# Electronic Supplementary Information

## For

# Water mediated synthesis of dialkylphosphine oxides from white phosphorus and *N*-(acyloxy)phthalimides

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# 1. General information

**General.** $^{1}H$, $^{13}C$ and $^{31}P$ NMR spectra were recorded on Bruker-500 or 600 spectrometer. $^{1}H$ and $^{13}C$ NMR chemical shifts were determined relative to internal standard TMS at 0.0, $CDCl_3$ ($\delta(^{1}H)$, 7.26 ppm; $\delta(^{13}C)$, 77.16 ppm). Chemical shifts ($\delta$) are reported in ppm, and coupling constants ($J$) are in Hertz (Hz). The following abbreviations are used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet. Analytical thin layer chromatography (TLC) was performed on 0.25 mm silica gel 60 F254 plates and viewed by UV light (254 nm). Column chromatographic purification was performed using 200-300 mesh silica gel. All products were firstly examined by Bruker AmaZon SL ESI-IT-MS (Bruker Daltonics Inc., Germany) in positive ion mode, then further characterized by **HRMS** (ESI-qTOF MS, Bruker micrOTOF-Q II) in positive ion mode too.

# 2. Safety note for $P_4$

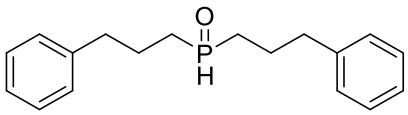
White phosphorus is spontaneously flammable; it should be stored in water or glove box. White phosphorus-toluene solution should be sealed in argon and stored away from light.

# 3. Preparation of $P_4$-toluene solution

A piece of $P_4$ was taken out of water and then put in ethanol under argon. Two minutes later, $P_4$ was taken out and the ethanol on the surface of $P_4$ was blown away by the argon. Then, the dry $P_4$ was put in a conical flask containing toluene. The mixture was stirred intensely with a magnetic stirrer until $P_4$ was completely dissolved in the toluene. (the concentration of $P_4$ was determined by $^{31}P$ NMR analysis using triphenyl phosphate $(C_6H_5O)_3P(O)$ as an internal standard, D1 = 20 s, zg30, LB = 1).

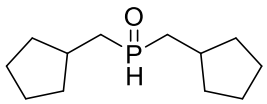
# 4. Characterization of the target products

**bis(3-phenylpropyl)phosphine oxide (3a)**



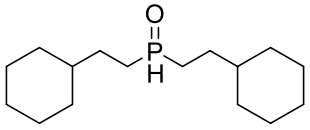
Pale yellow oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 51.2 mg, 90%. $^{1}H$ NMR (600 MHz, $CDCl_3$) $\delta$ 7.28 (t, $J$ = 7.5 Hz, 4H), 7.20 (t, $J$ = 7.4 Hz, 2H), 7.15 (d, $J$ = 7.3 Hz, 4H), 6.82 (d, $J$ = 442.5 Hz, 1H), 2.72 (t, $J$ = 7.3 Hz, 4H), 1.99-1.93 (m, 2H), 1.92-1.86 (m, 2H), 1.82-1.75 (m, 2H), 1.74-1.68 (m, 2H). $^{13}C$ NMR (150 MHz, $CDCl_3$) $\delta$ 140.6, 128.7, 128.6, 126.4, 36.6 (d, $J$ = 14.1 Hz), 27.7 (d, $J$ = 65.5 Hz), 23.5 (d, $J$ = 3.3 Hz). $^{31}P$ NMR (242 MHz, $CDCl_3$) $\delta$ 34.07 (d, $J$ = 452.2 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{18}H_{23}OPNa^+$ 309.1379, found 309.1375.

**bis(cyclopentylmethyl)phosphine oxide (3b)**



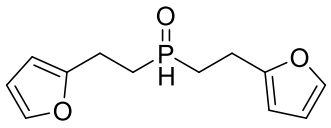
Pale yellow oil. Eluent $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 31.1 mg, 73%. $^{1}H$ NMR (600 MHz, $CDCl_3$) $\delta$ 6.93 (d, $J$ = 445.9 Hz, 1H), 2.22-2.14 (m, 2H), 1.99-1.91 (m, 6H), 1.76-1.71 (m, 2H), 1.68-1.62 (m, 4H), 1.58-1.53 (m, 4H), 1.24-1.18 (m, 4H). $^{13}C$ NMR (150 MHz, $CDCl_3$) $\delta$ 35.2 (d, $J$ = 64.4 Hz), 34.4 (d, $J$ = 9.1 Hz), 34.2 (d, $J$ = 4.3 Hz), 33.8 (d, $J$ = 7.7 Hz), 24.9, 24.8. $^{31}P$ NMR (242 MHz, $CDCl_3$) $\delta$ 31.36 (d, $J$ = 446.7 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{12}H_{24}OP^+$ 215.1559, found 215.1559.

**bis(2-cyclohexylethyl)phosphine oxide (3c)**



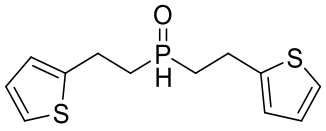
Colorless oil. Eluent $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 37.6 mg, 70%. $^{1}$H NMR (600 MHz, $CDCl_3$) δ 6.81 (d, $J$ = 447.2 Hz, 1H), 1.86-1.64 (m, 14H), 1.56-1.40 (m, 4H), 1.31-1.26 (m, 2H), 1.25-1.19 (m, 4H), 1.17-1.10 (m, 2H), 0.93-0.87 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 38.6 (d, $J$ = 13.4 Hz), 32.9 (d, $J$ = 14.2 Hz), 29.0 (d, $J$ = 3.5 Hz), 26.6, 26.3, 25.7 (d, $J$ = 65.2 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 37.32 (d, $J$ = 450.7 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{16}H_{32}OP^+$ 271.2185, found 271.2189.

**bis(2-(furan-2-yl)ethyl)phosphine oxide (3d)**



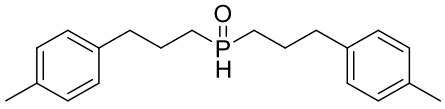
Colorless oil. Eluent $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 34.5 mg, 73%. $^{1}$H NMR (600 MHz, $CDCl_3$) δ 7.30 (d, $J$ = 1.2 Hz, 2H), 6.85 (d, $J$ = 459.7 Hz, 1H), 6.27 (t, $J$ = 2.5 Hz, 2H), 6.06 (d, $J$ = 3.1 Hz, 2H), 3.04-2.92 (m, 4H), 2.17-2.04 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 153.2 (d, $J$ = 12.2 Hz), 141.7, 110.5, 106.2, 26.8 (d, $J$ = 65.4 Hz), 20.5 (d, $J$ = 2.7 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 30.69 (d, $J$ = 457.7 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{12}H_{15}O_3PNa^+$ 261.0651, found 261.0651.

**bis(2-(thiophen-2-yl)ethyl)phosphine oxide (3e)**



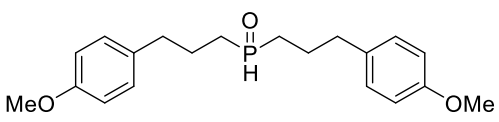
Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 36.4mg, 68%. $^{1}$H NMR (600 MHz, $CDCl_3$) δ 7.15 (d, $J$ = 5.1 Hz, 2H), 6.92 (dd, $J$ = 5.1, 3.5 Hz, 2H), 6.89 (d, $J$ = 458.3 Hz, 1H), 6.85 (d, $J$ = 3.1 Hz, 2H), 3.27-3.14 (m, 4H), 2.25-2.16 (m, 2H), 2.12-2.03 (m, 2H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 142.7 (d, $J$ = 13.3 Hz), 127.2, 125.2, 124.1, 30.6 (d, $J$ = 64.1 Hz), 22.4 (d, $J$ = 3.3 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 29.39 (d, $J$ = 458.2 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{12}H_{15}OPS_2Na^+$ 293.0194, found 293.0200.

**bis(3-(p-tolyl)propyl)phosphine oxide (3f)**



Pale yellow oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 53.5 mg, 85%. $^{1}$H NMR (600 MHz, $CDCl_3$) δ 7.06 (d, $J$ = 8.7 Hz, 4H), 6.81 (d, $J$ = 449.3 Hz, 1H), 6.82 (d, $J$ = 8.5 Hz, 4H), 3.78 (s, 6H), 2.66 (t, $J$ = 7.3 Hz, 4H), 1.97-1.89 (m, 2H), 1.88-1.82 (m, 2H), 1.78-1.74 (m, 2H), 1.73-1.70 (m, 2H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 158.2, 132.7, 129.5, 114.1, 55.4, 35.7 (d, $J$ = 14.5 Hz), 27.6 (d, $J$ = 65.4 Hz), 23.7 (d, $J$ = 3.3 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 33.85 (d, $J$ = 465.1 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{20}H_{28}OP^+$ 315.1872, found 315.1872.

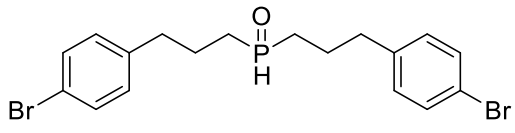
**bis(3-(4-methoxyphenyl)propyl)phosphine oxide (3g)**



White wax. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 61.0 mg, 88%. $^{1}$H NMR (600 MHz, $CDCl_3$) δ 7.06 (d, $J$ = 8.5Hz, 4H), 6.82 (t, $J$ = 8.6 Hz, 4H), 6.81 (d, $J$ = 448.3 Hz, 1H), 3.78 (s, 6H), 2.65 (t, $J$ = 7.3 Hz, 4H), 1.97-1.88 (m, 2H), 1.87-1.80 (m, 2H), 1.80-1.73 (m, 2H), 1.73-1.65 (m, 2H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 158.1, 132.7, 129.5, 114.0, 55.3, 35.7 (d, $J$ = 14.5 Hz), 27.6 (d, $J$ = 65.3 Hz), 23.7 (d, $J$ = 3.2 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 34.42 (d, $J$ = 449.1 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$

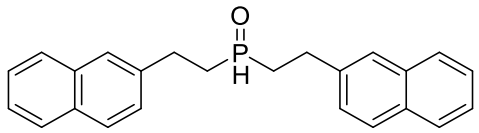
Calcd for $C_{20}H_{28}O_3P^+$ 347.1771, found 347.1768.

**bis(3-(4-bromophenyl)propyl)phosphine oxide (3h)**



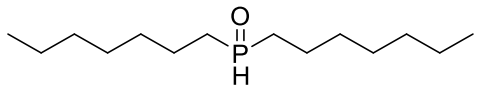
Pale yellow oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 70.5 mg, 80%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.41 (d, *J* = 8.3Hz, 4H), 7.03 (d, *J* = 8.5 Hz, 4H), 6.85 (d, *J* = 449.1 Hz, 1H), 2.69 (t, *J* = 7.4 Hz, 4H), 2.01-1.84 (m, 4H), 1.83-1.69 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 139.6, 131.7, 130.3, 120.2, 36.0 (d, *J* = 13.6 Hz), 27.7 (d, *J* = 65.7 Hz), 23.5 (d, *J* = 3.3 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 33.59 (d, *J* = 456.3 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{18}H_{21}Br_2OPNa^+$ 464.9589, found 464.9588.

**bis(2-(naphthalen-2-yl)ethyl)phosphine oxide (3i)**



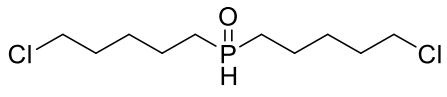
Pale yellow oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 58.9 mg, 83%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.4 Hz, 2H), 7.84 (d, *J* = 7.9 Hz, 2H), 7.72 (d, *J* = 8.3 Hz, 2H), 7.53-7.51 (m, 2H), 7.49-7.46 (m, 2H), 7.37 (t, *J* = 7.6 Hz, 2H), 7.31 (d, *J* = 6.7 Hz, 2H), 6.91 (d, *J* = 454.6 Hz, 1H), 3.48-3.41 (m, 2H), 3.34-3.27 (m, 2H), 2.25-2.17 (m, 2H), 2.09-2.02 (m, 2H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 136.0 (d, *J* = 12.3 Hz), 133.8, 131.1, 128.9, 127.5, 126.3, 126.0, 125.7, 125.5, 123.0, 29.2 (d, *J* = 63.8 Hz), 24.9 (d, *J* = 2.9 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 31.54 (d, *J* = 460.3 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{24}H_{24}OP^+$ 359.1559, found 359.1558.

**diheptylphosphine oxide (3j)**



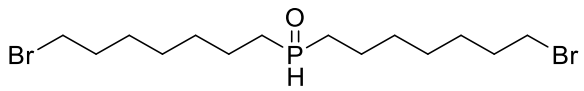
Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 41.6 mg, 85%. $^1$H NMR (600 MHz, $CDCl_3$) δ 6.84 (d, *J* = 445.5Hz, 1H), 1.86-1.68 (m, 4H), 1.68-1.53 (m, 4H), 1.45-1.37 (m, 4H), 1.33-1.24 (m, 12H), 0.87 (t, *J* = 7.1 Hz, 6H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 31.6, 30.8 (d, *J* = 13.9 Hz), 28.9, 28.4 (d, *J* = 65.1 Hz), 22.7, 21.9 (d, *J* = 4.1 Hz), 14.1. $^{31}$P NMR (242 MHz, $CDCl_3$) δ 35.19 (d, *J* = 446.9 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{14}H_{31}OPNa^+$ 269.2005, found 269.2004.

**bis(5-chloropentyl)phosphine oxide (3k)**



Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 36.7 mg, 71%. $^1$H NMR (600 MHz, $CDCl_3$) δ 6.87 (d, *J* = 450.1 Hz, 1H), 3.54 (t, *J* = 6.5 Hz, 4H), 1.89-1.75 (m, 8H), 1.73-1.57 (m, 8H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 44.7, 32.1, 28.3 (d, *J* = 65.3 Hz), 28.0 (d, *J* = 13.7 Hz), 21.4 (d, *J* = 3.9 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 33.70 (d, *J* = 450.5 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{10}H_{21}Cl_2OPNa^+$ 281.0599, found 281.0599.

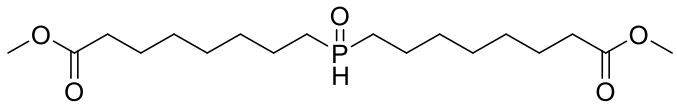
**bis(7-bromoheptyl)phosphine oxide (3l)**



Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 67.2 mg, 84%. $^1$H NMR (600 MHz, $CDCl_3$) δ 6.85 (d, *J* = 446.6 Hz, 1H), 3.39 (t, *J* = 6.7 Hz, 4H), 1.86-1.81 (m, 5H), 1.77-1.55 (m, 7H), 1.46-1.41 (m, 8H), 1.37-1.33 (m, 4H). $^{13}$C NMR

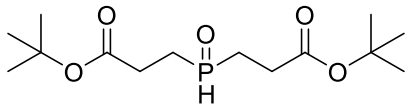
(150 MHz, $CDCl_3$) δ 33.9, 32.7, 30.6 (d, $J$ = 13.7 Hz), 28.4, 28.3 (d, $J$ = 65.5 Hz), 27.9, 21.8 (d, $J$ = 3.4 Hz). $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 34.48 (d, $J$ = 451.1 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{14}H_{29}Br_2OPNa^+$ 425.0215, found 425.0222.

**dimethyl 8,8'-(oxo-l5-phosphanediyl)dioctanoate (3m)**



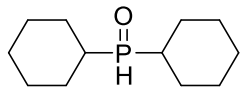
Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 58.3 mg,81%. $^1H$ NMR (600 MHz, $CDCl_3$) δ 6.82 (d, $J$ = 446.1 Hz, 1H), 3.63 (s, 6H), 2.27 (t, $J$ = 7.5 Hz, 4H), 1.82-1.67 (m, 4H), 1.64-1.52 (m, 8H), 1.42-1.34 (m, 4H), 1.32-1.28 (m, 8H). $^{13}C$ NMR (150 MHz, $CDCl_3$) δ 174.2, 51.5, 34.0, 30.5 (d, $J$ = 13.6 Hz), 28.8 (d, $J$ = 5.5 Hz), 28.3 (d, $J$ = 65.2 Hz), 24.8, 21.8 (d, $J$ = 3.5 Hz). $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 34.81 (d, $J$ = 450.1 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{18}H_{35}O_5PNa^+$ 385.2114, found 385.2119.

**di-tert-butyl 3,3'-(oxo-l5-phosphanediyl)dipropionate (3n)**



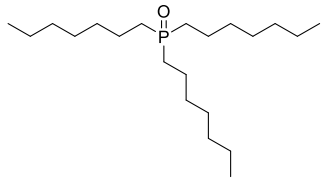
Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 46.1 mg, 75%. $^1H$ NMR (600 MHz, $CDCl_3$) δ 7.01 (d, $J$ = 467.2 Hz, 1H), 2.65-2.59 (m, 4H), 2.11-2.02 (m, 4H), 1.45 (s, 18H). $^{13}C$ NMR (150 MHz, $CDCl_3$) δ 171.3 (d, $J$ = 12.2 Hz), 81.6, 28.2, 27.5 (d, $J$ = 3.3 Hz), 23.9 (d, $J$ = 66.5 Hz). $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 31.87 (d, $J$ = 466.1 Hz). HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{14}H_{27}O_5PNa^+$ 329.1488, found 329.1492.

**dicyclohexylphosphine oxide (3o)**



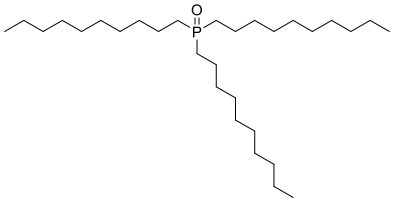
Colorless oil. $V_{DCM}$ : $V_{MeOH}$ = 20:1, Yield: 16.9 mg, 40%. $^1H$ NMR (600 MHz, $CDCl_3$) δ 6.29 (d, $J$ = 435.1 Hz, 1H), 2.00-1.98 (m, 2H), 1.86-1.85 (m, 4H), 1.79-1.72 (m, 6H), 1.49-1.40 (m, 4H), 1.33-1.22 (m, 6H). $^{13}C$ NMR (150 MHz, $CDCl_3$) δ 34.9 (d, $J$ = 64.9 Hz), 26.3 (d, $J$ = 14.3 Hz), 26.2, 26.1 (d, $J$ = 12.4 Hz), 25.9, 25.1 (d, $J$ = 3.4 Hz). $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 48.95 (d, $J$ = 436.4 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{12}H_{24}OP^+$ 215.1559, found 215.1564.

**triheptylphosphine oxide (3-2a)**



White solid. Eluent $V_{PE}$ : $V_{EA}$ = 1:2, Yield: 49.6 mg, 72%. $^1H$ NMR (600 MHz, $CDCl_3$) δ 1.69-1.64 (m, 5H), 1.58-1.51 (m, 5H), 1.42-1.35 (m, 6H), 1.32-1.22 (m, 20H), 0.87 (t, $J$ = 6.9 Hz, 9H). $^{13}C$ NMR (150 MHz, $CDCl_3$) δ 31.7, 31.3 (d, $J$ = 13.8 Hz), 28.9, 27.9 (d, $J$ = 64.7 Hz), 22.7, 21.8 (d, $J$ = 3.6 Hz), 14.2. $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 49.79. HRMS Calcd for $C_{21}H_{45}OP[M+H]^+$ 345.3281, found 345.3280.

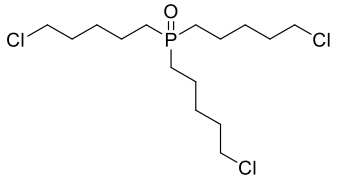
**tris(decyl)phosphine oxide (3-2b)**



Pale yellow oil. Eluent $V_{PE}$ : $V_{EA}$ = 1:2, Yield: 70.3 mg, 75%. $^1H$ NMR (600 MHz, $CDCl_3$) δ 1.67-1.62 (m, 6H), 1.57-1.50 (m, 6H), 1.40-1.35 (m, 6H), 1.31-1.22 (m, 36H), 0.87 (t, $J$ = 7.2 Hz, 9H). $^{13}C$ NMR (150 MHz, $CDCl_3$) δ 32.0, 31.3 (d, $J$ = 13.6 Hz), 29.7, 29.5, 29.4, 29.3, 28.0 (d, $J$ = 64.9 Hz), 22.8, 21.8 (d, $J$ = 3.9 Hz), 14.2. $^{31}P$ NMR (242 MHz, $CDCl_3$) δ 48.96.

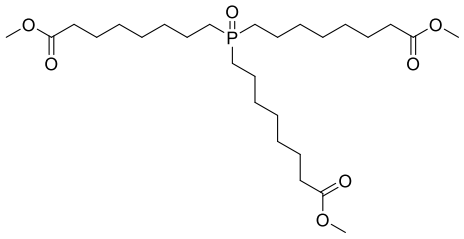
HRMS Calcd for $C_{30}H_{63}OP[M+H]^+$ 471.4689, found 471.4675.

**tris(5-chloropentyl)phosphine oxide (3-2c)**



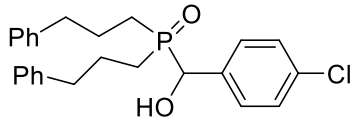
Pale yellow oil. Eluent $V_{PE}$ : $V_{EA}$ = 1:2, Yield: 48.4 mg, 67%. $^1$H NMR (600 MHz, $CDCl_3$) δ 3.54 (t, *J* = 6.5 Hz, 6H), 1.80 (quint, *J* = 7.2 Hz, 6H), 1.71-1.66 (m, 6H), 1.63-1.53 (m, 12H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 44.8, 32.2, 28.5 (d, *J* = 13.9 Hz), 28.1 (d, *J* = 64.8 Hz), 21.2 (d, *J* = 3.5 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 47.73. HRMS Calcd for $C_{15}H_{30}Cl_3OP[M+H]^+$ 363.1173, found 363.1175.

**trimethyl 8,8',8''-(oxo-l5-phosphanetriyl)trioctanoate (3-2d)**



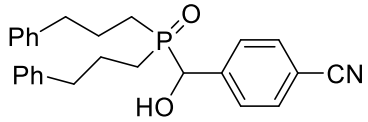
Pale yellow oil. Eluent $V_{PE}$ : $V_{EA}$ = 1:2, Yield: 42.4 mg, 41%. $^1$H NMR (600 MHz, $CDCl_3$) δ 3.57 (s, 9H), 2.21 (t, *J* = 7.5 Hz, 6H), 1.59-1.54 (m, 6H), 1.53-1.50 (m, 6H), 1.49-1.42 (m, 6H), 1,34-1.27 (m, 6H), 1.26-1.20 (m, 12H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 174.1, 51.4, 33.9, 30.9 (d, *J* = 14.2 Hz), 28.8, 28.7, 27.8 (d, *J* = 64.6 Hz), 24.7, 21.6 (d, *J* = 4.1 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 48.59. HRMS Calcd for $C_{27}H_{51}O_7P[M+H]^+$ 519.3445, found 519.3446.

**((4-chlorophenyl)(hydroxy)methyl)bis(3-phenylpropyl)phosphine oxide (4a)**



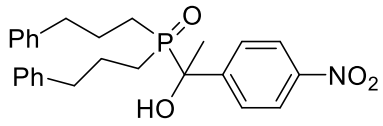
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 61.3 mg, 72%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.30-7.26 (m, 4H), 7.25-7.22 (m, 3H), 7.21 - 7.17 (m, 4H), 7.08 (dd, *J* = 16.3, 7.3 Hz, 4H), 4.91 (d, *J* = 6.6Hz, 1H), 4.57 (br s, 1H), 2.67-2.56 (m, 4H), 1.78-1.72 (m, 4H),1.67-1.57 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 140.8 (d, *J* = 8.4 Hz), 135.7, 134.0 (d, *J* = 3.1 Hz), 128.9, 128.7, 128.6, 127.8 (d, *J* = 3.8 Hz), 126.3 (d, *J* = 9.2 Hz), 71.6 (d, *J* = 72.8 Hz), 37.0 (d, *J* = 11.6 Hz), 36.9 (d, *J* = 11.2 Hz), 24.5 (d, *J* = 27.1 Hz), 24.1 (d, *J* = 28.6 Hz), 23.3 (d, *J* = 3.8 Hz), 23.2 (d, *J* = 3.4 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.11. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{25}H_{29}ClO_2P^+$ 427.1588, found 427.1588.

**4-((bis(3-phenylpropyl)phosphoryl)(hydroxy)methyl)benzonitrile (4b)**



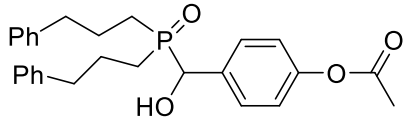
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 56.7 mg, 68%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.2 Hz, 2H), 7.34 (d, *J* = 7.1 Hz, 2H), 7.30-7.27 (m, 4H), 7.24-7.20 (m, 2H), 7.08 (t, *J* = 7.5 Hz, 4H), 4.99 (d, *J* = 7.3 Hz, 1H), 4.53 (br s, 1H), 2.68-2.56 (m, 4H), 1.88-1.70 (m, 4H), 1.64-1.45 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 142.6, 140.7 (d, *J* = 9.1 Hz), 132.4, 128.7 (d, *J* = 6.9 Hz), 128.6 (d, *J* = 11.3 Hz), 127.0 (d, *J* = 3.4 Hz), 126.5 (d, *J* = 6.2 Hz), 118.6, 111.9 (d, *J* = 2.5 Hz), 71.8 (d, *J* = 70.9 Hz), 36.9 (d, *J* = 13.1 Hz), 36.8 (d, *J* = 12.7 Hz), 24.5 (d, *J* = 8.6 Hz), 24.1 (d, *J* = 7.4 Hz), 23.3 (d, *J* = 3.6 Hz), 23.1 (d, *J* = 3.6 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.13. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{26}H_{29}NO_2P^+$ 418.1930, found 418.1935.

**(1-hydroxy-1-(4-nitrophenyl)ethyl)bis(3-phenylpropyl)phosphine oxide (4c)**



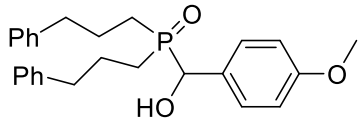
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 57.5 mg, 64%. $^1$H NMR (600 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8.7 Hz, 2H), 7.58 (dd, *J* = 8.9, 1.7 Hz, 2H), 7.27-7.23 (m, 4H), 7.21-7.18 (m, 2H), 7.09 (d, *J* = 7.2 Hz, 2H), 7.02 (d, *J* = 7.2 Hz, 2H), 4.31 (br s, 1H), 2.64-2.61 (m, 2H), 2.59-2.51 (m, 2H), 1.79 (d, *J* = 12.1 Hz, 3H), 1.74-1.61 (m, 4H), 1.59-1.40 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 149.3 (d, *J* = 3.2 Hz), 147.2 (d, *J* = 3.2 Hz), 1.40.7 (d, *J* = 24.3 Hz), 128.62, 128.59 (d, *J* = 2.5 Hz), 126.7 (d, *J* = 2.4 Hz), 126.4, 123.5 (d, *J* = 1.9 Hz), 74.1 (d, *J* = 74.3 Hz), 37.1 (d, *J* = 13.4 Hz), 36.9 (d, *J* = 13.4 Hz), 24.9 (d, *J* = 3.2 Hz), 24.1, 23.8 (d, *J* = 3.6 Hz), 23.7 (d, *J* = 4.7 Hz), 23.6 (d, *J* = 4.3 Hz), 23.3. $^{31}$P NMR (242 MHz, $CDCl_3$) δ 53.83. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{26}H_{30}NO_4PNa^+$ 447.1805, found 447.1810.

**4-((bis(3-phenylpropyl)phosphoryl)(hydroxy)methyl)phenyl acetate (4d)**



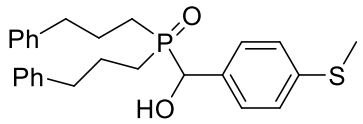
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 68.4 mg, 76%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.28-7.25 (m, 6H), 7.21-7.17 (m, 2H), 7.09 (t, *J* = 6.9 Hz, 4H), 6.98 (t, *J* = 8.4 Hz, 2H), 4.84 (d, *J* = 7.1 Hz, 1H), 2.63-2.54 (m, 4H), 2.30 (s, 3H), 1.87-1.71 (m, 4H), 1.69-1.48 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 169.5, 150.4, 141.0 (d, *J* = 13.2 Hz), 134.9, 128.6 (d, *J* = 3.1 Hz), 128.5 (d, *J* = 3.3 Hz), 127.6 (d, *J* = 4.1 Hz), 126.2 (d, *J* = 4.2 Hz), 121.8, 71.6 (d, *J* = 75.3 Hz), 37.1 (d, *J* = 11.2 Hz), 37.0 (d, *J* = 10.8 Hz), 24.4 (d, *J* = 35.6 Hz), 24.0 (d, *J* = 34.6 Hz), 23.3 (d, *J* = 3.6 Hz), 23.1 (d, *J* = 4.1 Hz), 21.3. $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.57. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{27}H_{31}O_4PNa^+$ 473.1852, found 473.1848.

**(hydroxy(4-methoxyphenyl)methyl)bis(3-phenylpropyl)phosphine oxide (4e)**



White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 43.1 mg, 51%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.28-7.26 (m, 2H), 7.26-7.23 (m, 2H), 7.21-7.17 (m, 4H), 7.09 (dd, *J* = 14.5, 7.4 Hz, 4H), 6.80 (d, *J* = 8.6 Hz, 2H), 4.88 (d, *J* = 5.5 Hz, 1H), 4.73 (br s, 1H), 3.78 (s, 3H), 2.65-2.55 (m, 4H), 1.87-1.70 (m, 4H), 1.69-1.43 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 159.5, 141.0 (d, *J* = 10.6 Hz), 129.1, 128.6 (d, *J* = 8.7 Hz), 128.5 (d, *J* = 7.7 Hz), 127.8 (d, *J* = 4.3 Hz), 126.2 (d, *J* = 8.8 Hz), 114.1, 72.0 (d, *J* = 75.2 Hz), 55.38, 37.1 (d, *J* = 8.6 Hz), 37.0 (d, *J* = 8.2 Hz), 24.5 (d, *J* = 39.5 Hz), 24.1 (d, *J* = 40.3 Hz), 23.3 ( d, *J* = 3.3 Hz), 23.2 (d, *J* = 4.1 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.28. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{26}H_{32}O_3P^+$ 423.2084, found 423.2089.

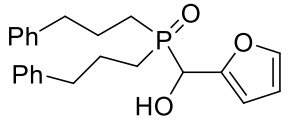
**(hydroxy(4-(methylthio)phenyl)methyl)bis(3-phenylpropyl)phosphine oxide (4f)**



White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 48.1 mg, 55%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.28-7.27 (m, 2H), 7.26-7.24 (m, 2H), 7.21-7.17 (m, 4H), 7.14 (d, *J* = 8.4 Hz, 2H), 7.09 (dd, *J* = 11.4, 7.4 Hz, 4H), 4.90 (d, *J* = 6.2 Hz, 1H), 4.74 (br s, 1H), 2.65-2.55 (m, 4H), 2.46 (s, 3H), 1.84-1.71 (m, 4H), 1.69-1.44 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 141.0 (d, *J* = 11.5 Hz), 138.6 (d, *J* = 2.9 Hz), 133.8, 128.6 (d, *J* = 7.3 Hz), 128.5 (d, *J* = 7.0 Hz), 127.0 (d, *J* = 4.3 Hz), 126.6 (d, *J* = 2.0 Hz), 126.3 (d, *J* = 8.5 Hz), 71.92 (d, *J* = 74.1 Hz), 37.1 (d, *J* = 10.2 Hz), 37.0 (d, *J* = 10.3 Hz), 24.5 (d, *J* = 33.3 Hz), 24.1 (d, *J* = 34.3 Hz), 23.3 (d, *J* = 3.4 Hz),

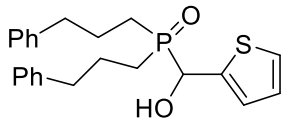
23.2 (d, $J$ = 3.9 Hz), 15.8. $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.44. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{26}H_{32}O_2PS^+$ 439.1855, found 439.1854.

**(furan-2-yl(hydroxy)methyl)bis(3-phenylpropyl)phosphine oxide (4g)**



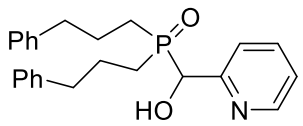
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 46.7 mg, 61%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.30-7.26 (m, 4H), 7.26-7.25 (m, 1H), 7.21-7.17 (m, 2H), 7.12 (t, $J$ = 8.5 Hz, 4H), 6.35-6.32 (m, 2H), 5.74 (br s, 1H), 5.02 (d, $J$ = 6.3 Hz, 1H), 2.69-2.58 (m, 4H), 1.93-1.79 (m, 4H), 1.78-1.53 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 150.6, 142.6 (d, $J$ = 1.8 Hz), 141.0 (d, $J$ = 19.1 Hz), 128.6 (d, $J$ = 3.1 Hz), 128.5 (d, $J$ = 7.6 Hz), 126.2 (d, $J$ = 11.2 Hz), 110.9, 108.9 (d, $J$ = 6.1 Hz), 66.9 (d, $J$ = 76.3 Hz), 37.1 (d, $J$ = 8.9 Hz), 37.0 (d, $J$ = 8.8 Hz), 25.6 (d, $J$ = 62.3 Hz), 24.8 (d, $J$ = 63.7 Hz), 23.1 (d, $J$ = 3.4 Hz), 23.0 (d, $J$ = 3.7 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.45. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{28}O_3P^+$ 383.1771, found 383.1774.

**(hydroxy(thiophen-2-yl)methyl)bis(3-phenylpropyl)phosphine oxide (4h)**



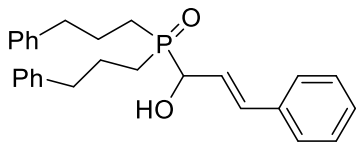
White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 51.0 mg, 64%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.28-7.27 (m, 4H), 7.26-7.23 (m, 3H), 7.21-7.16 (m, 2H), 7.10 (dd, $J$ = 13.1, 7.3 Hz, 4H), 6.94 (d, $J$ = 3.7 Hz, 2H), 5.28 (s, 1H), 5.19 (br s, 1H), 2.67-2.56 (m, 4H), 1.87-1.75 (m, 4H), 1.74-1.53 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 140.9 (d, $J$ = 10.3 Hz), 140.2, 128.6 (d, $J$ = 5.8 Hz), 128.5 (d, $J$ = 7.8 Hz), 127.3, 126.3 (d, $J$ = 10.1 Hz), 125.5 (d, $J$ = 2.3 Hz), 125.4 (d, $J$ = 5.7 Hz), 68.9 (d, $J$ = 77.2 Hz), 37.1 (d, $J$ = 6.2 Hz), 37.0 (d, $J$ = 5.7 Hz), 24.6 (d, $J$ = 44.8 Hz), 24.2 (d, $J$ = 45.4 Hz), 23.3 (d, $J$ = 3.7 Hz), 23.2 (d, $J$ = 3.6 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.42. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{23}H_{28}O_2PS^+$ 399.1542, found 399.1542.

**(hydroxy(pyridin-2-yl)methyl)bis(3-phenylpropyl)phosphine oxide (4i)**



White wax. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 40.7 mg, 52%. $^1$H NMR (600 MHz, $CDCl_3$) δ 8.50 (d, $J$ = 4.7 Hz, 1H), 7.72-7.69 (m, 1H), 7.62 (d, $J$ = 7.8 Hz, 1H), 7.29-7.26 (m, 2H), 7.24-7.14 (m, 7H), 7.00 (d, $J$ = 7.3 Hz, 2H), 5.38 (br s, 1H), 5.08 (d, $J$ = 7.7 Hz, 1H), 2.74 (d, $J$ = 7.5 Hz, 2H), 2.48 (t, $J$ = 7.5 Hz, 2H), 2.08-1.81 (m, 4H), 1.69-1.34 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 154.2, 147.9, 141.0 (d, $J$ = 27.1 Hz), 137.1, 128.6 (d, $J$ = 14.2 Hz), 128.4 (d, $J$ = 7.2 Hz), 126.1 (d, $J$ = 13.5 Hz), 123.2 (d, $J$ = 1.5 Hz), 122.5 (d, $J$ = 2.7 Hz), 70.3 (d, $J$ = 74.9 Hz), 37.1 (d, $J$ = 14.3 Hz), 37.0 (d, $J$ = 14.1 Hz), 26.0 (d, $J$ = 63.1 Hz), 23.2 (d, $J$ = 66.6 Hz), 23.1, 22.8 (d, $J$ = 3.6 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 51.57. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{28}NO_2PNa^+$ 416.1750, found 416.1756.

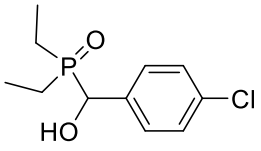
**(E)-(1-hydroxy-3-phenylallyl)bis(3-phenylpropyl)phosphine oxide (4j)**



White solid. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 43.4 mg, 52%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.31-7.27 (m, 5H), 7.25-7.21 (m, 4H), 7.20-7.15 (m, 2H), 7.11-7.09 (m, 4H), 6.70-6.67 (m, 1H), 6.23-6.18 (m, 1H), 5.21 (br s, 1H), 4.66 (t, $J$ = 7.5 Hz, 1H), 2.67-2.60 (m, 4H), 2.01-1.87 (m, 4H), 1.84-1.61 (m, 4H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 140.9 (d, $J$ = 14.4 Hz), 136.3 (d, $J$ = 2.1 Hz), 132.3 (d, $J$ = 10.8 Hz), 128.7, 128.6, 128.5 (d, $J$ = 4.5 Hz), 128.1,

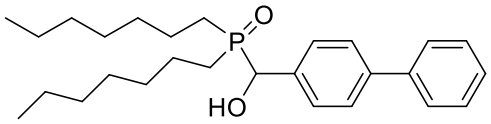
126.7, 126.2 (d, $J$ = 9.5 Hz), 124.3, 71.2 (d, $J$ = 75.8 Hz), 37.0 (d, $J$ = 6.8 Hz), 36.9 (d, $J$ = 6.8 Hz), 24.7 (d, $J$ = 61.4 Hz), 24.4 (d, $J$ = 62.1 Hz), 23.2 (d, $J$ = 3.7 Hz), 23.1 (d, $J$ = 3.7 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.62. HRMS (ESI-TOF) m/z: $[M+Na]^+$ Calcd for $C_{27}H_{31}O_2PNa^+$ 441.1954, found 441.1952.

