

Supporting Information:

Palladium-Catalyzed Dearomative Arylphosphorylation of Indoles

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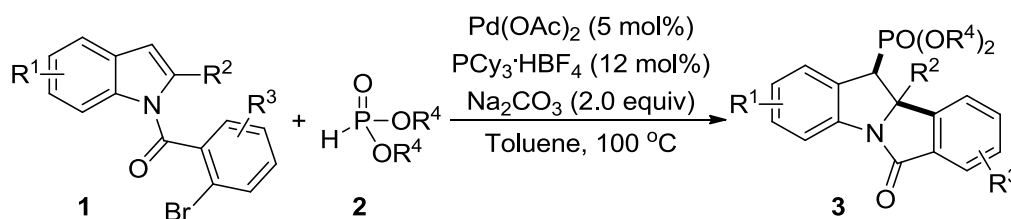
1. General information

Reactions and manipulations involving organometallic or moisture sensitive compounds were carried out under dry nitrogen and glassware heated under oven for two hours prior to use. ^1H NMR spectrum was recorded on 500 MHz, ^{13}C NMR spectrum was recorded on 125 MHz, and ^{31}P NMR spectrum was recorded on 243 MHz. Anhydrous THF, 1,4-Dioxane and toluene were freshly distilled over Na and benzophenone, DCE was freshly distilled over CaH_2 . Melting points were measured with a microscopic apparatus and uncorrected. Commercial reagents were used as received without further purification unless otherwise noticed. And dry-box operation was not necessary. The reaction was conducted in a sealed Schlenk tube, which was evacuated and purged with nitrogen for three times prior to use. HRMS were recorded on a TOF LC/MS mass spectrometer. Column chromatography was carried out using silica gel (200-300 mesh).

2. Substrate Synthesis

Substrates **1** were prepared according to the known method.¹

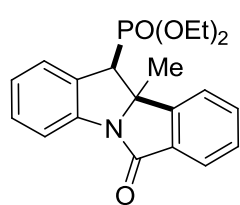
3. Procedure for the Pd-Catalyzed Dearomative Arylphosphorylation of Indoles



To a Schlenk tube was added $\text{Pd}(\text{OAc})_2$ (5 mol%), $\text{PCy}_3 \cdot \text{HBF}_4$ (12 mol%), **1** (0.2 mmol), Na_2CO_3 (0.4 mmol), and **2** (0.4 mmol) under N_2 , after which 2.0 mL toluene was added into the reaction mixture by a syringe. The mixture was stirred at $100\text{ }^\circ\text{C}$ for 24-60 hours. When the reaction was completed, the solvent was removed under vacuum and the residue was purified by chromatography on silica gel, eluting with EtOAc /petroleum ether = 1:2 (v/v) to afford the products **3**.

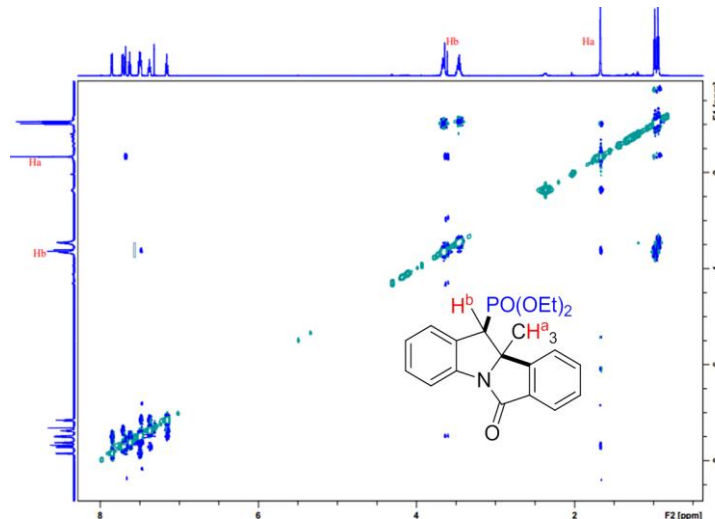
Diethyl(10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)

phosphon-ate (3a)



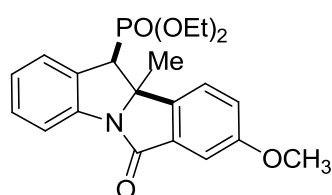
White solid; Mp 75-77 °C; 81% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.86 (d, $J = 7.5$ Hz, 1H), 7.72 (d, $J = 8.0$ Hz, 1H), 7.68 (d, $J = 7.5$ Hz, 1H), 7.63 (td, $J = 7.5, 1.0$ Hz, 1H), 7.52-7.45 (m, 2H), 7.39 (t, $J = 7.5$ Hz, 1H), 7.17 (t, $J = 7.5$ Hz, 1H), 3.70-3.64 (m, 2H), 3.64-3.60 (m, 1H), 3.49-3.41 (m, 2H), 1.68 (d, $J = 1.5$ Hz, 3H), 0.99 (t, $J = 7.0$ Hz, 3H), 0.94 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.5, 147.5 (d, $J_{\text{P-C}} = 5.6$ Hz), 139.0, 133.4, 131.7, 131.3 (d, $J_{\text{P-C}} = 8.2$ Hz), 129.1 (d, $J_{\text{P-C}} = 3.4$ Hz), 128.8, 127.7 (d, $J_{\text{P-C}} = 4.3$ Hz), 125.4, 124.5 (d, $J_{\text{P-C}} = 3.2$ Hz), 124.0, 117.3 (d, $J_{\text{P-C}} = 3.0$ Hz), 72.9 (d, $J_{\text{P-C}} = 3.3$ Hz), 62.3 (dd, $J_{\text{P-C}} = 120.2, 7.1$ Hz), 49.5 (d, $J_{\text{P-C}} = 139.8$ Hz), 29.33 (d, $J_{\text{P-C}} = 15.0$ Hz), 16.0 (dd, $J_{\text{P-C}} = 12.6, 5.7$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.24. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{22}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 394.1179, found 394.1174.

NOE spectrum



Diethyl(8-methoxy-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)

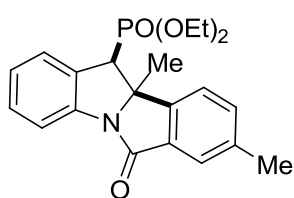
phosphonate (3b)



White solid; Mp 128-130 °C; 83% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.70 (d, $J = 8.0$ Hz, 1H), 7.54 (d, $J = 8.5$ Hz, 1H), 7.48-7.45 (m, 1H), 7.37 (t, $J = 7.5$ Hz, 1H), 7.31

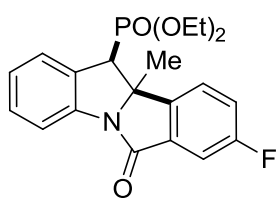
(d, $J = 2.5$ Hz, 1H), 7.18-7.13 (m, 2H), 3.87 (s, 3H), 3.70-3.62 (m, 2H), 3.57 (d, $J = 19.0$ Hz, 1H), 3.53-3.41 (m, 2H), 1.64 (d, $J = 2.0$ Hz, 3H), 0.98 (m, $J = 10.5, 7.1$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 160.4, 139.8 (d, $J_{\text{P-C}} = 5.3$ Hz), 139.0 (d, $J_{\text{P-C}} = 5.8$ Hz), 134.7, 131.4 (d, $J_{\text{P-C}} = 8.2$ Hz), 129.0 (d, $J_{\text{P-C}} = 3.4$ Hz), 127.6 (d, $J_{\text{P-C}} = 4.4$ Hz), 126.2, 124.4 (d, $J_{\text{P-C}} = 3.3$ Hz), 119.9, 117.2 (d, $J_{\text{P-C}} = 3.2$ Hz), 106.5, 72.5 (d, $J_{\text{P-C}} = 3.4$ Hz), 62.2 (dd, $J_{\text{P-C}} = 104.5, 7.4$ Hz), 55.7, 49.4 (d, $J_{\text{P-C}} = 139.9$ Hz), 29.3 (d, $J_{\text{P-C}} = 14.8$ Hz), 16.0 (t, $J_{\text{P-C}} = 6.3$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.38. HRMS m/z (ESI+): calculated for $\text{C}_{21}\text{H}_{24}\text{NO}_5\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 424.1284, found 424.1276.

Diethyl(8,10b-dimethyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3c)



White solid; Mp 106-108 °C; 80% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.69 (d, $J = 8.0$ Hz, 1H), 7.64 (s, 1H), 7.54 (d, $J = 8.0$ Hz, 1H), 7.47 – 7.41 (m, 2H), 7.36 (t, $J = 7.5$ Hz, 1H), 7.14 (t, $J = 7.5$ Hz, 1H), 3.70 – 3.63 (m, 2H), 3.58 (d, $J = 19.0$ Hz, 1H), 3.50 – 3.41 (m, 2H), 2.45 (s, 3H), 1.64 (d, $J = 2.0$ Hz, 3H), 0.99 (t, $J = 7.0$ Hz, 3H), 0.94 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.7, 144.8 (d, $J = 5.7$ Hz), 139.1 (d, $J = 5.7$ Hz), 138.9, 133.4, 132.8, 131.3 (d, $J_{\text{P-C}} = 8.8$ Hz), 129.0 (d, $J_{\text{P-C}} = 3.4$ Hz), 127.6 (d, $J_{\text{P-C}} = 3.8$ Hz), 125.1, 124.3 (d, $J_{\text{P-C}} = 3.3$ Hz), 124.0, 117.2 (d, $J_{\text{P-C}} = 2.6$ Hz), 72.6 (d, $J_{\text{P-C}} = 3.4$ Hz), 62.2 (dd, $J_{\text{P-C}} = 103.2, 7.3$ Hz), 49.4 (d, $J_{\text{P-C}} = 139.3$ Hz), 29.3 (d, $J_{\text{P-C}} = 15.0$ Hz), 21.3, 16.0 (dd, $J_{\text{P-C}} = 13.2, 5.6$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.28. HRMS m/z (ESI+): calculated for $\text{C}_{22}\text{H}_{26}\text{NO}_6\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 408.1335, found 408.1331.

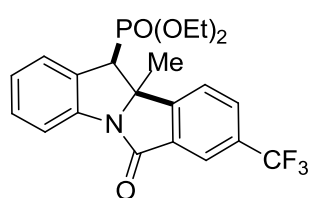
Diethyl(8-fluoro-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3d)



White solid; Mp 99-101 °C; 63% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.70 (d, $J = 8.0$ Hz, 1H), 7.64 (m, $J = 8.5, 4.4$ Hz, 1H), 7.49 (m, 2H), 7.38 (t, $J = 7.5$ Hz, 1H), 7.31 (m, $J = 8.5, 2.4$ Hz, 1H), 7.17 (t, $J = 7.5$ Hz, 1H), 3.70 (m, $J = 14.5, 5.0$ Hz,

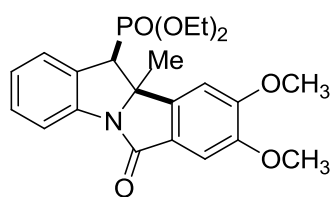
2H), 3.60 (d, $J = 18.5$ Hz, 1H), 3.55-3.45 (m, 2H), 1.66 (d, $J = 1.5$ Hz, 3H), 0.98 (m, $J = 18.5, 7.1$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 166.3 (d, $J = 3.3$ Hz), 163.2 (d, $J = 248.6$ Hz), 143.0 (dd, $J = 5.6, 2.4$ Hz), 138.8 (d, $J = 5.5$ Hz), 135.5 (d, $J = 8.2$ Hz), 131.3 (d, $J = 8.1$ Hz), 129.2 (d, $J = 3.5$ Hz), 127.7 (d, $J = 4.0$ Hz), 127.0 (d, $J = 8.2$ Hz), 124.73 (d, $J = 3.3$ Hz), 119.2 (d, $J = 23.4$ Hz), 117.3 (d, $J = 2.4$ Hz), 110.4 (d, $J = 23.2$ Hz), 72.6 (d, $J = 3.5$ Hz), 62.4 (dd, $J = 124.8, 7.1$ Hz), 49.4 (d, $J = 139.7$ Hz), 29.3 (d, $J = 14.9$ Hz), 16.0 (dd, $J = 12.1, 5.6$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.11. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{21}\text{FNO}_6\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 412.1084, found 412.1080.

Diethyl(10b-methyl-6-oxo-8-(trifluoromethyl)-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3e)



White solid; Mp 65-68 °C; 53% yield; ^1H NMR (500 MHz, CDCl_3): δ 8.14 (s, 1H), 7.89 (d, $J = 8.0$ Hz, 1H), 7.82 (d, $J = 8.0$ Hz, 1H), 7.74 (d, $J = 8.0$ Hz, 1H), 7.50 (m, $J = 7.5, 2.3$ Hz, 1H), 7.42 (t, $J = 7.5$ Hz, 1H), 7.21 (t, $J = 7.5$ Hz, 1H), 3.76-3.68 (m, 2H), 3.67-3.63 (m, 1H), 3.53 (m, 2H), 1.71 (d, $J = 1.5$ Hz, 3H), 1.00 (t, $J = 7.0$ Hz, 3H), 0.94 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 166.2, 150.9 (d, $J = 5.8$ Hz), 138.6 (d, $J = 5.7$ Hz), 134.5, 131.3, 131.8, 129.4 (d, $J = 3.4$ Hz), 128.5, 127.8 (d, $J = 4.2$ Hz), 126.4, 125.0 (d, $J = 3.3$ Hz), 122.7, 121.3 (d, $J = 3.6$ Hz), 117.4 (d, $J = 2.5$ Hz), 73.0 (d, $J = 3.5$ Hz), 62.6 (dd, $J = 138.8, 7.2$ Hz), 49.5 (d, $J = 139.1$ Hz), 29.2 (d, $J = 14.5$ Hz), 16.0 (dd, $J = 21.6, 5.9$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 19.88. HRMS m/z (ESI+): calculated for $\text{C}_{21}\text{H}_{21}\text{F}_3\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 462.1053, found 462.1064

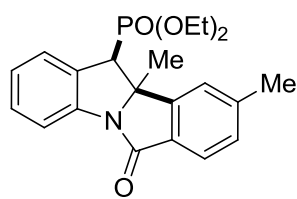
Diethyl(8,9-dimethoxy-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3f)



White solid; Mp 138-140 °C; 91% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.67 (d, $J = 8.0$ Hz, 1H), 7.43 (m, $J = 7.5, 2.1$ Hz, 1H), 7.36 (t, $J = 7.5$ Hz, 1H), 7.28 (s, 1H), 7.16 (s, 1H), 7.12 (t, $J = 7.5$ Hz, 1H), 4.02 (s, 3H), 3.95 (s, 3H),

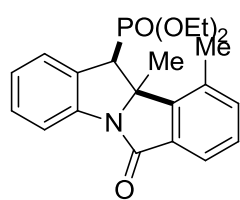
3.76 (m, $J = 7.0$ Hz, 2H), 3.59 (d, $J = 19.0$ Hz, 1H), 3.47-3.39 (m, 2H), 1.65 (d, $J = 1.5$ Hz, 3H), 1.06 (t, $J = 7.0$ Hz, 3H), 0.89 (d, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.8, 152.8, 150.2, 141.6 (d, $J_{\text{P-C}} = 6.2$ Hz), 139.2 (d, $J_{\text{P-C}} = 5.7$ Hz), 131.1 (d, $J_{\text{P-C}} = 8.2$ Hz), 129.1 (d, $J_{\text{P-C}} = 3.3$ Hz), 127.6 (d, $J_{\text{P-C}} = 4.3$ Hz), 125.4, 124.1 (d, $J_{\text{P-C}} = 3.3$ Hz), 117.0 (d, $J_{\text{P-C}} = 2.5$ Hz), 107.7, 105.1, 72.4 (d, $J_{\text{P-C}} = 2.6$ Hz), 68.1, 62.3 (dd, $J_{\text{P-C}} = 74.1, 7.1$ Hz), 56.3 (d, $J_{\text{P-C}} = 18.1$ Hz), 49.4 (d, $J_{\text{P-C}} = 139.0$ Hz), 29.6 (d, $J_{\text{P-C}} = 15.0$ Hz), 16.1 (dd, $J_{\text{P-C}} = 19.6, 5.8$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.34. HRMS m/z (ESI+): calculated for $\text{C}_{22}\text{H}_{26}\text{NO}_6\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 454.1390, found 454.1429.

Diethyl(9,10b-dimethyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3g)



White solid; Mp 135-137 °C; 71% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.73 (d, $J = 8.0$ Hz, 1H), 7.70 (d, $J = 8.0$ Hz, 1H), 7.48 (m, $J = 9.5, 4.0$ Hz, 2H), 7.37 (t, $J = 7.5$ Hz, 1H), 7.30 (d, $J = 7.5$ Hz, 1H), 7.15 (t, $J = 7.5$ Hz, 1H), 3.67-3.62 (m, 2H), 3.62-3.58 (m, 1H), 3.52-3.42 (m, 2H), 2.51 (s, 3H), 1.65 (d, $J = 1.5$ Hz, 3H), 0.96 (m, $J = 7.0$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.6, 147.8 (d, $J_{\text{P-C}} = 5.1$ Hz), 142.4, 139.1 (d, $J_{\text{P-C}} = 5.7$ Hz), 131.2 (d, $J_{\text{P-C}} = 8.3$ Hz), 130.8, 129.8, 129.1 (d, $J_{\text{P-C}} = 3.4$ Hz), 127.7 (d, $J_{\text{P-C}} = 4.4$ Hz), 125.9, 124.3 (d, $J_{\text{P-C}} = 3.3$ Hz), 123.7, 117.1 (d, $J_{\text{P-C}} = 3.0$ Hz), 72.6 (d, $J_{\text{P-C}} = 3.5$ Hz), 62.2 (dd, $J_{\text{P-C}} = 127.1, 7.1$ Hz), 49.4 (d, $J_{\text{P-C}} = 139.7$ Hz), 29.3 (d, $J_{\text{P-C}} = 15.1$ Hz), 22.1, 16.0 (dd, $J_{\text{P-C}} = 16.9, 5.7$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.32. HRMS m/z (ESI+): calculated for $\text{C}_{22}\text{H}_{26}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 408.1335, found 408.1341.

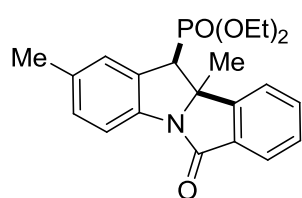
Diethyl(10,10b-dimethyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3h)



White solid; Mp 90-92 °C; 26% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.74-7.69 (m, 2H), 7.49 (m, $J = 7.5, 2.4$ Hz, 1H), 7.40 (m, $J = 9.0, 7.3$ Hz, 3H), 7.17 (t, $J = 7.5$ Hz, 1H), 3.70-3.66 (m, 1H), 3.65-3.54 (m, 2H), 3.46-3.33 (m, 2H), 2.59 (s, 3H), 1.71 (d,

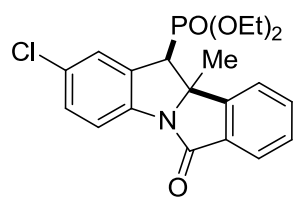
$J = 2.0$ Hz, 3H), 1.00 (m, $J = 8.5, 5.5$ Hz, 3H), 0.89 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.0, 145.1, 138.6, 135.3, 134.3, 134.1, 132.0 (d, $J_{\text{P-C}} = 9.1$ Hz), 129.1, 127.9 (d, $J_{\text{P-C}} = 4.5$ Hz), 124.4 (d, $J_{\text{P-C}} = 3.4$ Hz), 121.7, 117.4 (d, $J_{\text{P-C}} = 3.2$ Hz), 73.4, 62.4 (dd, $J_{\text{P-C}} = 123.8, 7.4$ Hz), 49.2 (d, $J_{\text{P-C}} = 138.7$ Hz), 26.0 (d, $J_{\text{P-C}} = 15.9$ Hz), 20.1, 16.0 (dd, $J_{\text{P-C}} = 37.7$ Hz, 5.0 Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.11. HRMS m/z (ESI+): calculated for $\text{C}_{22}\text{H}_{26}\text{NO}_6\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 408.1335, found 408.1325.

Diethyl(2,10b-dimethyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3i)



White solid; Mp 90-91 °C; 78% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.83 (d, $J = 7.5$ Hz, 1H), 7.65 (d, $J = 7.5$ Hz, 1H), 7.62-7.57 (m, 2H), 7.48 (m, $J = 7.5, 1.0$ Hz, 1H), 7.28 (s, 1H), 7.17 (d, $J = 8.0$ Hz, 1H), 3.67-3.61 (m, 2H), 3.57 (d, $J = 19.0$ Hz, 1H), 3.48-3.41 (m, 2H), 2.36 (s, 3H), 1.64 (d, $J = 2.0$ Hz, 3H), 0.95 (m, $J = 14.0, 7.1$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 147.4 (d, $J = 5.6$ Hz), 136.5 (d, $J_{\text{P-C}} = 5.8$ Hz), 134.1 (d, $J_{\text{P-C}} = 3.5$ Hz), 133.5, 131.5, 131.3 (d, $J_{\text{P-C}} = 8.3$ Hz), 129.6 (d, $J_{\text{P-C}} = 3.5$ Hz), 128.7, 128.3 (d, $J_{\text{P-C}} = 3.8$ Hz), 125.3, 123.8, 116.8 (d, $J_{\text{P-C}} = 2.8$ Hz), 72.9 (d, $J_{\text{P-C}} = 3.4$ Hz), 62.2 (dd, $J_{\text{P-C}} = 119.7, 7.4$ Hz), 49.3 (d, $J_{\text{P-C}} = 139.8$ Hz), 29.2 (d, $J_{\text{P-C}} = 15.0$ Hz), 21.2, 15.9 (t, $J_{\text{P-C}} = 6.3$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.39. HRMS m/z (ESI+): calculated for $\text{C}_{21}\text{H}_{24}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 408.1335, found 408.1326.

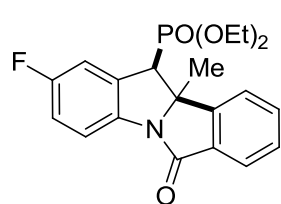
Diethyl(2-chloro-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3j)



White solid; Mp 42-45 °C; 60% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.85 (d, $J = 7.5$ Hz, 1H), 7.68 (d, $J = 7.5$ Hz, 1H), 7.66-7.62 (m, 2H), 7.52 (m, $J = 7.5, 1.0$ Hz, 1H), 7.43 (t, $J = 2.0$ Hz, 1H), 7.36 (m, $J = 8.5, 2.1$ Hz, 1H), 3.79-3.71 (m, 2H), 3.59 (d, $J = 19.5$ Hz, 1H), 3.47-3.38 (m, 2H), 1.67 (d, $J = 1.5$ Hz, 3H), 1.06 (t, $J = 7.0$ Hz, 3H), 0.92 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.5, 147.3 (d, $J_{\text{P-C}}$

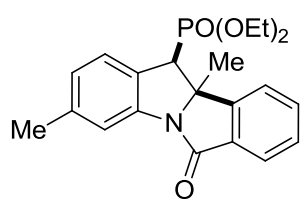
= 5.5 Hz), 137.7 (d, J_{P-C} = 5.8 Hz), 133.3 (d, J_{P-C} = 8.2 Hz), 129.7 (d, J_{P-C} = 4.4 Hz), 132.0, 129.2 (d, J_{P-C} = 3.5 Hz), 128.9, 127.8 (d, J_{P-C} = 4.4 Hz), 125.4, 118.0 (d, J_{P-C} = 2.4 Hz), 124.0, 118.0, 73.1 (d, J_{P-C} = 3.3 Hz), 62.4 (dd, J_{P-C} = 86.1, 7.1 Hz), 49.5 (d, J_{P-C} = 139.8 Hz), 29.4 (d, J_{P-C} = 14.9 Hz), 16.0 (dd, J_{P-C} = 21.6, 5.9 Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 19.31. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{21}\text{ClNO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 428.0789, found 428.0778.

Diethyl(2-fluoro-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3k)



White solid; Mp 92-94 °C; 62% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.85 (d, J = 7.5 Hz, 1H), 7.65 (m, 3H), 7.53-7.50 (m, 1H), 7.19 (m, J = 8.0, 2.4 Hz, 1H), 7.08 (m, 1H), 3.73 (m, 2H), 3.61-3.57 (m, 1H), 3.46-3.40 (m, 2H), 1.68 (d, J = 1.5 Hz, 3H), 1.04 (t, J = 7.0 Hz, 3H), 0.94 (d, J = 7.0 Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.9, 163.7, 147.3 (d, J = 5.4 Hz), 142.3, 135.2, 133.3, 131.9, 128.9, 125.7, 124.3, 117.9 (dd, J = 8.7, 2.7 Hz), 115.8 (dd, J = 23.5, 3.6 Hz), 115.2 (dd, J = 25.2, 4.4 Hz), 73.3, 62.4 (dd, J = 96.7, 7.2 Hz), 49.7 (d, J = 146.3 Hz), 29.3 (d, J = 14.9 Hz), 16.0 (dd, J = 19.6, 5.8 Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 19.44. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{21}\text{FNO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 412.1084, found 412.1077.

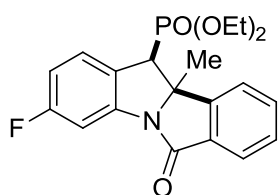
Diethyl(3,10b-dimethyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3l)



White solid; Mp 91-93 °C; 73% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.84 (d, J = 7.5 Hz, 1H), 7.66 (d, J = 7.5 Hz, 1H), 7.61 (m, J = 7.5, 1.1 Hz, 1H), 7.54 (s, 1H), 7.49 (m, J = 7.5, 1.0 Hz, 1H), 7.33 (m, J = 7.5, 2.7 Hz, 1H), 6.96 (d, J = 7.5 Hz, 1H), 3.67 (m, 2H), 3.56 (d, J = 18.5 Hz, 1H), 3.47-3.40 (m, 2H), 2.42 (d, J = 2.0 Hz, 3H), 1.65 (d, J = 2.0 Hz, 3H), 1.00 (t, J = 7.0 Hz, 3H), 0.92 (t, J = 7.0 Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 147.5 (d, J_{P-C} = 5.7 Hz), 139.3 (d, J_{P-C} = 3.5 Hz), 138.9 (d, J_{P-C} = 5.6 Hz), 133.4, 131.6, 128.7, 128.2 (d, J_{P-C} = 8.4 Hz), 127.2 (d, J_{P-C} = 4.1 Hz), 125.5, 125.1 (d, J_{P-C} = 3.4 Hz), 123.9, 117.8 (d, J_{P-C} = 3.2 Hz), 73.1 (d,

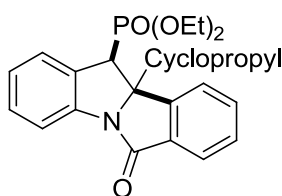
$J_{P-C} = 3.4$ Hz), 62.2 (dd, $J_{P-C} = 109.7, 7.4$ Hz), 49.1 (d, $J_{P-C} = 140.3$ Hz), 29.3 (d, $J_{P-C} = 15.0$ Hz), 21.6, 16.0 (dd, $J_{P-C} = 16.1, 5.8$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.41. HRMS m/z (ESI+): calculated for $\text{C}_{21}\text{H}_{24}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 408.1335, found 408.1328.

Diethyl(3-fluoro-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3m)



White solid; Mp 100-101 °C; 64% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.83 (d, $J = 7.5$ Hz, 1H), 7.63 (m, $J = 11.0, 8.6, 4.3$ Hz, 2H), 7.49 (m, $J = 7.5, 1.1$ Hz, 1H), 7.40 (m, $J = 8.0, 6.7, 2.5$ Hz, 2H), 6.83 (m, $J = 9.0, 2.4$ Hz, 1H), 3.69-3.63 (m, 2H), 3.56 (d, $J = 18.5$ Hz, 1H), 3.48-3.42 (m, 2H), 1.66 (d, $J = 1.5$ Hz, 3H), 0.97 (t, $J = 7.0$ Hz, 3H), 0.93 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 163.2 (dd, $J = 246.3, 3.6$ Hz), 147.4 (d, $J = 5.3$ Hz), 140.3 (dd, $J = 12.5, 5.6$ Hz), 132.9, 132.0, 128.9, 128.4 (dd, $J = 9.9, 4.1$ Hz), 126.7 (dd, $J = 8.5, 2.8$ Hz), 125.4, 124.1, 111.2 (dd, $J = 23.0, 3.3$ Hz), 105.3 (dd, $J = 26.7, 2.4$ Hz), 73.5 (d, $J = 3.6$ Hz), 62.3 (dd, $J = 108.7, 7.1$ Hz), 48.9 (d, $J = 140.2$ Hz), 29.3 (d, $J = 14.8$ Hz), 16.0 (dd, $J = 12.6, 5.8$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 19.98. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{21}\text{FNO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 412.1084, found 412.1076.

