Electronic Supplementary Material (ESI) for ChemComm.

Stereoselective synthesis of vinylphosphonates and phosphine oxides via silver-catalyzed phosphorylation of styrenes

Qingwen Gui,[a] Liang Hu,[a] Xiang Chen,[a] Jidan Liu,[a] and Ze Tan*[a]

[a]State Key Laboratory of Chemo/Biosensing and Chemometrics, College of Chemistry and Chemical Engineering, Hunan University, Changsha 410082, P. R. China.

E-mail: ztanze@gmail.com

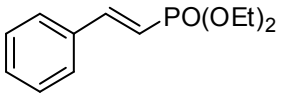
General Remarks:

All the solvents and commercially available reagents were purchased from commercial sources and used directly. Column chromatography was carried out on silica gel. ^{1}H NMR spectra were recorded on 400 MHz in $CDCl_3$ and ^{13}C NMR spectra were recorded on 100 MHz in $CDCl_3$ using TMS as internal standard. ^{31}P NMR spectra was recorded on the same instrument.

Typical procedure for the preparation of alkenylphosphine oxides.

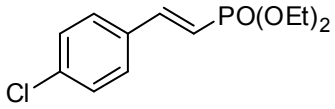
Dialkylphosphonate (0.45 mmol), styrene (0.3 mmol), potassium persulfate (0.6 mmol), TEMPO (0.12 mmol), $AgNO_3$ (0.015 mmol) and dry toluene (2.0 ml) were added to a 25-ml Schlenk flask equipped with a high-vacuum PTFE valve-to-glass seal. Then the flask was next sealed under air and stirred at 100 ^{o}C for 6 hours. After the completion of the reaction, The brownish suspension was cooled to rt, filtered over a plug of silica gel (washed with EtOAc), and concentrated. The crude residue was purified by flash chromatography over silica gel.

(*E*)-diethyl styrylphosphonate (**2a**)[1]



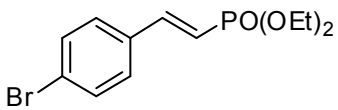
IR(KBr)/cm^{-1}:2956, 2924, 2850, 1604, 1511, 1461, 1257, 1173, 1025, 961. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57-7.27 (m, 6H), 6.27 (t, J = 20 Hz, 1H), 4.16-4.14 (m, 4H), 1.36 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.8 (d, $J_{C\text{-}P}$ = 6 Hz), 134.8 (d, $J_{C\text{-}P}$ = 25 Hz), 130.2, 128.8, 127.7, 113. 9 (d, $J_{C\text{-}P}$ = 190 Hz), 61.8 (d, $J_{C\text{-}P}$ = 5 Hz), 16.3 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.6. MS:m/z 240.1 (M^+).

(*E*)-diethyl 4-chlorostyrylphosphonate (**2b**)[1]



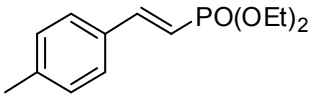
IR(KBr)/cm^{-1}: 2988, 2930, 2860, 1600, 1511, 1460, 899. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.45-7.41 (m, 3H), 7.32 (d, J = 8 Hz, 2H), 6.24 (t, J = 20 Hz, 1H), 4.17-4.10 (m, 4H), 1.36 (t, J = 8Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.2 (d, $J_{C\text{-}P}$ = 7 Hz), 136.1 133.3 (d, $J_{C\text{-}P}$ = 25 Hz), 129.1, 128.9, 114.8 (d, $J_{C\text{-}P}$ = 190 Hz), 61.9 (d, $J_{C\text{-}P}$ = 6 Hz), 16.4 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.0. MS:m/z 274.1 (M^+).

(*E*)-diethyl 4-bromostyrylphosphonate (**2c**) [1]



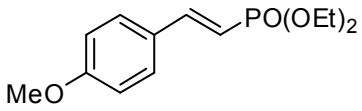
IR(KBr)/cm^{-1}: 2980, 2930, 1970, 1620, 1510, 1230, 1112, 975. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.53-7.45 (m, 3H), 7.37 (d, J = 8 Hz, 2H), 6.27 (t, J = 16 Hz, 1H), 4.26-4.02 (m, 4H), 1.36 (t, J = 4 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.3 (d, $J_{C\text{-}P}$ = 6 Hz), 133.6 (d, $J_{C\text{-}P}$ = 3 Hz), 132.1, 128.5, 124,5, 114.8 (d, $J_{C\text{-}P}$ = 194 Hz), 61.9 (d, $J_{C\text{-}P}$ = 5 Hz), 16.4 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.1. MS:m/z 318.0 (M^+).

(*E*)-diethyl 4-methylstyrylphosphonate (**2d**)[3]



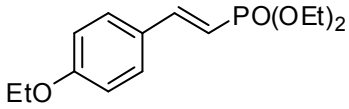
IR(KBr)/cm^{-1}: 2960, 2934, 2856, 1614, 1521, 1462, 1260, 1175, 1030, 961. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (d, J = 20 Hz, 1H), 7.42 (d, J = 12 Hz, 2H), 7.19 (d, J = 8 Hz, 2H), 6.20 (t, J = 20 Hz, 1H), 4.22-4.07 (m, 4H), 2.37 (s, 3H), 1.35 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.8 (d, $J_{C\text{-}P}$ = 6 Hz), 140.6, 132.1 (d, $J_{C\text{-}P}$ = 23 Hz), 129.5, 127.7, 112.4 (d, $J_{C\text{-}P}$ = 191 Hz), 61.7 (d, $J_{C\text{-}P}$ = 6 Hz), 21.4, 16.3 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 20.1. MS:m/z 254.1 (M^+).

(*E*)-diethyl 4-methoxystyrylphosphonate (**2e**) [1]



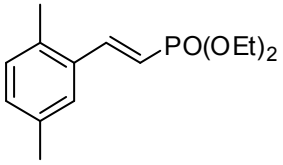
IR(KBr)/cm^{-1}: 2956, 2924, 2850, 1604, 1511, 1461, 1257, 1025, 751. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50-7.40 (m, 3H), 6.90 (d, J = 8 Hz, 2H), 6.08 (t, J = 20 Hz, 1H), 4.15- 4.08 (m, 4H), 3.84 (s, 3H), 1.35 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.3, 1.48.5 (d, $J_{C\text{-}P}$ = 7 Hz), 129.3, 127.5 (d, $J_{C\text{-}P}$ = 23 Hz), 114.2, 110.6 (d, $J_{C\text{-}P}$ = 192 Hz), 61.7 (d, $J_{C\text{-}P}$ = 5 Hz), 55.4, 16.3 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 20.5. MS:m/z 270.1 (M^+).

(*E*)-diethyl 4-ethoxystyrylphosphonate (**2f**) [1]



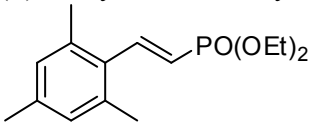
IR(KBr)/cm^{-1}: 2955, 2924, 2851, 1610, 1465, 1260, 1030, 788. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50-7.40 (m, 3H), 6.89 (d, J = 8 Hz, 2H), 6.08 (t, J = 16 Hz, 1H), 4.18-4.10 (m, 4H), 4.09-4.04 (m, 2H), 1.43 (t, J = 8 Hz, 3H), 1.35 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.7, 148.5 (d, $J_{C\text{-}P}$ = 7 Hz), 129.3, 127.4 (d, $J_{C\text{-}P}$ = 23 Hz), 114.7, 110.5 (d, $J_{C\text{-}P}$ = 192 Hz), 63.6, 61.7 (d, $J_{C\text{-}P}$ = 5 Hz), 16.4 (d, $J_{C\text{-}P}$ = 7 Hz), 14.7; ^{31}P NMR (162 MHz, $CDCl_3$): δ 20.6. MS:m/z 284.1 (M^+).

(*E*)-diethyl 2,5-dimethylstyrylphosphonate (**2g**)



IR(KBr)/cm^{-1}: 2963, 2935, 2860, 1614, 1520, 1455, 1256, 1160, 1031, 955.^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80-7.70 (m, 1H), 7.35 (s, 1H), 7.09 (s, 2H), 6.18 (t, J = 20 Hz, 1H), 4.17-4.10 (m, 4H), 2.39 (s, 3H), 2.33 (s, 3H), 1.36 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.5 (d, $J_{C\text{-}P}$ = 7 Hz), 135.7, 134.2, 133.6 (d, $J_{C\text{-}P}$ = 22 Hz), 130.7, 130.6, 136.5, 114.6 (d, $J_{C\text{-}P}$ = 189 Hz), 61.7 (d, $J_{C\text{-}P}$ = 6 Hz), 20.9, 19.2, 16.4 (d, $J_{C\text{-}P}$ = 7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.7. HRMS (EI, m/z): calcd for $C_{14}H_{21}O_3P^+$ [M^+]: 268.1228; Found: 268.1231.

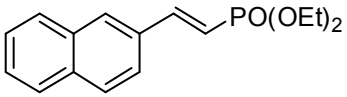
(*E*)-diethyl 2,4,6-trimethylstyrylphosphonate (**2h**)[4]



IR(KBr)/cm^{-1}: 2979, 2924, 1615, 1447, 1247, 1025, 963. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65-7.55 (m, 1H), 6.88 (d, J = 8 Hz, 2H), 5.87 (d, J = 20 Hz, 1H), 4.19-4.12 (m, 4H), 2.31(s, 6H), 2.28 (s,

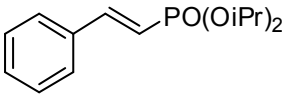
3H), 1.37 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.5 (d, $J_{C\text{-}P}$ = 6 Hz), 138.1, 136.0, 129.5 (d, $J_{C\text{-}P}$ = 6 Hz), 129.0, 119.8 (d, $J_{C\text{-}P}$ = 184 Hz), 61.7 (d, $J_{C\text{-}P}$ = 5 Hz), 20.9, 20.8, 16.3 (d, $J_{C\text{-}P}$ = 7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 18.8. MS:m/z 282.2 (M^+).

(*E*)-diethyl (2-(naphthalen-2-yl)vinyl)phosphonate (**2i**)[1]



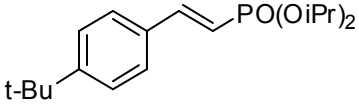
IR(KBr)/cm^{-1}: 2956, 2924, 2853, 1460, 1376, 1259, 1050, 1024, 668. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95-7.79 (m, 5H), 7.51 (d, J = 8 Hz, 3H), 6.37 (t, J = 20 Hz, 1H), 4.25-4.10 (m, 4H), 1.37 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.7 (d, $J_{C\text{-}P}$ = 7 Hz), 134.1, 133.1, 132.2 (d, $J_{C\text{-}P}$ = 23 Hz), 129.4, 128.6, 128.5, 127.7, 127.2, 126.7, 123.1, 113.8 (d, $J_{C\text{-}P}$ = 191 Hz), 61.8 (d, $J_{C\text{-}P}$ = 6 Hz), 16.3 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.7. MS:m/z 290.1 (M^+).

(*E*)-diisopropyl styrylphosphonate (**2j**)[5]



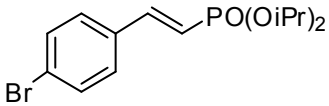
IR(KBr)/cm^{-1}: 3401, 2978, 1616, 1105, 984, 744. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54-7.44 (m, 3H), 7.38 (d, J = 4 Hz, 3H), 6.27 (t, J = 16 Hz, 1H), 4.76-4.68 (m, 2H), 1.37 (d, J = 8 Hz, 6H), 1.32 (d, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.9 (d, $J_{C\text{-}P}$ = 7 Hz), 134.9 (d, $J_{C\text{-}P}$ = 23 Hz), 130.0, 128.8, 127.6, 115.3 (d, $J_{C\text{-}P}$ = 191 Hz), 70.5 (d, $J_{C\text{-}P}$ = 6 Hz), 24.0 (d, $J_{C\text{-}P}$ = 5 Hz), 23.9 (d, $J_{C\text{-}P}$ = 4 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.4. MS:m/z 268.1 (M^+).

(*E*)-diisopropyl 4-(tert-butyl)styrylphosphonate (**2k**)



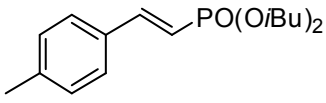
IR(KBr)/cm^{-1}: 2975, 2930, 2865, 2160, 1710, 1470, 1175, 975. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48-7.40 (m, 5H), 6.22 (t, J = 5 Hz, 1H), 4.74-4.68 (m, 2H), 1.37 (d, J = 4 Hz, 6H), 1.31 (d, J = 8 Hz, 15H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5, 117.7 (d, $J_{C\text{-}P}$ = 6 Hz), 132.2 (d, $J_{C\text{-}P}$ = 23 Hz), 127.44, 125.7, 114.4 (d, $J_{C\text{-}P}$ = 191 Hz), 70.3 (d, $J_{C\text{-}P}$ = 5 Hz), 34.8, 31.1, 24.1 (d, $J_{C\text{-}P}$ = 4 Hz), 23.9 (d, $J_{C\text{-}P}$ = 4 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.0. HRMS (EI, m/z): calcd for $C_{18}H_{29}O_3P^+$ [M^+]: 324.1854; Found: 324.1855.

(*E*)-diisopropyl 4-bromostyrylphosphonate (**2l**)



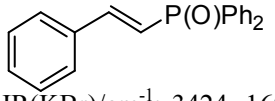
IR(KBr)/cm^{-1}: 3325, 2958, 2768, 1616, 1116, 988, 786. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.53-7.27 (m, 5H), 6.26 (t, J = 20 Hz, 1H), 4.76-4.69 (m, 2H), 1.37 (d, J = 8 Hz, 6H), 1.33 (d, J = 4 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.4 (d, $J_{C\text{-}P}$ = 7 Hz), 133.9 (d, $J_{C\text{-}P}$ = 24 Hz), 132.0, 129.1, 124.3, 116.3 (d, $J_{C\text{-}P}$ = 191 Hz), 70.6 (d, $J_{C\text{-}P}$ = 6 Hz), 24.1 (d, $J_{C\text{-}P}$ = 4 Hz), 24.0 (d, $J_{C\text{-}P}$ = 5 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.8. HRMS (EI, m/z): calcd for $C_{14}H_{20}BrO_3P^+$ [M^+]: 346.0333; Found: 346.0335.

(*E*)-diisobutyl 4-methylstyrylphosphonate (**2m**)



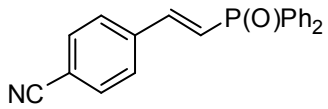
IR(KBr)/cm^{-1}: 2955, 2923, 2856, 1614, 1456, 1251, 1024, 966, 740. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58-7.48 (m, 3H), 7.45-7.39 (m, 2H), 6.27 (t, J = 16 Hz, 1H), 3.94-3.74 (m, 4H), 1.97 (t, J = 8 Hz, 2H), 0.96 (d, J = 8 Hz, 12H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 148.8, 134.8 (d, $J_{C\text{-}P}$ = 17 Hz), 132.2, 130.2 (d, $J_{C\text{-}P}$ =195 Hz), 128.1 (d, $J_{C\text{-}P}$ = 113 Hz), 113.5 (d, $J_{C\text{-}P}$ = 192 Hz), 71.8 (d, $J_{C\text{-}P}$ = 6 Hz), 29.1 (t, $J_{C\text{-}P}$ = 4 Hz), 18.7 (d, $J_{C\text{-}P}$ = 2 Hz), 18.6 (d, $J_{C\text{-}P}$ = 2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.6. HRMS (EI, m/z): calcd for $C_{17}H_{27}O_3P^+$ [M^+]: 310.1698; Found: 310.1700.

(*E*)-diphenyl(styryl)phosphine oxide (**2n**)[2]



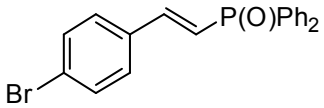
IR(KBr)/cm^{-1}: 3424, 1609, 1183, 1114, 745. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83-7.74 (m, 4H), 7.53-7.45 (m, 9H), 7.38 (d, J = 16 Hz, 3H), 6.85 (d, J = 20 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.4 (d, $J_{C\text{-}P}$ = 3 Hz), 134.9 (d, $J_{C\text{-}P}$ = 18 Hz), 133.4 (d, $J_{C\text{-}P}$ = 23 Hz), 132.1 (t, $J_{C\text{-}P}$ = 14 Hz), 131.8 (d, $J_{C\text{-}P}$ = 2 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10 Hz), 131.0 (d, $J_{C\text{-}P}$ = 10 Hz), 119.0 (d, $J_{C\text{-}P}$ = 104 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 24.5. MS:m/z 304.1 (M^+).

(*E*)-4-(2-(diphenylphosphoryl)vinyl)benzonitrile (**2o**)[2]



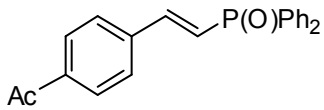
IR(KBr)/cm^{-1}: 3396, 2925, 1605, 1436, 1121, 1026, 726, 526. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (t, J = 8 Hz, 4H), 7.69-7.61 (m, 4H), 7.58- 7.46 (m, 7H), 6.99 (t, J = 16 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.2, 139.1 (d, $J_{C\text{-}P}$ = 18 Hz), 132.6, 132.5, 132.2 (d, $J_{C\text{-}P}$ = 2 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10 Hz), 128.8 (d, $J_{C\text{-}P}$ = 12 Hz), 128.2, 123.5 (d, $J_{C\text{-}P}$ = 100 Hz), 118.3, 113.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 24.2. MS:m/z 329.1 (M^+).

(*E*)-(4-bromostyryl)diphenylphosphine oxide (**2p**)[6]



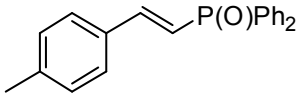
IR(KBr)/cm^{-1}: 3435, 3055, 1603, 1510, 1183, 1119, 510. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (t, J = 8 Hz, 4H), 7.56-7.45 (m, 9H), 7.38 (d, J = 8 Hz, 2H), 6.84 (t, J = 20 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 146.1 (d, $J_{C\text{-}P}$ = 4 Hz), 133.9 (d, $J_{C\text{-}P}$ = 18 Hz), 133.0, 132.0, 131.9, 131.3 (d, $J_{C\text{-}P}$ = 10 Hz), 129.2, 128.6 (d, $J_{C\text{-}P}$ = 12 Hz), 124.3, 119.8 (d, $J_{C\text{-}P}$ = 103 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 24.6. MS:m/z 382.0 (M^+).

(*E*)-1-(4-(2-(diphenylphosphoryl)vinyl)phenyl)ethanone (**2q**)[6]



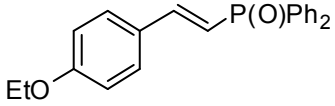
IR(KBr)/cm^{-1}: 3422, 2926, 1603, 1510, 1258, 1177, 517. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (t, J = 8 Hz, 4H), 7.54 (d, J = 8 Hz, 4H), 7.47 (t, J = 8 Hz, 5H), 7.12 (t, J = 8 Hz, 2H), 6.81 (t, J = 20 Hz, 1Hz), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 151.8, 146.3 (d, $J_{C\text{-}P}$ = 4 Hz), 131.8 (d, $J_{C\text{-}P}$ = 3 Hz), 131.2 (d, $J_{C\text{-}P}$ = 10 Hz), 130.8 (t, $J_{C\text{-}P}$ = 4 Hz), 128.8, 128.5 (d, $J_{C\text{-}P}$ = 12 Hz), 121.9, 121.6, 119.0 (d, $J_{C\text{-}P}$ = 104 Hz), 21.0; ^{31}P NMR (162 MHz, $CDCl_3$): δ 25.0. MS:m/z 346.1 (M^+).

(*E*)-(4-methylstyryl)diphenylphosphine oxide (**2r**)[2]



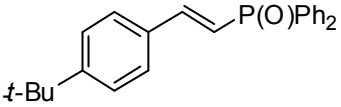
IR(KBr)/cm^{-1}: 3402, 2960, 1602, 1431, 1064, 768, 538. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (t, J = 8 Hz, 4H), 7.52-7.41 (m, 9H), 7.19 (t, J = 8 Hz, 2H), 6.78 (t, J = 20 Hz, 1H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 147.4 (d, $J_{C\text{-}P}$ = 3 Hz), 140.4, 133.3 (d, $J_{C\text{-}P}$ = 105 Hz), 132.2 (d, $J_{C\text{-}P}$ = 18 Hz), 131.7 (d, $J_{C\text{-}P}$ = 3 Hz), 131.3 (d, $J_{C\text{-}P}$ = 9 Hz), 131.0 (q, $J_{C\text{-}P}$ = 82 Hz), 128.5 (d, $J_{C\text{-}P}$ = 12 Hz), 118.0 (d, $J_{C\text{-}P}$ = 104 Hz), 21.3; ^{31}P NMR (162 MHz, $CDCl_3$): δ 25.1. MS:m/z 318.1 (M^+).

(*E*)-(4-ethoxystyryl)diphenylphosphine oxide (**2s**)



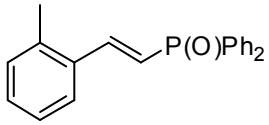
IR(KBr)/cm^{-1}: 3402, 2895, 1622, 1425, 1065, 775, 538. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (t, J = 8 Hz, 4H), 7.53-7.38 (m, 9H), 6.88 (d, J = 8 Hz, 2H), 6.66 (t, J = 20 Hz, 1H), 4.07-4.02 (m, 2H), 1.41 (t, J = 8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.5, 147.1 (d, $J_{C\text{-}P}$ = 4 Hz), 133.0 (d, $J_{C\text{-}P}$ = 105 Hz), 131.7 (d, $J_{C\text{-}P}$ = 2 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10 Hz), 129.3, 128.5 (d, $J_{C\text{-}P}$ = 12 Hz), 127.6 (d, $J_{C\text{-}P}$ = 18 Hz), 115.6 (d, $J_{C\text{-}P}$ = 106 Hz), 114.6, 63.5, 14.6; ^{31}P NMR (162 MHz, $CDCl_3$): δ 25.1. HRMS (EI, m/z): calcd for $C_{22}H_{21}O_2P^+$ [M^+]:348.1279; Found: 348.1280.

(*E*)-(4-(tert-butyl)styryl)diphenylphosphine oxide (**2t**)



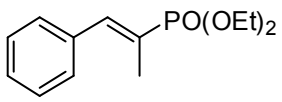
IR(KBr)/cm^{-1}: 3389, 2895, 2768, 1650, 1410, 1064, 778, 540.^{1}H NMR (400 MHz, $CDCl_3$): δ 4.76 (t, J = 8 Hz, 4H), 7.55-7.38 (m, 11H), 6.80 (t, J = 20 Hz, 1H), 1.30 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153. 6, 147.5 (d, $J_{C\text{-}P}$ = 3 Hz), 132.8 (d, $J_{C\text{-}P}$ = 106 Hz), 131.9 (d, $J_{C\text{-}P}$ = 2 Hz), 131.4 (d, $J_{C\text{-}P}$ = 10 Hz), 131.2 (d, $J_{C\text{-}P}$ = 9 Hz), 128.6 (d, $J_{C\text{-}P}$ = 12 Hz), 127.7, 125.8, 117.8 (d, $J_{C\text{-}P}$ = 104 Hz), 34.9, 31.2; ^{31}P NMR (162 MHz, $CDCl_3$): δ 25.3. HRMS (EI, m/z): calcd for $C_{24}H_{25}OP^+$ [M^+]: 360.1643; Found: 360.1640.

(*E*)-(2-methylstyryl)diphenylphosphine oxide (**2u**)[2]



IR(KBr)/cm^{-1}: 3405, 2863, 2754, 1645, 1260, 1006, 886.^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (t, J = 8 Hz, 3H), 7.48-7.36 (m, 9H), 6.40 (d, J = 24 Hz, 1H), 2.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3 (d, $J_{C\text{-}P}$ = 2 Hz), 141.8 (d, $J_{C\text{-}P}$ = 17 Hz), 131.4 (d, $J_{C\text{-}P}$ = 3 Hz), 130.8 (d, $J_{C\text{-}P}$ = 10 Hz), 129.1, 128. 6, 128.5, 128.4, 118.0 (d, $J_{C\text{-}P}$ = 104 Hz), 19.6 (d, $J_{C\text{-}P}$ = 8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 22.0. MS:m/z 318.1 (M^+).

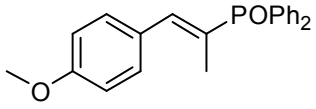
(*E*)-diethyl (1-phenylprop-1-en-2-yl)phosphonate (**2v**)[7]



IR(KBr)/cm^{-1}: 2955, 2924, 2853, 1681, 1256, 1051, 1024, 677. ^{1}H NMR (400 MHz, $CDCl_3$): δ7.51-7.28 (m, 6H), 4.16-4.08 (m, 4H), 2.08 (d, J = 16 Hz, 3H), 1.33 (t, J = 8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.6 (d, $J_{C\text{-}P}$ = 11 Hz), 135.5 (d, $J_{C\text{-}P}$ = 23 Hz), 133.3 (d, $J_{C\text{-}P}$ = 196 Hz),

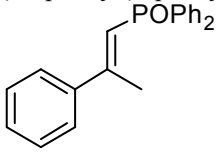
129.4, 128.3, 61.7 (d, $J_{C\text{-}P}$= 6 Hz), 16.3 (t, $J_{C\text{-}P}$= 6 Hz), 14.2 (d, $J_{C\text{-}P}$= 9 Hz);^{31}P NMR (162 MHz, $CDCl_3$): δ 22.2. MS:m/z 254.1 (M^+).

(*E*)-(1-(4-methoxyphenyl)prop-1-en-2-yl)diphenylphosphine oxide (**2w**)



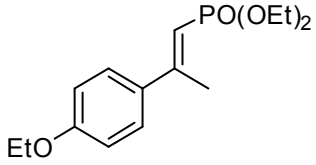
IR(KBr)/cm^{-1}: 3405, 2858,2825, 1645, 1260, 1026, 796. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (t, *J* = 8 Hz, 2H), 7.86 (d, *J* = 8 Hz, 2H), 7.74 (t, *J* = 8 Hz, 2H), 7.50 (d, *J* = 8 Hz, 2H), 7.46 (d, *J* = 8 Hz, 3H), 7.39 (d, *J* = 8 Hz, 2H), 6.82 (d, *J* = 8 Hz, 2H), 3.83 (s, 3H), 1.55 (dd, *J* = 16 Hz, *J* = 4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.6, 132.0 (d, $J_{C\text{-}P}$= 2 Hz), 131.8 (d, $J_{C\text{-}P}$= 9 Hz), 131.5 (d, $J_{C\text{-}P}$= 9 Hz),130.5 (d, $J_{C\text{-}P}$= 16 Hz), 130.3 (d, $J_{C\text{-}P}$= 49 Hz),128.5 (d, $J_{C\text{-}P}$= 5 Hz), 128.3 (d, $J_{C\text{-}P}$= 5 Hz), 55.5, 45.4 (d, $J_{C\text{-}P}$= 60 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.9. HRMS (EI, m/z): calcd for $C_{22}H_{21}O_2P^+$ [M^+]: 348.1279; Found: 348.1281.

