Supporting Information

Direct C-OH/P(O)-H Dehydration Coupling Forming Phosphine Oxides

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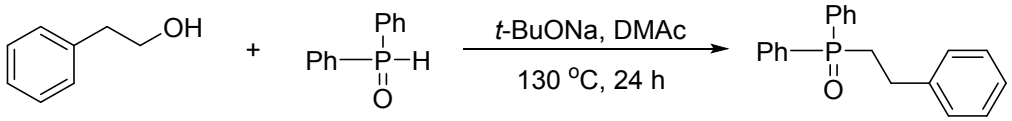
1. General information

All reactions were carried out in dry Schlenk tubes under N_2 atmosphere. Dry solvents were obtained by purification according to standard methods. Reagents were used as received unless otherwise noted. Column chromatography was performed using Silica Gel 60 (particle size 37–54 μm). The pure products were obtained by means of column chromatography. ^{1}H NMR, ^{13}C NMR and ^{31}P NMR data were acquired on a Bruker-400 spectrometer (400 MHz for ^{1}H, 100 MHz for ^{13}C, and 162 MHz for ^{31}P NMR spectroscopy). Chemical shifts for ^{1}H NMR are referred to internal Me_4Si (0 ppm) and reported as follows: chemical shift (δ ppm), multiplicity, coupling constant (Hz) and integration.

2. Procedures for the base-promoted dehydration coupling of P(O)-H compounds with phenylethanol

1) A Typical procedure.



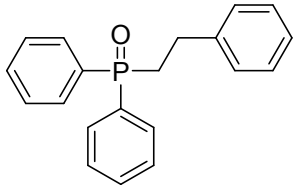
1a **2a** **3a**

Under the Nitrogen atmosphere, 0.5 mmol phenylethanol **1a**, 0.2 mmol diphenylphosphine oxide **2a**, 0.2 mmol sodium *tert*-butoxide and 1 mL DMAc were charged into a 25 mL Schleck tube, and the mixture was heated at 130 °C for 24 h. After being cooled to room temperature, the mixture was added to 10 mL CH_2Cl_2 and washed by 10 mL water for three times. After removal of the volatiles in vacuum, the residues were passed through a short silica chromatography (particle size 37–54 μm, ethyl acetate/petroleum ether as eluent) to afford analytically pure **3a** in 80% isolated yield.

2) 10 mmol scale experiment

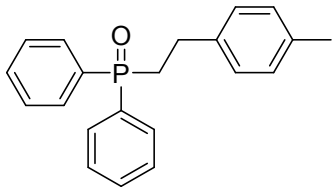
Under the Nitrogen atmosphere, 25 mmol phenylethanol **1a** (3.0541 g), 10 mmol diphenylphosphine oxide **2a** (2.0220 g), 10 mmol sodium *tert*-butoxide and 40 mL DMAc were charged into a 100 mL Schleck tube, and the mixture was heated at 130 °C for 24 h. After being cooled to room temperature, the mixture was added to 200 mL CH_2Cl_2 and washed by 100 mL water for three times. After removal of the volatiles in vacuum, the residues were passed through a silica chromatography (particle size 37–54 μm, ethyl acetate/petroleum ether as eluent) to afford analytically pure **3a** in 85% isolated yield (2.6041 g). When the experiment was conducted in the absence of solvent DMAc, **3a** was obtained in 76% isolated yield according to a similar procedure (2.3281 g).

3.Characterization and analytical data of products 3



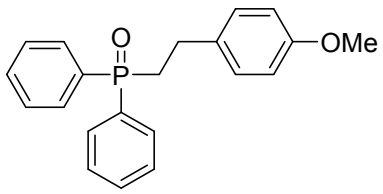
3a

phenethyldiphenylphosphine oxide (3a). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3a** (49.0 mg, 80% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.74 (m, 4H), 7.56–7.44 (m, 6H), 7.28–7.24 (m, 2H), 7.19–7.15 (m, 3H), 2.98–2.88 (m, 2H), 2.63–2.54 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.2 (d, $J_{C\text{-}P}$ = 15.3 Hz), 132.7 (d, $J_{C\text{-}P}$ = 97.8 Hz), 131.9 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.2 Hz), 128.8, 128.7 (d, $J_{C\text{-}P}$ = 6.5 Hz), 128.1, 126.4, 31.9 (d, $J_{C\text{-}P}$ = 69.6 Hz), 27.5 (d, $J_{C\text{-}P}$ = 3.0 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.69. This compound is known.[1]



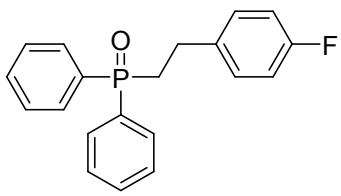
3b

(4-methylphenethyl)diphenylphosphine oxide (3b). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3b** (46.8 mg, 73% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81–7.71 (m, 4H), 7.55–7.43 (m, 6H), 7.05 (m, 4H), 2.92–2.86 (m, 2H), 2.60–2.53 (m, 2H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 138.1 (d, $J_{C\text{-}P}$ = 15.3 Hz), 135.9, 132.8 (d, $J_{C\text{-}P}$ = 97.6 Hz), 131.8 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 129.3, 128.7 (d, $J_{C\text{-}P}$ = 11.5 Hz), 128.0, 32.0 (d, $J_{C\text{-}P}$ = 69.3 Hz), 27.1 (d, $J_{C\text{-}P}$ = 3.1 Hz), 21.0; ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.66. This compound is known.[1]



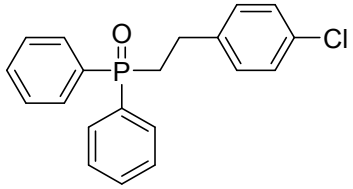
3c

(4-methoxyphenethyl)diphenylphosphine oxide (3c). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3c** (47.1 mg, 70% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82–7.71 (m, 4H), 7.55–7.48 (m, 6H), 7.09-7.07 (m, 2H), 6.81–6.79 (m, 2H), 3.77 (s, 3H), 2.91–2.85 (m, 2H), 2.59–2.52 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$); δ 158.1, 133.2 (d, $J_{C\text{-}P}$ = 15.6 Hz), 132.8 (d, $J_{C\text{-}P}$ = 97.5 Hz), 131.8 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 129.0, 128.7 (d, $J_{C\text{-}P}$ = 11.5 Hz), 114.0, 55.3, 32.1 (d, $J_{C\text{-}P}$ = 69.2 Hz), 26.7 (d, $J_{C\text{-}P}$ = 3.1 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.62. This compound is known.[2]



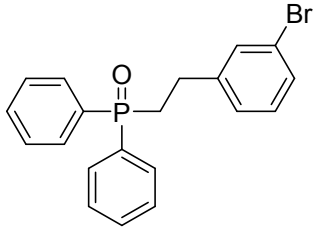
3d

(4-fluorophenethyl)diphenylphosphine oxide(3d). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (2/1) afforded **3d** (38.3 mg, 59% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72–7.64 (m, 4H), 7.48–7.36 (m, 6H), 7.06–7.00 (m, 2H), 6.84 (m, 2H), 2.83 (m, 2H), 2.47 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.5 (d, $J_{F\text{-}C}$ = 244.4 Hz), 136.7 (dd, $J_{C\text{-}P}$ = 15.0 Hz, $J_{C\text{-}F}$ = 3.1 Hz), 132.7 (d, $J_{C\text{-}P}$ = 98.3 Hz), 131.9 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 129.5 (d, $J_{C\text{-}F}$ = 7.9 Hz), 128.8 (d, $J_{C\text{-}P}$ = 11.6 Hz), 115.4 (d, $J_{C\text{-}F}$ = 21.3 Hz), 32.0 (d, $J_{C\text{-}P}$= 69.8 Hz), 26.8 (d, $J_{C\text{-}P}$ = 2.9 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.43. This compound is known.[2]



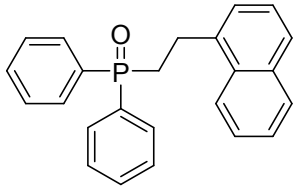
3e

(4-chlorophenethyl)diphenylphosphine oxide (3e). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3e** (60.7 mg, 89% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.70 (m, 4H), 7.53–7.48 (m, 6H), 7.21–7.20 (m, 2H), 7.09–7.07 (m, 2H), 2.94–2.88 (m, 2H), 2.58–2.52 (m, 2H);^{13}C NMR (100 MHz, $CDCl_3$): δ 139.6 (d, $J_{C\text{-}P}$ = 15.0 Hz), 132.6 (d, $J_{C\text{-}P}$ = 98.4 Hz), 132.1, 131.9 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 129.5, 128.8 (d, $J_{C\text{-}P}$ = 11.6 Hz), 128.7, 31.8 (d, $J_{C\text{-}P}$ = 69.5 Hz), 27.0 (d, $J_{C\text{-}P}$ = 2.9 Hz);^{31}P NMR (162 MHz, $CDCl_3$): δ 31.30. This compound is known.[2]



3f

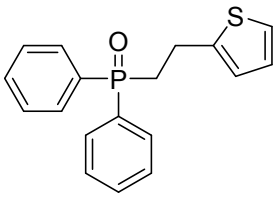
(3-bromophenethyl)diphenylphosphine oxide (3f). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3f** (67.8 mg, 88% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78–7.74 (m, 4H), 7.55–7.46 (m, 6H), 7.29–7.27 (m, 2H), 7.13–7.08 (m, 2H), 2.94–2.88 (m, 2H), 2.59–2.52 (m, 2H); ^{13}C NMR (100 MHz, CDCl3): δ 143.4 (d, $J_{C\text{-}P}$ = 14.9 Hz), 132.5 (d, $J_{C\text{-}P}$ = 98.1 Hz), 131.9 (d, $J_{C\text{-}P}$ = 2.7 Hz), 131.1, 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 130.2, 129.5, 128.8 (d, $J_{C\text{-}P}$ = 11.6 Hz), 126.9, 122.6, 31.6 (d, $J_{C\text{-}P}$ = 69.5 Hz), 27.3 (d, $J_{C\text{-}P}$ = 2.9 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.20. This compound is known.



3g

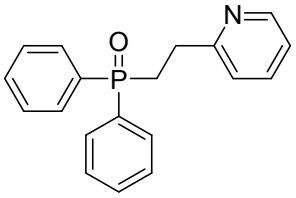
(2-(naphthalen-1-yl)ethyl)diphenylphosphine oxide(3g). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3g** (64.9 mg, 91% yield) as a pale yellow solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89–7.80 (m, 6H), 7.73–7.71 (m, 1H), 7.58–7.48 (m, 8H), 7.39–7.32 (m, 2H), 3.45–3.39 (m, 2H), 2.75–2.68 (m, 2H); ^{13}C NMR (100 MHz, CDCl3): δ 137.3 (d, $J_{C\text{-}P}$ = 14.6 Hz), 133.9, 132.8 (d, $J_{C\text{-}P}$ = 97.7 Hz), 131.9 (d, $J_{C\text{-}P}$ = 2.7 Hz), 131.3, 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 128.9, 128.7 (d, $J_{C\text{-}P}$ = 11.5 Hz), 127.2, 126.2,

125.8, 125.7, 125.6, 123.3, 31.2 (d, $J_{C\text{-}P}$ = 69.1 Hz), 24.8 (d, $J_{C\text{-}P}$ = 2.8 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.69. This compound is known.[1]



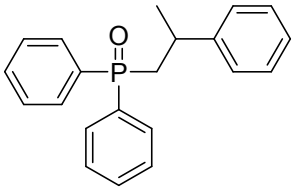
3h

diphenyl(2-(thiophen-2-yl)ethyl)phosphine oxide(3h). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3h** (48.7 mg, 78% yield) as a white solid;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.74 (m, 4H), 7.54–7.49 (m, 6H), 7.11 (s, 1H), 6.88 (s, 1H), 6.79 (s, 1H), 3.18–3.13 (m, 2H), 2.89–2.63 (m, 2H);^{13}C NMR (100 MHz, $CDCl_3$): δ 143.9 (d, $J_{C\text{-}P}$ = 17.5 Hz), 132.5 (d, J = 99.3 Hz), 132.0 (d, $J_{C\text{-}P}$ = 2.7 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.3 Hz), 128.8 (d, $J_{C\text{-}P}$ = 11.6 Hz), 126.9, 124.6, 123.6, 32.2 (d, $J_{C\text{-}P}$ = 69.2 Hz), 22.2 (d, $J_{C\text{-}P}$ = 2.1 Hz);^{31}P NMR (162 MHz, $CDCl_3$): δ 31.07.This compound is known.[1]



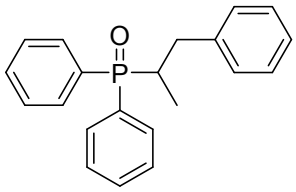
3i

diphenyl(2-(pyridin-2-yl)ethyl)phosphine oxide(3i). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3i** (40.0 mg, 65% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.49–8.48 (m, 1H), 7.81–7.78 (m, 4H), 7.55–7.44 (m, 7H), 7.14–7.12 (m, 1H), 7.10–7.07 (m, 1H), 3.15–3.09 (m, 2H), 2.82–2.78 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.2 (d, $J_{C\text{-}P}$ = 14.4 Hz), 149.3, 136.5, 132.8 (d, $J_{C\text{-}P}$ = 98.2 Hz), 131.8 (d, J = 2.7 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.4 Hz), 128.7 (d, $J_{C\text{-}P}$ = 11.7 Hz), 123.11, 121.51 , 29.7 (d, $J_{C\text{-}P}$ = 2.7 Hz), 29.2 (d, $J_{C\text{-}P}$ = 71.2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 32.39. This compound is known.[2]



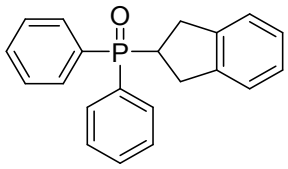
3j

diphenyl(2-phenylpropyl)phosphine oxide (3j). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3j** (48.7 mg, 76% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.72 (m, 2H), 7.68–7.63 (m, 2H), 7.49–7.35 (m, 6H), 7.21–7.17 (m, 2H), 7.13–7.09 (m, 3H), 3.38–3.27 (m, 1H), 2.63–2.54 (m, 2H), 1.38–1.37 (m, 3H); ^{13}C NMR (100 MHz, CDCl3) δ 147.0 (d, $J_{C\text{-}P}$ = 10.2 Hz), 134.4 (d, $J_{C\text{-}P}$ = 97.2 Hz), 132.8 (d, $J_{C\text{-}P}$ = 97.6 Hz), 131.6 (d, $J_{C\text{-}P}$ = 2.7 Hz), 131.5 (d, $J_{C\text{-}P}$ = 2.7 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.1 Hz), 130.5 (d, $J_{C\text{-}P}$ = 9.2 Hz), 128.6 (d, $J_{C\text{-}P}$ = 23.9 Hz), 128.55 (d, $J_{C\text{-}P}$ = 1.6 Hz), 128.5, 126.6, 126.4, 38.4 (d, $J_{C\text{-}P}$ = 69.0 Hz), 34.3 (d, $J_{C\text{-}P}$ = 3.1 Hz), 23.5 (d, $J_{C\text{-}P}$ = 5.2 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 30.30. This compound is known.[2]



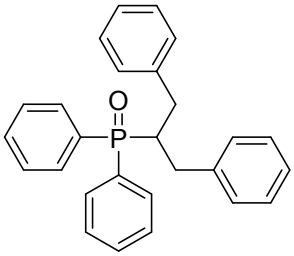
3k

diphenyl(1-phenylpropan-2-yl)phosphine oxide (3k). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3k** (36.5 mg, 57% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91–7.81 (m, 4H), 7.55–7.45 (m, 6H), 7.28–7.24 (m, 2H), 7.20–7.17 (m, 1H), 7.12–7.10 (m, 2H), 3.09–3.02 (m, 1H), 2.87–2.59 (m, 2H), 1.09–1.04 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.6 (d, $J_{C\text{-}P}$ = 14.7 Hz), 132.2 (d, $J_{C\text{-}P}$ = 94.1 Hz), 132.2 (d, $J_{C\text{-}P}$ = 96.2 Hz), 131.7 (d, $J_{C\text{-}P}$ = 2.8 Hz), 131.6 (d, $J_{C\text{-}P}$ = 2.6 Hz), 131.1, 131.0 (d, $J_{C\text{-}P}$ = 8.6 Hz), 129.0, 128.70, 128.7 (d, $J_{C\text{-}P}$ = 23.5 Hz), 128.5, 126.4, 35.0, 34.5 (d, $J_{C\text{-}P}$ = 70.6 Hz), 11.7 (d, $J_{C\text{-}P}$ = 2.5 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 36.16. This compound is known.[4]



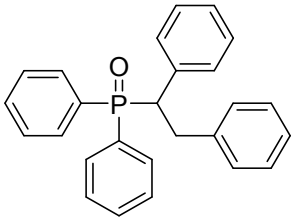
3l

(2,3-dihydro-1H-inden-2-yl)diphenylphosphine oxide(3l). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3l** (45.2 mg, 71% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84–7.80 (m, 4H), 7.54–7.46 (m, 6H), 7.12 (s, 4H), 3.46–3.10 (m, 3H), 3.06–3.01 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.7 (d, $J_{C\text{-}P}$ = 9.9 Hz), 132.8 (d, $J_{C\text{-}P}$ = 96.8 Hz), 131.8 (d, $J_{C\text{-}P}$ = 2.6 Hz), 131.0 (d, $J_{C\text{-}P}$ = 8.9 Hz), 128.7 (d, $J_{C\text{-}P}$ = 11.3 Hz), 126.7, 124.3, 37.8 (d, $J_{C\text{-}P}$ = 75.7 Hz), 33.1; ^{31}P NMR (162 MHz, $CDCl_3$) δ: 33.38. Melting point: 170.8-176.3 ^{o}C. HRMS: Cal. for $C_{21}H_{19}OP$ 318.1174. Found 318.1182. IR: 3021, 1435, 1183, 1118, 746, 722, 695 cm^{-1}.



