Supporting Information

Silver-Mediated Radical Phosphorylation/Cyclization of *N*-Allylbenzamides to Access Phosphoryl-Substituted Dihydroisoquinolones

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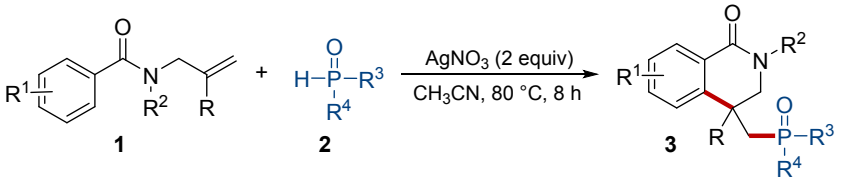
1. General information

All reagents were purchased and used without further purification. All reactions were monitored by thin layer chromatography (TLC), and column chromatography was performed on 200–300 mesh of silica gel purchased from Qing Dao Hai Yang Chemical Industry Co. ^{1}H, ^{13}C, ^{31}P spectra were record on a Bruker Avance 400 MHz spectrometer operating at 400 MHz, 101 MHz, and 162 MHz, respectively. All NMR spectra were recorded in $CDCl_3$ at room temperature (20 ± 2 °C). Proton chemical shifts δ were given in ppm relative to tetramethylsilane (0.00 ppm) in $CDCl_3$. High resolution mass spectra (HRMS) were obtained with a Waters Micromass Q-Tof Micro instrument using the ESI technique.

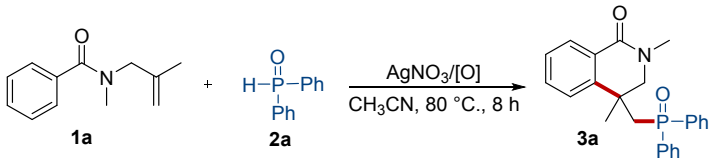
Experiment procedure

General experimental procedures for phosphoryl-substituted dihydroisoquinolones (3)



A mixture of *N*-methyl-*N*-(2-methylally)benzamides (0.5 mmol, 1 equiv), phosphine oxides (1 mmol, 2 equiv), $AgNO_3$ (2 equiv) were sequentially added in a 10-mL reaction vial. Then, CH_3CN (3 mL) was added into this reaction system. The reaction vial was sealed and stirred at 80 °C until TLC (petroleum ether: ethyl acetate= 1:1) revealed that conversion of the starting material **1** was completed. Next, the solvent was quenched with water (10 mL), extracted with ethyl acetate (3 × 10 mL). The combined organic layers were washed with brine (25 mL) and dried over anhydrous Na_2SO_4. After filtration, the solvent was evaporated in vacuo. The crude product was purified by silica gel chromatography (petroleum ether: ethyl acetate = 1:1) to give the desired products.

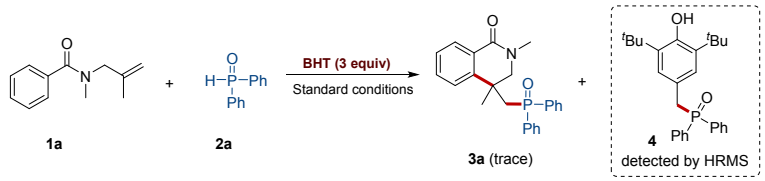
Table S1

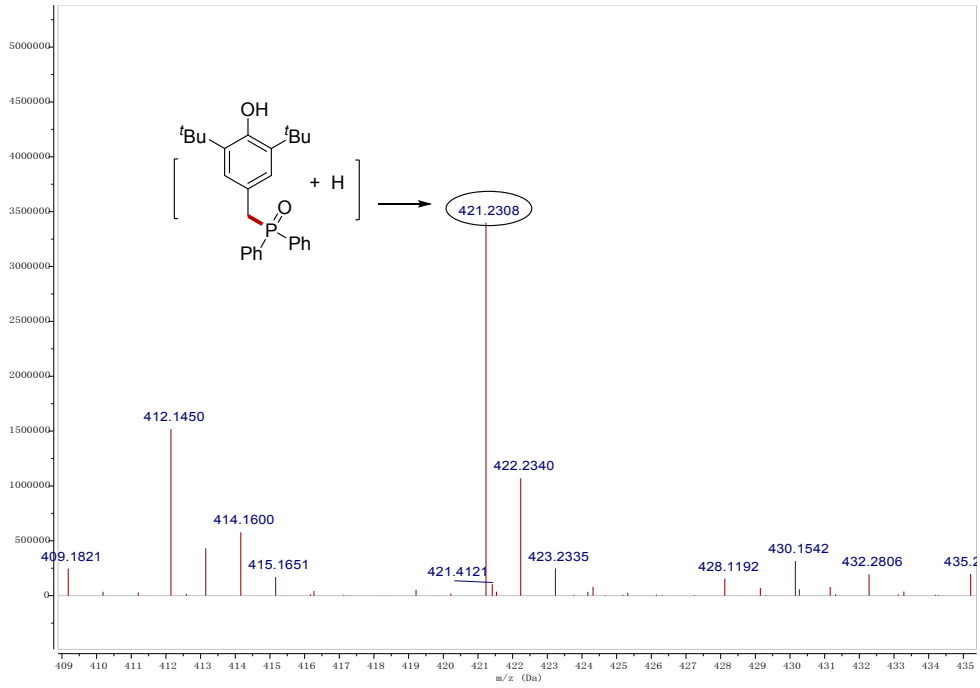


entry	$AgNO_3$ (mol%)	[O] (3 equiv)	Yield (%)
1	$AgNO_3$ (20)	BPO	trace
2	$AgNO_3$ (20)	$Mg(NO_3)_2$	27
3	$AgNO_3$ (20)	$Zn(NO_3)_2$	25
4	$AgNO_3$ (20)	$K_2S_2O_8$	trace

[a] Reaction conditions: **1a** (0.5 mmol), **2a** (1 mmol), $AgNO_3$ (20 mol%), oxidant (3 equiv), CH_3CN (3 mL) under 80 °C for 8 h. BPO = benzoyl peroxide. Yields were determined by ^{31}P NMR using trioctylphosphine oxide as internal standard

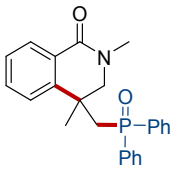
2. Mechanistic studies





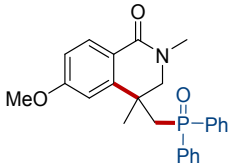
3. Characterization of products

4-((diphenylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one ***(3a)***



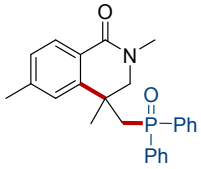
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.69 - 7.63 (m, 4H), 7.48 - 7.39 (m, 6H), 7.35 - 7.31 (m, 1H), 7.29 - 7.24 (m, 2H), 3.80 (d, *J* = 12.7 Hz, 1H), 3.50 (d, *J* = 12.7 Hz, 1H), 3.01 (s, 3H), 2.74 - 2.67 (m, 1H), 2.58 - 2.52 (m, 1H), 1.59 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 145.3 (d, *J* = 10.4 Hz), 134.8 (d, *J* = 98.7 Hz), 133.4 (d, *J* = 98.1 Hz), 132.1, 131.7 (d, *J* = 2.7 Hz), 131.4 (d, *J* = 2.8 Hz), 130.5 (d, *J* = 9.1 Hz), 130.2 (d, *J* = 9.2 Hz), 128.8 (d, *J* = 11.5 Hz), 128.59 (d, *J* = 11.5 Hz), 128.58, 127.8, 127.3, 123.9, 58.1 (d, *J* = 5.1 Hz), 37.9 (d, *J* = 67.6 Hz), 37.4 (d, *J* = 3.5 Hz), 34.9, 23.2 (d, *J* = 2.0 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.48; HRMS Calcd for $C_{24}H_{25}NO_2P$ $[M + H]^+$: 390.1617, found: 390.1612.

*4-((diphenylphosphoryl)methyl)-6-methoxy-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3b**)*



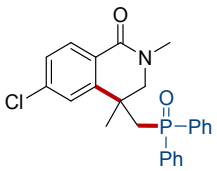
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 8.6 Hz, 1H), 7.67 - 7.59 (m, 4H), 7.48 - 7.34 (m, 6H), 6.76 (d, *J* = 2.5 Hz, 1H), 6.67 (dd, *J* = 8.7, 2.5 Hz, 1H), 3.77 (s, 3H), 3.66 (d, *J* = 12.7 Hz, 1H), 3.47 (d, *J* = 12.6 Hz, 1H), 2.98 (s, 3H), 2.66 - 2.55 (m, 2H), 1.59 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 162.4, 147.0 (d, *J* = 9.6 Hz), 134.9 (d, *J* = 98.7 Hz), 133.2 (d, *J* = 98.1 Hz), 131.6 (d, *J* = 2.8 Hz), 131.3 (d, *J* = 2.8 Hz), 130.8, 130.3 (d, *J* = 9.1 Hz), 130.1 (d, *J* = 9.2 Hz), 128.7 (d, *J* = 11.7 Hz), 128.5 (d, *J* = 11.7 Hz), 120.7, 112.1, 109.9, 58.7 (d, *J* = 6.1 Hz), 55.3, 37.8, (d, *J* = 68.7 Hz), 37.5 (d, *J* = 3.6 Hz), 34.7, 23.1 (d, *J* = 1.8 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.46; HRMS Calcd for $C_{25}H_{27}NO_3P$ $[M + H]^+$:420.1723, found: 420.1718.

*4-((diphenylphosphoryl)methyl)-2,4,6-trimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3c**)*



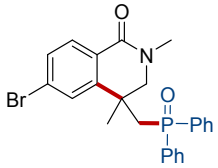
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 7.9 Hz, 1H), 7.67 - 7.60 (m, 4H), 7.47 - 7.34 (m, 6H), 7.04 - 6.97 (m, 2H), 3.68 (d, *J* = 12.7 Hz, 1H), 3.47 (d, *J* = 12.6 Hz, 1H), 2.99 (s, 3H), 2.67 - 2.55 (m, 2H), 2.25 (s, 3H), 1.60 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.8, 144.9 (d, *J* = 9.6 Hz), 142.5, 134.9 (d, *J* = 98.7 Hz), 133.3 (d, *J* = 98.0 Hz), 131.6 (d, *J* = 2.8 Hz), 131.3 (d, *J* = 2.9 Hz), 130.3 (d, *J* = 9.1 Hz), 130.1 (d, *J* = 9.2 Hz), 128.73 (d, *J* = 11.7 Hz), 128.67, 128.5 (d, *J* = 11.7 Hz), 128.1, 125.2, 124.7, 58.7 (d, *J* = 6.0 Hz), 37.9 (d, *J* = 68.1 Hz), 37.4 (d, *J* = 3.7 Hz), 34.8, 23.1, 21.7; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.50; HRMS Calcd for $C_{25}H_{27}NO_2P$ $[M + H]^+$:404.1774, found: 404.1767.

*6-chloro-4-((diphenylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3d**)*



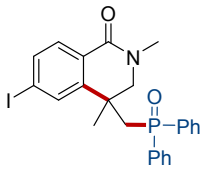
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 8.3 Hz, 1H), 7.69 - 7.64 (m, 4H), 7.51 - 7.39 (m, 6H), 7.25 (d, *J* = 2.0 Hz, 1H), 7.16 (dd, *J* = 8.3, 2.0 Hz, 1H), 3.78 (d, *J* = 12.0 Hz, 1H),, 3.51 (d, *J* = 12.8 Hz, 1H), 3.04 (s, 3H), 2.68 - 2.54 (m, 2H), 1.59 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.8, 146.6 (d, *J* = 9.7 Hz), 138.3, 134.7 (d, *J* = 99.1 Hz), 132.9 (d, *J* = 98.1 Hz), 131.8 (d, *J* = 2.8 Hz), 131.5 (d, *J* = 2.8 Hz), 130.5, 130.3 (d, *J* = 9.7 Hz), 130.1 (d, *J* = 9.3 Hz), 128.8 (d, *J* = 11.7 Hz), 128.6 (d, *J* = 11.8 Hz), 127.7, 126.4, 124.6, 58.4 (d, *J* = 5.8 Hz), 37.7 (d, *J* = 68.7 Hz), 37.6 (d, *J* = 3.4 Hz), 34.9, 23.0 (d, *J* = 2.1 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.16; HRMS Calcd for $C_{24}H_{23}ClNO_2P$ $[M + H]^+$: 424.1228, found: 424.1224.

*6-bromo-4-((diphenylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3e**)*



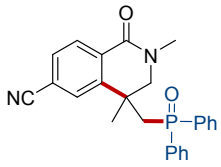
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 8.3 Hz, 1H), 7.68 - 7.63 (m, 4H), 7.49 - 7.39 (m, 7H), 7.32 (dd, *J* = 8.3, 1.9 Hz, 1H), 3.76 (d, *J* = 12.8 Hz, 1H), 3.51 (d, *J* = 12.8 Hz, 1H), 3.03 (s, 3H), 2.67 - 2.54 (m, 2H), 1.58 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.8, 146.7 (d, *J* = 9.7 Hz), 134.7 (d, *J* = 99.0 Hz), 132.8 (d, *J* = 98.3 Hz), 131.8 (d, *J* = 2.7 Hz), 131.5 (d, *J* = 2.8 Hz), 130.7, 130.4 (d, *J* = 8.9 Hz), 130.1 (d, *J* = 9.2 Hz), 128.8 (d, *J* = 11.6 Hz), 128.6 (d, *J* = 11.8 Hz), 127.5, 127.0, 126.8, 58.4 (d, *J* = 5.8 Hz), 37.7 (d, *J* = 67.7 Hz), 37.5 (d, *J* = 3.5 Hz), 34.9, 23.0 (d, *J* = 2.0 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.22; HRMS Calcd for $C_{24}H_{24}BrNO_2P$ $[M + H]^+$: 468.0723, found: 468.0723.

*4-((diphenylphosphoryl)methyl)-6-iodo-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3f**)*



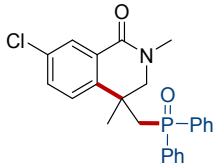
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.68 - 7.61 (m, 6H), 7.55 (dd, *J* = 8.2, 1.7 Hz, 1H), 7.50 - 7.39 (m, 6H), 3.73 (d, *J* = 12.8 Hz, 1H), 3.50 (dd, *J* = 12.8, 1.6 Hz, 1H), 3.03 (s, 3H), 2.65 - 2.54 (m, 2H), 1.58 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.0, 146.5 (d, *J* = 9.6 Hz), 136.7, 134.7 (d, *J* = 99.0 Hz), 133.5, 132.8 (d, *J* = 98.2 Hz), 131.7 (d, *J* = 2.5 Hz), 131.5 (d, *J* = 2.9 Hz), 130.4 (d, *J* = 9.1 Hz), 130.2, 130.1 (d, *J* = 9.2 Hz), 128.8 (d, *J* = 11.9 Hz), 128.7 (d, *J* = 11.9 Hz), 127.4, 99.9, 58.5 (d, *J* = 5.9 Hz), 38.1, 37.7 (d, *J* = 67.7 Hz), 37.4, 34.9, 23.0; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.23; HRMS Calcd for $C_{24}H_{24}INO_2P$ $[M + H]^+$: 516.0584, found: 516.0588.

*4-((diphenylphosphoryl)methyl)-2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinoline-6-carbonitrile (**3g**)*



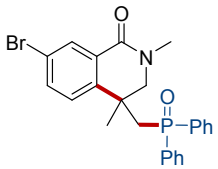
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02 (d, *J* = 8.0 Hz, 1H), 7.64 - 7.55 (m, 5H), 7.47 - 7.35 (m, 7H), 3.76 (d, *J* = 13.0 Hz, 1H), 3.53 (dd, *J* = 12.9, 1.9 Hz, 1H), 3.07 (s, 3H), 2.67 - 2.54 (m, 2H), 1.60 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 162.7, 145.5 (d, *J* = 9.0 Hz), 134.4 (d, *J* = 99.7 Hz), 132.5 (d, *J* = 98.3 Hz), 131.9 (d, *J* = 2.7 Hz), 131.7 (d, *J* = 2.8 Hz), 131.6, 130.9, 130.4 (d, *J* = 9.1 Hz), 130.0 (d, *J* = 9.4 Hz), 129.2, 128.8 (d, *J* = 10.7 Hz), 128.7 (d, *J* = 10.3 Hz), 128.7, 118.0, 115.3, 58.5 (d, *J* = 6.4 Hz), 37.6 (d, *J* = 68.7 Hz), 37.5 (d, *J* = 3.5 Hz), 35.1, 23.0 (d, *J* = 2.1 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.10; HRMS Calcd for $C_{25}H_{24}N_2O_2P$ $[M + H]^+$: 415.1570, found: 415.1568

*7-chloro-4-((diphenylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3h**)*



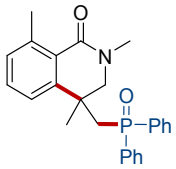
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.93 (d, *J* = 2.2 Hz, 1H), 7.68 - 7.56 (m, 4H), 7.52 - 7.36 (m, 6H), 7.25 - 7.19 (m, 2H), 3.69 (d, *J* = 12.8 Hz, 1H), 3.52 (dd, *J* = 12.8, 2.0 Hz, 1H), 3.06 (s, 3H), 2.65 - 2.56 (m, 2H), 1.64 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.3, 142.9 (d, *J* = 9.0 Hz), 134.7 (d, *J* = 99.1 Hz), 133.6, 132.7 (d, *J* = 98.3 Hz), 131.8, 131.7 (d, *J* = 2.9 Hz), 131.3 (d, *J* = 2.9 Hz), 130.5 (d, *J* = 9.1 Hz), 130.1 (d, *J* = 9.0 Hz), 129.5, 128.8 (d, *J* = 11.6 Hz), 128.6 (d, *J* = 11.7 Hz), 128.4, 126.1, 58.8 (d, *J* = 6.5 Hz), 38.0 (d, *J* = 68.3 Hz), 37.2 (d, *J* = 3.5 Hz), 35.1, 23.2; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.33; HRMS Calcd for $C_{24}H_{24}ClNO_2P$ $[M + H]^+$: 424.1228, found: 424.1220.

*7-bromo-4-((diphenylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3i**)*



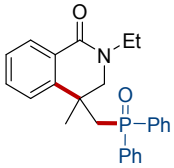
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.04 (d, *J* = 2.2 Hz, 1H), 7.65 - 7.61 (m, 2H), 7.58 - 7.53 (m, 2H), 7.48 - 7.31 (m, 7H), 7.15 (d, *J* = 8.3 Hz, 1H), 3.65 (d, *J* = 12.8 Hz, 1H), 3.49 (dd, *J* = 12.8, 2.0 Hz, 1H), 3.03 (s, 3H), 2.65 - 2.53 (m, 2H), 1.61 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.2, 143.3 (d, *J* = 9.0 Hz), 135.2, 134.67 (d, *J* = 100.0 Hz), 134.68, 132.6 (d, *J* = 98.4 Hz), 131.7 (d, *J* = 2.7 Hz), 131.3 (d, *J* = 1.9 Hz), 130.5 (d, *J* = 9.1 Hz), 130.1 (d, *J* = 9.3 Hz), 129.7, 128.8 (d, *J* = 11.6 Hz), 128.6 (d, *J* = 11.7 Hz), 126.4, 121.6, 58.7 (d, *J* = 6.9 Hz), 37.9 (d, *J* = 68.6 Hz), 37.2 (d, *J* = 3.5 Hz), 35.1, 23.2; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.40; HRMS Calcd for $C_{24}H_{24}BrNO_2P$ $[M + H]^+$: 468.0723, found: 468.0725.

*4-((diphenylphosphoryl)methyl)-2,4,8-trimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3j**)*



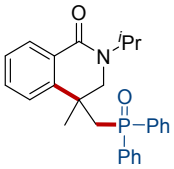
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.68 - 7.62 (m, 4H), 7.48 - 7.36 (m, 6H), 7.18 - 7.10 (m, 2H), 7.00 (d, *J* = 7.2 Hz, 1H), 3.75 (d, *J* = 12.8 Hz, 1H), 3.47 (d, *J* = 12.8 Hz, 1H), 3.08 (s, 3H), 2.68 - 2.51 (m, 5H), 1.53 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 165.1, 146.3 (d, *J* = 10.1 Hz), 141.0, 135.1 (d, *J* = 98.7 Hz), 133.2 (d, *J* = 97.9 Hz), 131.6 (d, *J* = 2.7 Hz), 131.3 (d, *J* = 2.2 Hz), 131.0, 130.5 (d, *J* = 9.1 Hz), 130.1 (d, *J* = 9.2 Hz), 128.7 (d, *J* = 11.6 Hz), 128.4 (d, *J* = 11.7 Hz), 126.5, 121.9, 57.9 (d, *J* = 5.1 Hz), 38.0 (d, *J* = 3.5 Hz), 37.2 (d, *J* = 67.9 Hz), 35.1, 23.4 (d, *J* = 1.9 Hz), 22.7; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.58; HRMS Calcd for $C_{25}H_{27}NO_2P$ $[M + H]^+$: 404.1774, found: 404.1771.

*4-((diphenylphosphoryl)methyl)-2-ethyl-4-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3k**)*



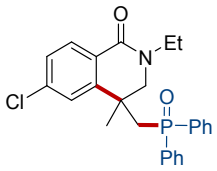
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.04 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.71 - 7.62 (m, 4H), 7.49 - 7.39 (m, 6H), 7.35 - 7.31 (m, 1H), 7.27 - 7.23 (m, 2H), 3.90 (d, *J* = 12.7 Hz, 1H), 3.82 - 3.73 (m, 1H), 3.53 (d, *J* = 12.7 Hz, 1H), 3.43 - 3.35 (m, 1H), 2.75 - 2.67 (m, 1H), 2.59 - 2.53 (m, 1H), 1.57 (s, 3H), 1.23 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.8, 145.2 (d, *J* = 10.5 Hz), 135.1 (d, *J* = 99.0 Hz), 133.4 (d, *J* = 97.7 Hz), 132.0, 131.6 (d, *J* = 2.7 Hz), 131.4 (d, *J* = 2.9 Hz), 130.5 (d, *J* = 9.1 Hz), 130.0 (d, *J* = 9.2 Hz), 128.7 (d, *J* = 12.5 Hz), 128.6 (d, *J* = 10.6 Hz), 128.2, 127.3, 123.8, 55.6(d, *J* = 4.8 Hz), 42.1, 37.8, 37.42 (d, *J* = 67.7 Hz), 37.36 (d, *J* = 3.6 Hz), 37.1, 23.1, 12.6; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.37; HRMS Calcd for $C_{25}H_{27}NO_2P$ [M + H]$^+$: 404.1774, found: 404.1765.

*4-((diphenylphosphoryl)methyl)-2-isopropyl-4-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3l**)*



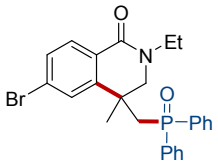
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06 - 7.97 (m, 1H), 7.68 - 7.60 (m, 4H), 7.46 - 7.36 (m, 6H), 7.30 - 7.24 (m, 2H), 7.22 - 7.18 (m, 1H), 5.14 – 5.08 (m, 1H), 3.81 (d, *J* = 12.7 Hz, 1H), 3.31 (dd, *J* = 12.8, 1.6 Hz, 1H), 2.69 - 2.57 (m, 2H), 1.59 (s, 3H), 1.28 (d, *J* = 6.8 Hz, 3H), 1.20 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.5, 144.3 (d, *J* = 9.2 Hz), 135.4 (d, *J* = 99.0 Hz), 133.3 (d, *J* = 97.9 Hz), 131.9, 131.5 (d, *J* = 2.8 Hz), 131.3 (d, *J* = 2.9 Hz), 130.5 (d, *J* = 8.9 Hz), 129.9 (d, *J* = 9.1 Hz), 128.8, 128.7 (d, *J* = 11.1 Hz), 128.54 (d, *J* = 12.1 Hz), 128.45, 127.3, 124.0, 50.4 (d, *J* = 5.8 Hz), 43.9, 37.1, 37.0 (d, *J* = 3.5 Hz), 36.7 (d, *J* = 68.7 Hz), 36.4, 23.4, 20.0, 19.3; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.10; HRMS Calcd for $C_{25}H_{29}NO_2P$ [M + H]$^+$: 418.1930, found: 418.1922.

*6-chloro-4-((diphenylphosphoryl)methyl)-2-ethyl-4-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3m**)*



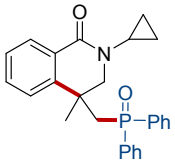
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.91 (d, *J* = 8.3 Hz, 1H), 7.70 - 7.61 (m, 4H), 7.48-7.38 (m, 6H), 7.22 (d, *J* = 2.0 Hz, 1H), 7.15 (dd, *J* = 8.3, 2.0 Hz, 1H), 3.85 - 3.69 (m, 2H), 3.53 - 3.38 (m, 2H), 2.67 - 2.54 (m, 2H), 1.55 (s, 3H), 1.22 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.0, 146.4 (d, *J* = 9.6 Hz), 138.2, 134.9 (d, *J* = 99.5 Hz), 132.8 (d, *J* = 98.0 Hz), 131.7 (d, *J* = 2.7 Hz), 131.5 (d, *J* = 2.9 Hz), 130.5 (d, *J* = 9.2 Hz), 130.3, 130.0 (d, *J* = 9.2 Hz), 128.8 (d, *J* = 12.0 Hz), 128.6, (d, *J* = 12.1 Hz), 127.6, 126.7, 124.5, 56.2 (d, *J* = 5.8 Hz), 42.1, 37.5 (d, *J* = 3.4 Hz), 37.2 (d, *J* = 67.7 Hz), 23.0 (d, *J* = 2.1 Hz), 12.5; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.16; HRMS Calcd for $C_{25}H_{26}ClNO_2P$ [M + H]$^+$: 438.1384, found: 438.1388.

*6-bromo-4-((diphenylphosphoryl)methyl)-2-ethyl-4-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3n**)*



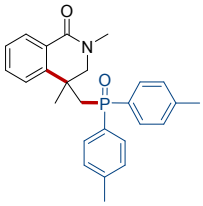
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.84 (d, *J* = 8.2 Hz, 1H), 7.69 - 7.61 (m, 4H), 7.48 - 7.38 (m, 7H), 7.31 (dd, *J* = 8.3, 1.9 Hz, 1H), 3.84 - 3.69 (m, 2H), 3.53 - 3.37 (m, 2H), 2.66 - 2.56 (m, 2H), 1.56 (s, 3H), 1.22 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 163.1, 146.6 (d, *J* = 9.7 Hz), 134.9 (d, *J* = 99.6 Hz), 132.8 (d, *J* = 97.9 Hz), 131.7 (d, *J* = 2.7 Hz), 131.5 (d, *J* = 2.8 Hz), 130.6, 130.47. (d, *J* = 99.6 Hz), 130.44, 130.0 (d, *J* = 9.2 Hz), 128.8 (d, *J* = 11.1 Hz), 128.6 (d, *J* = 11.1 Hz), 127.5, 127.1, 127.0, 56.3 (d, *J* = 5.9 Hz), 42.1, 37.6, 37.4(d, *J* = 3.3 Hz), 37.2 (d, *J* = 68.7 Hz), 36.9, 23.0 (d, *J* = 2.1 Hz), 12.5; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.17; HRMS Calcd for $C_{25}H_{26}BrNO_2P$ $[M + H]^+$: 482.0879, found: 482.0876.

*2-cyclopropyl-4-((diphenylphosphoryl)methyl)- 4-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3o**)*



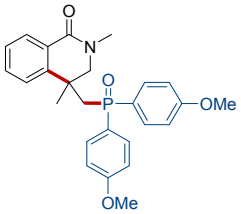
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.69 - 7.58 (m, 4H), 7.47 - 7.37 (m, 6H), 7.32 - 7.28 (m, 1H), 7.25 - 7.19 (m, 2H), 3.90 (d, *J* = 12.6 Hz, 1H), 3.43 (d, *J* = 12.6 Hz, 1H), 2.92 - 2.87 (m, 1H), 2.64 - 2.48 (m, 2H), 1.53 (s, 3H), 1.04 - 0.75 (m, 4H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 166.0, 145.0 (d, *J* = 10.0 Hz), 135.2 (d, *J* = 99.0 Hz), 133.1 (d, *J* = 97.8 Hz), 132.2, 131.6 (d, *J* = 2.7 Hz), 131.4 (d, *J* = 2.7 Hz), 130.6 (d, *J* = 9.0 Hz), 129.9 (d, *J* = 9.2 Hz), 128.8, 128.7 (d, *J* = 2.0 Hz), 128.5 (d, *J* = 1.7 Hz), 128.3, 127.3, 123.9, 57.0 (d, *J* = 5.0 Hz), 37.5 (d, *J* = 3.6 Hz), 37.1 (d, *J* = 68.3 Hz), 30.1, 23.1 (d, *J* = 2.4 Hz), 7.2, 6.1; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.49; HRMS Calcd for $C_{26}H_{27}NO_2P$ $[M + H]^+$: 416.1774, found: 416.1780

*4-((di-p-tolylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3p**)*



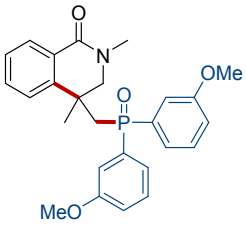
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.04 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.57 - 7.51 (m, 4H), 7.36 - 7.32 (m, 1H), 7.29 - 7.25 (m, 2H), 7.24 - 7.20 (m, 4H), 3.85 (d, *J* = 12.7 Hz, 1H), 3.49 (d, *J* = 12.7 Hz, 1H), 3.00 (s, 3H), 2.72 - 2.65 (m, 1H), 2.50 - 2.44 (m, 1H), 2.37 (s, 3H), 2.35 (s, 3H), 1.56 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 145.8 (d, *J* = 10.9 Hz), 142.1 (d, *J* = 2.8 Hz), 141.8 (d, *J* = 2.8 Hz), 132.1, 130.5 (d, *J* = 9.4 Hz), 130.5 (d, *J* = 101.0 Hz), 130.2 (d, *J* = 9.6 Hz), 131.7 (d, *J* = 102.0 Hz), 129.4 (d, *J* = 12.1 Hz), 129.3, 128.6, 127.8, 127.1, 123.7, 57.9 (d, *J* = 4.4 Hz), 38.1 (d, *J* = 67.4 Hz), 37.4 (d, *J* = 3.6 Hz), 34.8, 23.1 (d, *J* = 2.1 Hz), 21.5; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.80; HRMS Calcd for $C_{26}H_{29}NO_2P$ $[M + H]^+$: 418.1930, found: 418.1920.

*4-((bis(4-methoxyphenyl)phosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3q**)*



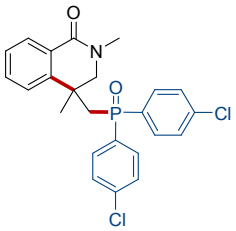
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.03 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.58 - 7.52 (m, 4H), 7.36 - 7.32 (m, 1H), 7.27 - 7.23 (m, 2H), 6.94 - 6.89 (m, 4H), 3.85 - 3.82 (m, 4H), 3.80 (s, 3H), 3.48 (d, *J* = 12.7 Hz, 1H), 3.02 (s, 3H), 2.64 (m, 1H), 2.43 (m, 1H), 1.56 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 162.2 (d, *J* = 2.8 Hz), 162.0 (d, *J* = 3.0 Hz), 145.7 (d, *J* = 10.7 Hz), 133.8 (d, *J* = 11.2 Hz), 132.3 (d, *J* = 10.4 Hz), 132.0 (d, *J* = 10.1 Hz), 128.6, 127.8, 127.2, 126.3 (d, *J* = 105.3 Hz), 124.8 (d, *J* = 104.5 Hz), 123.8, 114.3 (d, *J* = 9.6 Hz), 114.1 (d, *J* = 9.6 Hz), 58.0 (d, *J* = 4.6 Hz), 55.3 (d, *J* = 1.6 Hz), 38.3 (d, *J* = 68.2 Hz), 37.4 (d, *J* = 3.6 Hz), 34.9, 23.1; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.80; HRMS Calcd for $C_{26}H_{29}NO_4P$ $[M + H]^+$: 450.1829, found: 450.1826.

*4-((bis(3-methoxyphenyl)phosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3r**)*



^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.01 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.35 - 7.15 (m, 9H), 7.00 - 6.94 (m, 2H), 3.81 - 3.77 (m, 7H), 3.50 (d, *J* = 12.7 Hz, 1H), 3.03 (s, 3H), 2.70 - 2.63 (m, 1H), 2.56 – 2.51 (m, 1H), 1.59 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 159.7 (d, *J* = 15.2 Hz), 159.5, (d, *J* = 14.1 Hz), 145.3 (d, *J* = 10.3 Hz), 136.1 (d, *J* = 97.9 Hz), 134.7 (d, *J* = 97.1 Hz), 132.0, 130.0 (d, *J* = 13.6 Hz), 129.8 (d, *J* = 13.8 Hz), 128.5, 127.9, 127.3, 123.9, 122.5 (d, *J* = 9.2 Hz), 122.1 (d, *J* = 9.3 Hz), 117.7 (d, *J* = 2.8 Hz), 117.5 (d, *J* = 2.7 Hz), 115.3 (d, *J* = 4.5 Hz), 115.2 (d, *J* = 4.3 Hz), 58.2 (d, *J* = 5.2 Hz), 55.4 (d, *J* = 1.8 Hz), 37.9 (d, *J* = 67.7 Hz), 37.4 (d, *J* = 3.7 Hz), 34.9, 23.1 (d, *J* = 2.1 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.46; HRMS Calcd for $C_{26}H_{29}NO_4P$ $[M + H]^+$: 450.1829, found: 450.1825.