**((4-chlorophenyl)(hydroxy)methyl)diethylphosphine oxide (4k)**




White wax. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 20.2 mg, 41%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.36 (d, $J$ = 8.1 Hz, 2H), 7.31 (d, $J$ = 8.4 Hz, 2H), 5.21 (br s, 1H), 5.01 (d, $J$ = 7.2 Hz, 1H), 1.64 (m, 4H), 1.08 (m, 6H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 136.1, 133.9 (d, $J$ = 2.8 Hz), 128.8 (d, $J$ = 2.1 Hz), 128.1 (d, $J$ = 4.2 Hz), 71.1 (d, $J$ = 74.1 Hz), 17.5 (d, $J$ = 13.9 Hz), 17.1 (d, $J$ = 15.1 Hz), 5.6 (d, $J$ = 4.7 Hz), 5.5 (d, $J$ = 5.4 Hz). $^{31}$P NMR (242 MHz, $CDCl_3$) δ 53.38. HRMS Calcd for $C_{11}H_{16}ClO_2P$ $[M+Na]^+$ 269.0496, found 269.0498.

**([1,1'-biphenyl]-4-yl(hydroxy)methyl)diheptylphosphine oxide (4l)**




White wax. Eluent $V_{DCM}$ : $V_{MeOH}$ = 10:1, Yield: 43.5 mg, 51%. $^1$H NMR (600 MHz, $CDCl_3$) δ 7.61-7.58 (m, 4H), 7.48 (d, $J$ = 7.3 Hz, 2H), 7.44 (t, $J$ = 7.6 Hz, 2H), 7.35 (t, $J$ = 7.4 Hz, 1H), 5.34 (br s, 1H), 5.05 (t, $J$ = 4.8 Hz, 1H), 1.74-1.66 (m, 4H), 1.61-1.53 (m, 4H), 1.40-1.33 (m, 4H), 1.30-1.23 (m, 12H), 0.86 (m, 6H). $^{13}$C NMR (150 MHz, $CDCl_3$) δ 141.2, 140.6, 136.2, 128.9, 127.6, 127.5, 127.2, 127.0 (d, $J$ = 4.2 Hz), 72.1 (d, $J$ = 70.8 Hz), 31.7, 31.6, 31.3 (d, $J$ = 3.8 Hz), 31.2 (d, $J$ = 3.9 Hz), 29.8, 28.93, 28.91, 25.2, 22.72, 22.71, 21.6 (d, $J$ = 3.8 Hz), 21.4 (d, $J$ = 4.3 Hz), 14.19, 14.17. $^{31}$P NMR (242 MHz, $CDCl_3$) δ 50.18. HRMS (ESI-TOF) m/z: $[M+H]^+$ Calcd for $C_{27}H_{42}O_2P^+$ 429.2917, found 429.2918.

# 5. In situ $^{31}$P{$^1$H} NMR spectra for the synthesis of $R_2P(O)H$

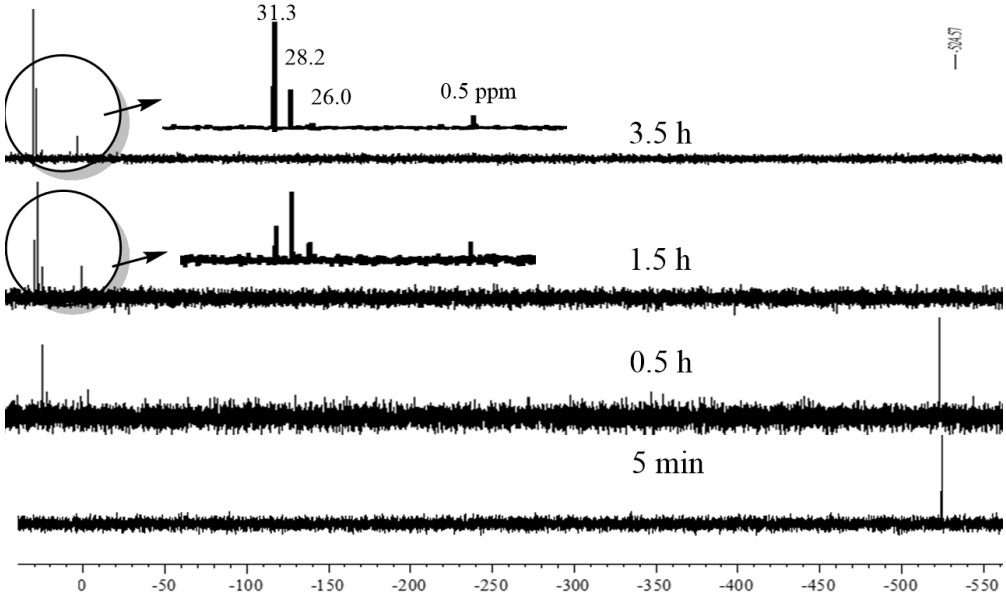



**Fig 1**

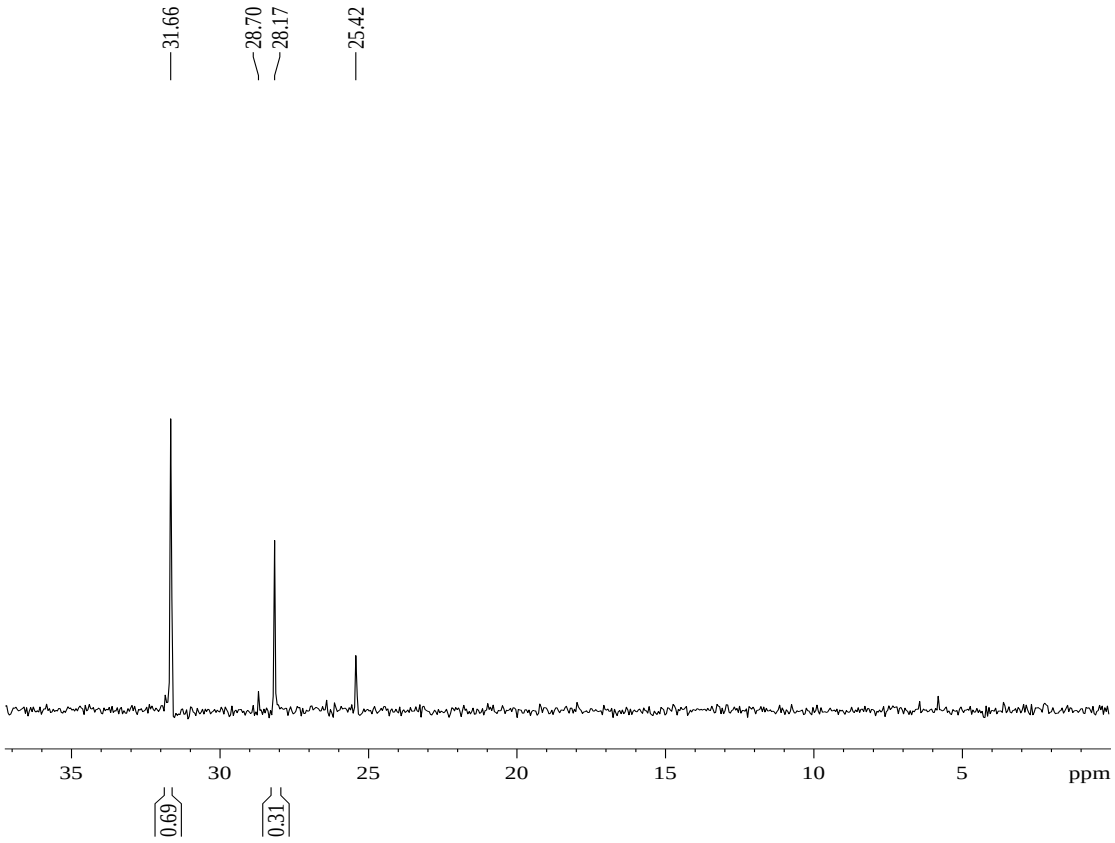



**Fig 2 In situ 31P{1H} NMR spectra for the synthesis of R2P(O)H (reaction time: 3.5 hours)**

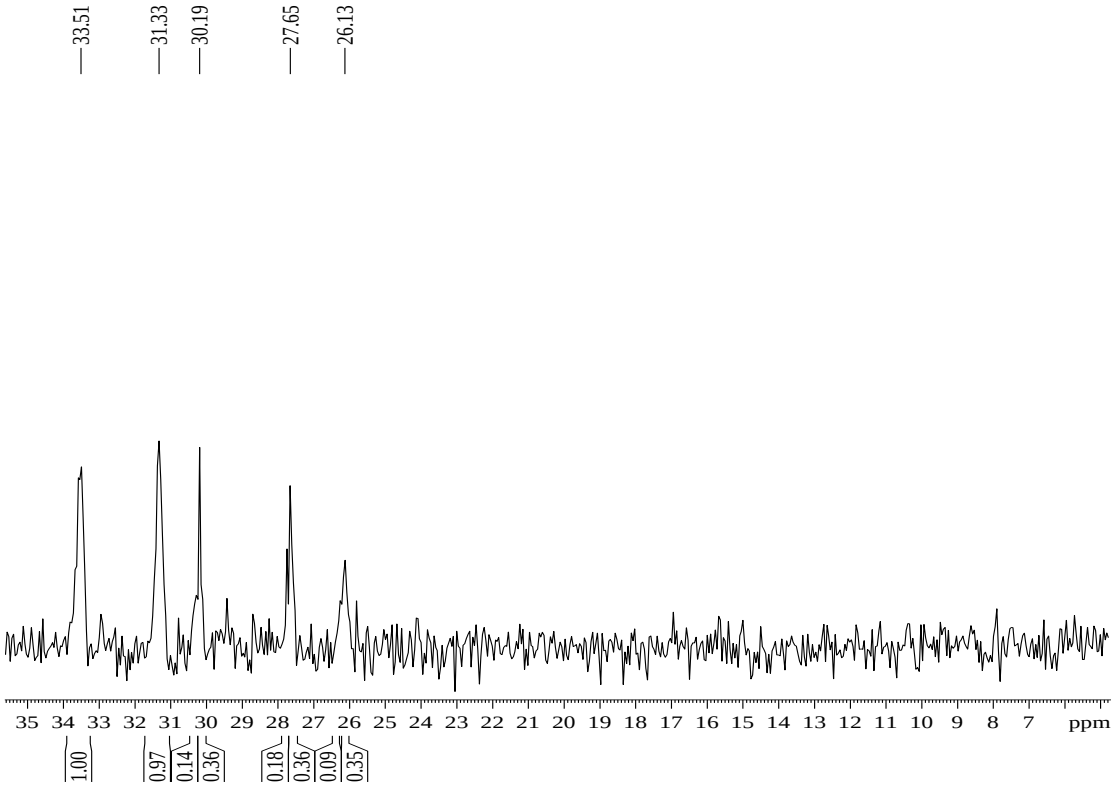
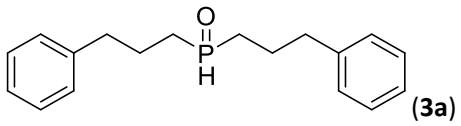
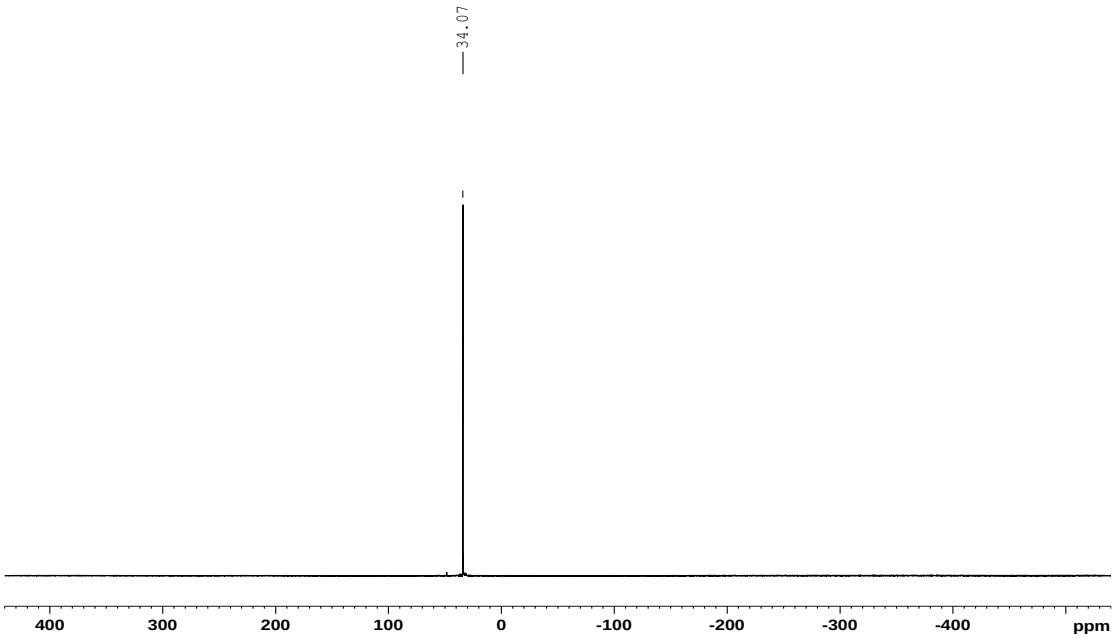



**Fig 3 In situ $^{31}$P NMR spectra for the synthesis of R2P(O)H (reaction time: 3.5 hours)**

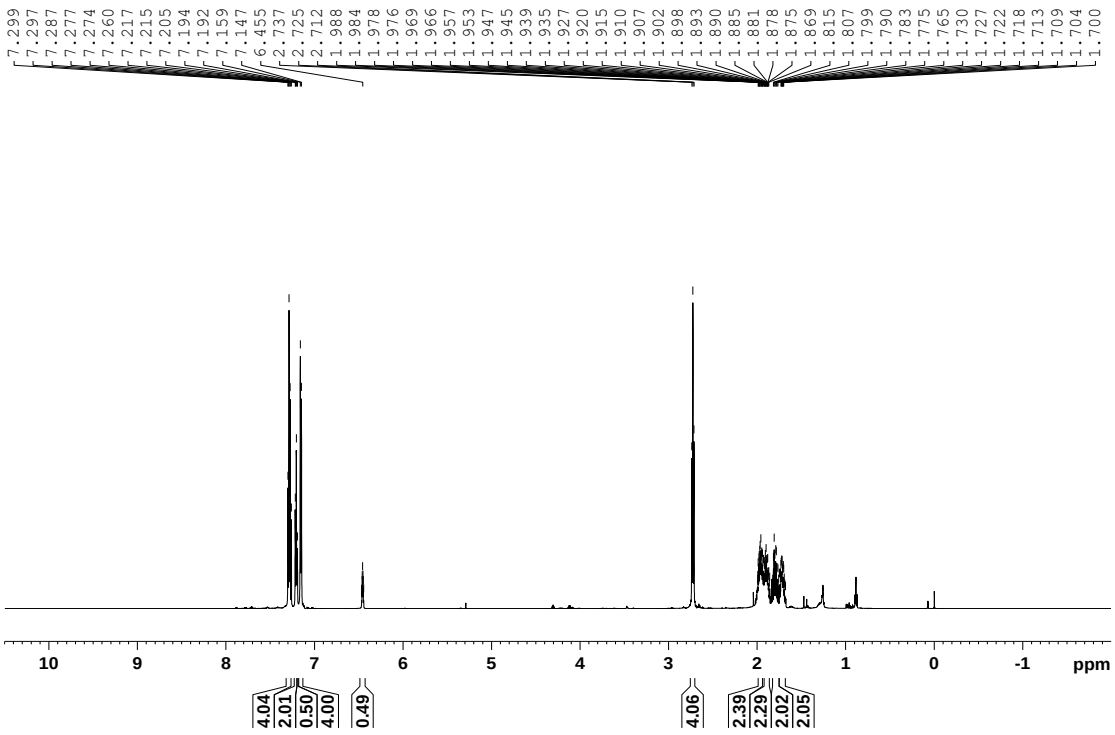
# 6. Copies of NMR spectra for products



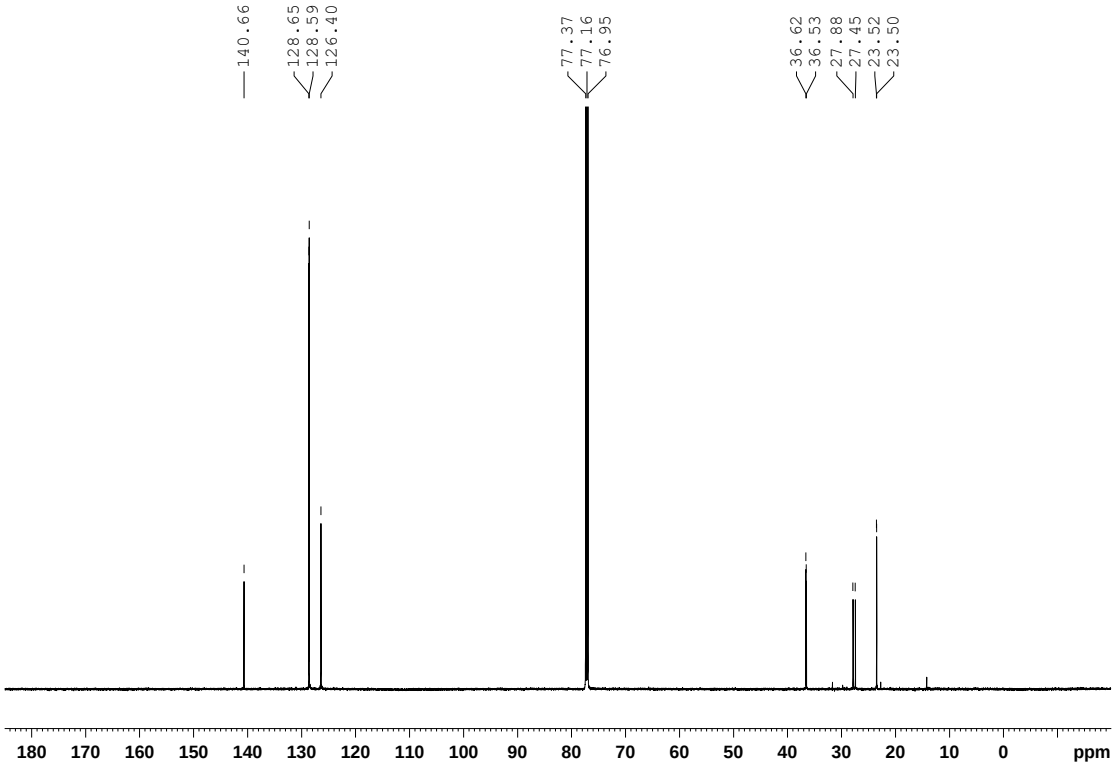

(**3a**)



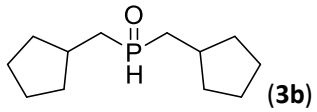

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3a**



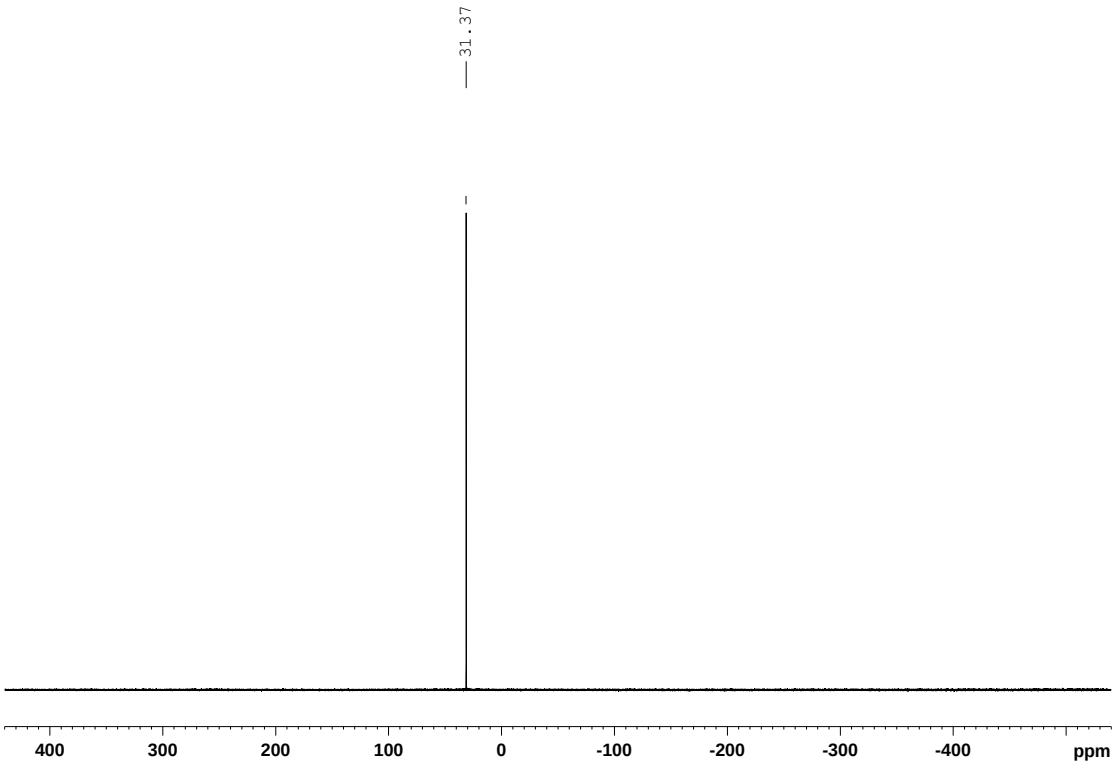

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3a**



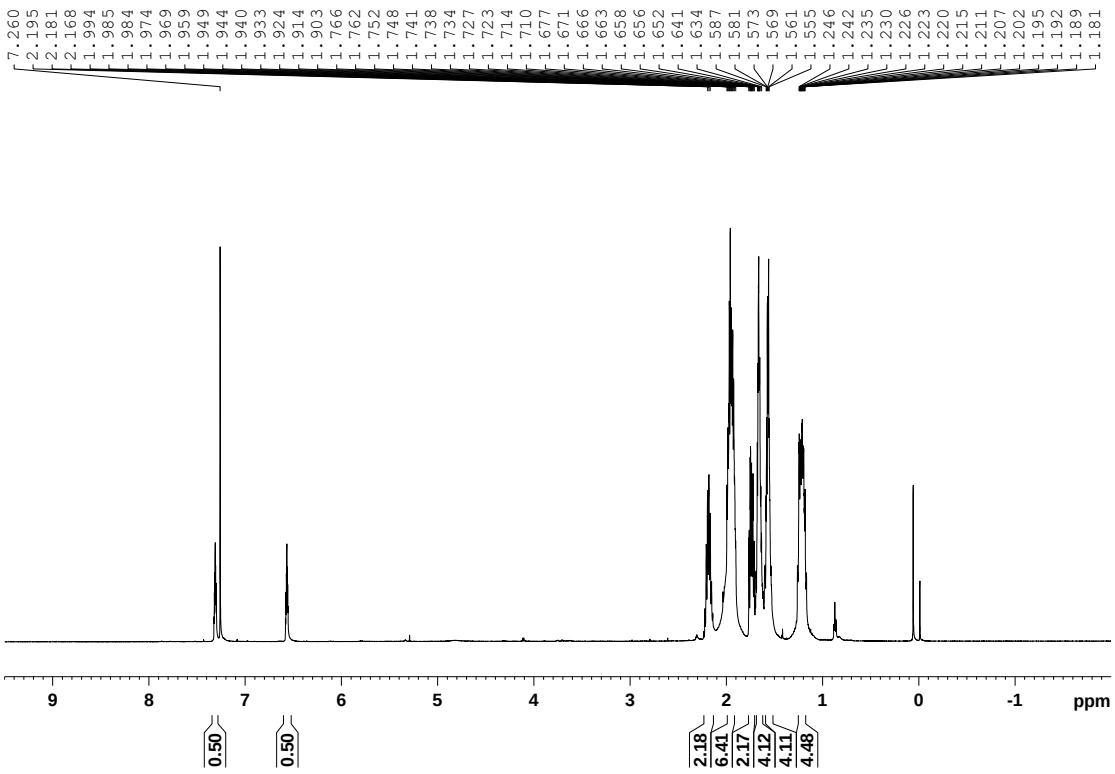

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3a**



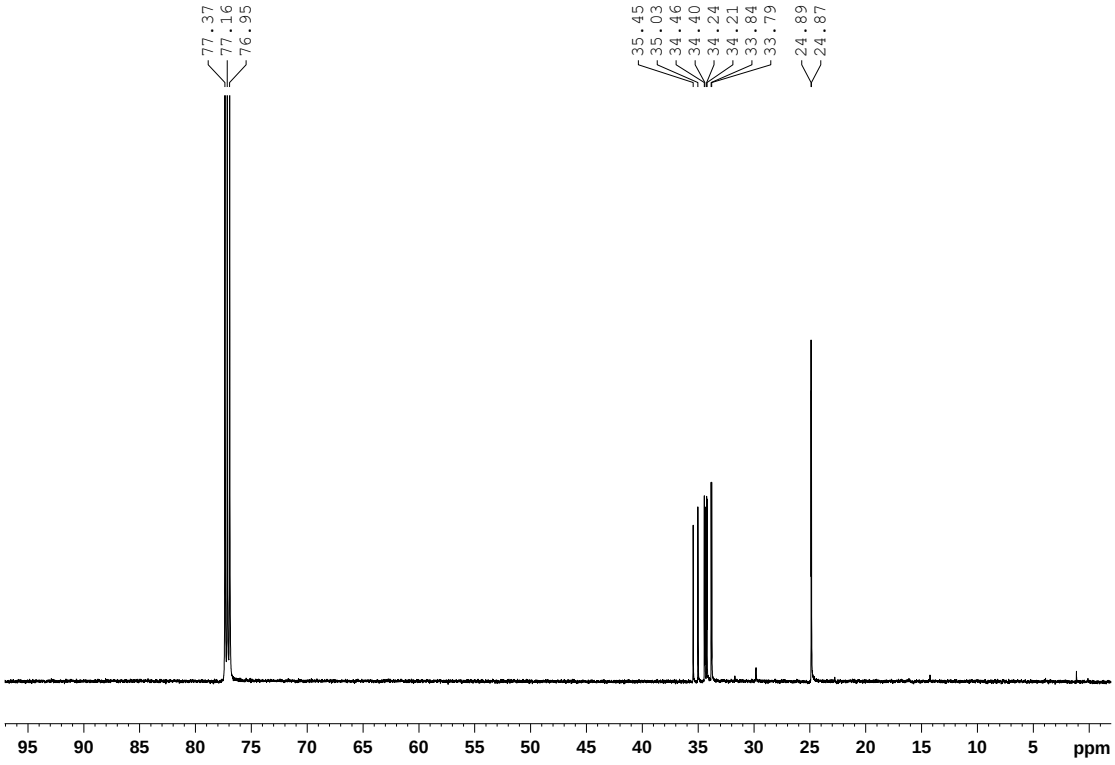

(**3b**)



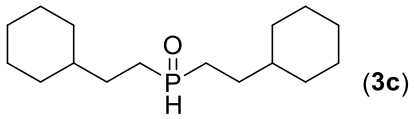

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3b**



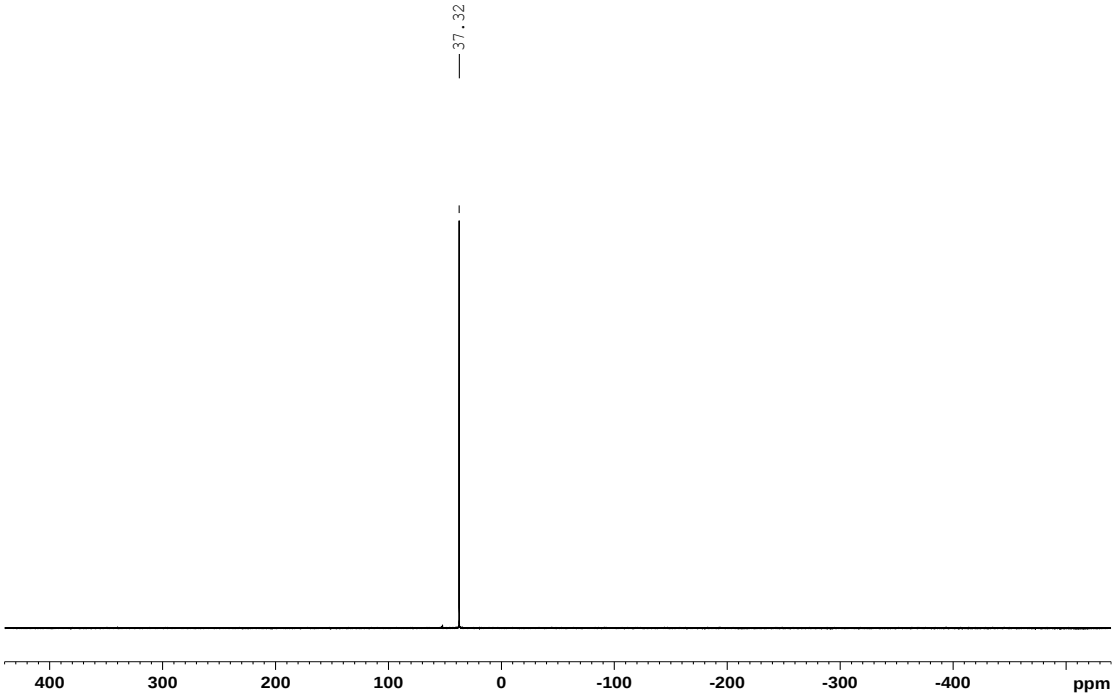

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3b**



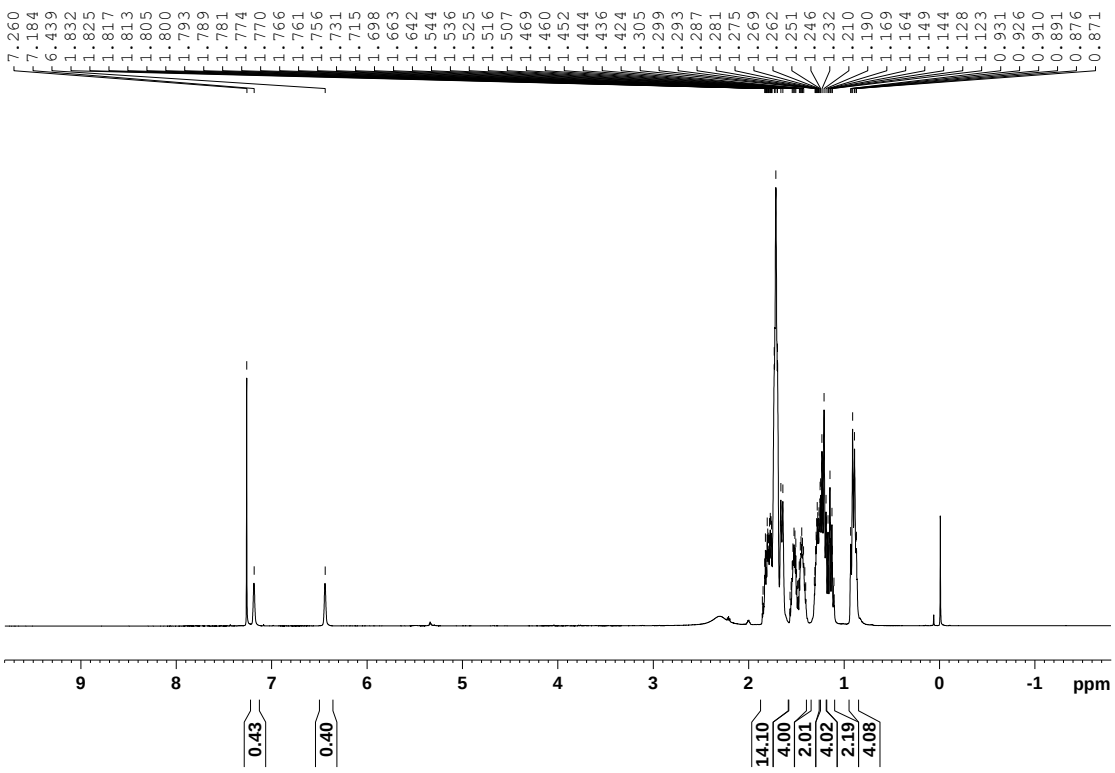

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3b**



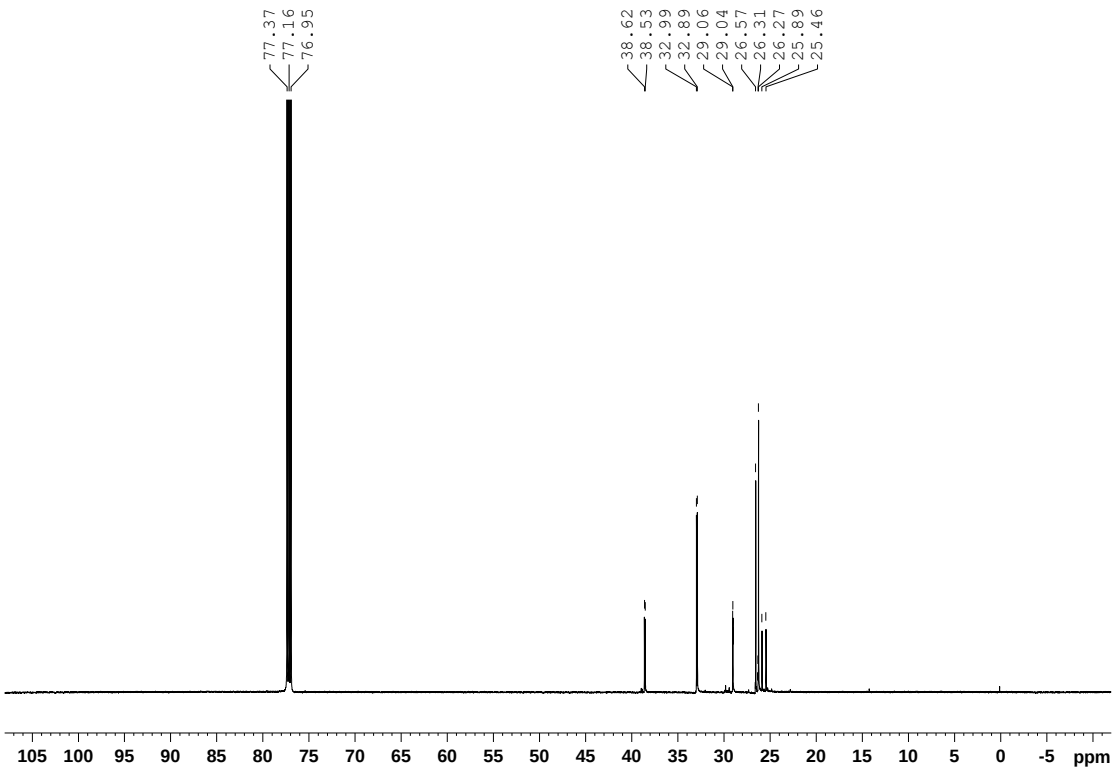

(**3c**)