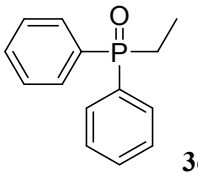
3m

(1,3-diphenylpropan-2-yl)diphenylphosphine oxide(3m). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3m** (36.5 mg, 46% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.74 (m, 4H), 7.43–7.34 (m, 6H), 7.05–7.04 (m, 6H), 6.81–6.79 (m, 4H), 3.10–3.02 (m, 2H), 2.93–2.79 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 139.7 (d, $J_{C\text{-}P}$ = 9.1 Hz), 132.6 (d, $J_{C\text{-}P}$ = 93.9 Hz), 131.4 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 8.7 Hz), 129.0, 128.5 (d, $J_{C\text{-}P}$ = 11.3 Hz), 128.2, 126.1, 42.2 (d, $J_{C\text{-}P}$ = 68.9 Hz), 33.8; ^{31}P NMR (162 MHz, $CDCl_3$): δ 34.59. This compound is known.[7]



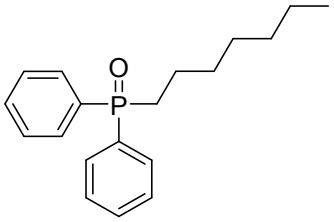
3n

(1,2-diphenylethyl)diphenylphosphine oxide(3n). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3n** (24.7 mg, 32% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.01–7.97 (m, 2H), 7.59 (s, 3H), 7.46–7.42 (m, 2H), 7.33–7.30 (m, 1H), 7.24–7.17 (m, 4H), 7.12–7.07 (m, 6H), 6.83–6.81 (m, 2H), 3.68–3.63 (m, 1H), 3.37–3.24 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) : δ 139.4 (d, $J_{C\text{-}P}$ = 14.1 Hz), 135.4 (d, $J_{C\text{-}P}$ = 5.3 Hz), 132.1 (d, $J_{C\text{-}P}$ = 98.7 Hz), 132.0 (d, $J_{C\text{-}P}$ = 94.1 Hz), 131.6 (d, $J_{C\text{-}P}$ = 59.1 Hz), 131.7 (d, $J_{C\text{-}P}$ = 59.1 Hz), 131.2 (d, $J_{C\text{-}P}$ = 39.7 Hz), 131.1 (d, $J_{C\text{-}P}$ = 40.1 Hz), 130.0 (d, $J_{C\text{-}P}$ = 5.9 Hz), 128.9 (d, $J_{C\text{-}P}$ = 11.2 Hz), 128.4 (d, $J_{C\text{-}P}$ = 53.9 Hz), 128.2, 128.2, 128.0 (d, $J_{C\text{-}P}$ = 11.6 Hz), 127.0 (d, $J_{C\text{-}P}$ = 2.4 Hz), 126.2, 49.2 (d, $J_{C\text{-}P}$ = 66.1 Hz), 36.0. ^{31}P NMR (162 MHz, $CDCl_3$): δ 32.86. This compound is known.[8]



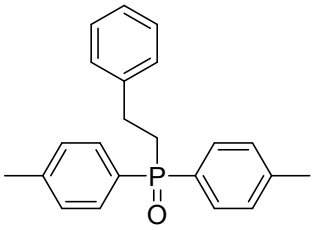
3o

ethyldiphenylphosphine oxide(3o). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3o** (16.1 mg, 35% yield) as a white solid;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76–7.72 (m, 4H), 7.54–7.45 (m, 6H), 2.33–2.24 (m, 2H), 1.26–1.24 (m, 1H), 1.20–1.16 (m, 2H);^{13}C NMR (100 MHz, $CDCl_3$): δ 132.9 (d, $J_{C\text{-}P}$ = 97.5 Hz), 131.7 (d, $J_{C\text{-}P}$ = 2.8 Hz), 130.9 (d, $J_{C\text{-}P}$ = 9.1 Hz), 128.6 (d, $J_{C\text{-}P}$ = 11.5 Hz), 22.7 (d, $J_{C\text{-}P}$ = 72.5 Hz), 5.6 (d, $J_{C\text{-}P}$ = 5.1 Hz);^{31}P NMR (162 MHz, $CDCl_3$): δ 34.06. This compound is known.[3]



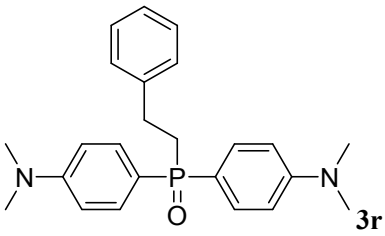
3p

heptyldiphenylphosphine oxide(3p). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3p** (22.8 mg, 38% yield) as a white solid;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68–7.63 (m, 4H), 7.45–7.36 (m, 6H), 2.21–2.14 (m, 2H), 1.59–1.49 (m, 2H), 1.32–1.27 (m, 2H), 1.18–1.15 (m, 6H), 0.78–0.75 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 133.2 (d, $J_{C\text{-}P}$ = 97.2 Hz), 131.6 (d, $J_{C\text{-}P}$ = 2.6 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.2 Hz), 128.6 (d, $J_{C\text{-}P}$ = 9.4 Hz), 31.6, 31.0 (d, $J_{C\text{-}P}$ = 14.6 Hz), 29.7 (d, $J_{C\text{-}P}$ = 76.9 Hz), 28.7, 22.6, 21.4 (d, $J_{C\text{-}P}$ = 3.8 Hz), 14.0; ^{31}P NMR (162 MHz, $CDCl_3$): δ 32.66. This compound is known.[5]



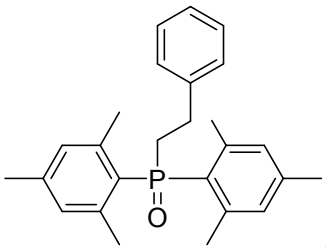
3q

phenethyldi-p-tolylphosphine oxide(3q). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3q** (50.8 mg, 76% yield) as a whitesolid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59–7.54 (m, 4H), 7.21–7.17 (m, 6H), 7.12–7.08 (m, 3H), 2.86–2.80 (m, 2H), 2.50–2.43 (m, 2H), 2.32 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ142.2 (d, $J_{C\text{-}P}$ = 2.6 Hz), 141.4 (d, $J_{C\text{-}P}$ = 15.2 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.6 Hz), 129.6 (d, $J_{C\text{-}P}$ = 100.2 Hz), 129.5 (d, $J_{C\text{-}P}$ = 12.0 Hz), 128.6, 128.1, 126.3, 32.1 (d, $J_{C\text{-}P}$ = 70.1 Hz), 27.6 (d, $J_{C\text{-}P}$ = 2.9 Hz), 21.6.; ^{31}P NMR (162 MHz, $CDCl_3$): δ 32.01. This compound is known.[1]



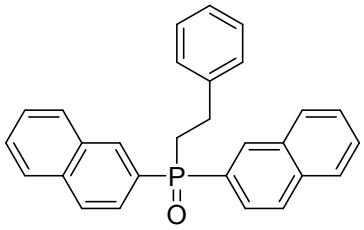
3r

bis(4-(dimethylamino)phenyl)(phenethyl)phosphine oxide(3r). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/1) afforded **3r** (65.9 mg, 84% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59–7.54 (m, 4H), 7.27–7.24 (m, 2H), 7.18–7.15 (m, 3H), 6.73–6.70 (m, 4H), 3.00 (s, 12H), 2.93–2.87 (m, 2H), 2.50–2.43 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.2 (d, $J_{C\text{-}P}$ = 2.3 Hz), 142.1 (d, $J_{C\text{-}P}$ = 15.5 Hz), 132.2 (d, $J_{C\text{-}P}$ = 10.4 Hz), 128.3 (d, $J_{C\text{-}P}$ = 39.0 Hz), 126.0, 118.9, 117.8, 111.5 (d, $J_{C\text{-}P}$ = 12.3 Hz), 40.0, 32.6 (d, $J_{C\text{-}P}$ = 70.8 Hz), 29.0 (d, $J_{C\text{-}P}$ = 2.7 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 32.84. Melting point: 177.5-179.1 ^{o}C. HRMS: Cal. for $C_{24}H_{29}N_2OP$ 392.2018. Found 392.2025. IR: 2943, 2861, 1452, 1400, 1165, 1118, 817, 740 cm^{-1}.



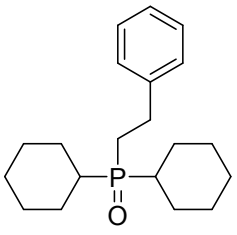
3s

dimesityl(phenethyl)phosphine oxide(3s). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3s** (55.5 mg, 71% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19–7.16 (m, 2H), 7.11–7.04 (m, 3H), 6.75 (s, 4H), 2.79–2.73 (m, 2H), 2.64–2.58 (m, 2H), 2.30 (s, 12H), 2.19 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 142.0 (d, $J_{C\text{-}P}$ = 16.8 Hz), 141.2 (d, $J_{C\text{-}P}$ = 10.0 Hz), 140.7 (d, $J_{C\text{-}P}$ = 2.6 Hz), 131.1 (d, $J_{C\text{-}P}$ = 11.0 Hz), 130.0 (d, $J_{C\text{-}P}$ = 94.1 Hz), 128.4 (d, $J_{C\text{-}P}$ = 28.2 Hz), 126.1, 38.2 (d, $J_{C\text{-}P}$ = 64.7 Hz), 28.8 (d, $J_{C\text{-}P}$ = 2.5 Hz), 22.9 (d, $J_{C\text{-}P}$ = 4.1 Hz), 20.9; ^{31}P NMR (162 MHz, $CDCl_3$): δ 40.39. Melting point: 219.8-223.5 ^{o}C. HRMS: Cal. for $C_{26}H_{31}OP$ 390.2113. Found 390.2116. IR: 2918, 1400, 1200, 1169, 764, 735, 699, 646 cm^{-1}.



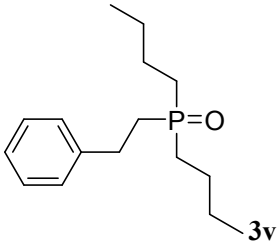
3t

di(naphthalen-2-yl)(phenethyl)phosphine oxide(3t). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (1/2) afforded **3t** (56.1 mg, 69% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.37–8.34 (m, 2H), 7.81–7.79 (m, 4H), 7.74–7.72 (m, 2H), 7.64–7.59 (m, 2H), 7.47–7.40 (m, 4H), 7.15–7.11 (m, 2H), 7.08–7.02 (m, 3H), 2.93–2.87 (m, 2H), 2.70–2.63 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.2 (d, $J_{C\text{-}P}$ = 15.2 Hz), 134.7 (d, $J_{C\text{-}P}$ = 2.3 Hz), 132.9 (d, $J_{C\text{-}P}$ = 8.5 Hz), 132.7 (d, $J_{C\text{-}P}$ = 12.5 Hz), 129.9 (d, $J_{C\text{-}P}$ = 98.2 Hz), 128.9, 128.8, 128.7, 128.3, 128.2, 127.9,127.1, 126.4, 125.6 (d, $J_{C\text{-}P}$ = 10.5 Hz), 31.8 (d, $J_{C\text{-}P}$ = 69.5 Hz), 27.7 (d, $J_{C\text{-}P}$ = 3.0 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 31.99. Melting point: 233.4-236.1 ^{o}C. HRMS: Cal. for $C_{28}H_{23}OP$ 406.1487. Found 406.1482. IR: 3094, 1452, 1440, 1167, 1094, 700, 653 cm^{-1}.



3u

dicyclohexyl(phenethyl)phosphine oxide(3u). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (2/1) afforded **3u** (38.2 mg, 60% yield) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32–7.28 (m, 2H), 7.23–7.19 (m, 3H), 2.97–2.91 (m, 2H), 1.98–1.93 (m, 5H), 1.85–1.75 (m, 9H), 1.42–1.39 (m, 4H), 1.28–1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.8 (d, $J_{C\text{-}P}$ = 12.5 Hz), 128.6, 128.0, 126.3, 36.4 (d, $J_{C\text{-}P}$ = 63.8 Hz), 28.1 (d, $J_{C\text{-}P}$ = 3.6 Hz), 26.6 (dd, $J_{C\text{-}P}$ = 12.1, 2.9 Hz), 26.0, 25.7 (d, $J_{C\text{-}P}$ = 3.1 Hz), 25.6 (d, $J_{C\text{-}P}$ = 58.4 Hz); ^{31}P NMR (162 MHz, $CDCl_3$): δ 50.24. This compound is known.[6]



3v

dibutyl(phenethyl)phosphine oxide(3v). Purification by column chromatography on silica gel and eluted with ethyl acetate/petroleum ether (2/1) afforded **3v** (34.6 mg, 65% yield) as a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32–7.28 (m, 2H), 7.24–7.20 (m, 3H), 2.96–2.90 (m, 2H), 2.05–1.99 (m, 2H), 1.75–1.68 (m, 4H), 1.60–1.50 (m, 4H), 1.46–1.37 (m, 4H), 0.946–0.910 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 141.2 (d, $J_{C\text{-}P}$ = 13.2 Hz), 128.7, 128.1, 126.4, 29.7 (d, $J_{C\text{-}P}$ = 62.6 Hz), 27.8 (d, $J_{C\text{-}P}$ = 64.5 Hz), 27.7 (d, $J_{C\text{-}P}$ = 3.1 Hz), 24.3 (d, $J_{C\text{-}P}$ = 14.3 Hz), 23.8 (d, $J_{C\text{-}P}$ = 3.7 Hz), 13.6; ^{31}P NMR (162 MHz, $CDCl_3$): δ 48.17. This compound is known.[1]

4.References:

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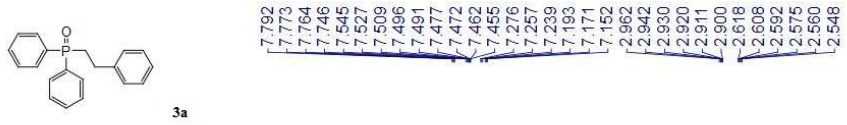
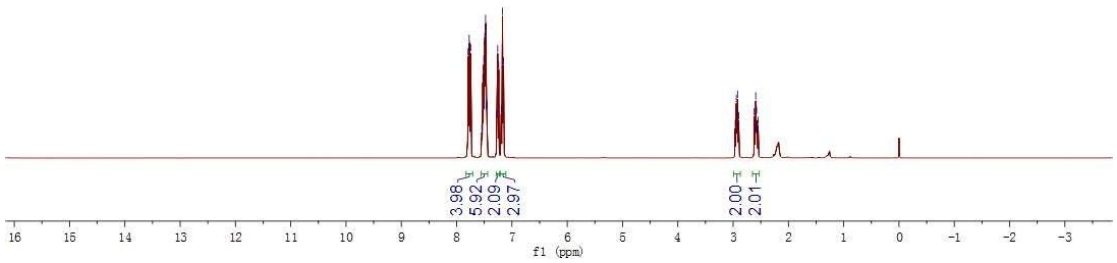
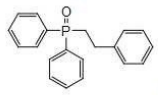
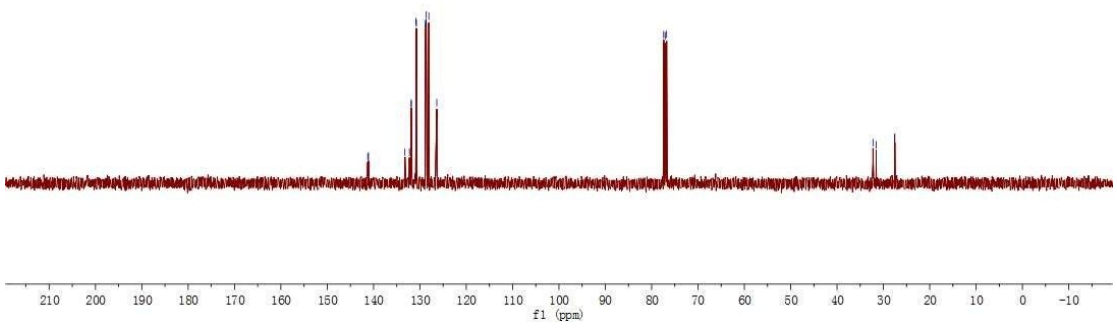
5. Copies of ^{1}H NMR, ^{31}P NMR and ^{13}C NMR spectroscopies

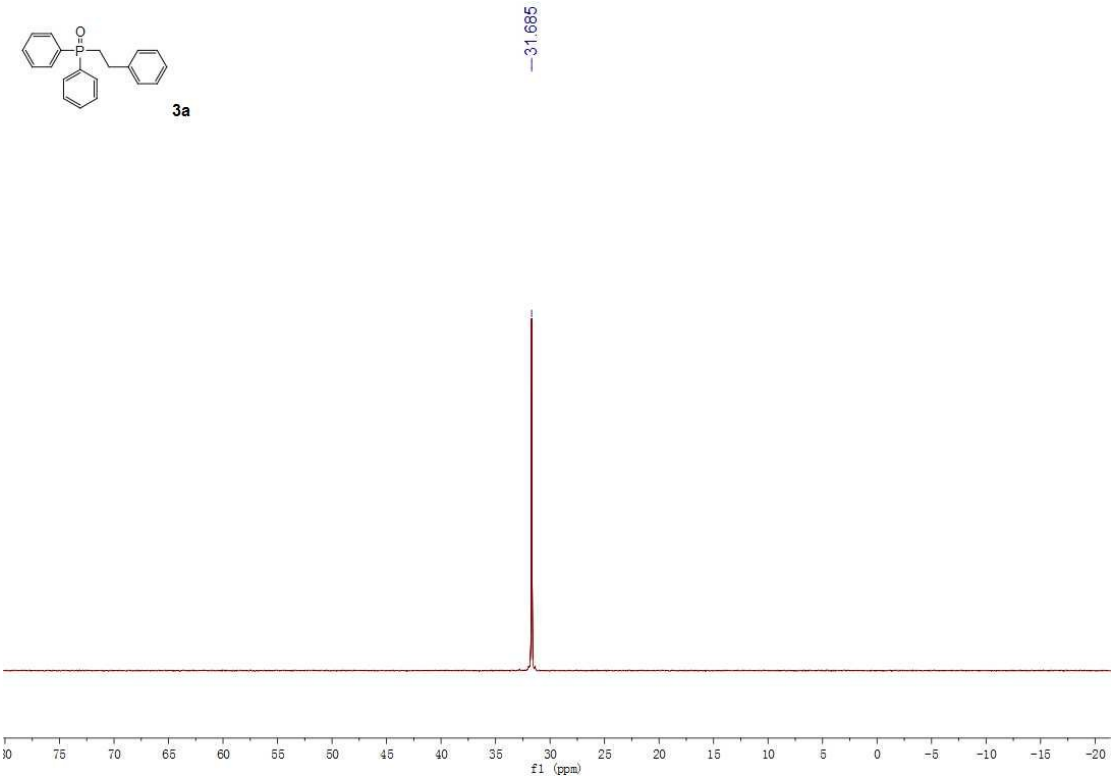








3a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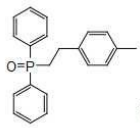

3b


7.787
7.766
7.741
7.532
7.516
7.498
7.482
7.464
7.449
7.056
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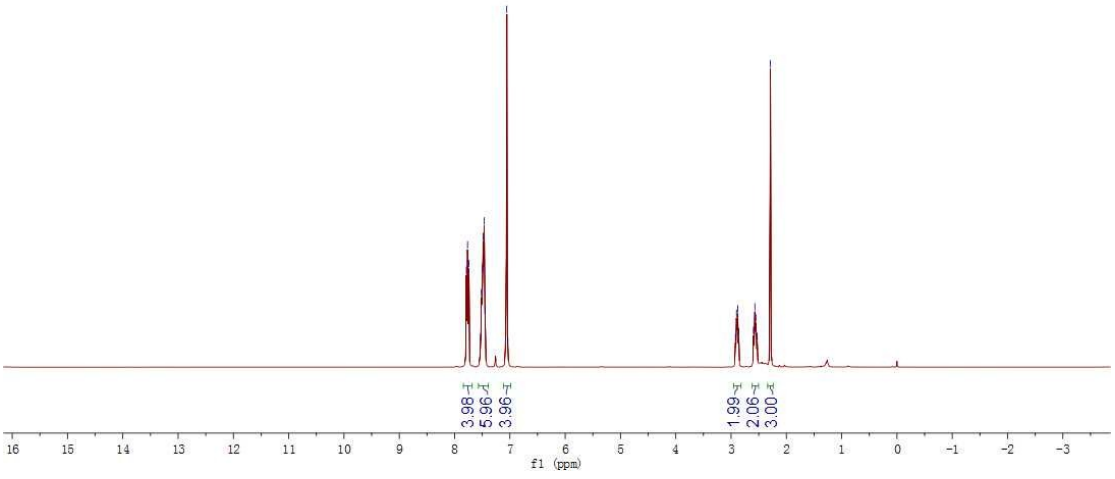
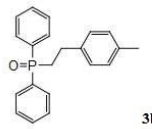
2.553
2.527
2.289


3.98
5.96
3.96
1.99
2.05
3.00
f1 (ppm)

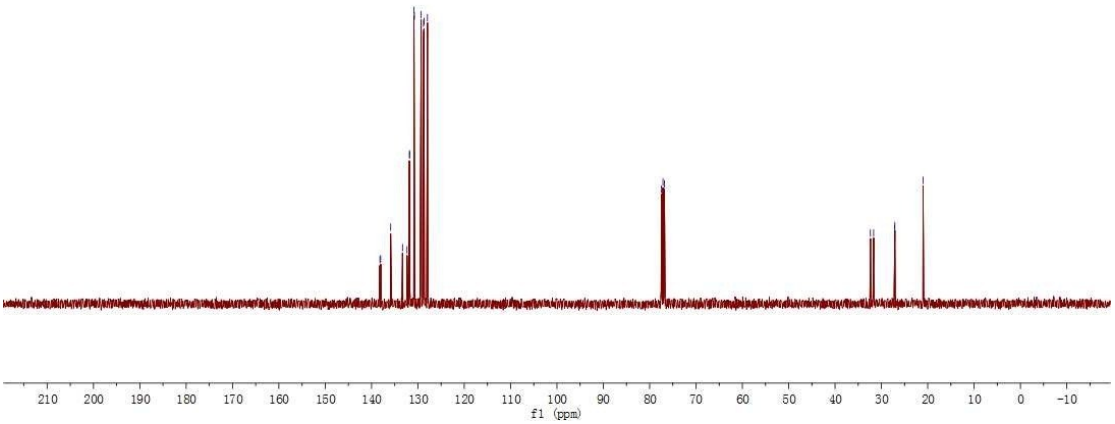


3b


138.191
138.038
135.877
133.320
132.344
131.826
131.800
130.844
130.751
129.298
128.796
128.681
127.945