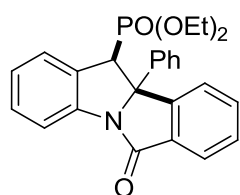
Diethyl(10b-cyclopropyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3n)



Light yellow solid; Mp 39-40 °C; 66% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.83 (d, $J = 7.5$ Hz, 1H), 7.74 (d, $J = 7.5$ Hz, 1H), 7.65 (d, $J = 8.0$ Hz, 1H), 7.62 (m, $J = 11.5, 3.8$ Hz, 1H), 7.49 (t, $J = 7.5$ Hz, 1H), 7.46 (m, $J = 7.5, 2.3$ Hz, 1H), 7.35 (t, $J = 7.5$ Hz, 1H), 7.13 (t, $J = 7.5$ Hz, 1H), 3.86 (d, $J = 19.0$ Hz, 1H), 3.72 (m, $J = 14.5, 7.5$ Hz, 2H), 3.47-3.41 (m, 2H), 1.49 (m, 1H), 1.01 (t, $J = 7.0$ Hz, 3H), 0.92 (t, $J = 7.0$ Hz, 3H), 0.42 (m, 1H), 0.29-0.24 (m, 1H), 0.18 (m, $J = 10.0, 5.1$ Hz, 1H), 0.09 (m, $J = 10.0, 5.3$ Hz, 1H). ^{13}C NMR (125 MHz, CDCl_3): δ 168.6, 147.2 (d, $J_{P-C} = 5.6$ Hz), 140.3 (d, $J_{P-C} = 6.1$ Hz), 133.1, 131.6, 128.9 (d, $J_{P-C} = 3.4$ Hz), 128.6, 127.2 (d, $J_{P-C} =$

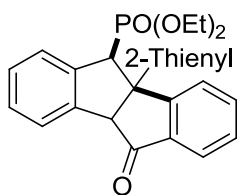
4.2 Hz), 125.7, 124.4 (d, $J_{P-C} = 3.2$ Hz), 123.8, 116.3, 74.6, 62.2 (dd, $J_{P-C} = 105.6, 7.3$ Hz), 48.8 (d, $J_{P-C} = 139.1$ Hz), 29.7, 22.54 (d, $J_{P-C} = 16.5$ Hz), 16.0 (dd, $J_{P-C} = 17.9, 5.7$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.21. HRMS m/z (ESI+): calculated for $\text{C}_{22}\text{H}_{24}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 420.1335, found 420.1327.

Diethyl(6-oxo-10b-phenyl-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3o)



White solid; Mp 127-129 °C; 52% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.85 (t, $J = 8.0$ Hz, 2H), 7.78 (d, $J = 8.0$ Hz, 1H), 7.66-7.63 (m, 2H), 7.56-7.50 (m, 1H), 7.44 (m, $J = 7.5, 0.6$ Hz, 1H), 7.39 (m, $J = 11.0, 4.6$ Hz, 2H), 7.31 (m, $J = 10.5, 4.9$ Hz, 2H), 7.23 (t, $J = 7.5$ Hz, 1H), 7.12 (t, $J = 7.5$ Hz, 1H), 4.26 (d, $J = 19.5$ Hz, 1H), 3.79-3.72 (m, 2H), 3.59-3.51 (m, 2H), 1.05 (t, $J = 7.0$ Hz, 3H), 1.01 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 168.3, 146.8 (d, $J_{P-C} = 5.5$ Hz), 143.7 (d, $J_{P-C} = 14.2$ Hz), 139.5 (d, $J_{P-C} = 5.7$ Hz), 132.5, 131.9, 131.1 (d, $J_{P-C} = 8.1$ Hz), 129.1 (d, $J_{P-C} = 3.4$ Hz), 128.9, 128.7, 128.0, 127.4 (d, $J_{P-C} = 4.2$ Hz), 126.6, 124.8 (d, $J_{P-C} = 3.3$ Hz), 124.4, 123.9, 117.1 (d, $J_{P-C} = 2.5$ Hz), 78.1 (d, $J_{P-C} = 2.9$ Hz), 62.5 (dd, $J_{P-C} = 115.3, 7.3$ Hz), 51.4 (d, $J_{P-C} = 2.5$ Hz), 16.1 (dd, $J_{P-C} = 10.0, 6.0$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.19. HRMS m/z (ESI+): calculated for $\text{C}_{25}\text{H}_{24}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 456.1335, found 456.1324.

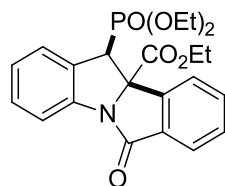
Diethyl(6-oxo-10b-(thiophen-2-yl)-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3p)



White solid; Mp 117-119 °C; 53% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.87 (d, $J = 7.5$ Hz, 1H), 7.77 (t, $J = 8.5$ Hz, 2H), 7.61 (m, $J = 7.5, 1.0$ Hz, 1H), 7.51 (m, $J = 11.0, 4.0$ Hz, 1H), 7.46 (m, $J = 7.5, 2.2$ Hz, 1H), 7.40 (t, $J = 7.5$ Hz, 1H), 7.19-7.10 (m, 3H), 6.88 (m, $J = 5.0, 3.7$ Hz, 1H), 4.29 (d, $J = 19.0$ Hz, 1H), 3.74-3.66 (m, 2H), 3.56 (m, 2H), 1.01 (t, $J = 7.0$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.9, 148.1, 148.0, 146.2 (d, $J_{P-C} = 4.7$ Hz), 139.4 (d, $J_{P-C} = 5.6$ Hz), 132.7, 131.9, 131.3 (d, $J_{P-C} = 8.1$ Hz), 129.3 (d, $J_{P-C} = 3.4$ Hz), 129.2, 127.5 (d, $J_{P-C} = 4.4$ Hz), 127.0 (d, $J_{P-C} = 4.5$ Hz),

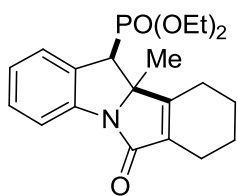
124.9 (d, $J_{P-C} = 3.3$ Hz), 124.8, 124.0 (d, $J_{P-C} = 4.8$ Hz), 117.5 (d, $J_{P-C} = 2.9$ Hz), 76.1, 62.6 (dd, $J_{P-C} = 119.3, 7.2$ Hz), 51.6 (d, $J_{P-C} = 137.9$ Hz), 16.1 (t, $J_{P-C} = 5.8$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 19.33. HRMS m/z (ESI+): calculated for $\text{C}_{23}\text{H}_{22}\text{NO}_4\text{PSNa}$ ($[\text{M}+\text{Na}]^+$): 462.0899, found 462.0888.

Ethyl-11-(diethoxyphosphoryl)-6-oxo-6H-isoindolo[2,1-a]indole-10b(11H)-carboxylate (3q)



Light yellow oil; 30% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.88 (d, $J = 7.5$ Hz, 1H), 7.76 (t, $J = 8.5$ Hz, 2H), 7.61 (m, 1H), 7.58-7.54 (m, 1H), 7.48-7.45 (m, 1H), 7.38 (t, $J = 7.5$ Hz, 1H), 7.16 (t, $J = 7.5$ Hz, 1H), 4.52 (d, $J = 19.5$ Hz, 1H), 4.11 (t, $J = 7.0$ Hz, 2H), 3.70-3.57 (m, 4H), 1.11 (t, $J = 7.0$ Hz, 3H), 1.02 (t, $J = 7.0$ Hz, 3H), 0.94 (t, $J = 4.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 170.6 (d, $J_{P-C} = 19.5$ Hz), 167.4, 140.8 (d, $J_{P-C} = 5.8$ Hz), 139.3 (d, $J_{P-C} = 5.8$ Hz), 134.4, 131.9, 130.3 (d, $J_{P-C} = 8.2$ Hz), 129.9, 129.2 (d, $J_{P-C} = 3.4$ Hz), 127.3 (d, $J_{P-C} = 4.4$ Hz), 126.1, 124.8 (d, $J_{P-C} = 3.3$ Hz), 124.1, 116.6 (d, $J_{P-C} = 3.1$ Hz), 77.8 (d, $J_{P-C} = 3.1$ Hz), 63.0 (dd, $J_{P-C} = 107.6, 7.0$ Hz), 46.0 (d, $J_{P-C} = 141.2$ Hz), 16.0 (t, $J_{P-C} = 6.3$ Hz), 13.8. ^{31}P NMR (243 MHz, CDCl_3): δ 19.77. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{26}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 452.1233, found 452.1219.

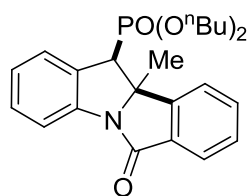
Diethyl(10b-methyl-6-oxo-7,8,9,10,10b,11-hexahydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3r)



White solid; Mp 111-113 °C; 70% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.52 (d, $J = 8.0$ Hz, 1H), 7.34 (m, 2H), 7.08 (t, $J = 7.5$ Hz, 1H), 3.94-3.70 (m, 4H), 3.34 (d, $J = 17.5$ Hz, 1H), 2.99-2.87 (m, 1H), 2.35-2.17 (m, 3H), 1.80 (m, $J = 11.5, 5.8$ Hz, 3H), 1.71-1.65 (m, 1H), 1.45 (d, $J = 2.0$ Hz, 3H), 1.18 (t, $J = 7.0$ Hz, 3H), 1.11 (t, $J = 7.0$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 171.0, 158.3 (d, $J_{P-C} = 5.8$ Hz), 139.3 (d, $J_{P-C} = 5.3$ Hz), 131.4 (d, $J_{P-C} = 8.4$ Hz), 128.9 (d, $J_{P-C} = 3.4$ Hz), 127.3 (d, $J_{P-C} = 4.5$ Hz), 123.9 (d, $J_{P-C} = 3.2$ Hz), 117.0 (d, $J_{P-C} = 3.2$ Hz), 74.7 (d, $J_{P-C} = 2.3$ Hz), 62.4 (dd, $J_{P-C} = 39.8, 7.4$ Hz), 49.1 (d, $J_{P-C} = 139.6$ Hz), 26.0 (d, $J_{P-C} = 15.6$ Hz), 23.7, 22.2, 21.6,

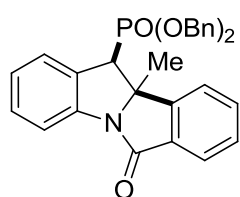
20.6, 16.3 (dd, $J_{P-C} = 18.0, 5.8$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 20.90. HRMS m/z (ESI+): calculated for $\text{C}_{20}\text{H}_{26}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 398.1492, found 398.1489.

Dibutyl(10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3s)



White solid; Mp 54-56 °C; 76% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.83 (d, $J = 7.5$ Hz, 1H), 7.70 (d, $J = 8.0$ Hz, 1H), 7.66 (d, $J = 7.5$ Hz, 1H), 7.60 (m, $J = 7.5, 1.1$ Hz, 1H), 7.47 (m, 2H), 7.36 (t, $J = 7.5$ Hz, 1H), 7.14 (t, $J = 7.5$ Hz, 1H), 3.64-3.59 (m, 2H), 3.57-3.50 (m, 1H), 3.40-3.34 (m, 2H), 1.66 (d, $J = 1.5$ Hz, 3H), 1.27 (m, 4H), 1.14-1.02 (m, 4H), 0.77 (m, $J = 12.0, 7.4$ Hz, 6H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 147.5 (d, $J_{P-C} = 5.2$ Hz), 138.9 (d, $J_{P-C} = 5.7$ Hz), 133.2, 131.7, 131.3 (d, $J_{P-C} = 8.3$ Hz), 129.0 (d, $J_{P-C} = 3.4$ Hz), 128.6, 127.6 (d, $J_{P-C} = 4.0$ Hz), 125.3, 124.3 (d, $J_{P-C} = 3.2$ Hz), 123.9, 117.1 (d, $J_{P-C} = 2.9$ Hz), 72.7 (d, $J_{P-C} = 3.4$ Hz), 65.91 (dd, $J_{P-C} = 97.5, 7.3$ Hz), 49.3 (d, $J_{P-C} = 139.7$ Hz), 32.1 (dd, $J_{P-C} = 17.2, 5.7$ Hz), 29.4 (d, $J_{P-C} = 15.0$ Hz), 18.3 (d, $J_{P-C} = 2.5$ Hz), 13.4. ^{31}P NMR (243 MHz, CDCl_3): δ 20.27. HRMS m/z (ESI+): calculated for $\text{C}_{24}\text{H}_{30}\text{NO}_4\text{PNa}$ ($[\text{M}+\text{Na}]^+$): 450.1805, found 450.1797.

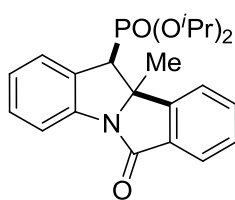
Dibenzyl(10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3t)



White solid; Mp 73-75 °C; 70% yield; ^1H NMR (500 MHz, CDCl_3): δ 7.80 (d, $J = 7.5$ Hz, 1H), 7.75 (d, $J = 8.0$ Hz, 1H), 7.58 (d, $J = 7.5$ Hz, 1H), 7.51-7.39 (m, 4H), 7.28-7.24 (m, 6H), 7.13 (t, $J = 7.5$ Hz, 1H), 7.01 (m, 4H), 4.43 (d, $J = 9.0$ Hz, 2H), 4.31 (t, $J = 11.5$ Hz, 1H), 4.20 (m, $J = 11.5, 7.9$ Hz, 1H), 3.67 (d, $J = 19.0$ Hz, 1H), 1.66 (d, $J = 1.5$ Hz, 3H). ^{13}C NMR (125 MHz, CDCl_3): δ 167.4, 147.3 (d, $J_{P-C} = 5.8$ Hz), 139.1 (d, $J_{P-C} = 5.7$ Hz), 135.7 (dd, $J_{P-C} = 25.5, 5.6$ Hz), 133.3, 131.8, 131.0 (d, $J_{P-C} = 8.2$ Hz), 129.2 (d, $J_{P-C} = 3.5$ Hz), 128.8, 128.3 (dd, $J_{P-C} = 11.3, 3.2$ Hz), 128.0, 127.8 (d, $J_{P-C} = 4.4$ Hz), 125.3, 124.5 (d, $J_{P-C} = 3.2$ Hz), 124.1, 117.3 (d, $J_{P-C} = 3.0$ Hz), 72.8 (d, $J_{P-C} = 3.3$ Hz), 67.65 (dd, $J_{P-C} = 39.1, 7.5$ Hz), 49.6 (d, $J_{P-C} = 139.5$ Hz), 29.4 (d, $J_{P-C} = 15.2$ Hz). ^{31}P NMR (243 MHz, CDCl_3): δ 21.11. HRMS m/z (ESI+): calculated for

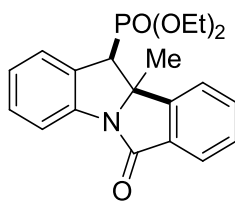
$C_{22}H_{26}NO_4PNa$ ($[M+Na]^+$): 518.1492, found 518.1476.

Diisopropyl(10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3u)



Orange yellow solid; Mp 82-84 °C; 78% yield; 1H NMR (500 MHz, $CDCl_3$): δ 7.82 (d, $J = 7.5$ Hz, 1H), 7.69 (d, $J = 8.0$ Hz, 1H), 7.66 (d, $J = 7.5$ Hz, 1H), 7.59 (m, $J = 7.5, 1.0$ Hz, 1H), 7.50-7.45 (m, 2H), 7.35 (t, $J = 7.5$ Hz, 1H), 7.13 (t, $J = 7.5$ Hz, 1H), 4.31 (m, $J = 12.5, 6.2$ Hz, 1H), 4.17 (m, $J = 12.5, 6.2$ Hz, 1H), 3.51 (d, $J = 18.5$ Hz, 1H), 1.65 (d, $J = 1.5$ Hz, 3H), 1.00 (d, $J = 6.0$ Hz, 3H), 0.93 (d, $J = 6.0$ Hz, 3H), 0.85 (m, $J = 9.5, 6.2$ Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 167.5, 147.6 (d, $J_{P-C} = 5.6$ Hz), 139.0 (d, $J_{P-C} = 5.7$ Hz), 133.5, 131.5 (t, $J_{P-C} = 3.9$ Hz), 128.8 (d, $J_{P-C} = 3.3$ Hz), 128.5, 127.7 (d, $J_{P-C} = 4.3$ Hz), 125.7, 124.2 (d, $J_{P-C} = 3.2$ Hz), 123.7, 117.0 (d, $J_{P-C} = 2.3$ Hz), 72.8 (d, $J_{P-C} = 3.8$ Hz), 71.4 (d, $J_{P-C} = 7.2$ Hz), 70.5 (d, $J_{P-C} = 7.6$ Hz), 50.1 (d, $J_{P-C} = 141.0$ Hz), 29.5 (d, $J_{P-C} = 15.1$ Hz), 23.2 (ddd, $J_{P-C} = 33.5, 25.3, 5.0$ Hz). ^{31}P NMR (243 MHz, $CDCl_3$): δ 18.40. HRMS m/z (ESI+): calculated for $C_{22}H_{26}NO_4PNa$ ($[M+Na]^+$): 422.1492, found 422.1484.

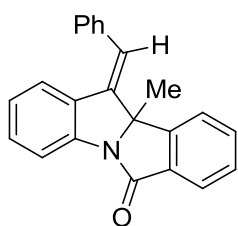
Diethyl (6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (3v)



White solid; Mp 116-117 °C; 15% yield; 1H NMR (500 MHz, $CDCl_3$): δ 7.88 (d, $J = 7.5$ Hz, 1H), 7.72 (dd, $J = 7.5, 3.7$ Hz, 2H), 7.62 (td, $J = 7.5, 1.0$ Hz, 1H), 7.54-7.48 (m, 2H), 7.37 (t, $J = 7.5$ Hz, 1H), 7.15 (t, $J = 7.5$ Hz, 1H), 5.81 (dd, $J = 31.5, 9.1$ Hz, 1H), 3.98 (dd, $J = 18.0, 9.1$ Hz, 1H), 3.70-3.61 (m, 2H), 3.60-3.47 (m, 2H), 0.97 (m, 6H). ^{13}C NMR (125 MHz, $CDCl_3$): δ 167.6, 142.2 (d, $J_{P-C} = 6.8$ Hz), 140.3 (d, $J_{P-C} = 5.5$ Hz), 134.9, 131.6 (d, $J_{P-C} = 9.4$ Hz), 129.1 (d, $J_{P-C} = 3.4$ Hz), 128.9, 127.5 (d, $J_{P-C} = 3.8$ Hz), 126.1, 124.5 (d, $J_{P-C} = 3.3$ Hz), 124.0, 116.4 (d, $J_{P-C} = 3.2$ Hz), 66.0 (d, $J_{P-C} = 5.5$ Hz), 62.3 (dd, $J_{P-C} = 136.8, 7.3$ Hz), 42.7 (d, $J_{P-C} = 139.3$ Hz), 16.0 (d, $J_{P-C} = 5.8$ Hz). ^{31}P NMR (243 MHz, $CDCl_3$): δ 20.67. HRMS m/z (ESI+): calculated for $C_{24}H_{30}NO_4PNa$ ($[M+Na]^+$): 380.1022, found 380.1017.

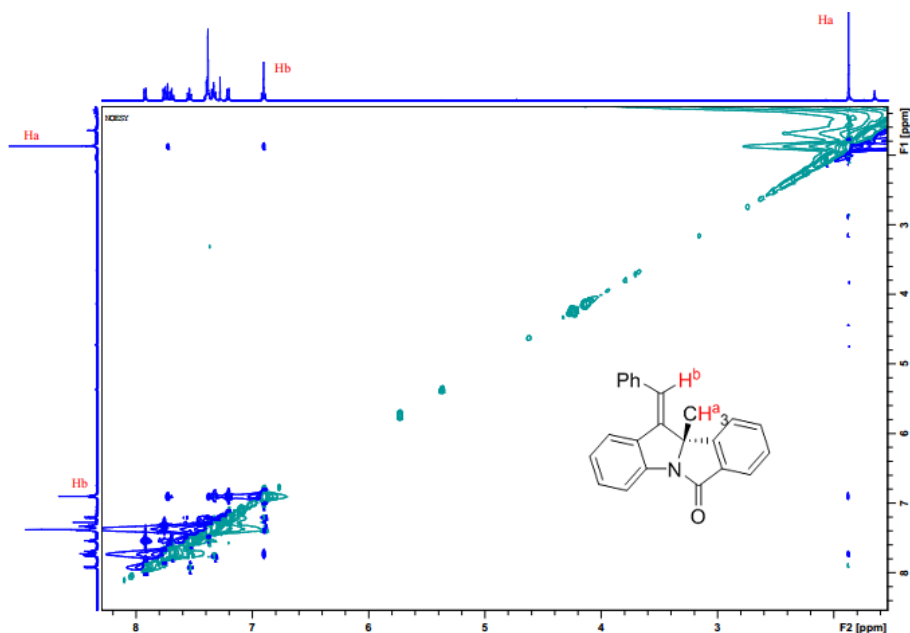
4. Synthetic transformations of **3a**

(*E*)-11-benzylidene-10b-methyl-10b,11-dihydro-6H-isoindolo[2,1-*a*]indol-6-one (**4**)



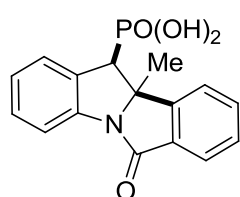
To a solution of **3a** (1.2 equiv) in THF was added NaH (60%, 2.0 equiv) at 0 °C in portions. After stirring at the same temperature for 30 min, benzaldehyde (0.5 mmol) in THF was added slowly. The reaction mixture was then allowed to stir at 0 °C for additional 4 h. After that, the resulting mixture was quenched with water and extracted with Et₂O. The combined organic phases were concentrated under vacuum. The residue was purified by flash column chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v) to give compound **4** (116.3 mg, 72%) as a white solid. Mp 181-183 °C; ¹H NMR (500 MHz, CDCl₃): δ 7.92 (d, *J* = 7.5 Hz, 1H), 7.75 (dd, *J* = 10.5, 7.7 Hz, 2H), 7.70 (m, *J* = 7.5, 3.8 Hz, 1H), 7.54 (m, *J* = 7.5, 1.0 Hz, 1H), 7.40-7.37 (m, 4H), 7.35-7.31 (m, 2H), 7.21 (d, *J* = 8.0 Hz, 1H), 6.92-6.89 (m, 2H), 1.87 (s, 3H). ¹³C NMR (125 MHz, CDCl₃): δ 169.1, 150.3, 142.1, 141.1, 136.3, 133.4, 132.4, 131.5, 130.1, 128.9, 128.6, 128.4, 127.7, 125.3, 124.9, 124.2, 123.2, 122.1, 117.8, 74.4, 30.4. HRMS *m/z* (ESI⁺): calculated for C₂₃H₁₈NO₄ ([M+H]⁺): 324.1383, found 324.1375.

NOE spectrum:



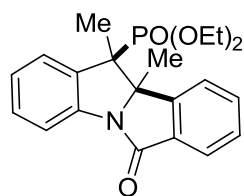
(10*b*-Methyl-6-oxo-10*b*,11-dihydro-6*H*-isoindolo[2,1-*a*]indol-11-yl)phosphonic acid

(5)



To a solution of **3a** (0.5 mmol) in concentrated HCl (2.0 mL) was stirred at 100 °C for 12 h. After that, the solid precipitated when the solution was cooled to room temperature. The product was then obtained by filtration without further purification. White solid; Mp 185-187 °C; 65% yield; ¹H NMR (500 MHz, DMSO-*d*₆): δ 7.66 (m, *J* = 15.0, 7.8 Hz, 3H), 7.50 (m, *J* = 12.5, 5.2 Hz, 2H), 7.41 (d, *J* = 7.5 Hz, 1H), 7.32 (t, *J* = 7.5 Hz, 1H), 7.14 (t, *J* = 7.5 Hz, 1H), 3.54 (d, *J* = 20.0 Hz, 1H), 2.50 (m, *J* = 3.5, 1.8 Hz, 3H), 1.54 (s, 3H). ¹³C NMR (125 MHz, DMSO): δ 166.9, 148.4, 138.6 (d, *J*_{P-C} = 5.0 Hz), 133.9, 132.8, 131.9, 128.3, 127.9 (d, *J*_{P-C} = 19.1 Hz), 125.7, 124.0, 123.2, 116.2, 72.7 (d, *J*_{P-C} = 2.2 Hz), 50.0 (d, *J*_{P-C} = 134.9 Hz), 29.5 (d, *J*_{P-C} = 13.8 Hz). ³¹P NMR (243 MHz, DMSO-*d*₆): δ 21.12. HRMS *m/z* (ESI⁺): calculated for C₁₆H₁₅NO₄P ([M+H]⁺): 316.0733, found 316.0733.

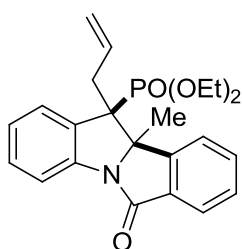
Diethyl(10*b*,11-dimethyl-6-oxo-10*b*,11-dihydro-6*H*-isoindolo[2,1-*a*]indol-11-yl)phosphonate (6)



To a solution of **3a** (0.5 mmol) in THF (2.0 mL) in ice bath was added NaH (60%, 2.0 equiv) in portions. After stirring at the same temperature for 30 min, CH₃I (1.2 equiv) was added into the system slowly. The mixture was then allowed to stir at room temperature for 12 h. After that, the resulting mixture was then quenched with H₂O and extracted with Et₂O. The combined organic phases were concentrated under vacuum. The residue was purified by flash column chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:2 (v/v) to give compound **4** (173.2 mg, 90%) as a white solid. Mp 135-138 °C; ¹H NMR (500 MHz, CDCl₃): δ 7.82 (d, *J* = 7.5 Hz, 1H), 7.78 (d, *J* = 7.5 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.53 (m, *J* = 7.5, 1.1 Hz, 1H), 7.47 (d, *J* = 7.5 Hz, 1H), 7.41 (m, *J* = 7.5, 0.8 Hz, 1H), 7.25 (m, *J* = 12.5, 4.8 Hz, 1H), 7.05 (m, *J* = 7.5, 1.0 Hz, 1H), 4.33-4.25 (m, 1H), 4.24-4.12 (m, 3H), 1.68 (s, 3H), 1.31 (m, *J* = 9.0, 7.1 Hz, 6H), 0.78 (d, *J* = 15.5 Hz, 3H). ¹³C NMR (125 MHz,

CDCl₃): δ 166.9, 147.8, 138.9, 137.0 (d, J_{P-C} = 10.6 Hz), 133.0, 132.5, 128.7, 128.4, 124.9, 124.6, 124.1, 123.8, 117.0, 76.7, 62.5 (dd, J_{P-C} = 191.0, 7.4 Hz), 50.6 (d, J_{P-C} = 156.6 Hz), 25.1, 23.0, 16.4 (dd, J_{P-C} = 24.0, 5.6 Hz). ³¹P NMR (243 MHz, CDCl₃): δ 27.96. HRMS m/z (ESI⁺): calculated for C₂₁H₂₅NO₄P ([M+H]⁺): 386.1516, found 386.1555.

Diethyl(11-allyl-10b-methyl-6-oxo-10b,11-dihydro-6H-isoindolo[2,1-a]indol-11-yl)phosphonate (7)



To a solution of **3a** (0.5 mmol) in THF in ice bath was added NaH (60%, 2.0 equiv) in portions. After stirring at the same temperature for 30 min, then allyl bromide (2.0 equiv) was added into the system slowly. The reaction mixture was allowed to stir at room temperature for 8 h. After that, the resulting mixture was then quenched with H₂O and extracted with Et₂O. The combined organic phase was concentrated under vacuum. The residue was purified by flash column chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:2 (v/v) to give compound **7** (176.7 mg, 86%) as a white solid. Mp 74-76 °C; ¹H NMR (500 MHz, CDCl₃): δ 7.82 (d, J = 7.5 Hz, 1H), 7.75 (d, J = 7.5 Hz, 1H), 7.65 (d, J = 7.5 Hz, 1H), 7.58-7.51 (m, 2H), 7.44 (t, J = 7.5 Hz, 1H), 7.32 (t, J = 7.5 Hz, 1H), 7.11 (t, J = 7.5 Hz, 1H), 4.81-4.71 (m, 1H), 4.40 (d, J = 10.0 Hz, 1H), 4.34-4.13 (m, 4H), 3.91 (d, J = 17.0 Hz, 1H), 2.45 (m, 1H), 2.08-1.99 (m, 1H), 1.71 (s, 3H), 1.39 (t, J = 7.0 Hz, 3H), 1.32 (t, J = 7.0 Hz, 3H). ¹³C NMR (125 MHz, CDCl₃): δ 166.0, 147.5, 138.0 (d, J_{P-C} = 10.9 Hz), 135.1, 134.1, 132.0, 131.0 (d, J_{P-C} = 10.3 Hz), 128.5, 125.7, 124.1, 123.9, 123.5, 117.8, 116.2, 76.5 (d, J_{P-C} = 4.3 Hz), 62.4 (dd, J_{P-C} = 198.8 Hz, 7.5 Hz), 54.3 (d, J_{P-C} = 153.8 Hz), 39.5, 27.0 (d, J_{P-C} = 1.6 Hz), 16.2 (dd, J_{P-C} = 12.6, 5.7 Hz). ³¹P NMR (243 MHz, CDCl₃): δ 27.17. HRMS m/z (ESI⁺): calculated for C₂₃H₂₇NO₄P ([M+H]⁺): 412.1672, found 412.1673.