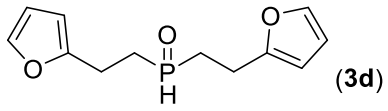

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3c**



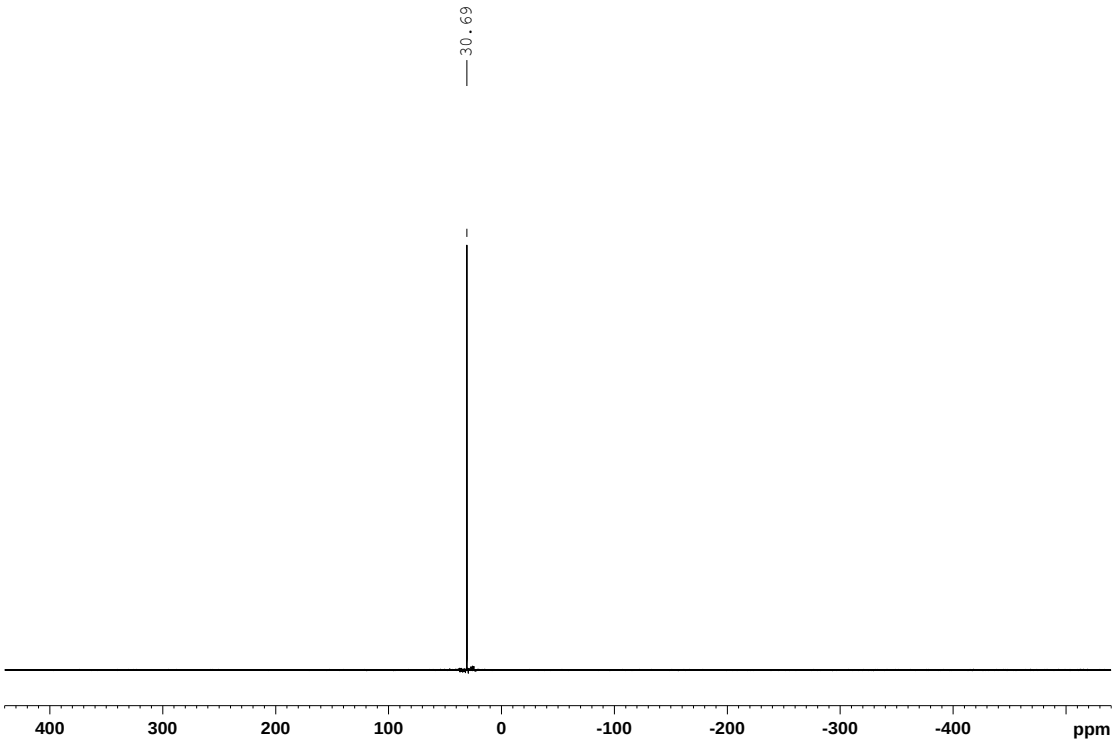

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3c**



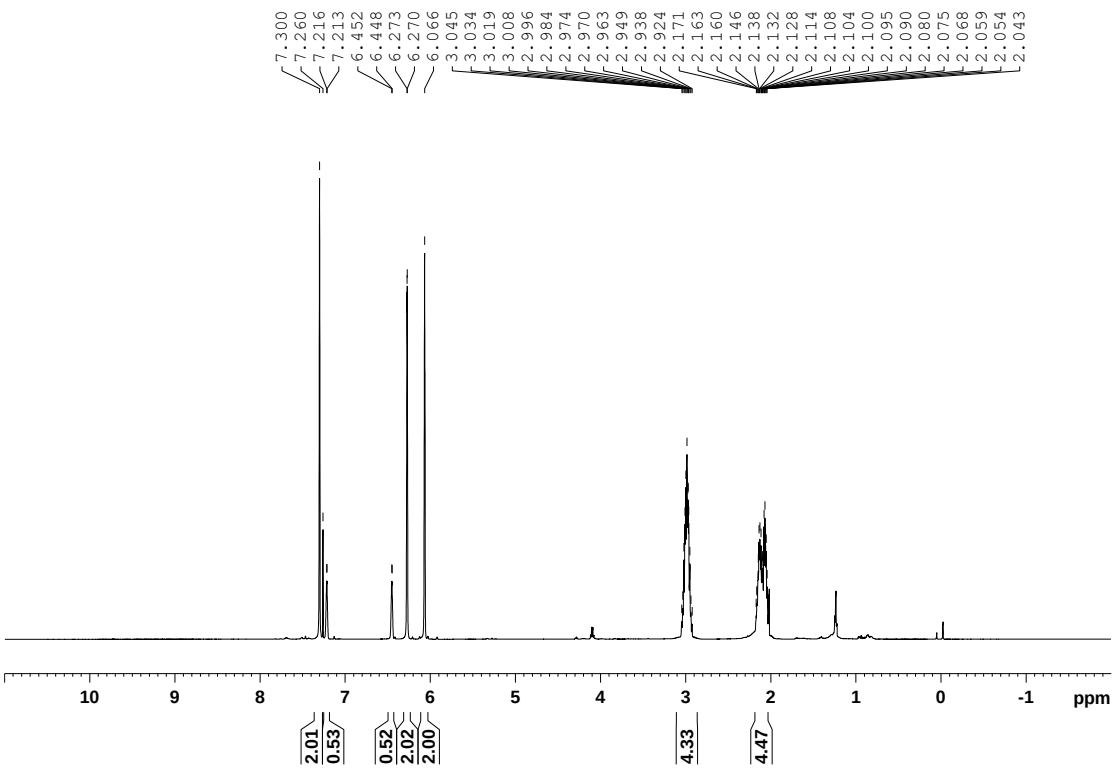

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3c**



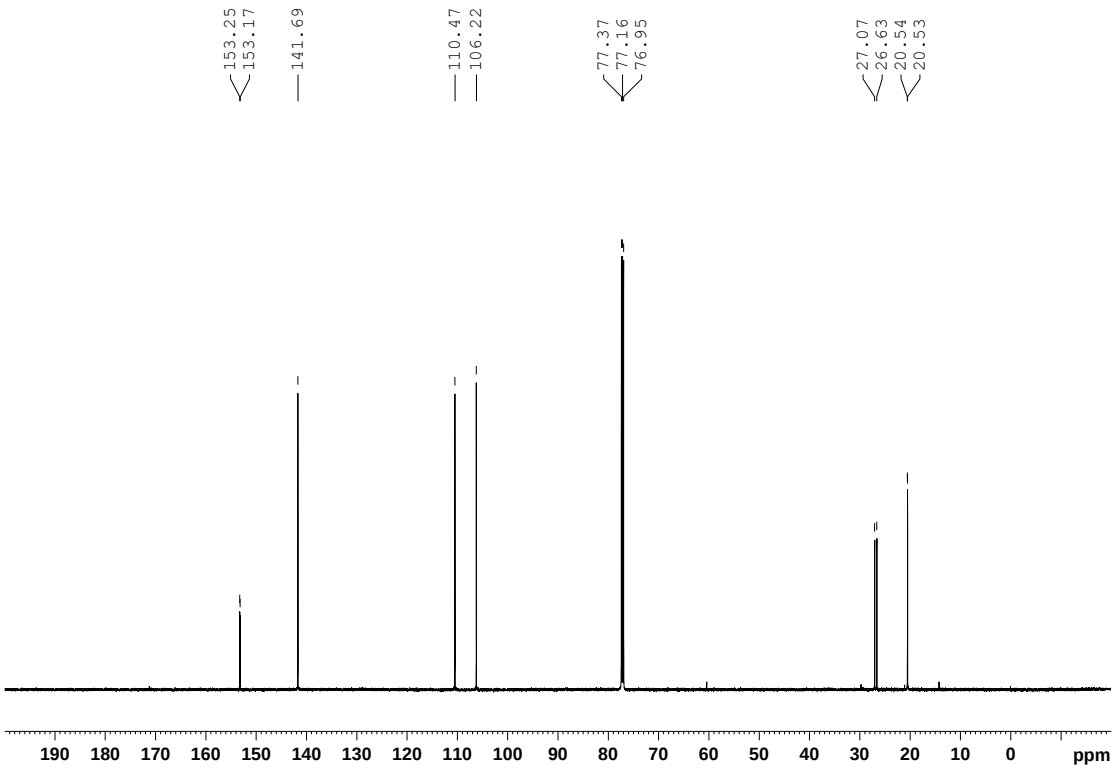

(**3d**)



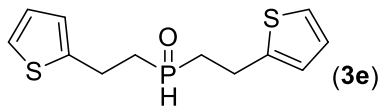

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3d**



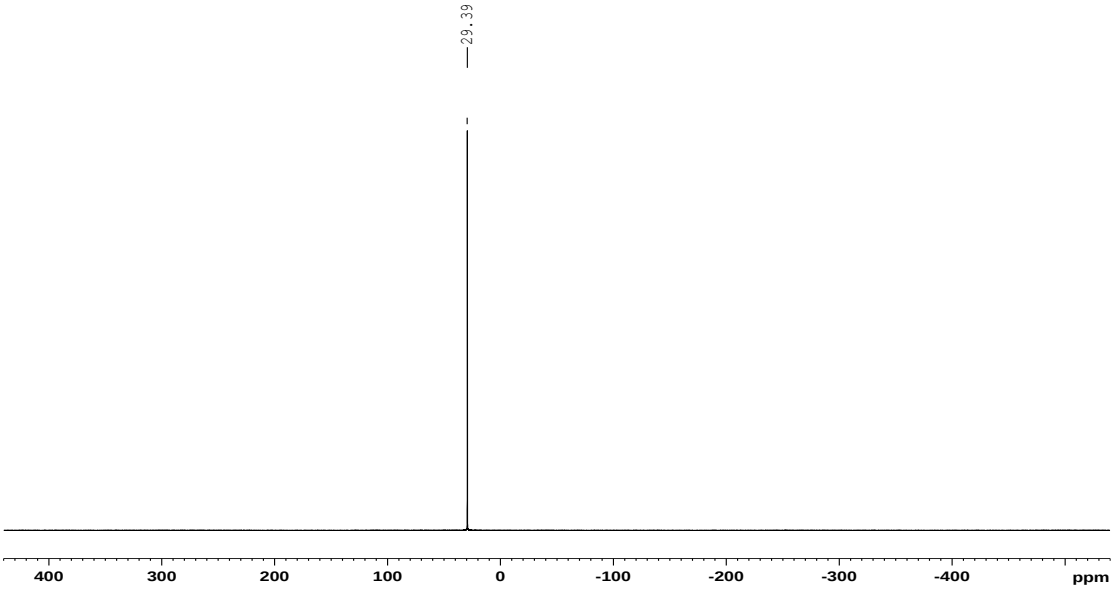

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3d**



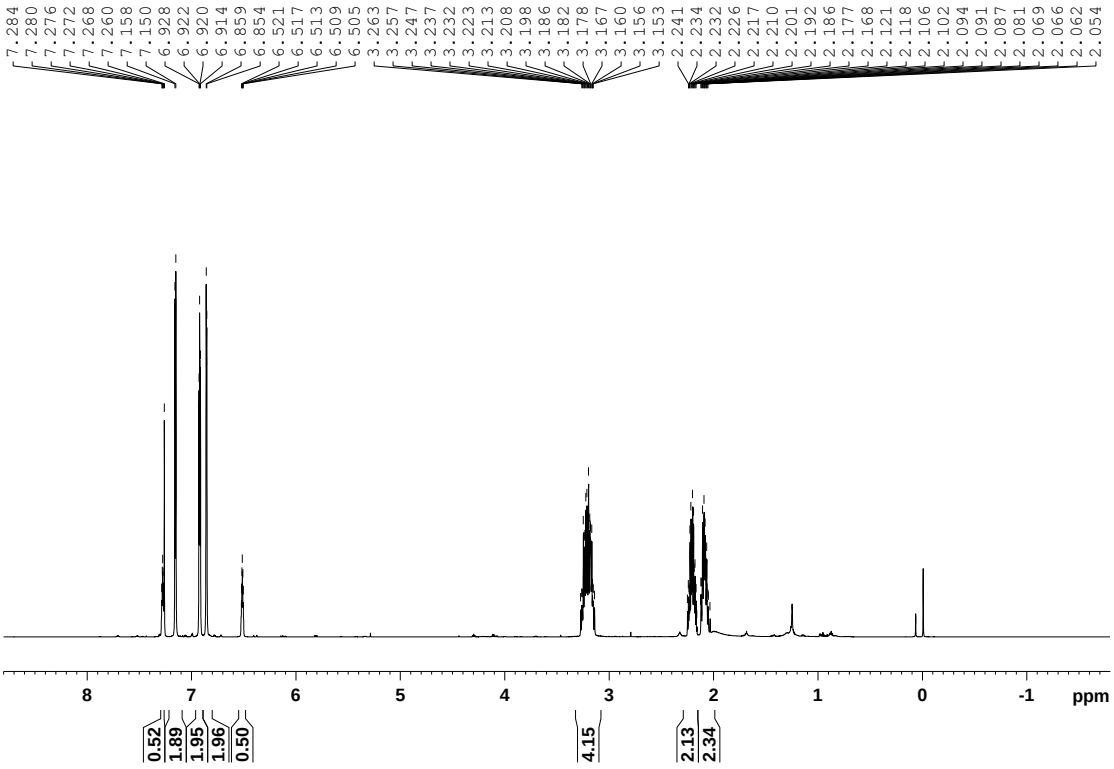

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3d**



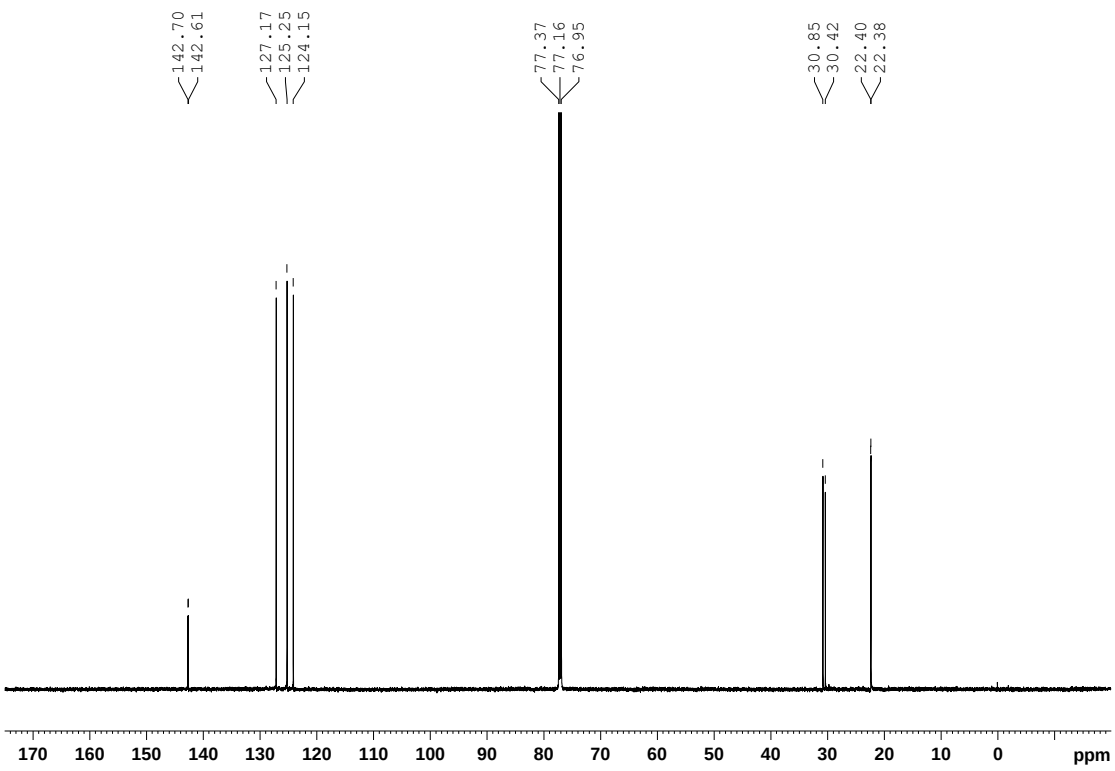

(**3e**)



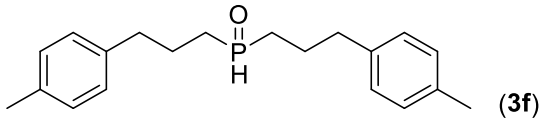

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3e**



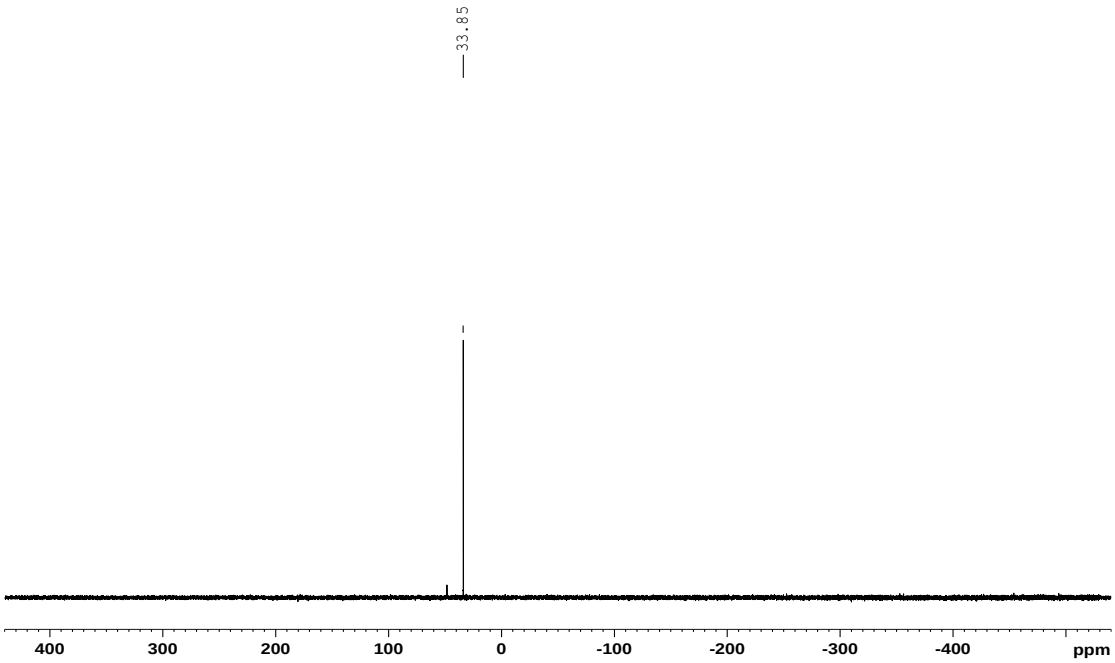

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3e**



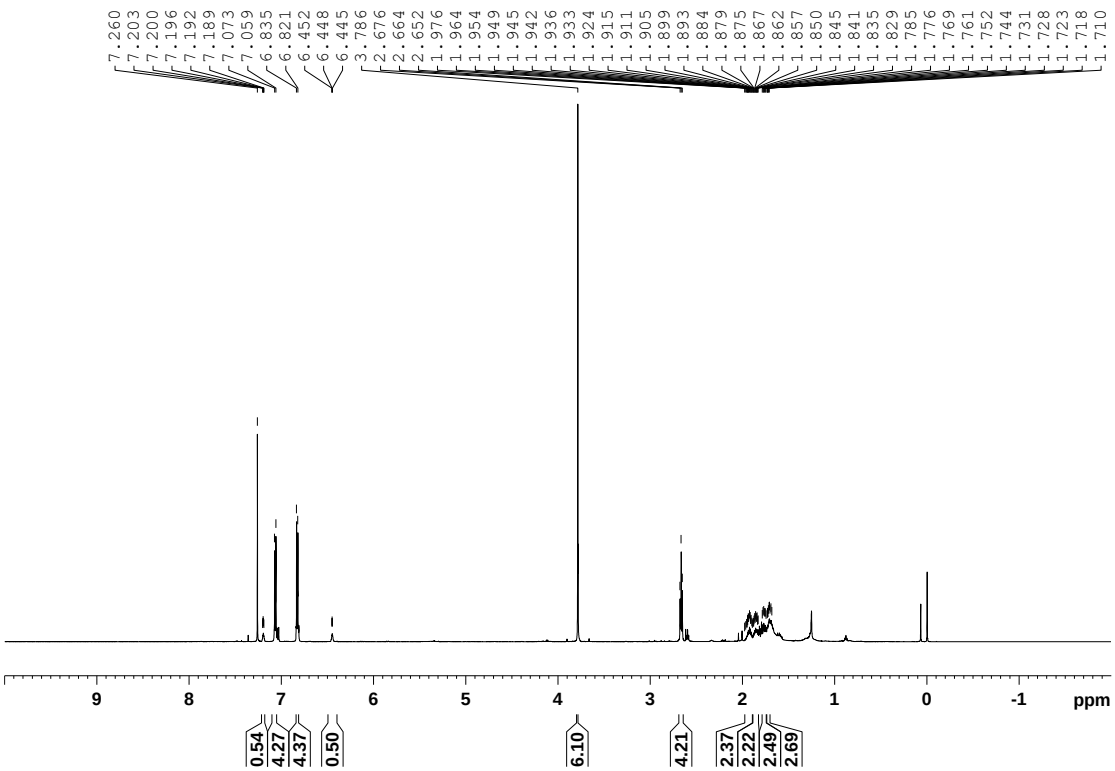

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3e**



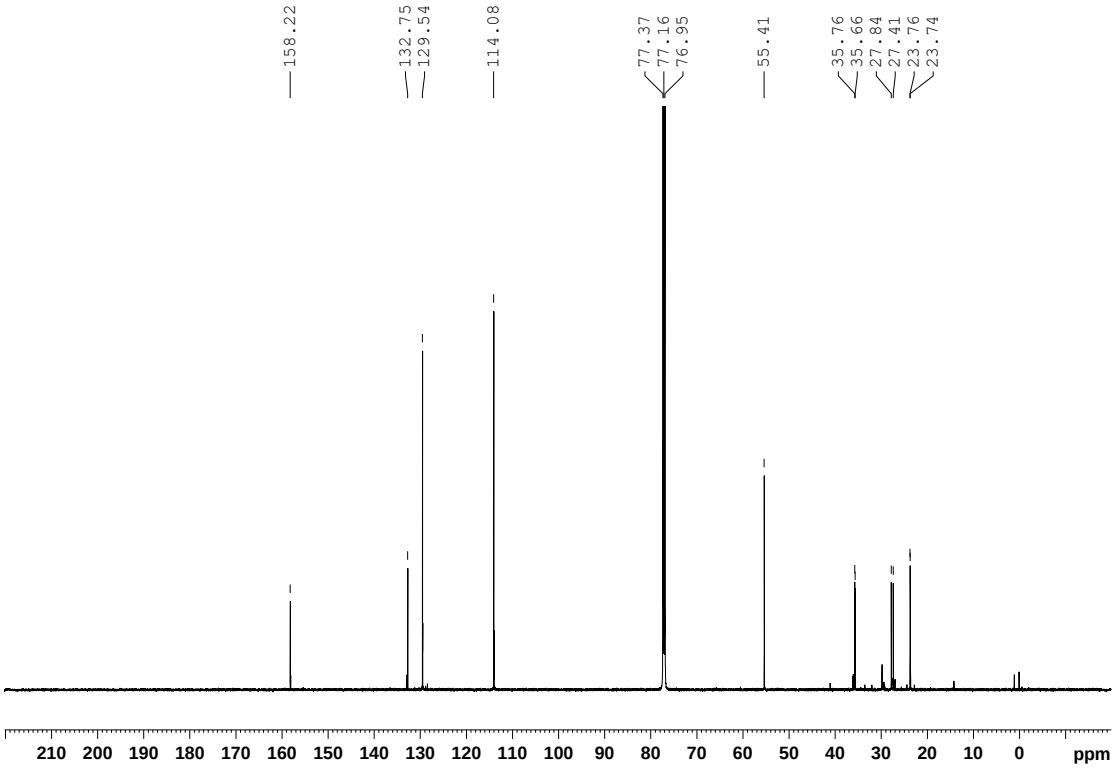

(**3f**)



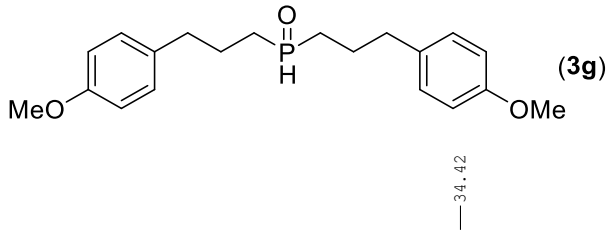

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3f**

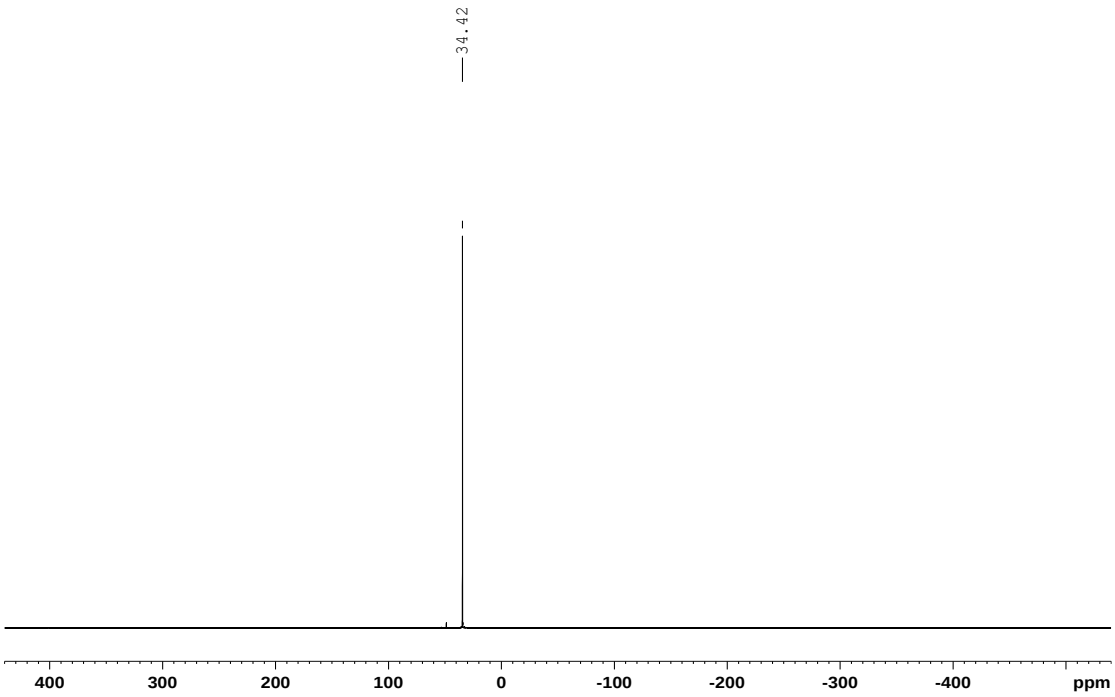



$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3f**

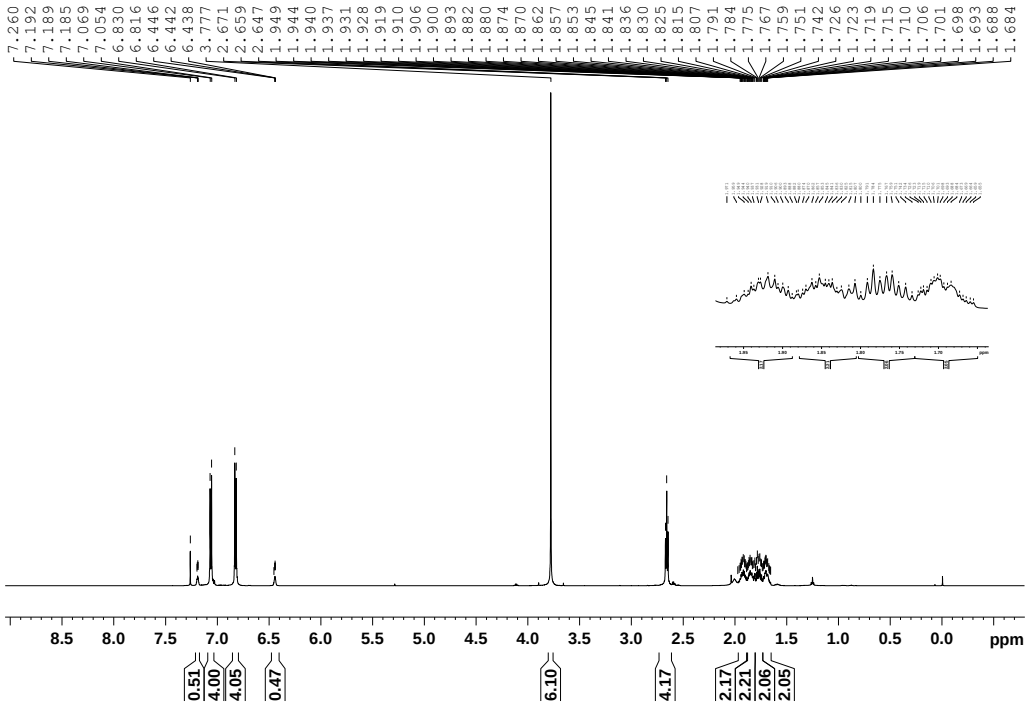



$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3f**

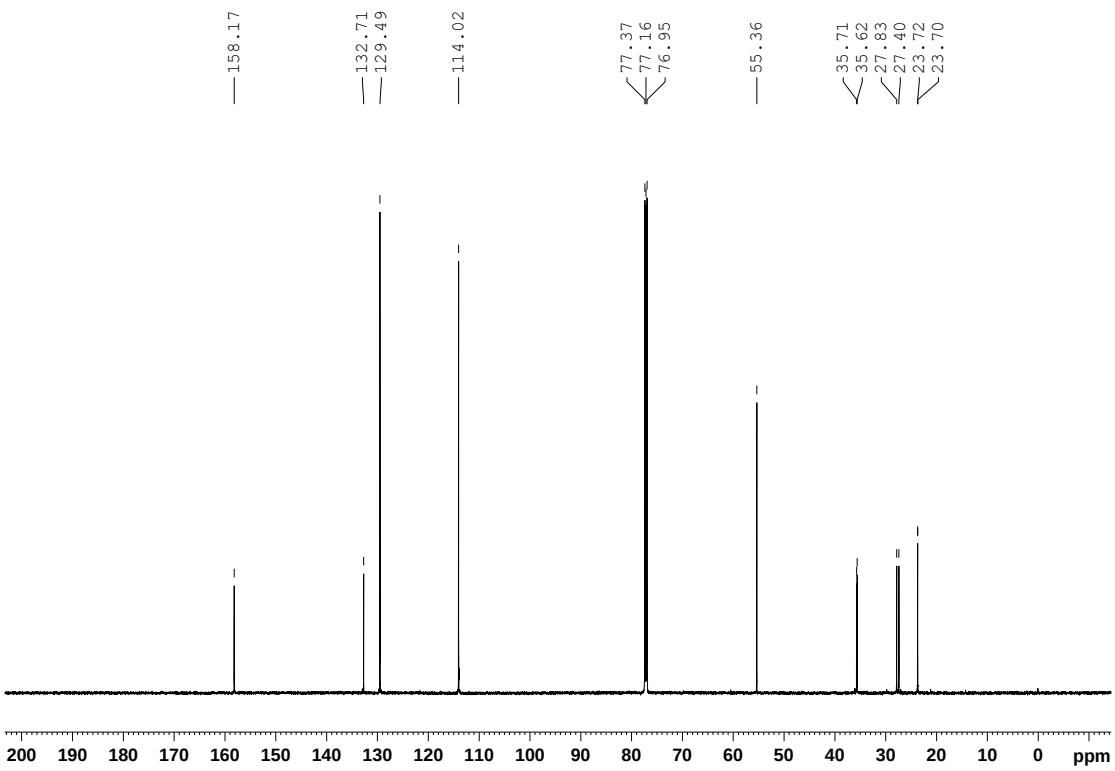


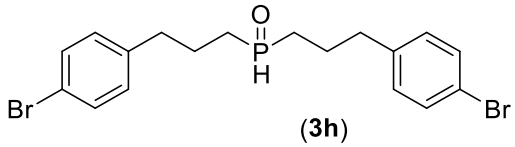

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3g**



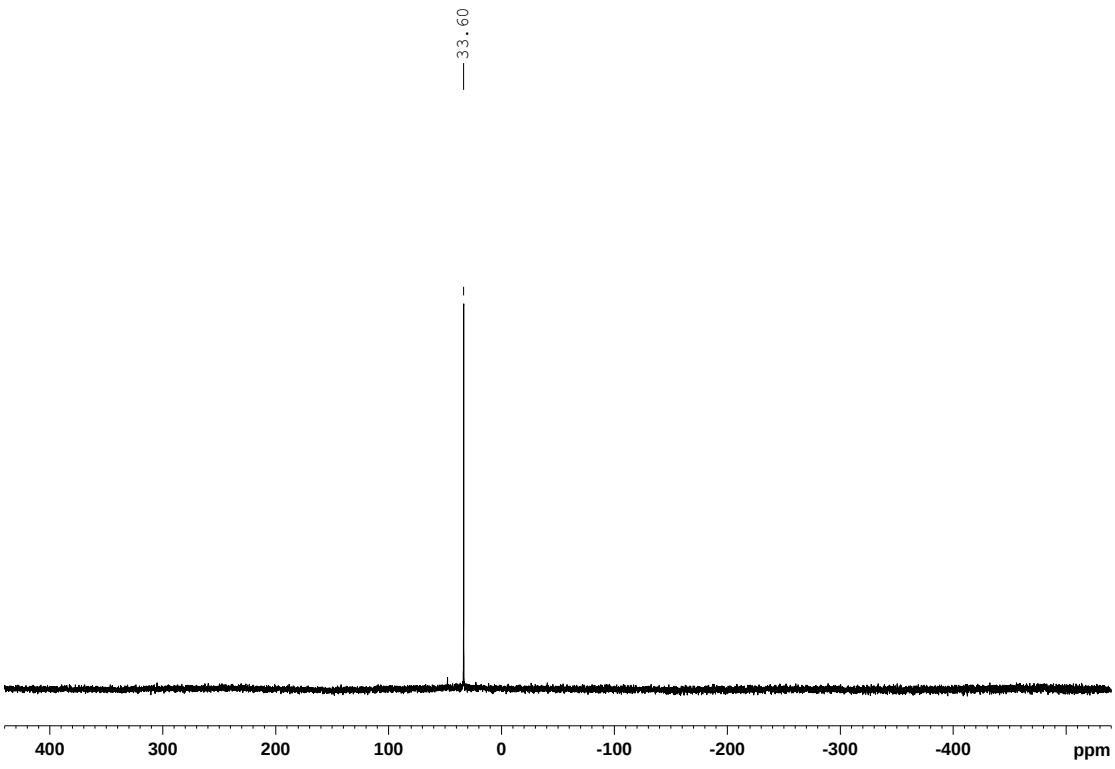

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3g**



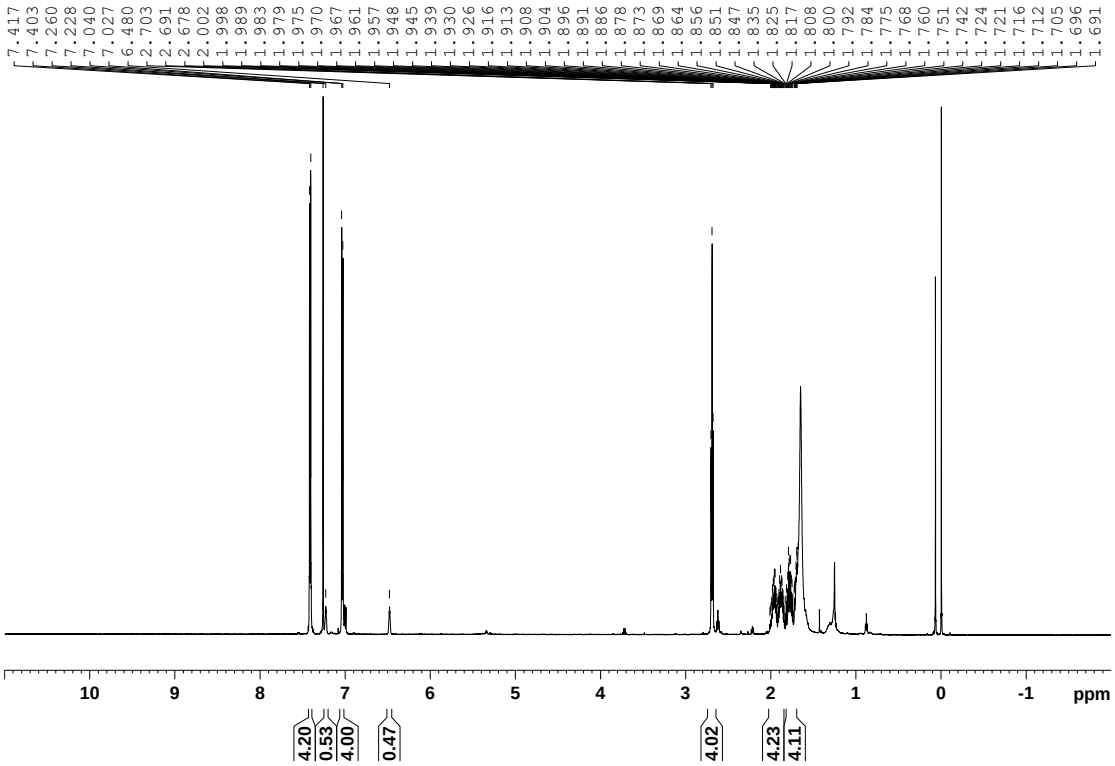

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3g**



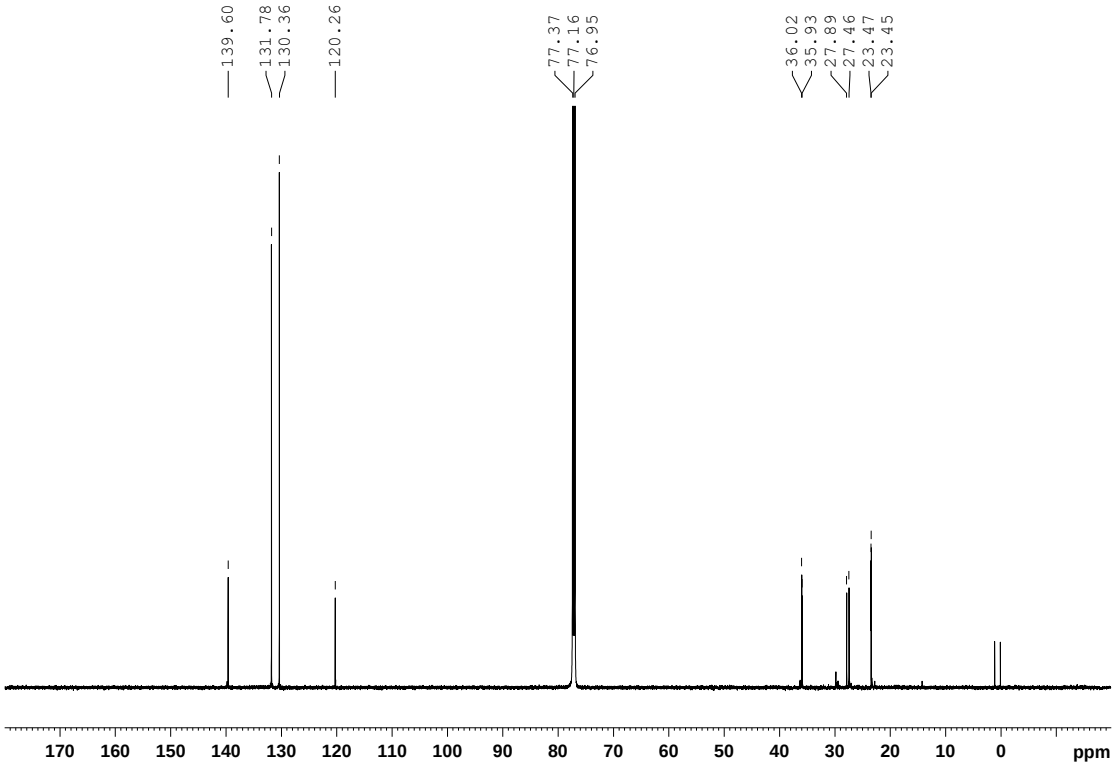

(**3h**)



