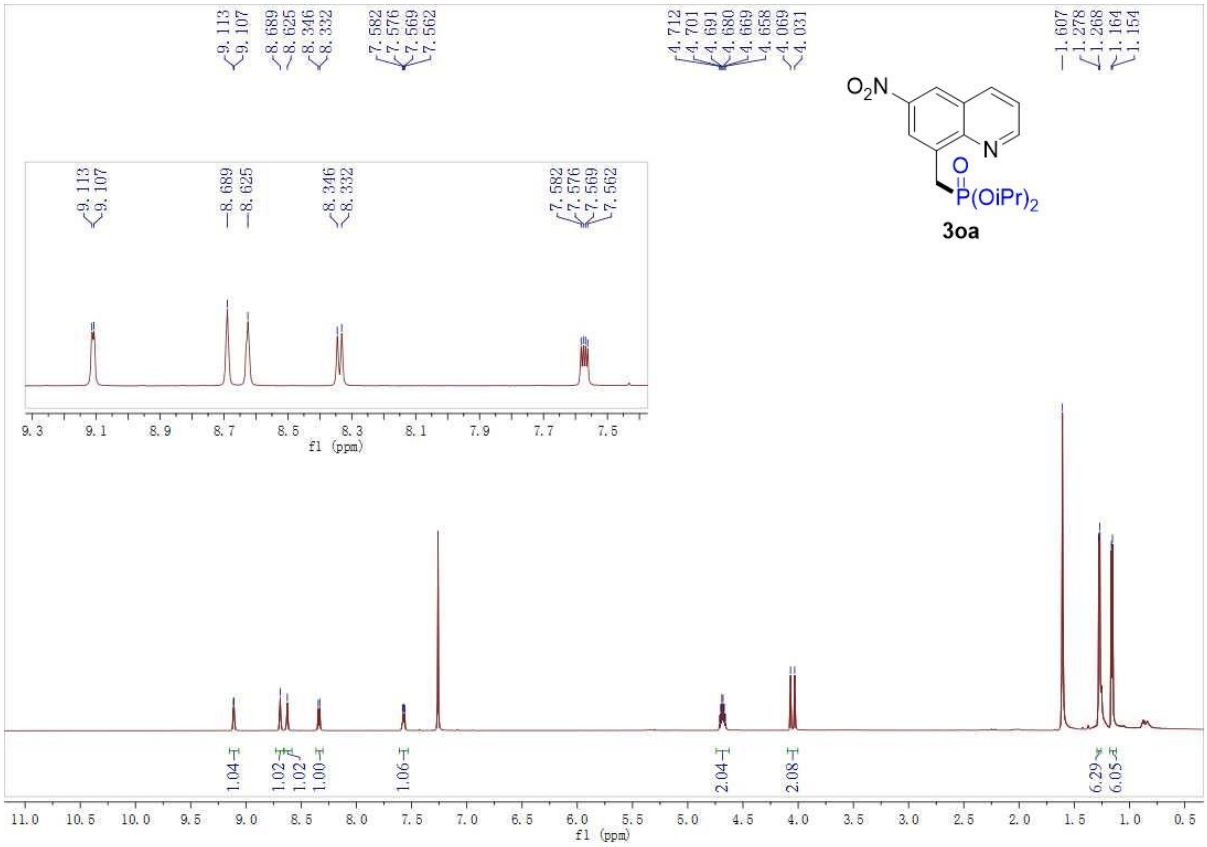
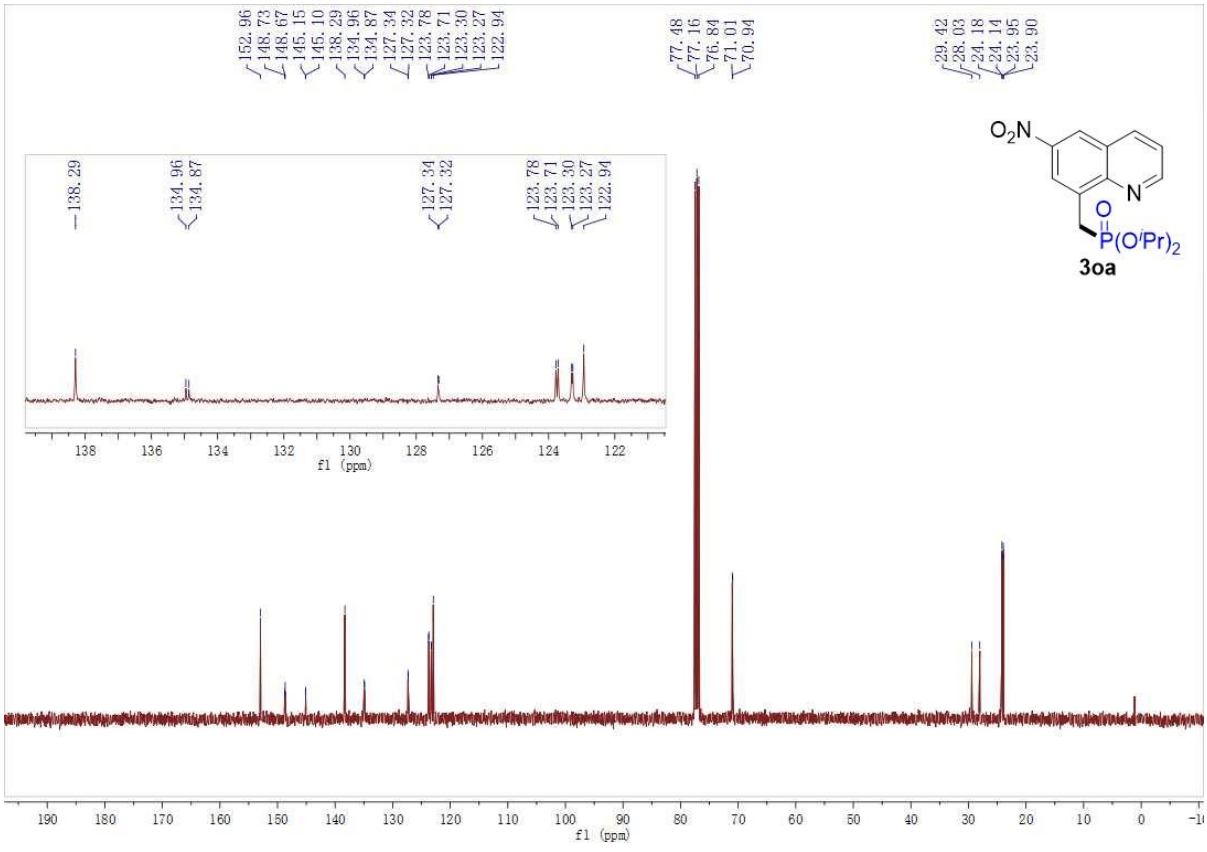
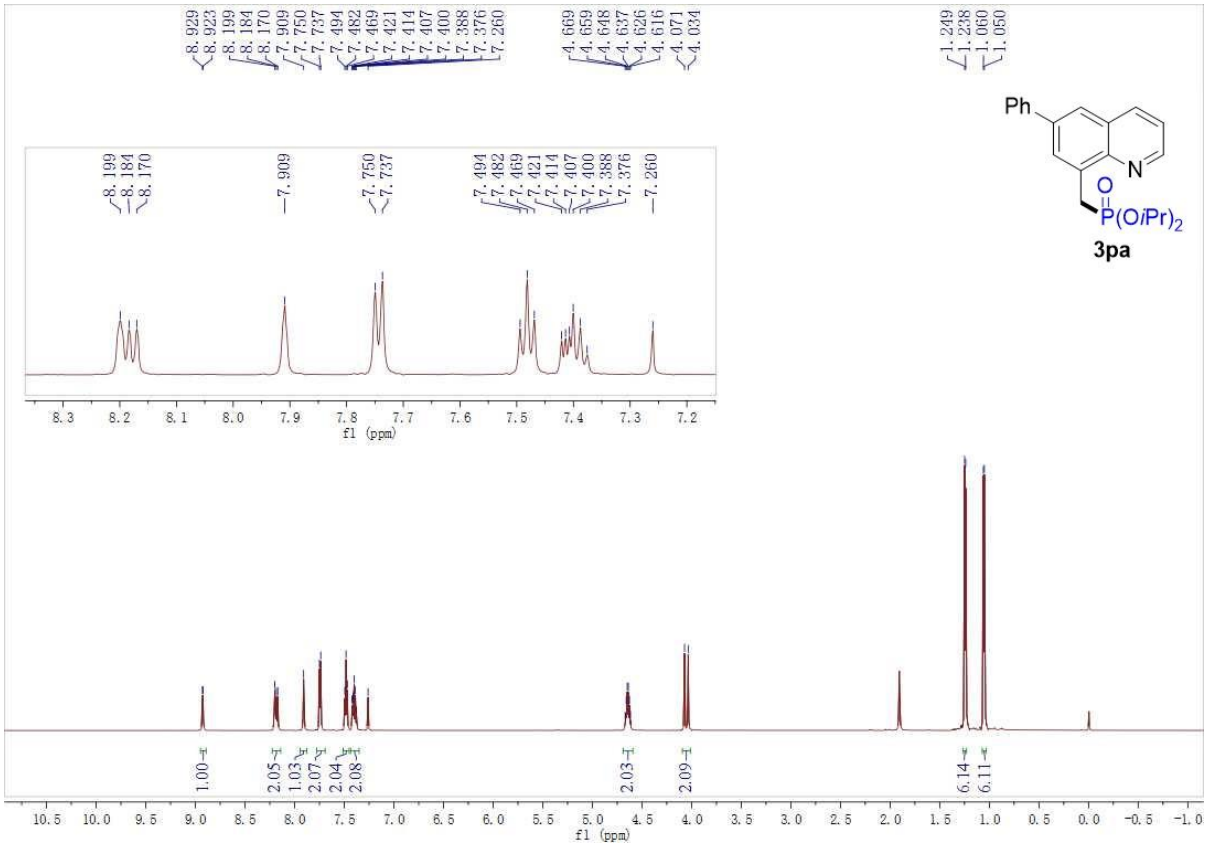
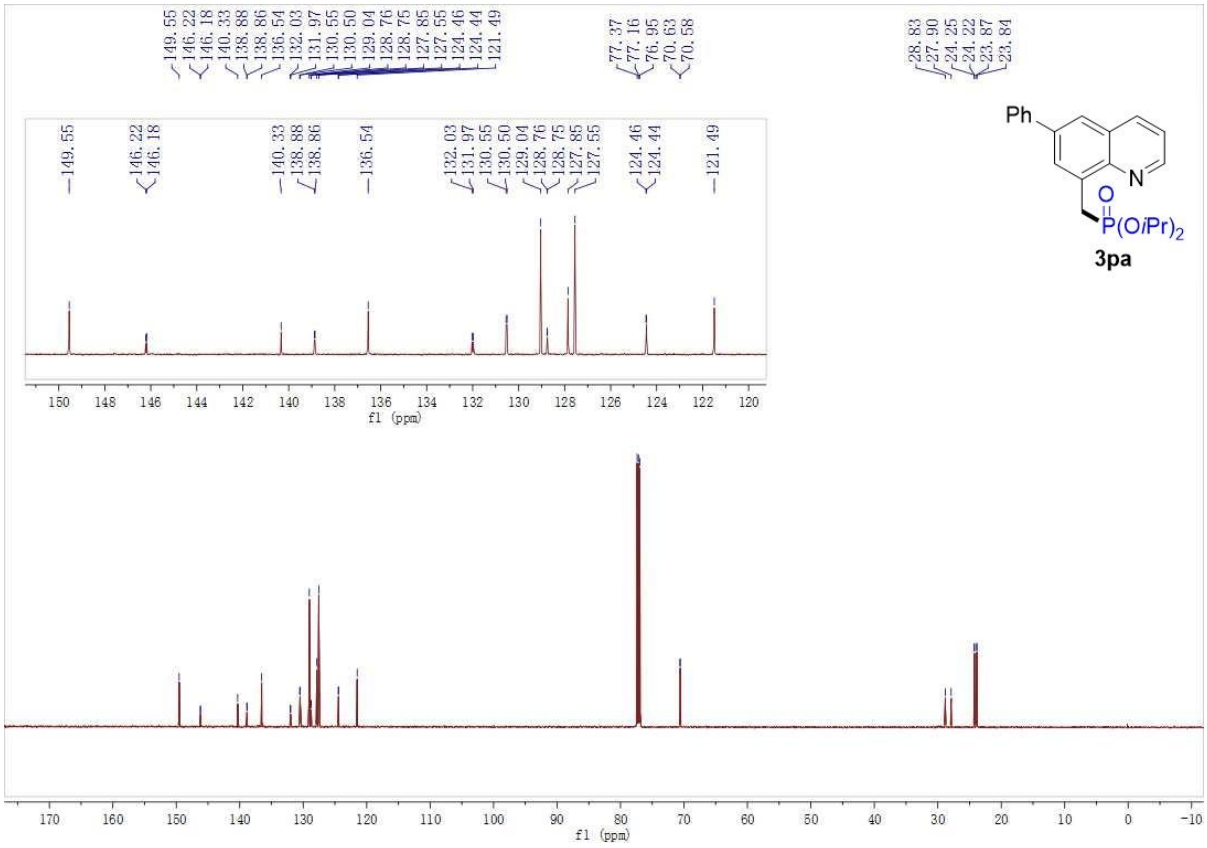
Br
N
P(OiPr)2
O
3na
f1 (ppm)