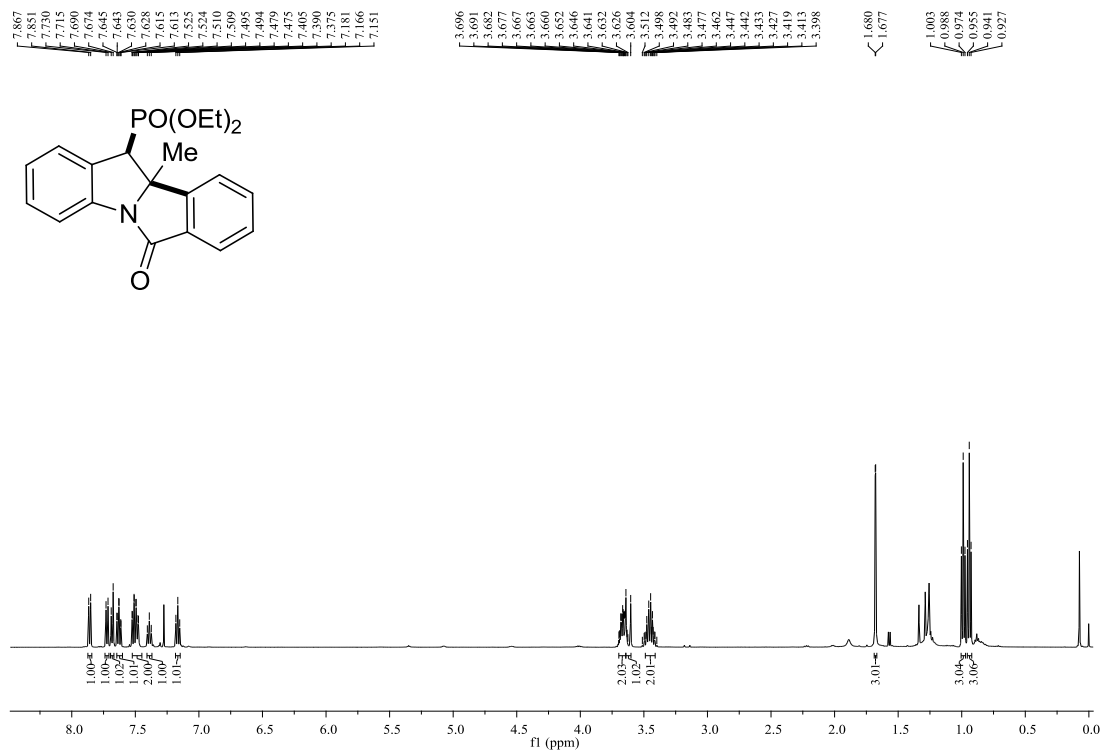
References:

- [1] (a) C. Shen, R.-R. Liu, R.-J. Fan, Y.-L. Li, T.-F. Xu, J.-R. Gao, Y.-X. Jia, *J. Am. Chem. Soc.* **2015**, *137*, 4936; (b) R.-X. Liang, R.-Z. Yang, R.-R. Liu, Y.-X. Jia, *Org. Chem. Front.* **2018**, *5*, 1840; (c) W. Zhang, G. Pugh, *Tetrahedron Lett.* **1999**, *40*, 7591.

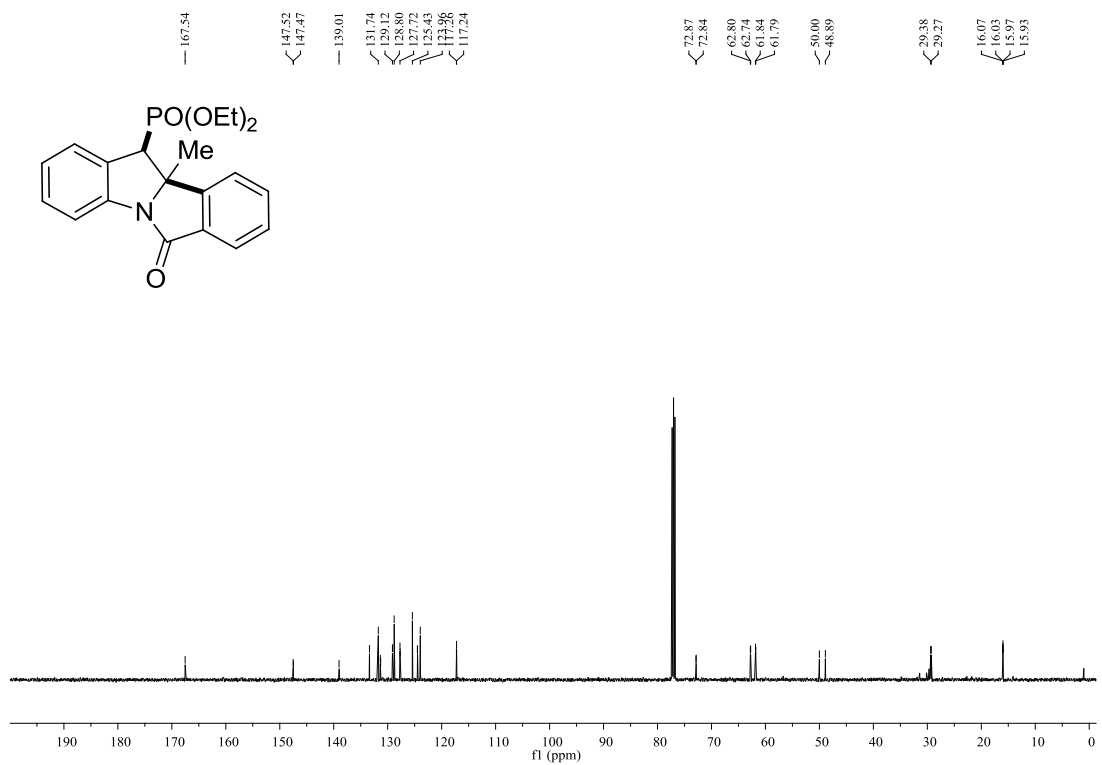
5. Copies of NMR spectra

3a

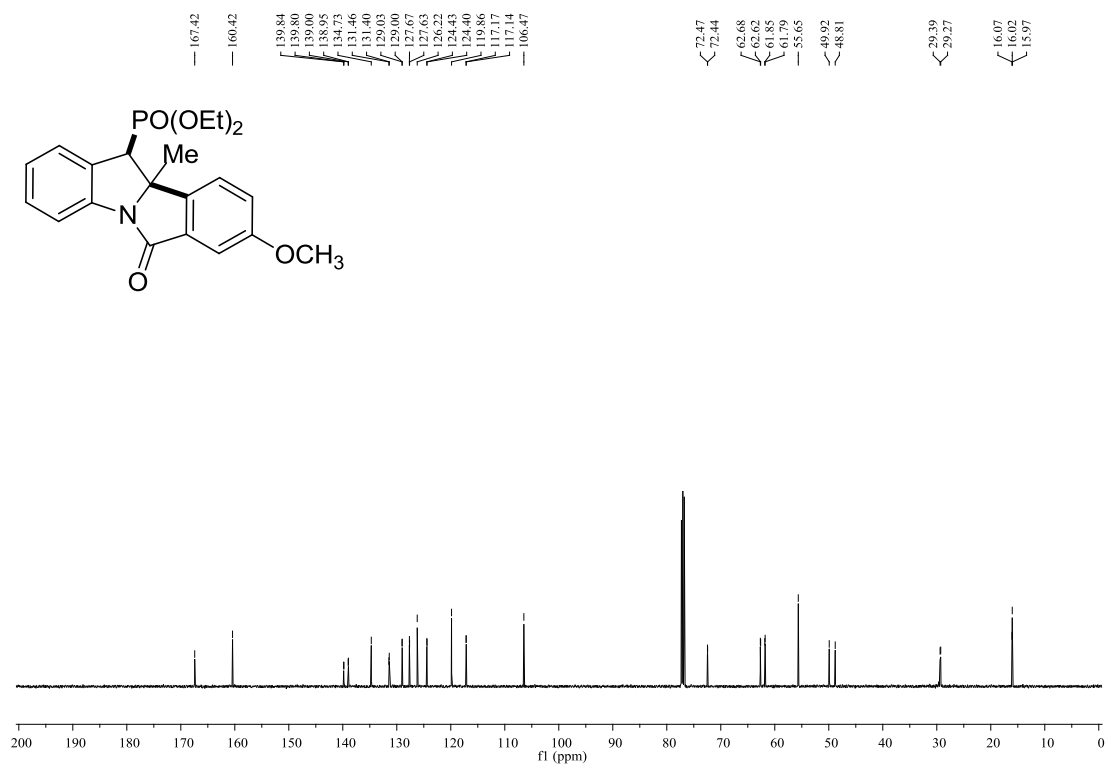
^1H NMR (CDCl_3 , 500 MHz)



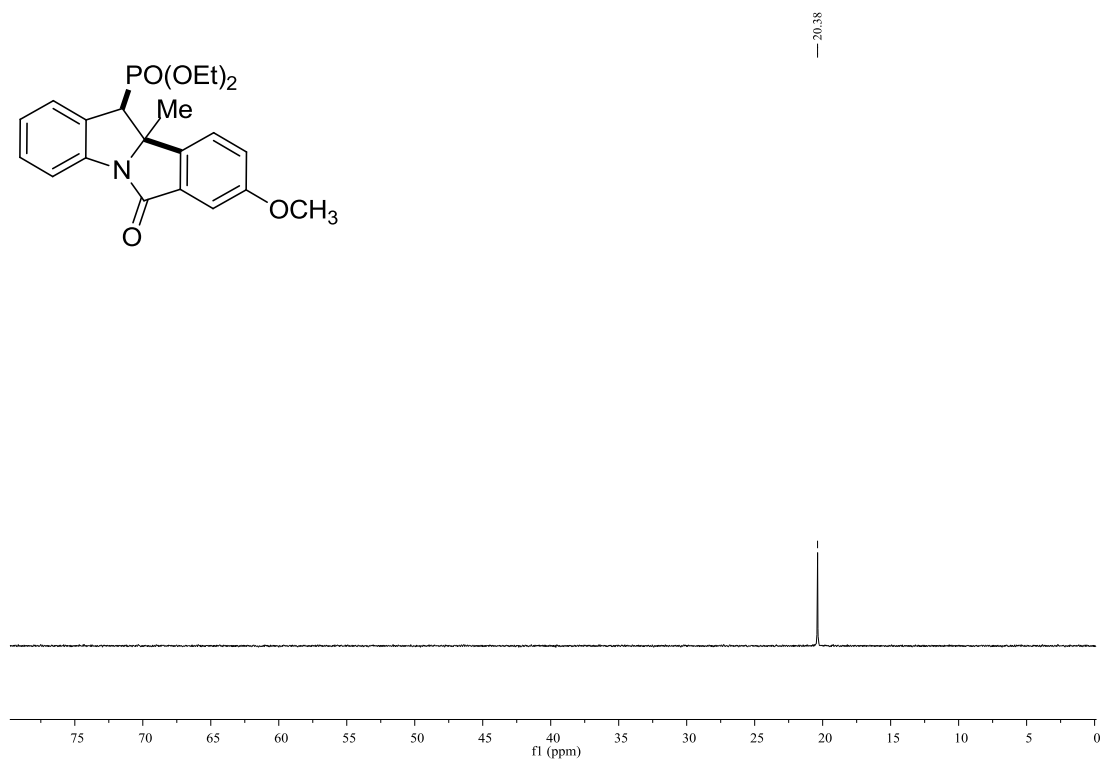
^{13}C NMR (CDCl_3 , 125 MHz)



¹³C NMR (CDCl₃, 125 MHz)

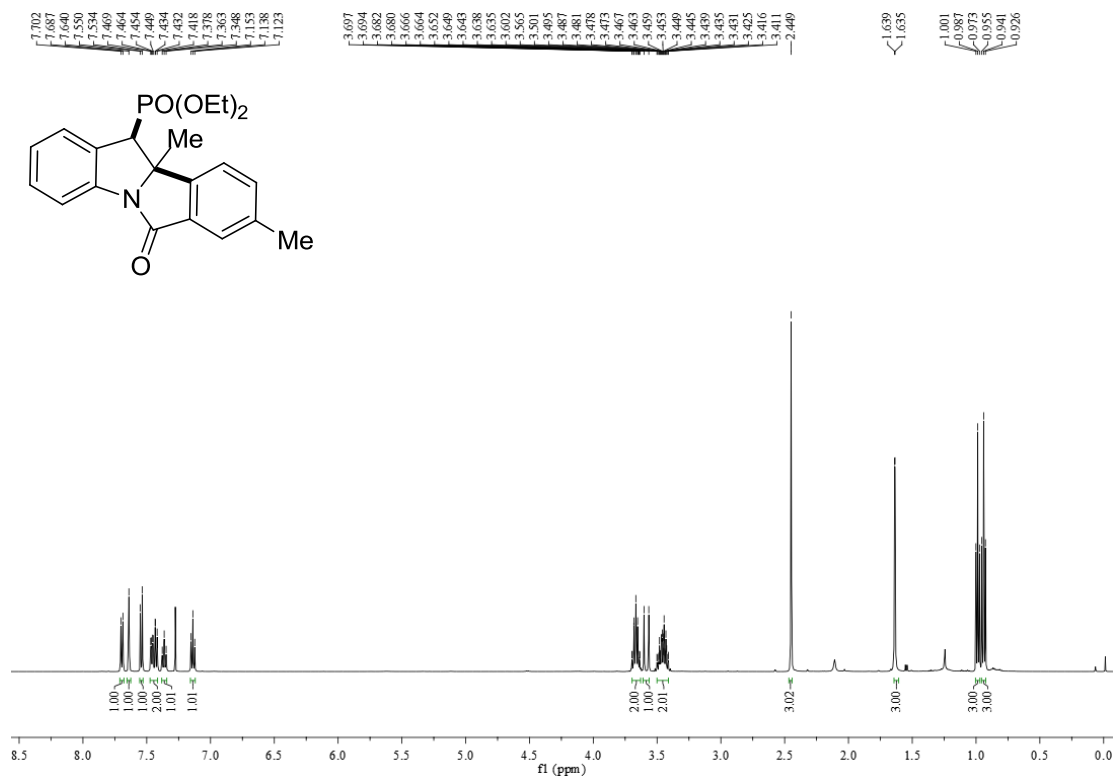


³¹P NMR (CDCl₃, 243 MHz)

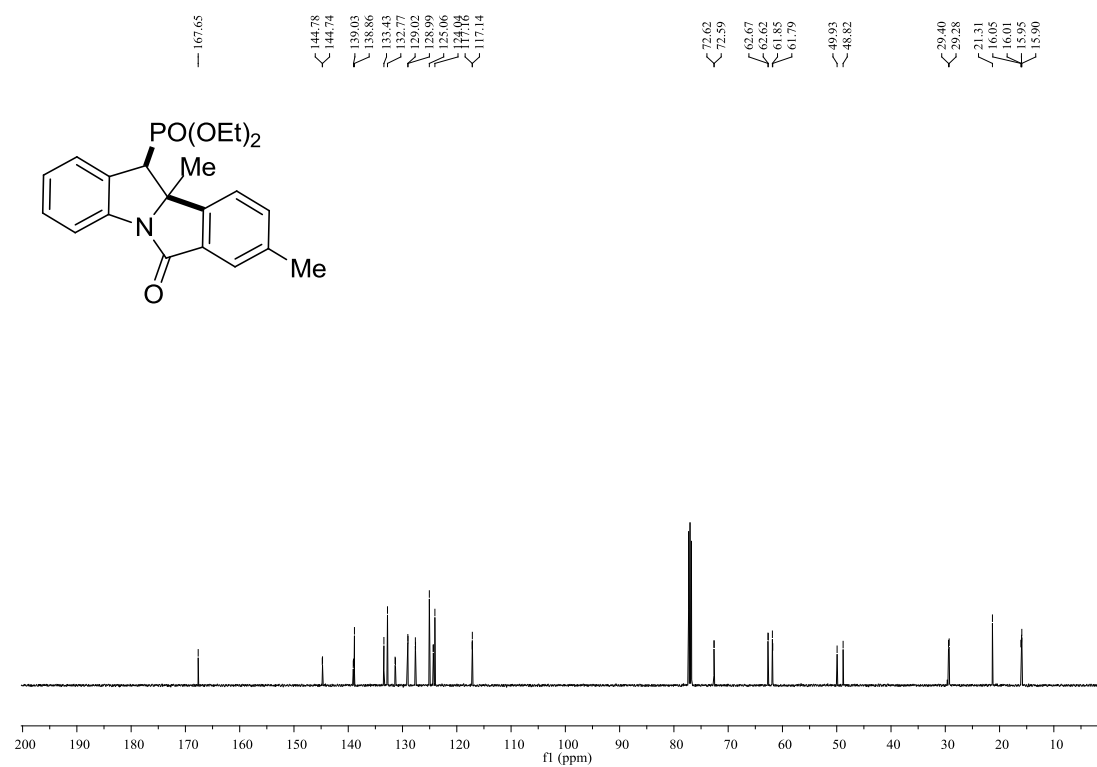


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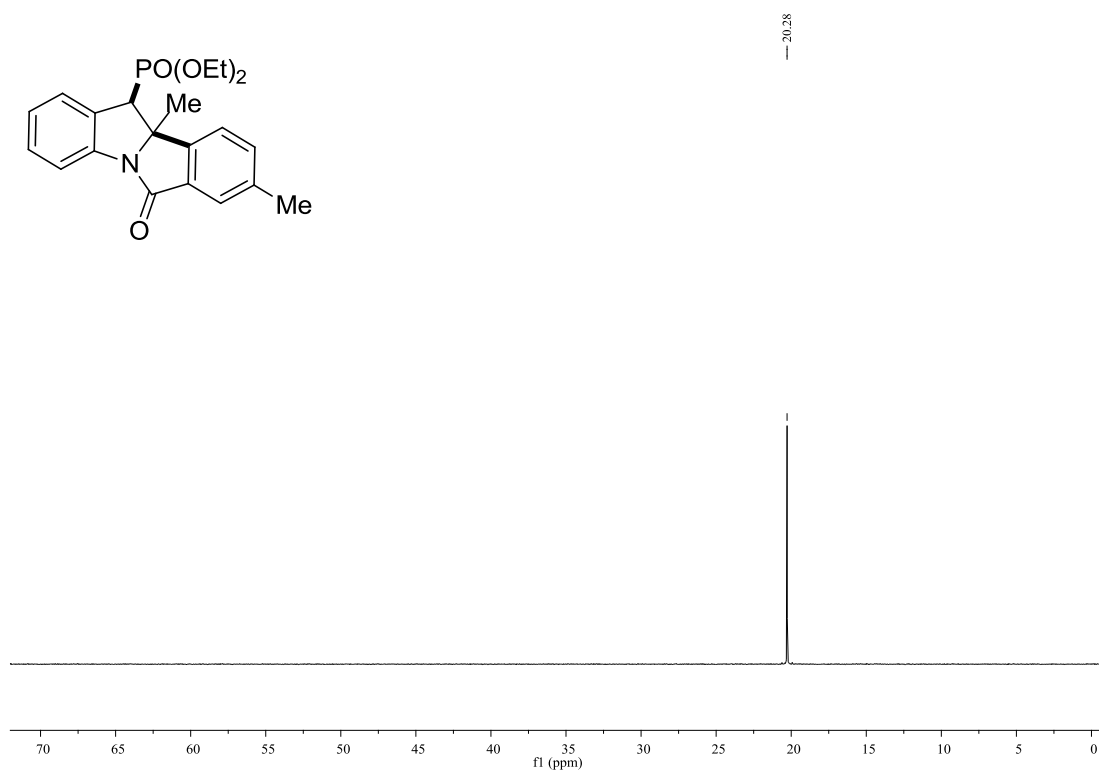
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

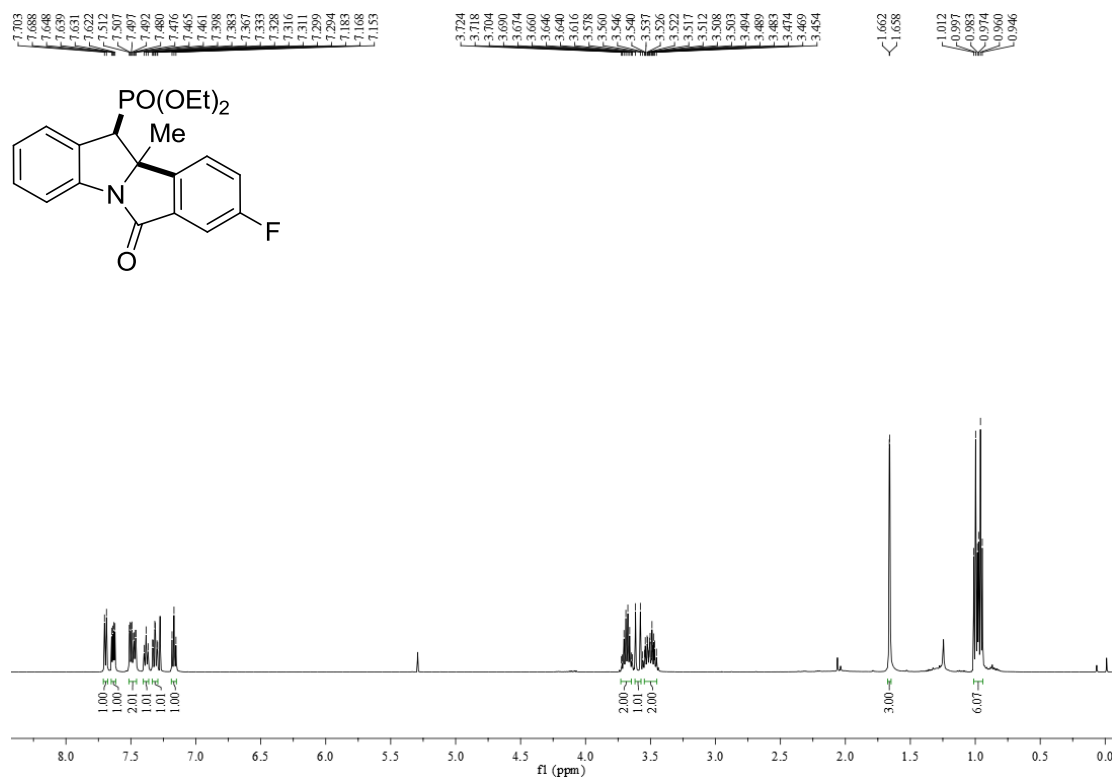


^{31}P NMR (CDCl_3 , 243 MHz)

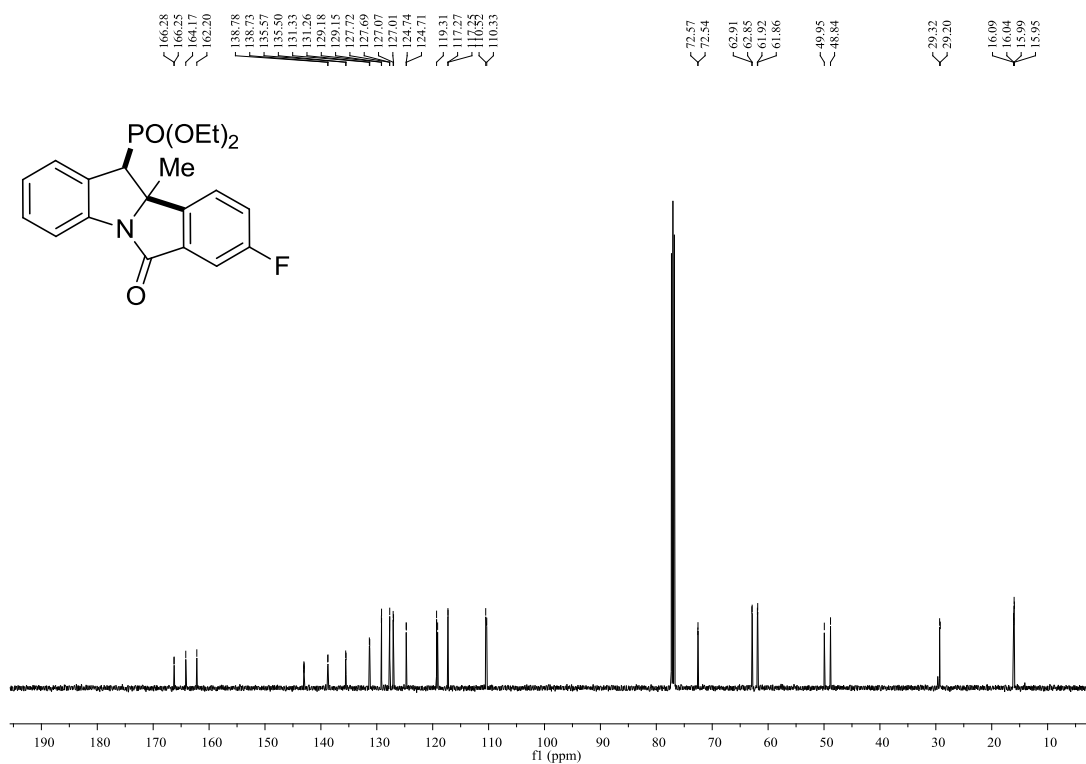


3d

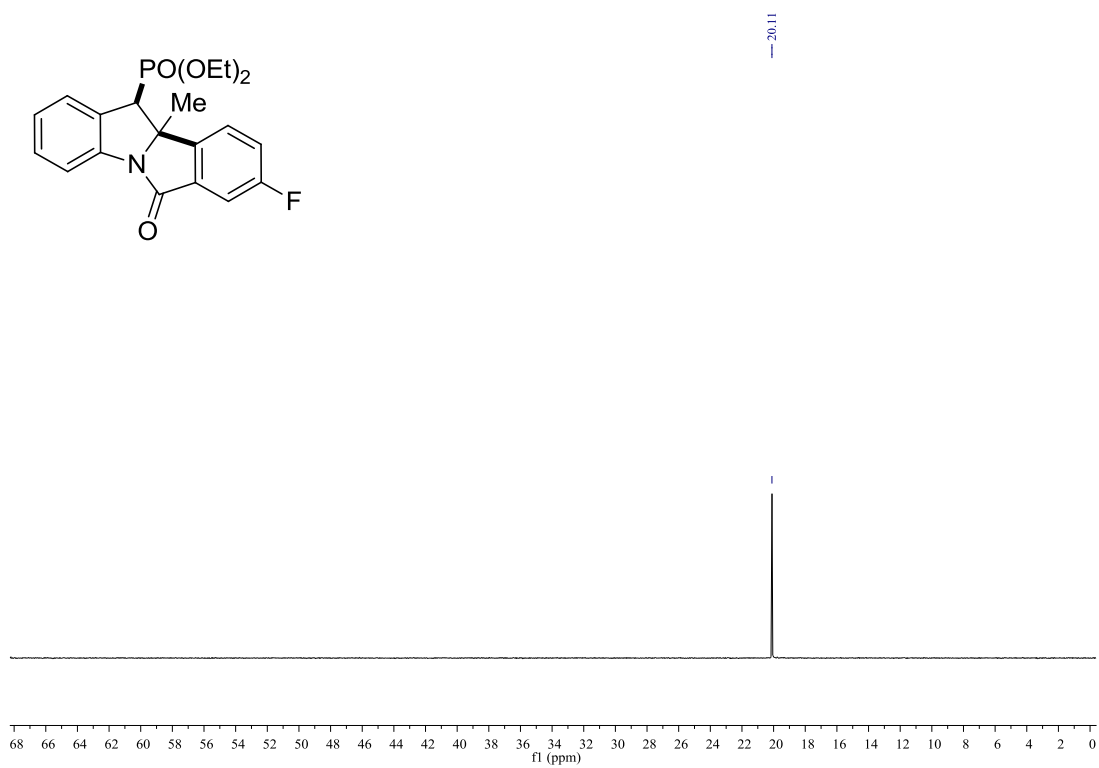
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

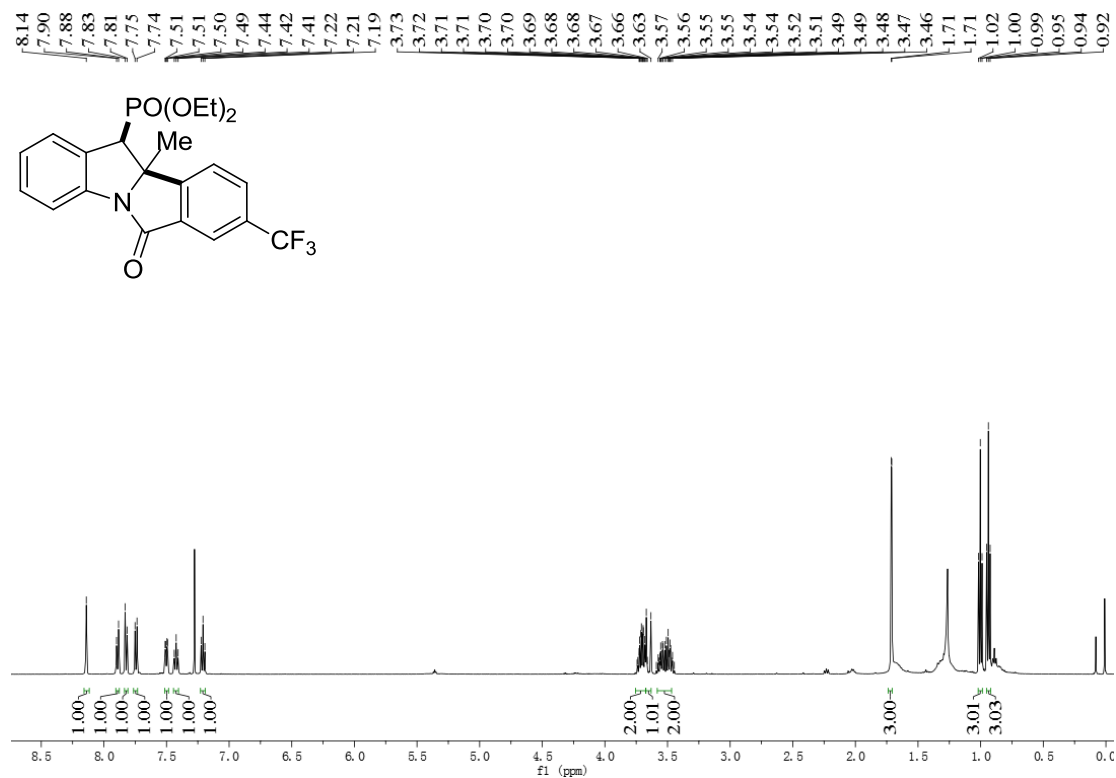


^{31}P NMR (CDCl_3 , 243 MHz)

