Supporting Information

Cross Hetero Dehydrogenative Coupling Reaction of Phosphites: A Catalytic Metal-Free Phosphorylation of amines and Alcohols

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General experimental

NMR spectra were recorded on a JEOL LA-300, BRUKER-AV400 spectrometer in $CDCl_3$, Tetramethylsilane (TMS; δ = 0.00 ppm) served as an internal standard for ^{1}H NMR. The corresponding residual non-deuterated solvent signal ($CDCl_3$; δ = 77.00 ppm) was used as internal standard for ^{13}C NMR. IR spectra were measured using a JASCO FT/IR-410 spectrometer and Perkin-Elmer FT/IR Spectrum BX, GX. Mass spectra were measured with Micromass Q-Tof (ESI-HRMS). Column chromatography was carried out on Silica gel 100-200 mesh (commercial suppliers) and thin-layer chromatography was carried out using SILICA GEL GF-254.

Typical experimental procedure

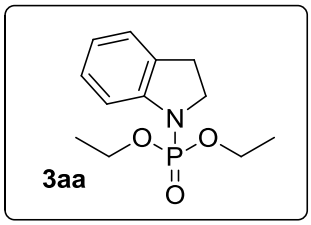
A. **Amine with dialkyl *H*- phosphite:** Diethyl *H*-phosphite (100 mg, 0.72 mmol), indoline (1 equiv. 0.72 mmol) and molecular iodine (0.1 equiv. 0.072 mmol) and H_2O_2 (50% solution in water, 1 equiv, 0.72 mmol, 0.04 mL) in CH_2Cl_2 (2 mL) were stirred at room temperature (24-36 h). After the completion of the reaction (monitored by TLC) the solvent was removed under vacuum, added water (3 mL) and extracted with CH_2Cl_2 (3x10mL). The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified on a silica gel column using hexane/ EtOAc to get the pure product.

B. **Alcohol with dialkyl *H*- phosphite:** Diethyl *H*-phosphite (100 mg, 0.72 mmol), alcohol (3equiv, 2.17 mmol)* and molecular iodine (0.1 equiv. 0.072 mmol) and H_2O_2 (50% solution in water, 1 equiv, 0.72 mmol, 0.04 mL) in neat condition were stirred at room temperature (12-24 h). After the completion of the reaction (monitored by TLC) the solvent was removed under vacuum, added water (3 mL) and extracted with EtOAc (3x10mL). The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified on a silica gel column using hexane/ EtOAc to get the pure product.

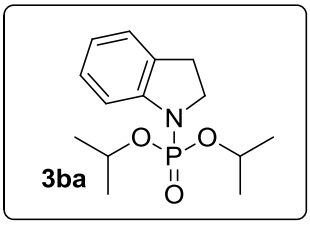
* *0.5 mL of following alcohols was needed to complete the reaction: MeOH (**5aa**), EtOH (**5ab**), propanol (5**ac**), butanol (**5ad**), pentanol (**5ae**), 2-methylpropanol (**5af**), allyl alcohol (**5ah**), propargyl alcohol (**5a**i), and 2-propanol (**5an**).*

C. Sulfoximine with dialkyl *H*- phosphite: Diethyl *H*-phosphite (100 mg, 0.72 mmol), sulfoximine (1equiv, 0.72 mmol) and molecular iodine (0.1 equiv. 0.072mmol) and H_2O_2 (50% solution in water, 1 equiv, 0.72 mmol, 0.04 mL) in DCM (2 mL) were stirred at room temperature (12-24h). After the completion of the reaction (monitored by TLC) the solvent was removed under vacuum, added water (3 mL) and extracted with EtOAc (3x10mL). The combined organic layer was dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified on a silica gel column using MeOH/EtOAc to get the pure product.

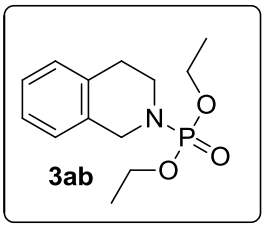
Characterization data for Phosphoramidates



Diethyl indolin-1-ylphosphonate: Dark brown liquid; Yield - 95%; R_f (30% EtOAc/Hexane) 0.3; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 2982, 2932, 1484, 1265, 1050, 1023, 970; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.16-7.08 (m, 3H), 6.86 (t, *J* = 7.2 Hz, 1H), 4.20-4. 01 (m, 4H), 3.91 (t, *J* = 8.8 Hz, 2H), 3.11 (t, *J* = 8.8 Hz, 2H), 1.32 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 144.7 (d, *J* = 6.4 Hz), 131.0 (d, *J* = 12.6 Hz), 127.4, 124.7, 121.0, 112.2, 62.6 (d, *J* = 5.1 Hz), 49.3 (d, *J* = 4.5 Hz), 28.9 (d, *J* = 6.7 Hz), 16.1 (d, *J* = 7.1 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 1.640; **HRESI-MS** *(m/z)*: Calculated for $C_{12}H_{18}NO_3P$ (M + Na): 278.0922, found (M + Na): 278.0923.



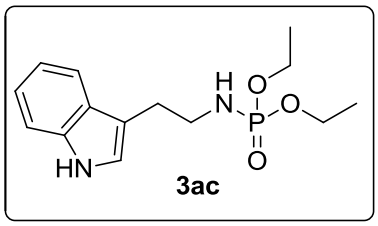
Diisopropyl indolin-1-ylphosphonate: Dark brown liquid; Yield - 82%; R_f (30% EtOAc/Hexane) 0.3; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3404, 2923, 1590, 1265, 1041, 1019, 990; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.17-7.06 (m, 3H), 6.83 (t, *J* = 7.2 Hz, 1H), 4.70-4.60 (m, 2H), 3.90 (t, *J* = 8.8 Hz, 2H), 3.08 (t, *J* = 8.4 Hz, 2H), 1.37 (d, *J* = 6.4 Hz, 6H), 1.24 (d, *J* = 6.0 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 145.0 (d, *J* = 6.5 Hz), 130.9 (d, *J* = 12.3 Hz), 127.3, 124.6, 120.7, 112.5, 71.3 (d, *J* = 5.3 Hz), 49.3 (d, *J* = 4.7 Hz), 28.8 (d, *J* = 6.9 Hz), 23.8 (d, *J* = 4.6 Hz), 23.6 (d, *J* = 5.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.099; **HRESI-MS** *(m/z)*: Calculated for $C_{14}H_{22}NO_3P$ (M + H): 284.1416, found (M + H): 284.1420.



Diethyl (3,4-dihydroisoquinolin-2(1H)-yl)phosphonate: Orange liquid; Yield - 82%; R_f (50% EtOAc/Hexane) 0.2; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3449, 2983, 2855, 1637, 1256, 1058, 1027, 966; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.16-7.09 (m, 3H), 7.06-7.02 (m, 1H), 4.31 (d, *J* = 6 Hz,

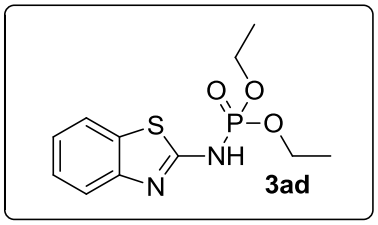
2H), 4.11-3.93 (m, 4H), 3.51-3.40 (m, 2H), 2.84 (t, *J* = 5.6 Hz, 6H), 1.29 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 134.1, 133.6 (d, *J* = 6.6 Hz), 129.2, 126.3, 126.0 (d , *J* = 2. 9 Hz), 62.2 (d, *J* = 5.5 Hz), 46.2 (d, *J* = 4.0 Hz), 42.1 (d, *J* = 2.6 Hz), 28.9 (d, *J* = 3.7 Hz), 16.1 (d, *J* = 7.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.547; **HRESI-MS** *(m/z)*: Calculated for $C_{13}H_{20}NO_3P$ (M + Na): 292.1079, found (M + Na): 292.1076.

Diethyl (2-(1H-indol-3-yl)ethyl)phosphoramidate: Dark brown liquid; Yield - 64%; R_f (50% EtOAc/Hexane) 0.3; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3400, 3281, 2927, 1618, 1441, 1221, 1054, 1028, 968; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.55 (s, 1H), 7.58 (d, *J* = 7.6 Hz, 1H), 7.37 (d, *J* = 8.4 Hz, 1H), 7.18 (t, *J* = 7.2 Hz, 1H), 7.10 (t, *J* = 7.6 Hz, 1H), 7.01 (s, 1H), 4.12-3.93 (m, 4H), 3.26-3.20 (m, 2H), 2.95 (t, *J* = 6.4 Hz, 2H), 2.73 (brs, 1H), 1.27 (m, 8H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.5, 127.1, 122.5, 122.1, 119.3, 118.5, 112.3 11.3, 62.2 (d, *J* = 5.4 Hz), 41.4, 27.5 (d, *J* = 6.3 Hz), 16.2 (d, *J* = 7.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 9.173; **HRESI-MS** *(m/z)*: Calculated for $C_{14}H_{21}N_2O_3P$ (M + Na): 319.1188, found (M + Na): 319.1184.

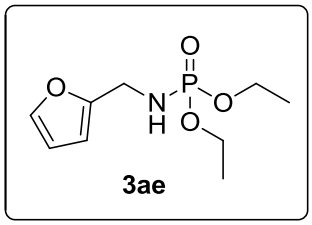


3ac

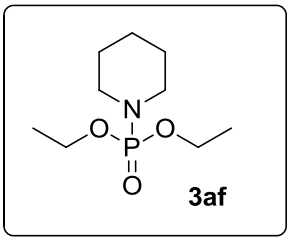
Diethyl benzo[d]thiazol-2-ylphosphoramidate: Brown oil; Yield - 40%; R_f (50% EtOAc/Hexane) 0.6; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3449, 2931, 1597, 1581, 1470, 1204, 1031, 979; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.54-7.51 (m, 2H), 7.33 (t, *J* = 7.2 Hz, 1H), 7.19 (t, *J* = 8.0 Hz, 1H), 4.25-4.10 (m, 4H), 1.36 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 167.6 (d, *J* = 3.7 Hz), 141.1, 126.8, 126.5, 123.4, 121.6, 115.0, 63.1 (d, *J* = 5.6 Hz), 16.2 (d, *J* = 6.8 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 4.274; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{15}N_2O_3PS$ (M + Na): 309.0439, found (M + Na): 309.0439.



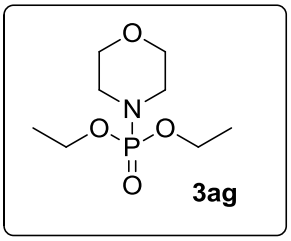
3ad



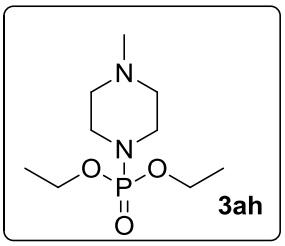
Diethyl (furan-2-ylmethyl)phosphoramidate: Yellow liquid; Yield - 85%; R_f (100% EtOAc) 0.7; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3398, 3229, 2983, 1443, 1233, 1055, 1029, 968; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.35 (s, 1H), 6.31 (d, *J* = 2.8 Hz, 1H), 6.21 (d, *J* = 2.8 Hz, 1H), 4.10-3.98 (m, 6H), 3.21 (s, 1H), 1.30 (t, *J* = 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 152.9 (d, *J* = 6.4 Hz), 142.0, 110.3, 106.6, 62.3 (d, *J* = 5.2 Hz), 38.3, 16.1 (d, *J* = 7.1 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.099; **HRESI-MS** *(m/z)*: Calculated for $C_9H_{16}NO_4P$ (M + Na): 256.0715, found (M + Na): 256.0711.



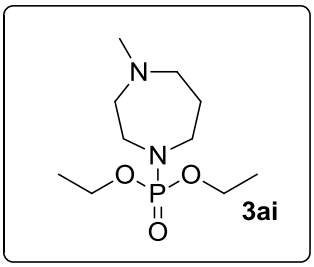
Diethyl piperidin-1-ylphosphonate[1]: Yellow liquid; Yield - 82%; R_f (100% MeOH/EtOAc) 0.4; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3468, 2981, 2935, 2854, 1384, 1244, 1167, 1057, 1028, 964; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.09-3.95 (m, 4H), 3.11-3.07(m, 4H),1.6-1.57 (m, 3H), 1.56-1.51 (m, 3H), 1.31 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 61.9 (d, *J* = 5.5 Hz), 45.2 (d, *J* = 2.0 Hz), 25.9 (d, *J* = 4.9 Hz), 24.3, 16.0 (d, *J* = 7.2 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.864; **HRESI-MS** *(m/z)*: Calculated for $C_9H_{20}NO_3P$ (M + Na): 244.1079, found (M + Na): 244.1077.



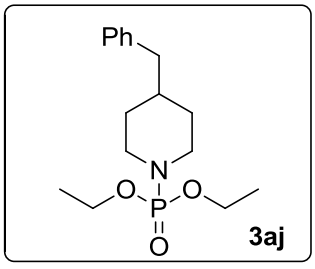
Diethyl morpholinophosphonate[1]: Pale yellow liquid; Yield - 78%; R_f (100% MeOH/EtOAc) 0.7; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3448, 2981, 1647, 1254, 1022, 974; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.08-4.03 (m, 4H), 3.66-3.64 (m, 4H), 3.16-3.12 (m, 4H), 1.33 (t, *J* = 5.6 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 66.9 (d, *J* = 5.8 Hz), 62.3 (d, *J* = 5.7 Hz), 44.5, 16.1 (d, *J* = 6.8 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 7.749; **HRESI-MS** *(m/z)*: Calculated for $C_8H_{18}NO_4P$ (M + Na): 246.0871, found (M + Na): 246.0872.



Diethyl (4-methylpiperazin-1-yl)phosphonate: Yellow liquid; Yield - 78%; R_f (100% MeOH/EtOAc) 0.6; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3436, 2981, 1242, 1052, 1021, 978; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11-3.97 (m, 4H), 3.19-3.17 (m, 4H), 2.37-2.35 (m, 4H), 2.29 (s, 3H), 1.32 (t, *J* = 6.4 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 62.1 (d, *J* = 5.5 Hz), 55.0 (d, *J* = 5.7 Hz), 46.2, 44.2, (d, *J* = 1.4 Hz), 16.0 (d, *J* = 7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.315; **HRESI-MS** *(m/z)*: Calculated for $C_9H_{21}N_2O_3P$ (M + H): 237.1368, found (M + H): 237.1366.



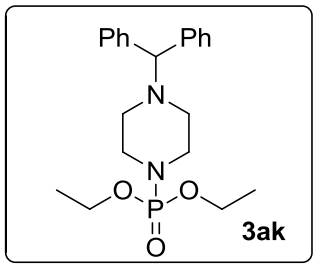
Diethyl (4-methyl-1,4-diazepan-1-yl)phosphonate: Yellow liquid; Yield - 73%; R_f (100% MeOH/EtOAc) 0.5; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3449, 2936, 1655, 1239, 1058, 1025, 963; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.10-3.96 (m, 4H), 3.33-3.24 (m, 4H), 2.64-2.60 (m, 4H), 2.37 (s, 3H), 1.90-.1.84 (m, 2H), 1.32 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 62.0 (d, *J* = 5.3 Hz), 60.3, 56.8, 46.8, 45.9 (d, *J* = 3.5 Hz), 28.6 (d, *J* = 5.8 Hz), 16.2 (d, *J* = 7.1 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 9.575; **HRESI-MS** *(m/z)*: Calculated for $C_{10}H_{23}N_2O_3P$ (M + H): 251.1525, found (M + H): 251.1520.



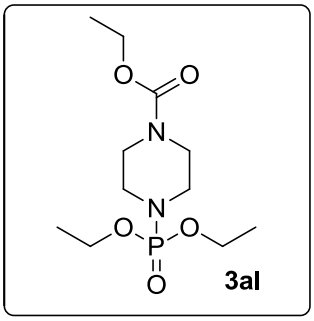
Diethyl (4-benzylpiperidin-1-yl)phosphonate: Yellow liquid; Yield - 83%; R_f (50% EtOAc/Hexane) 0.4; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3439, 2924, 1604, 1244, 1046, 1027, 959; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.27 (t, *J* = 7.2 Hz, 2H), 7.18 (t, *J* = 7.2 Hz, 1H), 7.13 (d, *J* = 7.2 Hz, 2H), 4.08-3.93 (m, 4H), 3.54-3.50 (m, 2H), 2.64 (m, 2H), 2.53 (d, *J* = 6.8 Hz, 2H), 1.61 (m, 3H), 1.30 (t, *J* = 7.2 Hz, 6H), 1.20-1.11 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 140.0, 129.0, 128.1, 125.8, 62.0 (d, *J* = 5.6 Hz), 44.7 (d, *J* = 2.3 Hz), 43.2, 37.9, 32.2 (d, *J* = 5.2

Hz), 16.1 (d, *J* = 7.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.816; **HRESI-MS** *(m/z)*: Calculated for $C_{16}H_{26}NO_3P$ (M + Na): 334.1548, found (M + Na): 334.1549.

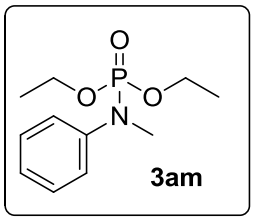
Diethyl (4-benzhydrylpiperazin-1-yl)phosphonate: Yellow liquid; Yield - 76%; R_f (50% EtOAc/Hexane) 0.4; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3401, 1654, 1450, 1253, 1199, 1138, 1110, 1059, 1026, 979; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.40 (d, *J* = 7.2 Hz, 4H), 7.28-7.18 (m, 4H), 7.16 (t, *J* = 4.0 Hz, 2H), 4.23 (s, 1H), 4.08-3.94 (m, 4H), 3.18-3.14 (m, 4H), 2.35-2.32(m, 4H), 1.29 (t, *J* = 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 142.3, 128.5, 127.9, 127.0, 76.3, 62.1 (d, *J* = 5.6 Hz), 52.1 (d, *J* = 6.2 Hz), 44.6, 16.2 (d, *J* = 6.9 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.363; **HRESI-MS** *(m/z)*: Calculated for $C_{21}H_{29}N_2O_3P$ (M + Na): 411.1814, found (M + Na): 411.1808.



Ethyl 4-(diethoxyphosphoryl)piperazine-1-carboxylate: Pale yellow liquid; Yield - 96%; R_f (100% EtOAc) 0.6; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3479, 2984, 2909, 1703, 1697, 1434, 1246, 1055, 1024, 968; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.15 (q, *J* = 7.2 Hz, 2H), 4.10-3.99 (m, 4H), 3.45-3.44 (m, 4H), 3.14-3.09 (m, 4H), 1.74 (s, 1H), 1.32 (t, *J* = 6.8 Hz, 6H), 1.26 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 155.4, 62.4 (d, *J* = 5.6 Hz), 61.5, 44.2, 16.1 (d, *J* = 6.8 Hz), 14.6; **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.022; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{23}N_2O_5P$ (M + Na): 317.1242, found (M + Na): 317.1242.

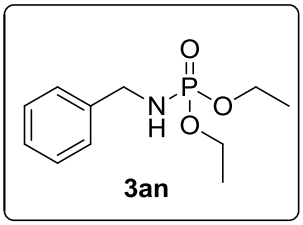


Diethyl methyl(phenyl)phosphoramidate: Brown liquid; Yield - 60%; R_f (30% EtOAc/Hexane) 0.2; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3474, 2983, 2932, 2907, 1600, 1497, 1276, 1047, 1024, 967; **^{1}H NMR** (400 MHz, $CDCl_3$): δ

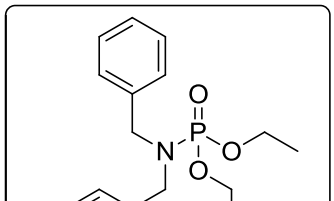


7.32-7.28(m, 3H), 7.08 (t, *J* = 6.8 Hz, 1H), 4.17-3.98 (m, 4H), 3.21 (d, *J* = 8.8Hz, 3H), 1.28 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 144.0 (d, *J* = 5.0 Hz), 128.9, 123.5, 121.8 (d, *J* = 4 Hz), 62.5 (d, *J* = 6Hz), 36.8 (d, *J* = 5 Hz), 15.9 (d, *J* = 7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 5.857; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{18}NO_3P$ (M + Na): 266.0922, found (M + Na): 266.0925.

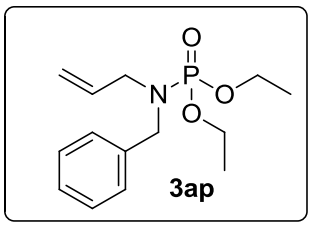
Diethyl benzylphosphoramidate[1]: Orange liquid; Yield - 70%; R_f (50% EtOAc/Hexane) 0.3; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3422, 2982, 2929, 1646, 1457, 1261, 1054, 1027, 966; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.33-7.25(m, 5H), 4.11-3.98 (m, 6H), 3.22 (brs, 1H), 1.29 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 139.6 (d, *J* = 6.2Hz), 128.5, 128.3, 127.2, 62.3 (d, *J* = 5.3 Hz), 45.2, 16.9 (d, *J* = 7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.501; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{18}NO_3P$ (M + Na): 266.0922, found (M + Na): 266.0925.



Diethyl dibenzylphosphoramidate: Yellow liquid; Yield - 72%; R_f (30% EtOAc/Hexane) 0.4; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3449, 2982, 2930, 1637, 1253, 1056, 1027, 953; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.35-7.27(m, 10H), 4.18-4.00 (m, 8H), 1.32 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 137.4 (d, *J* = 2.5 Hz), 128.6, 128.4, 127.3, 62.4 (d, *J* = 4.9 Hz), 48.3 (d, *J* = 4.9 Hz), 16.2 (d, *J* = 7.3 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 9.758; **HRESI-MS** *(m/z)*: Calculated for $C_{18}H_{24}NO_3P$ (M + Na): 356.1392, found (M + Na): 356.1392.

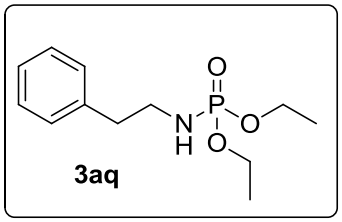


Diethyl allyl(benzyl)phosphoramidate: Yellow oil; Yield - 78%; R_f (30% EtOAc/Hexane) 0.4; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3460, 2981,



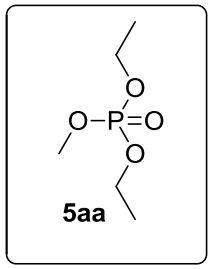
1638, 1369, 1252, 1054, 1027, 957; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.35-7.24 (m, 5H), 5.80-5.70 (m, 1H), 5.12 (dd, *J* = 14 Hz, 10 Hz, 2H), 4.17 (d, *J* = 9.6 Hz, 2H), 4.15- 3.98(m, 4H), 3.49 (dd, 6.4 Hz, 4.8 Hz, 2H), 1.32 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 137.8 (d, *J* = 3.6 Hz), 134.2, 128.5, 128.3, 127.2, 118.1, 62.3 (d, *J* = 5.6 Hz), 48.5 (d, *J* = 4.9 Hz), 16.1 (d, *J* = 7.2 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 9.771; **HRESI-MS** *(m/z)*: Calculated for $C_{14}H_{22}NO_3P$ (M + Na): 306.1235, found (M + Na): 306.1234.

Diethyl phenethylphosphoramidate: Pale green liquid; Yield - 71%; R_f (50% EtOAc/Hexane) 0.3; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3420, 3236, 2981, 1455, 1233, 1057, 1030, 965; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.32-7.24 (m, 2H), 7.22-7.18 (m, 3H), 4.09-3.93 (m, 4H), 3.21-3.14 (m, 2H), 2.79 (t, *J* = 6.8 Hz, 2H), 2.64 (d, *J* = 8 Hz, 1H), 1.30 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 138.6, 128.8, 128.6, 126.5, 62.1 (d, *J* = 5.3 Hz), 42.6, 37.9 (d, *J* = 6.2 Hz), 16.1 (d, *J* = 7.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 8.970; **HRESI-MS** *(m/z)*: Calculated for $C_{12}H_{20}NO_3P$ (M + Na): 280.1079, found (M + Na): 280.1077.

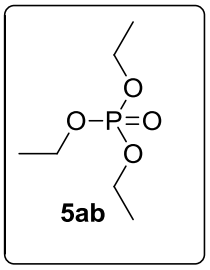


Characterization data for phosphate triester.

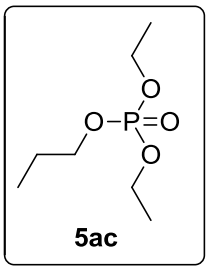
Diethyl methyl phosphate: Dark orange liquid; Yield - 97%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3439, 2920, 1578, 1411, 1020, 848; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.12 (q, *J* = 7.2 Hz, 4H), 3.76 (d, *J* = 11.2 Hz, 3H), 1.35 (t, *J* = 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 63.7 (d, *J* = 6Hz), 54.0 (d, *J* = 6.1 Hz), 16.0 (d, *J* = 6 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 0.116; **HRESI-MS** *(m/z)*: Calculated for $C_5H_{13}O_4P$ (M + Na): 191.0449, found (M + Na): 191.0455.



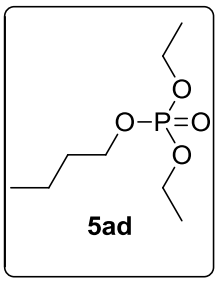
Triethyl phosphate: Pale yellow liquid; Yield - 96%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3411, 2923, 1619, 1425, 1019; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11 (q, *J* = 7.2 Hz, 6H), 1.34 (t, *J* = 7.2 Hz, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 63.5 (d, *J* = 5.8 Hz), 16.0 (d, *J* = 6.7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.004; **HRESI-MS** *(m/z)*: Calculated for $C_6H_{15}O_4P$ (M + Na): 205.0606, found (M + Na): 205.0607.



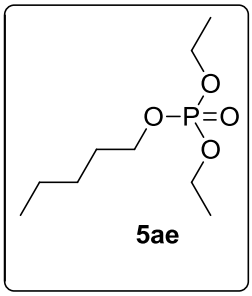
Diethyl propyl phosphate: Pale yellow liquid; Yield - 95%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3489, 2979, 1266, 1033, 980; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11 (quin, *J* = 7.2 Hz, 4H), 4.0 (q, *J* = 6.8 Hz, 2H), 1.71 (sex, *J* = 7.2 Hz, 2H), 1.34 (t, *J* = 6.8 Hz, 6H), 0.97 (t, *J* = 7.6 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 69.1 (d, *J* = 6.2 Hz), 63.6 (d, *J* = 5.7 Hz), 23.6 (d, *J* = 6.0 Hz), 16.1 (d, 5.7 Hz), 9.9 ; **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.916; **HRESI-MS** *(m/z)*: Calculated for $C_7H_{17}O_4P$ (M + Na): 219.0762, found (M + Na): 219.0768.



Butyl diethyl phosphate: Orange liquid; Yield - 97%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3483, 2963, 1265, 1031, 980; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11 (quin, *J* = 8.0 Hz, 4H), 4.0 (q, *J* = 7.6 Hz, 2H), 1.67 (quin, *J* = 7.8 Hz, 2H), 1. 41 (sex, *J* = 8.0 Hz, 2H), 1.34 (t, *J* = 8.1 Hz, 6H), 0.94 (t, *J* = 8.0 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 67.3 (d, *J* = 5.8 Hz), 63.6 (d, *J* = 5.9 Hz), 32.2 (d, *J* = 6.7 Hz), 18.6, 16.1 (d, *J* = 6.8 Hz), 13.5 ; **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.868; **HRESI-MS** *(m/z)*: Calculated for $C_8H_{18}O_4P$ (M + Na): 233.0919, found (M + Na): 233.0914.

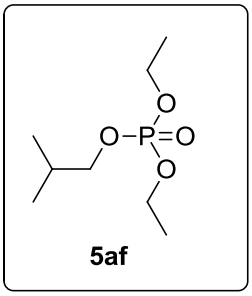


Diethyl pentyl phosphate: Pale green liquid; Yield - 97%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3482, 2960, 1264, 1033, 980; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11 (quin, *J* = 8.0 Hz,

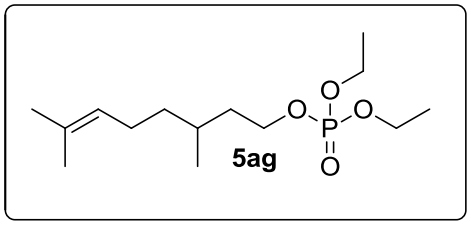


4H), 4.0 (q, *J* = 8.0 Hz, 2H), 1.68 (t, *J* = 4 Hz, 2H), 1.36-1.32 (m, 10H), 0.91 (t, *J* = 4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 67.6 (d, *J* = 6 Hz), 63.6 (d, *J* = 6 Hz), 29.9 (d, *J* = 6.2 Hz), 27.5, 22.1, 16.1 (d, *J* = 5.8 Hz), 13.9; **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.915; **HRESI-MS** *(m/z)*: Calculated for $C_9H_{21}O_4P$ (M + Na): 247.1075, found (M + Na): 247.1074.

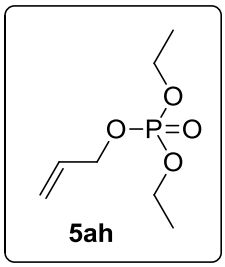
Diethyl isobutyl phosphate:[2] Pale yellow liquid; Yield - 96%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3487, 2966, 1263, 1026, 975, 866; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.11 (m, 4H), 3.80 (t, *J* = 8.0 Hz, 2H), 1.96 (m, 1H), 1.34 (t, 7.2 Hz, 6H), 0.95 (d, *J* = 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 73.5 (d, *J* = 6.3 Hz), 63.6 (d, *J* = 5.8 Hz), 29.0 (d, *J* = 7.2 Hz), 18.6, 16.1 (d, *J* = 6.6 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.870; **HRESI-MS** *(m/z)*: Calculated for $C_8H_{19}O_4P$ (M + Na): 233.0919, found (M + Na): 233.0916.



3,7-dimethyloct-6-en-1-yl diethyl phosphate:[2] Orange liquid; Yield - 74%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3736, 2965, 2927, 1525, 1263, 1032; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 5.08 (t, *J* = 6.7 Hz, 1H), 4.10-4.14 (m, 6H), 2.02-1.92 (m, 2H), 1.78-1.71 (m, 1H), 1.68 (s, 3H), 1.64-1.52 (m, 4H), 1.52-1.41 (m, 1H), 1.39-1.28 (m, 7H), 1.22-1.12 (m,2H), 0.91 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 131.3, 124.5, 77.3, 66.0 (d, *J* = 6 Hz), 37.1 (d, *J* = 7 Hz), 36.9, 28.9, 25.7, 25.3, 19.2, 17.6, 16.1 (d, *J* = 6.7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.831; **HRESI-MS** *(m/z)*: Calculated for $C_{14}H_{29}O_4P$ (M + Na): 315.1701, found (M + Na): 315.1704.

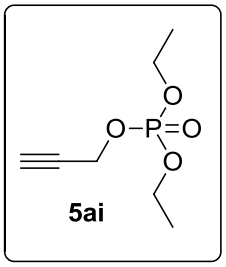


Allyl diethyl phosphate:[2] Dark orange liquid; Yield - 95%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3854, 3736, 1683, 1526, 1260, 1020; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 6.02-5.9 (m, 1H), 5.37 (d, *J* = 17 Hz, 1H), 5.25 (d, *J* = 10.4 Hz, 1H), 4.53 (t, *J* = 6.8 Hz, 2H), 4.12 (m, 4H), 1.34 (t, 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 132.6

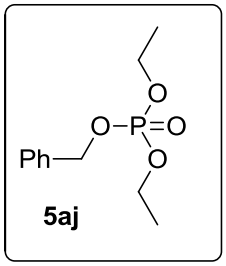


(d, *J* = 6.8 Hz), 118.0, 67.9 (d, *J* = 5.4 Hz), 63.8 (d, *J* = 5.6 Hz), 16.0 (d, *J* = 6.6 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.958; **HRESI-MS** *(m/z)*: Calculated for $C_7H_{15}O_4P$ (M + Na): 217.0606, found (M + Na): 217.0606.

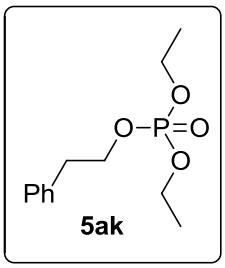
Diethyl prop-2-yn-1-yl phosphate:[2] Pale green liquid; Yield - 89%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3220, 2986, 2125, 1652, 1523, 1260, 1023; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.67 (dd, *J* = 8 Hz, *J*2 = 2.4 Hz, 2H), 4.15 (m, 4H), 2.57 (t, *J* = 2.4 Hz, 1H), 1.36 (t, 7.2 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 77.7 (d, *J* = 7.5 Hz), 75.7, 64.1 (d, *J* = 5.7 Hz), 54.8 (d, *J* = 4.6 Hz), 16.0 (d, *J* = 6.8 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.089; **HRESI-MS** *(m/z)*: Calculated for $C_7H_{13}O_4P$ (M + Na): 215.0449, found (M + Na): 215.0447.



Benzyl diethyl phosphate:[2] Pale yellow liquid; Yield - 82%; *Rf* (30% EtOAc/Hexane) 0.3. Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 2985, 1265, 1025, 983; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.41-7.31 (m, 5H), 5.06 (d, *J* = 8.0 Hz, 2H), 4.15-4.02 (m, 4H), 1.30 (t, 8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 136.0 (d, *J* = 7.0 Hz), 128.5, 128.4, 127.8, 69.0 (d, *J* = 5.2 Hz), 63.8 (d, *J* = 5.4 Hz), 16.0 (d, *J* = 6.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.961; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{17}O_4P$ (M + Na): 267.0762, found (M + Na): 267.0763.

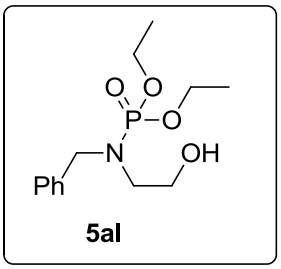


Diethyl phenethyl phosphate:[2] Pale green liquid; Yield - 71%; *Rf* (30% EtOAc/Hexane) 0.2. Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3448, 2983, 1266, 1029, 975; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.32-7.24 (m, 2H), 7.23- 7.22 (m, 3H), 4.23 (q, *J* = 7. 8 Hz, 2H), 4.03 (m, 4H), 2.99 (t, *J* = 6.0 Hz, 2H), 1.28 (t, 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 137.1, 128.9, 128.4, 126.6, 67.8 (d, *J* = 6.1 Hz), 63.6 (d, *J*



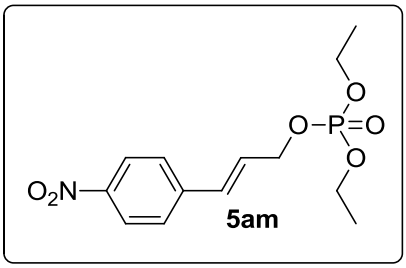
= 6 Hz), 36.7 (d, *J* = 6 Hz), 16.0 (d, *J* = 6.1 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.141; **HRESI-MS** *(m/z)*: Calculated for $C_{12}H_{19}O_4P$ (M + Na): 281.0919, found (M + Na): 281.0921.

Diethyl (2-hydroxyethyl)(phenyl)phosphoramidate: Liquid; Yield - 44%; *Rf* (100% EtOAc) 0.3. Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3510(br), 2892, 1266, 1029, 975; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.34-7.27 (m, 5H), 4.23 (d, *J* = 9.5Hz, 2H), 4.19-4.04 (m, 4H), 3.61 (t, *J* = 5.0 Hz, 2H), 3.16-3.11(m, 2H), 1.34 (t, 7.3 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 137.6, 129.0, 128.5, 128.2, 127.5, 126.3, 77.2, 62.8 (d, *J* = 6.3 Hz), 60.6, 50.2 (d, *J* = 4.5 Hz), 48.2 (d, *J* = 4.8 Hz), 16.1 (d, *J* = 7.1 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 11.36; **HRESI-MS** *(m/z)*: Calculated for $C_{13}H_{22}NO_4P$ (M + Na): 310.1184, found (M + Na): 310.1186.



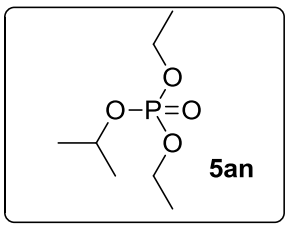
5al

(E)-diethyl (3-(4-nitrophenyl)allyl) phosphate: Yellow liquid; Yield - 50%; *Rf* (50% EtOAc/Hexane) 0.4. Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3430, 1636, 1518, 1344, 1261, 1027, 979; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.20 (d, *J* = 8.8 Hz, 2H), 7.53 (d, *J* = 8.8 Hz, 2H), 6.76 (d, *J* = 16 Hz, 1H), 6.47 (dt, *J* = 8Hz, 5.6 Hz, 1H), 4.80-4.73 (m, 2H), 4.15 (m, 4H), 1.36 (t, 8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 147.3, 142.4, 130.7, 128.5 (d, *J* = 7 Hz), 127.2, 124.0, 123.7, 67.0 (d, *J* = 5.3 Hz), 64.0 (d, *J* = 5.3 Hz), 16.1 (d, *J* = 6.7 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -0.0827; **HRESI-MS** *(m/z)*: Calculated for $C_{13}H_{18}NO_6P$ (M + Na): 338.0769, found (M + Na): 338.0769.



5am

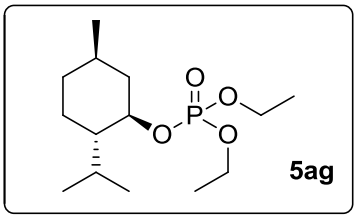
Diethyl isopropyl phosphate: [2] Colorless liquid; Yield - 97%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3421, 2982, 1683, 1522, 1260, 1016, 814; **^{1}H NMR** (400



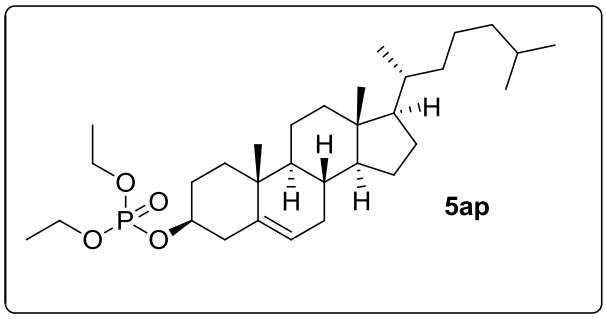
5an

MHz, $CDCl_3$): δ 4.65 (sep, *J* = 6.4 Hz, 1H), 4.01 (m, 4H), 1.34 (m, 12H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 72.4 (d, *J* = 5.9 Hz), 63.4 (d, *J* = 5.9 Hz), 23.6 (d, *J* = 5.1 Hz), 16.1 (d, *J* = 6.3 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.850; **HRESI-MS** *(m/z)*: Calculated for $C_7H_{17}O_4P$ (M + Na): 219.0762, found (M + Na): 219.0762.

Diethyl ((1R,2S,5R)-2-isopropyl-5-methylcyclohexyl) phosphate:[2] Liquid; Yield - 32%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3435, 2956, 2928, 2871, 1644, 1261, 1015; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 4.19-4.05 (m, 5H), 2.25-2.13 (m, 2H), 1.67-1.59(m, 3H), 1.36-1.25 (m, 10H), 0.92-0.86 (m, 5H), 0.81 (d, *J* = 7 Hz, 4H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 79.1 (d, *J* = 6.6 Hz), 77.2, 63.42 (d, *J* = 6.3 Hz), 48.47 (d, *J* = 7.27Hz), 42.5, 34.0, 31.5, 25.5, 22.8, 21.9, 20.9, 16.1 (d, *J* = 6.8 Hz), 15.6; **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.634; **HRESI-MS** *(m/z)*: Calculated for $C_{14}H_{29}O_4P$ (M + Na): 315.1701, found (M + Na): 315.1706.



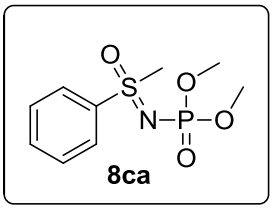
(3S,8S,9S,10R,13R,14S,17R)-10,13-dimethyl-17-((R)-6-methylheptan-2-yl)-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-3-yl diethyl phosphate: [2] Liquid; Yield - 23%; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3445, 2986, 2929, 2865, 1620, 1258, 1112; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 5.38-5.37 (m, 1H), 4.25-4.06 (m, 4H), 2.44-2.42 (m, 1H), 2.02-1.94 (m, 3H), 1.87-1.80 (m, 2H), 1.70-1.25 (m, 25H), 1.22-1.0 (m, 6H), 0.94-0.85 (m, 10H), 0.68 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 139.4, 122.9, 63.5 (d, *J* = 6.8 Hz), 56.7, 56.1, 50.0, 42.31, 39.7, 39.5, 36.9, 36.4, 36.1, 35.8, 31.9, 31.0, 29.6, 28.2. 28.0, 24.3, 23.8, 22.8, 22.5, 21.0.



