

Palladium/Silver Reagent-Promoted Aryl Phosphorylation: Flexible Synthesis of Substituted-3-Benzylidene-2-(2-(diphenylphosphoryl)-aryl)-isoindolin-1-one

Peng Shi,[†] Qing Wang,[†] Xiao Zeng,^{††} Yingsheng Zhao,^{*†} Runsheng Zeng^{*†}

[†]Key Laboratory of Organic Synthesis of Jiangsu Province, College of Chemistry Chemical Engineering and Materials Science, Soochow University, Suzhou, Jiangsu 215123, China.

^{††}Department of Chemistry, National University of Singapore, Singapore

*yszha@suda.edu.cn

*zengrunsheng@suda.edu.cn

Table of contents

1. General information.	S2
2. Instrumentation	S2
3. Synthetic procedures and silver catalyzed mechanism	S2
4. Characterization data	S3
5. NMR spectra	S8
6. References:	S38

1. General information.

Unless otherwise noted, all reactions were carried out open to air atmosphere in the oven-dried glass tubes with magnetic stirring. All reagents and solvents were purchased for commercial suppliers. Analytical thin layer chromatography (TLC) was performed using Silica Gel 60 F 254 aluminum plates and visualized with UV light (254 nm). The pure products were obtained by means of column chromatography which was performed on silica gel (200-300 mesh).

2. Instrumentation.

The ^1H NMR (400 MHz), ^{13}C NMR (101 MHz), ^{19}F NMR (376 MHz) and ^{31}P NMR (162 MHz) spectra were recorded at 23 °C with DMSO- d_6 as solvent on a Bruker 400 spectrometer and tetramethylsilane (TMS) as internal standard. Chemical shifts were reported in ppm from internal TMS (δ), all coupling constants (J values) were reported in Hertz (Hz). High resolution mass spectra (HRMS) were obtained on a TOF machine (ESI-TOF).

3. Synthetic procedures and silver catalyzed mechanism

3.1 General procedure for synthesis of 3-benzylidene-2-phenylisoindolin-1-one (**1a**).^[1]

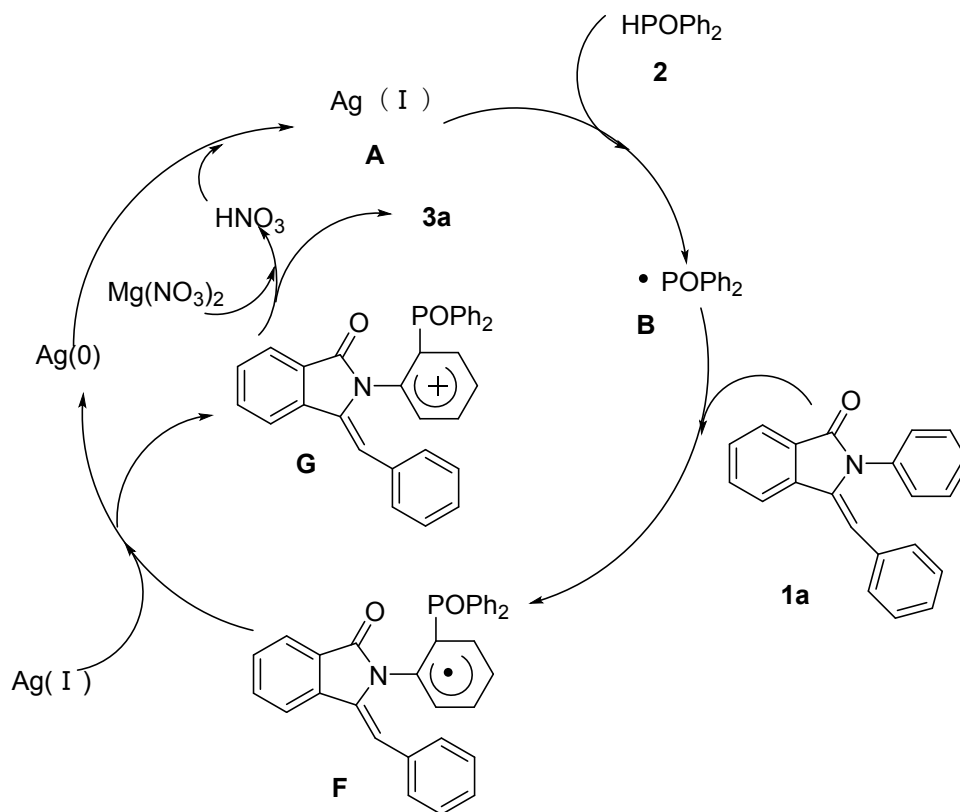
A oven-dried Schlenk tube charged with a magnetic stirring bar was added 2-bromobenzamide (1.380 g, 5 mmol), CuI (95 mg, 0.5 mmol), L-proline (180 mg, 1.5 mmol) and potassium carbonate (1.380 g, 10 mmol), and the tube was evacuated and backfilled with argon (3 times), and then phenylacetylene (830 μl , 7.5 mmol), and *i*-PrOH (10 mL) were added. The reaction mixture was stirred at 80 °C for 16 h. After removal of *i*-PrOH, the residues were filtrated with 20 ml water (3 times). The product (**1a**) was purified by regular column chromatography.

3.2 General procedure for Synthesis of 3-benzylidene-2-(2-(diphenylphosphoryl) phenyl) isoindolin-1-one (**3a**).

To a reaction tube equipped with a magnetic stirring bar were added (E)-3-benzylidene-2-phenylisoindolin-1-one (**1a**) (60 mg, 0.2 mmol), HPOPh_2 (81 mg, 0.4 mmol), $\text{Pd}(\text{OAc})_2$ (5 mg, 0.02 mmol), Ag_2CO_3 (6 mg, 0.02 mmol) and $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ (103 mg, 0.4 mmol), and then CH_3CN (2 ml) was added. The reaction mixture was stirred at 25 °C for 3h. Then the solvent was removed under vacuum, and the residues were

purified by regular column chromatography (petroleum ether: ethyl acetate: dichloromethane=2:1:1).

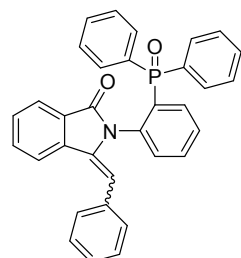
3.3 silver catalyzed mechanism



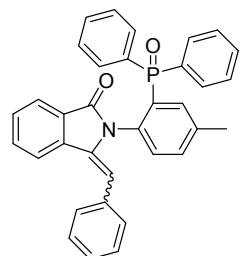
Initially, the diphenylphosphine oxide (**2**) was excited by Ag (I) (**A**) to generate the key intermediate P-centered radical (**B**), which then undergoes addition with substrate (**1a**) to form radical intermediate **F**. Thereafter, the radical intermediate **F** was oxidized by Ag (I) which can regenerate Ag (0) to produce the cation intermediate **G**. What's more, due to the presence of Mg(NO₃)₂, the cation intermediate **G** undergoes deprotonation to yield the corresponding product **3a** and generate HNO₃. Finally, Ag (0) was able to be oxidized to Ag (I) by HNO₃ and complete the catalytic cycle.

4. Characterization data

4.1 3-benzylidene-2-(2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3a)



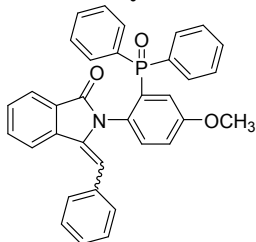
White solid, 78 mg (78 % yield), mp 145.2-146.1 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.94 (d, *J* = 7.7 Hz, 1H), 7.94 – 7.89 (m, 2H), 7.79 – 7.75 (m, 1H), 7.69 (d, *J* = 7.7 Hz, 2H), 7.59 (d, *J* = 8.9 Hz, 3H), 7.57 – 7.54 (m, 3H), 7.52 – 7.39 (m, 4H), 7.37 – 7.32 (m, 2H), 7.12 – 7.04 (m, 3H), 6.83 (t, *J* = 6.6 Hz, 2H), 4.65 (d, *J* = 10.3 Hz, 1H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.66 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 165.00 (s), 145.40 (s), 136.80 (s), 135.92 (s), 135.80 (s), 134.79 (s), 134.70 (s), 133.80 (s), 132.02 (s), 131.75 (s), 130.65 (s), 130.25 (s), 130.17 (s), 129.53 (s), 128.60 (s), 128.14 (s), 128.02 (s), 127.78 (s), 127.67 (s), 127.07 (s), 126.86 (s), 126.51 (s), 125.70 (s), 122.05 (s), 95.88 (s), 51.33 (s), 50.64 (s); HRMS(ESI-TOF): [M+H]⁺ *m/z* calcd for C₃₃H₂₅NO₂P⁺: 498.1623, found; 498.1629.



4.2 3-benzylidene-2-(2-(diphenylphosphoryl)-4-methylphenyl)isoindolin-1-one (3b)

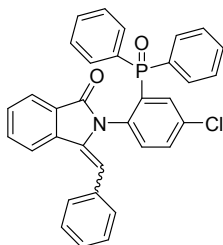
White solid, 64 mg (62 % yield), mp 142.2-142.7 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.92 (d, *J* = 7.6 Hz, 1H), 7.95 – 7.83 (m, 2H), 7.75 (t, *J* = 7.3 Hz, 1H), 7.54 (d, *J* = 8.6 Hz, 5H), 7.49 – 7.44 (m, 2H), 7.41 (d, *J* = 7.3 Hz, 1H), 7.38 – 7.31 (m, 2H), 7.18 – 7.09 (m, 3H), 7.09 – 7.04 (m, 2H), 6.81 (d, *J* = 6.1 Hz, 3H), 4.61 (d, *J* = 10.1 Hz, 1H), 3.90 (s, 3H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.93 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 164.91 (s), 157.56 (s), 145.42 (s), 136.91 (s), 135.90 (s), 134.89 (s), 134.60 (s), 133.90 (s), 131.80 (s), 130.87 (s), 130.63 (s), 130.24 (s), 130.16 (s), 129.43 (s), 128.24 (s), 128.11 (s), 127.99 (s), 127.73 (s), 127.62 (s), 127.49 (s), 127.01 (s), 126.86 (s), 121.91 (s), 113.75 (s), 95.54 (s), 55.30 (s), 51.25 (s), 50.57 (s); HRMS(ESI-TOF): [M+H]⁺ *m/z* calcd for C₃₄H₂₇NO₂P⁺: 512.1779, found; 512.1780.

4.3 3-benzylidene-2-(2-(diphenylphosphoryl)-4-methoxyphenyl)isoindolin-1-one (3c)



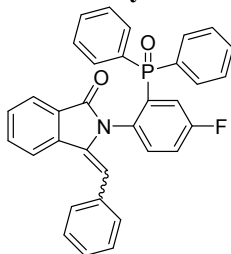
White solid, 69 mg (65 % yield), mp 168.2-168.9 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.97 (d, *J* = 7.7 Hz, 1H), 7.94 (dd, *J* = 9.8, 4.7 Hz, 2H), 7.78 (t, *J* = 7.4 Hz, 1H), 7.63 – 7.55 (m, 6H), 7.50 (t, *J* = 7.3 Hz, 1H), 7.47 – 7.42 (m, 2H), 7.41 – 7.35 (m, 3H), 7.11 (dd, *J* = 14.9, 6.4 Hz, 3H), 6.85 (d, *J* = 6.4 Hz, 2H), 4.69 (d, *J* = 10.2 Hz, 1H), 2.49 (s, 3H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.80 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 164.96 (s), 145.40 (s), 136.83 (s), 135.82 (s), 135.65 (s), 134.83 (s), 133.84 (s), 133.23 (s), 131.89 (s), 131.79 (s), 130.78 (s), 130.68 (s), 130.27 (s), 130.18 (s), 129.46 (s), 129.06 (s), 128.12 (s), 128.00 (s), 127.77 (s), 127.66 (s), 127.03 (s), 126.85 (s), 125.65 (s), 121.96 (s), 51.29 (s), 50.60 (s), 20.88 (s); HRMS(ESI-TOF): [M+H]⁺ *m/z* calcd for C₃₄H₂₇NO₃P⁺: 528.1779, found: 528.1741.

4.4 3-benzylidene-2-(4-chloro-2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3d)

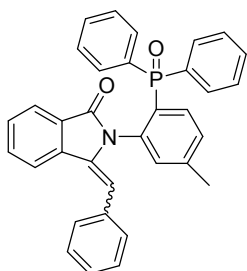


White solid, 87 mg (82 % yield), mp 163.1-163.5 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.97 (d, *J* = 7.7 Hz, 1H), 8.03 – 7.96 (m, 2H), 7.77 (t, *J* = 7.4 Hz, 1H), 7.71 (d, *J* = 8.8 Hz, 2H), 7.68 – 7.62 (m, 3H), 7.55 (s, 3H), 7.51 – 7.38 (m, 5H), 7.09 (dd, *J* = 14.5, 6.2 Hz, 3H), 6.81 (d, *J* = 6.1 Hz, 2H), 4.72 (d, *J* = 10.2 Hz, 1H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.67 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 164.97 (s), 145.34 (s), 136.85 (s), 135.84 (s), 134.92 (s), 134.76 (s), 133.77 (s), 132.17 (s), 131.85 (s), 131.82 (s), 130.70 (s), 130.41 (s), 130.33 (s), 130.30 (s), 130.21 (s), 129.59 (s), 128.68 (s), 128.17 (s), 128.05 (s), 127.72 (s), 127.61 (s), 127.06 (s), 126.95 (s), 122.08 (s), 96.09 (s), 51.30 (s), 50.62 (s); HRMS(ESI-TOF): [M+H]⁺ *m/z* calcd for C₃₃H₂₄ClNO₂P⁺: 532.1233, found: 532.1216.

4.5 3-benzylidene-2-(2-(diphenylphosphoryl)-4-fluorophenyl)isoindolin-1-one (3e)



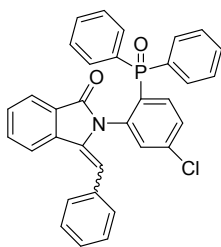
White solid, 78 mg (76 % yield), mp 152.1-152.4 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.97 (d, *J* = 7.7 Hz, 1H), 7.99 – 7.94 (m, 2H), 7.77 (dd, *J* = 10.6, 4.2 Hz, 1H), 7.69 (dd, *J* = 9.0, 5.1 Hz, 2H), 7.64 (s, 1H), 7.59 – 7.50 (m, 4H), 7.49 – 7.45 (m, 3H), 7.45 – 7.41 (m, 3H), 7.13 – 7.04 (m, 3H), 6.83 (t, *J* = 6.7 Hz, 2H), 4.67 (d, *J* = 10.3 Hz, 1H); ³¹P NMR (162 MHz, DMSO) δ 27.84 (s); ¹⁹F NMR (376 MHz, DMSO-d₆) δ -114.58 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 165.45 (s), 162.56 (s), 160.13 (s), 145.67 (s), 136.97 (s), 136.31 (s), 135.96 (s), 135.14 (s), 134.15 (s), 132.61 (s), 131.25 (s), 131.15 (s), 130.91 (s), 130.71 (d, *J* = 8.3 Hz), 130.14 (s), 129.15 (s), 128.57 (d, *J* = 11.8 Hz), 128.35 (s), 128.24 (s), 127.29 (s), 127.04 (s), 126.17 (s), 122.61 (s), 114.42 (d, *J* = 21.1 Hz), 96.30 (s), 51.04 (s), 50.35 (s); HRMS(ESI-TOF): [M+H]⁺ *m/z* calcd for C₃₃H₂₄FNO₂P⁺: 516.1529, found: 516.1526.



4.6 3-benzylidene-2-(2-(diphenylphosphoryl)-5-methylphenyl)isoindolin-1-one (3f)

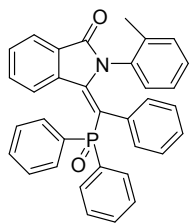
White solid, 88 mg (86 % yield), mp 138.4-138.9 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 9.00 (d, *J* = 7.7 Hz, 1H), 7.98 – 7.91 (m, 2H), 7.77 (t, *J* = 7.0 Hz, 1H), 7.61 (s, 1H), 7.55 (s, 4H), 7.53 – 7.40 (m, 5H), 7.39 – 7.34 (m, 2H), 7.27 (d, *J* = 6.8 Hz, 1H), 7.07 (dd, *J* = 13.9, 6.3 Hz, 3H), 6.82 (s, 2H), 4.68 (d, *J* = 10.3 Hz, 1H), 2.44 (s, 3H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.73 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 165.01 (s), 145.40 (s), 137.84 (s), 136.92 (s), 135.97 (s), 134.80 (s), 133.81 (s), 132.00 (s), 131.78 (s), 130.72 (s), 130.29 (s), 130.24 (s), 130.15 (s), 129.49 (s), 128.35 (s), 128.19 (s), 128.07 (s), 127.76 (s), 127.65 (s), 127.05 (s), 126.94 (s), 125.67 (s), 123.02 (s), 122.01 (s), 95.95 (s), 51.32 (s), 50.64 (s), 21.42 (s); HRMS(ESI-TOF): [M+H]⁺ m/z calcd for C₃₄H₂₇NO₂P⁺: 512.1779, found: 512.1784.

4.7 3-benzylidene-2-(5-chloro-2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3g)



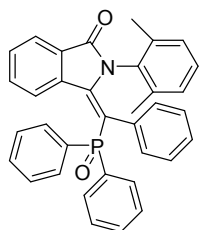
White solid, 78 mg (74 % yield), mp 159.2-159.9 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 9.02 (d, *J* = 7.5 Hz, 1H), 8.03 (s, 2H), 7.85 (s, 1H), 7.82 – 7.74 (m, 2H), 7.71 (d, *J* = 7.7 Hz, 1H), 7.65 – 7.54 (m, 4H), 7.53 – 7.40 (m, 5H), 7.16 – 7.02 (m, 3H), 6.75 (d, *J* = 58.3 Hz, 3H), 4.78 (d, *J* = 10.1 Hz, 1H); ³¹P NMR (162 MHz, DMSO-d₆) δ 27.56 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 165.01 (s), 145.30 (s), 137.58 (s), 136.92 (s), 135.91 (s), 134.72 (s), 133.73 (s), 133.10 (s), 132.34 (s), 131.84 (s), 130.64 (s), 130.33 (s), 130.23 (s), 130.11 (s), 129.66 (s), 128.31 (s), 128.19 (s), 127.74 (s), 127.63 (s), 127.01 (s), 126.08 (s), 124.15 (s), 123.96 (s), 122.17 (s), 96.31 (s), 51.22 (s), 50.53 (s); HRMS(ESI-TOF): [M+H]⁺ m/z calcd for C₃₃H₂₄ClNO₂P⁺: 532.1233, found: 532.1216.

4.8 3-((diphenylphosphoryl)(phenyl)methylene)-2-(o-tolyl)isoindolin-1-one (3h)



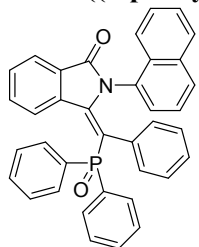
White solid, 63 mg (62 % yield), mp 218.6-219.4 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.84 (d, *J* = 8.0 Hz, 1H), 7.82 (d, *J* = 7.4 Hz, 1H), 7.60 – 7.52 (m, 3H), 7.51 (d, *J* = 2.8 Hz, 1H), 7.46 – 7.38 (m, 3H), 7.32 (dd, *J* = 7.6, 2.6 Hz, 3H), 7.26 (dd, *J* = 7.5, 2.6 Hz, 2H), 6.91 – 6.81 (m, 3H), 6.78 (d, *J* = 7.3 Hz, 1H), 6.61 (s, 3H), 6.45 (s, 2H), 1.94 (s, 3H); ³¹P NMR (162 MHz, DMSO-d₆) δ 29.63 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 167.30 (s), 147.18 (s), 147.03 (s), 135.85 (s), 135.60 (s), 135.16 (s), 134.88 (s), 133.42 (s), 132.32 (s), 132.17 (s), 131.71 (s), 131.59 (s), 131.49 (s), 130.77 (s), 129.87 (s), 129.70 (s), 128.88 (s), 128.48 (s), 128.27 (s), 128.15 (s), 128.03 (s), 127.73 (s), 126.13 (s), 125.88 (s), 122.97 (s), 117.73 (s), 116.78 (s), 17.79 (s); HRMS(ESI-TOF): [M+H]⁺ m/z calcd for C₃₄H₂₇NO₂P⁺: 512.1779, found: 512.1775.

4.9 2-(2,6-dimethylphenyl)-3-((diphenylphosphoryl)(phenyl)methylene)isoindolin-1-one (3i)



White solid, 42 mg (40 % yield), mp 226.1-226.6 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.96 (d, *J* = 7.5 Hz, 1H), 7.97 – 7.92 (m, 1H), 7.60 (s, 1H), 7.58 (d, *J* = 4.5 Hz, 2H), 7.56 – 7.48 (m, 3H), 7.39 (t, *J* = 6.9 Hz, 2H), 7.28 (td, *J* = 7.6, 2.9 Hz, 4H), 6.82 – 6.77 (m, 1H), 6.70 – 6.63 (m, 3H), 6.54 (d, *J* = 5.1 Hz, 4H), 2.10 (s, 6H); ³¹P NMR (162 MHz, DMSO-d₆) δ 29.77 (s); ¹³C NMR (101 MHz, DMSO-d₆) δ 166.74 (s), 145.67 (s), 145.52 (s), 135.95 (s), 134.82 (s), 134.59 (s), 134.00 (s), 133.30 (s), 132.22 (s), 131.61 (s), 131.51 (s), 131.45 (s), 130.79 (s), 129.30 (s), 128.77 (s), 128.69 (s), 128.23 (s), 128.11 (s), 127.98 (s), 127.51 (s), 126.42 (s), 126.32 (s), 123.01 (s), 117.42 (s), 116.47 (s), 18.11 (s); HRMS(ESI-TOF): [M+H]⁺ m/z calcd for C₃₅H₂₉NO₂P⁺: 526.1936, found: 526.1946.

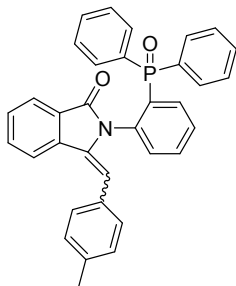
4.10 3-((diphenylphosphoryl)(phenyl)methylene)-2-(naphthalen-1-yl)isoindolin-1-one (3j)



White solid, 50 mg (46 % yield), mp 198.1-198.6 °C; ¹H NMR (400 MHz, DMSO-d₆) δ 8.92 (d, *J* = 7.9 Hz, 1H), 7.87 (d, *J* = 7.3 Hz, 1H), 7.73 (d, *J* = 8.0 Hz, 1H), 7.64 (t, *J* = 7.4 Hz, 1H), 7.59 (d, *J* = 7.9 Hz, 1H), 7.55 (d, *J* = 8.1 Hz, 1H), 7.51 (d, *J* = 3.5 Hz, 2H), 7.47 –

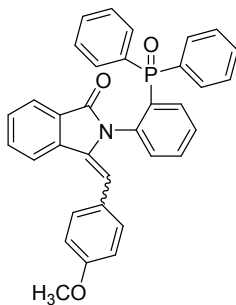
7.41 (m, 3H), 7.40 (s, 1H), 7.35 (d, $J = 9.8$ Hz, 3H), 7.27 (d, $J = 6.4$ Hz, 4H), 7.17 (d, $J = 7.0$ Hz, 1H), 7.14 – 7.09 (m, 1H), 6.51 (d, $J = 6.8$ Hz, 1H), 6.41 (t, $J = 7.2$ Hz, 1H), 6.29 (s, 1H), 5.79 (s, 2H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 29.72 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 167.82 (s), 147.55 (s), 147.40 (s), 135.09 (s), 135.05 (s), 134.38 (s), 134.33 (s), 133.37 (s), 133.31 (s), 133.20 (s), 133.13 (s), 132.29 (d, $J = 7.2$ Hz), 131.57 (dd, $J = 9.3, 5.1$ Hz), 131.40 (s), 130.90 (s), 130.32 (s), 129.71 (s), 128.85 (s), 128.60 (s), 128.10 (dd, $J = 11.8, 3.8$ Hz), 127.87 (s), 126.36 (s), 125.95 (s), 125.55 (s), 125.30 (s), 125.04 (s), 123.10 (s), 122.73 (s), 117.99 (s), 117.04 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{37}\text{H}_{27}\text{NO}_2\text{P}^+$: 548.1779, found: 548.1777.

4.11 2-(2-(diphenylphosphoryl)phenyl)-3-(4-methylbenzylidene)isoindolin-1-one (3k)



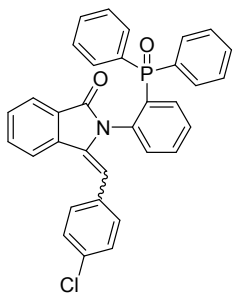
White solid, 62mg (61 % yield), mp 166.3-167.1 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.96 (d, $J = 7.7$ Hz, 1H), 7.95 – 7.87 (m, 2H), 7.78 – 7.70 (m, 3H), 7.61 – 7.56 (m, 3H), 7.53 (d, $J = 1.8$ Hz, 3H), 7.46 (dd, $J = 12.8, 6.6$ Hz, 3H), 7.38 – 7.32 (m, 2H), 7.12 – 7.03 (m, 3H), 6.56 (s, 2H), 4.64 (d, $J = 10.4$ Hz, 1H), 1.94 (s, 3H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 27.80 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 165.08 (s), 145.51 (s), 137.01 (s), 136.03 (s), 135.97 (s), 134.91 (s), 133.92 (s), 132.00 (s), 130.68 (s), 130.63 (s), 130.31 (s), 130.21 (s), 130.13 (s), 129.48 (s), 128.58 (s), 128.11 (s), 127.99 (s), 127.81 (s), 127.68 (d, $J = 3.6$ Hz), 127.66 (s), 126.87 (s), 126.50 (s), 125.71 (s), 95.96 (s), 50.84 (s), 50.02 – 48.66 (m), 20.38 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{34}\text{H}_{27}\text{NO}_2\text{P}^+$: 512.1779, found: 512.1763.

4.12 2-(2-(diphenylphosphoryl)phenyl)-3-(4-methoxybenzylidene)isoindolin-1-one (3l)



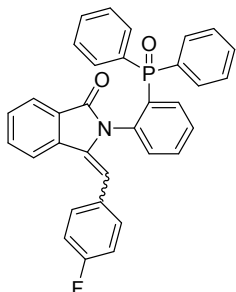
White solid, 88 mg (84 % yield), mp 171.1-171.5 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.95 (d, $J = 7.7$ Hz, 1H), 7.91 (dd, $J = 9.7, 4.8$ Hz, 2H), 7.80 – 7.69 (m, 3H), 7.58 (dd, $J = 18.5, 11.0$ Hz, 6H), 7.47 (dd, $J = 15.9, 6.7$ Hz, 3H), 7.39 – 7.31 (m, 2H), 7.09 (dd, $J = 12.4, 6.5$ Hz, 3H), 6.33 (s, 2H), 4.60 (d, $J = 10.6$ Hz, 1H), 3.45 (s, 3H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 28.04 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 165.57 (s), 158.34 (s), 145.99 (s), 137.48 (s), 136.45 (s), 135.47 (s), 134.48 (s), 132.48 (s), 131.20 (s), 131.10 (s), 130.68 (s), 130.61 (s), 129.97 (s), 129.07 (s), 128.57 (s), 128.46 (s), 128.29 (s), 128.18 (s), 127.30 (s), 126.98 (s), 126.22 (s), 123.90 (s), 122.56 (s), 112.88 (s), 96.48 (s), 55.11 (s), 50.85 (s), 50.16 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{34}\text{H}_{27}\text{NO}_3\text{P}^+$: 528.1779, found: 528.1734.

4.13 3-(4-chlorobenzylidene)-2-(2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3m)



White solid, 61 mg (58% yield), mp 147.5-147.9 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.90 (d, $J = 7.7$ Hz, 1H), 7.94 – 7.89 (m, 2H), 7.77 (t, $J = 6.8$ Hz, 1H), 7.69 – 7.64 (m, 3H), 7.60 – 7.53 (m, 5H), 7.50 (s, 1H), 7.49 – 7.44 (m, 3H), 7.44 – 7.36 (m, 3H), 7.15 (d, $J = 6.9$ Hz, 1H), 7.10 (d, $J = 5.3$ Hz, 2H), 4.67 (d, $J = 10.2$ Hz, 1H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 27.52 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 164.93 (s), 145.08 (s), 135.75 (s), 134.69 (s), 134.57 (s), 132.16 (s), 131.78 (s), 130.60 (s), 130.25 (s), 129.71 (s), 128.83 (s), 128.68 (s), 128.49 (s), 128.16 (s), 128.04 (s), 127.93 (s), 127.82 (s), 127.40 (s), 127.07 (s), 126.80 (s), 126.58 (s), 125.68 (s), 123.41 (s), 122.14 (s), 95.71 (s), 50.70 (s), 50.02 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{33}\text{H}_{24}\text{ClNO}_2\text{P}^+$: 532.1233, found: 532.1234.