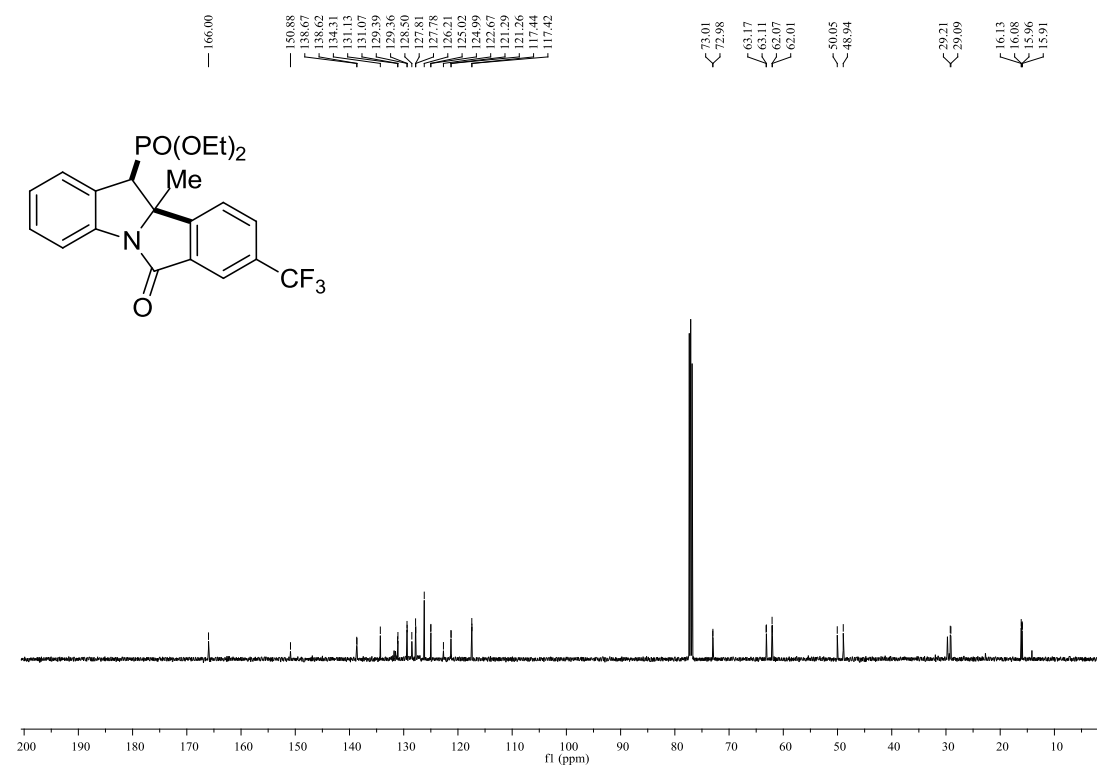


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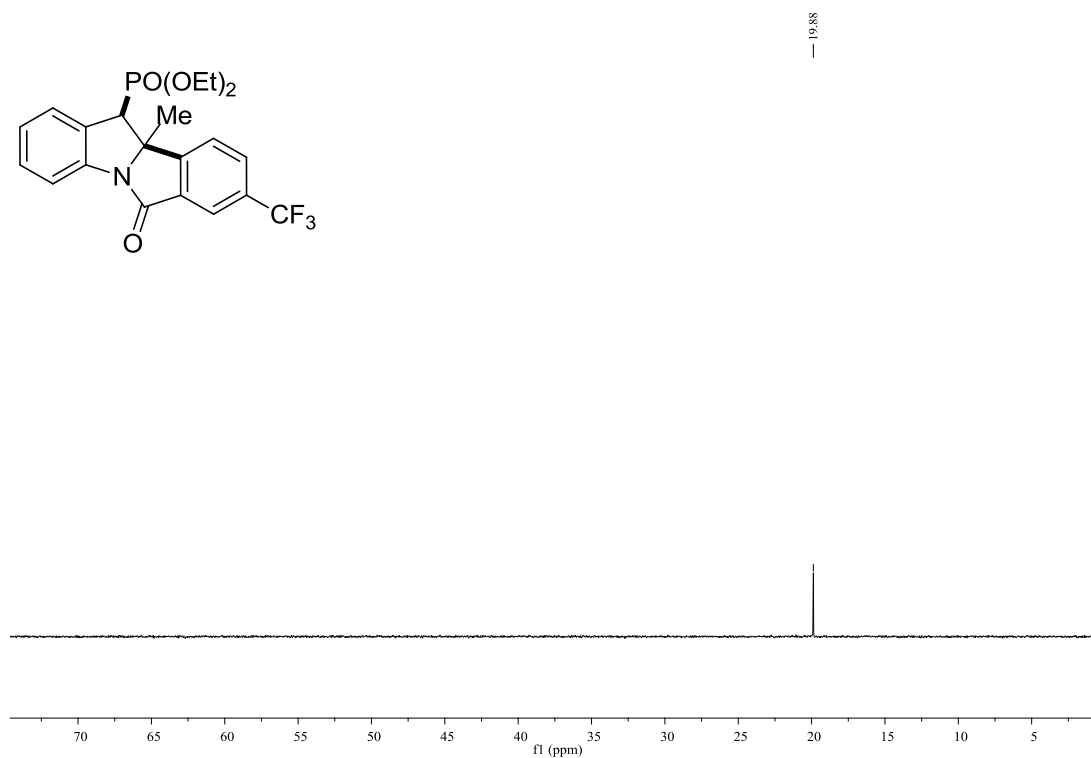
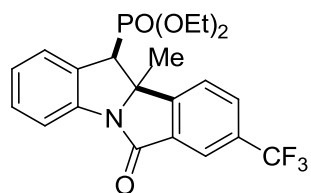
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

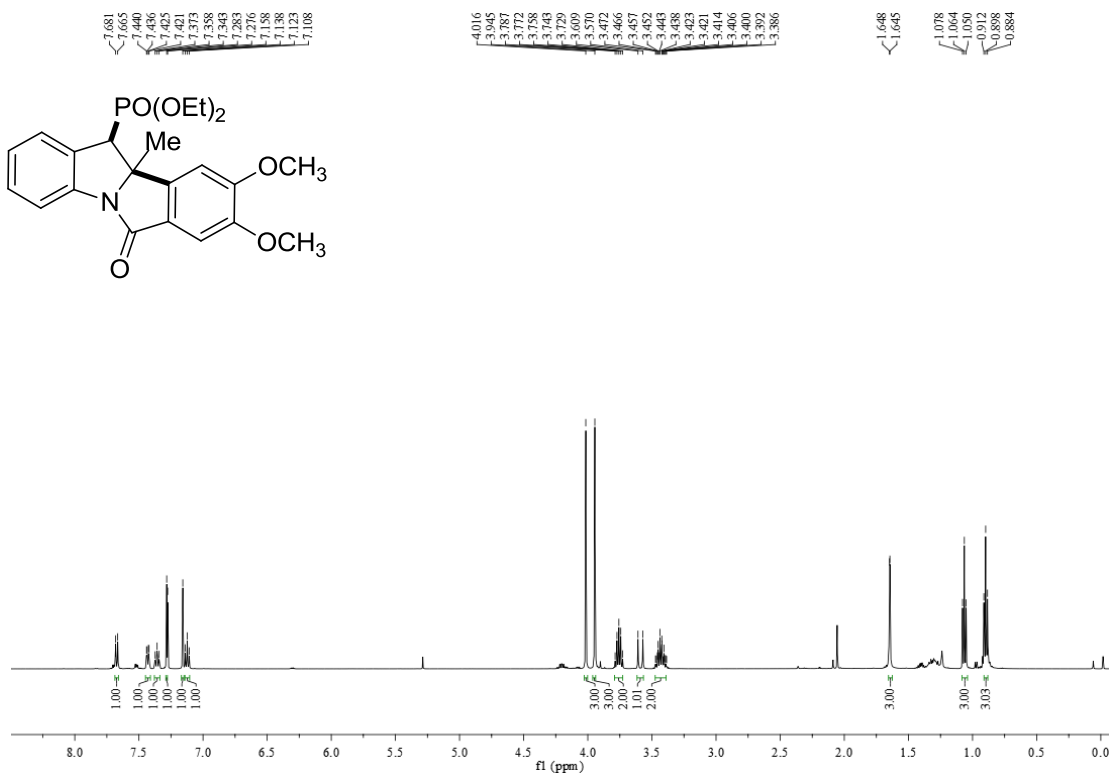


^{31}P NMR (CDCl_3 , 243 MHz)

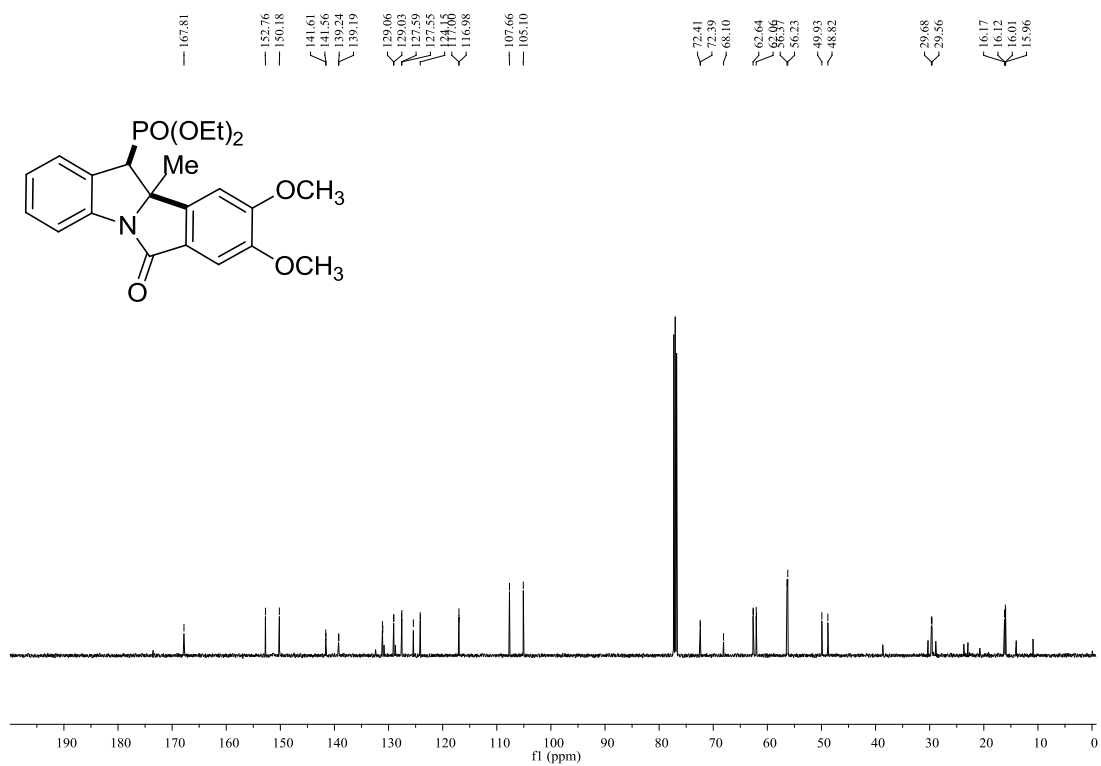


3f

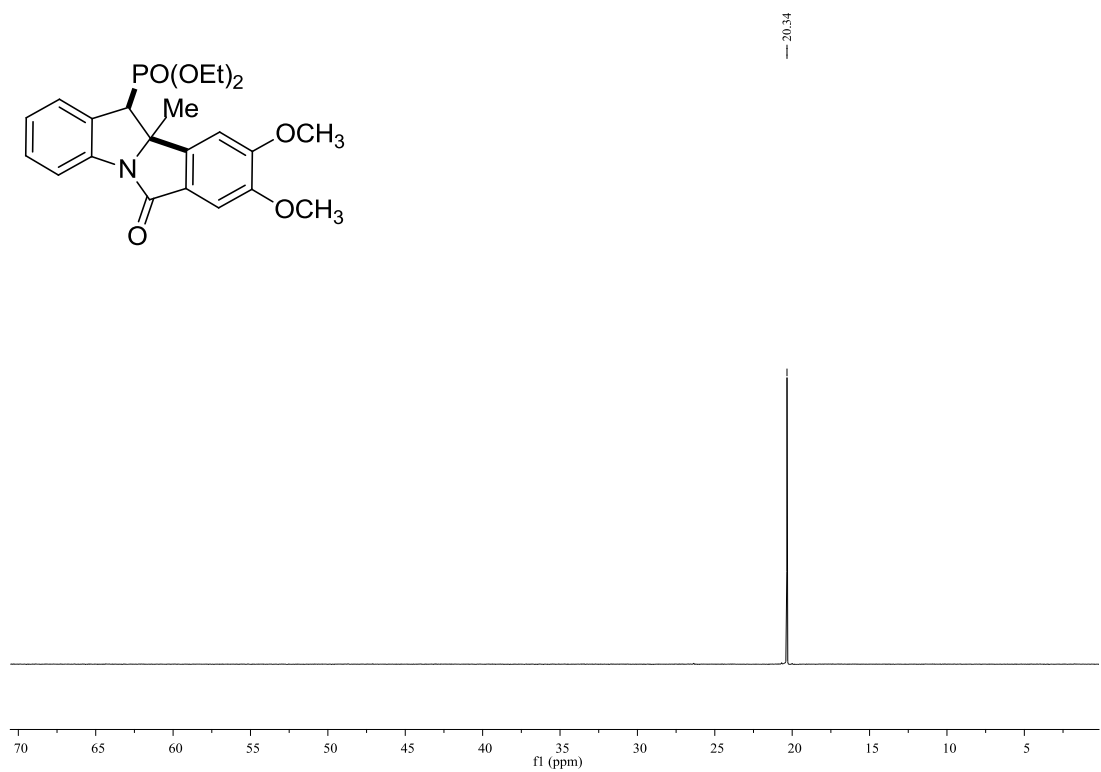
^1H NMR (CDCl_3 , 500 MHz)



¹³C NMR (CDCl₃, 125 MHz)

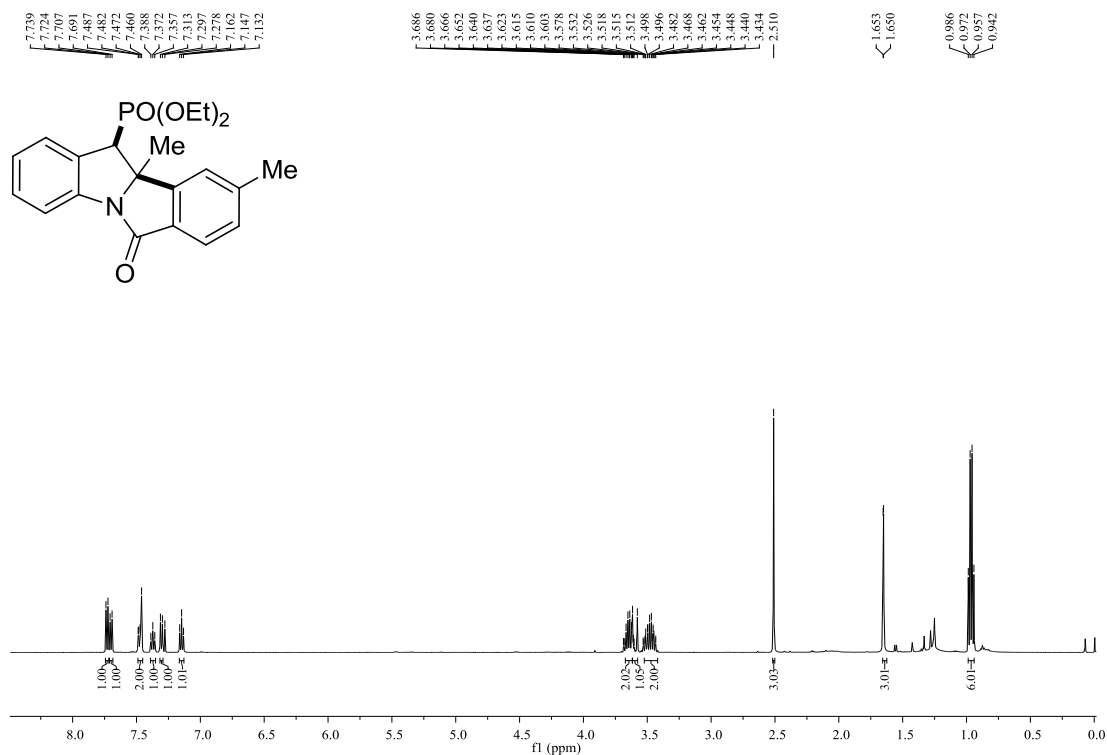


³¹P NMR (CDCl₃, 243 MHz)

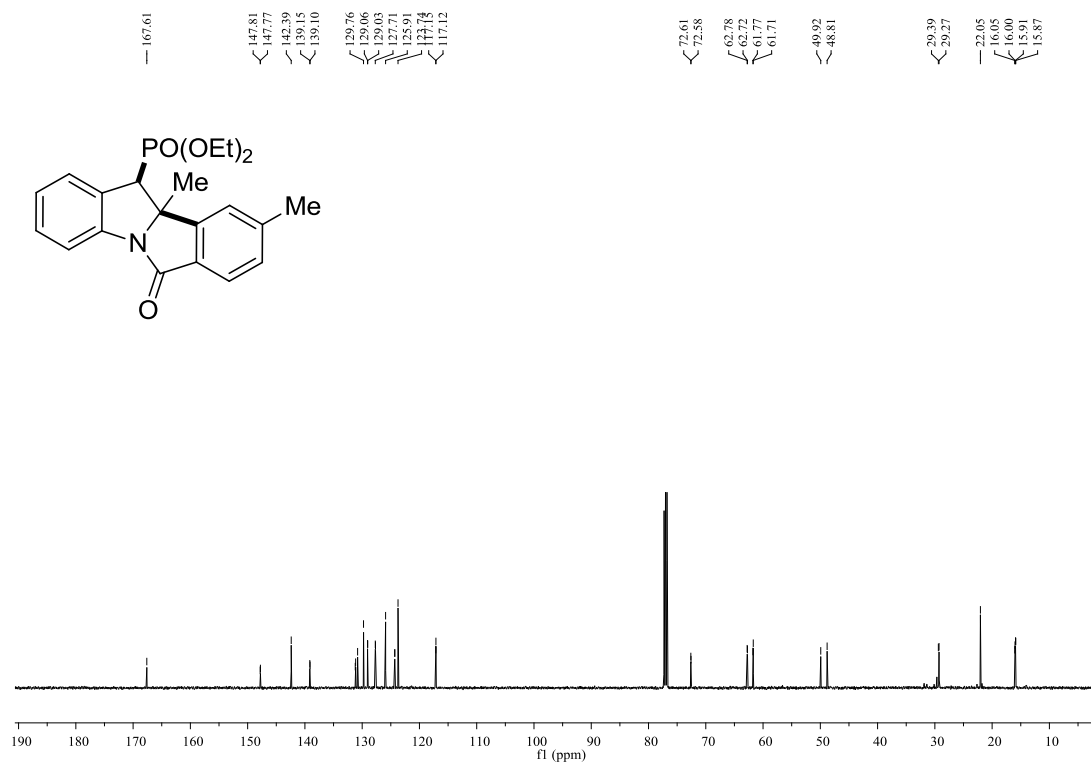


3g

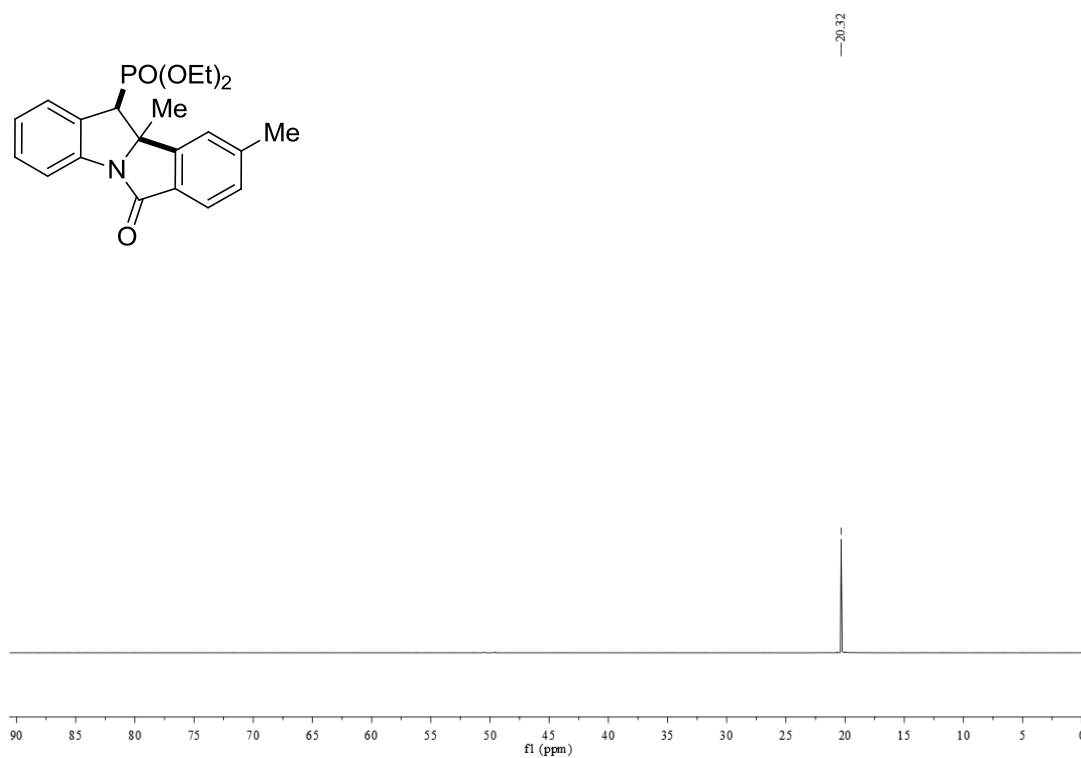
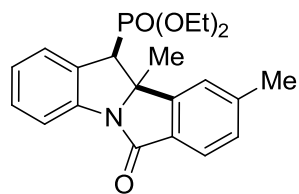
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

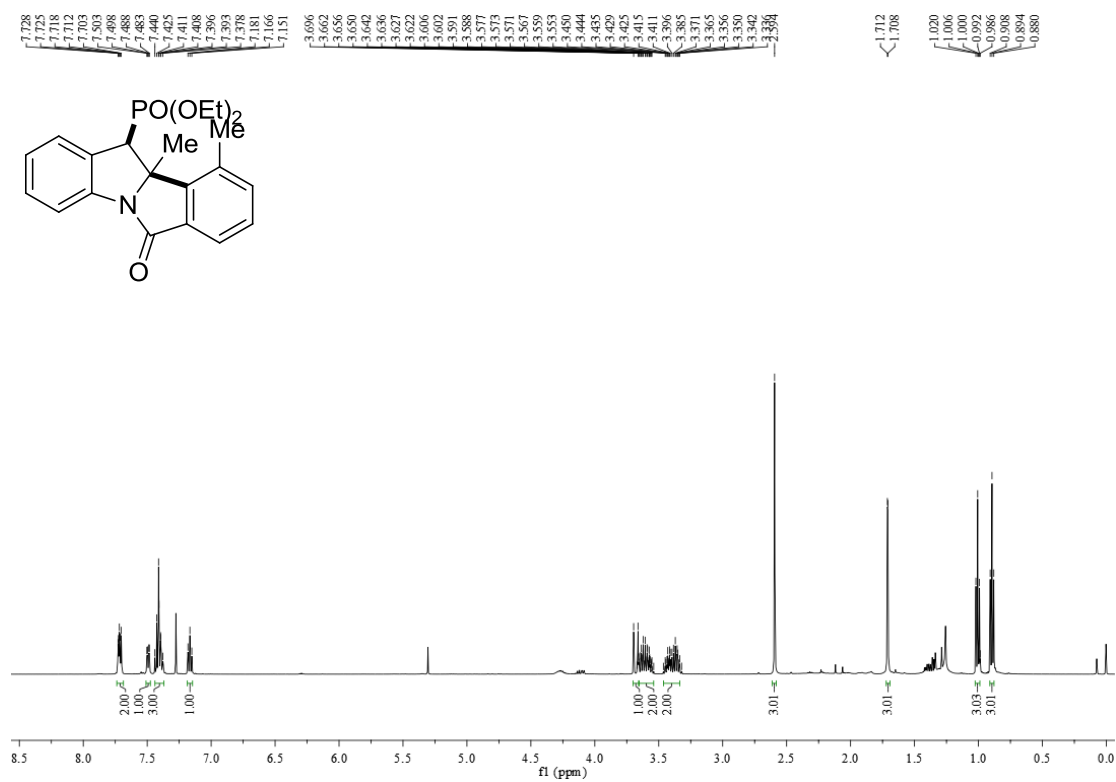
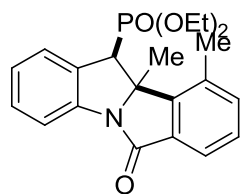


^{31}P NMR (CDCl_3 , 243 MHz)

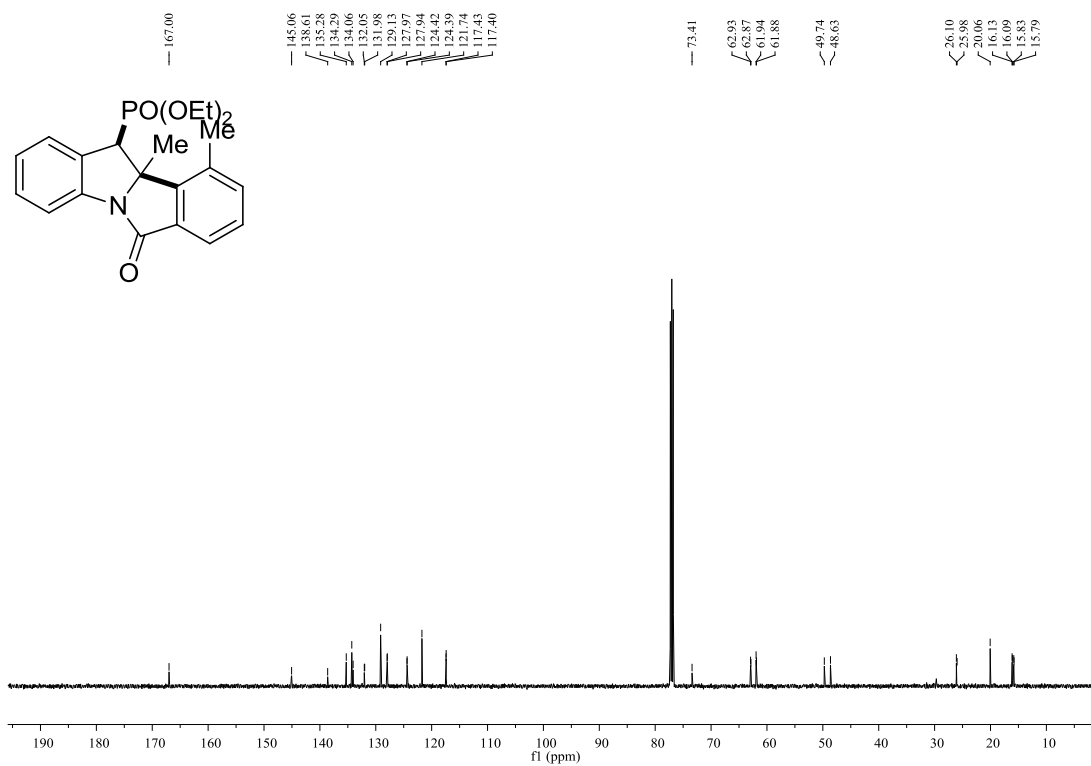


3h

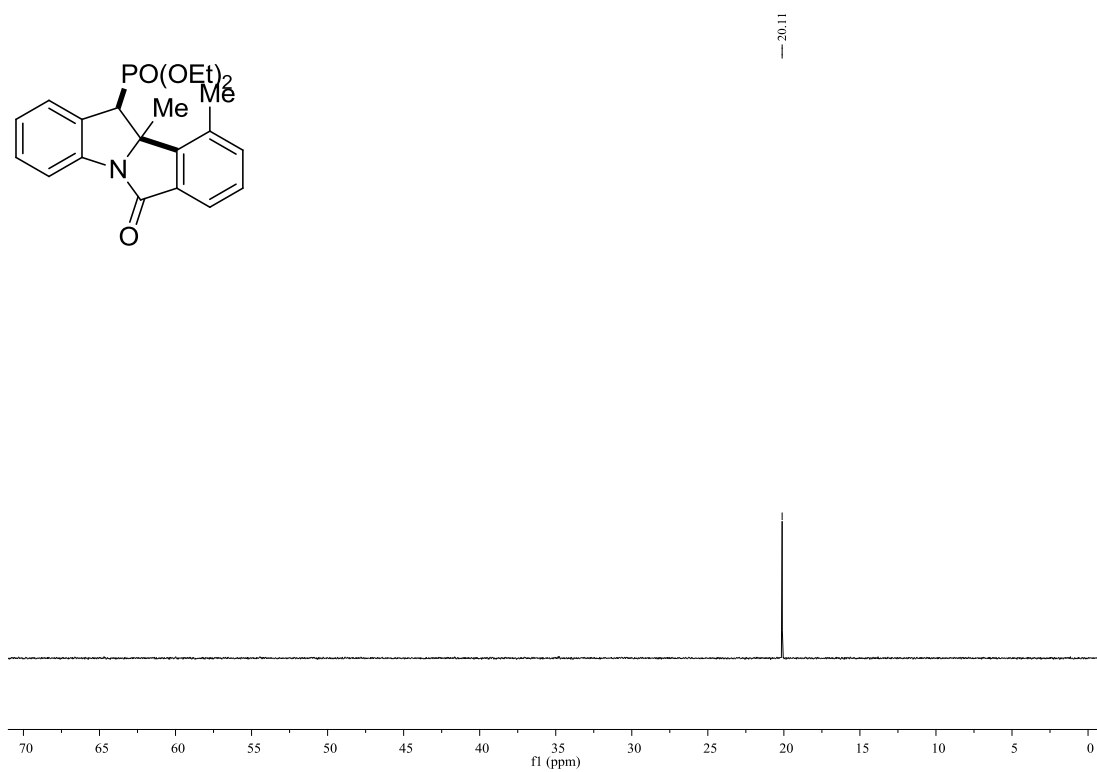
^1H NMR (CDCl_3 , 500 MHz)