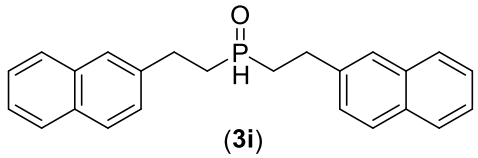

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3h**



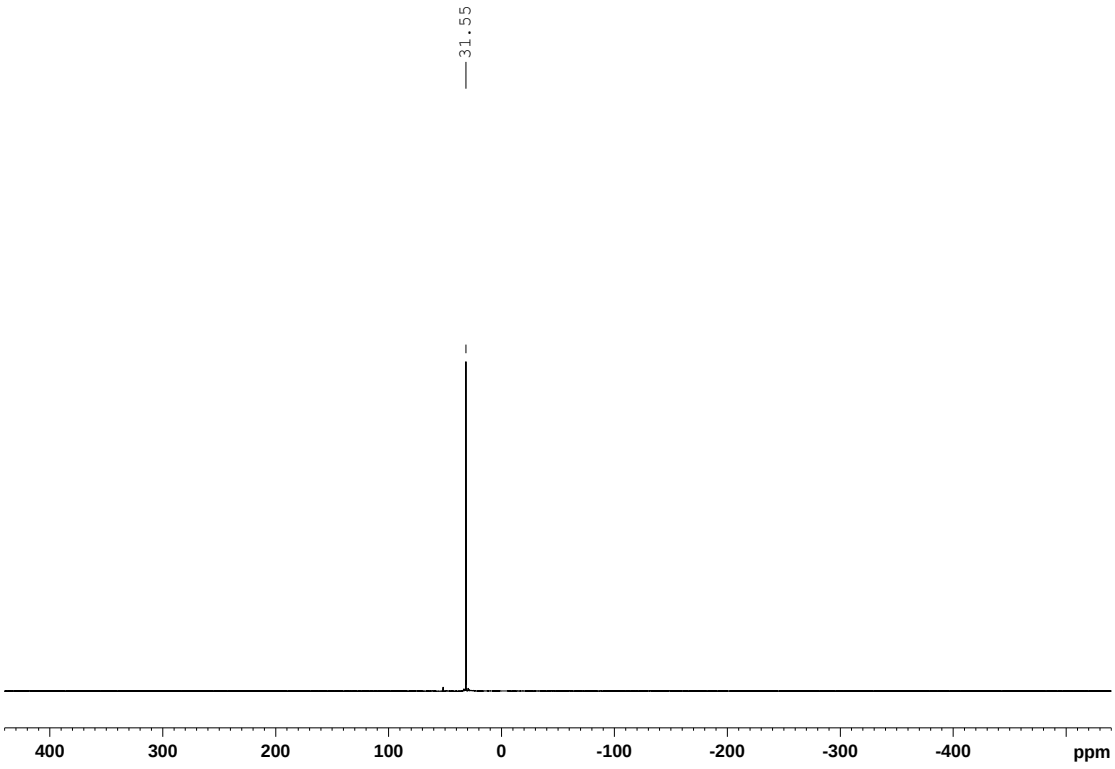

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3h**



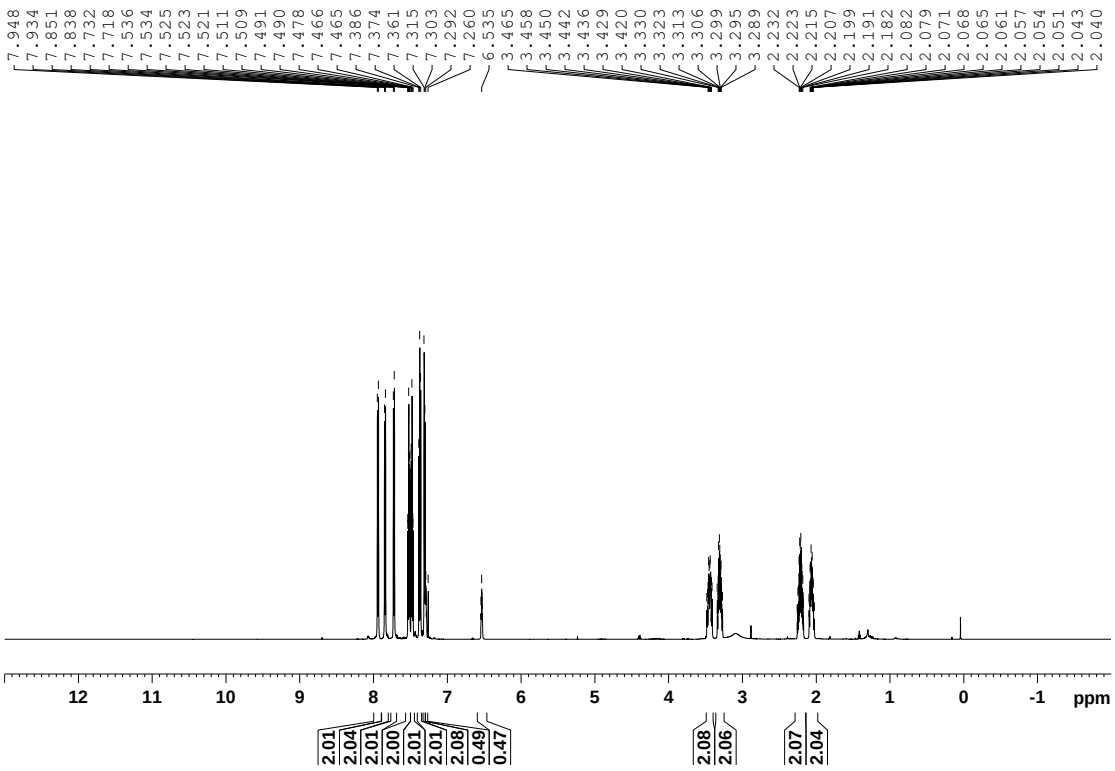

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3h**



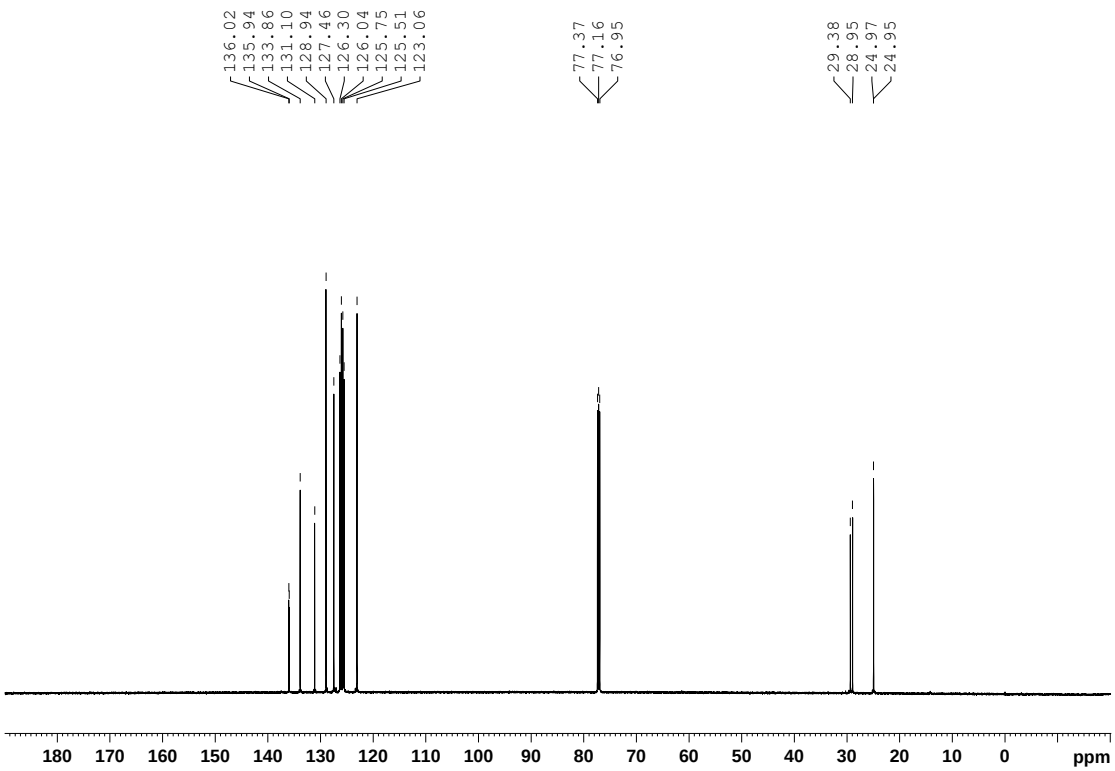
(**3i**)



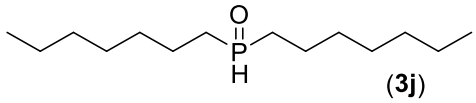

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3i**



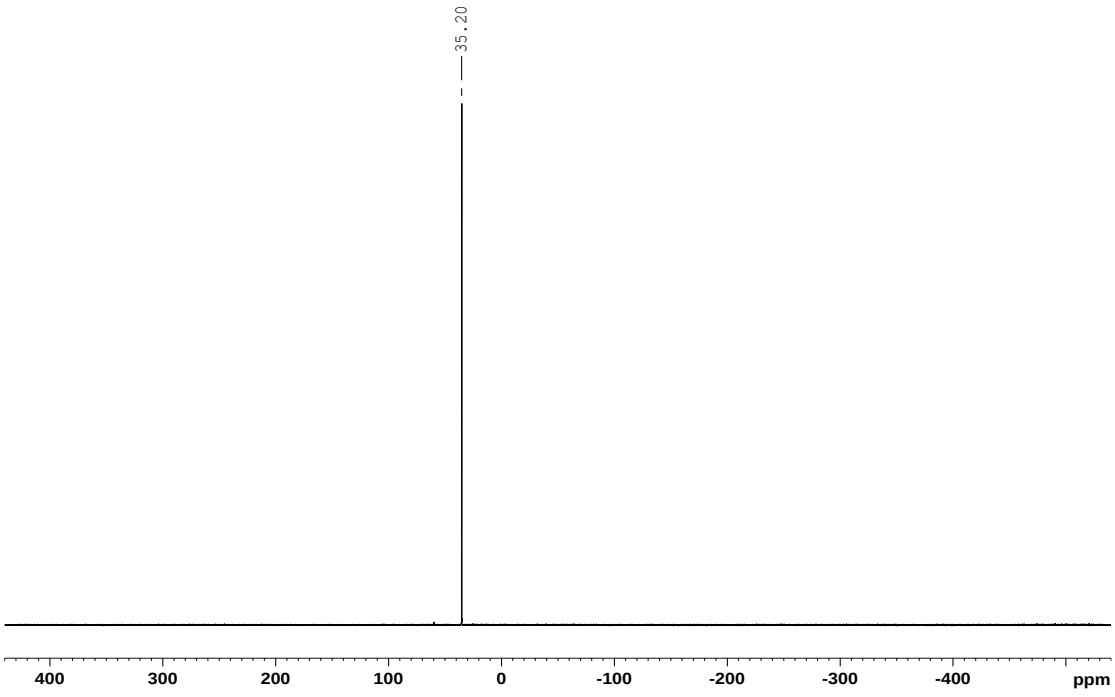

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3i**



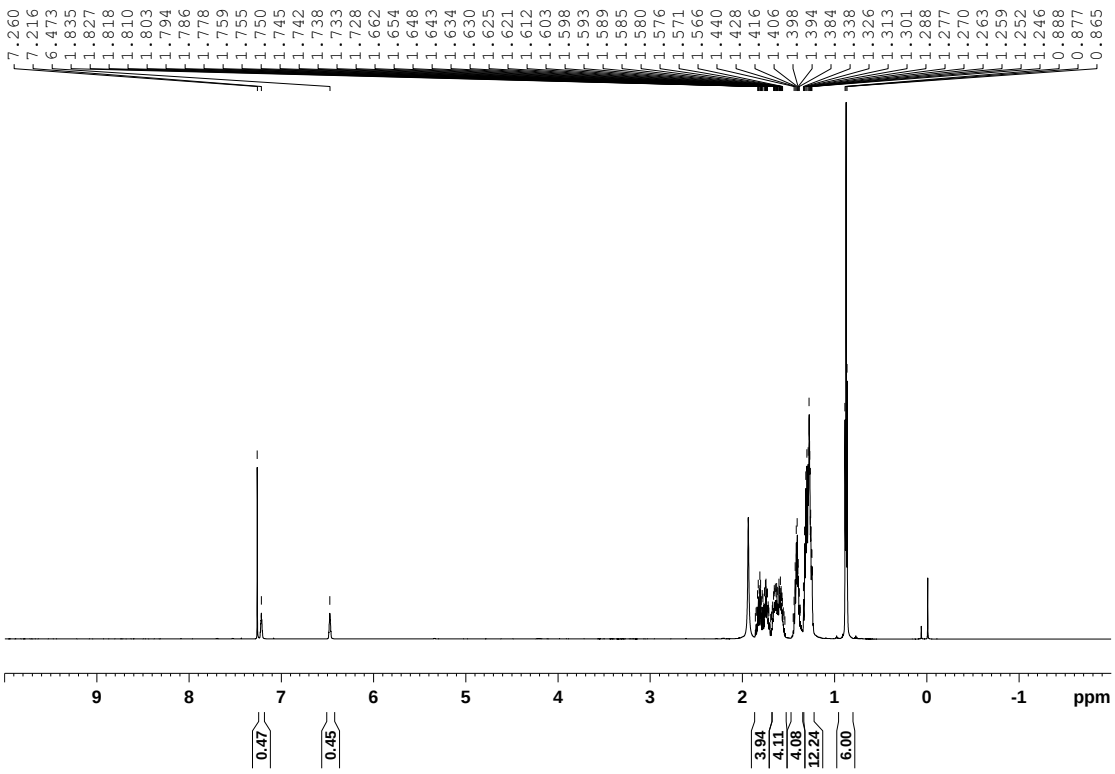

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3i**



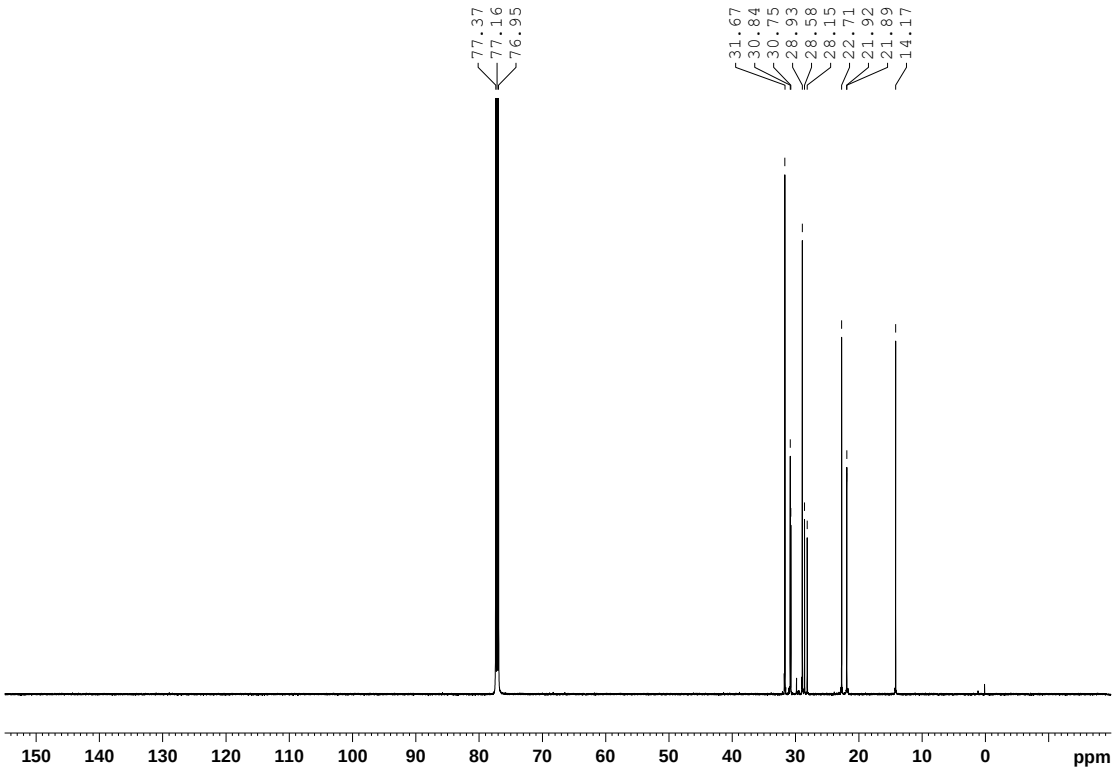

(**3j**)



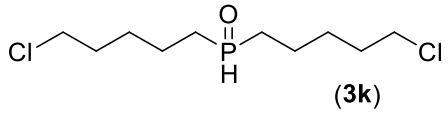

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3j**



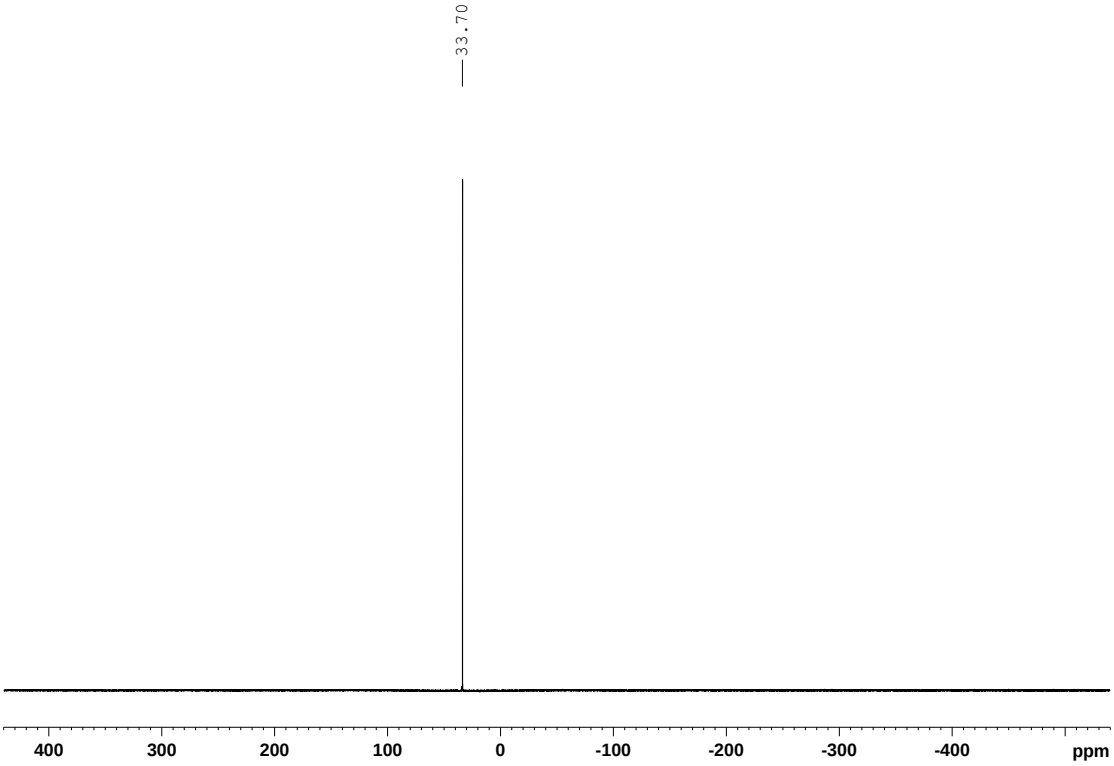

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3j**



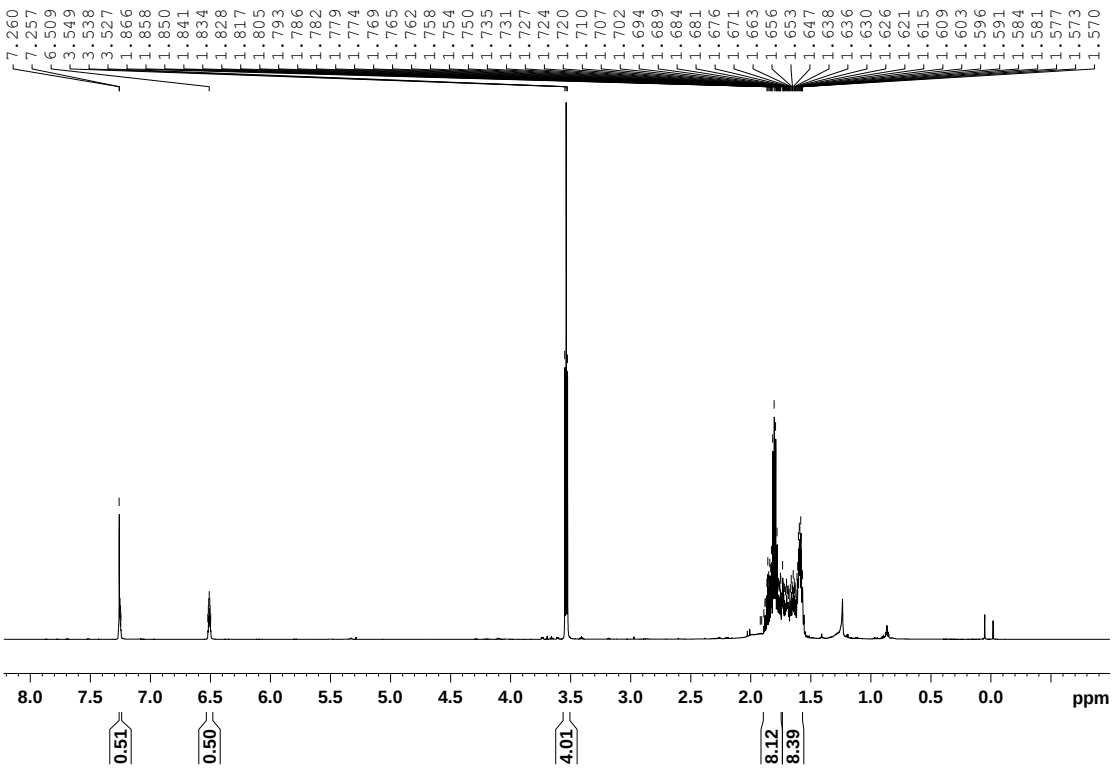

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3j**



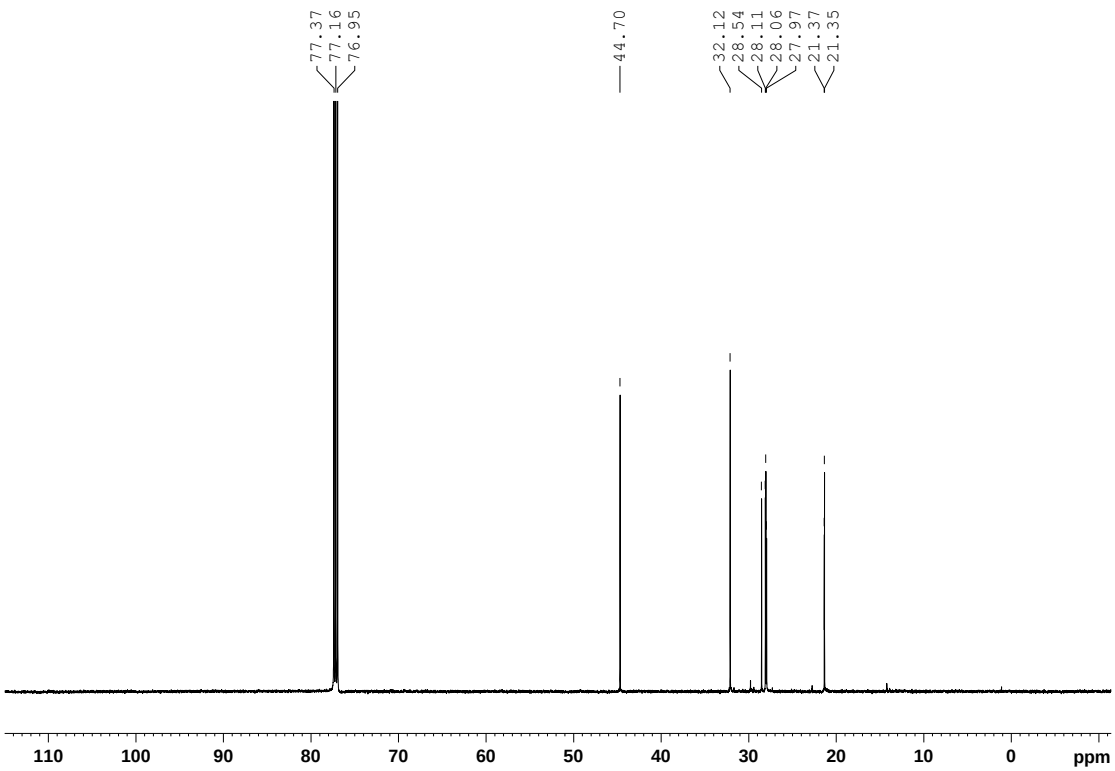

(**3k**)



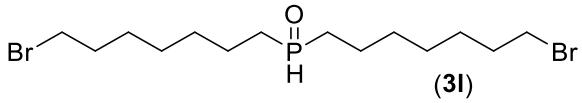

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3k**



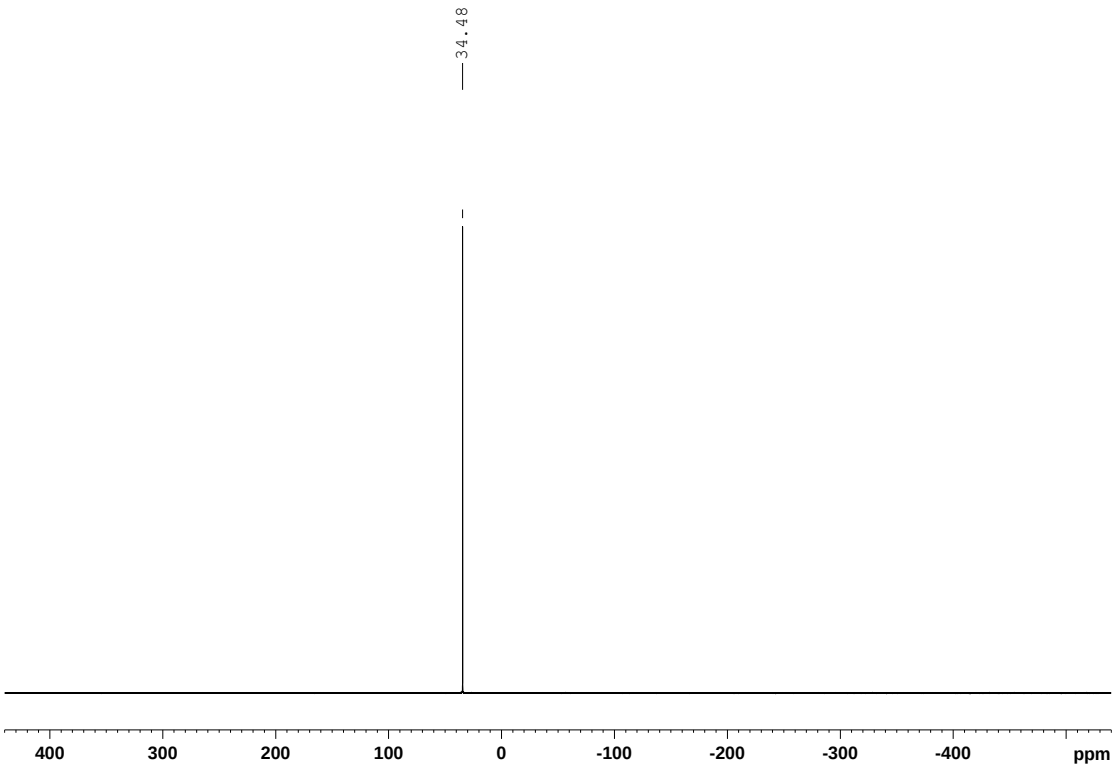

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3k**



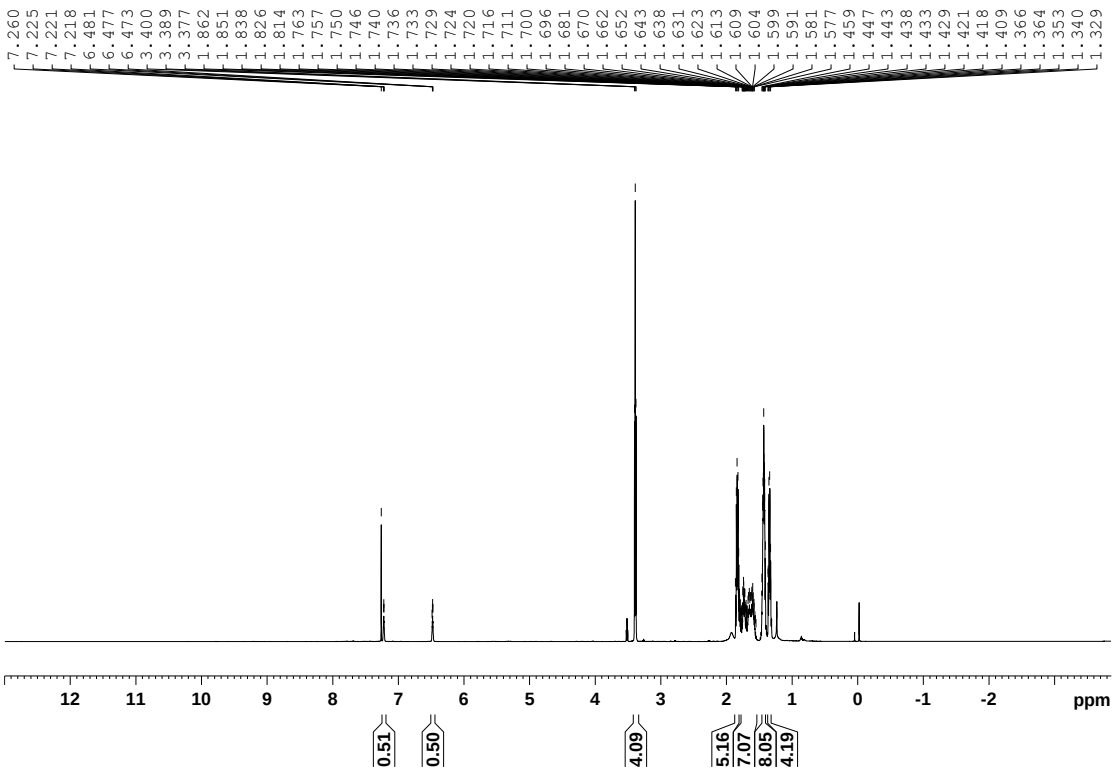

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3k**



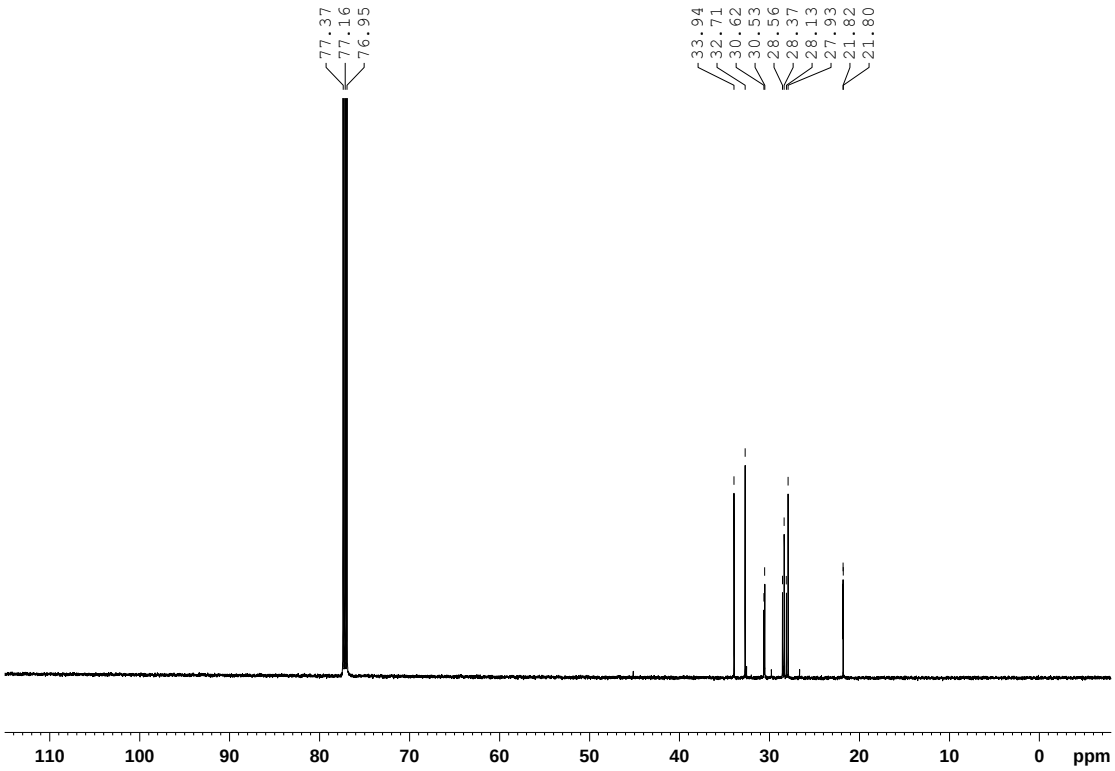

(**3l**)



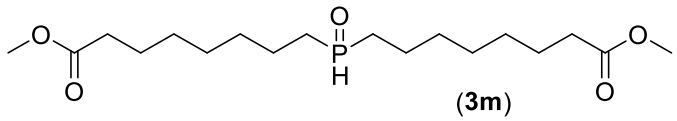

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3l**



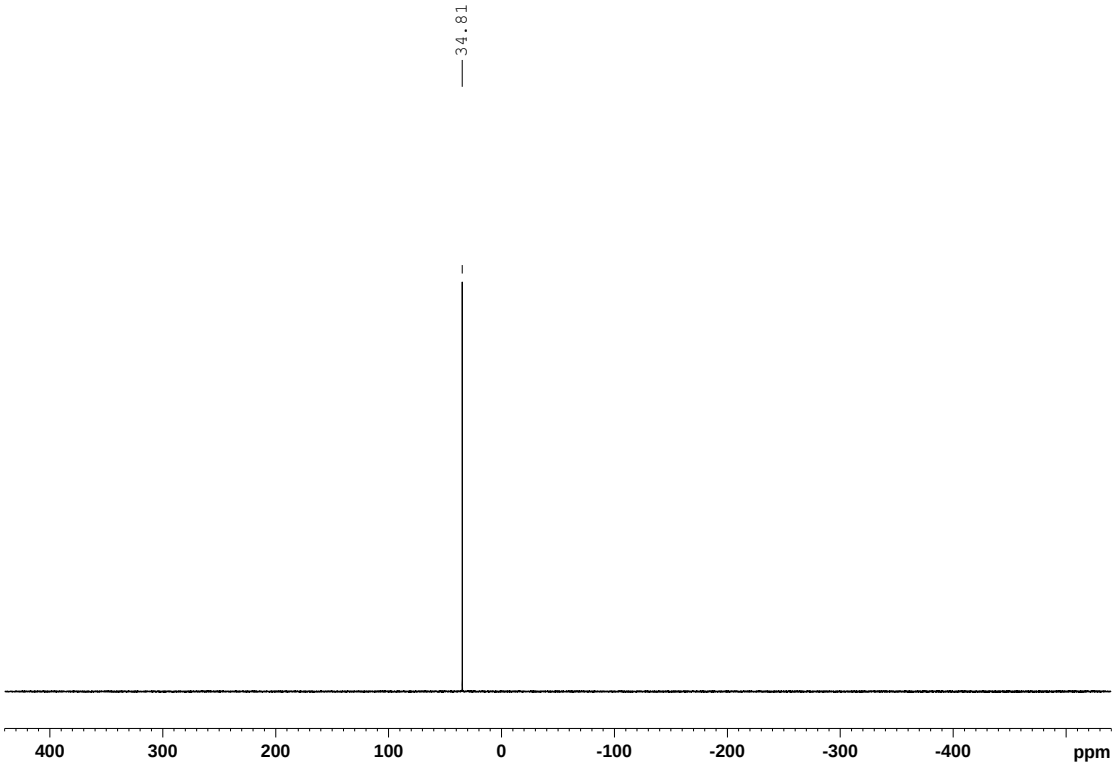

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3l**



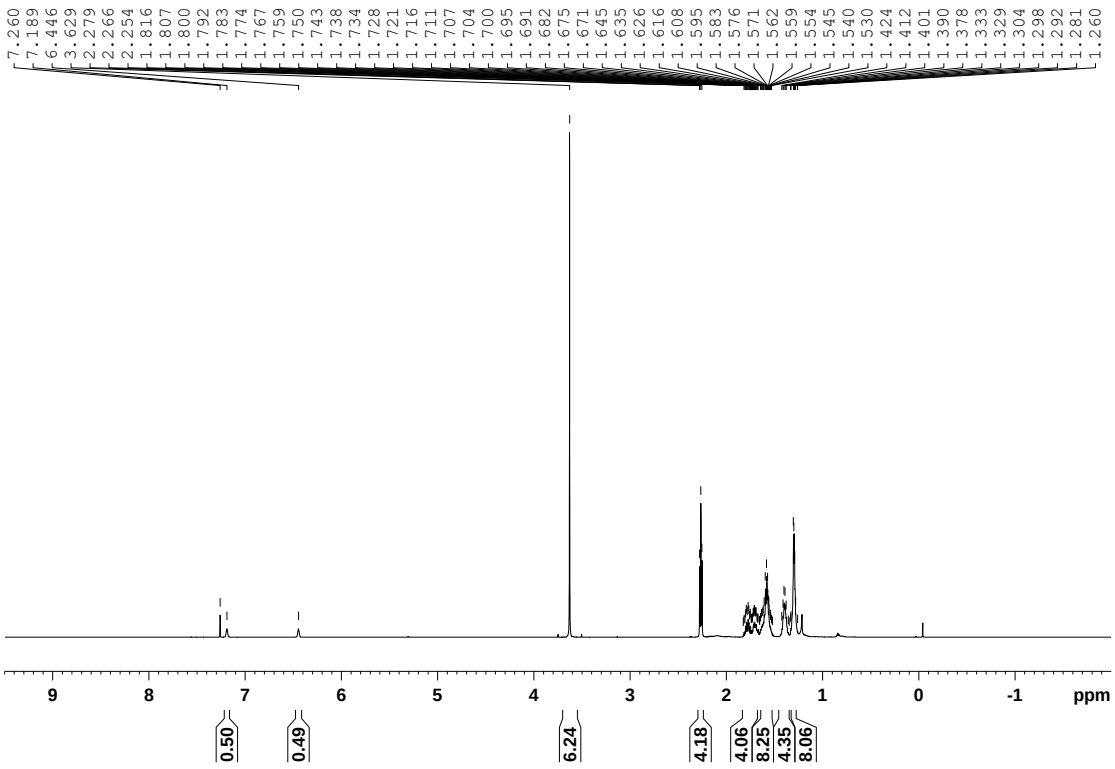

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3l**



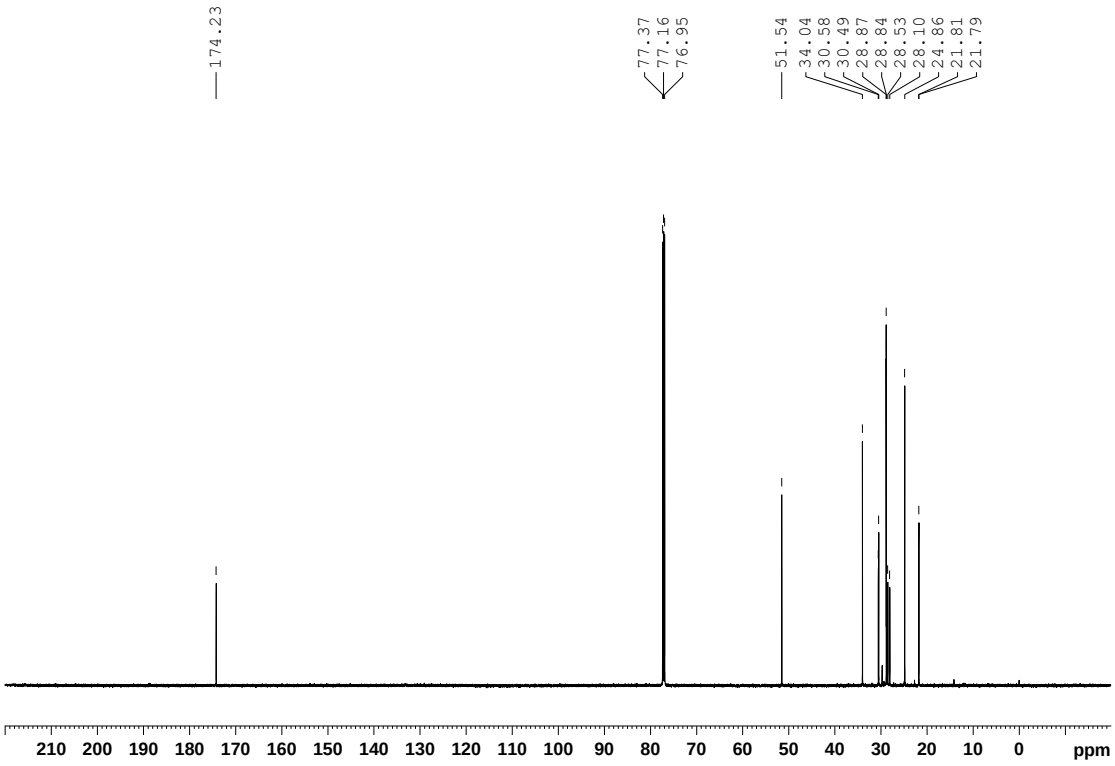
(**3m**)