77.445
77.127
76.810


32.365
31.672
27.127
27.096
21.005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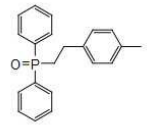
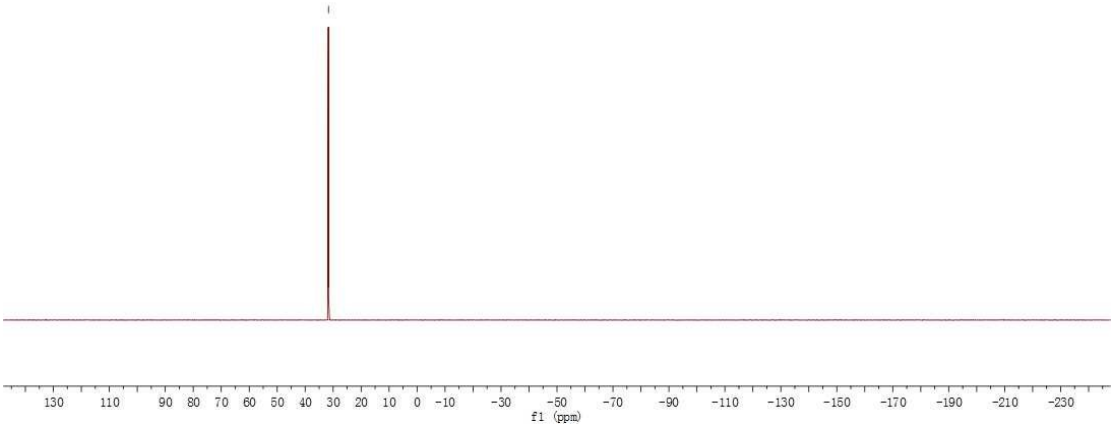


3b


31.659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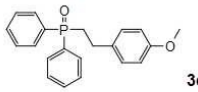
f1 (ppm)



3c


7.786
7.764
7.740
7.546
7.531
7.514
7.496
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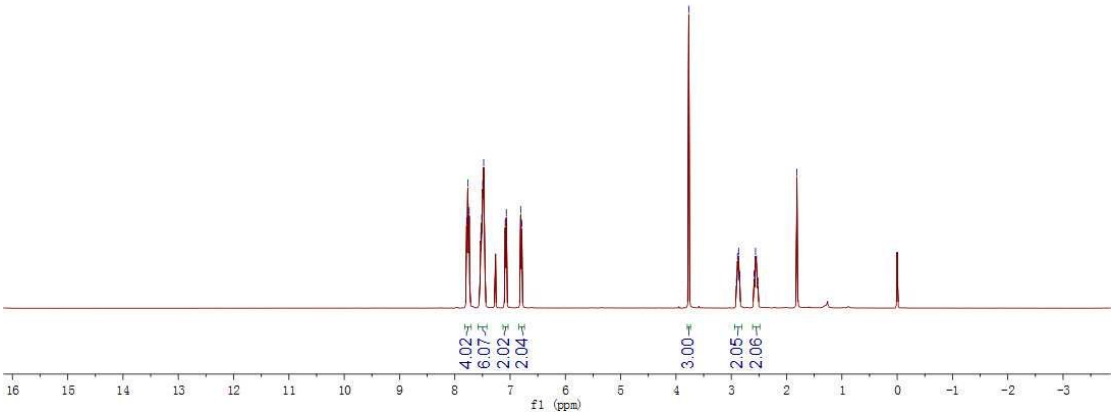
2.545
1.813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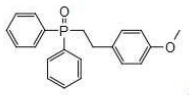
2.04
3.00
2.05
2.06
f1 (ppm)



3c


158.11
133.31
133.29
131.82
131.79
130.84
130.75
129.03
128.79
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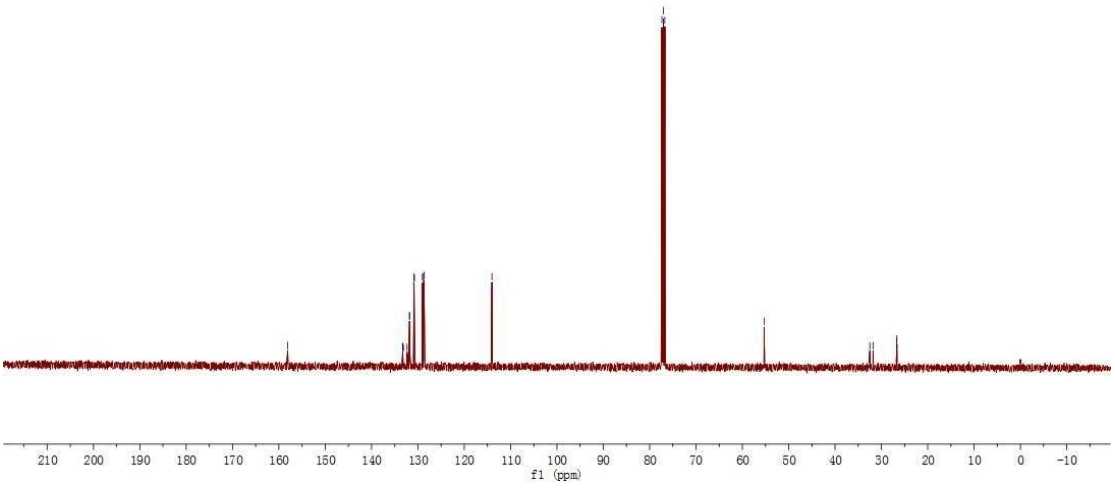
31.79
26.70
26.66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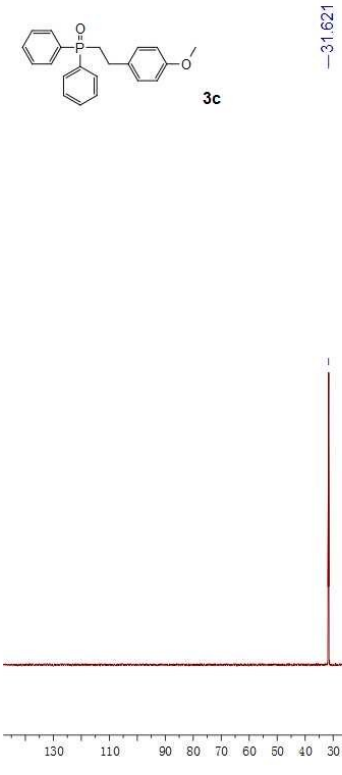
3c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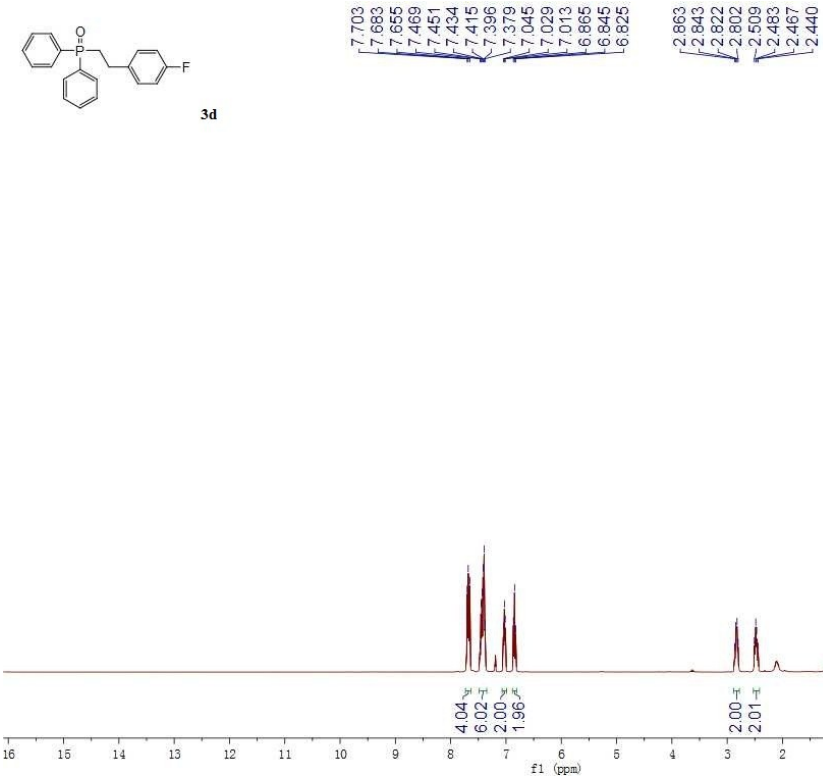
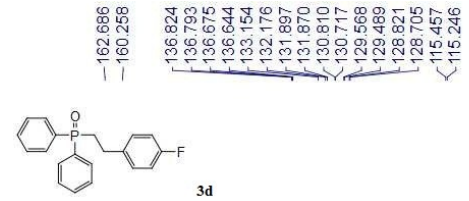
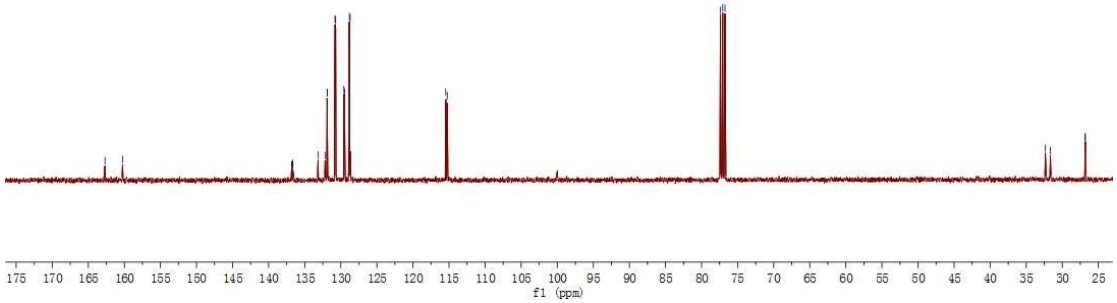
f1 (ppm)

3d


7.703
7.683
7.655
7.469
7.451
7.434
7.415
7.396
7.379
7.045
7.029
7.013
6.865
6.845
6.825
2.863
2.843
2.822
2.802
2.509
2.483
2.467
2.440
4.04
6.02
2.00
1.96
2.00
2.01
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

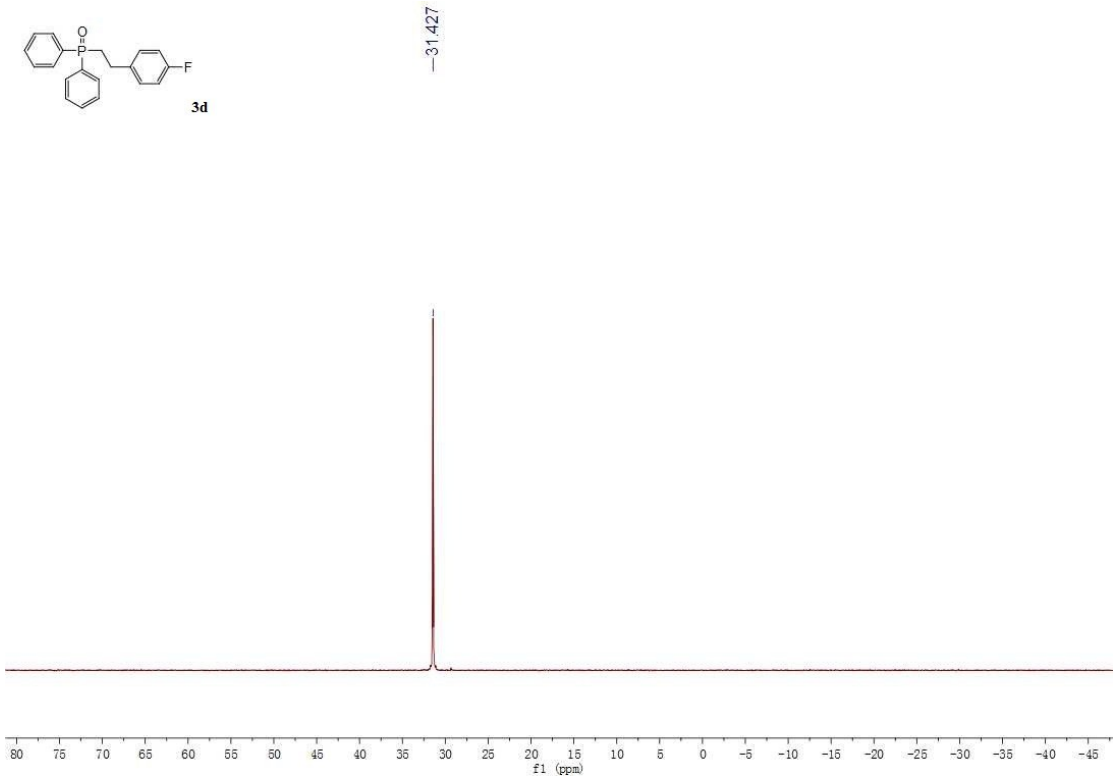

162.686
160.258
136.824
136.793
136.675
136.644
133.154
132.176
131.897
131.870
130.810
130.717
129.568
129.489
128.821
128.705
115.457
115.246
77.388
77.070
76.752
32.342
31.649
26.834
26.805
O
P
F

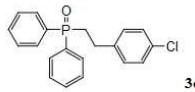
3d


175 170 165 160 155 150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25
f1 (ppm)

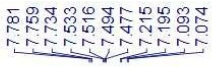
O
P
F

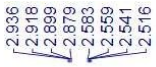
3d

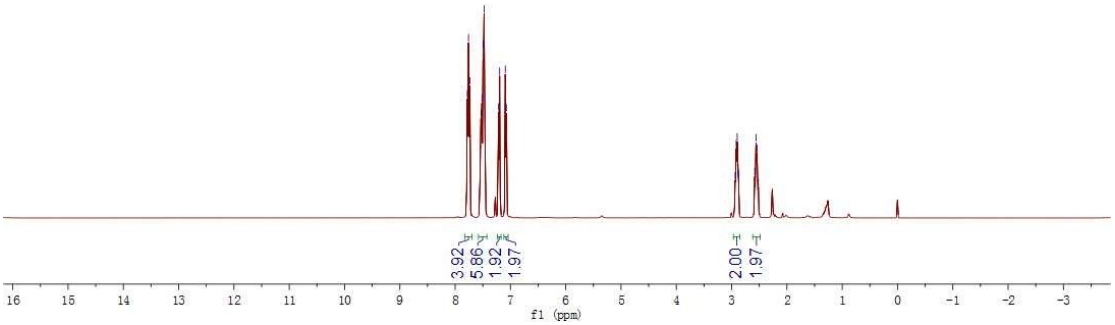

31.427
80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45
f1 (ppm)

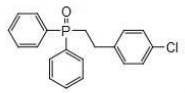

O
P
Cl

3e


7.781
7.759
7.734
7.533
7.516
7.494
7.477
7.215
7.195
7.093
7.074


2.936
2.918
2.899
2.879
2.583
2.559
2.541
2.516


3.92
5.86
1.92
1.97
2.00
1.97
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

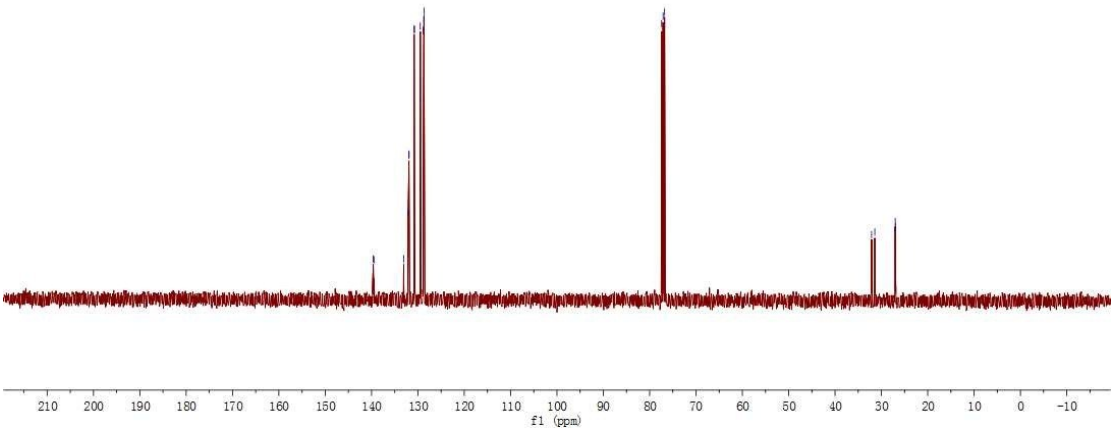

O
P
Cl

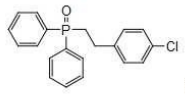
3e


139.63
139.48
133.08
132.10
131.93
131.90
130.81
130.72
129.49
128.84
128.73
128.69


77.42
77.10
76.78

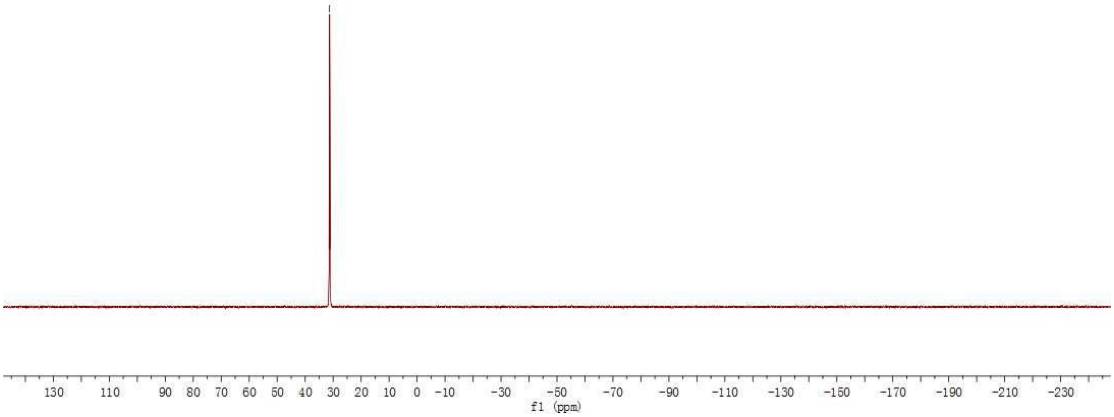

32.12
31.42
27.01
26.98

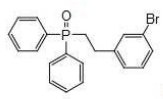

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



3e

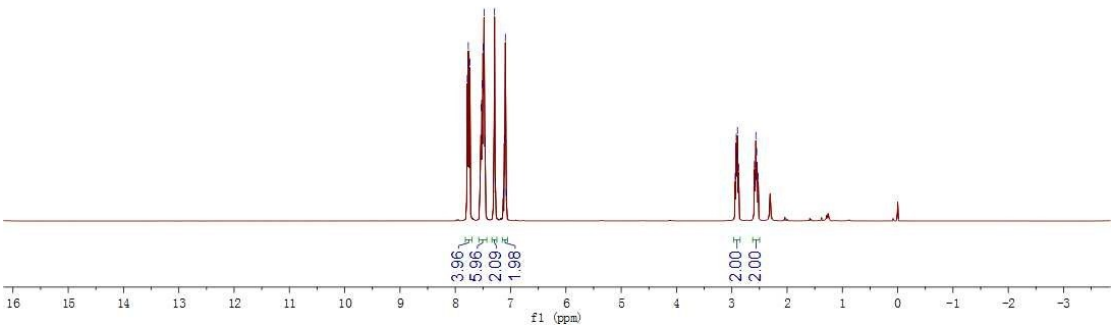
31.295

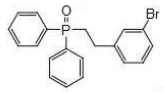




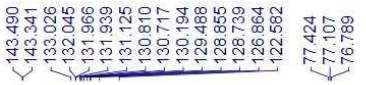
3f

7.784
7.765
7.756
7.737
7.551
7.533
7.516
7.499
7.480
7.463
7.291
7.274
7.132
7.113
7.095
7.081
2.939
2.919
2.907
2.898
2.877
2.592
2.580
2.565
2.550
2.522