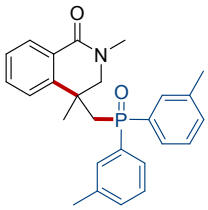
*4-((bis(4-chlorophenyl)phosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one (**3s**)*



^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.99 (dd, *J* = 7.2, 1.4 Hz, 1H), 7.56 - 7.46 (m, 4H), 7.40 (dd, *J* = 8.5, 2.4 Hz, 2H), 7.33 (dd, *J* = 8.5, 2.4 Hz, 2H), 7.28 - 7.23 (m, 3H), 3.66 (d, *J* = 12.7 Hz, 1H), 3.54 (dd, *J* = 12.8, 2.0 Hz, 1H), 3.07 (s, 3H), 2.59 (d, *J* = 10.5 Hz, 2H), 1.62 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 144.2 (d, *J* = 9.0 Hz), 138.5 (d, *J* = 3.3 Hz), 138.2 (d, *J* = 3.5 Hz), 133.0 (d, *J* =

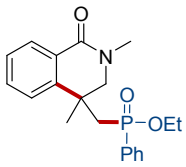
100.3 Hz), 132.1, 131.8 (d, *J* = 10.0 Hz), 131.4 (d, *J* = 10.1 Hz), 131.1 (d, *J* = 100.0 Hz), 129.2 (d, *J* = 12.2 Hz), 129.0 (d, *J* = 12.3 Hz), 128.6, 127.9, 127.5, 124.2, 58.9 (d, *J* = 6.7 Hz), 37.9 (d, *J* = 69.4 Hz), 37.4 (d, *J* = 3.6 Hz), 35.0, 23.2 (d, *J* = 2.1 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 26.64; HRMS Calcd for $C_{24}H_{23}Cl_2NO_2P$ $[M + H]^+$: 458.0838, found: 458.0831.

4-((di-m-tolylphosphoryl)methyl)-2,4-dimethyl-3,4-dihydroisoquinolin-1(2H)-one ***(3t)***



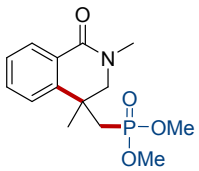
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.04 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.53 - 7.39 (m, 4H), 7.33 - 7.22 (m, 7H), 3.77 (d, *J* = 12.7 Hz, 1H), 3.50 (d, *J* = 12.7 Hz, 1H), 3.01 (s, 3H), 2.70 - 2.63 (m, 1H), 2.58 - 2.52 (m, 1H), 2.36 (s, 3H), 2.35 (s, 3H), 1.61 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 145.3 (d, *J* = 10.1 Hz), 138.7 (d, *J* = 11.5 Hz), 138.4 (d, *J* = 11.5 Hz), 134.8 (d, *J* = 98.1 Hz), 133.4 (d, *J* = 97.6 Hz), 132.4 (d, *J* = 2.9 Hz), 132.2 (d, *J* = 2.8 Hz), 132.0, 131.0 (d, *J* = 8.8 Hz), 130.6 (d, *J* = 9.0 Hz), 128.6 (d, *J* = 12.3 Hz), 128.5, 128.4 (d, *J* = 13.1 Hz), 127.9, 127.4 (d, *J* = 9.4 Hz), 127.3, 127.2 (d, *J* = 9.5 Hz), 123.9, 58.3 (d, *J* = 5.1 Hz), 37.9 (d, *J* = 67.3 Hz), 37.4 (d, *J* = 3.6 Hz), 34.8, 23.2 (d, *J* = 2.0 Hz), 21.4 (d, *J* = 3.1 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.52; HRMS Calcd for $C_{26}H_{29}NO_2P$ $[M + H]^+$: 418.1930, found: 418.1928.

ethyl-((-2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)(phenyl)phosphinate ***(3u)****, dr=1.15:1*



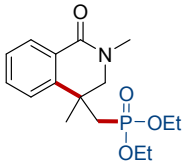
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.74 - 7.68 (m, 2H), 7.56 - 7.46 (m, 4H), 7.35 - 7.29 (m, 2H), 3.98 - 3.92 (m, 1H), 3.77 (d, *J* = 12.7 Hz, 1H), 3.71 - 3.65 (m, 1H), 3.49 (d, *J* = 12.7 Hz, 1H), 2.99 (s, 3H), 2.48 - 2.21 (m, 2H), 1.75 (s, 3H), 1.20 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.50, 164.45, 146.14, 146.01, 145.58, 145.45, 132.61, 132.38, 132.35, 132.19, 132.16, 132.07, 132.02, 131.99, 131.49, 131.39, 131.36, 131.26, 130.85, 128.86, 128.73, 128.67, 128.58, 128.54, 128.51, 127.81, 127.19, 127.15, 123.63, 123.58, 60.46, 60.43, 60.39, 60.36, 57.94, 57.89, 57.51, 57.47, 39.09, 38.62, 38.12, 37.65, 36.71, 36.67, 36.31, 36.29, 35.12, 34.75, 23.11, 23.09, 22.96, 22.94, 16.47, 16.40, 16.38, 16.32; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 40.54, 40.40; HRMS Calcd for $C_{20}H_{25}NO_3P$ $[M + H]^+$: 358.1567, found: 358.1563.

dimethyl((2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)phosphonate ***(3v)***



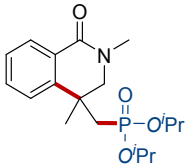
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.11 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.51 - 7.47 (m, 1H), 7.39-7.34 (m, 2H), 3.70 - 3.52 (m, 8H), 3.20 (s, 3H), 2.22 - 2.13 (m, 1H), 2.07 - 1.99 (m, 1H), 1.61 (s, 3H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 145.4 (d, *J* = 14.8 Hz), 132.1, 128.7, 128.0, 127.4, 123.7, 57.8 (d, *J* = 5.8 Hz), 52.2 (dd, *J* = 6.8, 1.6 Hz), 35.5 (d, *J* = 2.2 Hz), 35.1, 34.4, 33.1, 22.9 (d, *J* = 2.4 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 29.60; HRMS Calcd for $C_{14}H_{21}NO_4P$ $[M + H]^+$: 298.1203, found: 298.1194.

*diethyl((2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)phosphonate (**3w**)*



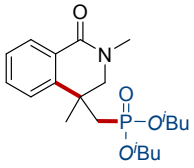
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.11 (dd, *J* = 8.2, 1.5 Hz, 1H), 7.50 - 7.46 (m, 1H), 7.38 - 7.34 (m, 2H), 4.06 - 3.94 (m, 4H), 3.73 (d, *J* = 12.7 Hz, 1H), 3.53 (d, *J* = 12.6 Hz, 1H), 3.20 (s, 3H), 2.21 - 1.98 (m, 2H), 1.61 (s, 3H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.24 (t, *J* = 7.1 Hz, 4H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 145.6 (d, *J* = 14.9 Hz), 132.0, 128.6, 128.0, 127.3, 123.7, 61.6 (d, *J* = 5.7 Hz), 61.5, (d, *J* = 6.1 Hz), 57.7 (d, *J* = 5.7 Hz), 35.6 (d, *J* = 2.3 Hz), 35.2 (d, *J* = 36.4 Hz), 23.0 (d, *J* = 2.4 Hz), 16.43 (d, *J* = 6.3 Hz), 16.35 (d, *J* = 6.3 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.01; HRMS Calcd for $C_{16}H_{25}NO_4P$ $[M + H]^+$: 326.1516, found: 326.1502.

*diisopropyl((2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)phosphonate (**3x**)*



^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.10 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.49 - 7.45 (m, 1H), 7.37 - 7.32 (m, 2H), 4.69 - 4.61 (m, 2H), 3.82 (d, *J* = 12.6 Hz, 1H), 3.50 (d, *J* = 12.6 Hz, 1H), 3.21 (s, 3H), 2.18 - 2.09 (m, 1H), 1.98 - 1.89 (m, 1H), 1.60 (s, 3H), 1.30 - 1.25 (m, 12H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 146.1 (d, *J* = 16.0 Hz), 132.1, 128.6, 127.9, 127.2, 123.6, 70.3 (d, *J* = 6.5 Hz), 70.2 (d, *J* = 7.0 Hz), 57.4 (d, *J* = 4.4 Hz), 36.1 (d, *J* = 137.4 Hz), 35.7 (d, *J* = 2.5 Hz), 35.1, 24.1 (d, *J* = 4.1 Hz), 24.1 (d, *J* = 5.2 Hz), 23.0 (d, *J* = 2.4 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 25.32; HRMS Calcd for $C_{18}H_{29}NO_4P$ $[M + H]^+$: 354.1829, found: 354.1830.

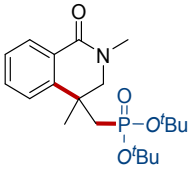
*diisobutyl((2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)phosphonate (**3y**)*



^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.11 (dd, *J* = 8.0, 1.5 Hz, 1H), 7.50 - 7.46 (m, 1H), 7.38 - 7.34 (m, 2H), 3.77 (d, *J* = 12.7 Hz, 1H), 3.74 - 3.65 (m, 4H), 3.53 (d, *J* = 12.7 Hz, 1H), 3.21 (s, 3H), 2.23 - 2.15 (m, 1H), 2.08 - 1.99 (m, 1H), 1.90 - 1.81 (m, 2H), 1.61 (s, 3H), 0.92 (d, *J* = 1.4 Hz, 6H), 0.90 (d, *J* = 1.5 Hz, 6H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 145.7 (d, *J* = 15.2 Hz), 132.1, 128.6, 127.9, 127.3, 123.7, 71.6 (d, *J* = 6.8 Hz), 71.5 (d, *J* = 7.2 Hz), 57.6 (d, *J* = 5.2 Hz), 35.5 (d, *J* = 2.2 Hz), 35.1,

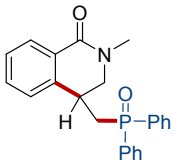
34.3 (d, *J* = 136.6 Hz), 29.2 (d, *J* = 6.4 Hz), 29.1, (d, *J* = 7.1 Hz),, 23.2 (d, *J* = 2.3 Hz), 18.80, 18.76; ^{31}P NMR (162 MHz, Chloroform-*d*) δ 27.10; HRMS Calcd for $C_{20}H_{33}NO_4P$ $[M + H]^+$: 382.2142, found: 382.2133.

*di-tert-butyl((2,4-dimethyl-1-oxo-1,2,3,4-tetrahydroisoquinolin-4-yl)methyl)phosphonate (**3z**)*



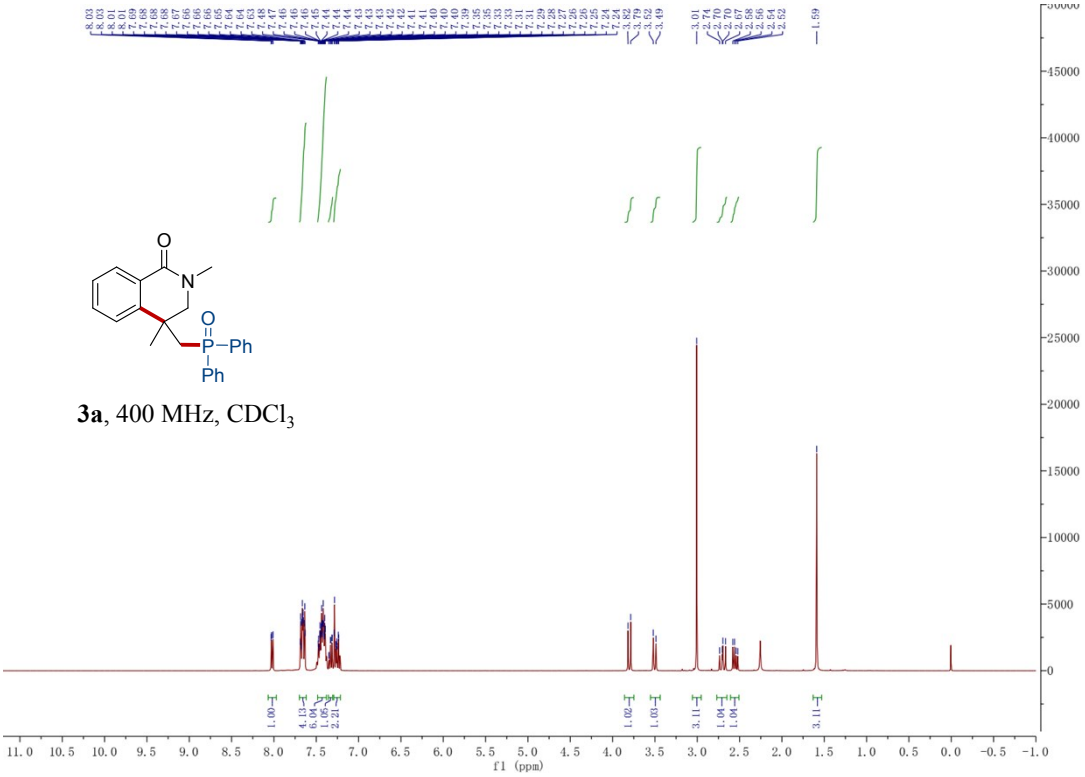
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.10 (dd, *J* = 7.6, 1.5 Hz, 1H), 7.49 - 7.45 (m, 1H), 7.36 - 7.31 (m, 2H), 3.95 (d, *J* = 12.6 Hz, 1H), 3.47 (d, *J* = 12.5 Hz, 1H), 3.21 (s, 3H), 2.16 - 2.08 (m, 1H), 1.91 - 1.82 (m, 1H), 1.58 (s, 3H), 1.49 (s, 9H), 1.45 (s, 9H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.6, 146.7 (d, *J* = 16.6 Hz), 132.0, 128.5, 127.9, 127.0, 123.6, 82.6 (d, *J* = 9.5 Hz), 82.2 (d, *J* = 8.2 Hz), 57.0 (d, *J* = 3.7 Hz), 38.7 (d, *J* = 141.1 Hz), 35.9 (d, *J* = 2.9 Hz), 35.0, 30.6 (d, *J* = 4.1 Hz), 30.4 (d, *J* = 3.8 Hz), 23.1 (d, *J* = 2.6 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 19.02; HRMS Calcd for $C_{20}H_{33}NO_4P$ $[M + H]^+$: 382.2142, found: 382.2149.

*4-((diphenylphosphoryl)methyl)-2-methyl-3,4-dihydroisoquinolin-1(2H)-one (**3aa**)*

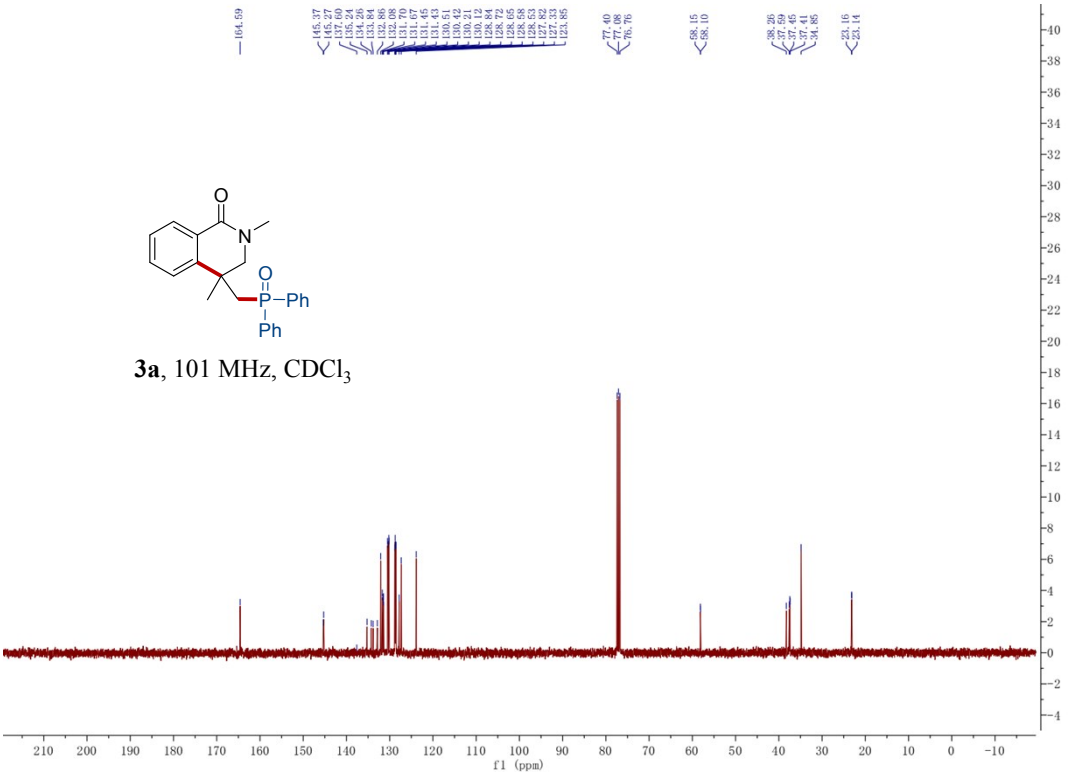


^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07 – 8.04 (m, 1H), 7.78 - 7.70 (m, 4H), 7.55 - 7.45 (m, 6H), 7.34 - 7.28 (m, 2H), 7.04 - 7.02 (m, 1H), 3.76 (dd, *J* = 12.9, 4.0 Hz, 1H), 3.59 (dd, *J* = 12.9, 2.2 Hz, 1H), 3.52 – 3.44 (m, 1H), 2.91 (s, 3H), 2.85 – 2.73 (m, 1H), 2.46 – 2.39 (m, 1H); ^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.5, 141.7 (d, *J* = 11.6 Hz), 133.7 (d, *J* = 98.4 Hz), 132.5 (d, *J* = 102.0 Hz), 132.0 (d, *J* = 2.7 Hz), 131.9 (d, *J* = 2.9 Hz), 130.6 (d, *J* = 9.2 Hz), 130.4 (d, *J* = 9.5 Hz), 128.9 (d, *J* = 8.3 Hz), 128.8 (d, *J* = 8.2 Hz), 128.4 (d, *J* = 2.0 Hz), 127.6, 126.2, 51.7 (d, *J* = 3.2 Hz), 35.1, 33.2 (d, *J* = 68.3 Hz), 32.5 (d, *J* = 2.7 Hz); ^{31}P NMR (162 MHz, Chloroform-*d*) δ 29.29; HRMS Calcd for $C_{23}H_{23}NO_2P$ $[M + H]^+$:376.1461, found: 376.1460