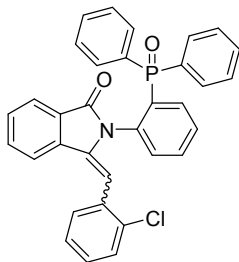
4.14 2-(2-(diphenylphosphoryl)phenyl)-3-(4-fluorobenzylidene)isoindolin-1-one (3n)



White solid, 55 mg (54 % yield), mp 156.8-157.2 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.93 (d, $J = 7.7$ Hz, 1H), 7.98 – 7.89 (m, 2H), 7.71 (dd, $J = 23.9, 16.3$ Hz, 5H), 7.63 – 7.51 (m, 6H), 7.48 (dd, $J = 13.0, 6.7$ Hz, 3H), 7.38 (dd, $J = 9.5, 8.1$ Hz, 2H), 7.16 – 7.05 (m, 3H), 4.68 (d, $J = 10.4$ Hz, 1H); ^{19}F NMR (376 MHz, DMSO- d_6) δ -114.58 (s);

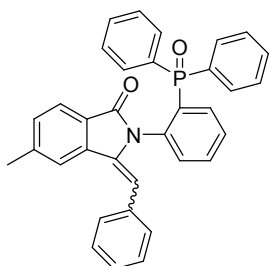
^{31}P NMR (162 MHz, DMSO- d_6) δ 27.84 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 165.45 (s), 145.67 (s), 136.97 (s), 136.31 (s), 135.96 (s), 135.14 (s), 134.15 (s), 132.61 (s), 131.25 (s), 131.15 (s), 130.91 (s), 130.76 (s), 130.67 (s), 130.14 (s), 129.15 (s), 128.63 (s), 128.51 (s), 128.35 (s), 128.24 (s), 127.29 (s), 127.04 (s), 126.17 (s), 122.61 (s), 114.42 (d, $J = 21.1$ Hz), 96.30 (s), 51.04 (s), 50.35 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{33}\text{H}_{24}\text{FNO}_2\text{P}^+$: 516.1529, found: 516.1538.

4.15 3-(2-chlorobenzylidene)-2-(2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3o)



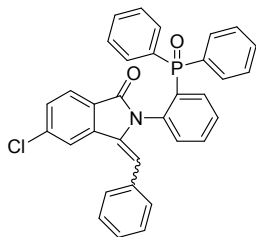
White solid, 72 mg (68 % yield), mp 132.4-132.8 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.95 (d, $J = 7.8$ Hz, 1H), 8.12 – 7.96 (m, 2H), 7.88 – 7.78 (m, 1H), 7.71 (s, 1H), 7.66 (d, $J = 1.1$ Hz, 1H), 7.63 (d, $J = 7.7$ Hz, 2H), 7.58 (t, $J = 6.9$ Hz, 2H), 7.44 (t, $J = 7.8$ Hz, 2H), 7.31 (t, $J = 7.3$ Hz, 1H), 7.20 – 7.13 (m, 3H), 7.06 – 6.99 (m, 2H), 6.95 – 6.89 (m, 1H), 6.85 (d, $J = 7.8$ Hz, 1H), 6.78 – 6.70 (m, 2H), 5.31 (d, $J = 11.3$ Hz, 1H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 29.27 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 164.86 (s), 145.31 (s), 136.19 (s), 135.13 (s), 134.77 (s), 133.77 (s), 133.39 (s), 132.39 (s), 132.26 (s), 131.27 (s), 130.97 (s), 130.76 (s), 130.48 (s), 130.39 (s), 129.92 (s), 129.41 (s), 129.05 (s), 128.83 (s), 128.38 (s), 127.36 (s), 125.95 (s), 125.62 (s), 124.78 (s), 122.24 (s), 96.17 (s), 47.61 (s), 46.94 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{33}\text{H}_{24}\text{ClNO}_2\text{P}^+$: 532.1233, found: 532.1221.

4.16 3-benzylidene-2-(2-(diphenylphosphoryl)phenyl)-5-methylisoindolin-1-one (3p)



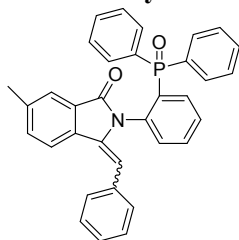
White solid, 68 mg (67 % yield), mp 158.2-158.9 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.76 (s, 1H), 7.98 – 7.84 (m, 2H), 7.69 (d, $J = 7.7$ Hz, 2H), 7.61 – 7.50 (m, 6H), 7.44 (t, $J = 7.3$ Hz, 1H), 7.35 (dd, $J = 12.6, 8.2$ Hz, 3H), 7.29 (d, $J = 7.6$ Hz, 1H), 7.07 (dd, $J = 8.0, 6.0$ Hz, 3H), 6.87 – 6.72 (m, 3H), 4.65 (d, $J = 10.4$ Hz, 1H), 2.54 (s, 3H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 27.68 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 165.03 (s), 145.75 (s), 142.10 (s), 136.84 (s), 136.06 (s), 135.84 (s), 134.86 (s), 133.87 (s), 131.79 (s), 130.68 (s), 130.18 (s), 128.55 (s), 128.25 (s), 128.12 (s), 128.01 (s), 127.78 (s), 127.67 (s), 127.16 (s), 127.03 (s), 126.38 (s), 125.70 (s), 121.98 (s), 95.73 (s), 51.34 (s), 50.65 (s), 21.93 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{34}\text{H}_{27}\text{NO}_2\text{P}^+$: 512.1779, found: 512.1777.

4.17 3-benzylidene-5-chloro-2-(2-(diphenylphosphoryl)phenyl)isoindolin-1-one (3q)



White solid, 68 mg (64 % yield), mp 162.7-163.2 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 9.10 (s, 1H), 7.93 (dd, $J = 6.3, 4.5$ Hz, 2H), 7.80 (s, 1H), 7.68 (d, $J = 7.8$ Hz, 2H), 7.58 (dd, $J = 15.6, 7.3$ Hz, 6H), 7.50 – 7.44 (m, 2H), 7.44 – 7.36 (m, 2H), 7.09 (dd, $J = 14.4, 6.2$ Hz, 3H), 6.85 (d, $J = 5.3$ Hz, 3H), 4.69 (d, $J = 10.1$ Hz, 1H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 28.15 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 164.44 (s), 147.74 (s), 137.49 (s), 137.12 (s), 136.11 (s), 134.94 (s), 133.95 (s), 132.05 (s), 131.26 (s), 130.91 (s), 130.75 (d, $J = 8.3$ Hz), 130.61 (d, $J = 8.5$ Hz), 130.33 (s), 129.94 (s), 129.18 (s), 128.68 (s), 128.56 (s), 128.31 (s), 128.20 (s), 127.74 (s), 127.50 (s), 127.19 (s), 126.02 (s), 124.43 (s), 95.97 (s), 51.52 (s), 50.84 (s); HRMS(ESI-TOF): $[\text{M}+\text{H}]^+$ m/z calcd for $\text{C}_{33}\text{H}_{24}\text{ClNO}_2\text{P}^+$: 532.1233, found: 532.1218.

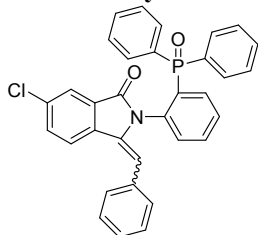
4.18 3-benzylidene-2-(2-(diphenylphosphoryl)phenyl)-6-methylisoindolin-1-one (3r)



White solid, 63 mg (62 % yield), mp 166.5-167.2 °C; ^1H NMR (400 MHz, DMSO- d_6) δ 8.82 (d, $J = 7.8$ Hz, 1H), 7.92 (dd, $J = 9.8, 4.6$ Hz, 2H), 7.70 (d, $J = 7.8$ Hz, 2H), 7.62 – 7.50 (m, 7H), 7.47 – 7.42 (m, 1H), 7.38 – 7.31 (m, 2H), 7.27 (s, 1H), 7.07 (dd, $J = 14.4, 6.3$ Hz, 3H), 6.87 – 6.71 (m, 3H), 4.66 (d, $J = 10.3$ Hz, 1H), 2.36 (s, 3H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 27.74 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 165.61 (s), 143.27 (s), 139.58 (s), 137.32 (s), 136.55 (s), 136.32 (s), 135.32 (s), 134.34 (s), 133.26

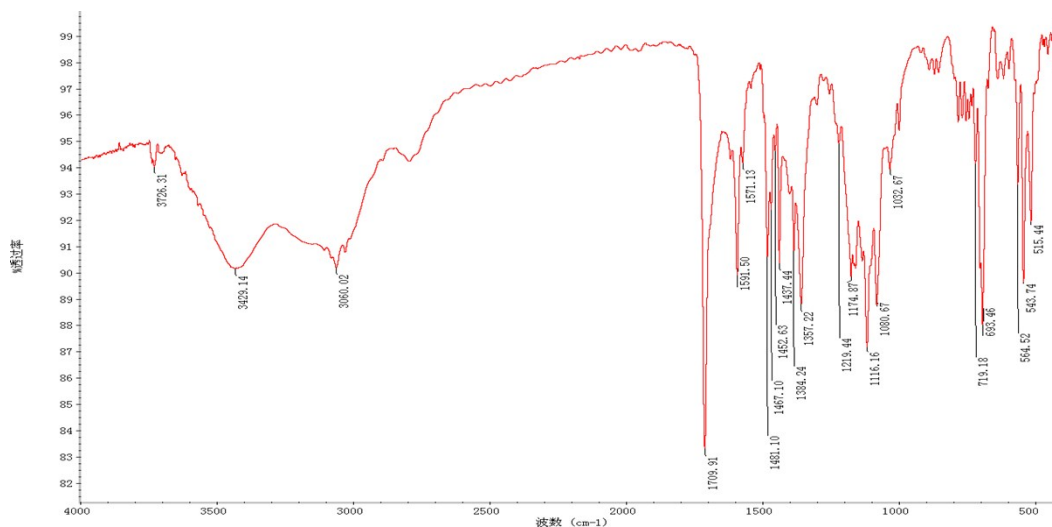
(s), 132.32 (s), 132.29 (s), 131.37 (s), 131.14 (s), 130.71 (s), 129.03 (s), 128.60 (s), 128.48 (s), 128.23 (s), 128.12 (s), 127.52 (s), 127.17 (s), 126.88 (s), 126.13 (s), 122.69 (s), 96.27 (s), 51.89 (s), 51.20 (s), 21.35 (s); HRMS(ESI-TOF): $[M+H]^+$ m/z calcd for $C_{34}H_{27}NO_2P^+$: 512.1779, found: 512.1766.

4.19 3-benzylidene-6-chloro-2-(2-(diphenylphosphoryl)phenyl)isoindolin-1-one(3s)



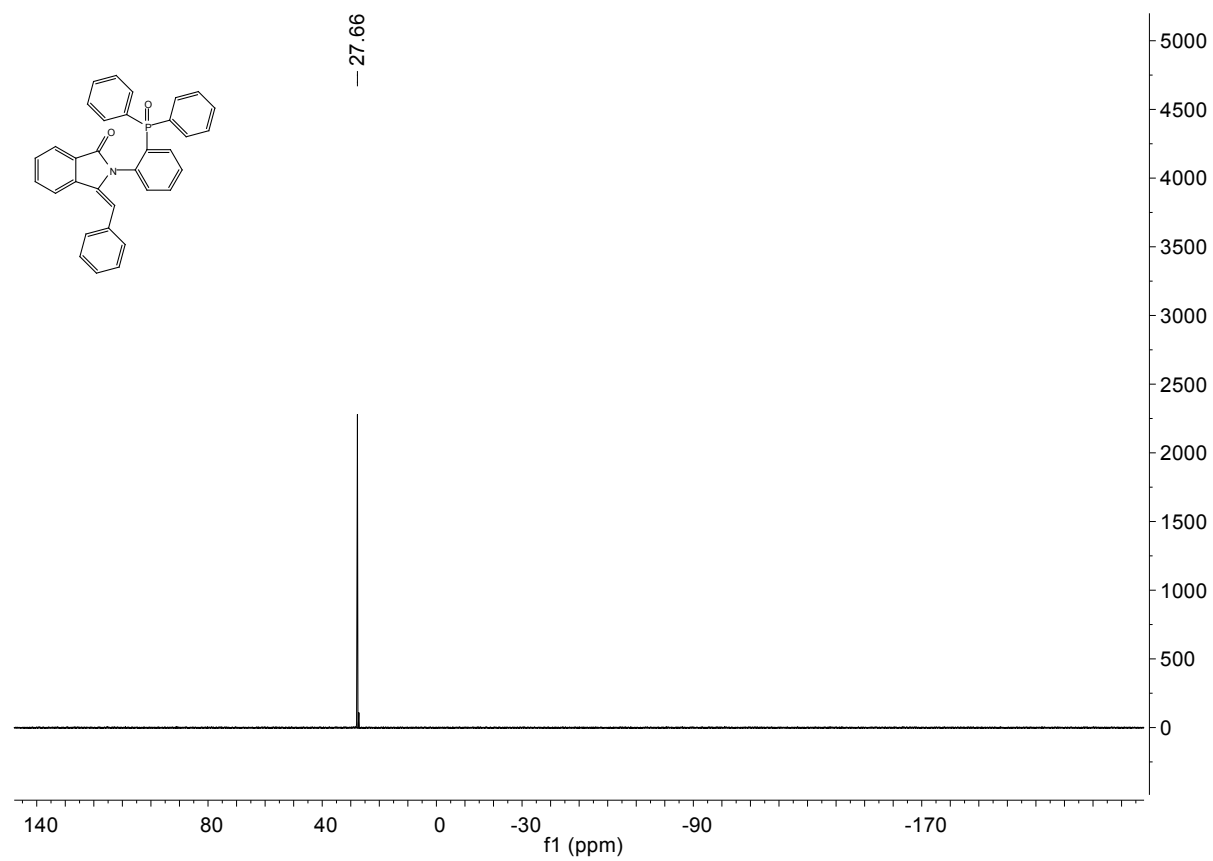
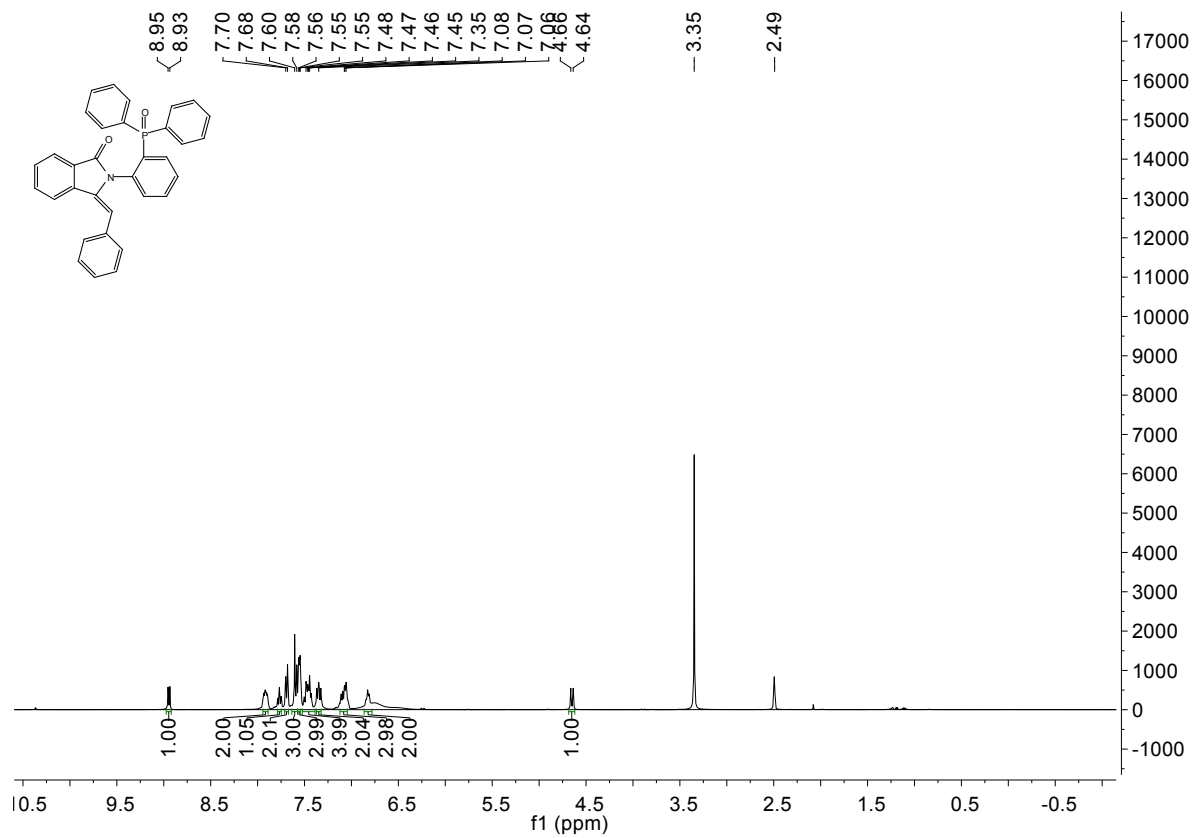
White solid, 64 mg (60% yield), mp 148.9-149.4 °C; 1H NMR (400 MHz, DMSO- d_6) δ 9.00 (d, $J = 8.3$ Hz, 1H), 7.96 – 7.89 (m, 2H), 7.86 (dd, $J = 8.3, 1.8$ Hz, 1H), 7.79 (s, 1H), 7.71 (d, $J = 7.9$ Hz, 2H), 7.62 – 7.53 (m, 5H), 7.47 (dd, $J = 8.6, 4.6$ Hz, 2H), 7.42 – 7.35 (m, 2H), 7.08 (dd, $J = 15.9, 6.3$ Hz, 3H), 6.85 (d, $J = 6.0$ Hz, 3H), 4.69 (d, $J = 10.2$ Hz, 1H); ^{31}P NMR (162 MHz, DMSO- d_6) δ 28.02 (s); ^{13}C NMR (101 MHz, DMSO- d_6) δ 163.67 (s), 144.09 (s), 136.63 (s), 135.62 (s), 134.52 (s), 134.39 (s), 133.53 (s), 132.72 (s), 132.09 (s), 131.58 (s), 130.76 (s), 130.39 (s), 130.27 (s), 130.20 (s), 128.91 (s), 128.71 (s), 128.17 (s), 128.05 (s), 127.82 (s), 127.71 (s), 127.27 (s), 126.79 (s), 125.61 (s), 121.79 (s), 95.79 (s), 51.17 (s), 50.49 (s); HRMS(ESI-TOF): $[M+H]^+$ m/z calcd for $C_{33}H_{24}ClNO_2P^+$: 532.1233, found: 532.1220.

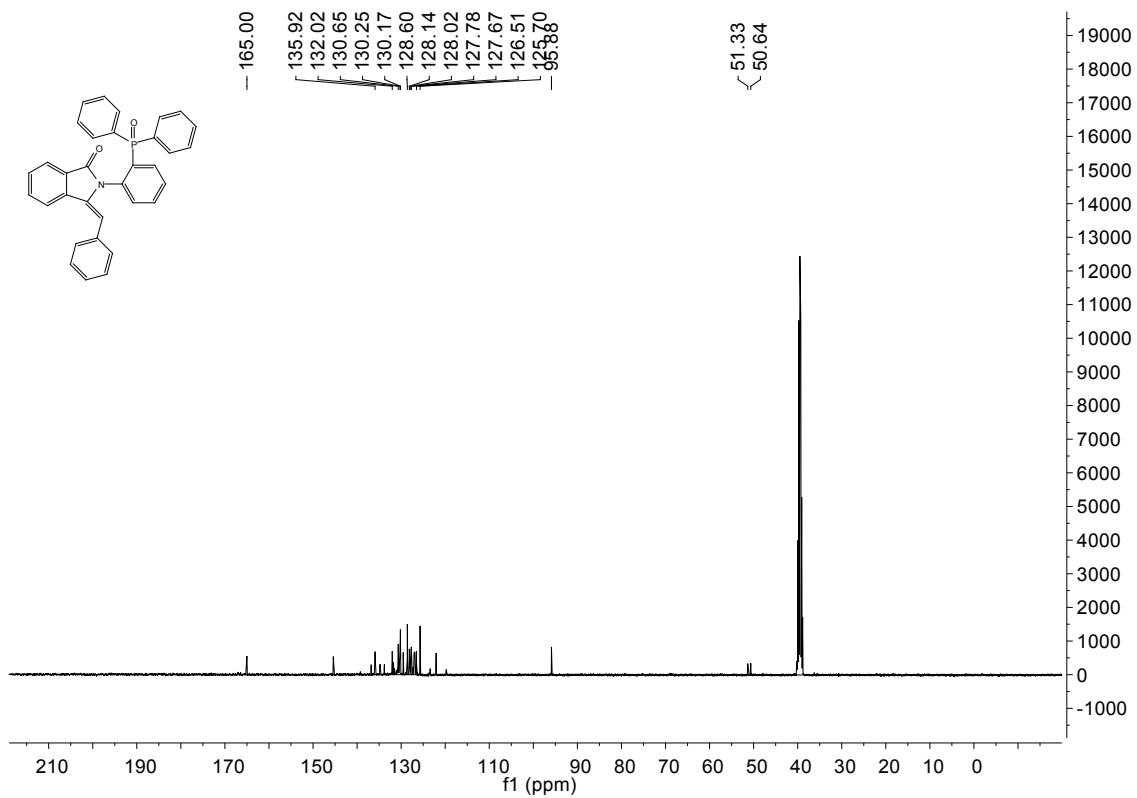
5. IR spectra (3d).



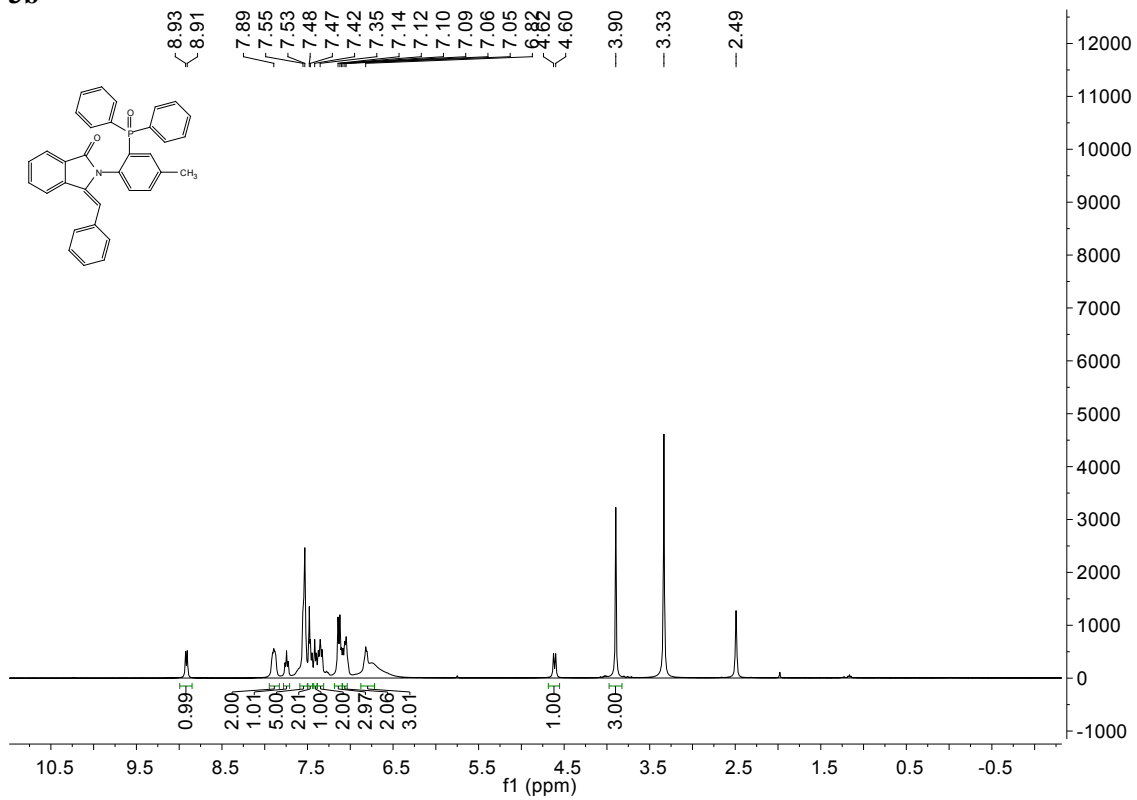
6. NMR spectra.