O
P
Br

3f


143.490
143.341
133.026
132.045
131.966
131.939
131.125
130.810
130.717
130.194
129.488
128.855
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126.864
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77.107
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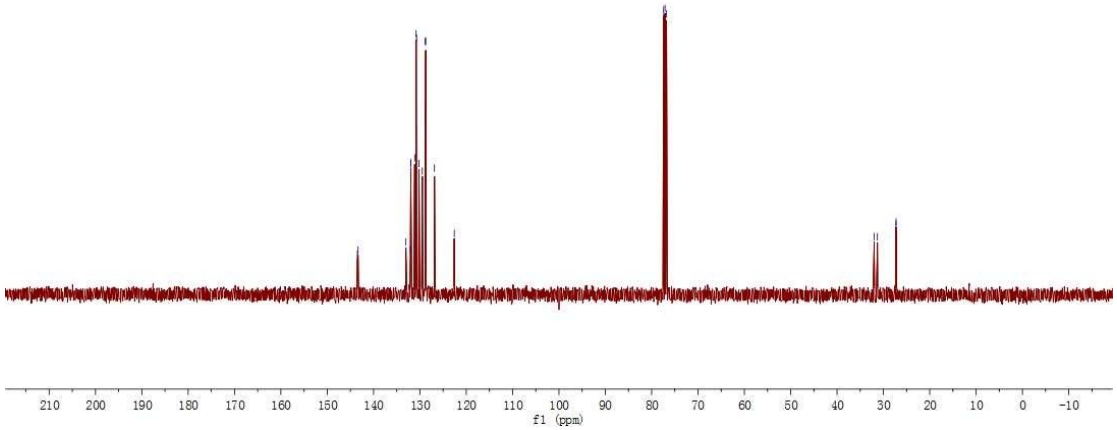
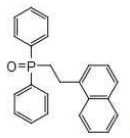
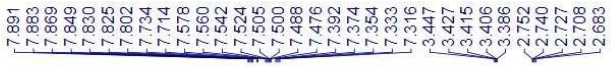
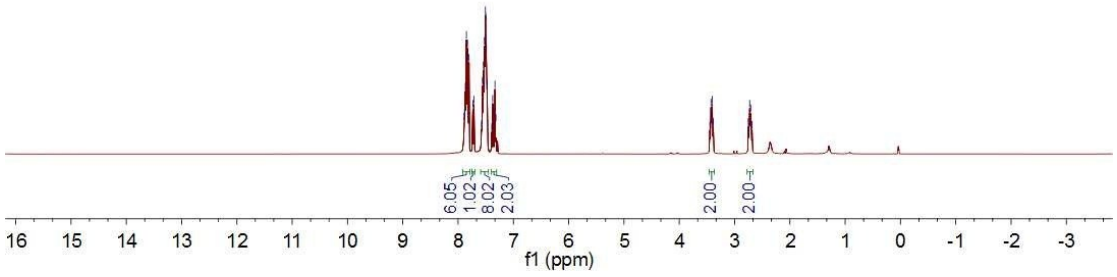
31.287
27.285
27.256

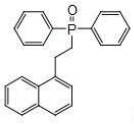

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


O=P

3g


7.891
7.883
7.869
7.849
7.830
7.825
7.802
7.734
7.714
7.578
7.560
7.542
7.524
7.505
7.500
7.488
7.476
7.392
7.374
7.354
7.333
7.316
3.447
3.427
3.415
3.406
3.386
2.752
2.740
2.727
2.708
2.683


6.05
1.02
8.02
2.03
2.00
2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

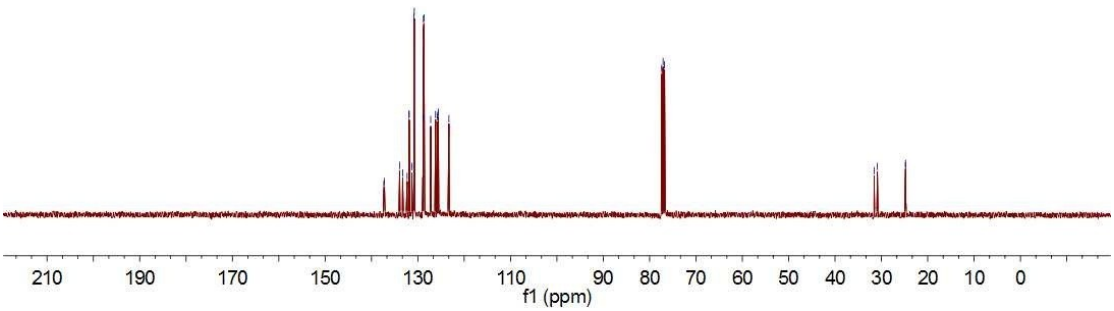


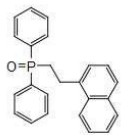
3g

137.344
137.198
133.929
133.287
132.310
131.895
131.868
131.306
130.866
130.773
128.903
128.802
128.687
127.235
126.187
125.833
125.671
125.599
123.306

77.414
77.096
76.778

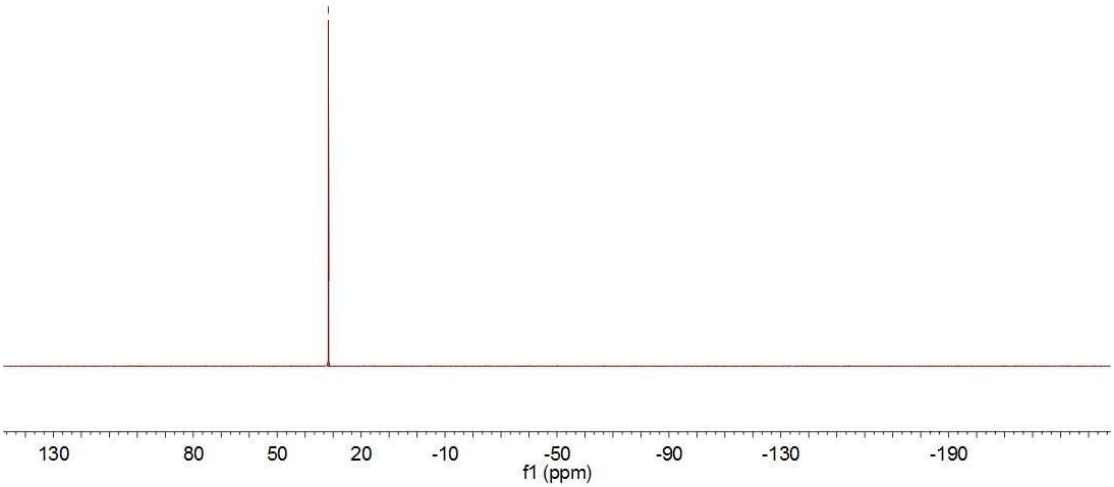
31.554
30.863
24.812
24.784

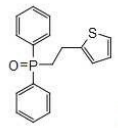




3g

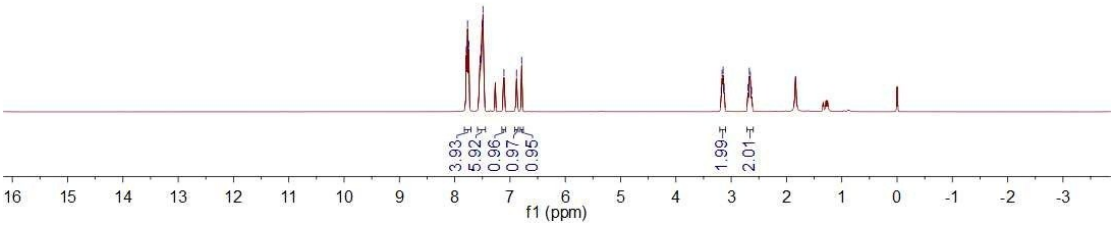
31.695

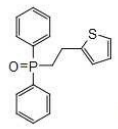




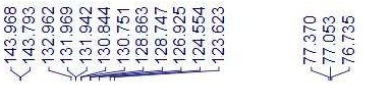
3h

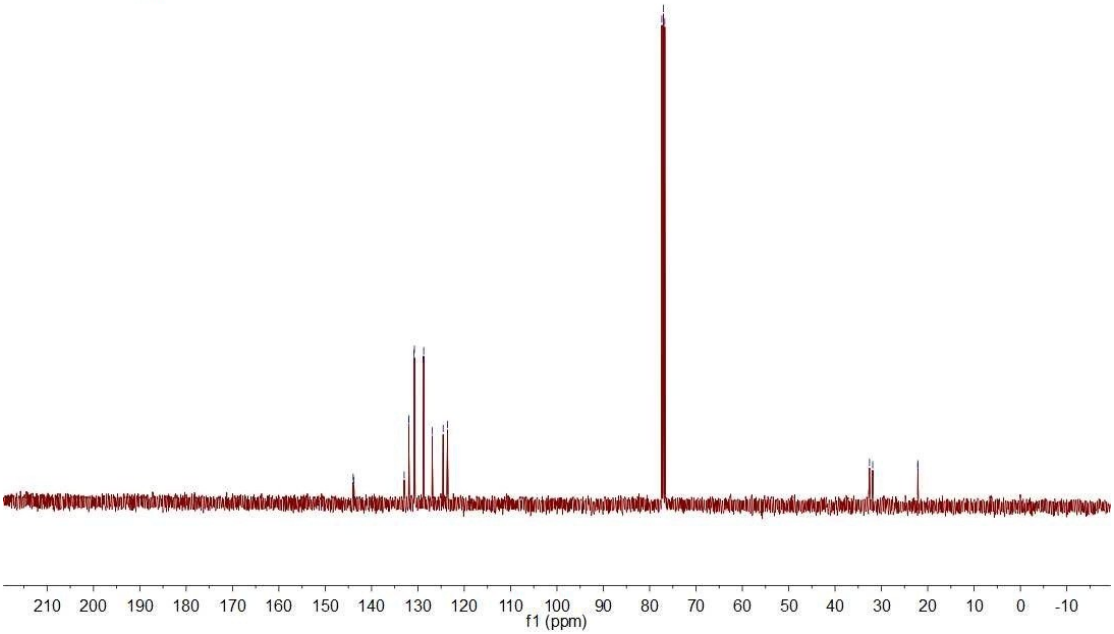

7.791
7.768
7.744
7.543
7.526
7.507
7.489
7.110
6.882
6.790
3.181
3.165
3.146
3.128
2.695
2.672
2.654
2.631


3.93
5.92
0.96
0.97
0.95
1.99
2.01
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

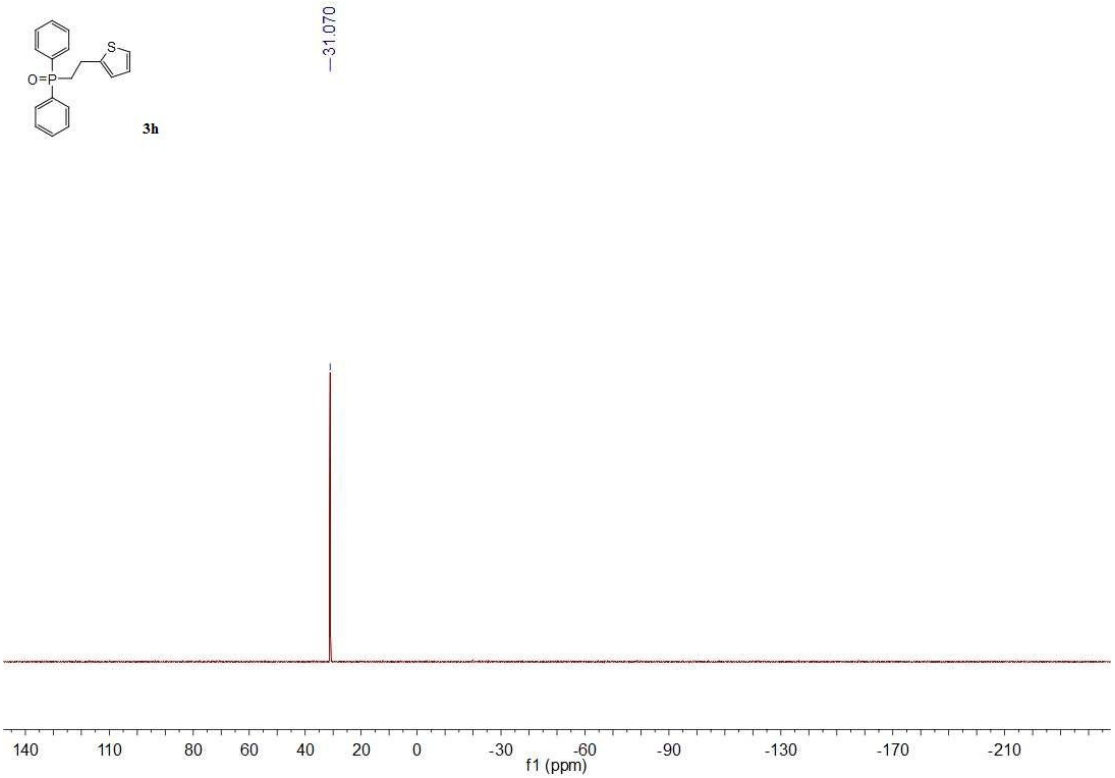


3h

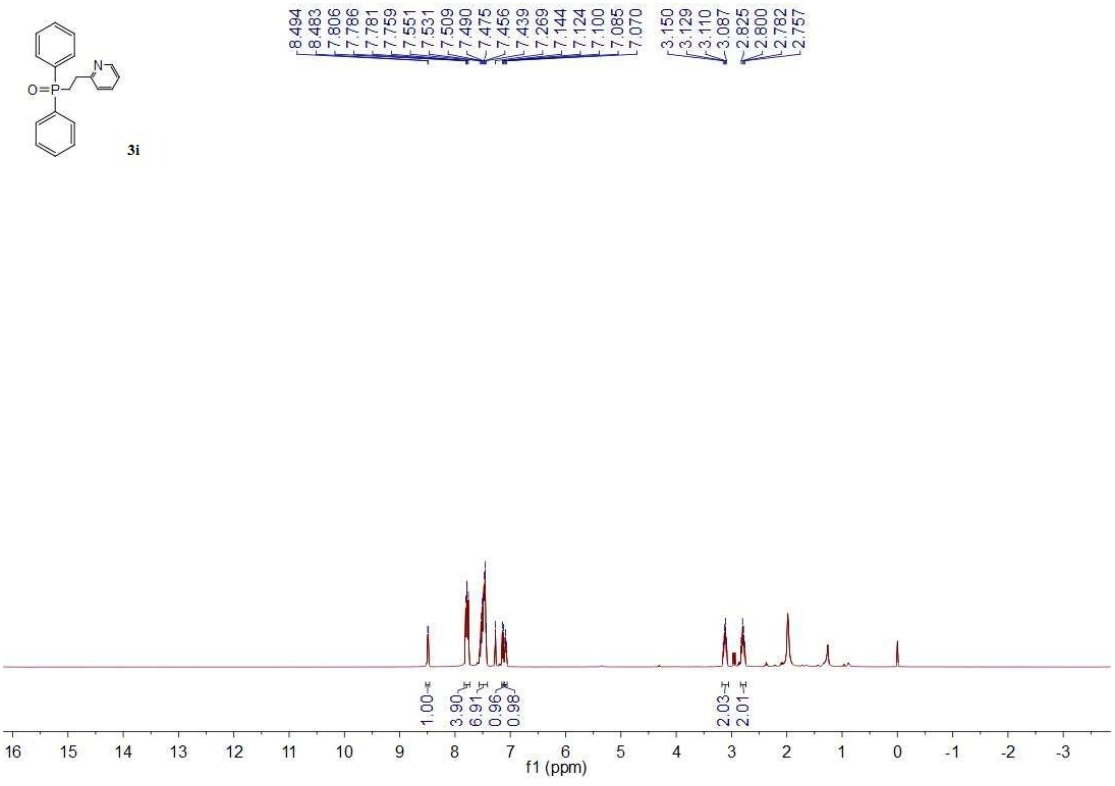

143.968
143.793
132.962
131.969
131.942
130.844
130.751
128.863
128.747
126.925
124.554
123.623
77.370
77.053
76.735
32.566
31.874
22.159
22.138

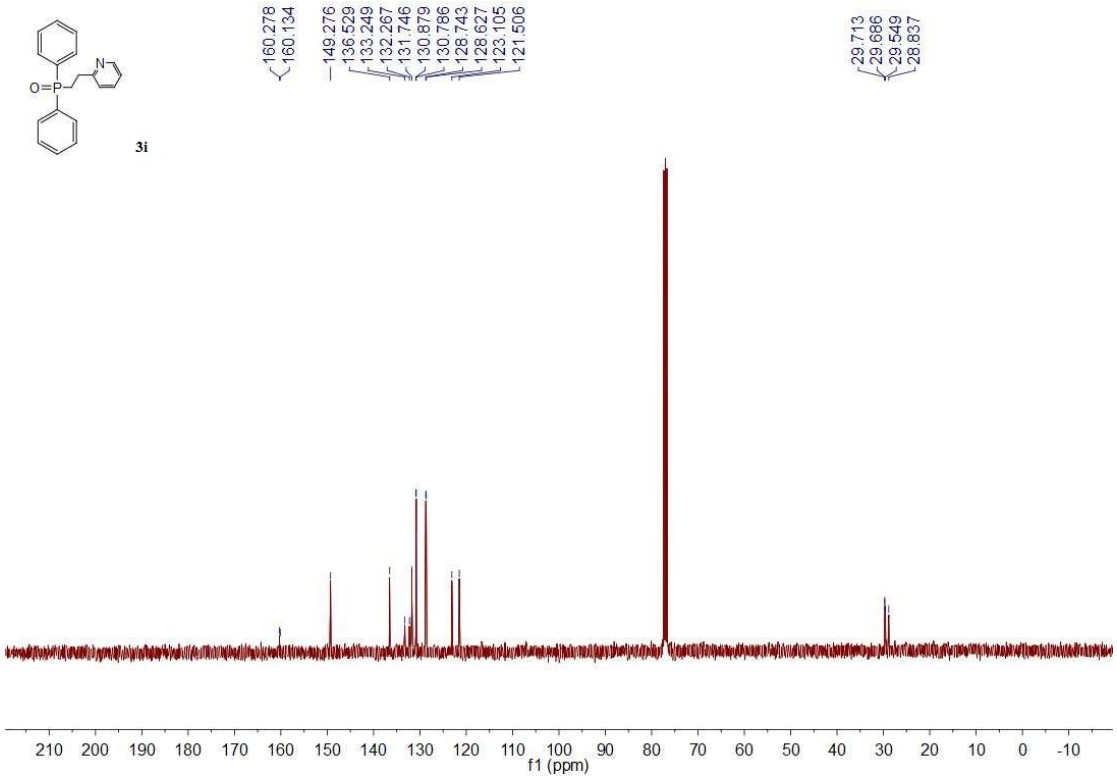

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

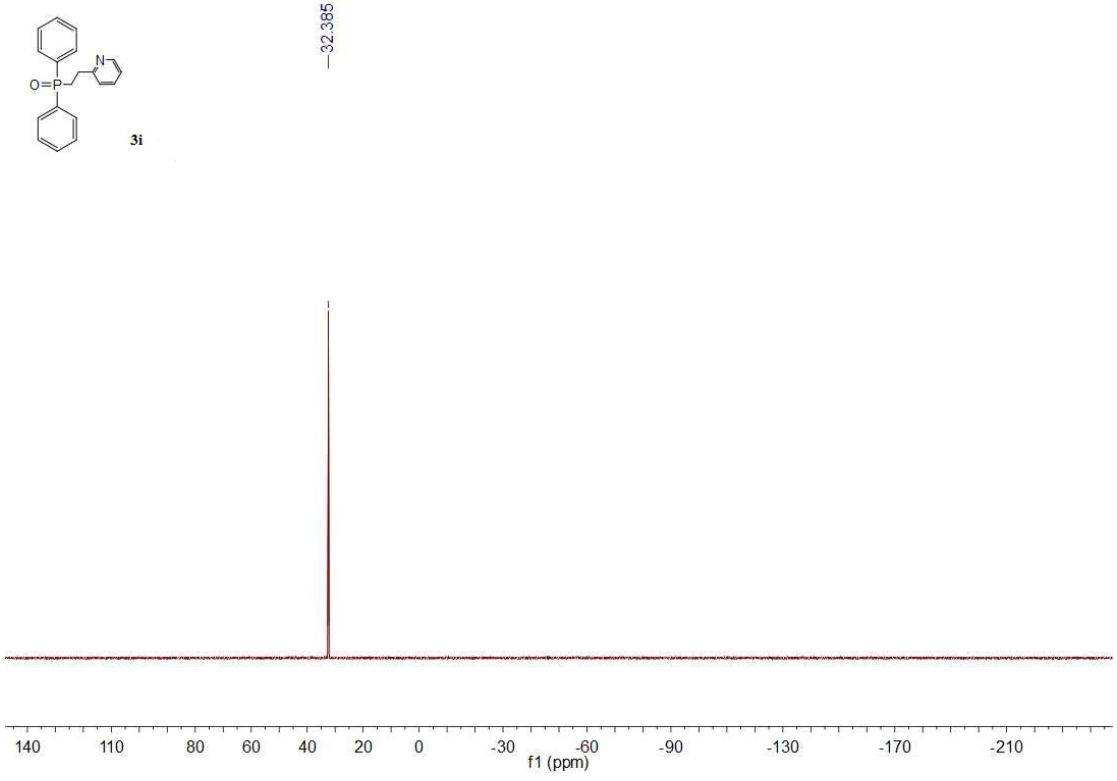
3h

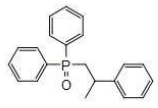

31.070
140
110
80
60
40
20
0
-30
-60
-90
-130
-170
-210
f1 (ppm)