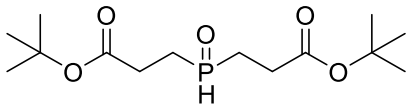

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3m**



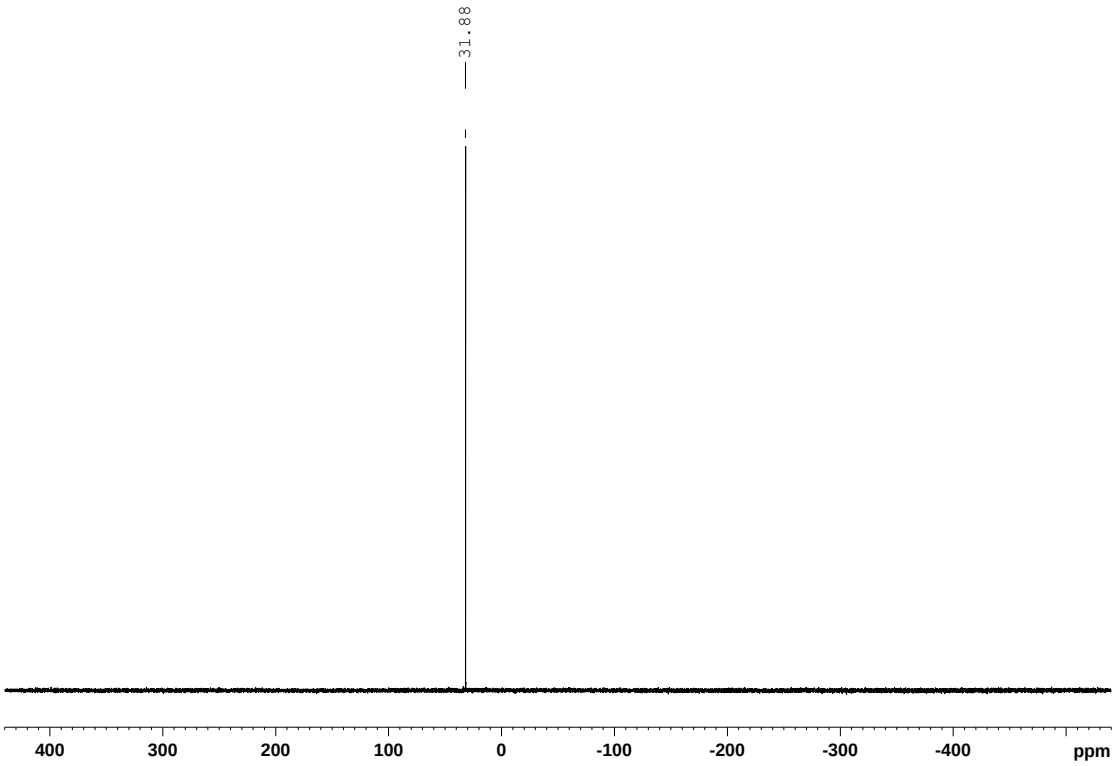

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3m**



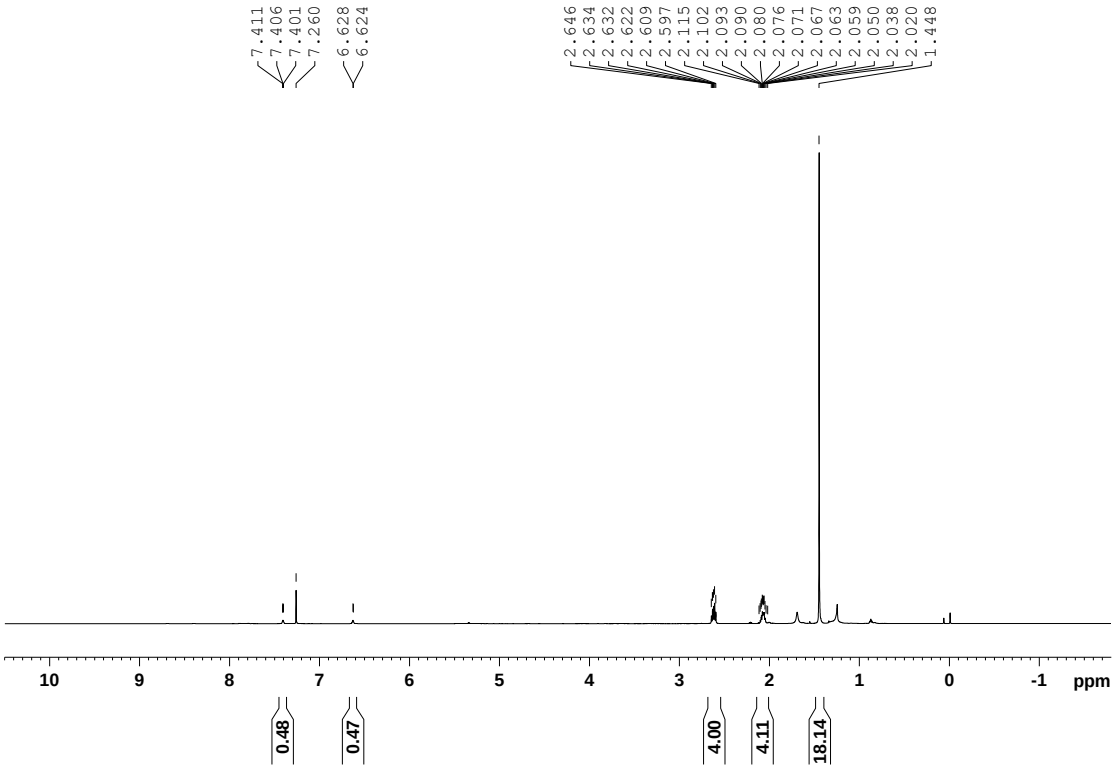

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3m**



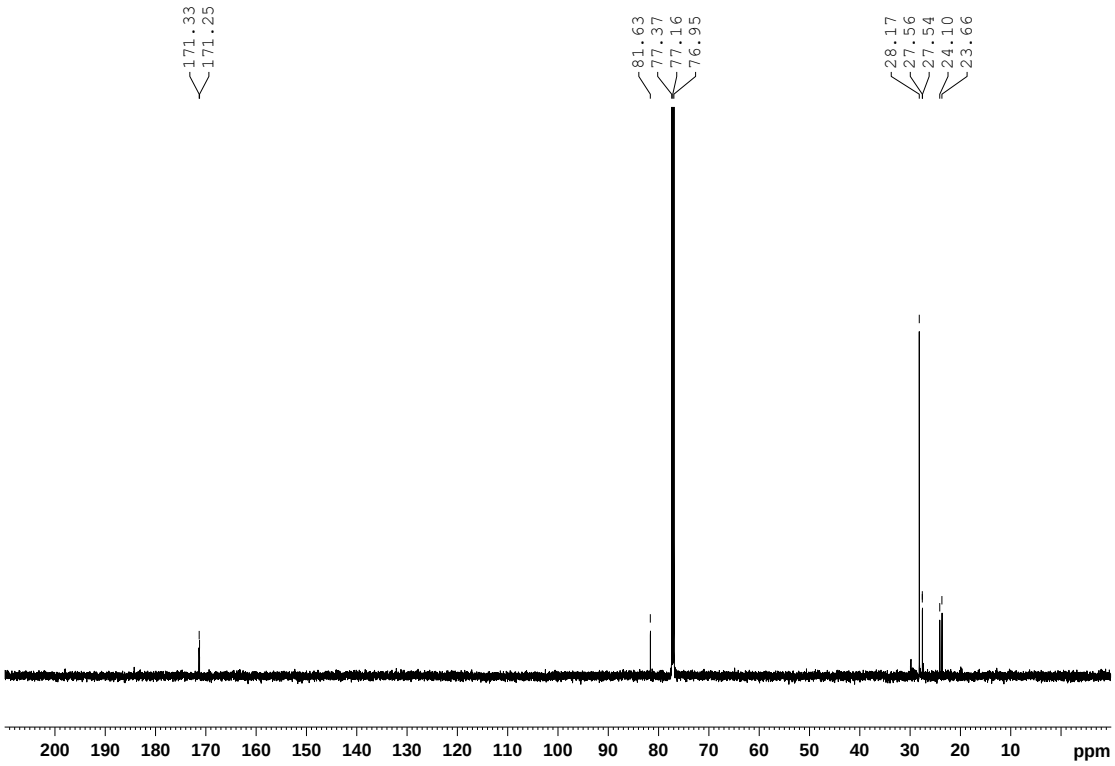
(**3n**)



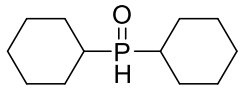
$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3n**



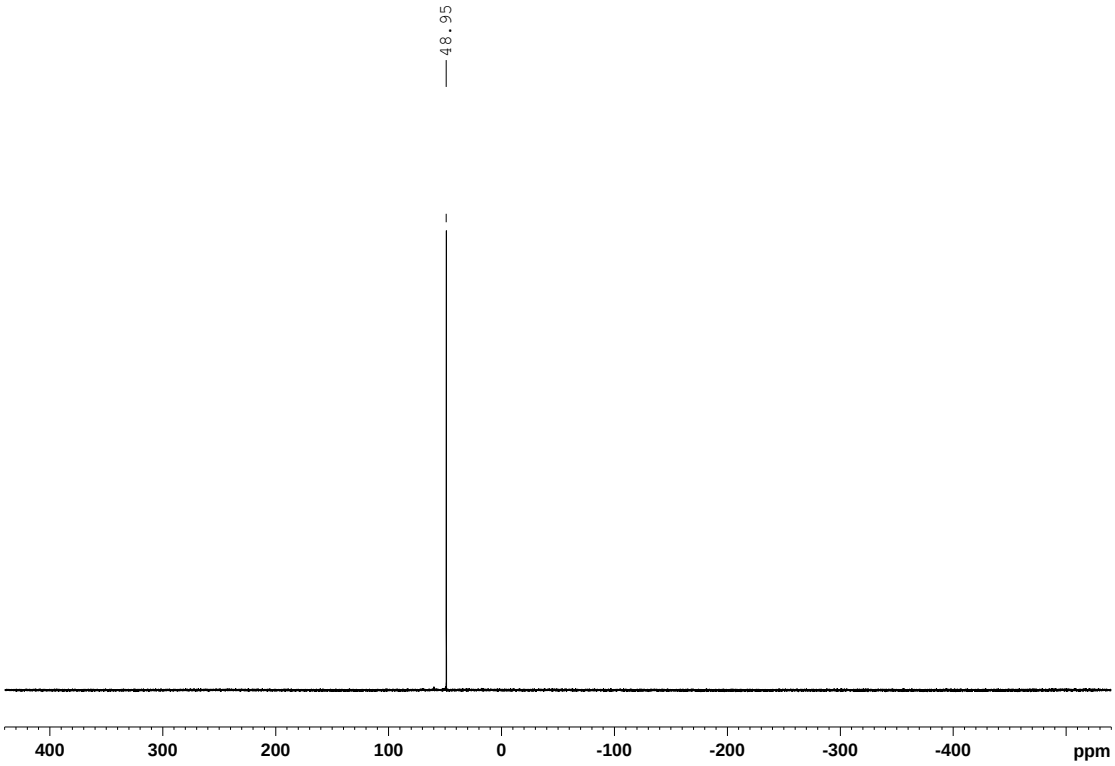

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3n**



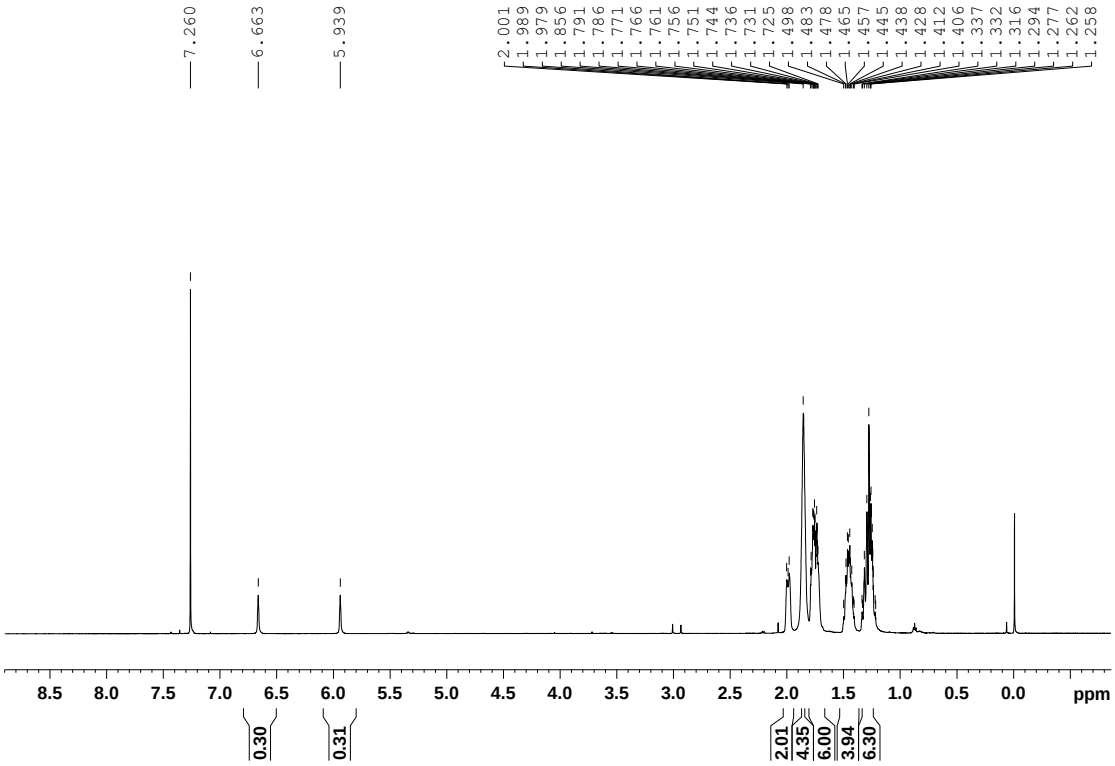

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3n**



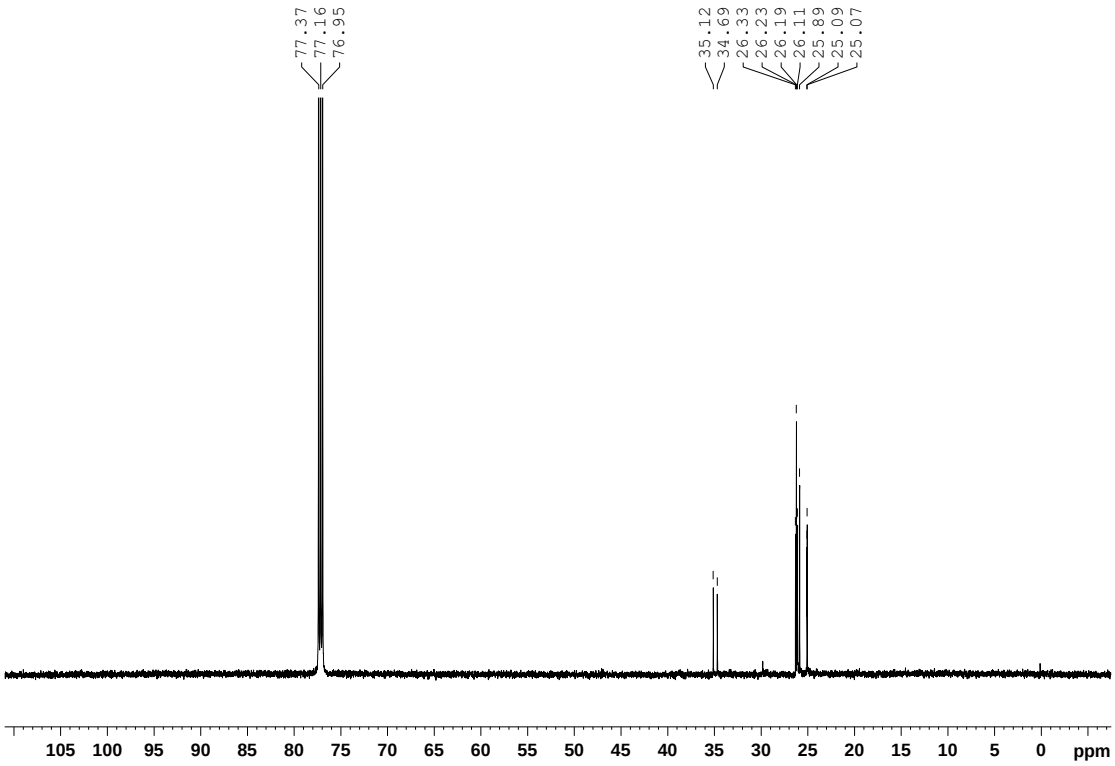
(**3o**)