(*E*)-diphenyl(2-phenylprop-1-en-1-yl)phosphine oxide (**2x**)[8]



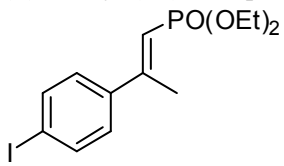
IR(KBr)/cm^{-1}: 3415, 2798, 1655, 1255, 1026, 776.^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (t, *J* = 8 Hz, 4H), 7.59-7.36 (m, 11H), 6.40 (d, *J* = 24 Hz, 1H), 2.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3, 141.8 (d, $J_{C\text{-}P}$= 17 Hz), 134.4 (d, $J_{C\text{-}P}$= 104 Hz), 131.4 (d, $J_{C\text{-}P}$= 2 Hz), 130.8 (d, $J_{C\text{-}P}$= 10 Hz), 129.1, 128.6, 128.4 (d, $J_{C\text{-}P}$= 7 Hz), 125.8, 118.3 (d, $J_{C\text{-}P}$= 104 Hz), 19.6 (d, $J_{C\text{-}P}$= 8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 22.0. MS:m/z 318.1 (M^+).

(*E*)-diethyl (2-(4-ethoxyphenyl)prop-1-en-1-yl)phosphonate (**2y**)



IR(KBr)/cm^{-1}: 2956, 2924, 2850, 1610, 1465, 1260, 788. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.45-7.43 (d, *J* = 8 Hz, 2H), 6.88 (d, *J* = 8 Hz, 2H), 5.85 (d, *J* = 16 Hz, 1H), 4.15-4.08 (m, 4H), 4.06-4.01 (m, 2H), 2.48 (s, 3H), 1.43 (t, *J* = 8 Hz, 3H), 1.35 (t, *J* = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.9, 156.4 (d, $J_{C\text{-}P}$= 8 Hz), 132.5 (d, $J_{C\text{-}P}$= 24 Hz), 136.3, 113.2, 119.9 (d, $J_{C\text{-}P}$= 191 Hz), 62.52, 60.4 (d, $J_{C\text{-}P}$= 6 Hz), 18.0 (d, $J_{C\text{-}P}$= 8 Hz), 15.4 9(d, $J_{C\text{-}P}$= 7 Hz), 13.7; ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.1. HRMS (EI, m/z): calcd for $C_{15}H_{23}O_4P^+$ [M^+]: 298.1334; Found: 298.1337.

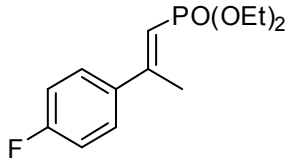
(*E*)-diethyl (2-(4-iodophenyl)prop-1-en-1-yl)phosphonate (**2z**)



IR(KBr)/cm^{-1}: 2957, 2925, 2854, 1251, 1051, 1027, 961, 803. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8 Hz, 2H), 7.20 (d, *J* = 8 Hz, 2H), 5.90 (d, *J* = 16 Hz, 1H), 4.16-4.09 (m, 4H), 3.47 (s, 3H),1.36 (t, *J* = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.8 (d, $J_{C\text{-}P}$= 9 Hz), 141.1 (d, $J_{C\text{-}P}$= 23 Hz), 137.6, 137.1 (d, $J_{C\text{-}P}$= 12 Hz), 127.7, 114.5 (d, $J_{C\text{-}P}$= 189 Hz), 61.6 (d, $J_{C\text{-}P}$= 5 Hz), 19.0 (d, $J_{C\text{-}P}$= 7 Hz), 16.4 (d, $J_{C\text{-}P}$= 7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 17.7. HRMS (EI, m/z): calcd

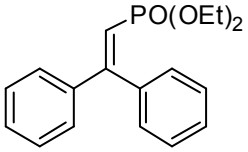
for $C_{13}H_{18}O_3IP^+$ [M^+]: 380.0038; Found: 380.0041.

(E)-diethyl (2-(4-fluorophenyl)prop-1-en-1-yl)phosphonate (**2aa**)[8]



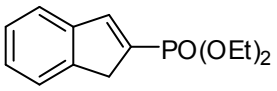
IR(KBr)/cm^{-1}: 2960, 2914, 2846, 1620, 1465, 1258, 768. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48-7.44 (m, 2H), 7.06 (t, J = 8 Hz, 2H), 5.86 (d, J = 16 Hz, 1H), 4.17-4.10 (m, 4H), 2.49 (d, J = 4 Hz, 3H), 1.36 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.5, 162.0, 156.8 (d, $J_{C\text{-}P}$ = 9 Hz), 127.8 (d, $J_{C\text{-}P}$ = 8 Hz), 115.49, 115.28, 113.4 (d, $J_{C\text{-}P}$ = 190 Hz), 61.5 (d, $J_{C\text{-}P}$ = 6 Hz), 19.3 (d, $J_{C\text{-}P}$ = 7 Hz), 16.4 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.1. MS:m/z 336.1 (M+).

diethyl (2,2-diphenylvinyl)phosphonate (**2ab**)[8]



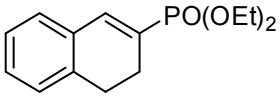
IR(KBr)/cm^{-1}: 2958, 2914, 2846, 1626, 1462, 1258, 1056, 998, 865, 706. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38-7.27 (m, 10H), 6.19 (d, J = 16 Hz, 1H), 3.95-3.79 (m, 4H), 1.13 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.0 (d, $J_{C\text{-}P}$ = 6 Hz), 141.5 (d, $J_{C\text{-}P}$ = 22 Hz), 138.8 (d, $J_{C\text{-}P}$ = 7 Hz), 129.7 (d, $J_{C\text{-}P}$ = 2 Hz), 129.3, 128.6, 128.2, 127.9 (d, $J_{C\text{-}P}$ = 28 Hz), 125.6, 114.7 (d, $J_{C\text{-}P}$ = 192 Hz), 61.4 (d, $J_{C\text{-}P}$ = 6 Hz), 16.1 (d, $J_{C\text{-}P}$ = 7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.7. MS:m/z 316.1 (M+).

diethyl 1*H*-inden-2-ylphosphonate (**2ac**)[9]



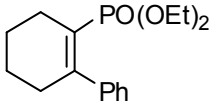
IR(KBr)/cm^{-1}: 2960, 2925, 2867, 1444, 1242, 1051, 1025, 864, 794, 697. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 (d, J = 12 Hz, 1H), 7.52 (d, J = 8 Hz, 2H), 7.34-7.28 (m, 2H), 4.19-4.10 (m, 4H), 3.65 (s, 2H), 1.35 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.4, 145.3 (d, $J_{C\text{-}P}$ = 3 Hz), 142.5 (d, $J_{C\text{-}P}$ = 20 Hz), 133.3 (d, $J_{C\text{-}P}$ = 189 Hz), 127.2, 126.8, 124.0 (d, $J_{C\text{-}P}$ = 2 Hz), 122.8, 61.9 (d, $J_{C\text{-}P}$ = 5 Hz), 40.0 (d, $J_{C\text{-}P}$ = 14 Hz), 16.3 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 16.2. MS:m/z 252.1 (M^+).

diethyl (3,4-dihydronaphthalen-2-yl)phosphonate (**2ad**)



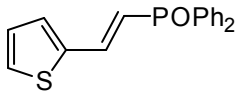
IR(KBr)/cm^{-1}: 2956, 2924, 1253, 1055, 1023, 968, 762. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (d, J = 20 Hz, 1H), 7.26-7.14 (m, 4H), 4.15-4.09 (m, 4H), 2.86 (t, J = 8 Hz, 2H), 2.47 (t, J = 8 Hz, 2H), 1.35 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.4 (d, $J_{C\text{-}P}$ = 10 Hz), 136.2 (d, $J_{C\text{-}P}$ = 2 Hz), 132.0 (d, $J_{C\text{-}P}$ = 19 Hz), 129.9 (d, $J_{C\text{-}P}$ = 43 Hz), 128.3 (d, $J_{C\text{-}P}$ = 50 Hz), 128.0, 127.3 (d, $J_{C\text{-}P}$ = 63 Hz), 126.3 (d, $J_{C\text{-}P}$ = 88 Hz), 61.8 (d, $J_{C\text{-}P}$ = 6 Hz), 27.2 (d, $J_{C\text{-}P}$ = 9 Hz), 22.7 (d, $J_{C\text{-}P}$ = 9 Hz), 16.4 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 19.9. HRMS (EI, m/z): calcd for $C_{14}H_{19}O_3P^+$ [M^+]: 266.1072; Found: 266.1073.

diethyl (3,4,5,6-tetrahydro-[1,1'-biphenyl]-2-yl)phosphonate (**2ae**)



IR(KBr)/cm^{-1}: 2954, 2924, 2842, 1454, 1222, 1024, 745. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (d, J = 8 Hz, 3H), 7.21 (t, J = 8 Hz, 2H), 3.95-3.86 (m, 4H), 3.84-3.74 (m, 2H), 3.56-3.46 (m, 2H), 3.27 (d, J = 24 Hz, 2H), 2.14-2.04 (m, 2H), 1.13 (t, J = 8 Hz, 6H), 0.94 (t, J = 8 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.7, 133.2 (d, $J_{C\text{-}P}$ = 9 Hz), 130.7 (d, $J_{C\text{-}P}$ = 12 Hz), 128.0, 126.7, 126.5, 61.5 (d, $J_{C\text{-}P}$ = 7 Hz), 61.3 (d, $J_{C\text{-}P}$ = 7 Hz), 36.4, 35.0, 25.4 (d, $J_{C\text{-}P}$ = 4 Hz), 23.8 (d, $J_{C\text{-}P}$ = 4 Hz), 18.5 (d, $J_{C\text{-}P}$ = 2 Hz), 16.1 (d, $J_{C\text{-}P}$ = 6 Hz), 16.0 (d, $J_{C\text{-}P}$ = 6 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 29.2. HRMS (EI, m/z): calcd for $C_{16}H_{23}O_3P^+$ [M^+]: 294.1385; Found: 294.1387.

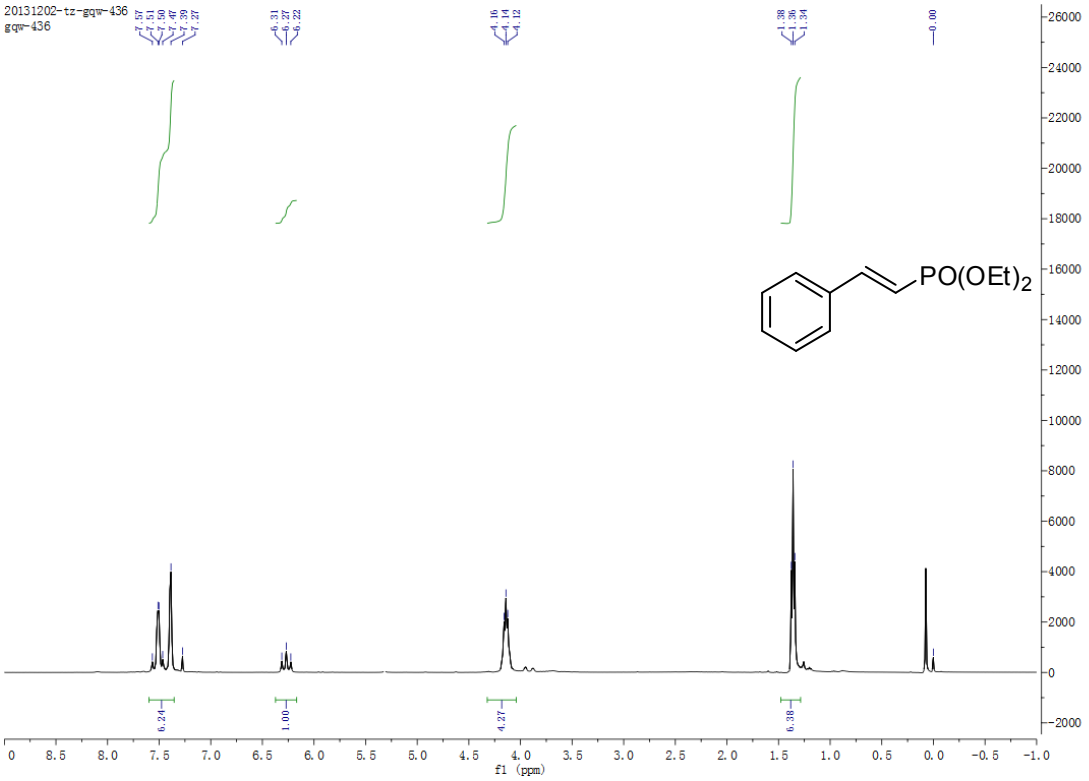
(*E*)-(2-(thiophen-2-yl)vinyl) diphenylphosphine oxide (**2af**)[5]

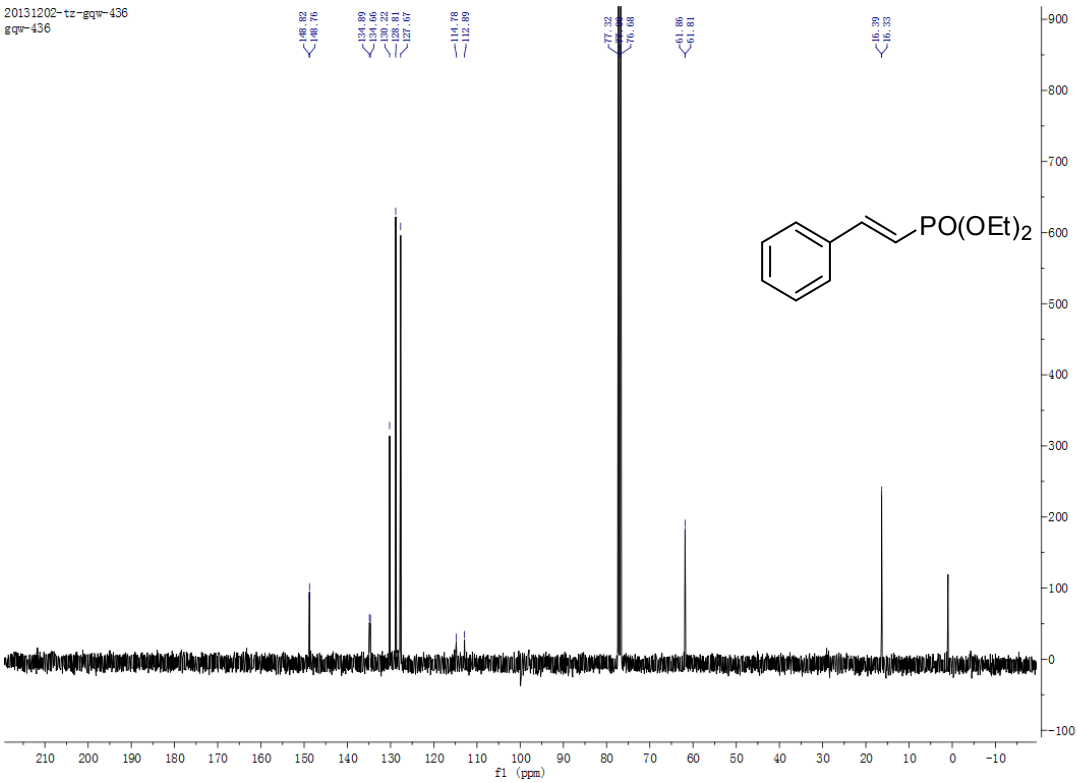


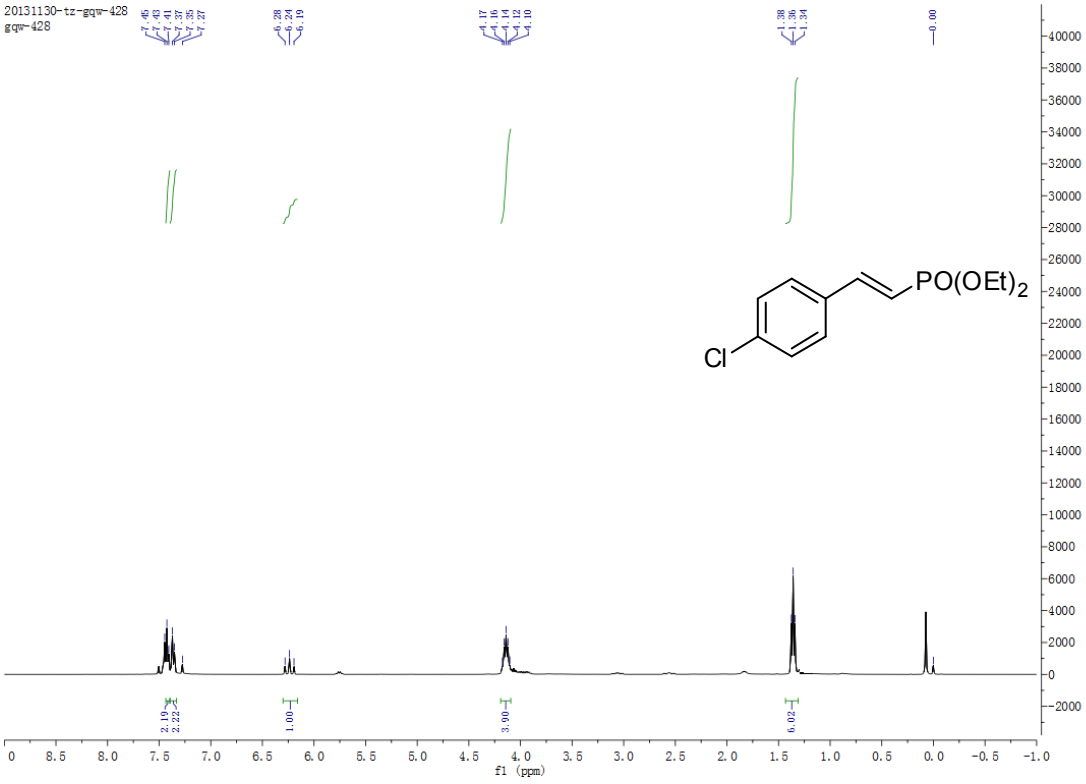
IR(KBr)/cm^{-1}: 3451, 2820, 1616, 1206, 1125, 864, 755. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77-7.72 (m, 4 H), 7.60-7.48 (m, 7 H), 7.35 (d, J = 4 Hz, 1 H), 7.19 (d, J = 4 Hz, 1 H), 7.03 (d, J = 4 Hz, 1 H), 6.58 (dd, J = 20 Hz, J = 16 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.9, 140.6, 140.0 (d, $J_{C\text{-}P}$ = 4 Hz), 133.2 (d, $J_{C\text{-}P}$ = 106 Hz), 131.8 (d, $J_{C\text{-}P}$ = 2 Hz), 131.3 (d, $J_{C\text{-}P}$ = 10 Hz), 130.1, 128.6 (d, $J_{C\text{-}P}$ = 12 Hz), 128.0 (d, $J_{C\text{-}P}$ = 4 Hz),118.0 (d, $J_{C\text{-}P}$ = 106 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 22.4. MS:m/z 310.1 (M^+).

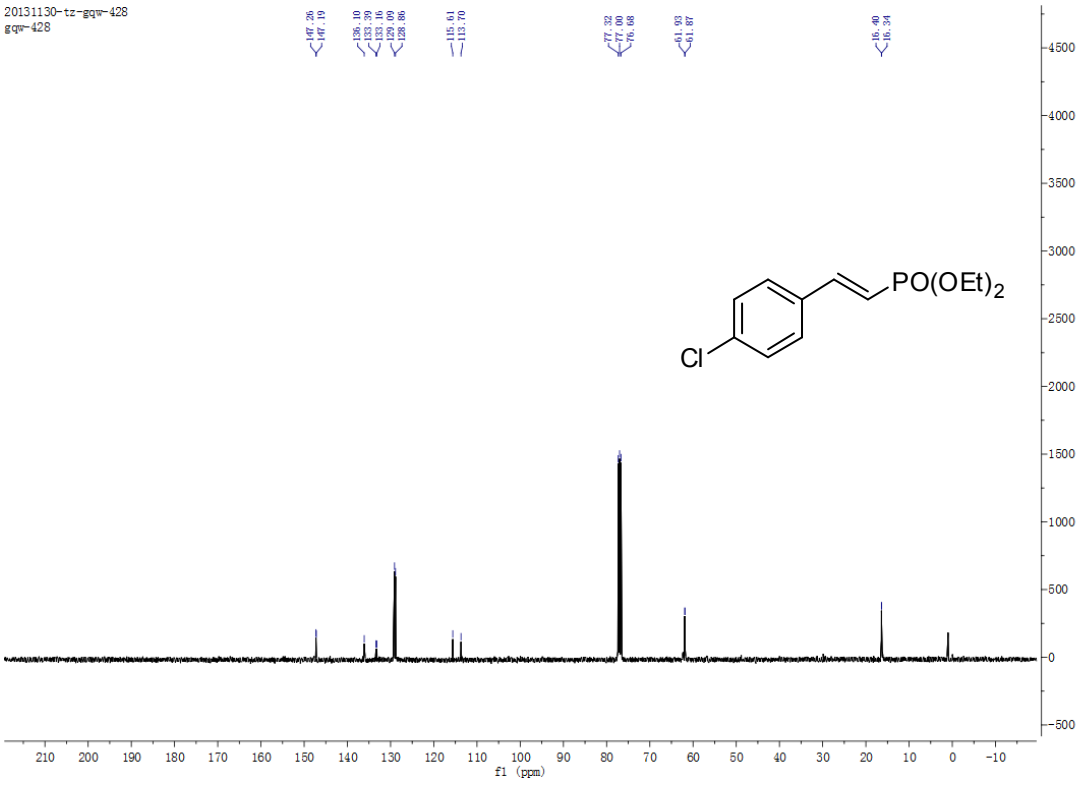
References:

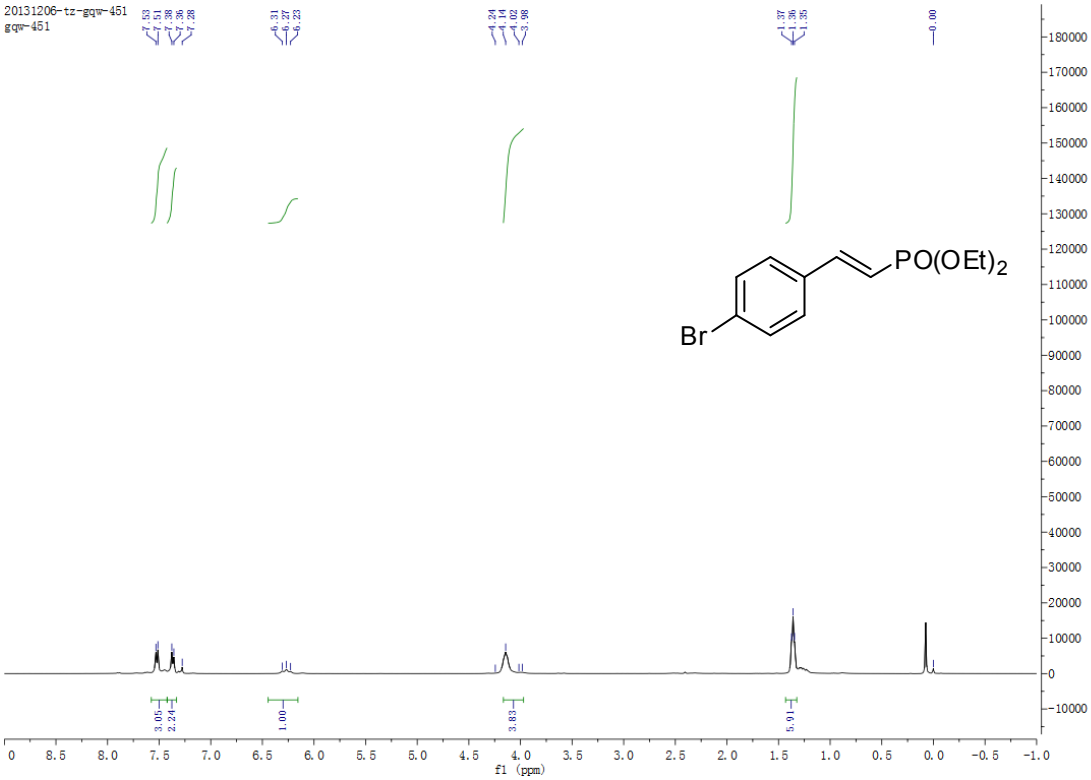
1. W. Al-Maksoud, J. Mesnager, F. Jaber, C. Pinel, L. Djakovitch, *J. Organomet. Chem.* 2009, **694**, 3222.
2. J. Hu, N. Zhao, B. Yang, G. Wang, L.-N. Guo, Y.-M. Liang, S.-D. Yang, *Chem. Eur. J.* 2011, **17**, 5516.
3. C. Wang, Y. Pan, D. Yang, *J. Organomet. Chem.* 2005, **690**, 1705.
4. H. Lahrache, S. Robin, G. Rousseau, *Tetrahedron L.* 2005, **46**, 1635.
5. Y. Wu, L. Liu, K. Yan, P. Xu, Y. Gao, Y. Zhao, *J. Org. Chem.* 2014, **79**, 8118.
6. G. Hu, Y. Gao, Y. Zhao, *Org. Lett.* 2014, **16**, 4464.
7. G. W. Kabalka, S. K. Guchhait, *Org. Lett.* 2003, 5, 729.
8. Z.-C. Duan, X.-P. Hu, D.-Y. Wang, J.-D. Huang, S.-B. Yu, J. Deng, Z. Zheng, *Adv. Synth. Catal.* 2008, **350**, 1979.
9. D. N. Kazulkin, A. N. Ryabov, V. V. Izmer, A. V. Churakov, I. P. Beletskaya, C. J. Burns, A. Z. Voskoboynikov, *Organometallics* 2005, **24**, 3024.