4. ^{1}H, ^{13}C and ^{31}P NMR spectra

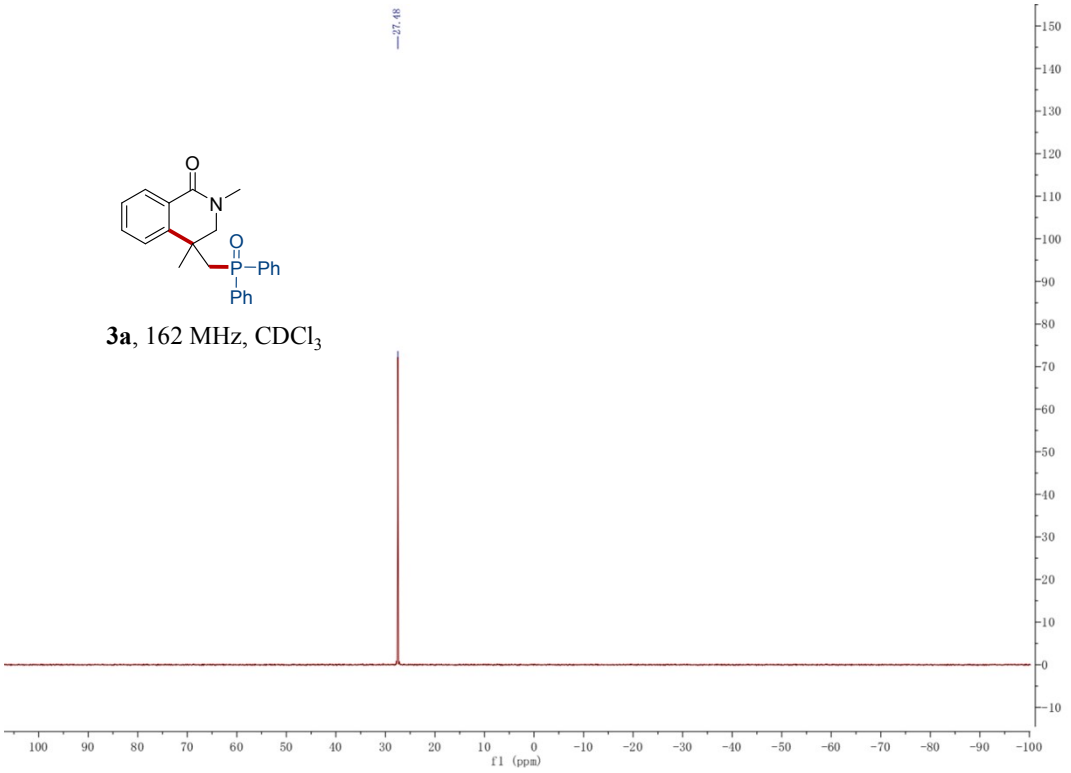


3a, 400 MHz, $CDCl_3$

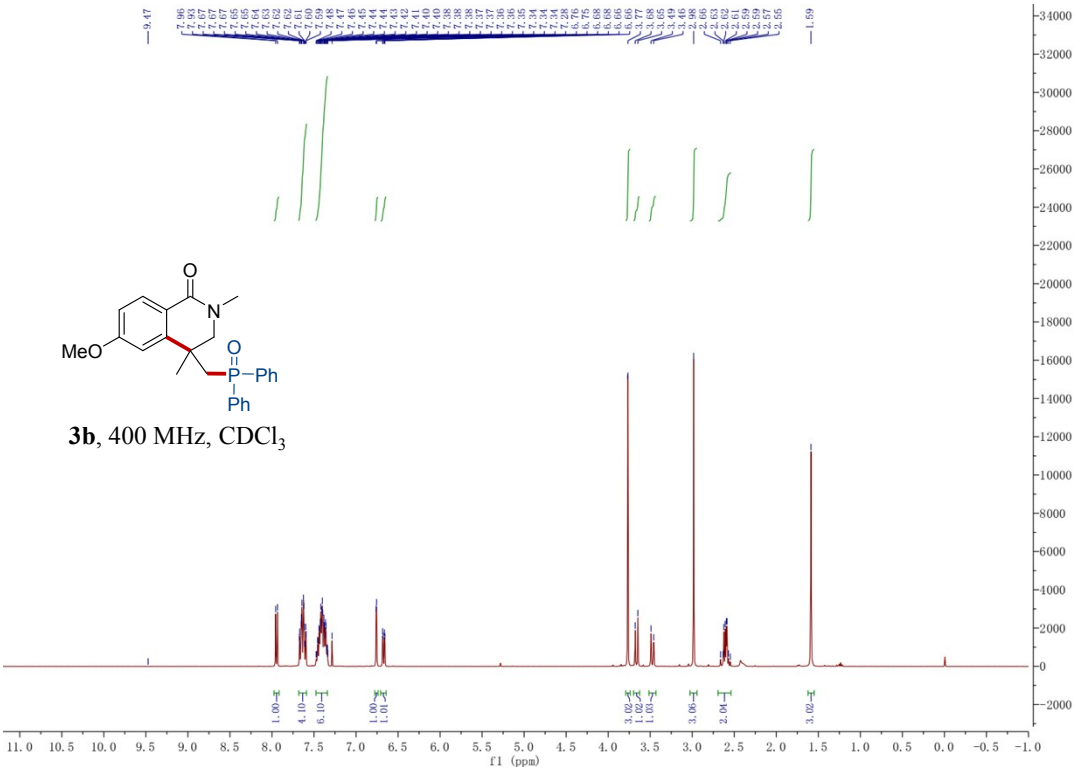


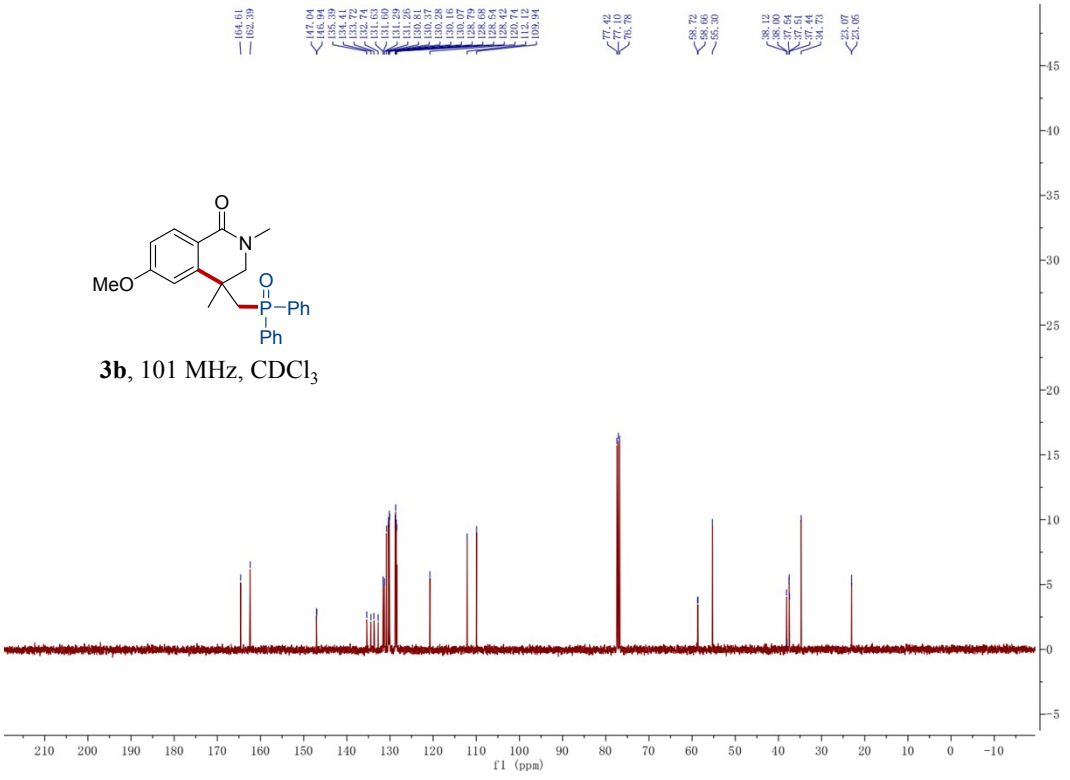
3a, 101 MHz, $CDCl_3$

3a, 162 MHz, $CDCl_3$

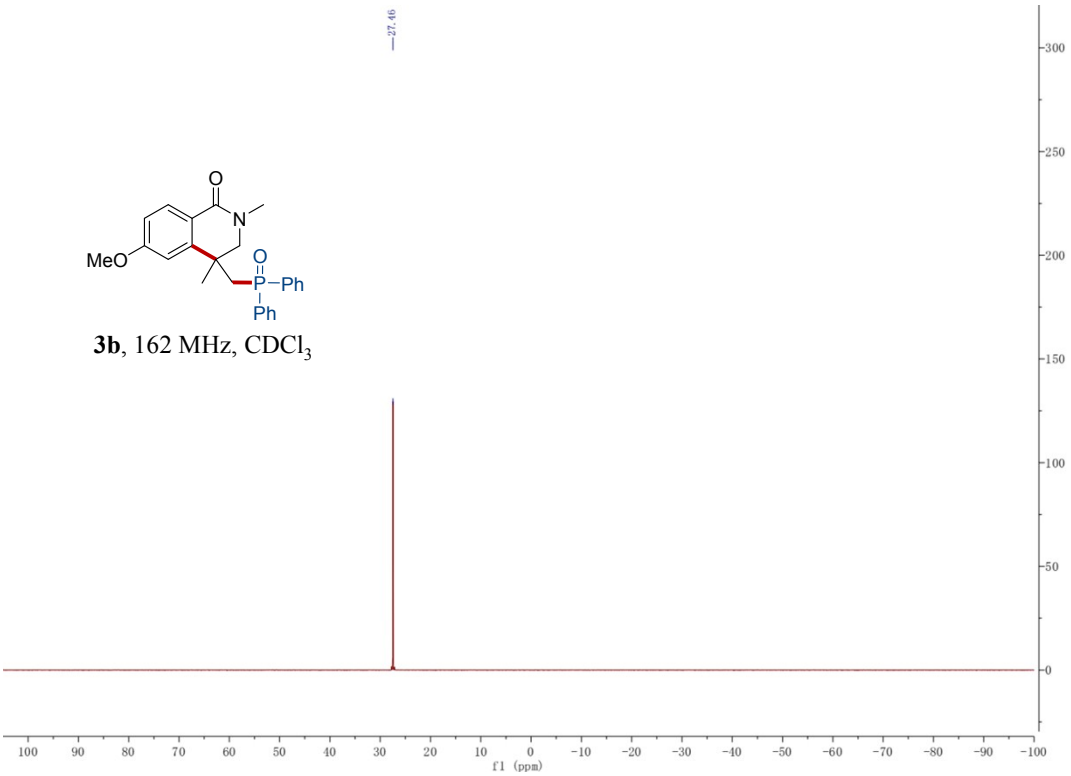


3b, 400 MHz, $CDCl_3$

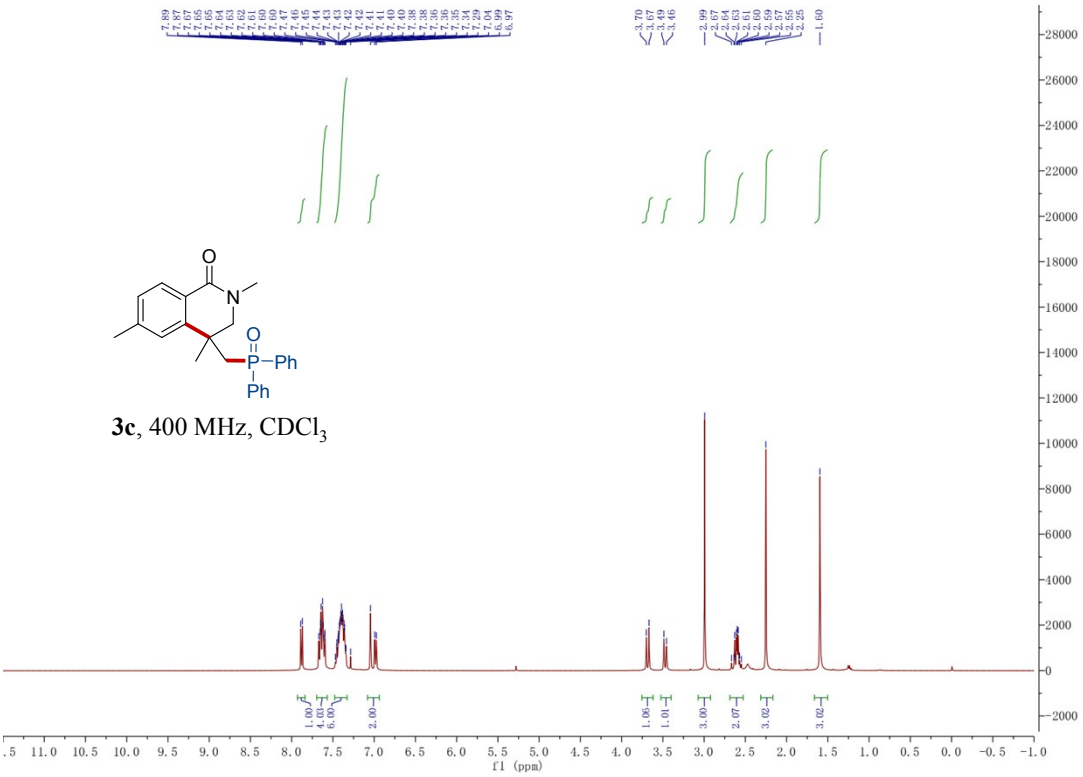




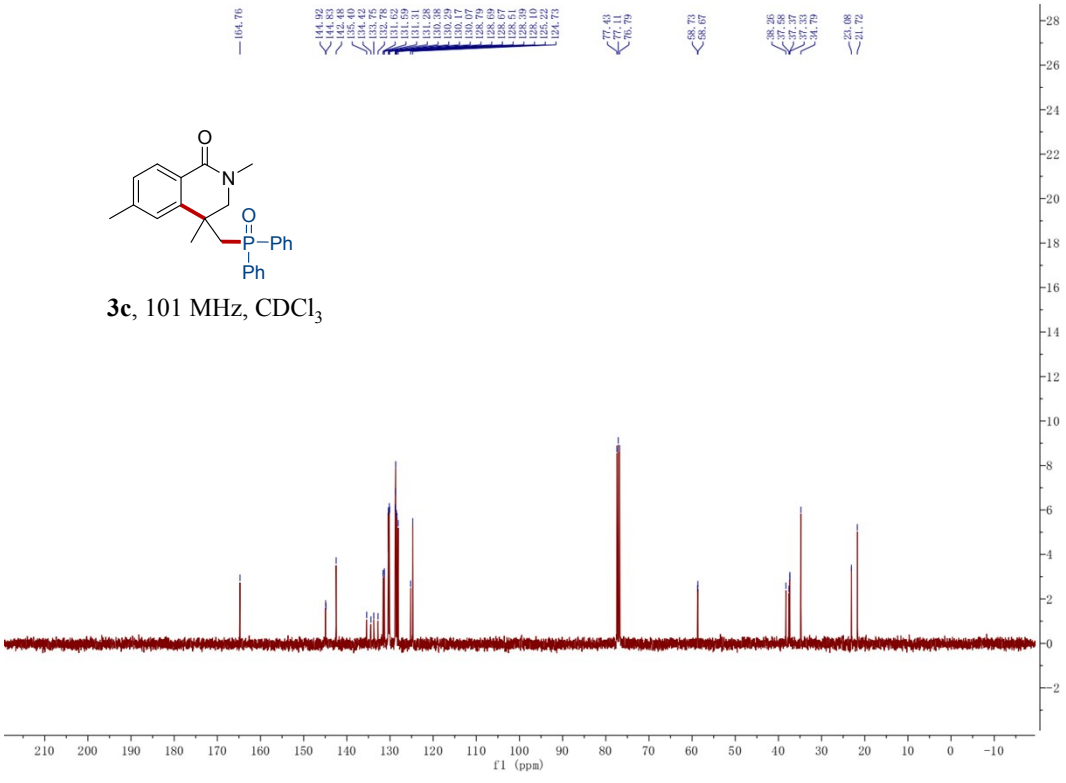
3b, 101 MHz, $CDCl_3$



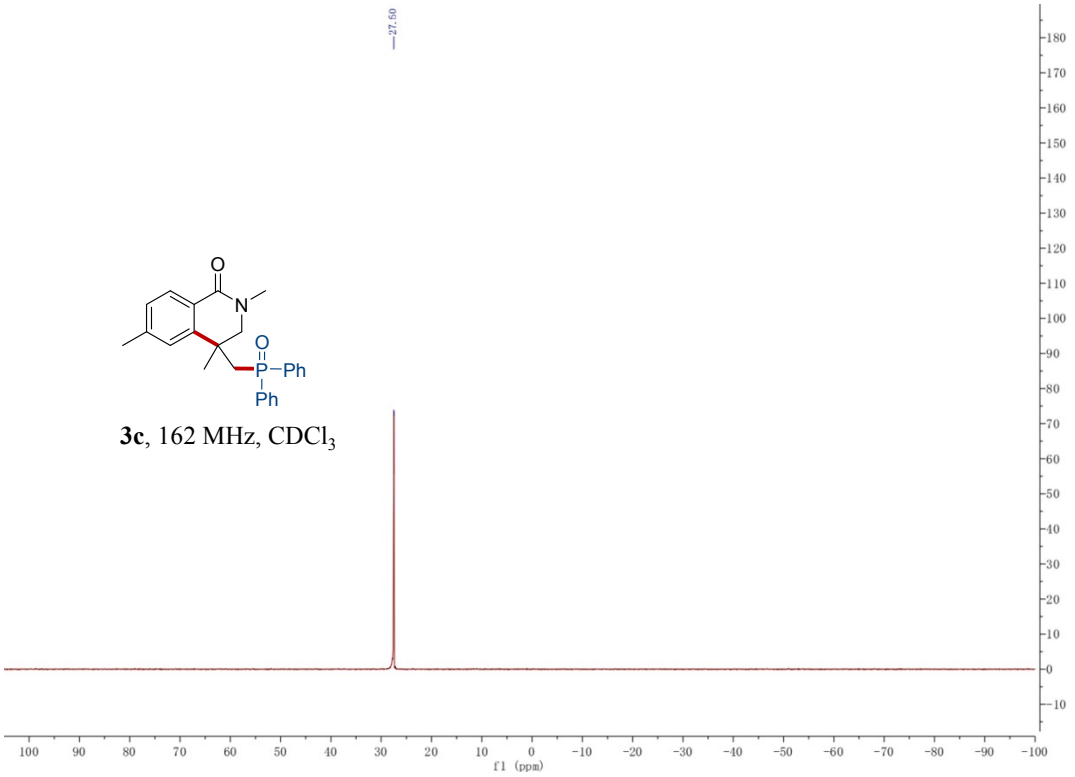
3b, 162 MHz, $CDCl_3$



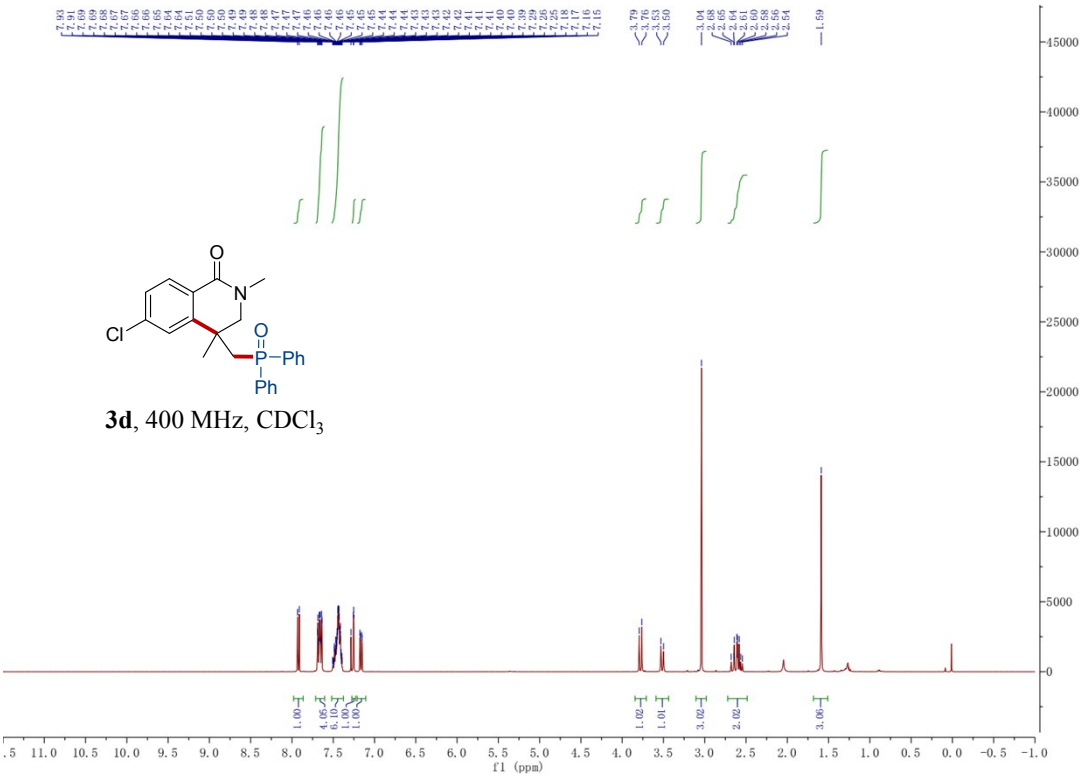
3c, 400 MHz, $CDCl_3$



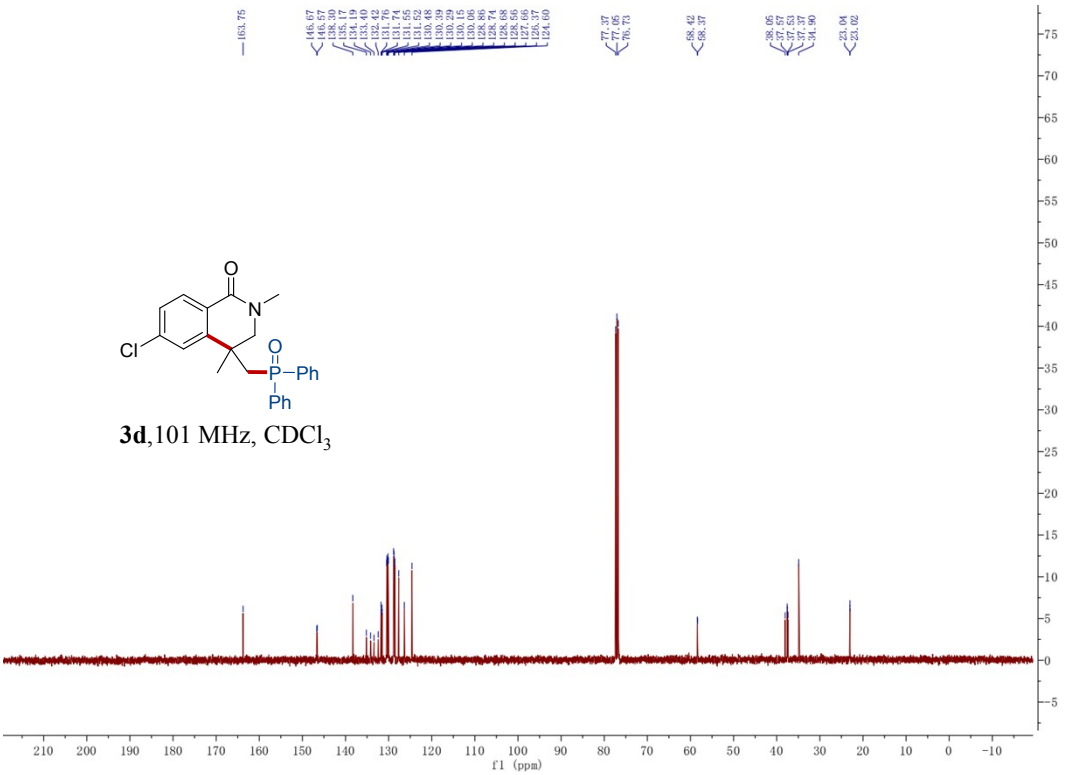
3c, 101 MHz, $CDCl_3$



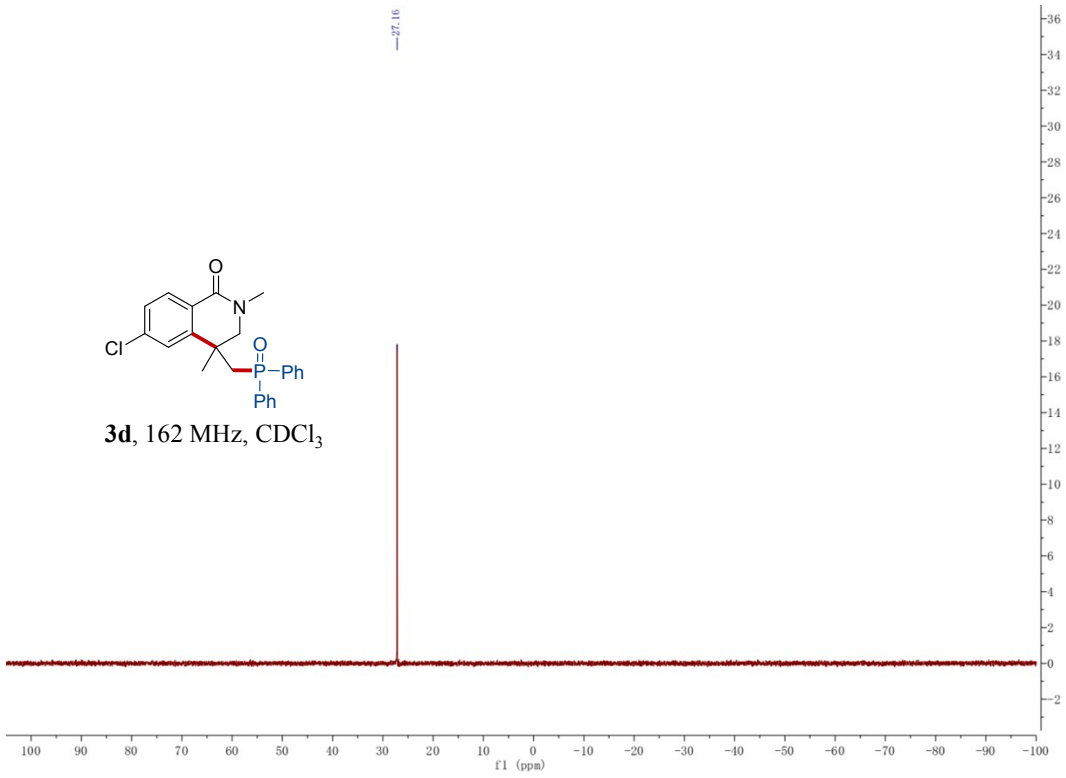
3c, 162 MHz, $CDCl_3$



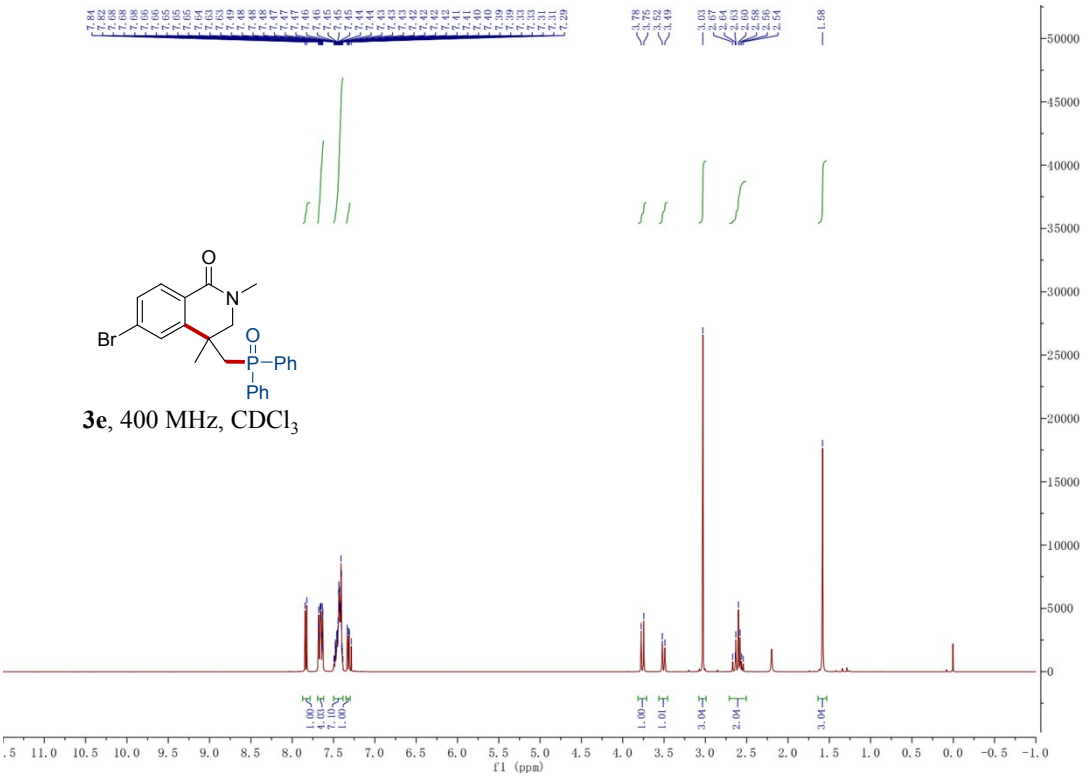
3d, 400 MHz, $CDCl_3$



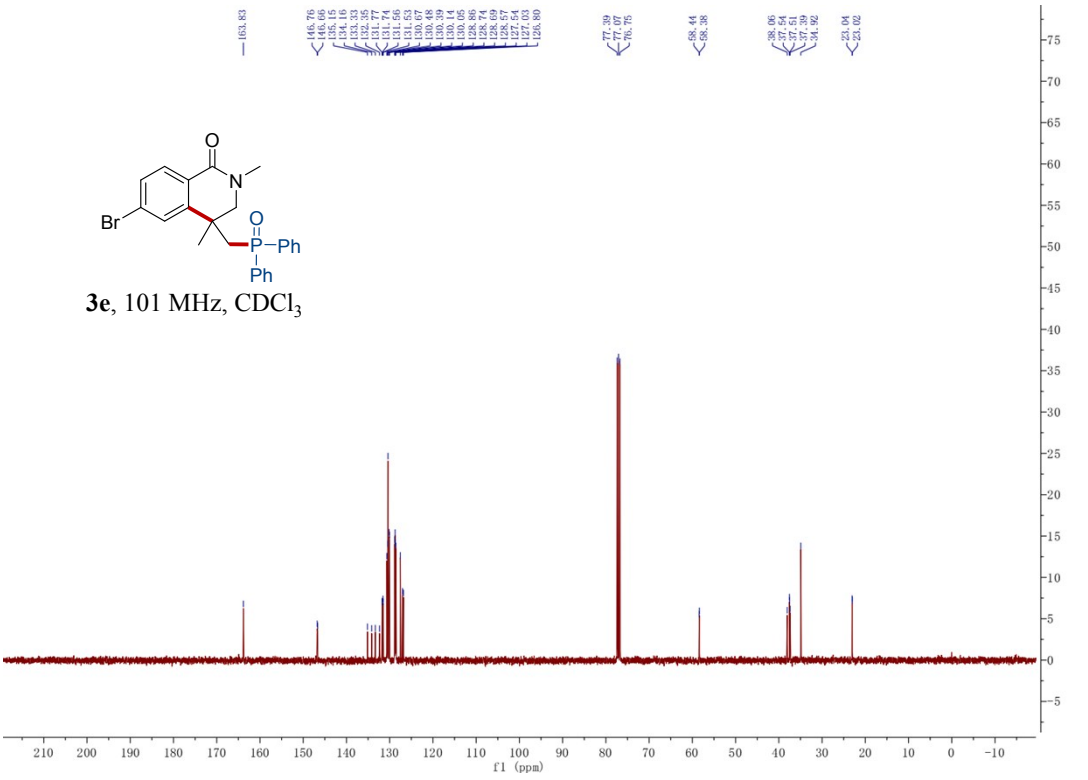
3d,101 MHz, $CDCl_3$



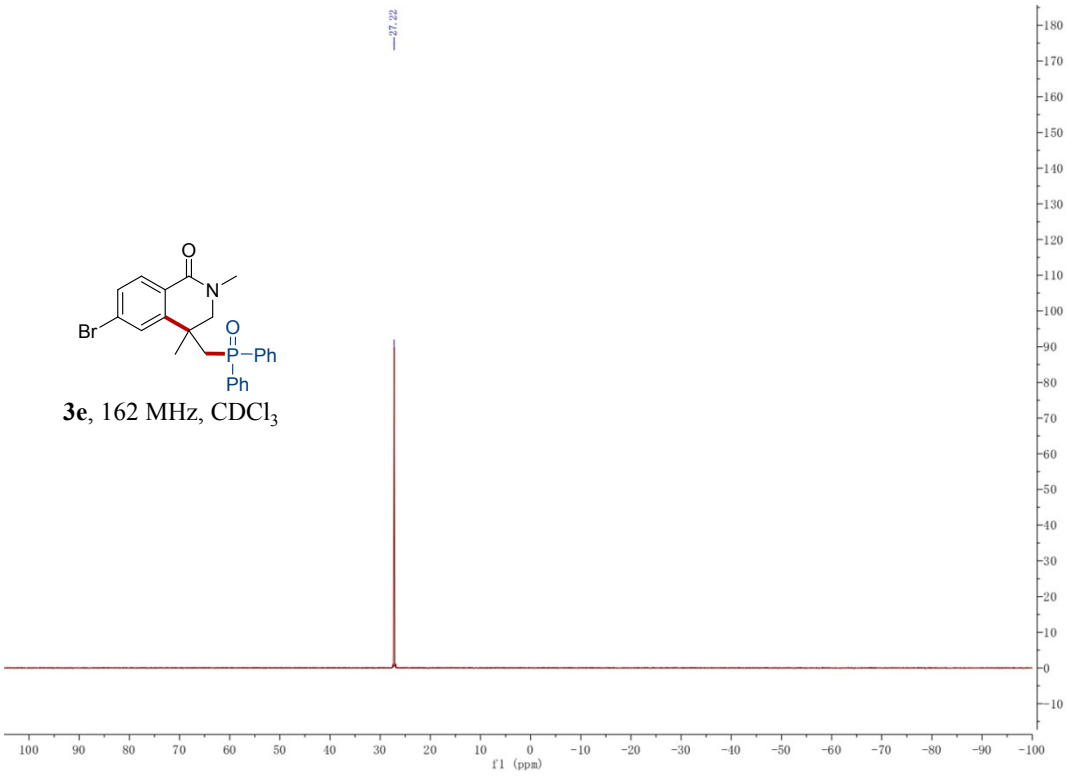
3d, 162 MHz, $CDCl_3$



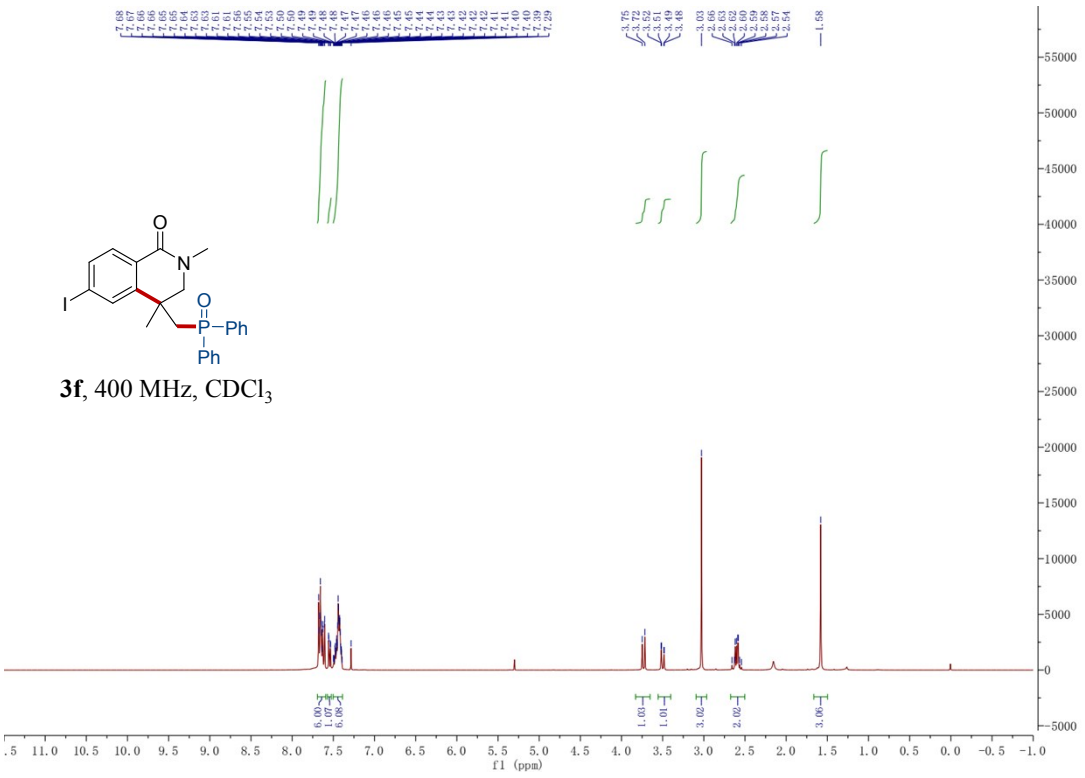
3e, 400 MHz, $CDCl_3$



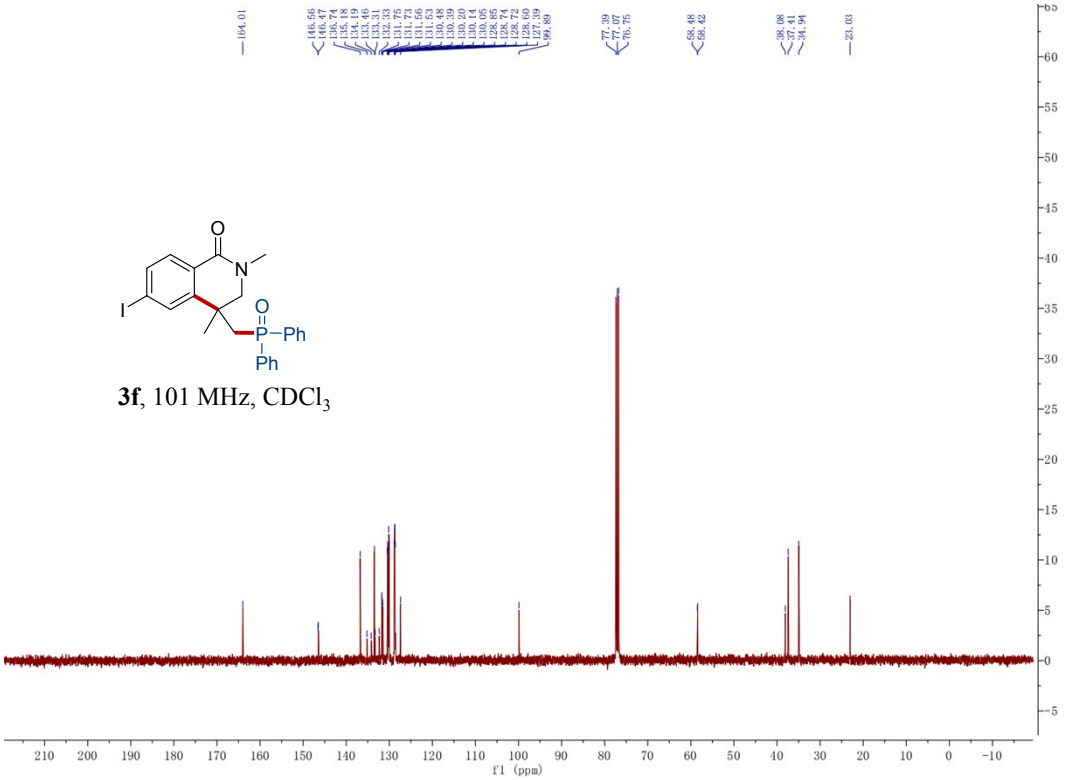