9.113
9.107
8.689
8.625
8.346
8.332
7.582
7.576
7.569
7.562
4.712
4.701
4.691
4.680
4.669
4.658
4.069
4.031
1.607
1.278
1.268
1.164
1.154
O2N
N
O
P(OiPr)2
3oa
f1 (ppm)
1.04
1.02
1.02
1.00
1.06
2.04
2.08
6.29
6.05


152.96
148.73
148.67
145.15
145.10
138.29
134.96
134.87
127.34
127.32
123.78
123.71
123.30
123.27
122.94
77.48
77.16
76.84
71.01
70.94
29.42
28.03
24.18
24.14
23.95
23.90
O2N
N
O
P(O/Pr)2
3oa
f1 (ppm)


8.929
8.923
8.199
8.184
8.170
7.909
7.750
7.737
7.494
7.482
7.469
7.421
7.414
7.407
7.400
7.388
7.376
7.260
4.669
4.659
4.648
4.637
4.626
4.616
4.071
4.034
1.249
1.238
1.060
1.050
Ph
N
O
P(OiPr)2
3pa
f1 (ppm)
1.00
2.05
1.03
2.07
2.04
2.08
2.03
2.09
6.14
6.11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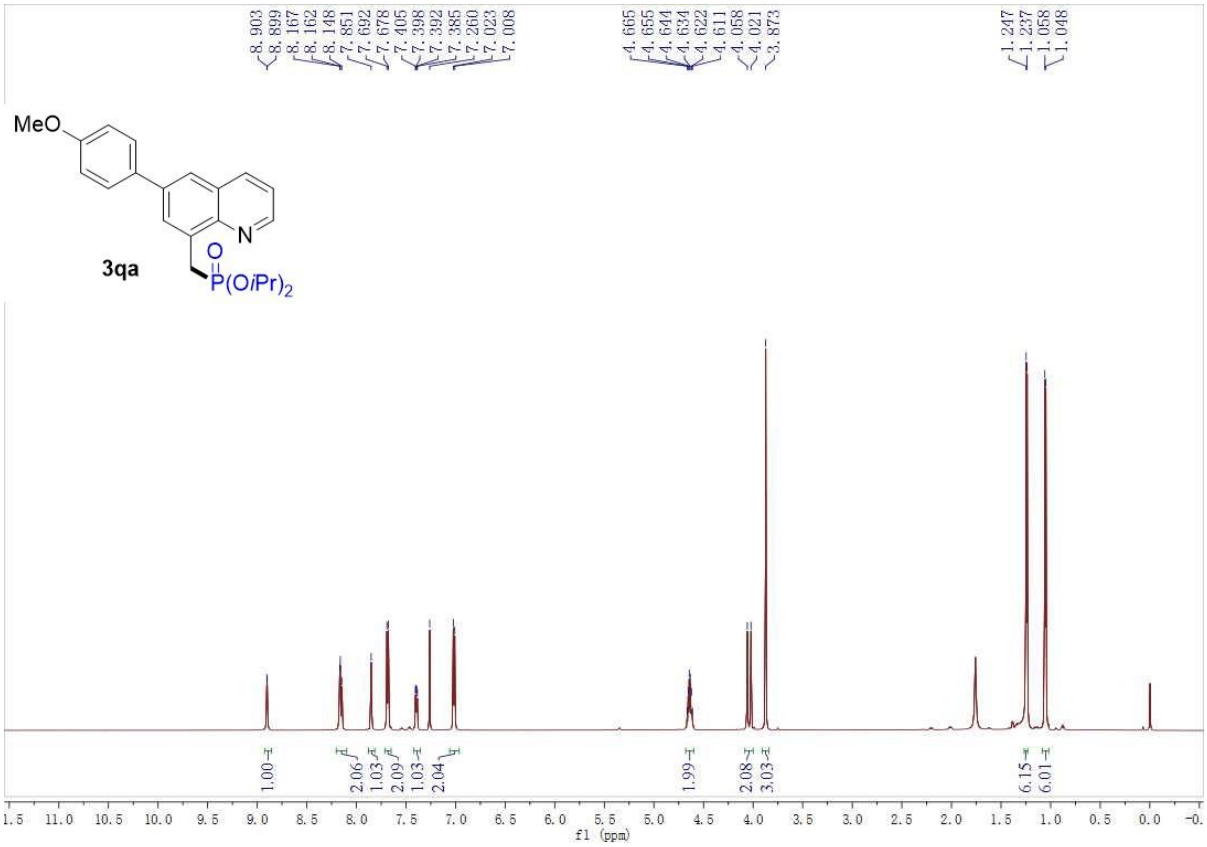
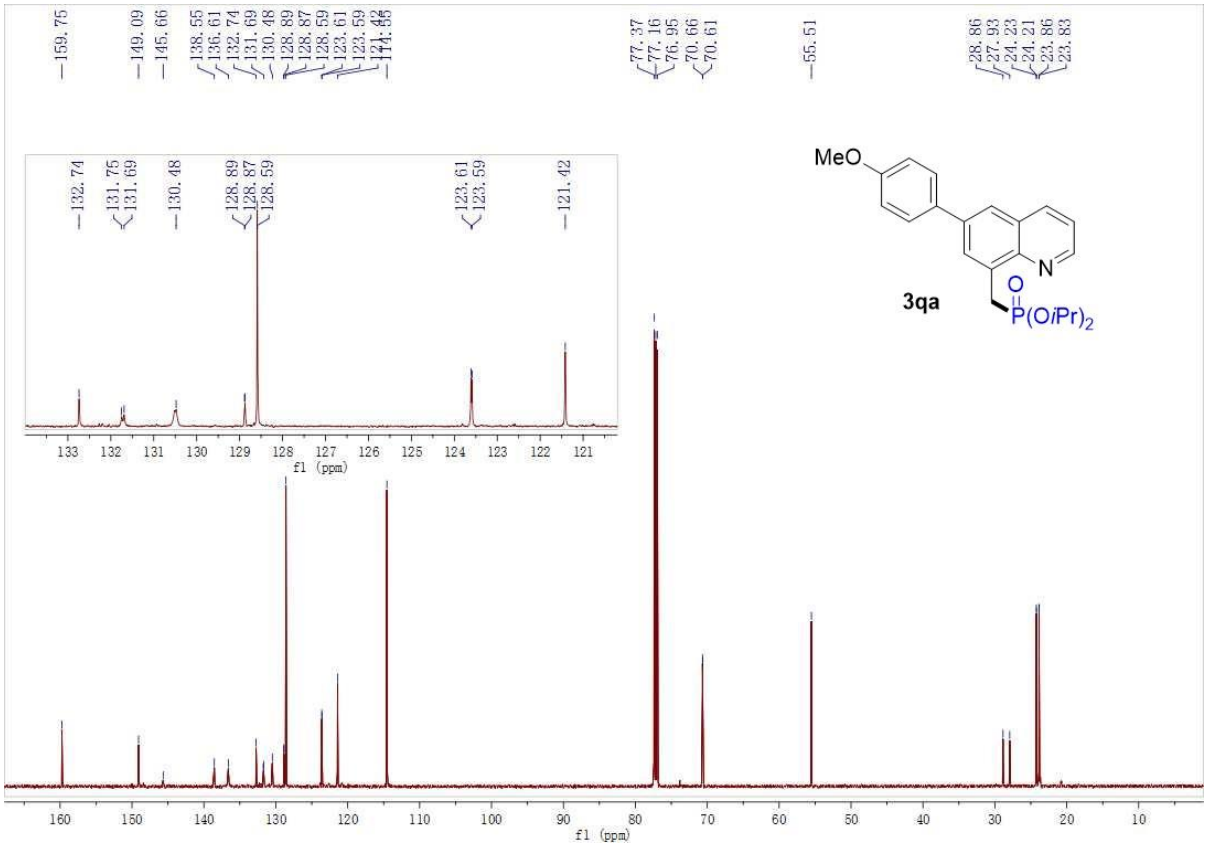
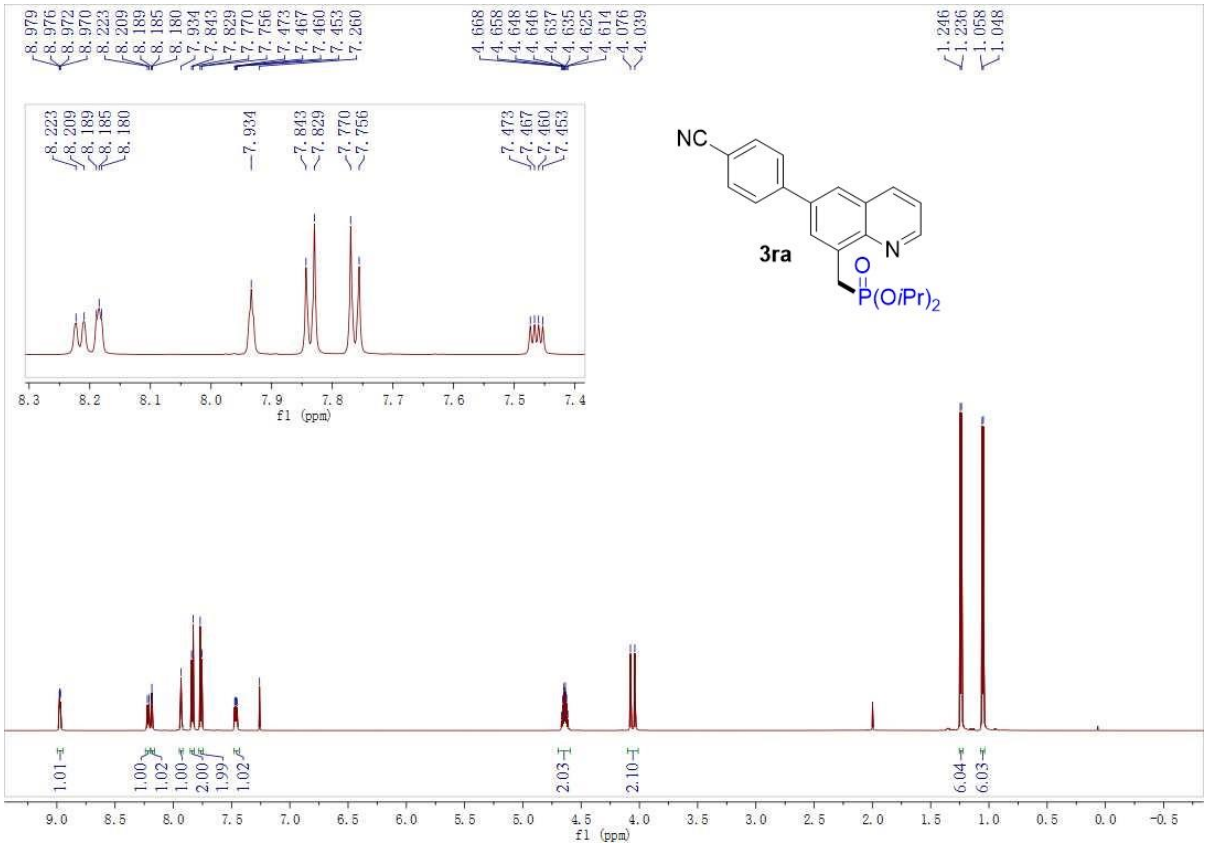
146.18
140.33
138.88
138.86
136.54
132.03
131.97
130.55
130.50
129.04
128.76
128.75
127.85
127.55
124.46
124.44
121.49
77.37
77.16
76.95
70.63
70.58
28.83
27.90
24.25
24.22
23.87
23.84
Ph
N
O
P(OiPr)2
3pa
f1 (ppm)