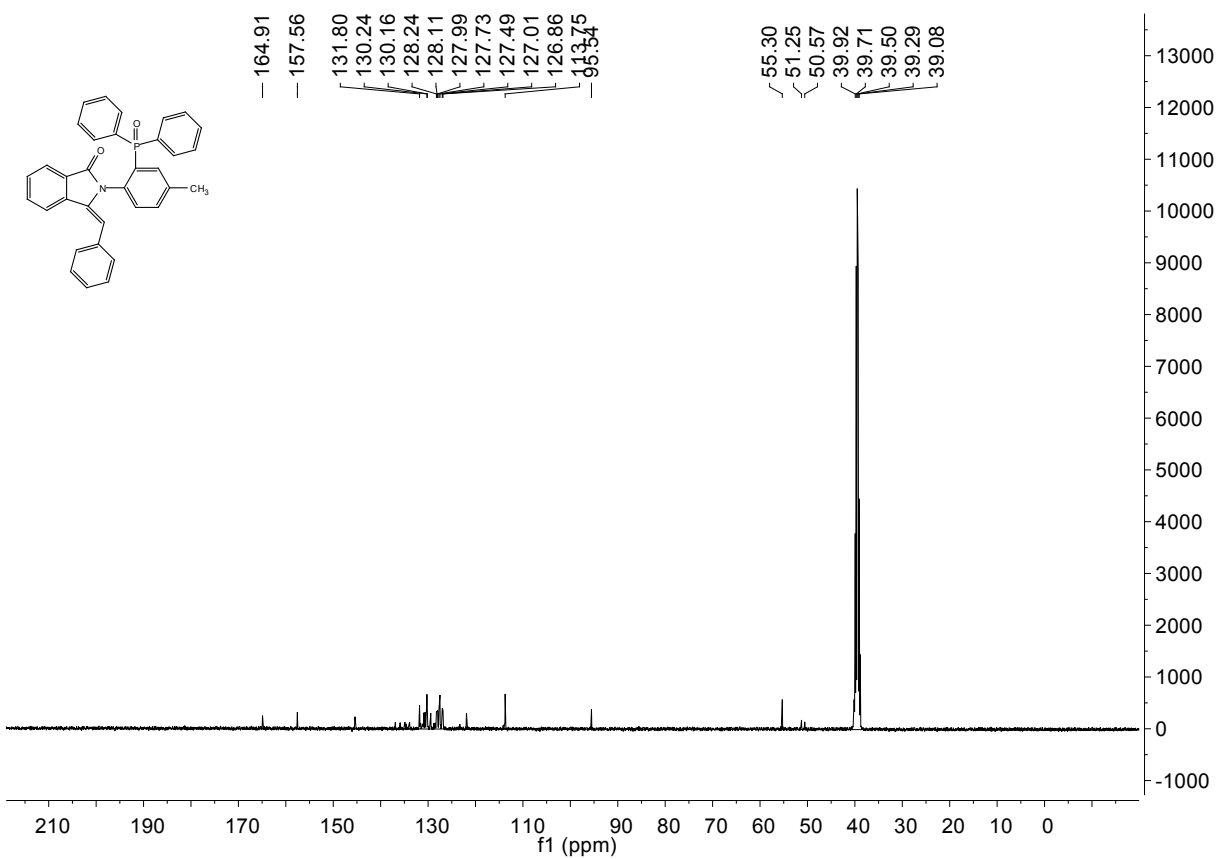
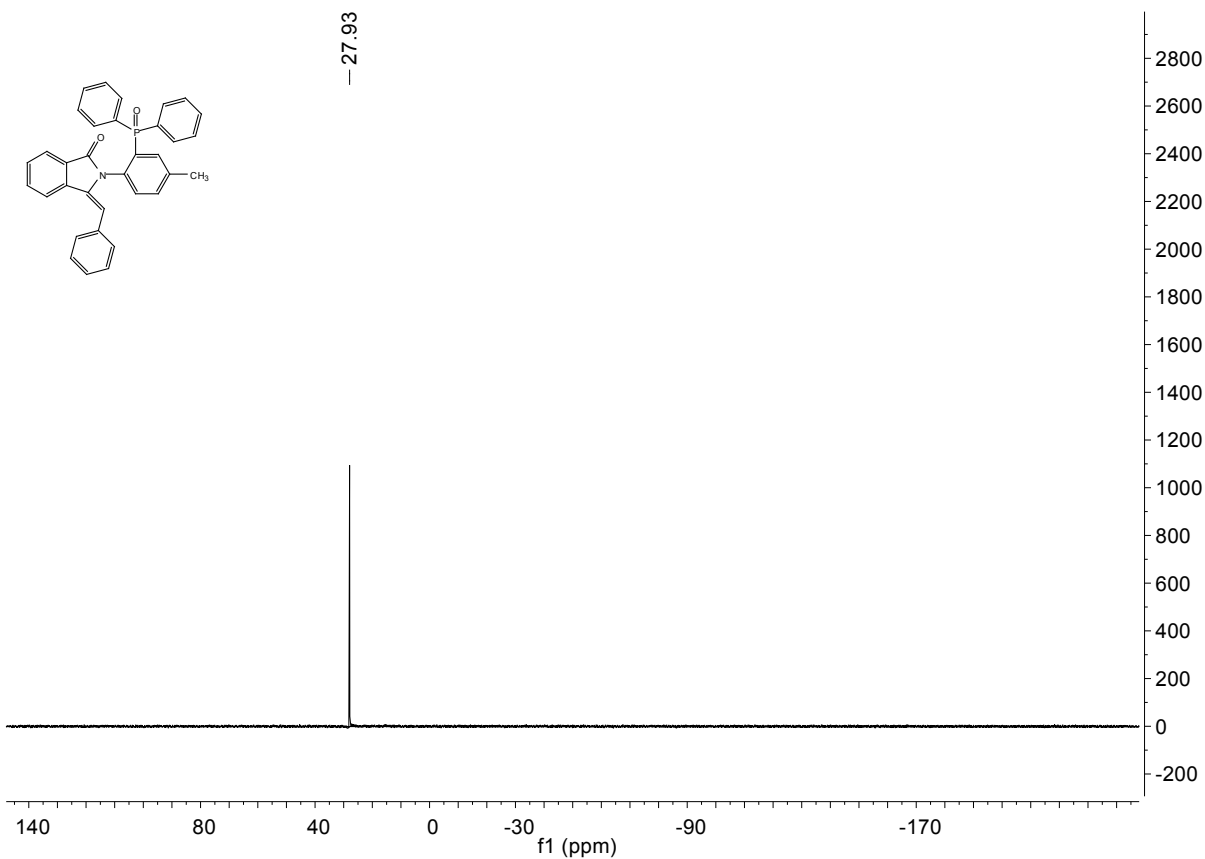
3a



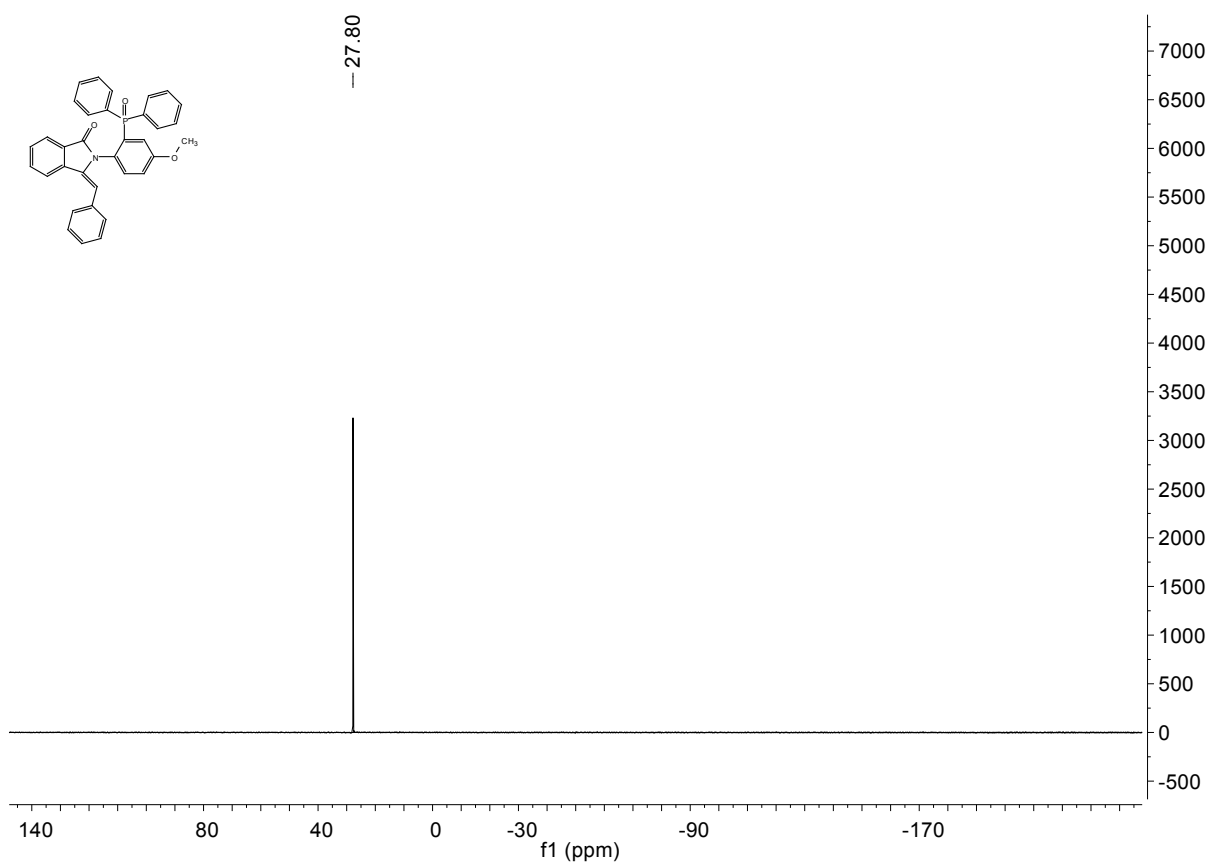
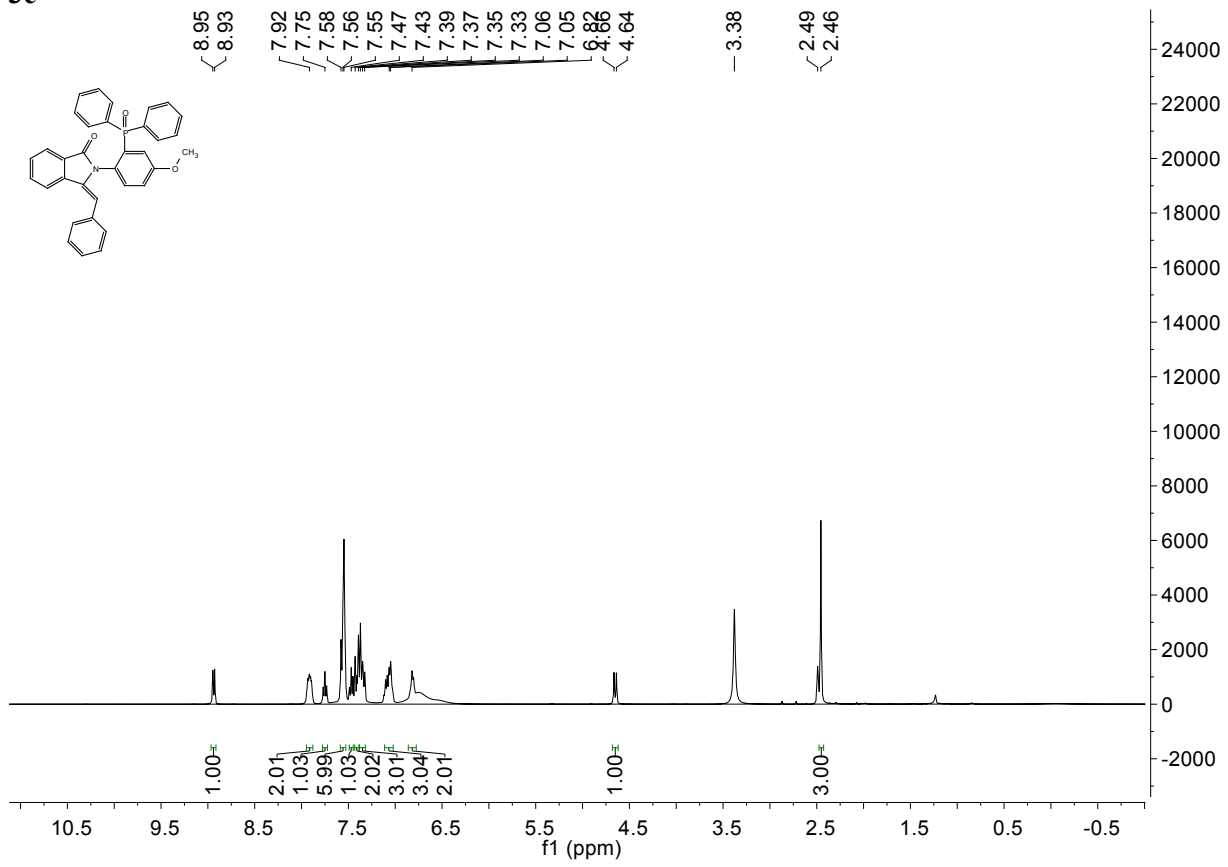


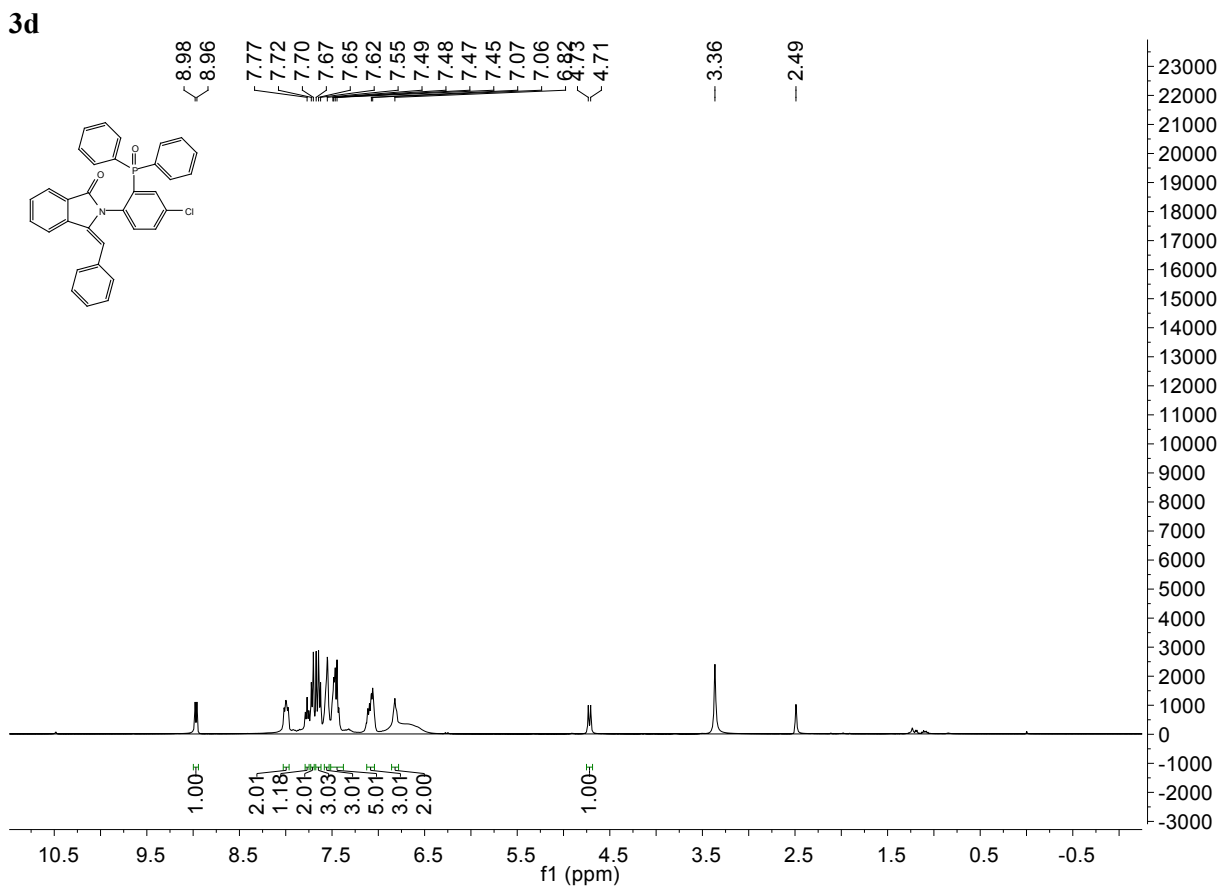
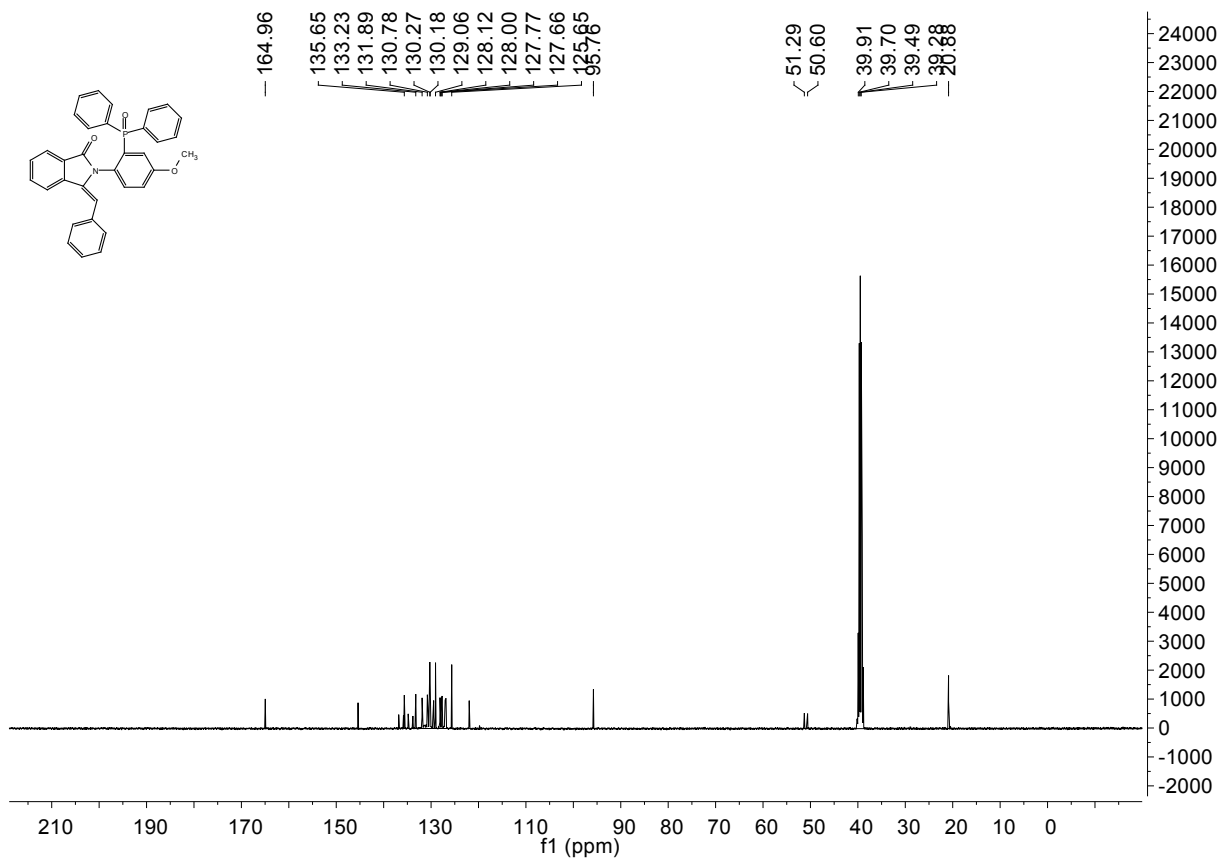
3b

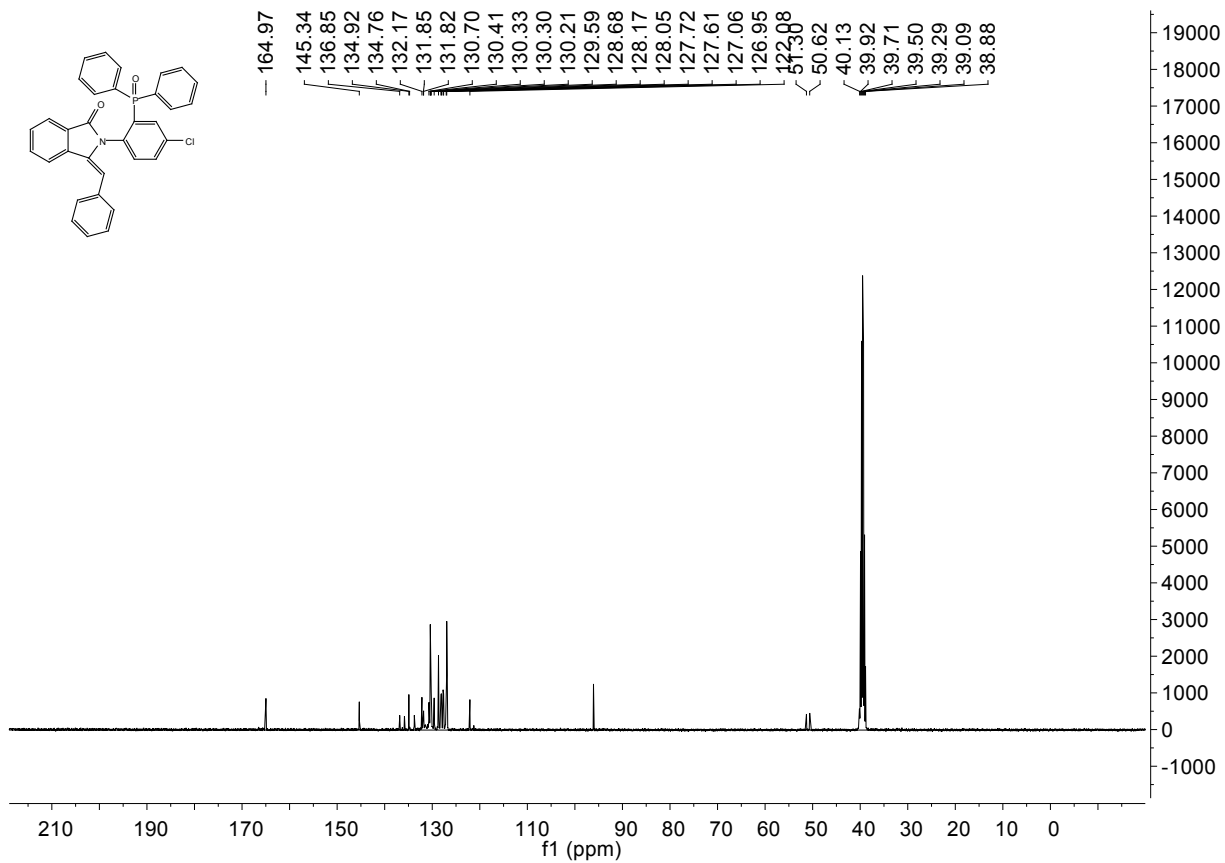
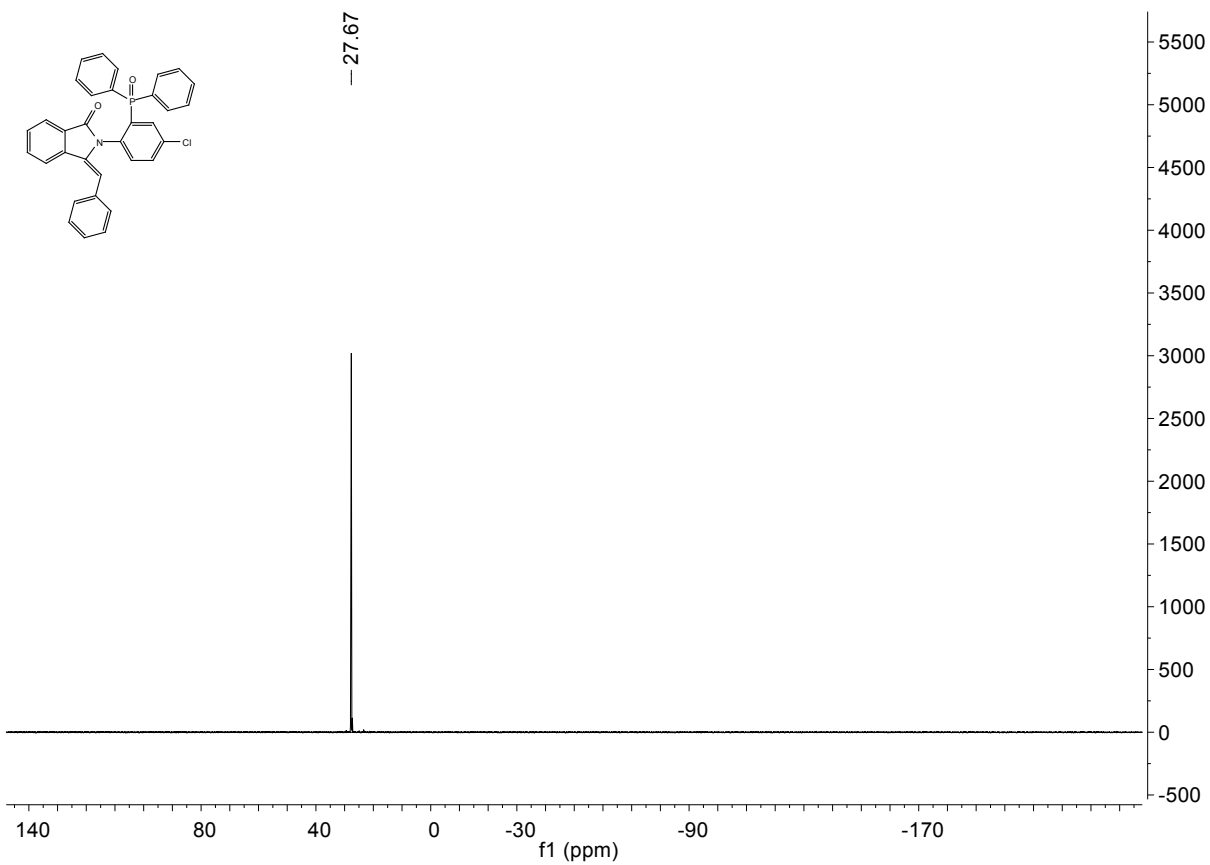




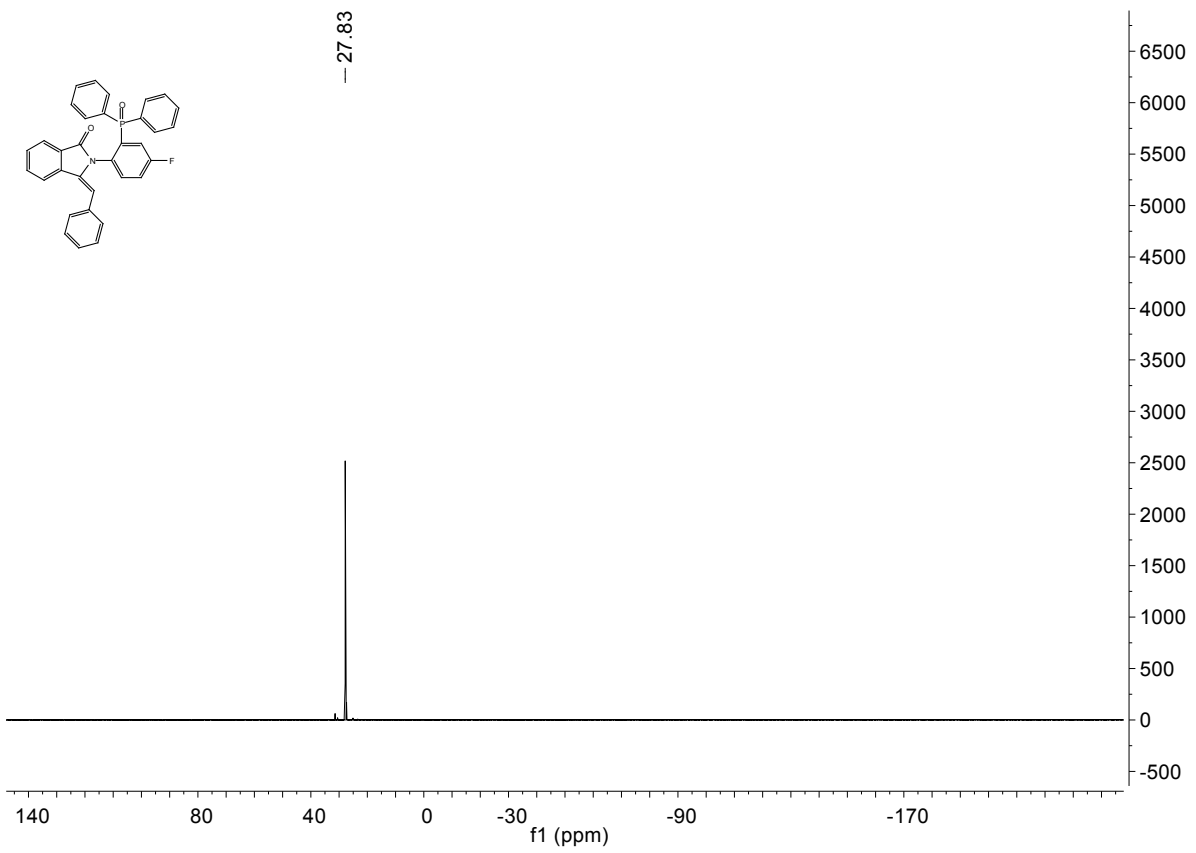
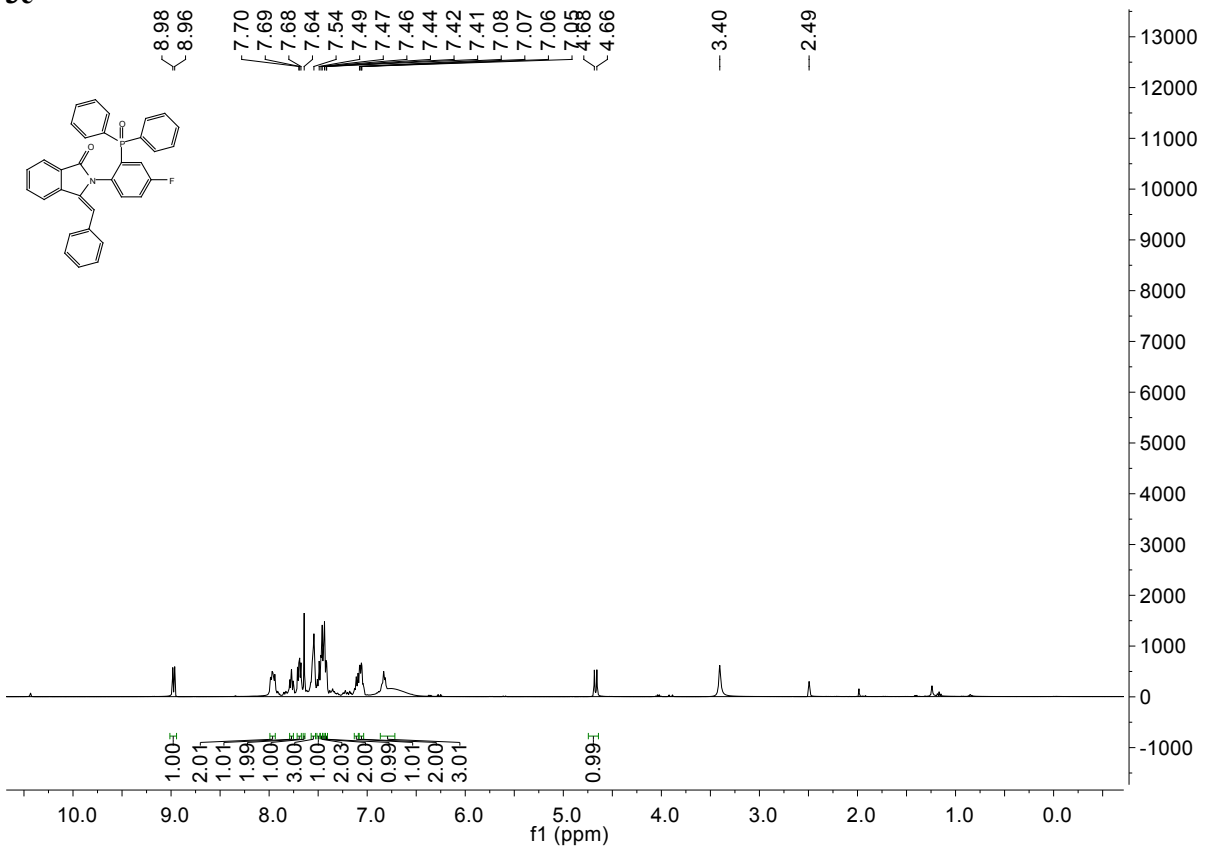
3c