3e, 101 MHz, $CDCl_3$



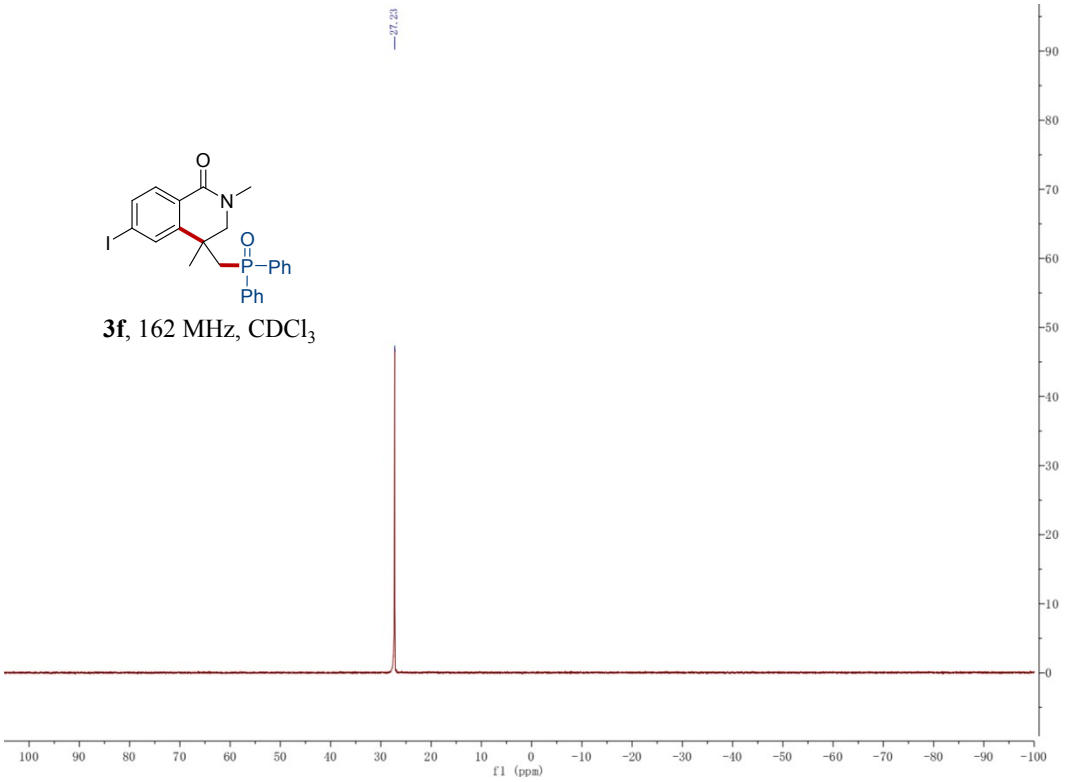
3e, 162 MHz, $CDCl_3$



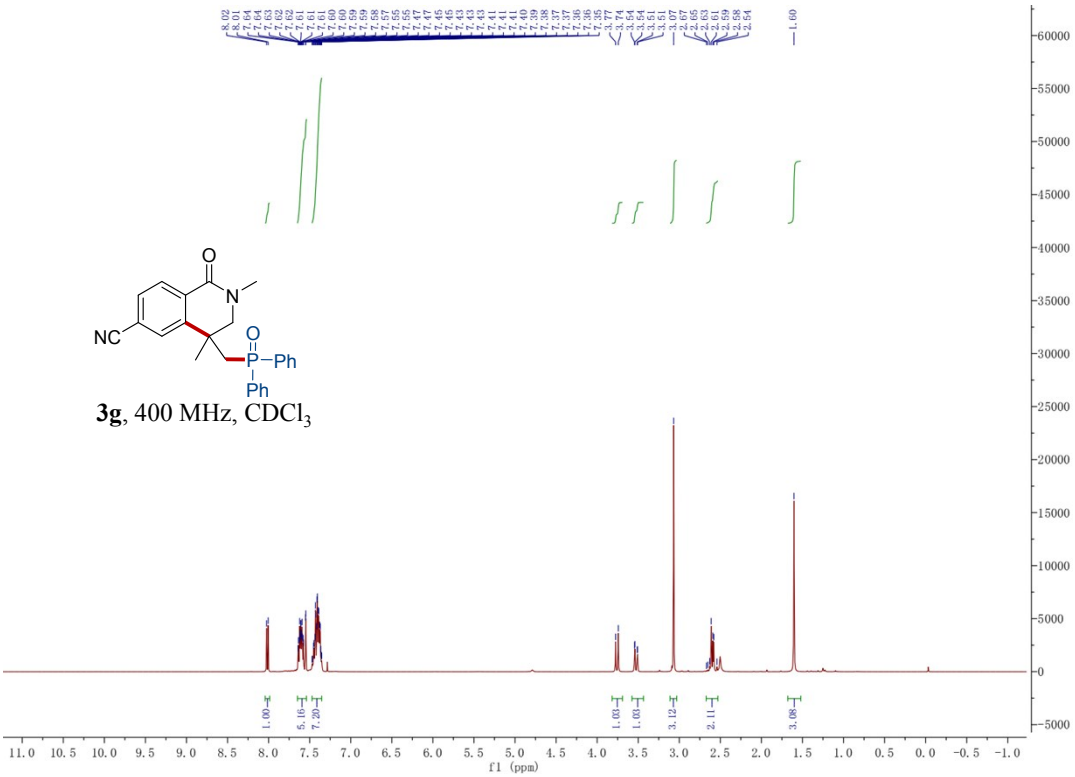
3f, 400 MHz, $CDCl_3$



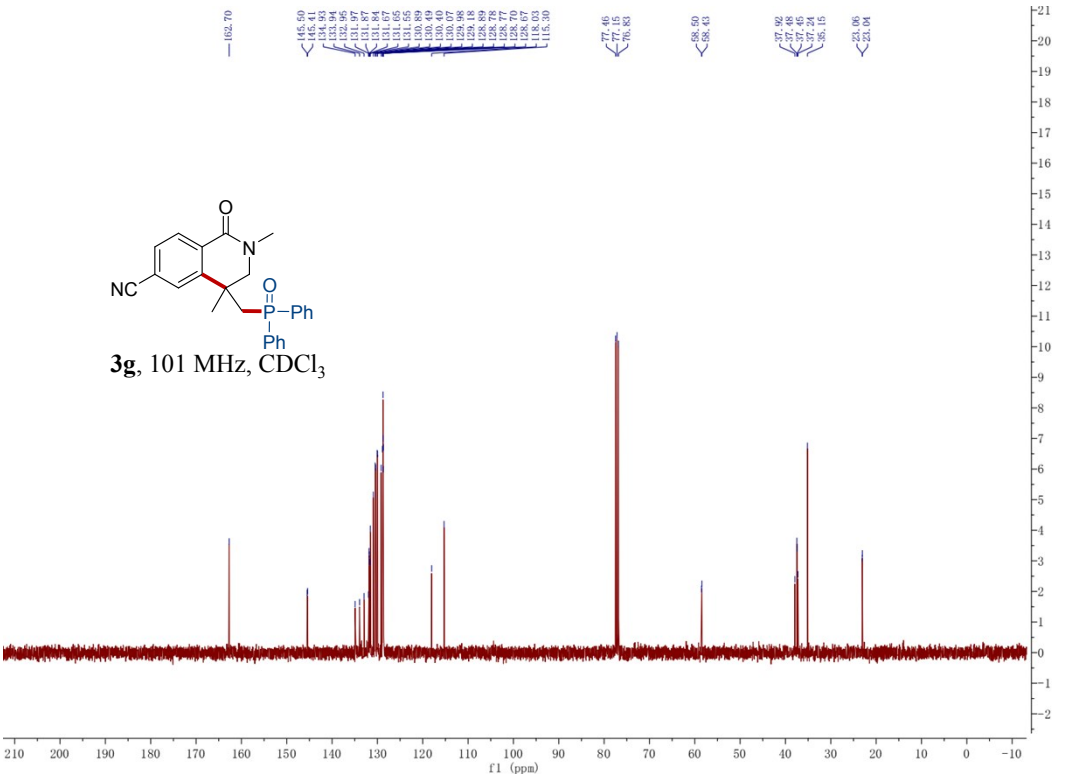
3f, 101 MHz, $CDCl_3$



3f, 162 MHz, $CDCl_3$

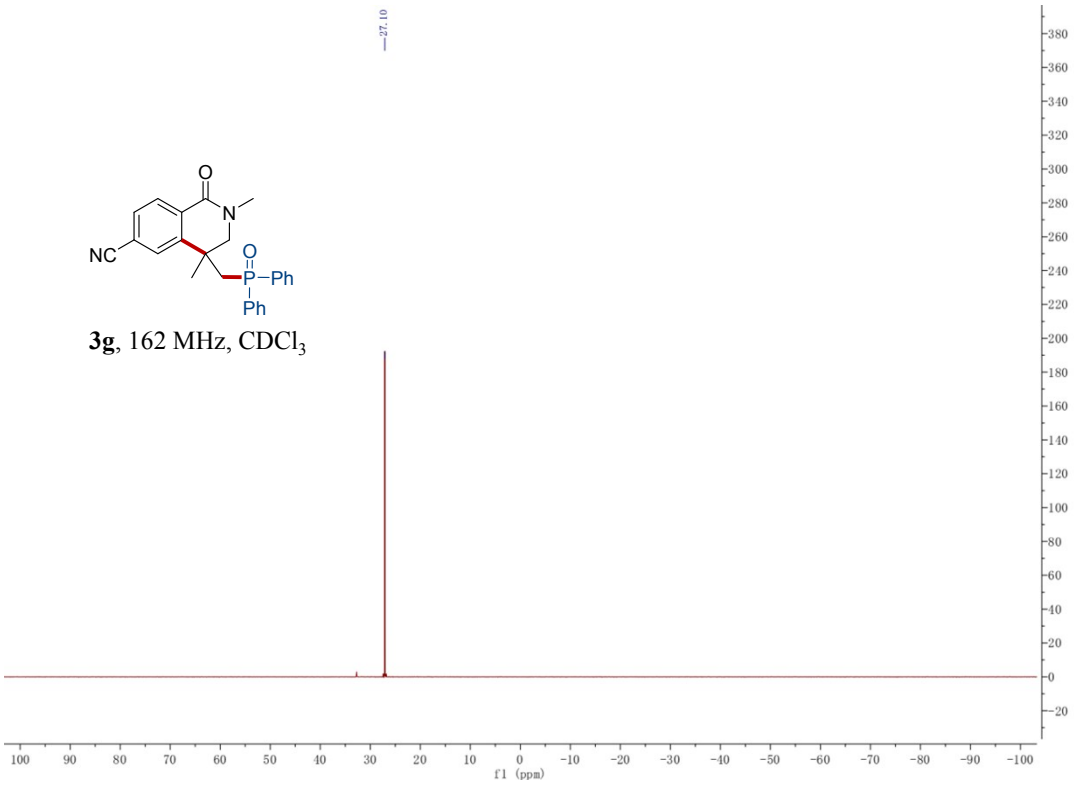


3g, 400 MHz, $CDCl_3$

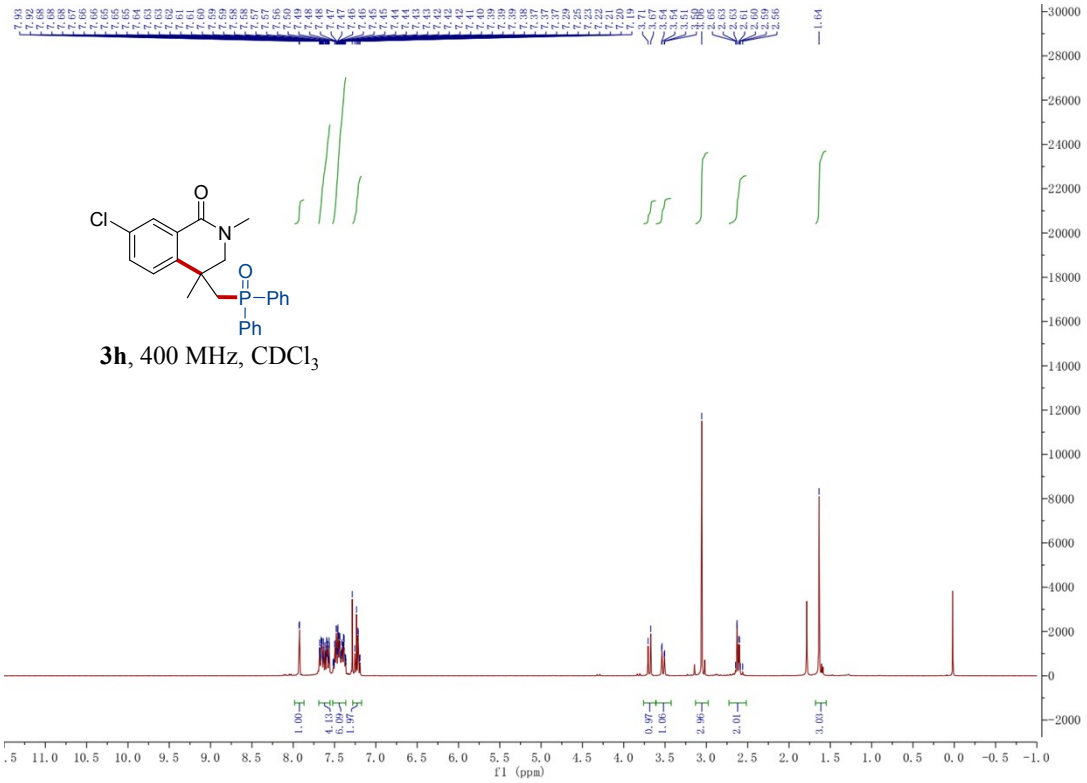


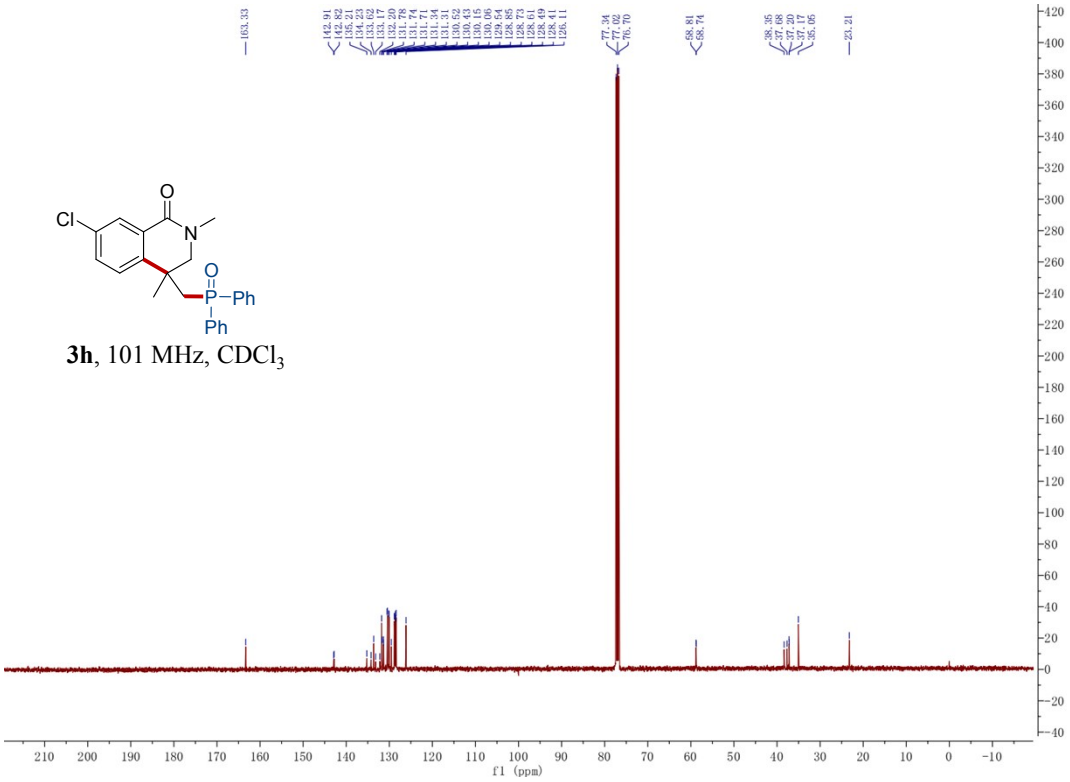
3g, 101 MHz, $CDCl_3$

3g, 162 MHz, $CDCl_3$

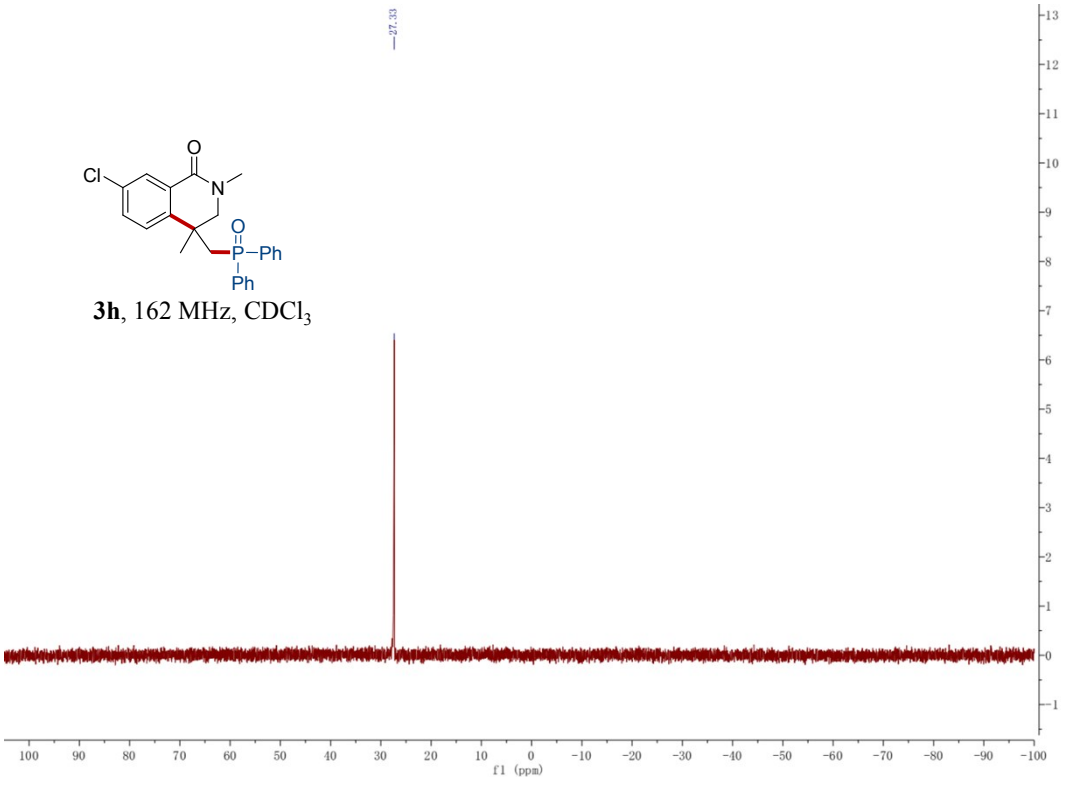


3h, 400 MHz, $CDCl_3$

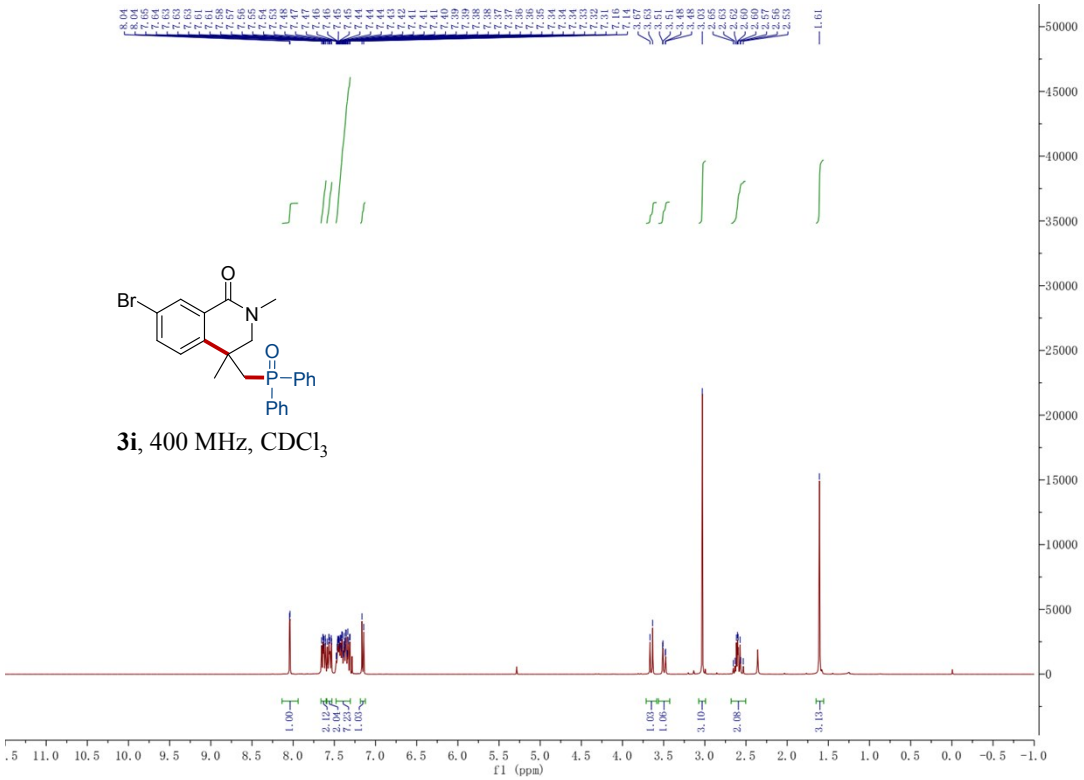




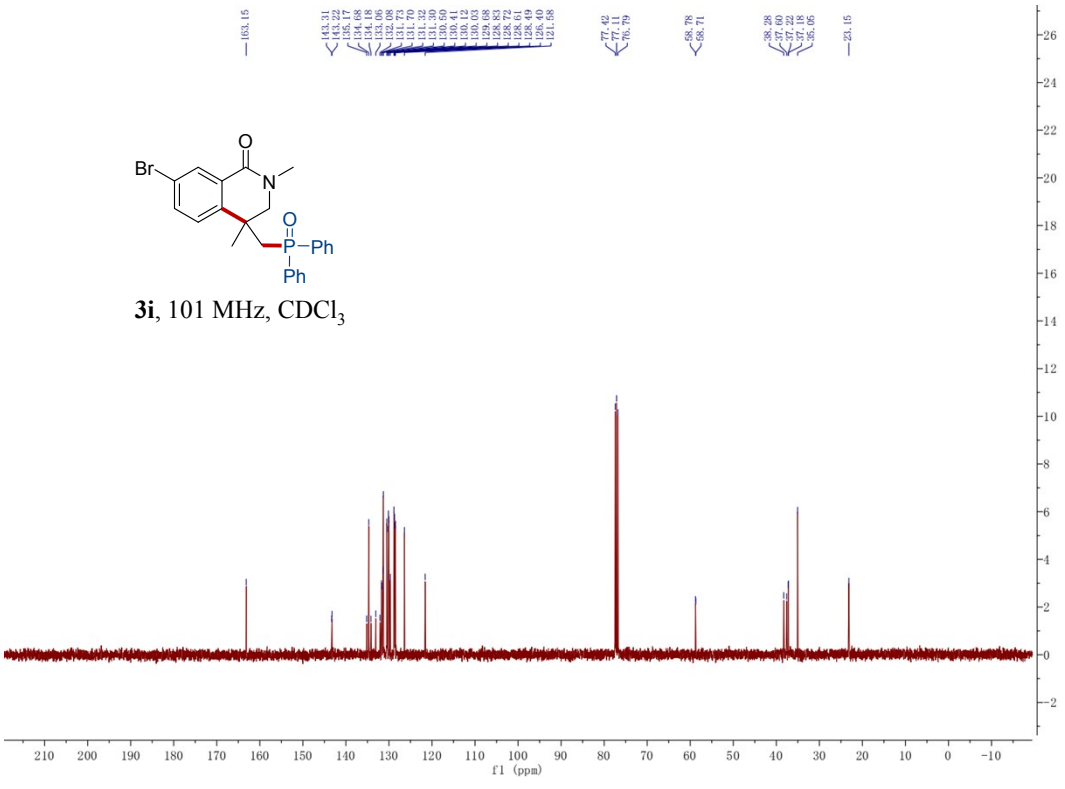
3h, 101 MHz, $CDCl_3$



3h, 162 MHz, $CDCl_3$

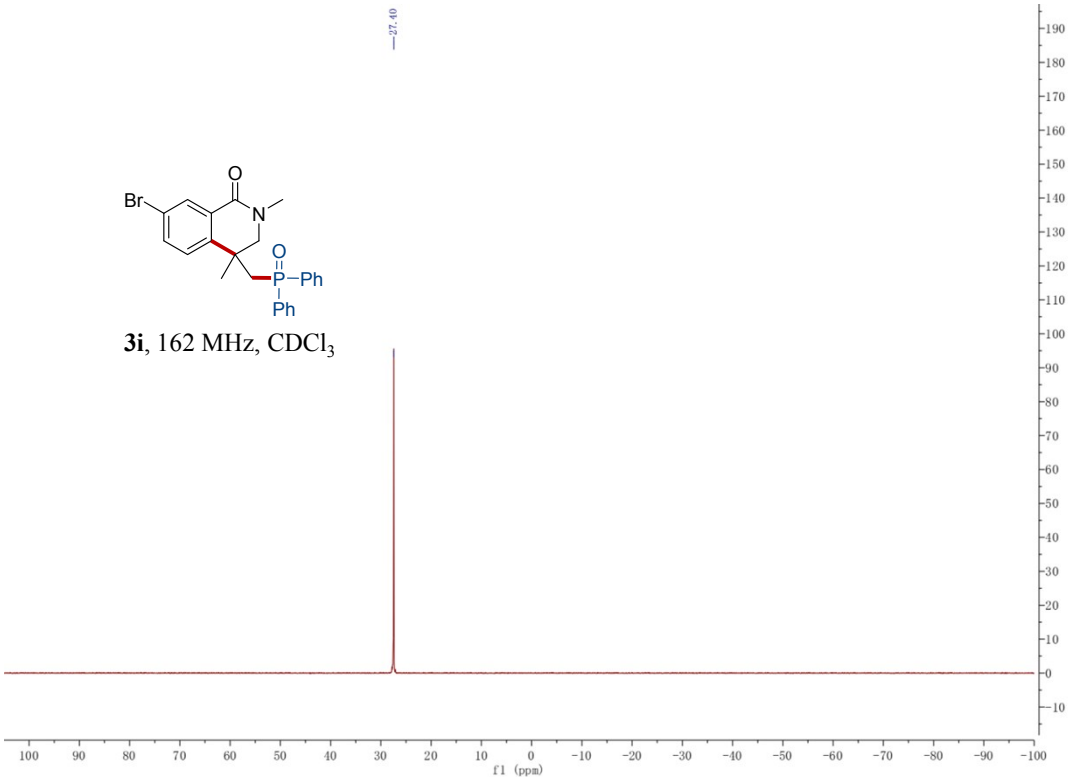


3i, 400 MHz, $CDCl_3$

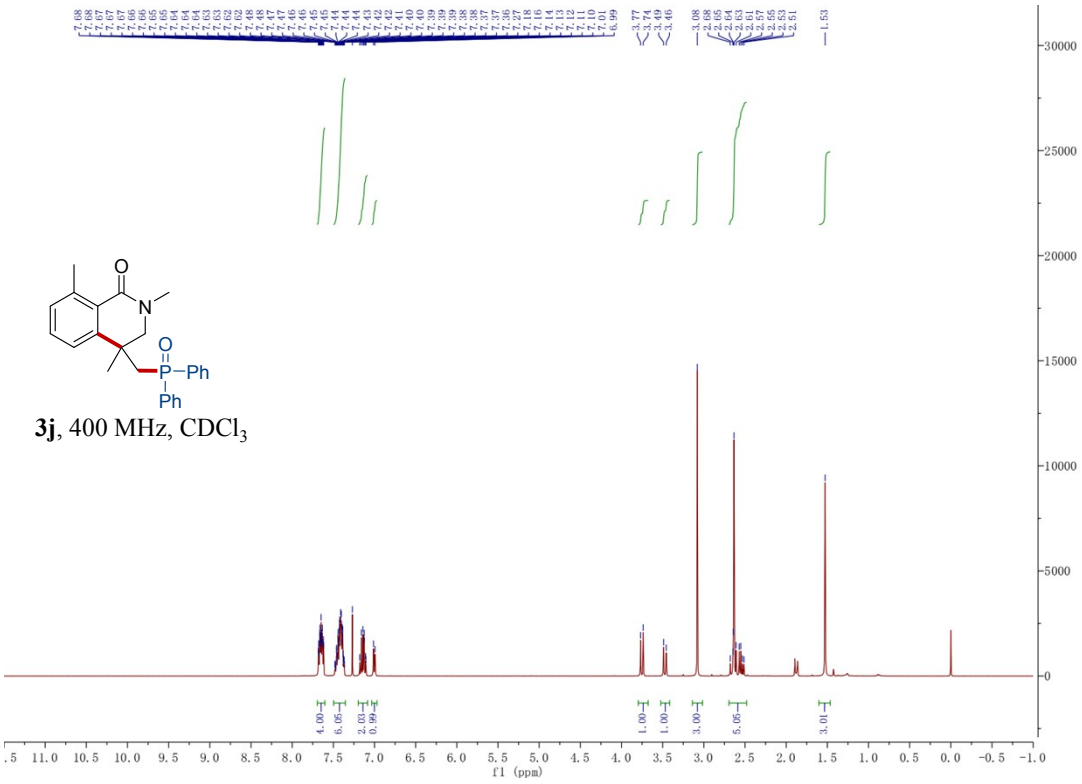


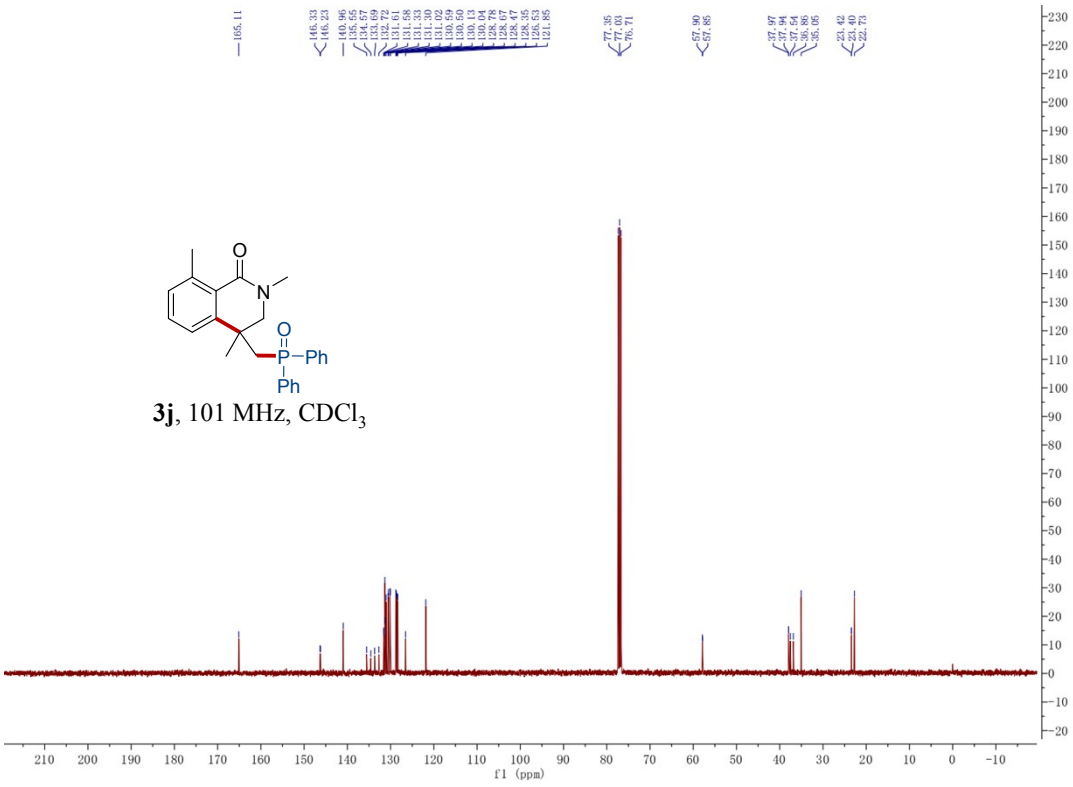
3i, 101 MHz, $CDCl_3$

3i, 162 MHz, $CDCl_3$

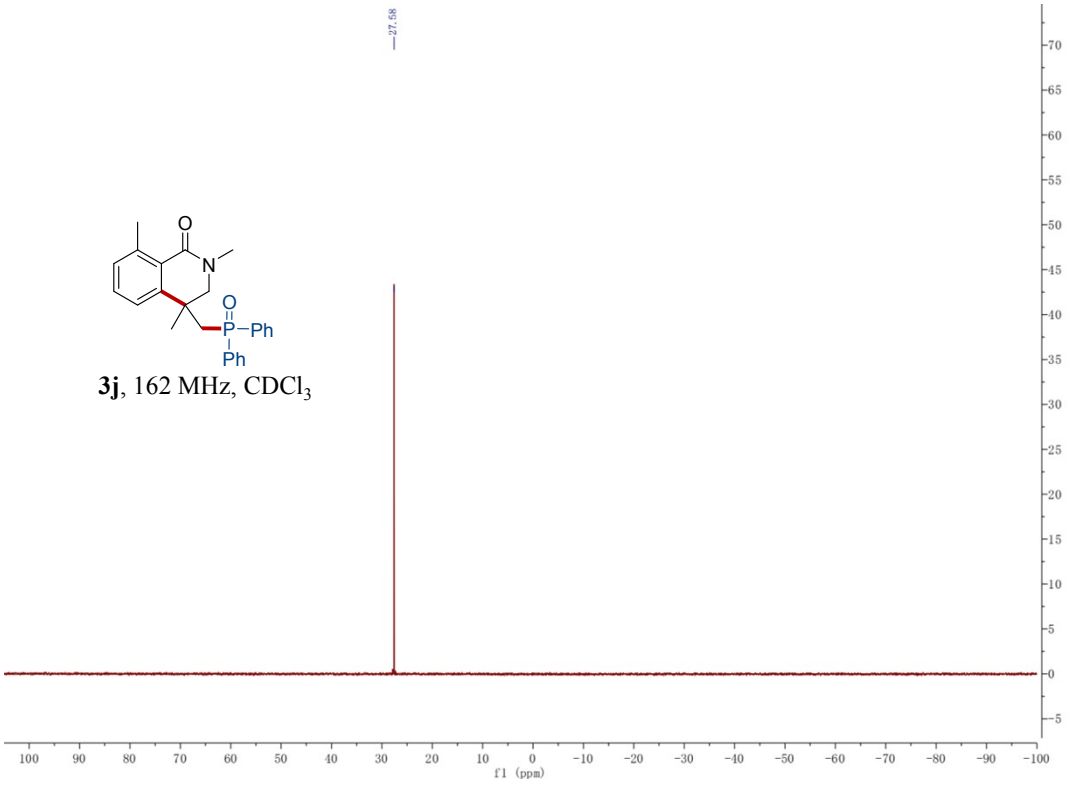


3j, 400 MHz, $CDCl_3$

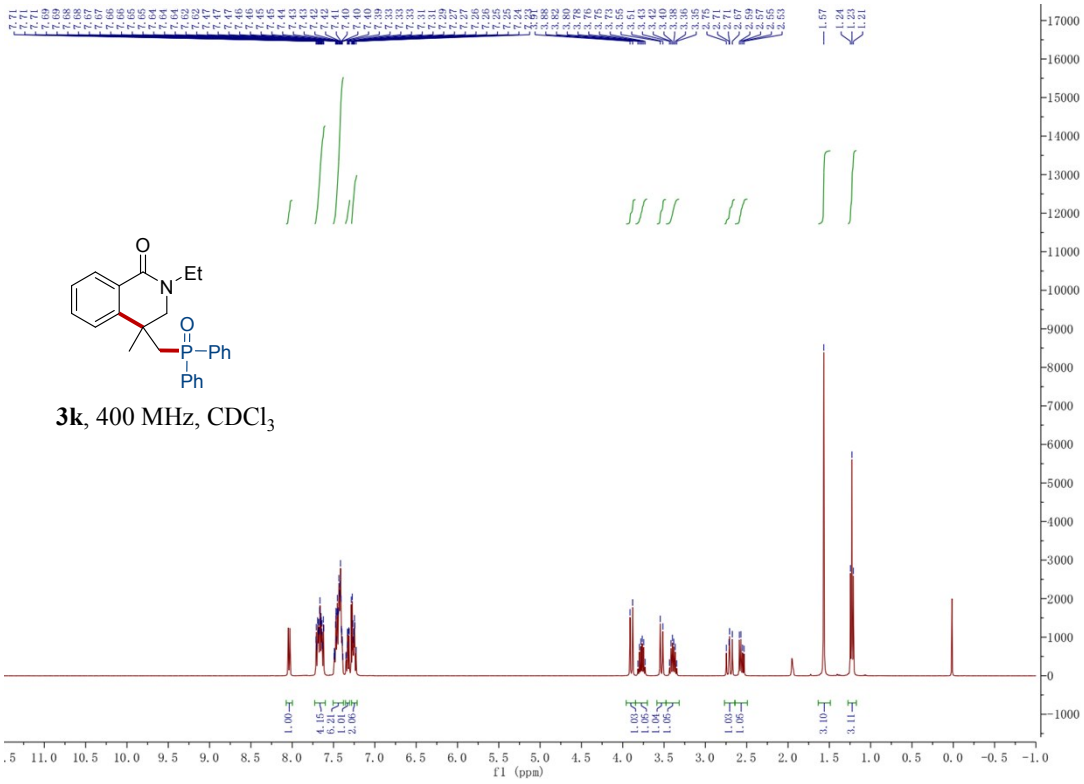