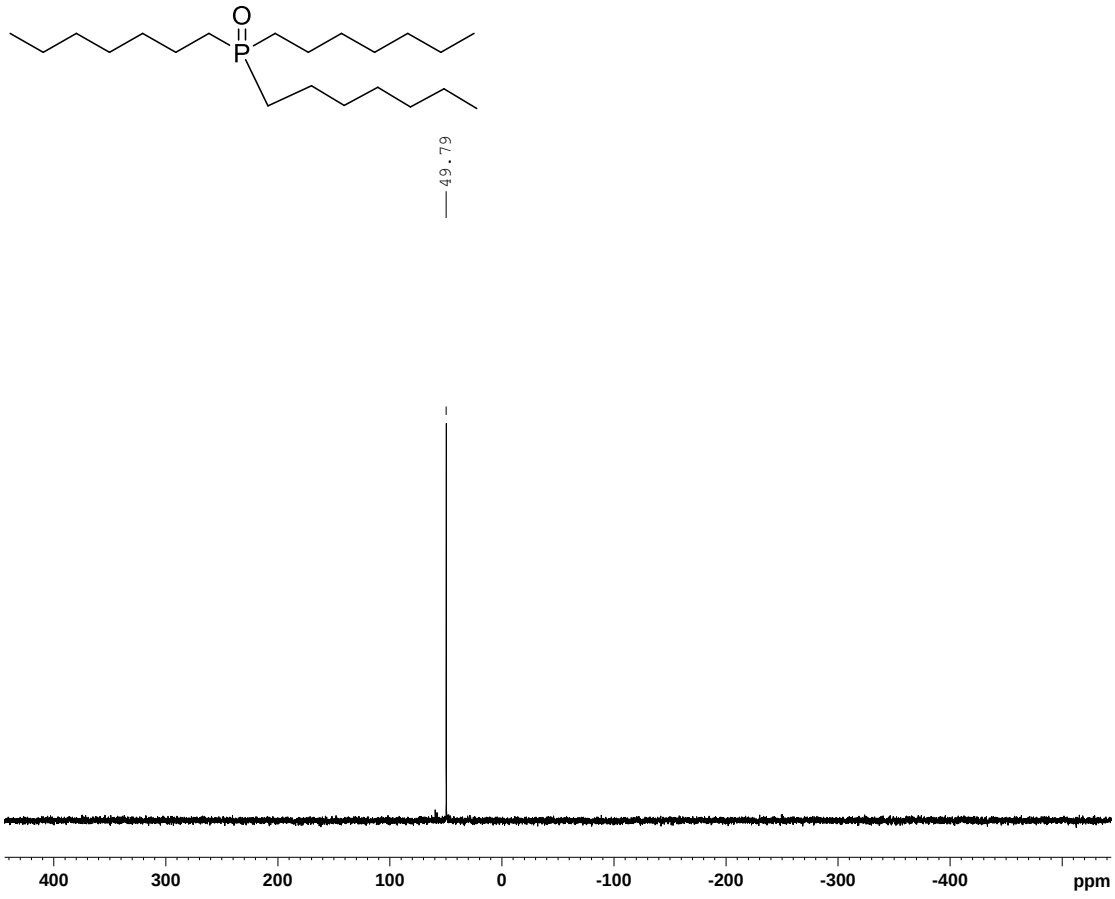

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3o**



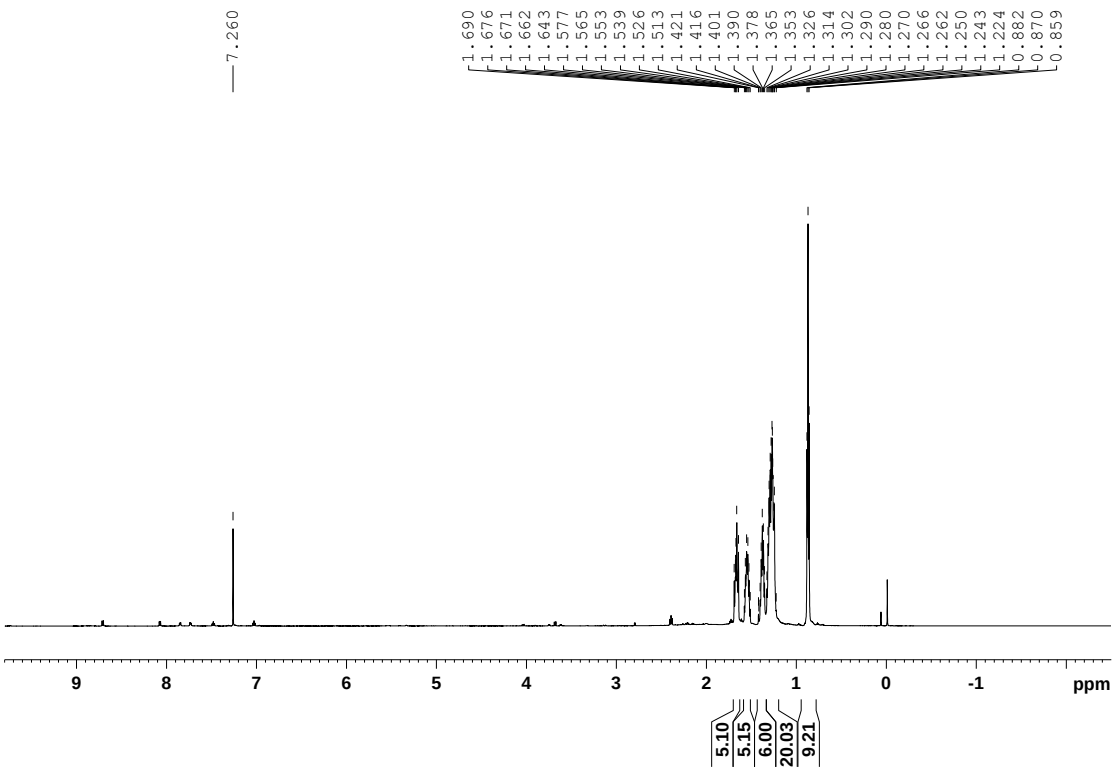

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3o**



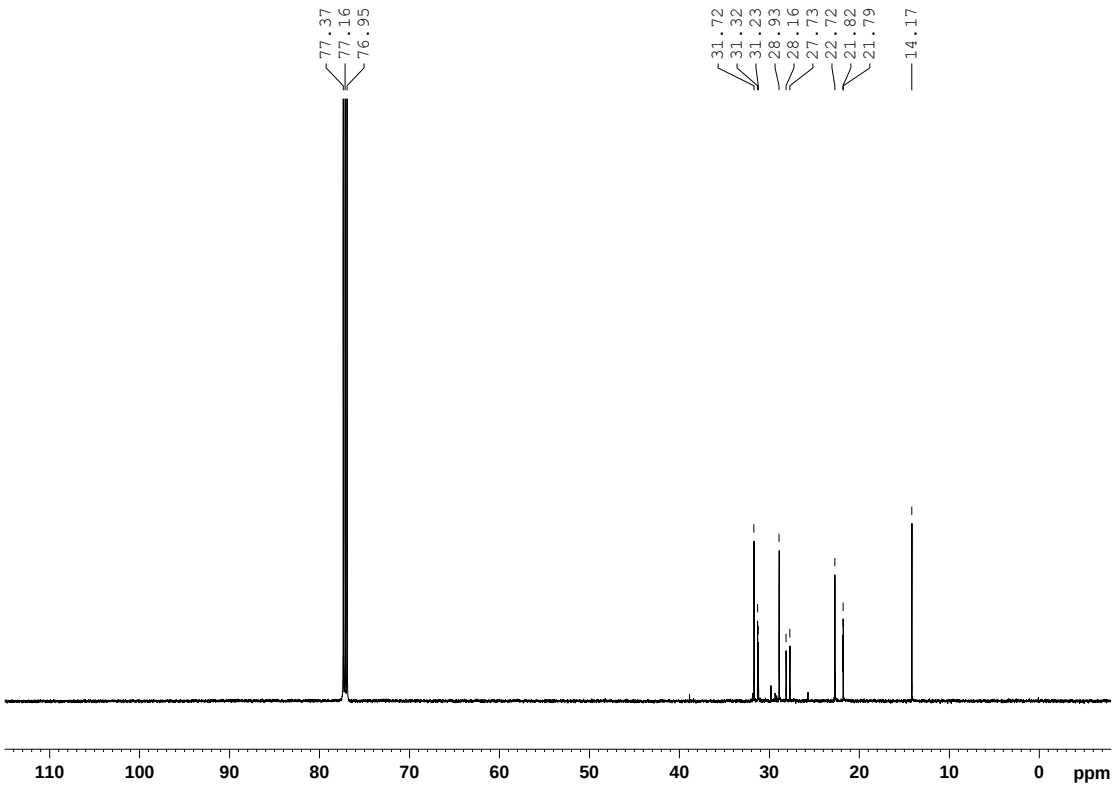

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3o**



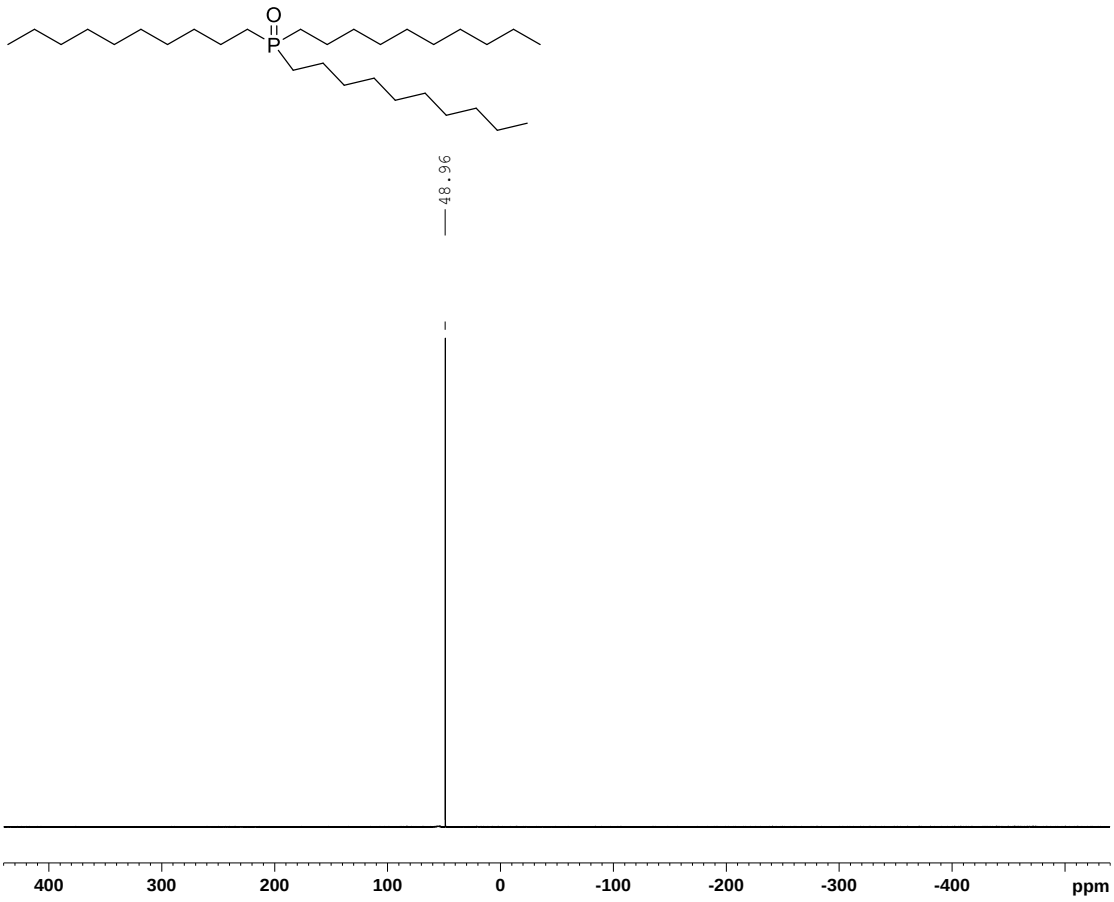

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3-2a**



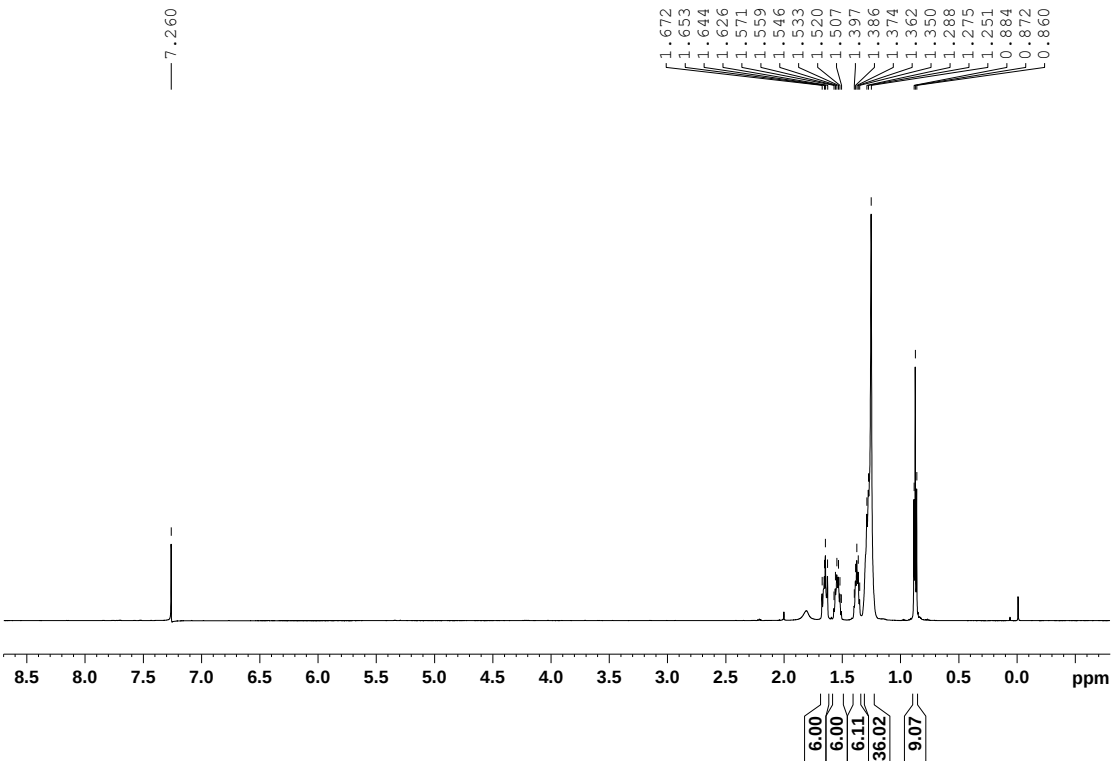

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3-2a**



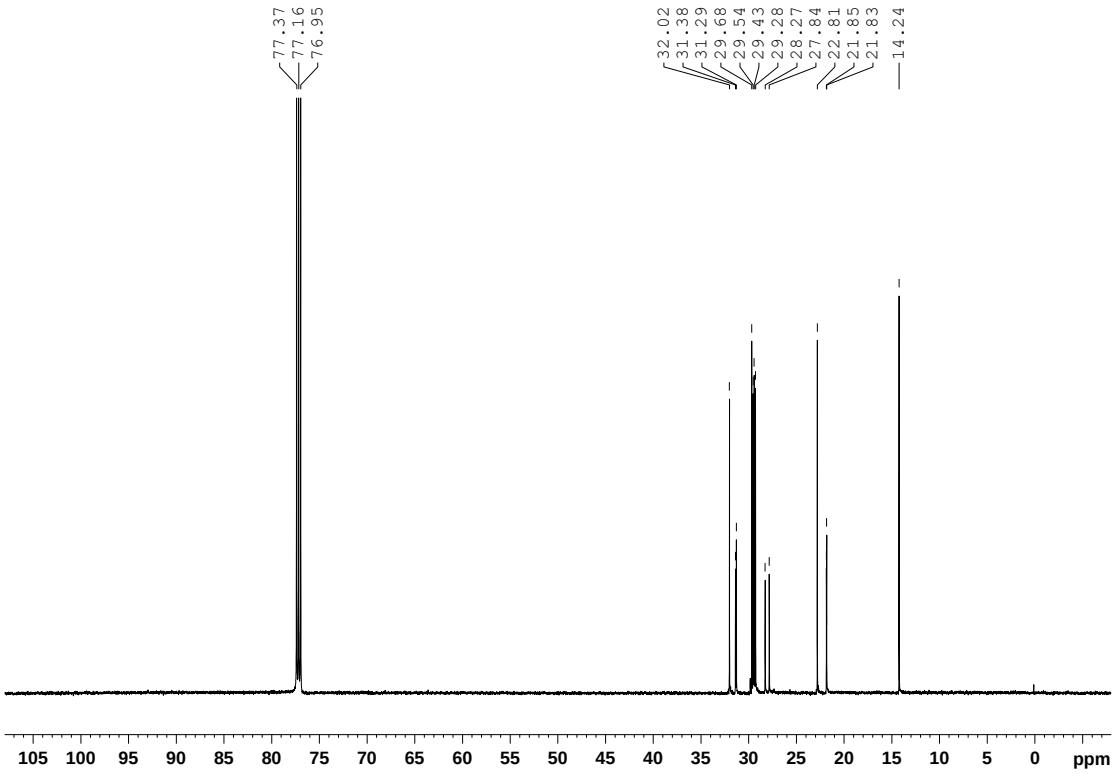

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3-2a**



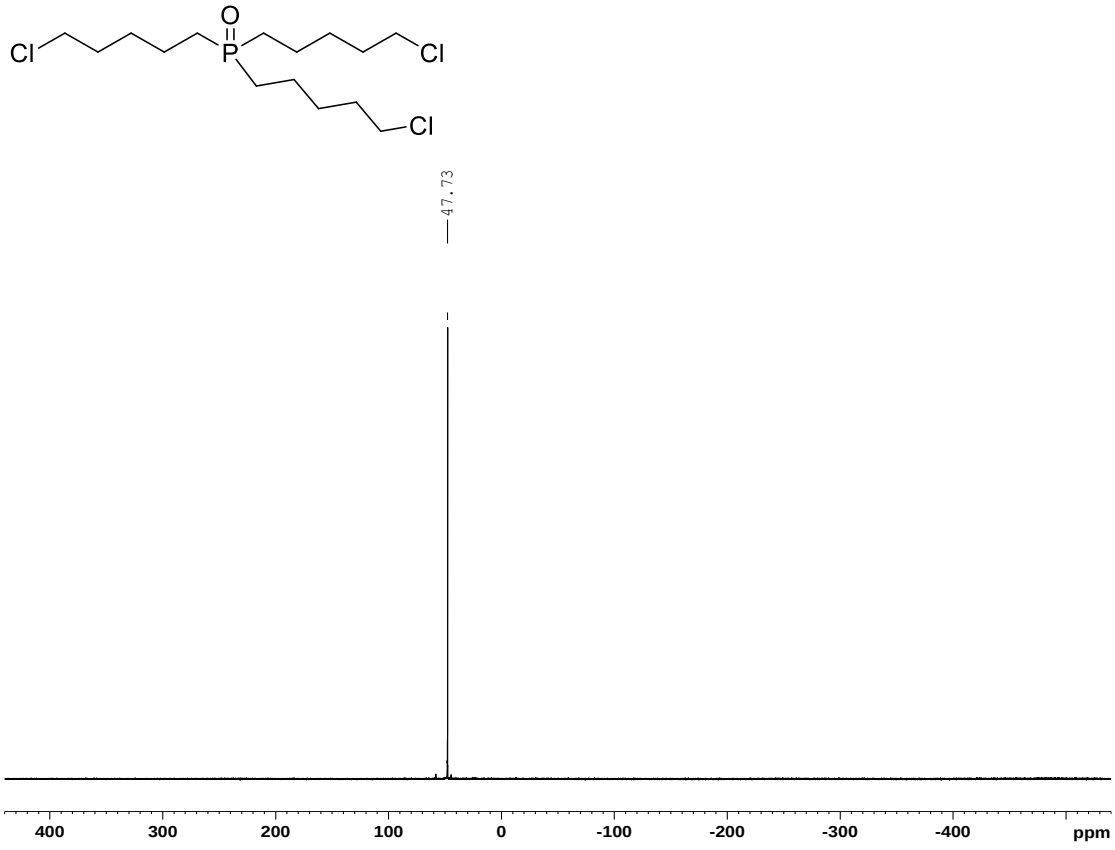

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3-2b**



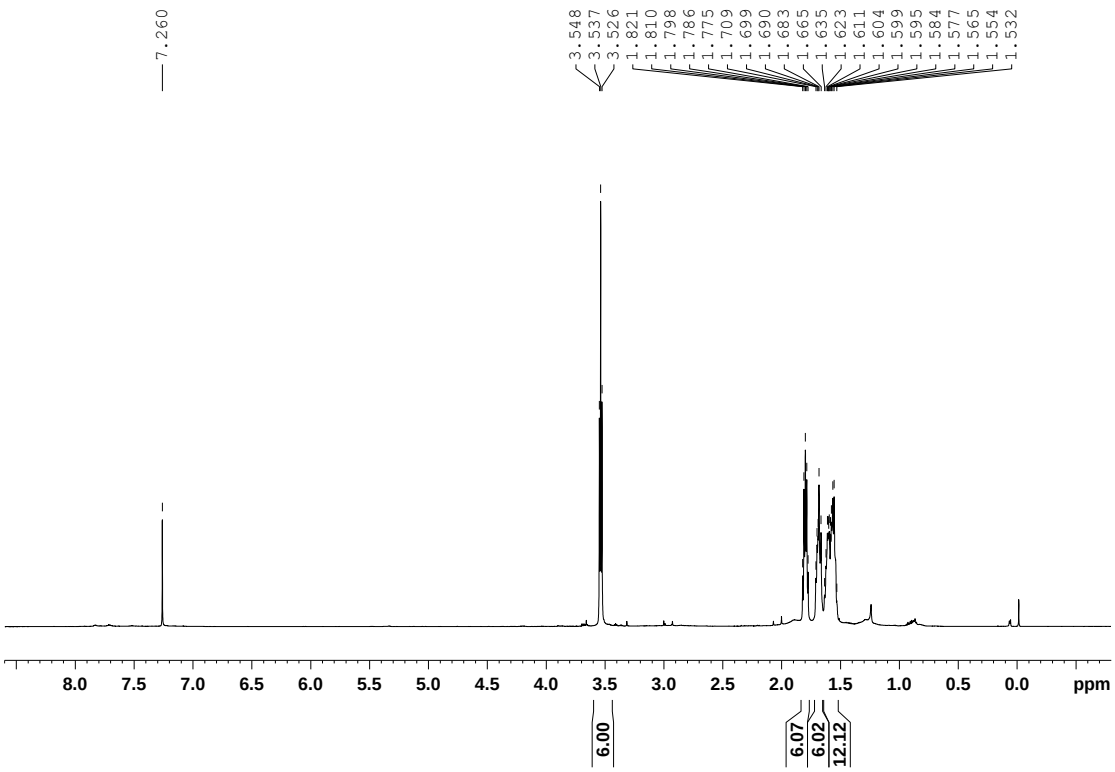

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3-2b**



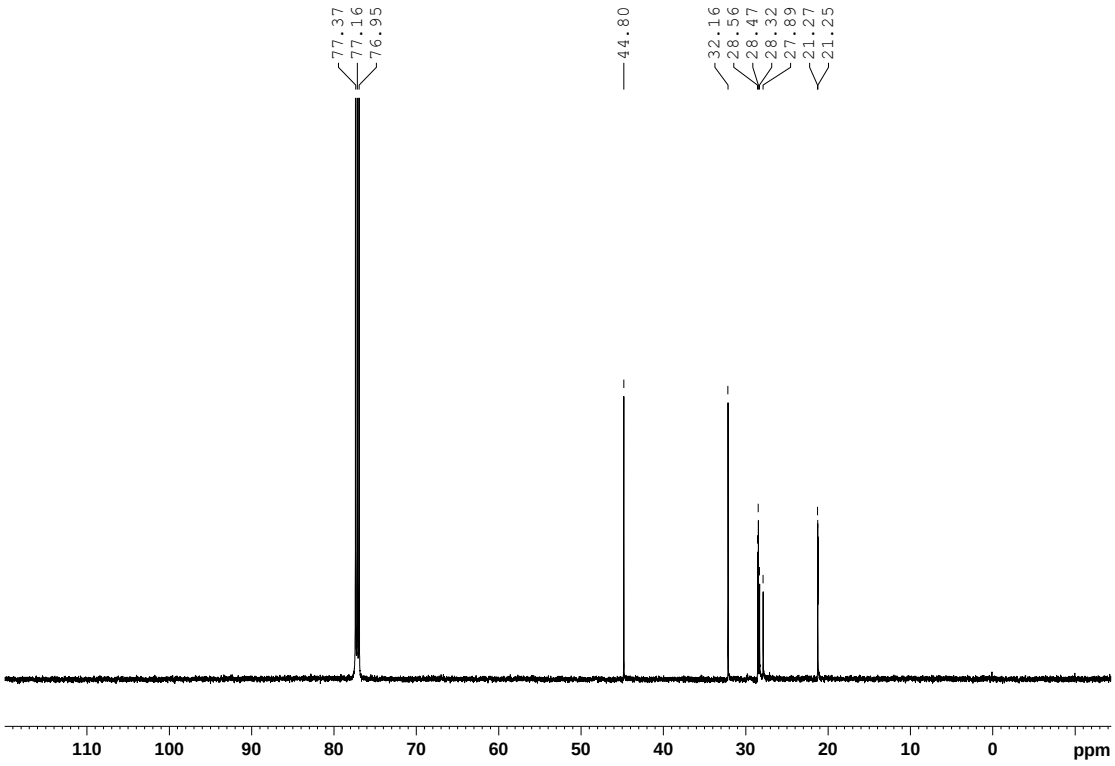

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3-2b**



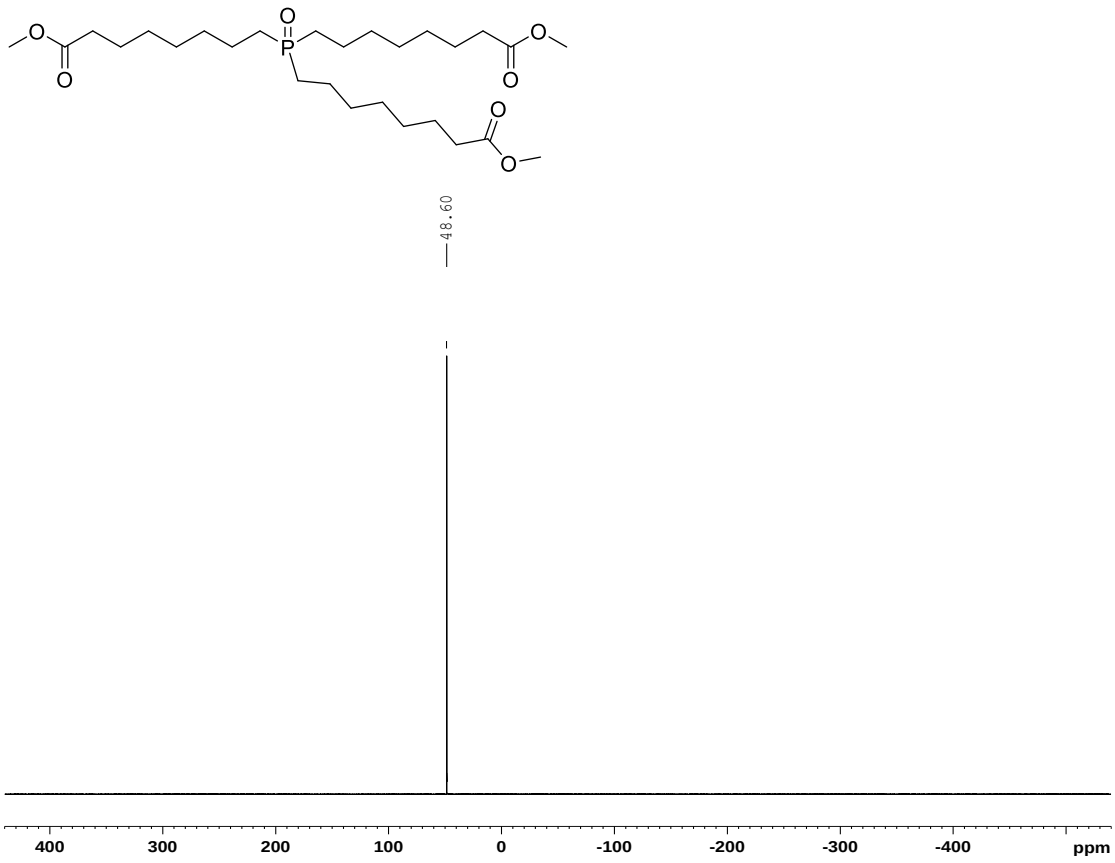

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3-2c**



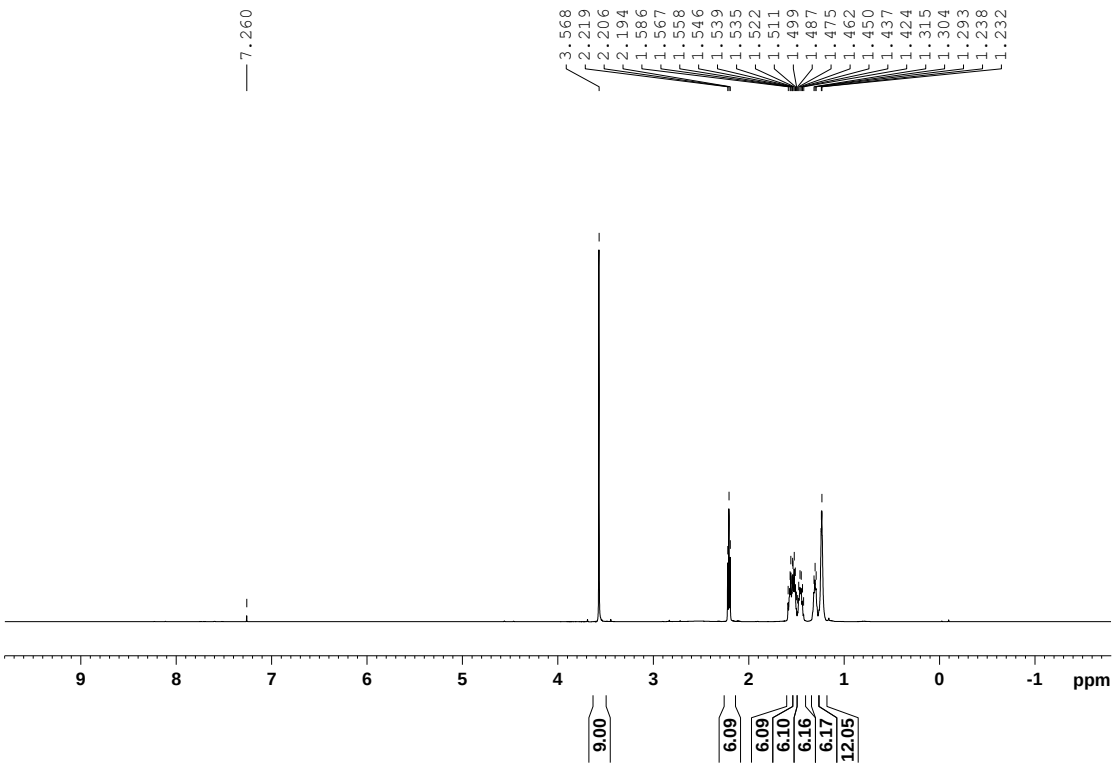

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **3-2c**



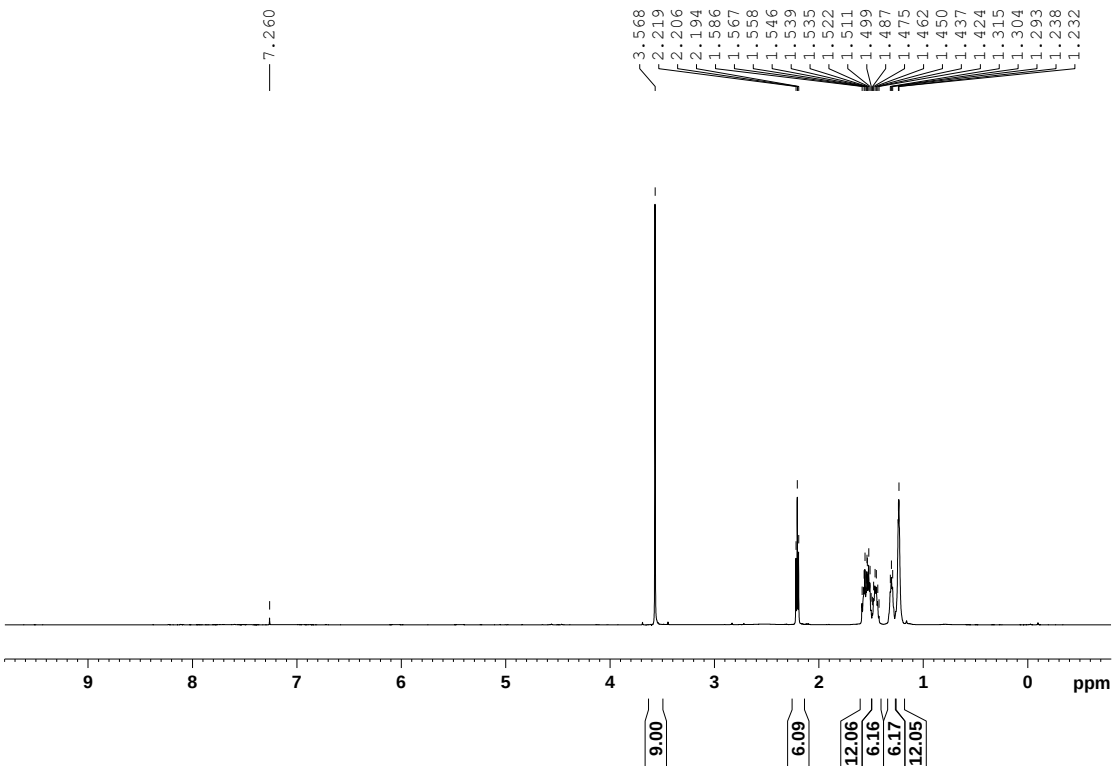

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **3-2c**



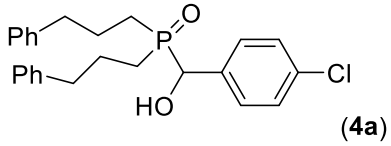

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **3-2d**



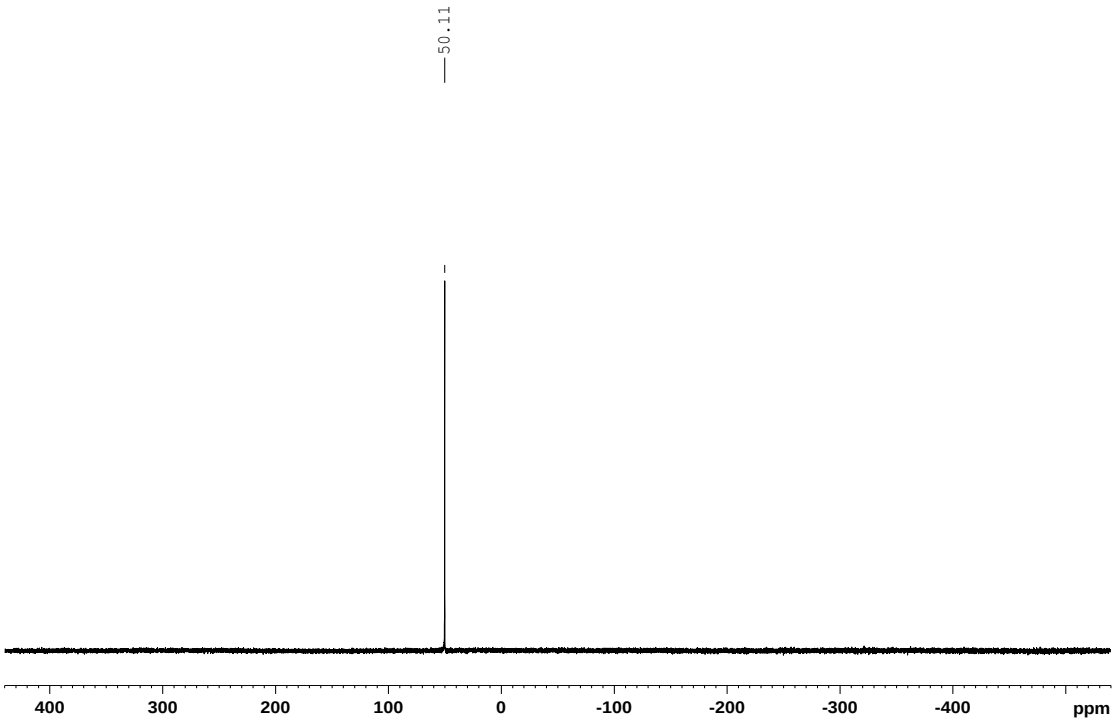

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **3-2d**



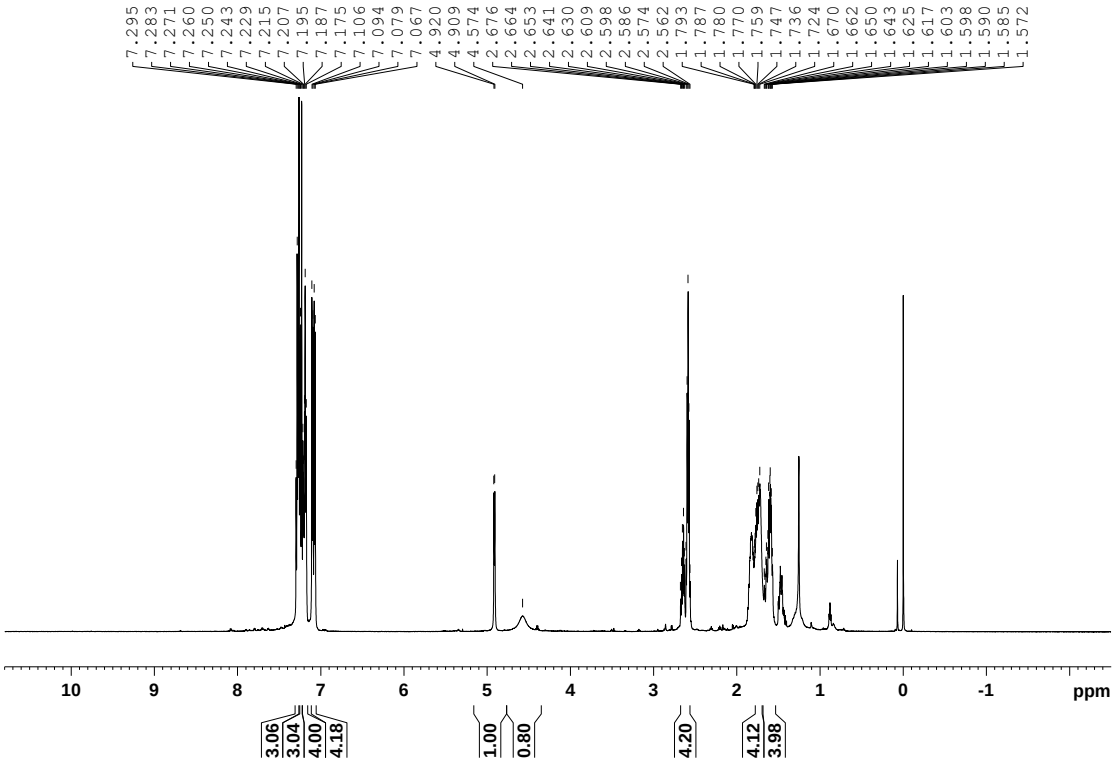

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **3-2d**



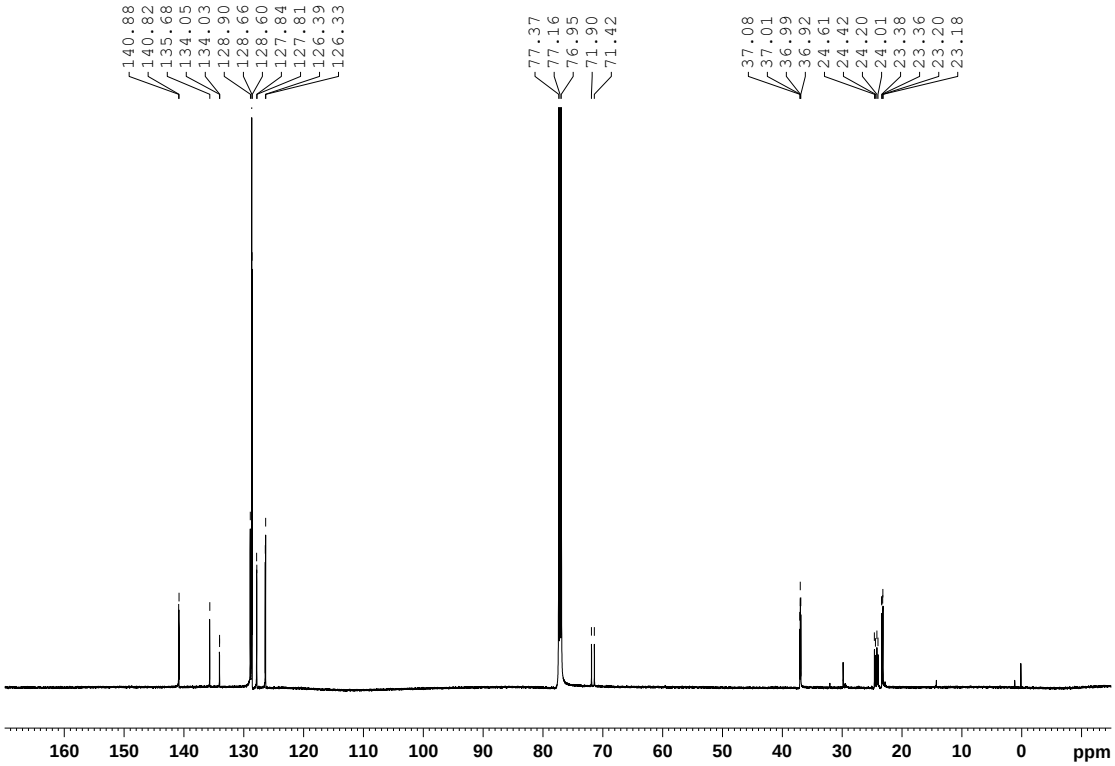

(**4a**)



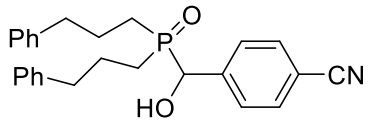

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4a**



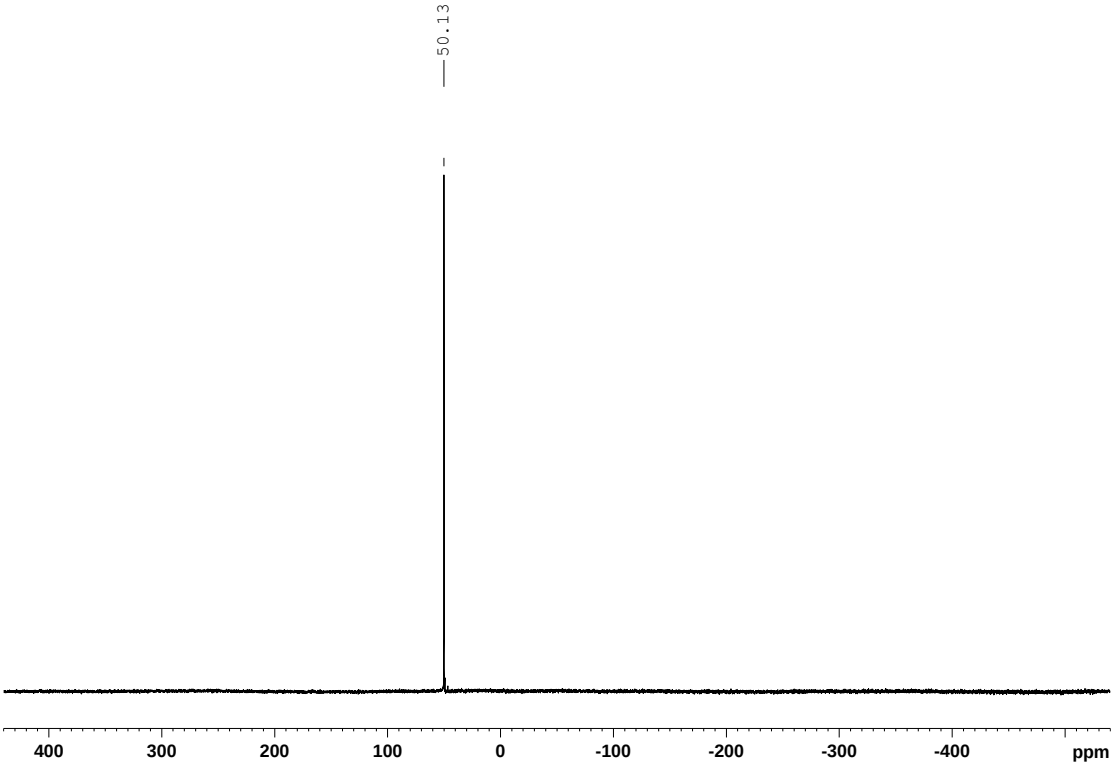

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4a**



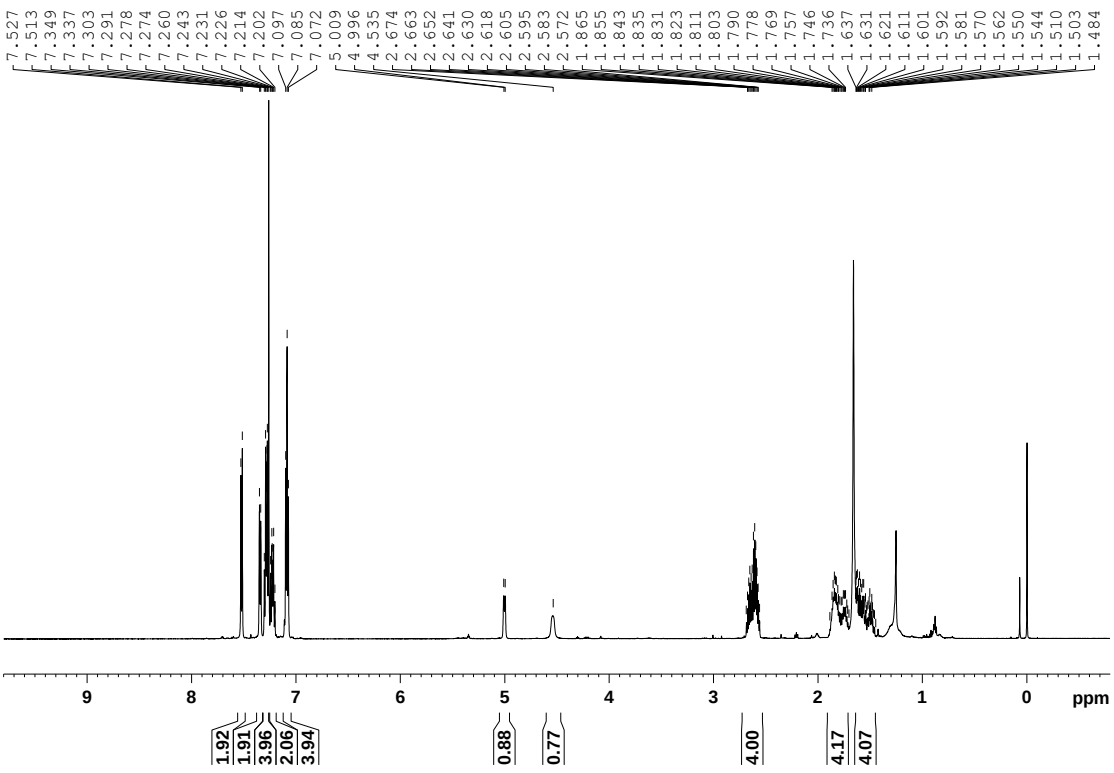

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4a**



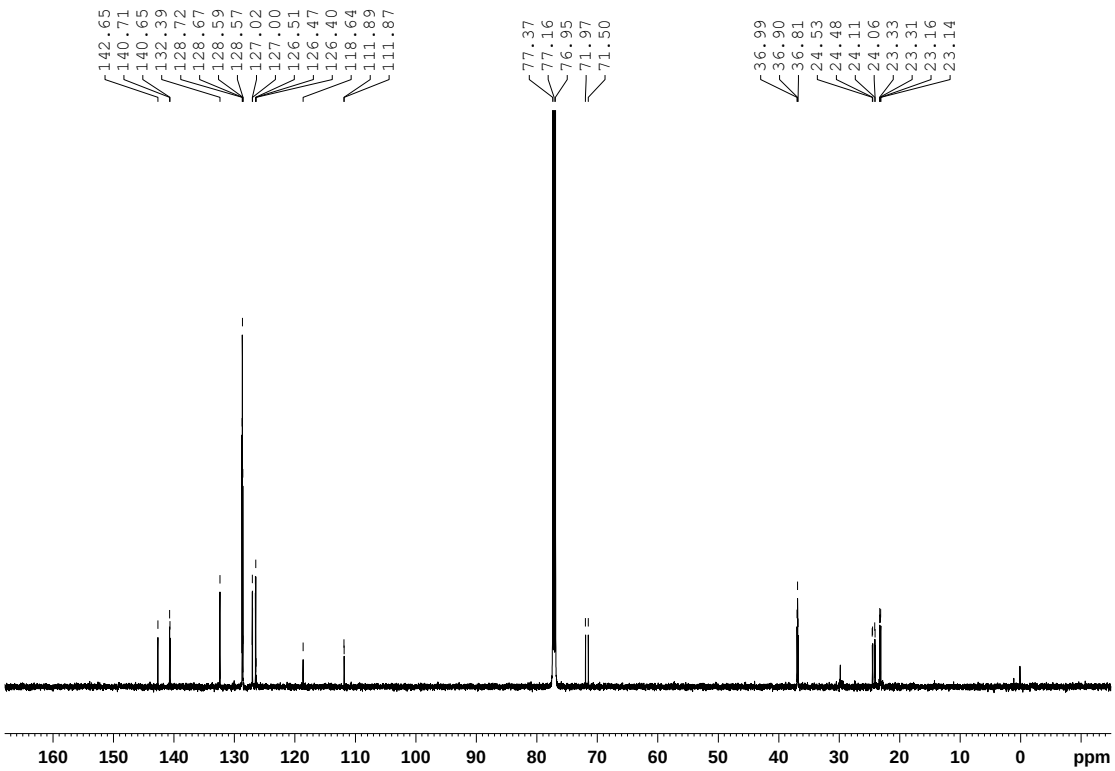

(**4b**)



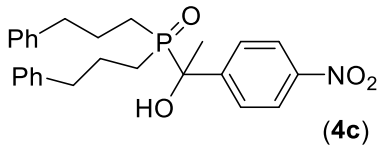

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4b**



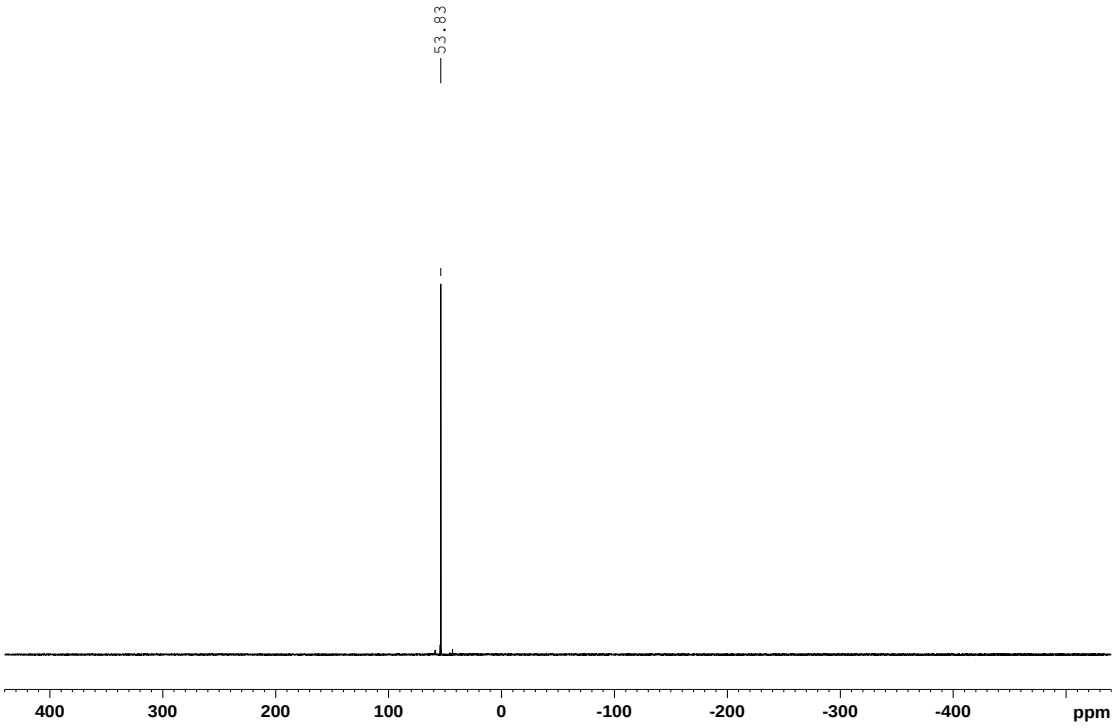

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4b**



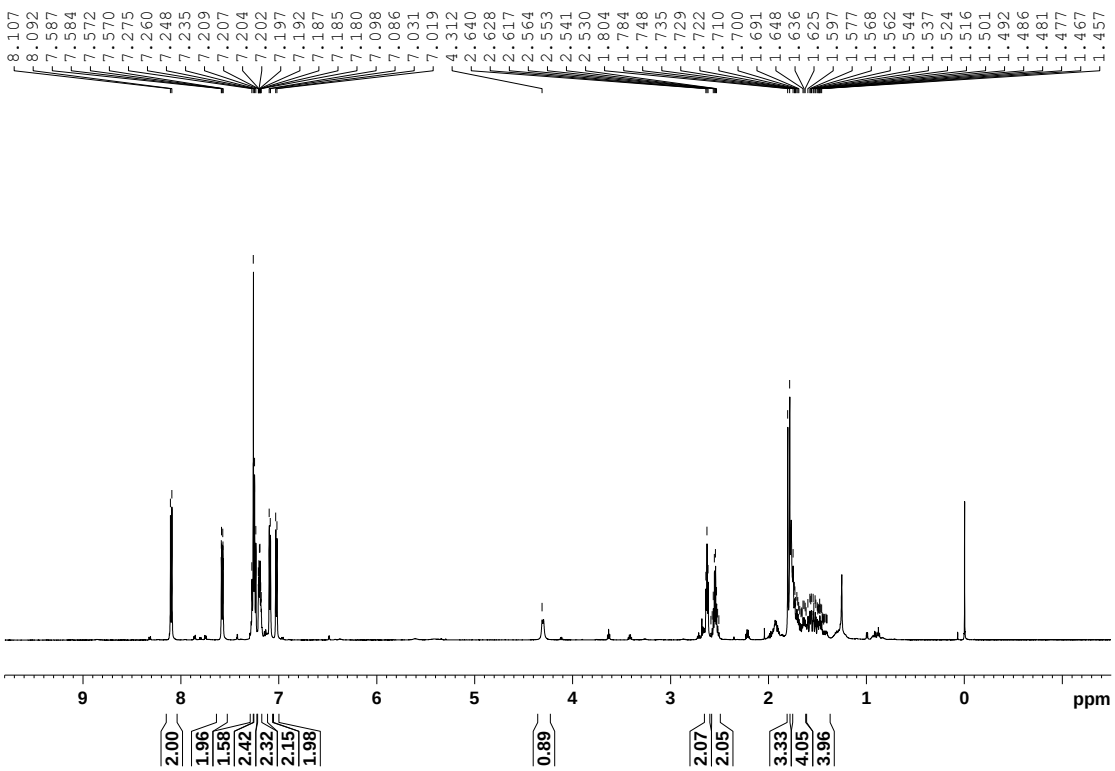

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4b**



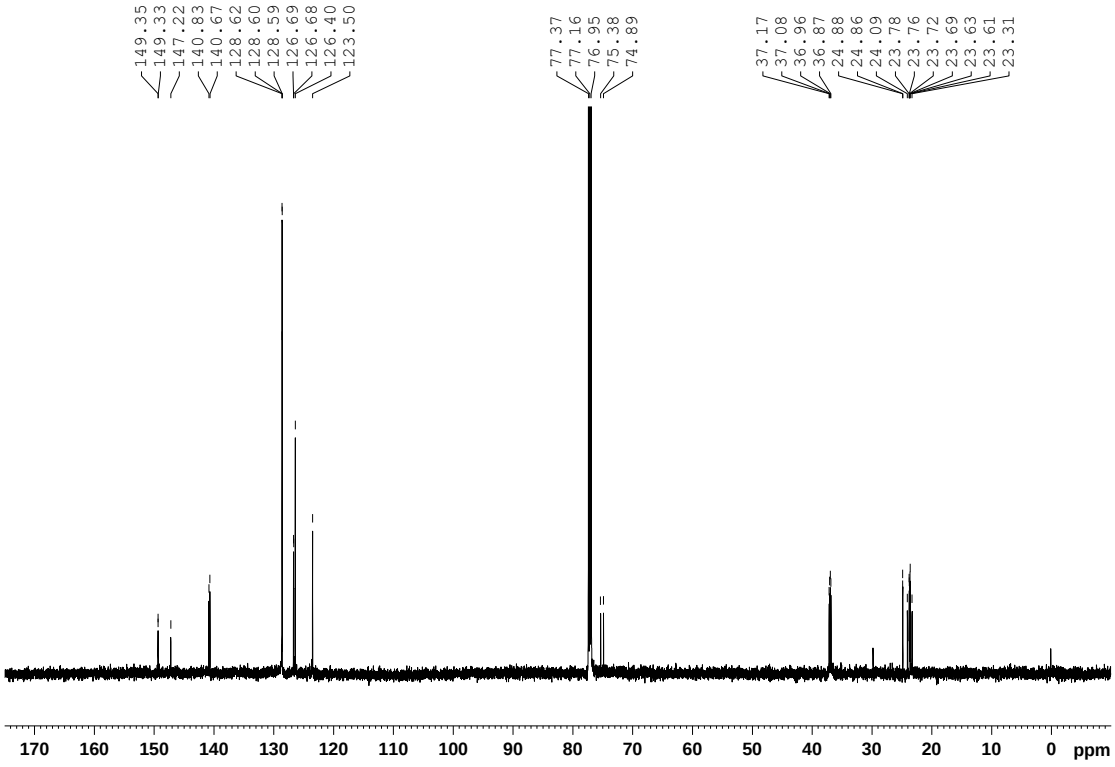

(**4c**)