3i


8.494
8.483
7.806
7.786
7.781
7.759
7.551
7.531
7.509
7.490
7.475
7.456
7.439
7.269
7.144
7.124
7.100
7.085
7.070
3.150
3.129
3.110
3.087
2.825
2.800
2.782
2.757
1.00
3.90
6.91
0.96
0.98
2.03
2.01
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)

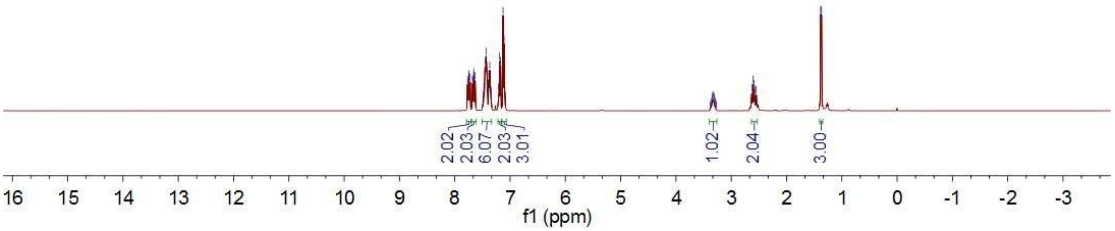

160.278
160.134
149.276
136.529
133.249
132.267
131.746
130.879
130.786
128.743
128.627
123.105
121.506
29.713
29.686
29.549
28.837
3i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

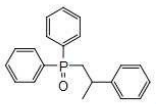

32.385
3i
140 110 80 60 40 20 0 -30 -60 -90 -130 -170 -210
f1 (ppm)



3j


7.768
7.749
7.744
7.721
7.678
7.659
7.654
7.631
7.492
7.474
7.451
7.431
7.385
7.367
7.349
7.208
7.189
7.171
7.127
7.109
7.091
3.347
3.335
3.319
3.306
2.626
2.604
2.587
2.575
2.553
1.384
1.367


2.02
2.03
6.07
2.03
3.01
1.02
2.04
3.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



3j


147.088
146.981
134.864
133.892
133.303
132.327
131.605
131.578
131.472
131.445
130.869
130.778
130.582
130.490
128.680
128.559
128.543
128.441
126.636
126.377
77.454
77.136
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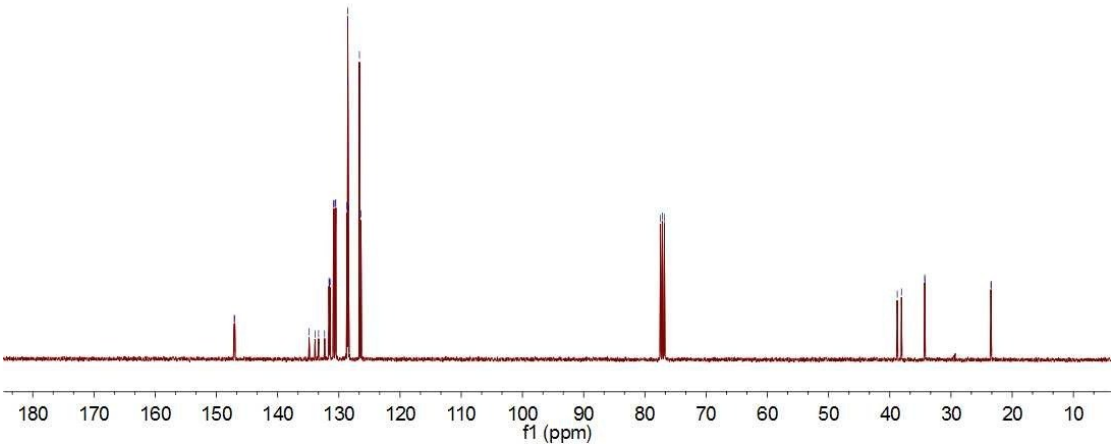
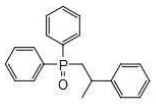
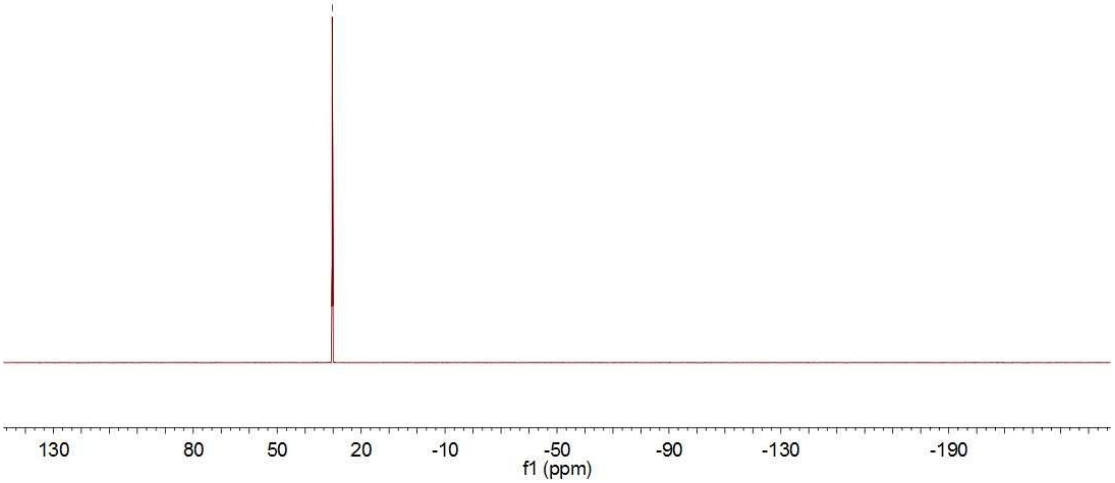
34.265
23.476
23.424

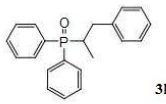

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)



3j

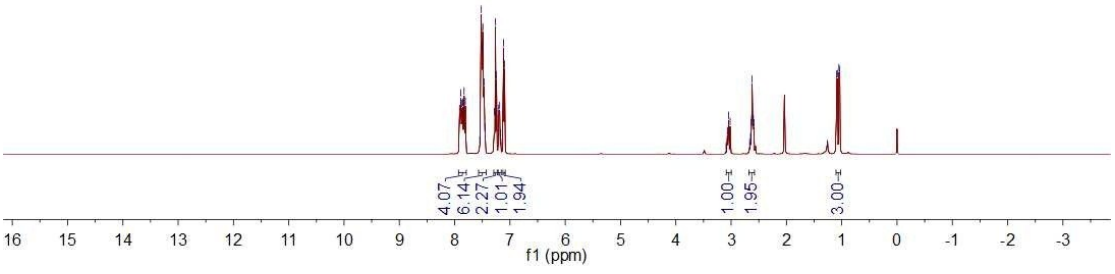

30.301

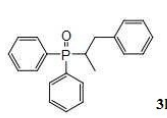

130
80
50
20
-10
-50
-90
-130
-190
f1 (ppm)



3k

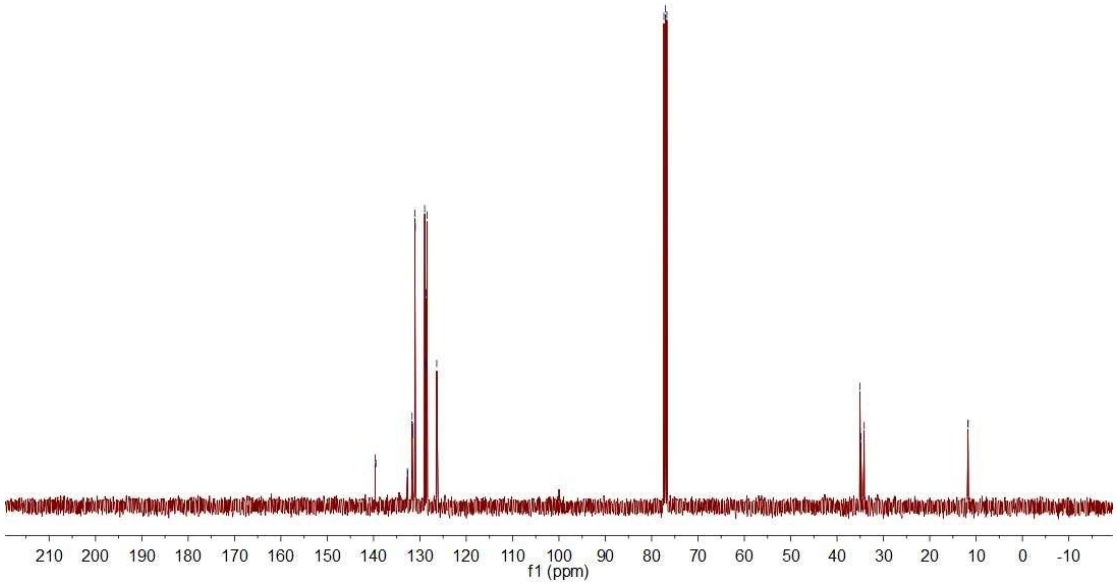

7.912
7.888
7.867
7.853
7.829
7.807
7.547
7.520
7.508
7.490
7.470
7.454
7.280
7.262
7.244
7.204
7.186
7.168
7.117
7.098
3.069
3.046
3.019
2.665
2.650
2.635
2.620
2.598
1.078
1.051
1.036

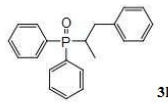

4.07
6.14
2.27
1.01
1.94
1.00
1.95
3.00
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)



3k

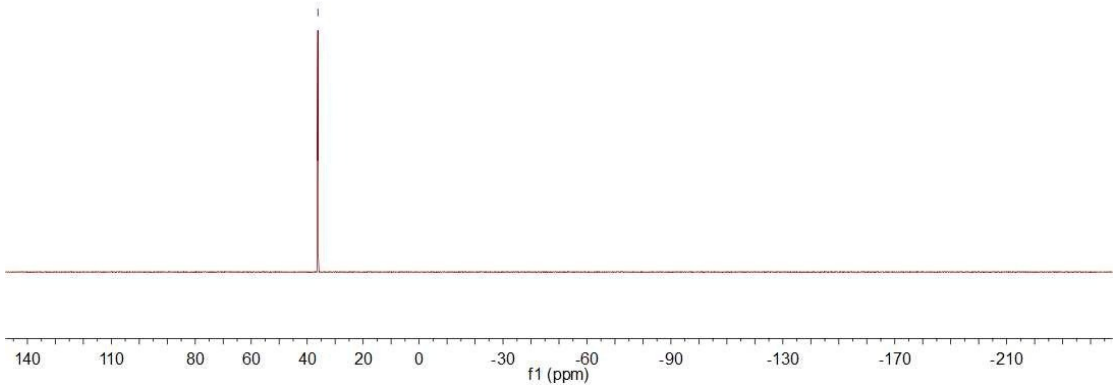

139.641
139.495
132.703
132.648
131.762
131.686
131.658
131.610
131.584
131.077
130.991
128.970
128.821
128.705
128.586
128.456
126.365
77.360
77.042
76.724
35.040
34.849
34.143
11.738
11.713

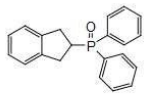

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



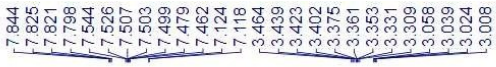
3k

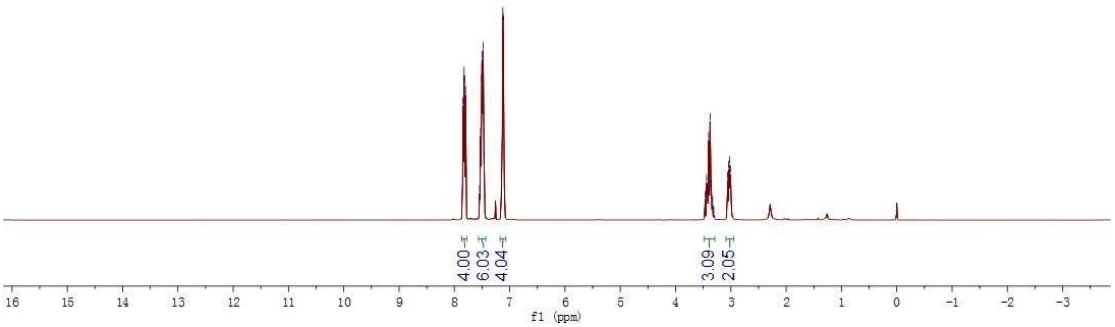

36.164

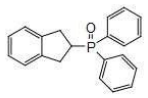

140 110 80 60 40 20 0 -30 -60 -90 -130 -170 -210
f1 (ppm)



3l

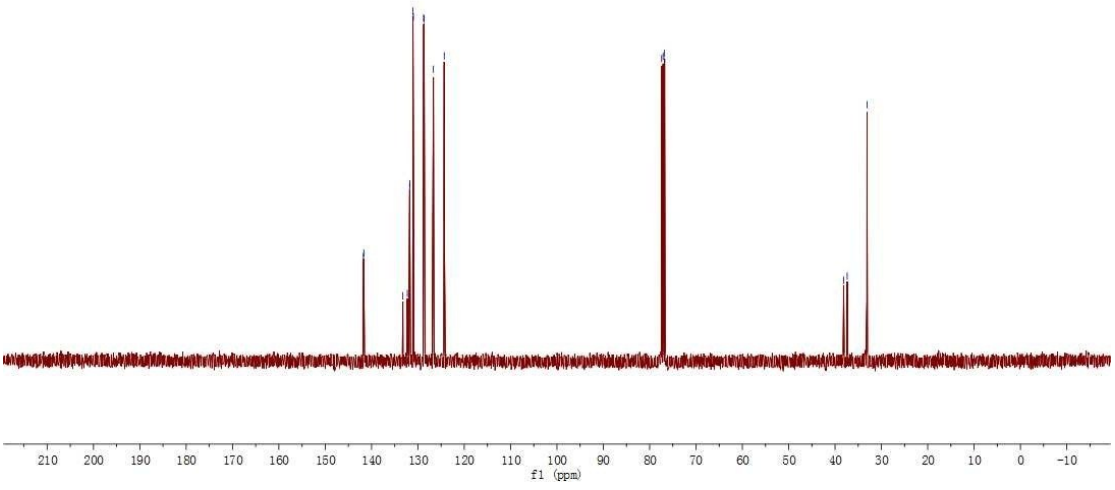

7.844
7.825
7.821
7.798
7.544
7.526
7.507
7.503
7.499
7.479
7.462
7.124
7.118
3.464
3.439
3.423
3.402
3.375
3.361
3.353
3.331
3.309
3.058
3.039
3.024
3.008

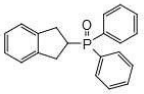

4.00
6.03
4.04
3.09
2.05
f1 (ppm)



3l

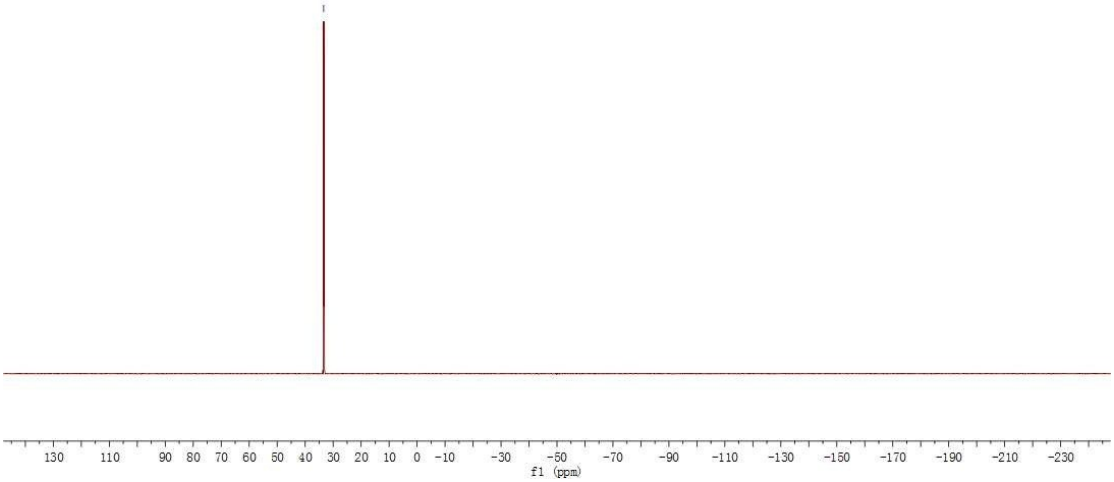

141.766
141.667
133.245
132.277
131.784
131.758
131.066
130.977
128.777
128.664
126.656
124.321
77.412
77.094
76.776
38.135
37.378
33.109

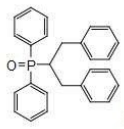

f1 (ppm)



3l

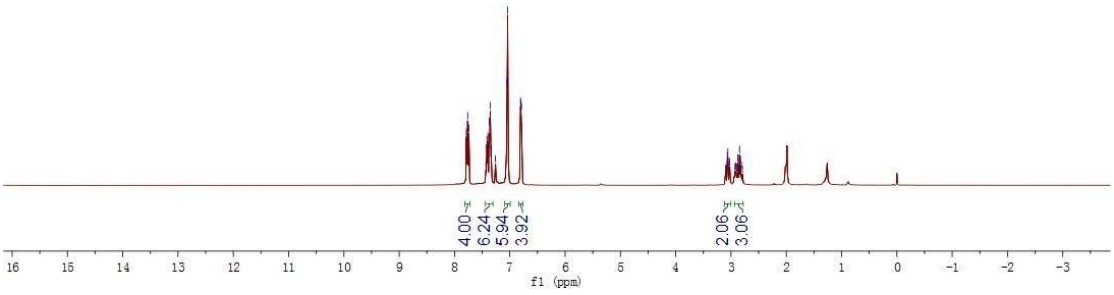
33.384

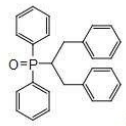




3m

7.786
7.763
7.740
7.432
7.414
7.396
7.372
7.353
7.337
7.259
7.052
7.040
6.806
6.802
6.789
3.100
3.090
3.068
3.057
3.034
3.023
2.928
2.914
2.899
2.877
2.860
2.845
2.827
2.812
2.794