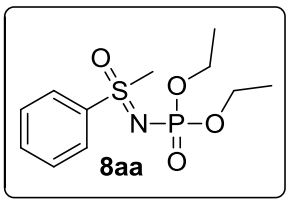
19.2, 18.7, 16.1 (d, *J* = 7.12 Hz), 11.84; **^{31}P NMR** (162 MHz, $CDCl_3$); δ -1.860; **HRESI-MS** *(m/z)*: Calculated for $C_{31}H_{55}O_4P$ (M + Na): 545.3736, found (M + Na): 545.3737.

Characterization data for CHDC reaction of sulfoximines with dialkyl *H*- phosphites.

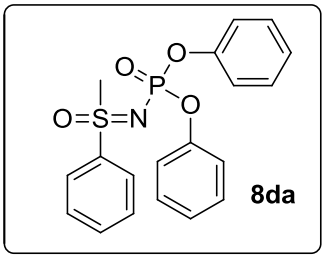
Dimethyl (S-methylsulfonimidoyl)benzene phosphoroamidate: Yellow oil; Yield - 50%; R_f (100% EtOAc) 0.2; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3433, 2954, 2924, 1254, 1168, 1034, 834; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.04 (d, *J* = 8.0Hz, 2H), 7.69 (t, *J* = 7.2 Hz, 1H), 7.60 (t, *J* = 7.6 Hz, 2H), 3.75 (dd, *J* = 12 Hz, 12 Hz, 6H), 3.37 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 140.3 (d, *J* = 9.3 Hz), 133.9, 129.5, 127.2, 53.4 (d, *J* = 5.9 Hz), 46.8 (d, *J* = 3.0 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ 0.698; **HRESI-MS** *(m/z)*: Calculated for $C_9H_{14}NO_4PS$ (M + Na): 286.0279, found (M + Na): 286.0275.



Diethyl (S-methylsulfonimidoyl)benzene phosphoroamidate:[3] Dark brown oil; Yield - 31%; R_f (100% EtOAc) 0.2; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3399, 2981, 1259, 1163, 1022, 748; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.04 (d, *J* = 8.0Hz, 2H), 7.69 (t, *J* = 7.6 Hz, 1H), 7.60 (t, *J* = 7.6 Hz, 2H), 4.15-4.05 (m, 4H), 3.38 (s, 3H), 1.30 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 140.3 (d, *J* = 8.8 Hz), 133.8, 129.4, 127.2, 62.7 (d, *J* = 6.1 Hz), 46.8 (d, *J* = 3.5 Hz), 16.1 (d, *J* = 7.9Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -2.020; **HRESI-MS** *(m/z)*: Calculated for $C_{11}H_{18}NO_4PS$ (M + Na): 314.0592, found (M + Na): 314.0593.



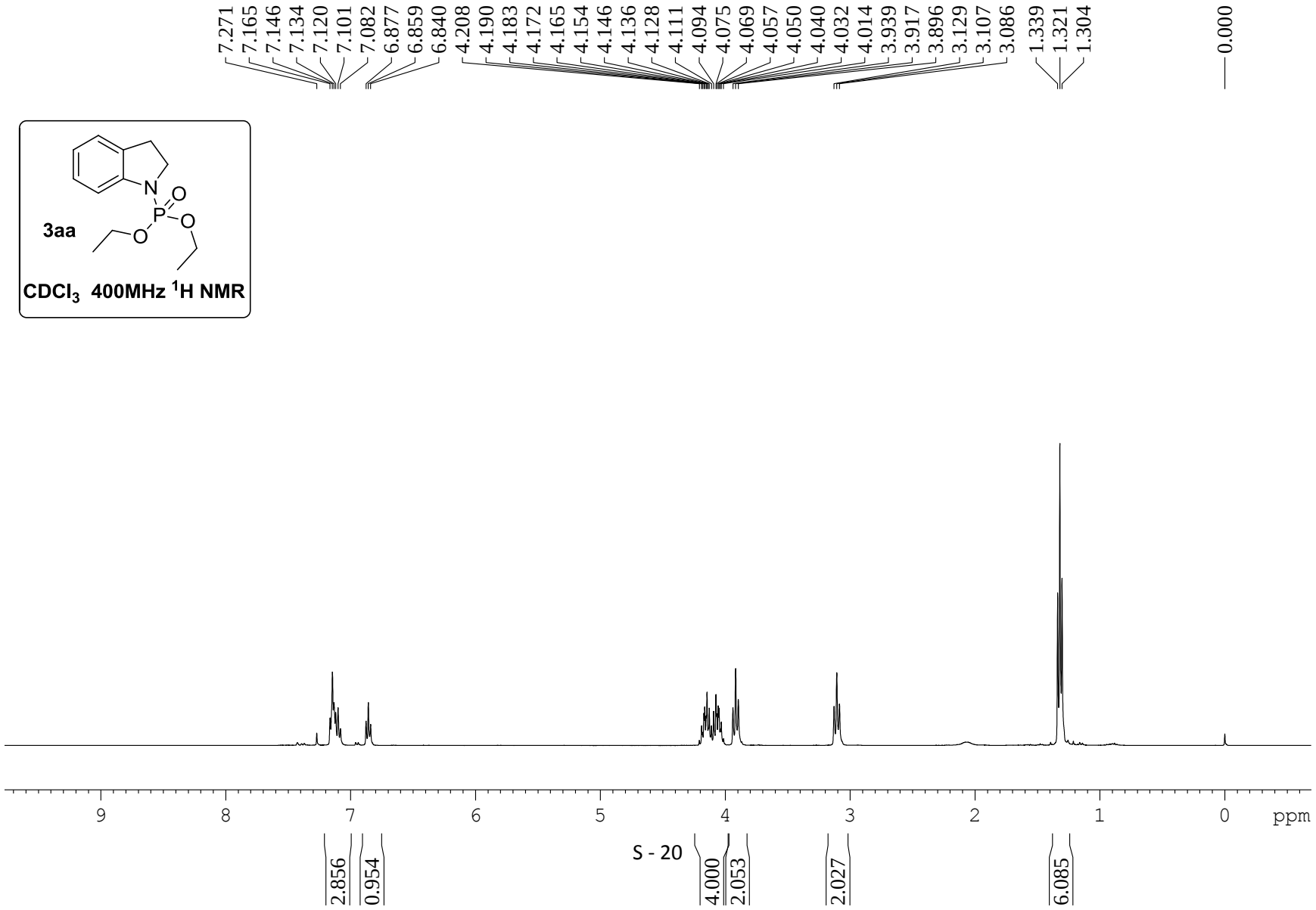
Diphenyl (S-methylsulfonimidoyl)benzene phosphoroamidate: Yellow oil; Yield - 35%; R_f (100% EtOAc) 0.2; Prepared as shown in general experimental procedure. **IR** (Neat, cm^{-1}): 3468, 2926, 1489, 1216, 1193, 1159, 929; **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.84 (d, *J* = 7.6 Hz, 2H), 7.66



(t, *J* = 4.0 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 2H), 7.33-7.23 (m, 8H), 7.15 (t, *J* = 6.8Hz, 2H), 3.32 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$): δ 151.2 (d, *J* = 8.6 Hz), 151.0, 139.9 (d, *J* = 9.3 Hz), 133.9, 129.5 (d, *J* = 10.9Hz), 129.4 (d, *J* = 2.7Hz), 127.1 (d, *J* = 9.1 Hz), 124.8, 120.7 (d, *J* = 4.9 Hz), 120.6 (d, *J* = 5.1Hz), 46.8 (d, *J* = 3.2 Hz); **^{31}P NMR** (162 MHz, $CDCl_3$); δ -12.172; **HRESI-MS** *(m/z)*: Calculated for $C_{19}H_{18}NO_4PS$ (M + Na): 410.0592, found (M + Na): 410.0590.

References:

1. Fraser, J.; Wilson, L. J.; Blundell, R. K.; Hayes, C. J. *Chem. Commun.* **2013**, *49*, 8919.
2. (a) Jones, S.; Selitsianos, D. *Org. Lett.* **2002**, *4*, 3671-3673. (b) Jones, S.; Selitsianos, D.; Thompson, K. J.; Toms, S. M. *J. Org. Chem.* **2003**, *68*, 5211-5216. (c) Jones, S.; Smanmoo, C. *Org. Lett.* **2005**, *7*, 3271. (d) Liu, C.-Y.; Pawar, V. D.; Kao, J.-Q.; Chen, C.-T. *Adv. Synth. Catal*. **2010**, *352*, 188–194.
3. Reinhard, B. M.; Licastro, S. A. *Molecules* **2005**, *10*, 1369.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7.146
7.134
7.120
7.101
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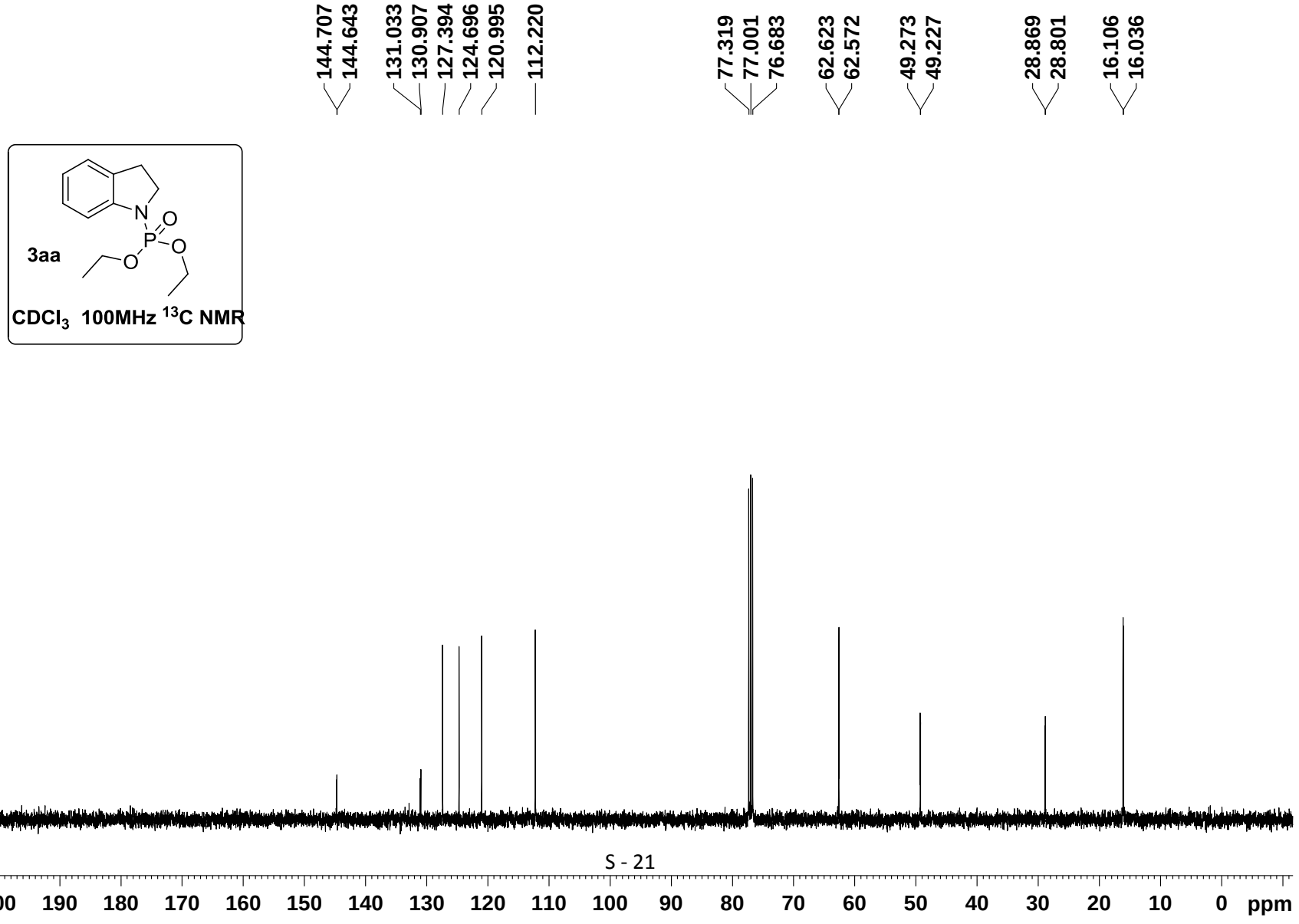
6.877
6.859
6.840
4.208
4.190
4.183
4.172
4.165
4.154
4.146
4.136
4.128
4.111
4.094
4.075
4.069
4.057
4.050
4.040
4.032
4.014
3.939
3.917
3.896
3.129
3.107
3.086
1.339
1.321
1.304
0.000
3aa
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.856
0.954
4.000
2.053
2.027
6.085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144.643
131.033
130.907
127.394
124.696
120.995
112.220
77.319
77.001
76.683
62.623
62.572
49.273
49.227
28.869
28.801
16.106
16.036
3aa
CDCl3 100MHz 13C NMR
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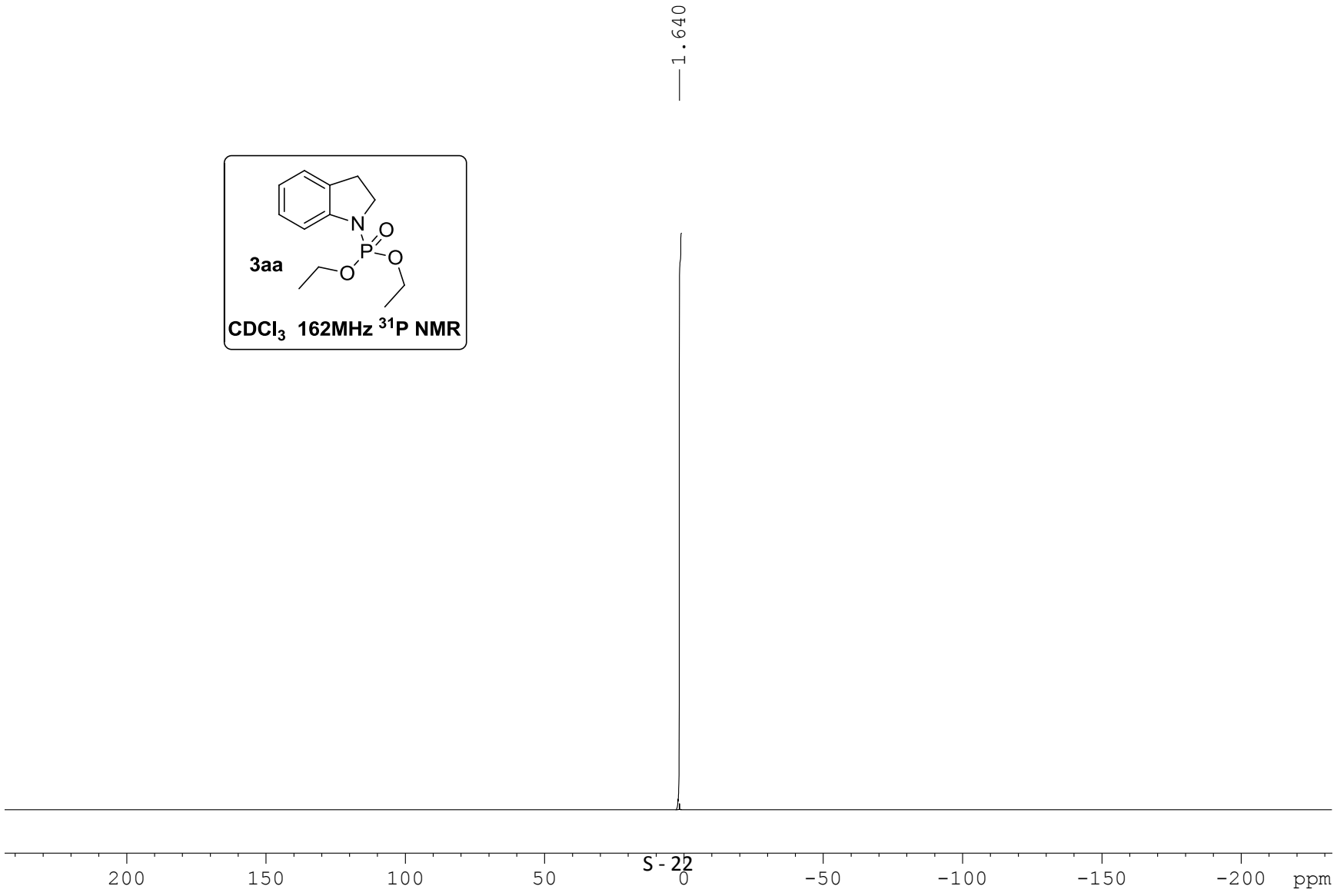
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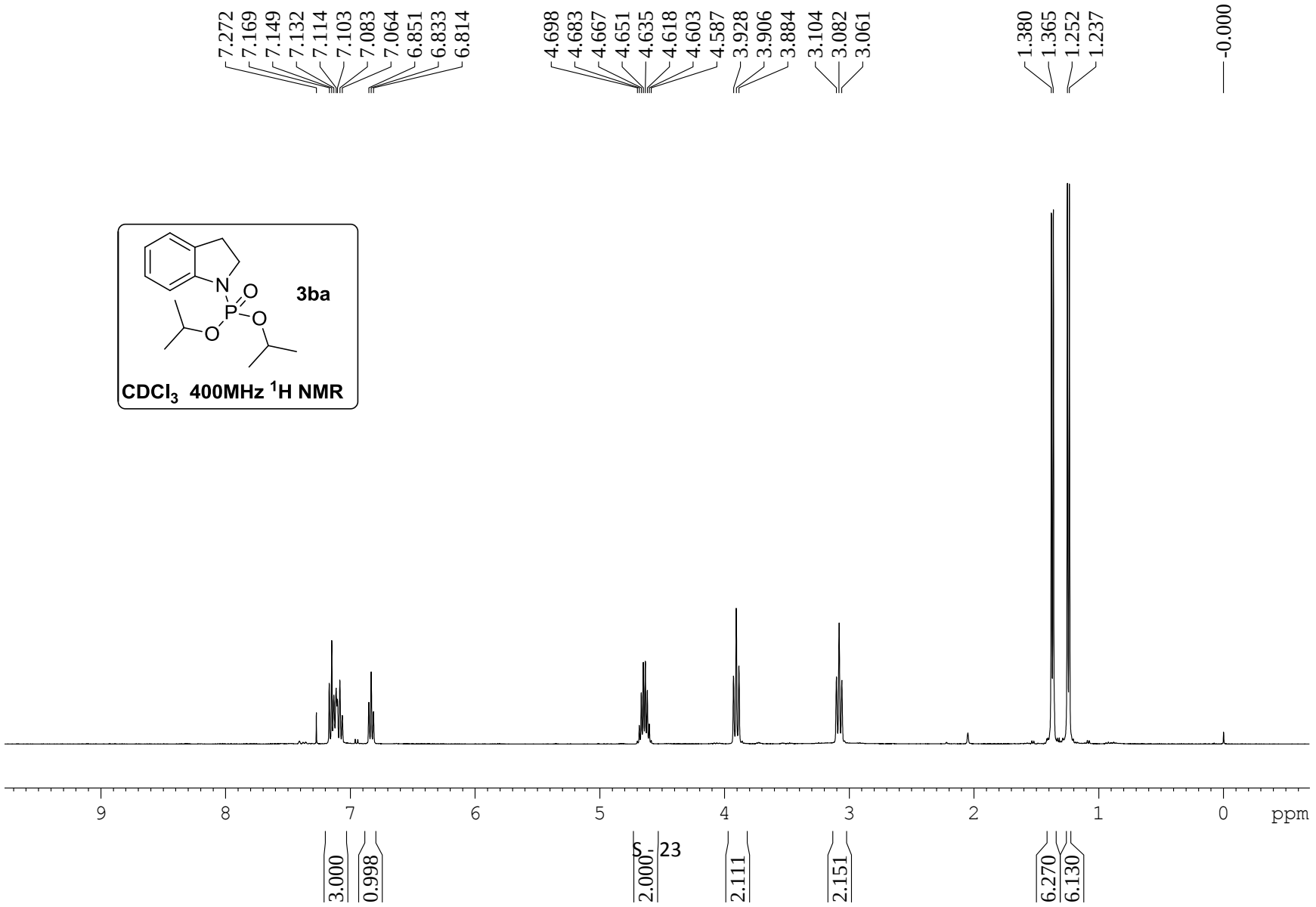
150
100
50
0
-50
-100
-150
-200
ppm


7.272
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7.149
7.132
7.114
7.103
7.083
7.064
6.851
6.833
6.814
4.698
4.683
4.667
4.651
4.635
4.618
4.603
4.587
3.928
3.906
3.884
3.104
3.082
3.061
1.380
1.365
1.252
1.237
-0.000
3ba
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
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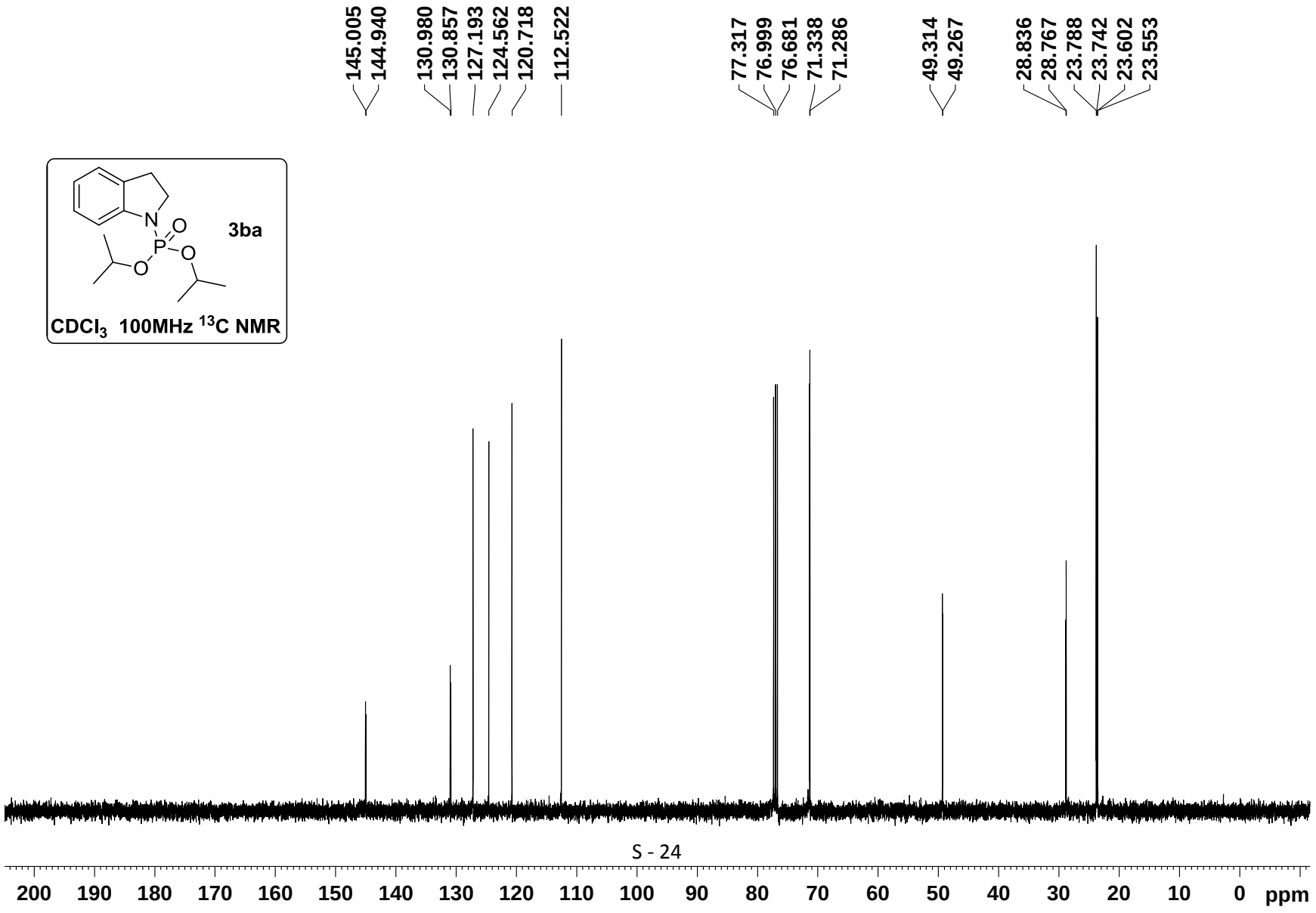
0.998
2.000
2.111
2.151
6.270
6.130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130.980
130.857
127.193
124.562
120.718
112.522
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76.999
76.681
71.338
71.286
49.314
49.267
28.836
28.767
23.788
23.742
23.602
23.553
3ba
CDCl3 100MHz 13C NMR
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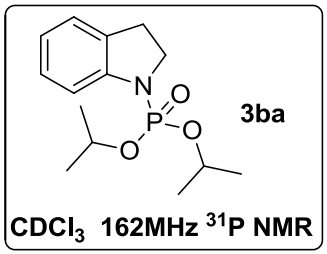
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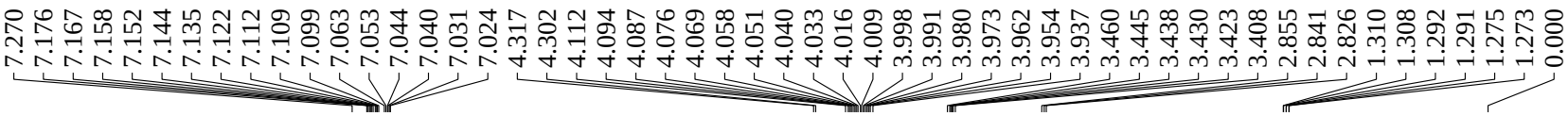
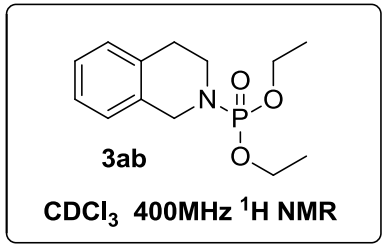
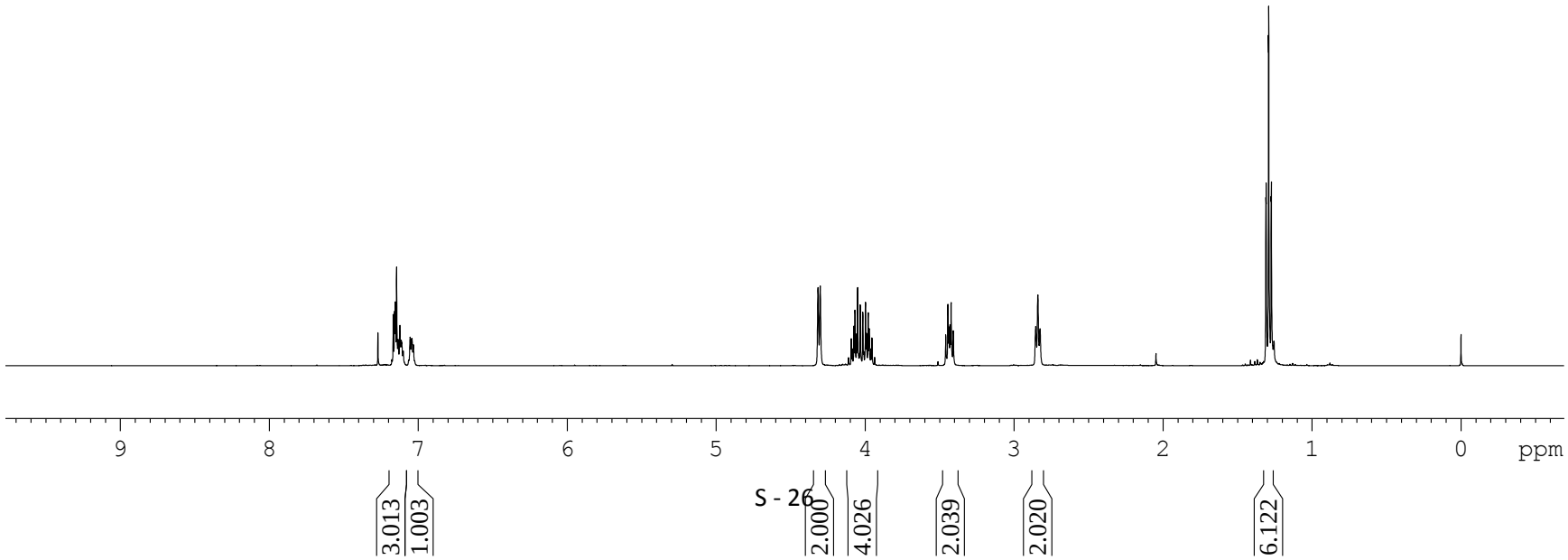
0
-50
-100
-150
-200
ppm