MeO
N
O
P(O*i*Pr)$_2$
3qa
f1 (ppm)


MeO
N
O
P(O*i*Pr)$_2$
3qa
f1 (ppm)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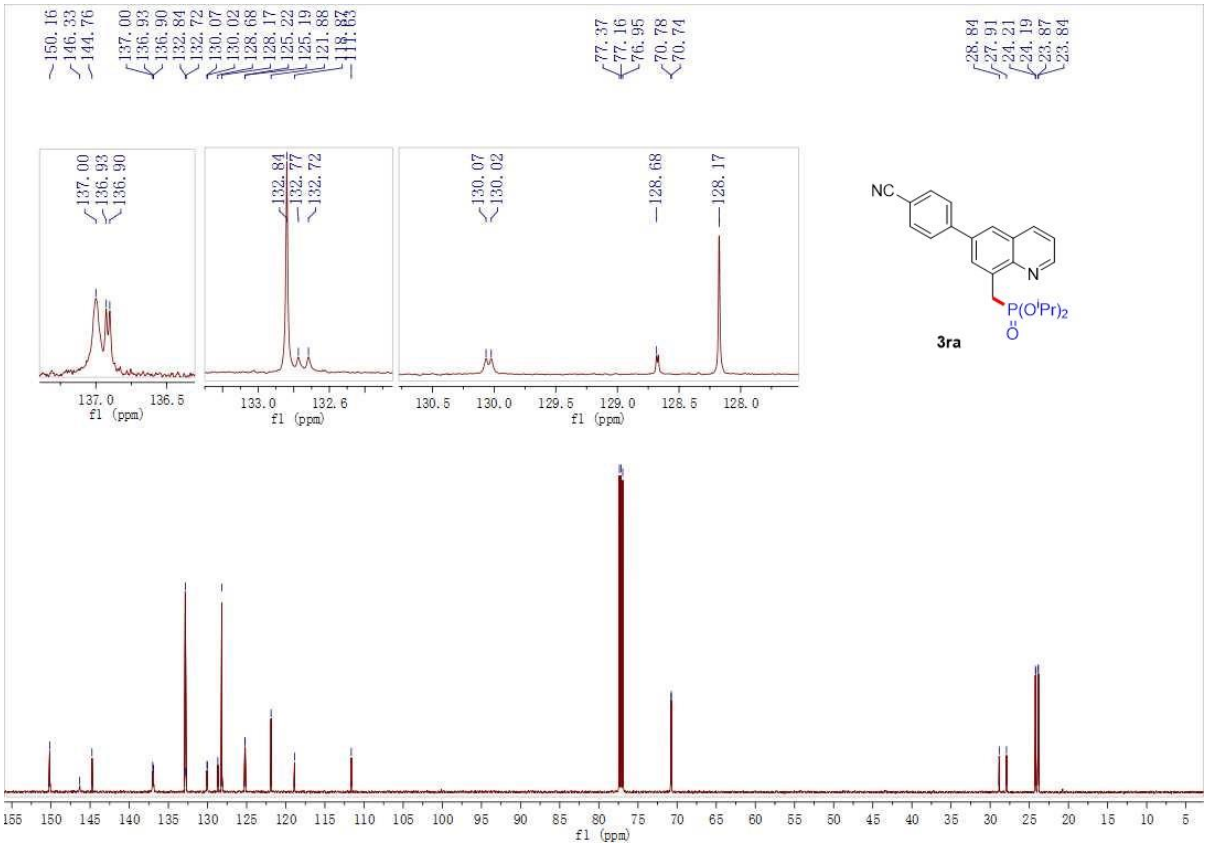
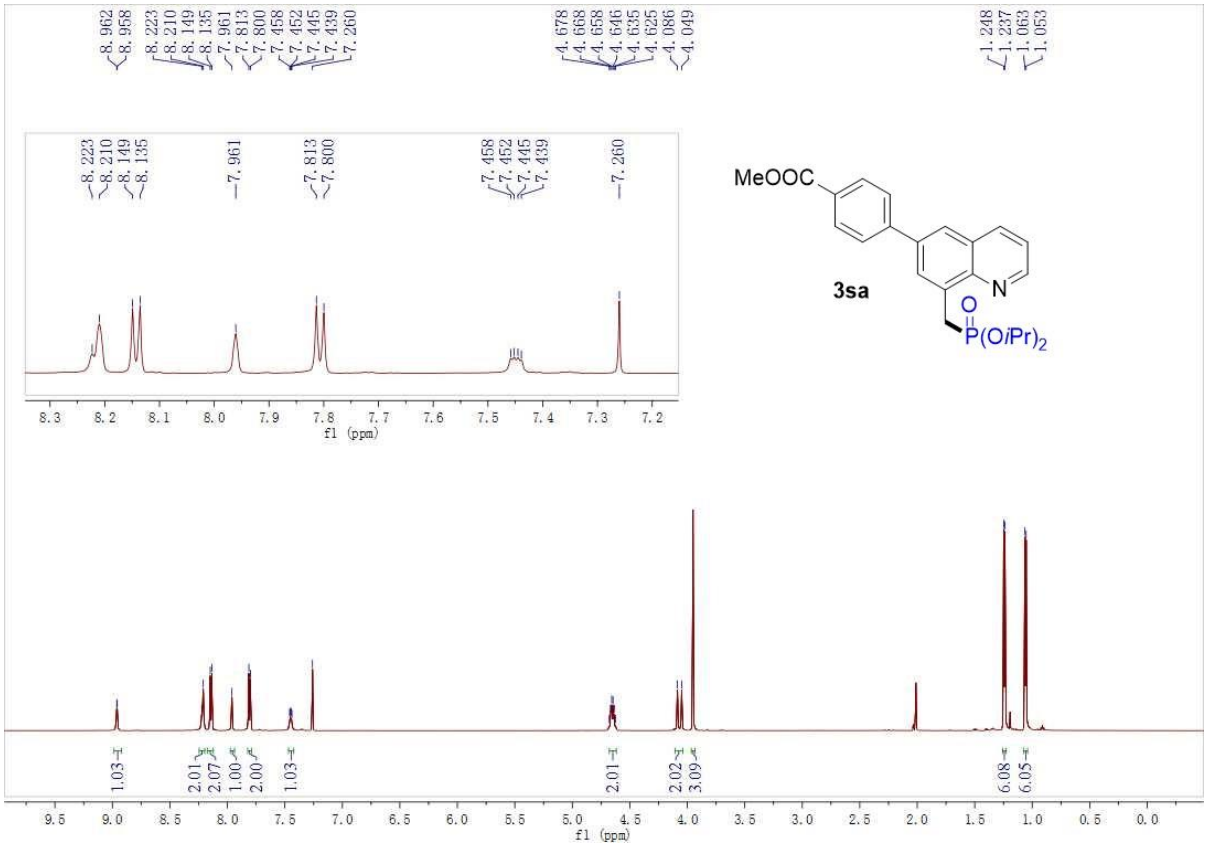
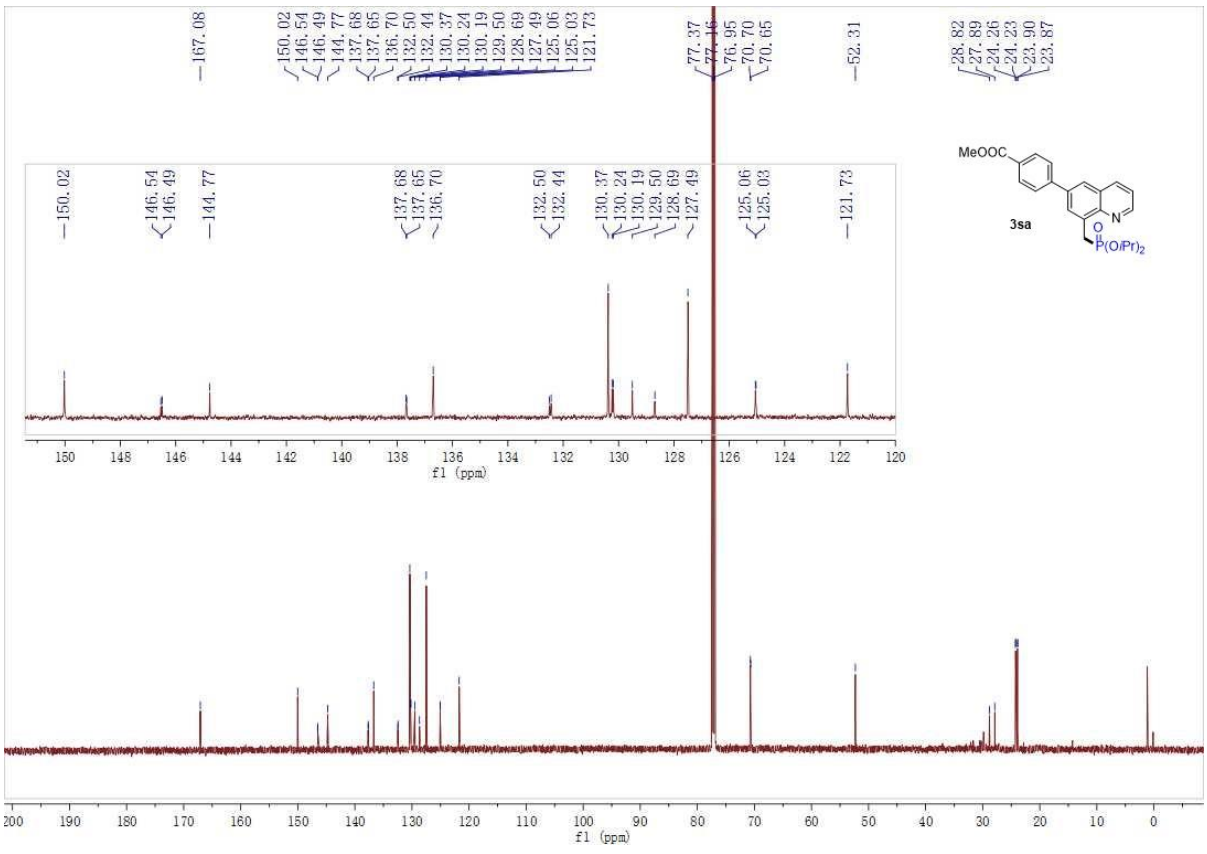
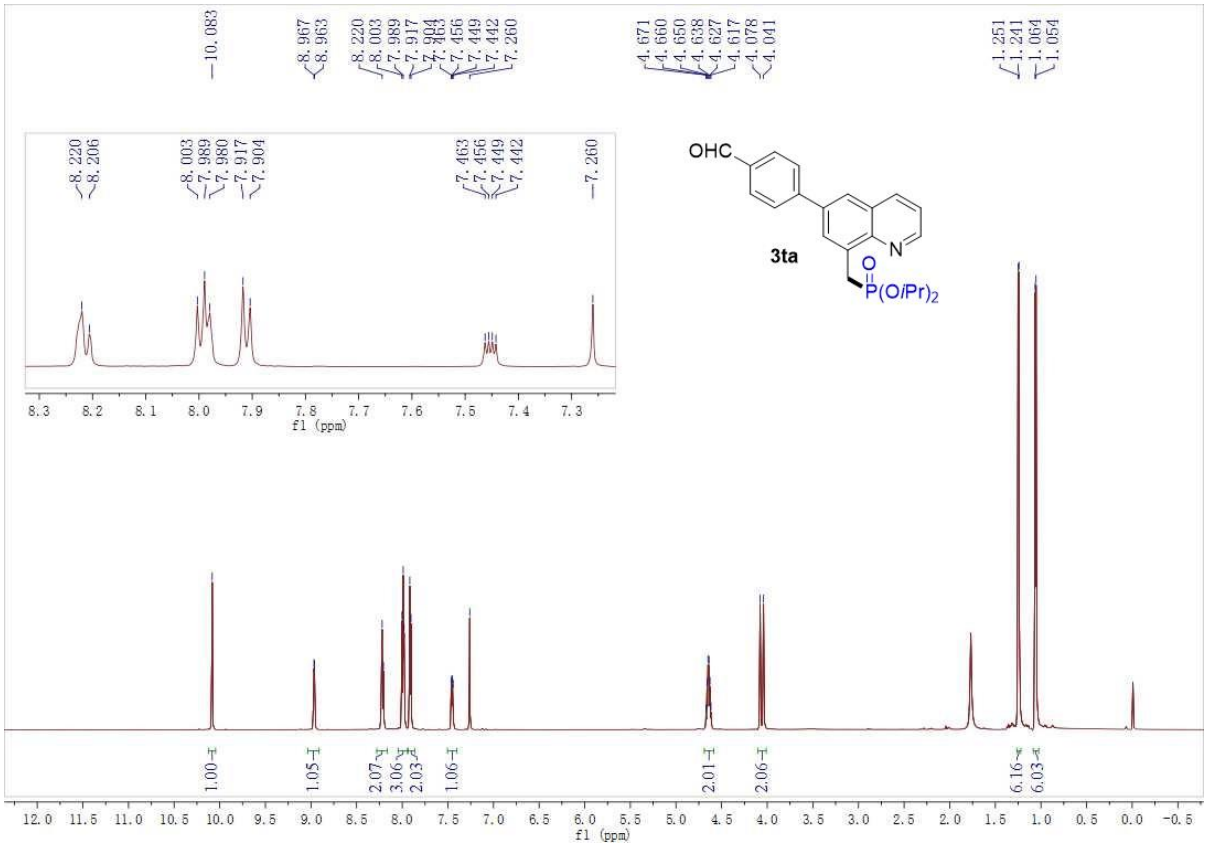
8.972
8.970
8.223
8.209
8.189
8.185
8.180
7.934
7.843
7.829
7.770
7.756
7.473
7.467
7.460
7.453
7.260
4.668
4.658
4.648
4.646
4.637
4.635
4.625
4.614
4.076
4.039
1.246
1.236
1.058
1.048
NC
N
O
P(OiPr)2
3ra
f1 (ppm)