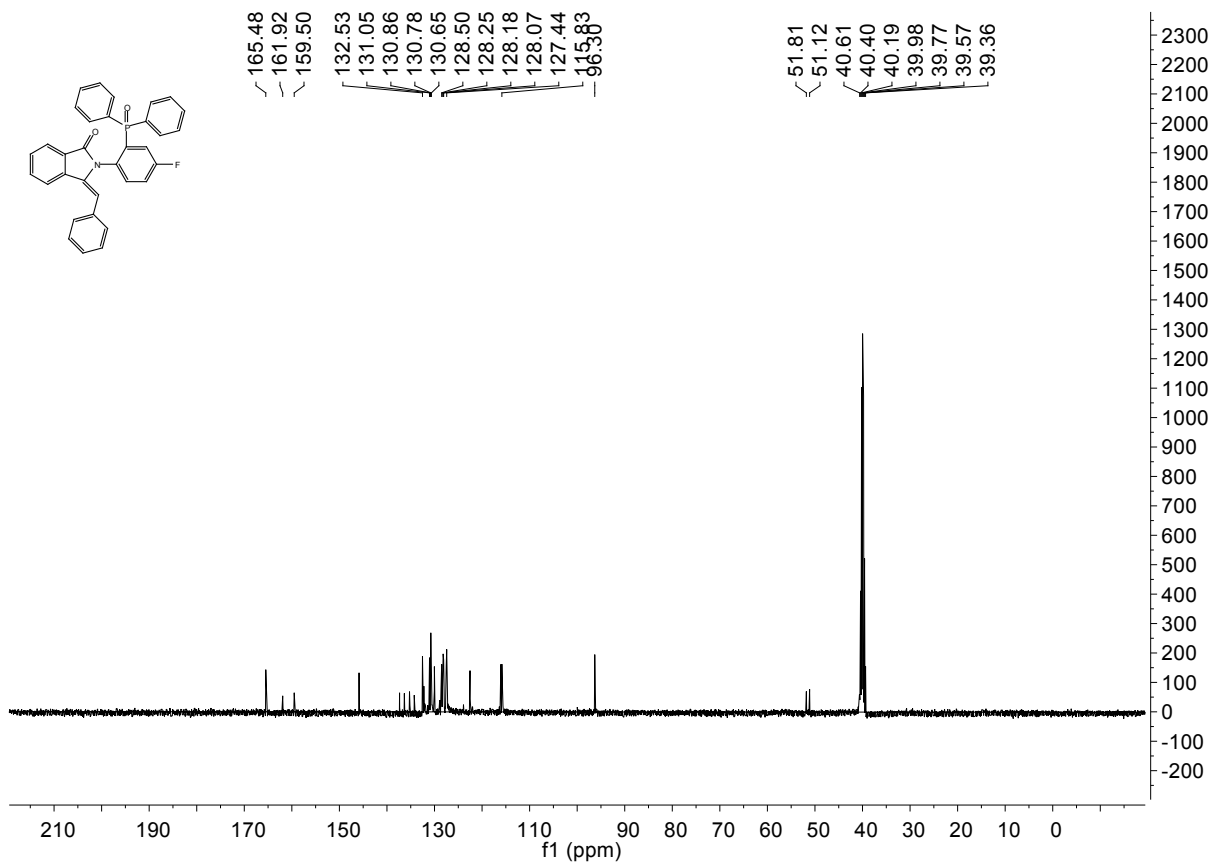
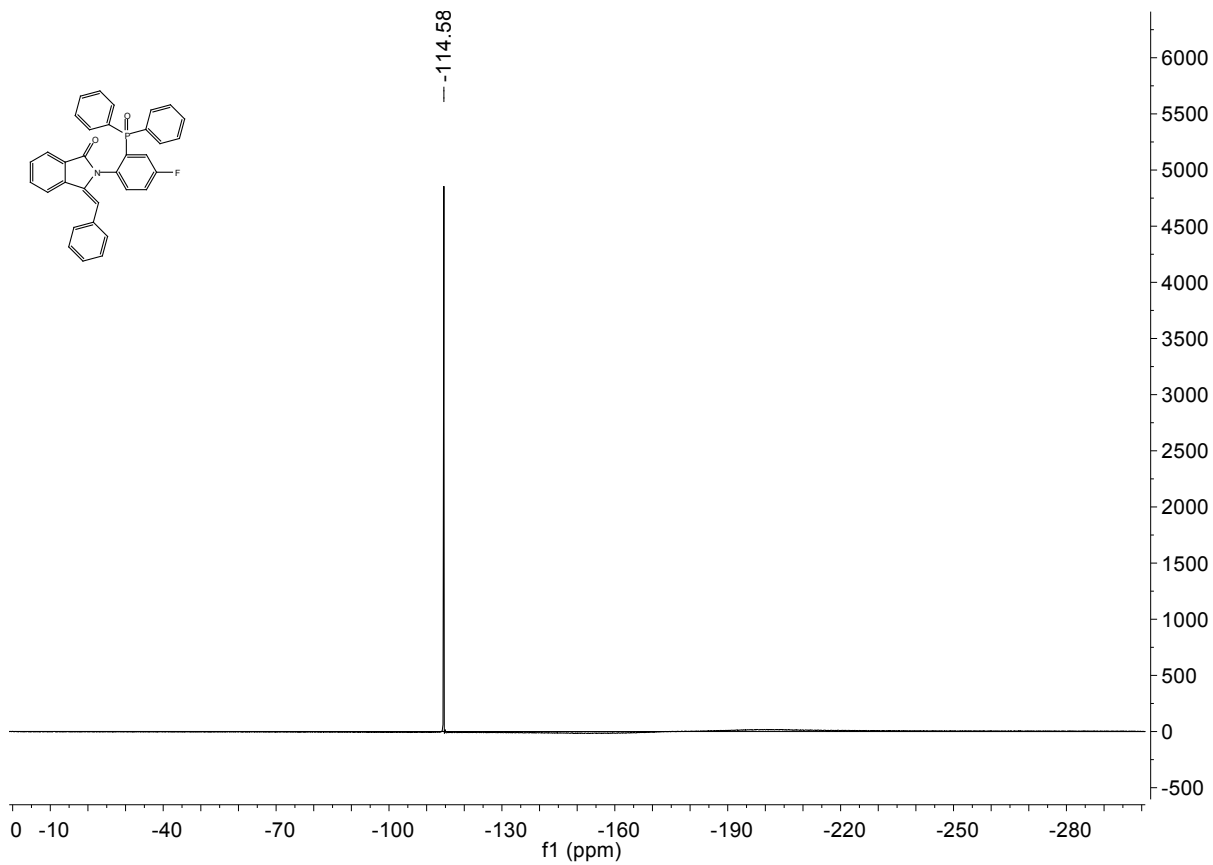




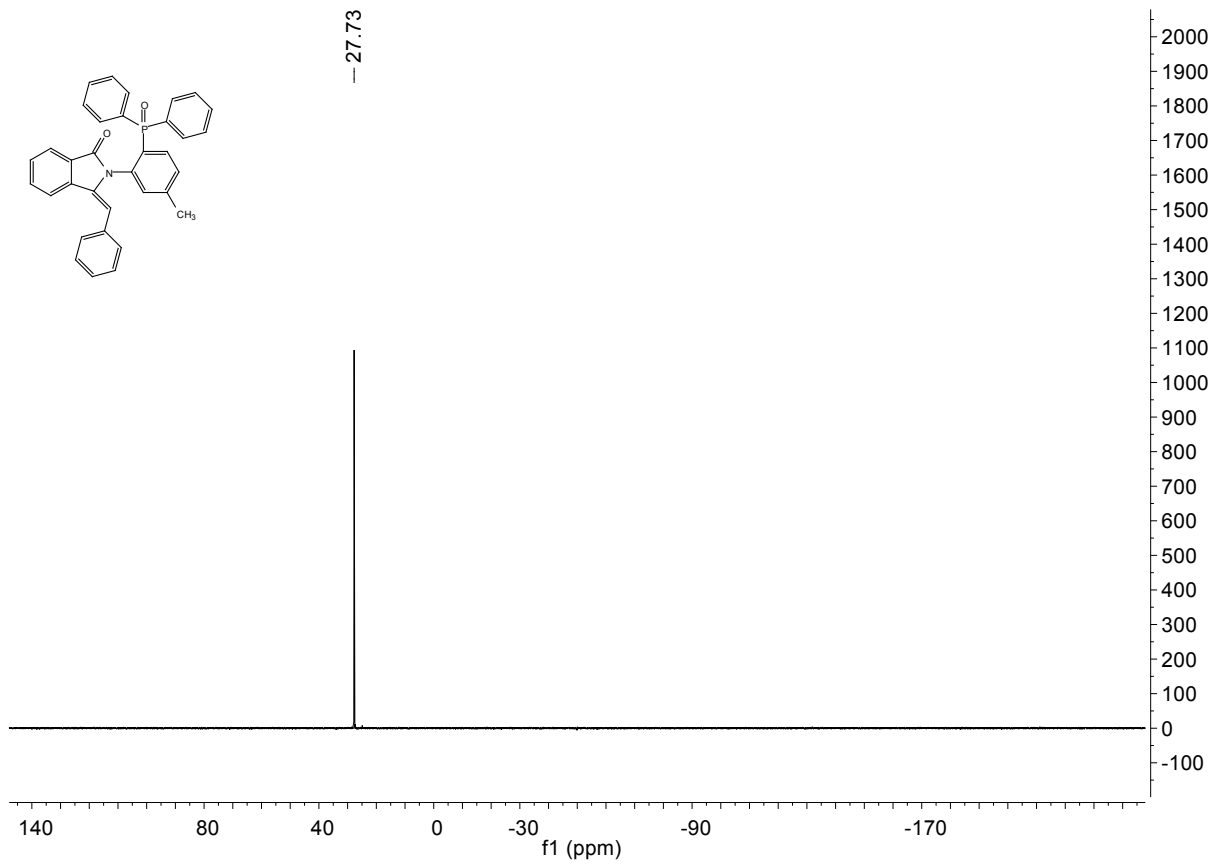
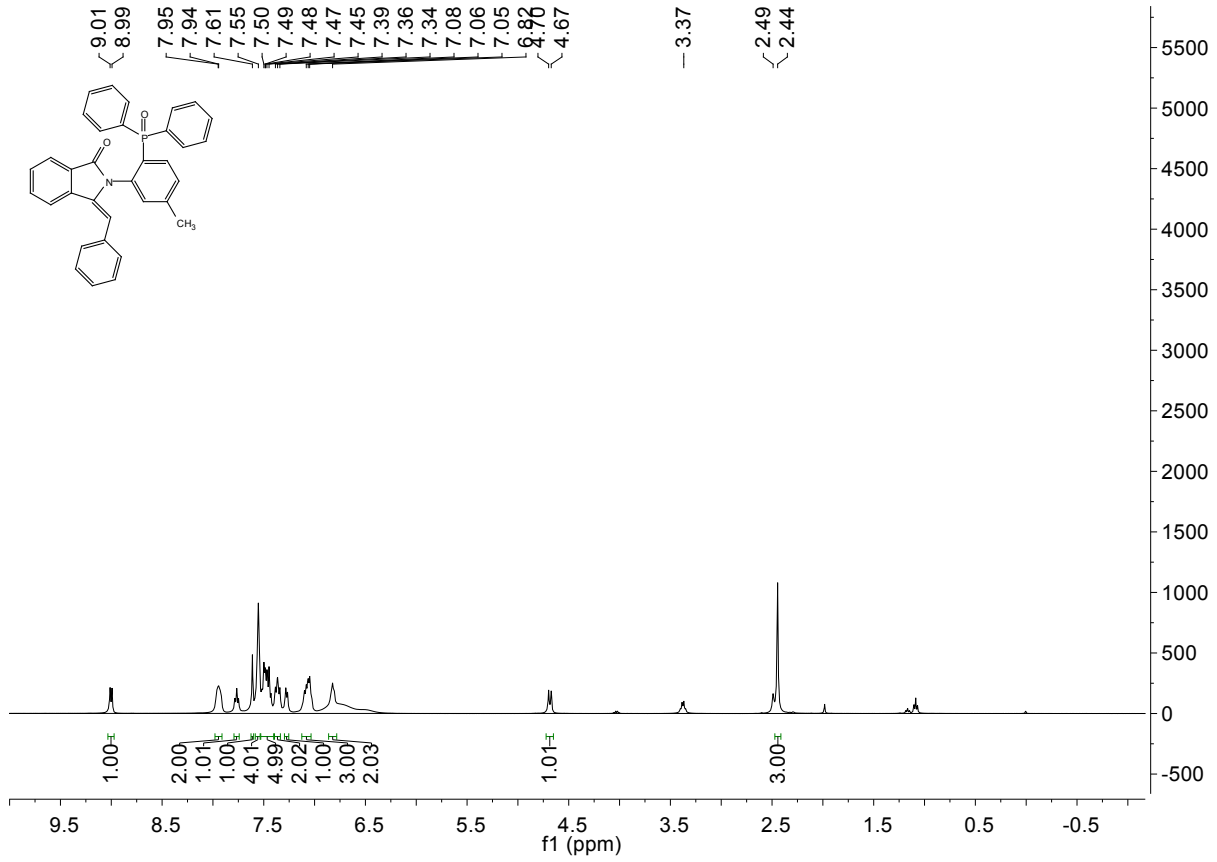


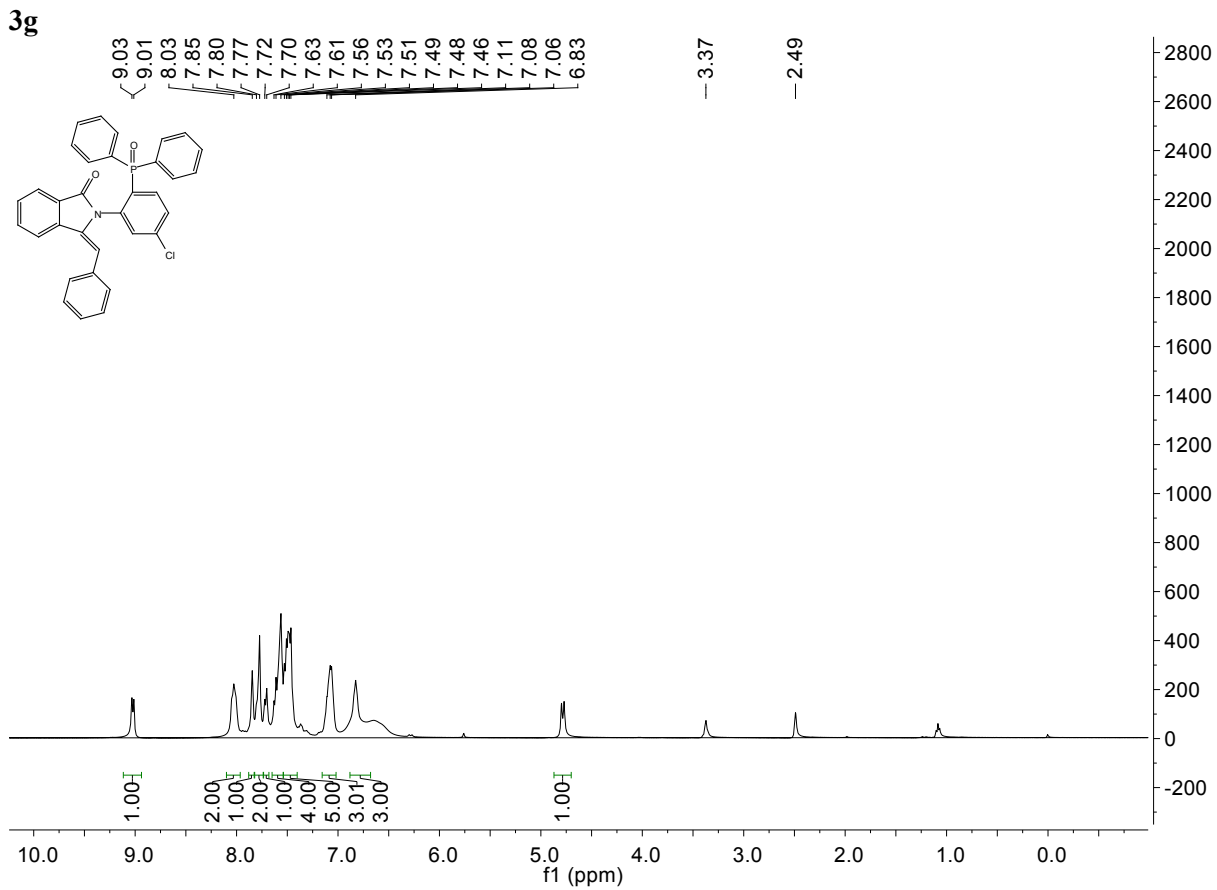
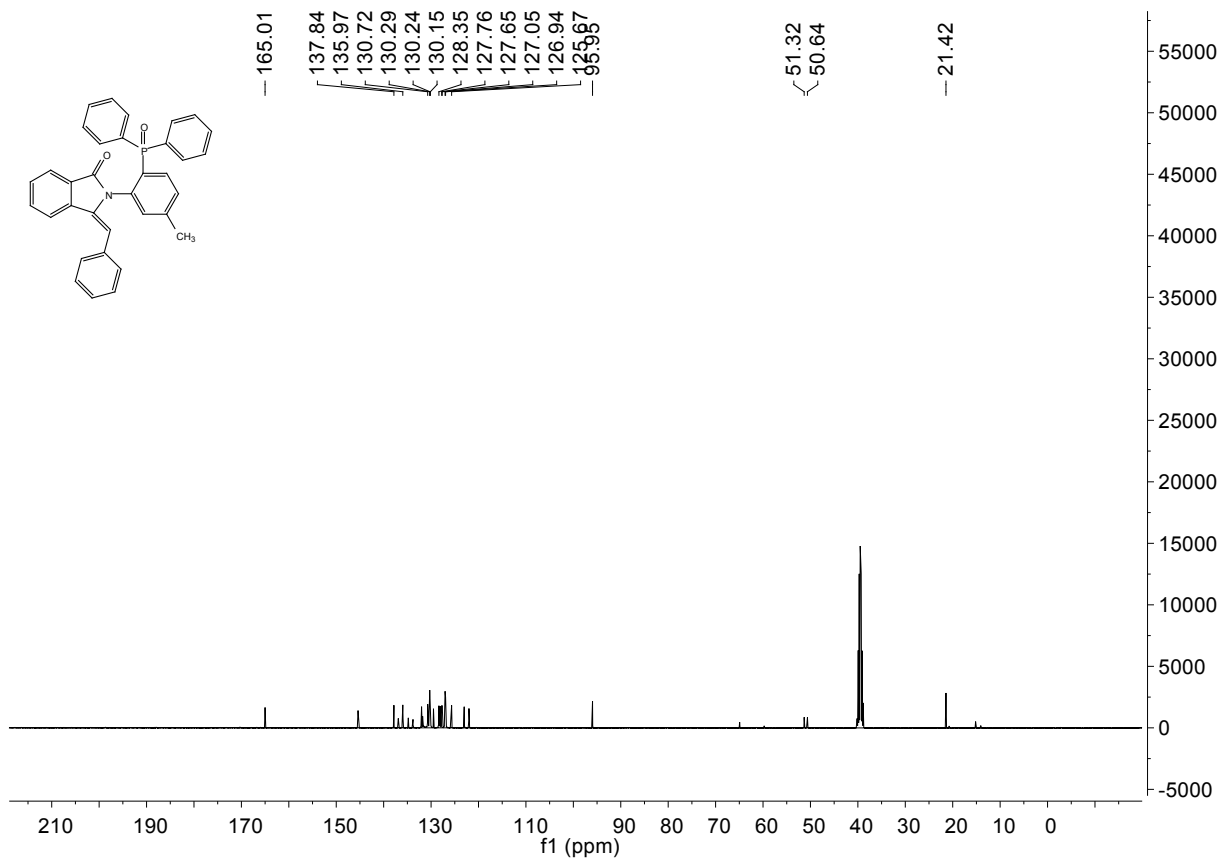
3e

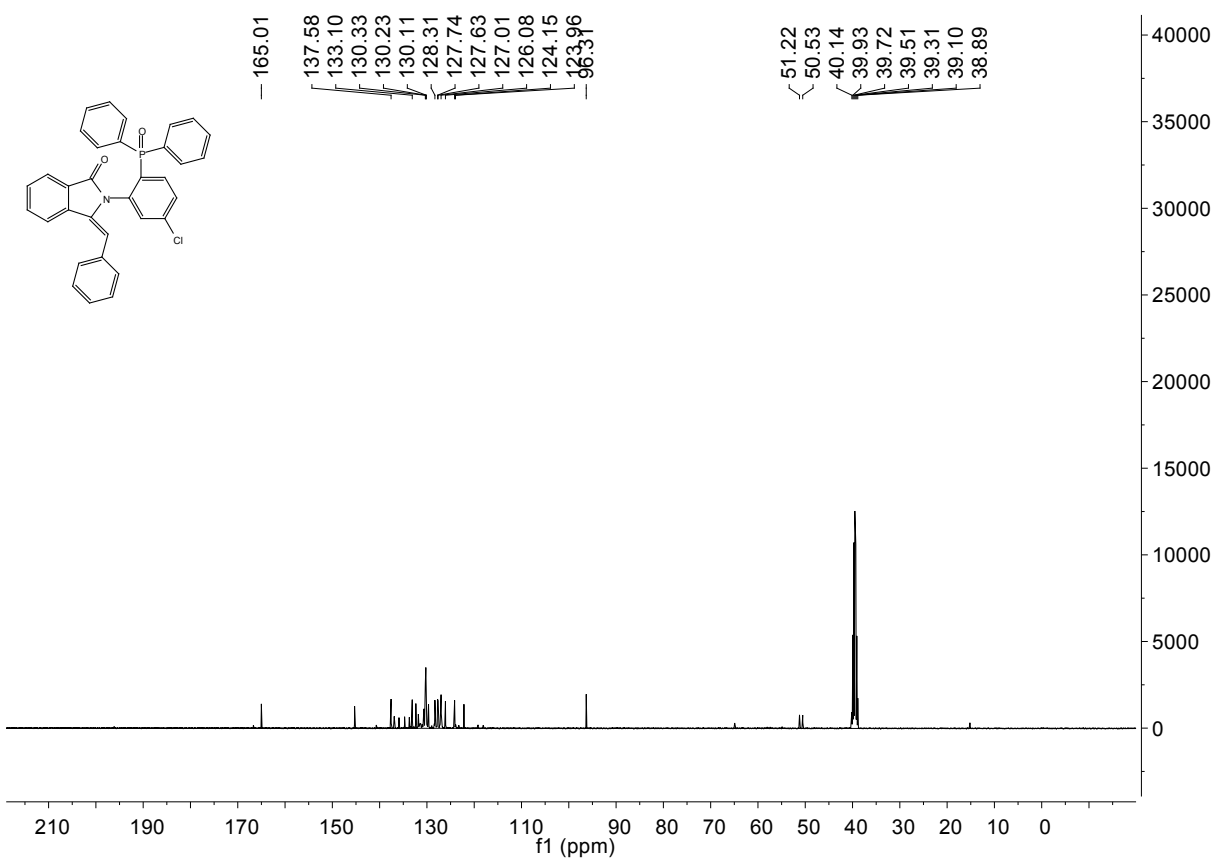
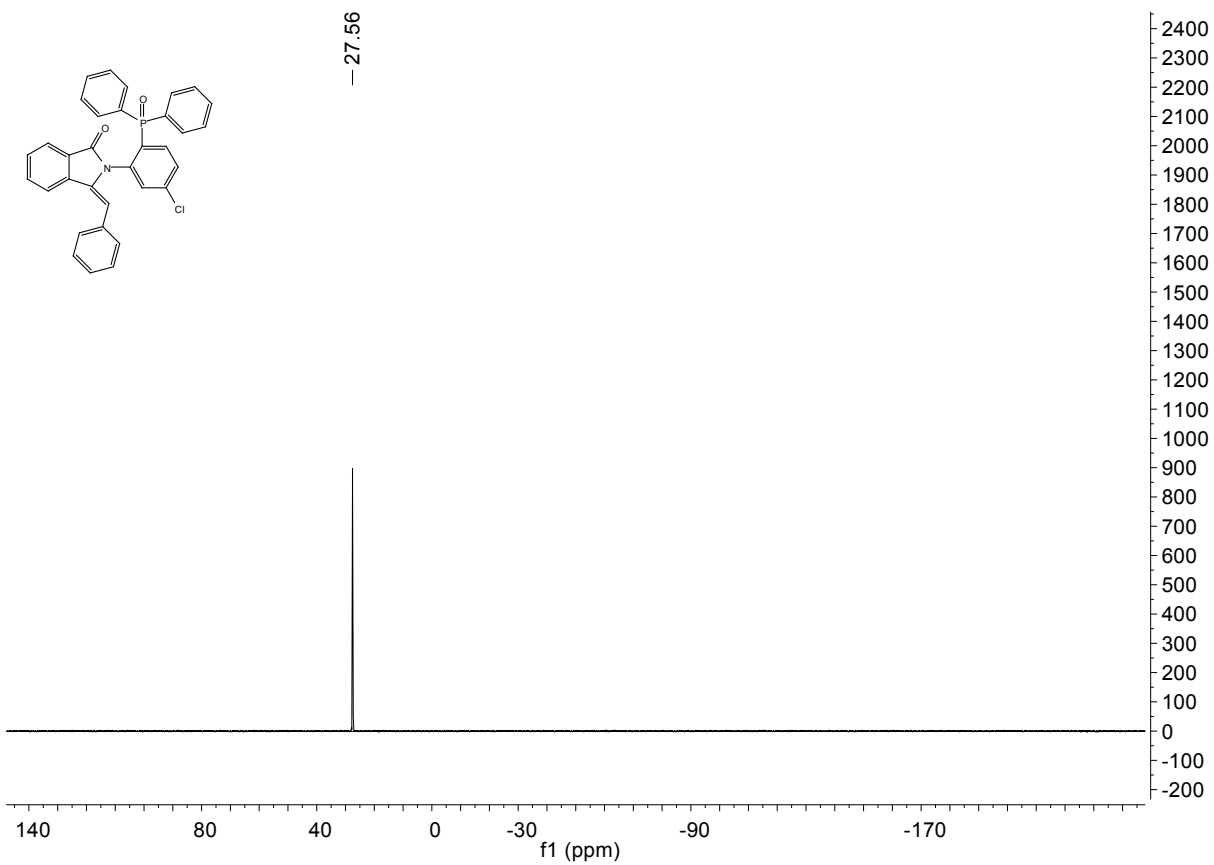