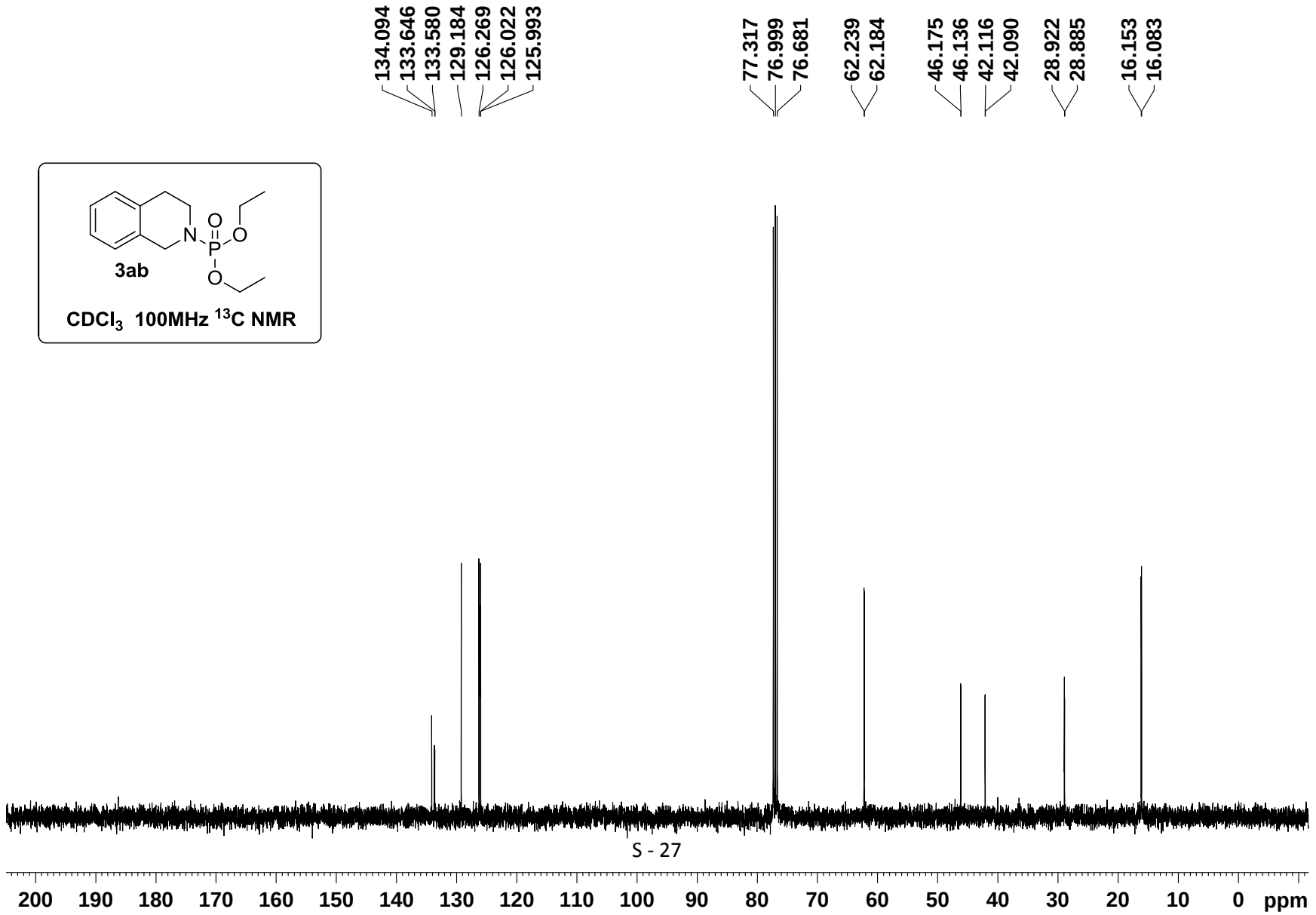




3ab

$CDCl_3$ 400MHz ^1H NMR

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129.184
126.269
126.022
125.993
77.317
76.999
76.681
62.239
62.184
46.175
46.136
42.116
42.090
28.922
28.885
16.153
16.083
3ab
CDCl3 100MHz 13C NMR
S - 27
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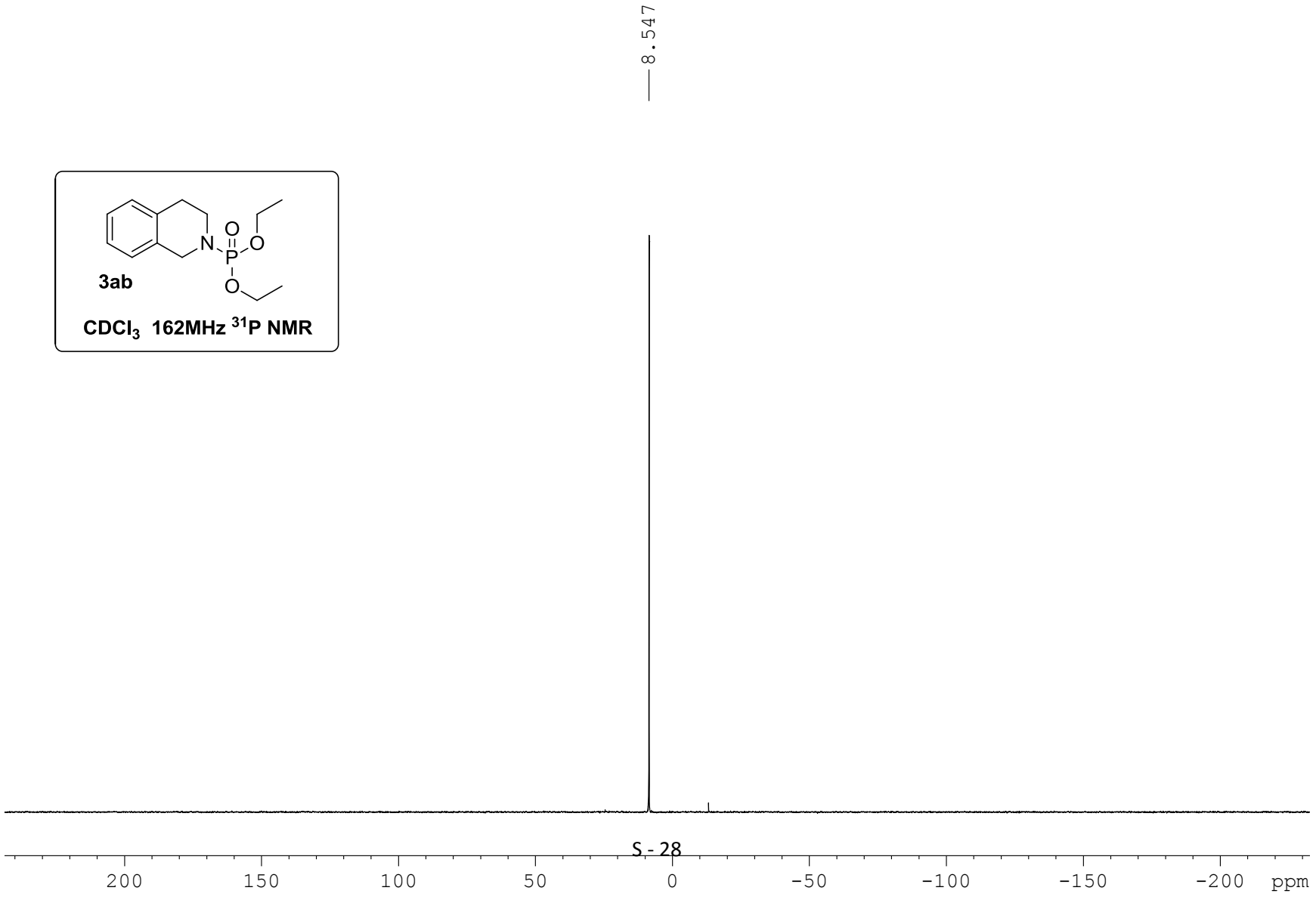
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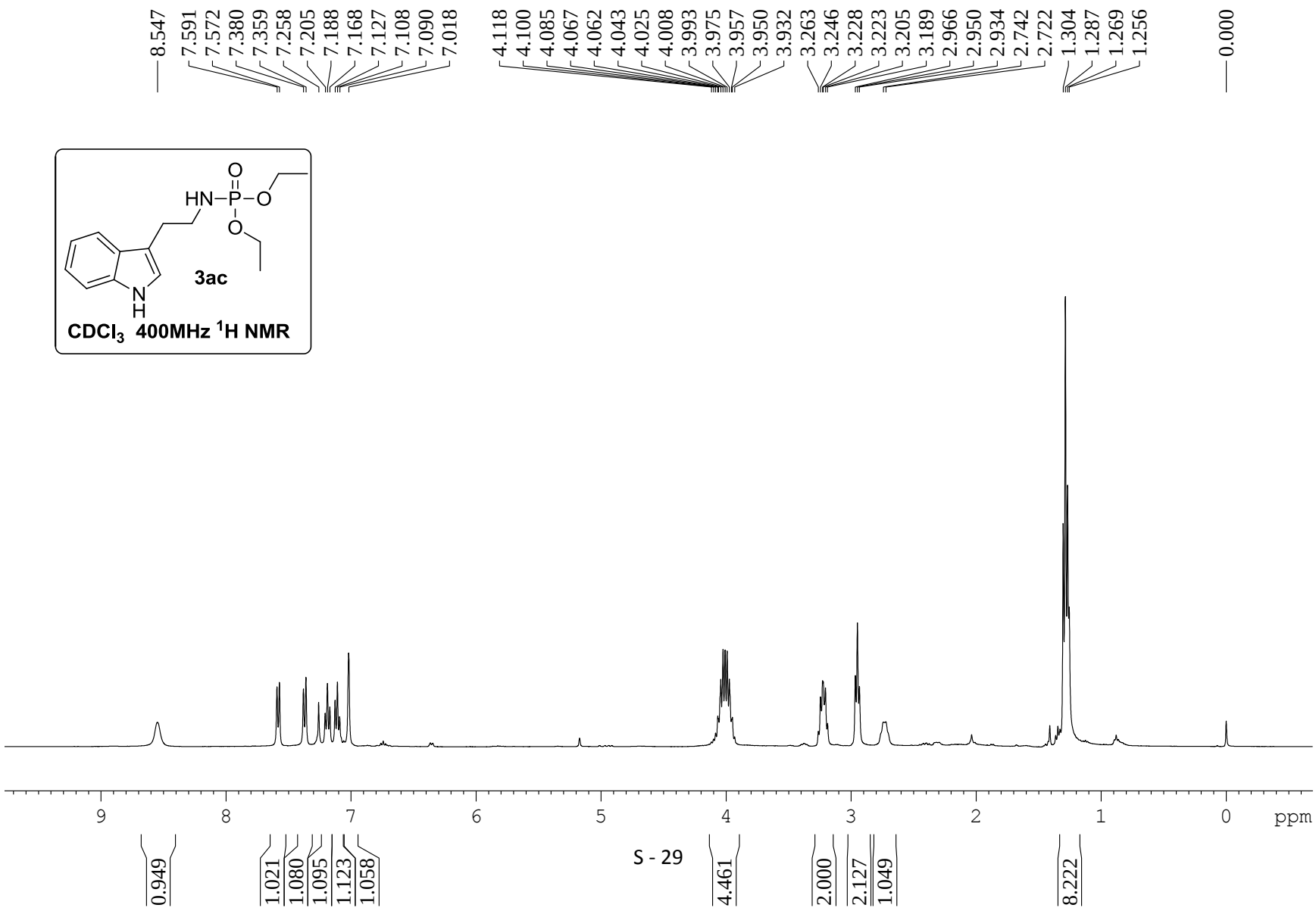
ppm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7.127
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7.018
4.118
4.100
4.085
4.067
4.062
4.043
4.025
4.008
3.993
3.975
3.957
3.950
3.932
3.263
3.246
3.228
3.223
3.205
3.189
2.966
2.950
2.934
2.742
2.722
1.304
1.287
1.269
1.256
0.000
HN
P
O
O
O
N
H
3ac
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
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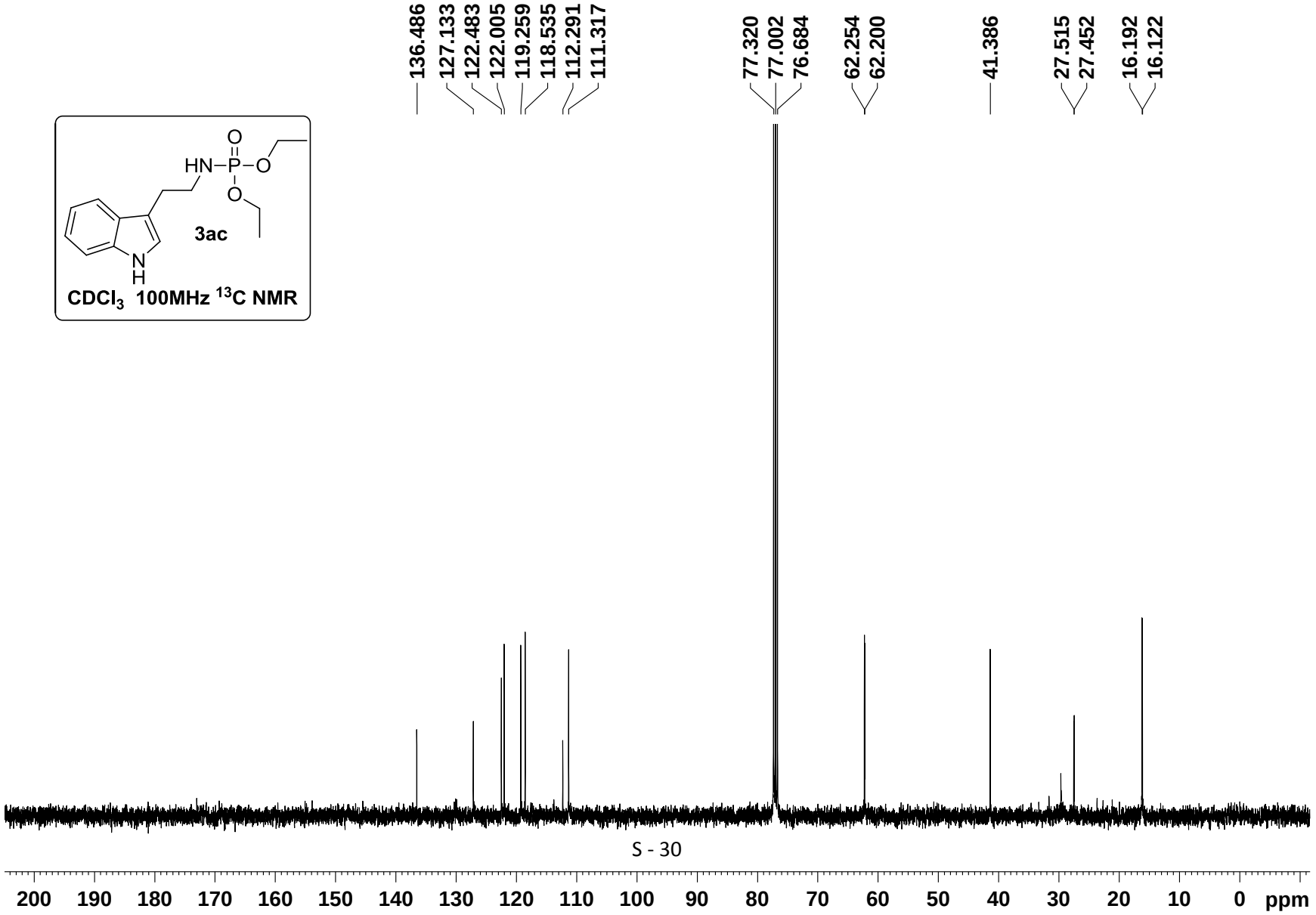
1.095
1.123
1.058
4.461
2.000
2.127
1.049
8.222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62.254
62.200
41.386
27.515
27.452
16.192
16.122
HN–P–O
O
O
3ac
N
H
CDCl3 100MHz 13C NMR
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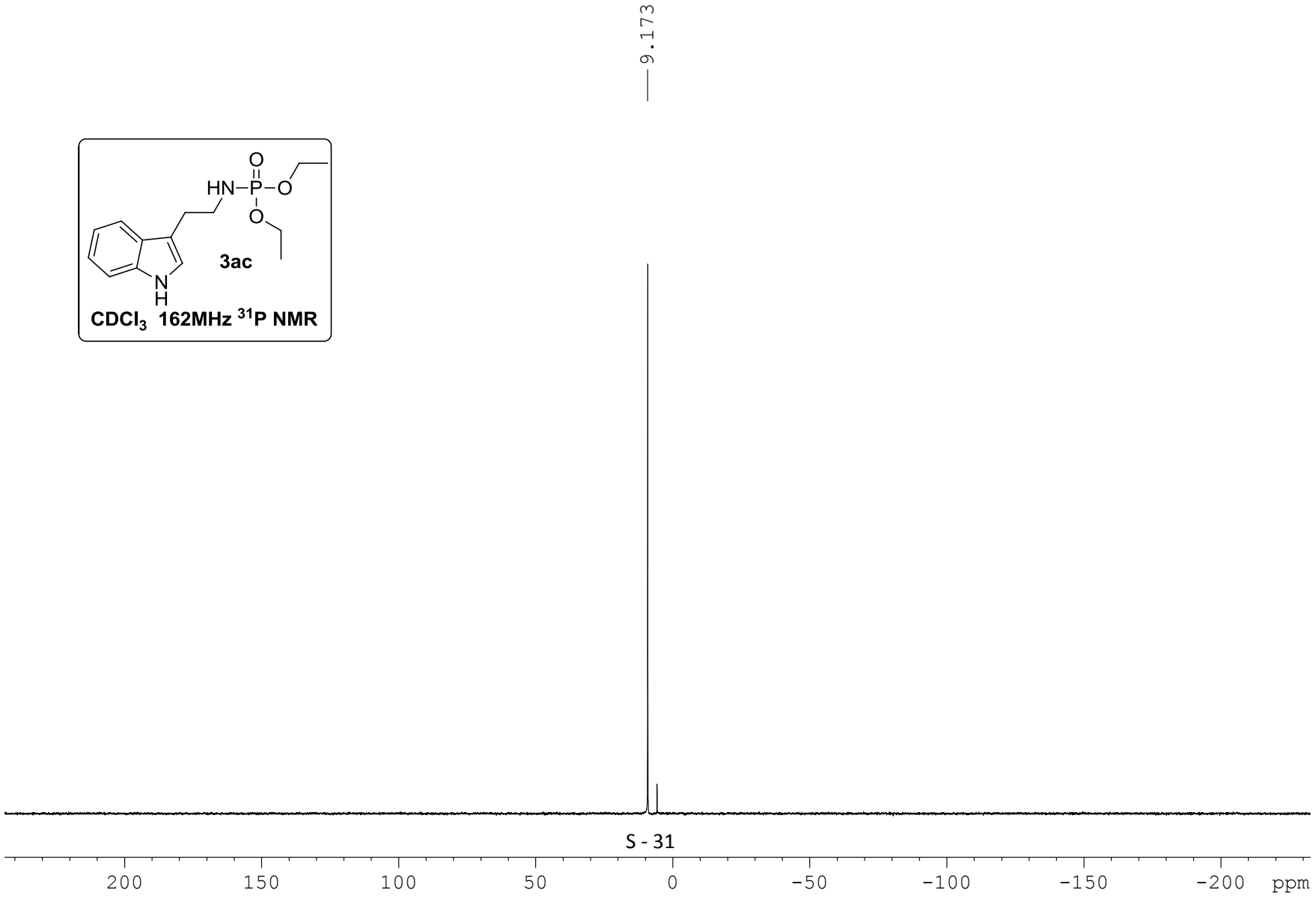
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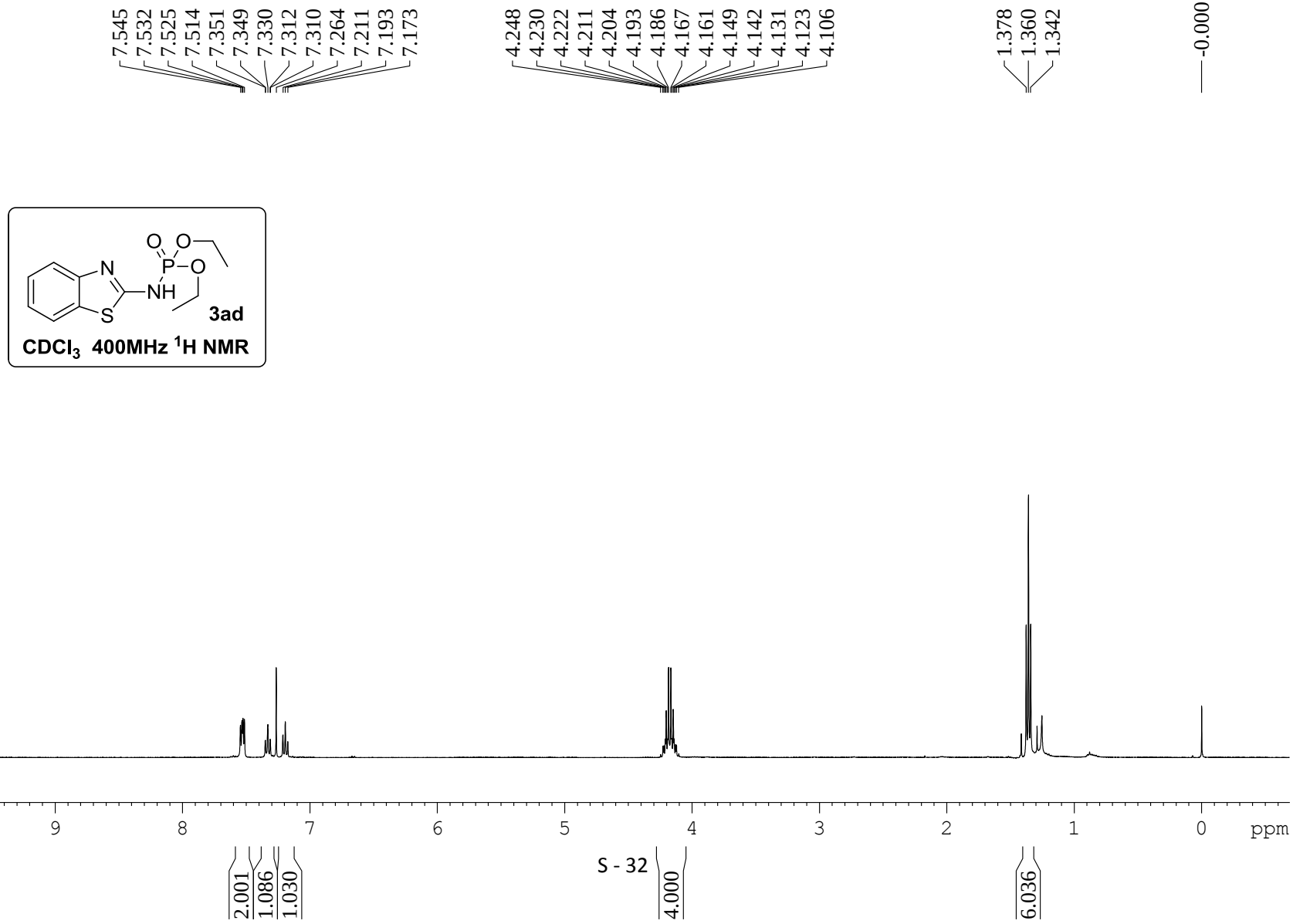
-200
ppm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7.264
7.211
7.193
7.173
4.248
4.230
4.222
4.211
4.204
4.193
4.186
4.167
4.161
4.149
4.142
4.131
4.123
4.106
1.378
1.360
1.342
-0.000
3ad
CDCl3 400MHz 1H NMR
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8
7
6
5
4
3
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ppm
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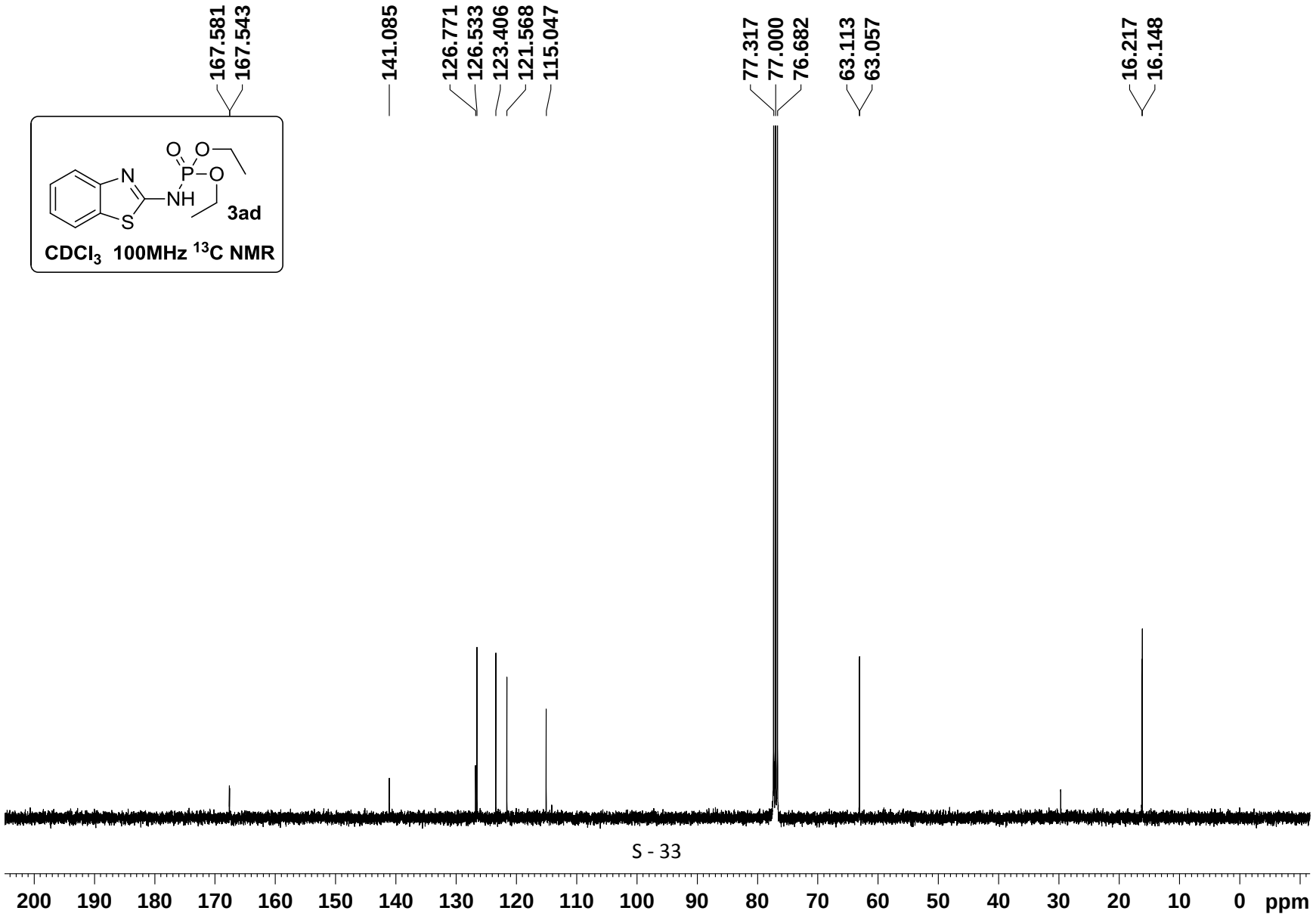
1.030
4.000
6.036
S - 32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77.317
77.000
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16.217
16.148
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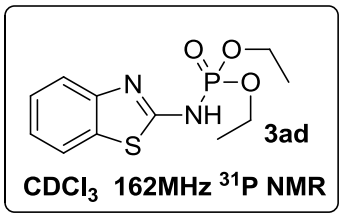
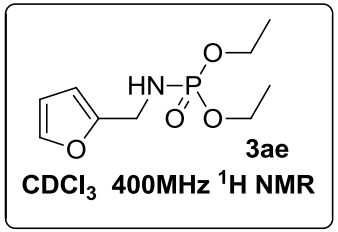
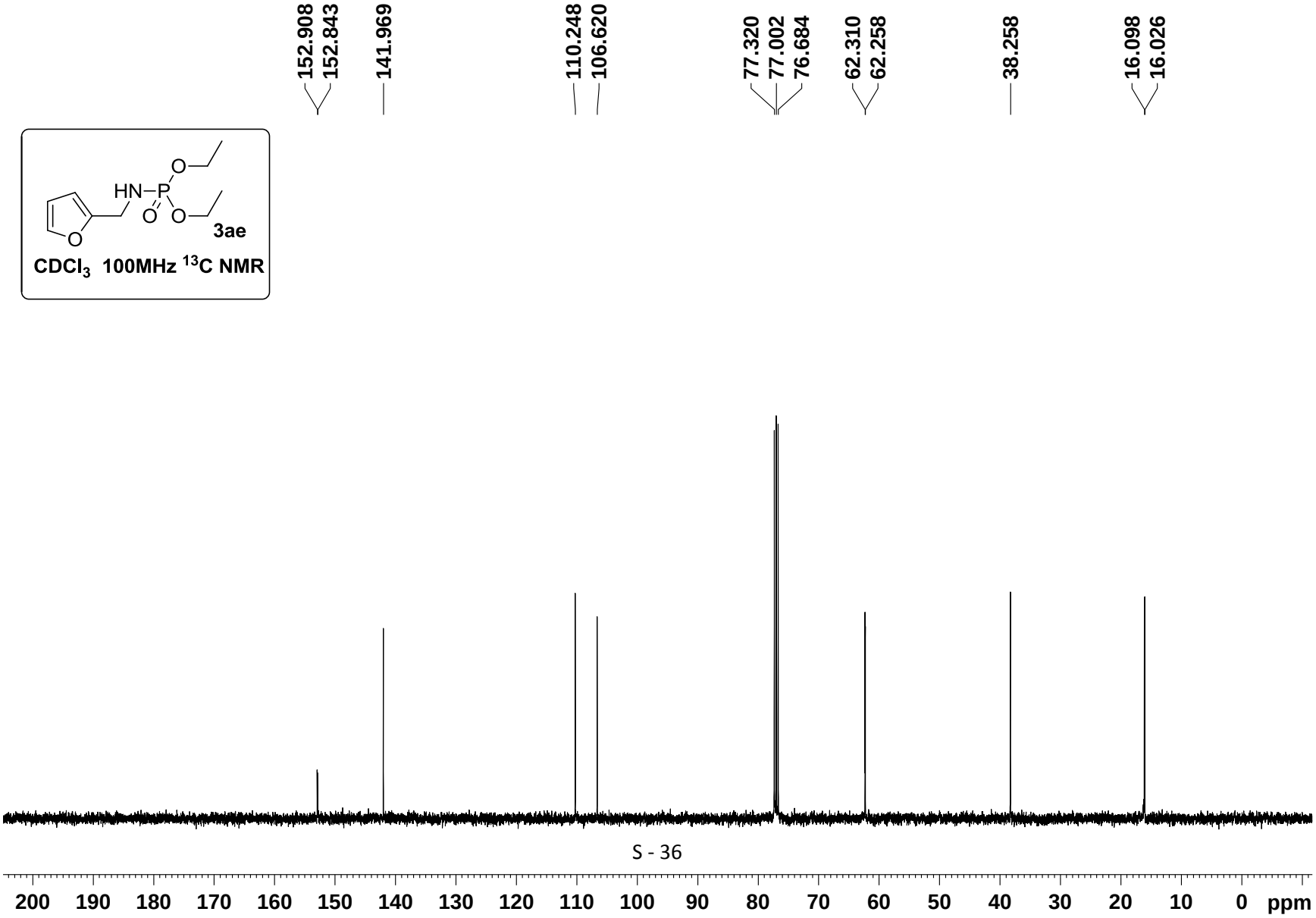
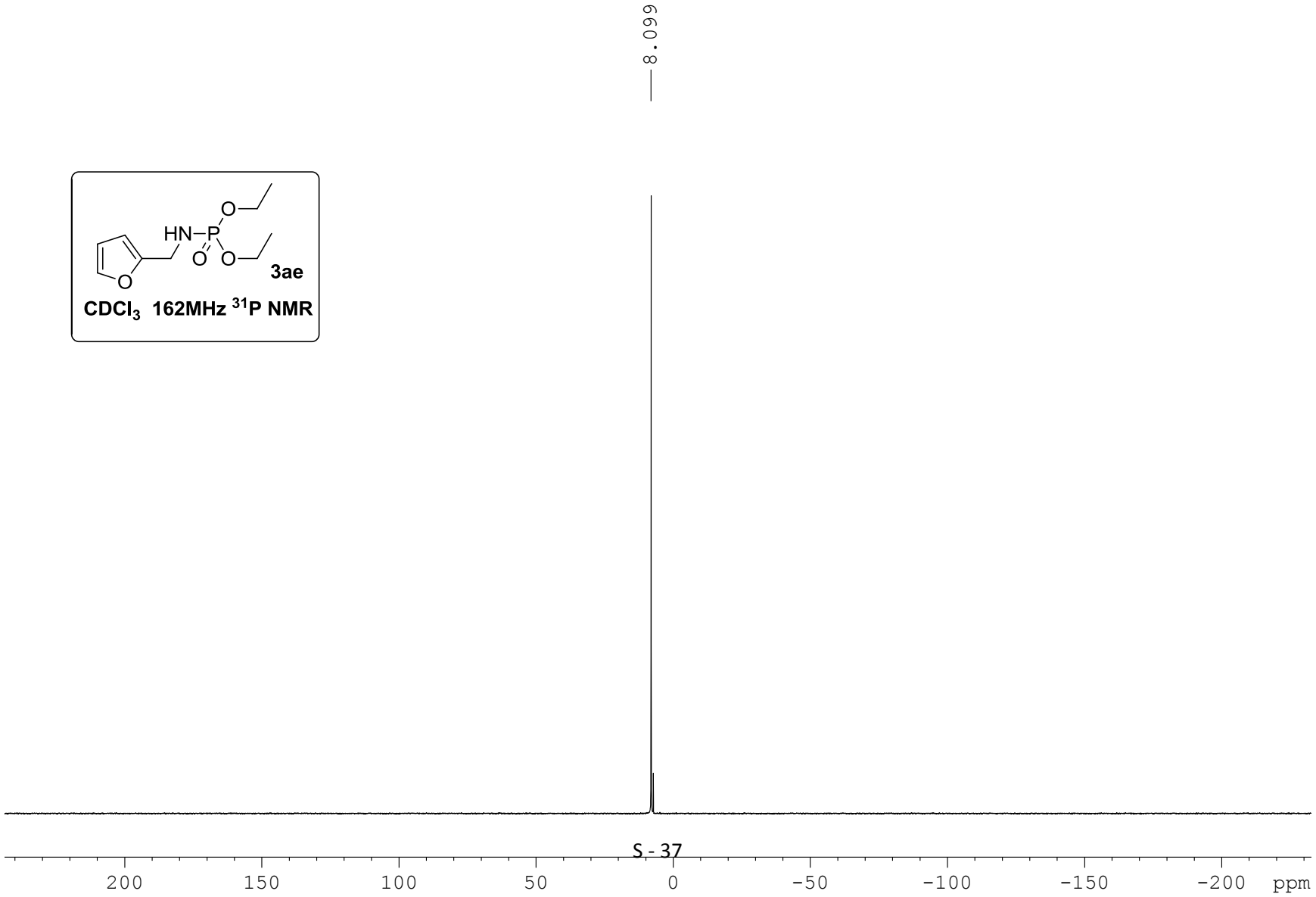


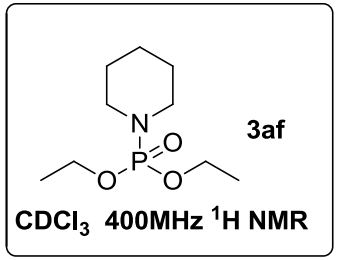
$CDCl_3$ 162MHz ^{31}P NMR


HN
P
O
O
O
O
O
3ae
CDCl3 400MHz 1H NMR

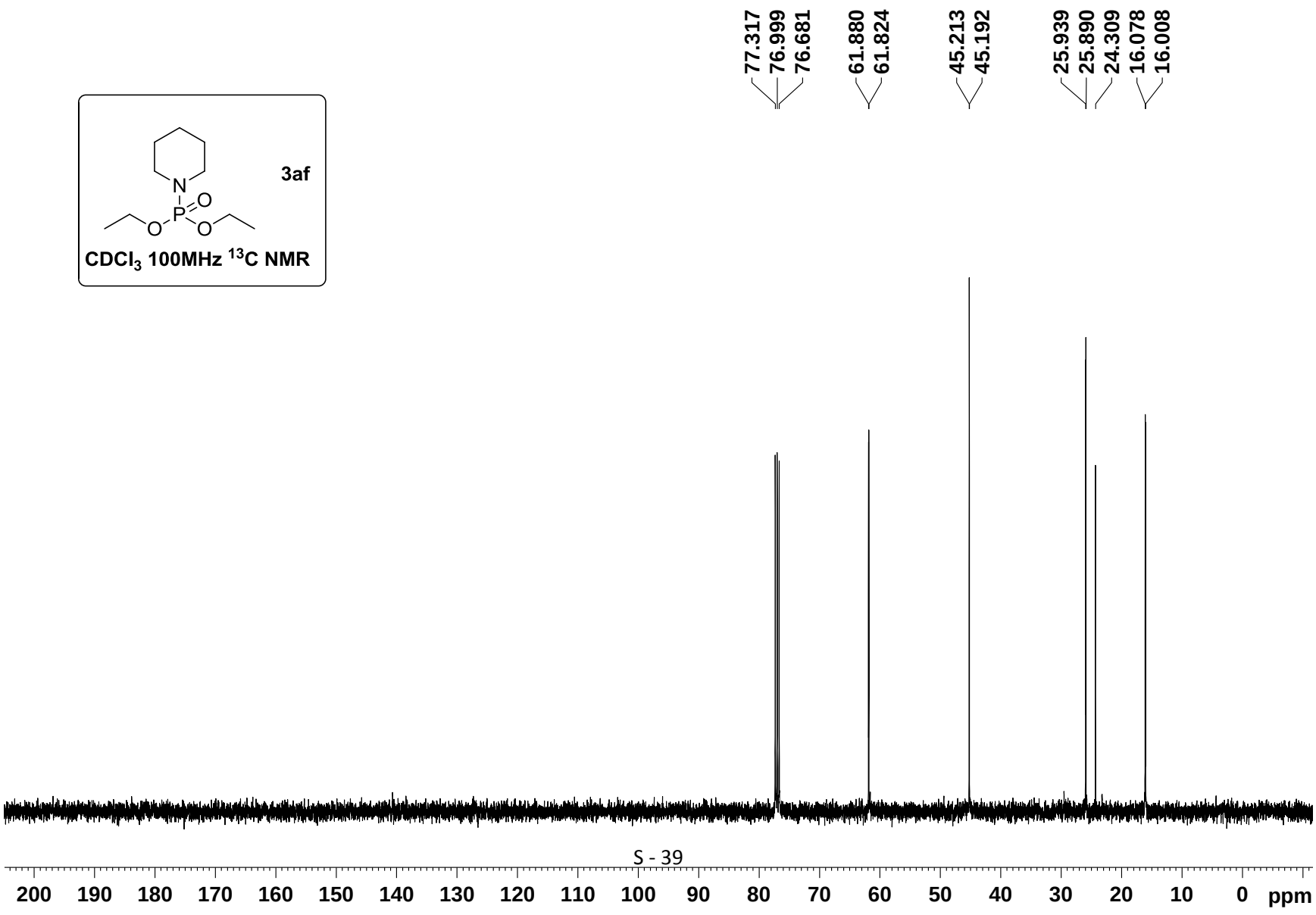
7.350
7.289
6.319
6.312
6.308
6.217
6.210
4.173
4.155
4.151
4.133
4.117
4.099
4.088
4.082
4.072
4.062
4.057
4.040
4.022
4.004
3.997
3.986
3.979
3.961
3.216
2.188
1.322
1.304
1.287
-0.000
9
8
7
6
5
4
3
2
1
0
ppm
0.936
1.903
6.000
0.952
6.014

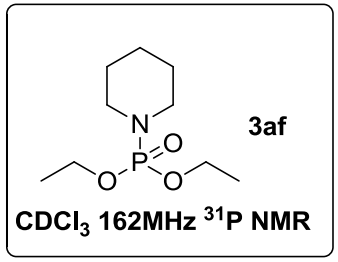

152.908
152.843
141.969
110.248
106.620
77.320
77.002
76.684
62.310
62.258
38.258
16.098
16.026
HN
P
O
O
O
O
3ae
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.099
3ae
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm


3af
CDCl3 400MHz 1H NMR

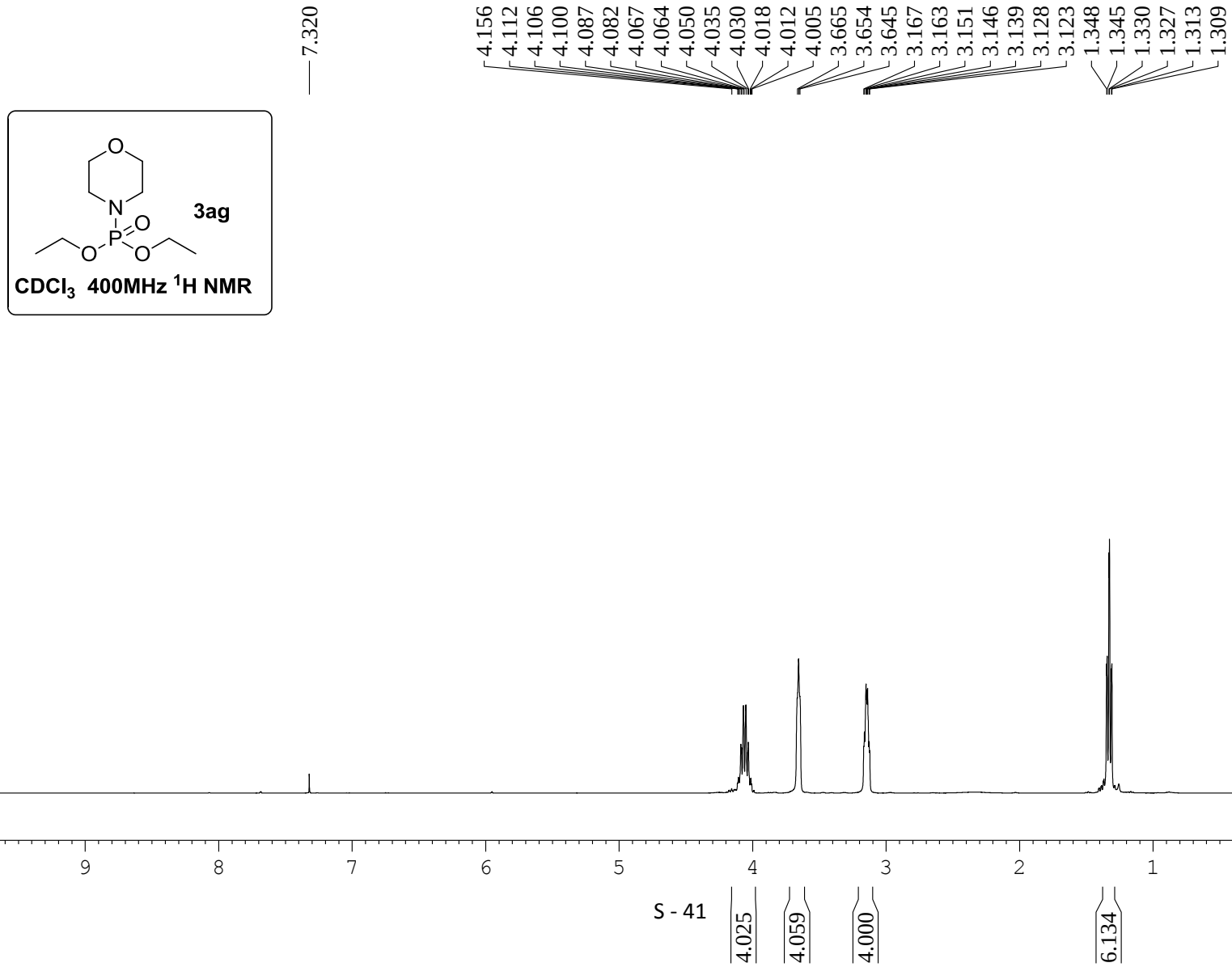
4.095
4.077
4.069
4.058
4.051
4.040
4.032
4.023
4.014
4.007
3.995
3.988
3.977
3.970
3.952
3.116
3.098
3.089
3.072
1.602
1.583
1.572
1.562
1.529
1.517
1.490
1.330
1.295
9
8
7
6
5
4
3
2
1
0
ppm
4.000
4.043
6.180
6.230

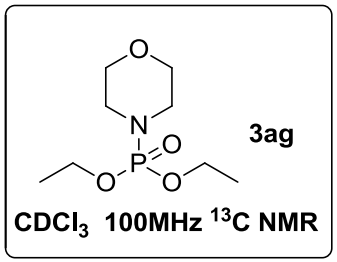

77.317
76.999
76.681
61.880
61.824
45.213
45.192
25.939
25.890
24.309
16.078
16.008
3af
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



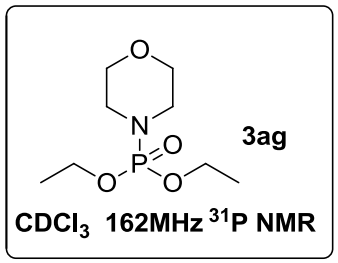
3af

$CDCl_3$ 162MHz ^{31}P NMR

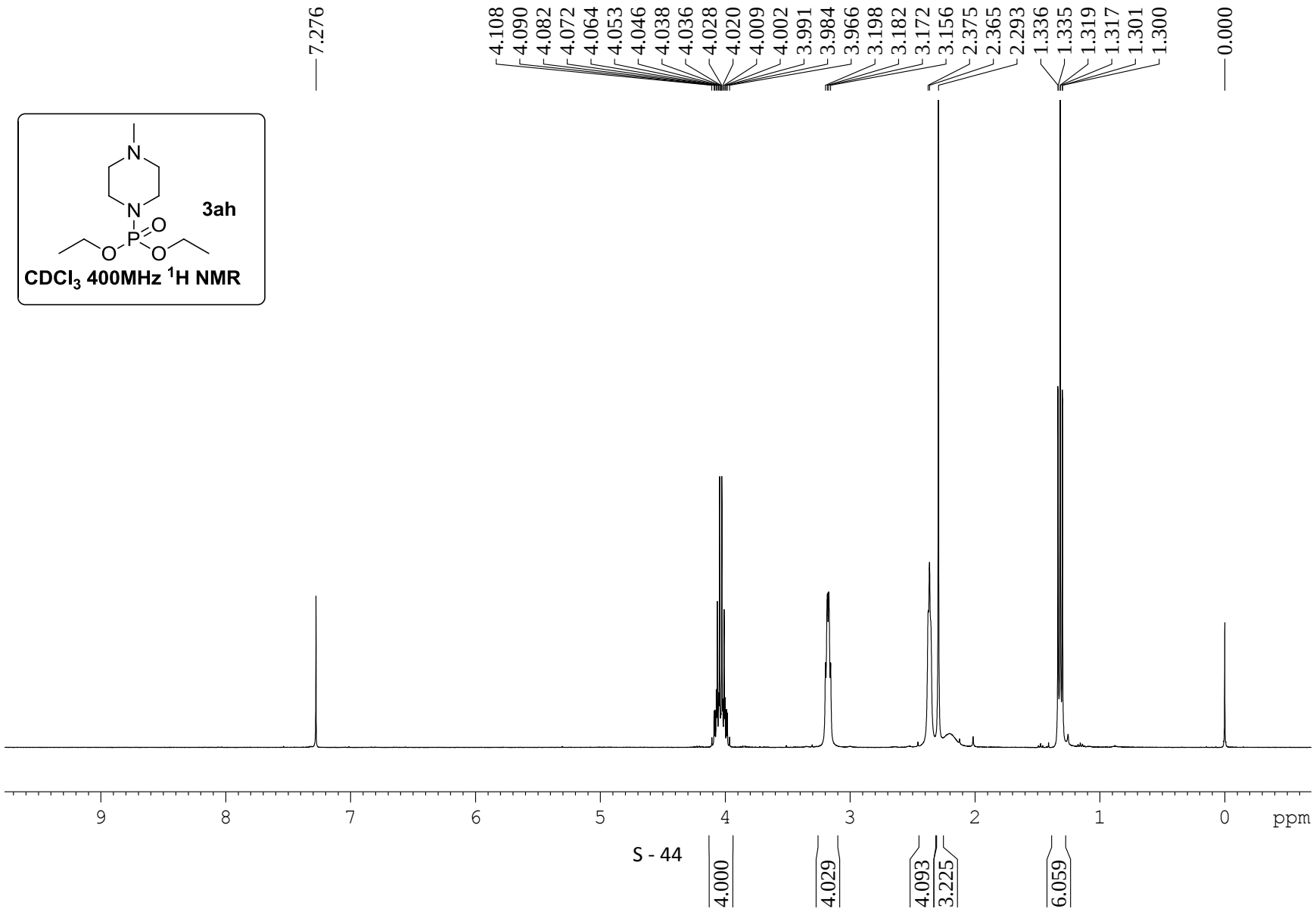

7.320
4.156
4.112
4.106
4.100
4.087
4.082
4.067
4.064
4.050
4.035
4.030
4.018
4.012
4.005
3.665
3.654
3.645
3.167
3.163
3.151
3.146
3.139
3.128
3.123
1.348
1.345
1.330
1.327
1.313
1.309
3ag
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.025
4.059
4.000
6.134

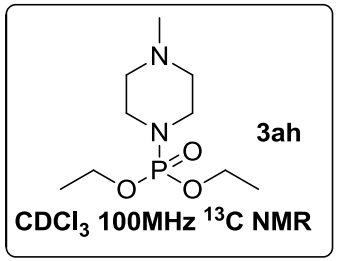

3ag
CDCl3 100MHz 13C NMR

77.319
77.000
76.682
66.936
66.879
62.326
62.270
44.484
16.118
16.050
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