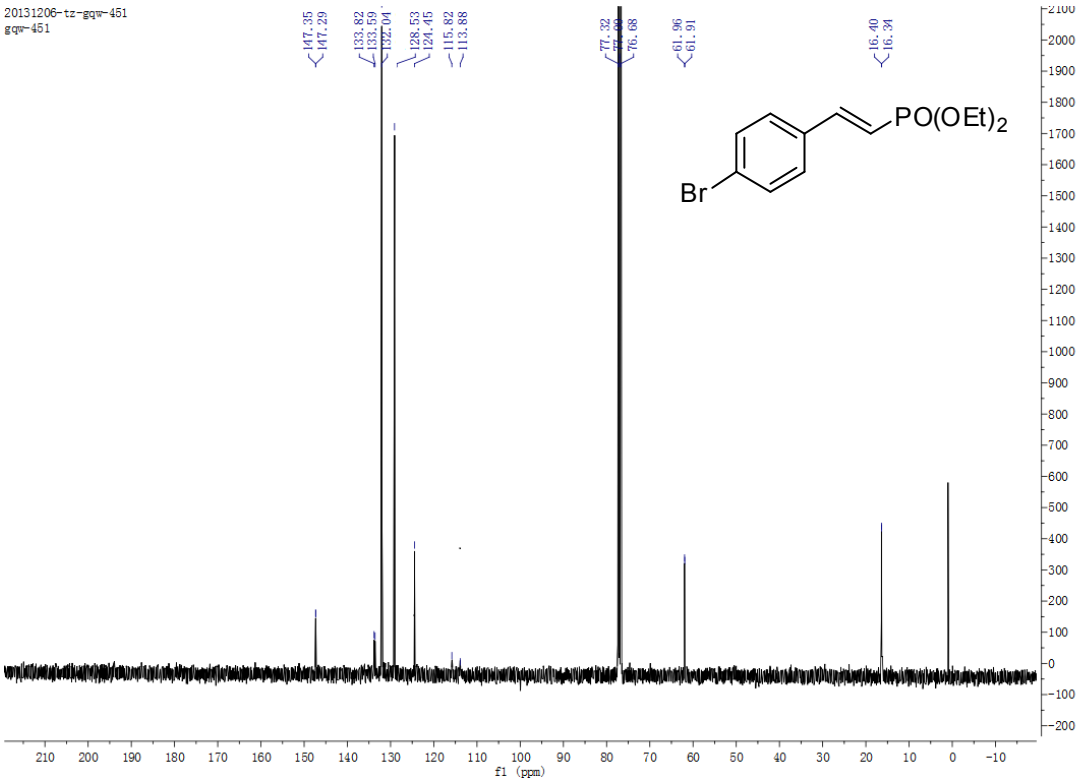

20131202-tz-gqw-436
gqw-436
7.57
7.51
7.50
7.47
7.39
7.27
6.31
6.27
6.22
4.16
4.14
4.12
1.38
1.36
1.34
0.00
PO(OEt)2
6.24
1.00
4.27
6.38
f1 (ppm)

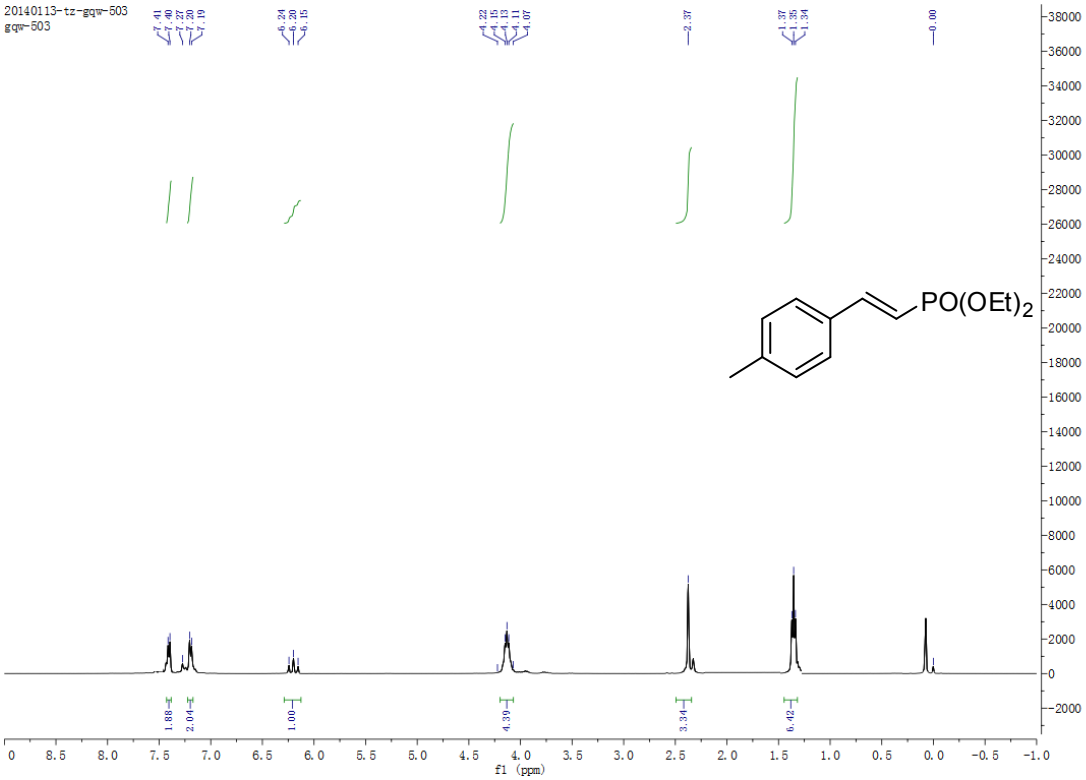

20131202-tz-gqw-436
gqw-436
148.82
148.76
134.89
134.46
130.22
128.81
127.67
114.78
112.89
77.32
77.00
76.68
61.86
61.81
16.39
16.33
PO(OEt)2
f1 (ppm)

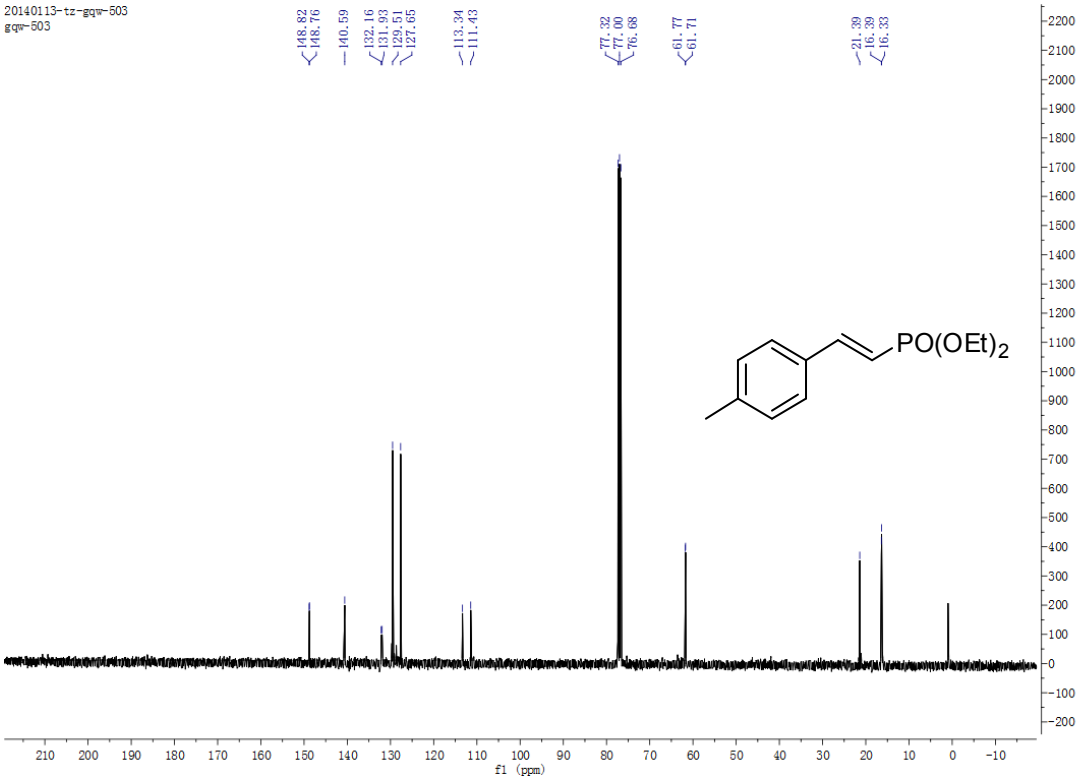

20131130-tz-gqw-428
gqw-428
PO(OEt)2
Cl
f1 (ppm)

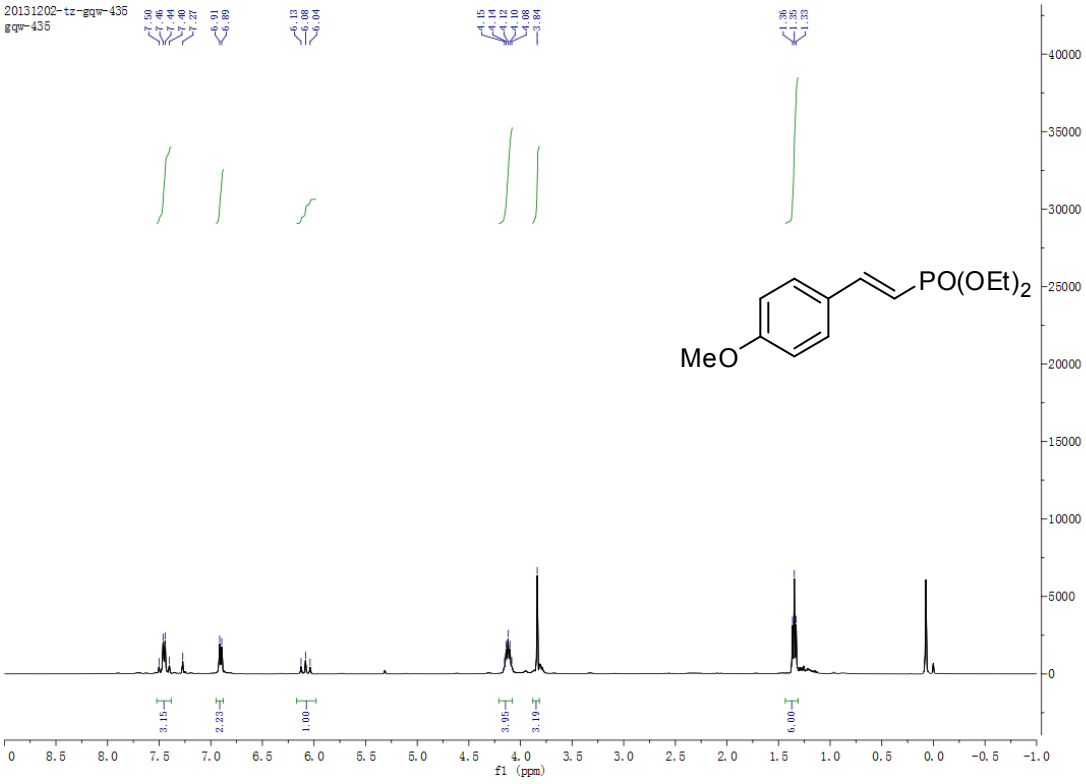

20131130-tz-gqw-428
gqw-428
PO(OEt)2
Cl
f1 (ppm)

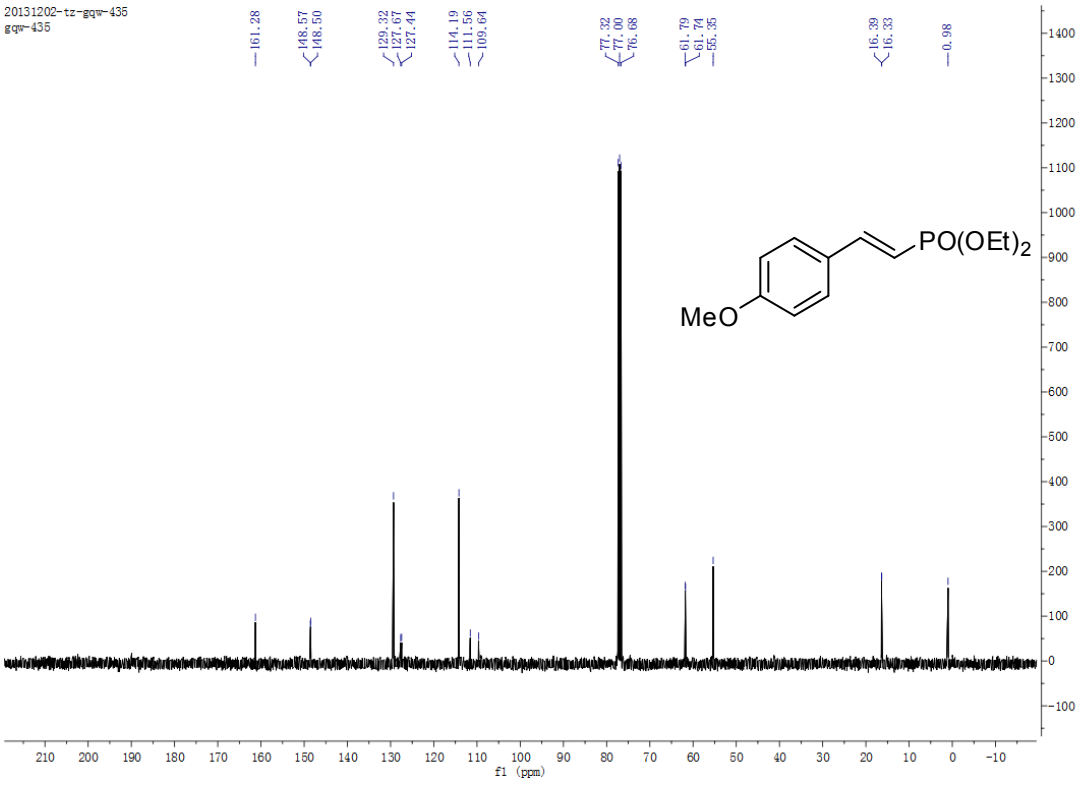

20131206-tz-gqw-451
gqw-451
7.53
7.51
7.38
7.36
7.28
6.31
6.27
6.23
4.24
4.14
4.02
3.98
1.37
1.36
1.35
0.00
PO(OEt)2
Br
3.05
2.24
1.00
3.83
5.91
f1 (ppm)

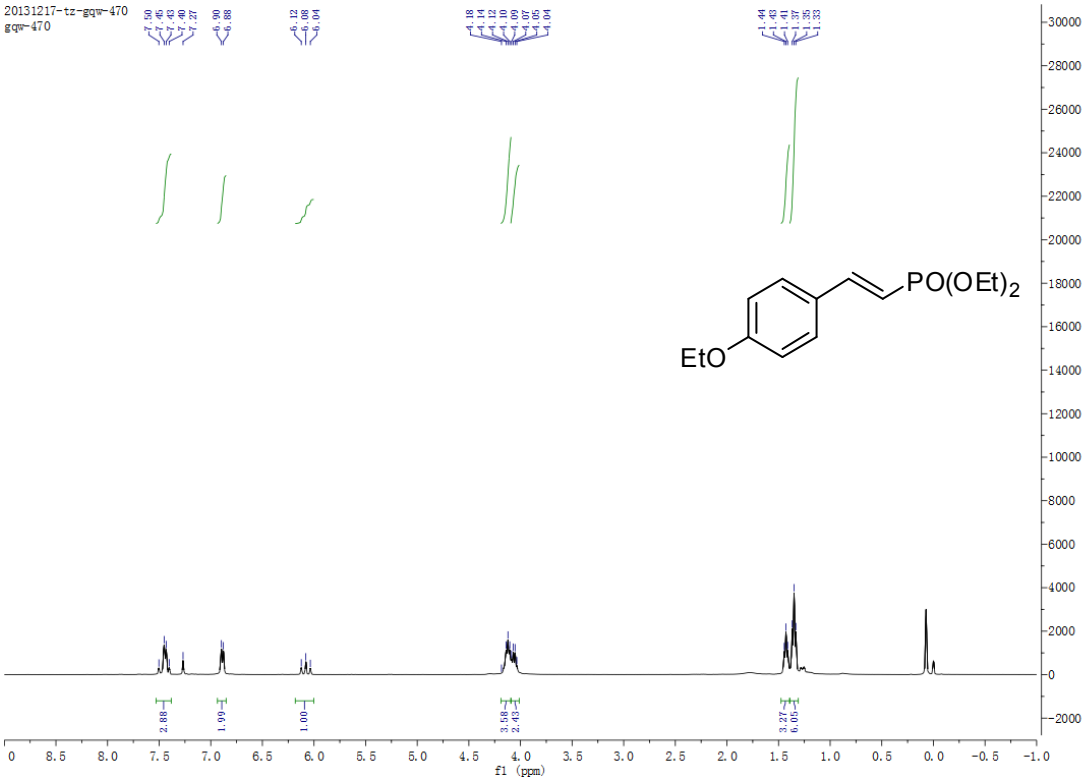

20131206-tz-gqw-451
gqw-451
147.35
147.29
133.82
133.59
132.04
128.53
124.45
115.82
113.88
77.32
77.00
76.68
61.96
61.91
16.40
16.34
PO(OEt)2
Br
f1 (ppm)

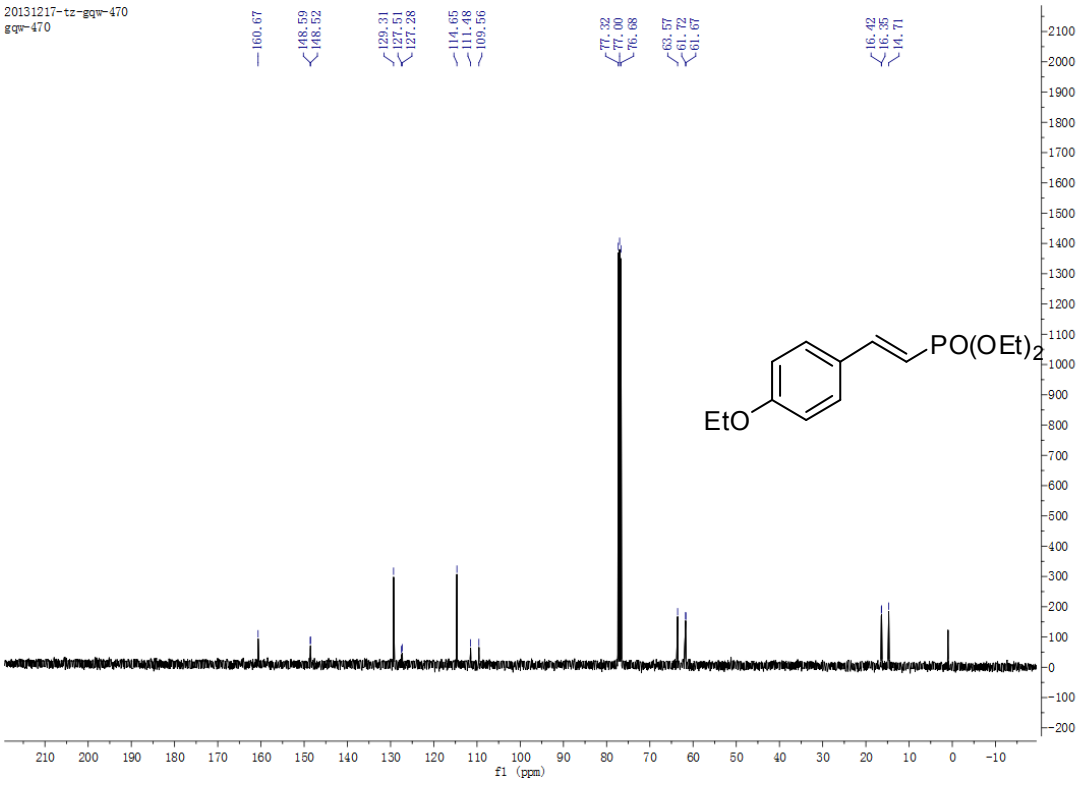

20140113-tz-gqw-503
gqw-503
7.41
7.40
7.27
7.26
7.19
6.24
6.20
6.15
4.22
4.15
4.13
4.11
4.07
2.37
1.37
1.35
1.34
0.00
PO(OEt)2
1.88
2.04
1.00
4.39
3.34
6.42
f1 (ppm)

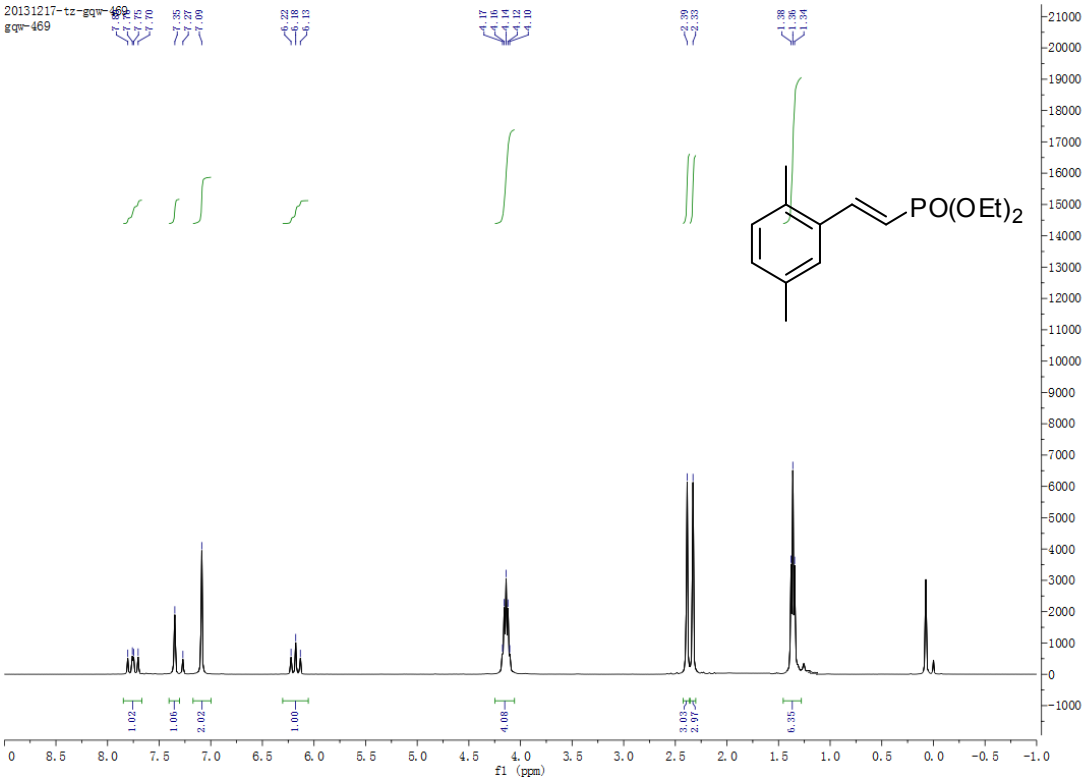

20140113-tz-gqw-503
gqw-503
148.82
148.76
140.59
132.16
131.93
129.51
127.65
113.34
111.43
77.32
77.00
76.68
61.77
61.71
21.39
16.39
16.33
PO(OEt)2
f1 (ppm)

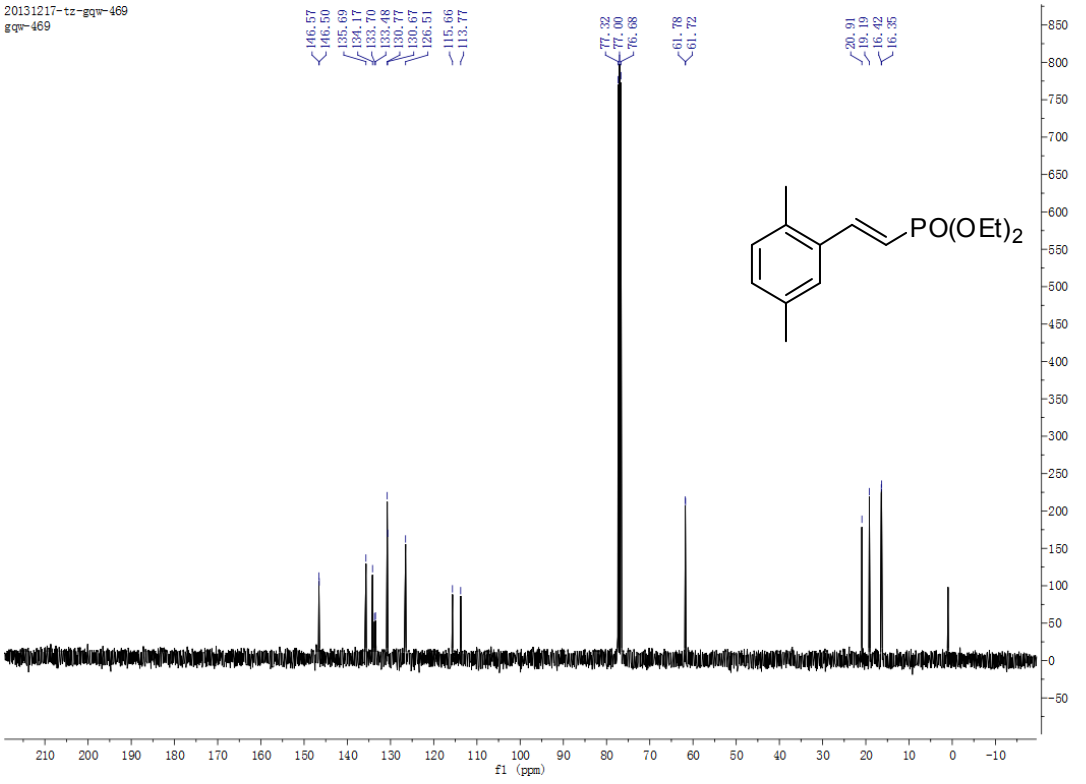

20131202-tz-gqw-435
gqw-435
7.50
7.46
7.44
7.40
7.27
6.91
6.89
6.13
6.08
6.04
4.15
4.14
4.12
4.10
4.08
3.84
1.36
1.35
1.33
PO(OEt)2
MeO
3.15
2.23
1.00
3.95
3.19
6.00
f1 (ppm)

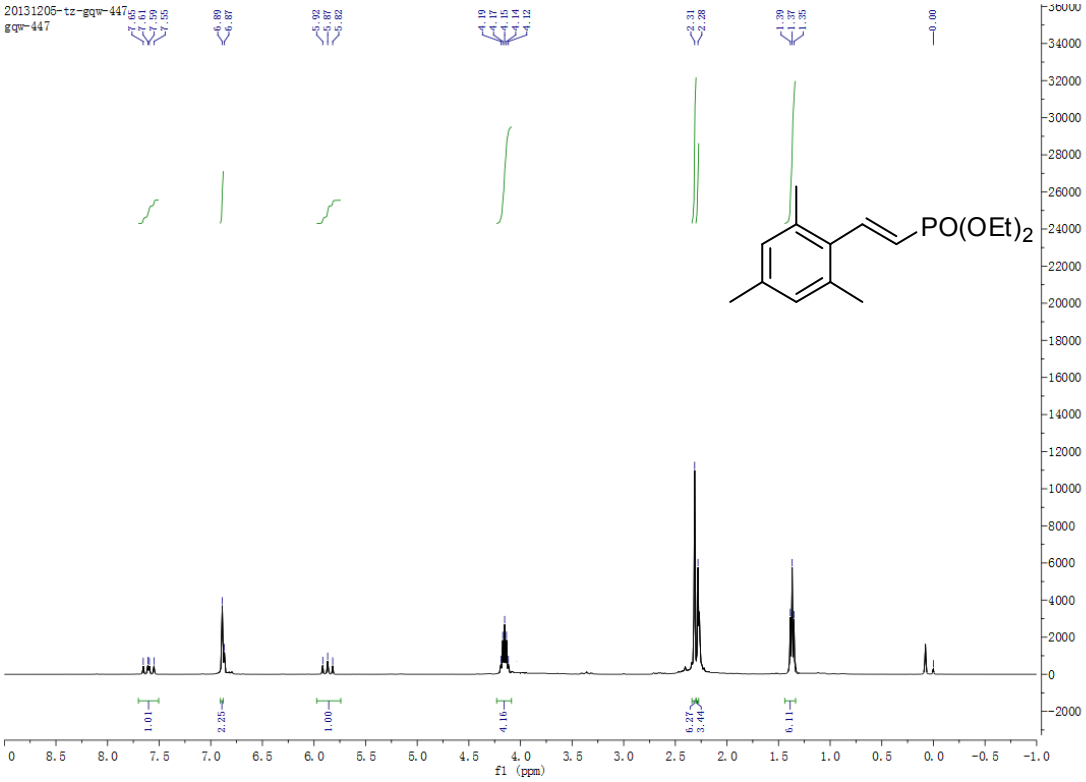

20131202-tz-gqw-435
gqw-435
161.28
148.57
148.50
129.32
127.67
127.44
114.19
111.56
109.64
77.32
77.00
76.68
61.79
61.74
55.35
16.39
16.33
0.98
PO(OEt)2
MeO
f1 (ppm)