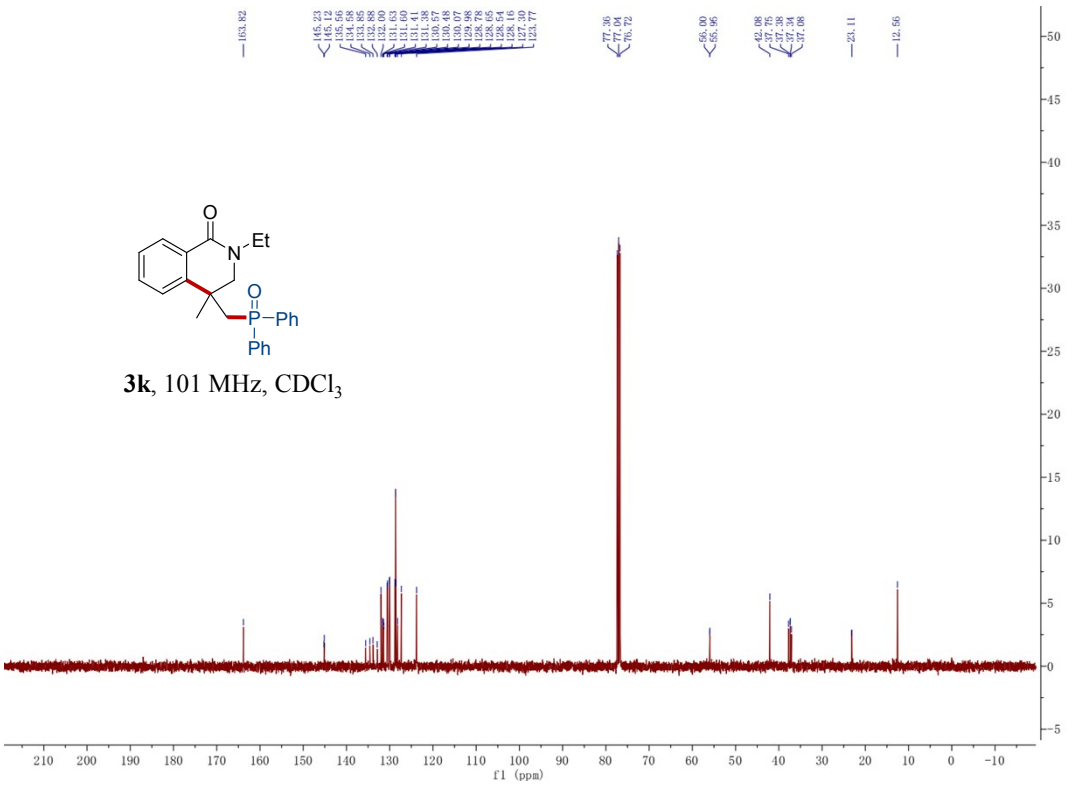
3j, 101 MHz, $CDCl_3$



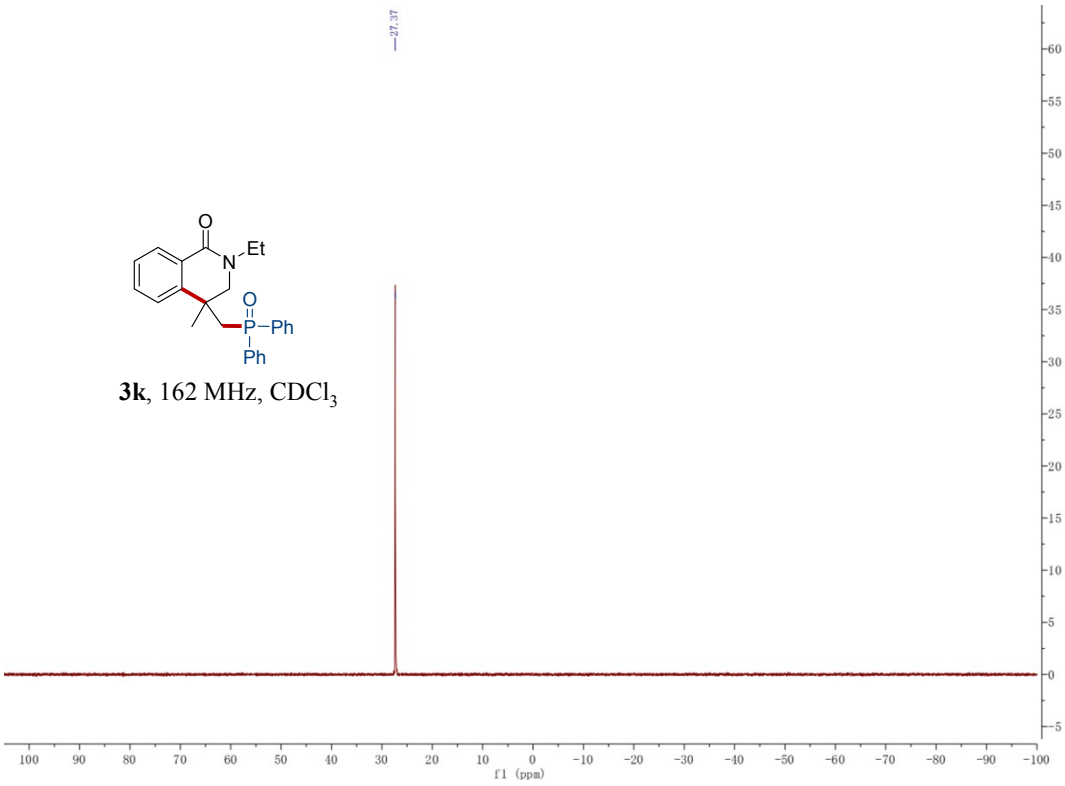
3j, 162 MHz, $CDCl_3$



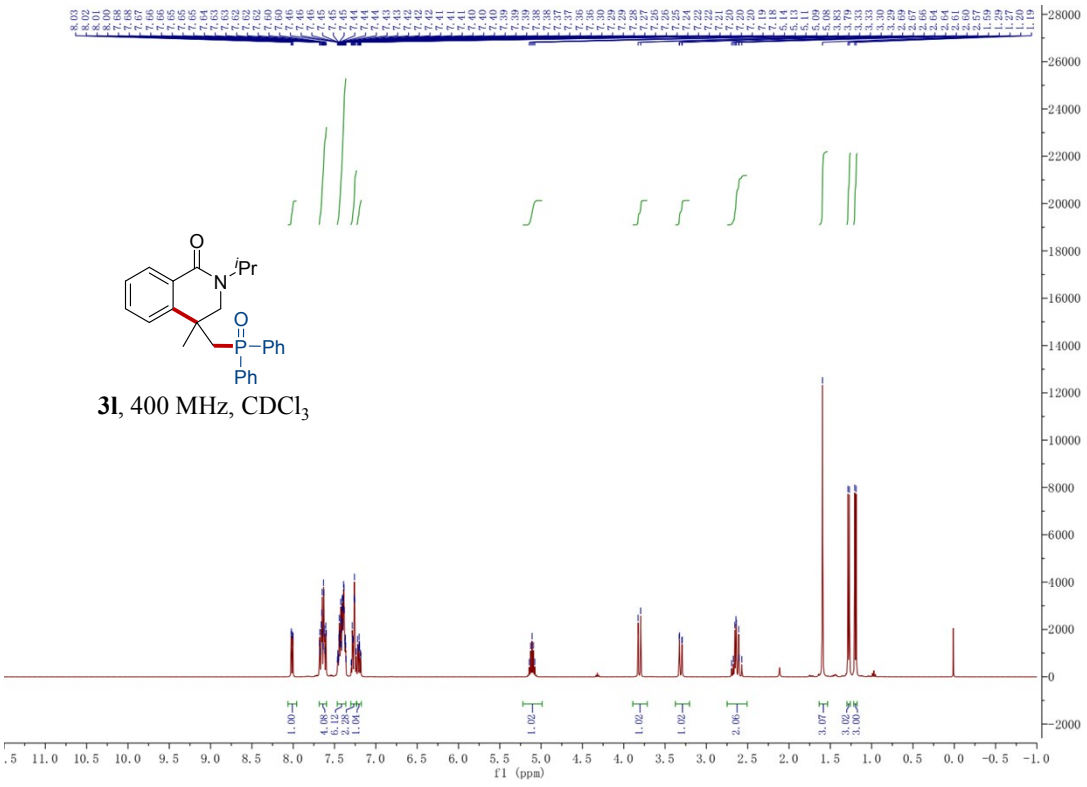
3k, 400 MHz, $CDCl_3$



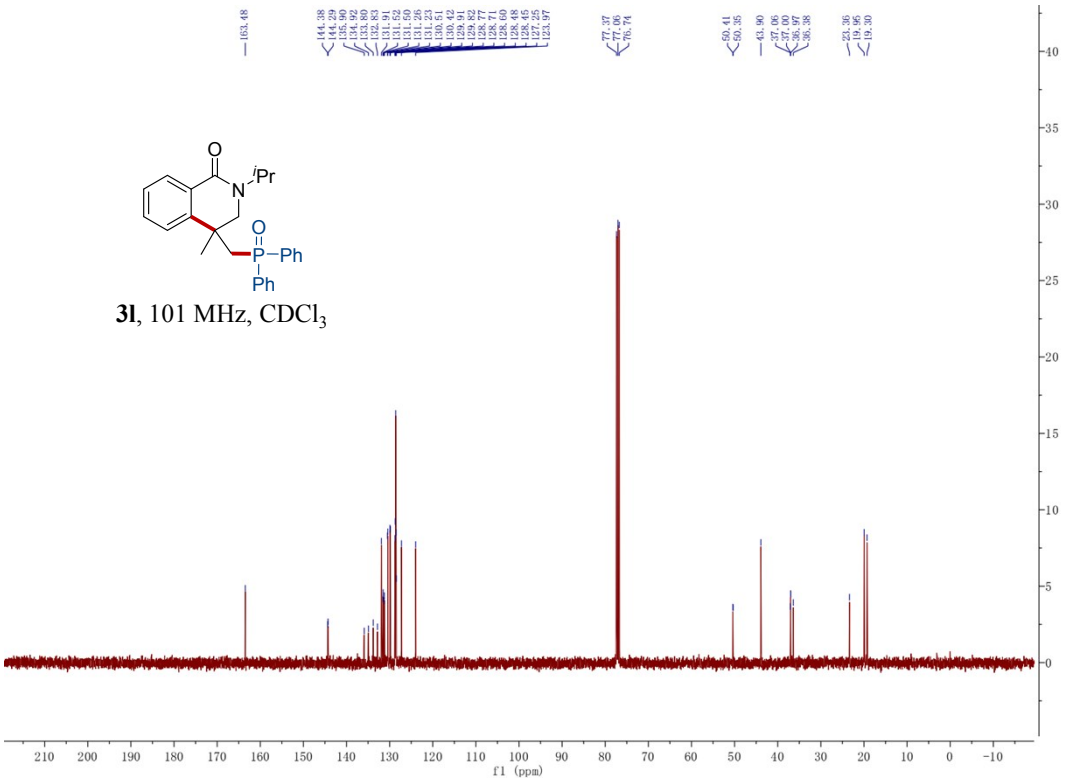
3k, 101 MHz, $CDCl_3$



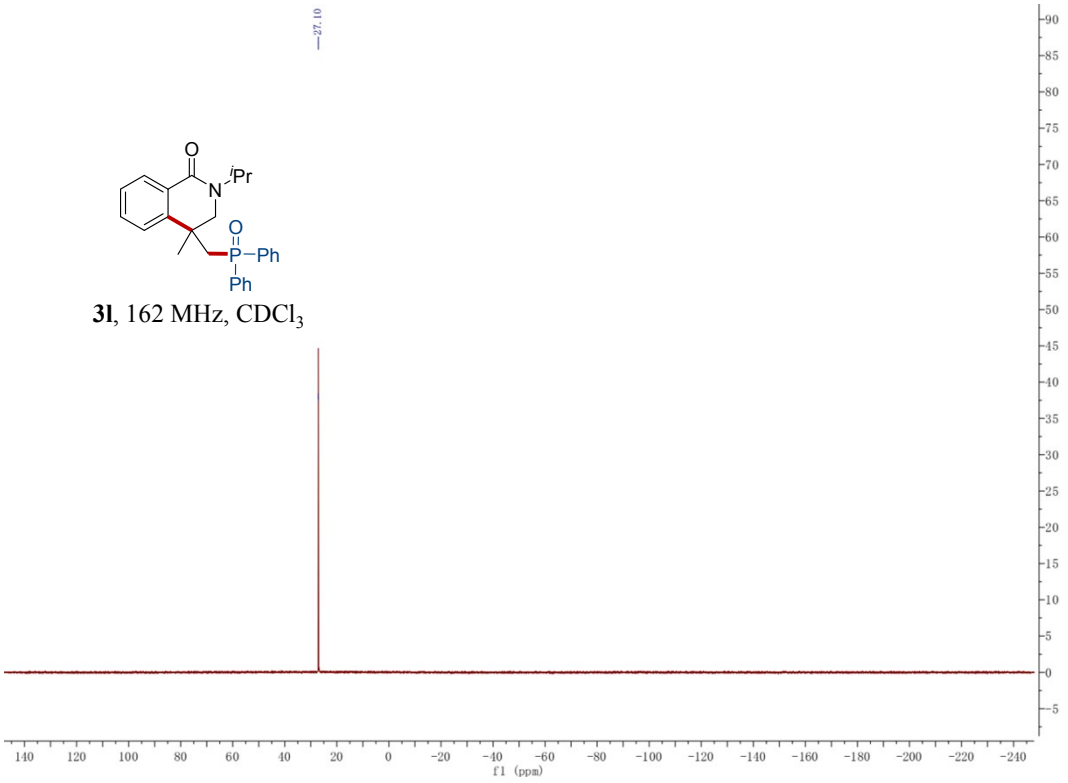
3k, 162 MHz, $CDCl_3$



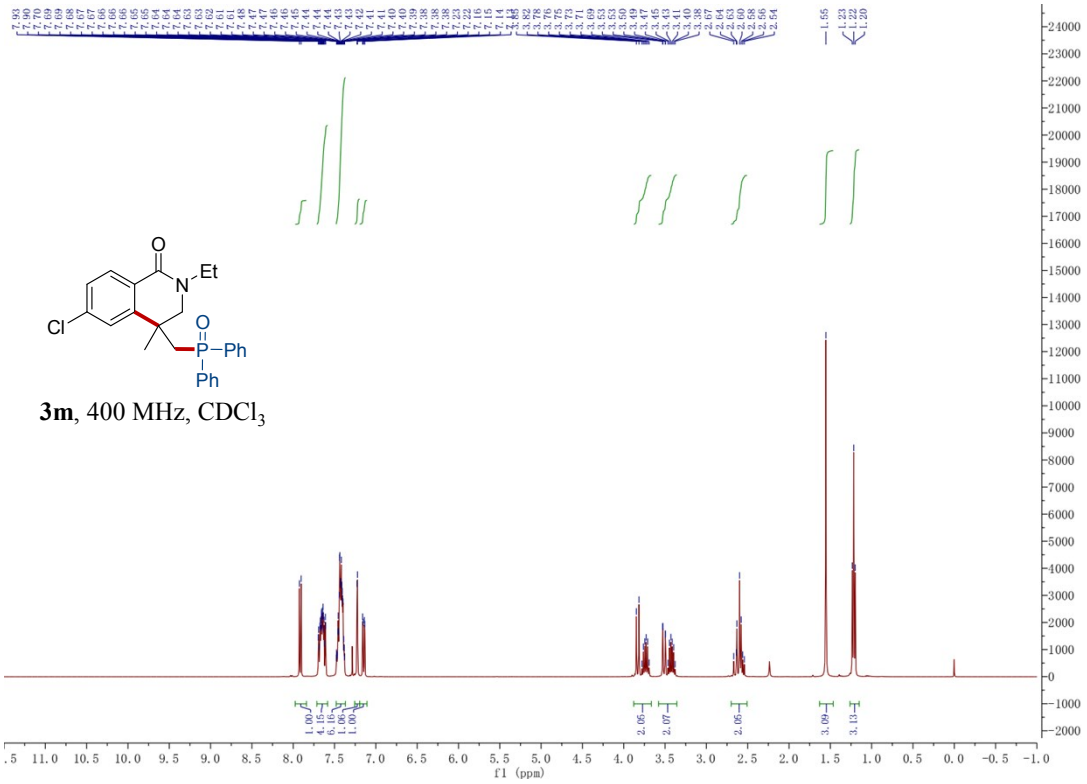
3l, 400 MHz, $CDCl_3$



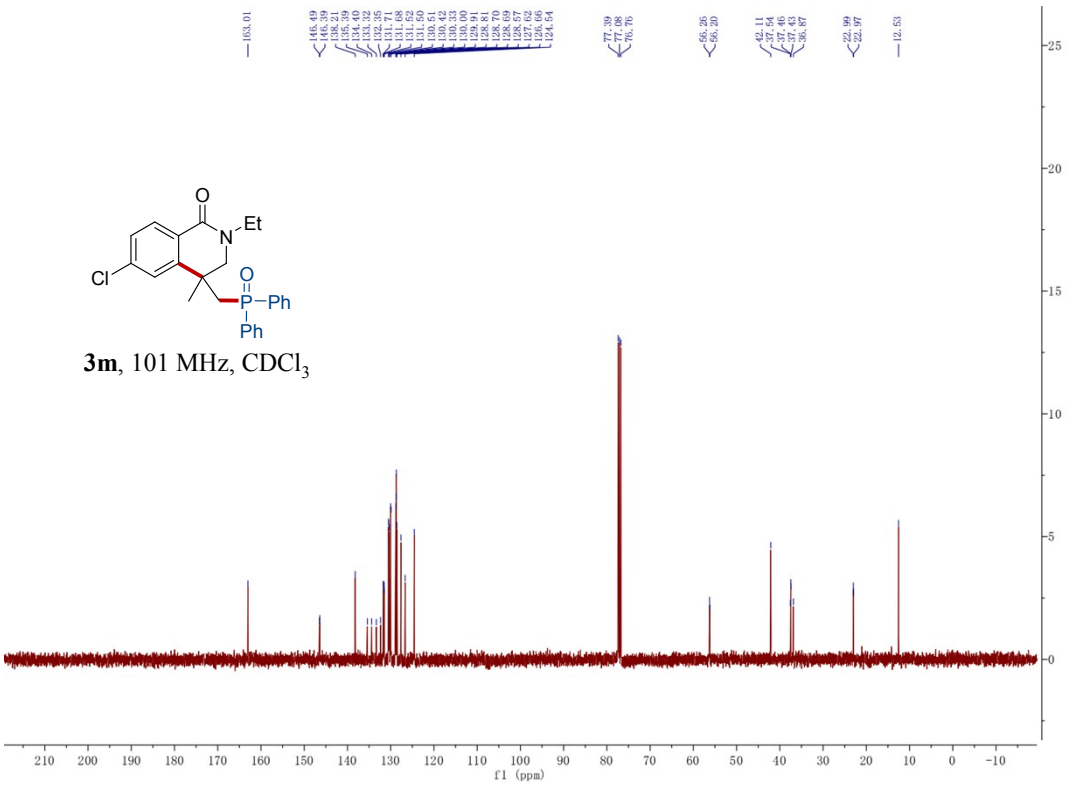
3l, 101 MHz, $CDCl_3$



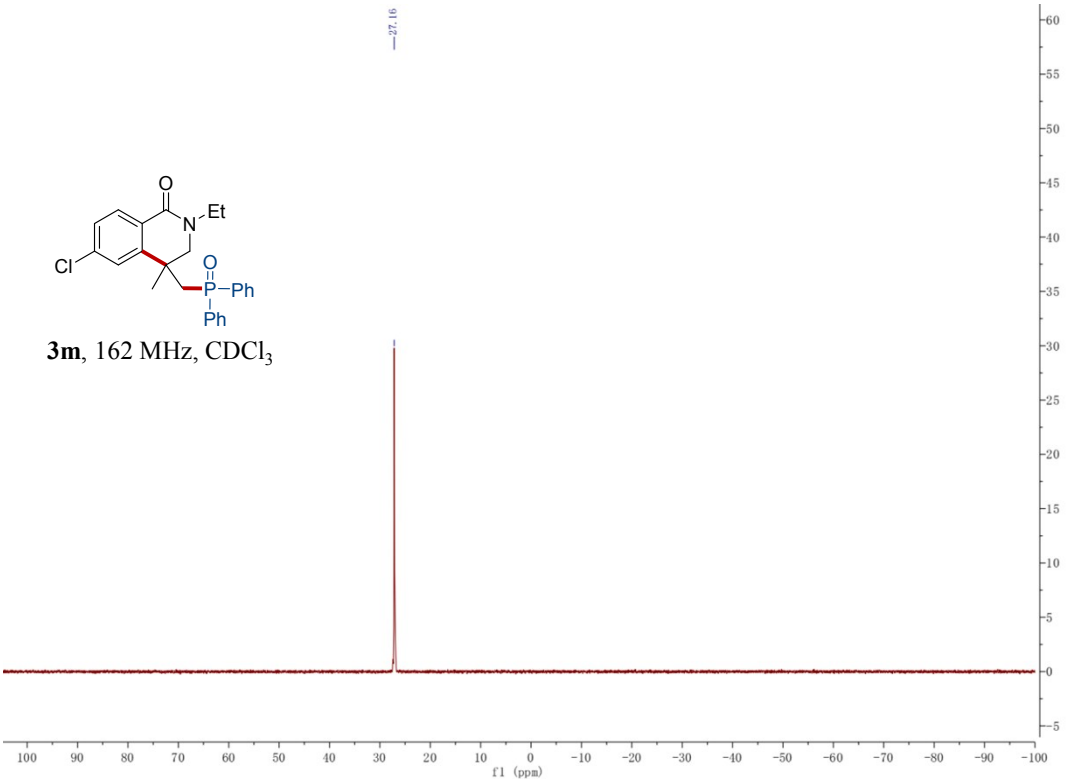
3l, 162 MHz, $CDCl_3$



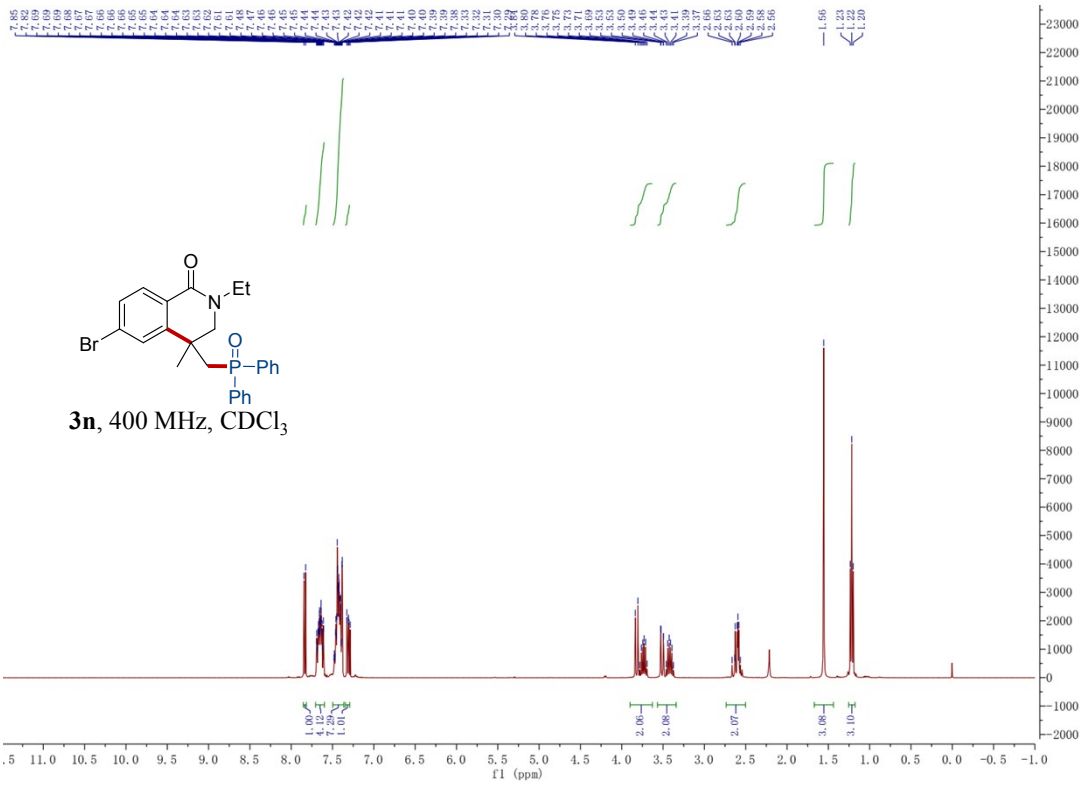
3m, 400 MHz, $CDCl_3$



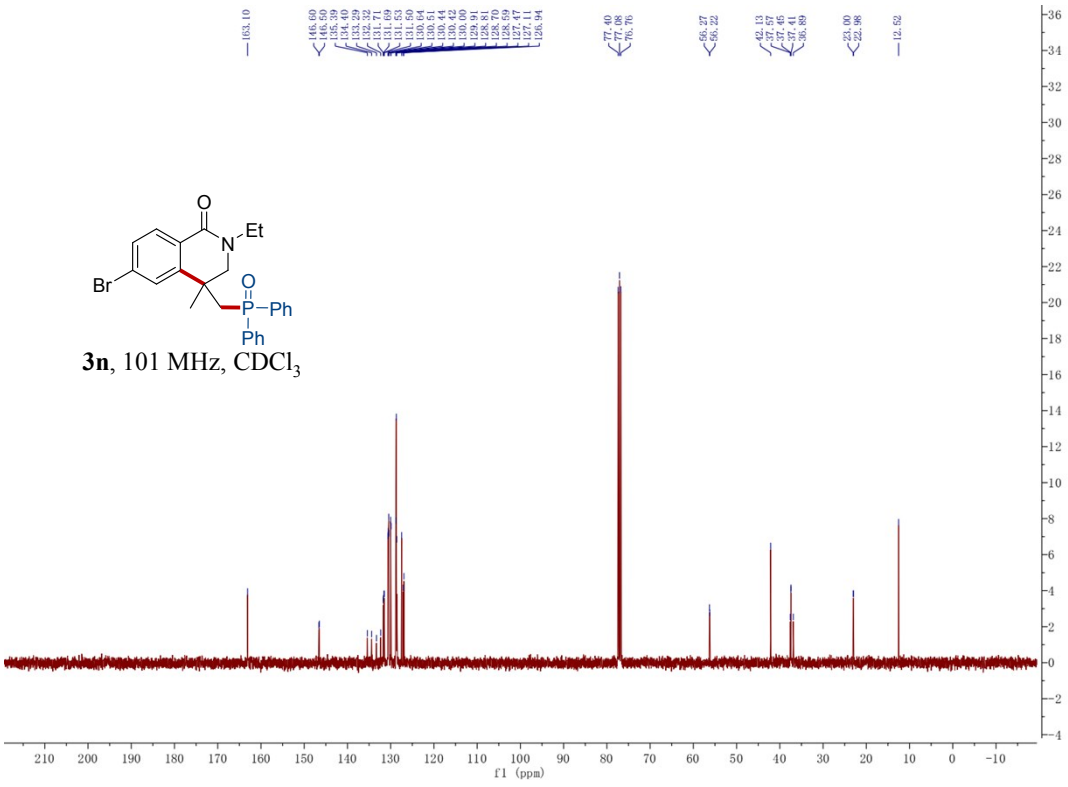
3m, 101 MHz, $CDCl_3$



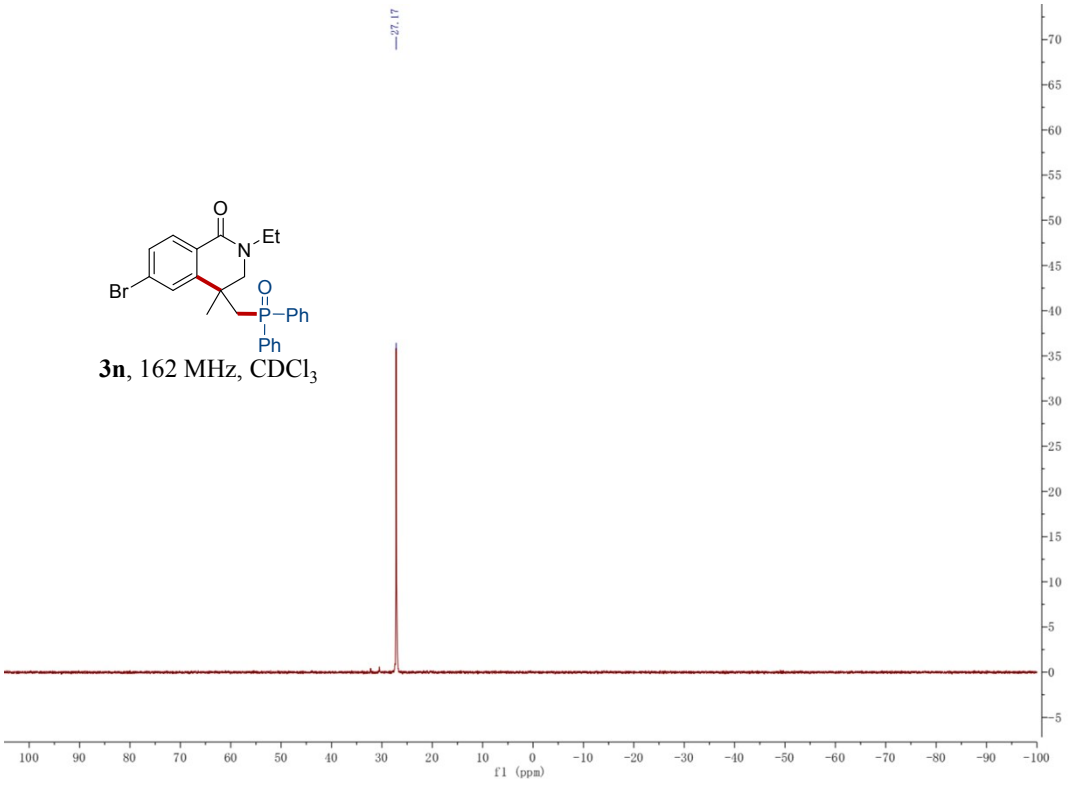
3m, 162 MHz, $CDCl_3$



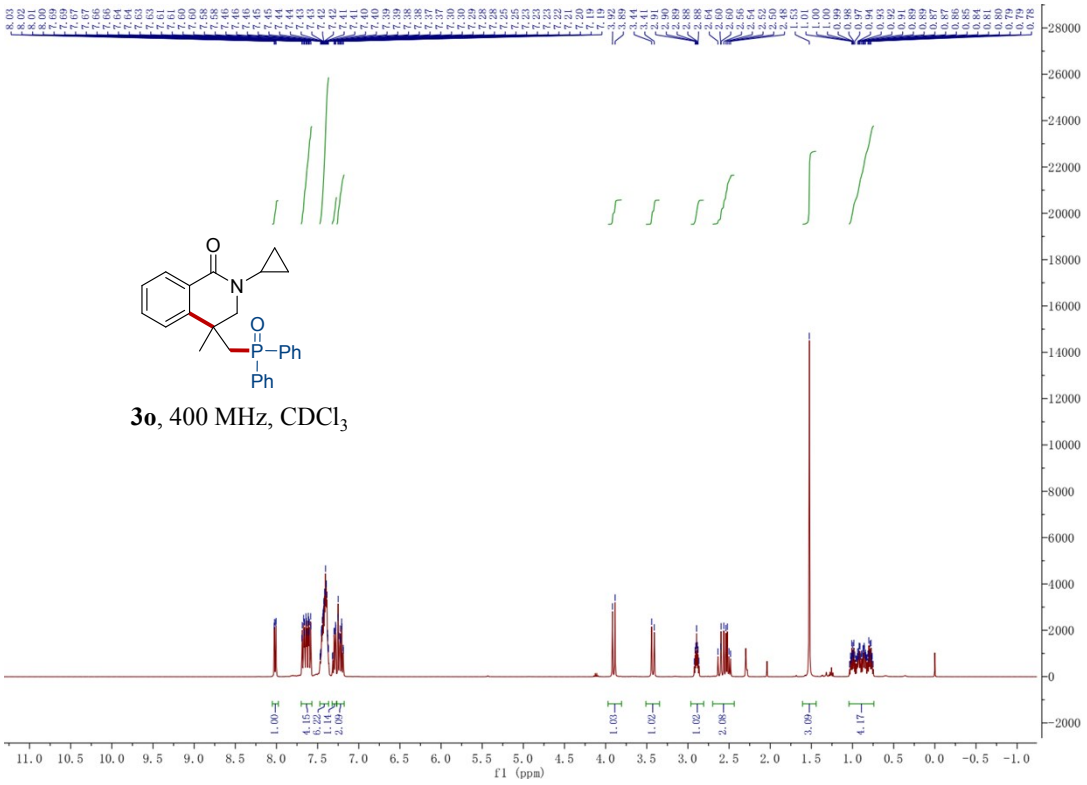
3n, 400 MHz, $CDCl_3$



3n, 101 MHz, $CDCl_3$



3n, 162 MHz, $CDCl_3$



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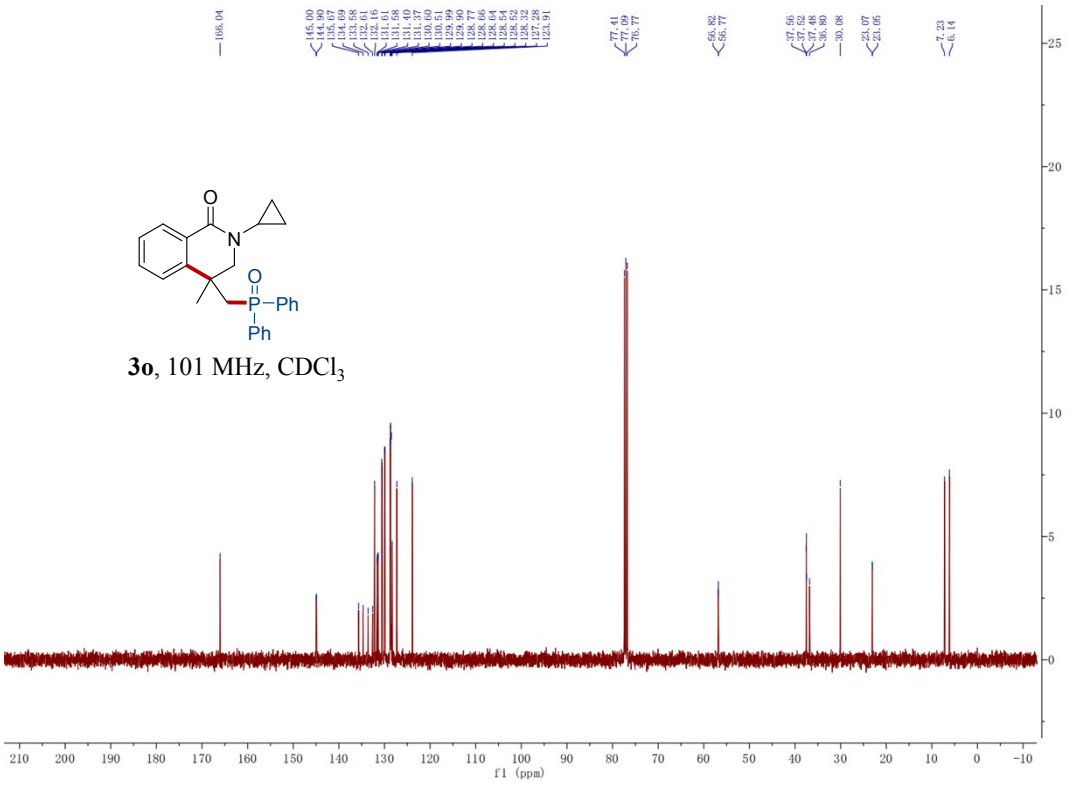
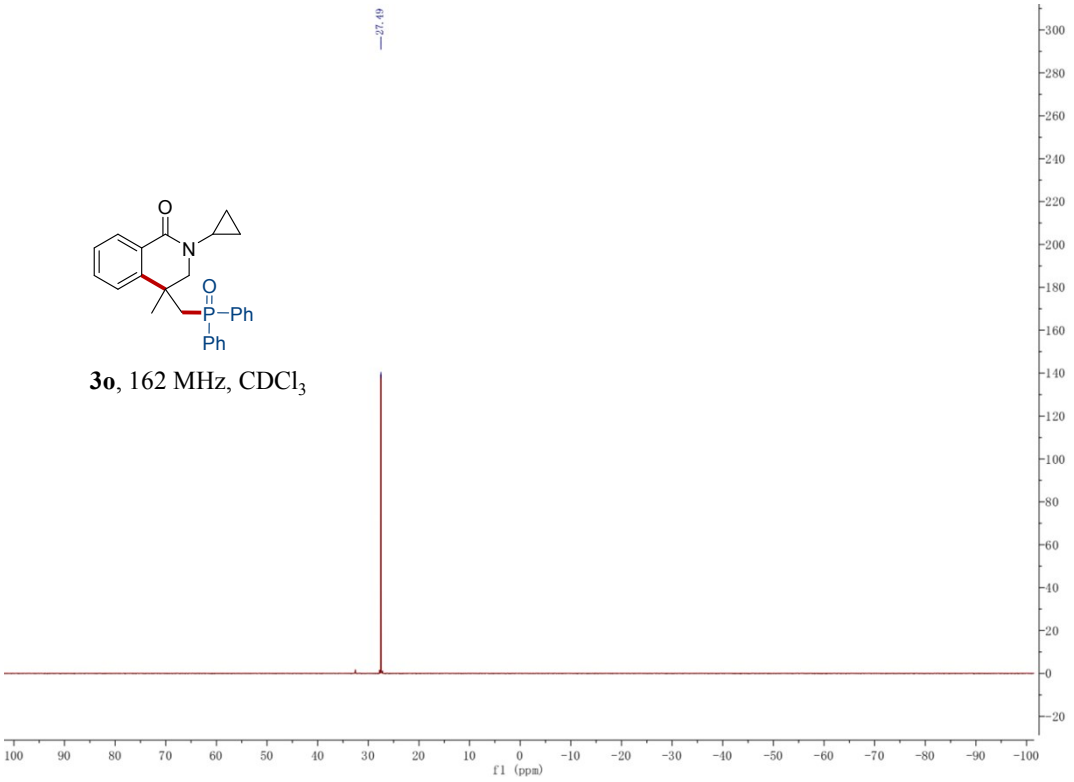