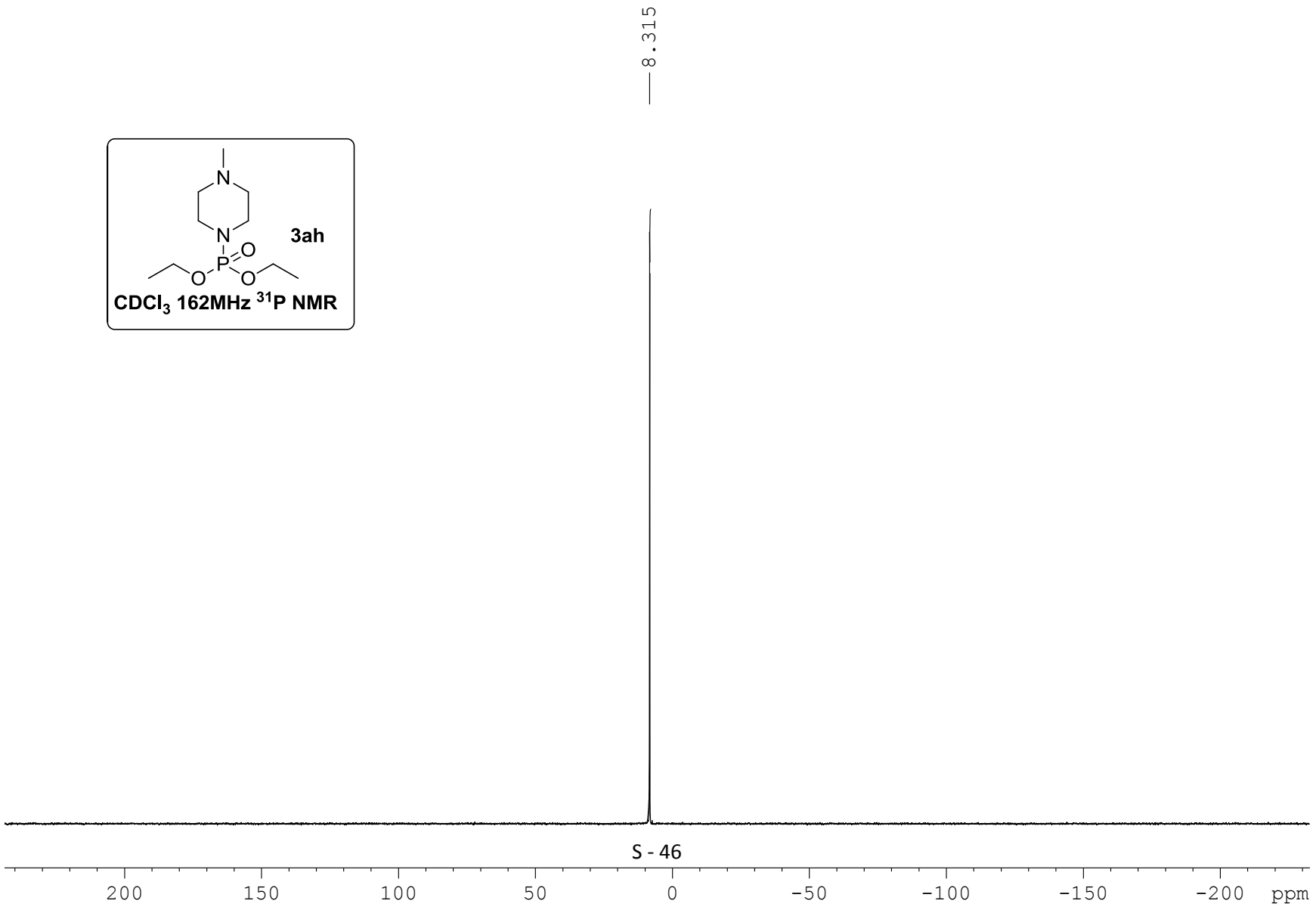


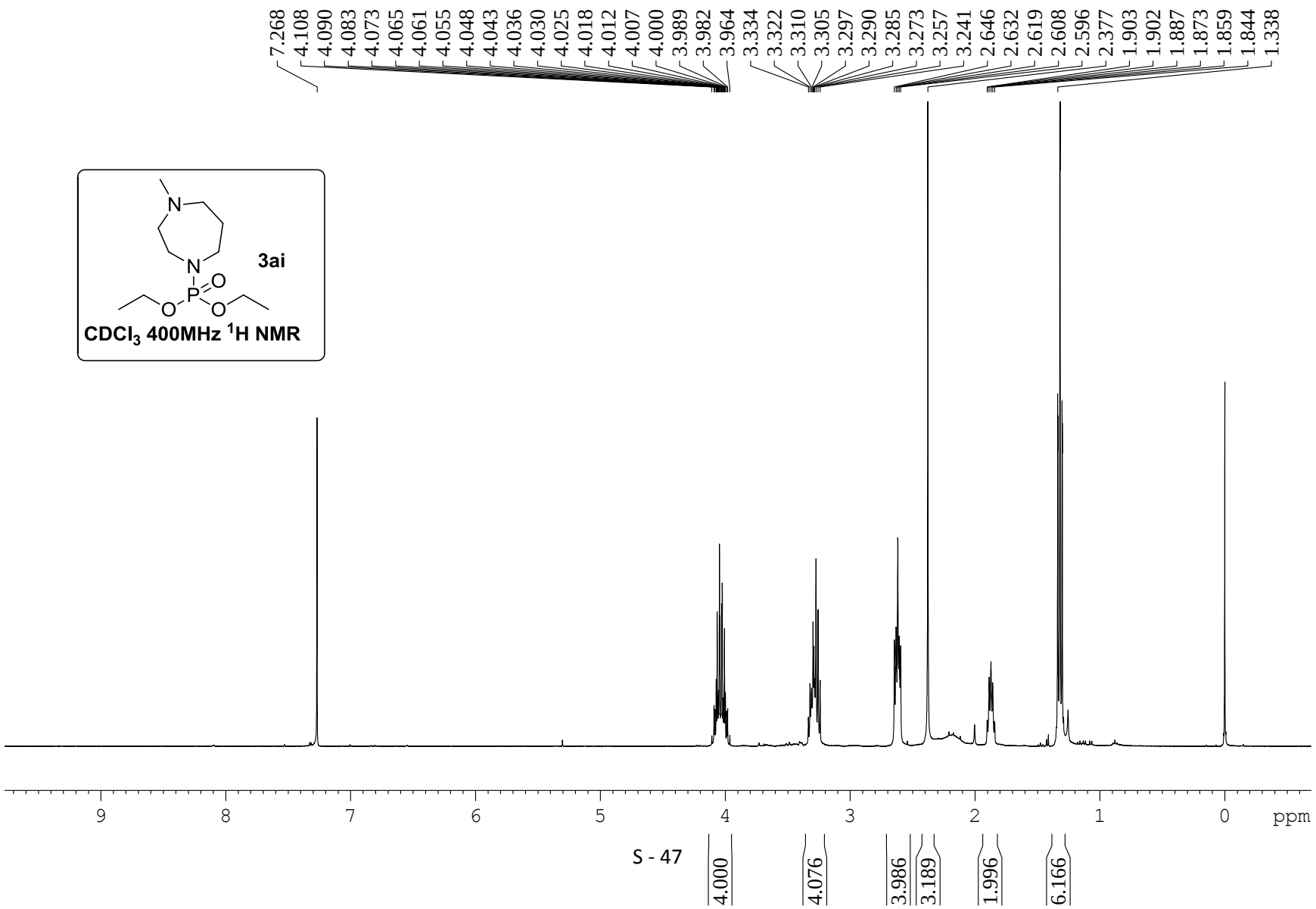
$CDCl_3$ 162MHz ^{31}P NMR


7.276
4.108
4.090
4.082
4.072
4.064
4.053
4.046
4.038
4.036
4.028
4.020
4.009
4.002
3.991
3.984
3.966
3.198
3.182
3.172
3.156
2.375
2.365
2.293
1.336
1.335
1.319
1.317
1.301
1.300
0.000
3ah
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.000
4.029
4.093
3.225
6.059


3ah
CDCl3 100MHz 13C NMR

77.319
77.001
76.682
62.107
62.051
54.998
54.941
46.222
44.181
44.167
16.074
16.004
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.315
3ah
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm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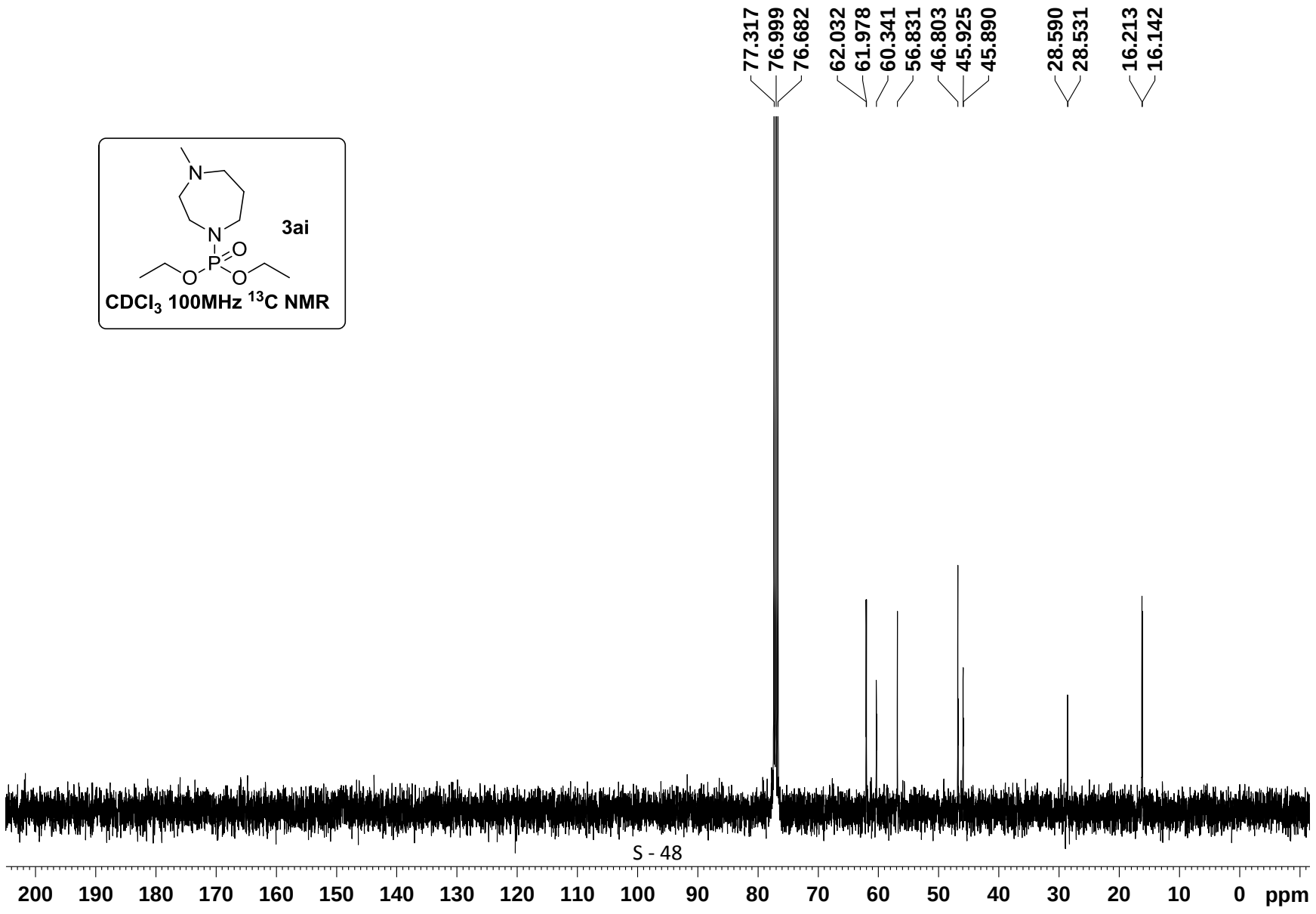
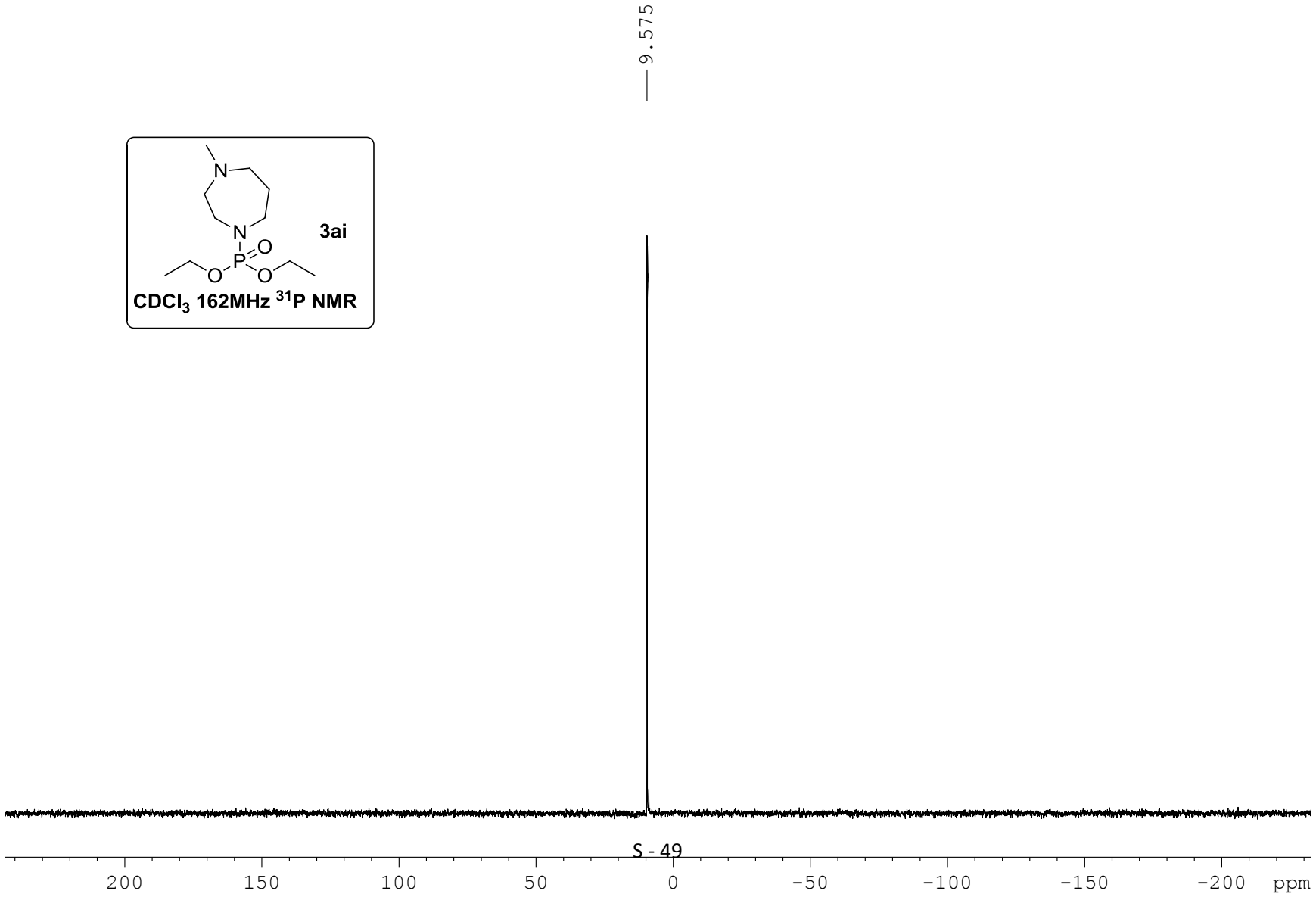
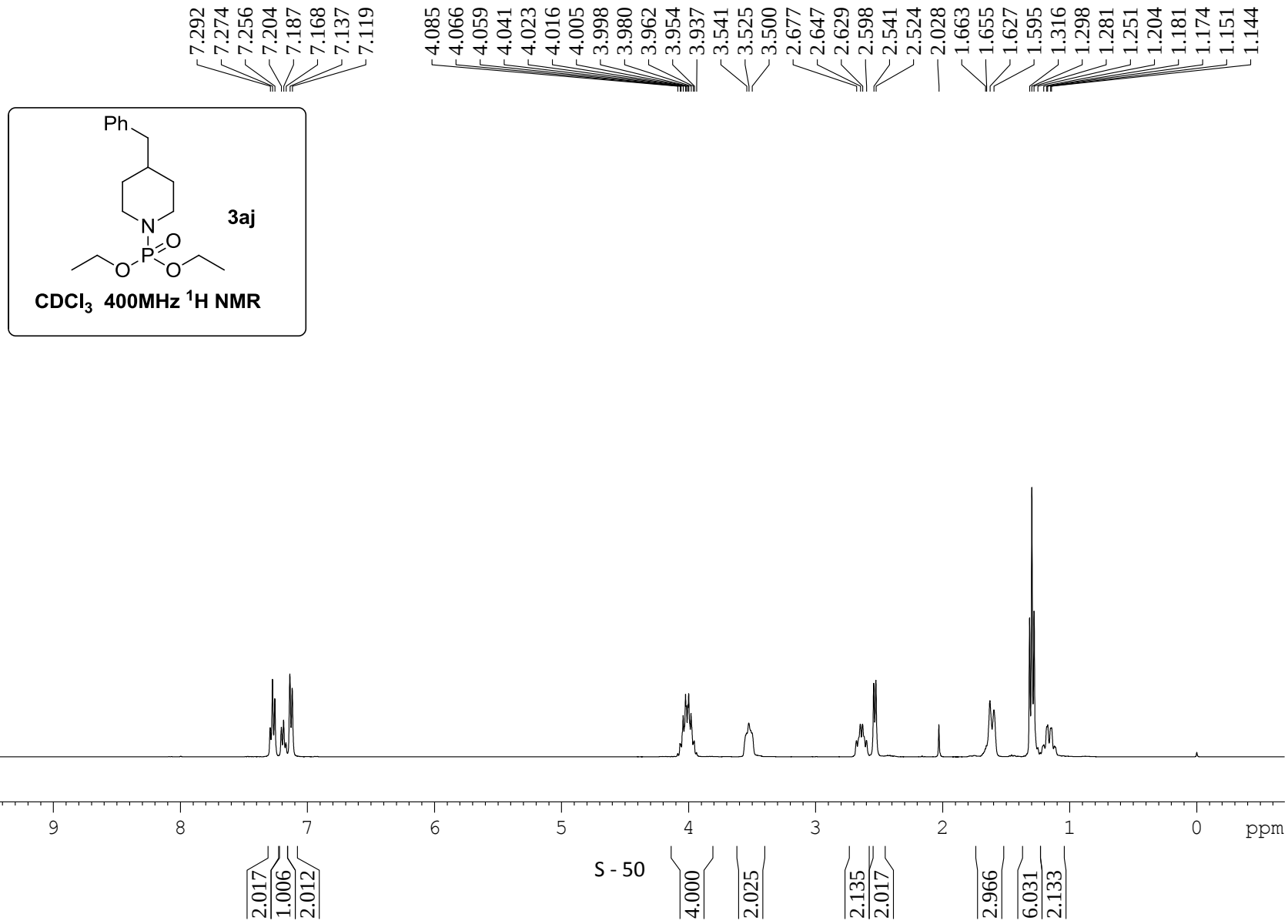
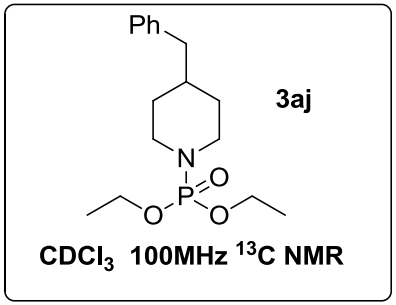
4.108
4.090
4.083
4.073
4.065
4.061
4.055
4.048
4.043
4.036
4.030
4.025
4.018
4.012
4.007
4.000
3.989
3.982
3.964
3.334
3.322
3.310
3.305
3.297
3.290
3.285
3.273
3.257
3.241
2.646
2.632
2.619
2.608
2.596
2.377
1.903
1.902
1.887
1.873
1.859
1.844
1.338
3ai
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.000
4.076
3.986
3.189
1.996
6.166


77.317
76.999
76.682
62.032
61.978
60.341
56.831
46.803
45.925
45.890
28.590
28.531
16.213
16.142
3ai
CDCl3 100MHz 13C NMR
S - 48
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

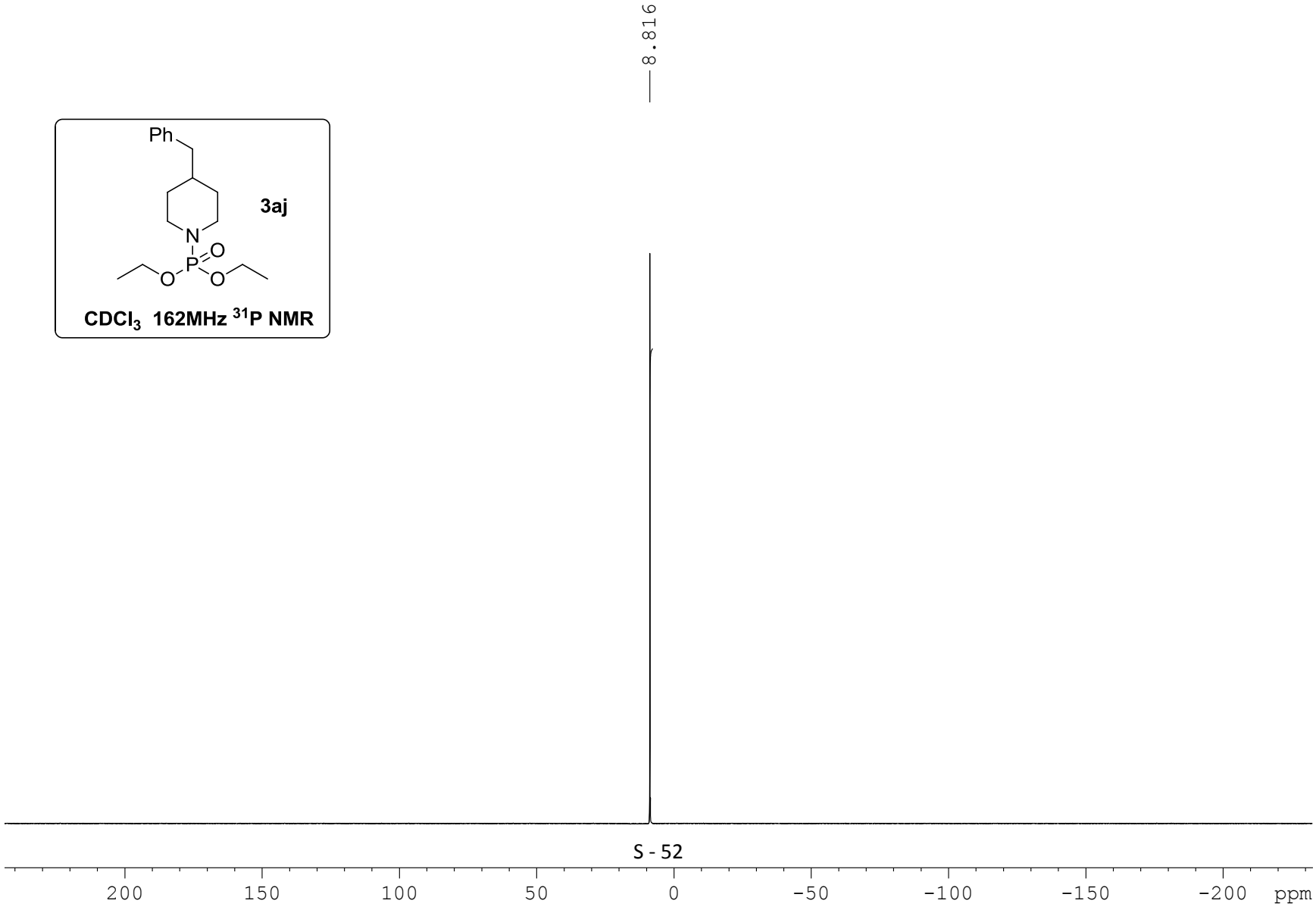

9.575
3ai
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

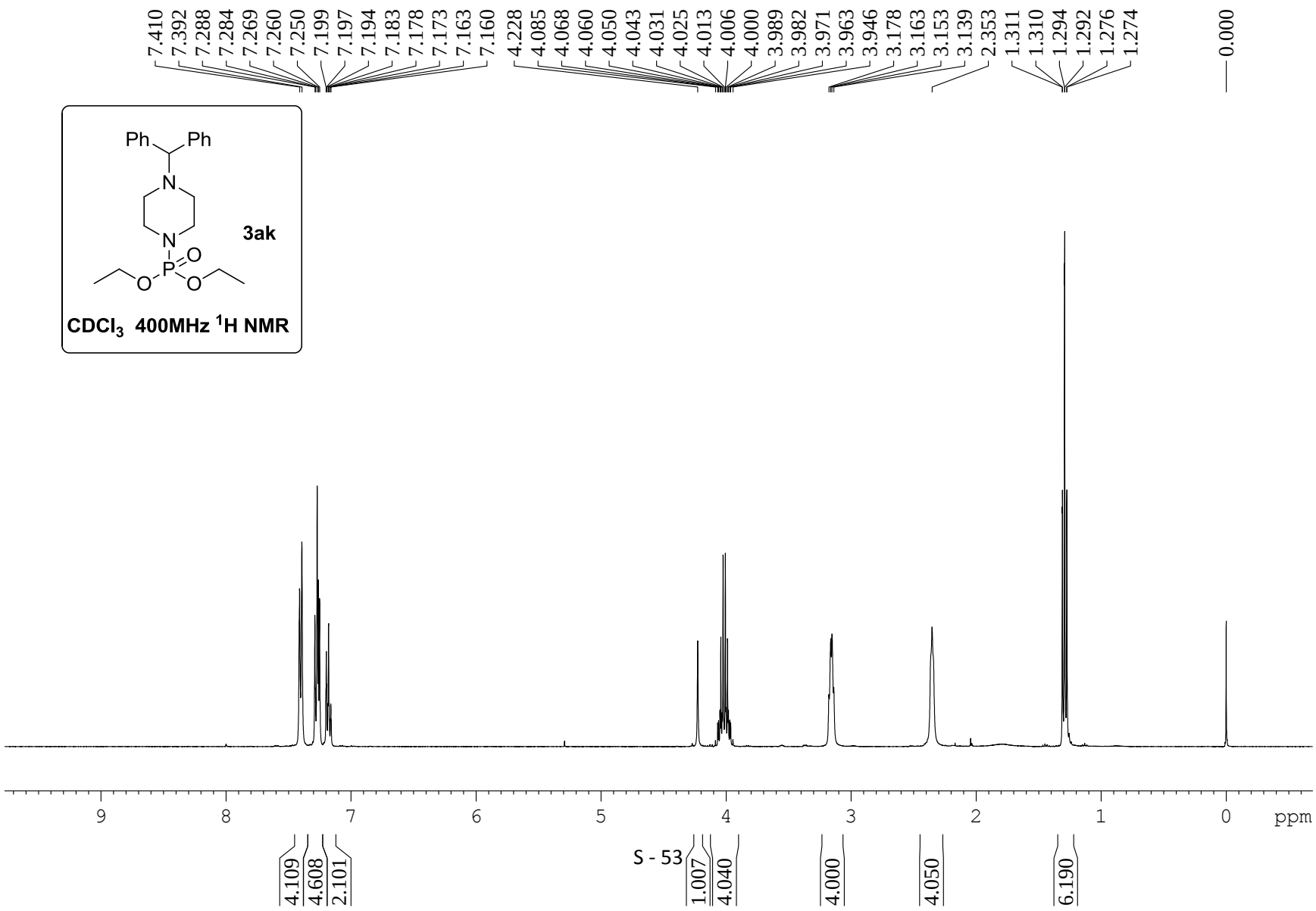

7.292
7.274
7.256
7.204
7.187
7.168
7.137
7.119
4.085
4.066
4.059
4.041
4.023
4.016
4.005
3.998
3.980
3.962
3.954
3.937
3.541
3.525
3.500
2.677
2.647
2.629
2.598
2.541
2.524
2.028
1.663
1.655
1.627
1.595
1.316
1.298
1.281
1.251
1.204
1.181
1.174
1.151
1.144
Ph
N
P
O
O
O
3aj
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.017
1.006
2.012
4.000
2.025
2.135
2.017
2.966
6.031
2.133

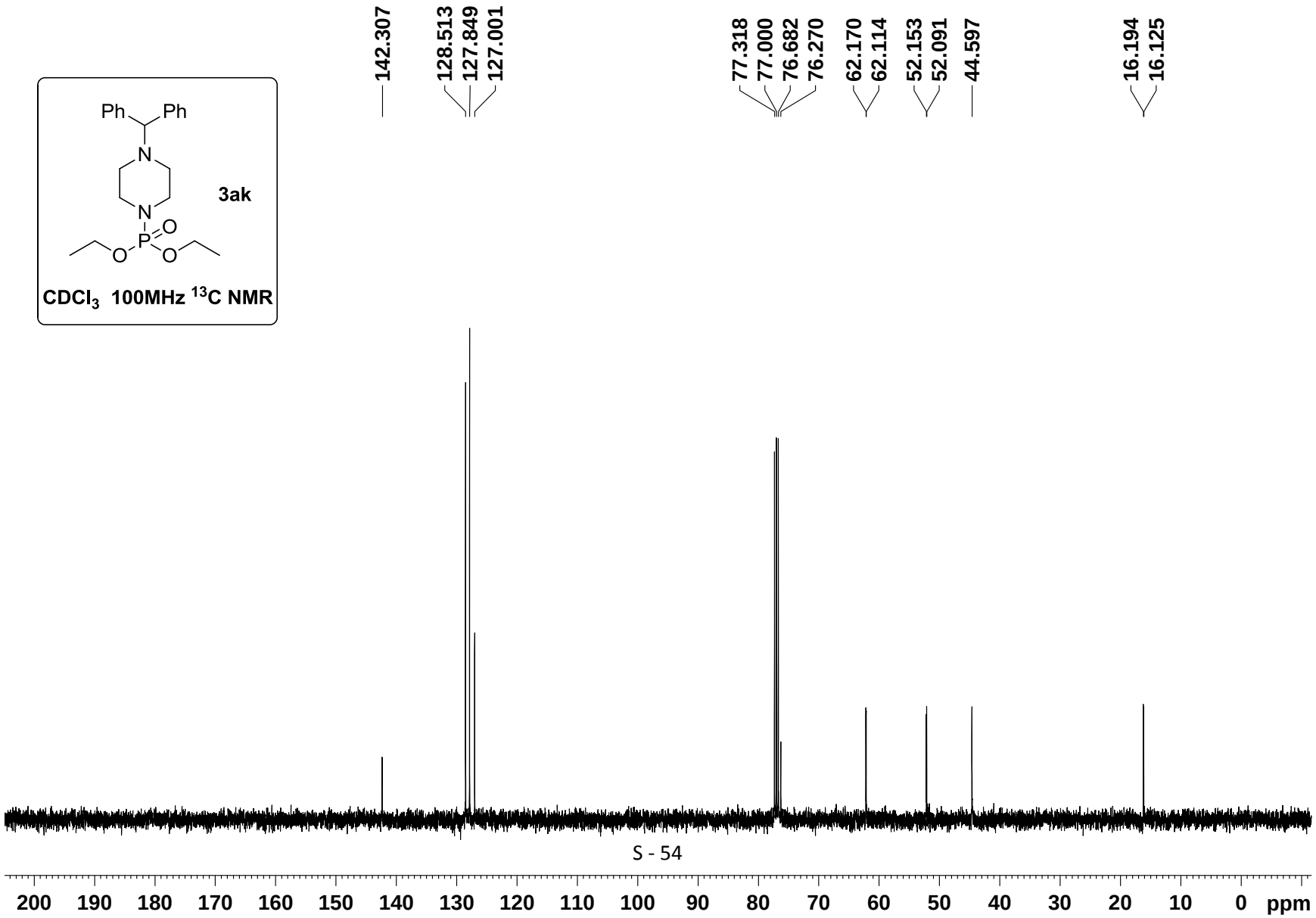
S - 50


Ph
N
P
O
O
O
3aj
CDCl3 100MHz 13C NMR

139.958
128.971
128.084
125.793
77.318
76.999
76.681
62.021
61.965
44.710
44.686
43.230
37.959
32.262
32.210
16.107
16.036
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


8.816
Ph
3aj
N
P
O
O
O
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm


7.410
7.392
7.288
7.284
7.269
7.260
7.250
7.199
7.197
7.194
7.183
7.178
7.173
7.163
7.160
4.228
4.085
4.068
4.060
4.050
4.043
4.031
4.025
4.013
4.006
4.000
3.989
3.982
3.971
3.963
3.946
3.178
3.163
3.153
3.139
2.353
1.311
1.310
1.294
1.292
1.276
1.274
0.000
Ph
Ph
N
N
P
O
O
O
3ak
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.109
4.608
2.101
S - 53
1.007
4.040
4.000
4.050
6.190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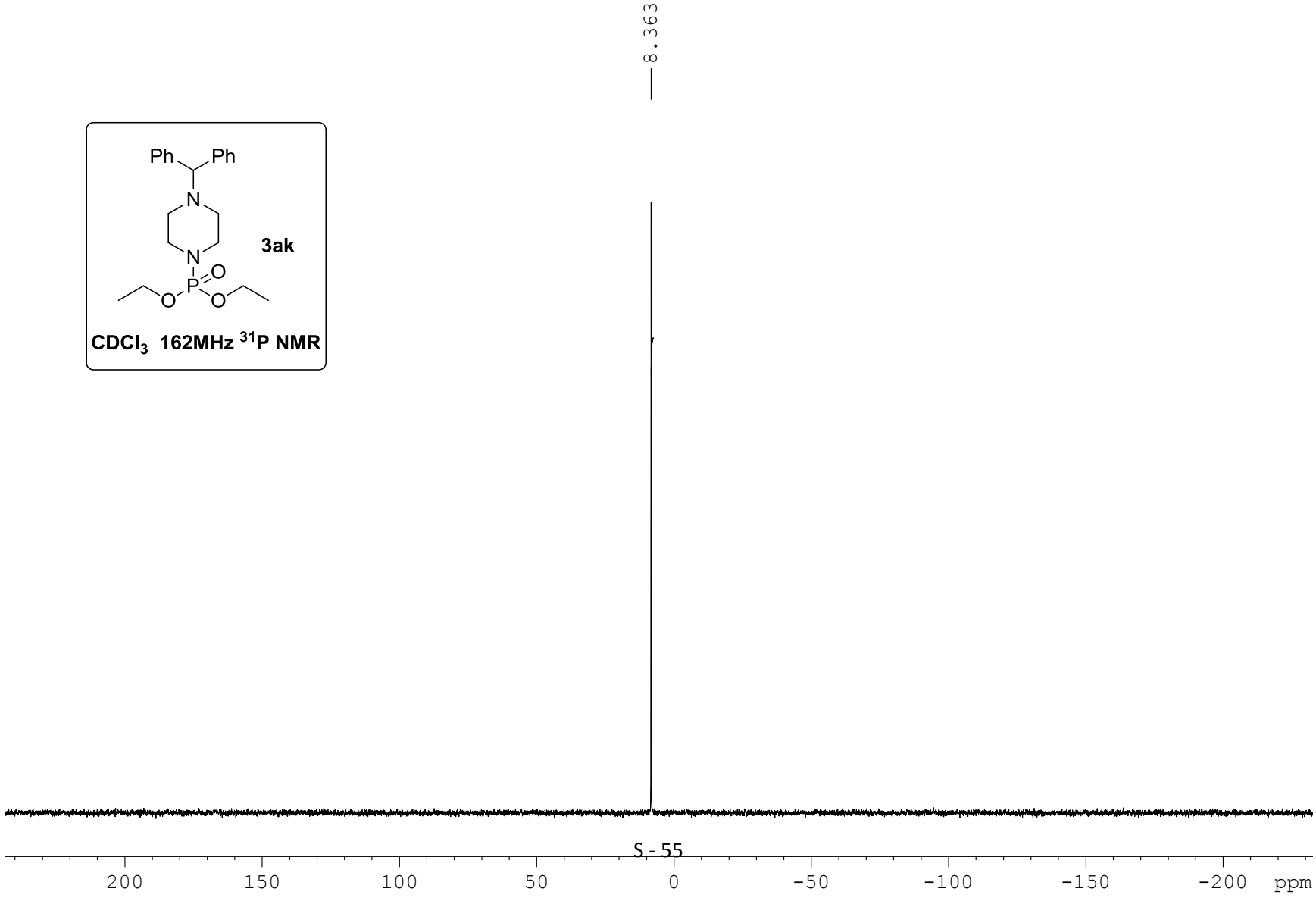
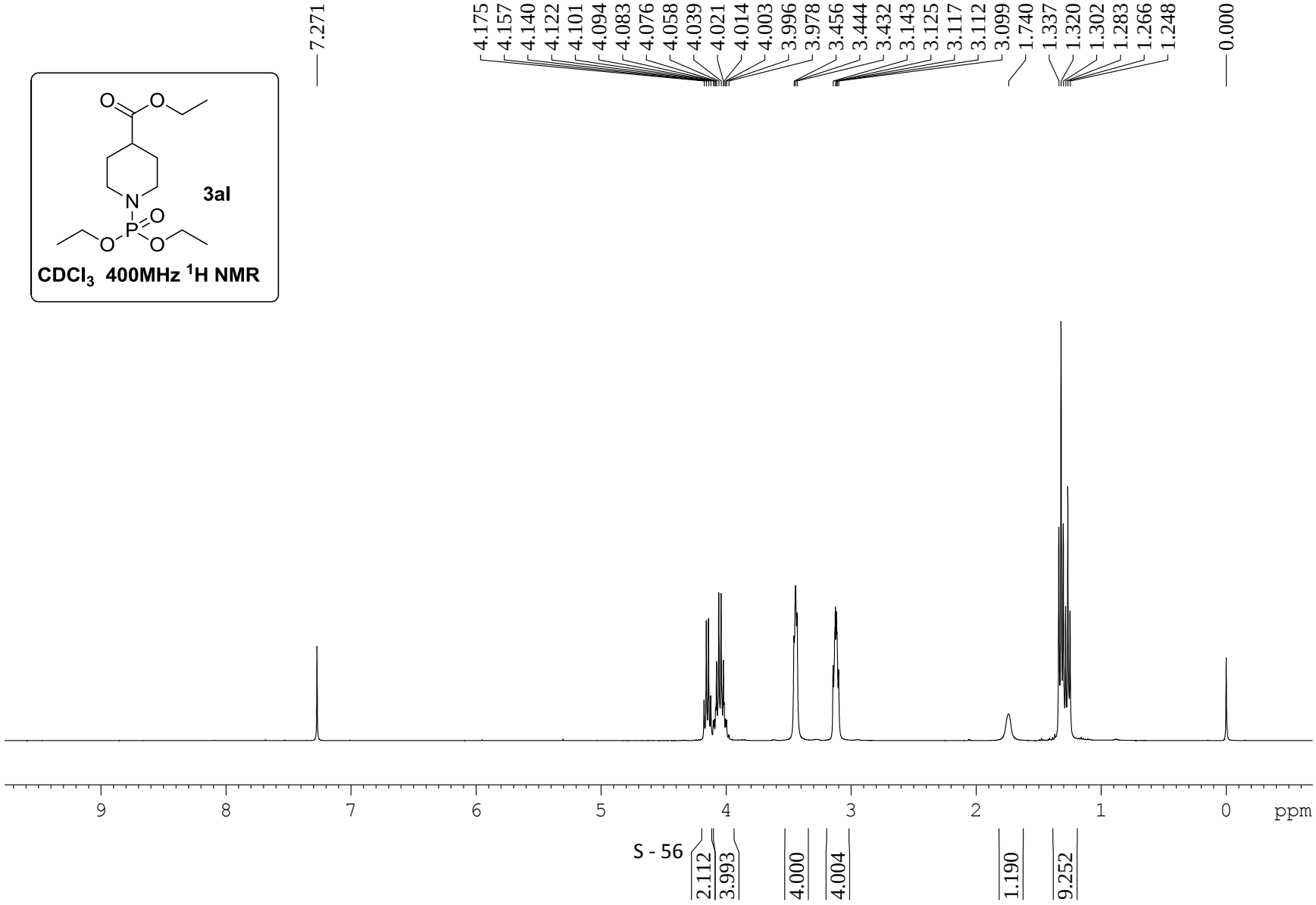
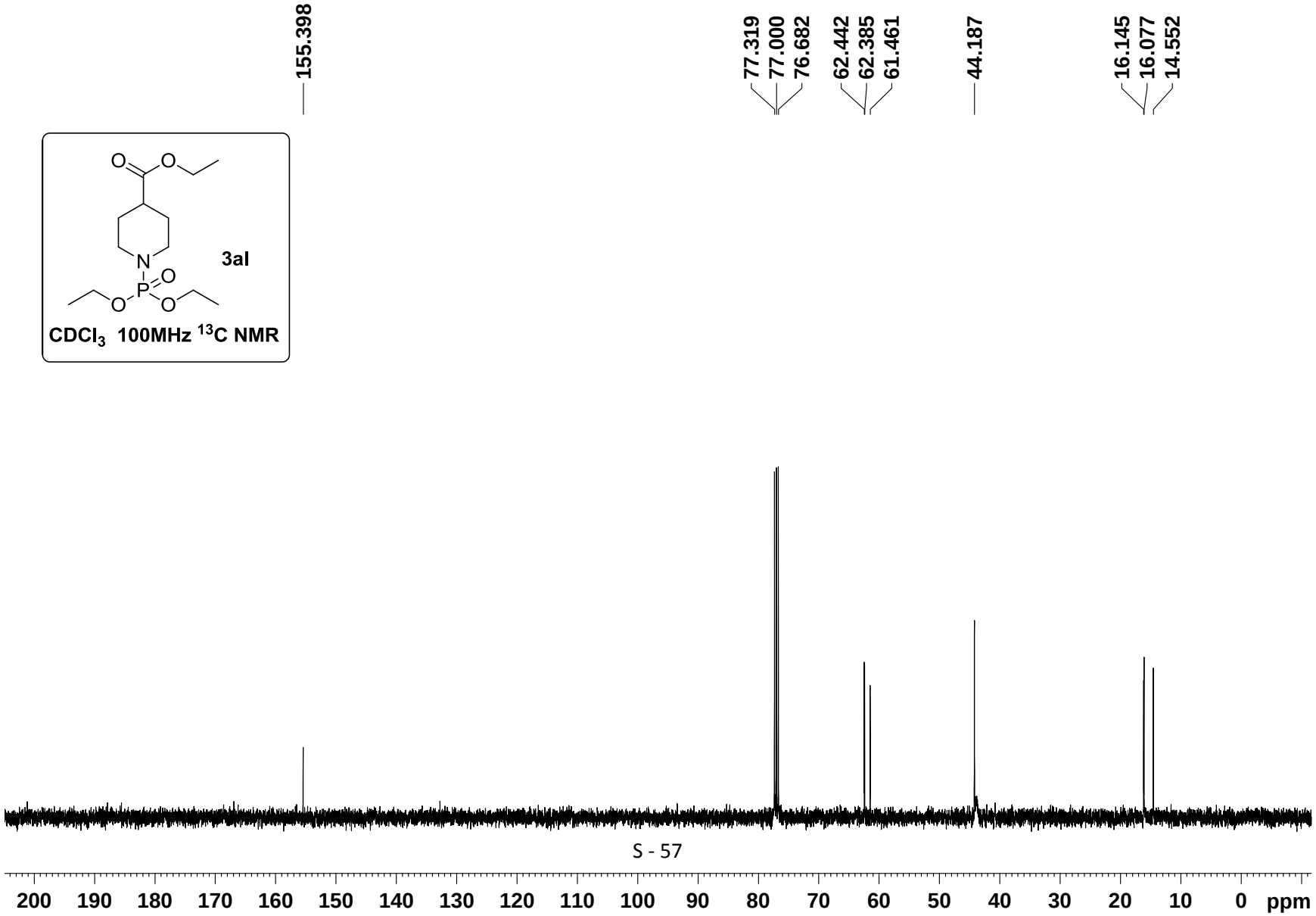
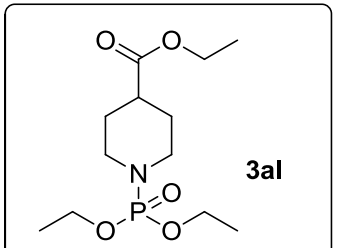
128.513
127.849
127.001
77.318
77.000
76.682
76.270
62.170
62.114
52.153
52.091
44.597
16.194
16.125
Ph
Ph
N
N
O
P
O
O
3ak
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.363
Ph
Ph
N
N
O
P
O
O
3ak
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