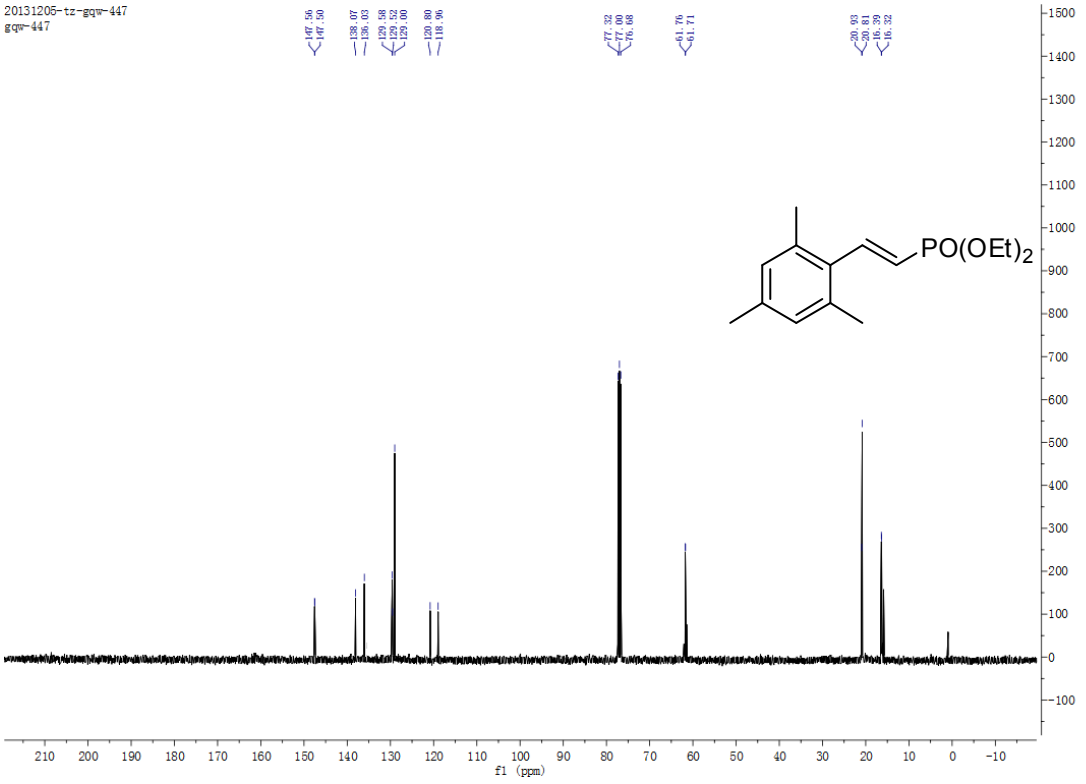

20131217-tz-gqw-470
gqw-470
7.50
7.46
7.43
7.40
7.27
6.90
6.88
6.12
6.08
6.04
4.18
4.14
4.12
4.10
4.09
4.07
4.05
4.04
1.44
1.43
1.41
1.37
1.35
1.33
PO(OEt)2
EtO
2.88
1.99
1.00
3.58
2.43
3.27
6.05
f1 (ppm)

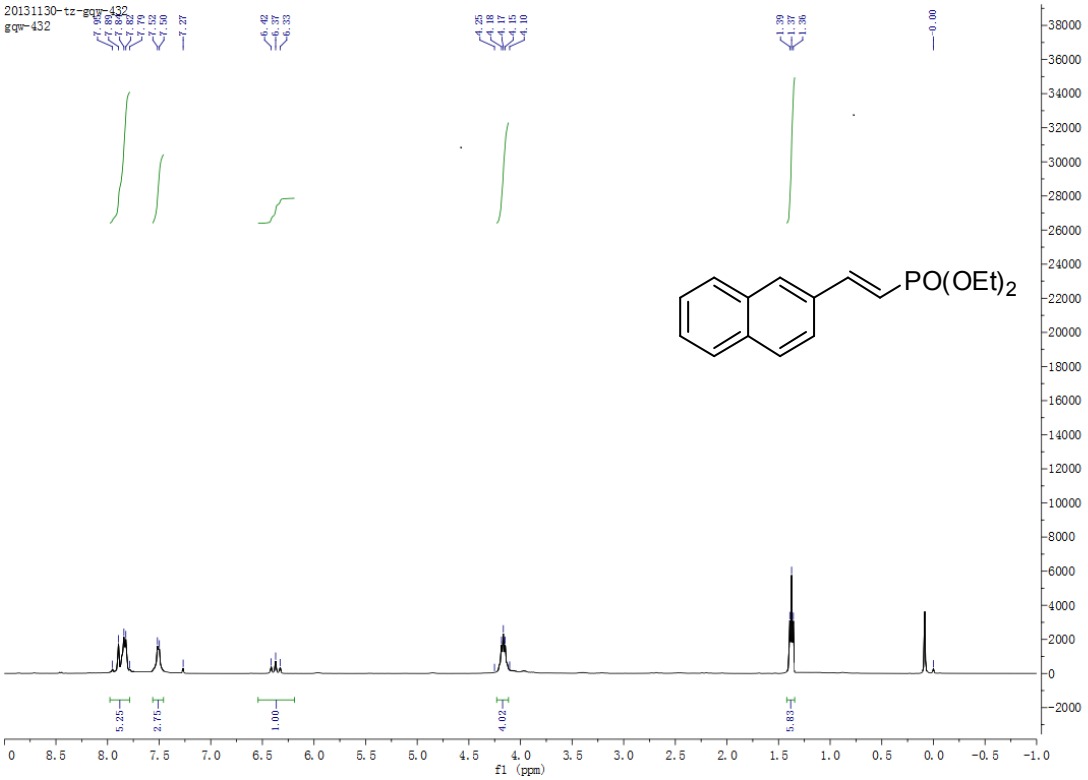

20131217-tz-gqw-470
gqw-470
160.67
148.59
148.52
129.31
127.51
127.28
114.65
111.48
109.56
77.32
77.00
76.68
63.57
61.72
61.67
16.42
16.35
14.71
PO(OEt)2
EtO
f1 (ppm)

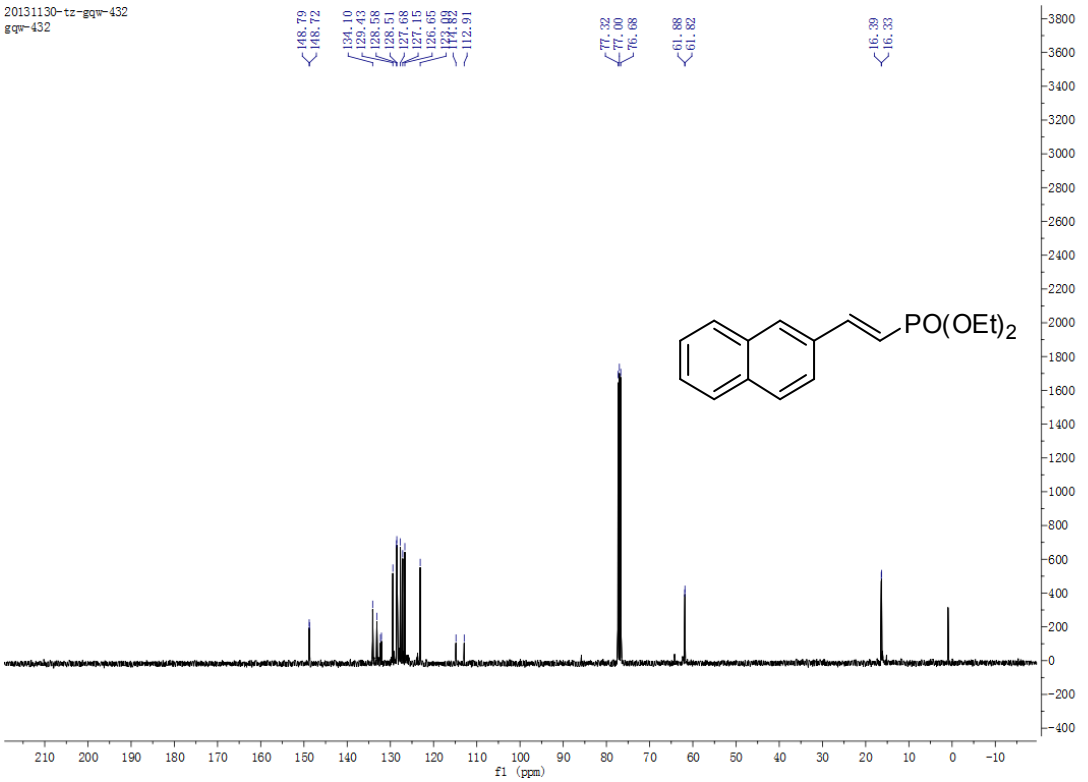

20131217-tz-gqw-469
gqw-469
PO(OEt)2
f1 (ppm)

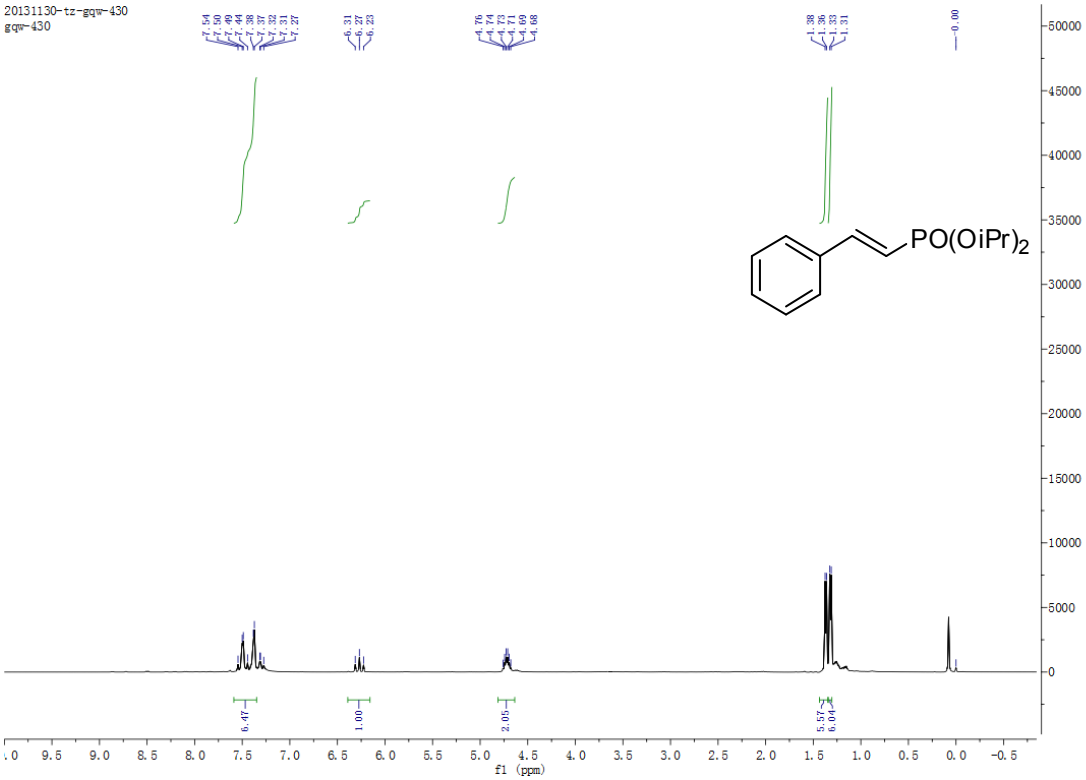

20131217-tz-gqw-469
gqw-469
PO(OEt)2
f1 (ppm)

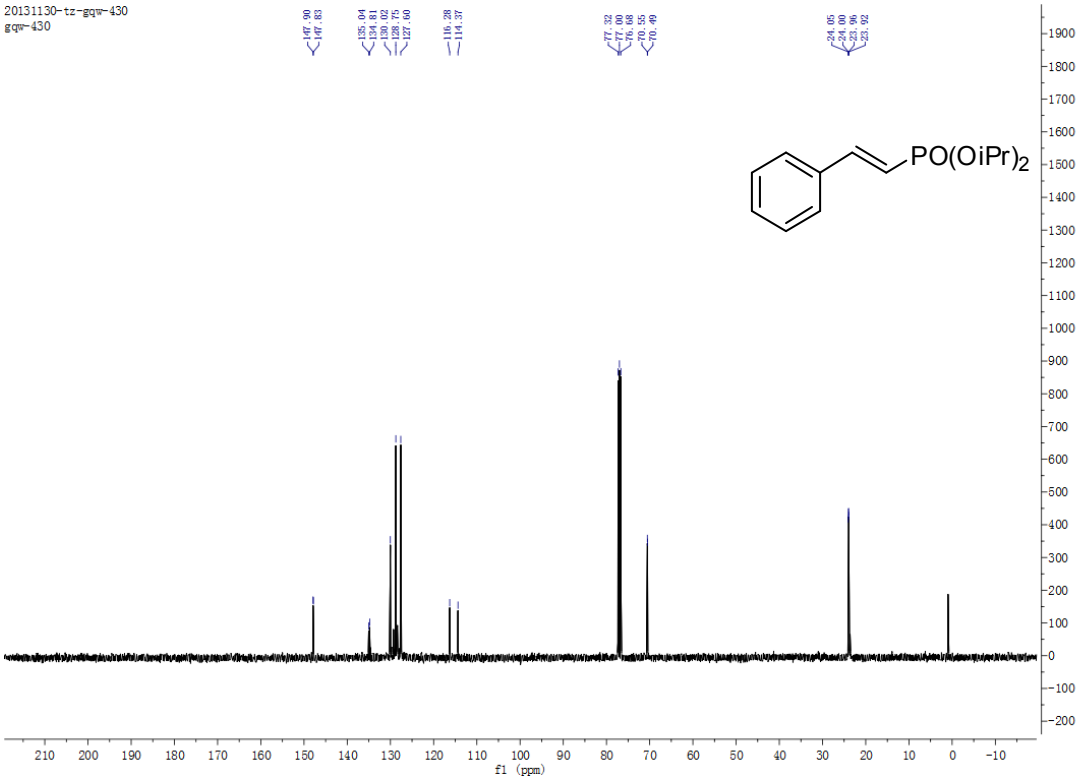

20131205-tz-gqw-447
gqw-447
PO(OEt)2
f1 (ppm)

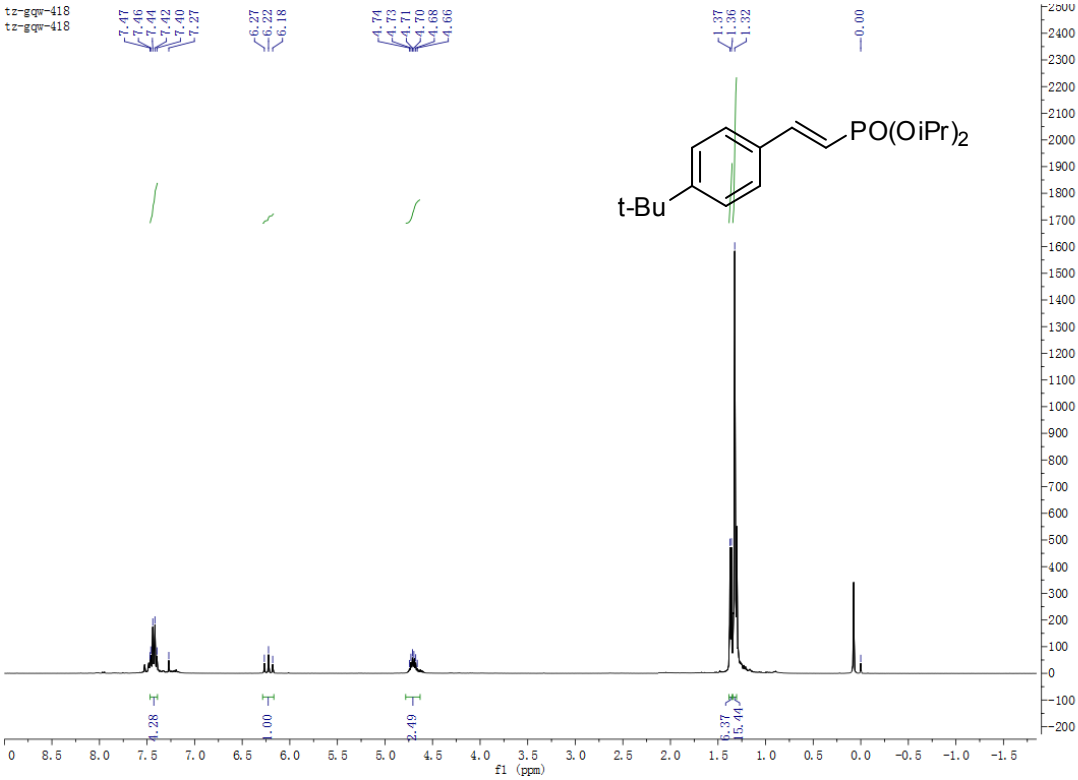

20131205-tz-gqw-447
gqw-447
PO(OEt)2
f1 (ppm)

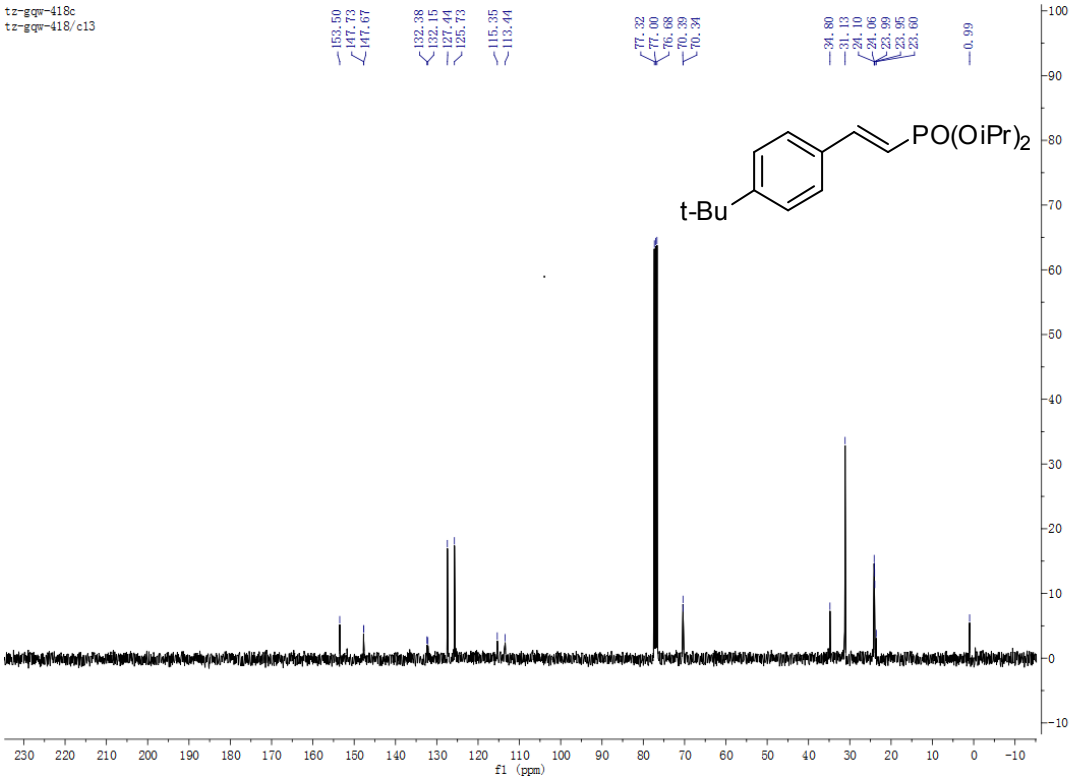

20131130-tz-gqw-432
gqw-432
PO(OEt)2
f1 (ppm)

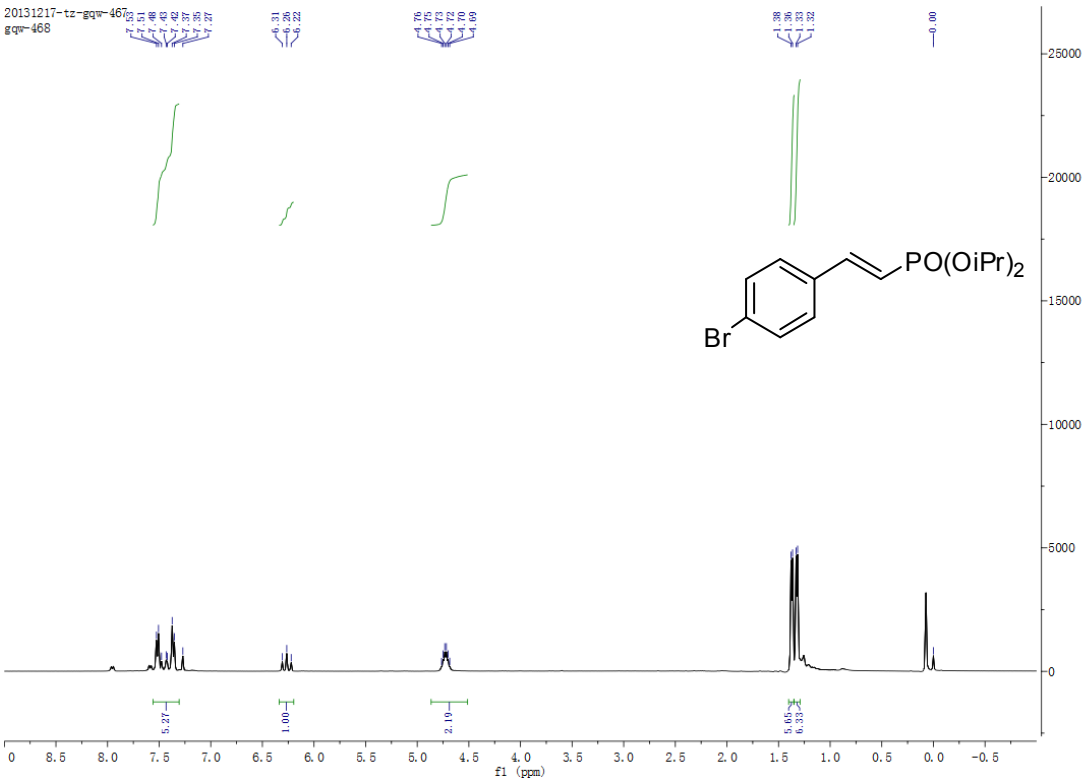

20131130-tz-gqw-432
gqw-432
PO(OEt)2
f1 (ppm)

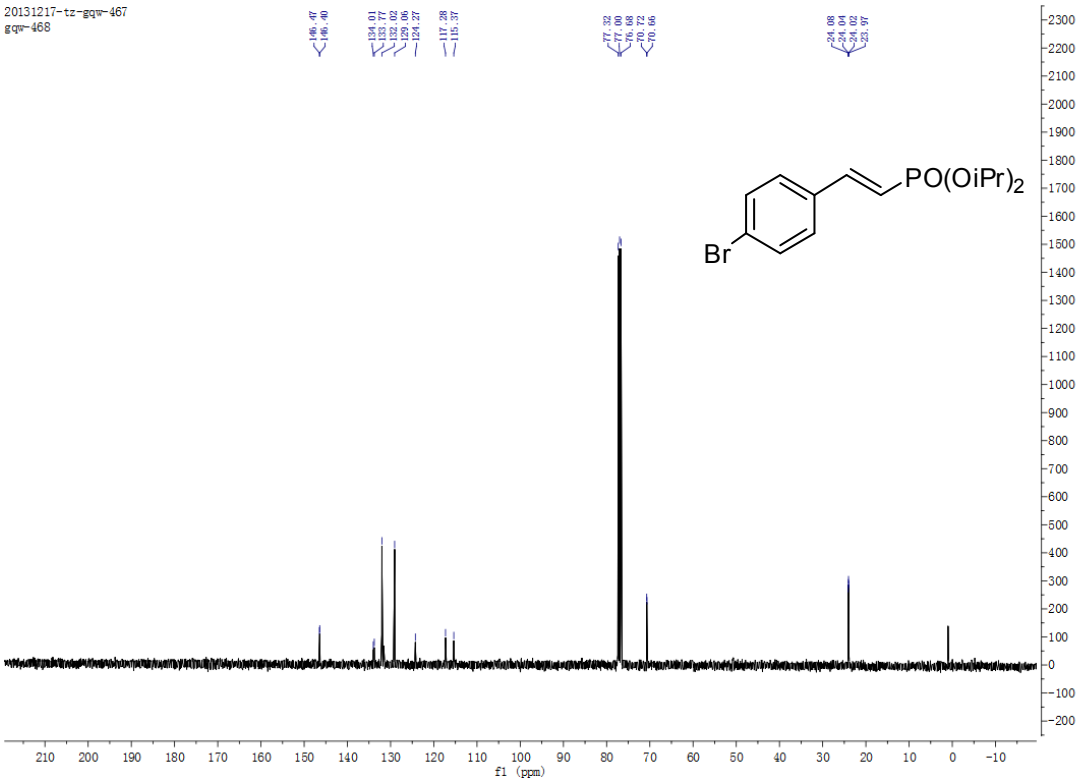

20131130-tz-gqw-430
gqw-430
7.54
7.50
7.49
7.44
7.38
7.37
7.32
7.31
7.27
6.31
6.27
6.23
4.76
4.74
4.73
4.71
4.69
4.68
1.38
1.36
1.33
1.31
0.00
PO(OiPr)2
6.47
1.00
2.05
5.57
6.04
f1 (ppm)