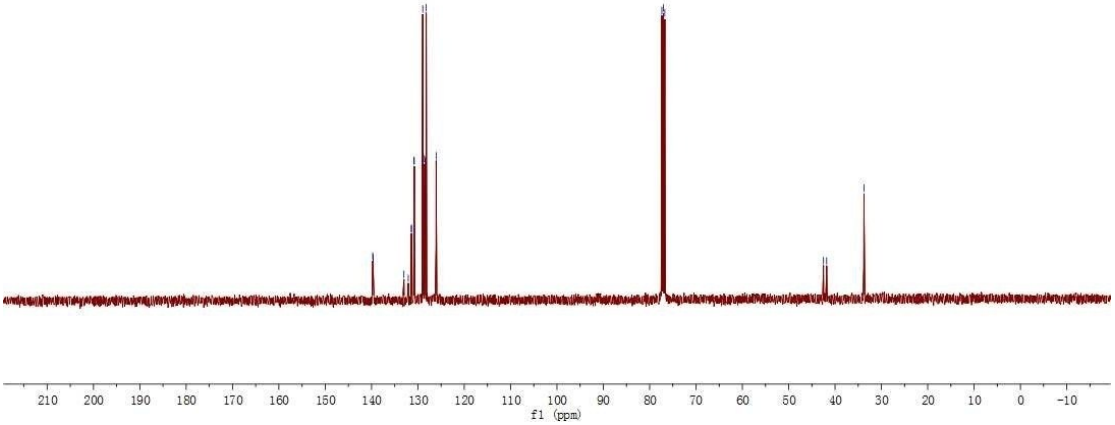


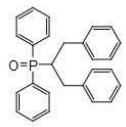
3m


139.760
139.669
133.021
132.082
131.416
131.390
130.868
130.781
128.955
128.588
128.475
128.197
126.060


77.369
77.052
76.734

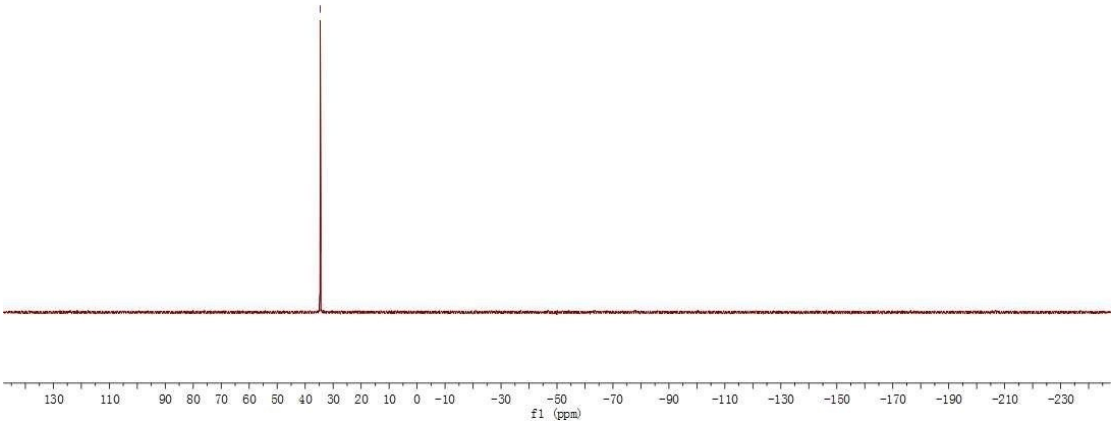

42.499
41.810
33.769

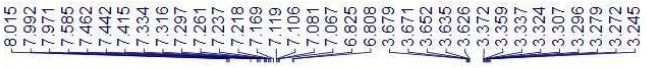

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

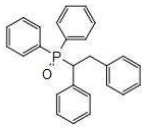


3m

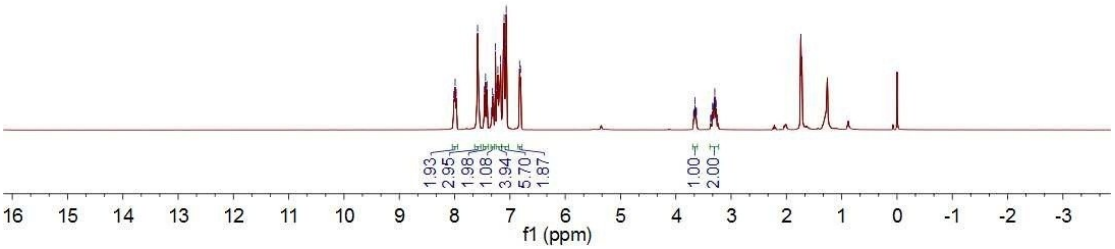

34.589


130 110 90 80 70 60 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

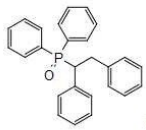

8.015
7.992
7.971
7.585
7.462
7.442
7.415
7.334
7.316
7.297
7.261
7.237
7.218
7.169
7.119
7.106
7.081
7.067
6.825
6.808
3.679
3.671
3.652
3.635
3.626
3.372
3.359
3.337
3.324
3.307
3.296
3.279
3.272
3.245



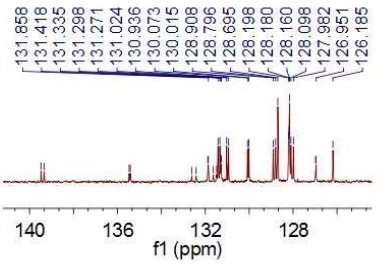
3n

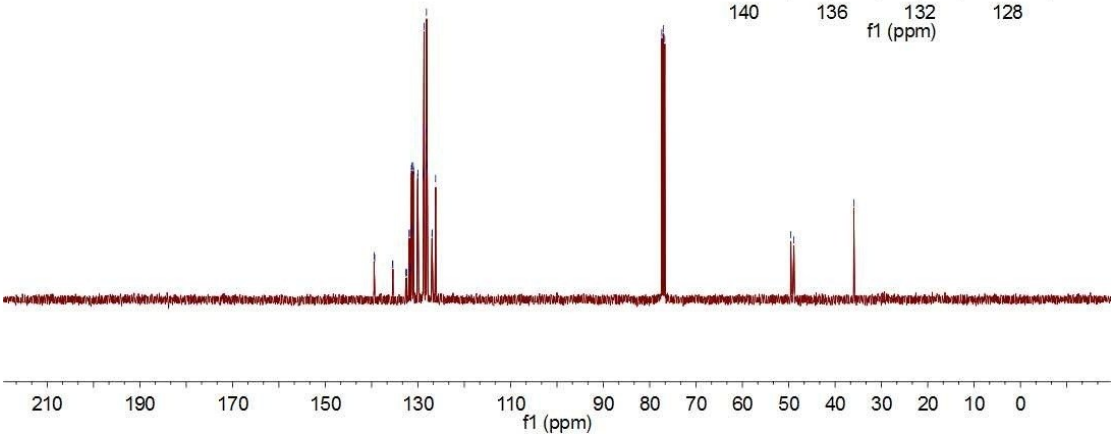

1.93
2.95
1.98
1.08
3.94
5.70
1.87
1.00
2.00
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)

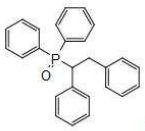

139.470
139.330
135.466
135.413
132.612
132.415
131.885
131.858
131.632
131.480
131.418
131.335
131.298
131.271
131.024
130.936
130.073
130.015
128.908
128.796
128.695
128.198
128.180
128.160
128.098
127.982
126.974
126.951
126.185
77.394
77.076
76.759
49.546
48.889
35.958



3n

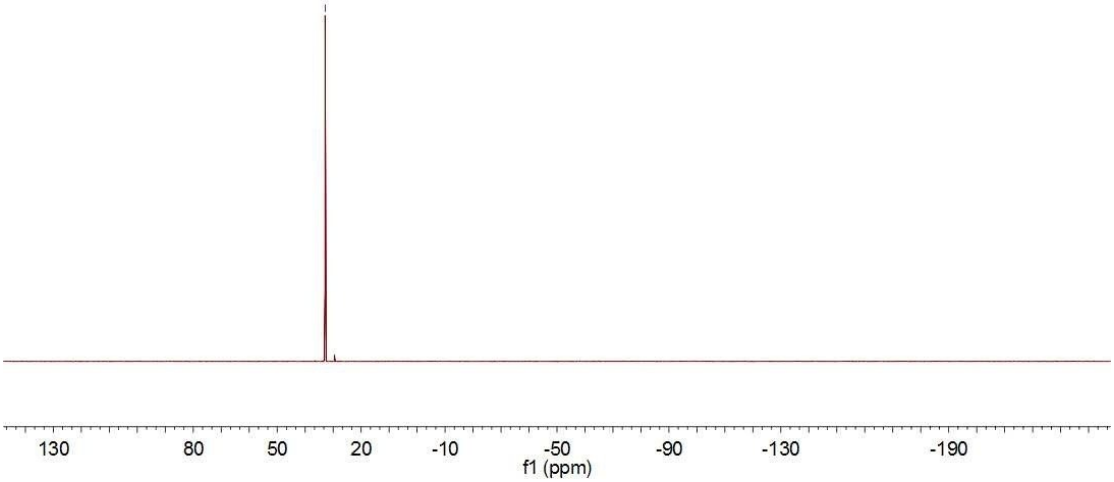

131.858
131.418
131.335
131.298
131.271
131.024
130.936
130.073
130.015
128.908
128.796
128.695
128.198
128.180
128.160
128.098
127.982
126.951
126.185
140 136 132 128
f1 (ppm)

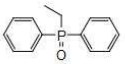

210 190 170 150 130 110 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



3n

32.858

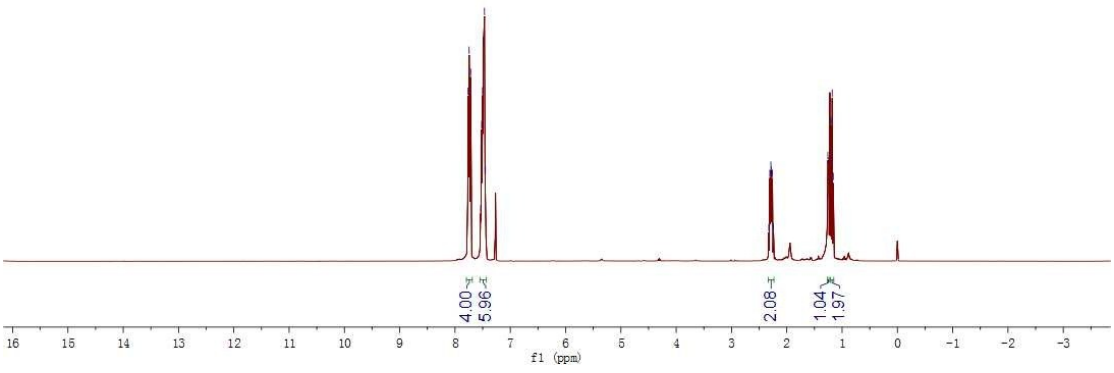


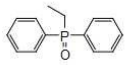


3o

7.763
7.744
7.717
7.537
7.520
7.503
7.487
7.468
7.450

2.326
2.307
2.288
2.279
2.260
2.241
1.257
1.242
1.201
1.179
1.160





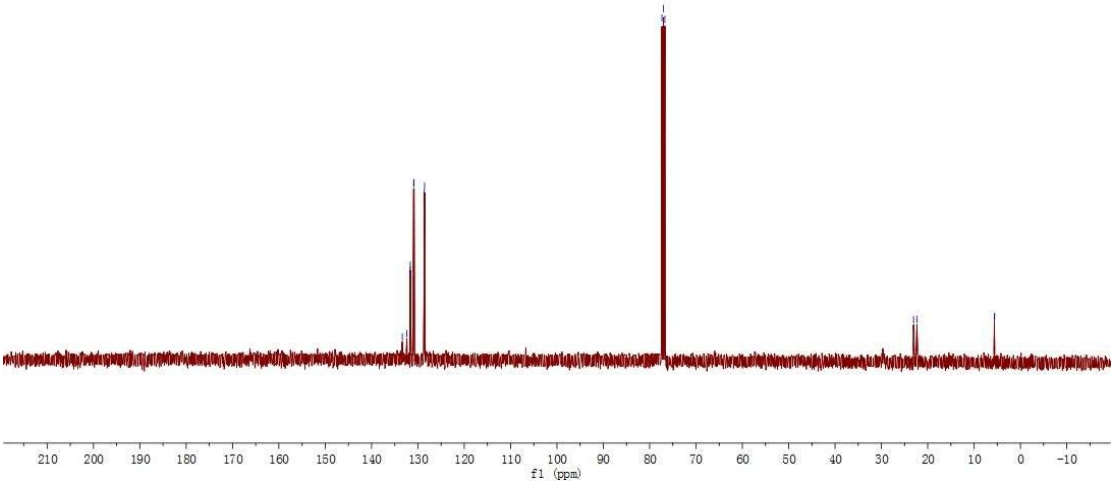
3o

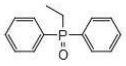
133.366
132.391
131.670
131.642
130.917
130.826
128.677
128.562

77.350
77.032
76.714

23.053
22.328

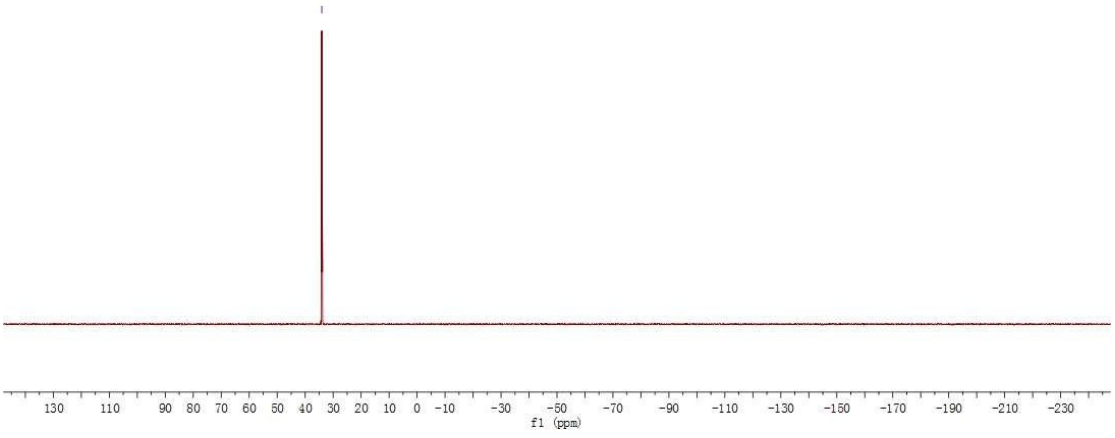
5.620
5.569

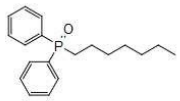




3o

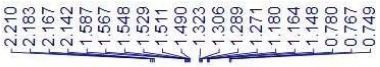
34.056

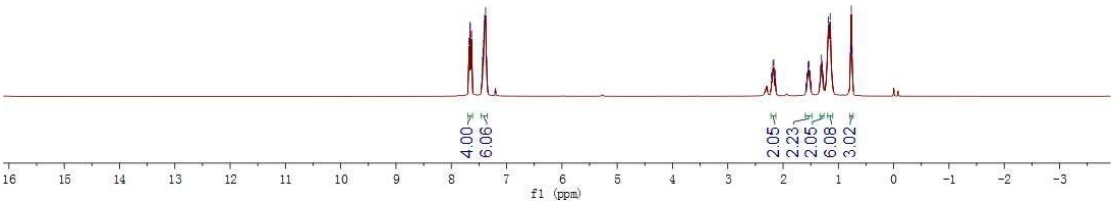


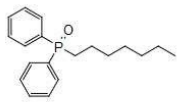


3p


7.680
7.660
7.657
7.633
7.446
7.429
7.411
7.398
7.379
7.363

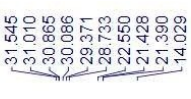

2.210
2.183
2.167
2.142
1.587
1.567
1.548
1.529
1.511
1.490
1.323
1.306
1.289
1.271
1.180
1.164
1.148
0.780
0.767
0.749

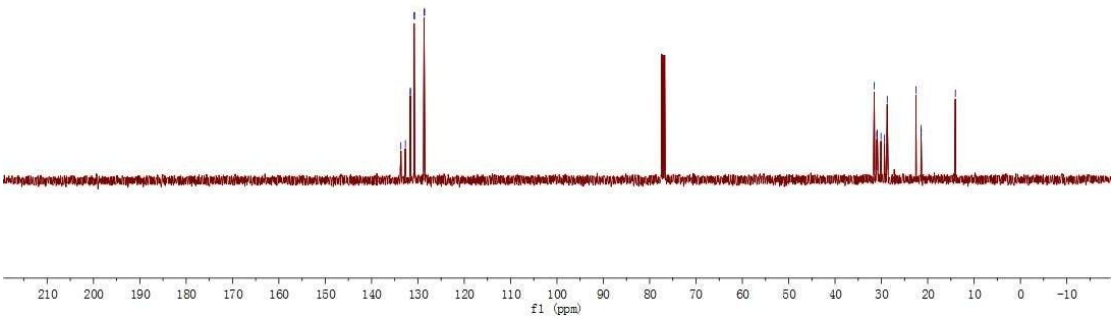

4.00
6.06
2.05
2.23
2.05
6.08
3.02
f1 (ppm)