150.16
146.33
144.76
137.00
136.93
136.90
132.84
132.72
130.07
130.02
128.68
128.17
125.22
125.19
121.88
118.84
111.63
77.37
77.16
76.95
70.78
70.74
28.84
27.91
24.21
24.19
23.87
23.84
NC
N
P(OiPr)2
O
3ra
f1 (ppm)


8.962
8.958
8.223
8.210
8.149
8.135
7.961
7.813
7.800
7.458
7.452
7.445
7.439
7.260
4.678
4.668
4.658
4.646
4.635
4.625
4.086
4.049
1.248
1.237
1.063
1.053
MeOOC
3sa
O
P(OiPr)2
N
f1 (ppm)
1.03
2.01
2.07
1.00
2.00
1.03
2.01
2.02
3.09
6.08
6.05


167.08
150.02
146.54
146.49
144.77
137.68
137.65
136.70
132.50
132.44
130.37
130.24
130.19
129.50
128.69
127.49
125.06
125.03
121.73
77.37
77.16
76.95
70.70
70.65
52.31
28.82
27.89
24.26
24.23
23.90
23.87
MeOOC
3sa
O
P(OiPr)2
N
f1 (ppm)


10.083
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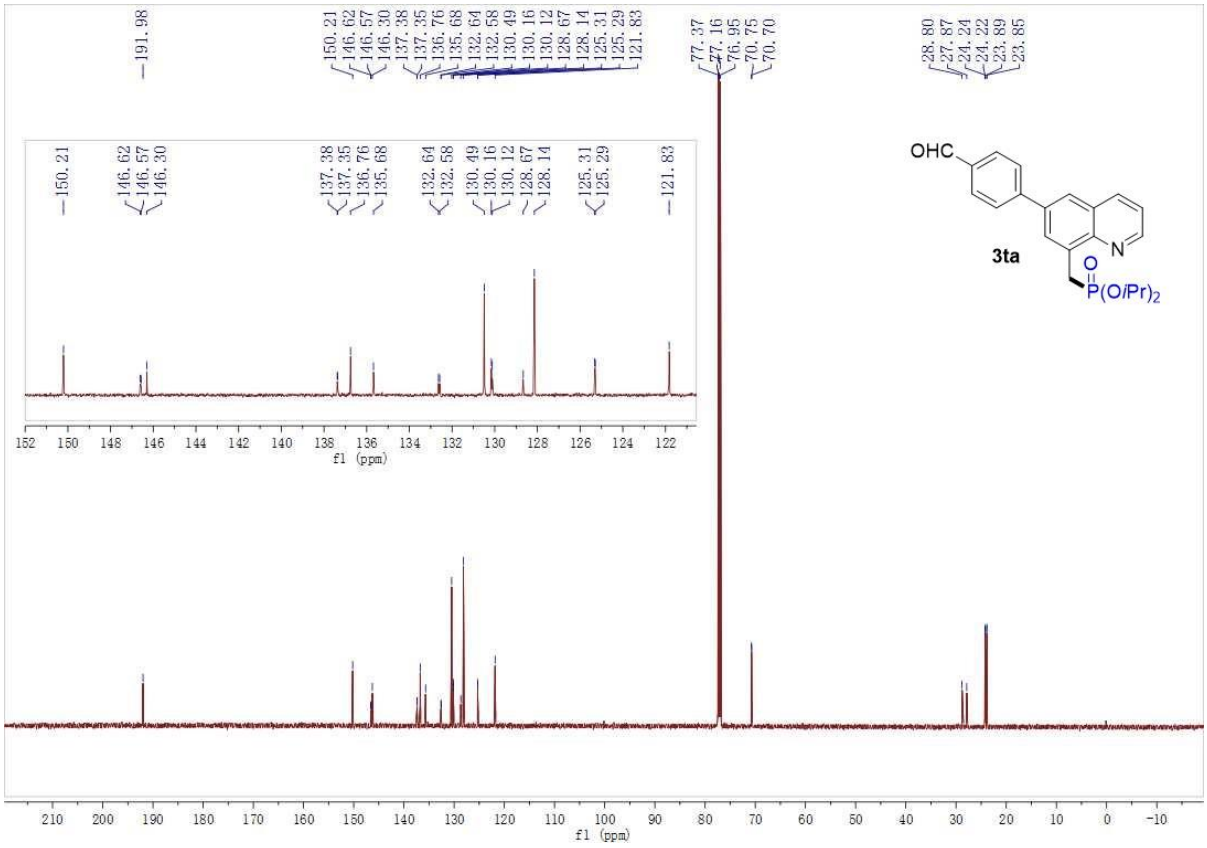
8.963
8.220
8.206
8.003
7.989
7.980
7.917
7.904
7.463
7.456
7.449
7.442
7.260
4.671
4.660
4.650
4.638
4.627
4.617
4.078
4.041
1.251
1.241
1.064
1.054
OHC
N
O
P(O/Pr)2
3ta
f1 (ppm)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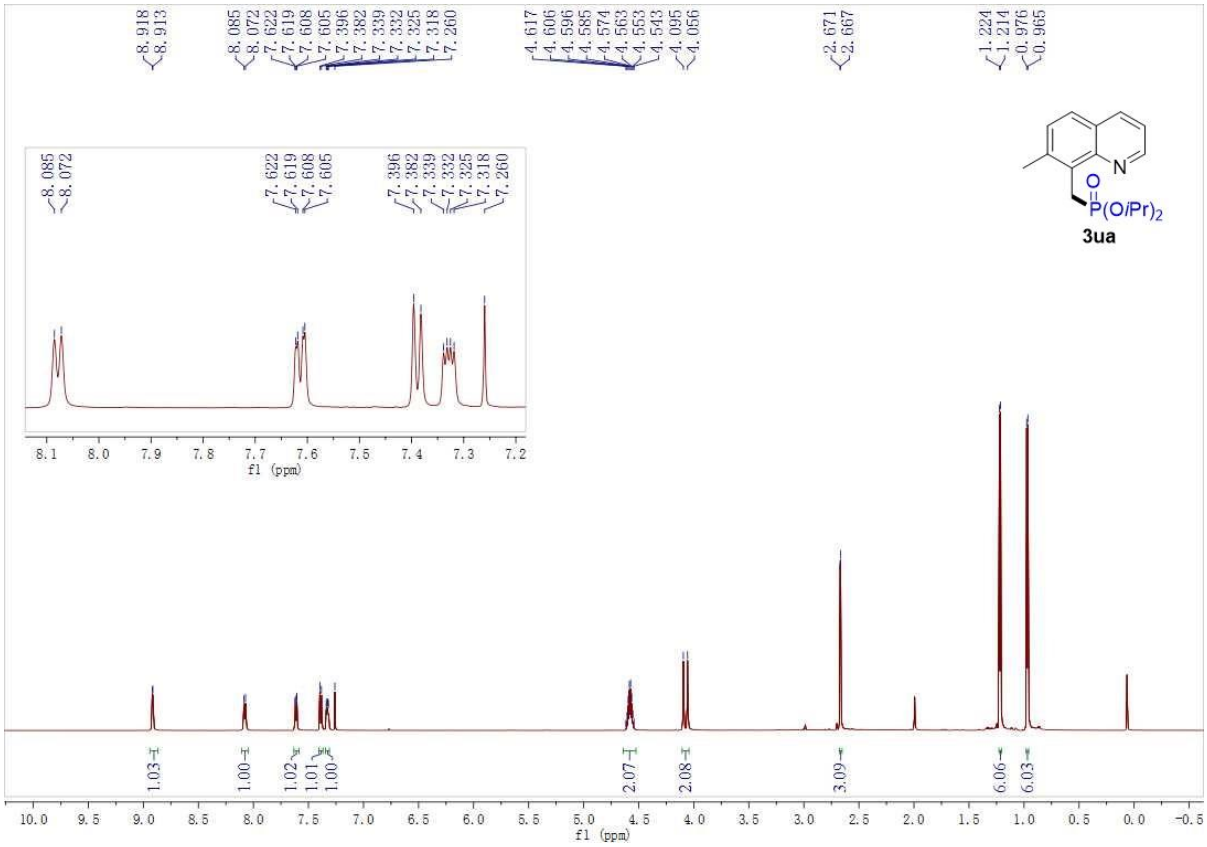
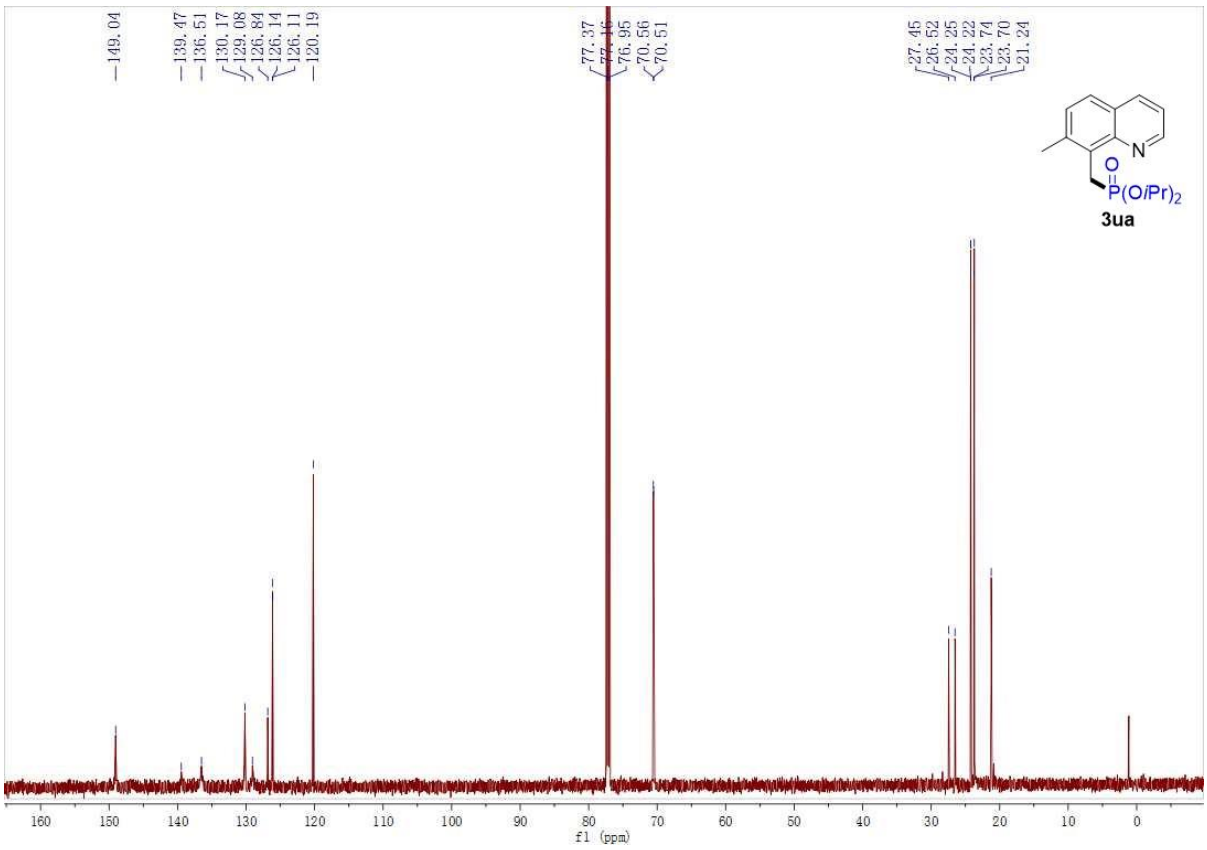
146.57
146.30
137.38
137.35
136.76
135.68
132.64
132.58
130.49
130.16
130.12
128.67
128.14
125.31
125.29
121.83
77.37
77.16
76.95
70.75
70.70
28.80
27.87
24.24
24.22
23.89
23.85
OHC
N
O
P(O/Pr)2
3ta
f1 (ppm)


8.918
8.913
8.085
8.072
7.622
7.619
7.608
7.605
7.396
7.382
7.339
7.332
7.325
7.318
7.260
4.617
4.606
4.596
4.585
4.574
4.563
4.553
4.543
4.095
4.056
2.671
2.667
1.224
1.214
0.976
0.965
3ua
f1 (ppm)