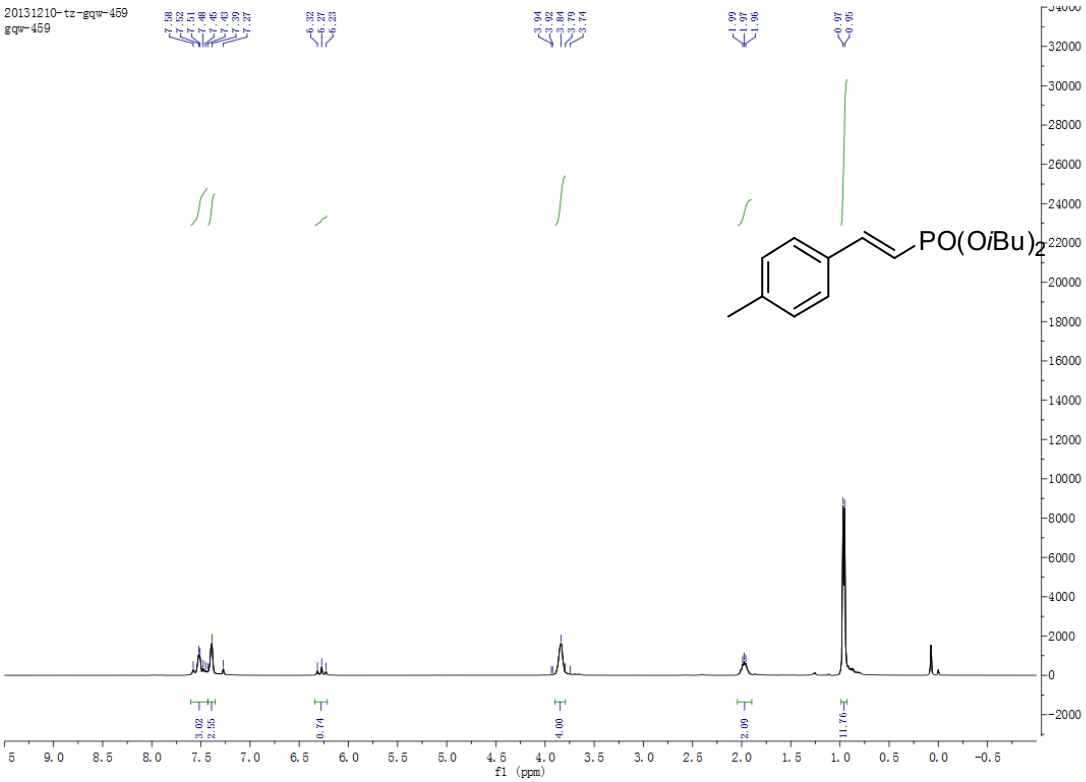

20131130-tz-gqw-430
gqw-430
147.90
147.83
135.04
134.81
130.02
128.75
127.60
116.28
114.37
77.32
77.00
76.68
70.55
70.49
24.65
24.60
23.96
23.92
PO(OiPr)2
f1 (ppm)

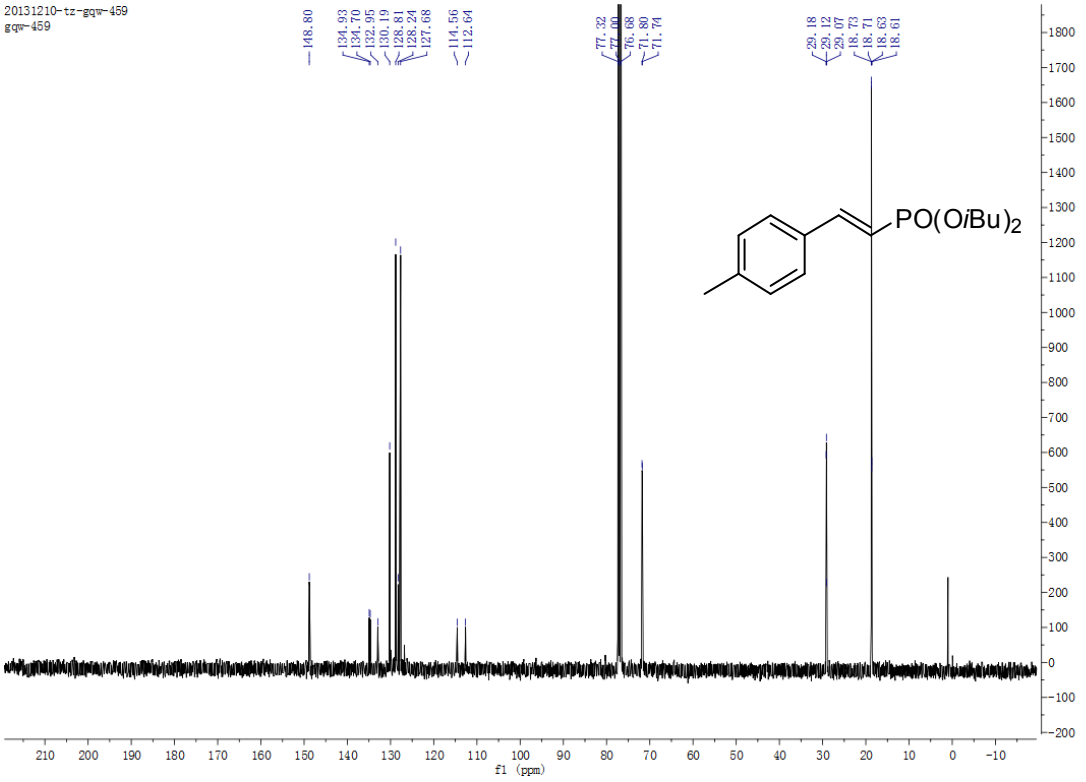

tz-gqw-418
tz-gqw-418
7.47
7.46
7.44
7.42
7.40
7.27
6.27
6.22
6.18
4.74
4.73
4.71
4.70
4.68
4.66
1.37
1.36
1.32
0.00
PO(OiPr)2
t-Bu
4.28
1.00
2.49
6.37
15.44
f1 (ppm)

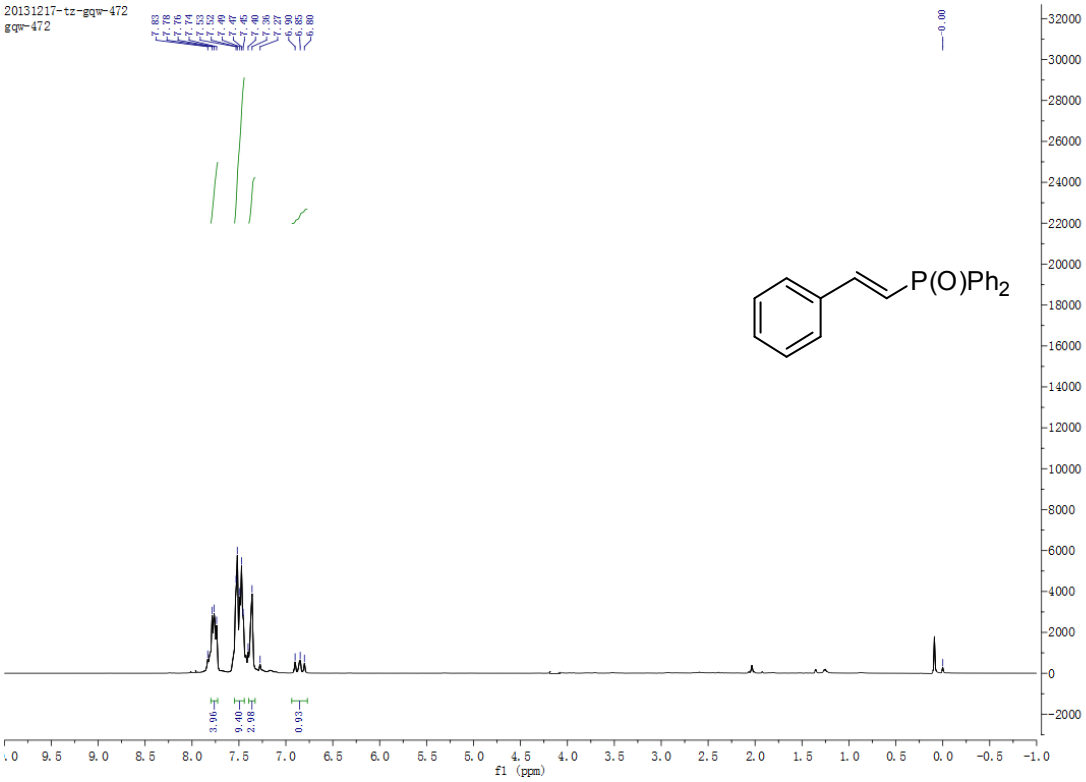

tz-gqw-418c
tz-gqw-418/c13
153.50
147.73
147.67
132.38
132.15
127.44
125.73
115.35
113.44
77.32
77.00
76.68
70.39
70.34
34.80
31.13
24.10
24.06
23.99
23.95
23.60
0.99
PO(OiPr)2
t-Bu
f1 (ppm)

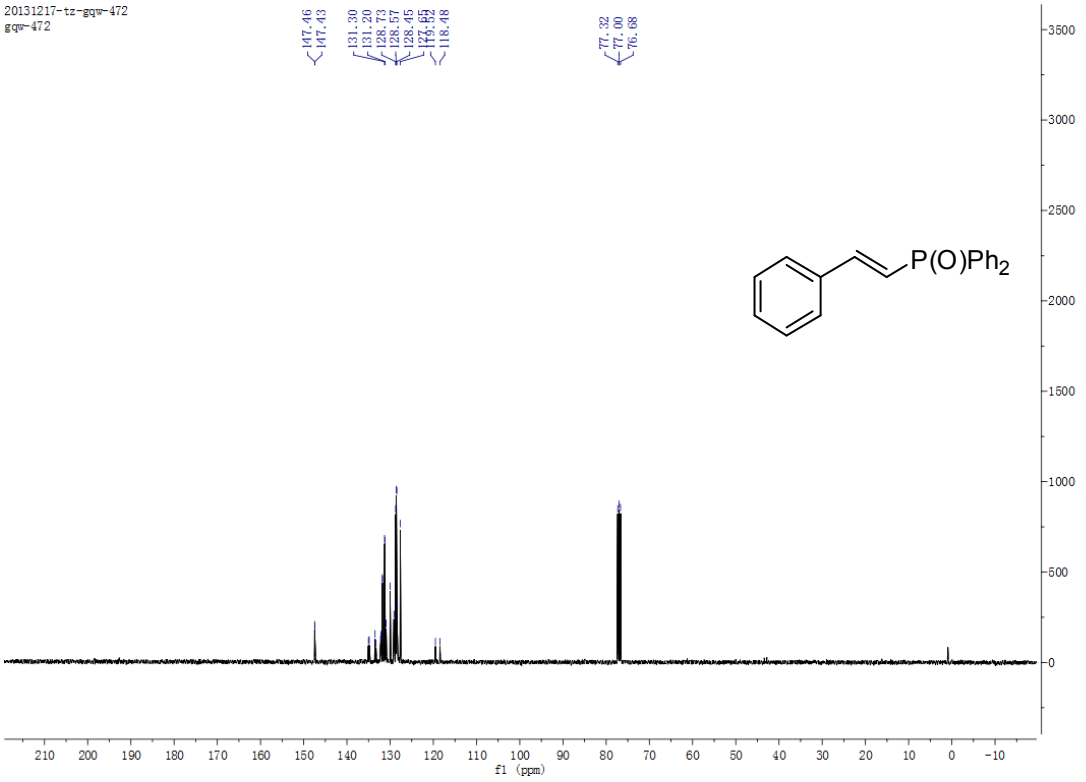

20131217-tz-gqw-467
gqw-468
PO(OiPr)2
Br
f1 (ppm)

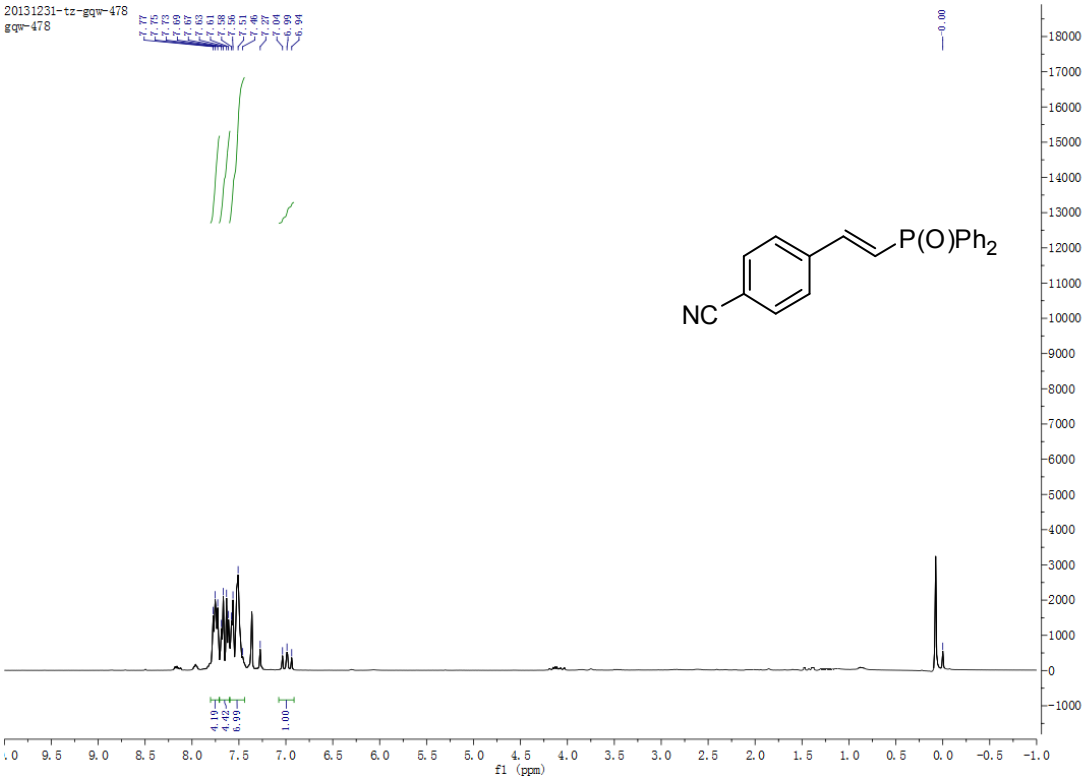

20131217-tz-gqw-467
gqw-468
PO(OiPr)2
Br
f1 (ppm)

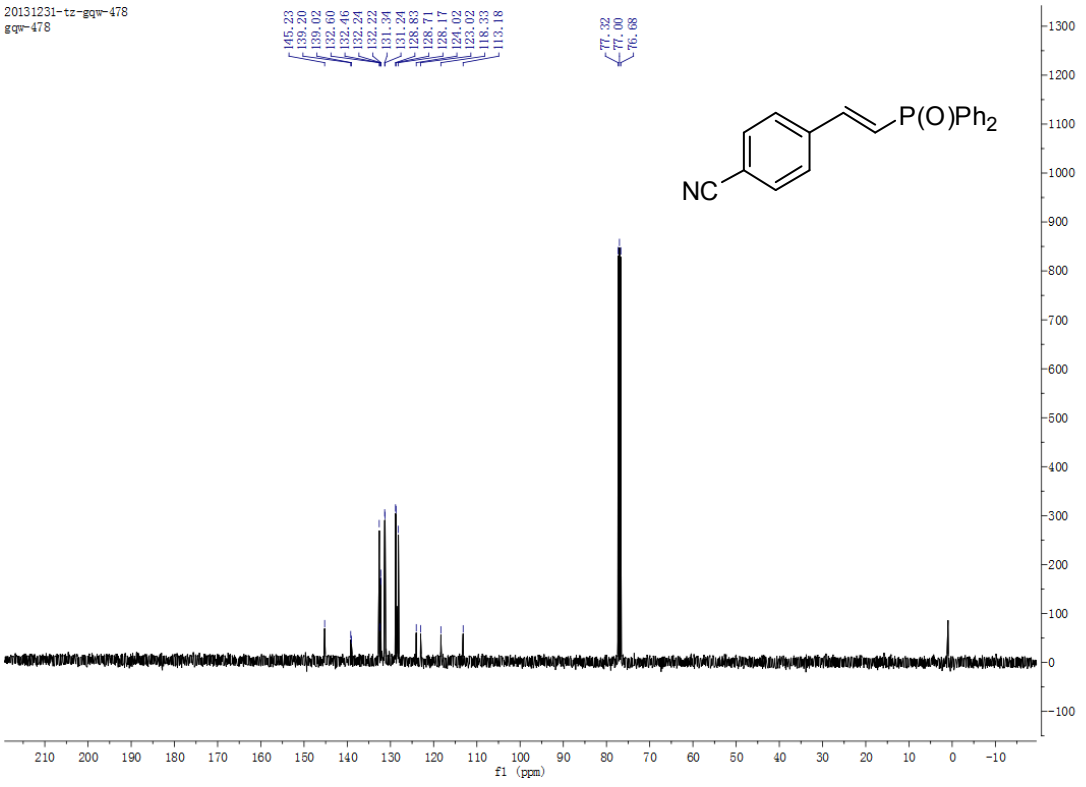

20131210-tz-gqw-459
gqw-459
PO(OiBu)2
f1 (ppm)

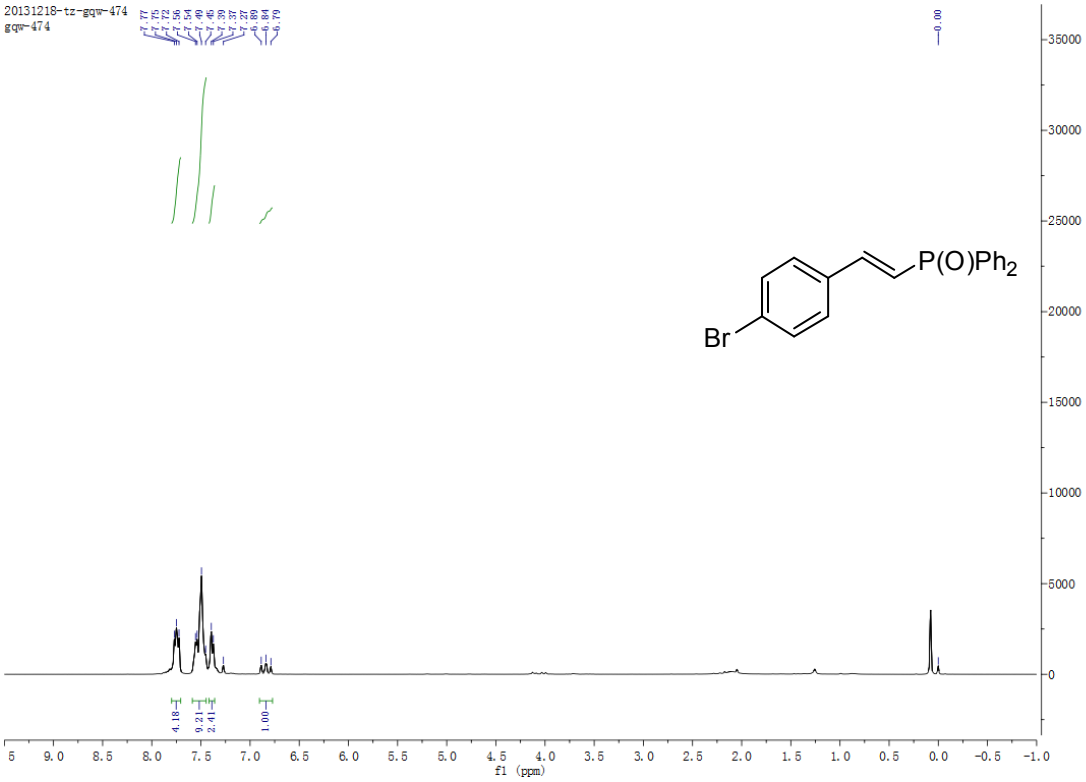

20131210-tz-gqw-459
gqw-459
PO(OiBu)2
f1 (ppm)

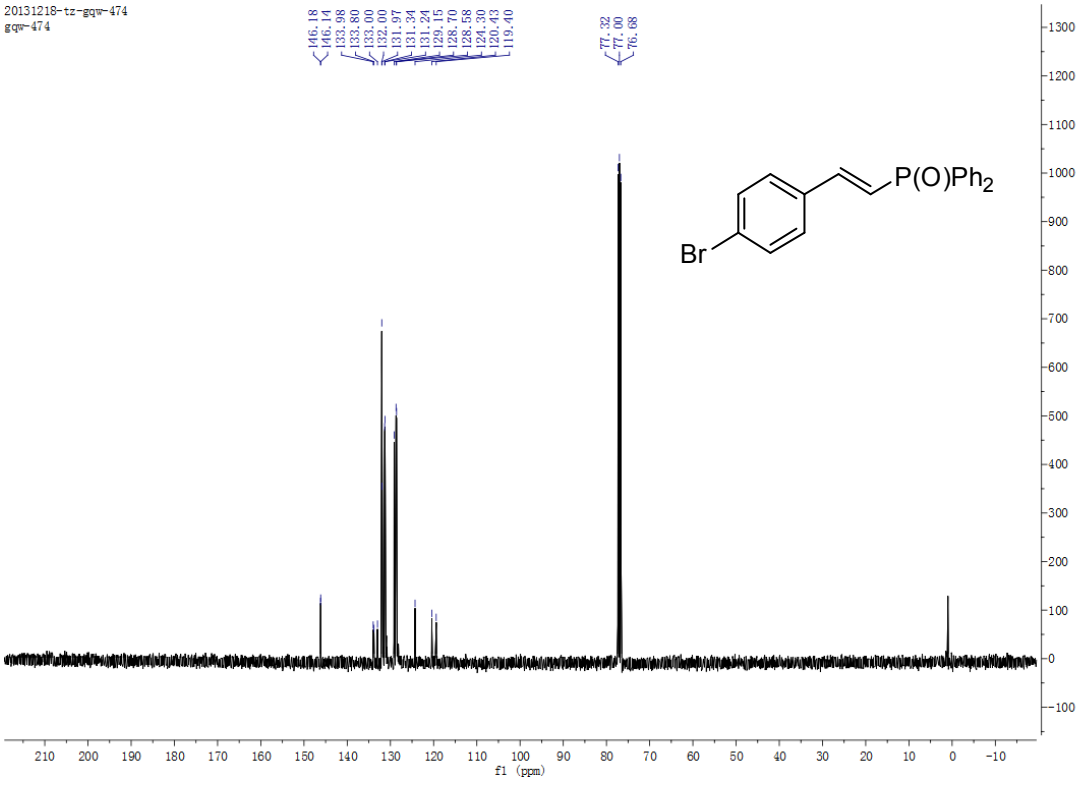

20131217-tz-gqw-472
gqw-472
7.83
7.78
7.76
7.74
7.53
7.52
7.49
7.47
7.45
7.40
7.38
7.37
6.90
6.85
6.80
0.00
P(O)Ph2
3.96
9.40
2.98
0.93
f1 (ppm)

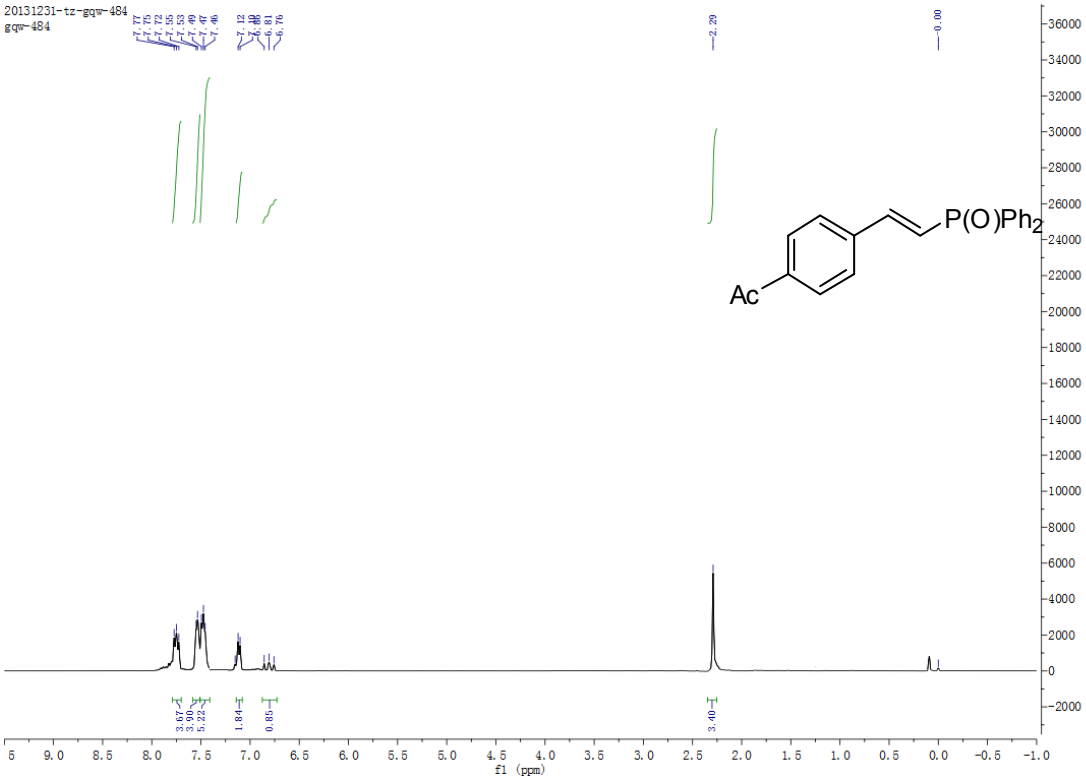

20131217-tz-gqw-472
gqw-472
147.46
147.43
131.30
131.20
128.73
128.57
128.45
118.48
77.32
77.00
76.68
P(O)Ph2
f1 (ppm)

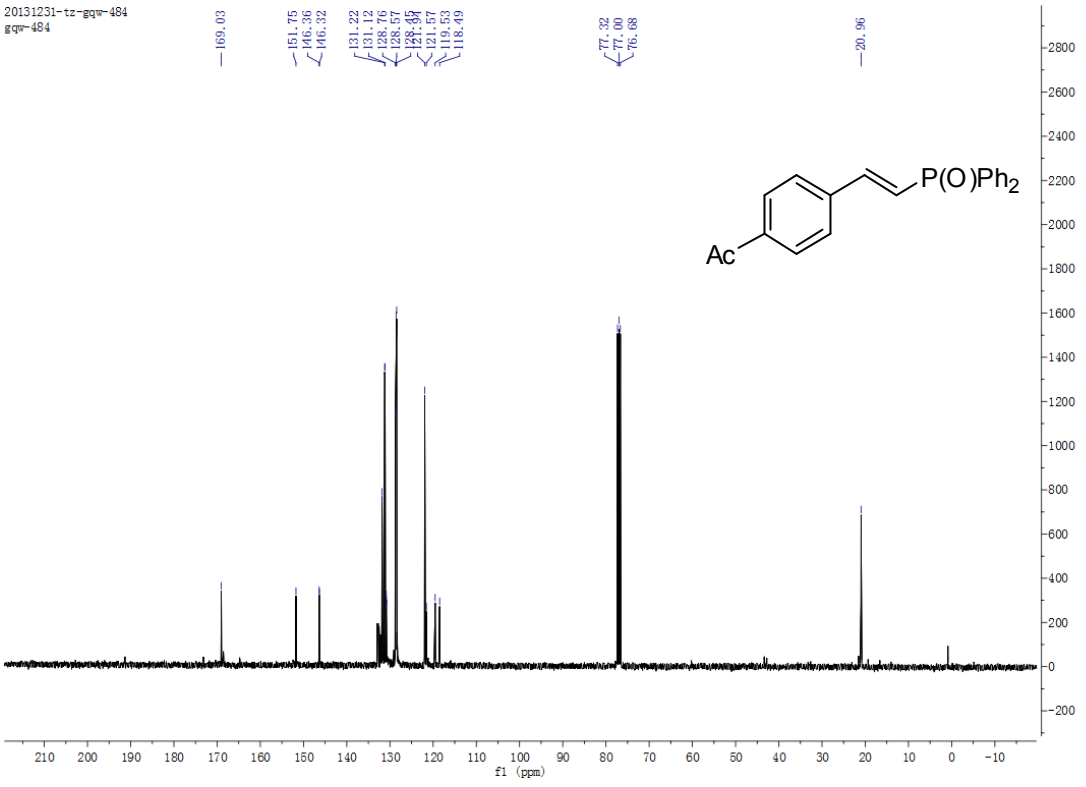

20131231-tz-gqw-478
gqw-478
7.77
7.75
7.73
7.69
7.67
7.63
7.61
7.58
7.56
7.51
7.46
7.27
7.04
6.99
6.94
0.00
P(O)Ph2
NC
4.19
4.05
6.95
1.00
f1 (ppm)