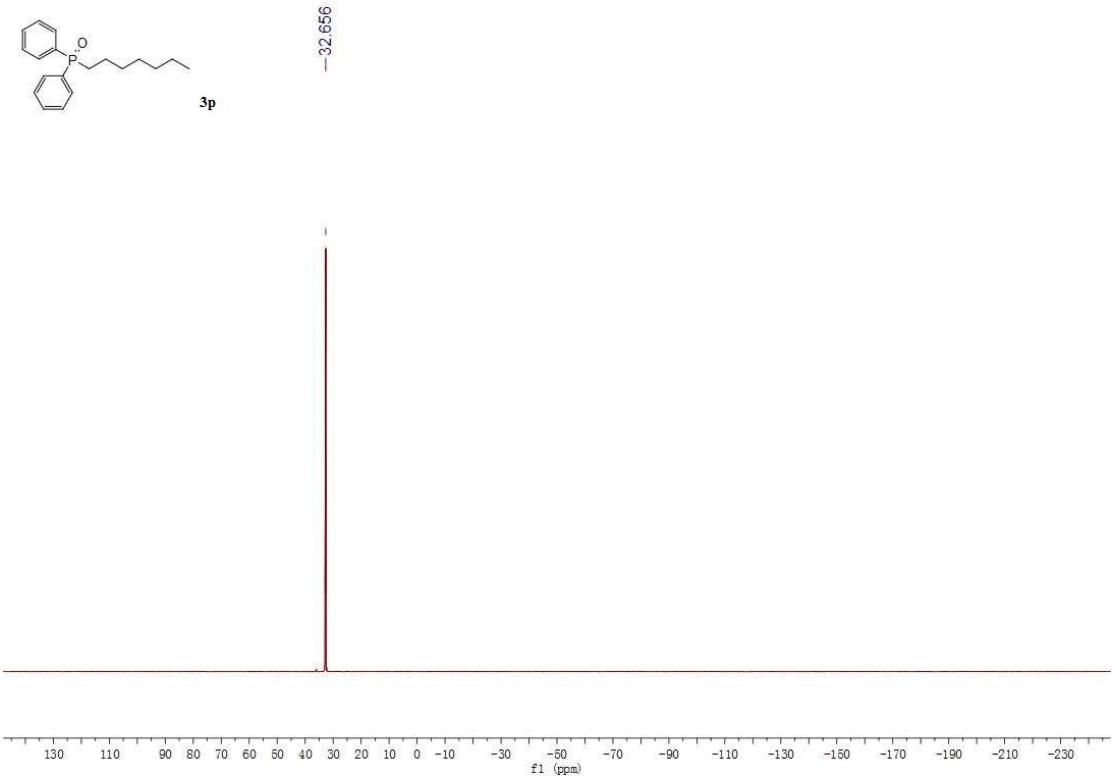
3p


133.672
132.700
131.639
131.613
130.817
130.725
128.671
128.557

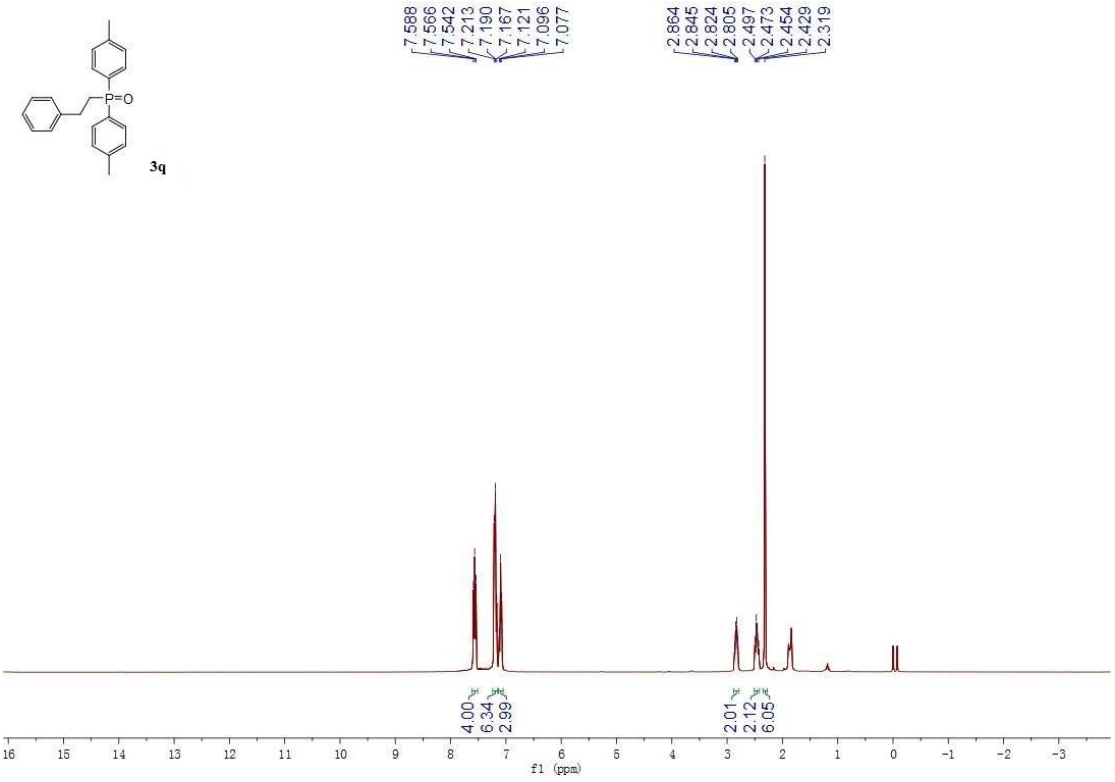

31.545
31.010
30.865
30.086
29.371
28.733
22.550
21.428
21.390
14.029

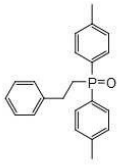

f1 (ppm)

3p


32.656
130 110 90 80 70 60 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

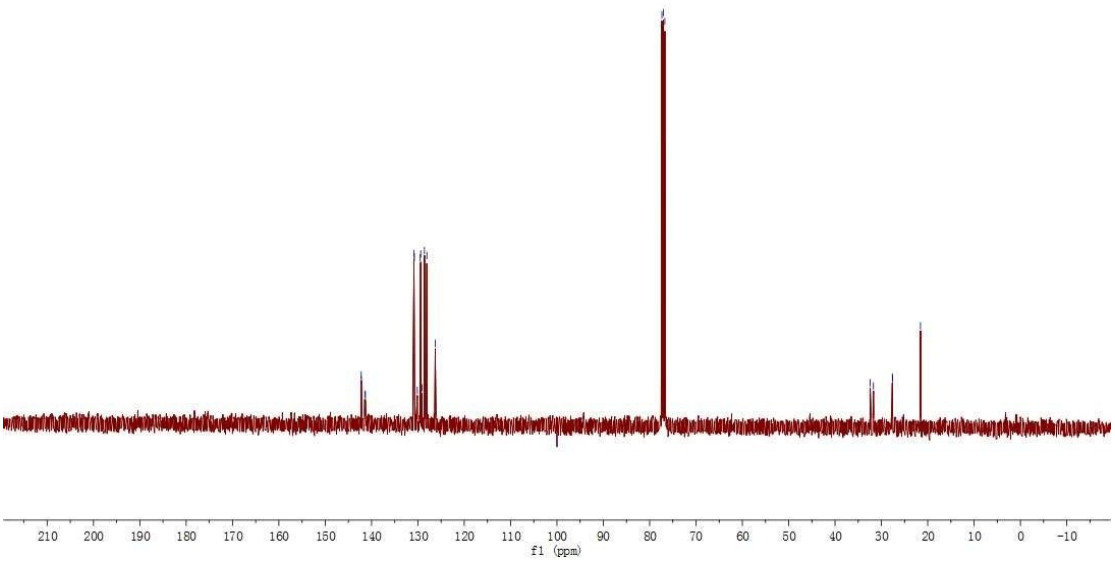
3q

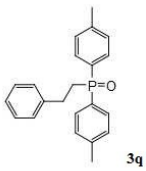

7.588
7.566
7.542
7.213
7.190
7.167
7.121
7.096
7.077
2.864
2.845
2.824
2.805
2.497
2.473
2.454
2.429
2.319
4.00
6.34
2.99
2.01
2.12
6.05
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



3q

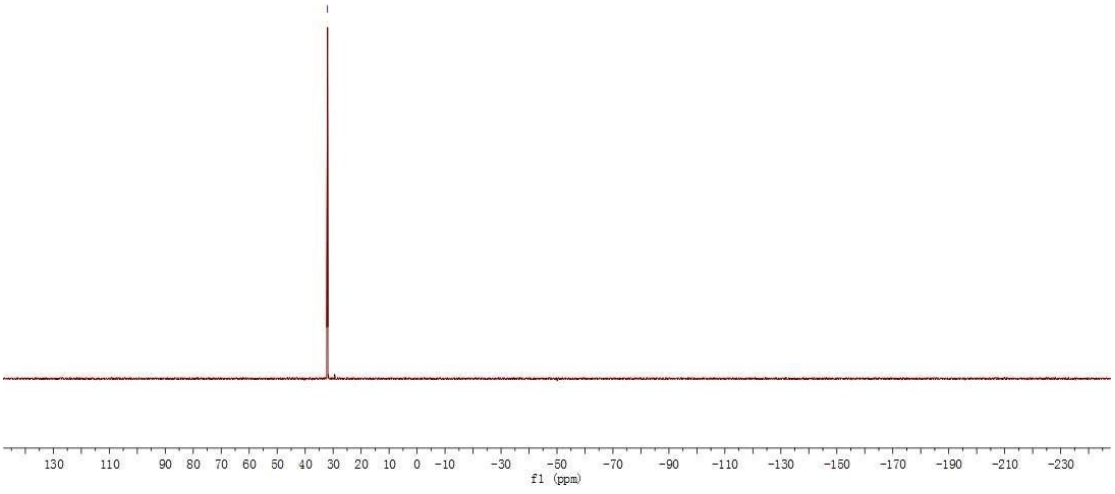
142.224
142.198
141.470
141.318
130.852
130.756
130.138
129.507
129.387
129.136
128.591
128.067
126.260
77.361
77.044
76.726
32.407
31.711
27.634
27.605
21.569

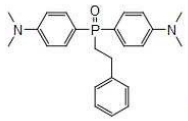




3q

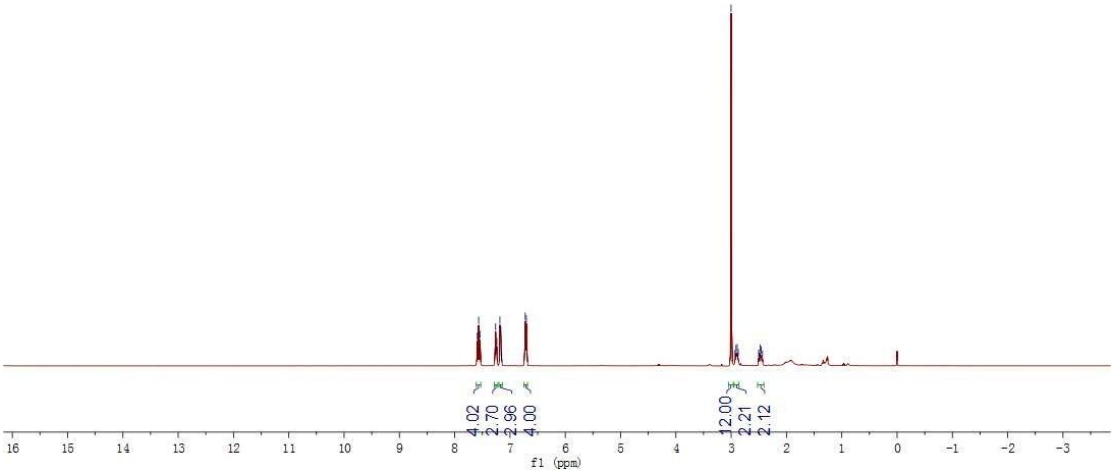
32.008

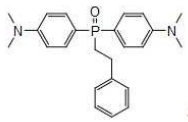




3r

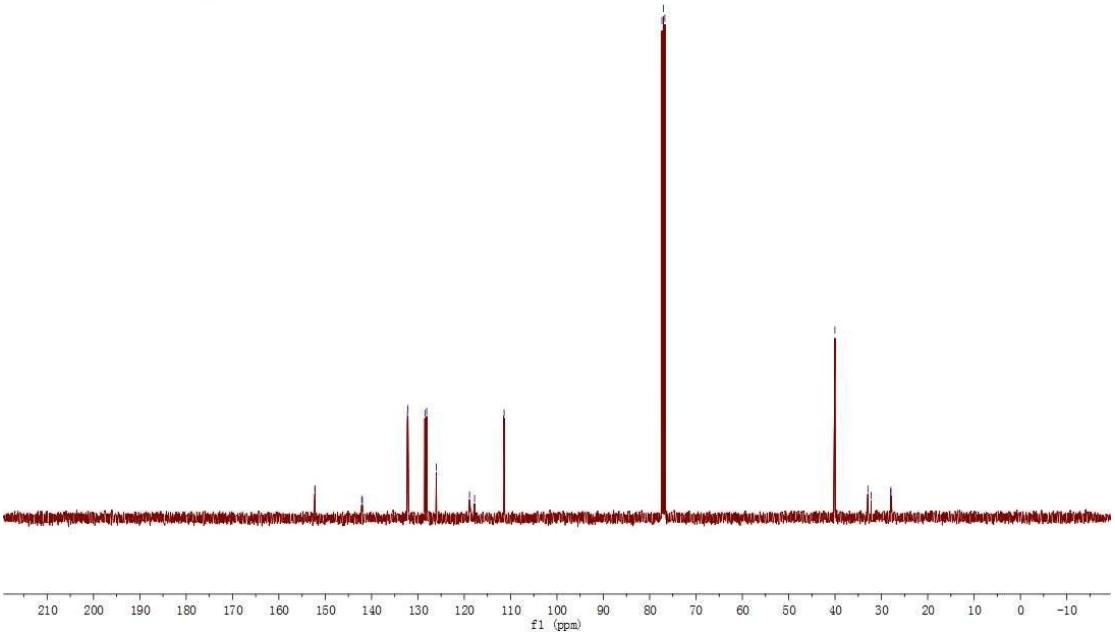

7.591
7.567
7.544
7.273
7.260
7.237
7.183
7.165
7.150
6.725
6.704
3.002
2.931
2.913
2.891
2.871
2.504
2.494
2.477
2.458
2.433

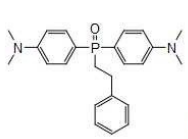

4.02
2.70
2.96
4.00
12.00
2.21
2.12
f1 (ppm)



3r

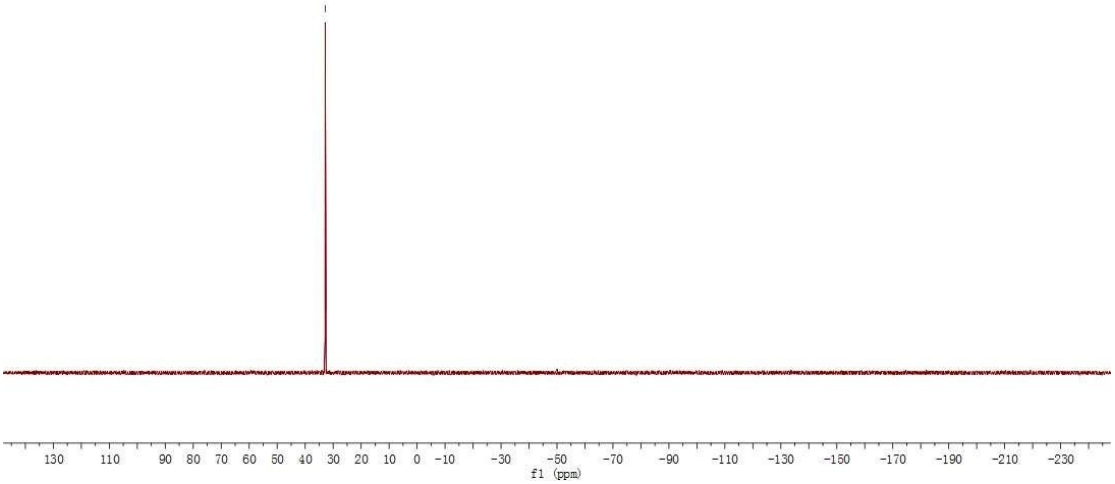

152.231
152.208
142.129
141.974
132.262
132.158
128.489
128.099
126.029
118.865
117.775
111.520
111.397
77.353
77.035
76.718
40.021
32.916
32.208
27.973
27.946

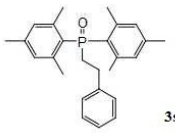

f1 (ppm)



3r

32.841

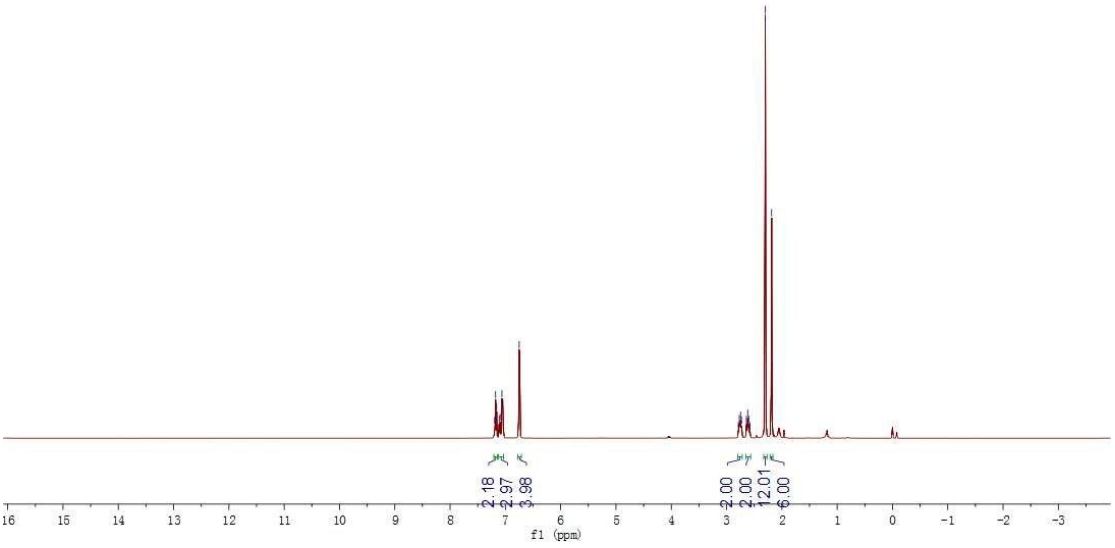


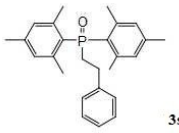


3s

7.194
7.177
7.158
7.112
7.094
7.062
7.044
6.750

2.787
2.770
2.747
2.730
2.641
2.618
2.599
2.577
2.299
2.185



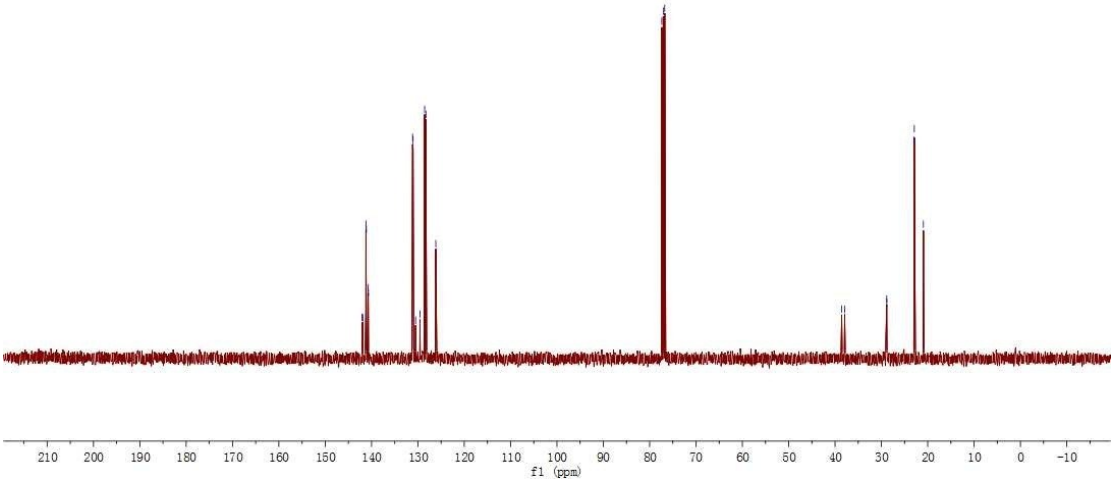


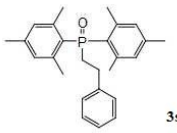
3s

142.039
141.873
141.219
141.120
140.716
140.690
131.151
131.042
130.491
129.556
128.550
128.270
126.140

77.381
77.064
76.746

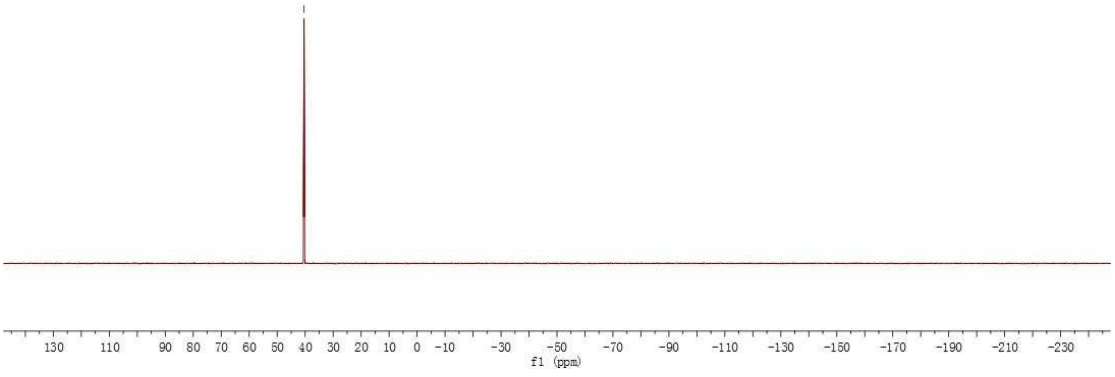
38.564
37.920
28.852
28.827
22.943
22.902
20.937