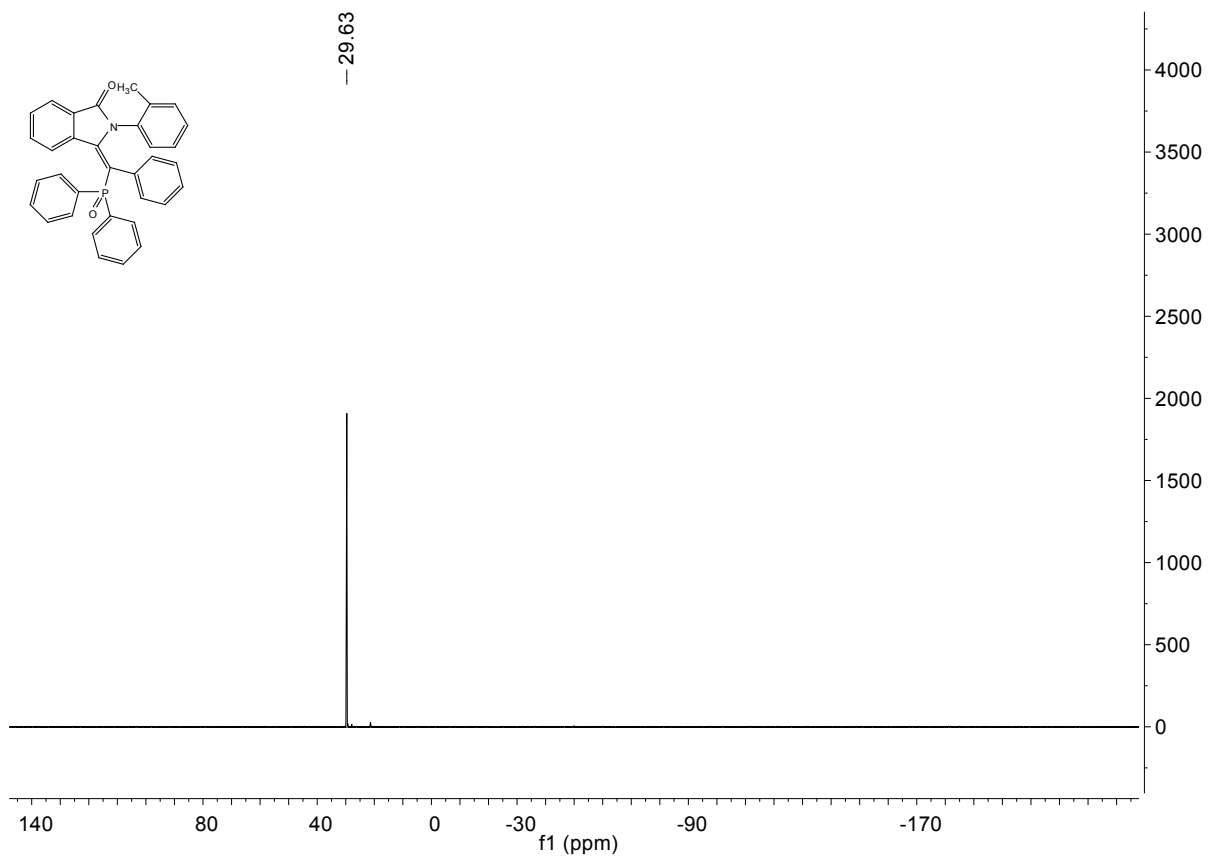
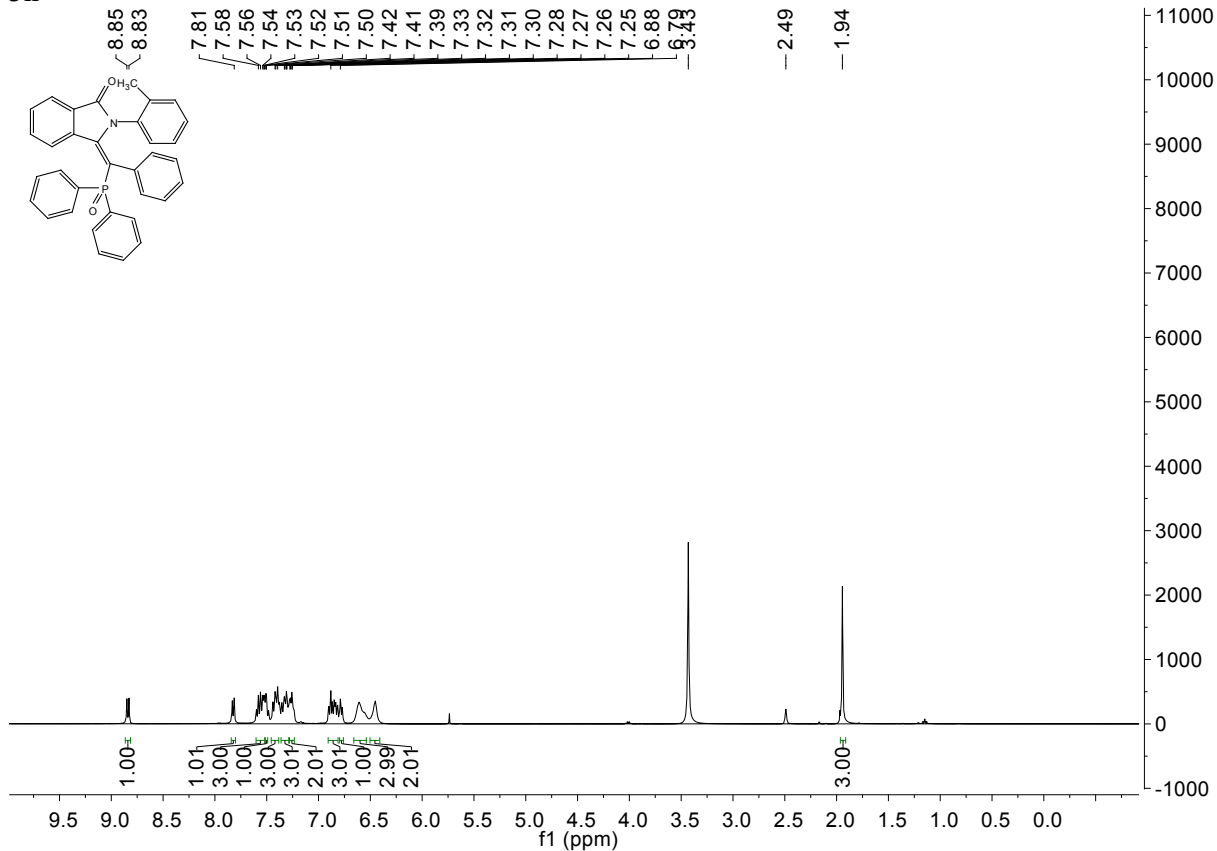
3f

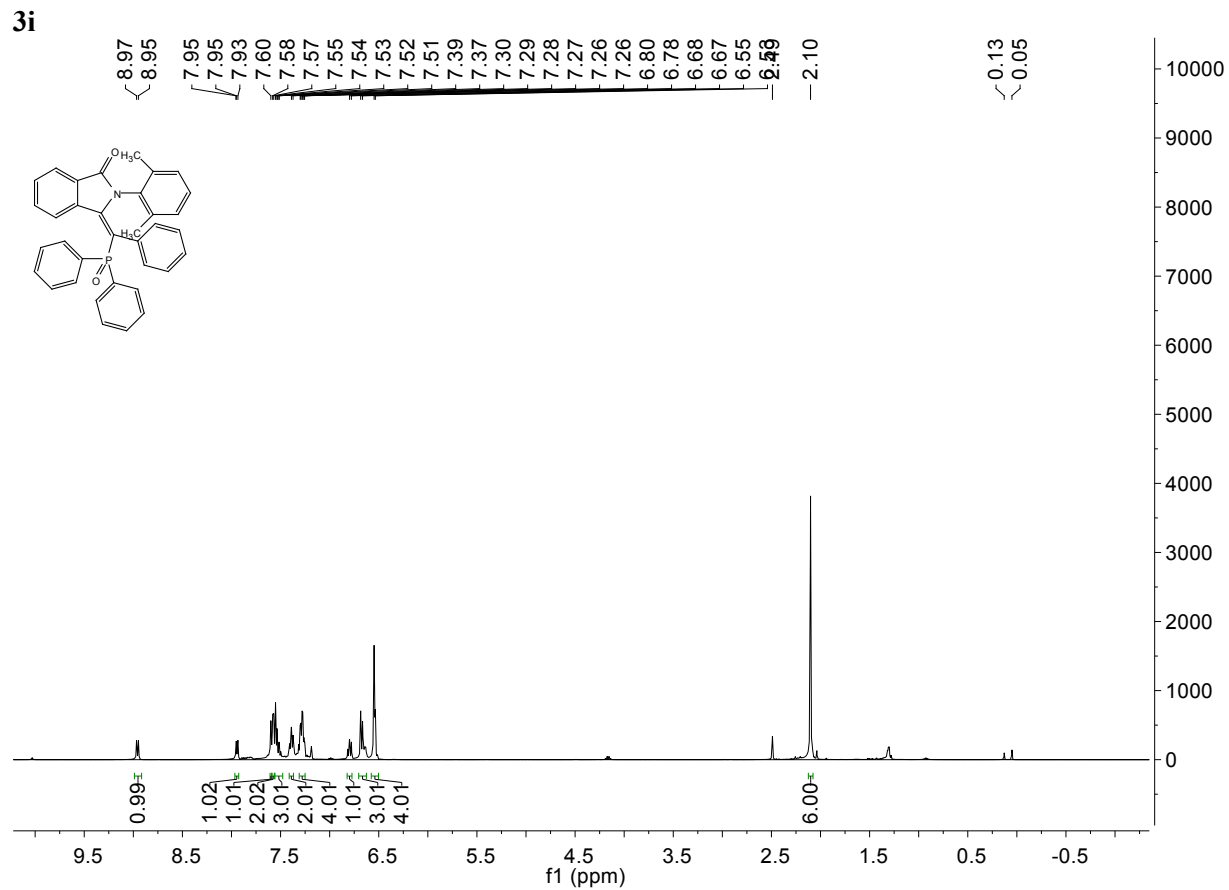
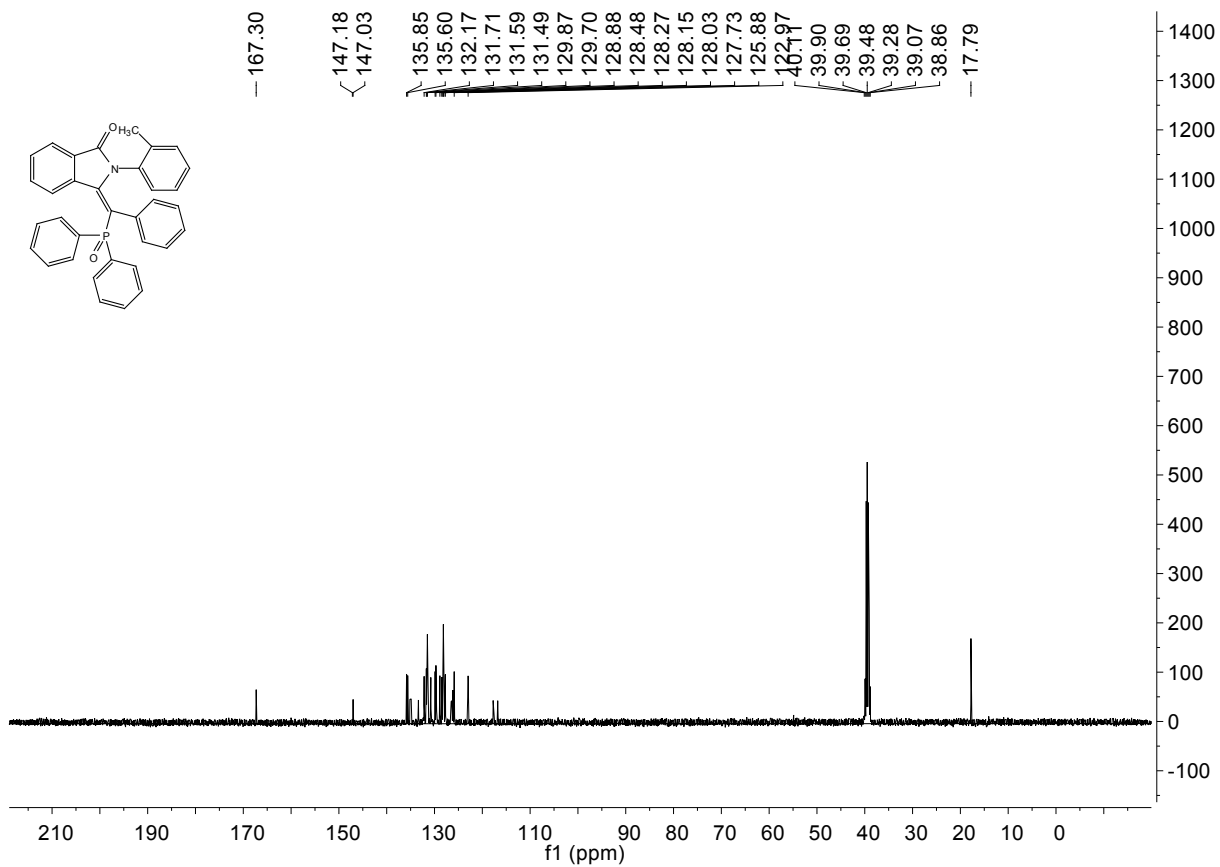


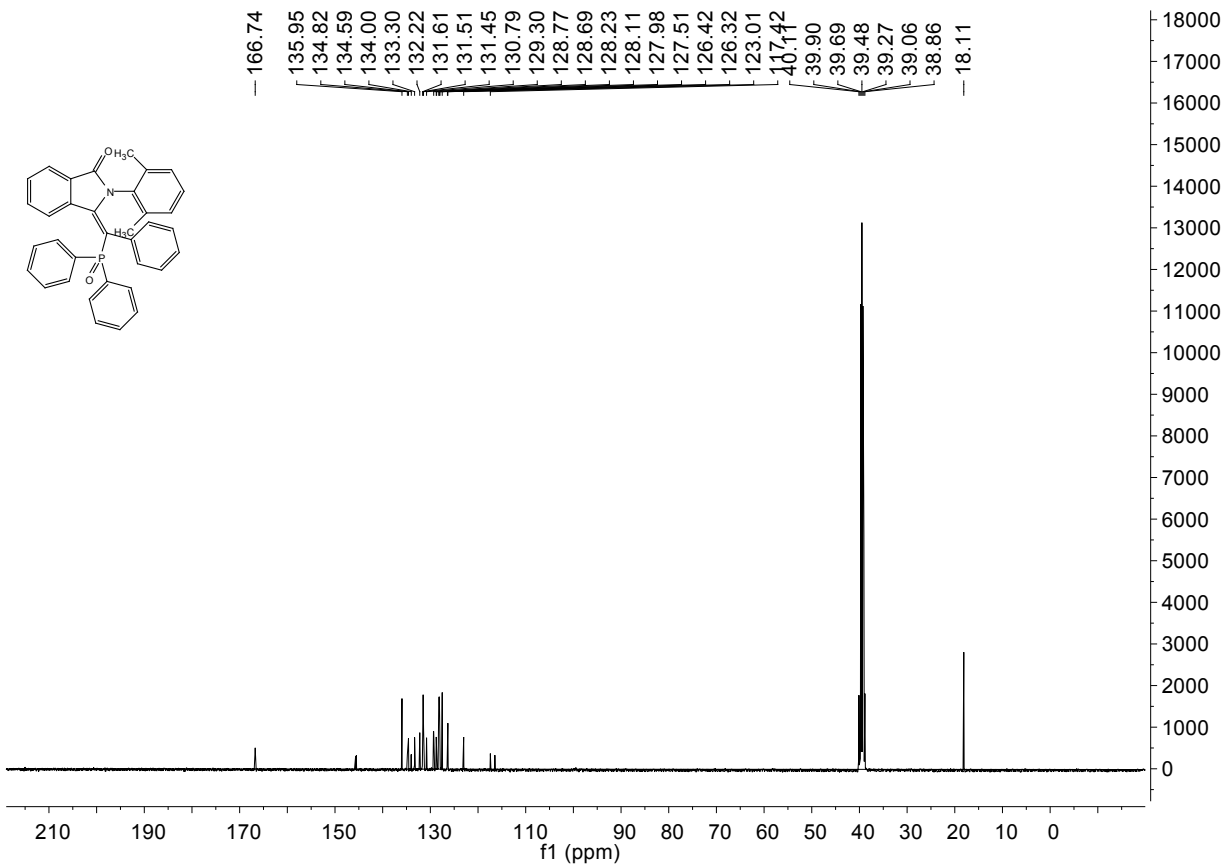
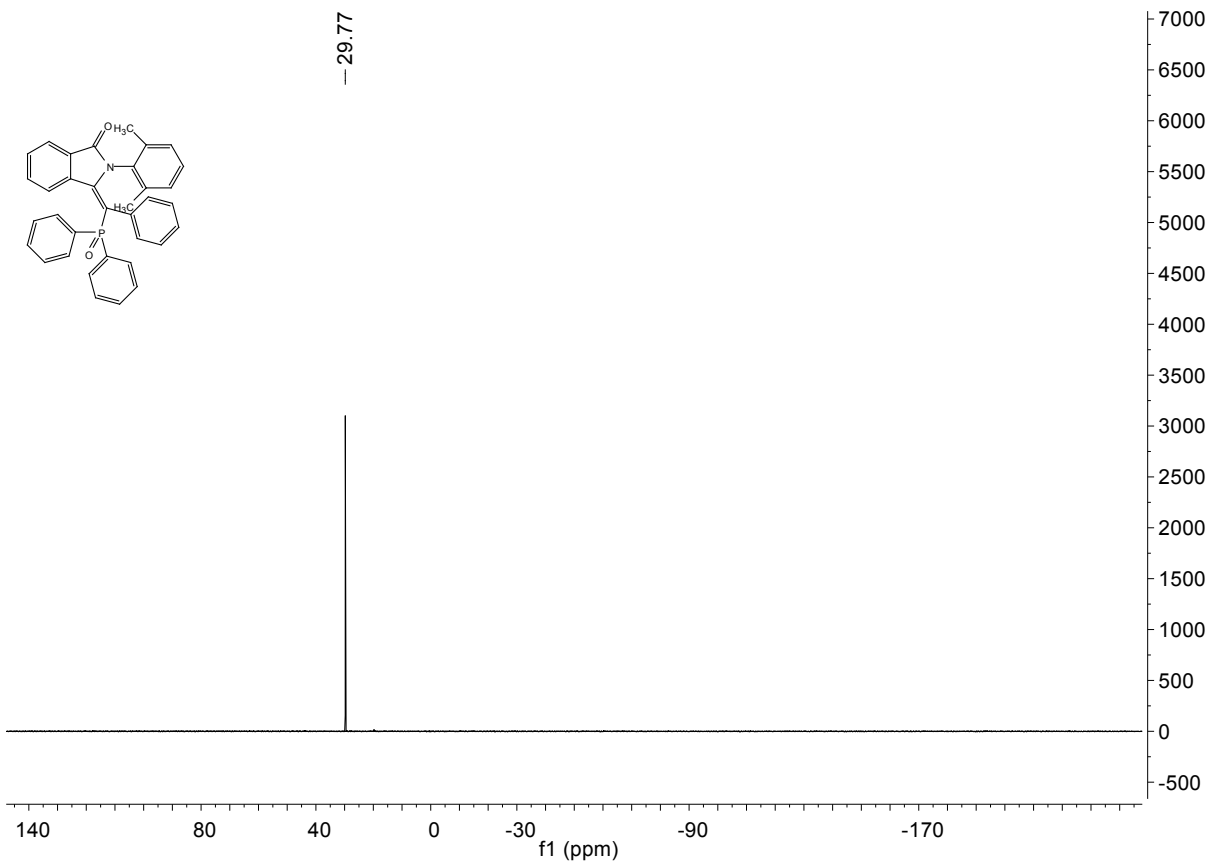




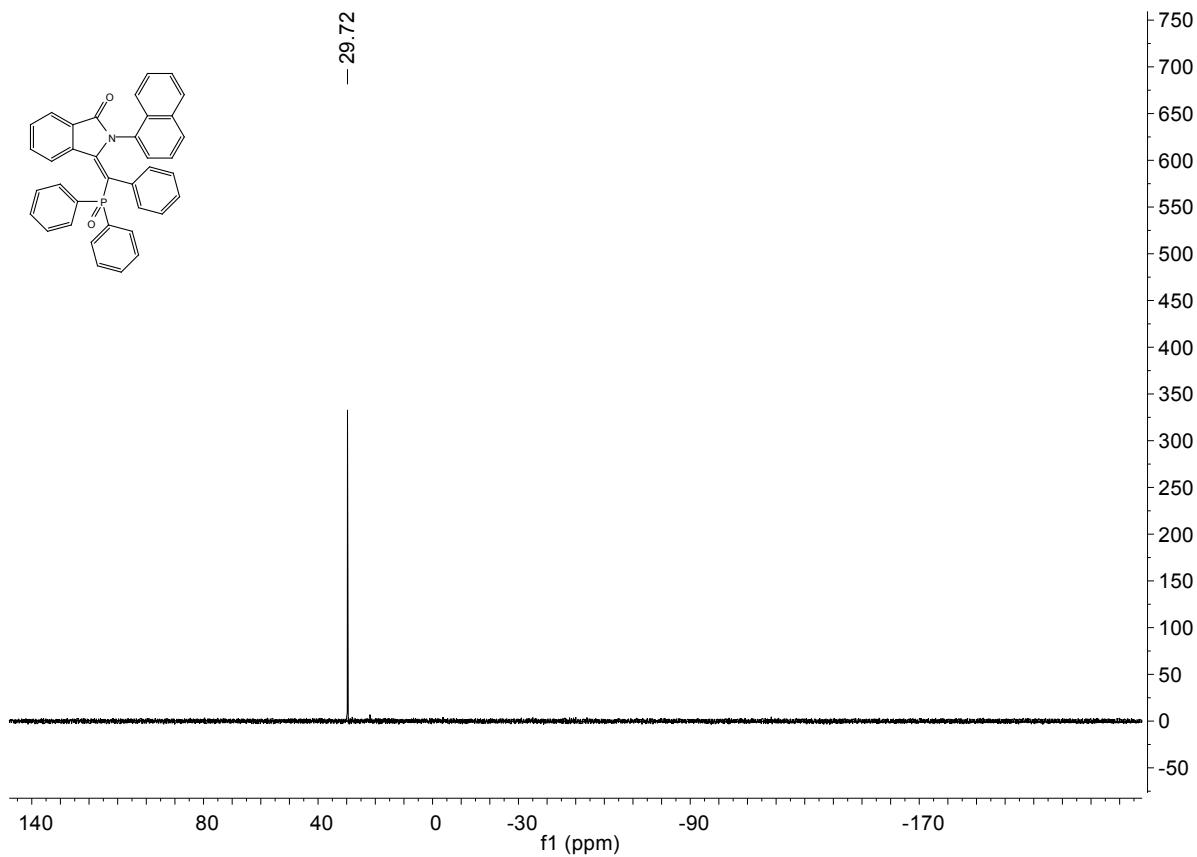
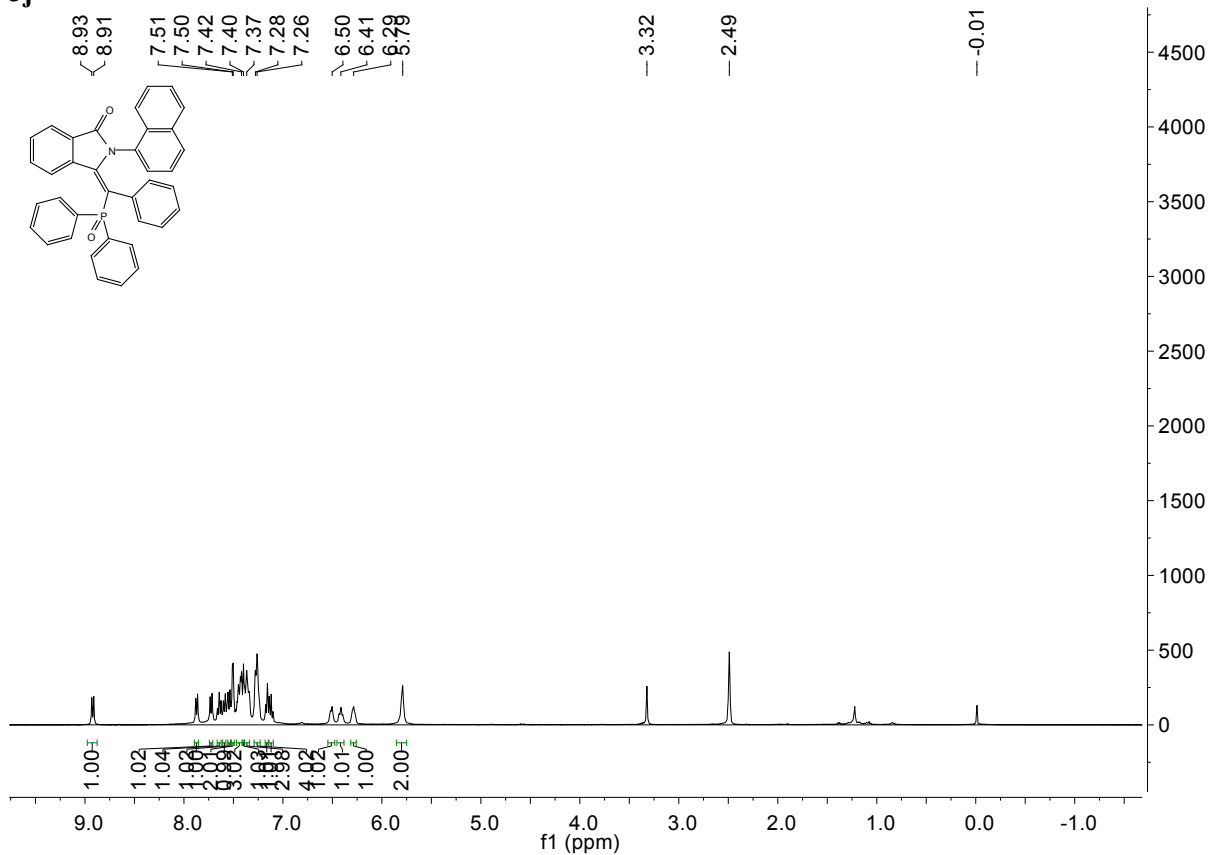
3h

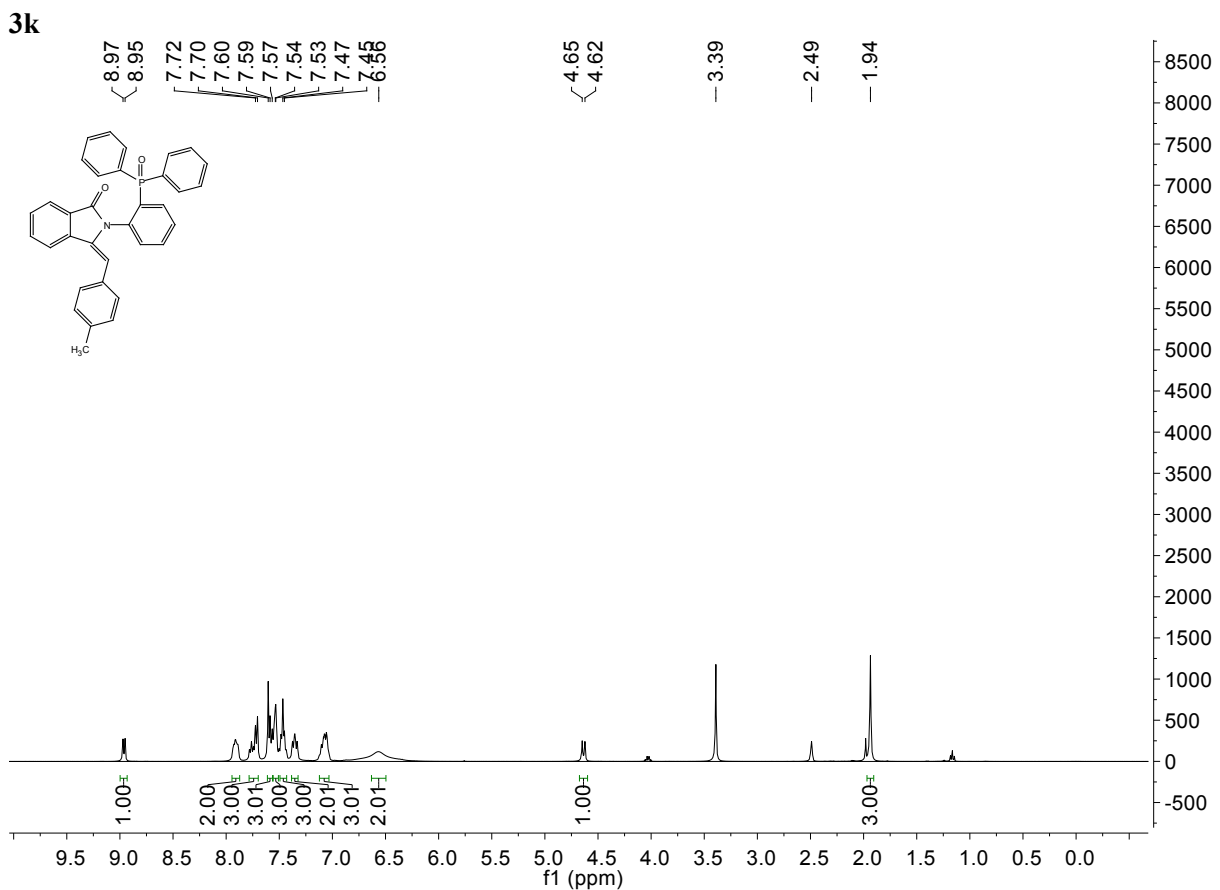
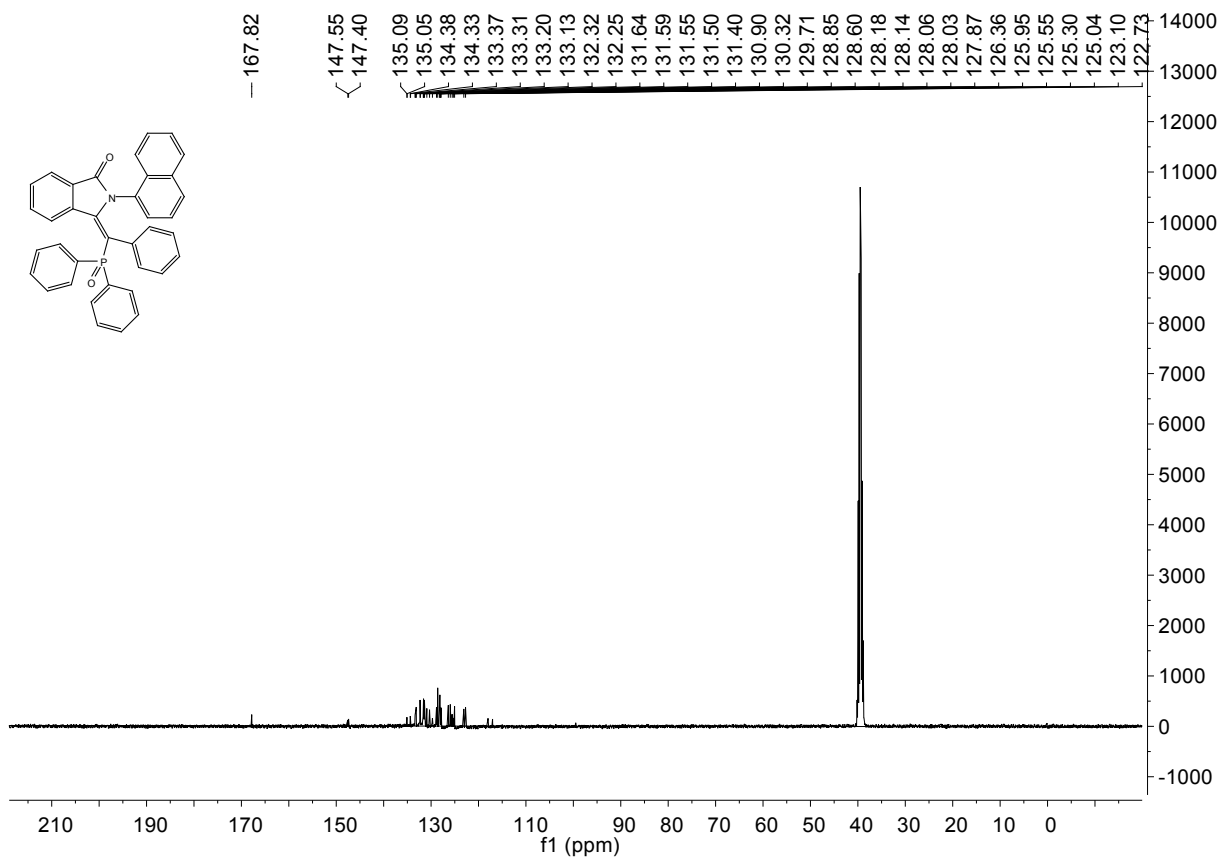