¹³C NMR (CDCl₃, 125 MHz)

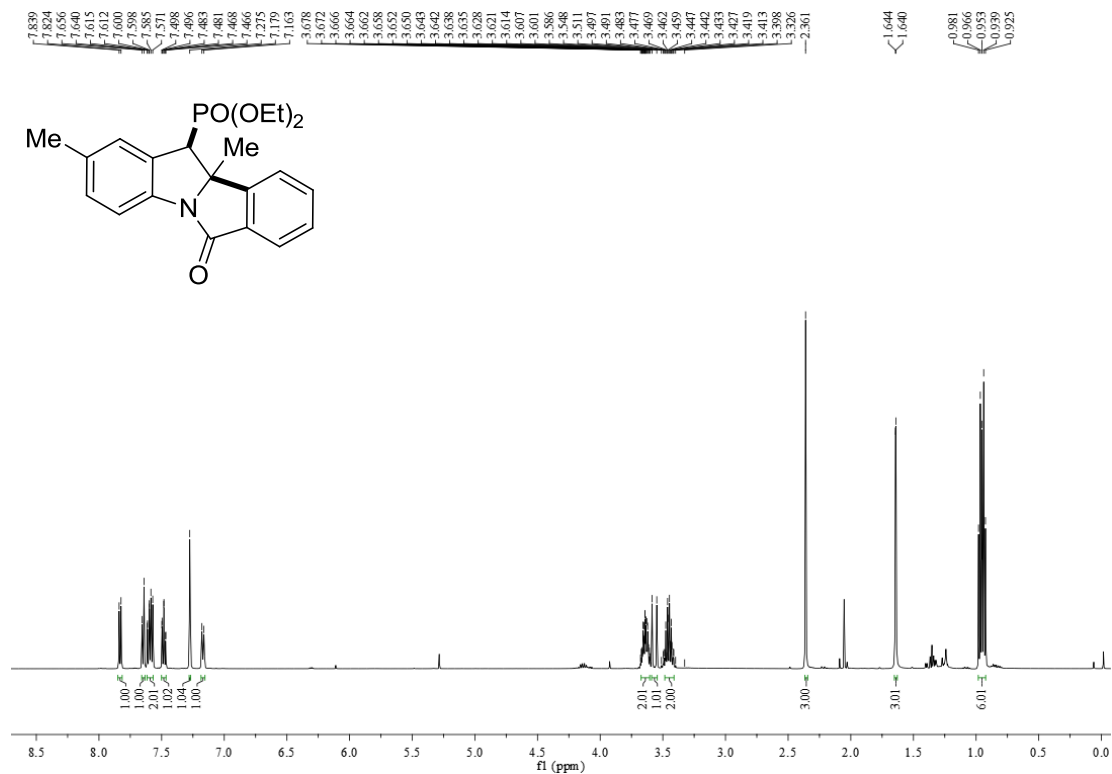


³¹P NMR (CDCl₃, 243 MHz)

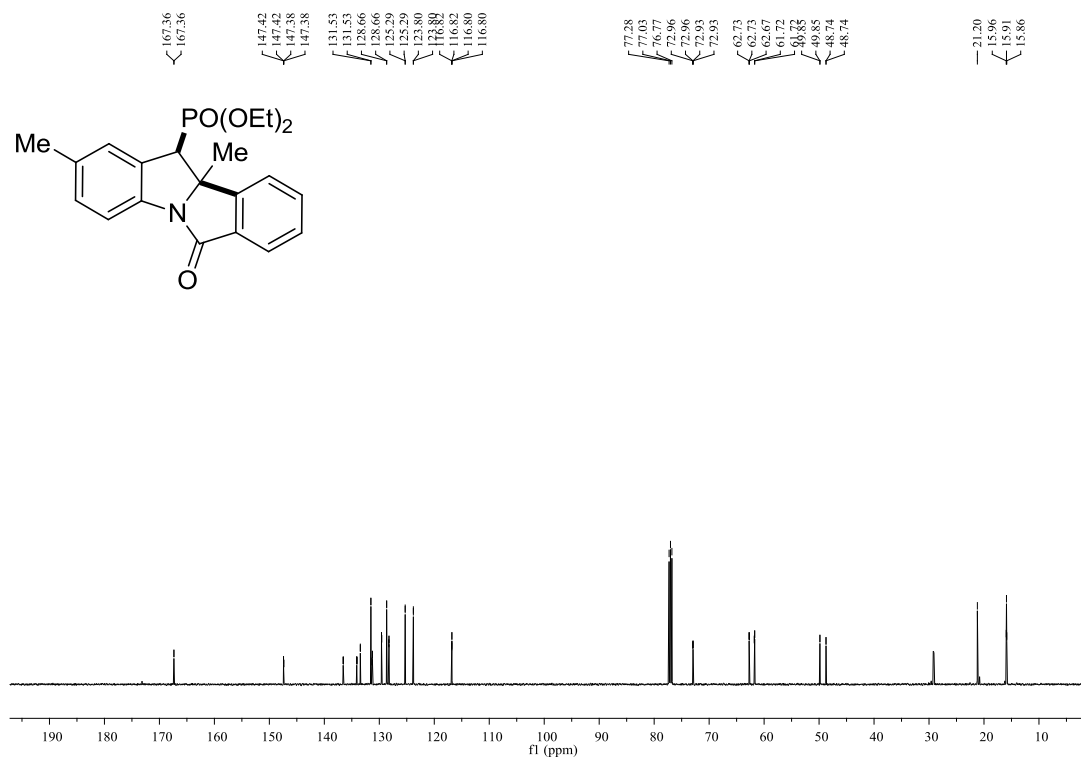


3i

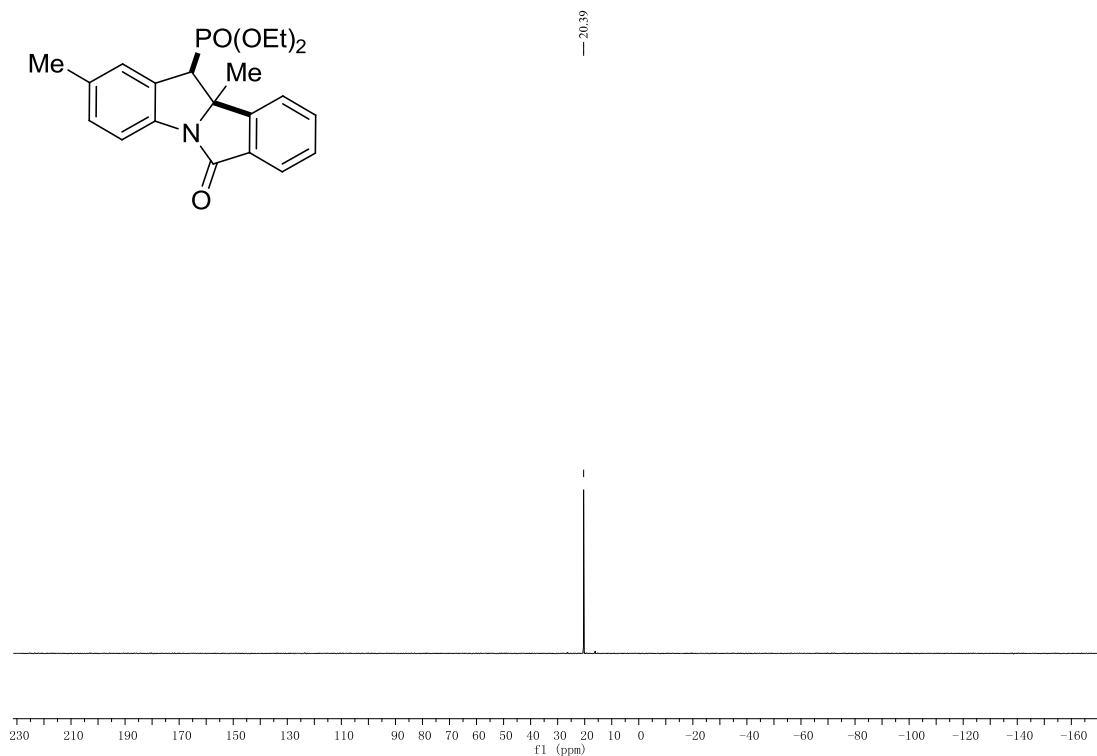
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

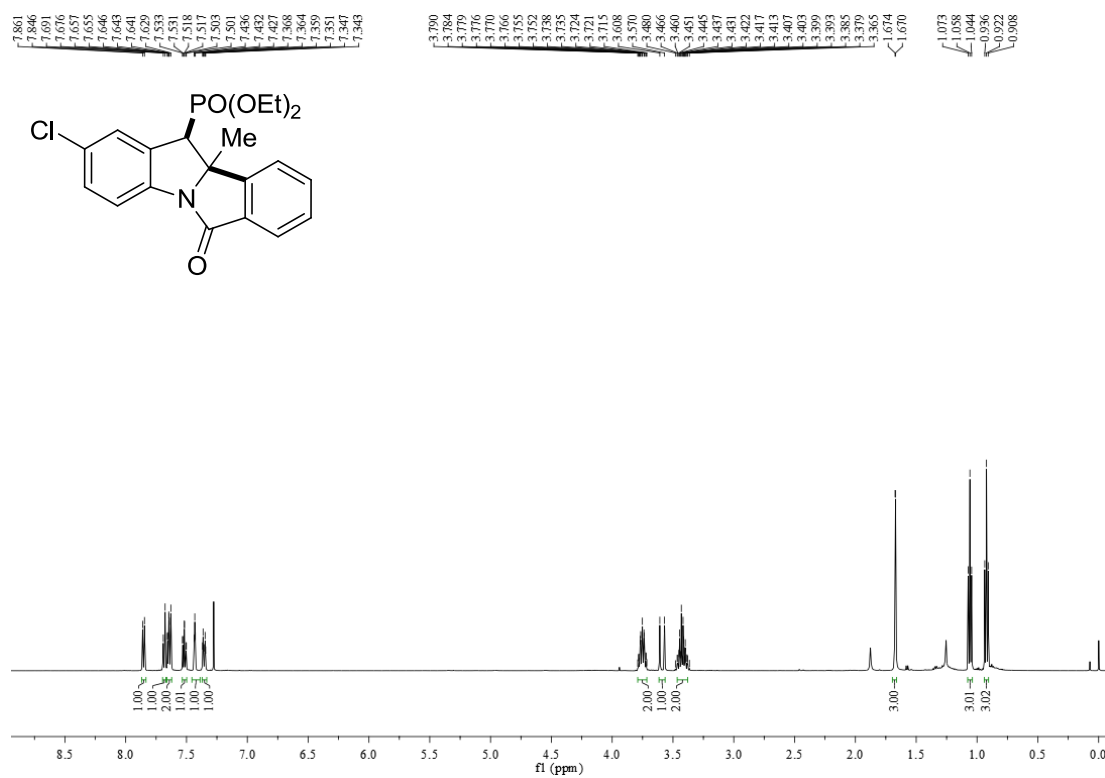


^{31}P NMR (CDCl_3 , 243 MHz)

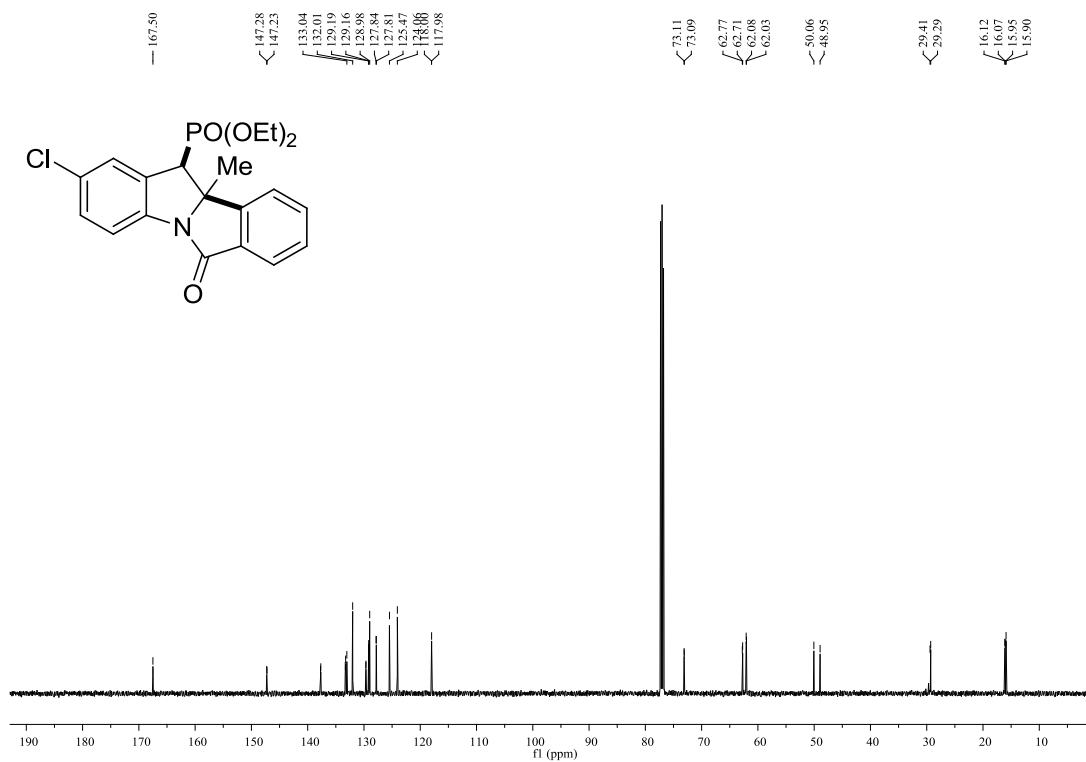


3j

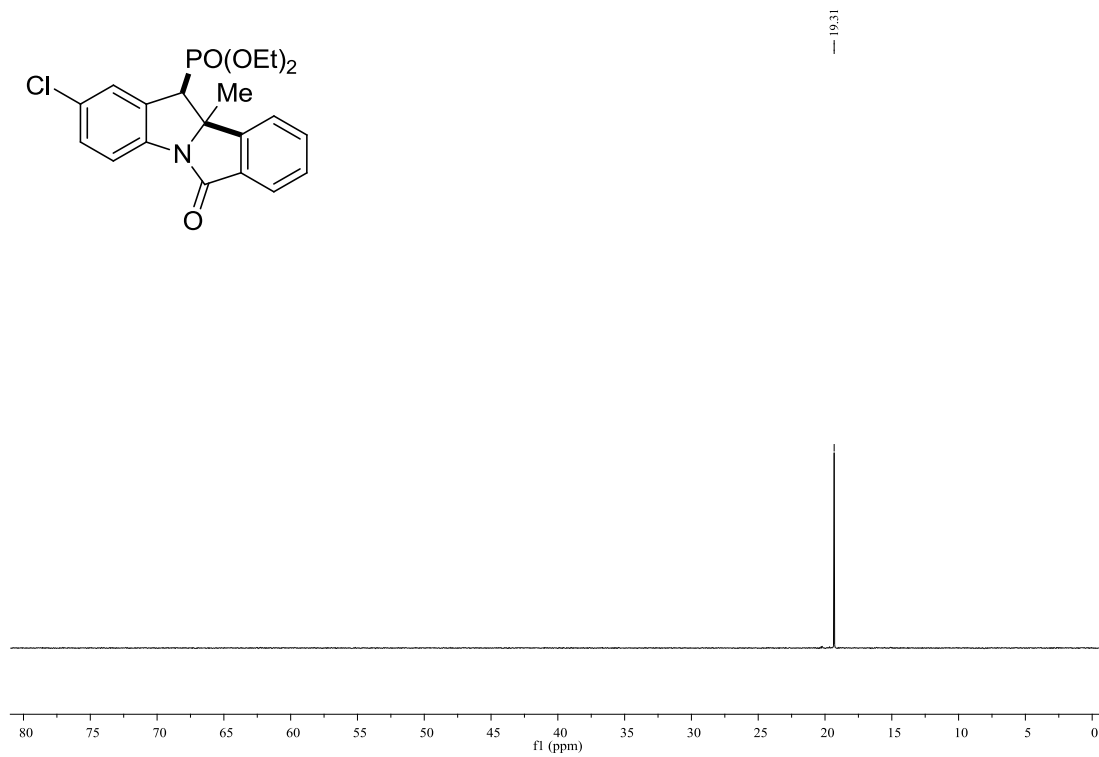
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

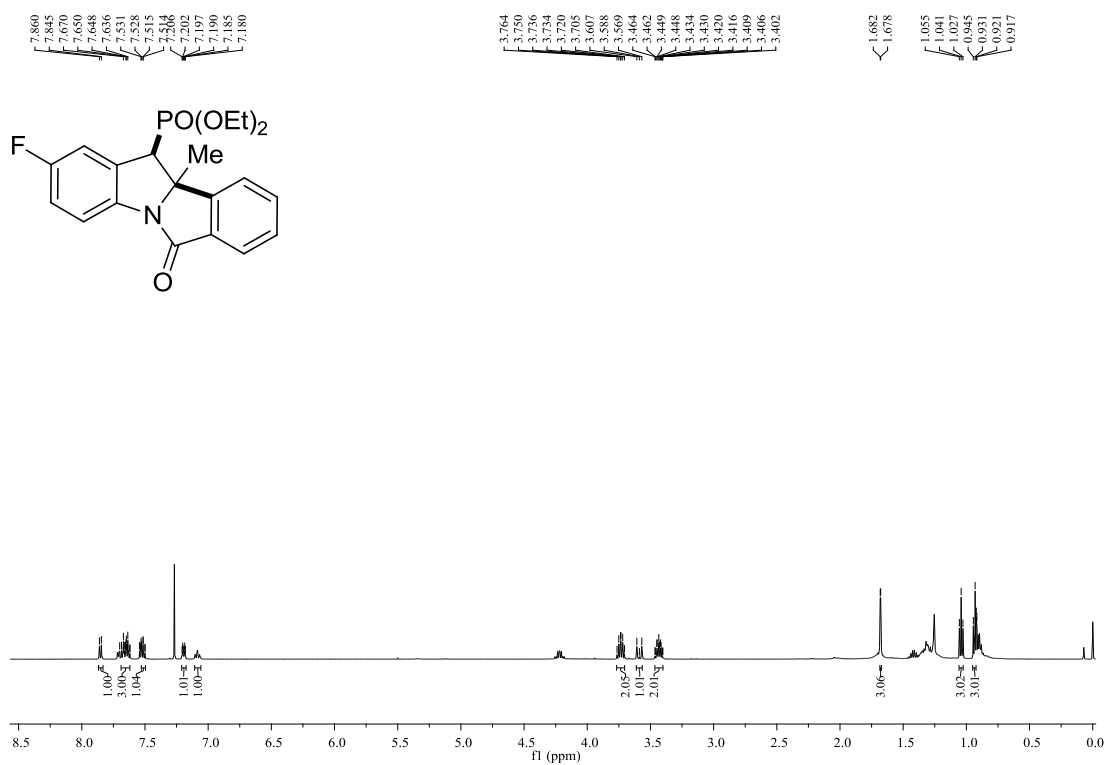


^{31}P NMR (CDCl_3 , 243 MHz)

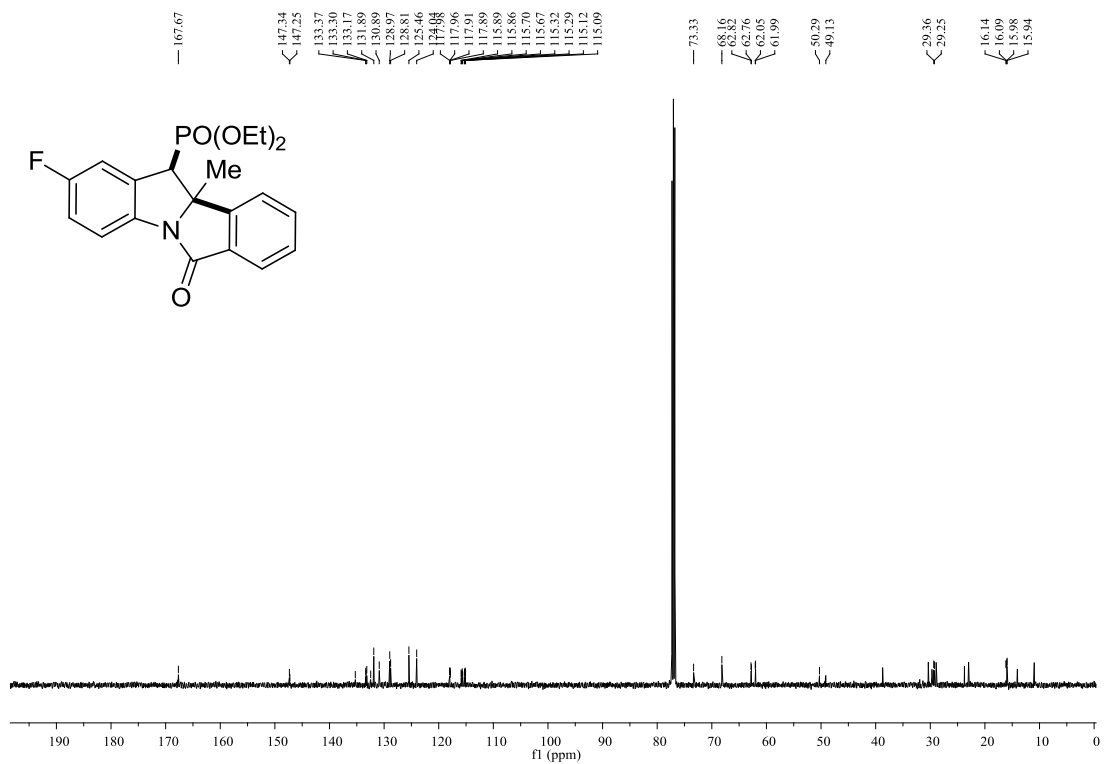


3k

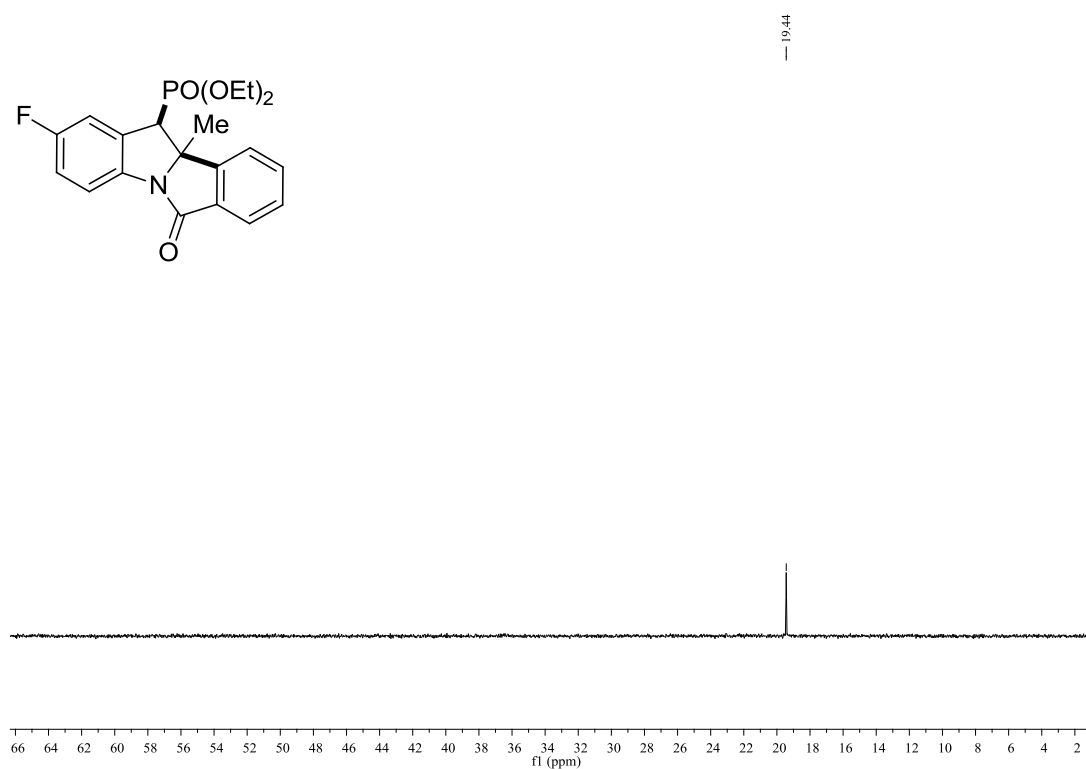
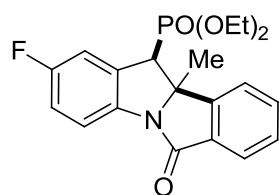
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

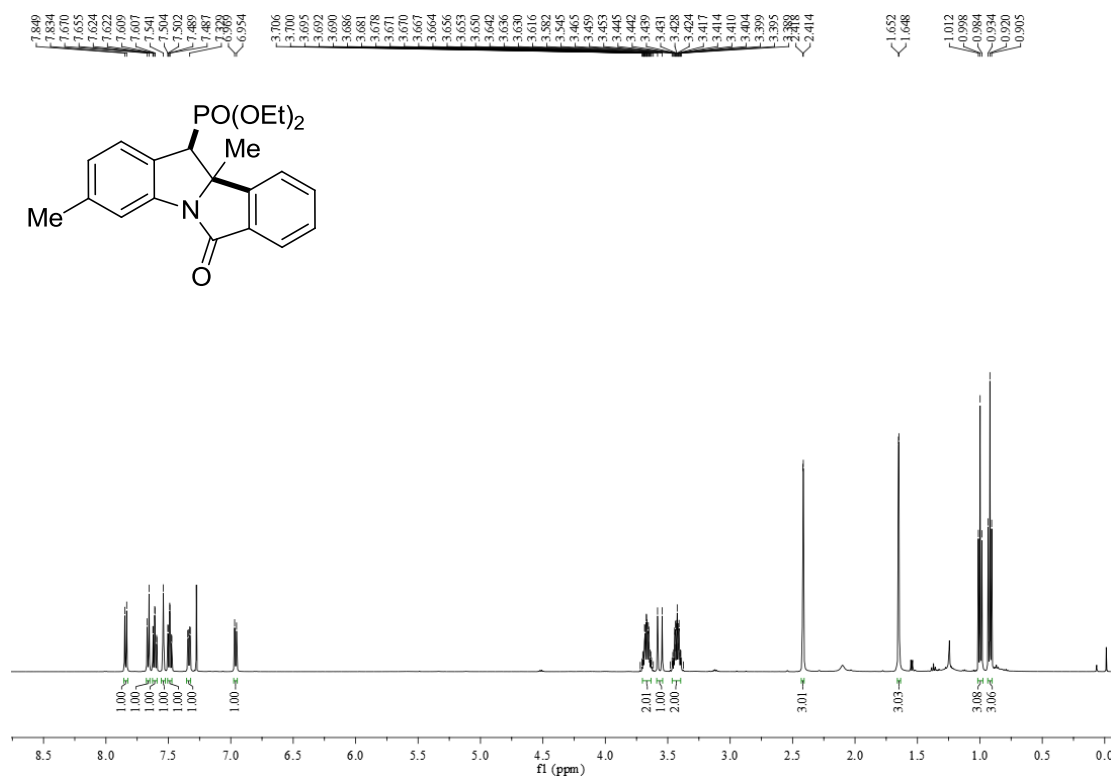
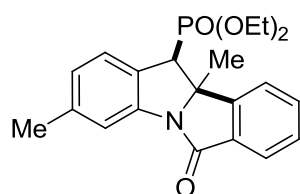


^{31}P NMR (CDCl_3 , 243 MHz)