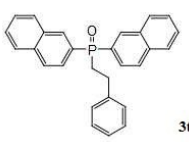




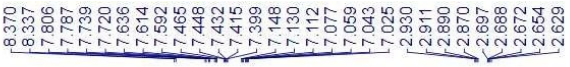
3s

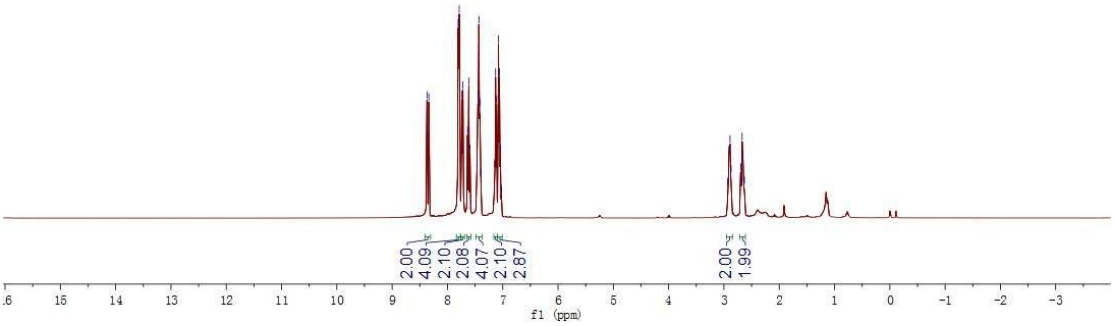
40.391

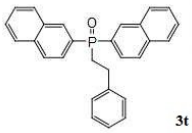




3t


8.370
8.337
7.806
7.787
7.739
7.720
7.636
7.614
7.592
7.465
7.448
7.432
7.415
7.399
7.148
7.130
7.112
7.077
7.059
7.043
7.025
2.930
2.911
2.890
2.870
2.697
2.688
2.672
2.654
2.629


2.00
4.09
2.10
2.08
4.07
2.10
2.87
2.00
1.99
f1 (ppm)

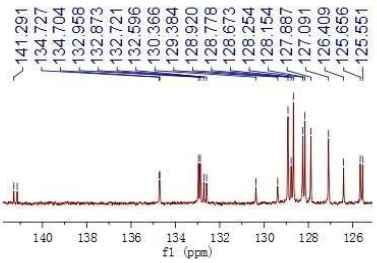


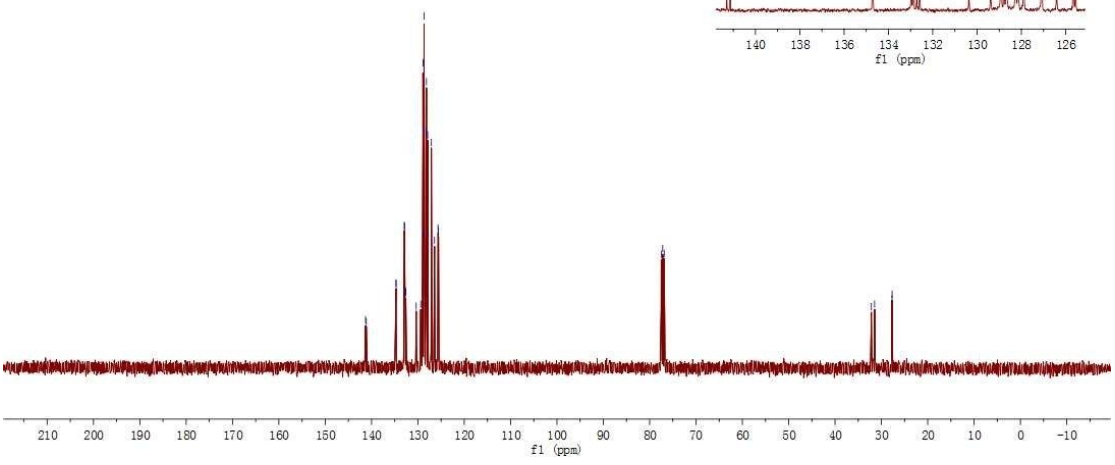
3t


141.291
141.139
134.727
134.704
132.958
132.873
132.721
132.596
130.366
129.384
128.920
128.778
128.673
128.254
128.154
127.887
127.091
126.409
125.656
125.551

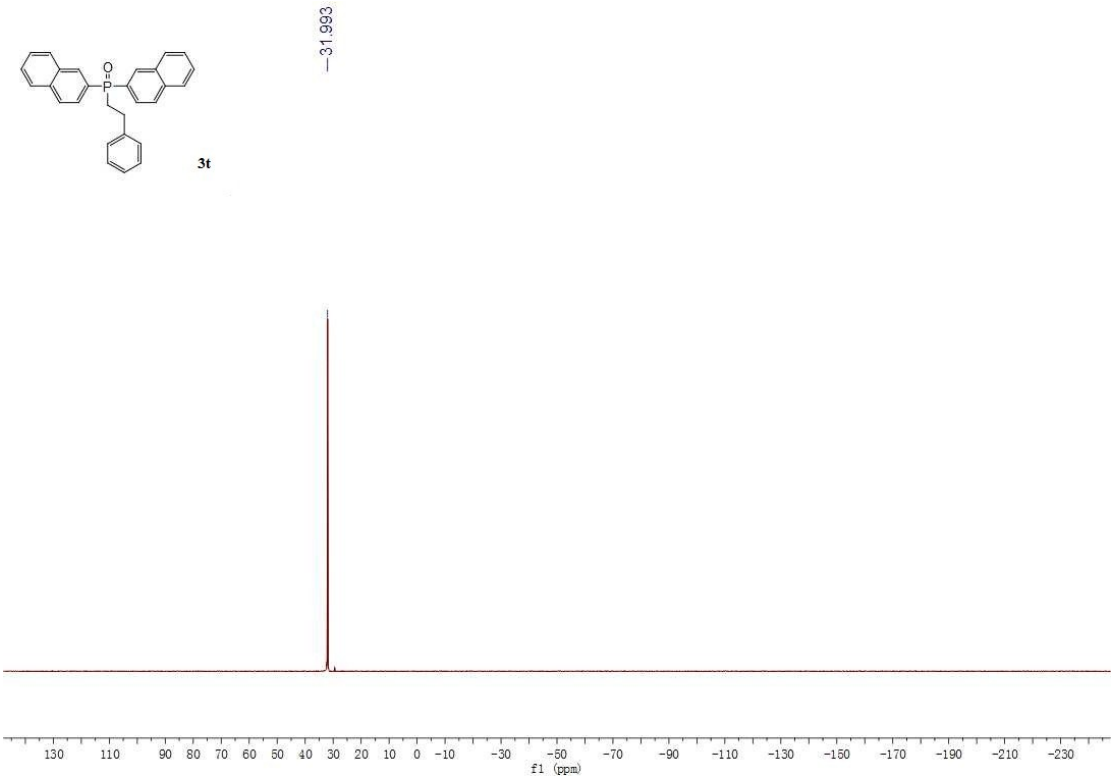

77.496
77.179
76.859

32.162
31.467
27.718
27.688

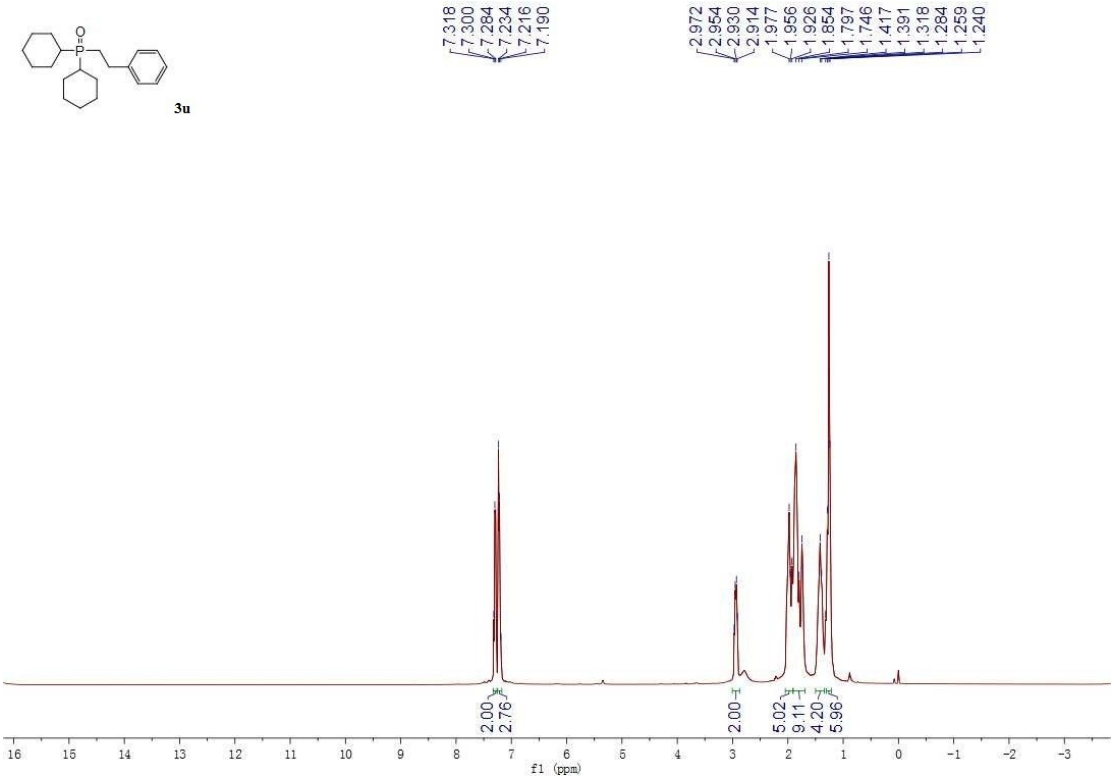

141.291
134.727
134.704
132.958
132.873
132.721
132.596
130.366
129.384
128.920
128.778
128.673
128.254
128.154
127.887
127.091
126.409
125.656
125.551
140
138
136
134
132
130
128
126
f1 (ppm)

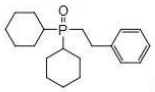

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

3t


31.993
130 110 90 80 70 60 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

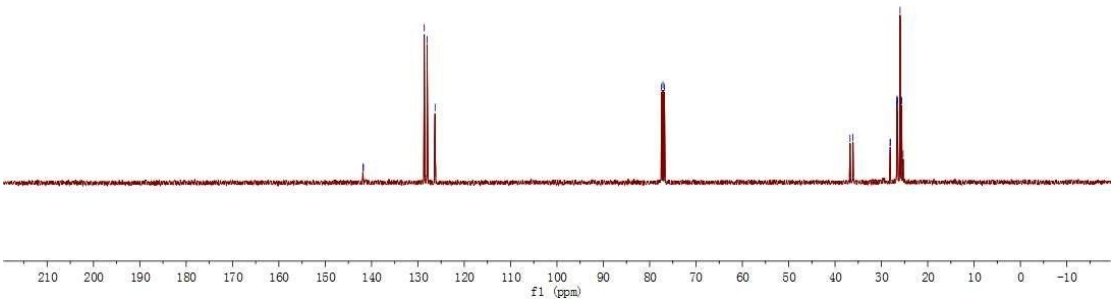
3u

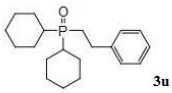

7.318
7.300
7.284
7.234
7.216
7.190
2.972
2.954
2.930
2.914
1.977
1.956
1.926
1.854
1.797
1.746
1.417
1.391
1.318
1.284
1.259
1.240
2.00
2.76
2.00
5.02
9.11
4.20
5.96
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3
f1 (ppm)



3u

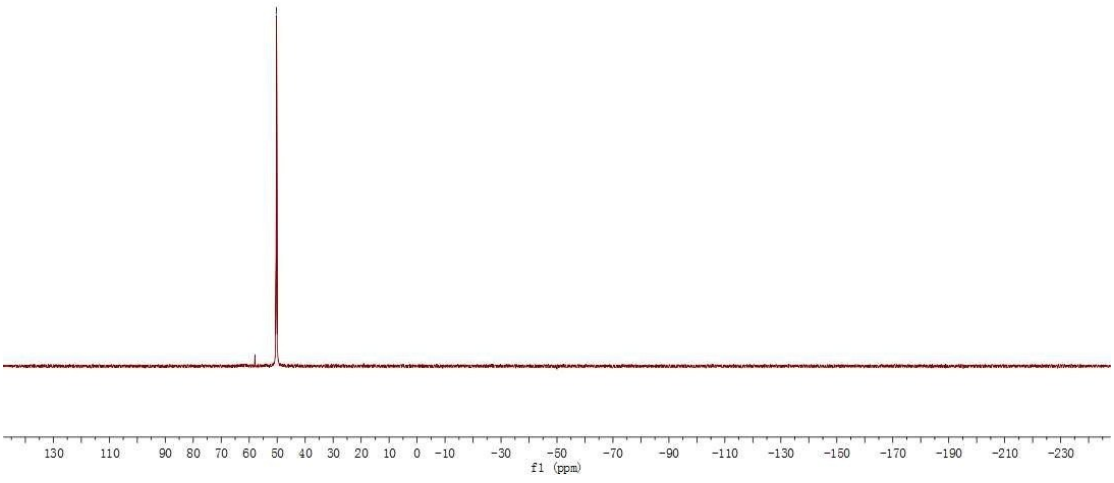

141.878
141.754
128.630
128.011
126.296
77.444
77.126
76.807
36.761
36.127
28.115
28.080
26.690
26.659
26.568
26.541
25.973
25.683
25.653
25.312

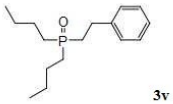

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



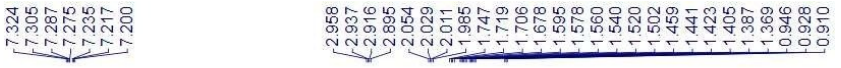
3u

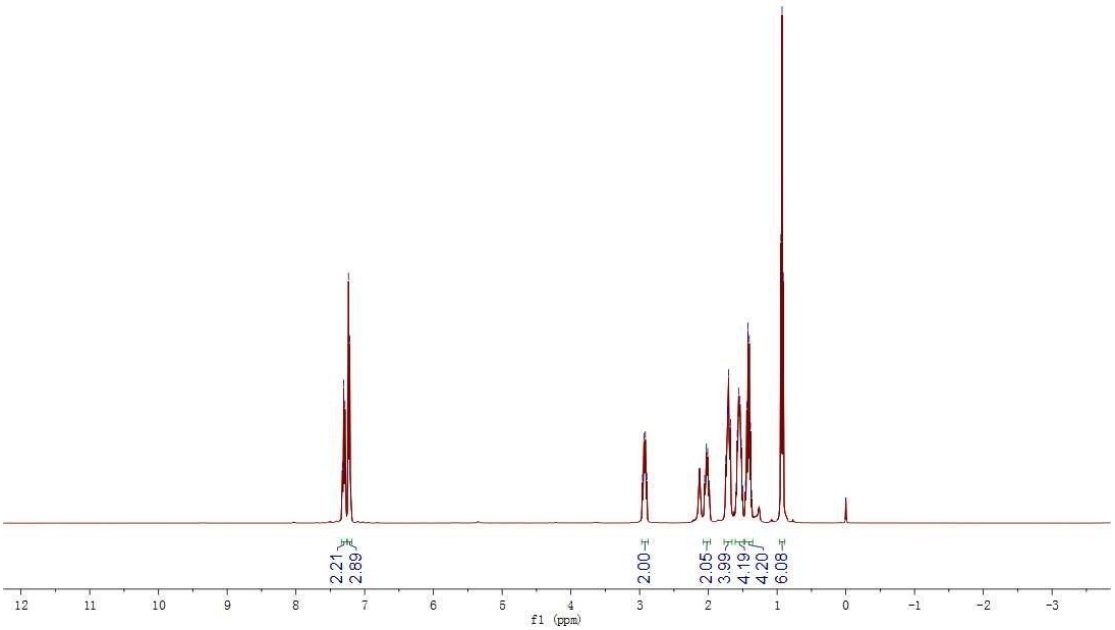

50.244

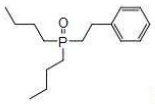

130 110 90 80 70 60 50 40 30 20 10 0 -10 -30 -50 -70 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)



3v

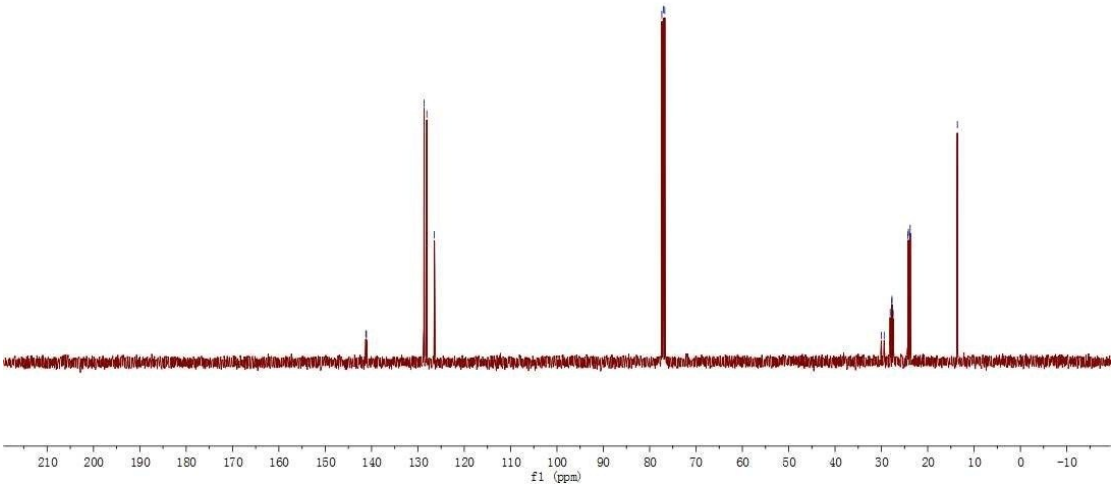

7.324
7.305
7.287
7.275
7.235
7.217
7.200
2.958
2.937
2.916
2.895
2.054
2.029
2.011
1.985
1.747
1.719
1.706
1.678
1.595
1.578
1.560
1.540
1.520
1.502
1.459
1.441
1.423
1.405
1.387
1.369
0.946
0.928
0.910

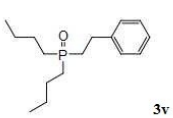

2.21
2.89
2.00
2.05
3.99
4.19
4.20
6.08
f1 (ppm)



3v

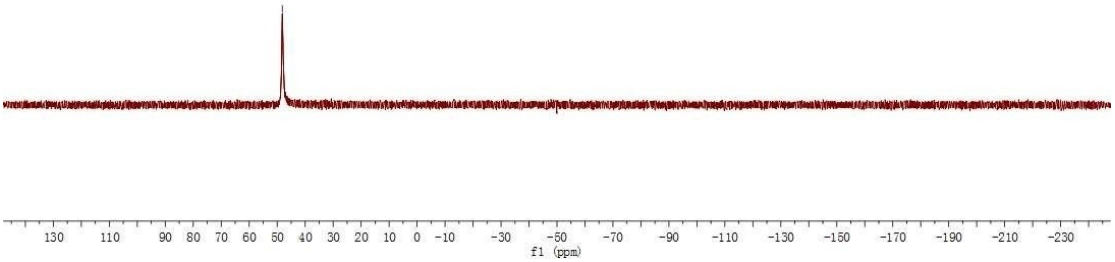

141.232
141.100
128.685
128.080
126.441
77.379
77.062
76.744
30.015
29.389
28.099
27.748
27.717
27.454
24.321
24.178
23.823
23.786
13.609


f1 (ppm)



3v

48.166


130
110
90
80
70
60
50
40
30
20
10
0
-10
-30
-50
-70
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)