3o, 101 MHz, $CDCl_3$



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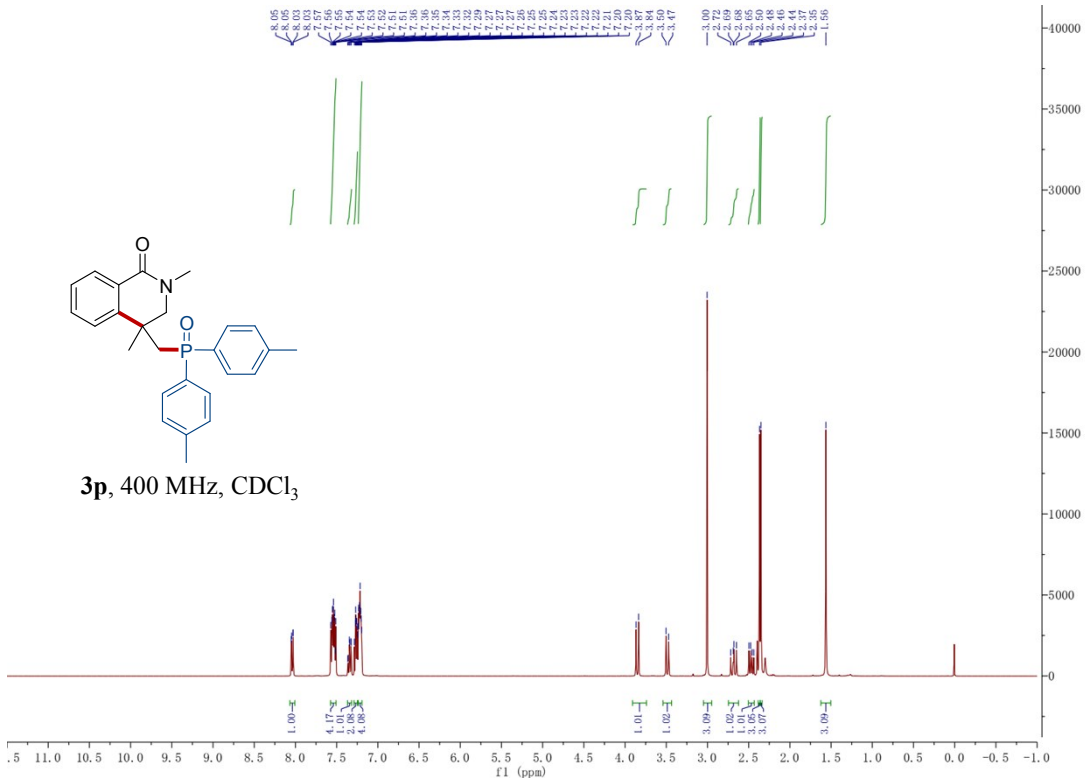
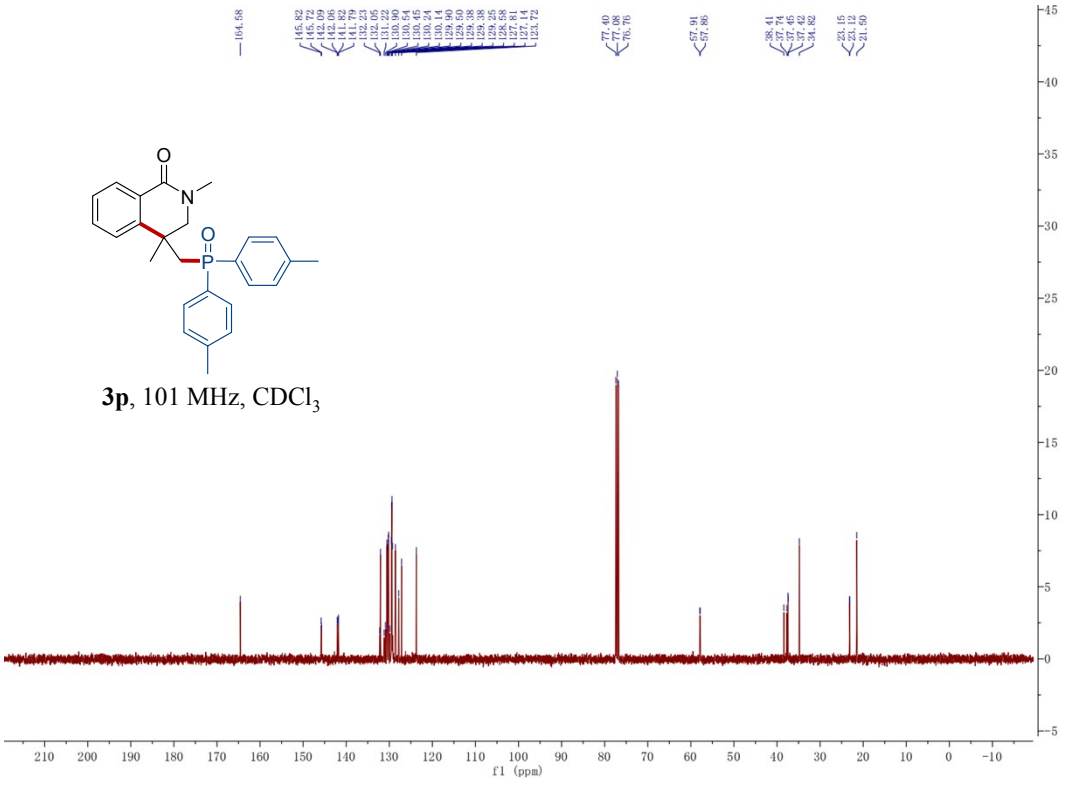
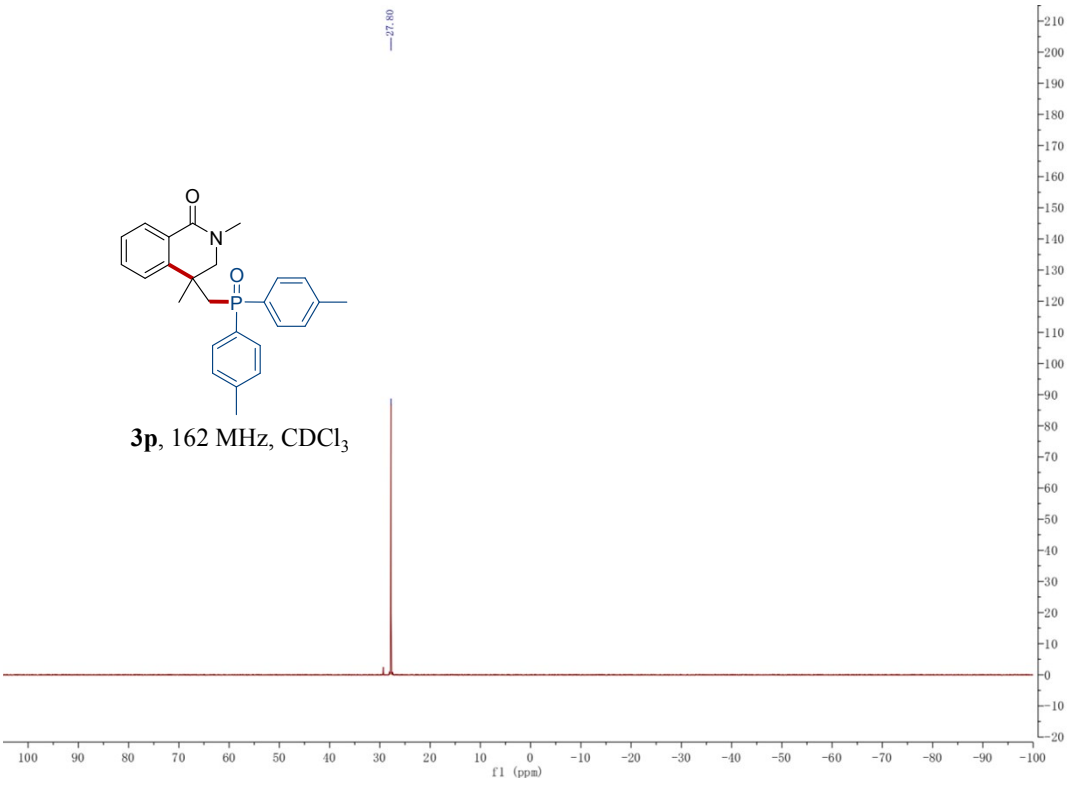