149.04
139.47
136.51
130.17
129.08
126.84
126.14
126.11
120.19
77.37
77.16
76.95
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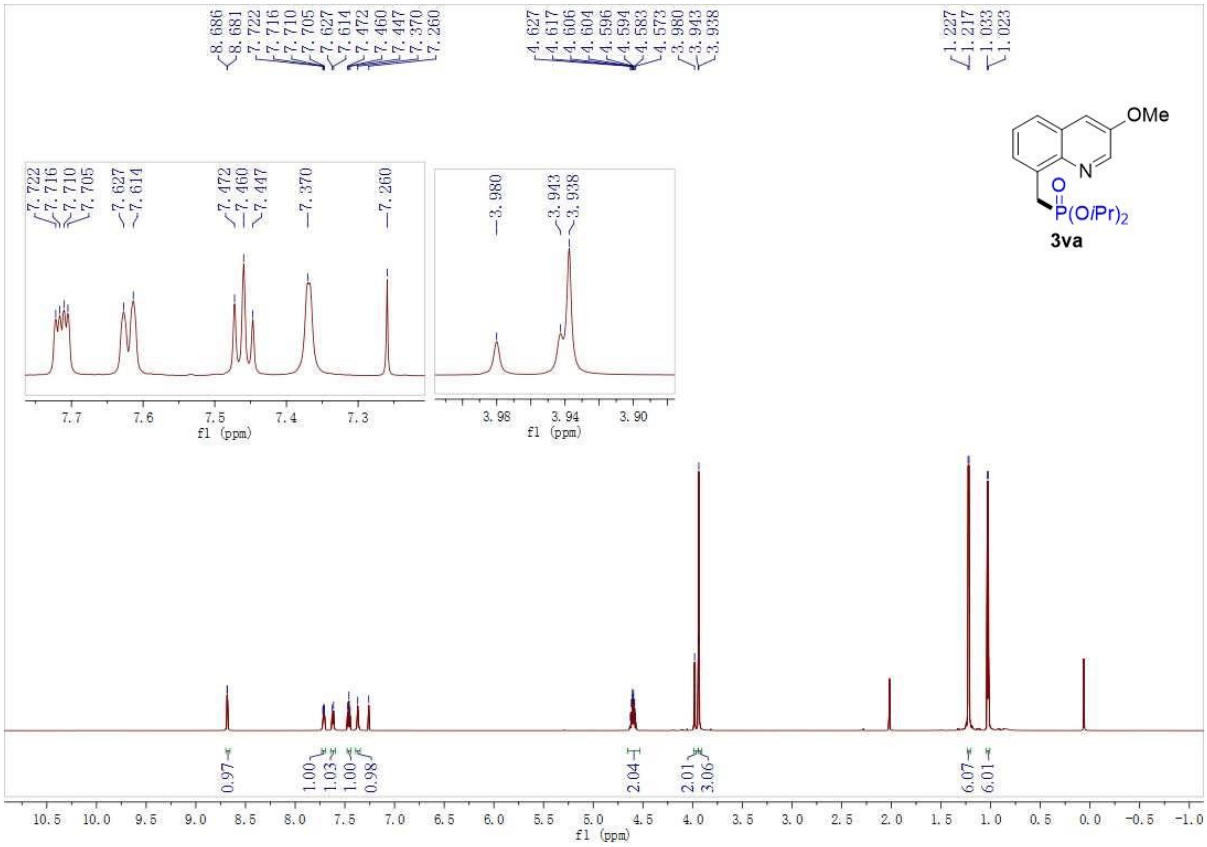