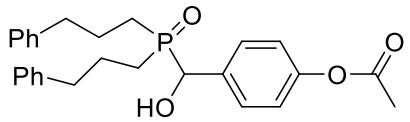

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4c**



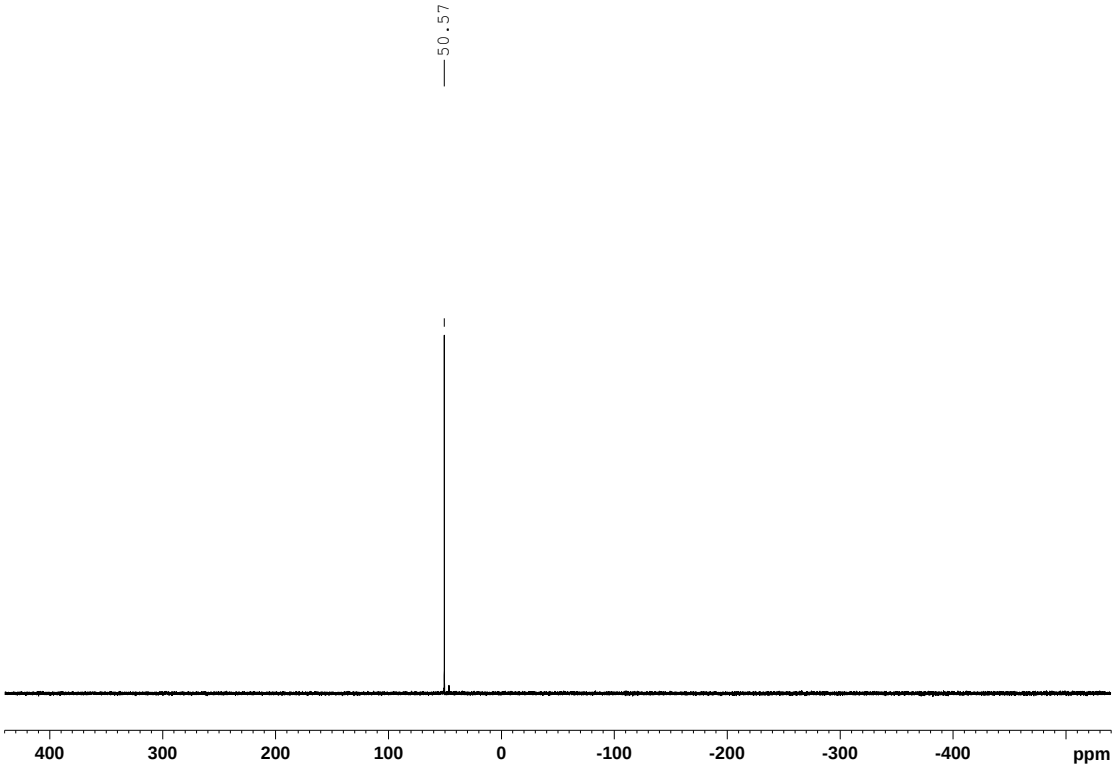

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4c**



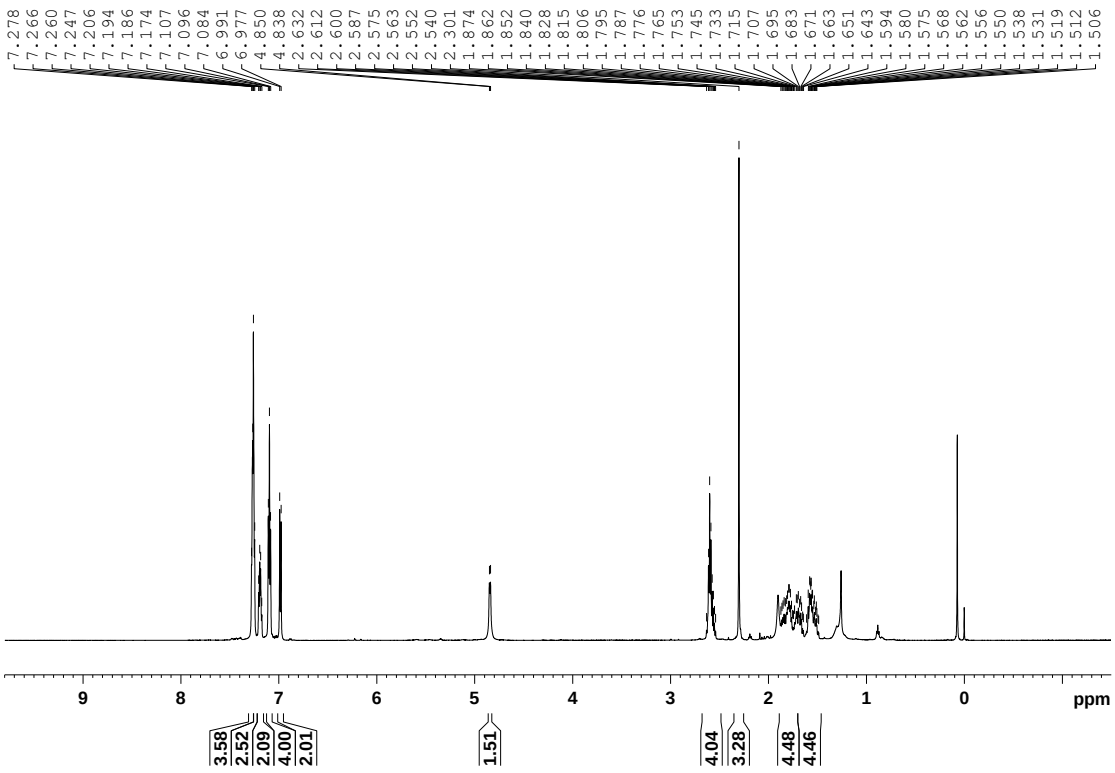

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4c**



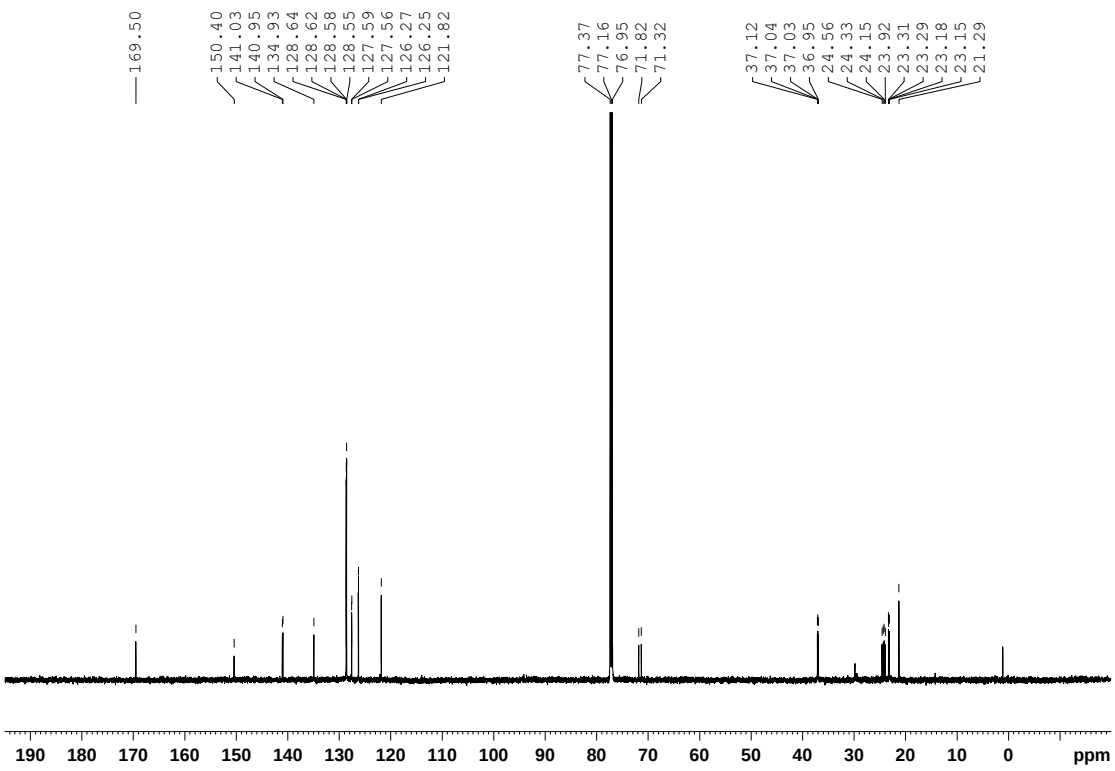

(**4d**)



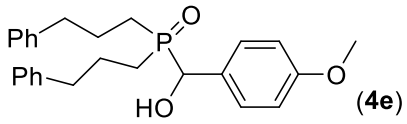

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4d**



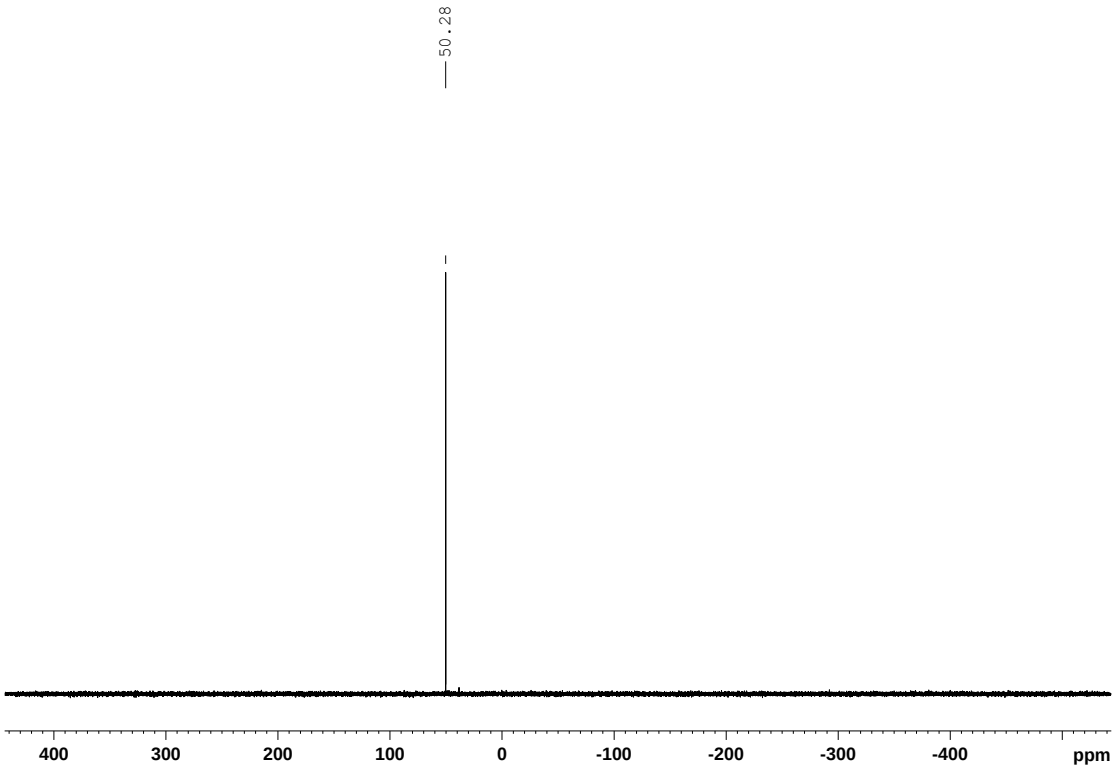

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4d**



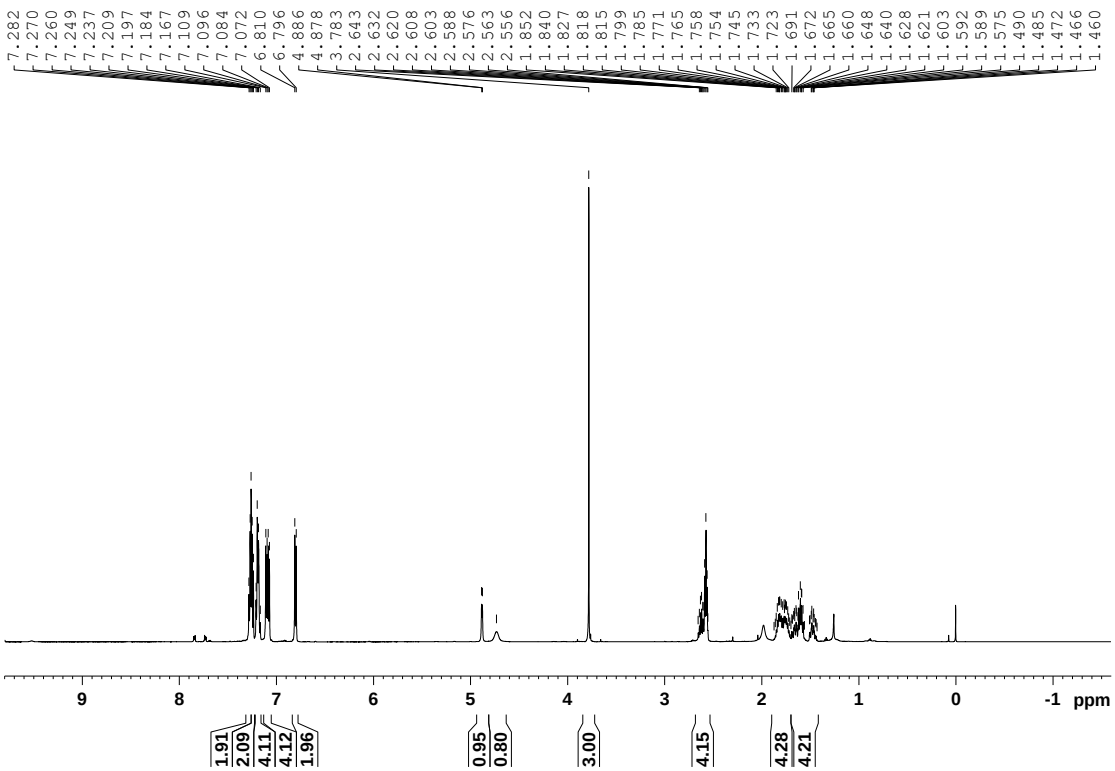

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4d**



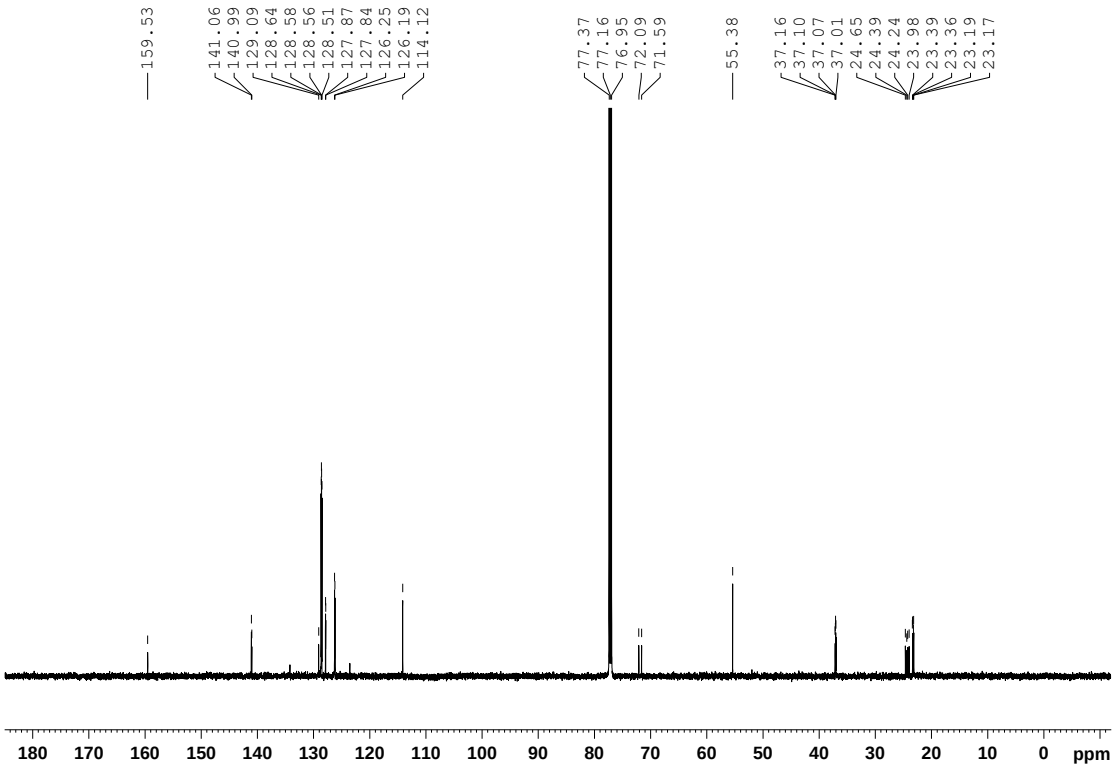

(**4e**)



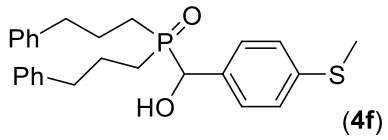

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4e**



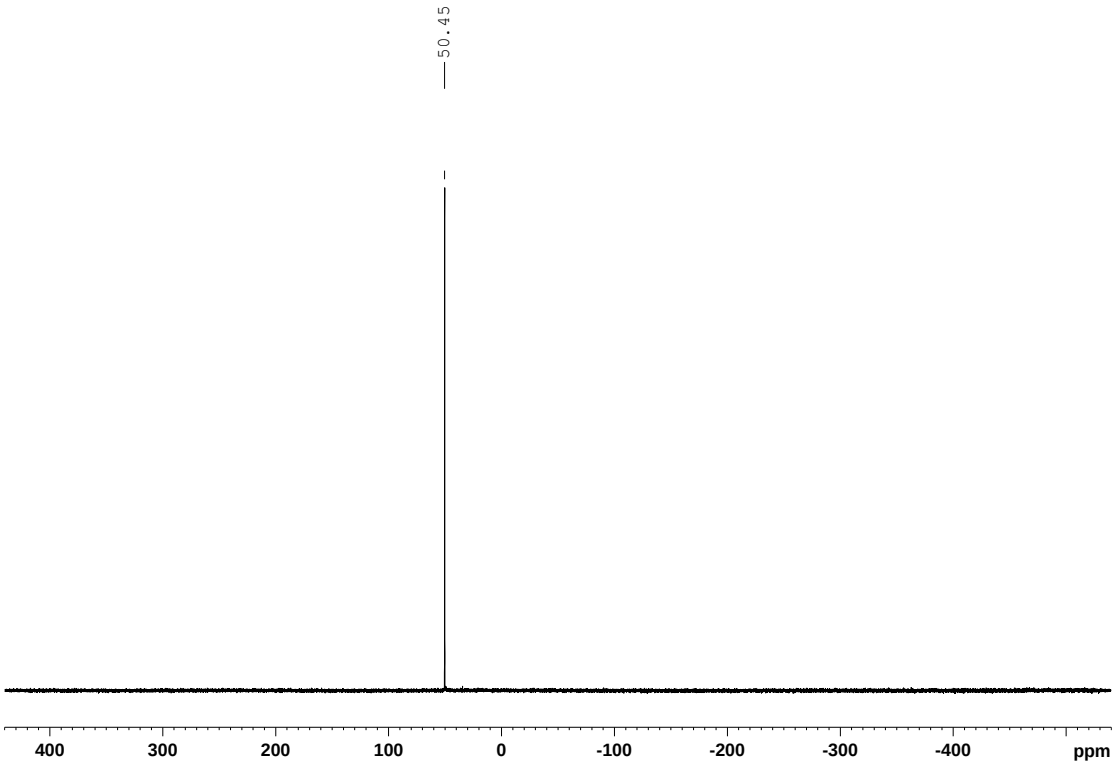

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4e**



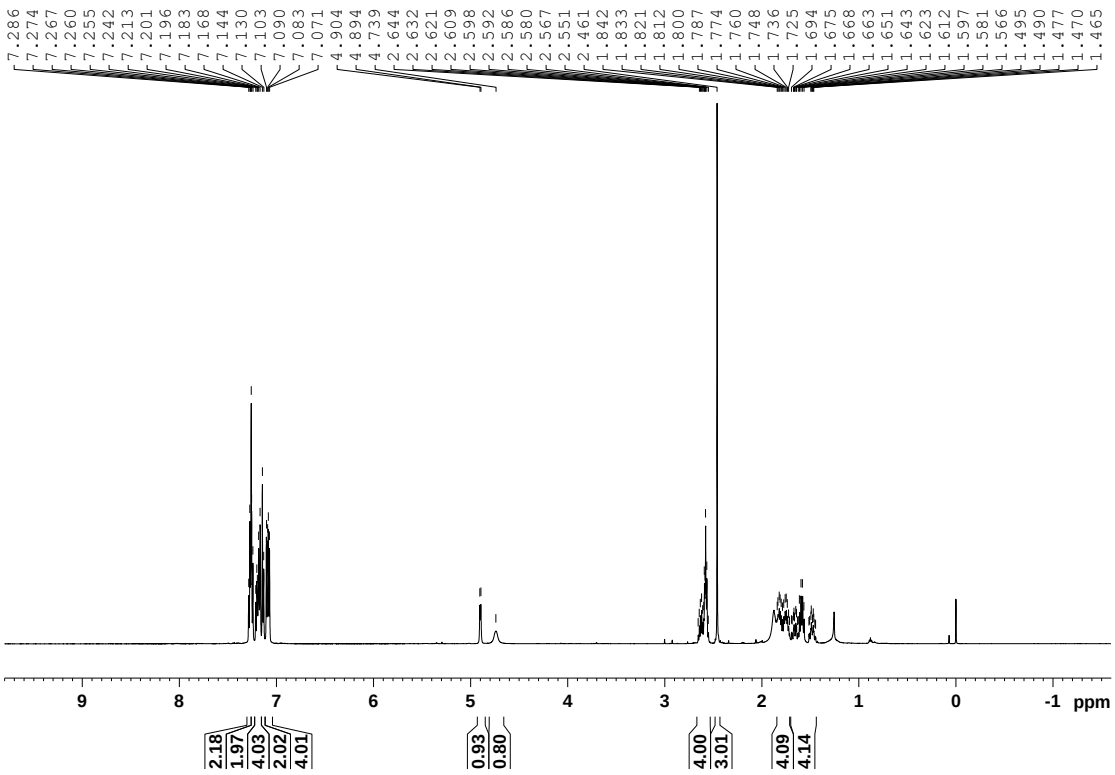

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4e**



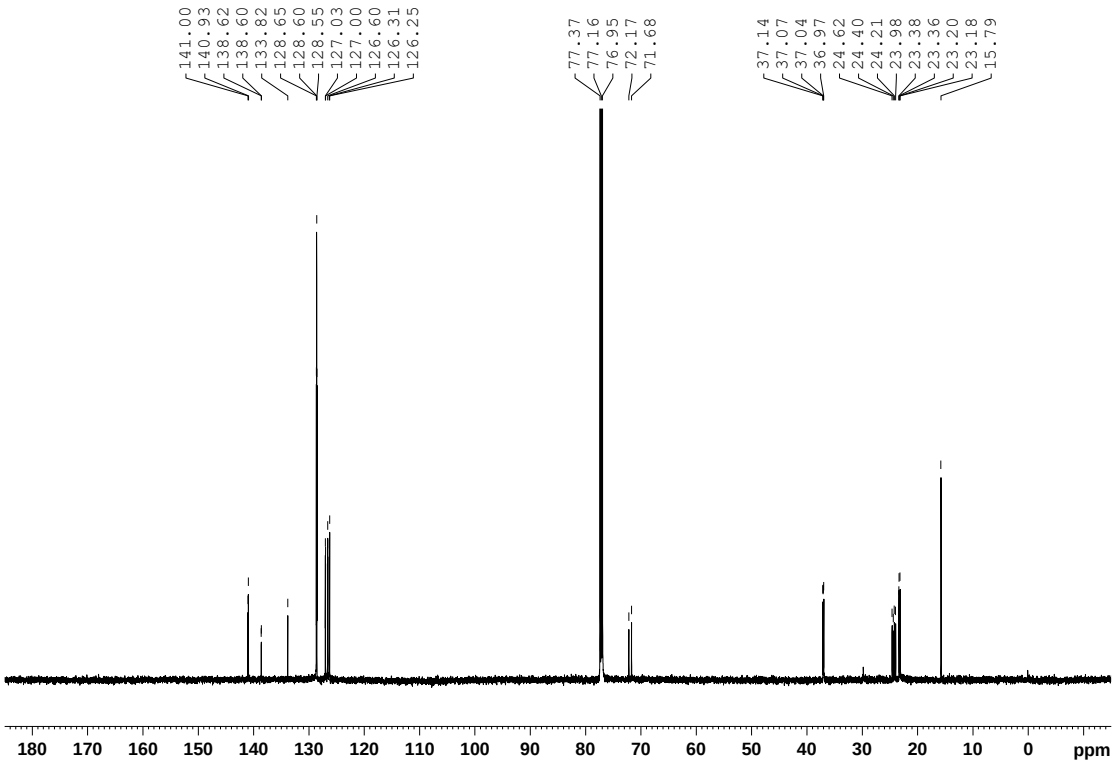

(**4f**)



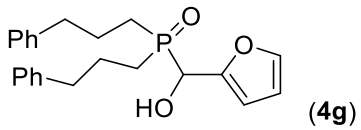

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4f**



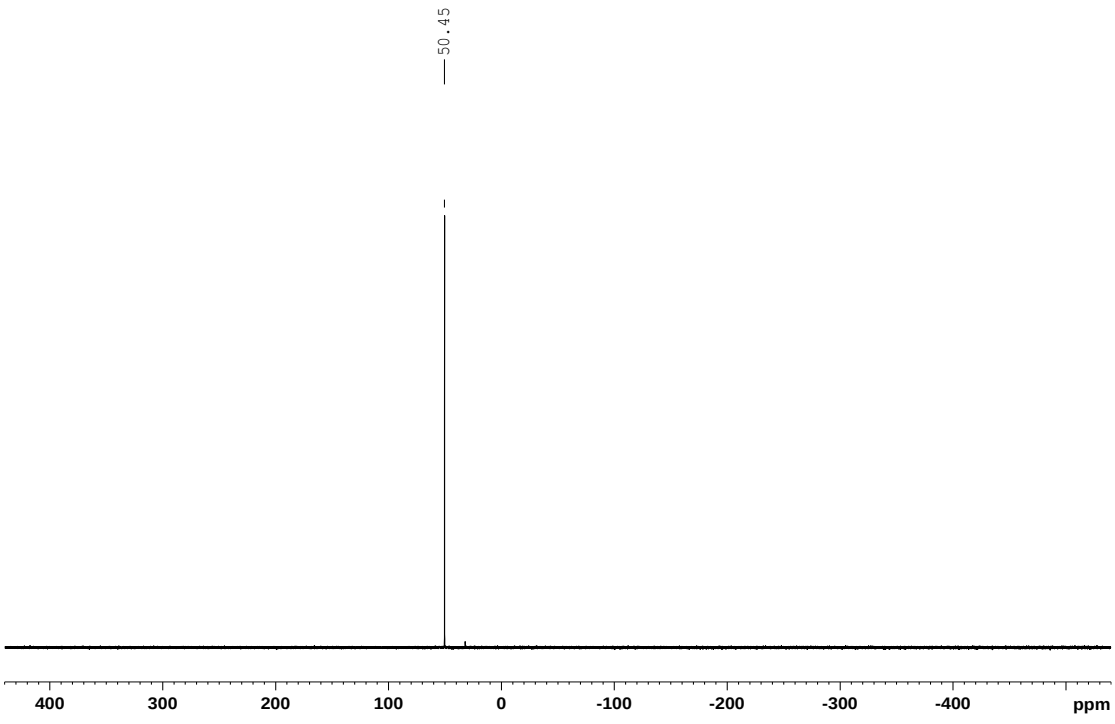

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4f**



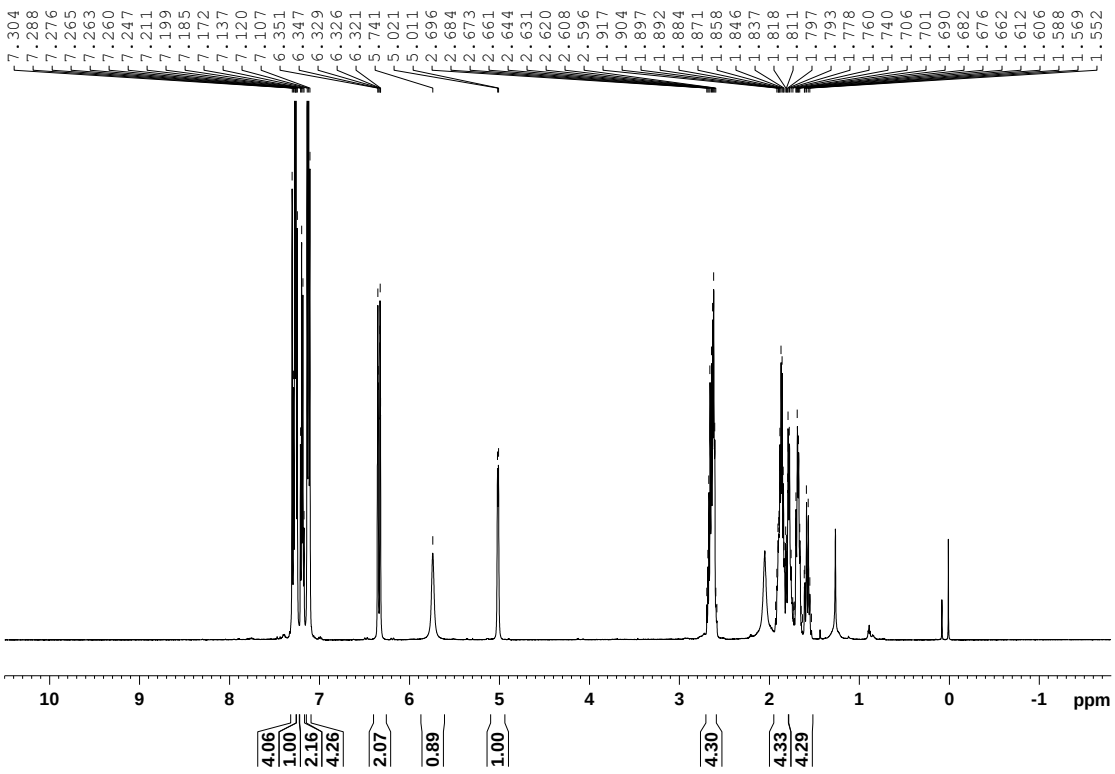

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4f**



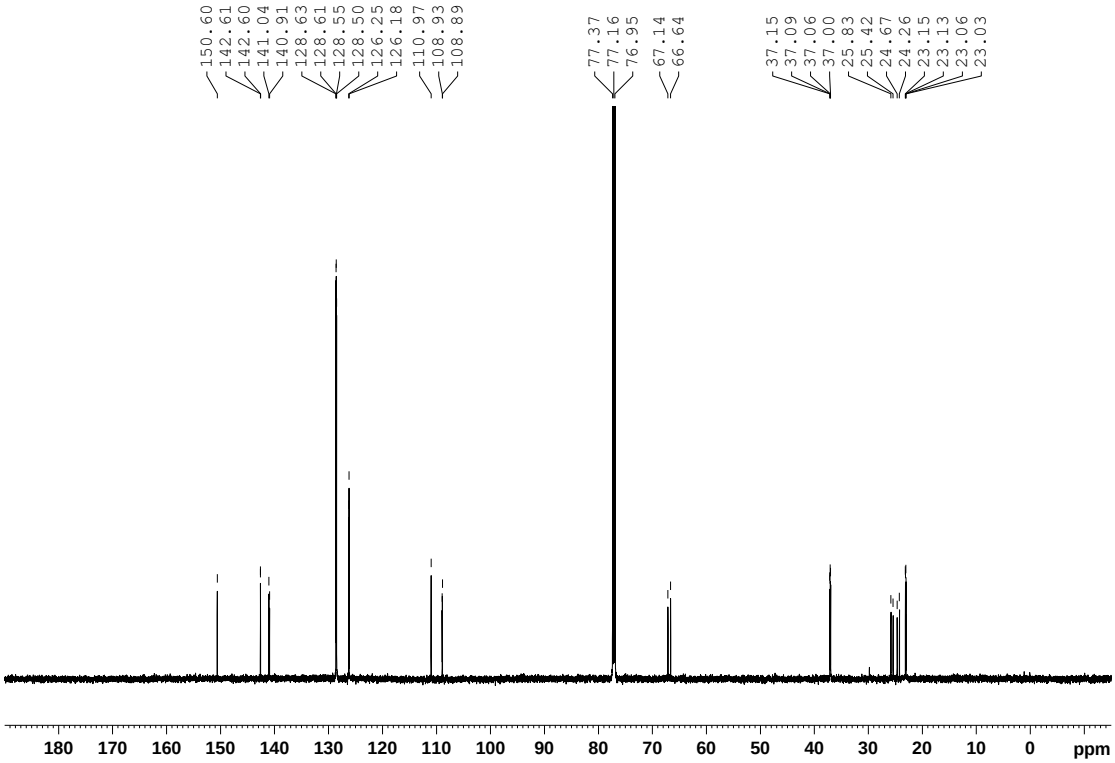

(**4g**)