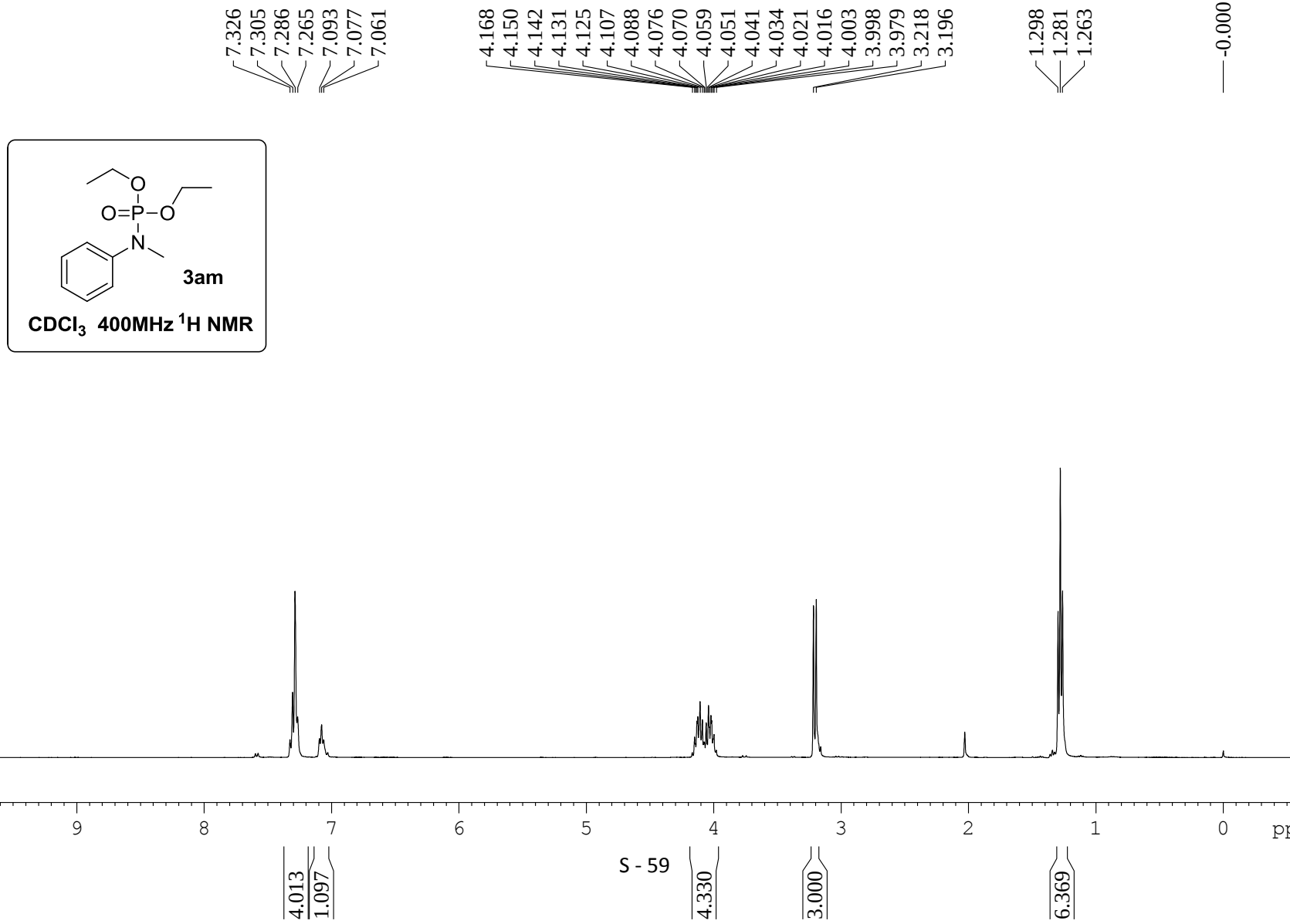

7.271
4.175
4.157
4.140
4.122
4.101
4.094
4.083
4.076
4.058
4.039
4.021
4.014
4.003
3.996
3.978
3.456
3.444
3.432
3.143
3.125
3.117
3.112
3.099
1.740
1.337
1.320
1.302
1.283
1.266
1.248
0.000
3al
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 56
2.112
3.993
4.000
4.004
1.190
9.252

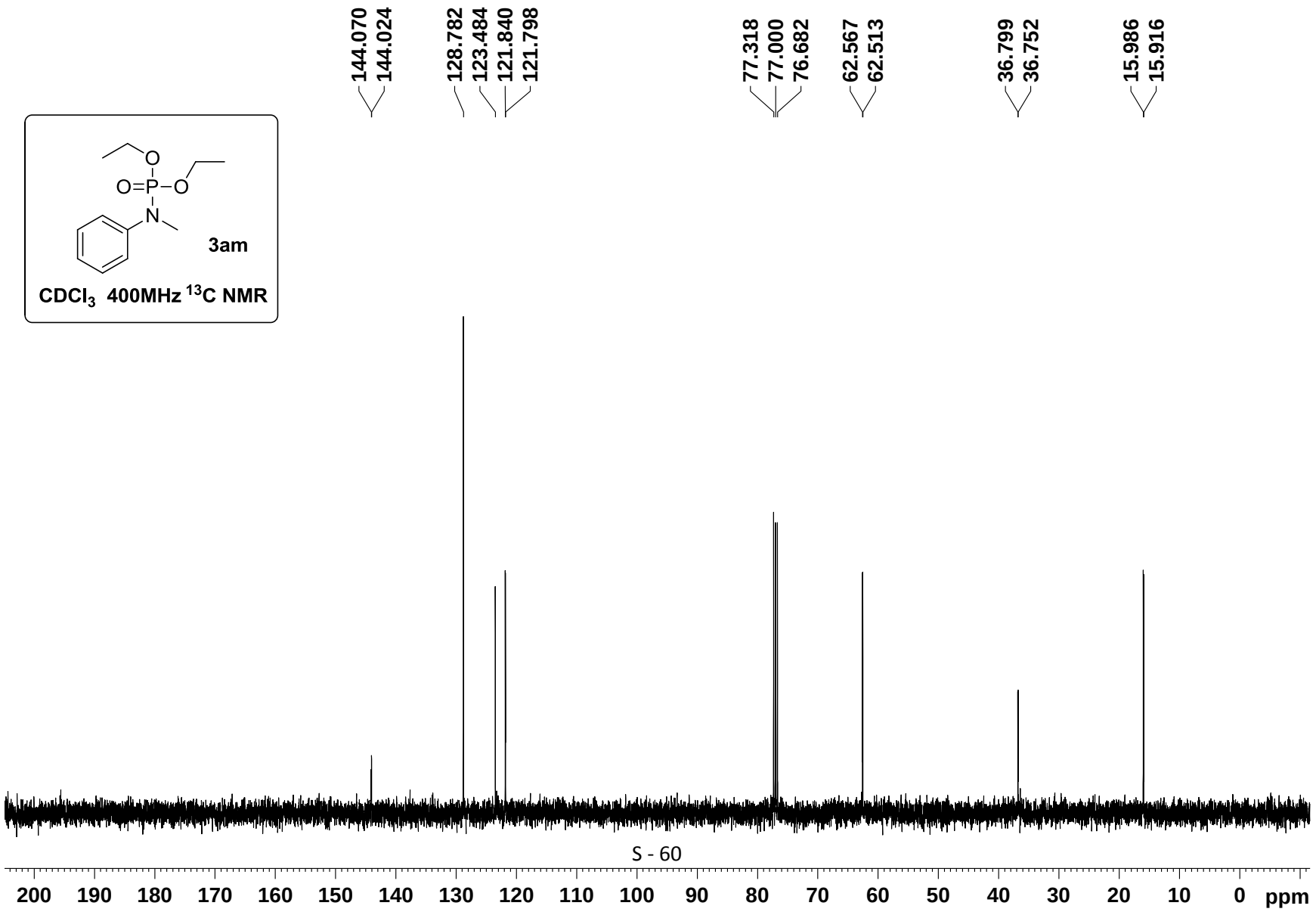

155.398
77.319
77.000
76.682
62.442
62.385
61.461
44.187
16.145
16.077
14.552
3aI
CDCl3 100MHz 13C NMR
S - 57
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

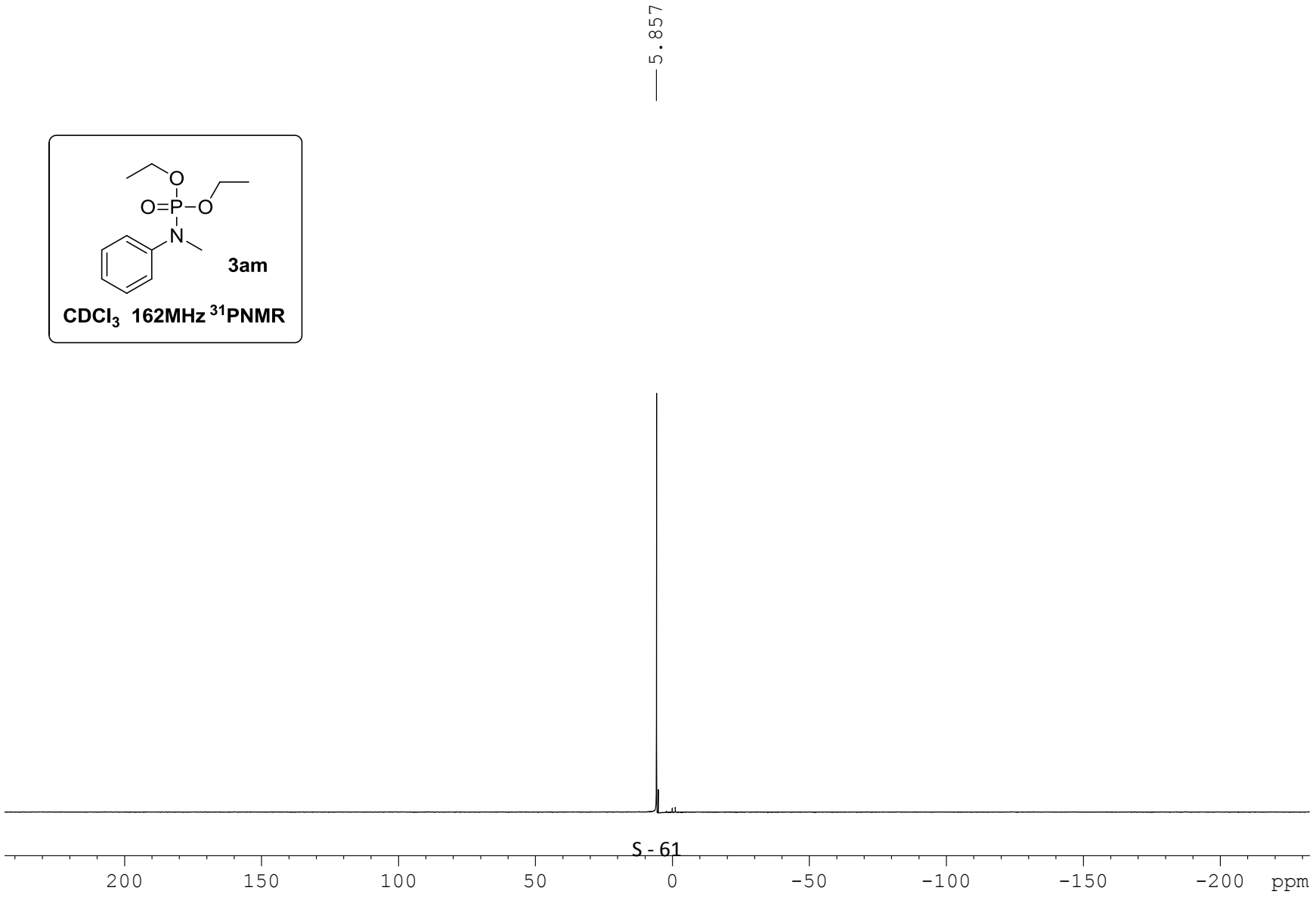


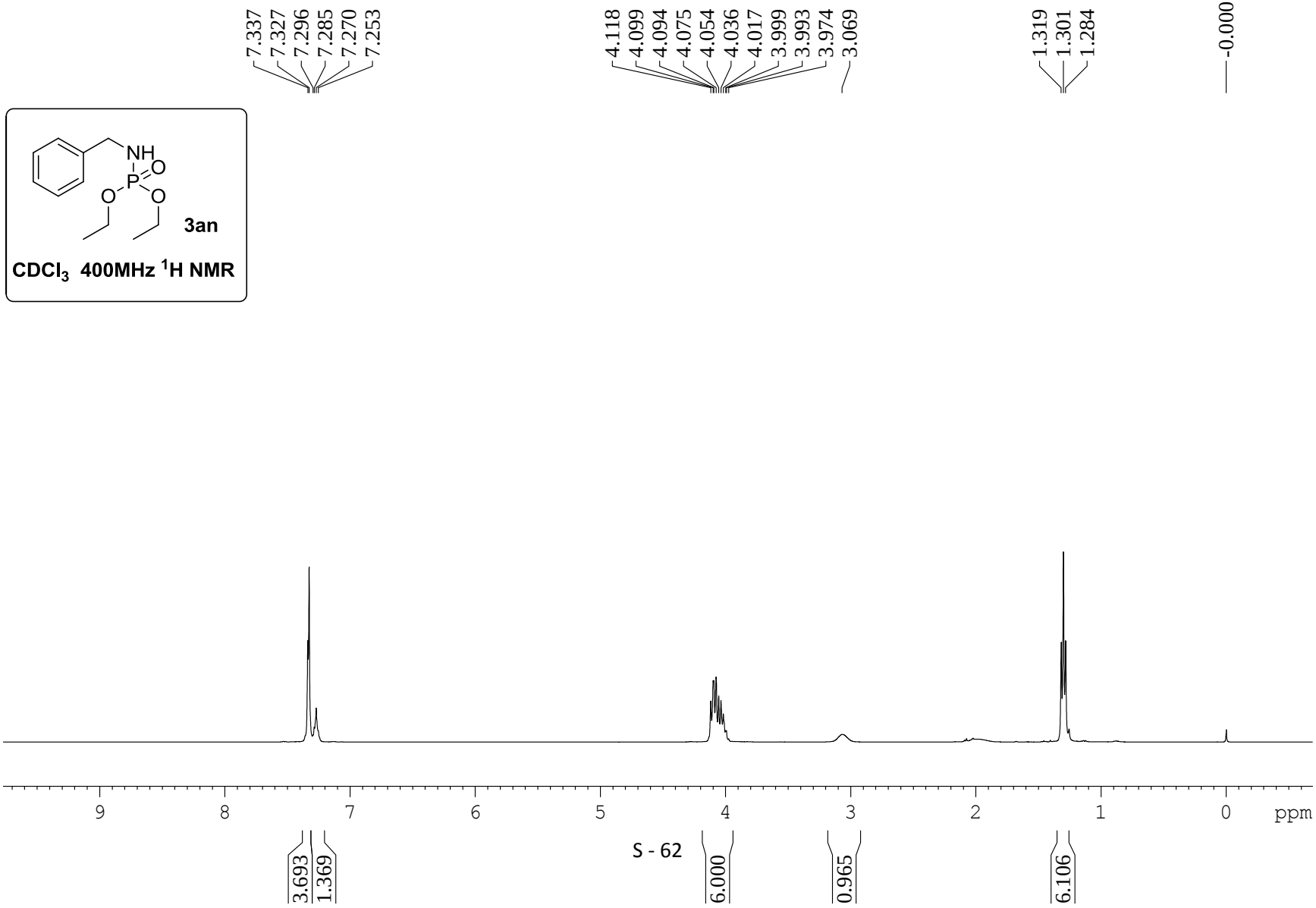
3al

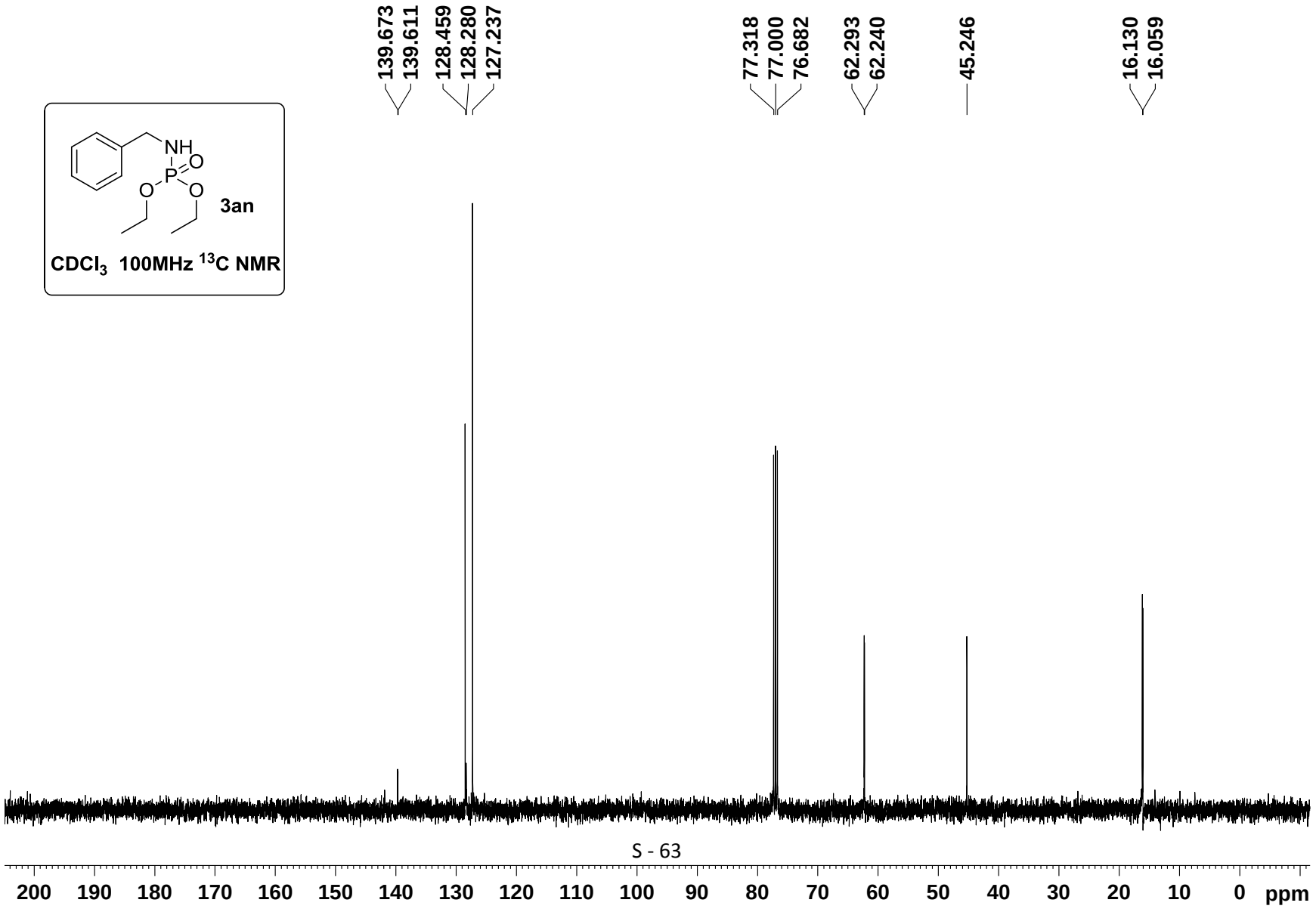
$CDCl_3$ 162MHz ^{31}P NMR

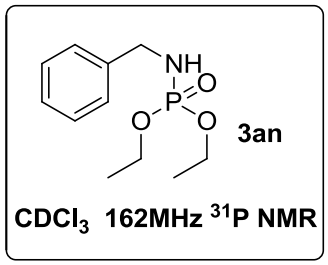

7.326
7.305
7.286
7.265
7.093
7.077
7.061
4.168
4.150
4.142
4.131
4.125
4.107
4.088
4.076
4.070
4.059
4.051
4.041
4.034
4.021
4.016
4.003
3.998
3.979
3.218
3.196
1.298
1.281
1.263
-0.000
3am
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.013
1.097
4.330
3.000
6.369


144.070
144.024
128.782
123.484
121.840
121.798
77.318
77.000
76.682
62.567
62.513
36.799
36.752
15.986
15.916
3am
CDCl3 400MHz 13C NMR
S - 60
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

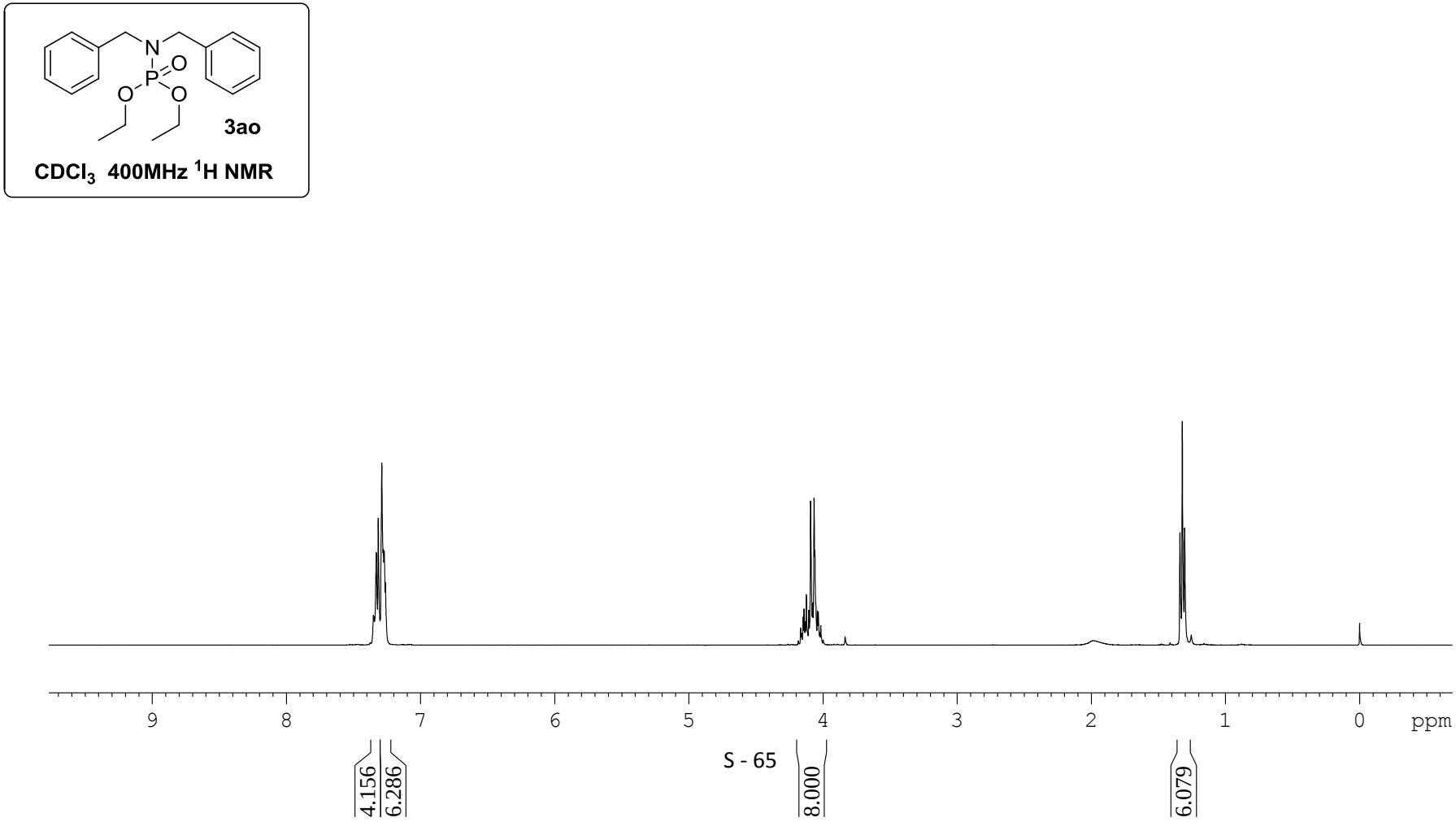

5.857
3am
CDCl3 162MHz 31PNMR
200
150
100
50
0
-50
-100
-150
-200
ppm

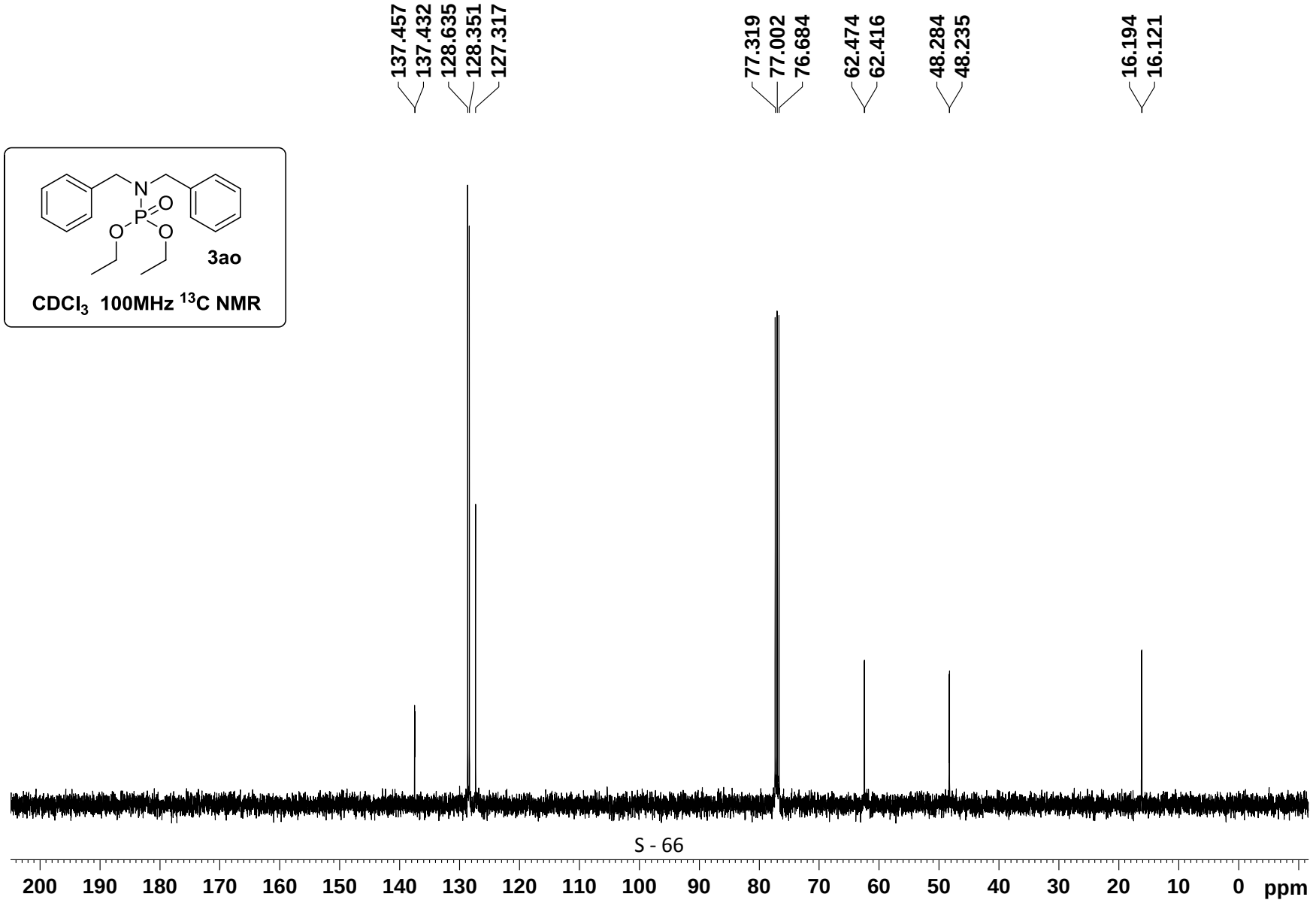

7.337
7.327
7.296
7.285
7.270
7.253
4.118
4.099
4.094
4.075
4.054
4.036
4.017
3.999
3.993
3.974
3.069
1.319
1.301
1.284
-0.000
NH
O
P
O
O
O
3an
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
3.693
1.369
6.000
0.965
6.106

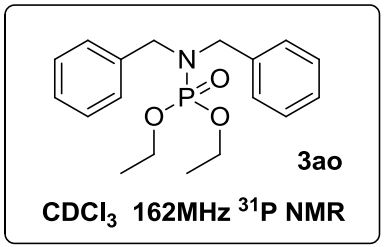

139.673
139.611
128.459
128.280
127.237
77.318
77.000
76.682
62.293
62.240
45.246
16.130
16.059
NH
O
P
O
O
3an
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm



$CDCl_3$ 162MHz ^{31}P NMR

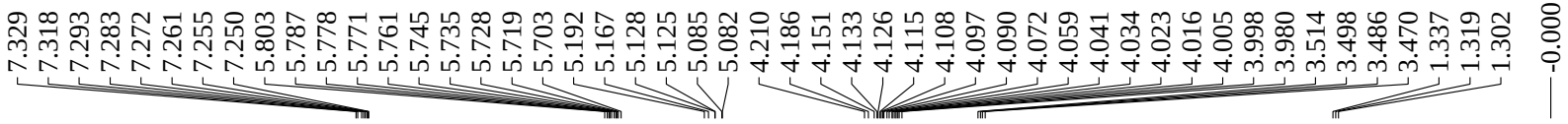

7.350
7.346
7.329
7.314
7.288
7.276
7.270
7.261
4.184
4.166
4.159
4.149
4.141
4.131
4.123
4.114
4.106
4.091
4.077
4.065
4.059
4.053
4.041
4.034
4.023
4.016
3.998
1.340
1.322
1.305
0.000
N
P
O
O
O
3ao
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.156
6.286
8.000
6.079
S - 65

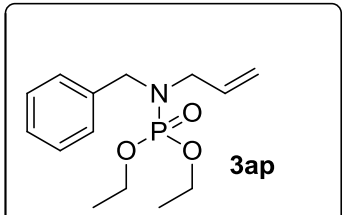

137.457
137.432
128.635
128.351
127.317
77.319
77.002
76.684
62.474
62.416
48.284
48.235
16.194
16.121
3ao
CDCl3 100MHz 13C NMR
S - 66
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm



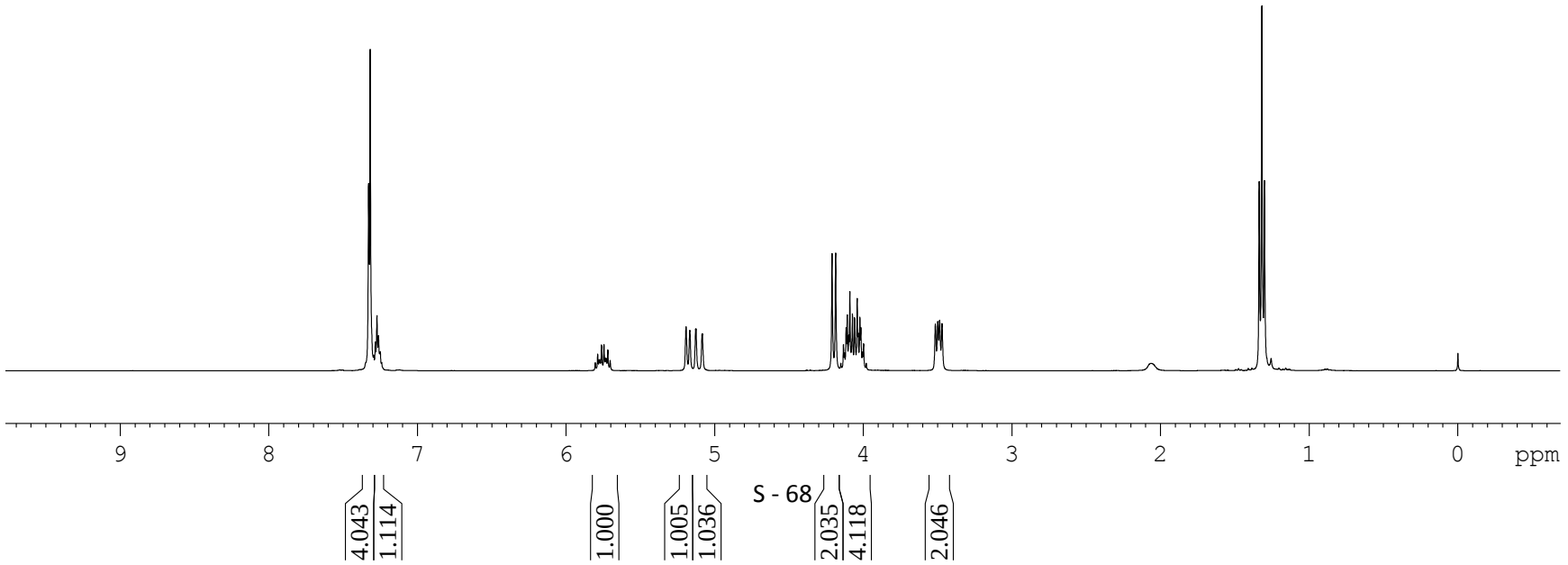
3ao

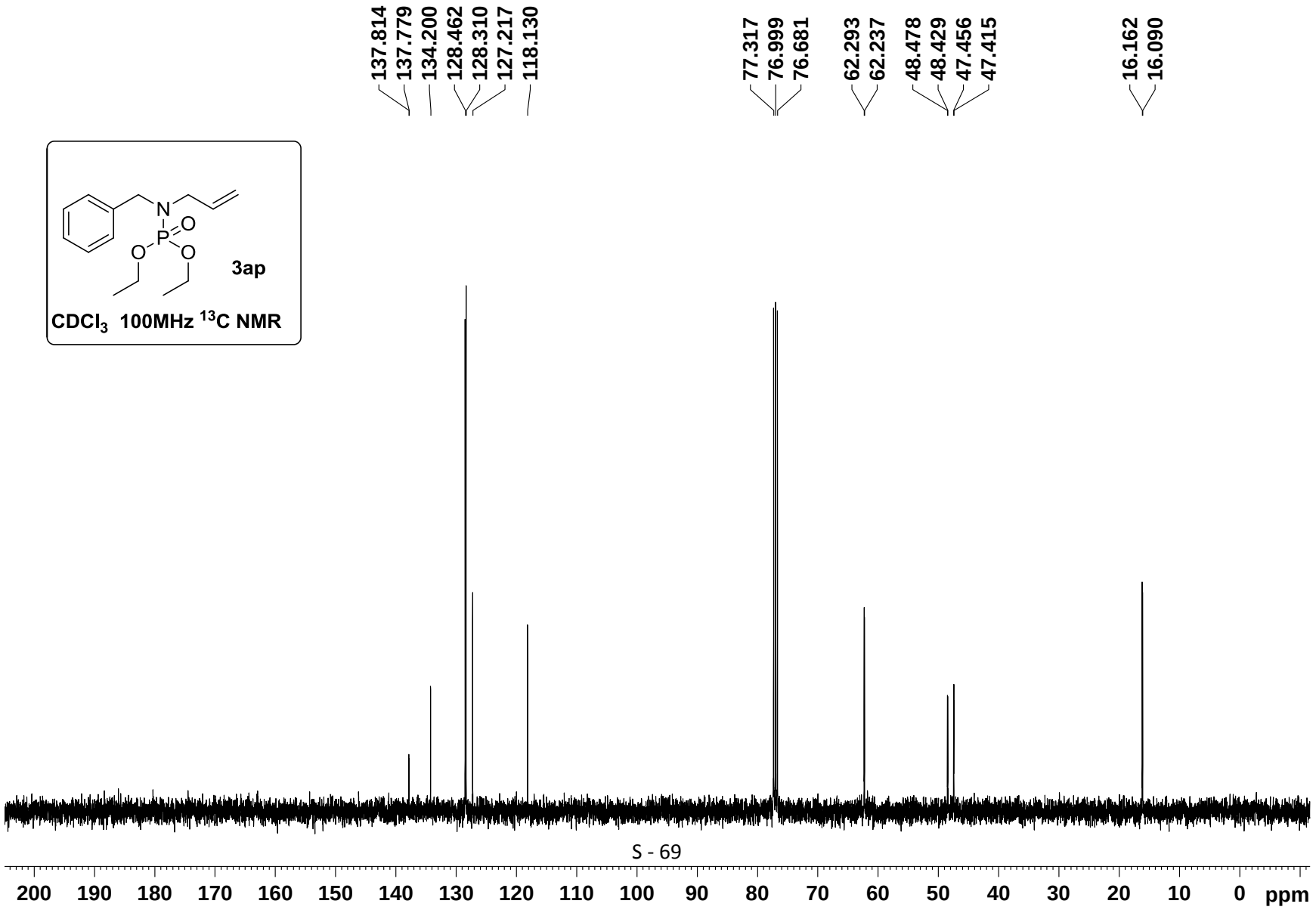
$CDCl_3$ 162MHz ^{31}P NMR

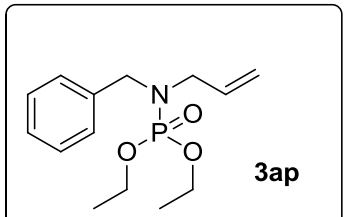




$CDCl_3$ 400MHz ^1H NMR

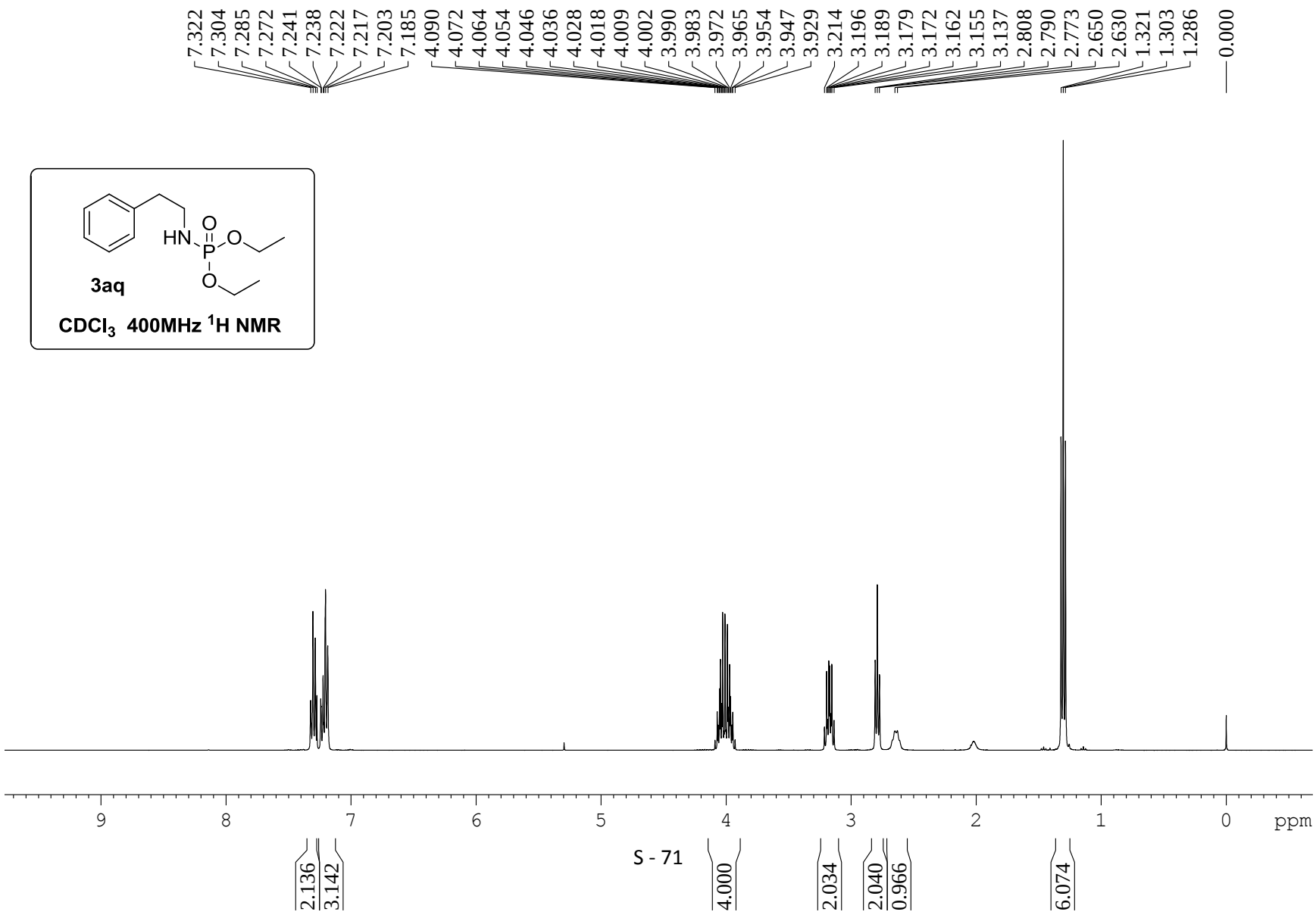


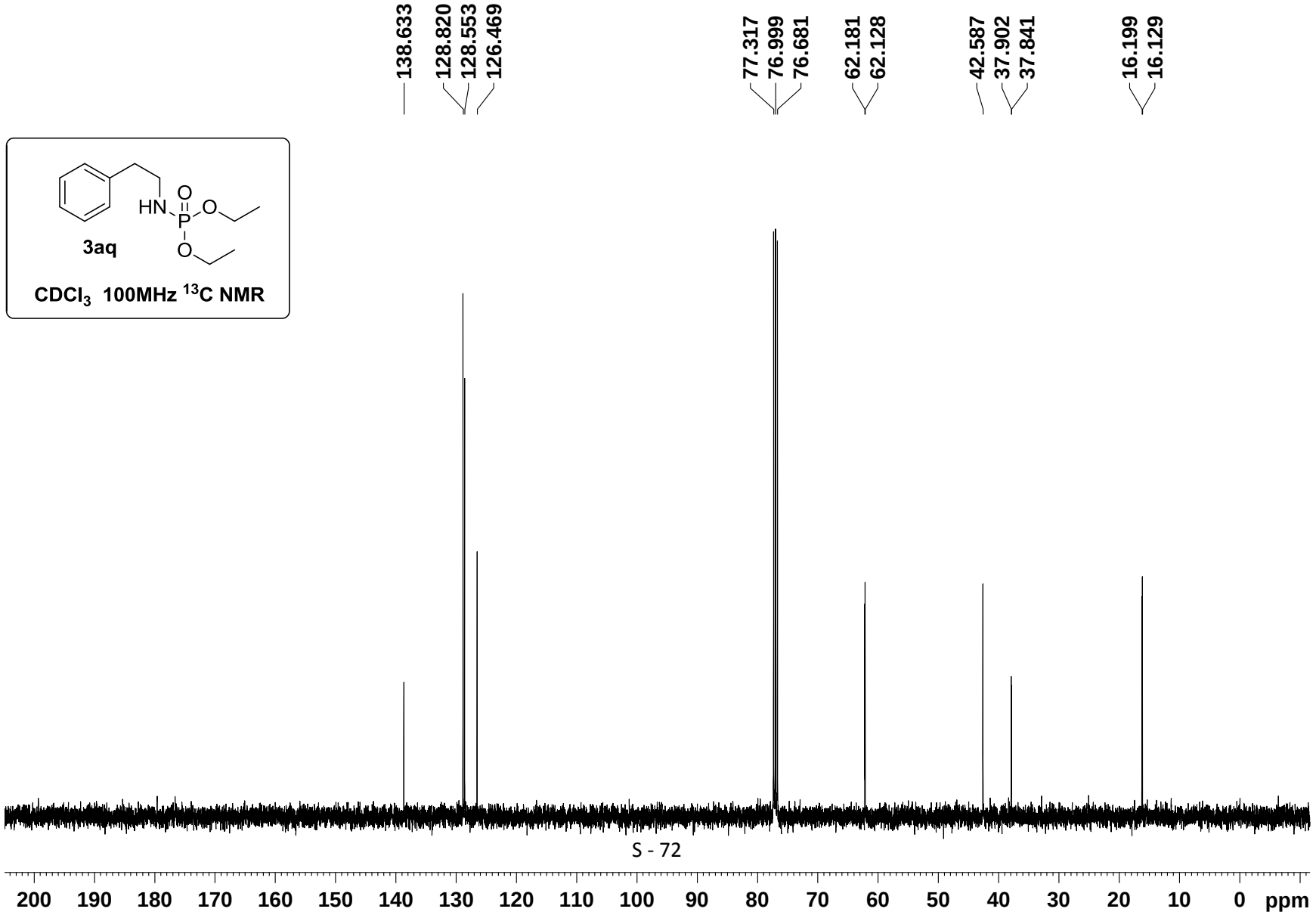

137.814
137.779
134.200
128.462
128.310
127.217
118.130
77.317
76.999
76.681
62.293
62.237
48.478
48.429
47.456
47.415
16.162
16.090
3ap
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