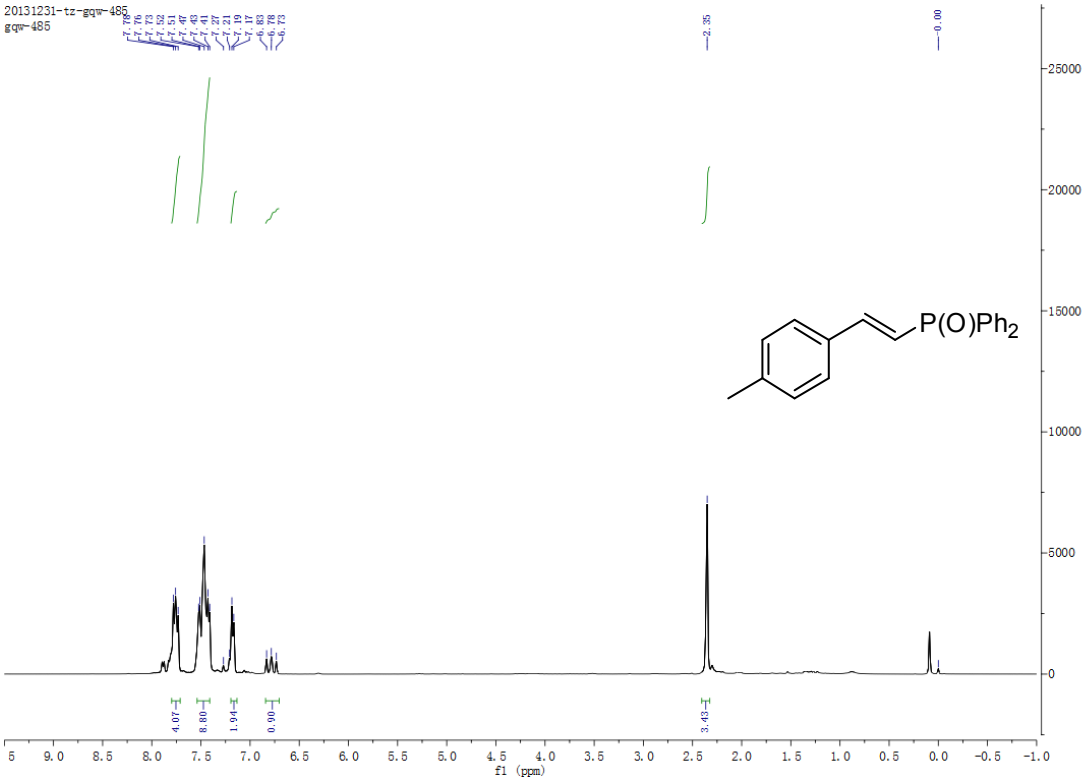

20131231-tz-gqw-478
gqw-478
145.23
139.20
139.02
132.60
132.46
132.24
132.22
131.34
131.24
128.83
128.71
128.17
124.02
123.02
118.33
113.18
77.32
77.00
76.68
P(O)Ph2
NC
f1 (ppm)

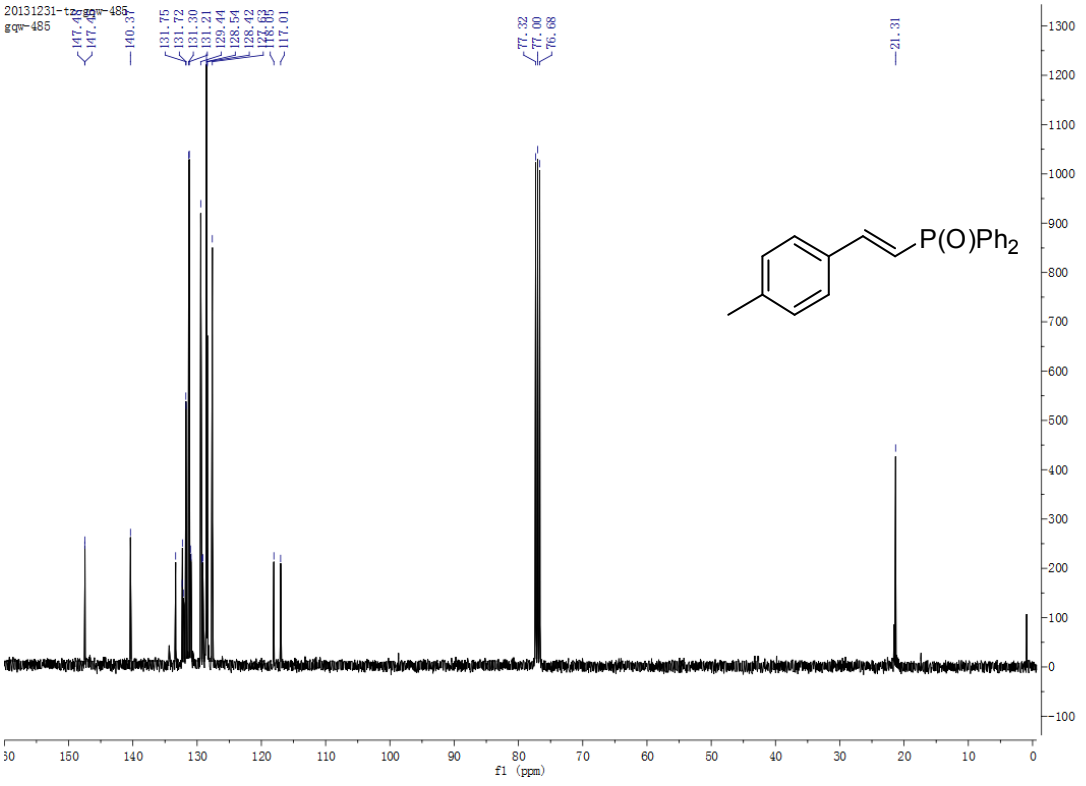

20131218-tz-gqw-474
gqw-474
7.77
7.75
7.72
7.56
7.54
7.49
7.46
7.39
7.37
7.27
6.89
6.84
6.79
0.00
P(O)Ph2
Br
4.18
9.21
2.41
1.00
f1 (ppm)

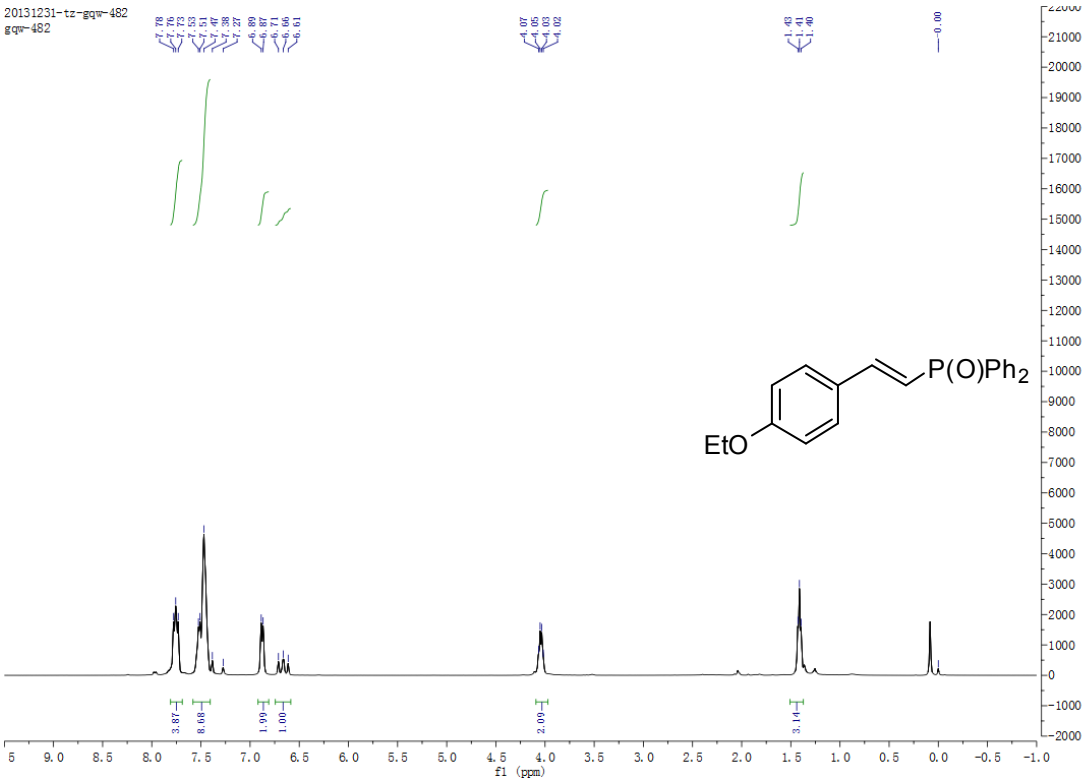

20131218-tz-gqw-474
gqw-474
146.18
146.14
133.98
133.80
133.00
132.00
131.97
131.34
131.24
129.15
128.70
128.58
124.30
120.43
119.40
77.32
77.00
76.68
P(O)Ph2
Br
f1 (ppm)

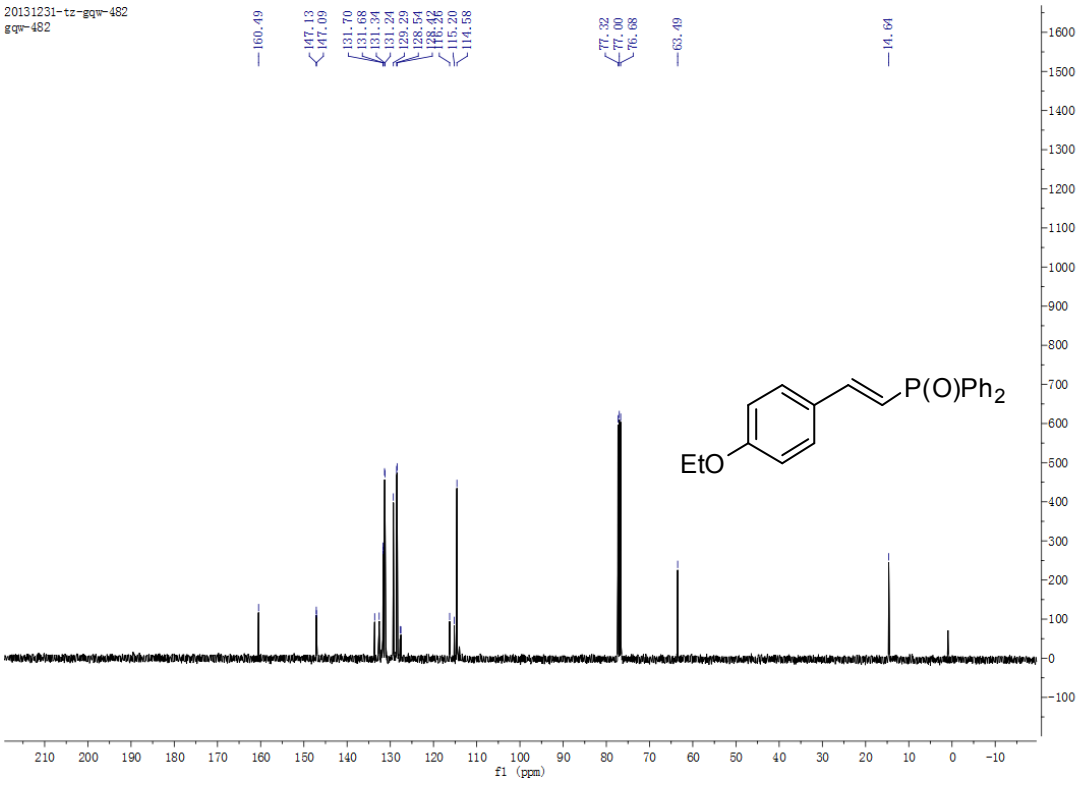

20131231-tz-gqw-484
gqw-484
7.77
7.75
7.72
7.55
7.53
7.49
7.47
7.46
7.12
6.81
6.76
2.29
0.00
3.67
3.90
5.22
1.84
0.85
3.40
f1 (ppm)
P(O)Ph2
Ac

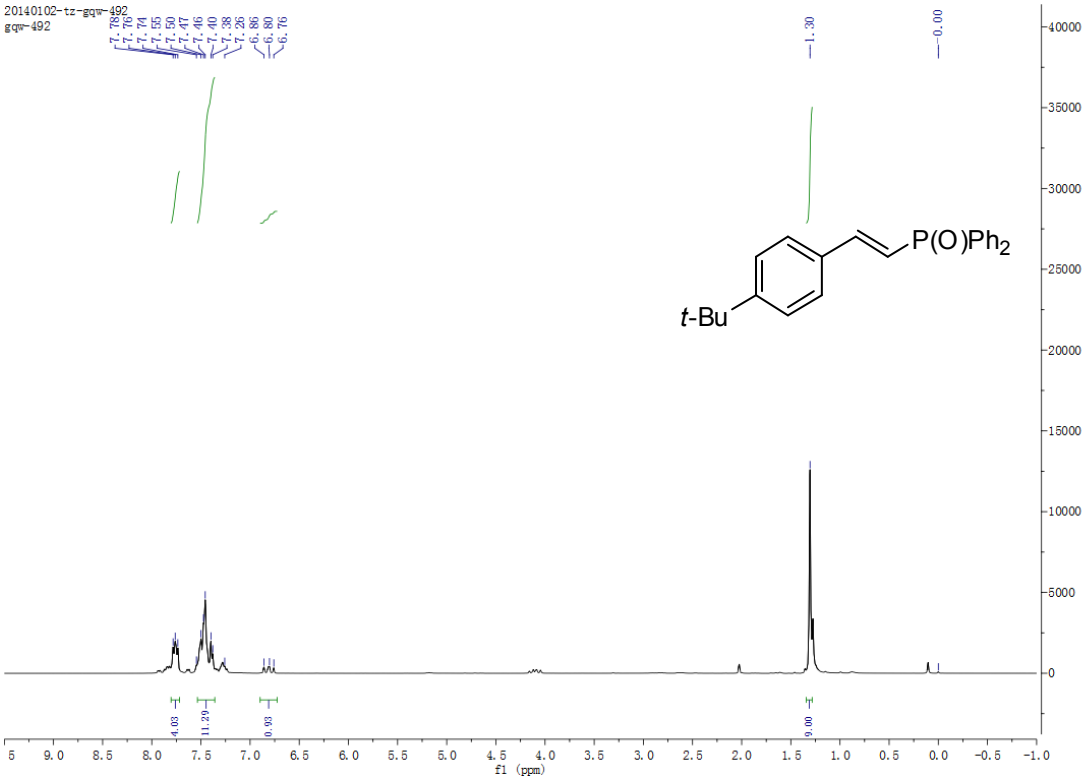

20131231-tz-gqw-484
gqw-484
169.03
151.75
146.36
146.32
131.22
131.12
128.76
128.57
121.57
119.53
118.49
77.32
77.00
76.68
20.96
f1 (ppm)
P(O)Ph2
Ac

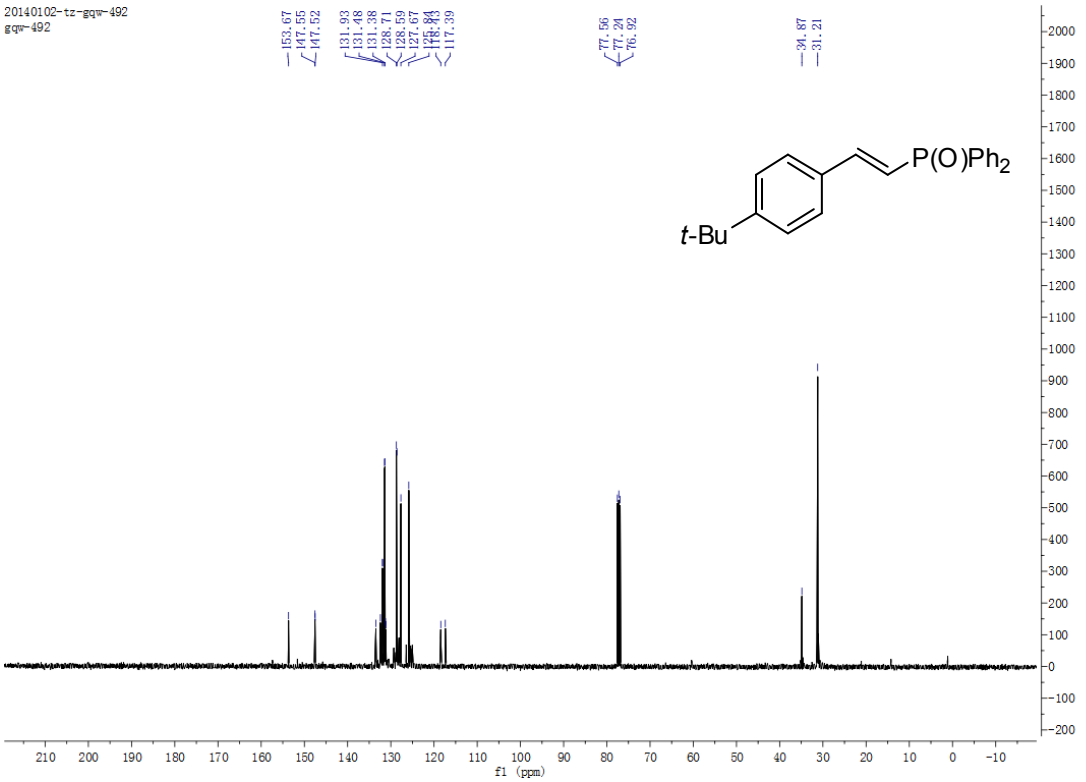

20131231-tz-gqw-485
gqw-485
7.78
7.76
7.73
7.52
7.51
7.46
7.43
7.41
7.27
7.21
7.19
7.17
6.83
6.78
6.73
2.35
0.00
P(O)Ph2
4.07
8.80
1.94
0.90
3.43
f1 (ppm)

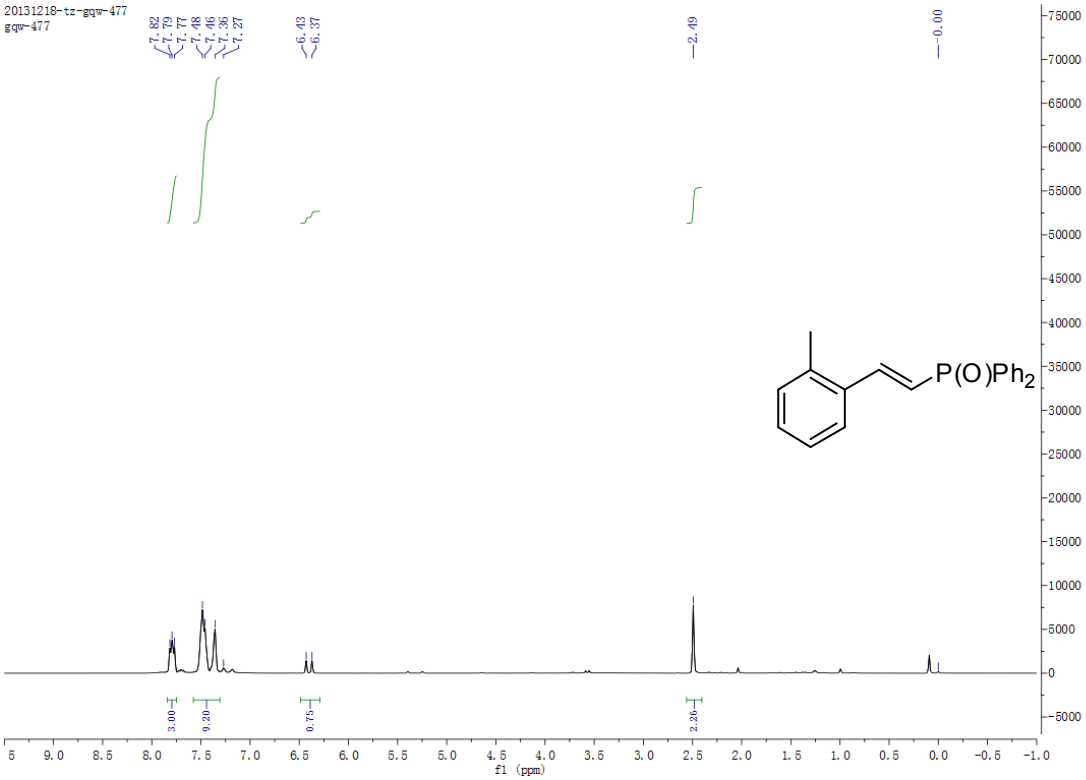

20131231-tz-gqw-485
gqw-485
147.48
147.40
140.37
131.75
131.72
131.30
131.21
129.44
128.54
128.42
77.32
77.00
76.68
21.31
P(O)Ph2
f1 (ppm)

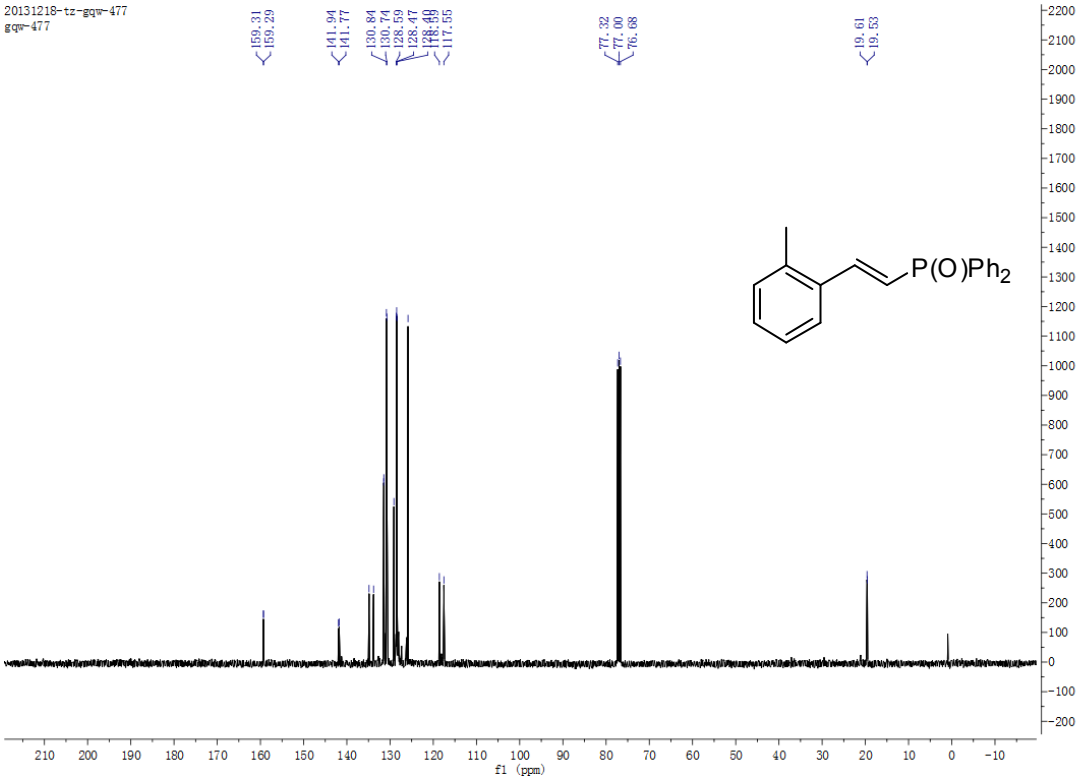

20131231-tz-gqw-482
gqw-482
7.78
7.76
7.73
7.53
7.51
7.47
7.38
7.27
6.89
6.87
6.71
6.66
6.61
4.07
4.05
4.03
4.02
1.43
1.41
1.40
0.00
P(O)Ph2
EtO
3.87
8.68
1.99
1.00
2.09
3.14
f1 (ppm)

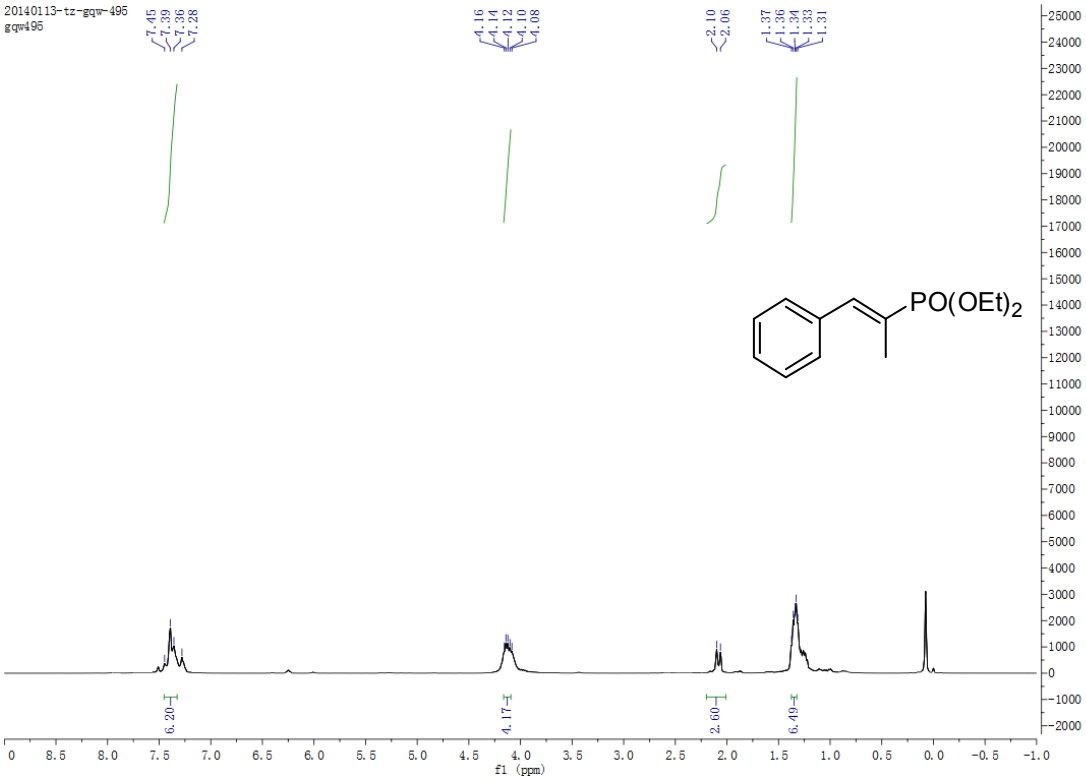

20131231-tz-gqw-482
gqw-482
160.49
147.13
147.09
131.70
131.68
131.34
131.24
129.29
128.54
128.42
116.26
115.20
114.58
77.32
77.00
76.68
63.49
14.64
P(O)Ph2
EtO
f1 (ppm)