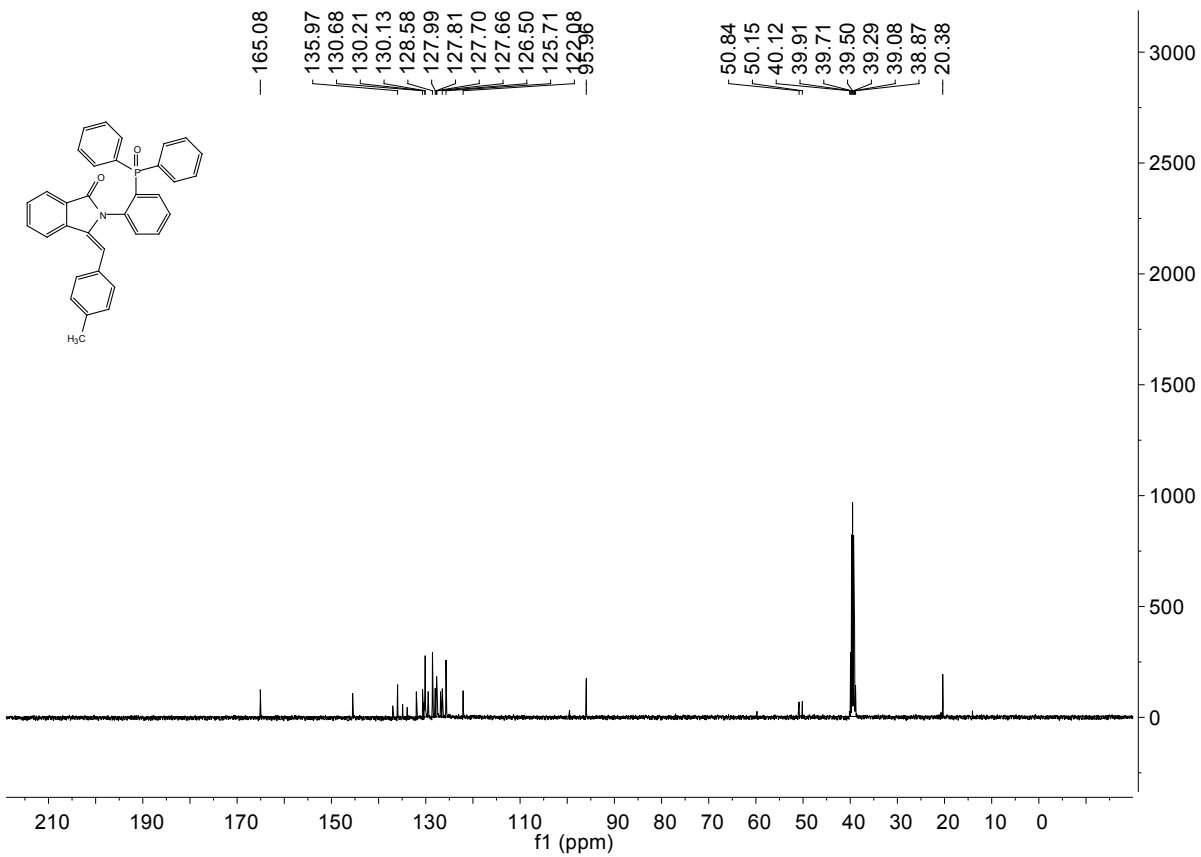
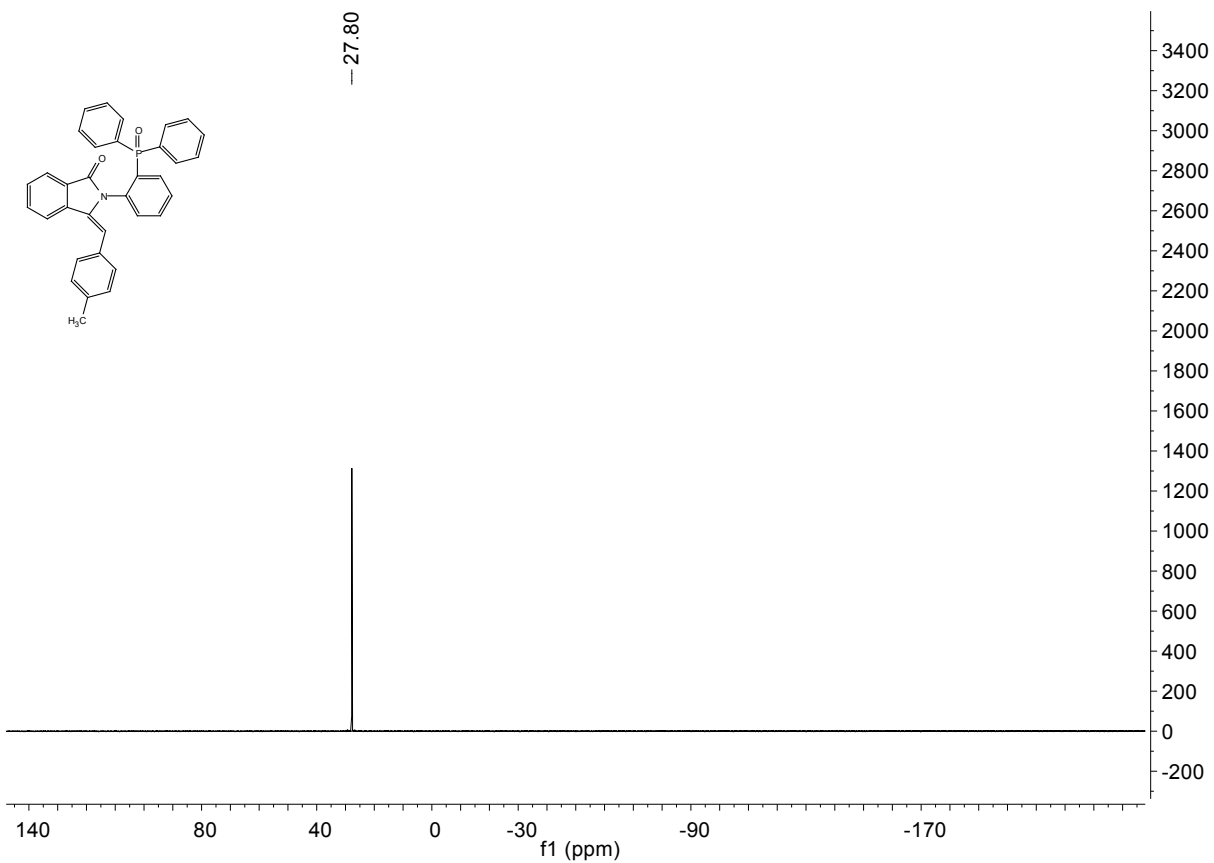




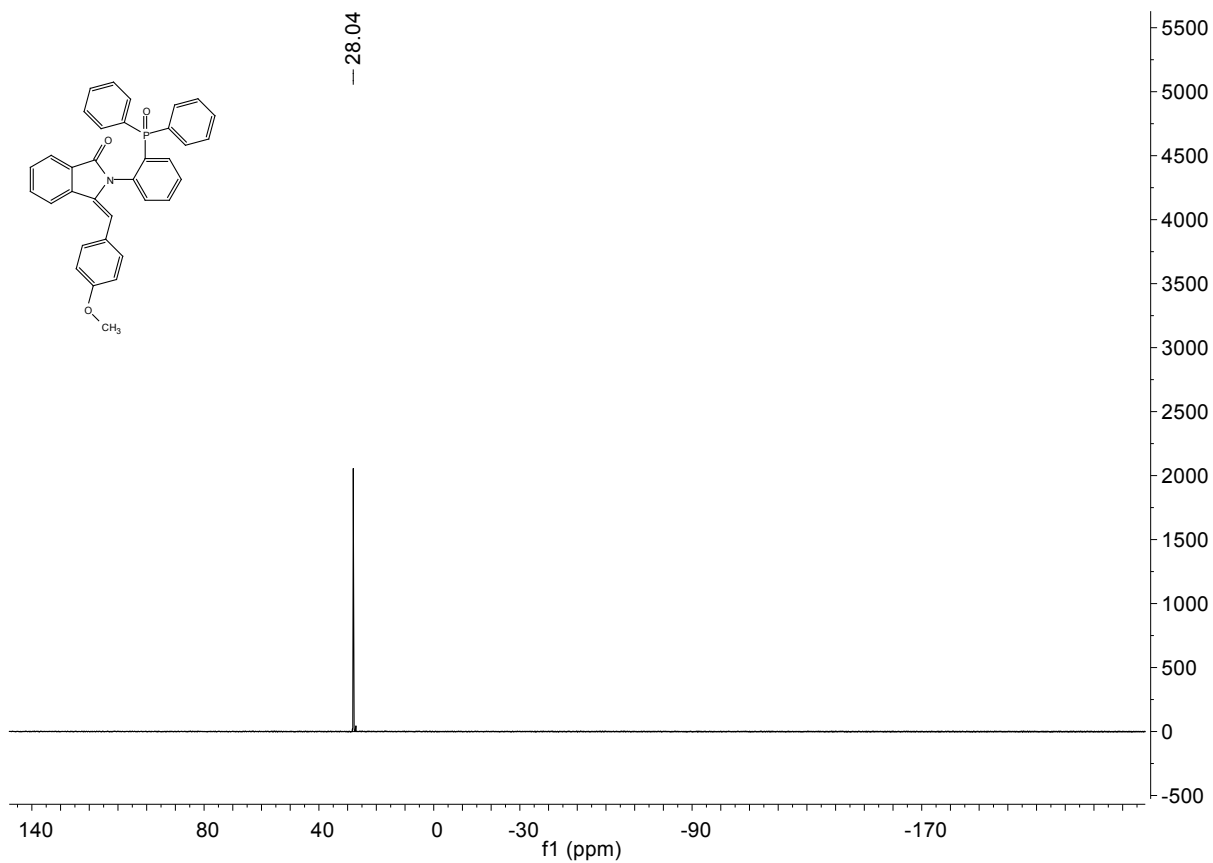
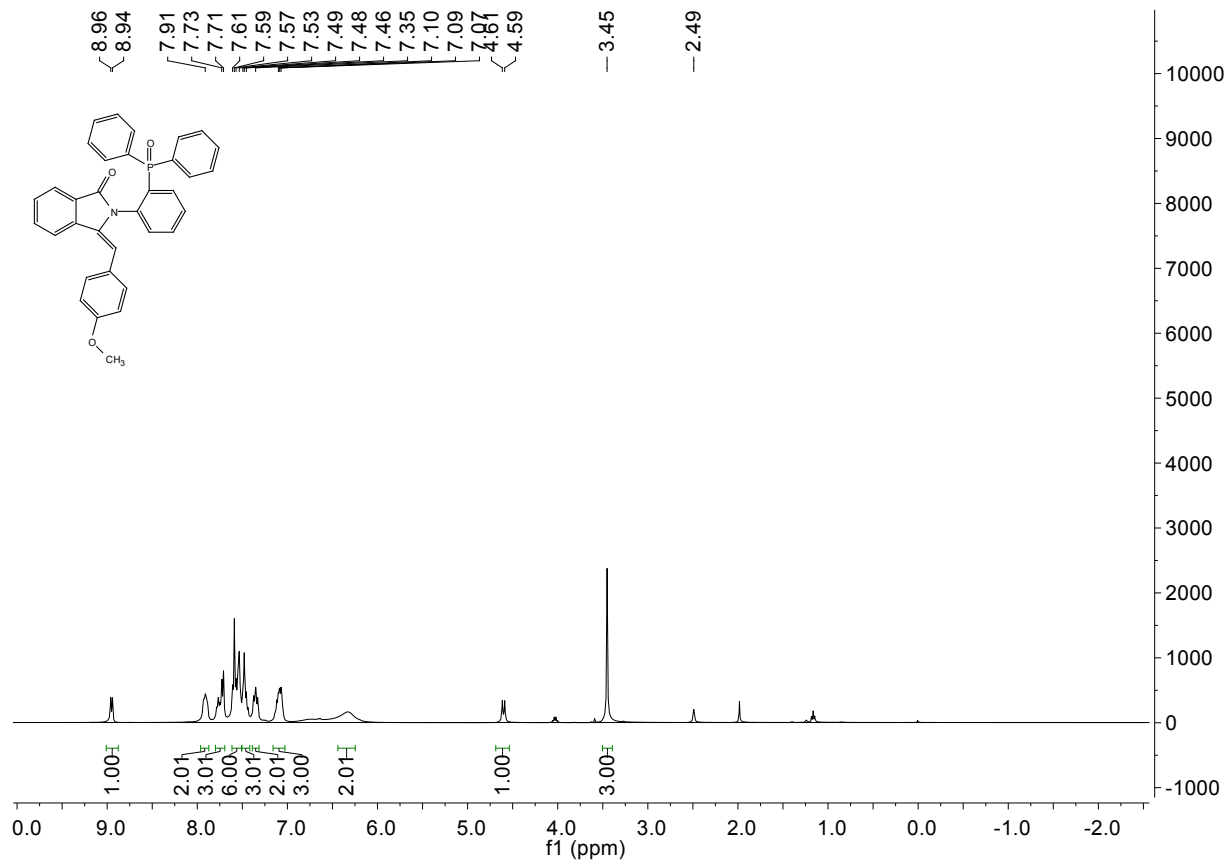
3j

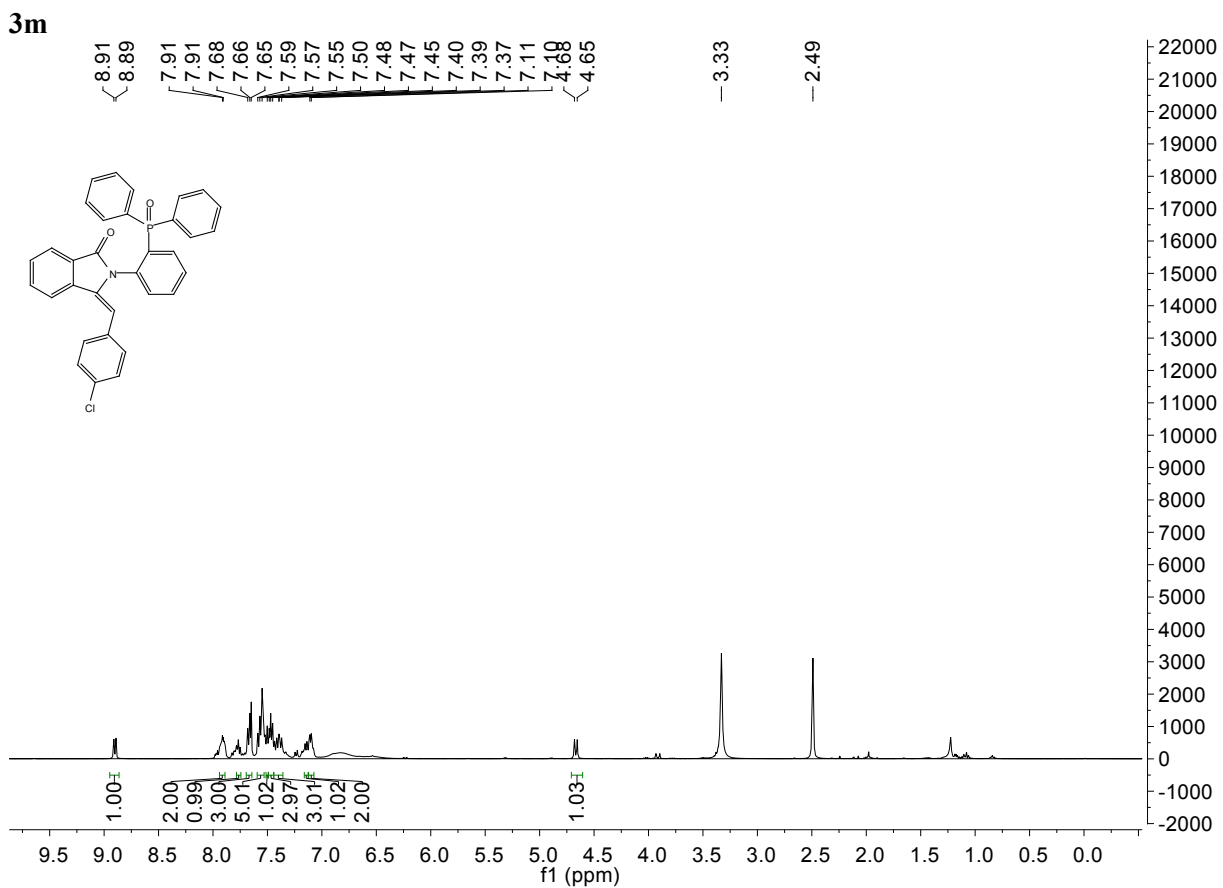
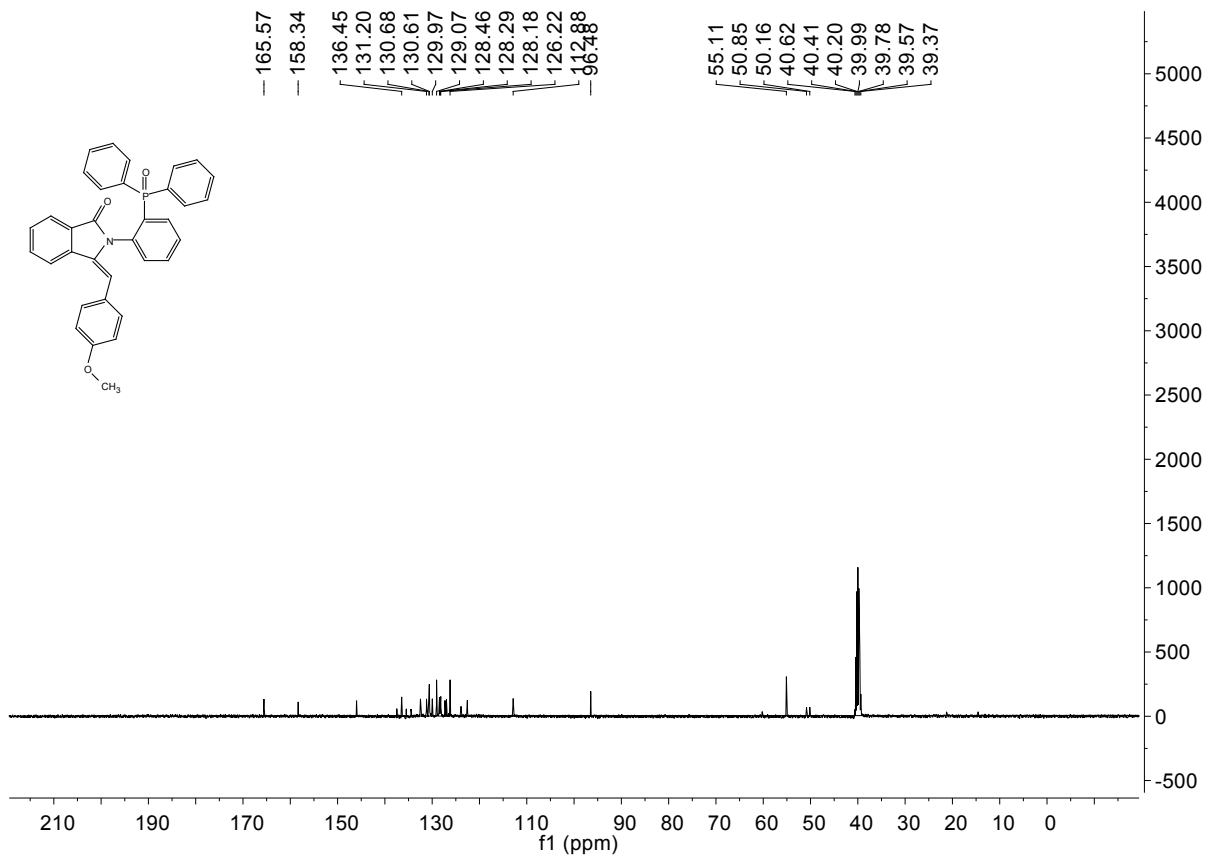


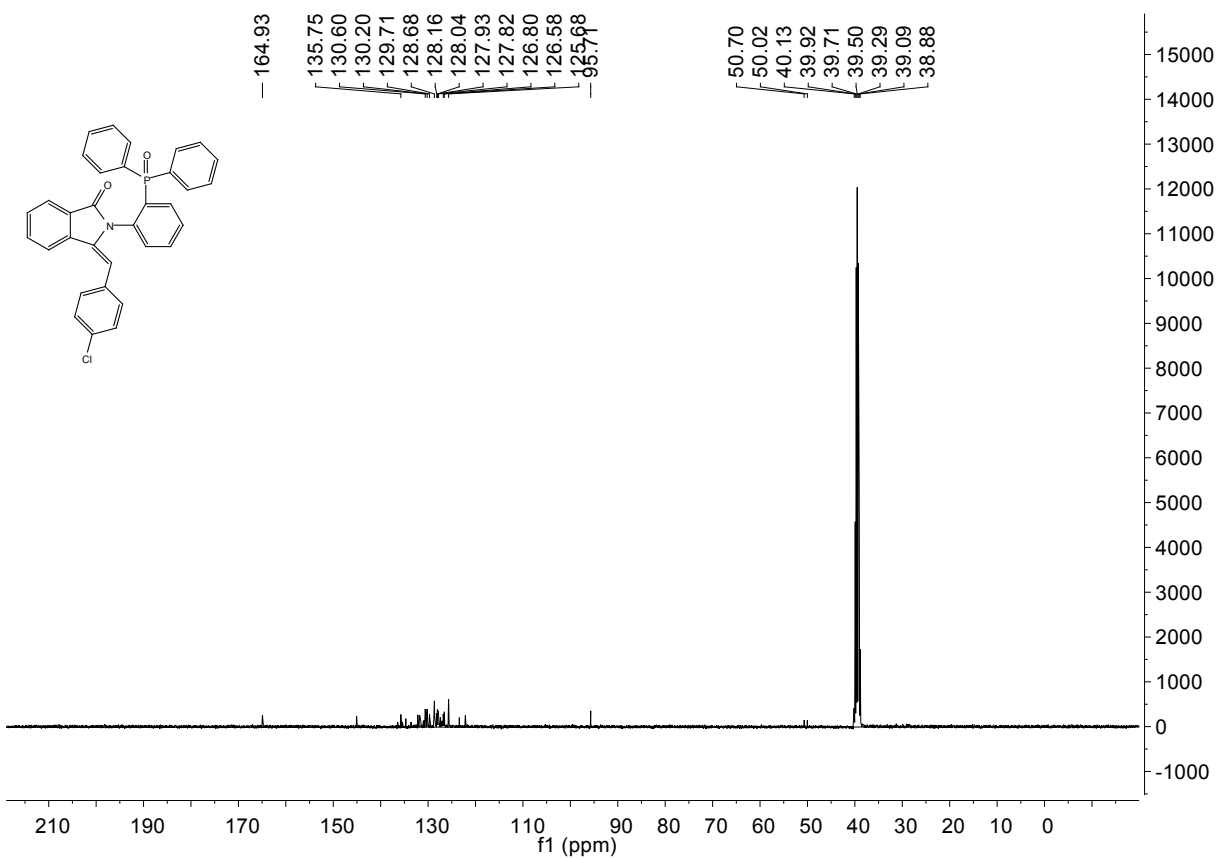
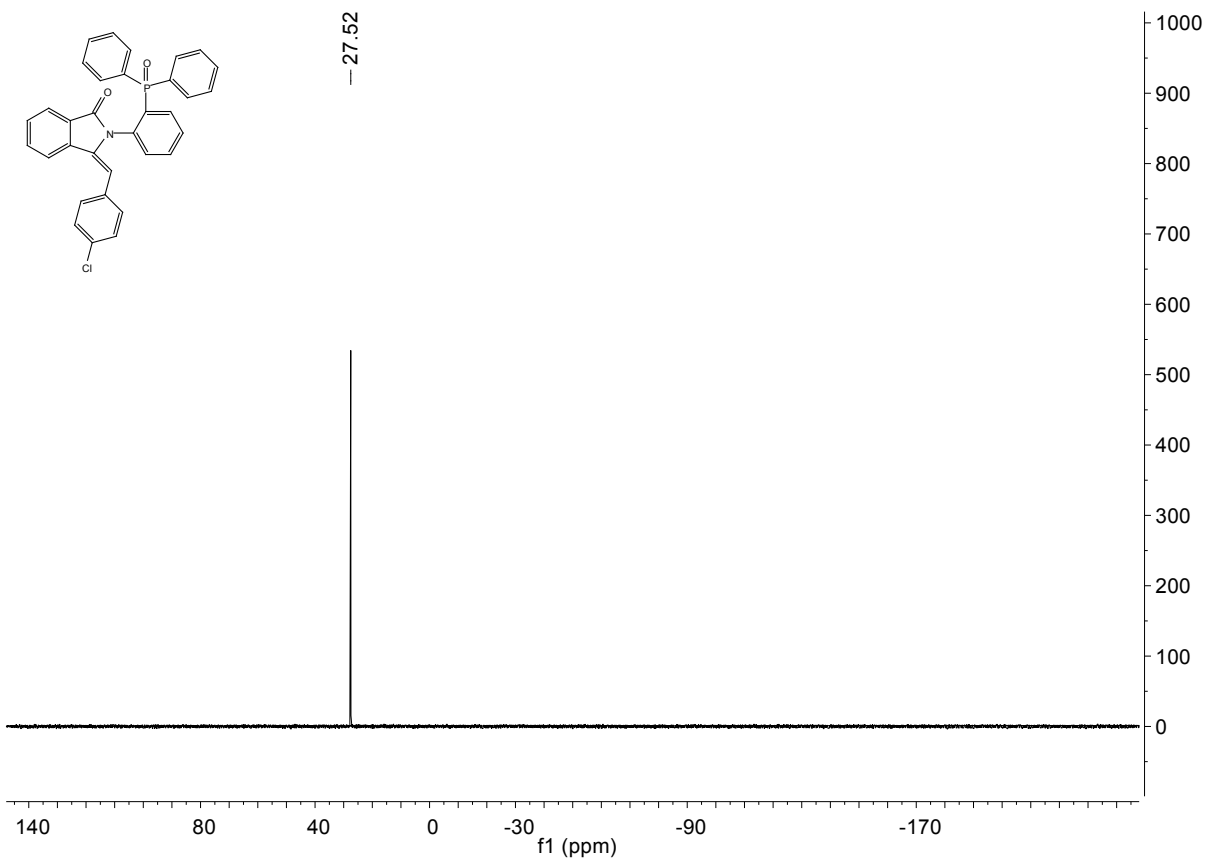