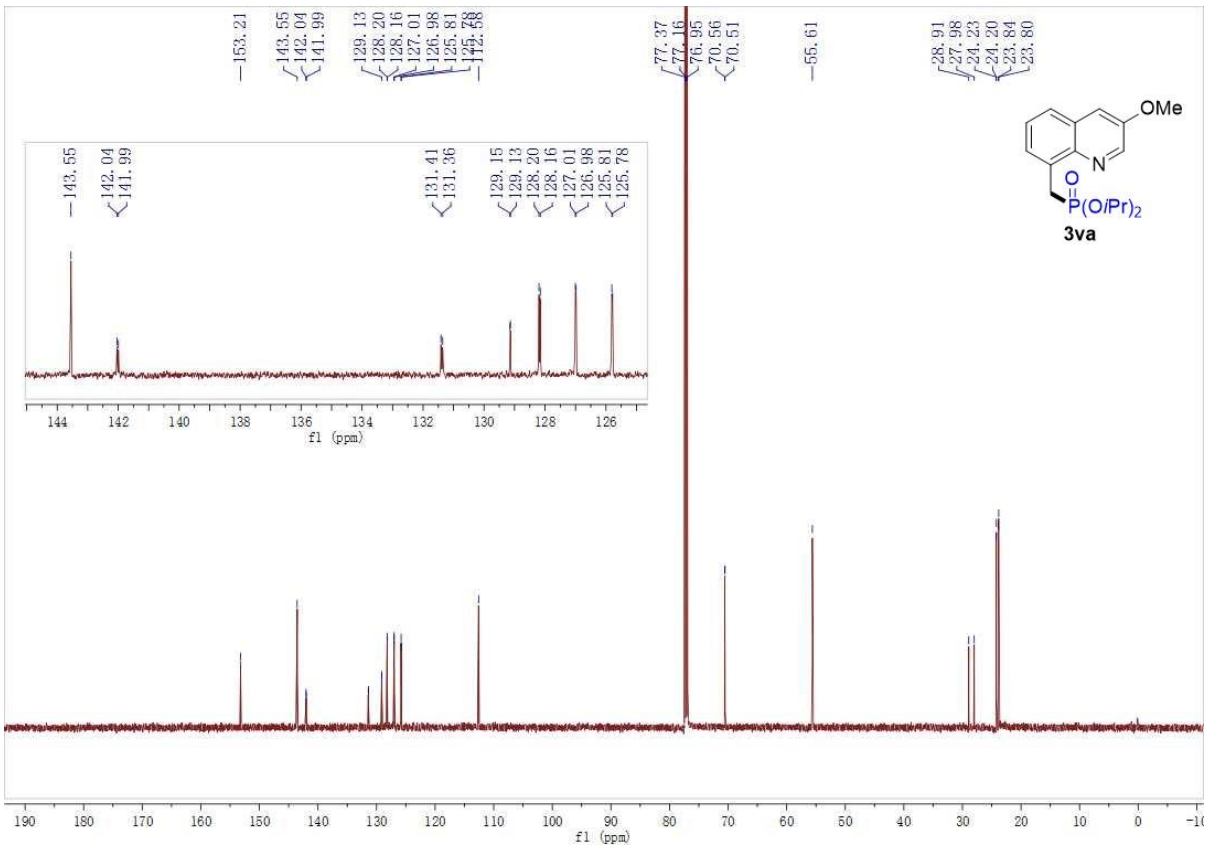
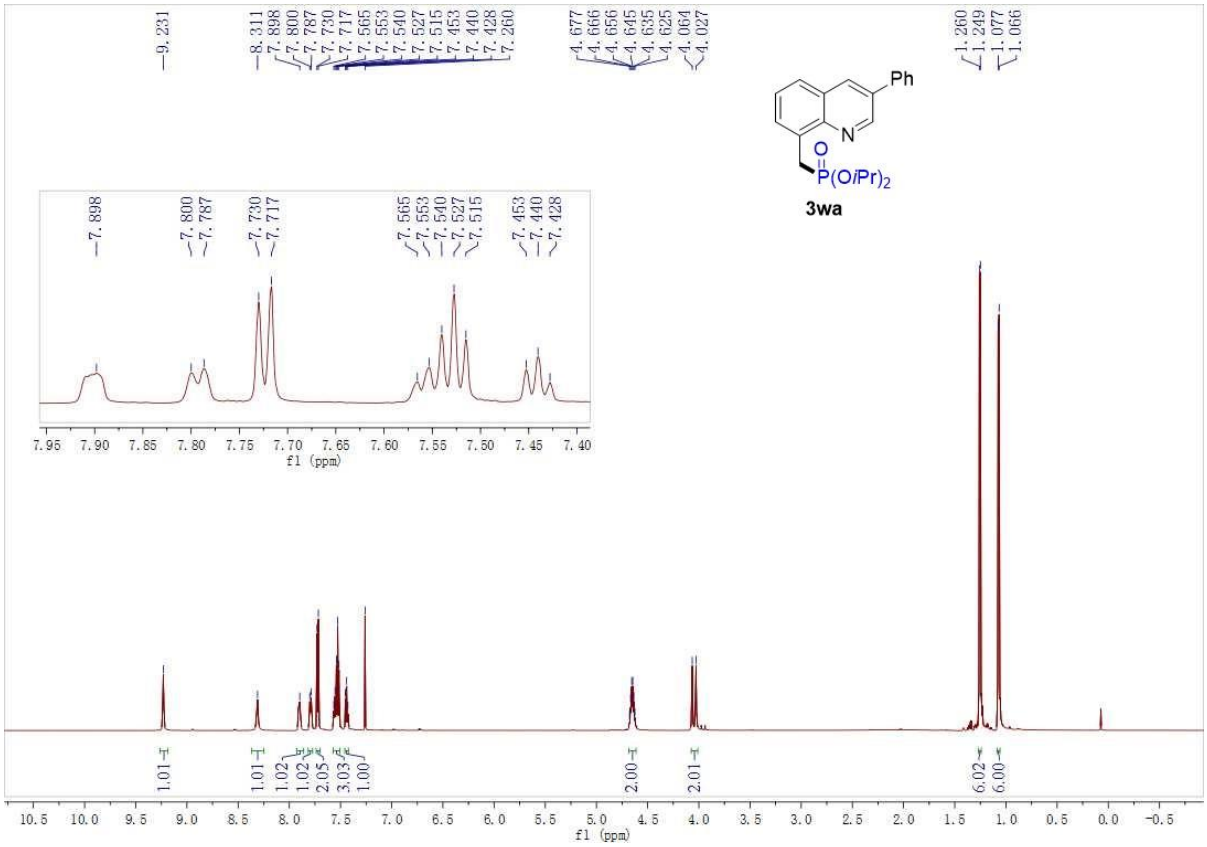
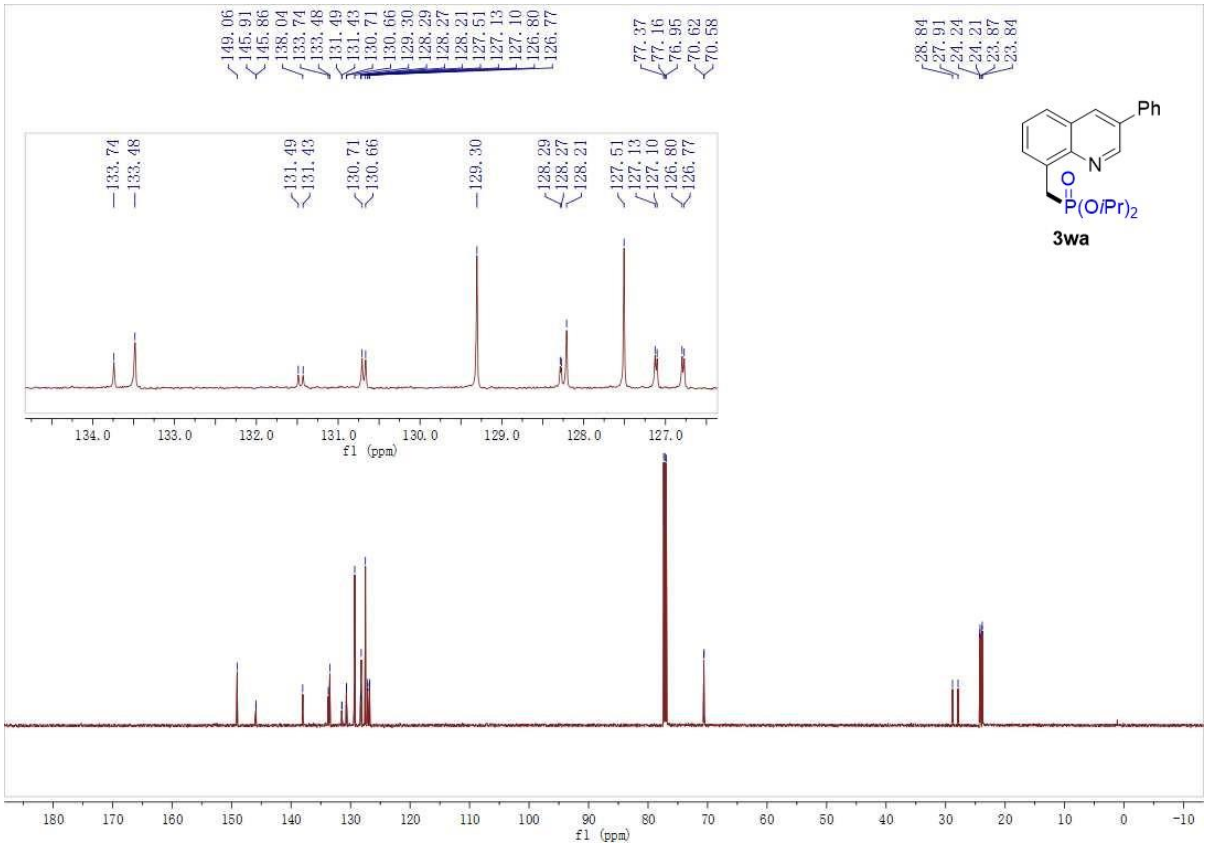
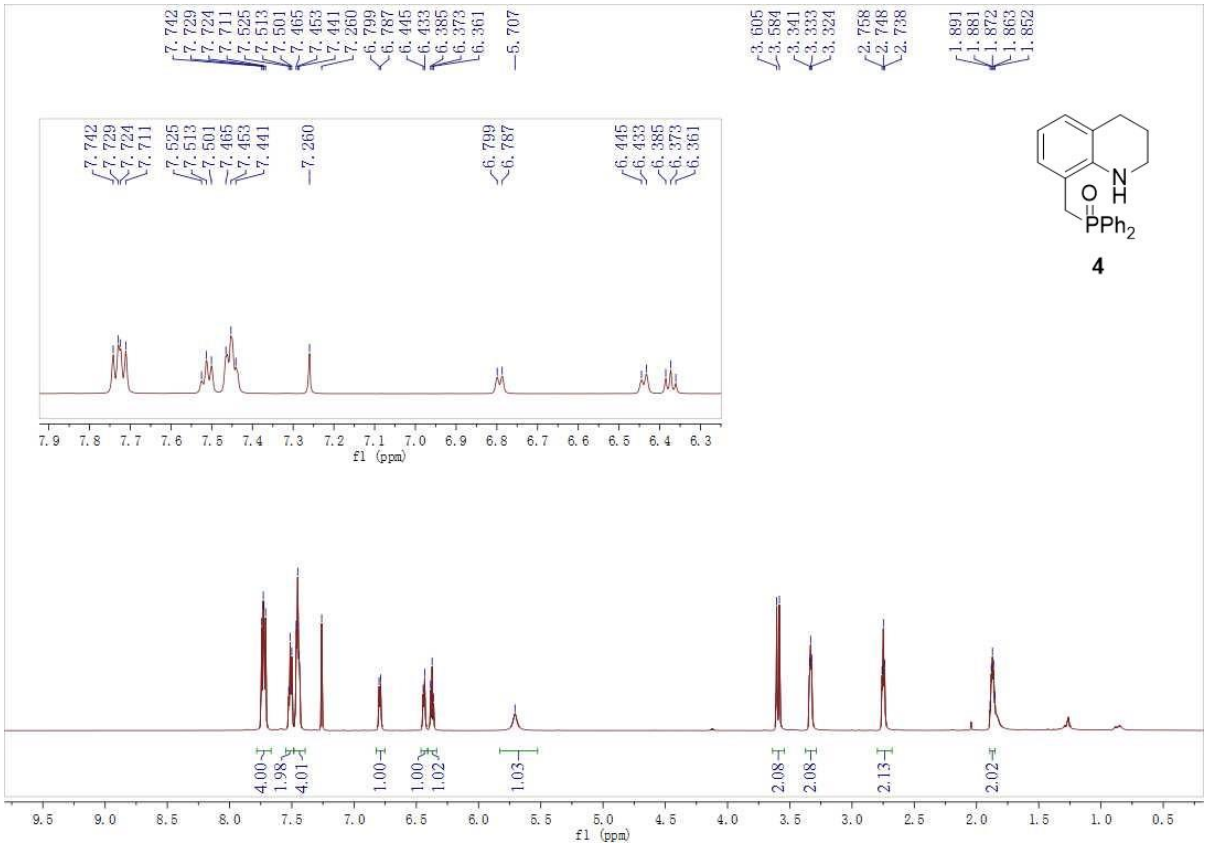
23.74
23.70
21.24
3ua
f1 (ppm)