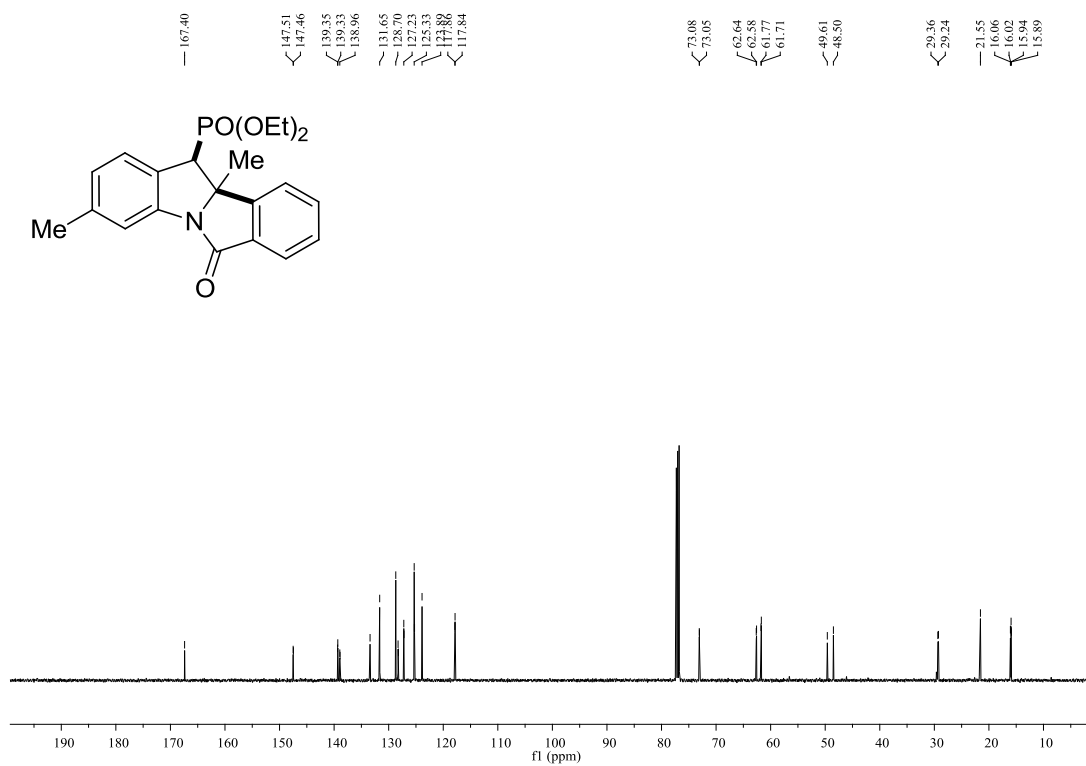


31

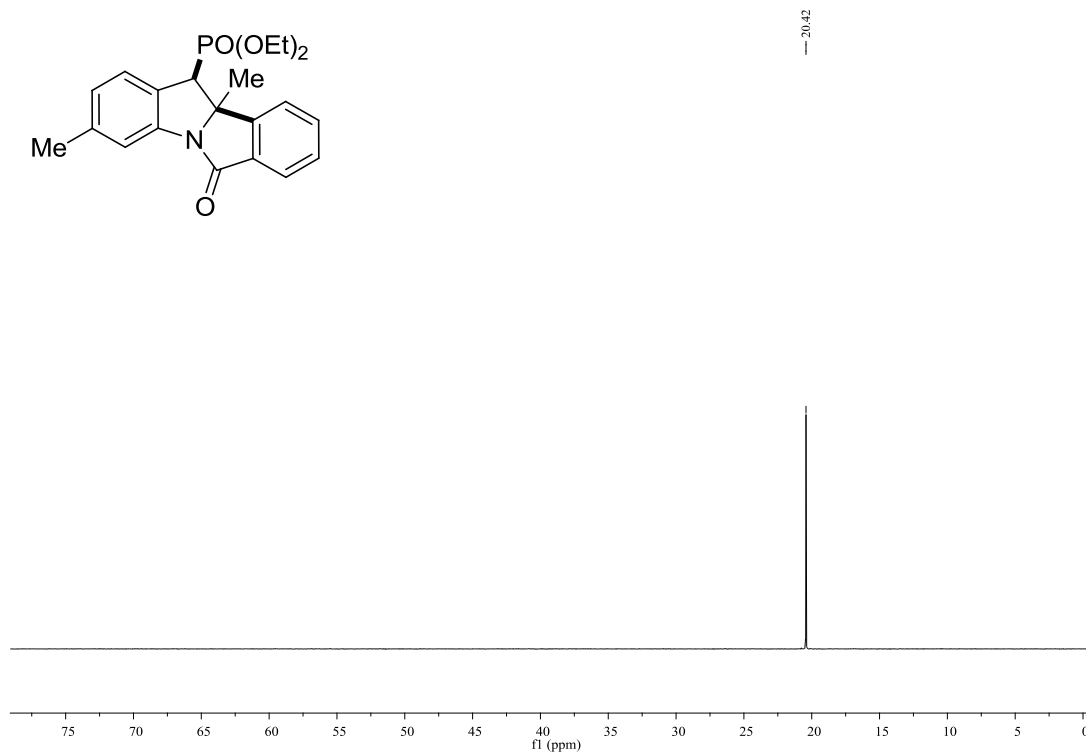
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

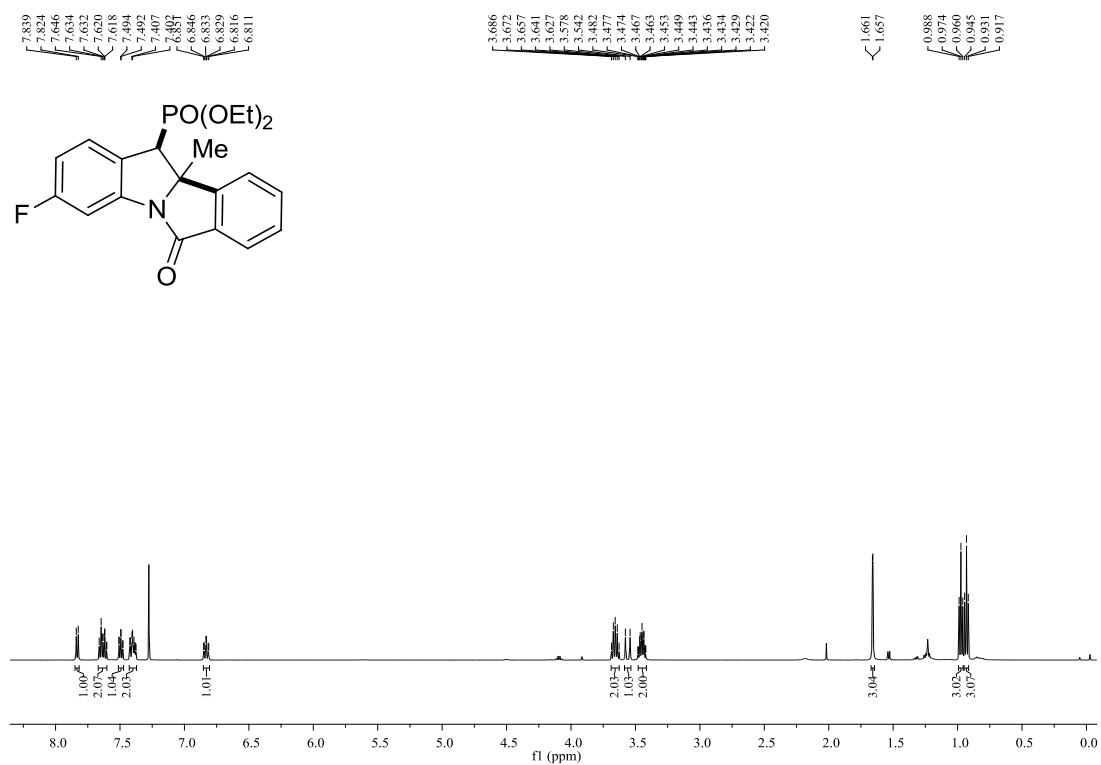


^{31}P NMR (CDCl_3 , 243 MHz)

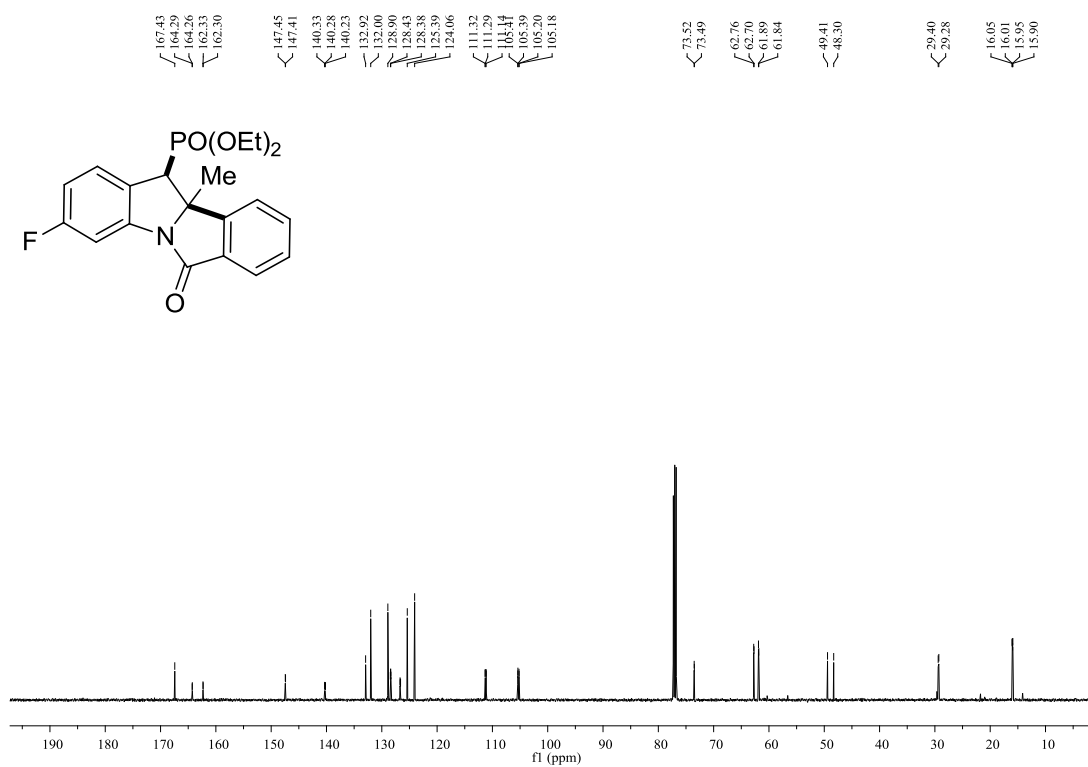


3m

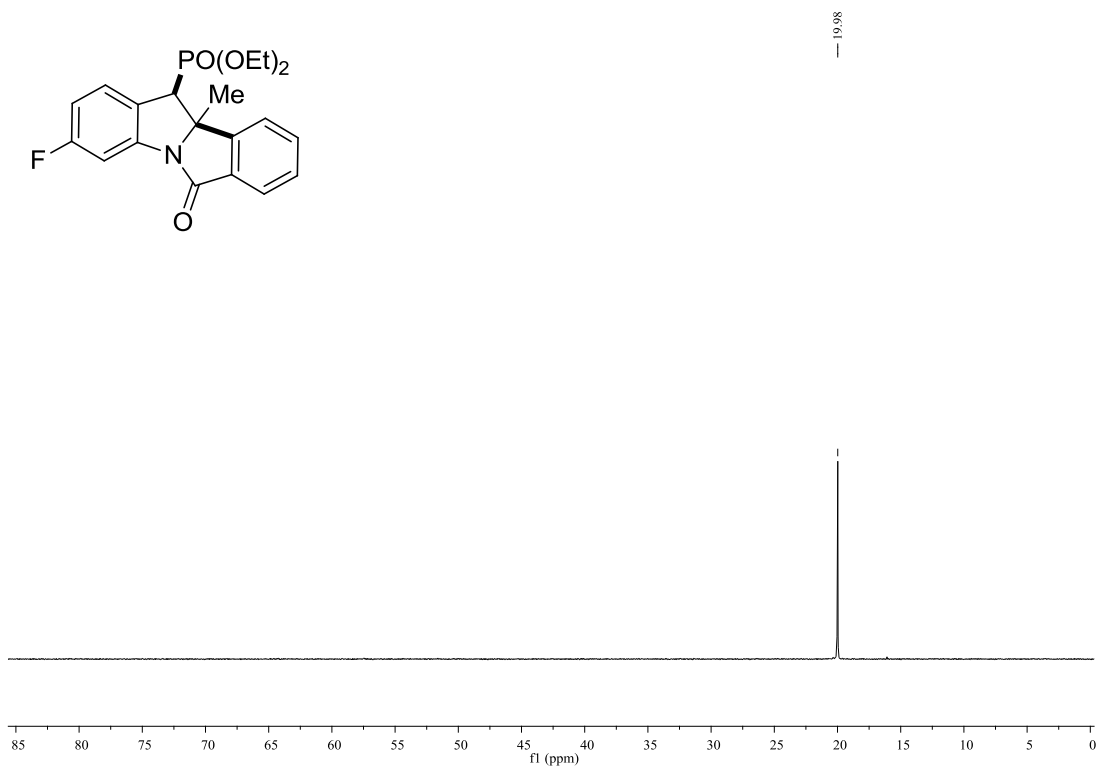
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

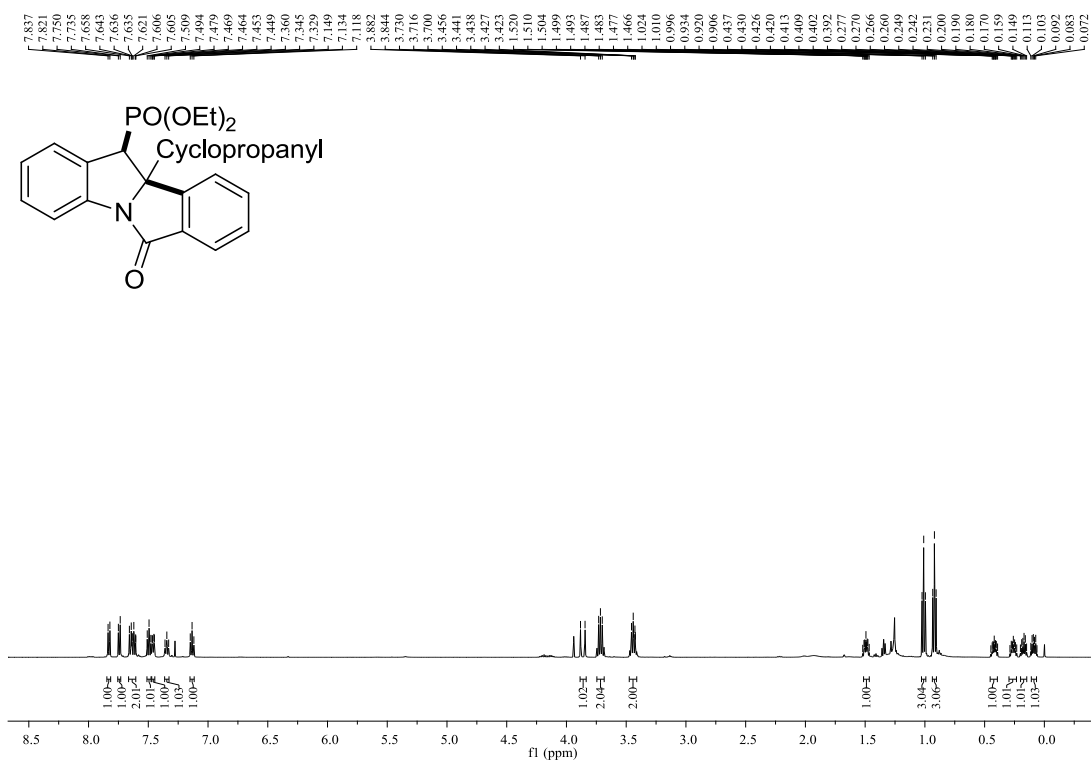


^{31}P NMR (CDCl_3 , 243 MHz)



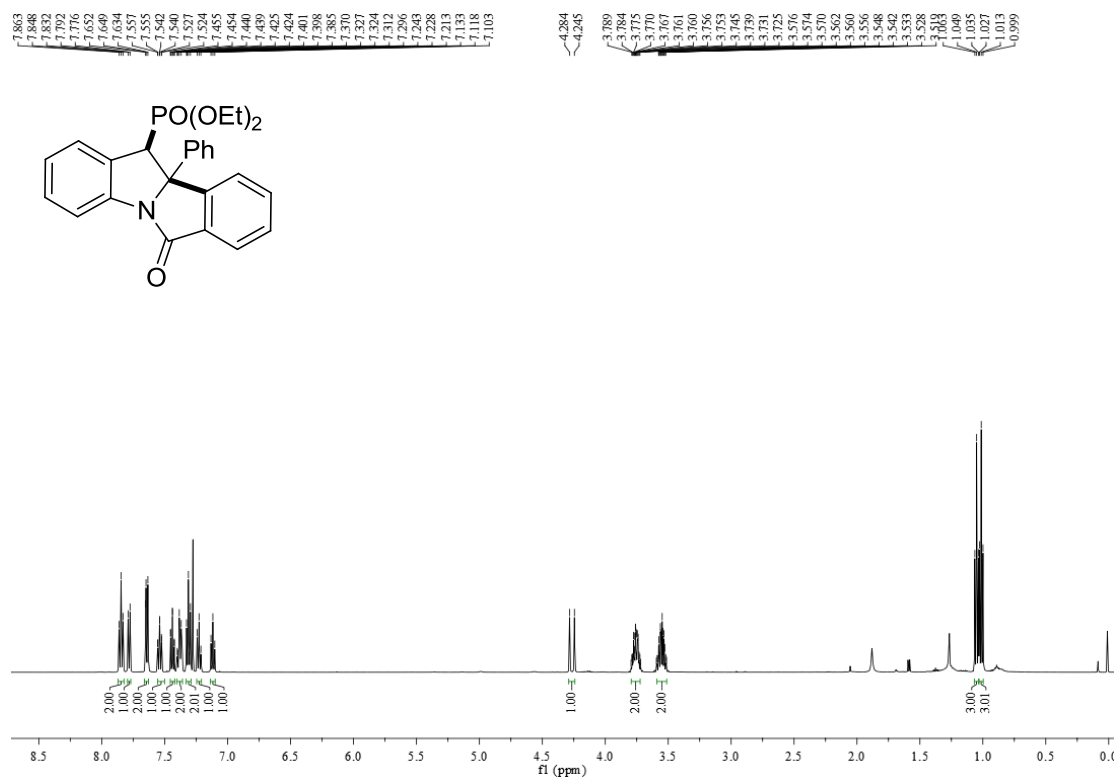
3n

^1H NMR (CDCl_3 , 500 MHz)

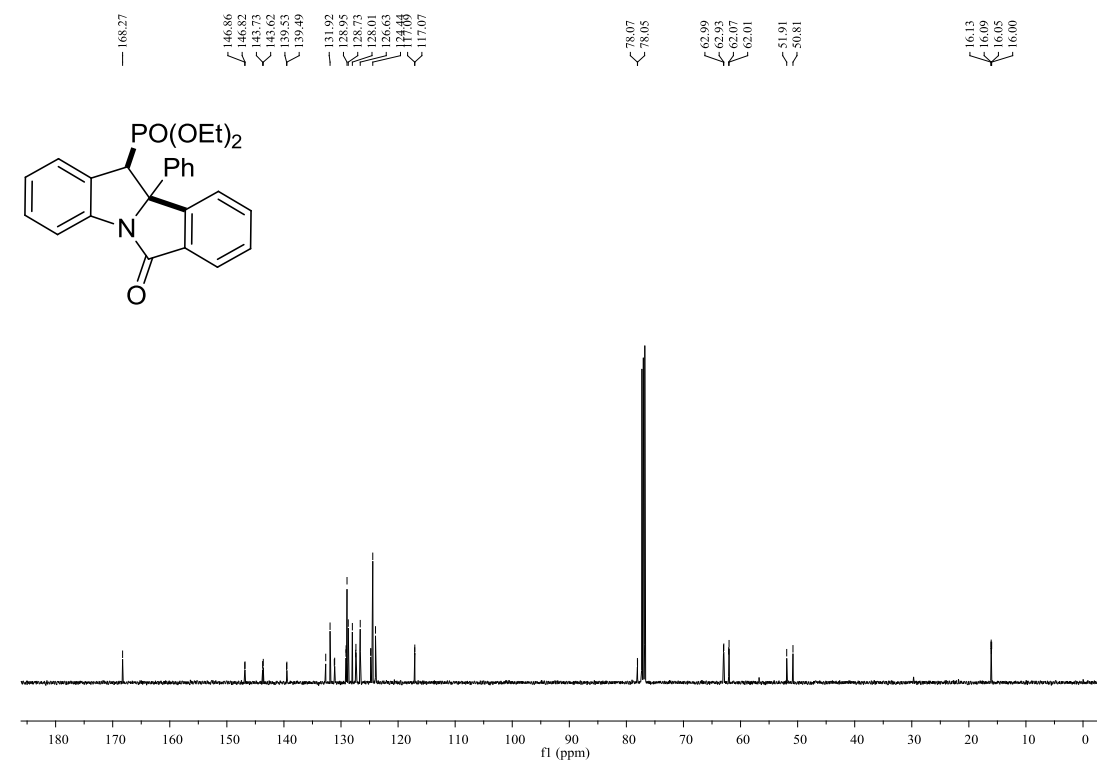


30

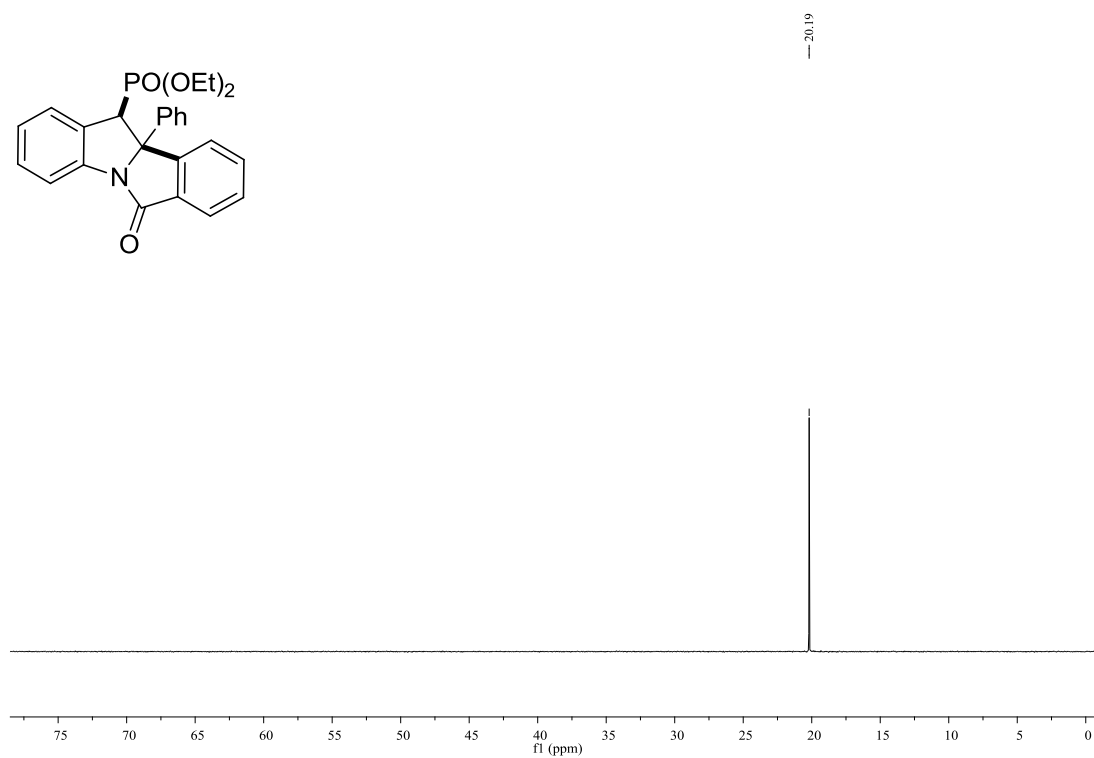
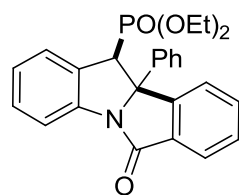
¹H NMR (CDCl₃, 500 MHz)



¹³C NMR (CDCl₃, 125 MHz)



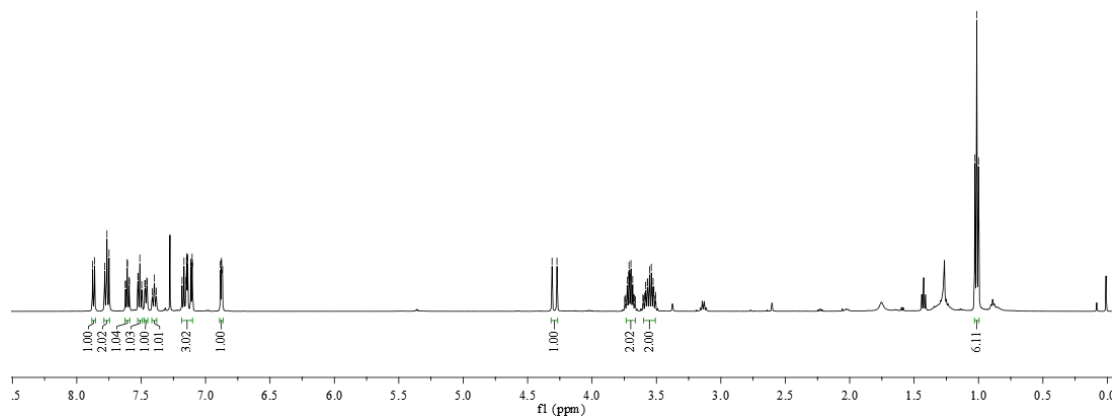
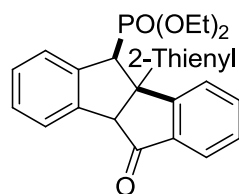
^{31}P NMR (CDCl_3 , 243 MHz)



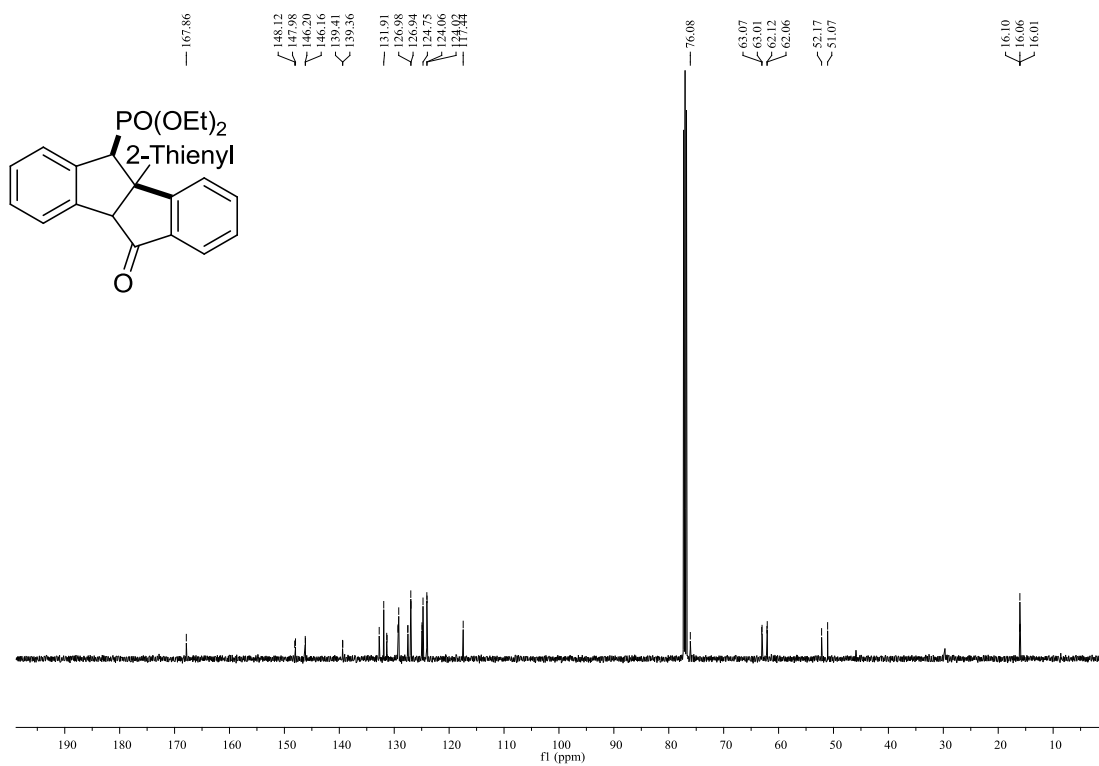
3p

^1H NMR (CDCl_3 , 500 MHz)