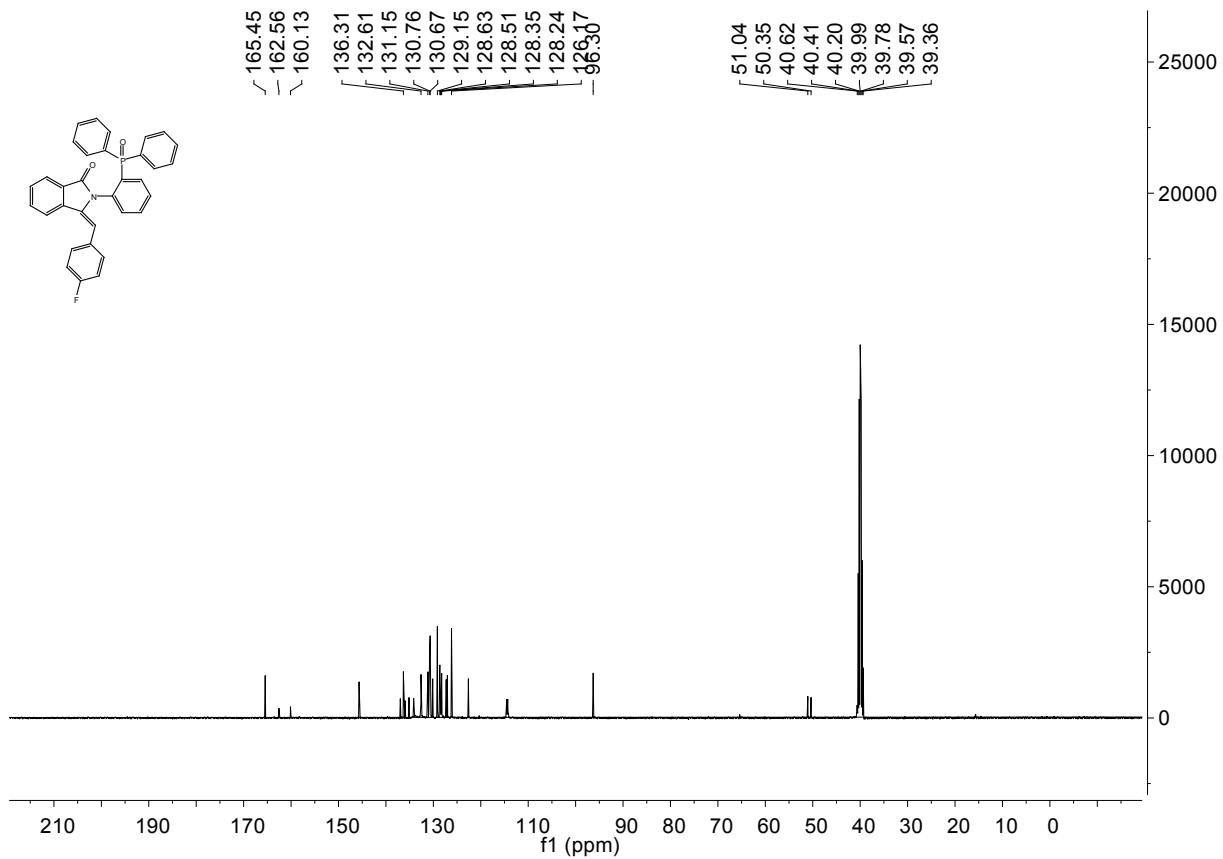
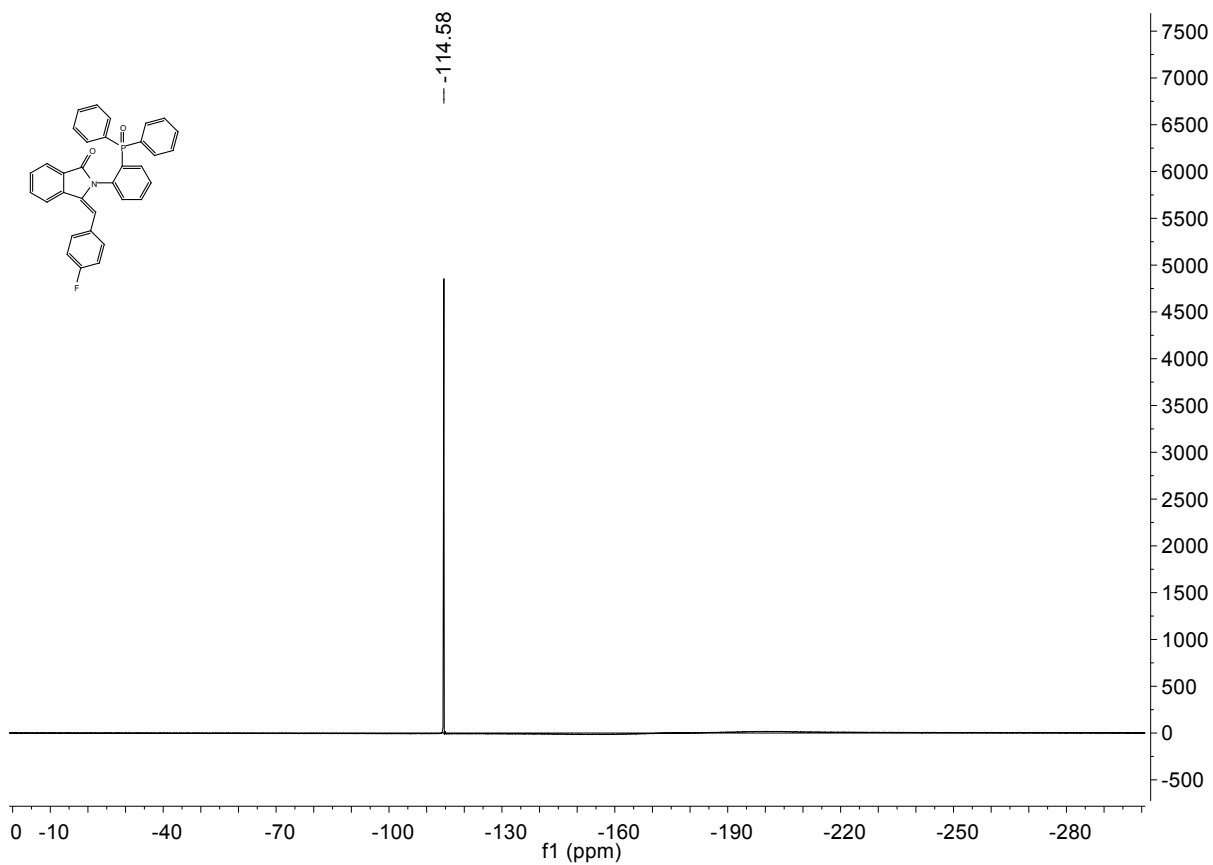


31

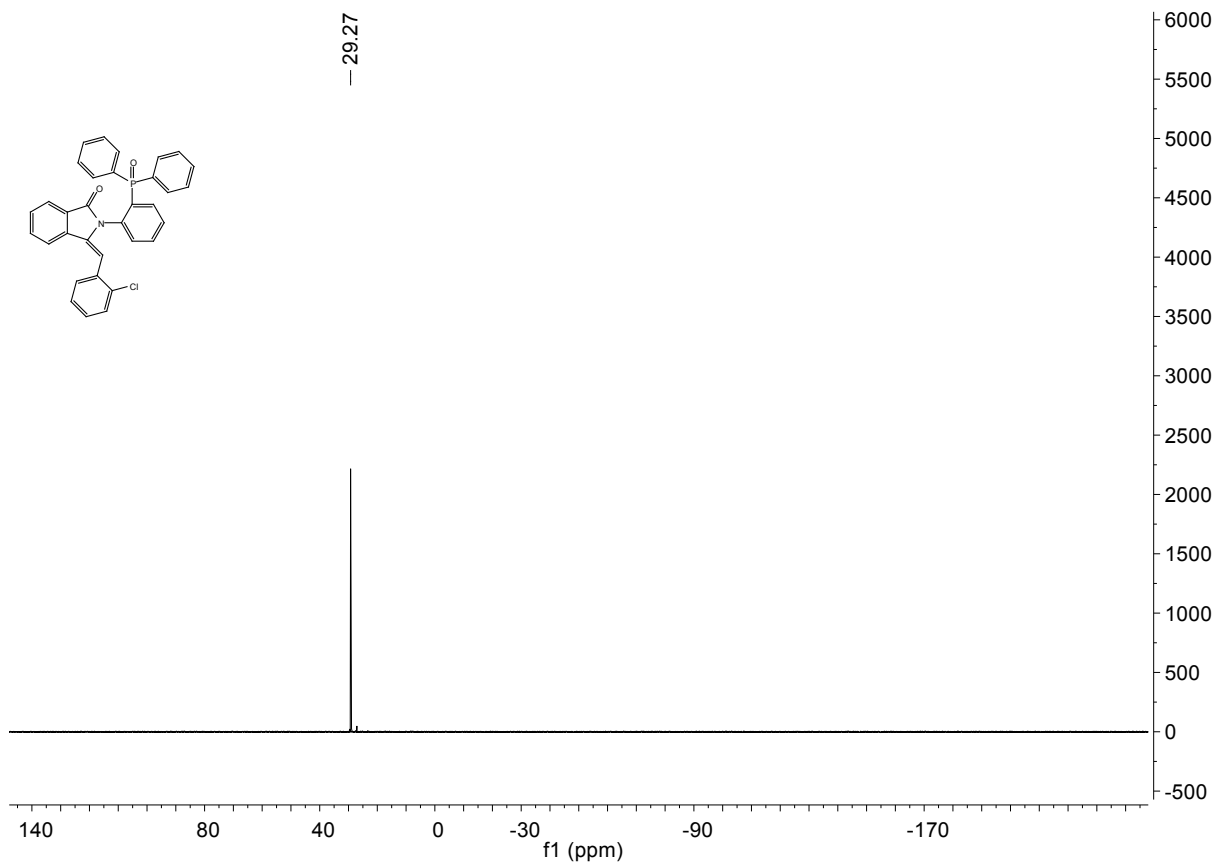
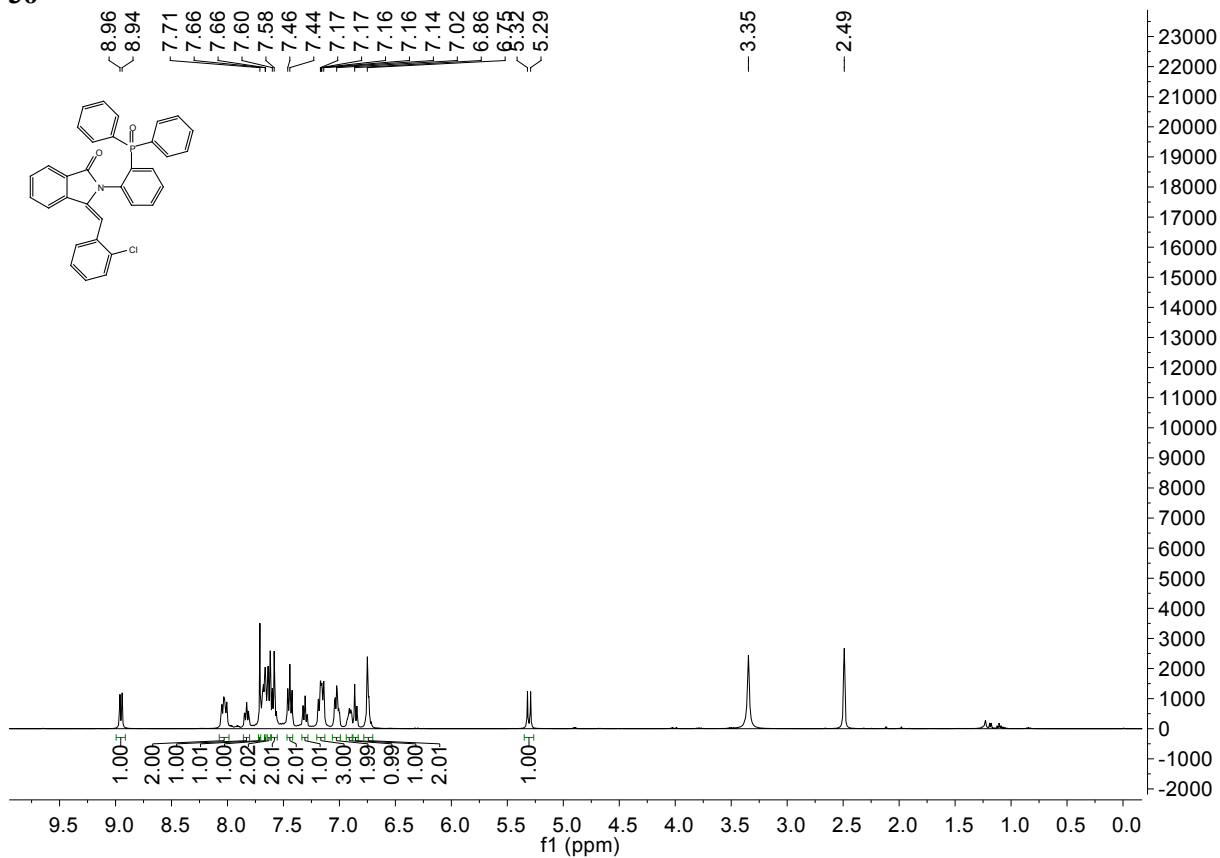


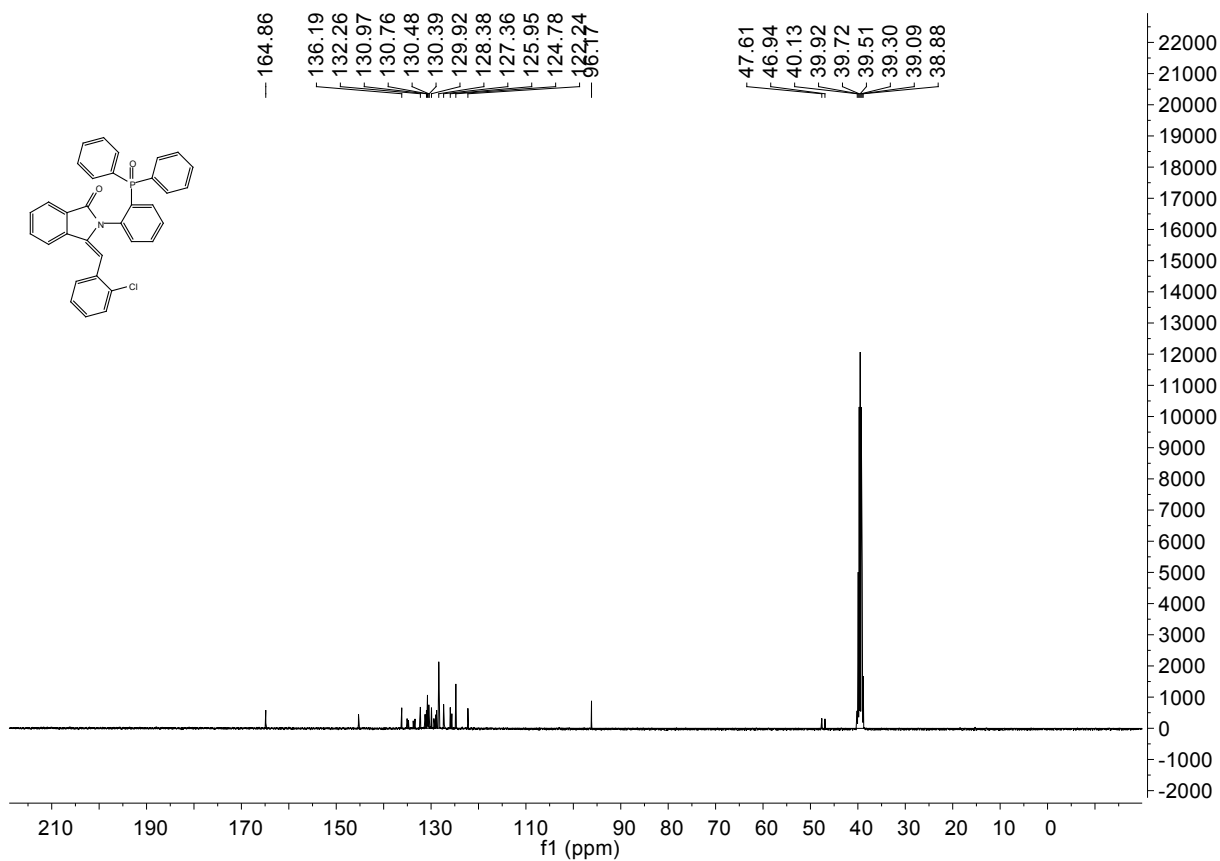




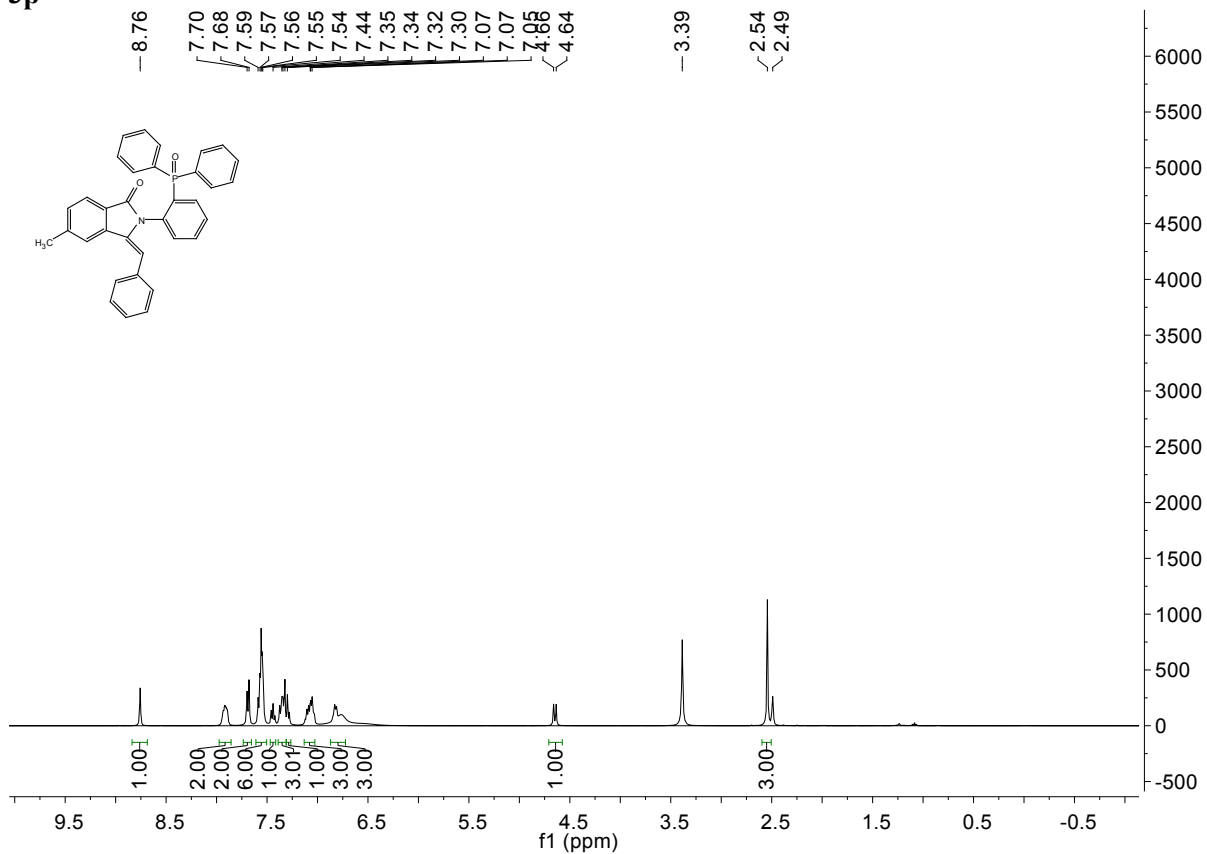


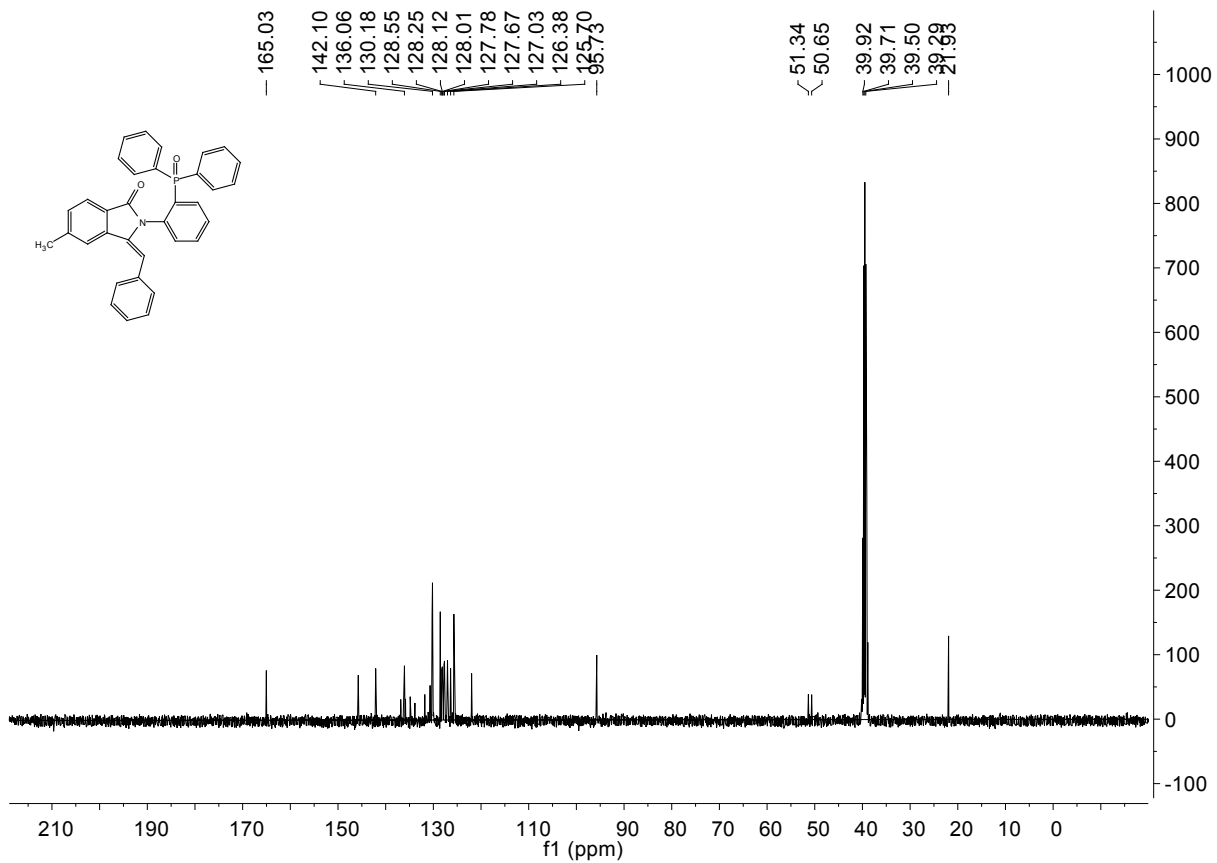
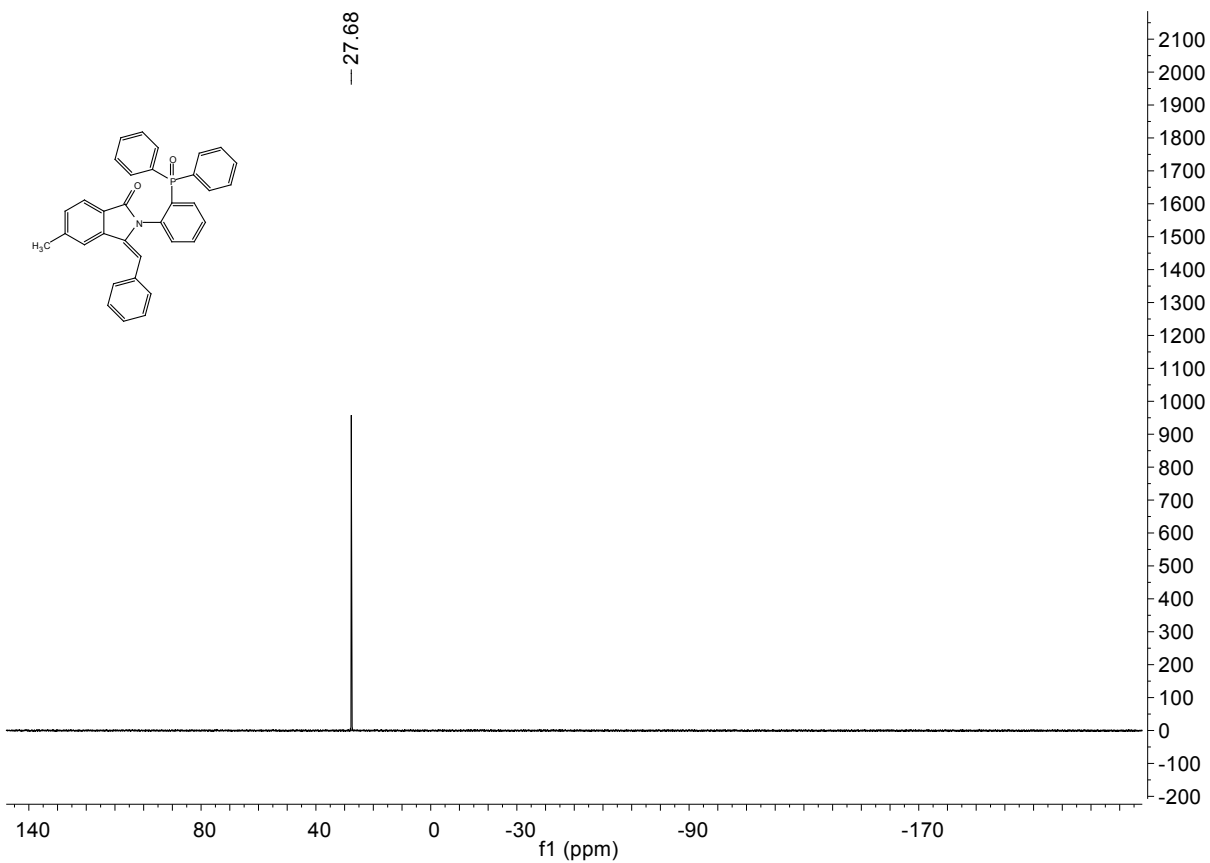
30