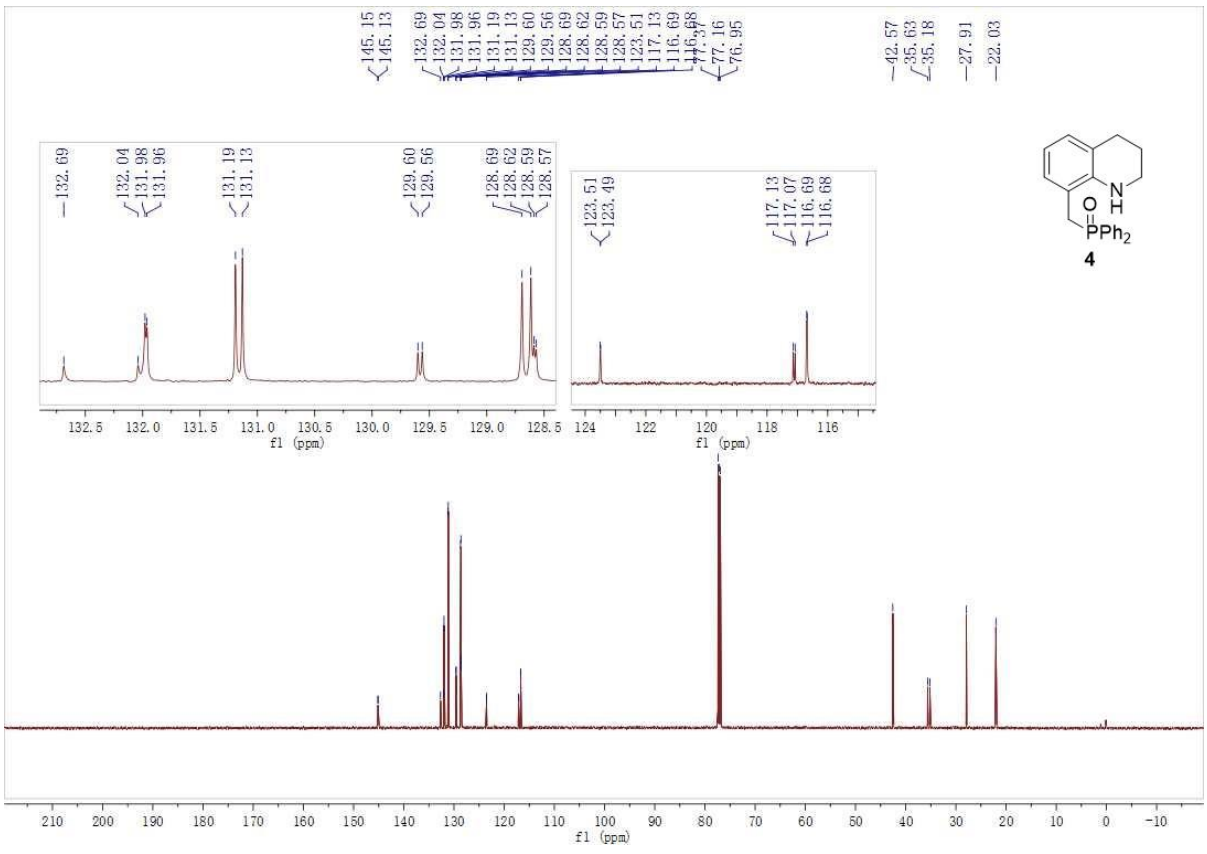

8.686
8.681
7.722
7.716
7.710
7.705
7.627
7.614
7.472
7.460
7.447
7.370
7.260
4.627
4.617
4.606
4.604
4.596
4.594
4.583
4.573
3.980
3.943
3.938
1.227
1.217
1.033
1.023
OMe
N
O
P(O/Pr)2
3va
f1 (ppm)
0.97
1.00
1.03
1.00
0.98
2.04
2.01
3.06
6.07
6.01

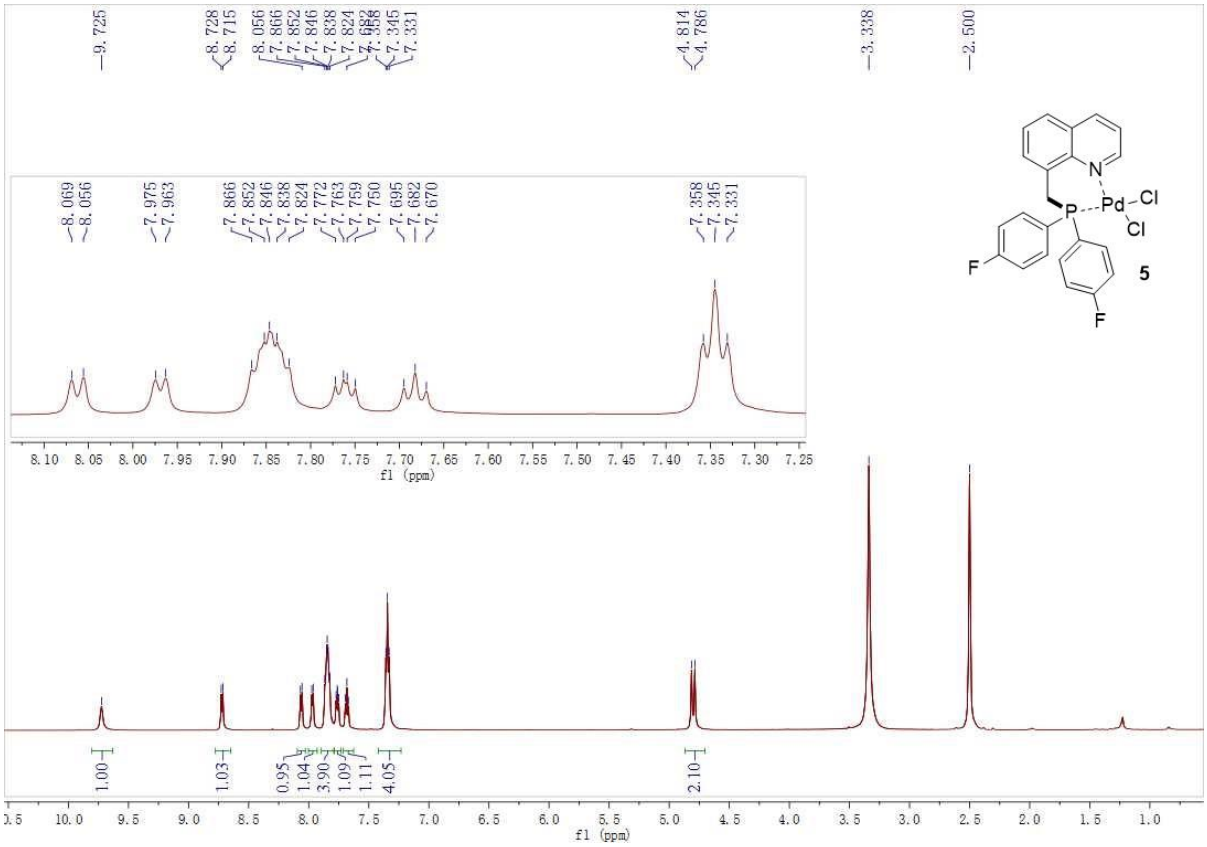

153.21
143.55
142.04
141.99
129.13
128.20
128.16
127.01
126.98
125.81
125.58
112.58
77.37
77.16
76.95
70.56
70.51
55.61
28.91
27.98
24.23
24.20
23.84
23.80
131.41
131.36
129.15
129.13
128.20
128.16
127.01
126.98
125.81
125.78
OMe
N
O
P(O/Pr)2
3va
f1 (ppm)