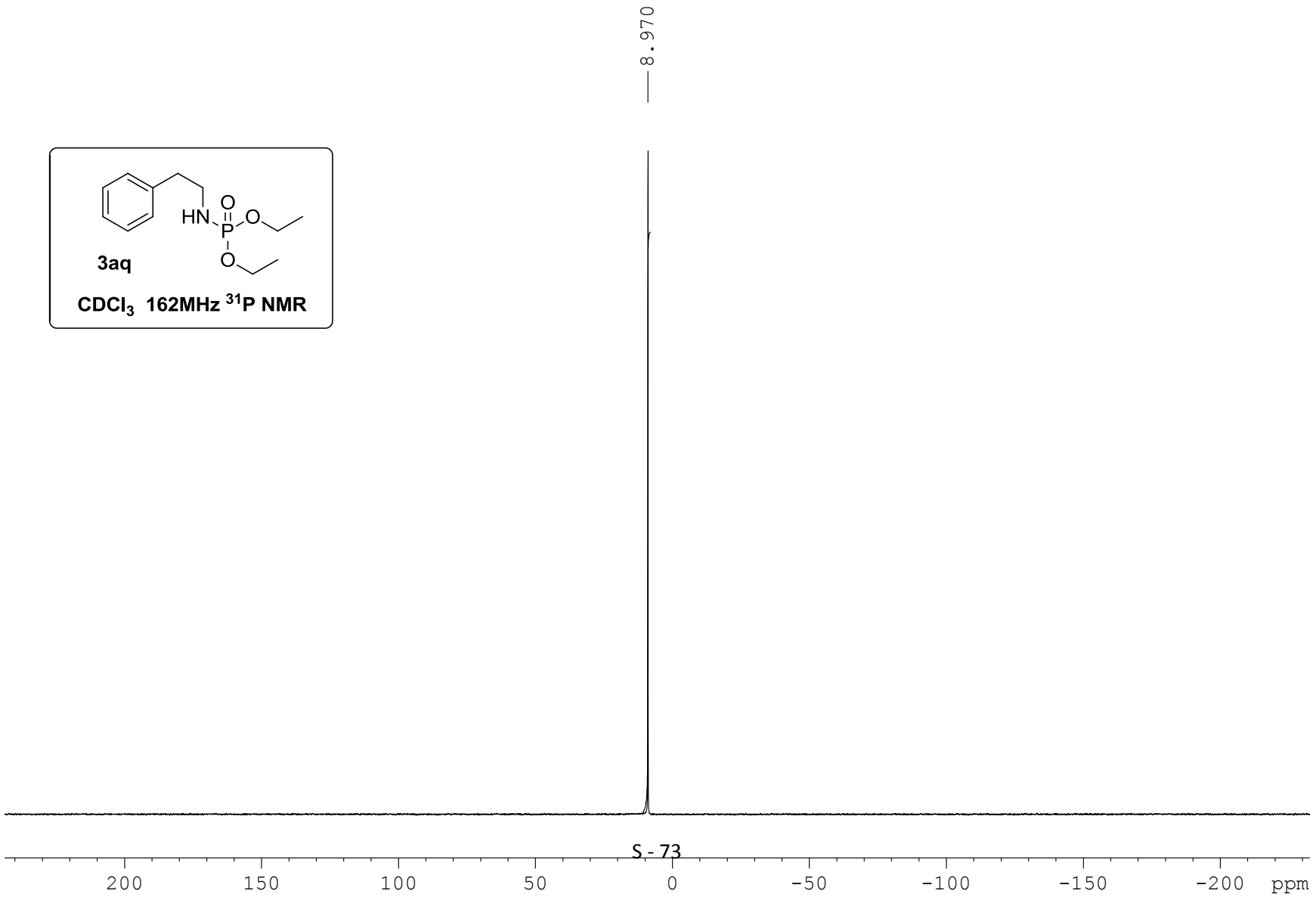


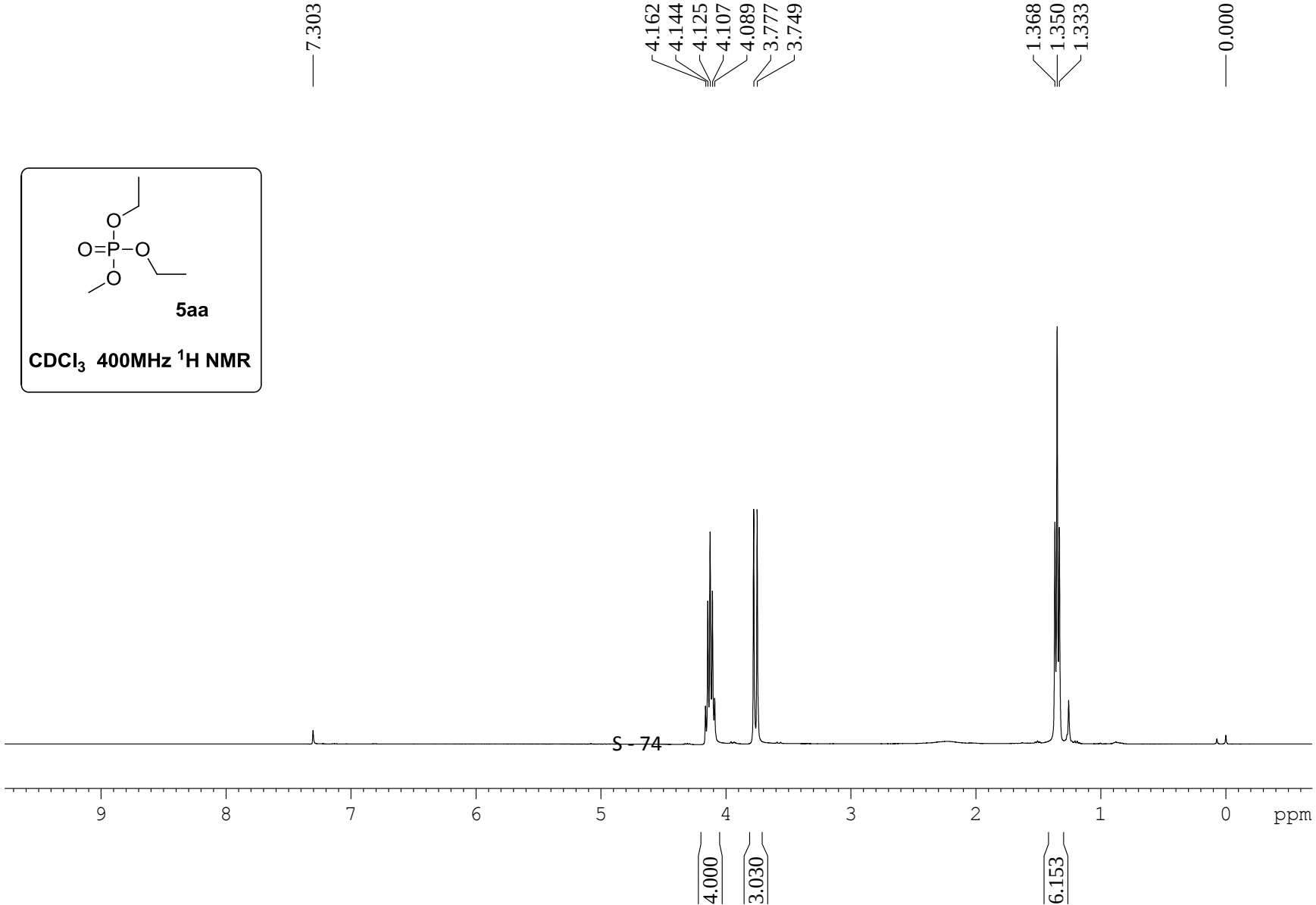
3ap

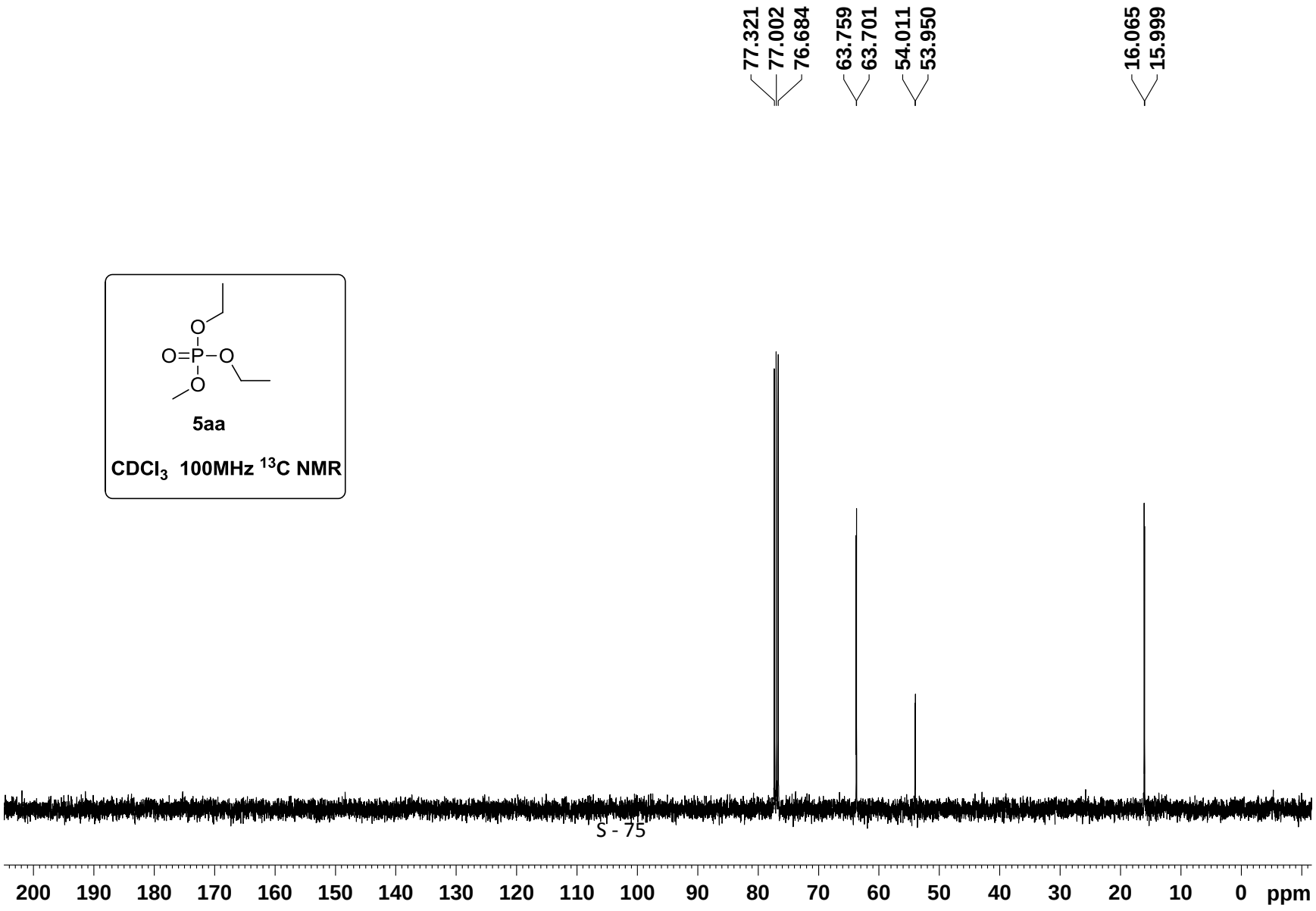
$CDCl_3$ 162MHz ^{31}P NMR

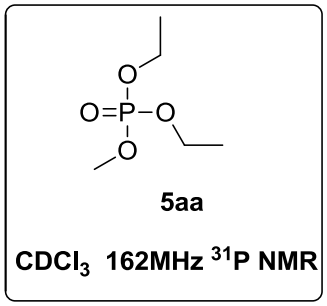

7.322
7.304
7.285
7.272
7.241
7.238
7.222
7.217
7.203
7.185
4.090
4.072
4.064
4.054
4.046
4.036
4.028
4.018
4.009
4.002
3.990
3.983
3.972
3.965
3.954
3.947
3.929
3.214
3.196
3.189
3.179
3.172
3.162
3.155
3.137
2.808
2.790
2.773
2.650
2.630
1.321
1.303
1.286
0.000
HN
O
P
O
O
3aq
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.136
3.142
4.000
2.034
2.040
0.966
6.074


138.633
128.820
128.553
126.469
77.317
76.999
76.681
62.181
62.128
42.587
37.902
37.841
16.199
16.129
HN
O
P
O
O
3aq
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.970
HN
O
P
O
O
3aq
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

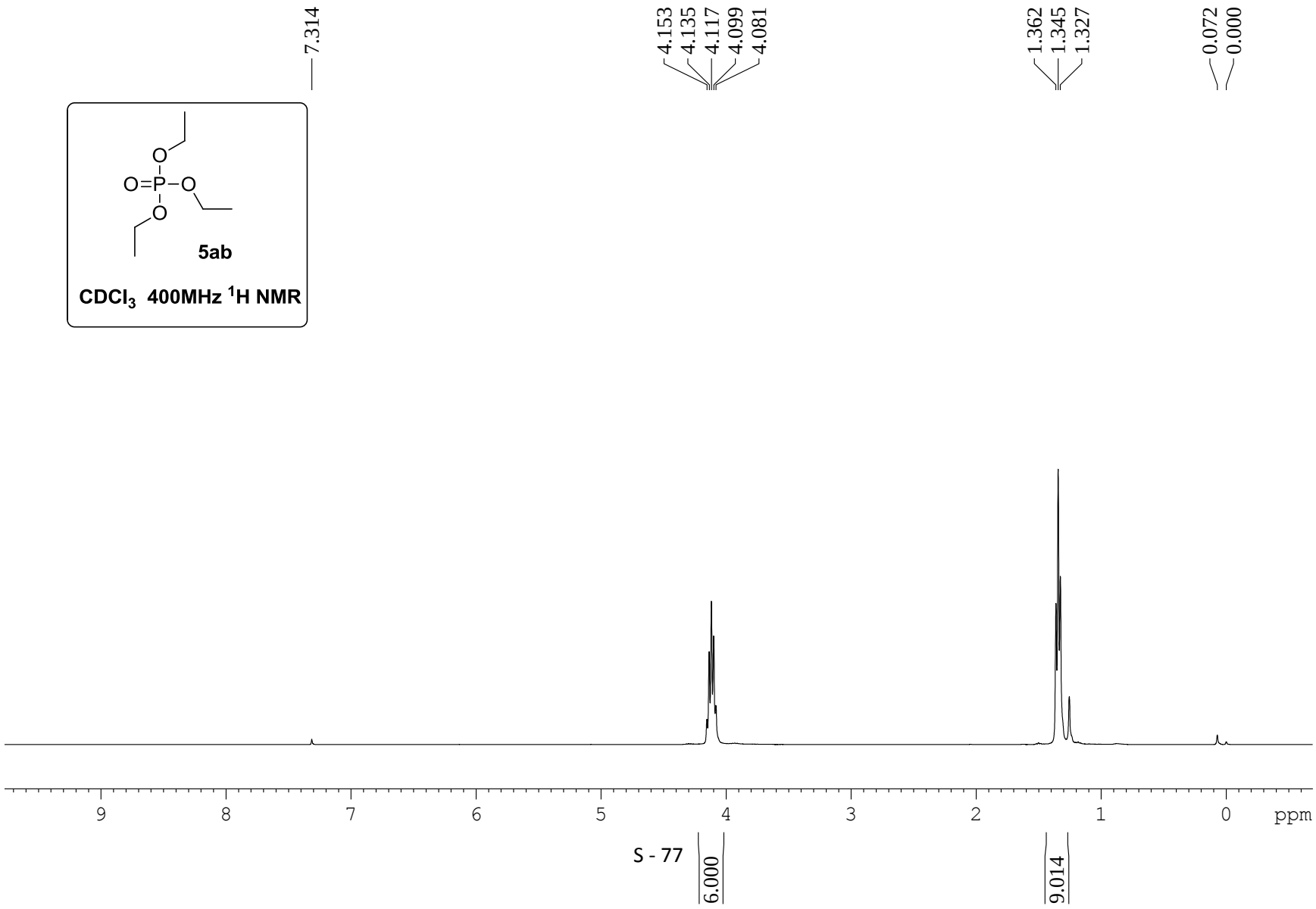

7.303
4.162
4.144
4.125
4.107
4.089
3.777
3.749
1.368
1.350
1.333
0.000
5aa
CDCl3 400MHz 1H NMR
S - 74
9
8
7
6
5
4
3
2
1
0
ppm
4.000
3.030
6.153

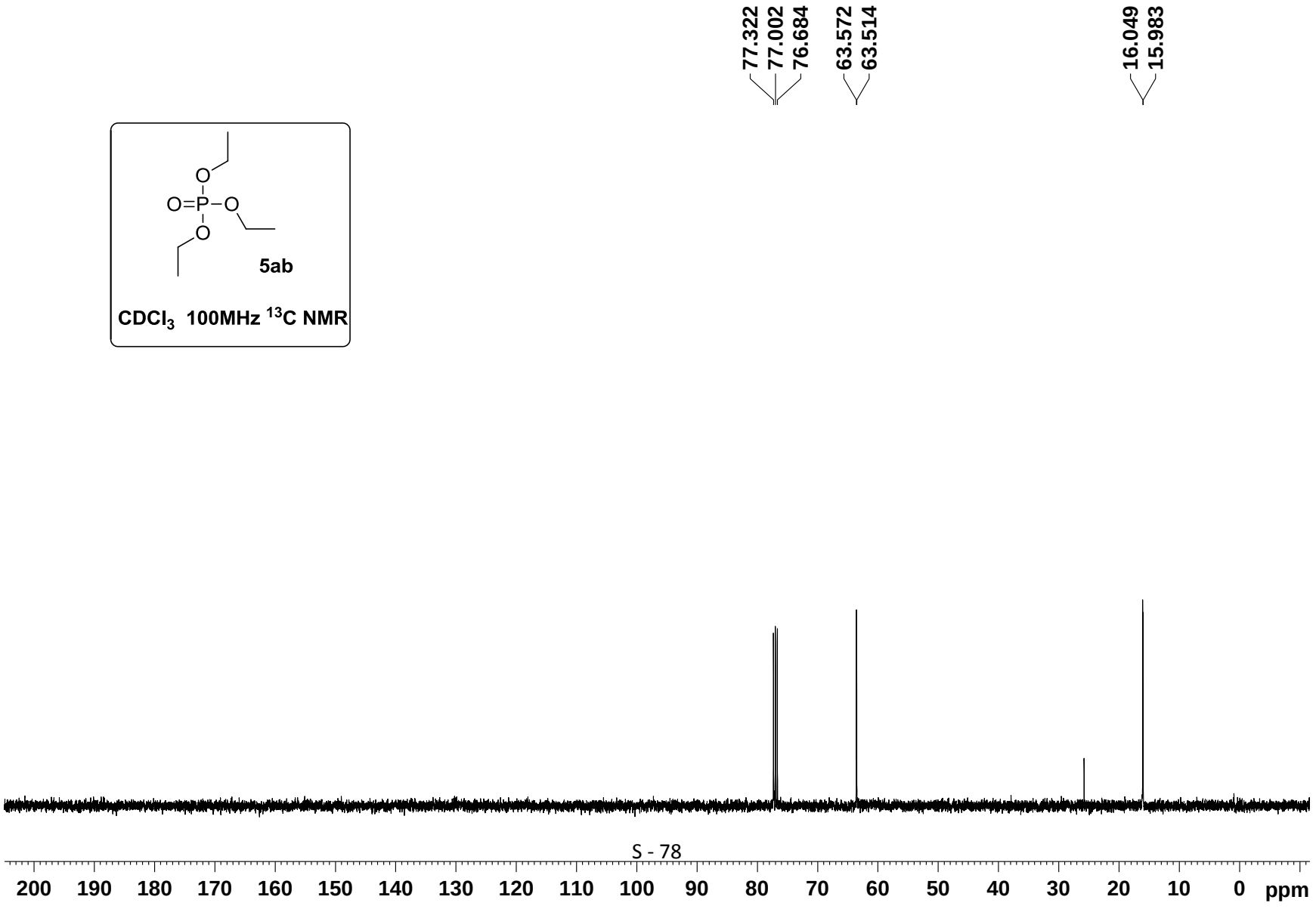

77.321
77.002
76.684
63.759
63.701
54.011
53.950
16.065
15.999
5aa
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

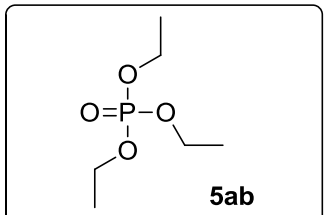


5aa

$CDCl_3$ 162MHz ^{31}P NMR

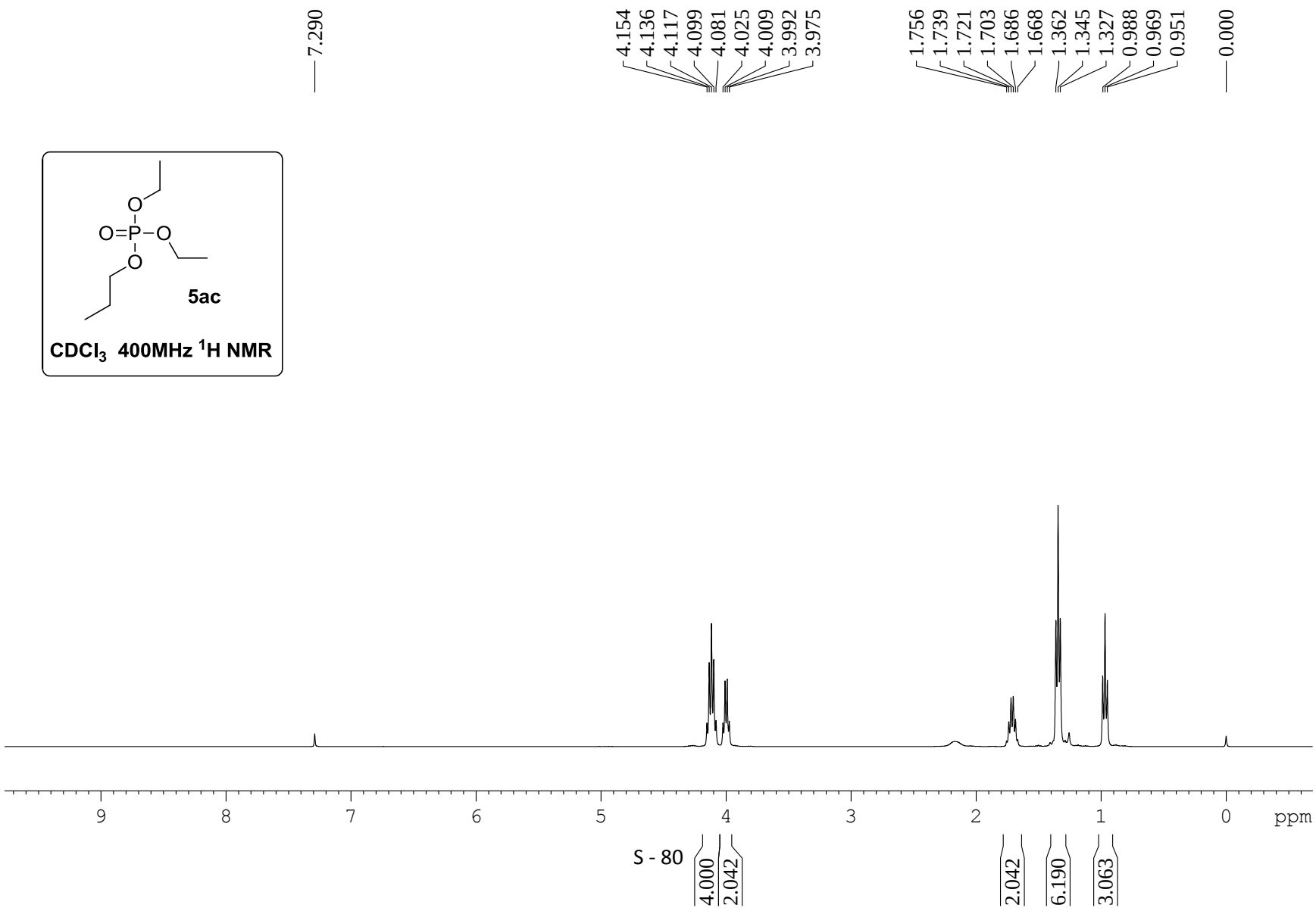

7.314
4.153
4.135
4.117
4.099
4.081
1.362
1.345
1.327
0.072
0.000
5ab
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 77
6.000
9.014

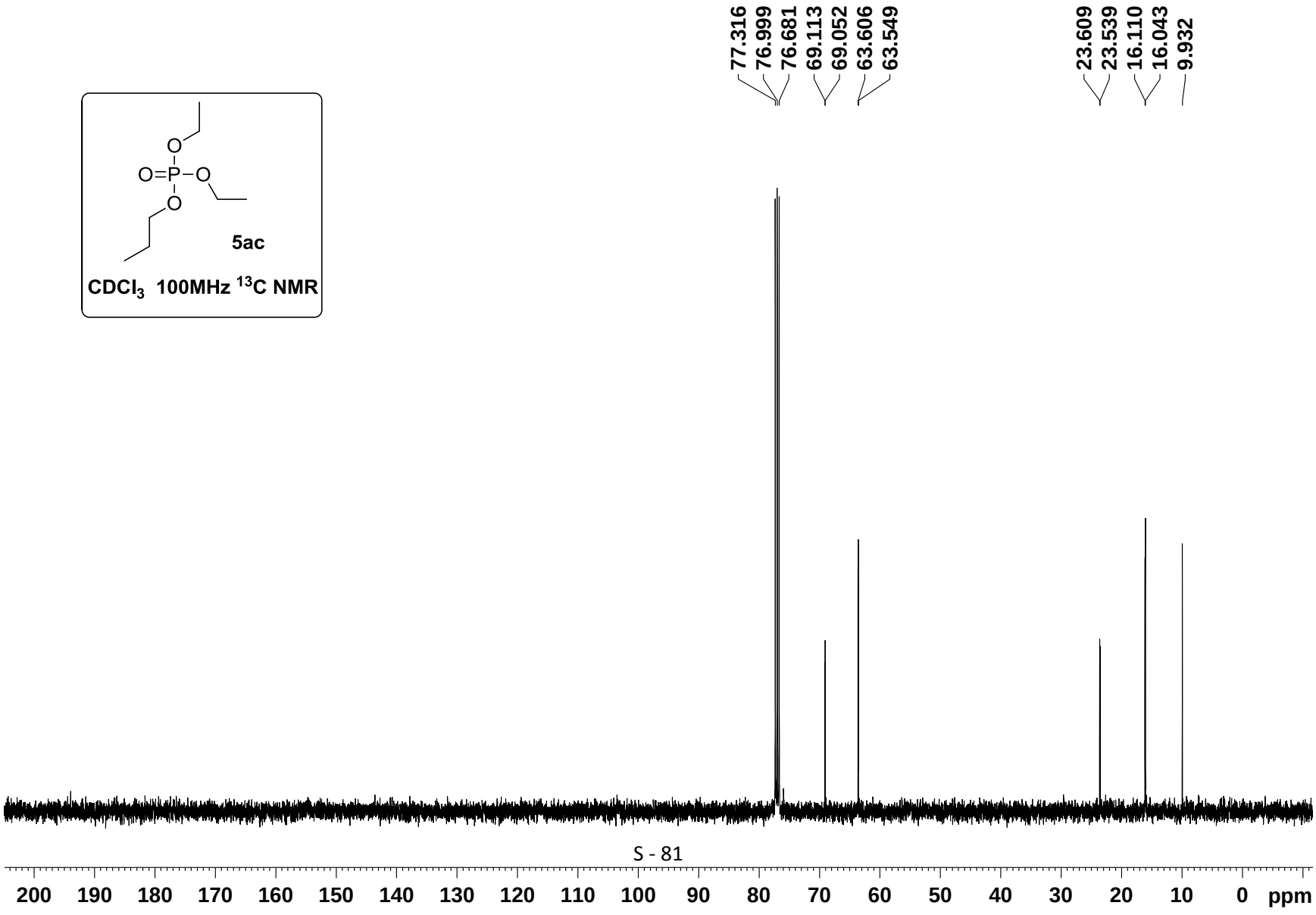

77.322
77.002
76.684
63.572
63.514
16.049
15.983
O
O=P–O
O
5ab
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