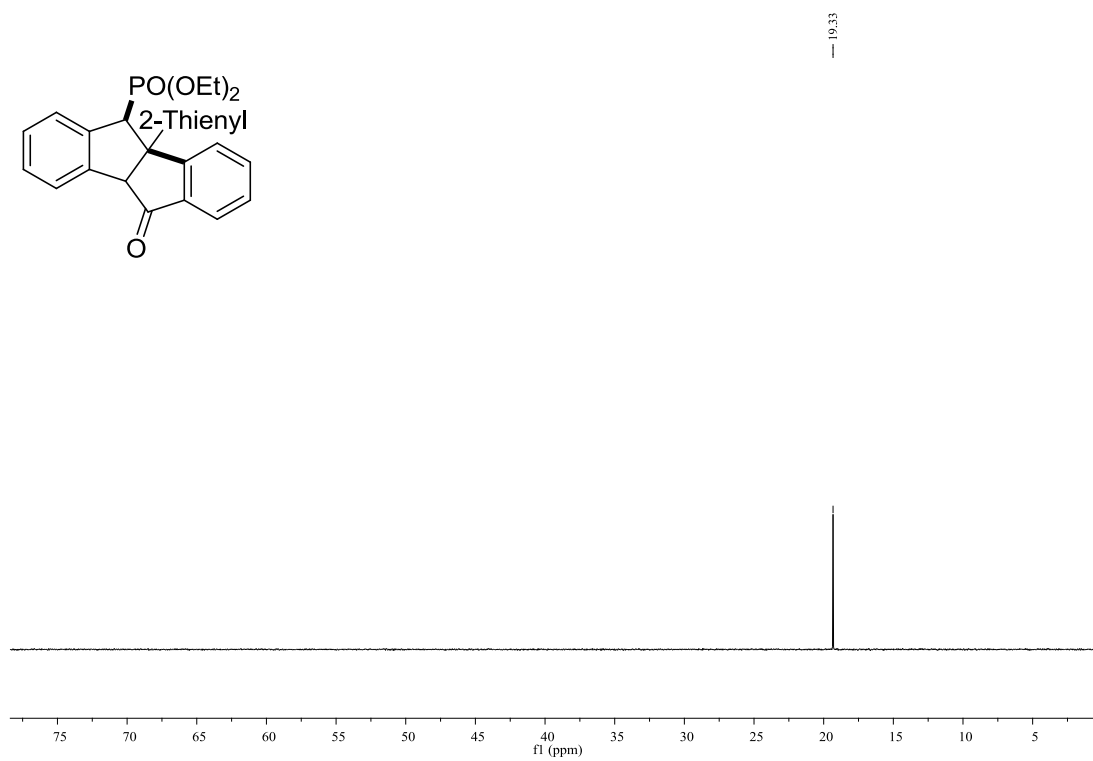
7.876, 7.861, 7.783, 7.765, 7.749, 7.731, 7.681, 7.608, 7.606, 7.593, 7.591, 7.525, 7.524, 7.510, 7.495, 7.467, 7.467, 7.457, 7.452, 7.413, 7.397, 7.382, 7.382, 7.383, 7.167, 7.152, 7.148, 7.146, 7.146, 7.140, 7.138, 7.138, 7.114, 7.112, 7.104, 7.102, 6.885, 6.875, 6.875, 6.868, 4.310, 4.272, 3.747, 3.741, 3.727, 3.727, 3.715, 3.712, 3.701, 3.686, 3.686, 3.678, 3.670, 3.664, 3.664, 3.605, 3.599, 3.591, 3.585, 3.582, 3.571, 3.571, 3.554, 3.540, 3.540, 3.534, 3.526, 3.520, 3.511, 3.505, 1.028, 1.013, 0.999



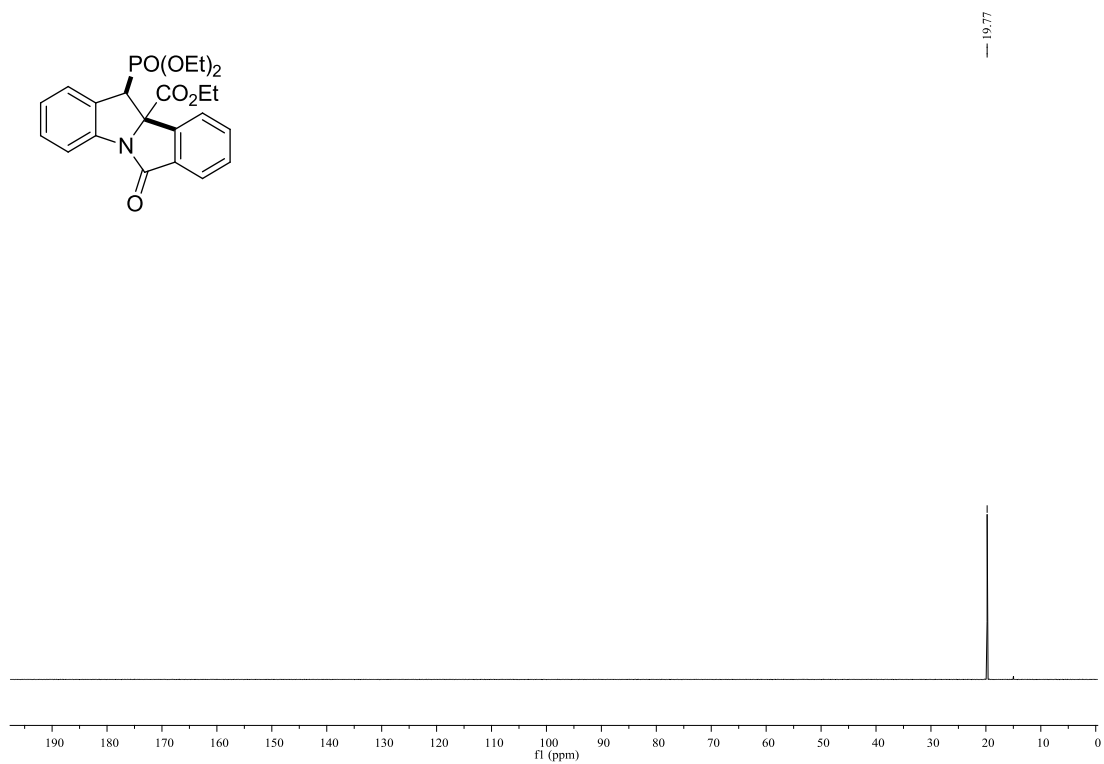
^{13}C NMR (CDCl_3 , 125 MHz)



^{31}P NMR (CDCl_3 , 243 MHz)

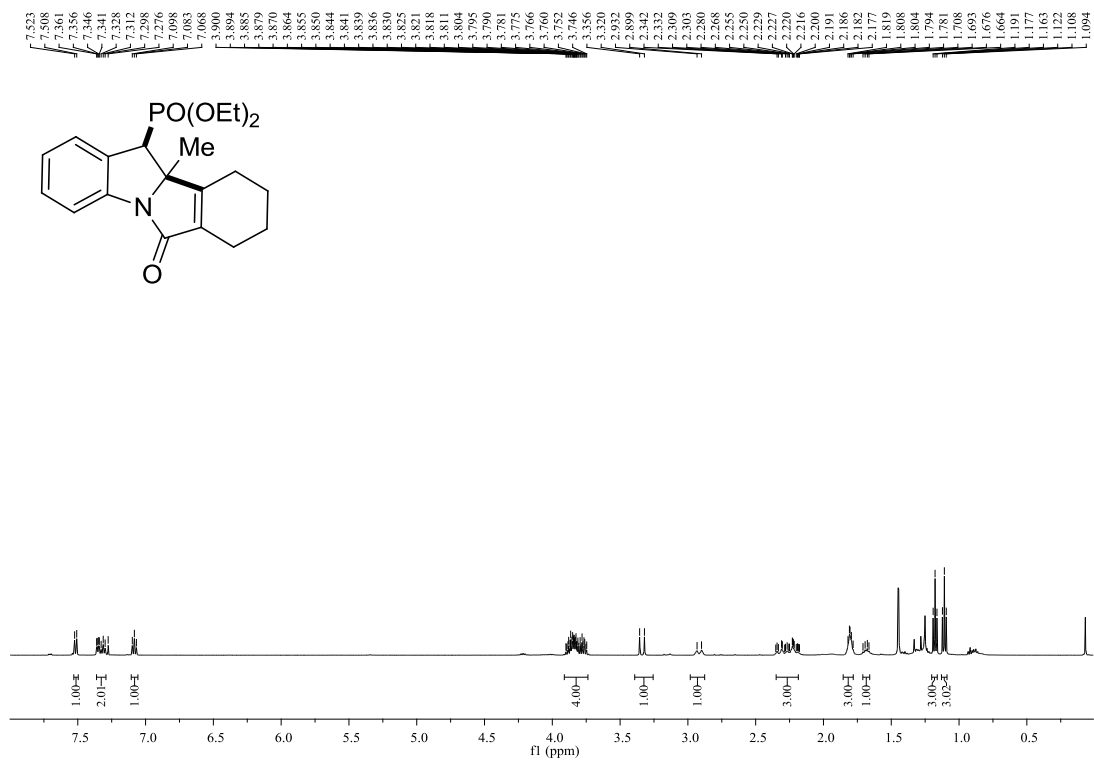


^{31}P NMR (CDCl_3 , 243 MHz)

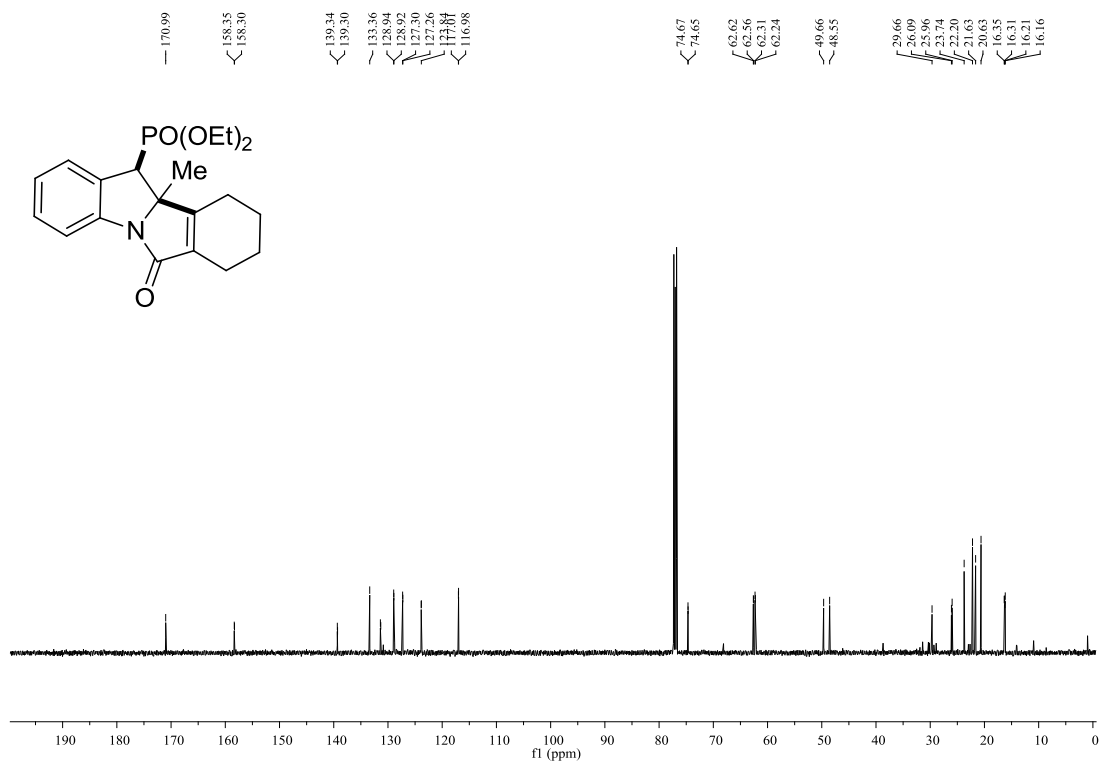


3r

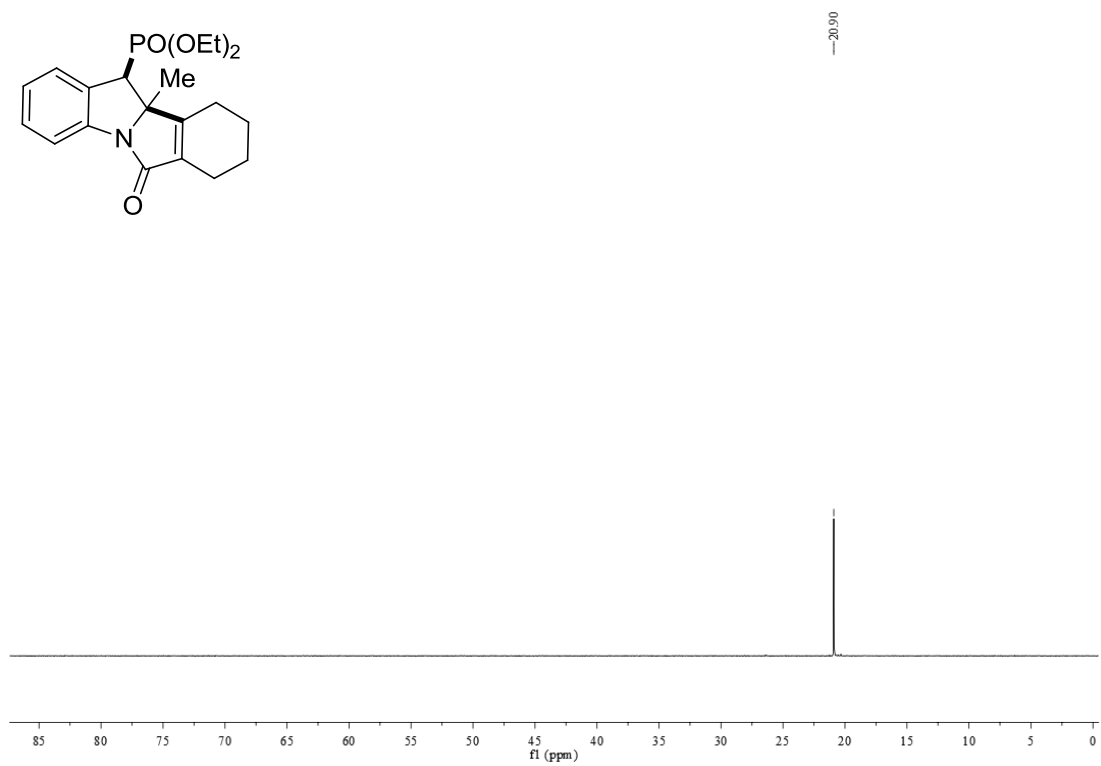
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

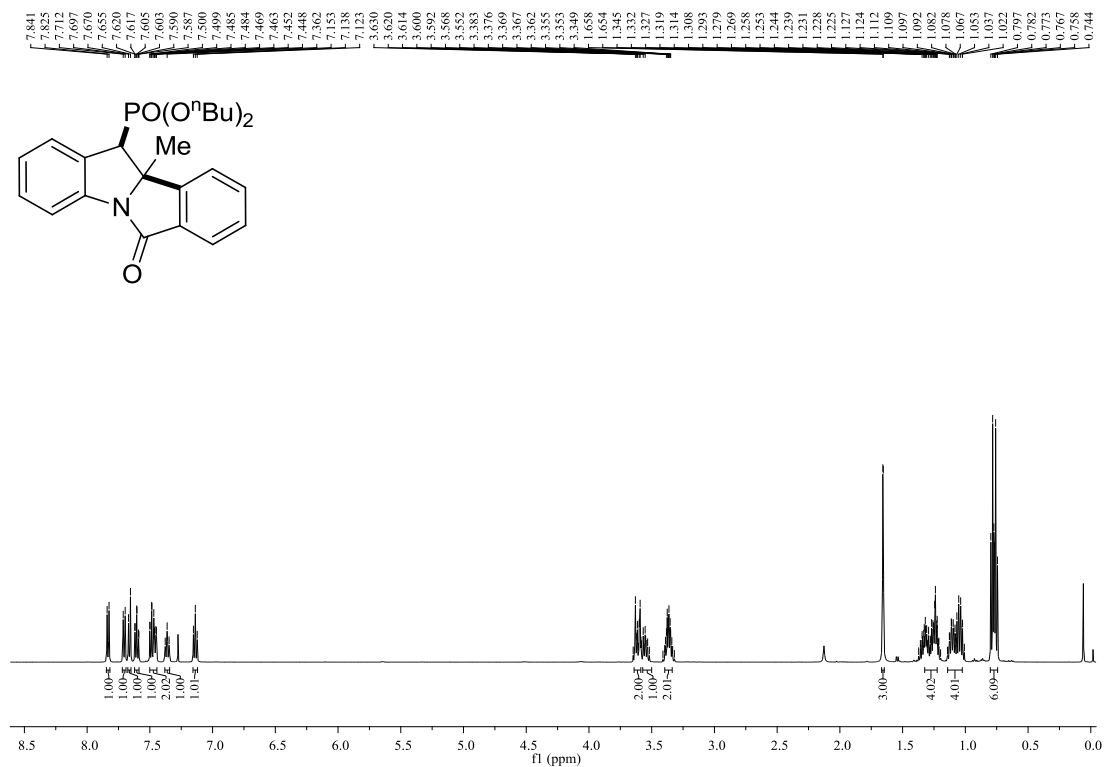


^{31}P NMR (CDCl_3 , 243 MHz)

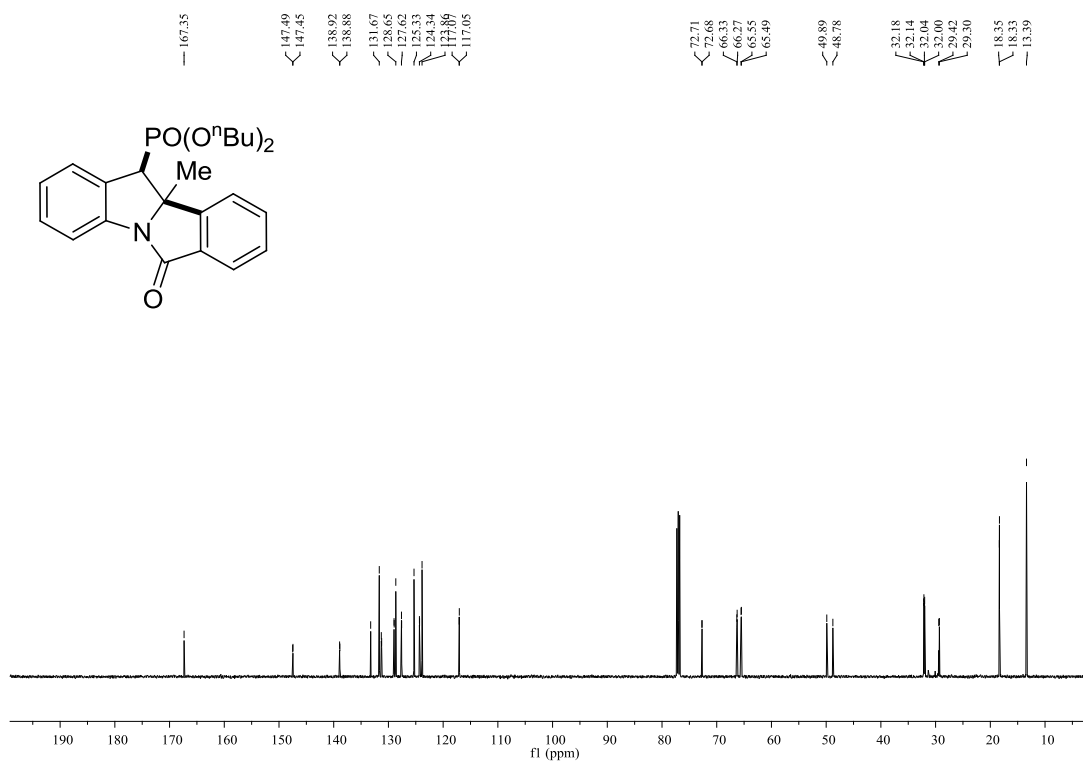


3s

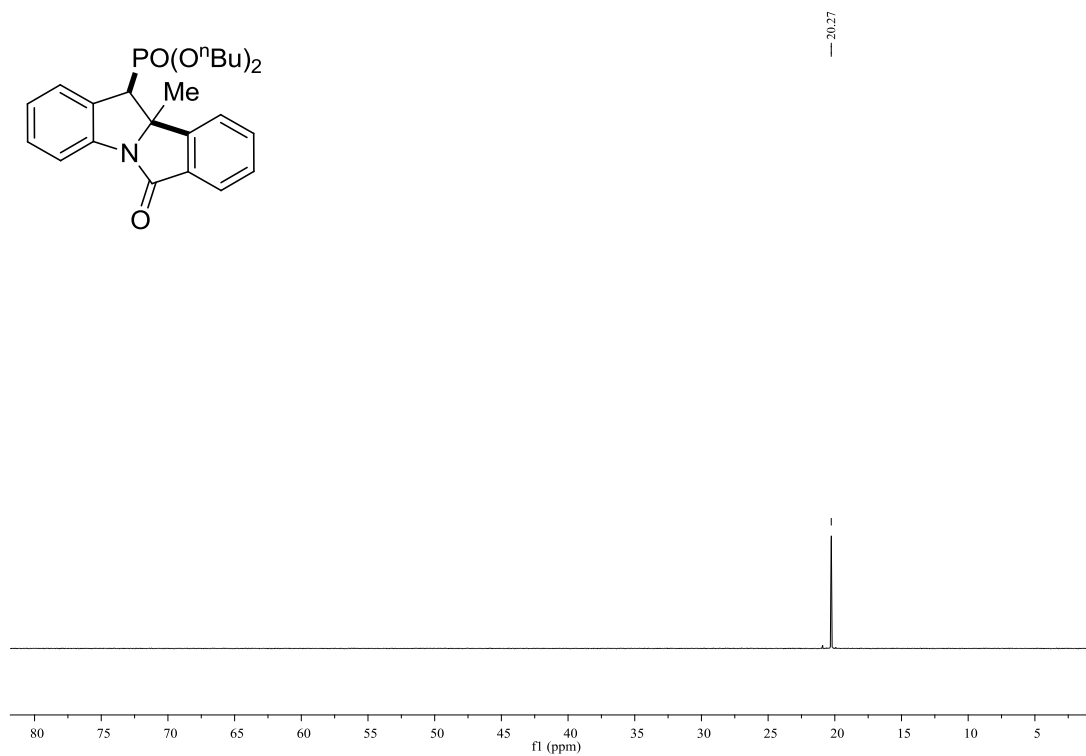
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

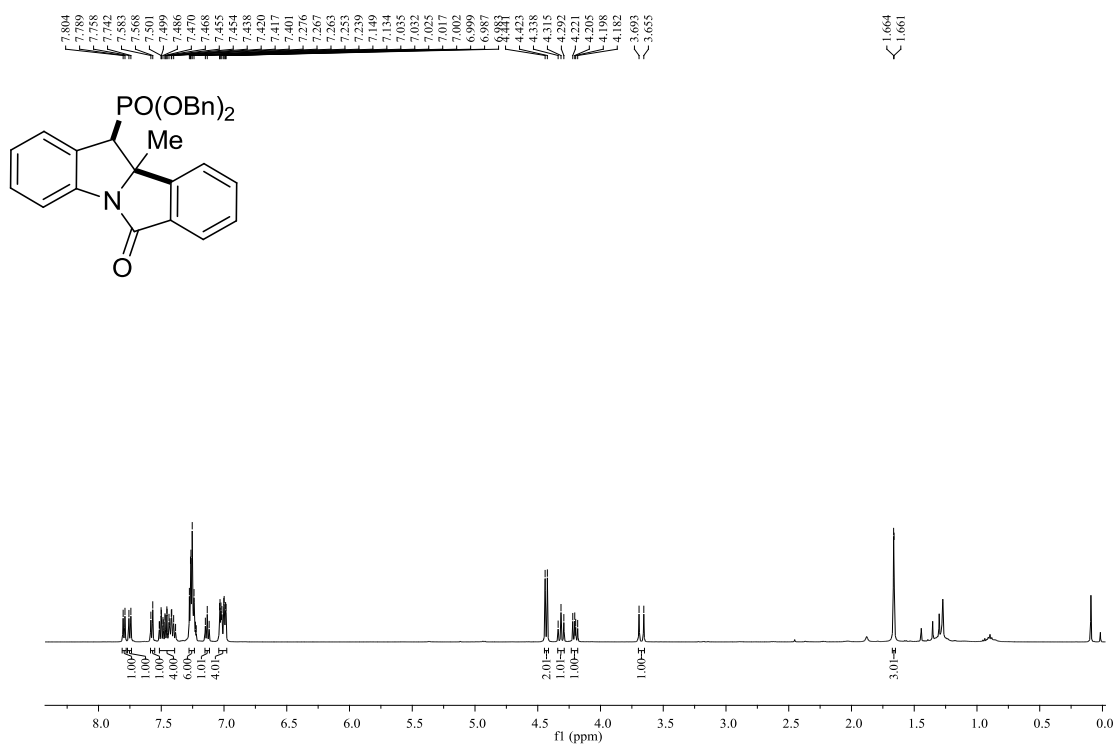


^{31}P NMR (CDCl_3 , 243 MHz)

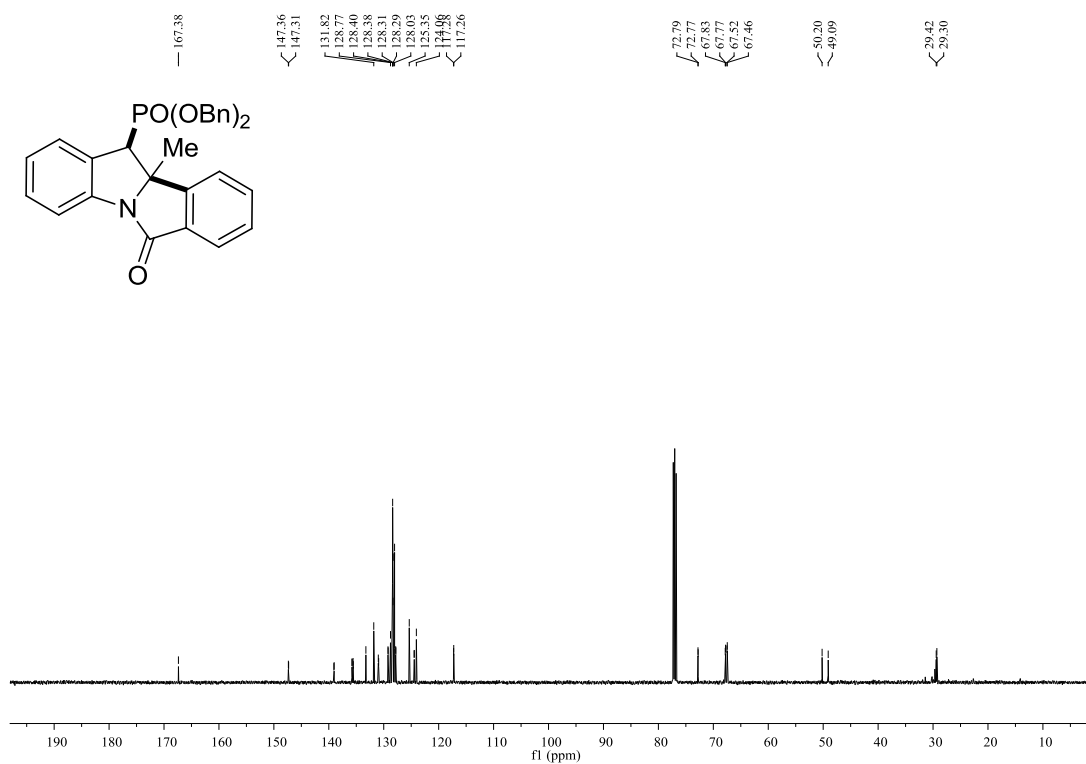


3t

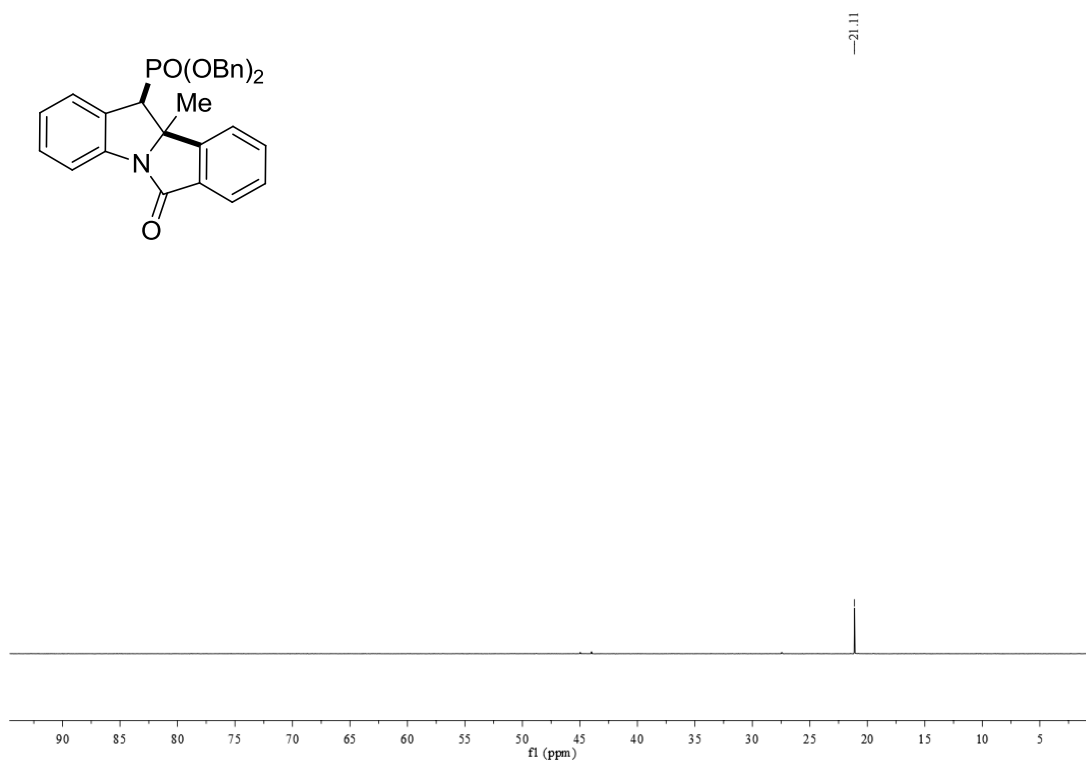
^1H NMR (CDCl_3 , 500 MHz)