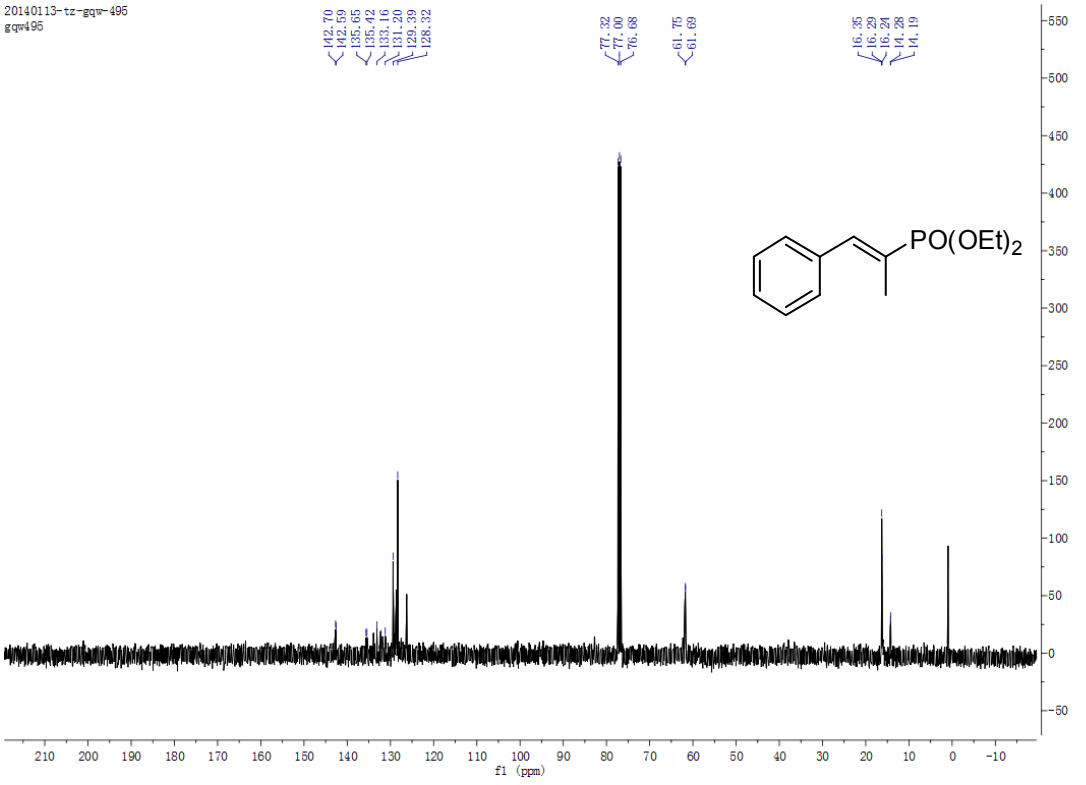

20140102-tz-gqw-492
gqw-492
7.78
7.76
7.74
7.55
7.50
7.47
7.46
7.40
7.38
7.26
6.86
6.80
6.76
1.30
0.00
P(O)Ph2
t-Bu
4.03
11.20
0.93
9.00
f1 (ppm)

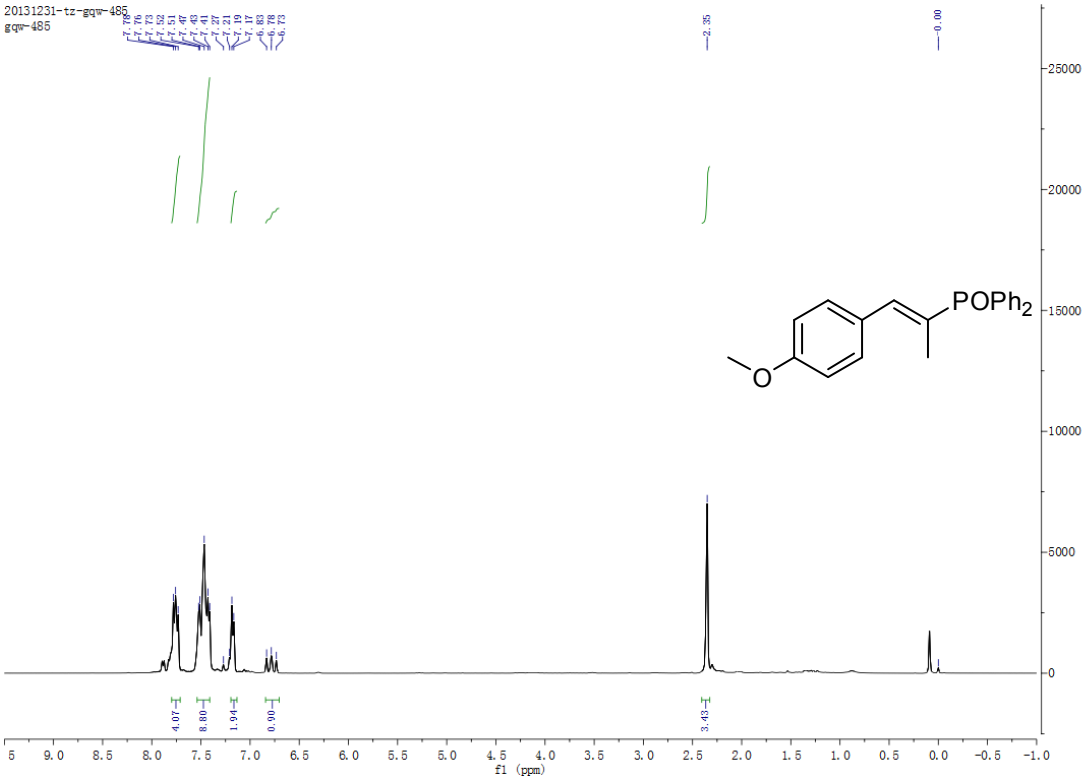

20140102-tz-gqw-492
gqw-492
153.67
147.55
147.52
131.93
131.48
131.38
128.71
128.59
127.67
117.39
77.56
77.24
76.92
34.87
31.21
P(O)Ph2
t-Bu
f1 (ppm)

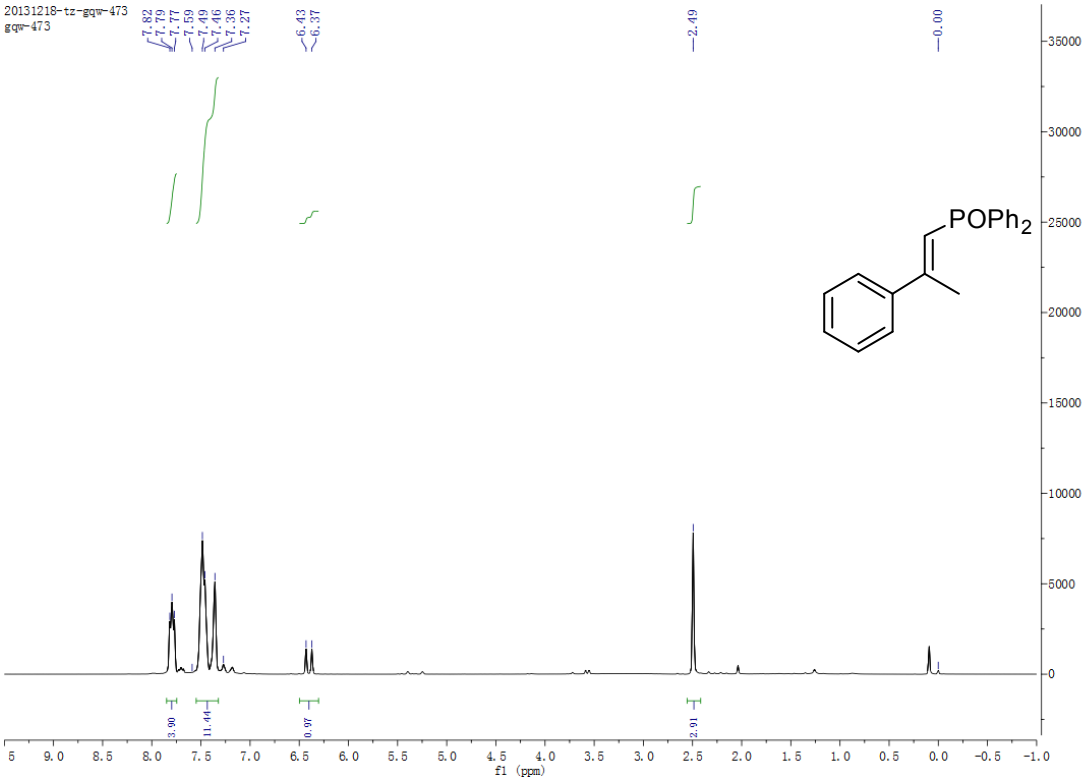

20131218-tz-gqw-477
gqw-477
7.82
7.79
7.77
7.48
7.46
7.36
7.27
6.43
6.37
2.49
0.00
P(O)Ph2
3.00
9.20
0.75
2.26
f1 (ppm)

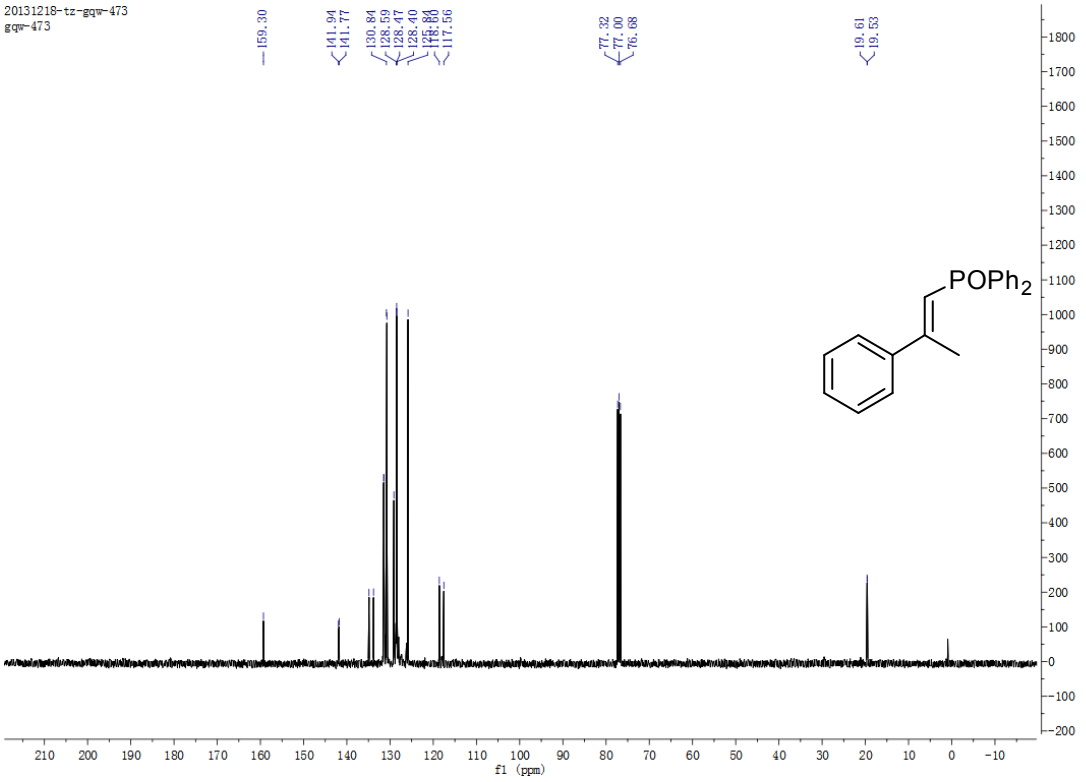

20131218-tz-gqw-477
gqw-477
159.31
159.29
141.94
141.77
130.84
130.74
128.59
128.47
117.55
77.32
77.00
76.68
19.61
19.53
P(O)Ph2
f1 (ppm)

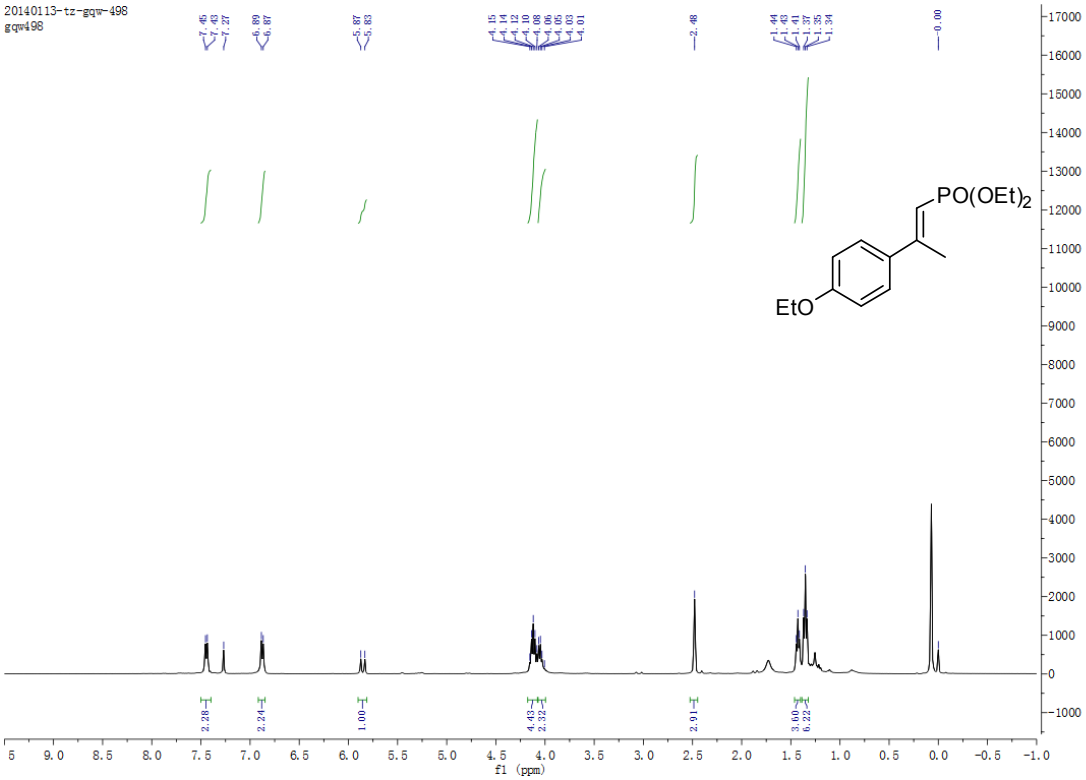

20140113-tz-gqw-496
gqw496
7.45
7.39
7.36
7.28
4.16
4.14
4.12
4.10
4.08
2.10
2.06
1.37
1.36
1.34
1.33
1.31
PO(OEt)2
6.20
4.17
2.60
6.49
f1 (ppm)

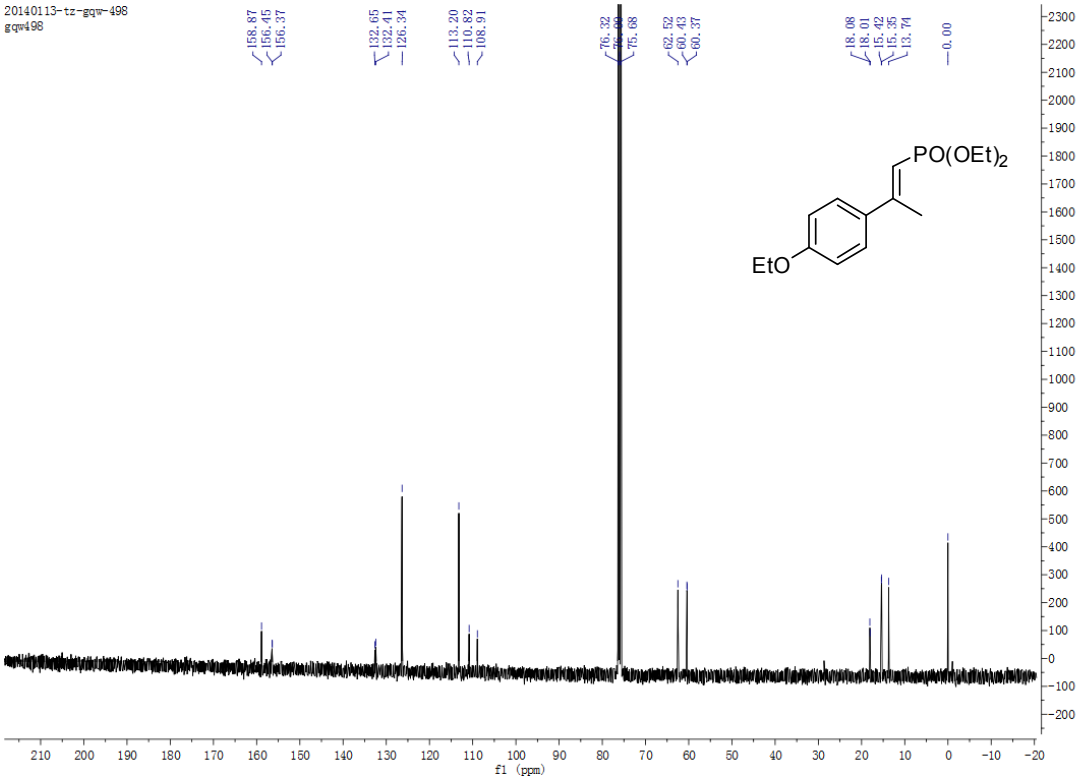

20140113-tz-gqw-496
gqw496
142.70
142.59
135.65
135.42
133.16
131.20
129.39
128.32
77.32
77.00
76.68
61.75
61.69
16.35
16.29
16.24
14.28
14.19
PO(OEt)2
f1 (ppm)

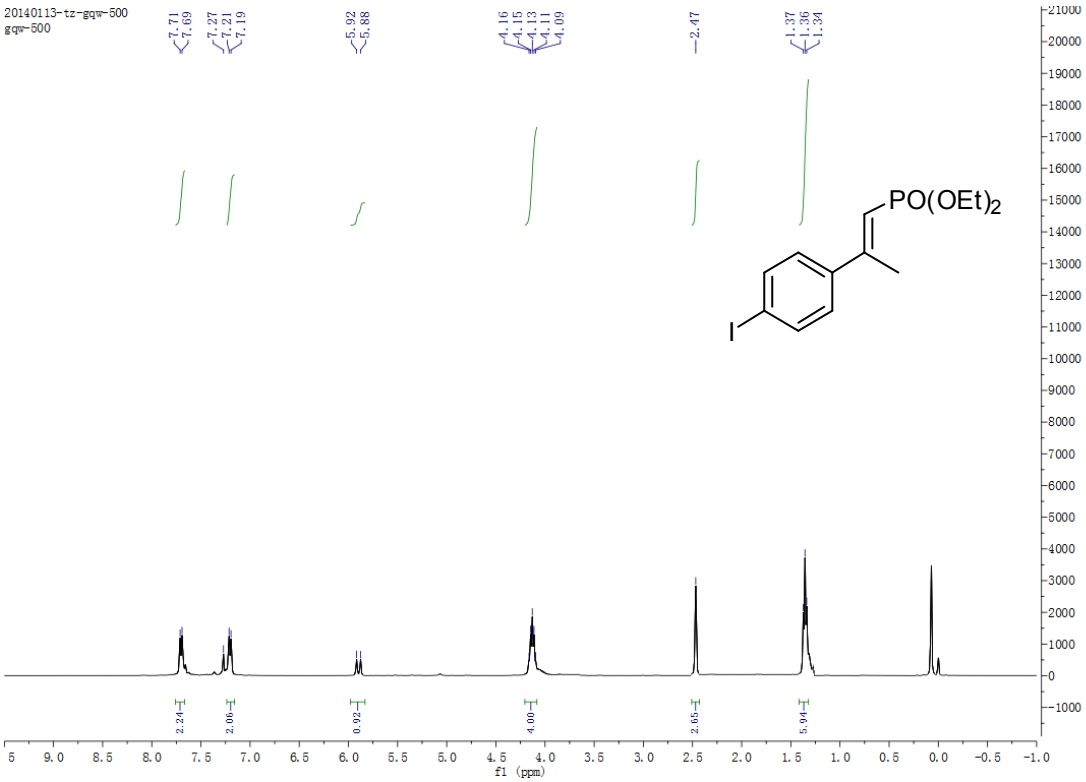

20131231-tz-gqw-486
gqw-486
POPh2
O
f1 (ppm)

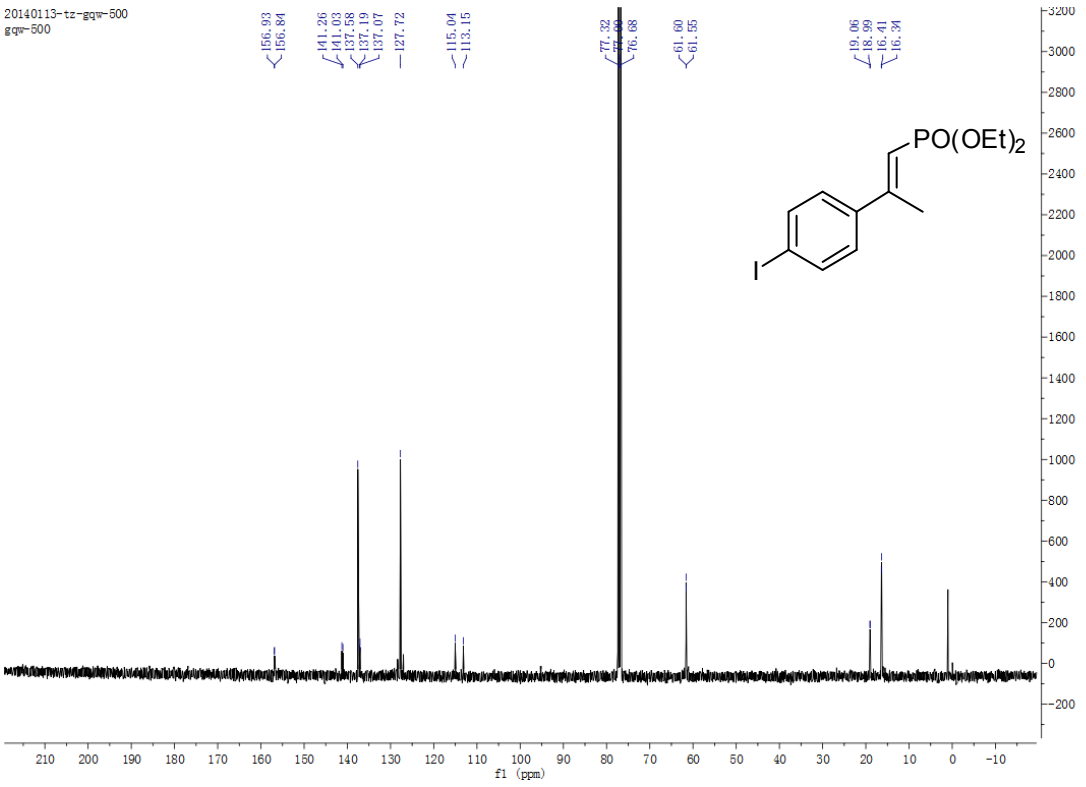

20131218-tz-gqw-473
gqw-473
7.82
7.79
7.77
7.59
7.49
7.46
7.36
7.27
6.43
6.37
2.49
0.00
POPh2
3.90
11.44
0.97
2.91
f1 (ppm)

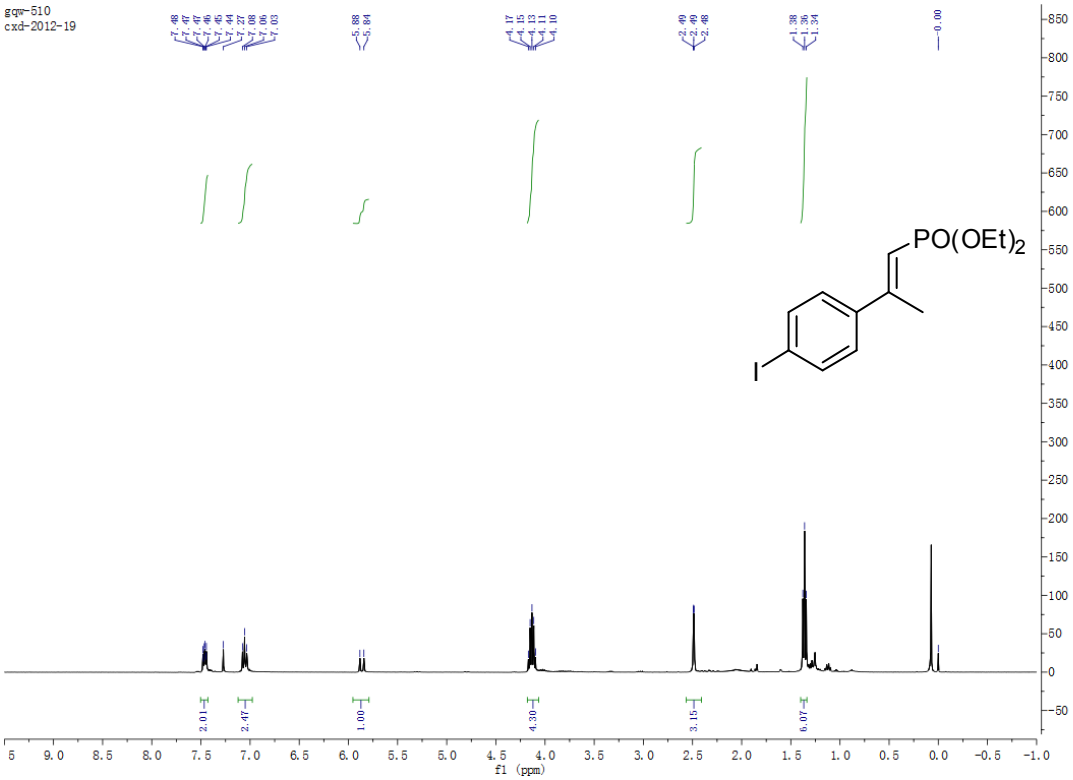

20131218-tz-gqw-473
gqw-473
159.30
141.94
141.77
130.84
128.59
128.47
128.40
117.56
77.32
77.00
76.68
19.61
19.53
POPh2
f1 (ppm)


20140113-tz-gqw-498
gqw498
PO(OEt)2
EtO
f1 (ppm)