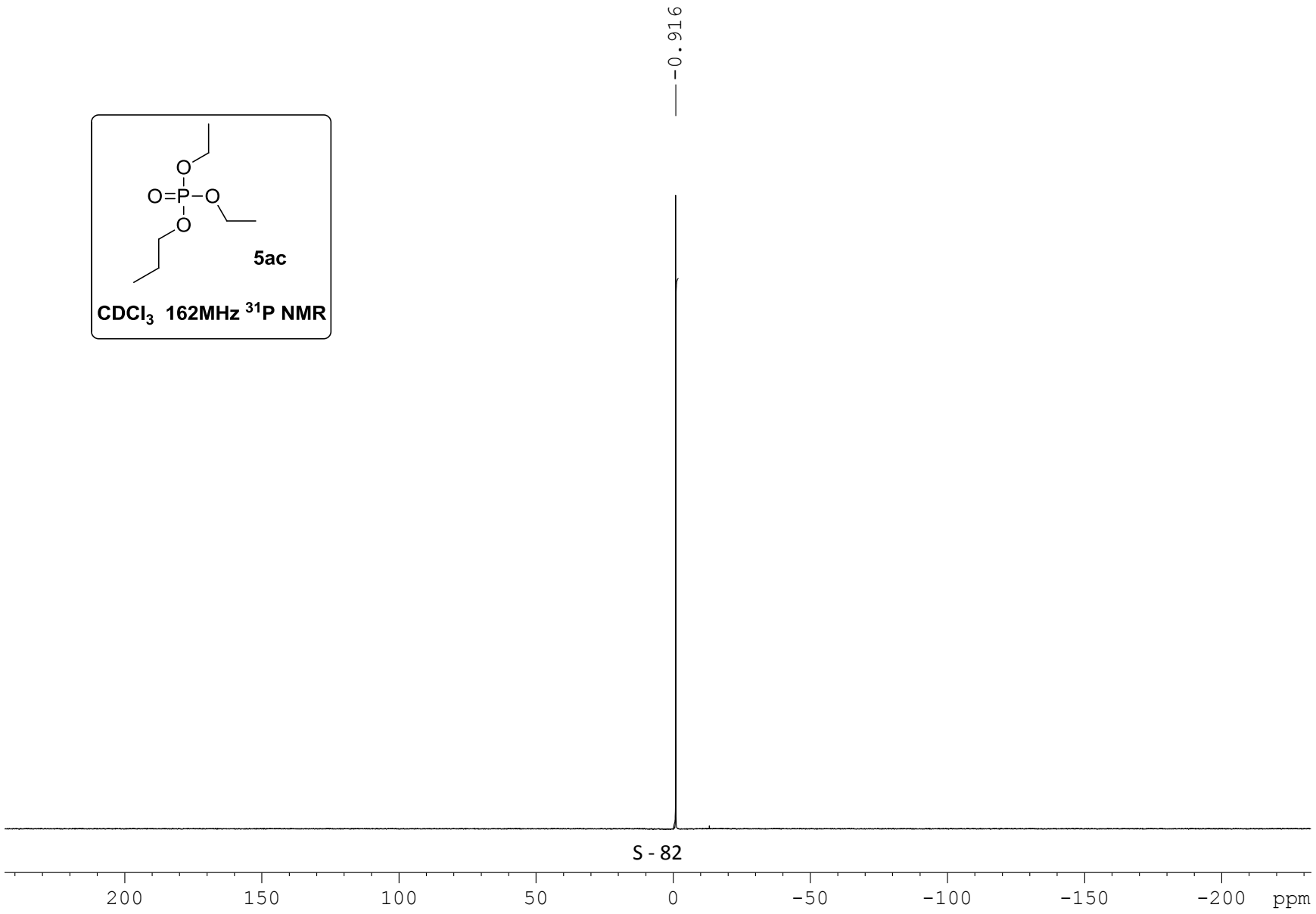


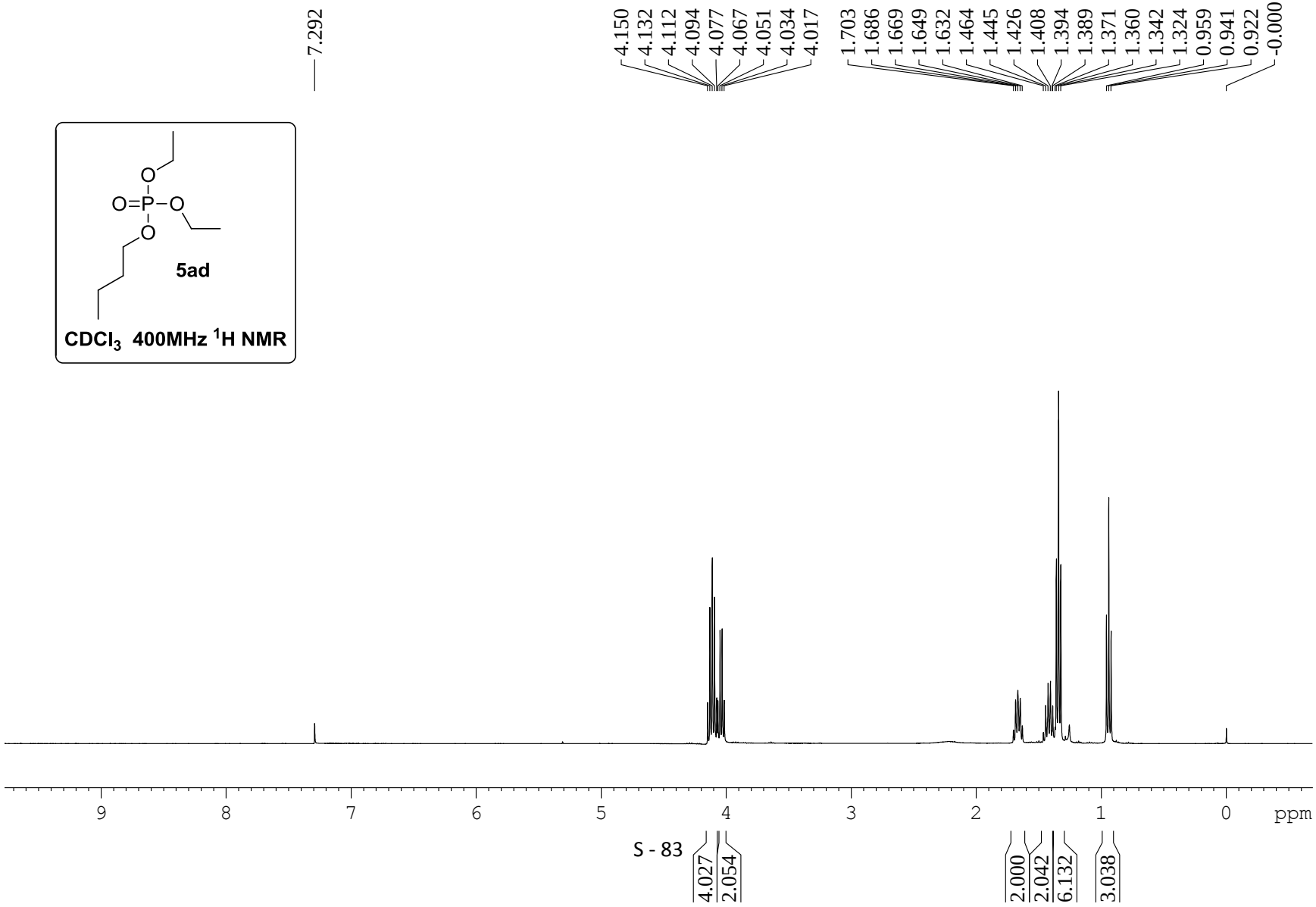
5ab

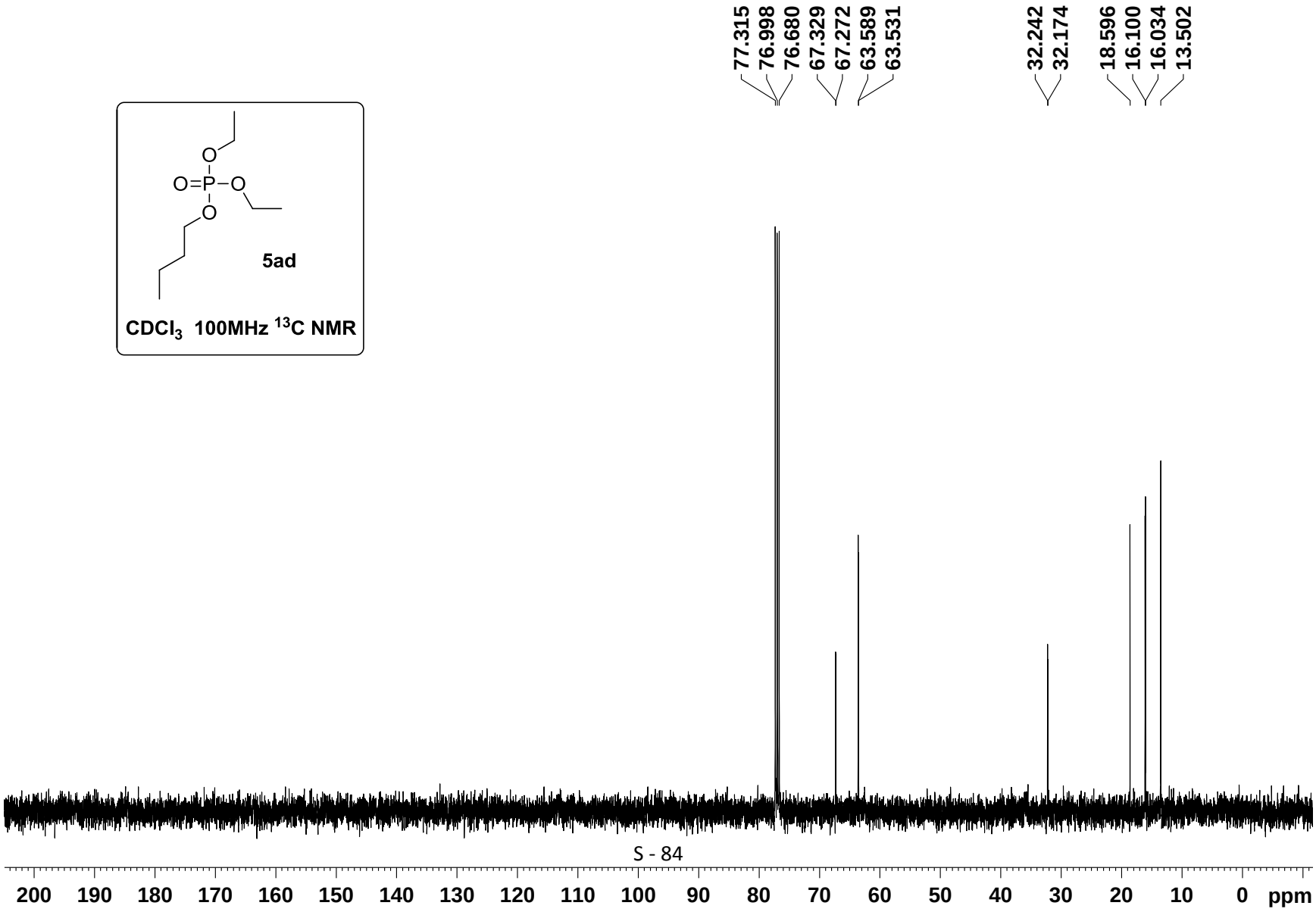
$CDCl_3$ 162MHz ^{31}P NMR

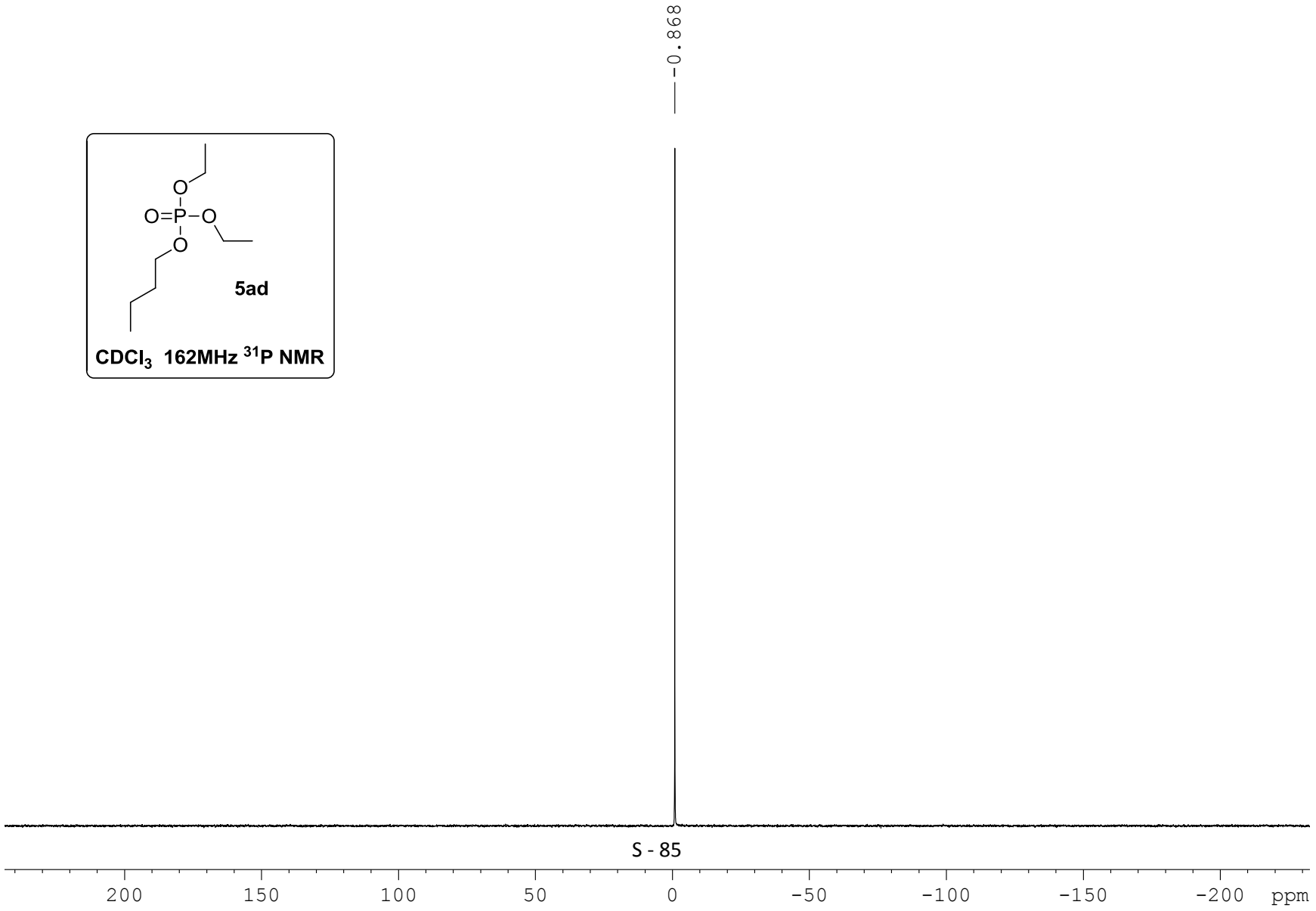

7.290
4.154
4.136
4.117
4.099
4.081
4.025
4.009
3.992
3.975
1.756
1.739
1.721
1.703
1.686
1.668
1.362
1.345
1.327
0.988
0.969
0.951
0.000
5ac
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 80
4.000
2.042
2.042
6.190
3.063

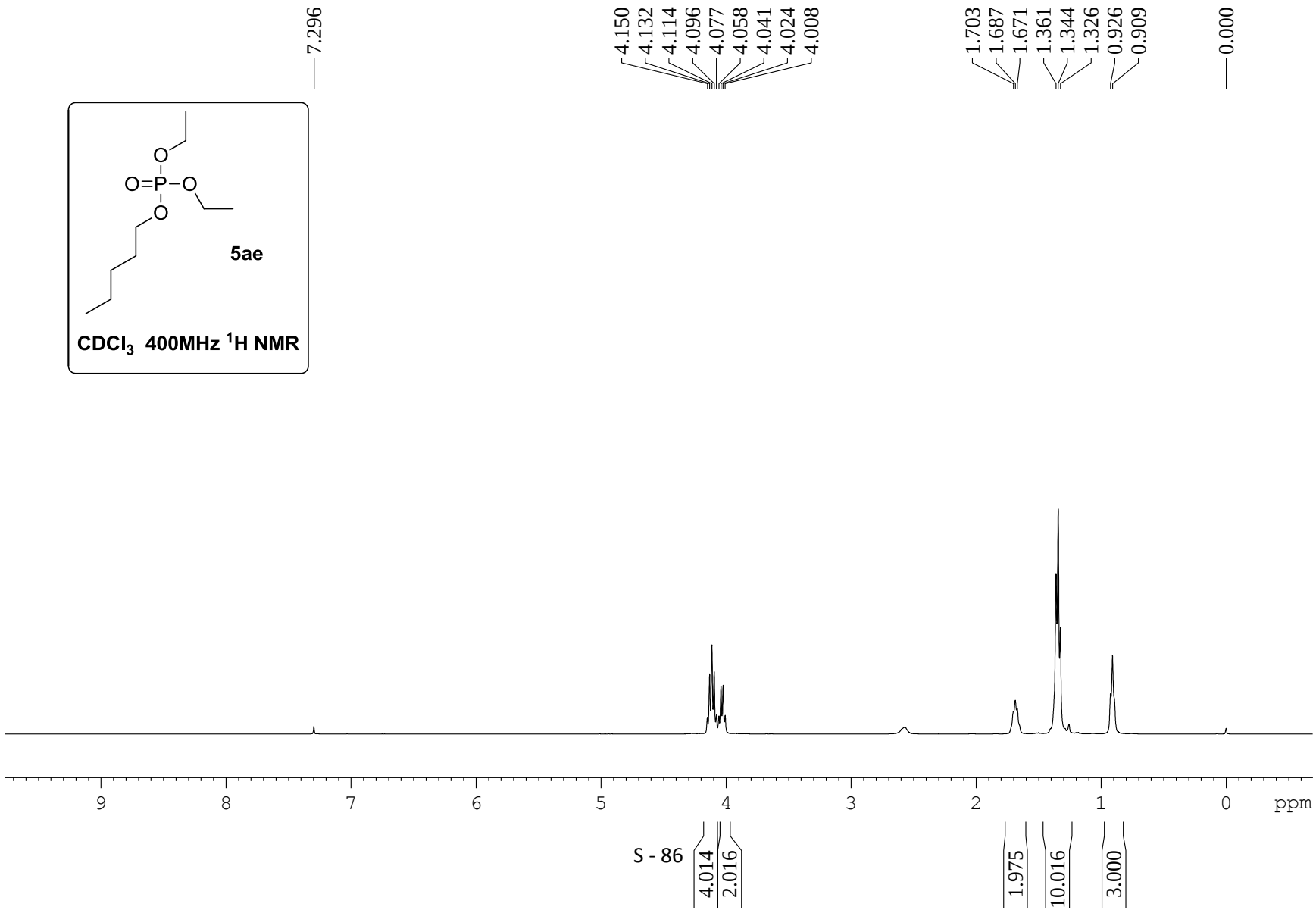

77.316
76.999
76.681
69.113
69.052
63.606
63.549
23.609
23.539
16.110
16.043
9.932
5ac
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

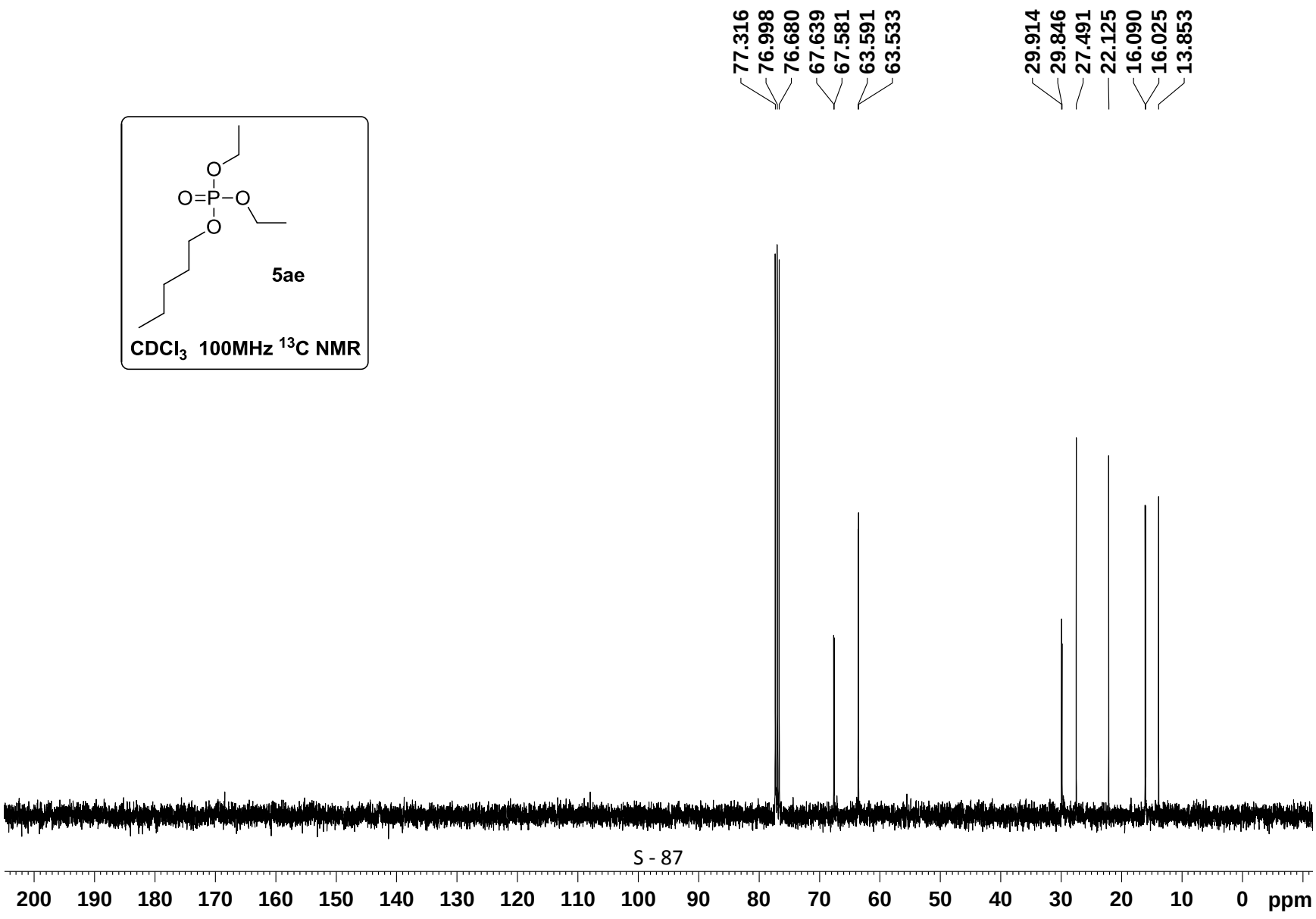

-0.916
5ac
CDCl3 162MHz 31P NMR
S - 82
200
150
100
50
0
-50
-100
-150
-200
ppm

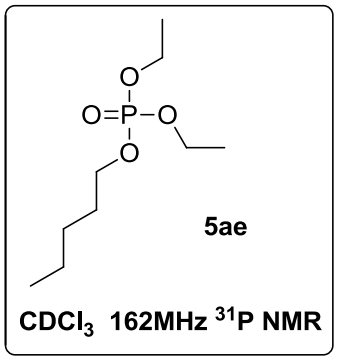

7.292
4.150
4.132
4.112
4.094
4.077
4.067
4.051
4.034
4.017
1.703
1.686
1.669
1.649
1.632
1.464
1.445
1.426
1.408
1.394
1.389
1.371
1.360
1.342
1.324
0.959
0.941
0.922
-0.000
5ad
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 83
4.027
2.054
2.000
2.042
6.132
3.038


77.315
76.998
76.680
67.329
67.272
63.589
63.531
32.242
32.174
18.596
16.100
16.034
13.502
5ad
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

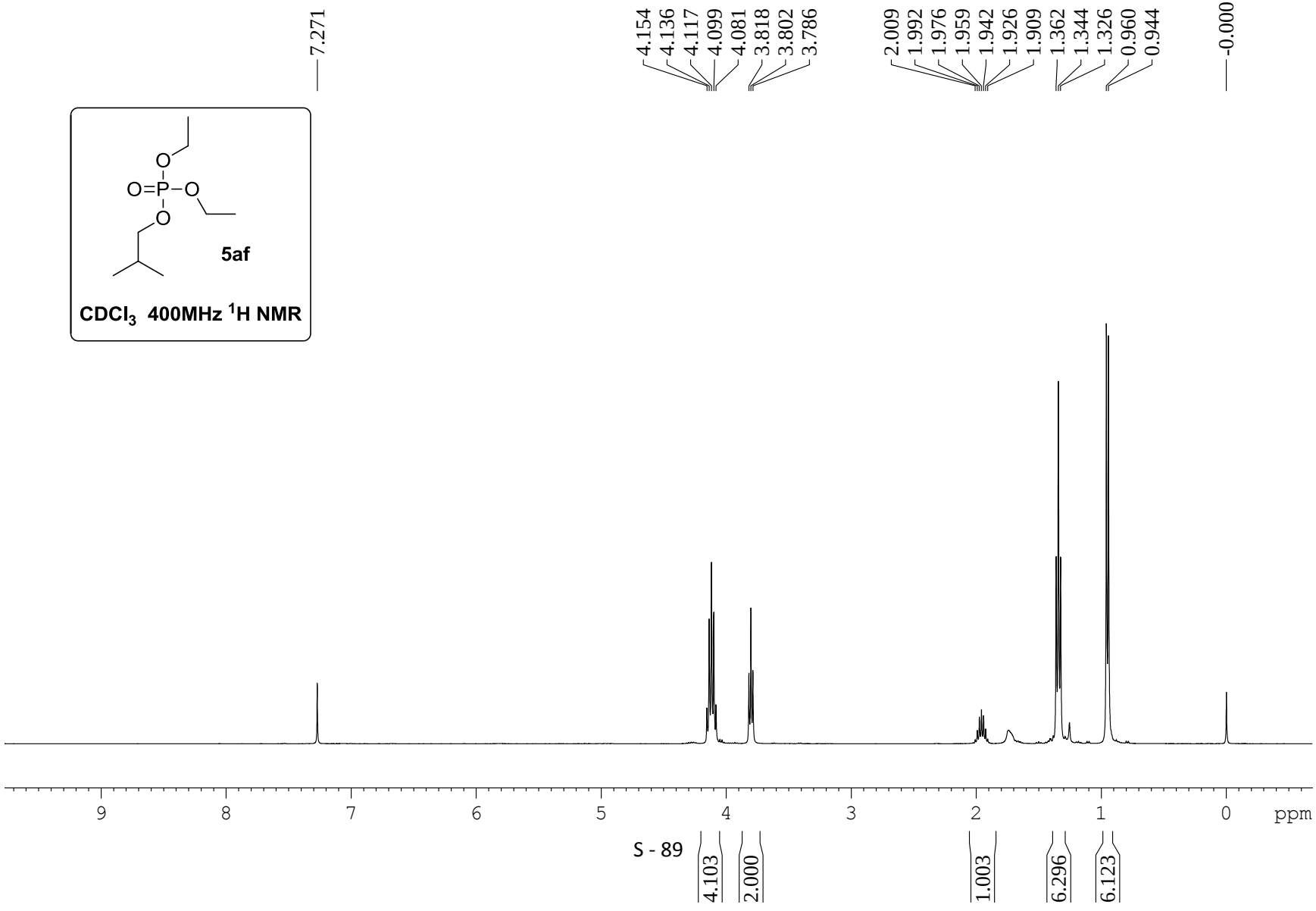

-0.868
O
O=P–O
O
5ad
CDCl3 162MHz 31P NMR
S - 85
200
150
100
50
0
-50
-100
-150
-200
ppm

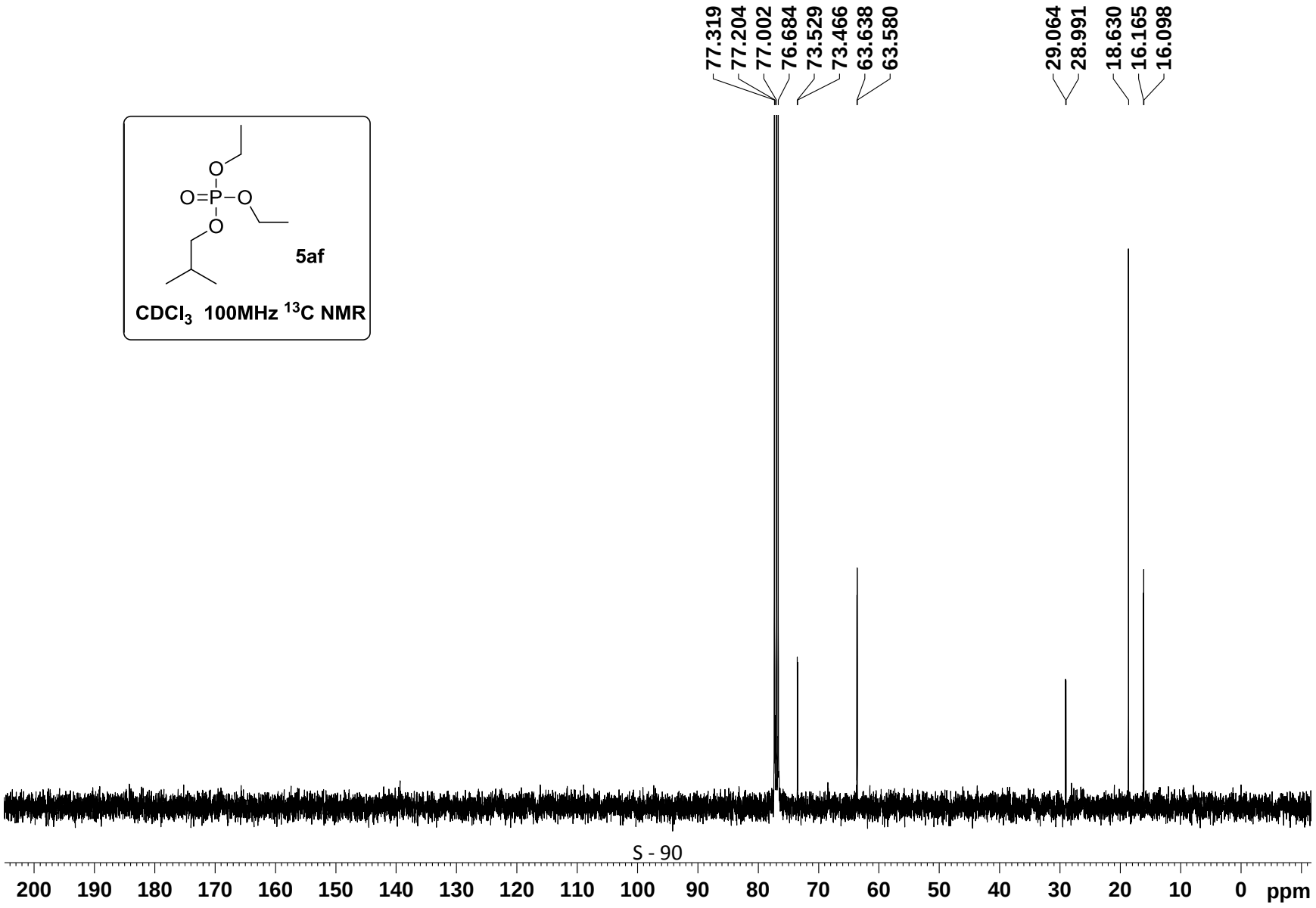

7.296
4.150
4.132
4.114
4.096
4.077
4.058
4.041
4.024
4.008
1.703
1.687
1.671
1.361
1.344
1.326
0.926
0.909
0.000
5ae
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 86
4.014
2.016
1.975
10.016
3.000

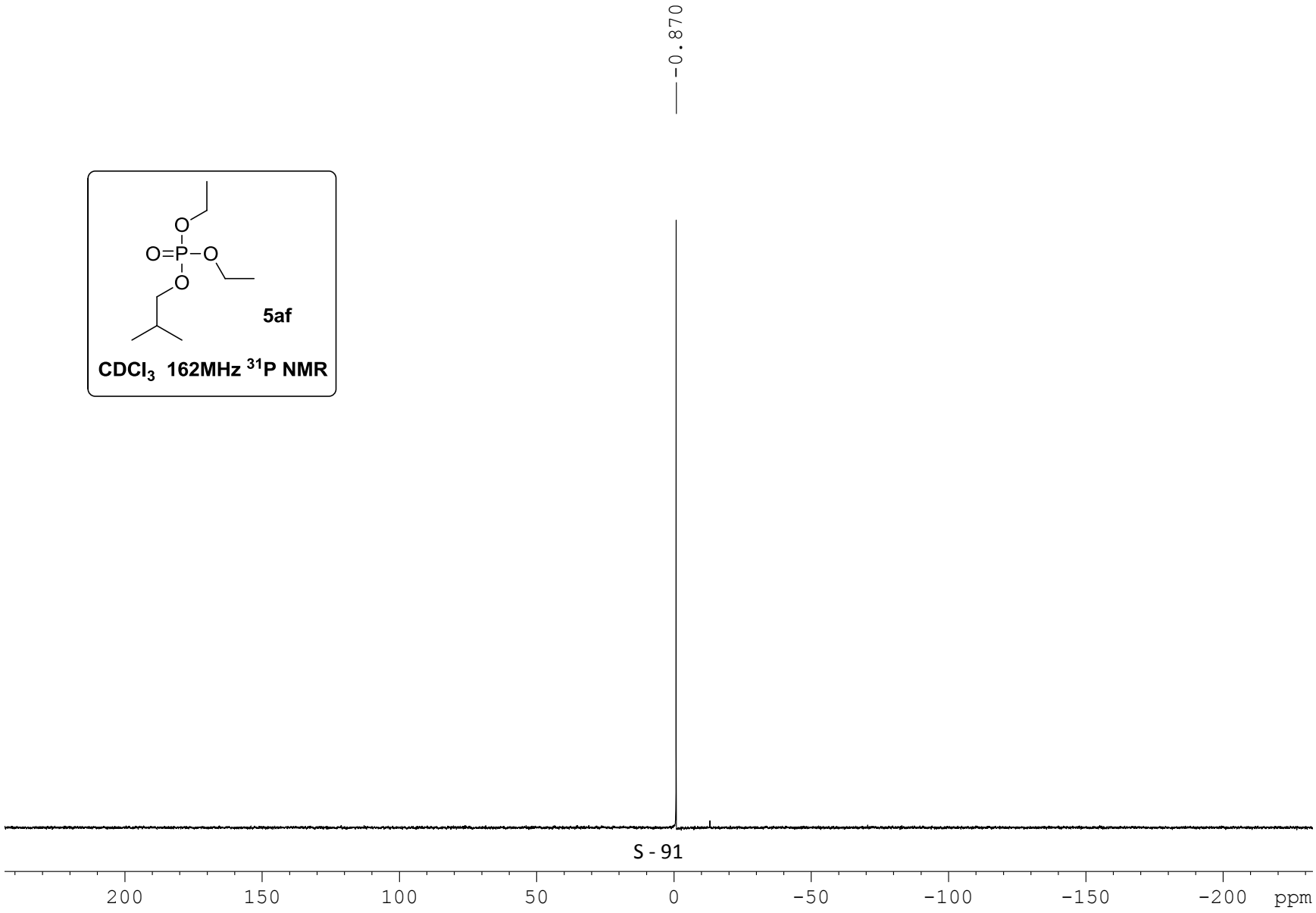

77.316
76.998
76.680
67.639
67.581
63.591
63.533
29.914
29.846
27.491
22.125
16.090
16.025
13.853
5ae
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

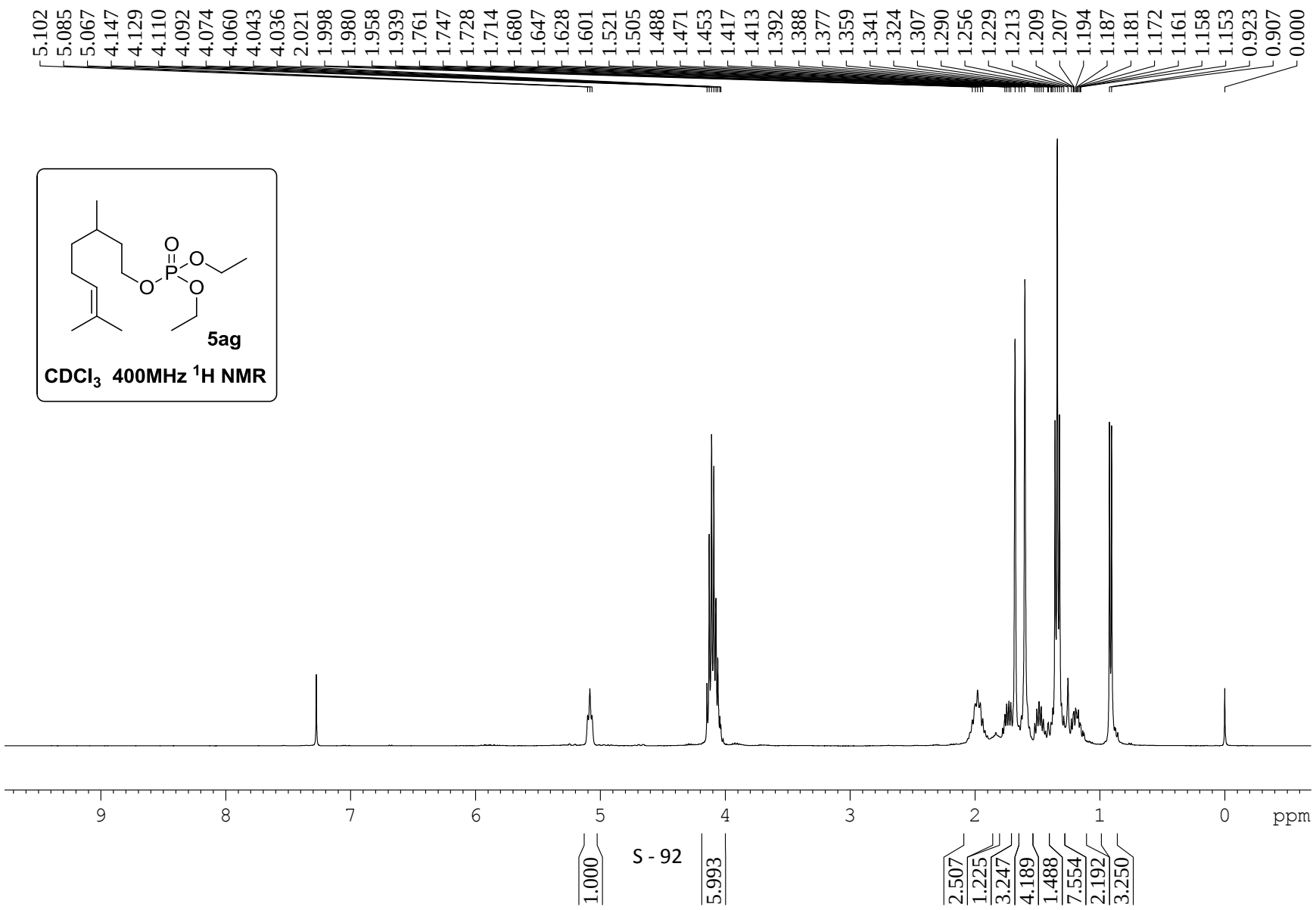

5ae
CDCl3 162MHz 31P NMR

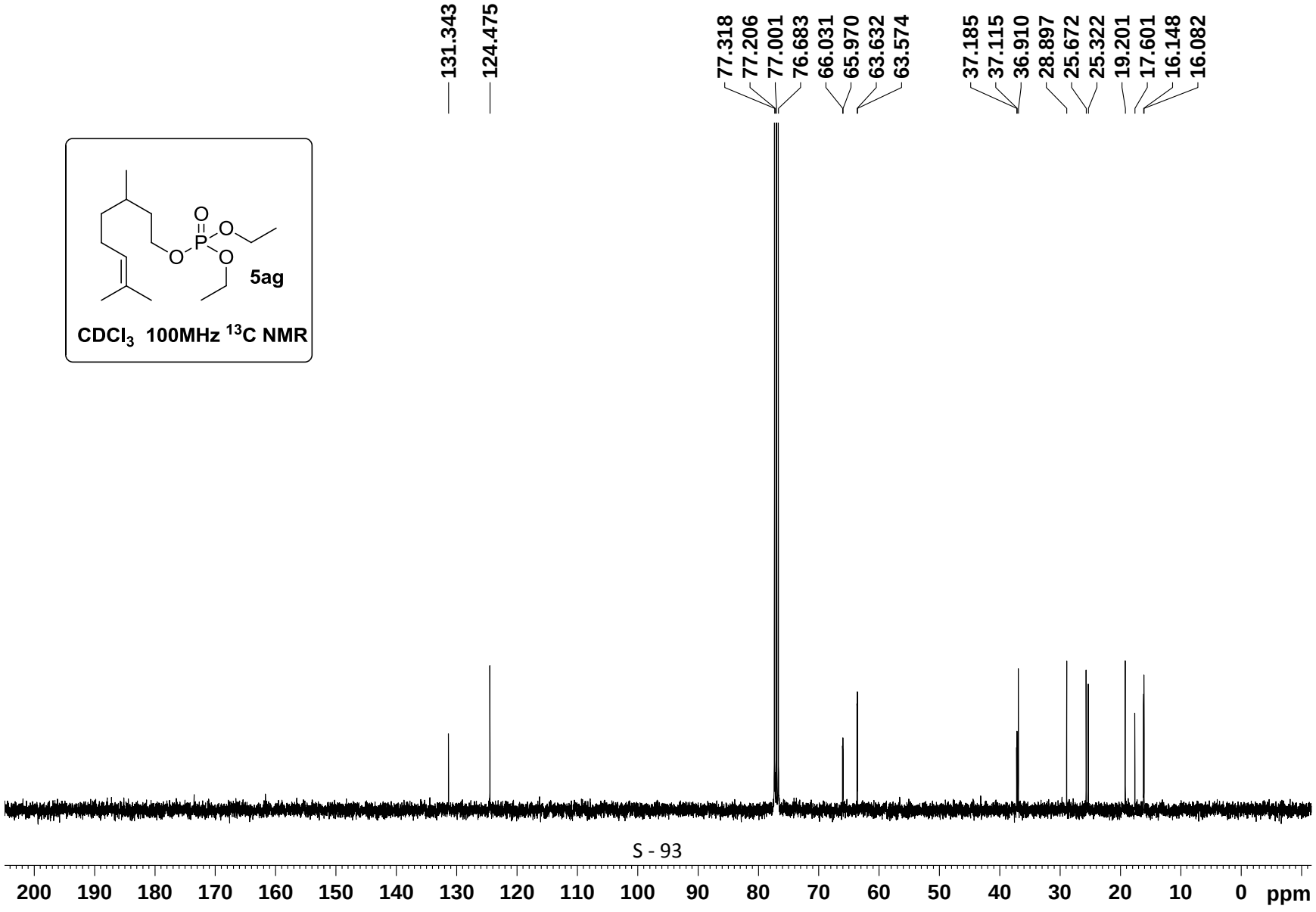
-0.915
S - 88
200
150
100
50
0
-50
-100
-150
-200
ppm

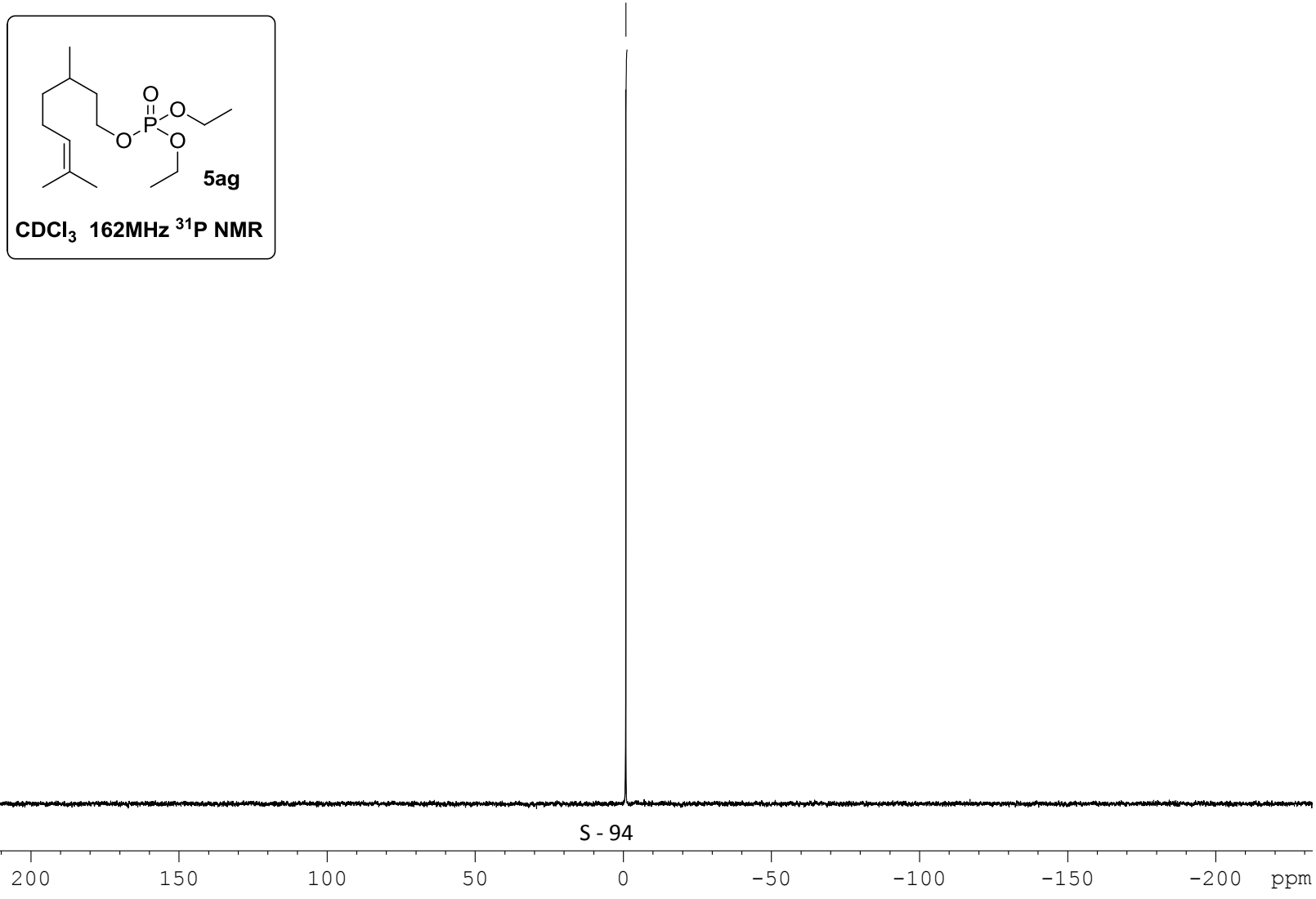

7.271
4.154
4.136
4.117
4.099
4.081
3.818
3.802
3.786
2.009
1.992
1.976
1.959
1.942
1.926
1.909
1.362
1.344
1.326
0.960
0.944
-0.000
5af
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 89
4.103
2.000
1.003
6.296
6.123