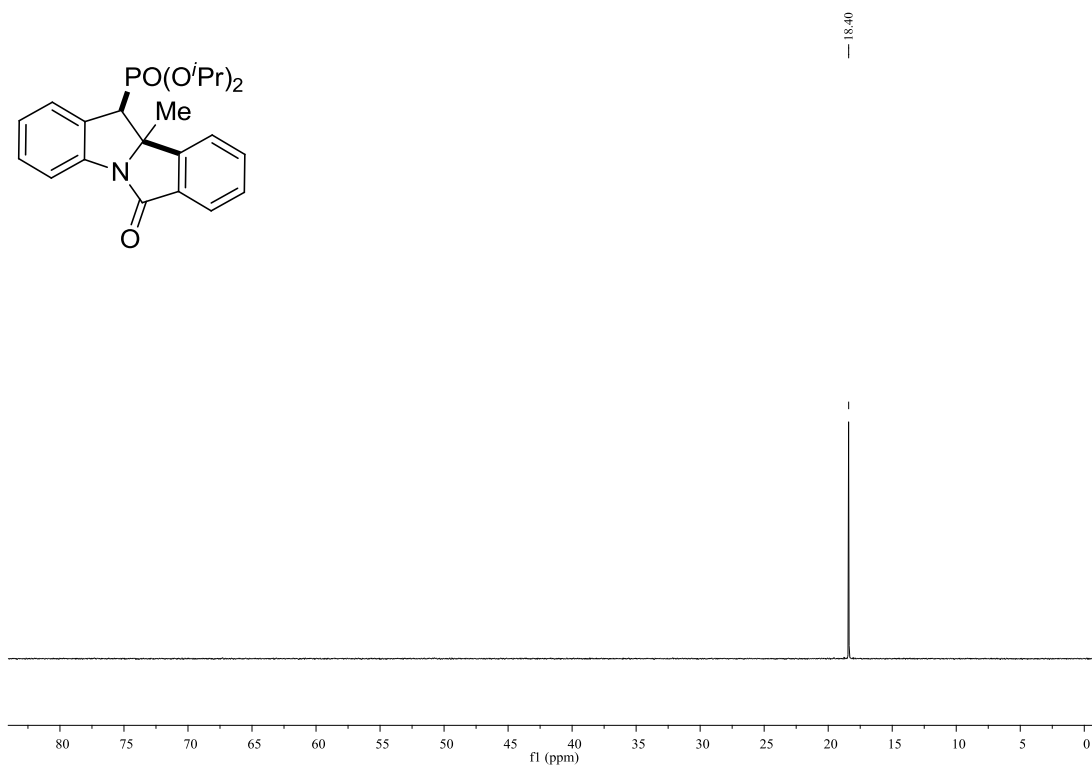
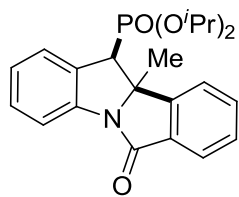
^{13}C NMR (CDCl_3 , 125 MHz)



^{31}P NMR (CDCl_3 , 243 MHz)

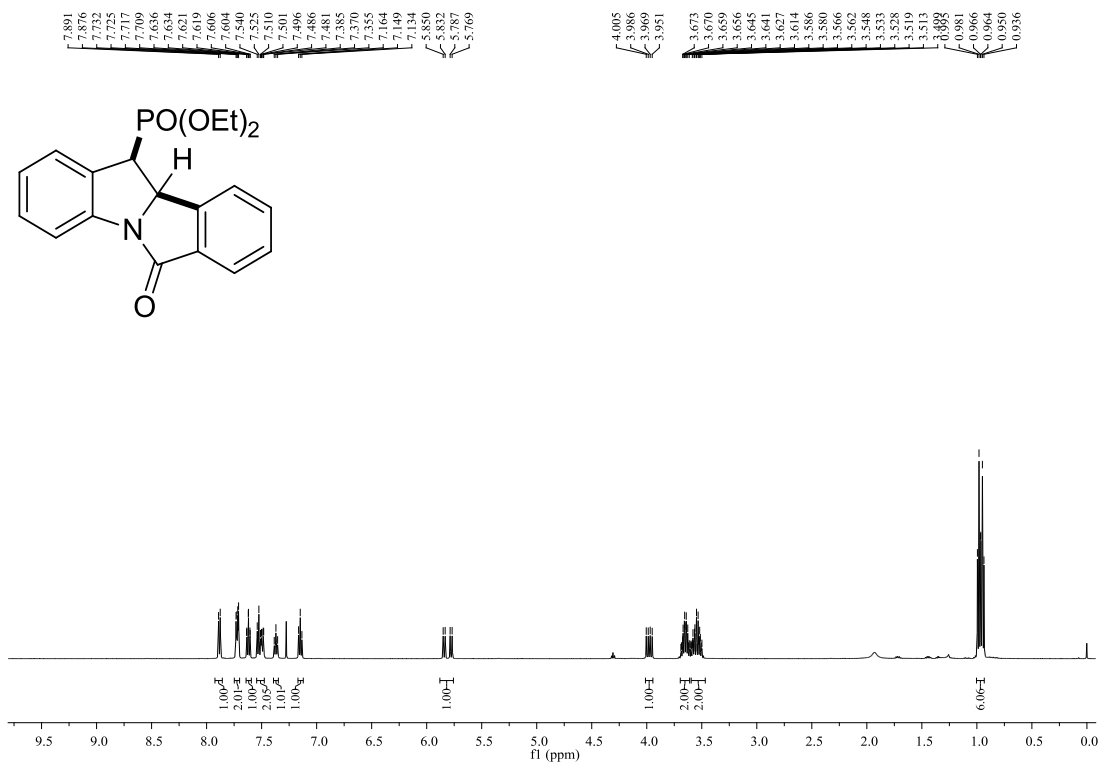
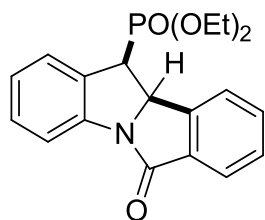


^{31}P NMR (CDCl_3 , 243 MHz)

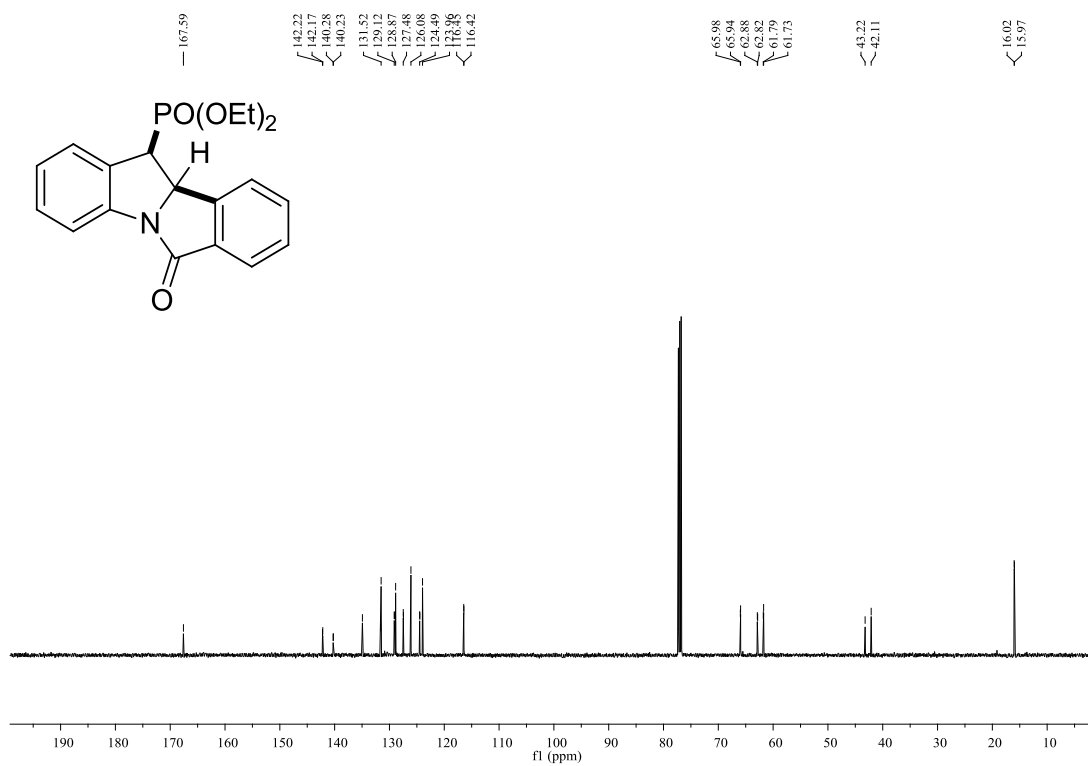


3v

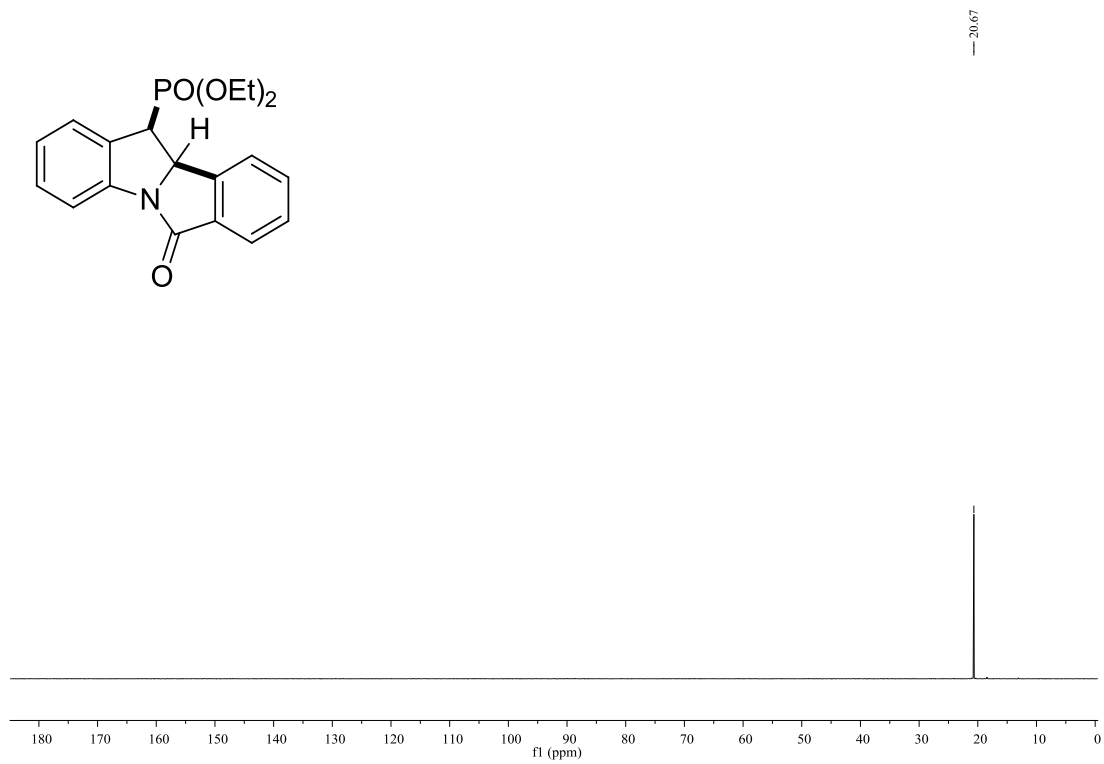
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)

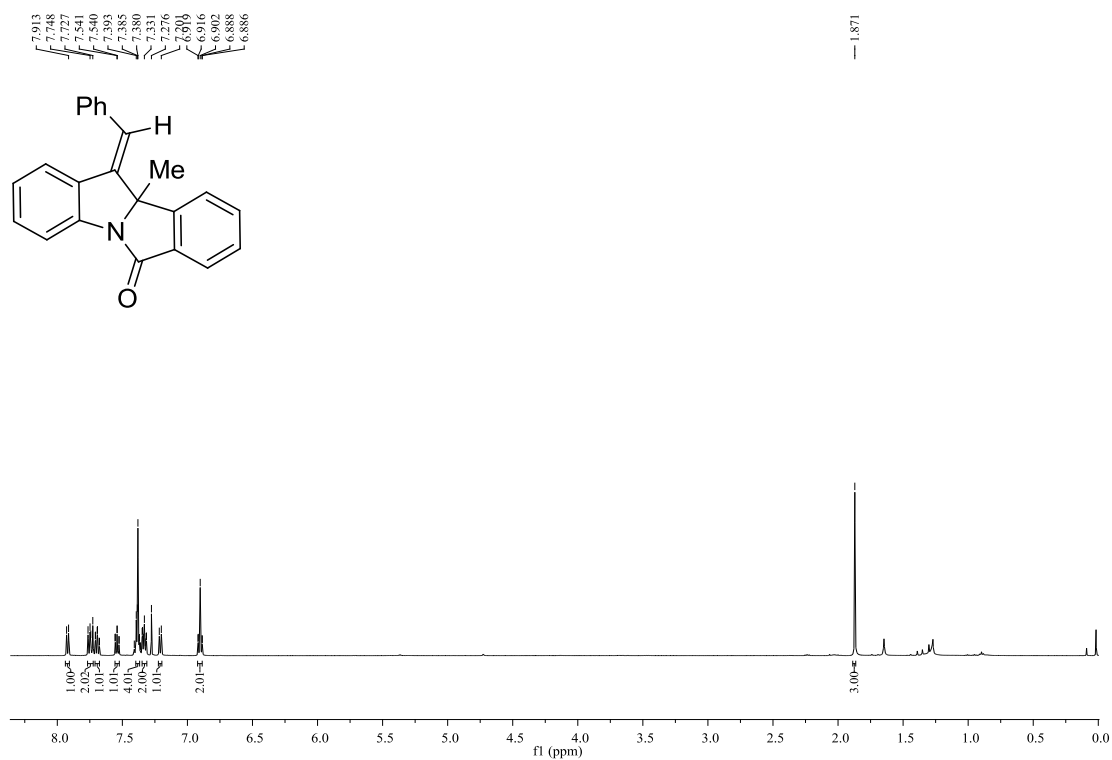


^{31}P NMR (CDCl_3 , 243 MHz)

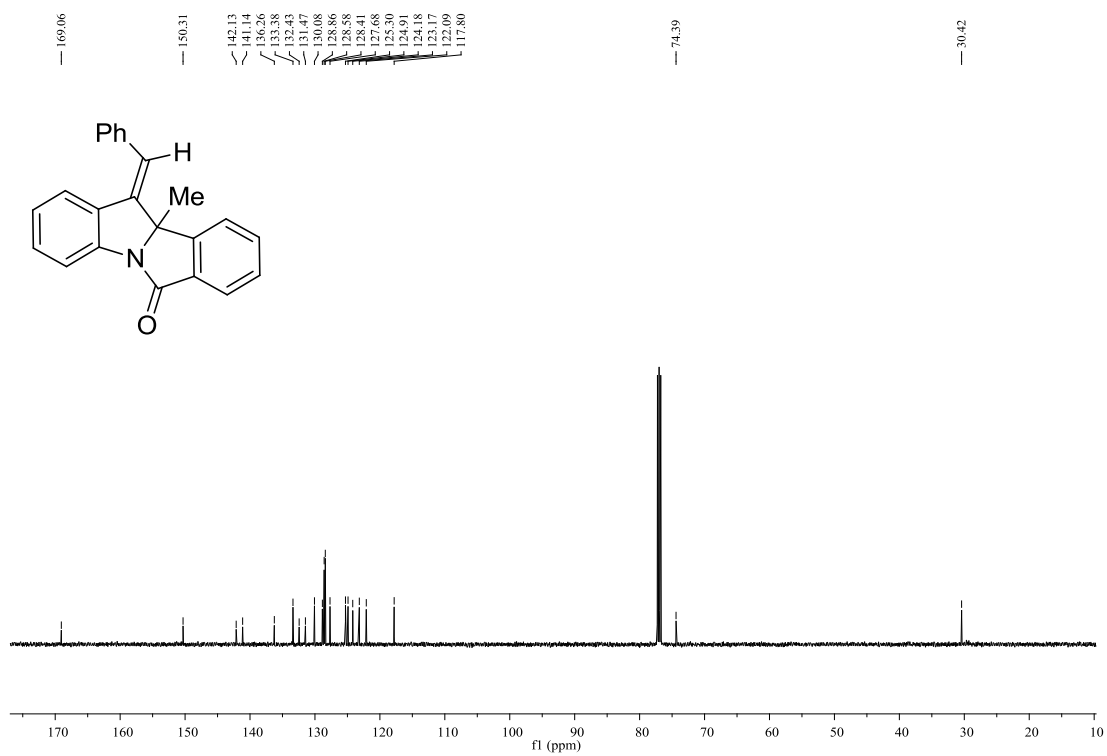


4

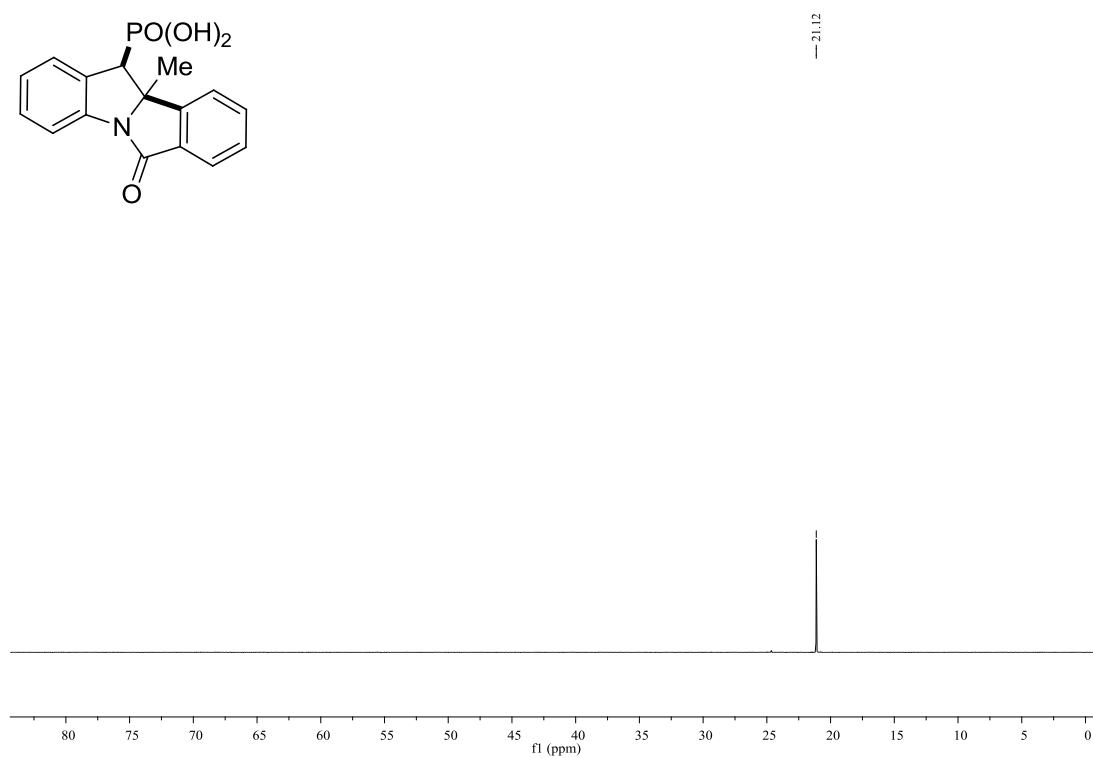
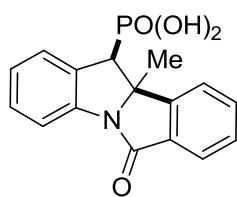
^1H NMR (CDCl_3 , 500 MHz)



^{13}C NMR (CDCl_3 , 125 MHz)



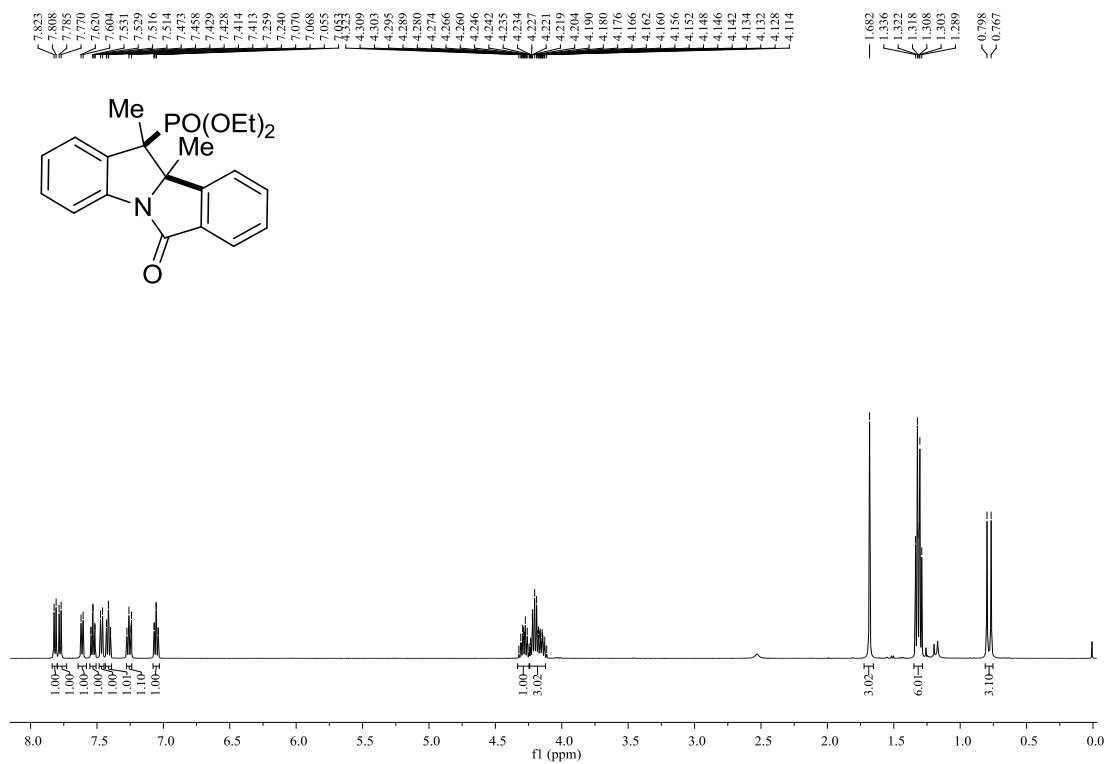
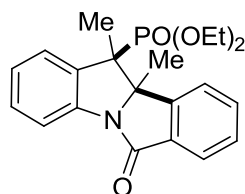
^{31}P NMR (DMSO- d_6 , 243 MHz)



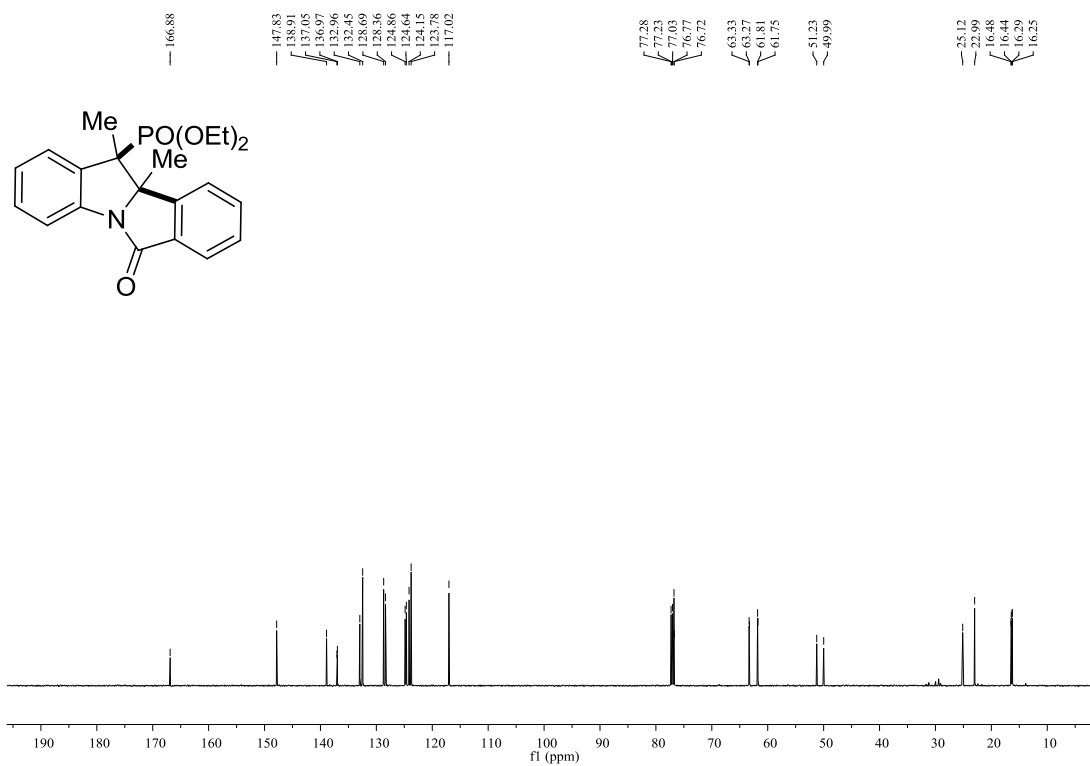
6

^1H NMR (CDCl_3 , 500 MHz)

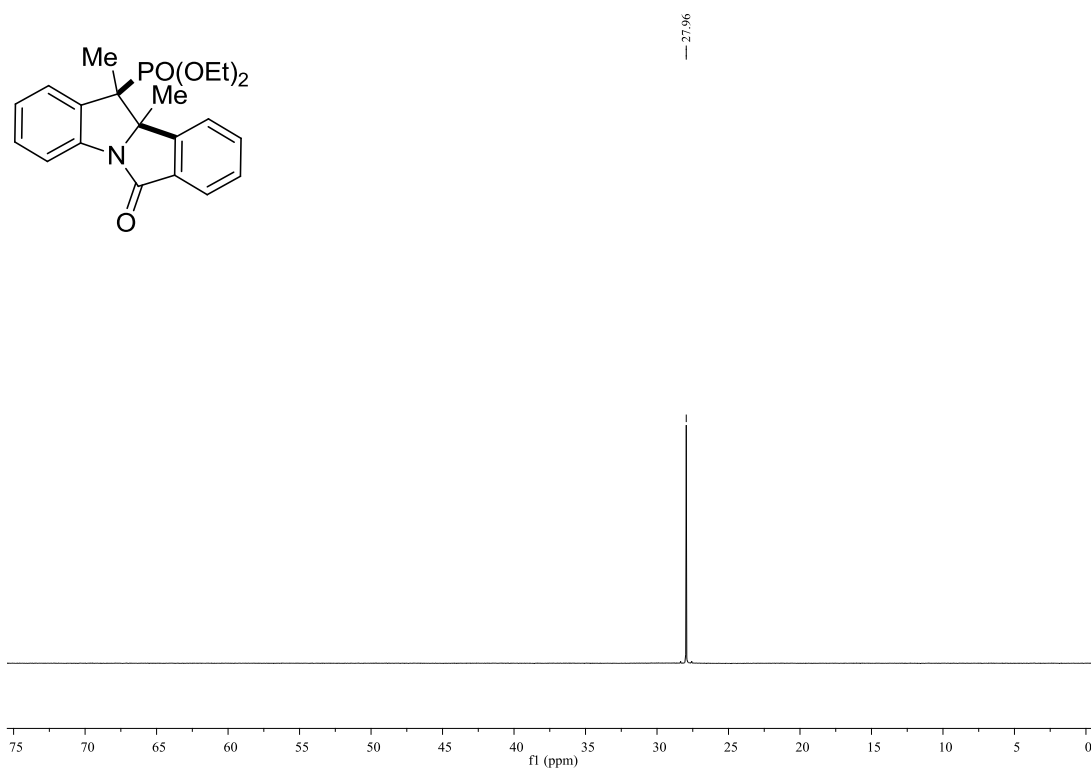
7.823, 7.808, 7.785, 7.770, 7.620, 7.604, 7.581, 7.559, 7.516, 7.514, 7.473, 7.458, 7.429, 7.428, 7.414, 7.405, 7.289, 7.240, 7.070, 7.068, 7.055, 7.053, 4.309, 4.303, 4.295, 4.289, 4.280, 4.274, 4.266, 4.260, 4.242, 4.235, 4.234, 4.227, 4.221, 4.219, 4.204, 4.190, 4.180, 4.166, 4.162, 4.160, 4.156, 4.152, 4.148, 4.146, 4.142, 4.134, 4.128, 4.114, 1.682, 1.336, 1.332, 1.318, 1.308, 1.303, 1.289, 0.798, 0.767



^{13}C NMR (CDCl_3 , 125 MHz)



^{31}P NMR (CDCl_3 , 243 MHz)



^{31}P NMR (CDCl_3 , 243 MHz)