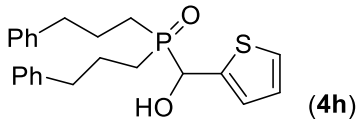

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4g**



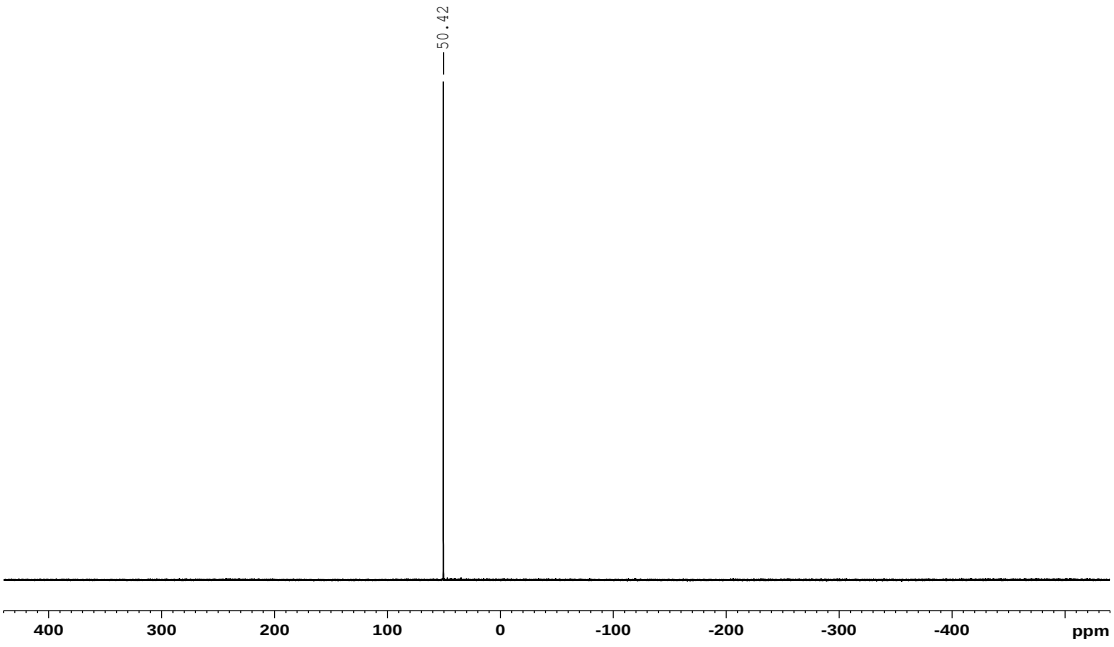

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4g**



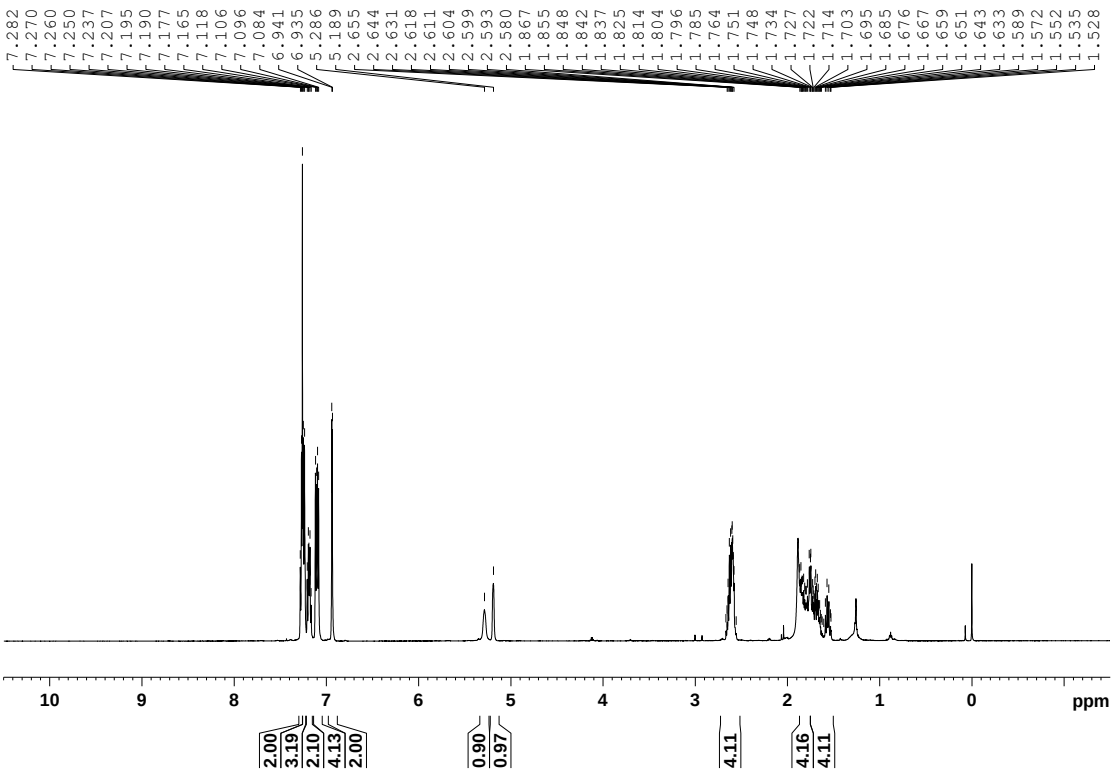

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4g**



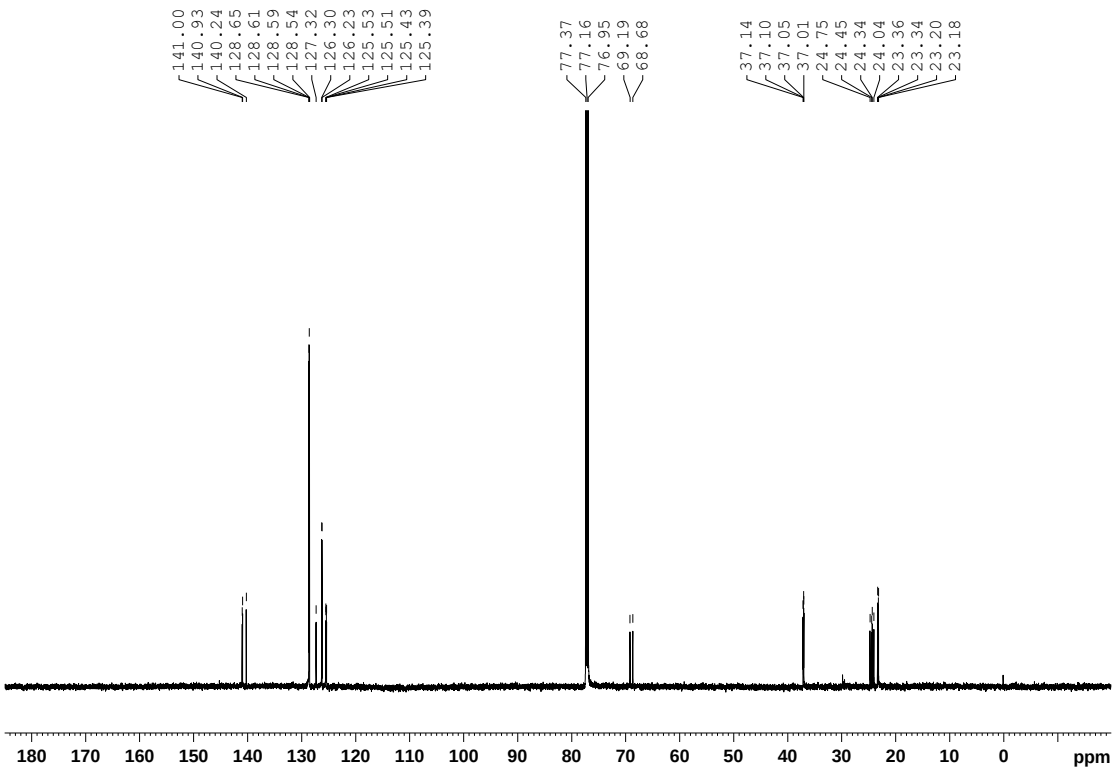

(**4h**)



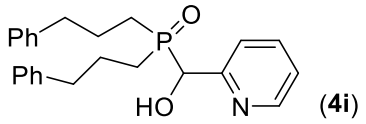

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4h**



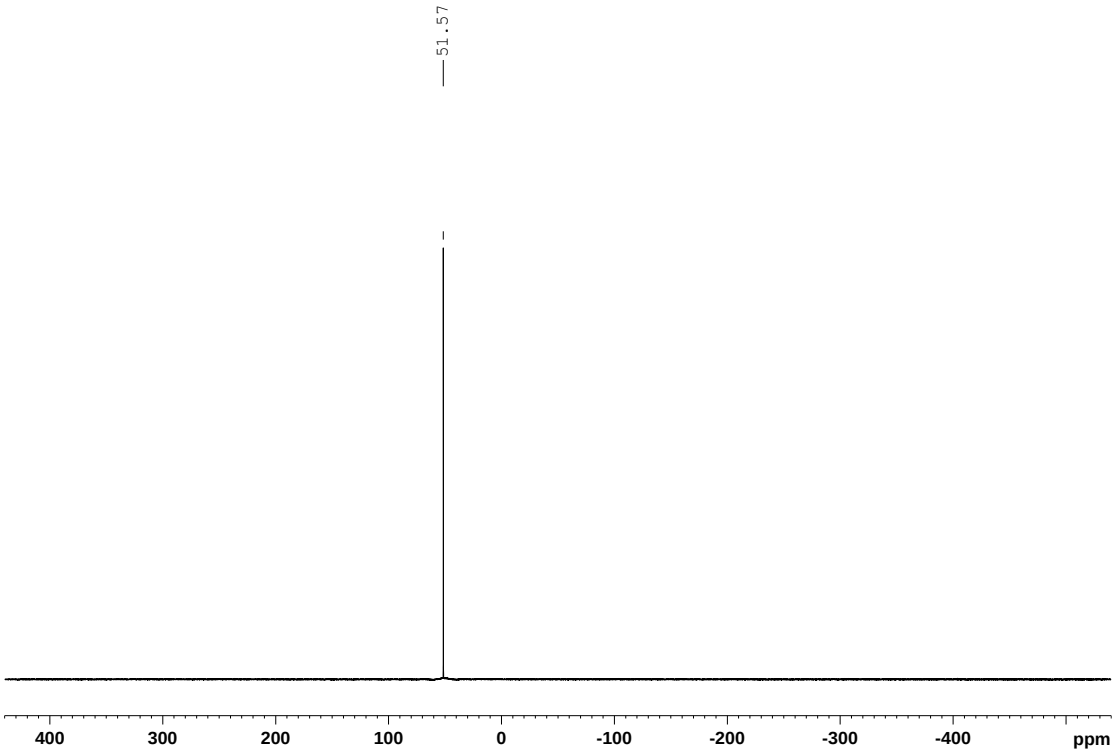

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4h**



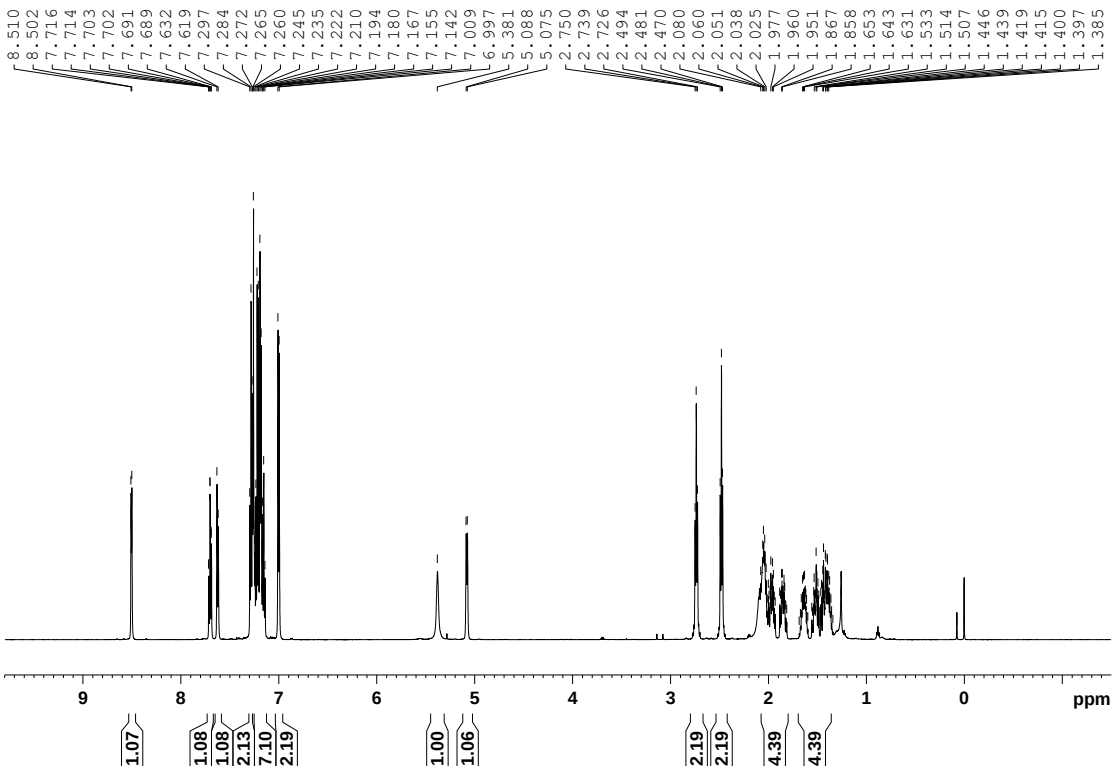

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4h**



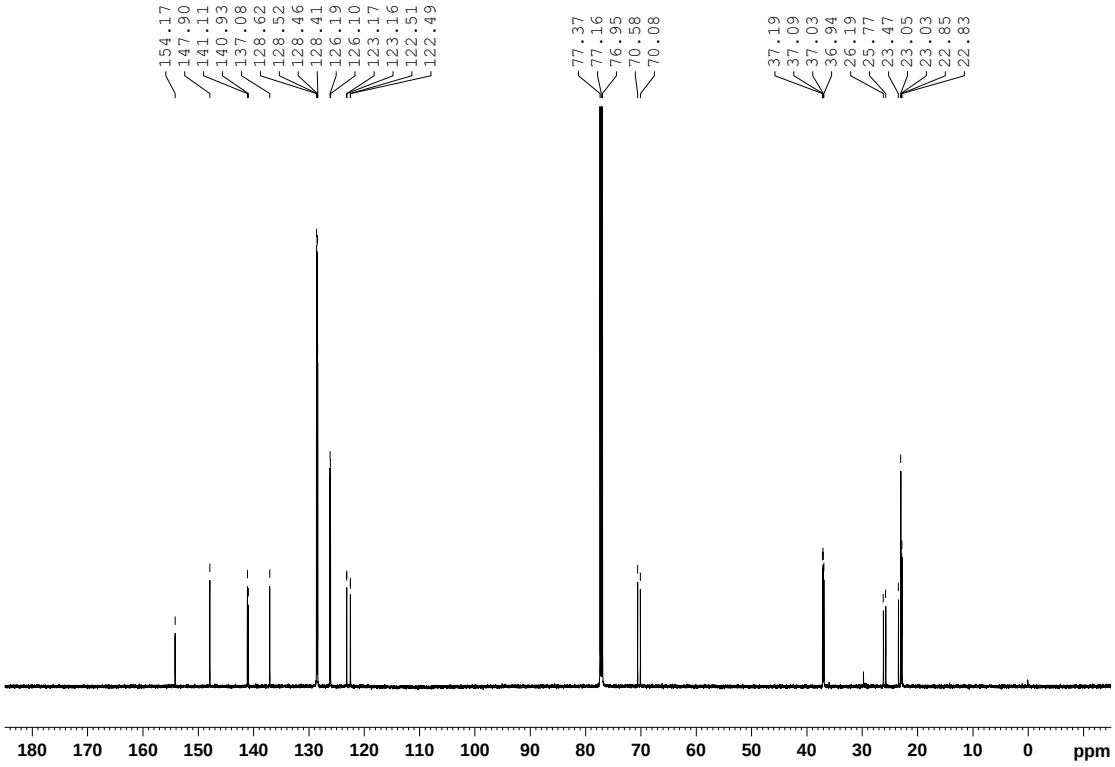

(**4i**)



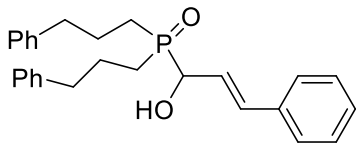

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4i**



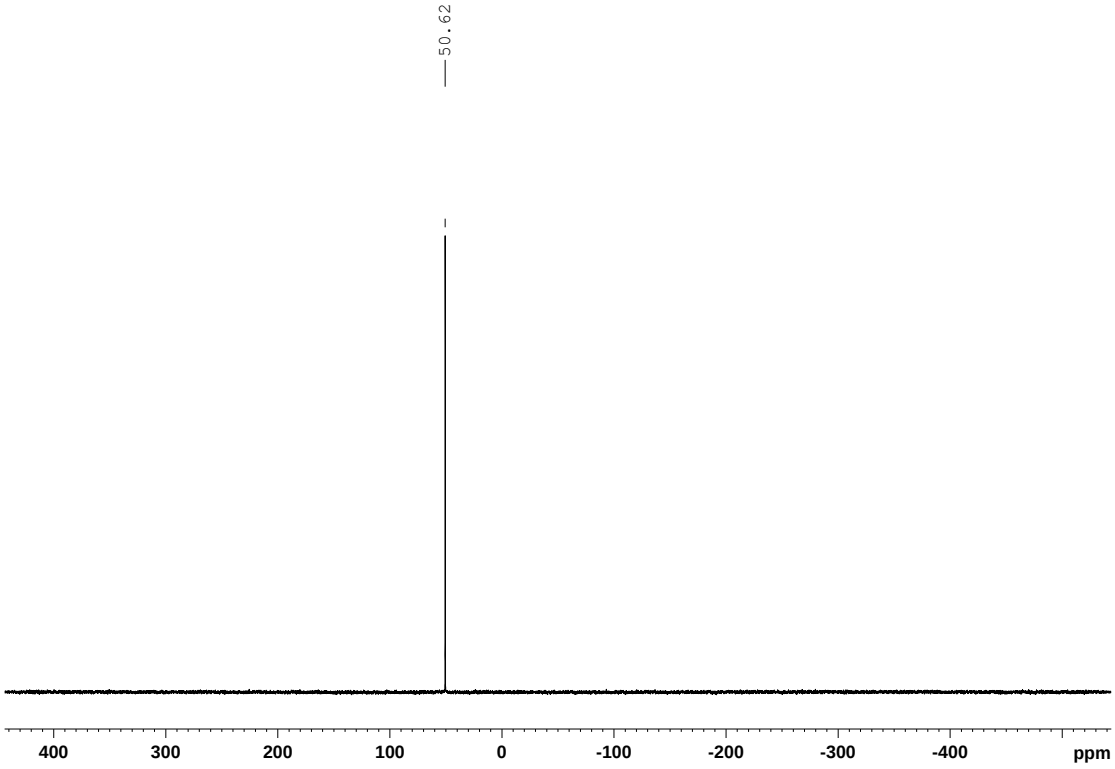

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4i**



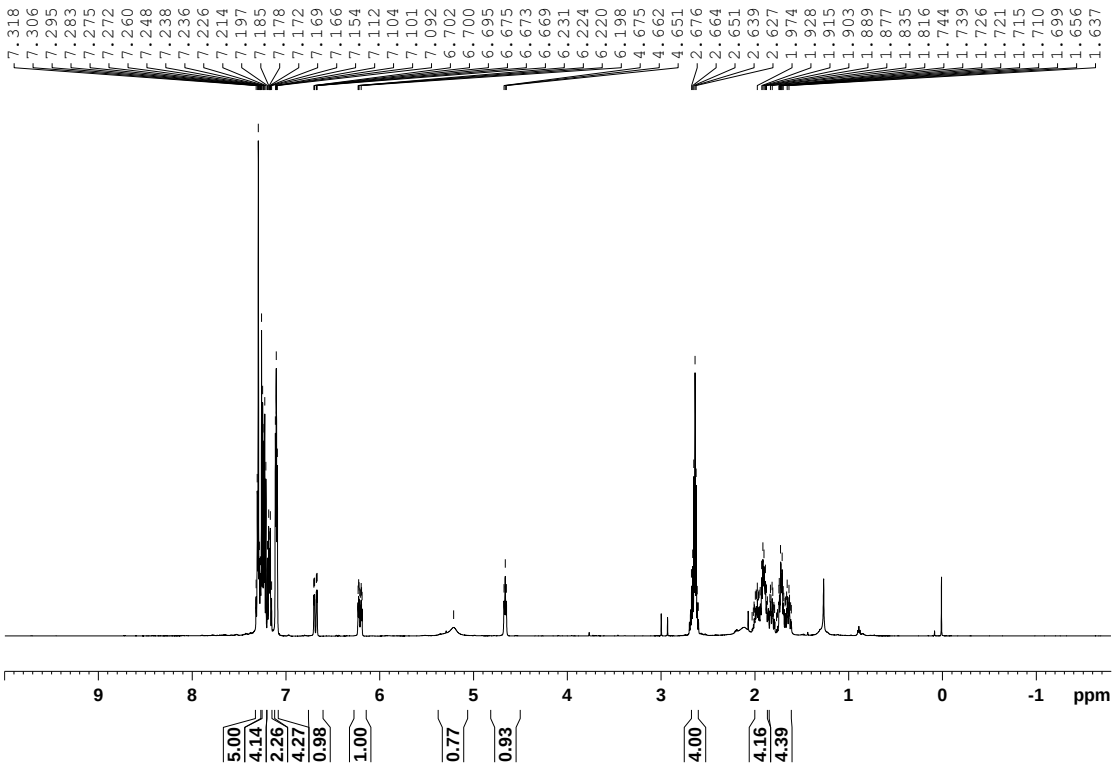

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4i**



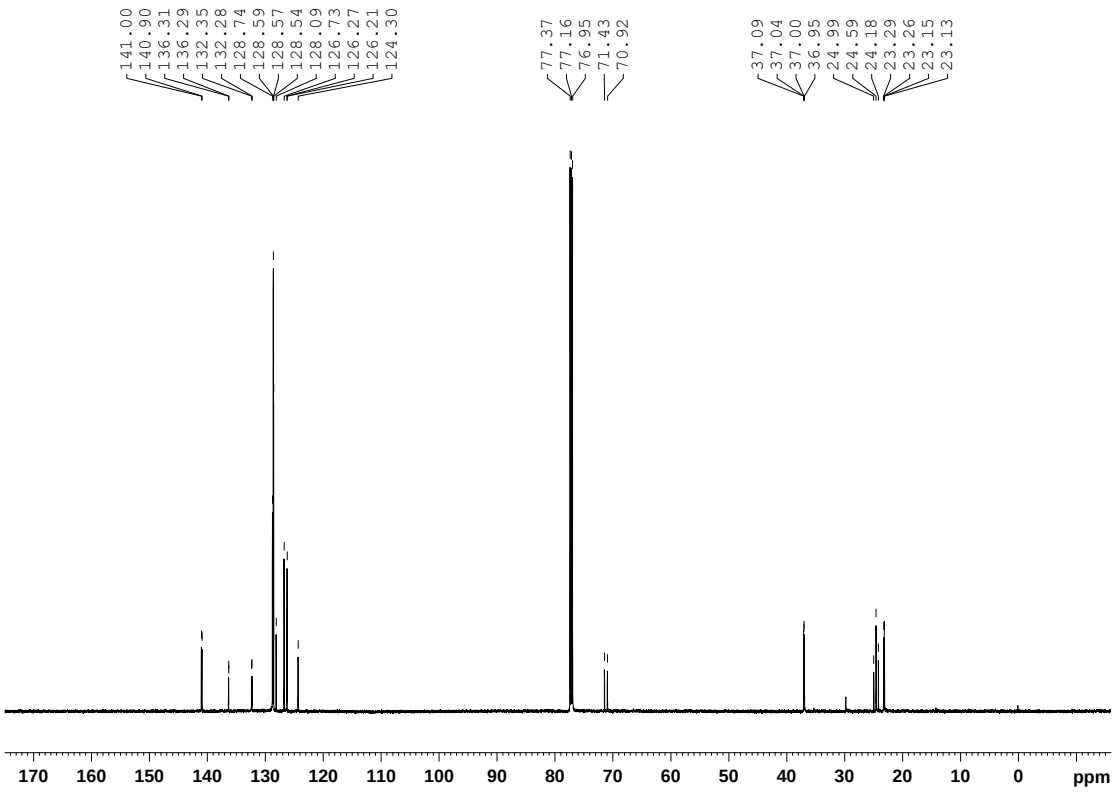

(**4j**)



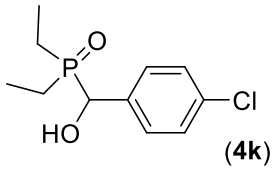

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4j**



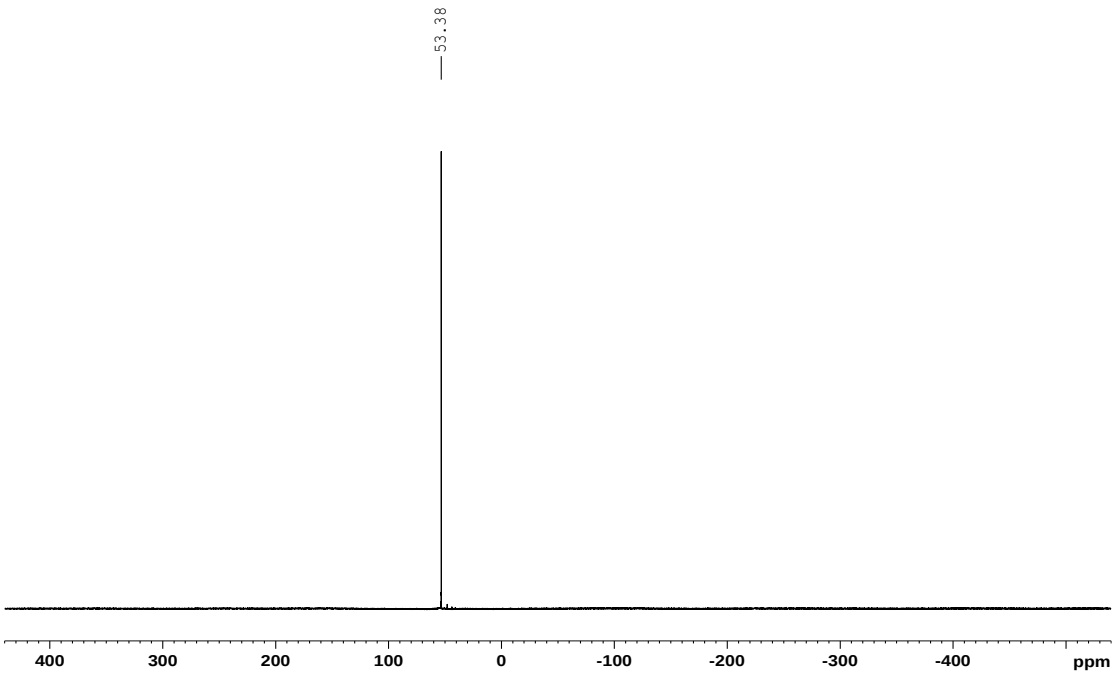

$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4j**



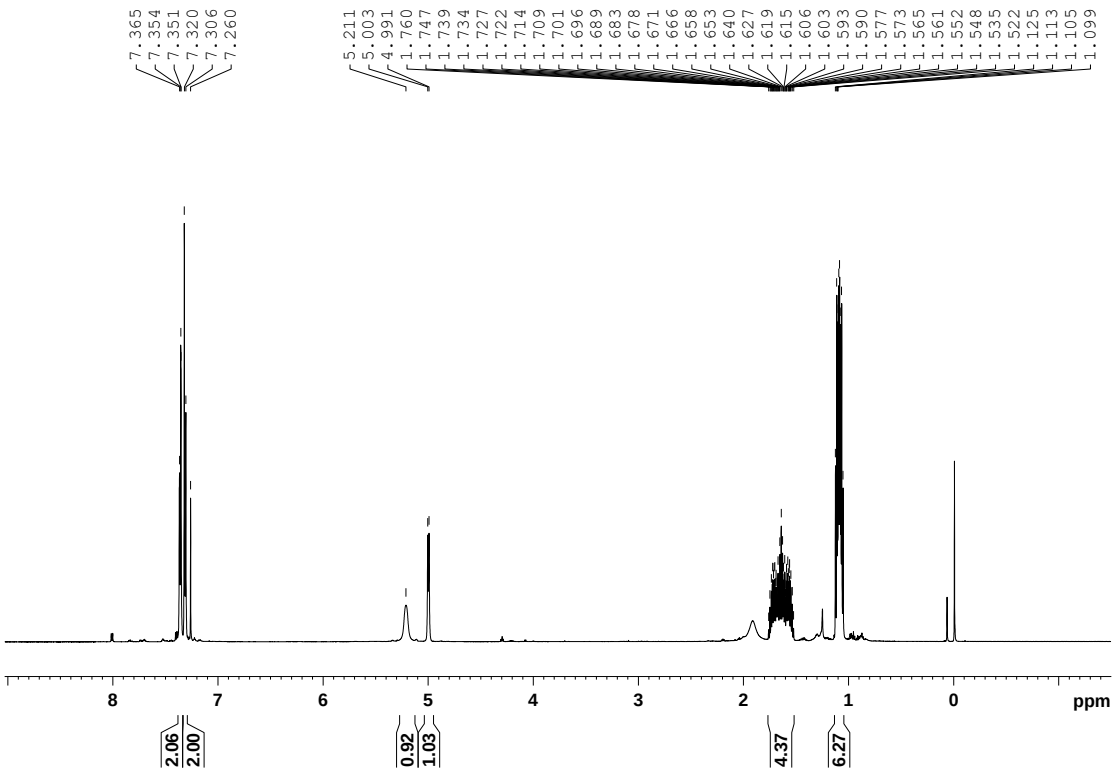

$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4j**



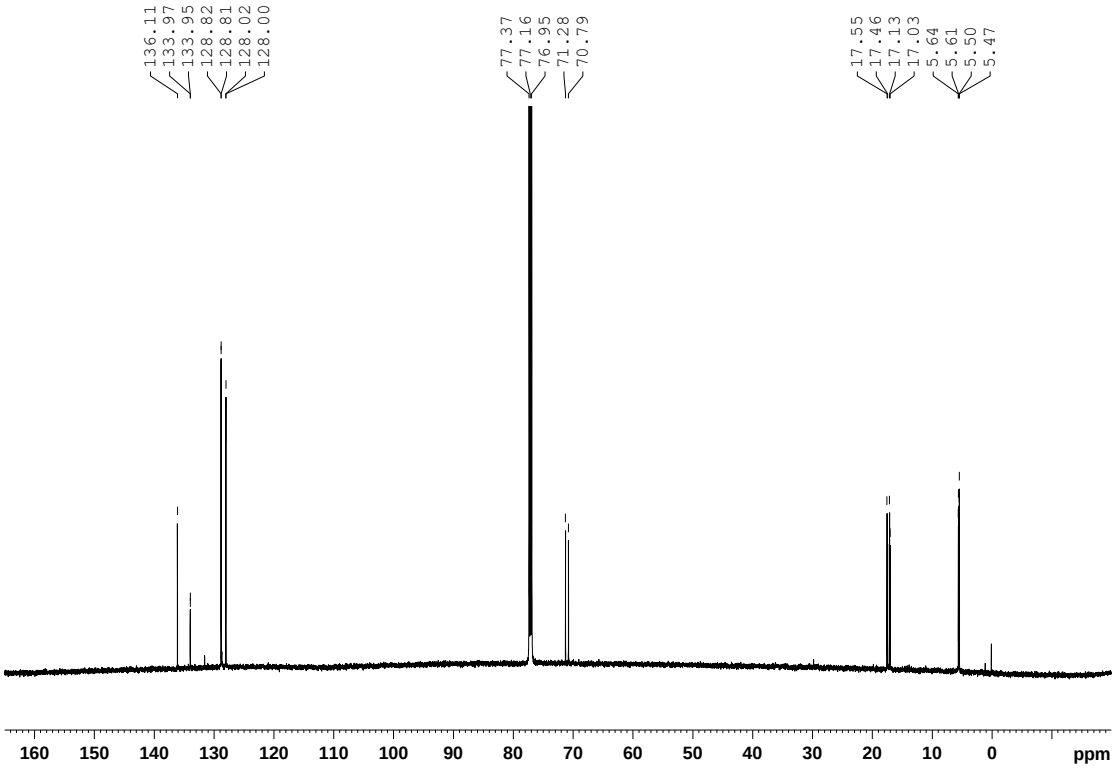

(**4k**)



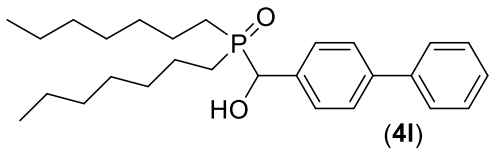

$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4k**



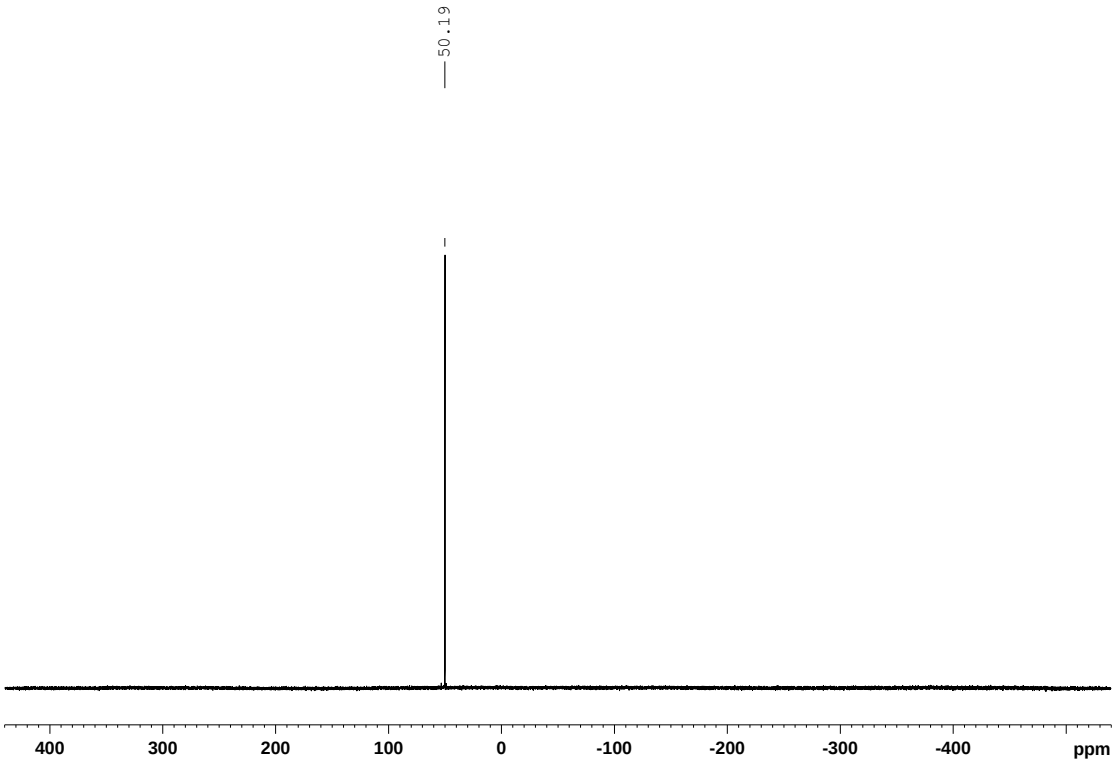

$^{1}$H NMR (600 MHz, $CDCl_3$) spectrum of compound **4k**



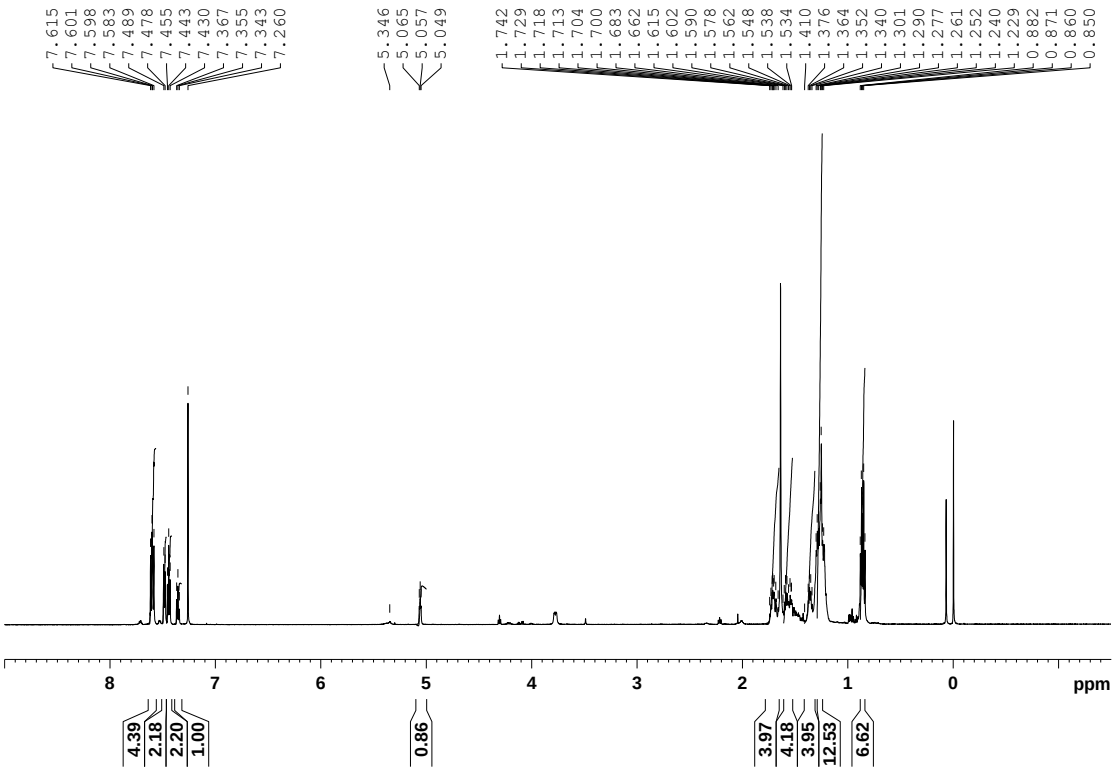

$^{13}$C{H} NMR (150 MHz, $CDCl_3$) spectrum of compound **4k**



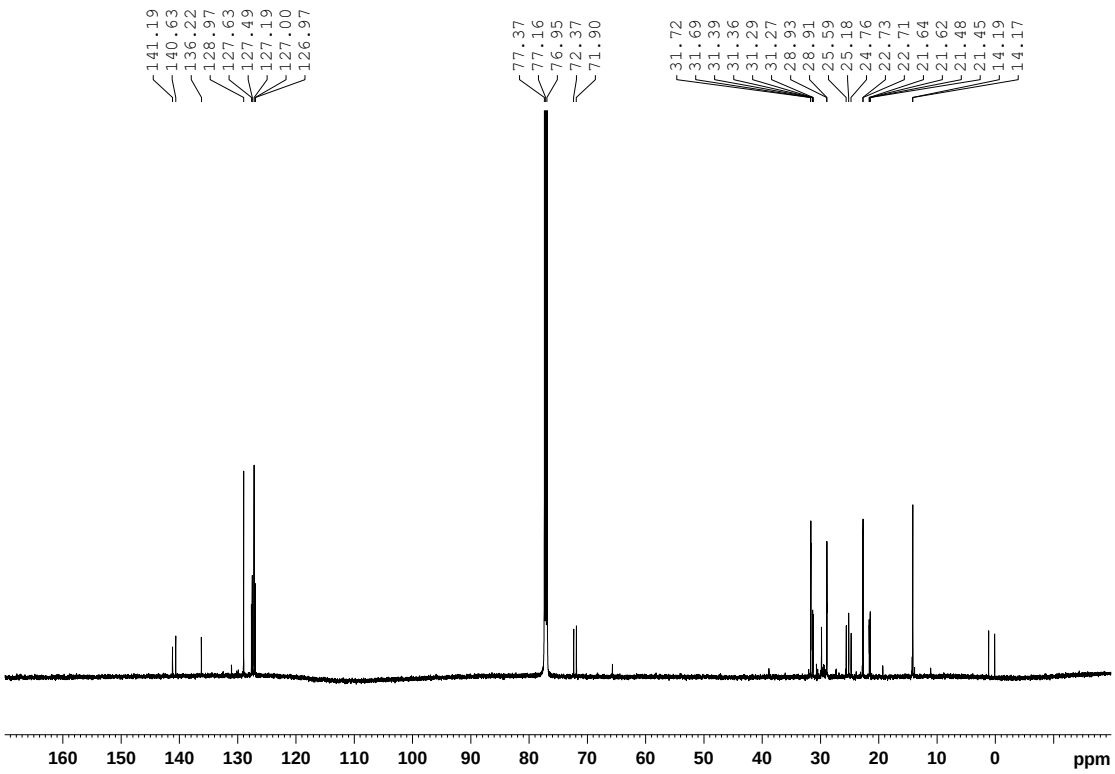

(**4l**)




$^{31}P\{H\}$ NMR (242 MHz, $CDCl_3$) spectrum of compound **4l**




$^{1}H$ NMR (600 MHz, $CDCl_3$) spectrum of compound **4l**




$^{13}C\{H\}$ NMR (150 MHz, $CDCl_3$) spectrum of compound **4l**