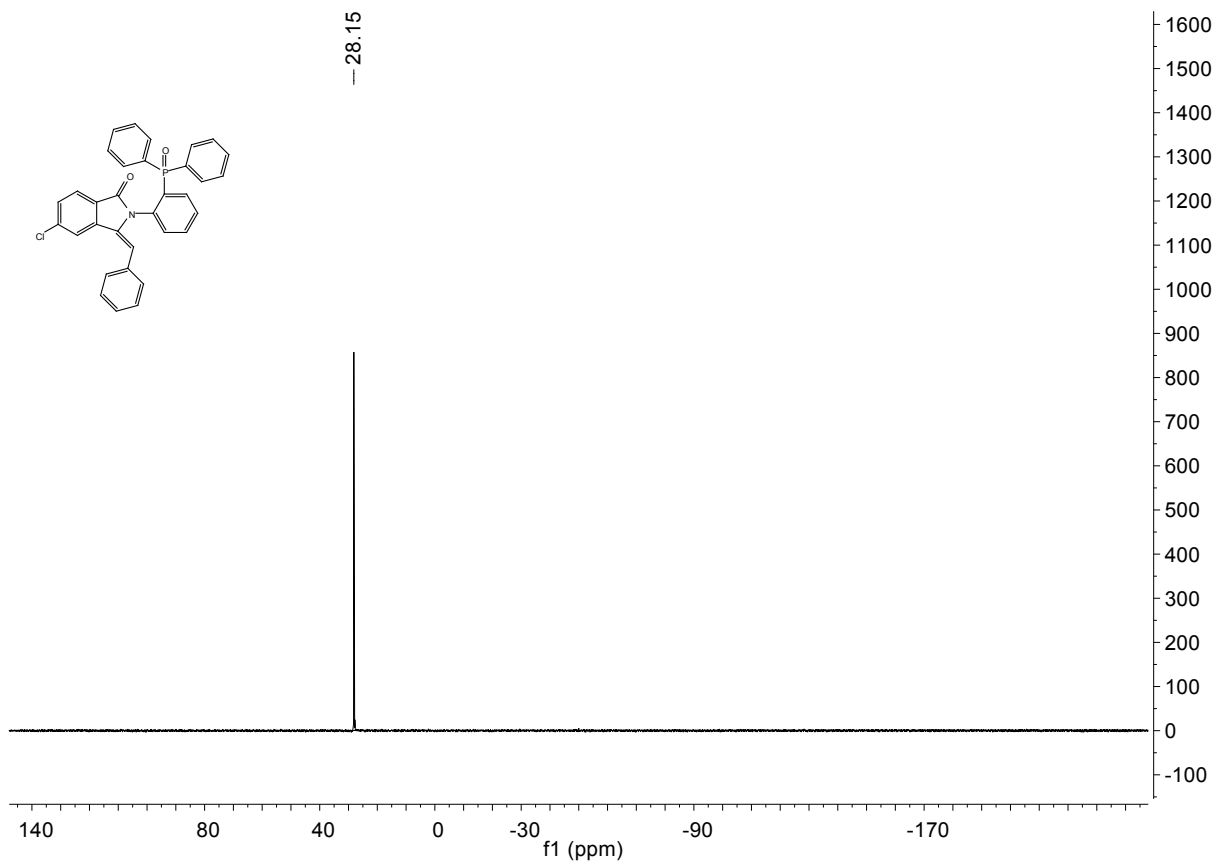
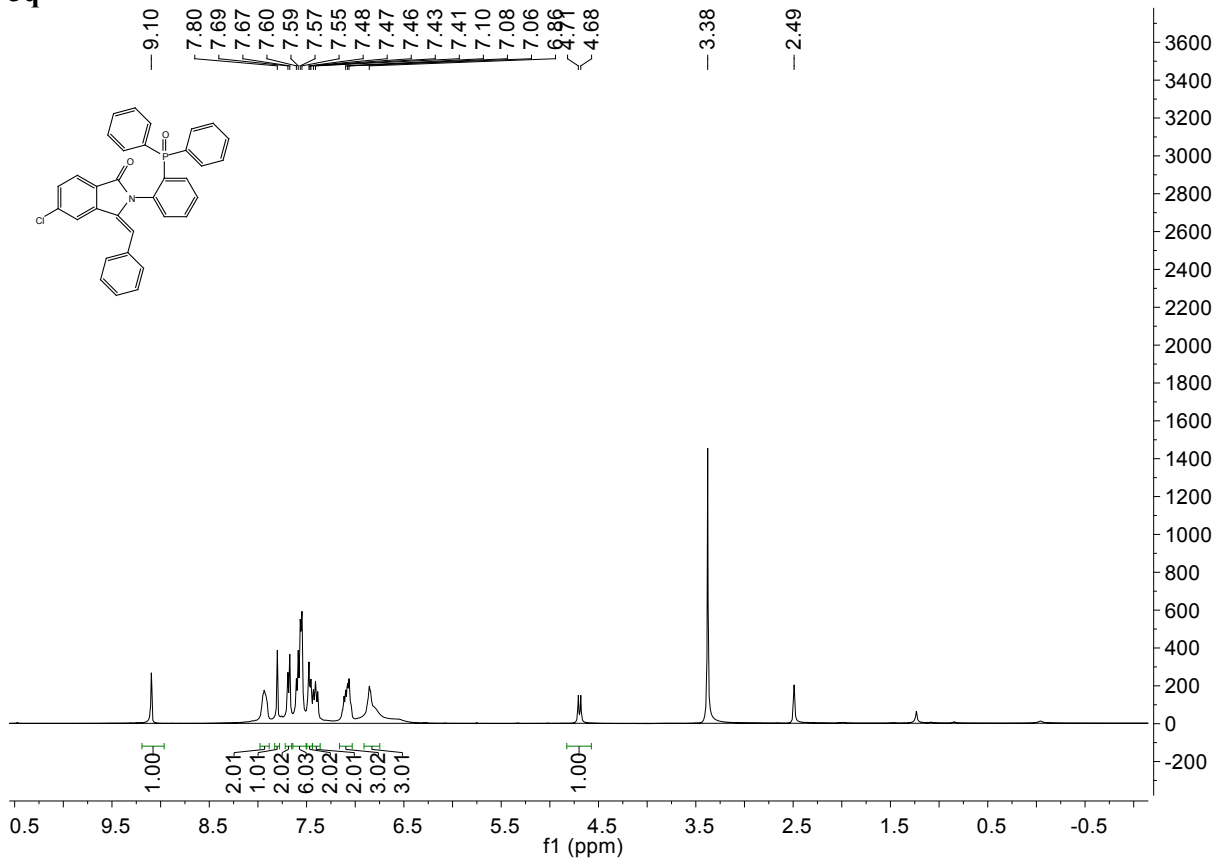


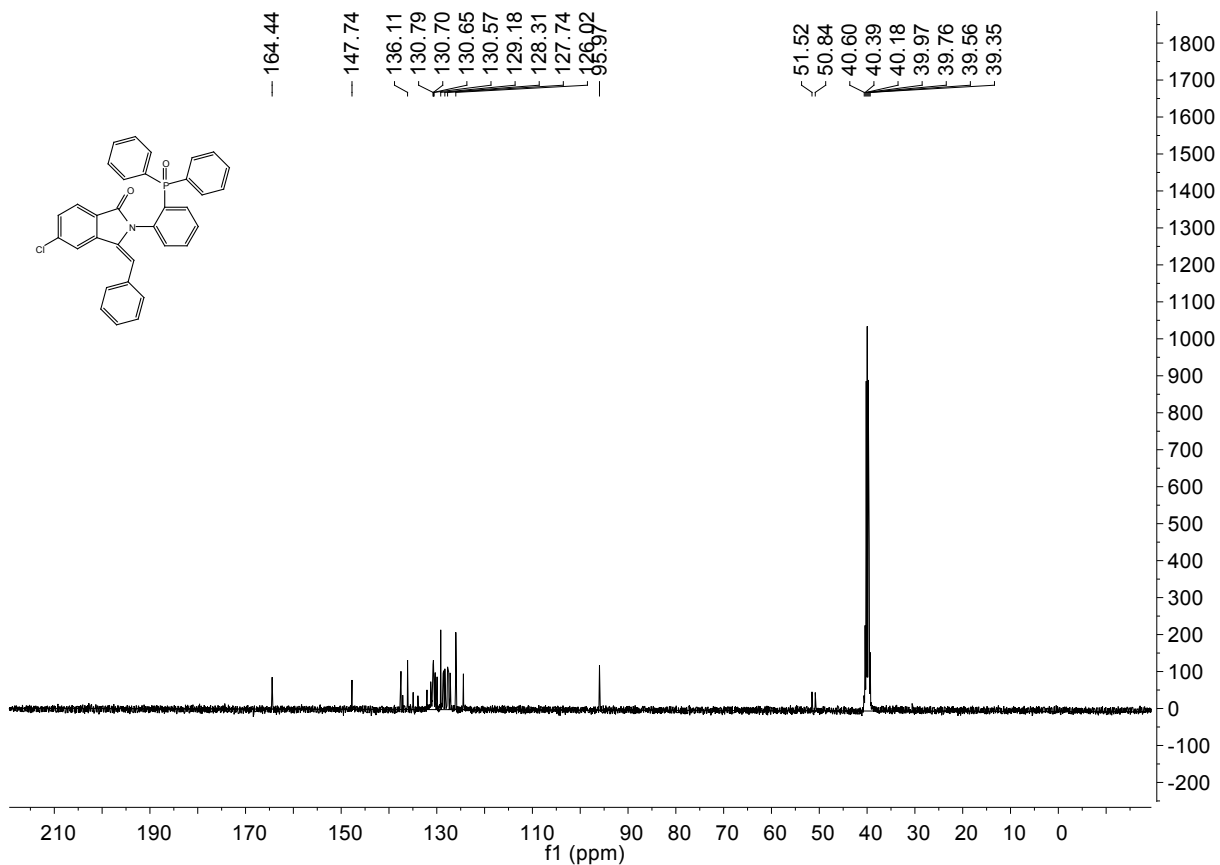
3p



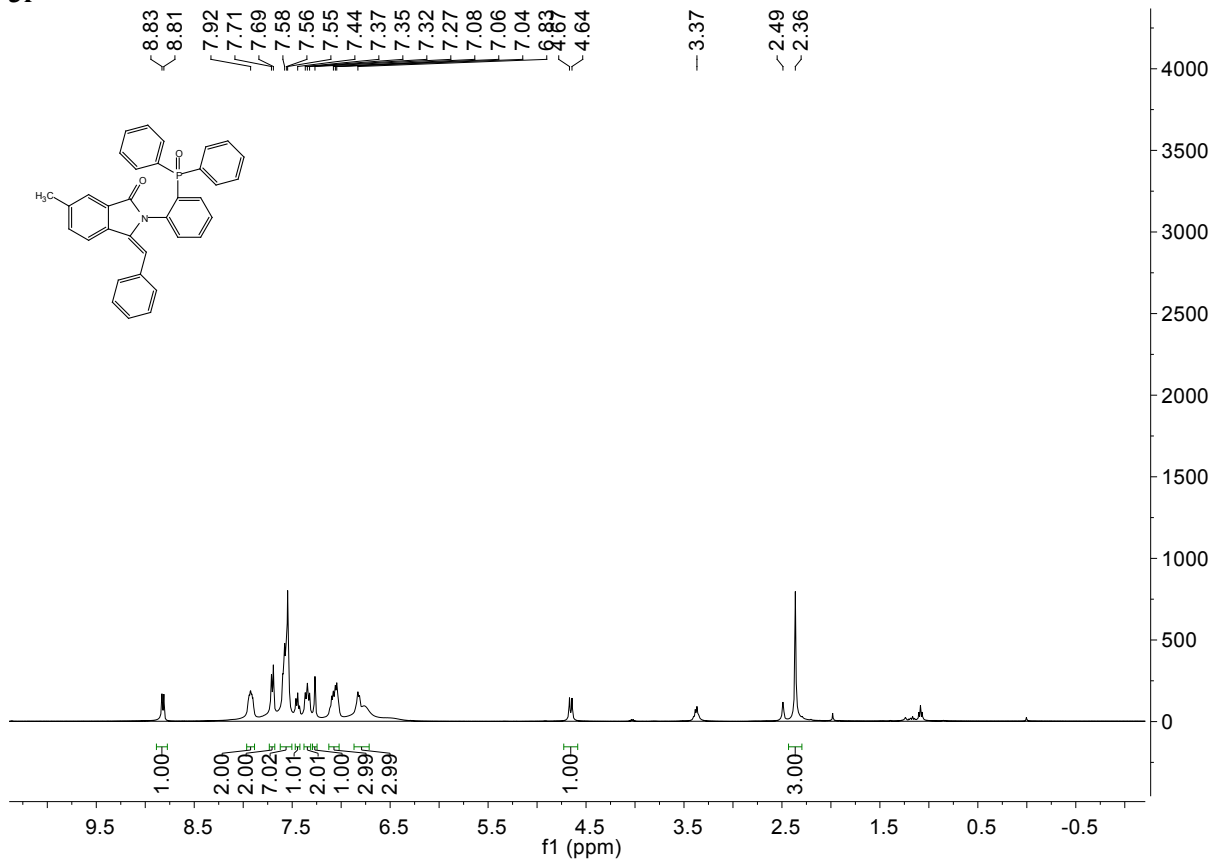


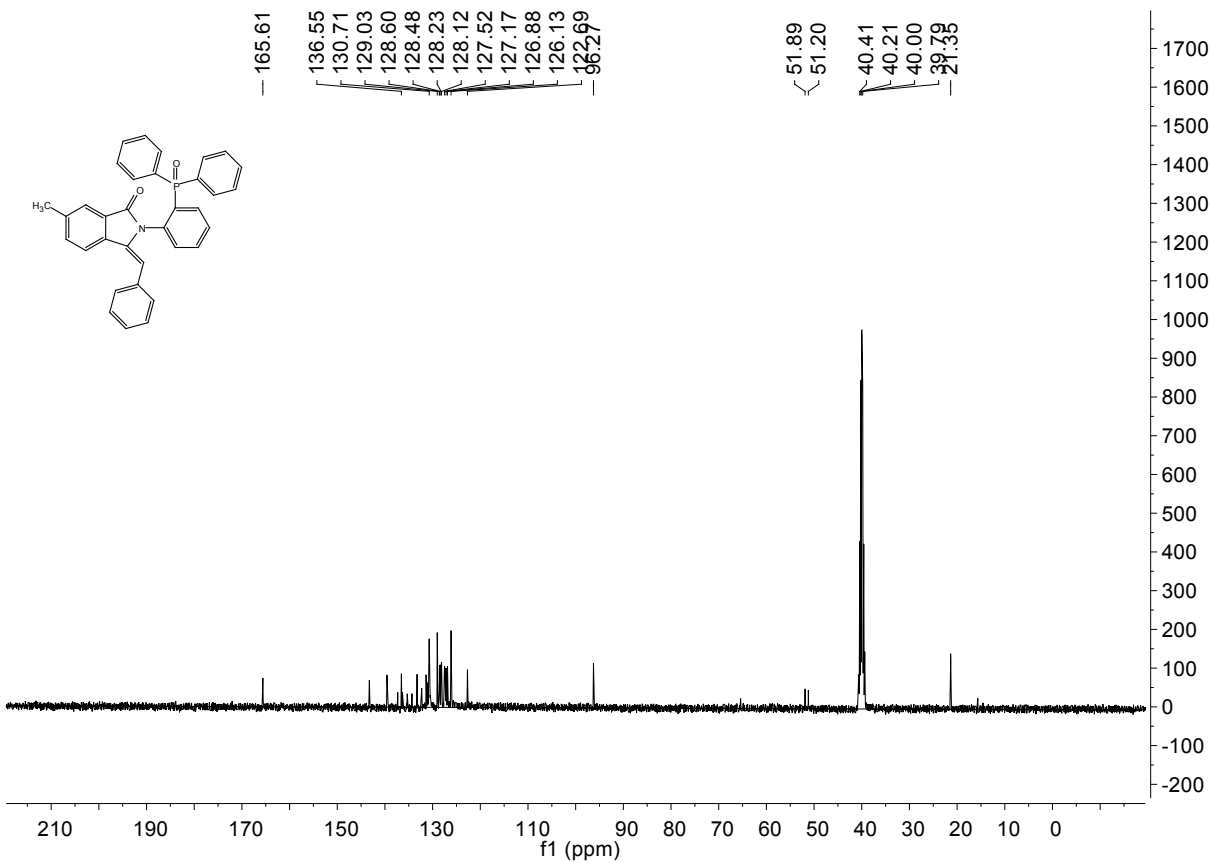
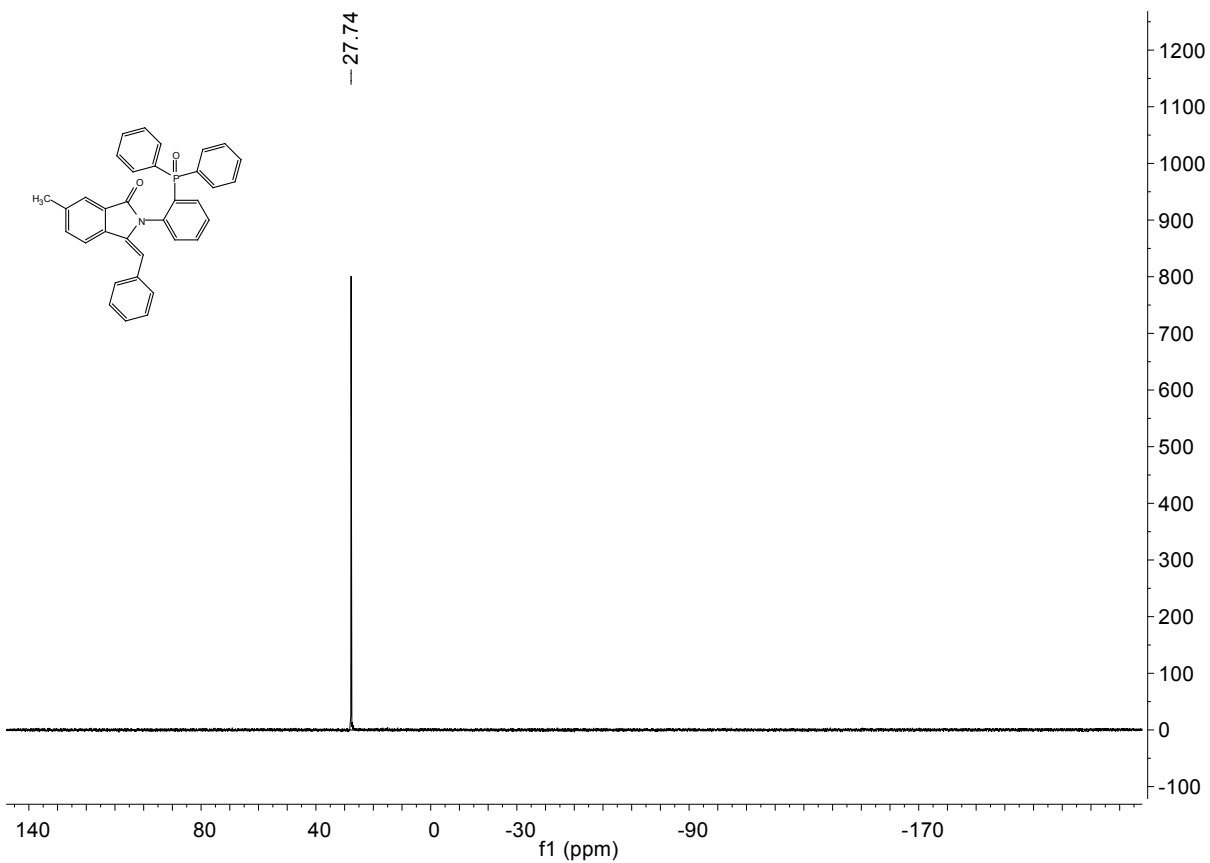
3q



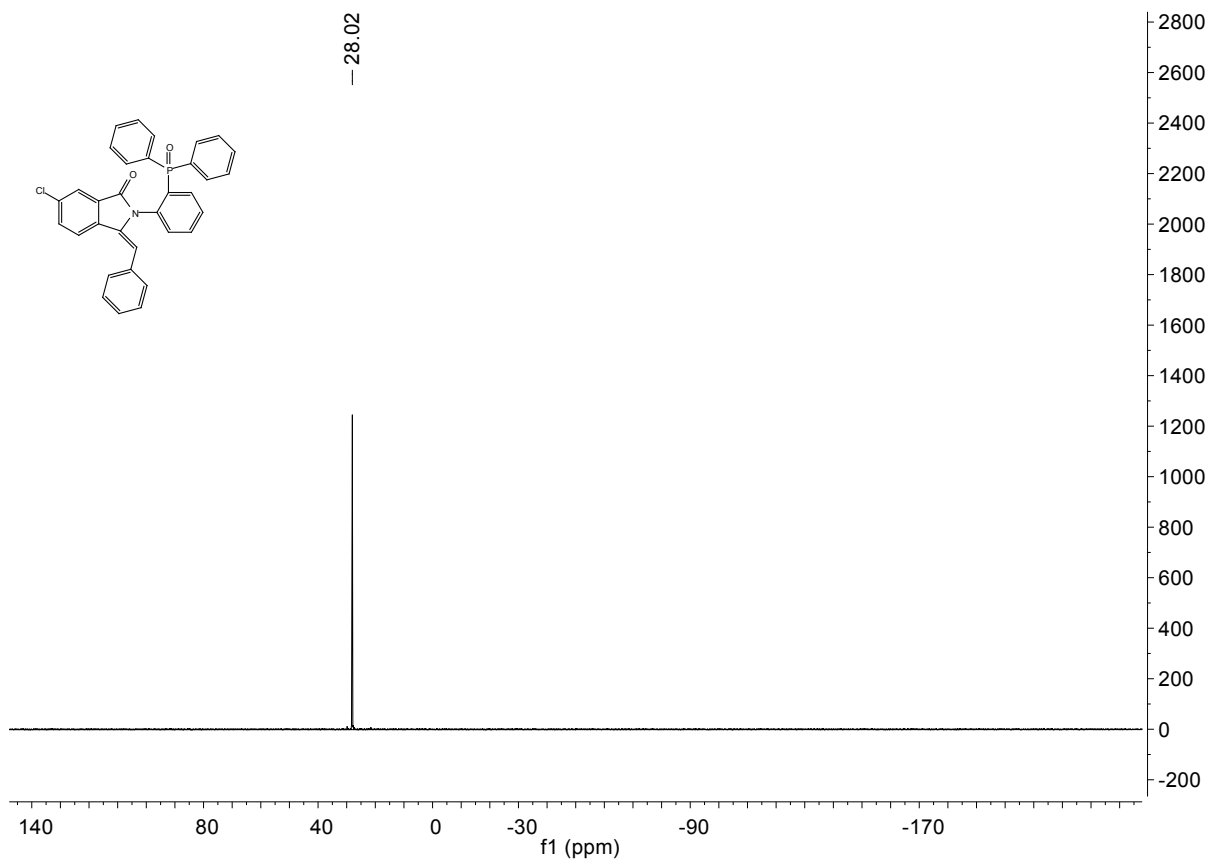
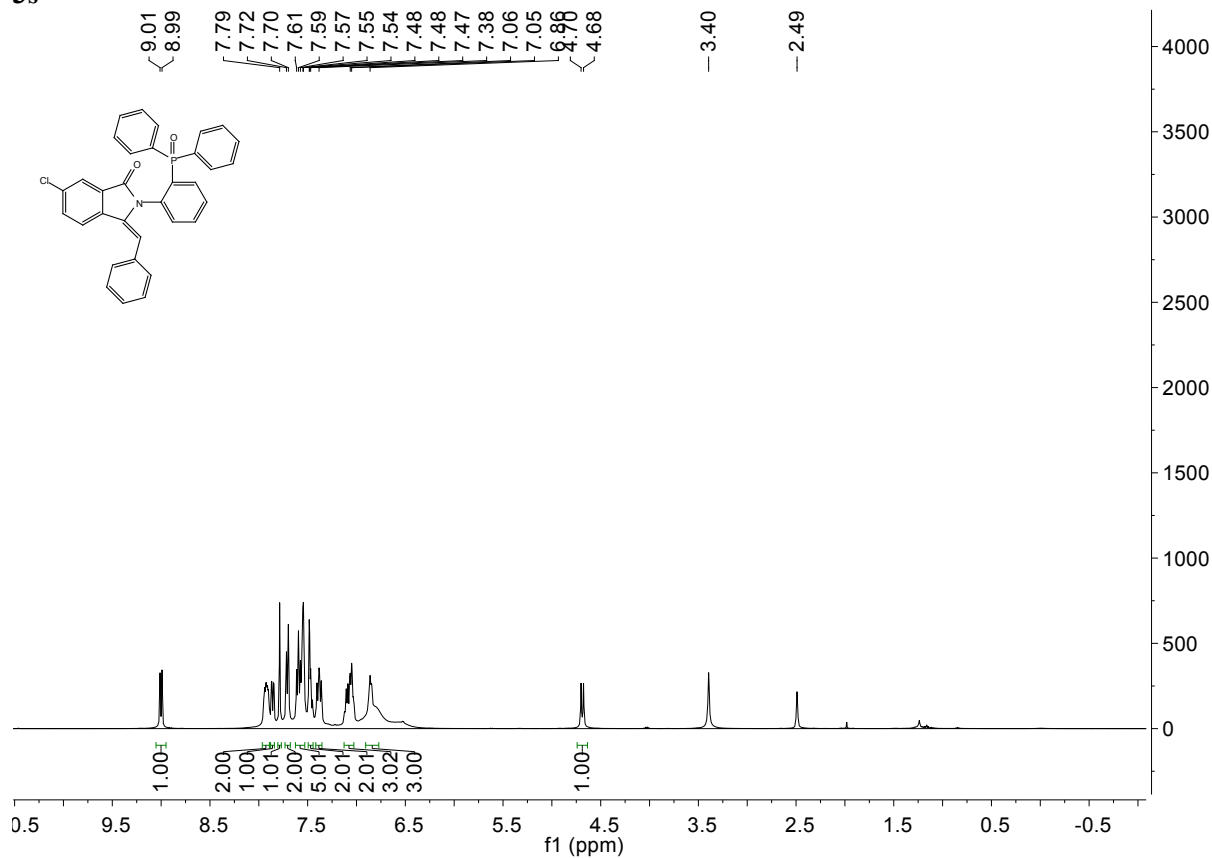


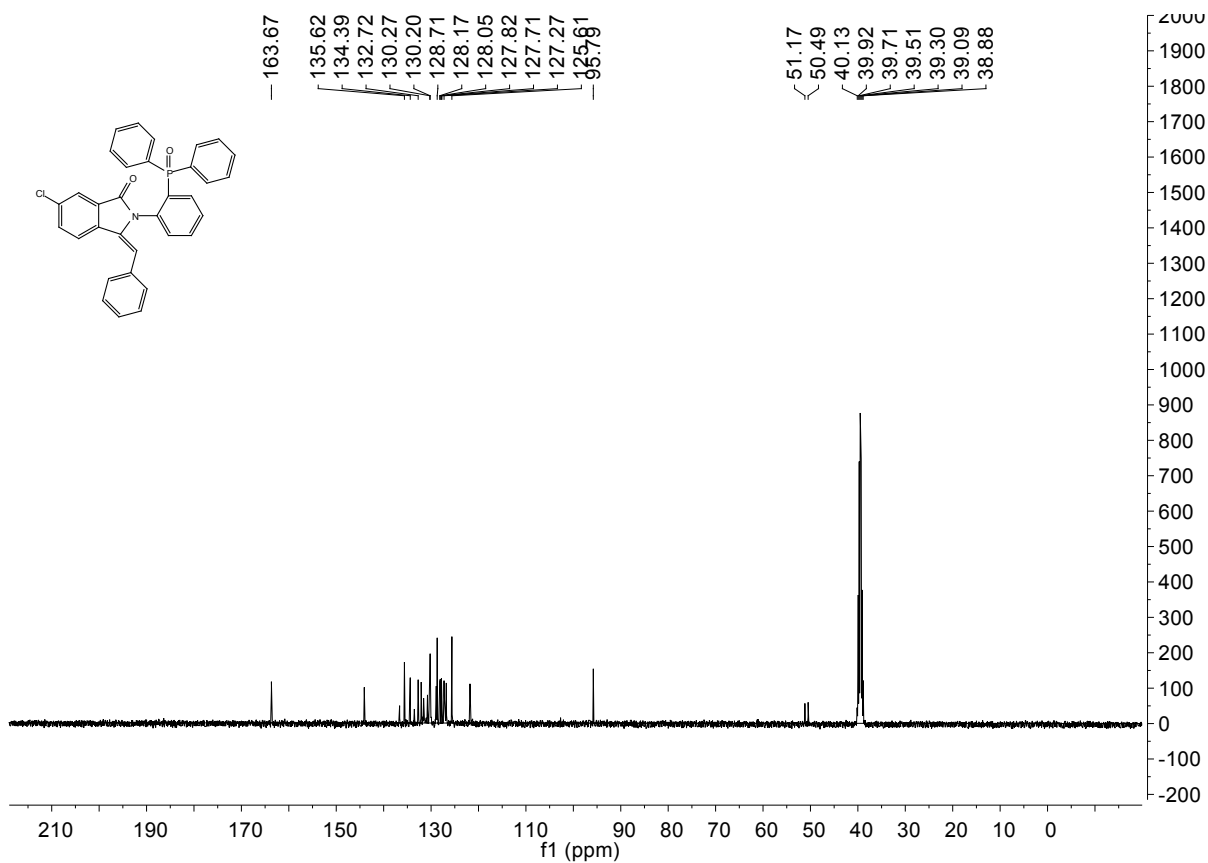
3r





3s





6. References:

[1] Li, M. W. Zhang, X. j. Jiang, Y. W. and Ma, D. *Organic Letters*, **2009**. *11*, 1309-1312.