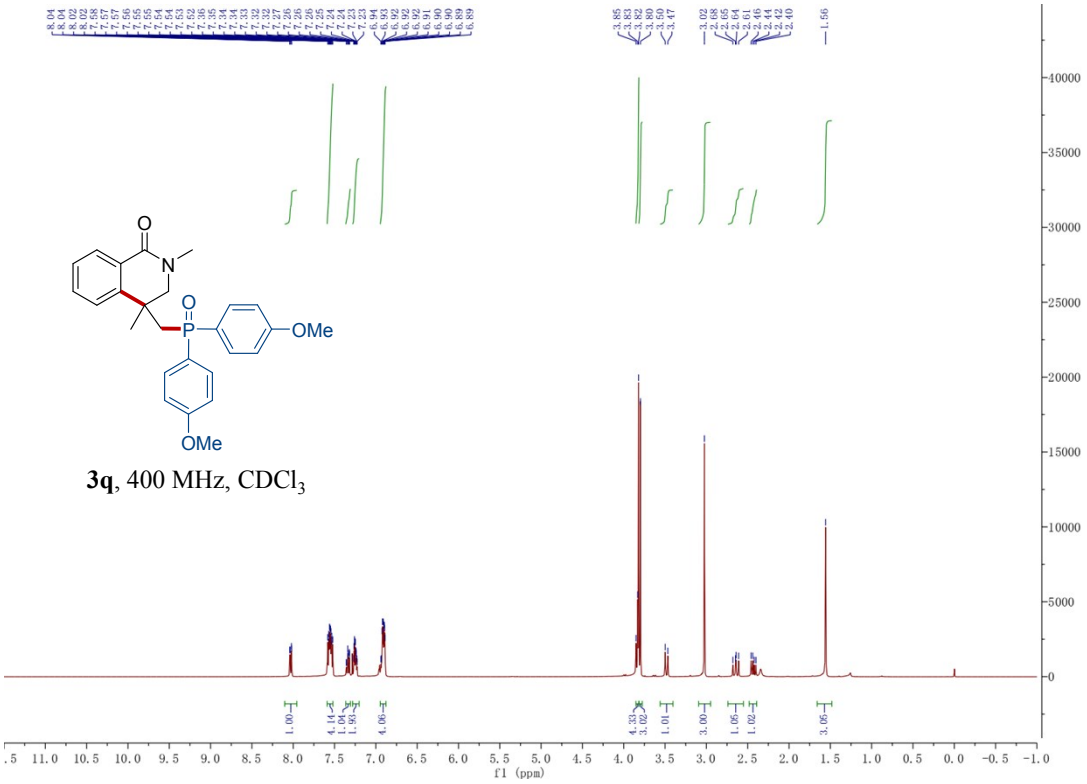
3p, 400 MHz, $CDCl_3$



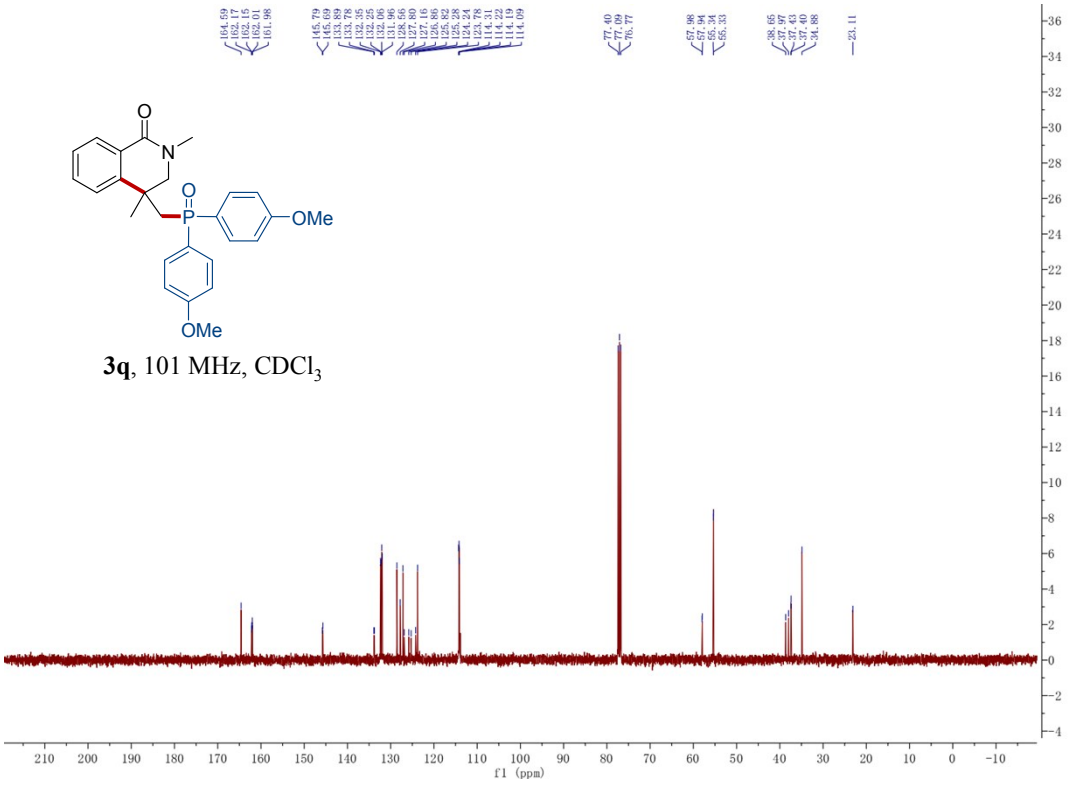
3p, 101 MHz, $CDCl_3$



3p, 162 MHz, $CDCl_3$

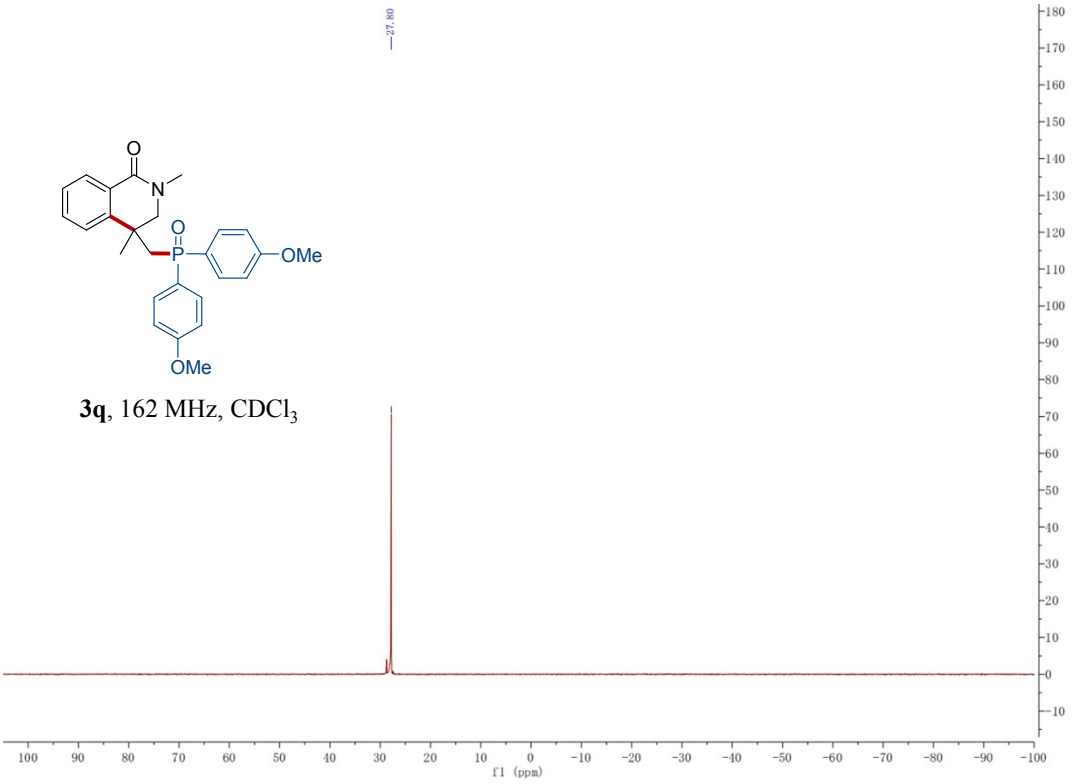


3q, 400 MHz, $CDCl_3$

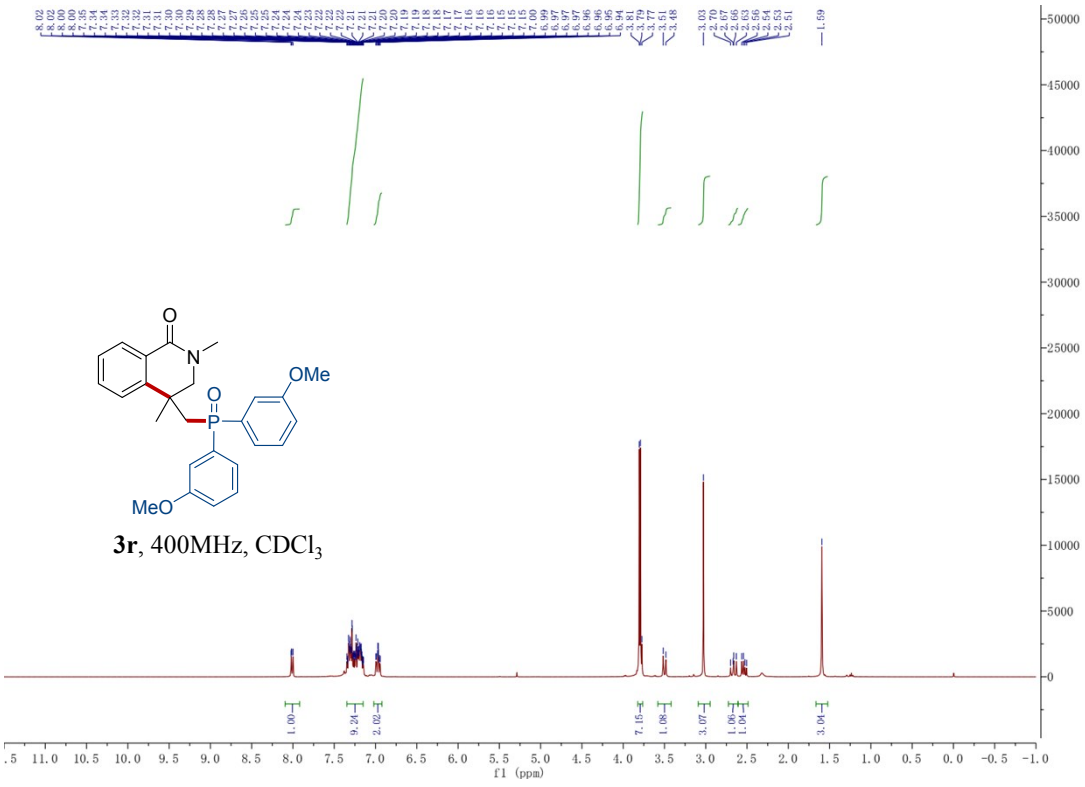


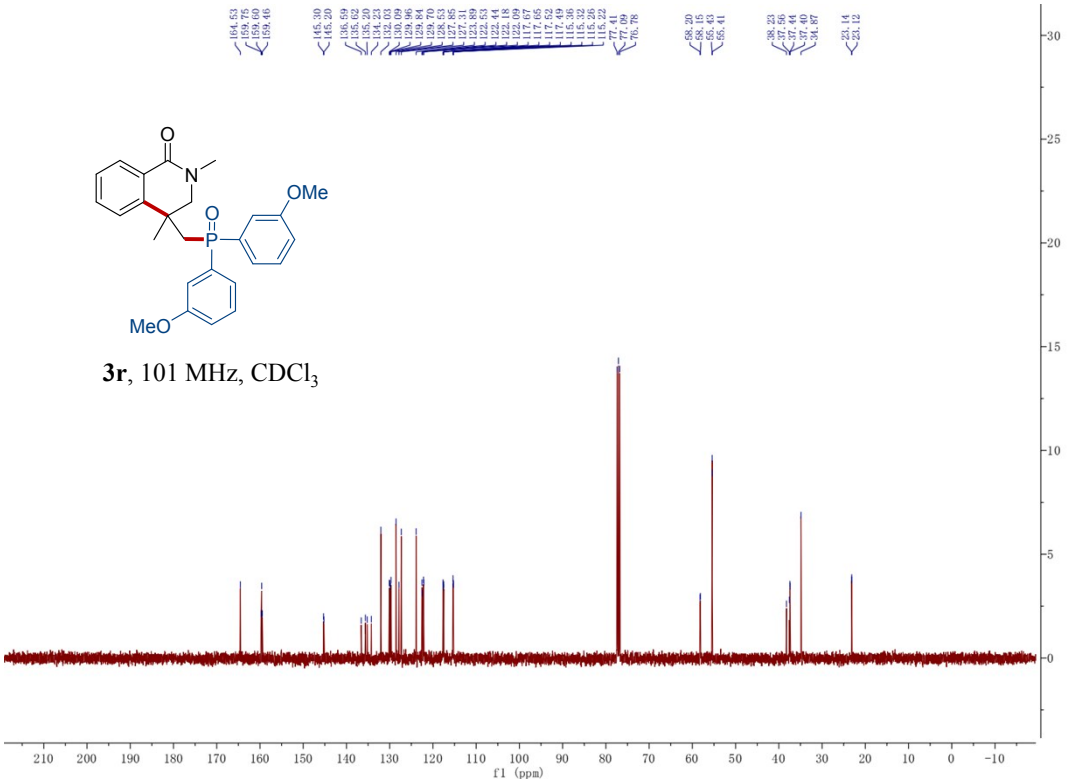
3q, 101 MHz, $CDCl_3$

3q, 162 MHz, $CDCl_3$

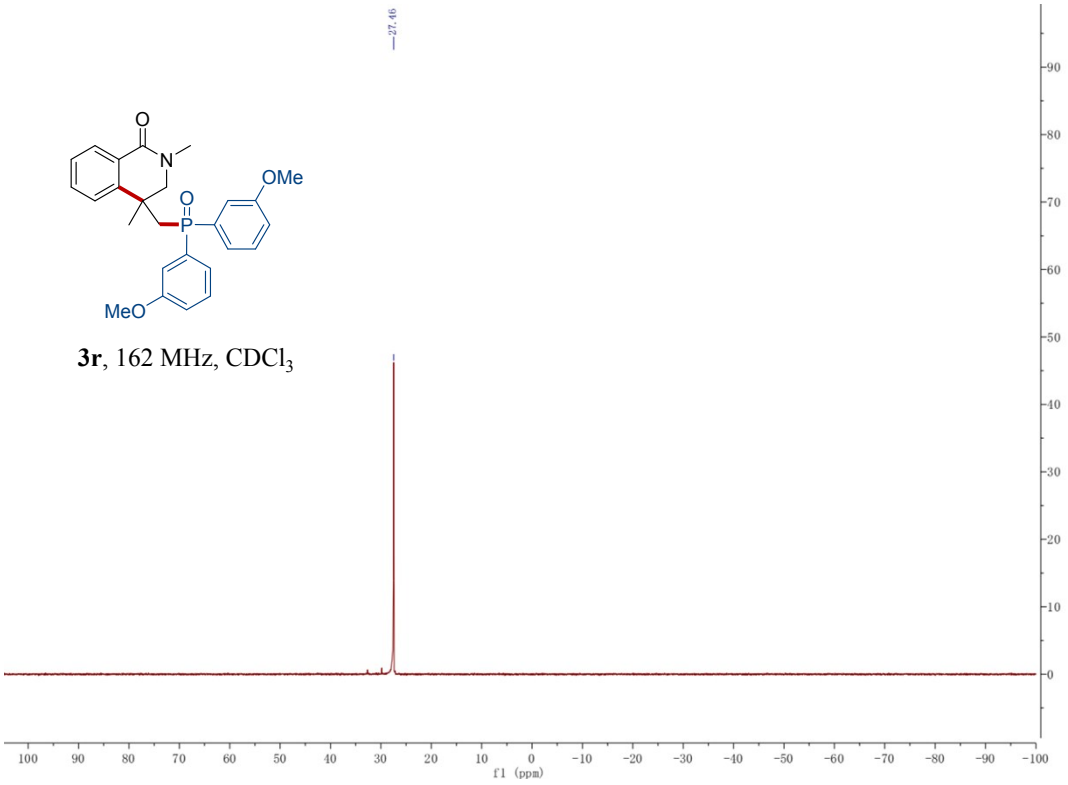


3r, 400MHz, $CDCl_3$

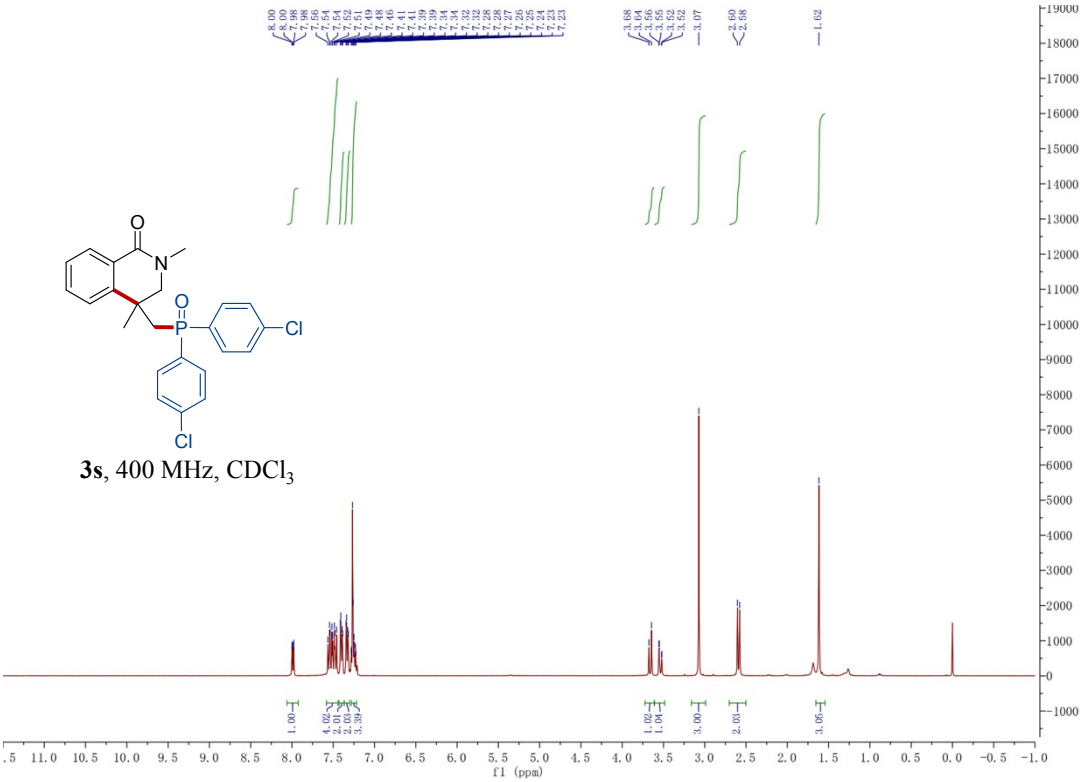




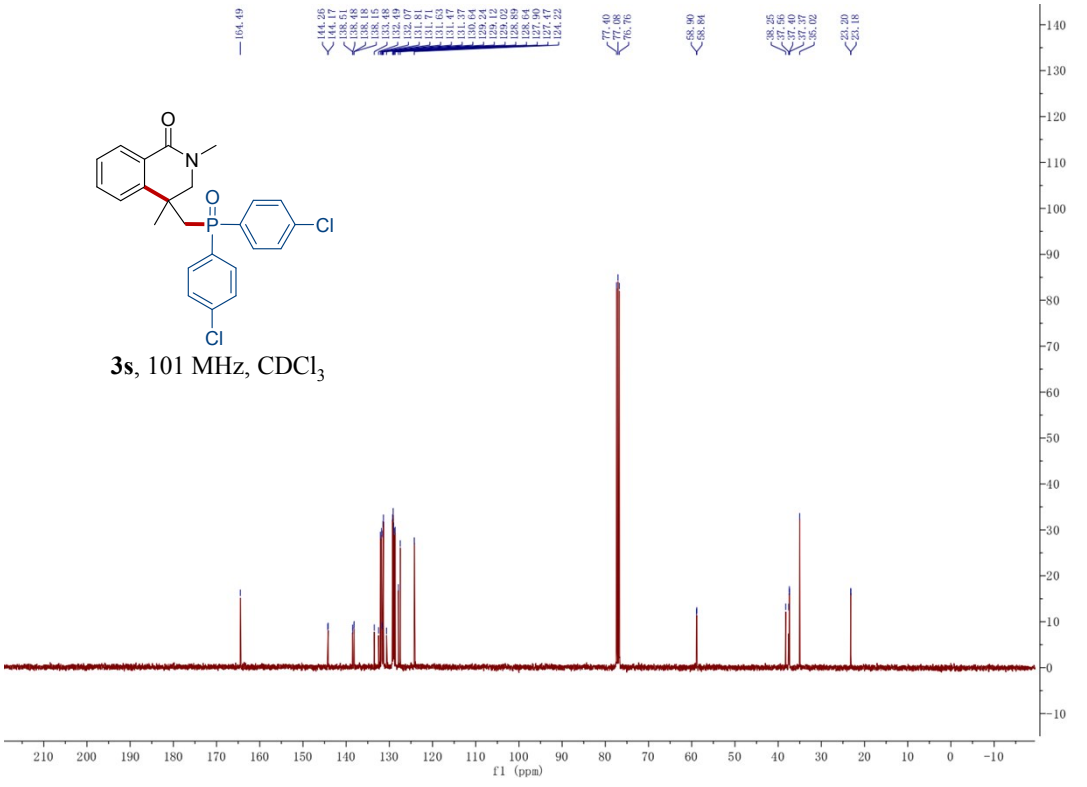
3r, 101 MHz, $CDCl_3$



3r, 162 MHz, $CDCl_3$

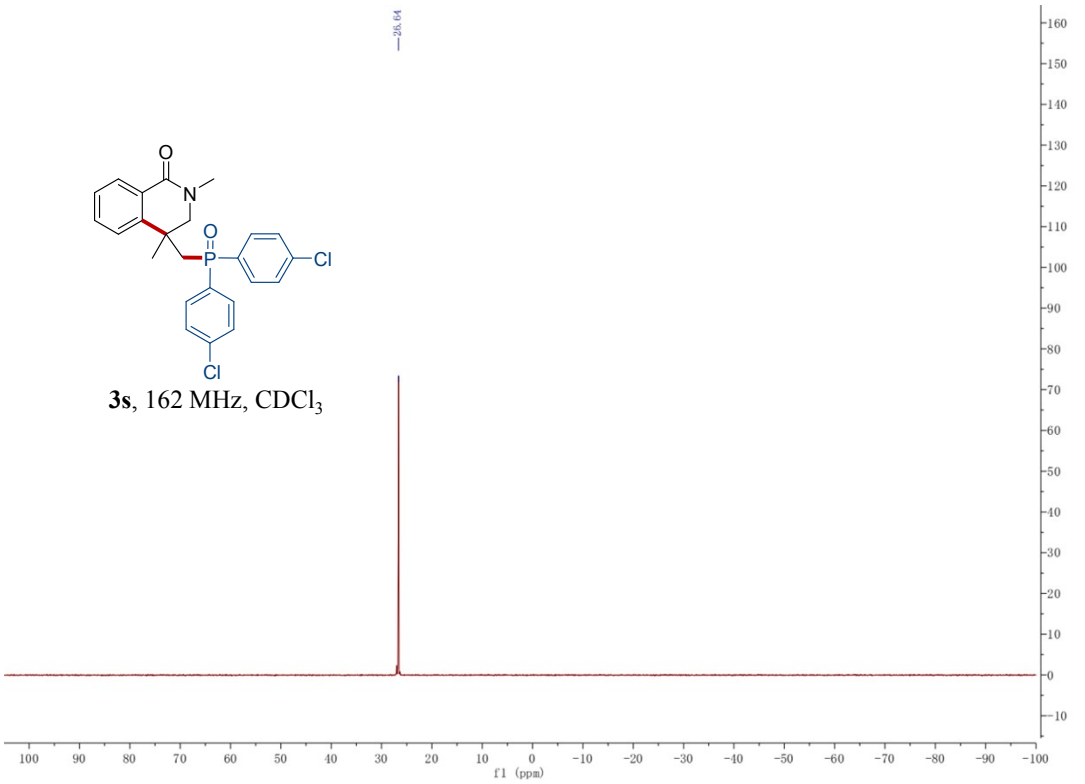


3s, 400 MHz, $CDCl_3$

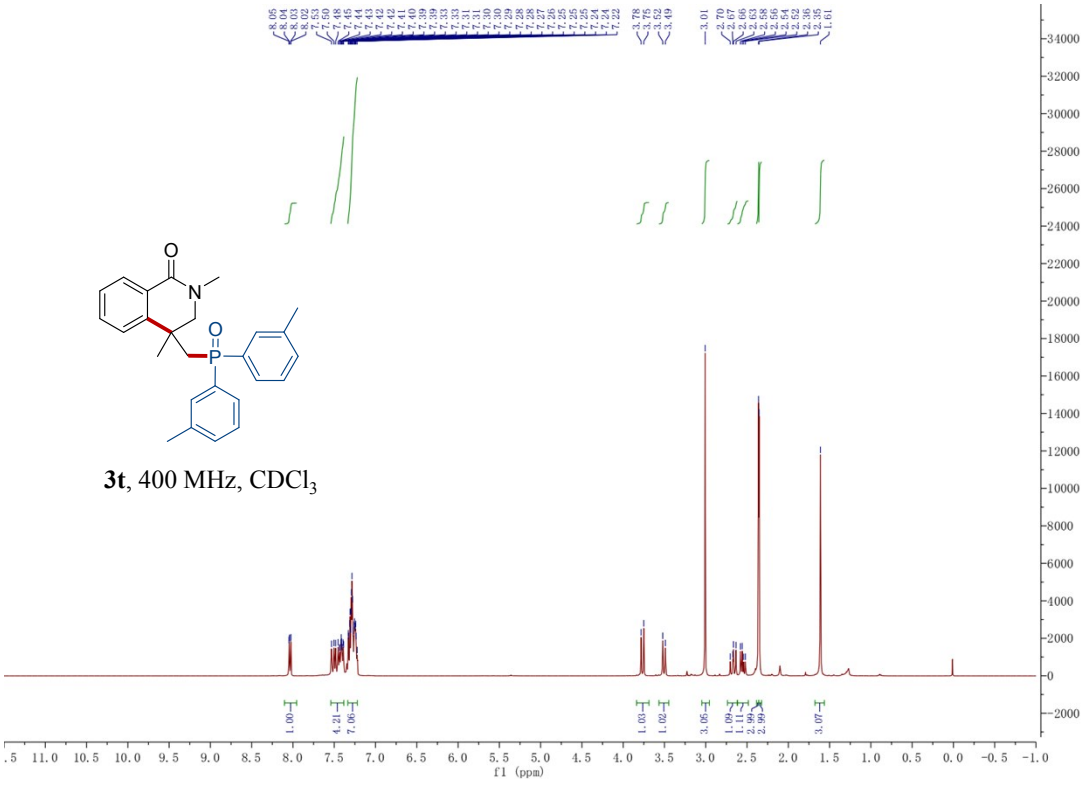


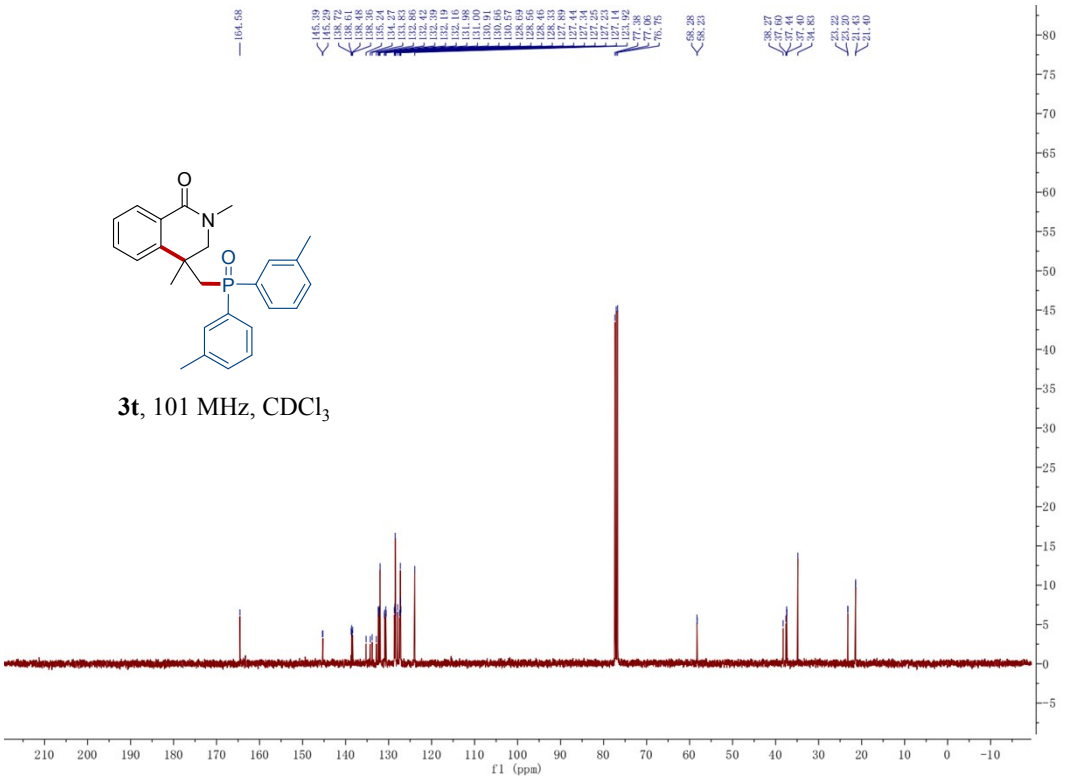
3s, 101 MHz, $CDCl_3$

3s, 162 MHz, $CDCl_3$

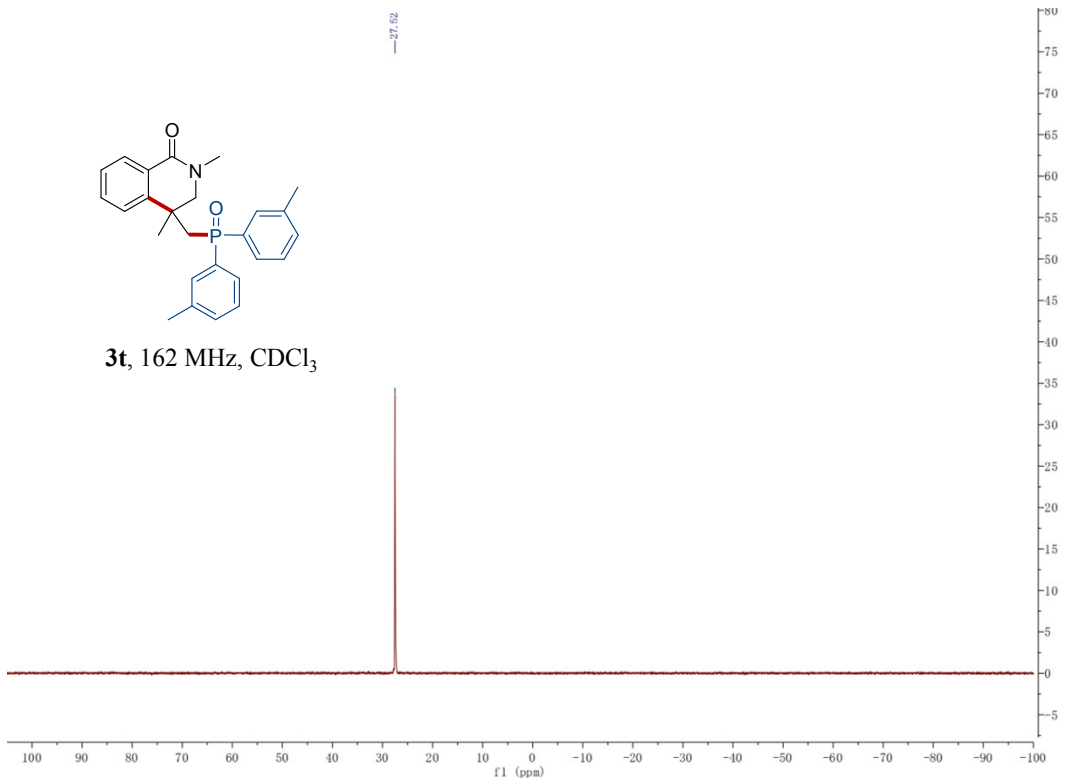


3t, 400 MHz, $CDCl_3$

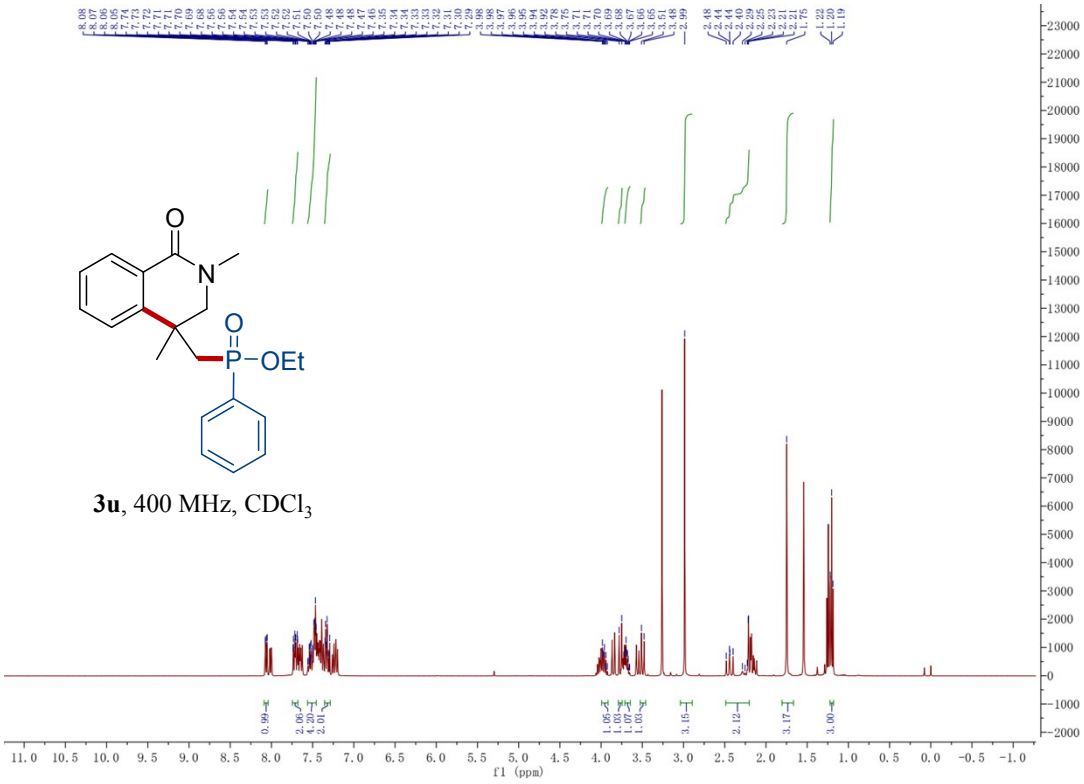




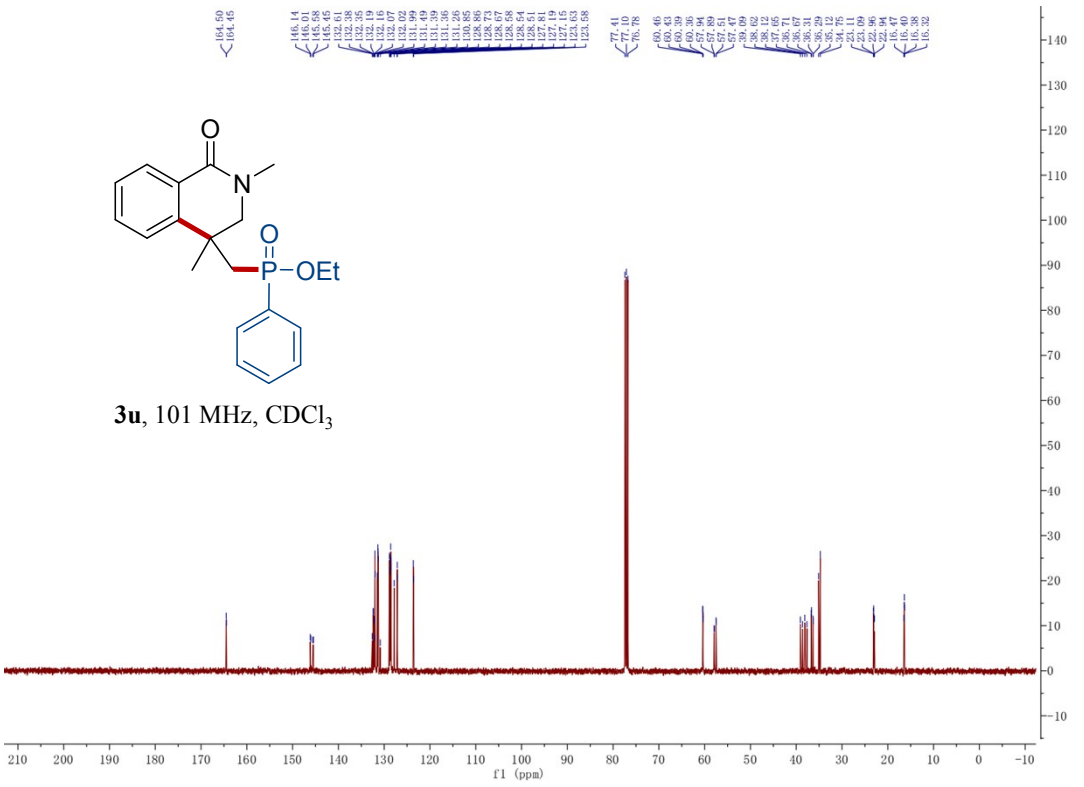
3t, 101 MHz, $CDCl_3$



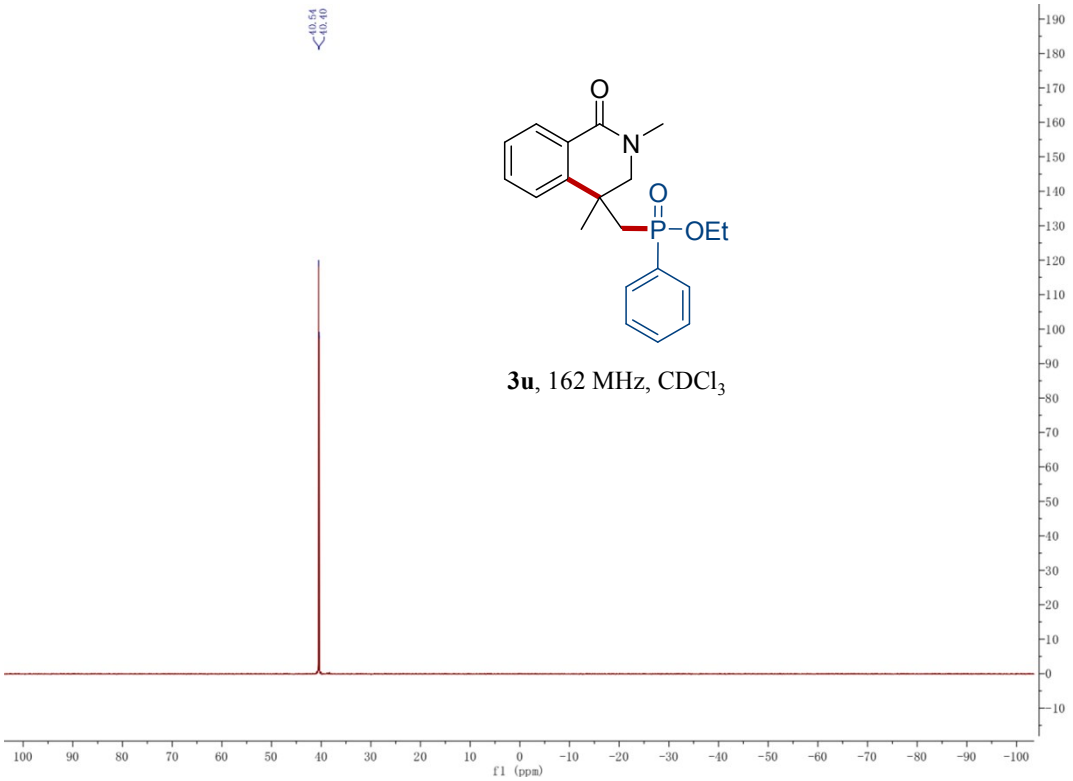
3t, 162 MHz, $CDCl_3$



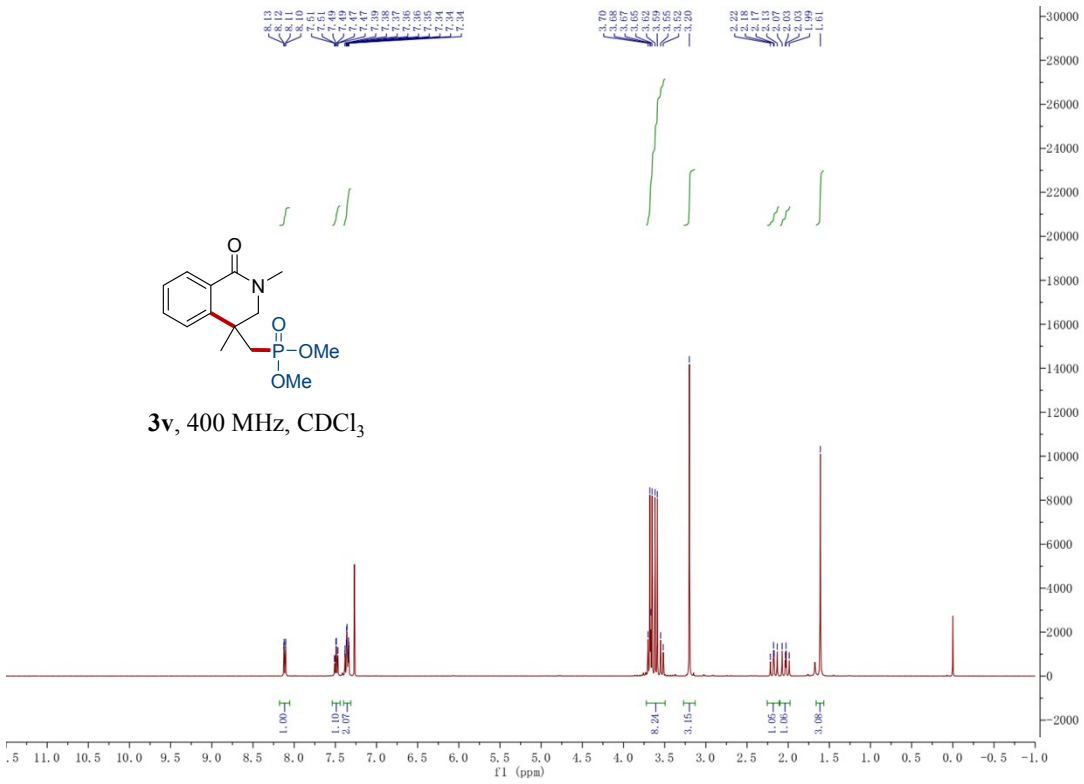
3u, 400 MHz, $CDCl_3$



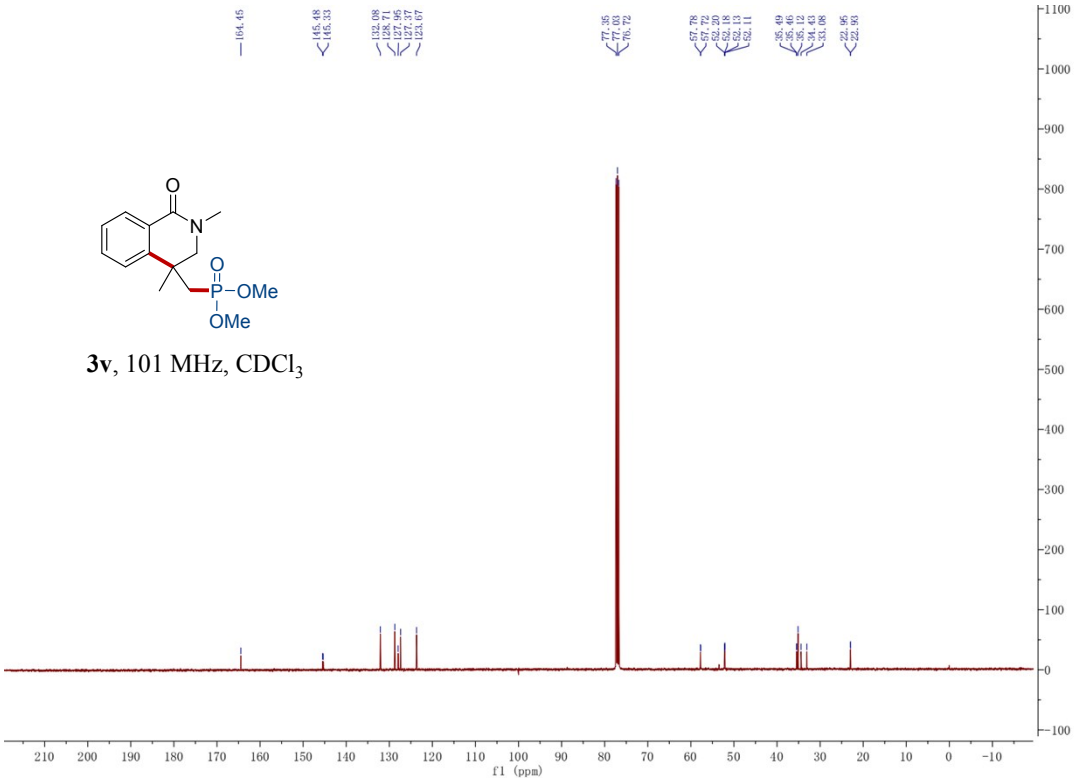
3u, 101 MHz, $CDCl_3$