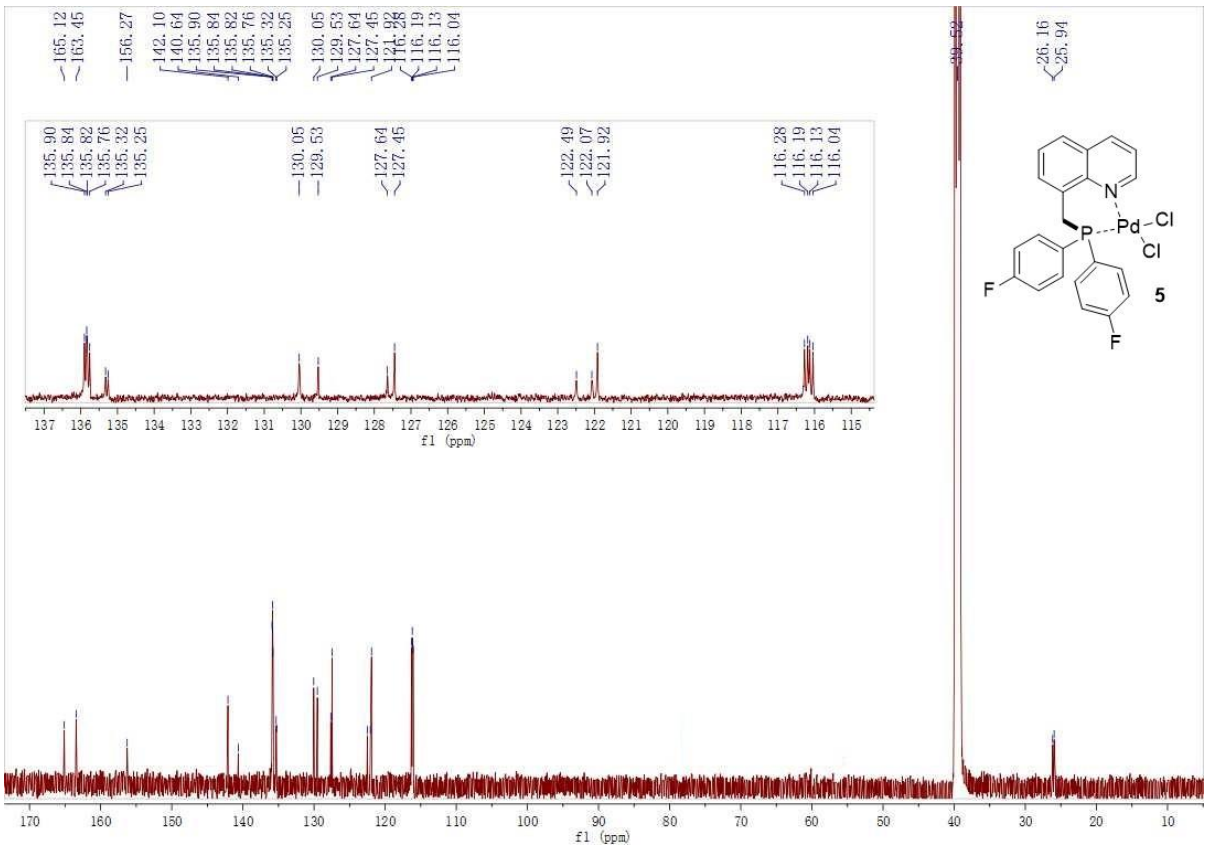

9.231
8.311
7.898
7.800
7.787
7.730
7.717
7.565
7.553
7.540
7.527
7.515
7.453
7.440
7.428
7.260
4.677
4.666
4.656
4.645
4.635
4.625
4.064
4.027
1.260
1.249
1.077
1.066
Ph
N
O
P(O/Pr)2
3wa
f1 (ppm)
1.01
1.01
1.02
1.02
2.05
3.03
1.00
2.00
2.01
6.02
6.00

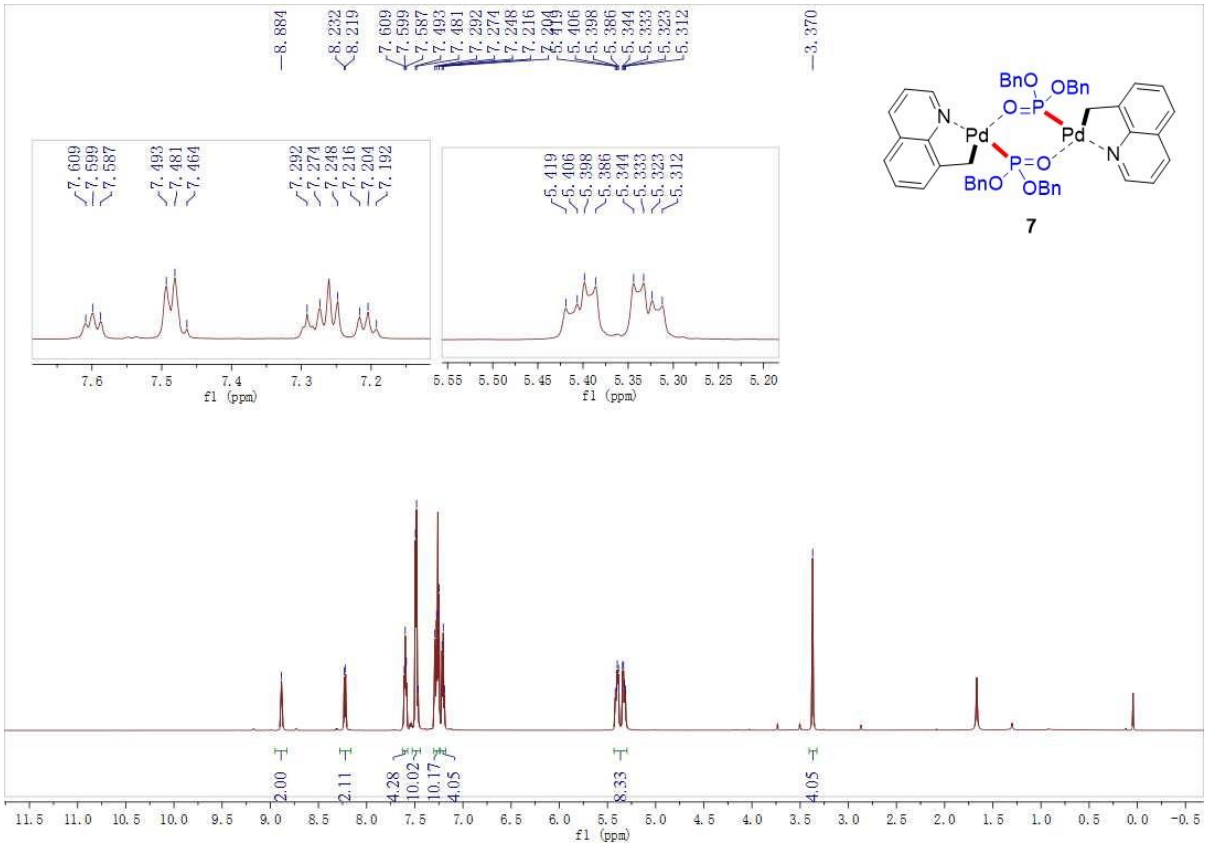

149.06
145.91
145.86
138.04
133.74
133.48
131.49
131.43
130.71
130.66
129.30
128.29
128.27
128.21
127.51
127.13
127.10
126.80
126.77
77.37
77.16
76.95
70.62
70.58
28.84
27.91
24.24
24.21
23.87
23.84
Ph
N
O
P(O/Pr)2
3wa
f1 (ppm)

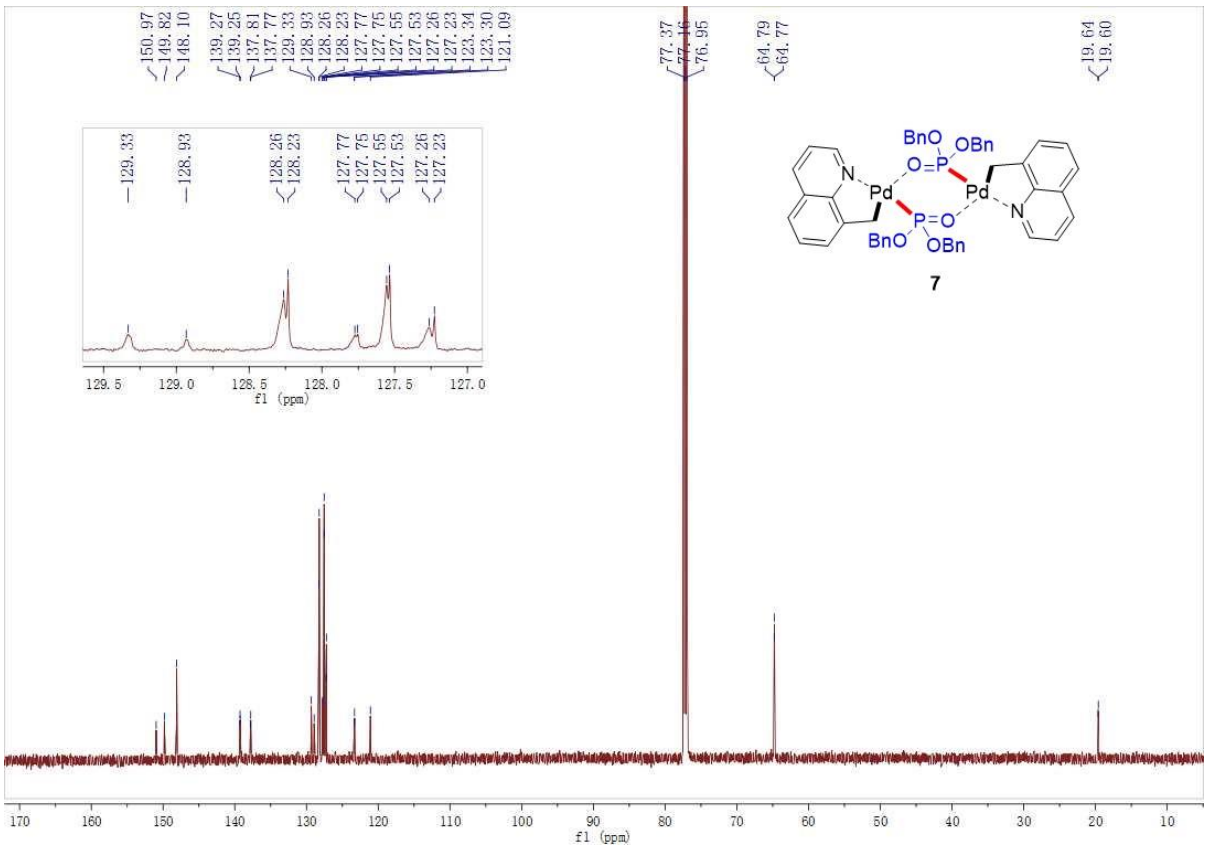

7.742
7.729
7.724
7.711
7.525
7.513
7.501
7.465
7.453
7.441
7.260
6.799
6.787
6.445
6.433
6.385
6.373
6.361
5.707
3.605
3.584
3.341
3.333
3.324
2.758
2.748
2.738
1.891
1.881
1.872
1.863
1.852
f1 (ppm)
4


145.15
145.13
132.69
132.04
131.98
131.96
131.19
131.13
129.60
129.56
128.69
128.62
128.59
128.57
123.51
123.49
117.13
117.07
116.69
116.68
77.16
76.95
42.57
35.63
35.18
27.91
22.03
f1 (ppm)
4


9.725
8.728
8.715
8.056
7.866
7.852
7.846
7.838
7.824
7.682
7.345
7.331
4.814
4.786
3.338
2.500
8.069
8.056
7.975
7.963
7.866
7.852
7.846
7.838
7.824
7.772
7.763
7.759
7.750
7.695
7.682
7.670
7.358
7.345
7.331
1.00
1.03
0.95
1.04
3.90
1.09
1.11
4.05
2.10
f1 (ppm)
N
P
Pd
Cl
Cl
F
F
5


165.12
163.45
156.27
142.10
140.64
135.90
135.84
135.82
135.76
135.32
135.25
130.05
129.53
127.64
127.45
122.49
122.07
121.92
116.28
116.19
116.13
116.04
39.52
26.16
25.94
f1 (ppm)
N
P
Pd
Cl
Cl
F
F
5


8.884
8.232
8.219
7.609
7.599
7.587
7.493
7.481
7.292
7.274
7.248
7.216
7.204
5.419
5.406
5.398
5.386
5.344
5.333
5.323
5.312
3.370
BnO
OBn
O=P
Pd
P=O
N
7
f1 (ppm)
2.00
2.11
4.28
10.02
10.17
4.05
8.33
4.05


150.97
149.82
148.10
139.27
139.25
137.81
137.77
129.33
128.93
128.26
128.23
127.77
127.75
127.55
127.53
127.26
127.23
123.34
123.30
121.09
77.37
77.16
76.95
64.79
64.77
19.64
19.60
BnO
OBn
O=P
Pd
P=O
N
7
f1 (ppm)