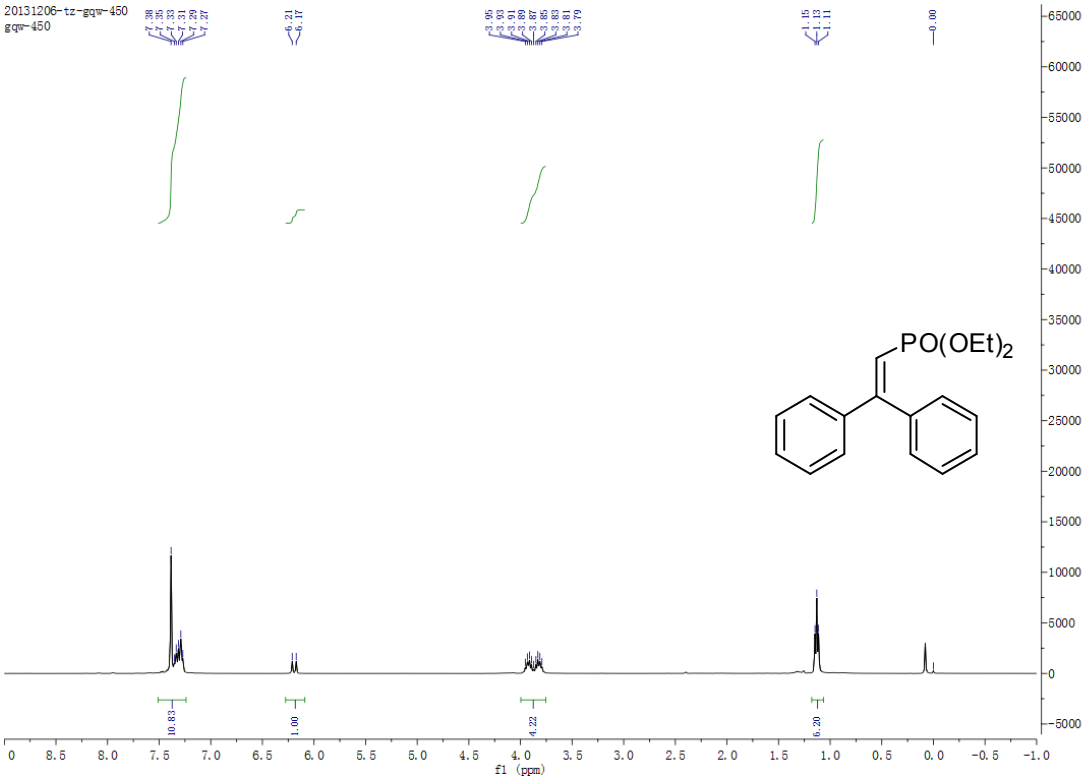

20140113-tz-gqw-498
gqw498
PO(OEt)2
EtO
f1 (ppm)

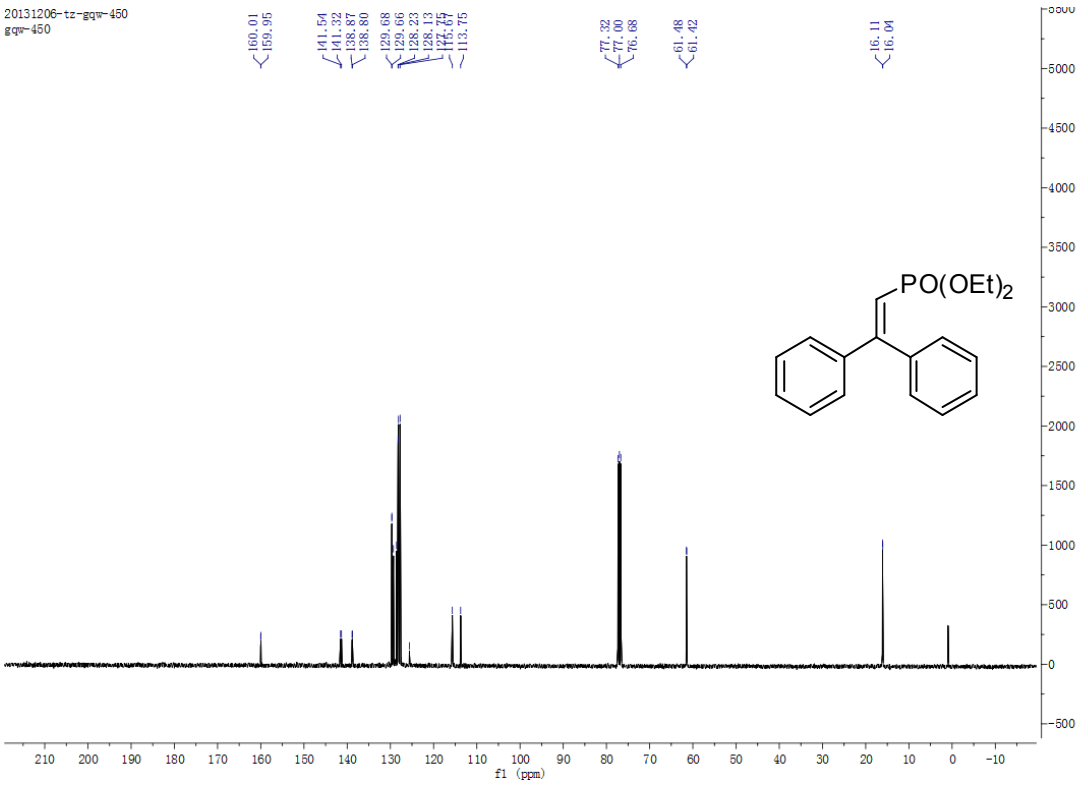

20140113-tz-gqw-500
gqw-500
7.71
7.69
7.27
7.21
7.19
5.92
5.88
4.16
4.15
4.13
4.11
4.09
2.47
1.37
1.36
1.34
PO(OEt)2
I
2.24
2.06
0.92
4.00
2.65
5.94
f1 (ppm)


20140113-tz-gqw-500
gqw-500
156.93
156.84
141.26
141.03
137.58
137.19
137.07
127.72
115.04
113.15
77.32
77.00
76.68
61.60
61.55
19.06
18.99
16.41
16.34
PO(OEt)2
I
f1 (ppm)

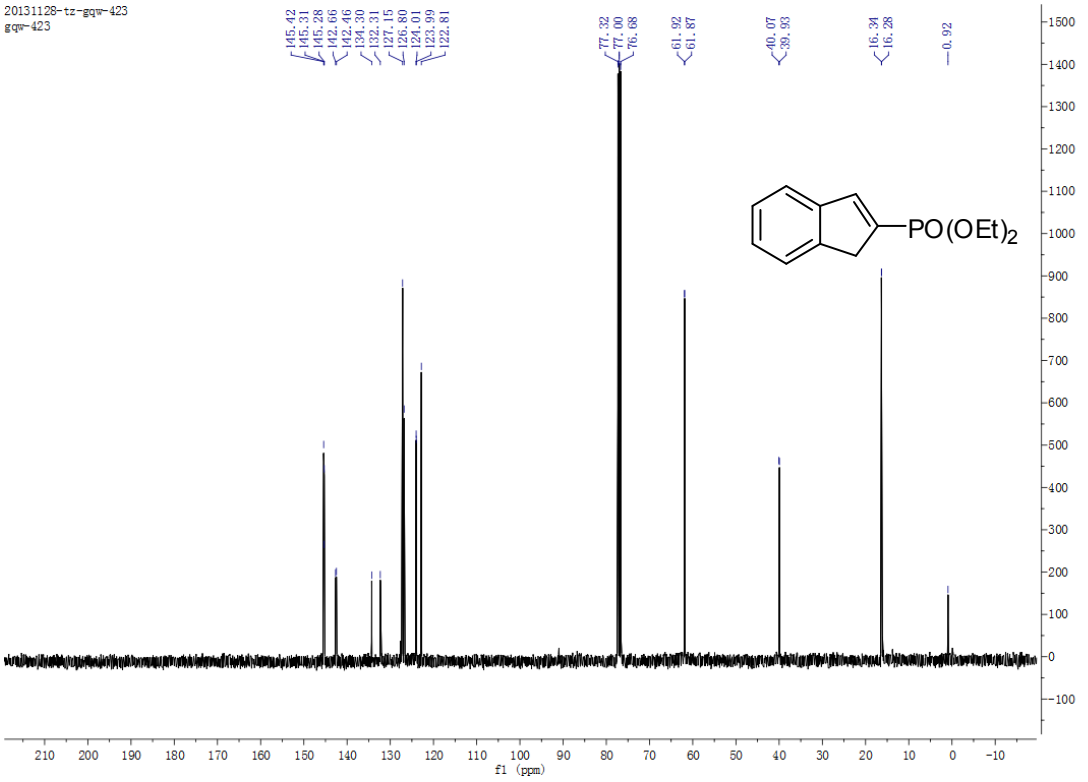

gqw-510
cxd-2012-19
PO(OEt)2
I
f1 (ppm)

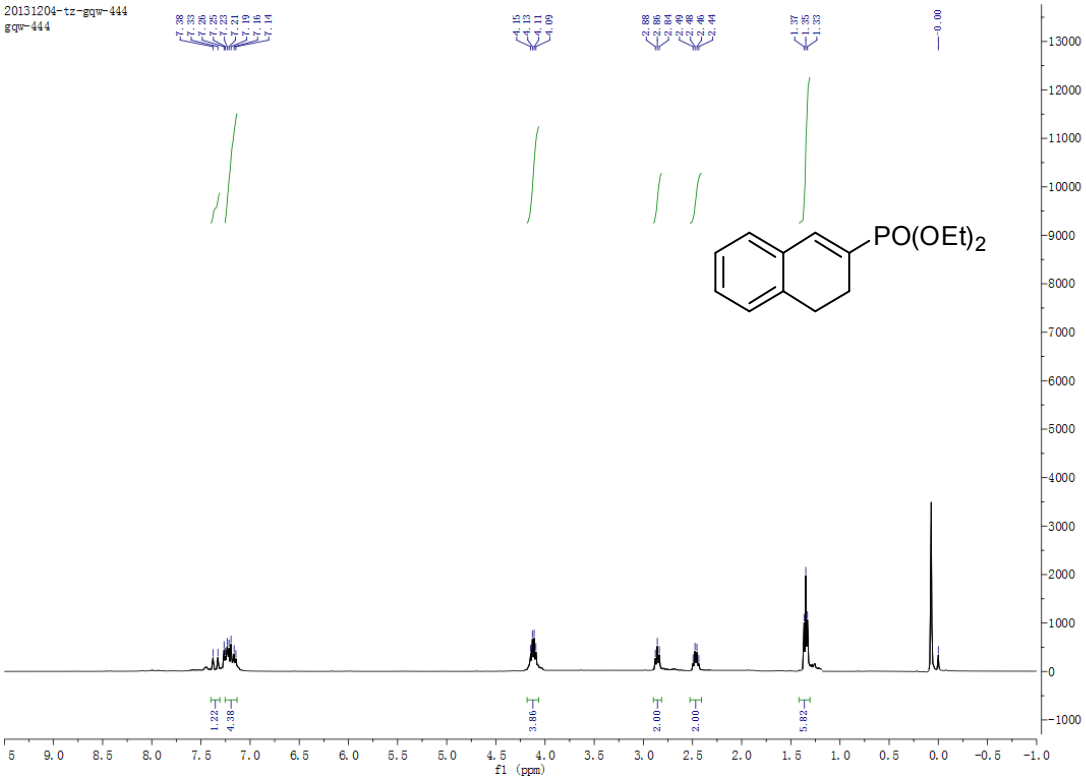

gqw-510c
A3-10-4/C13
PO(OEt)2
I
f1 (ppm)

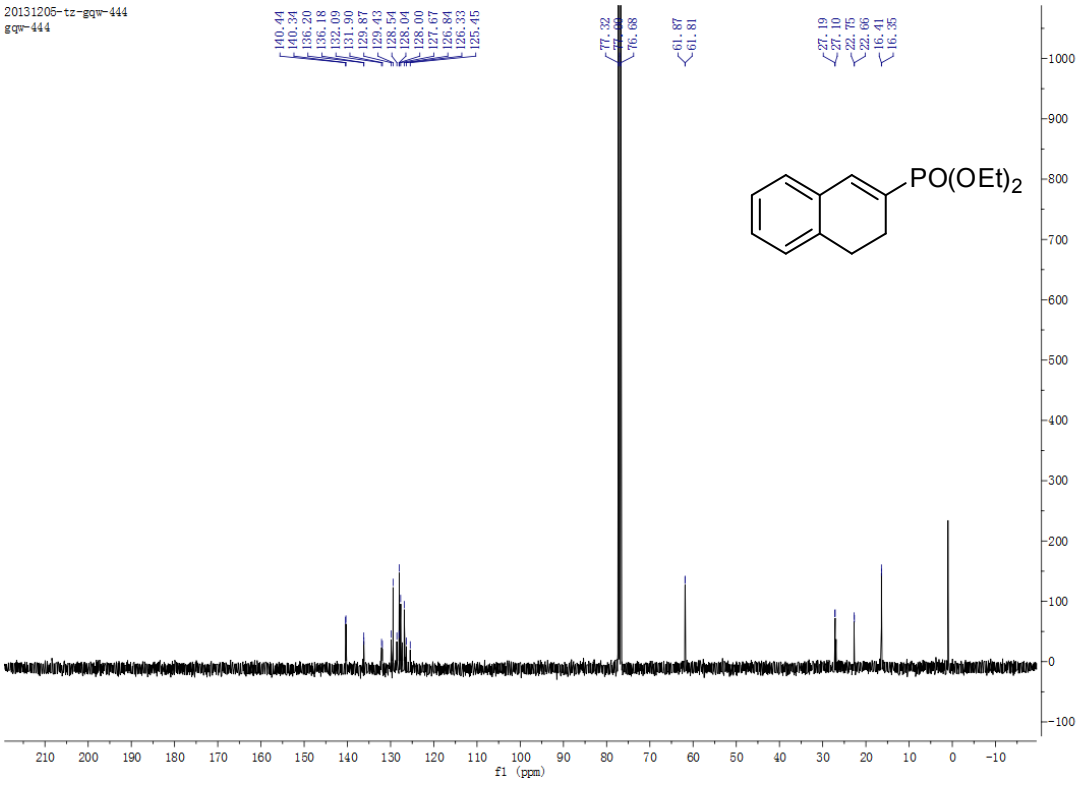

20131206-tz-gqw-450
gqw-450
7.38
7.35
7.33
7.31
7.29
7.27
6.21
6.17
3.95
3.93
3.91
3.89
3.87
3.85
3.83
3.81
3.79
1.15
1.13
1.11
0.00
PO(OEt)2
10.83
1.00
4.22
6.20
f1 (ppm)

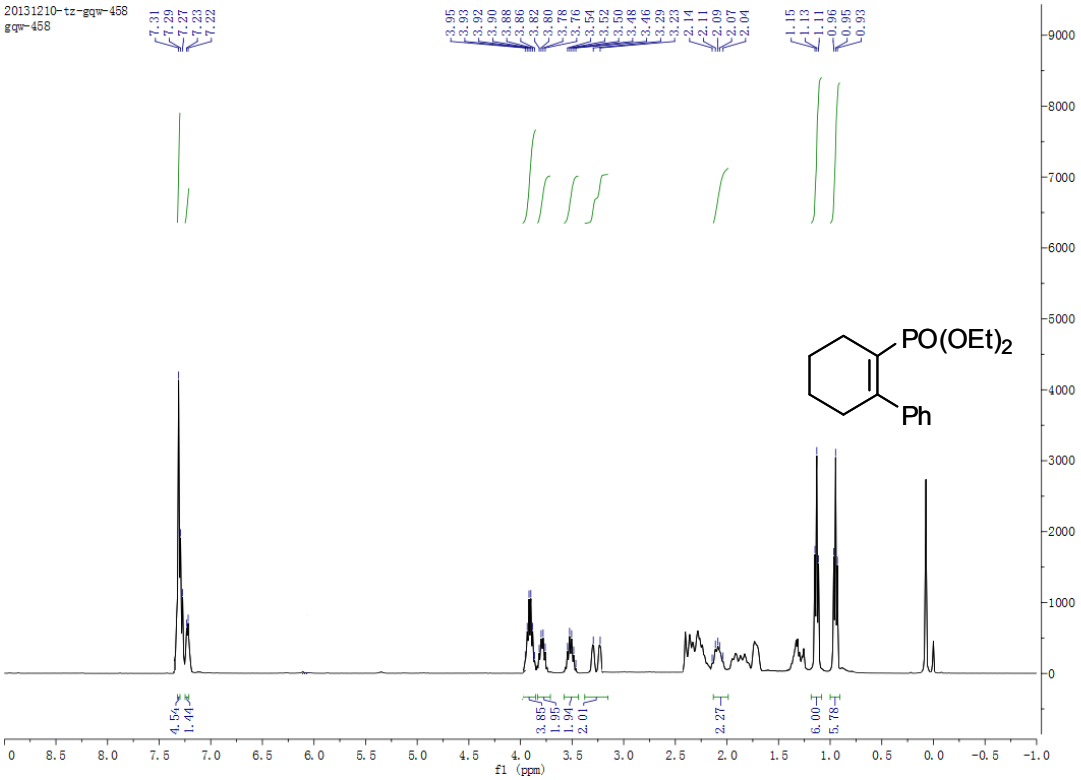

20131206-tz-gqw-450
gqw-450
160.01
159.95
141.54
141.32
138.87
138.80
129.68
129.66
128.23
128.13
113.75
77.32
77.00
76.68
61.48
61.42
16.11
16.04
PO(OEt)2
f1 (ppm)

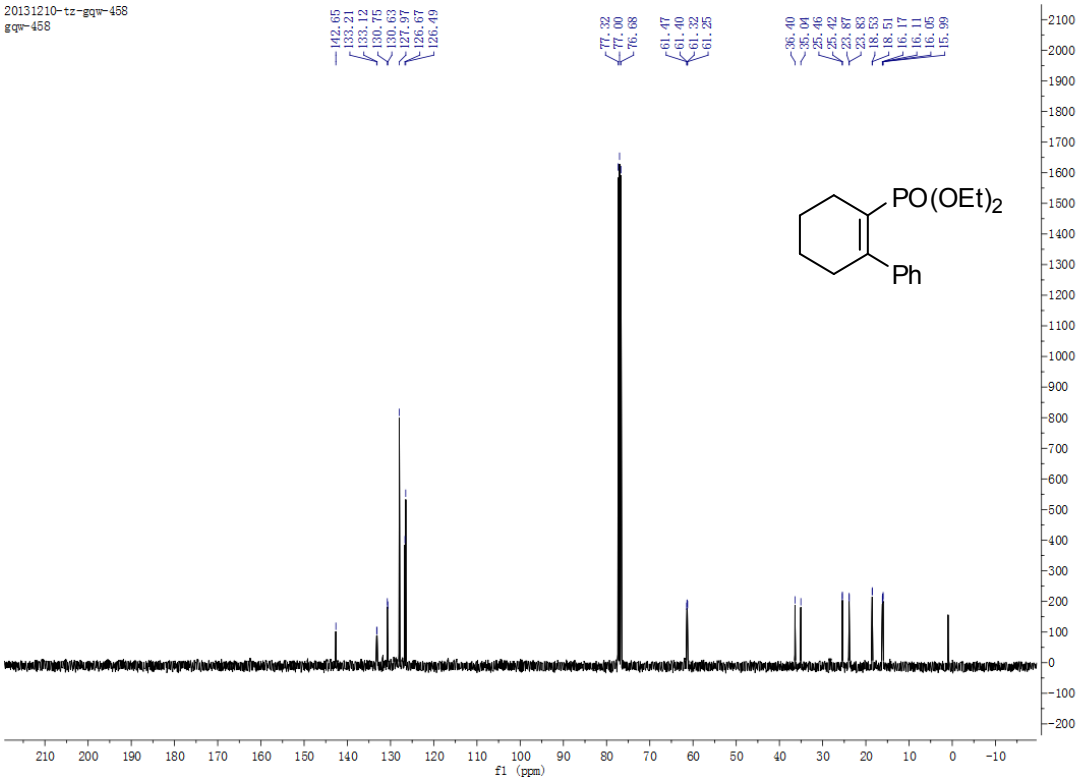

20131128-tz-gqw-423
gqw-423
7.65
7.62
7.53
7.52
7.51
7.38
7.34
7.33
7.31
7.28
4.17
4.16
4.14
4.12
4.10
3.65
1.37
1.35
1.33
PO(OEt)2
0.96
1.83
1.85
4.00
1.78
5.75
f1 (ppm)

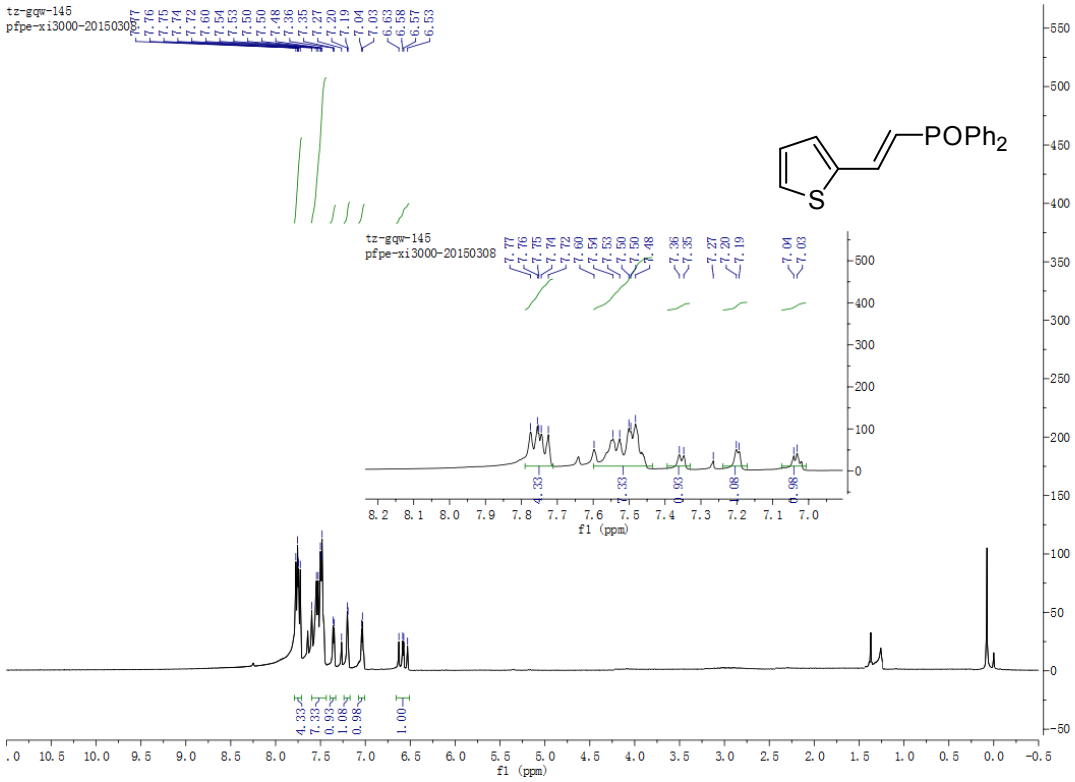

20131128-tz-gqw-423
gqw-423
145.42
145.31
145.28
142.66
142.46
134.30
132.31
127.15
126.80
124.01
123.99
122.81
77.32
77.00
76.68
61.92
61.87
40.07
39.93
16.34
16.28
0.92
PO(OEt)2
f1 (ppm)

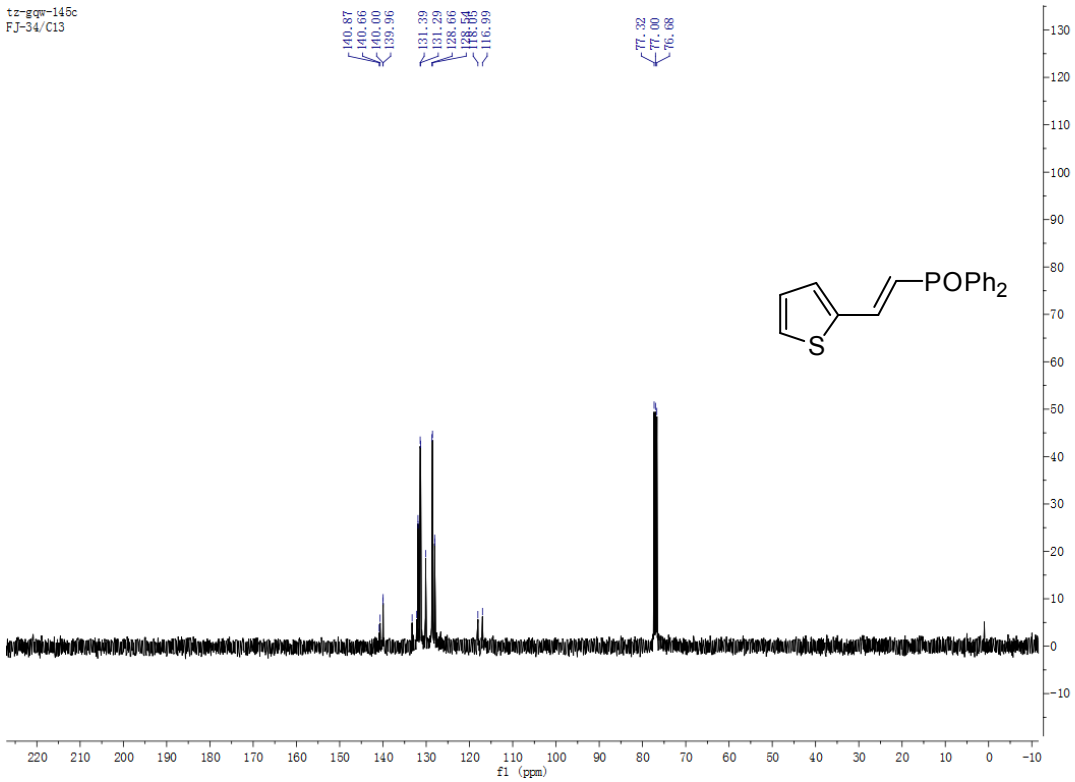

20131204-tz-gqw-444
gqw-444
7.38
7.33
7.26
7.25
7.23
7.21
7.19
7.16
7.14
4.15
4.13
4.11
4.09
2.88
2.86
2.84
2.49
2.48
2.46
2.44
1.37
1.35
1.33
0.00
PO(OEt)2
1.22
4.38
3.86
2.00
2.00
5.82
f1 (ppm)


20131205-tz-gqw-444
gqw-444
140.44
140.34
136.20
136.18
132.09
131.90
129.87
129.43
128.54
128.04
128.00
127.67
126.84
126.33
125.45
77.32
77.00
76.68
61.87
61.81
27.19
27.10
22.75
22.66
16.41
16.35
PO(OEt)2
f1 (ppm)


20131210-tz-gqw-458
gqw-458
PO(OEt)2
Ph
f1 (ppm)


20131210-tz-gqw-458
gqw-458
PO(OEt)2
Ph
f1 (ppm)


tz-gqw-145
pfpe-xi3000-20150308
POPh2
S
f1 (ppm)


tz-gqw-145c
FJ-34/C13
POPh2
S
f1 (ppm)