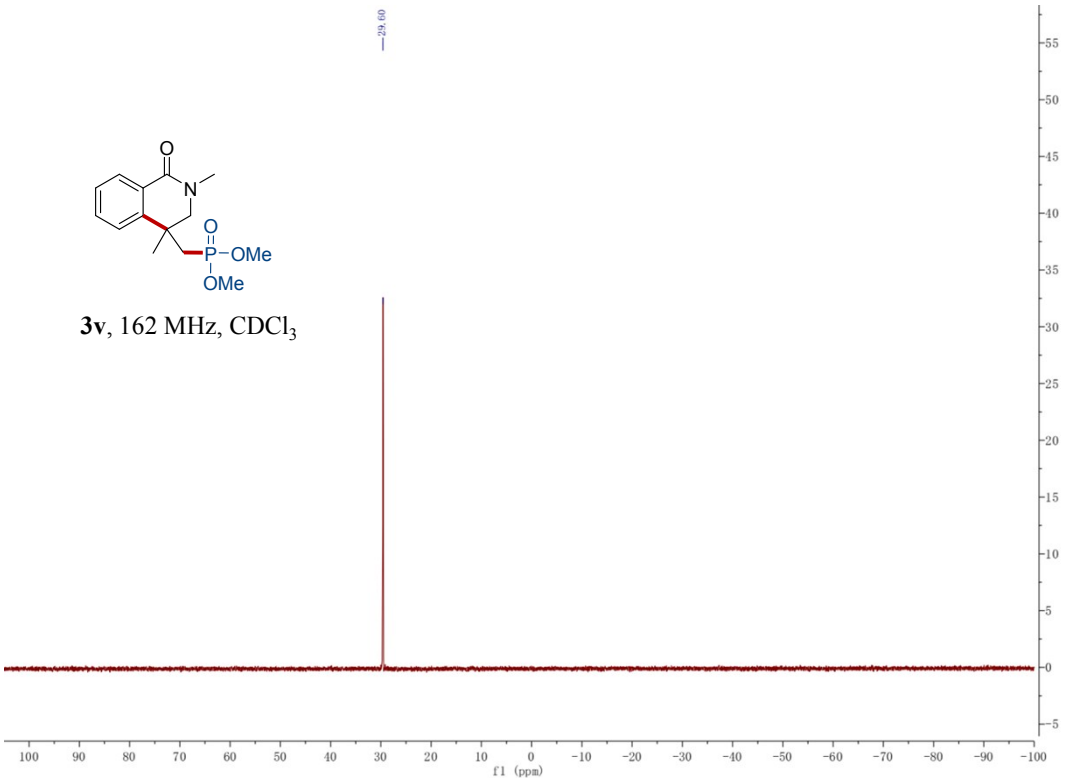
3u, 162 MHz, $CDCl_3$



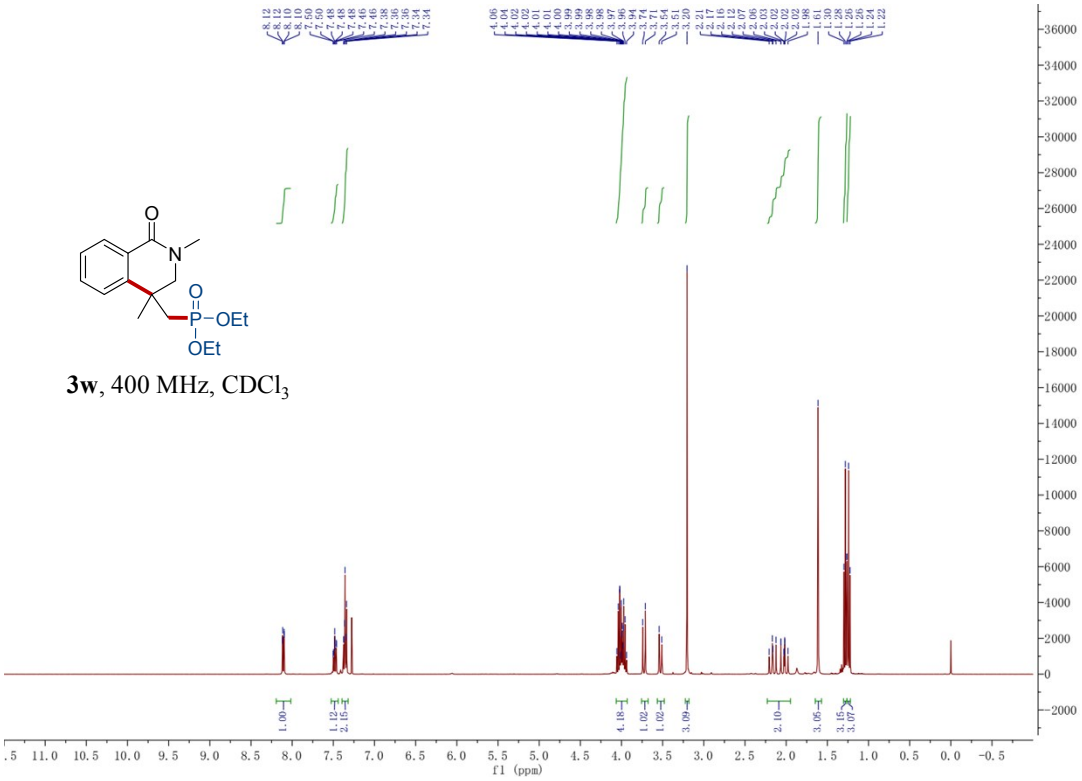
3v, 400 MHz, $CDCl_3$



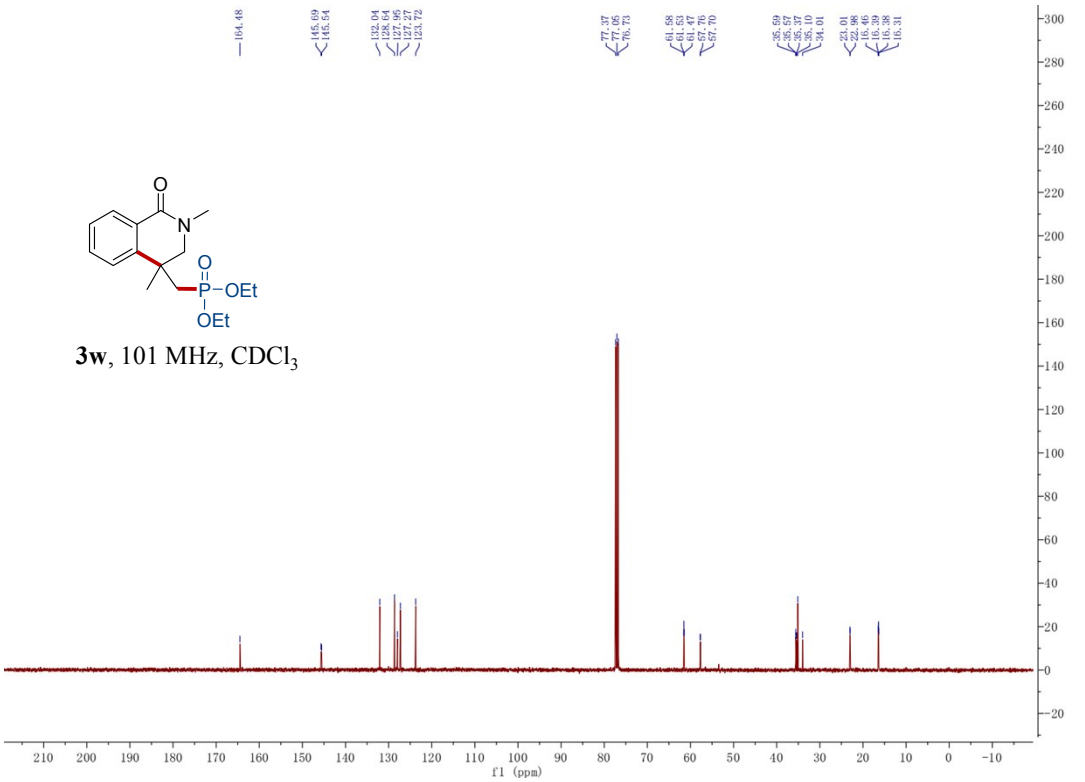
3v, 101 MHz, $CDCl_3$



3v, 162 MHz, $CDCl_3$

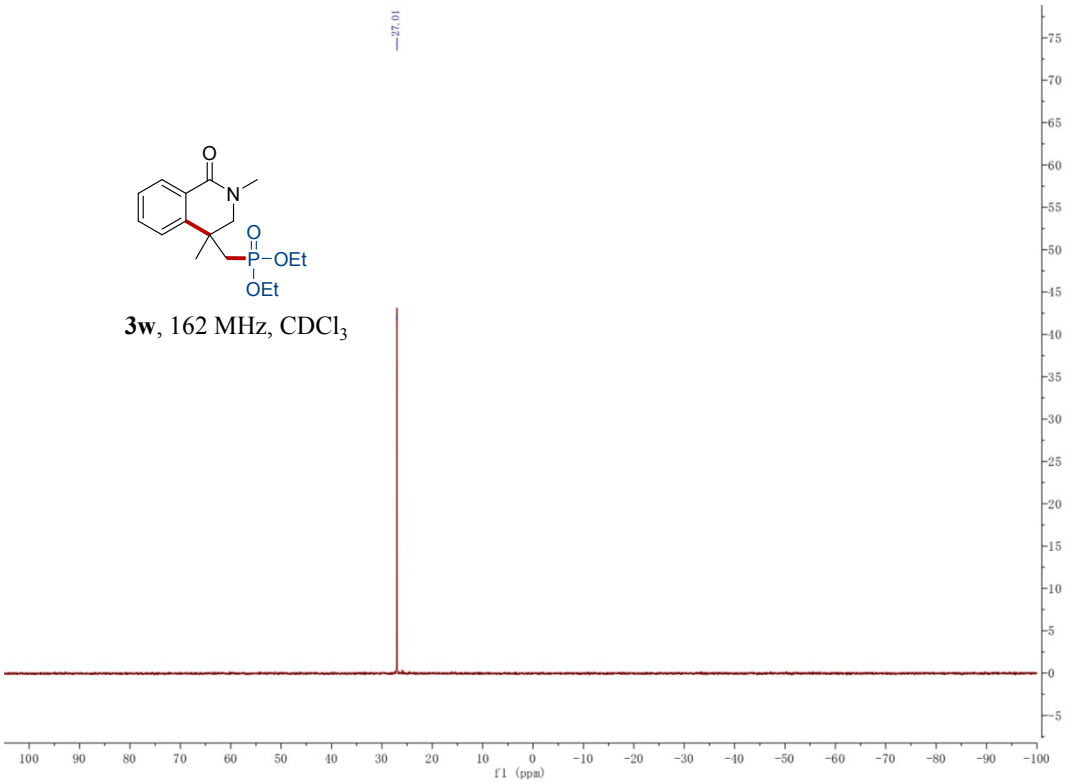


3w, 400 MHz, $CDCl_3$

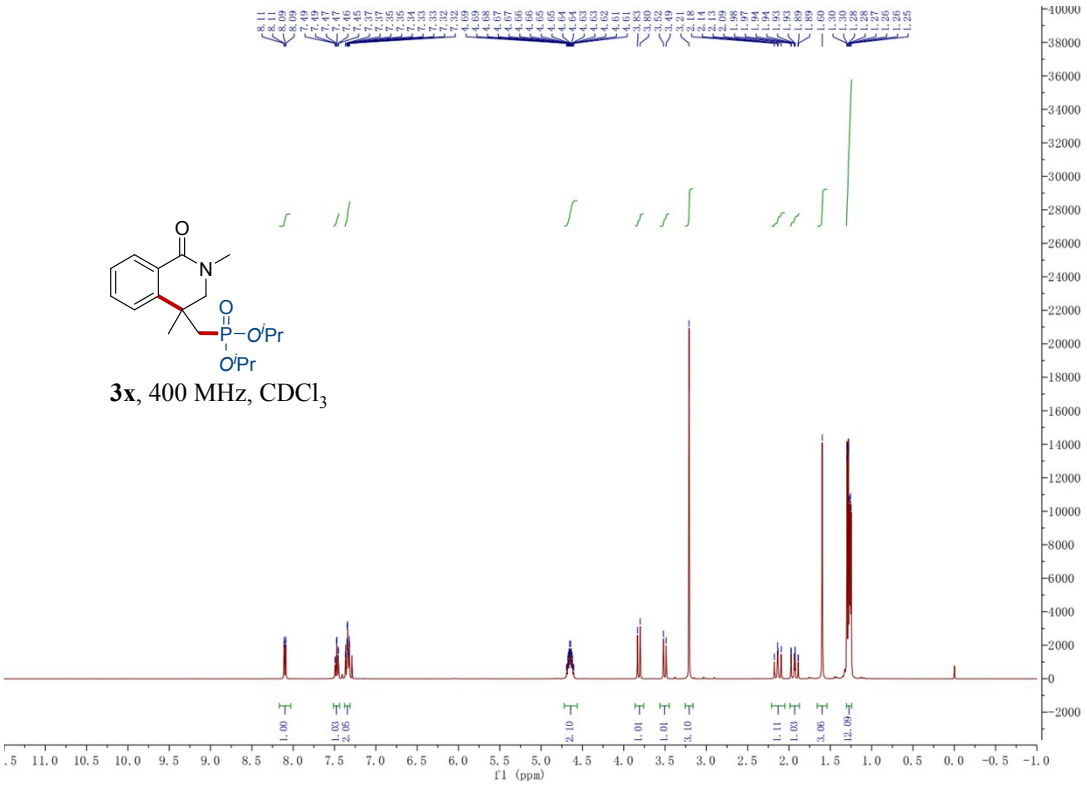


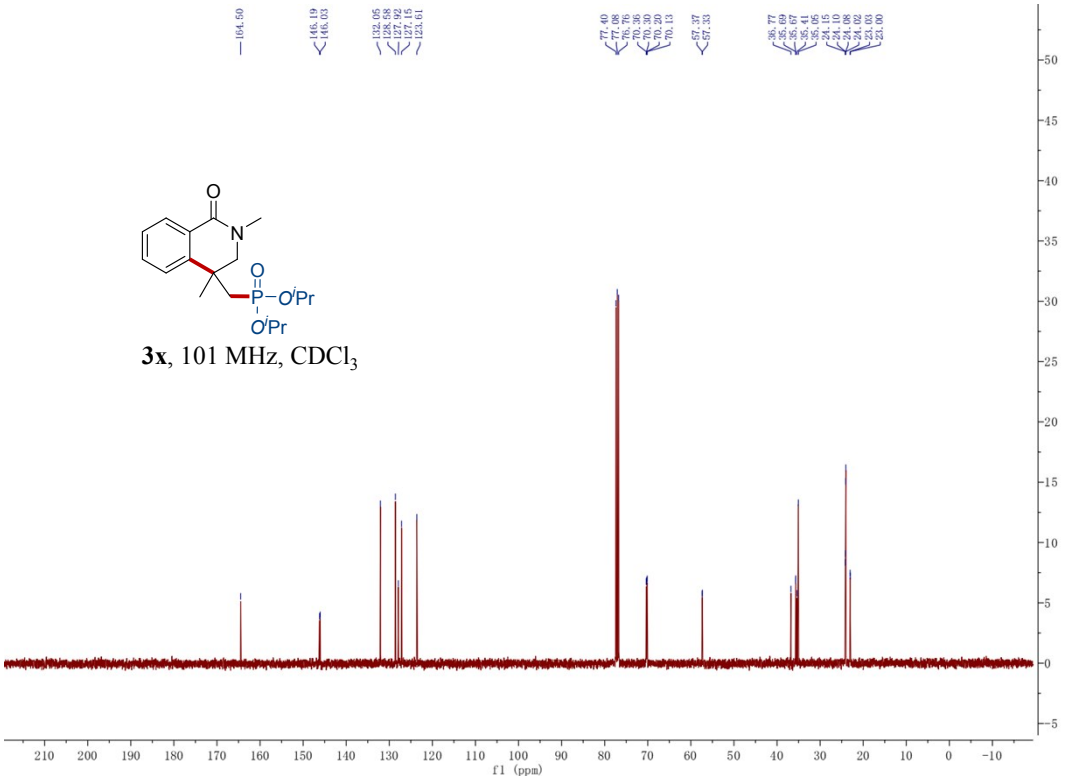
3w, 101 MHz, $CDCl_3$

3w, 162 MHz, $CDCl_3$

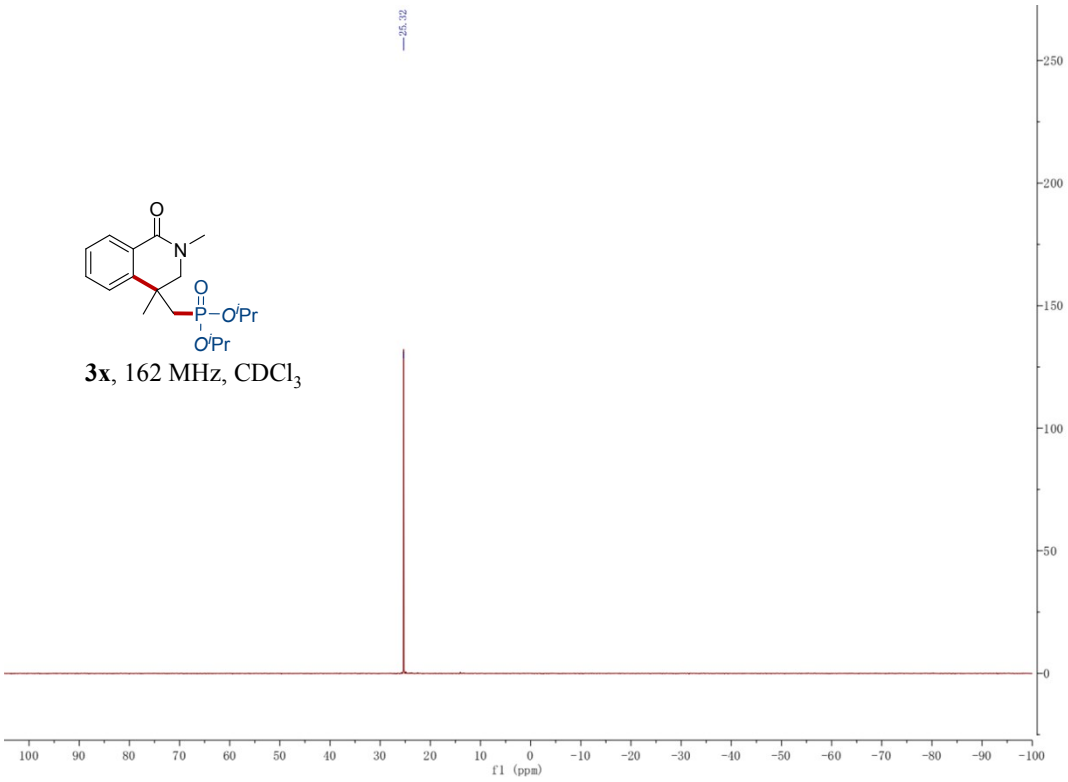


3x, 400 MHz, $CDCl_3$

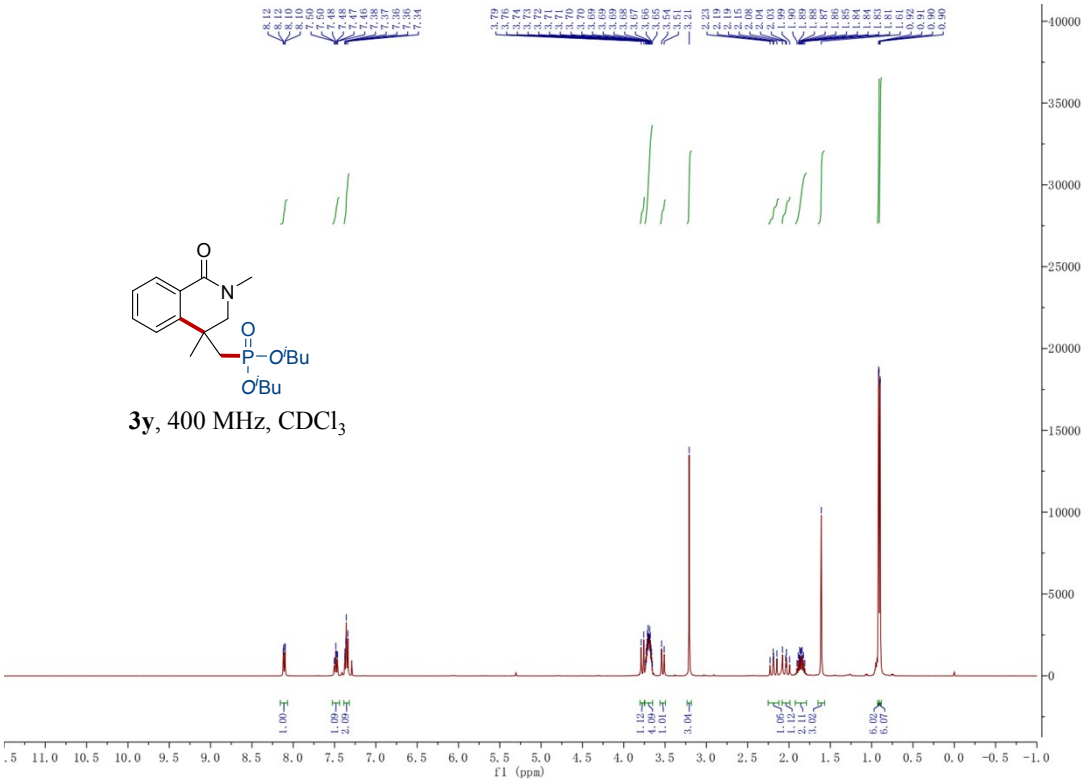




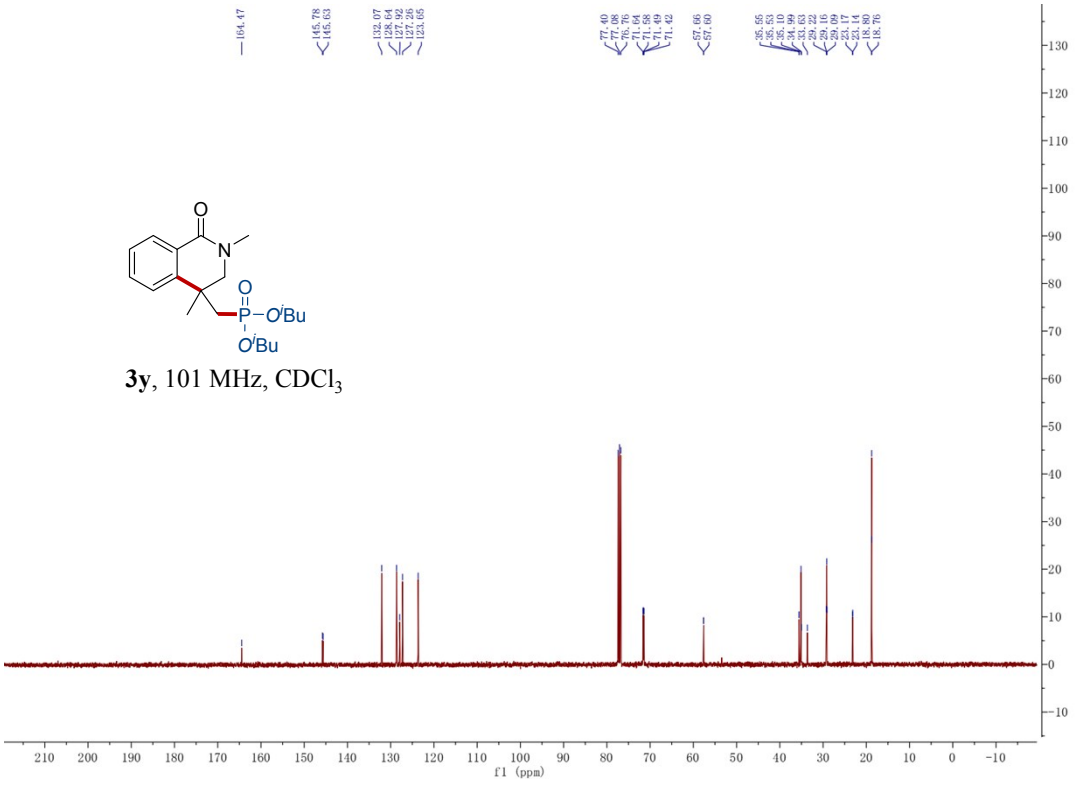
3x, 101 MHz, $CDCl_3$



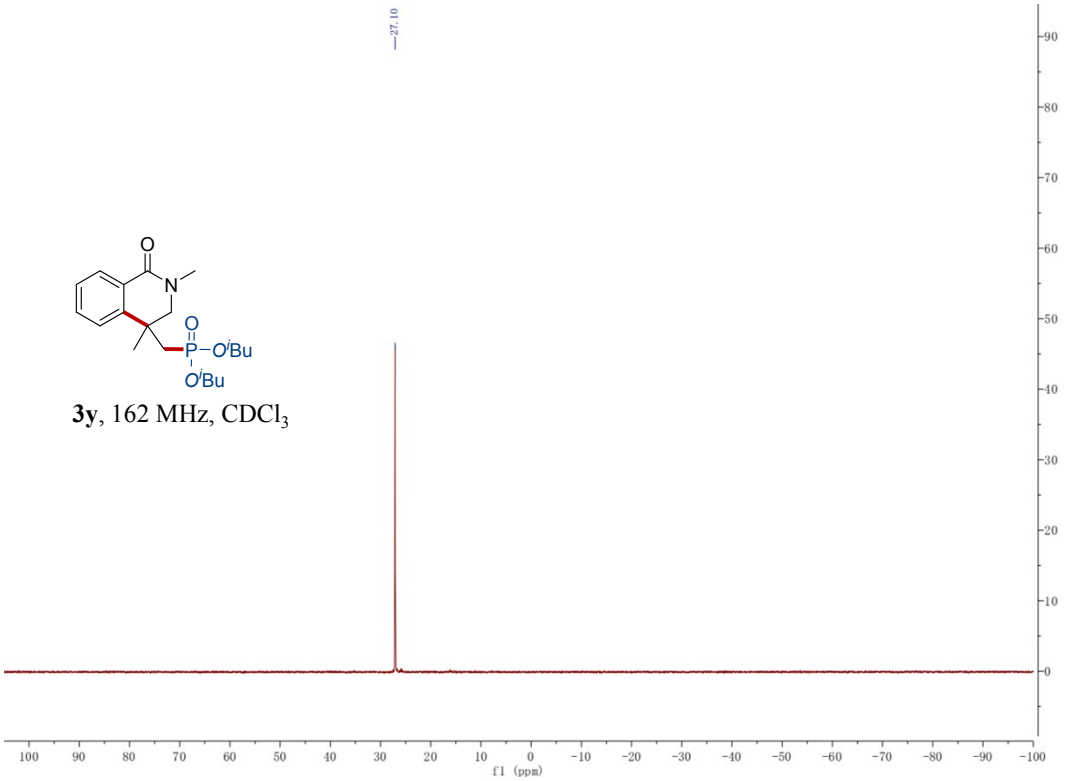
3x, 162 MHz, $CDCl_3$



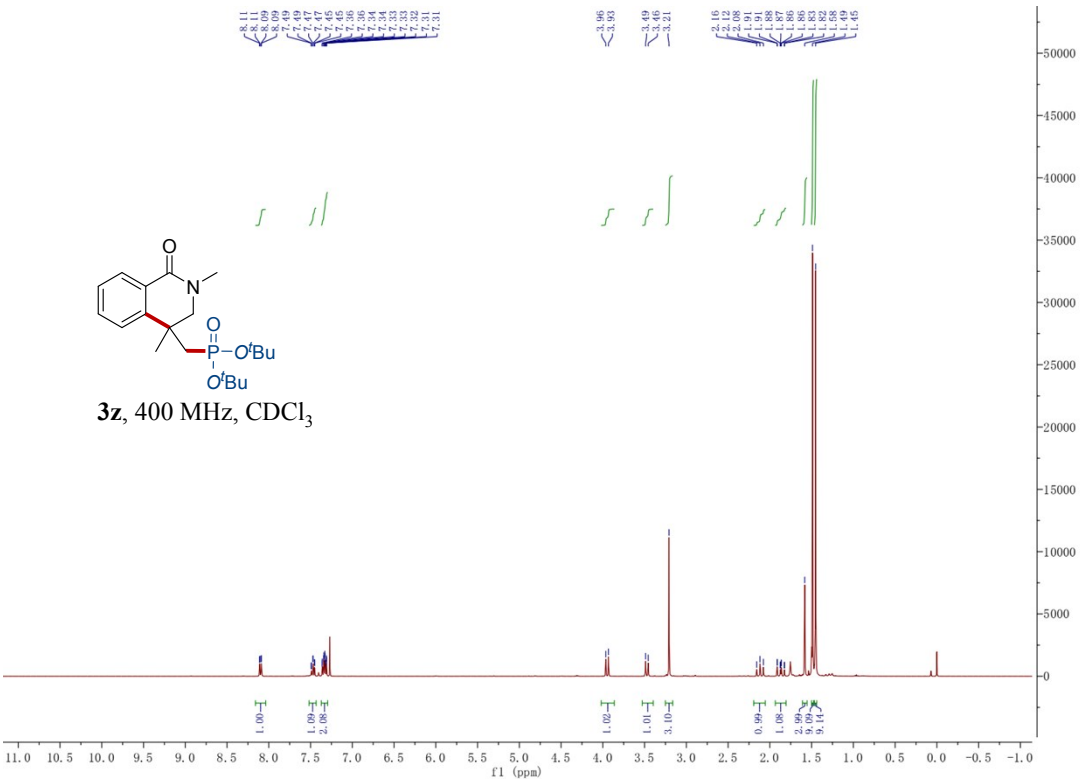
3y, 400 MHz, $CDCl_3$



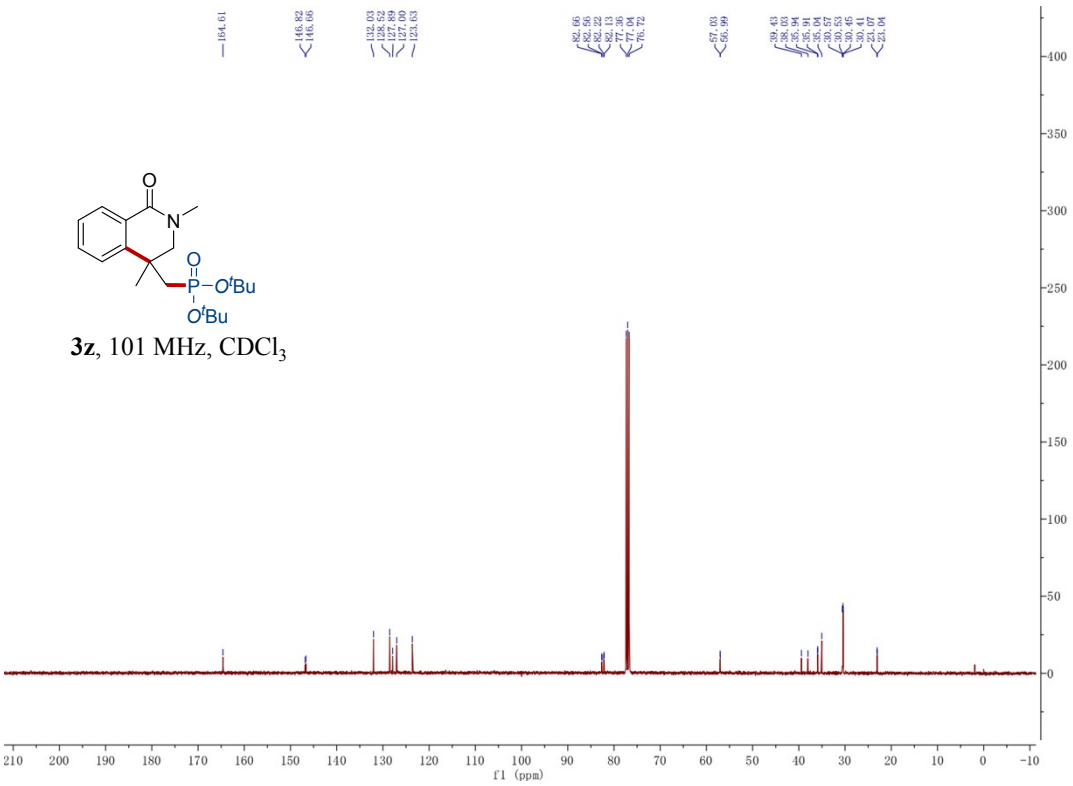
3y, 101 MHz, $CDCl_3$



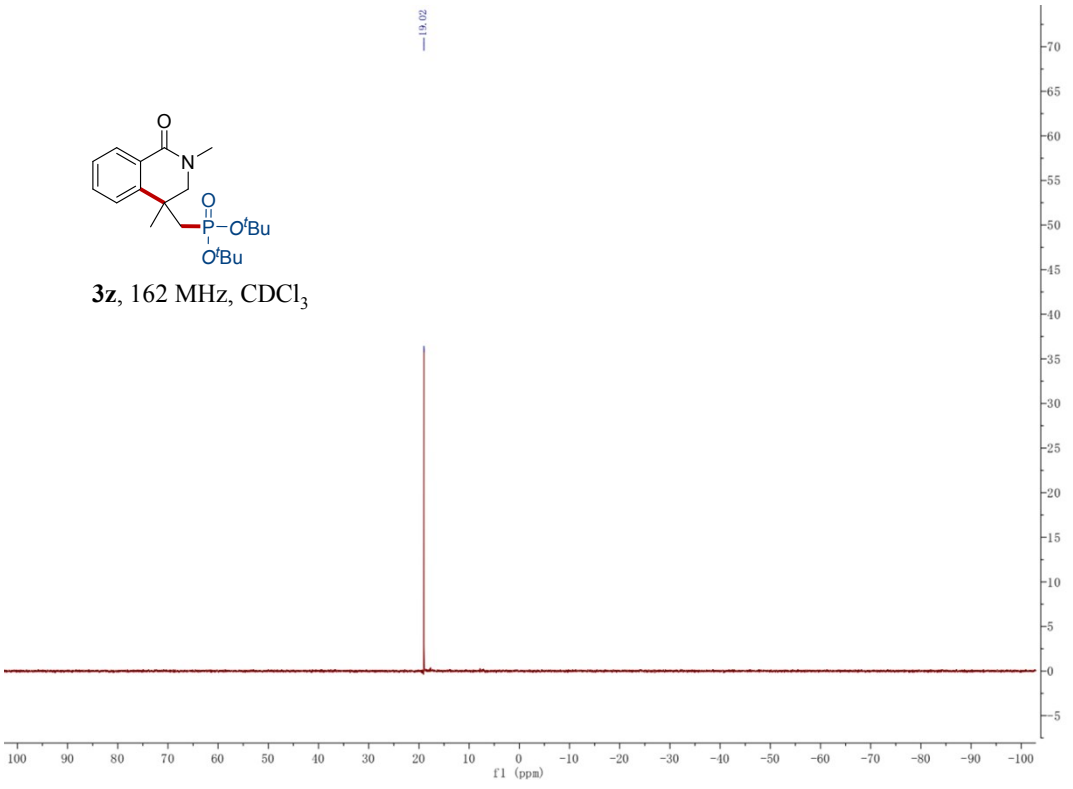
3y, 162 MHz, $CDCl_3$



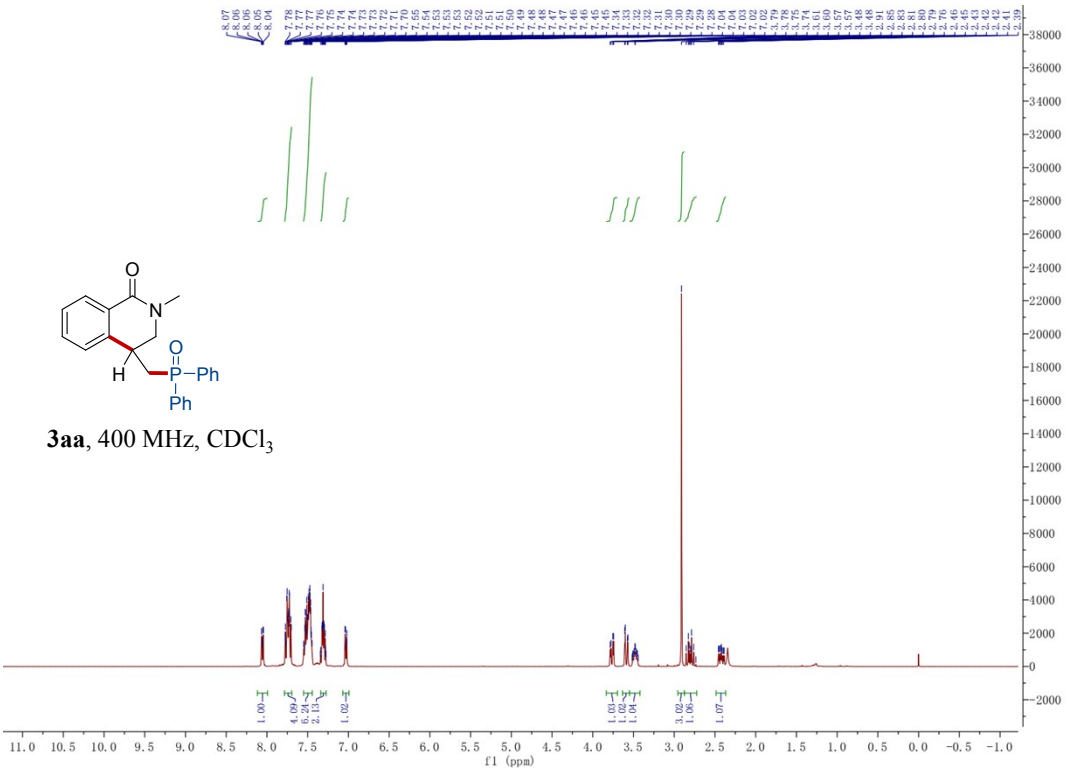
3z, 400 MHz, $CDCl_3$



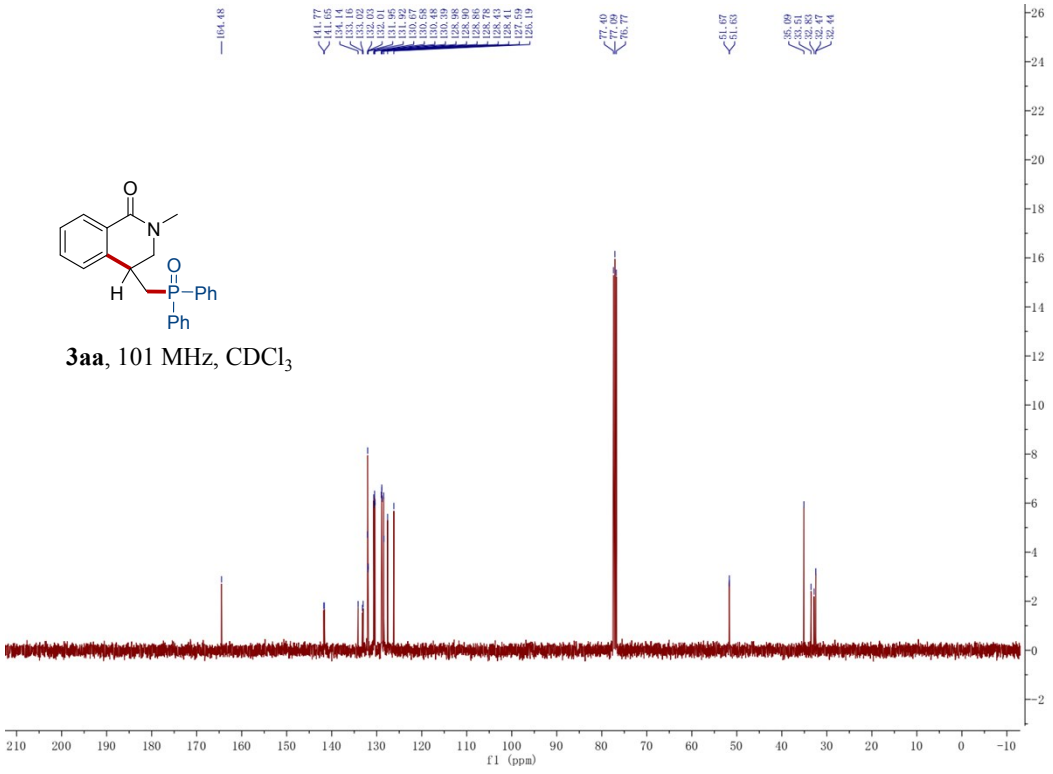
3z, 101 MHz, $CDCl_3$



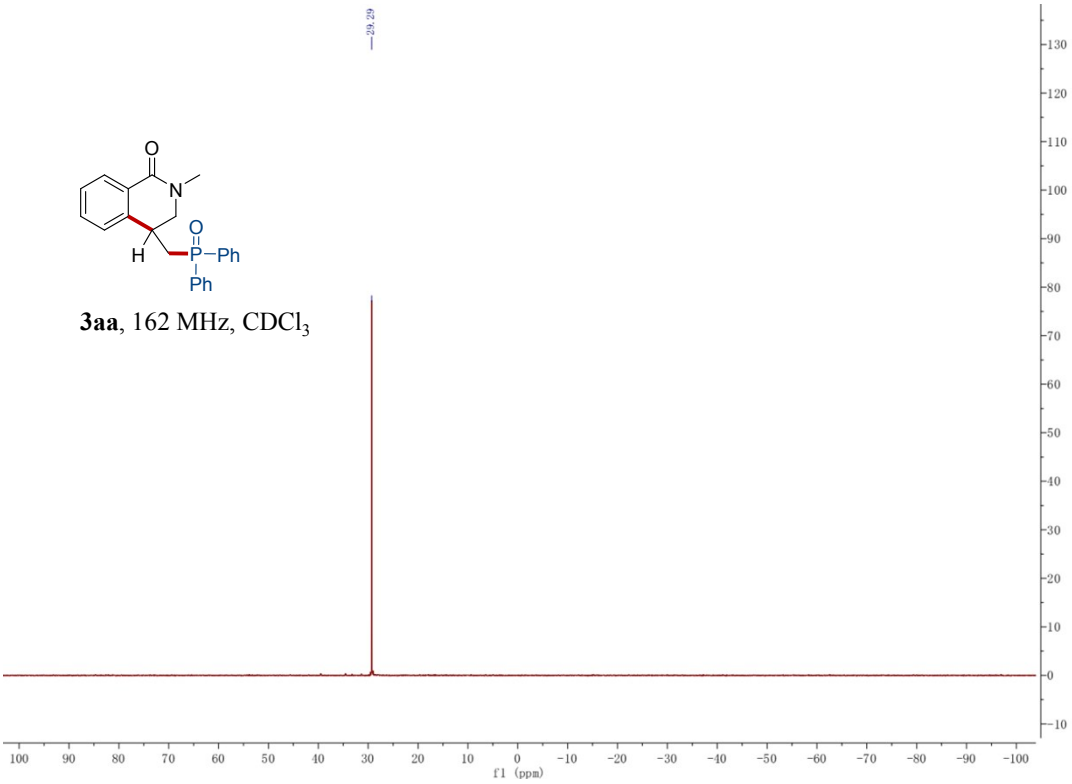
3z, 162 MHz, $CDCl_3$



3aa, 400 MHz, $CDCl_3$



3aa, 101 MHz, $CDCl_3$



3aa, 162 MHz, $CDCl_3$