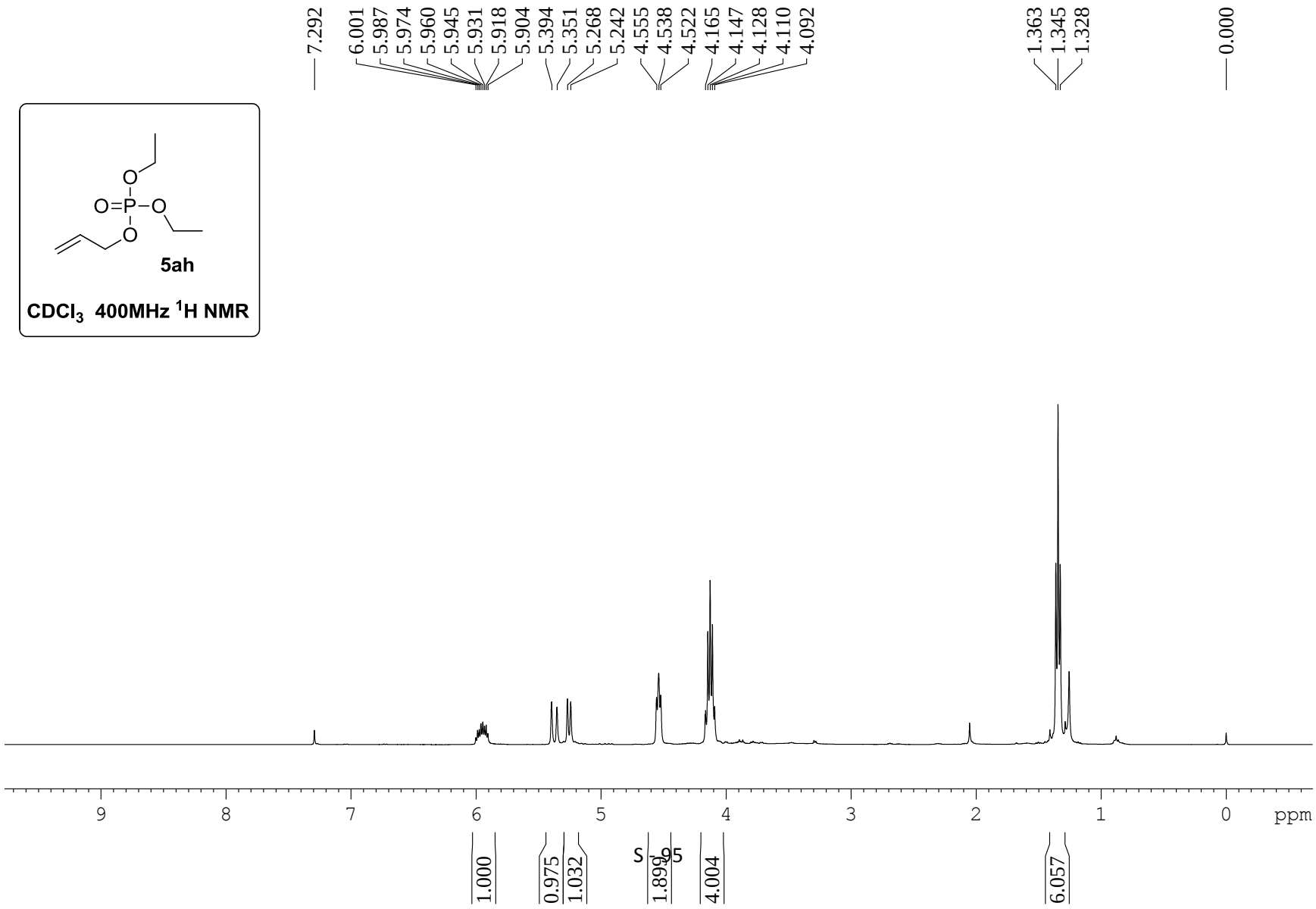

77.319
77.204
77.002
76.684
73.529
73.466
63.638
63.580
29.064
28.991
18.630
16.165
16.098
5af
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

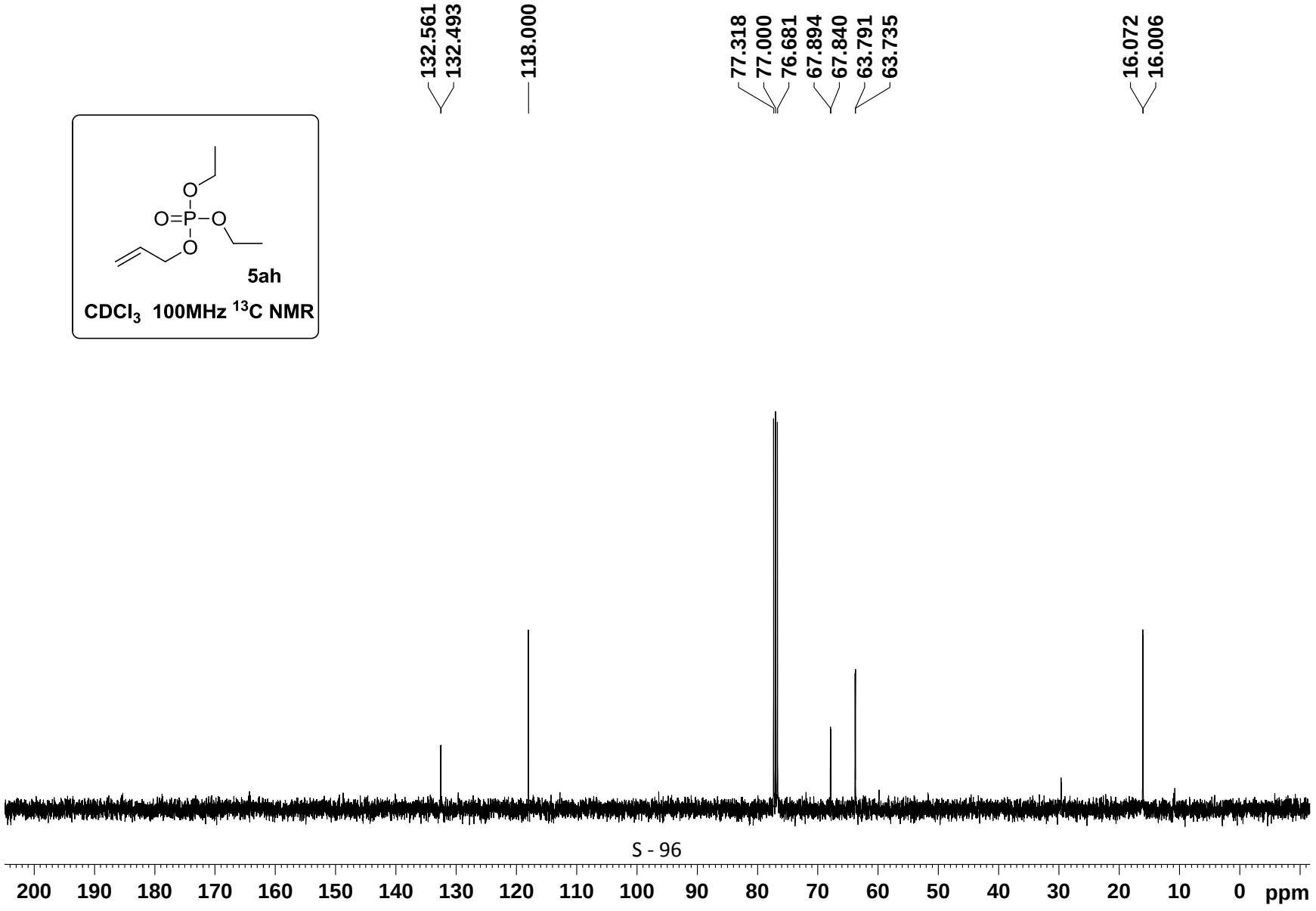

-0.870
5af
CDCl3 162MHz 31P NMR
S - 91
200
150
100
50
0
-50
-100
-150
-200
ppm

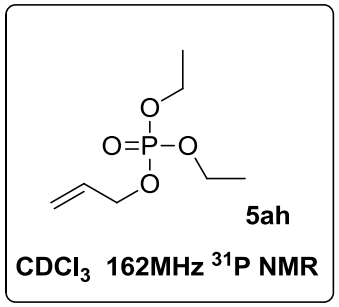

5.102
5.085
5.067
4.147
4.129
4.110
4.092
4.074
4.060
4.043
4.036
2.021
1.998
1.980
1.958
1.939
1.761
1.747
1.728
1.714
1.680
1.647
1.628
1.601
1.521
1.505
1.488
1.471
1.453
1.417
1.413
1.392
1.388
1.377
1.359
1.341
1.324
1.307
1.290
1.256
1.229
1.213
1.209
1.207
1.194
1.187
1.181
1.172
1.161
1.158
1.153
0.923
0.907
0.000
5ag
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
1.000
5.993
2.507
1.225
3.247
4.189
1.488
7.554
2.192
3.250
S - 92


131.343
124.475
77.318
77.206
77.001
76.683
66.031
65.970
63.632
63.574
37.185
37.115
36.910
28.897
25.672
25.322
19.201
17.601
16.148
16.082
5ag
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


-0.831
5ag
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

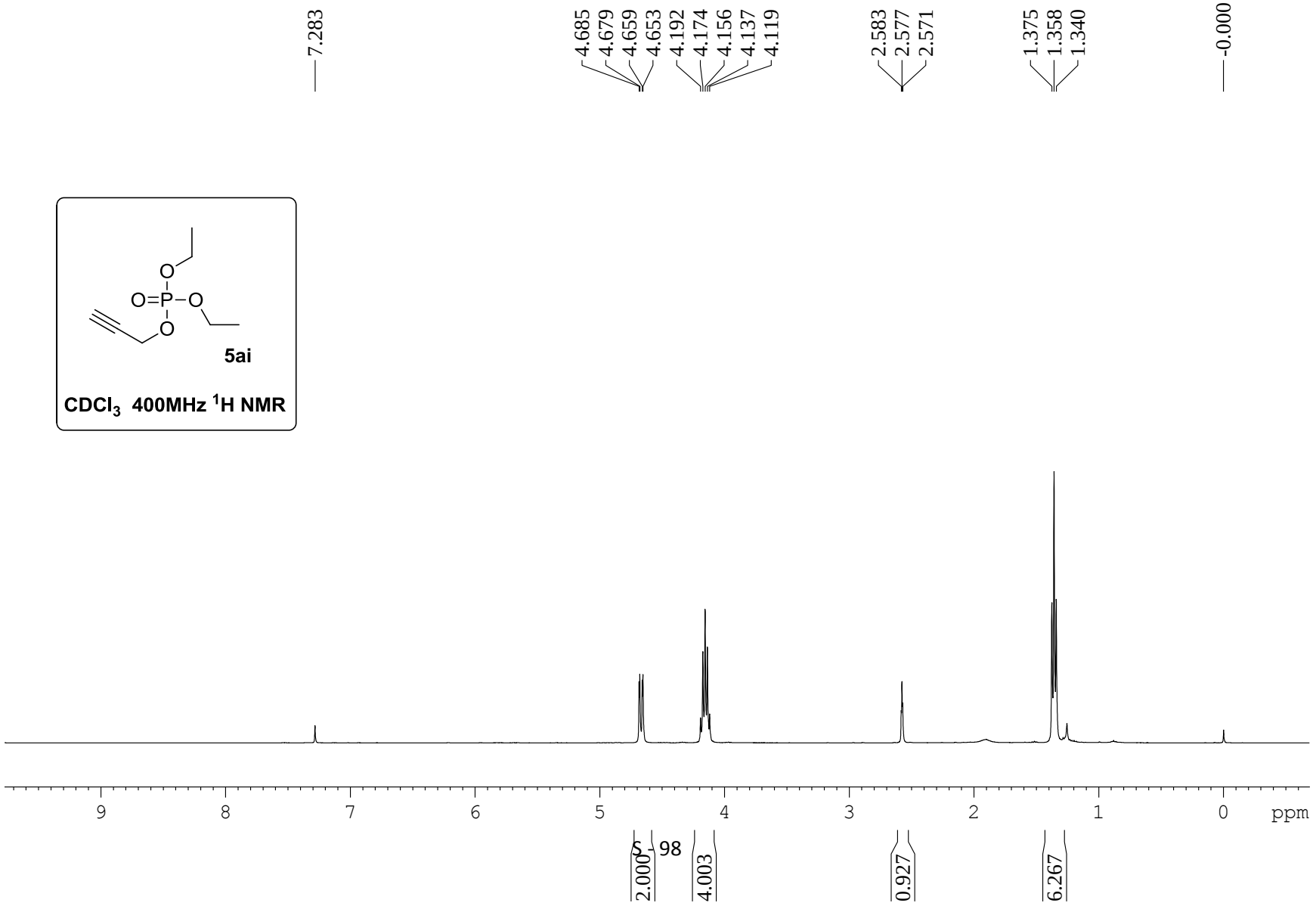

7.292
6.001
5.987
5.974
5.960
5.945
5.931
5.918
5.904
5.394
5.351
5.268
5.242
4.555
4.538
4.522
4.165
4.147
4.128
4.110
4.092
1.363
1.345
1.328
0.000
5ah
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
1.000
0.975
1.032
1.899
4.004
6.057

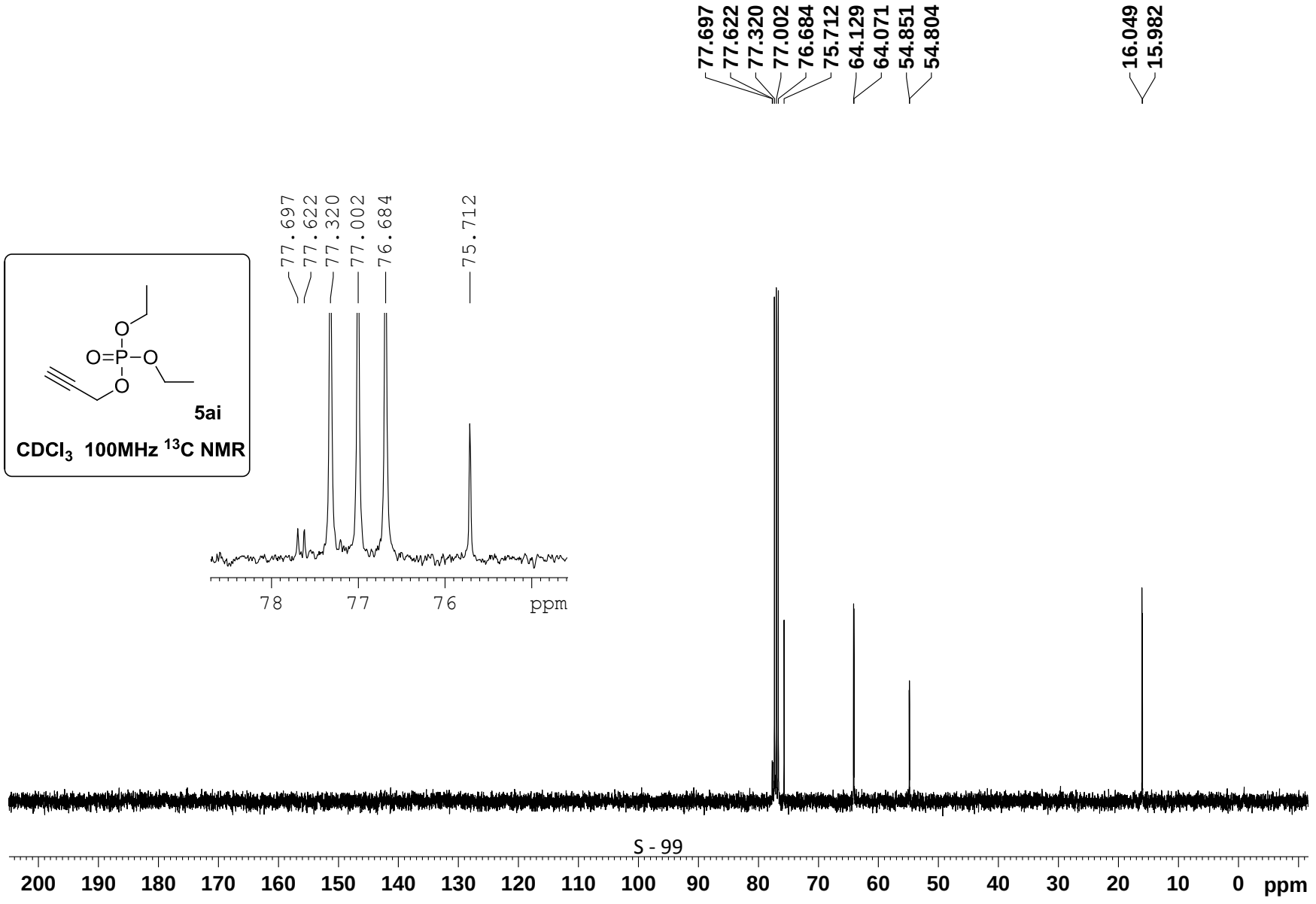

132.561
132.493
118.000
77.318
77.000
76.681
67.894
67.840
63.791
63.735
16.072
16.006
5ah
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

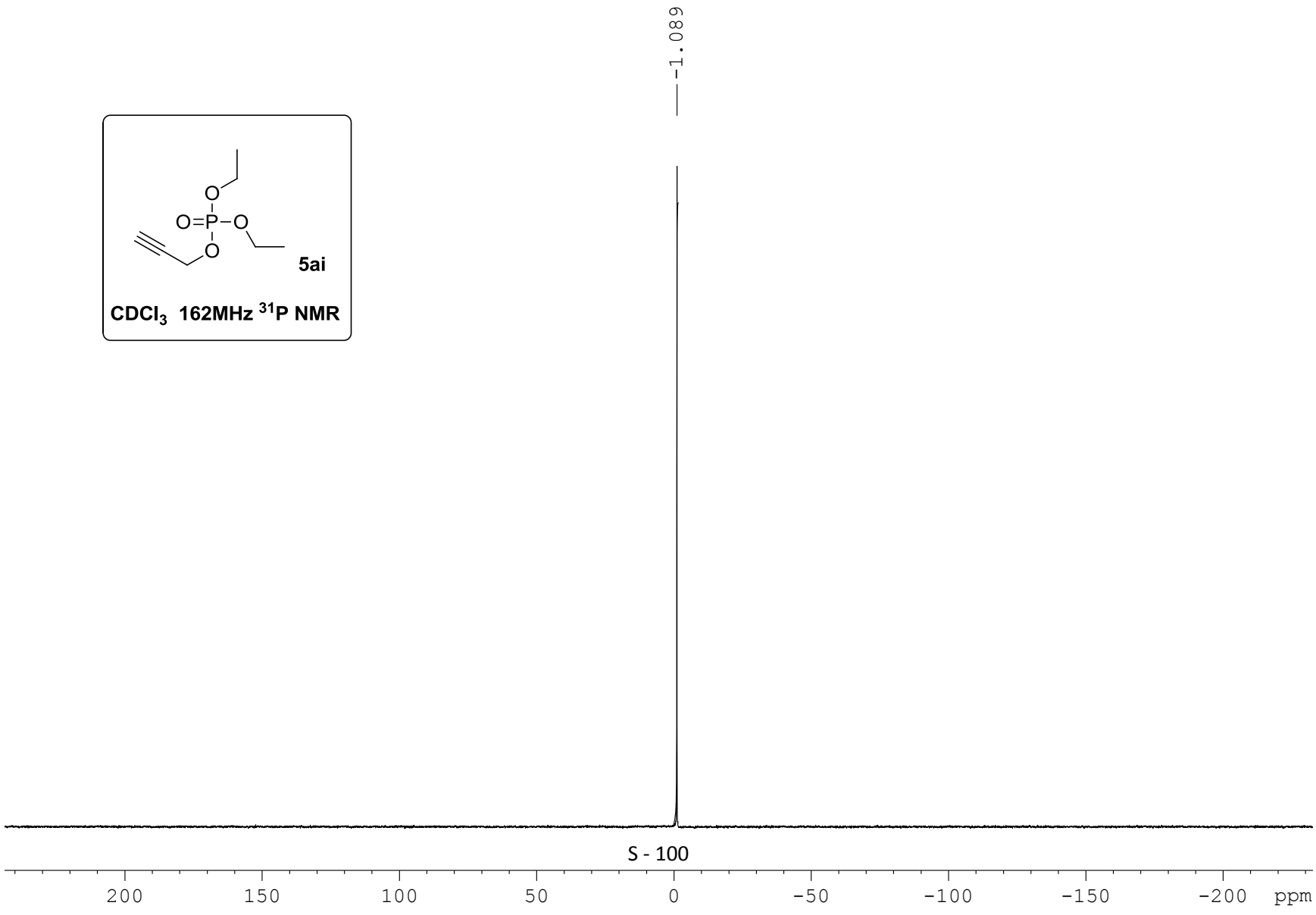


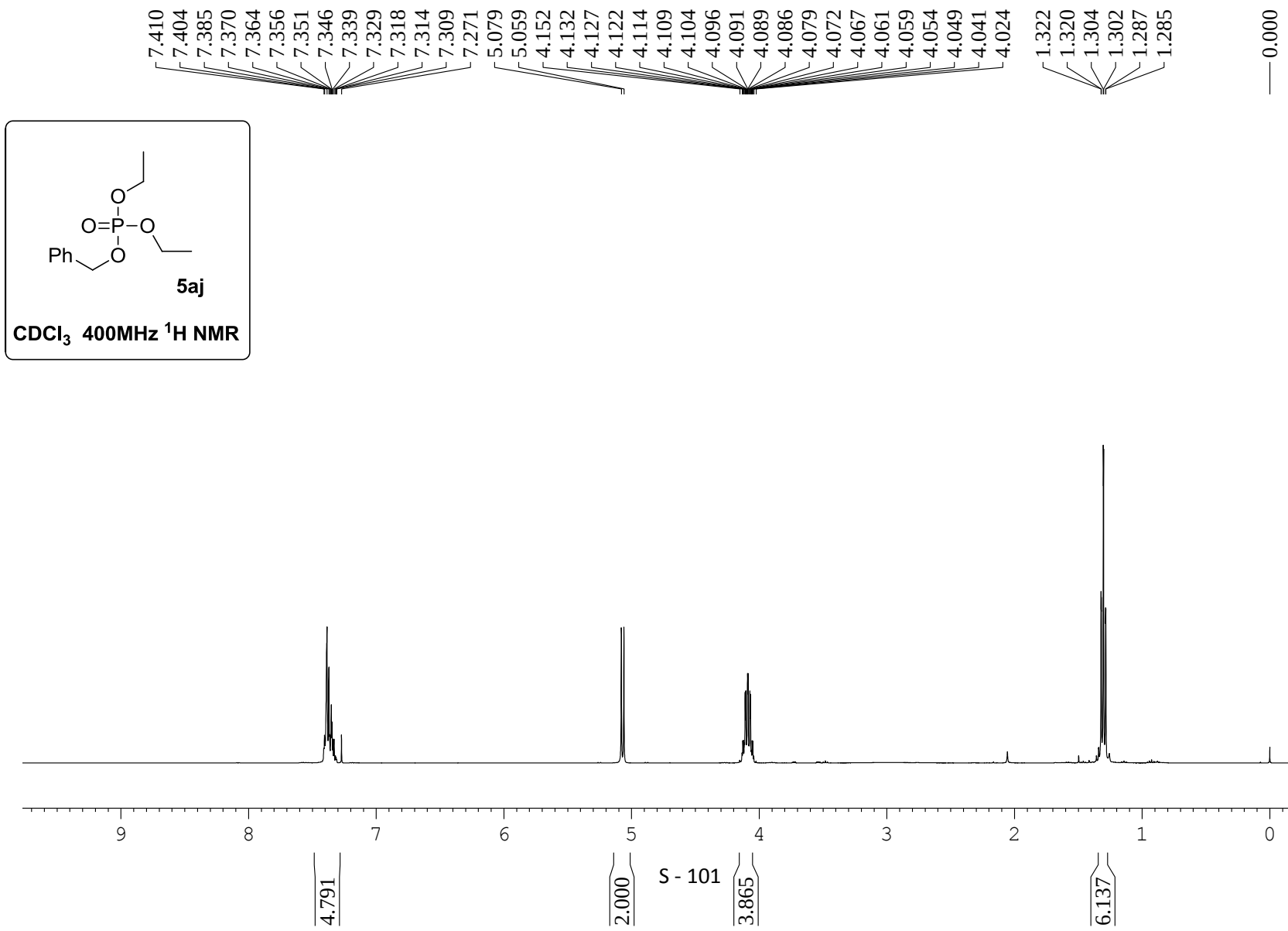
5ah

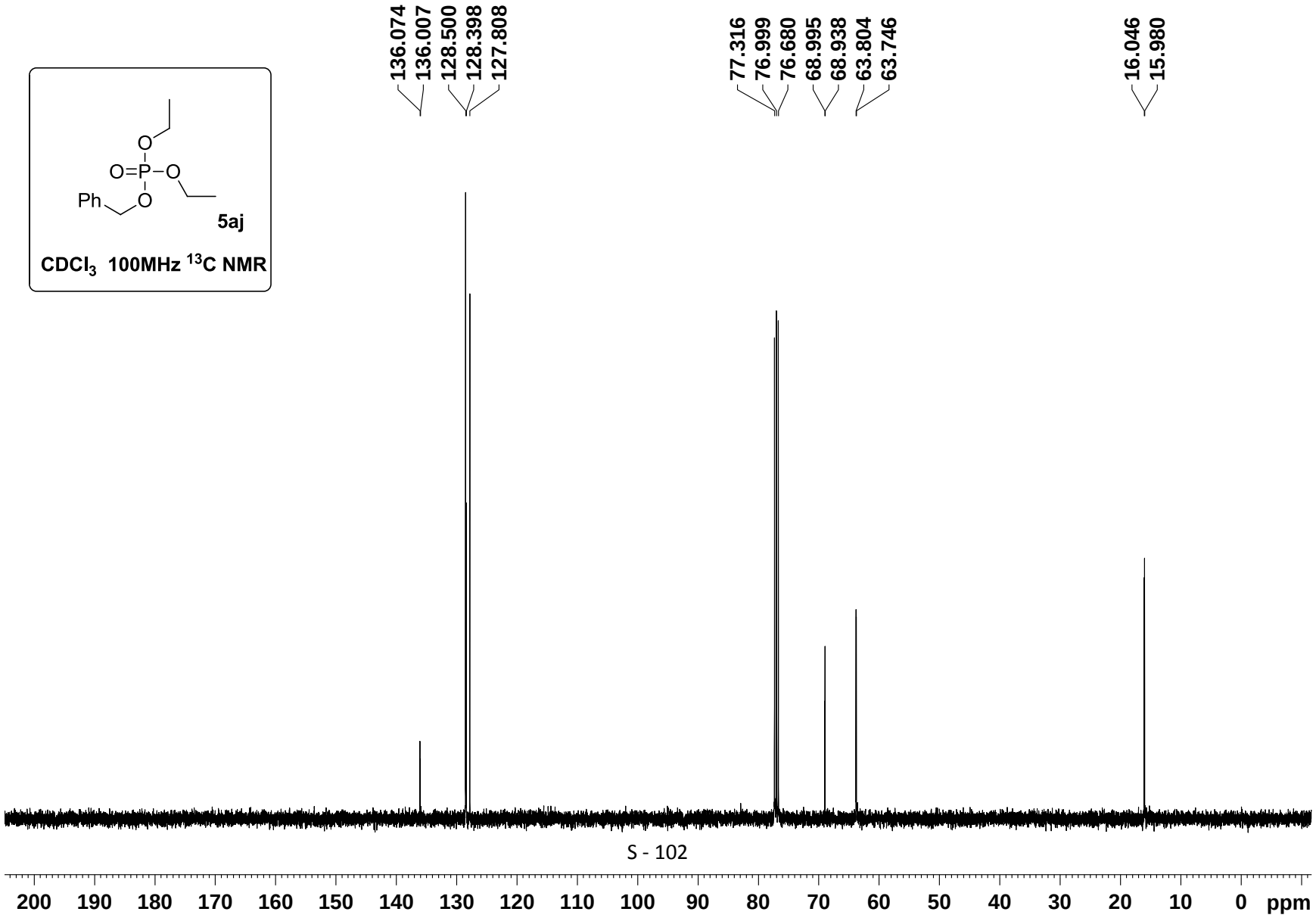
$CDCl_3$ 162MHz ^{31}P NMR

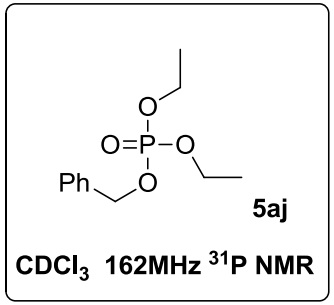

7.283
4.685
4.679
4.659
4.653
4.192
4.174
4.156
4.137
4.119
2.583
2.577
2.571
1.375
1.358
1.340
-0.000
5ai
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.000
4.003
0.927
6.267


77.697
77.622
77.320
77.002
76.684
75.712
64.129
64.071
54.851
54.804
16.049
15.982
5ai
CDCl3 100MHz 13C NMR
78
77
76
ppm
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

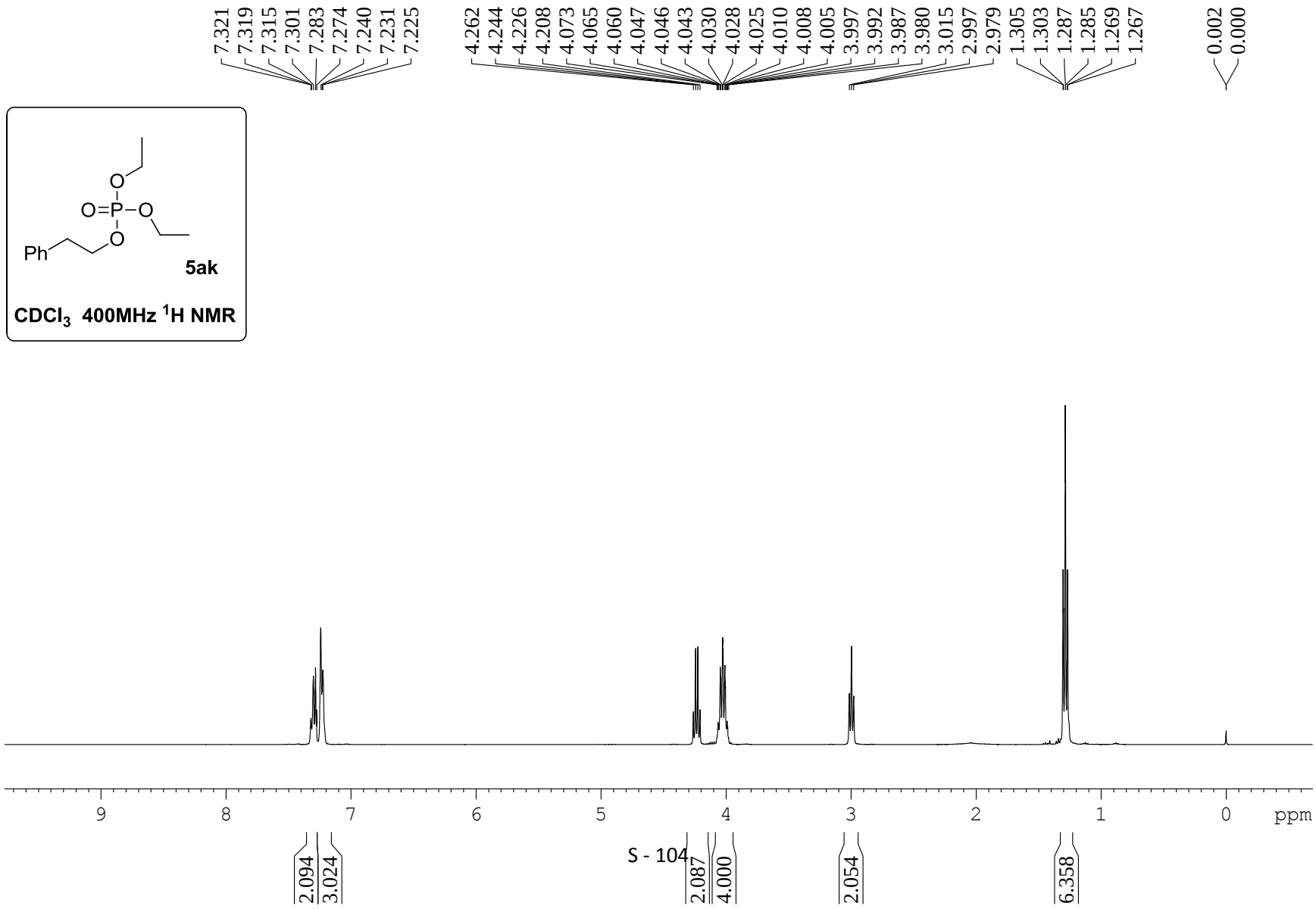

-1.089
5ai
CDCl3 162MHz 31P NMR
S - 100
200
150
100
50
0
-50
-100
-150
-200
ppm

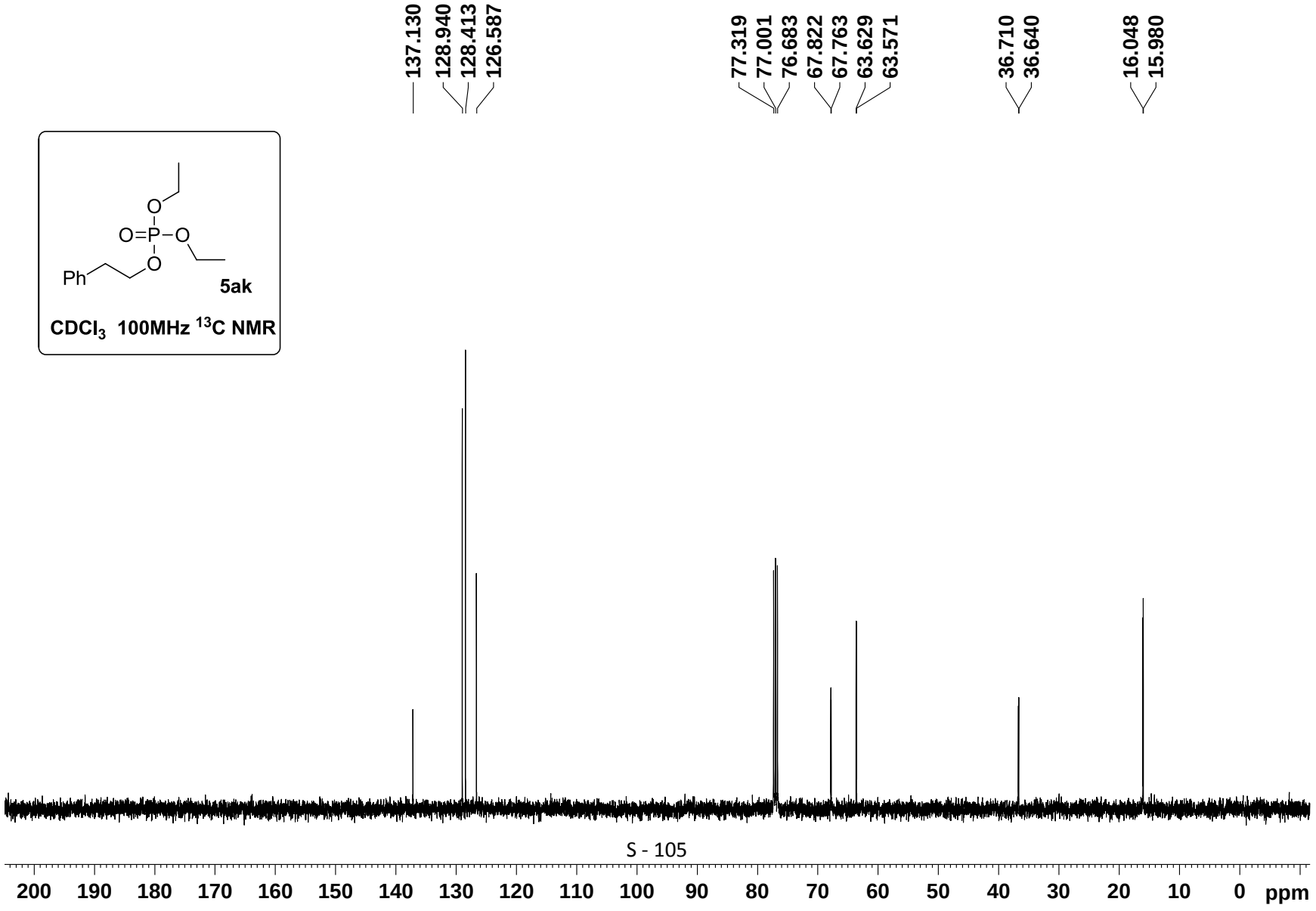

7.410
7.404
7.385
7.370
7.364
7.356
7.351
7.346
7.339
7.329
7.318
7.314
7.309
7.271
5.079
5.059
4.152
4.132
4.127
4.122
4.114
4.109
4.104
4.096
4.091
4.089
4.086
4.079
4.072
4.067
4.061
4.059
4.054
4.049
4.041
4.024
1.322
1.320
1.304
1.302
1.287
1.285
0.000
O
O=P–O
Ph
O
5aj
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
4.791
2.000
3.865
6.137
S - 101

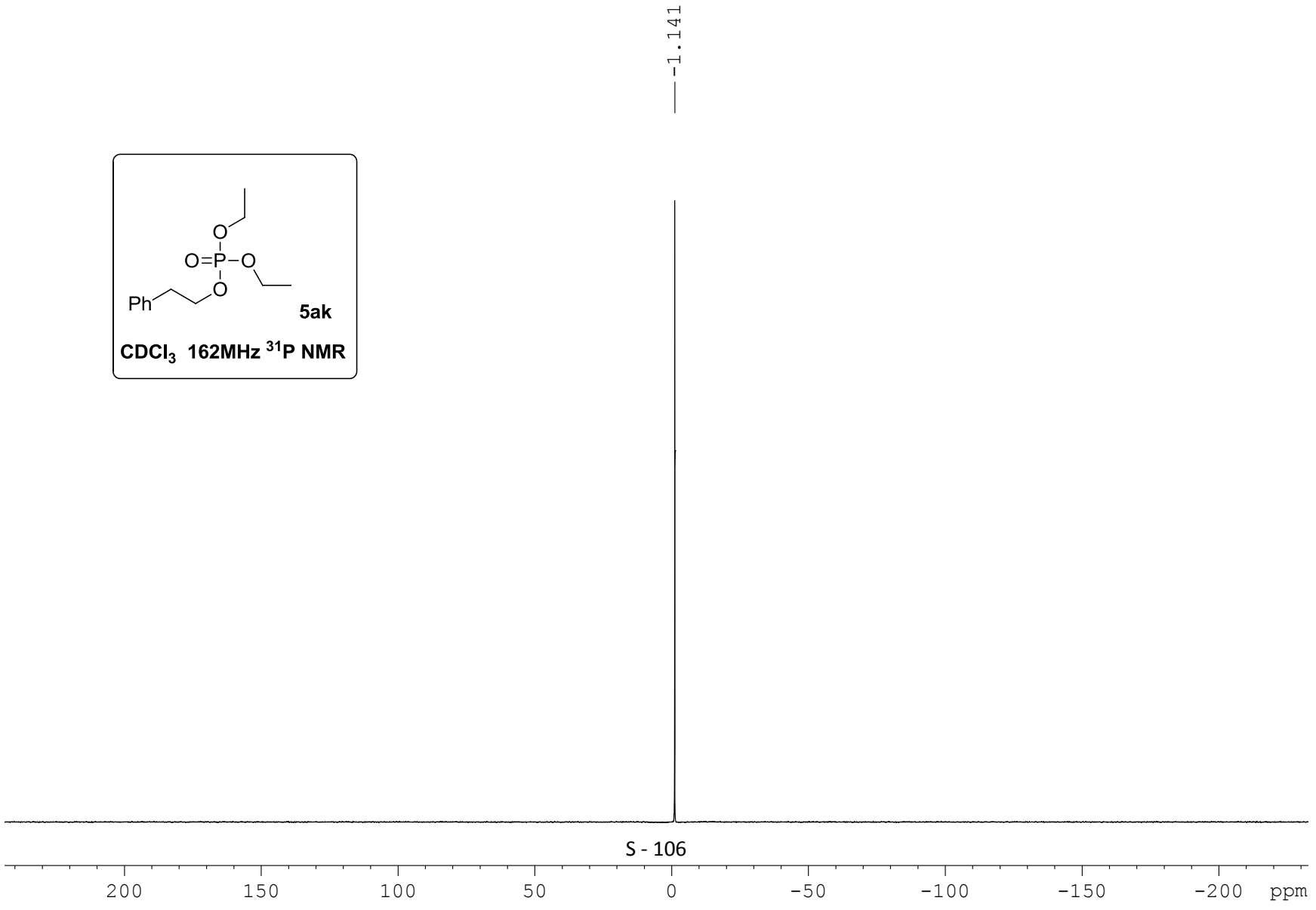

136.074
136.007
128.500
128.398
127.808
77.316
76.999
76.680
68.995
68.938
63.804
63.746
16.046
15.980
O
O=P–O
Ph
O
5aj
CDCl3 100MHz 13C NMR
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

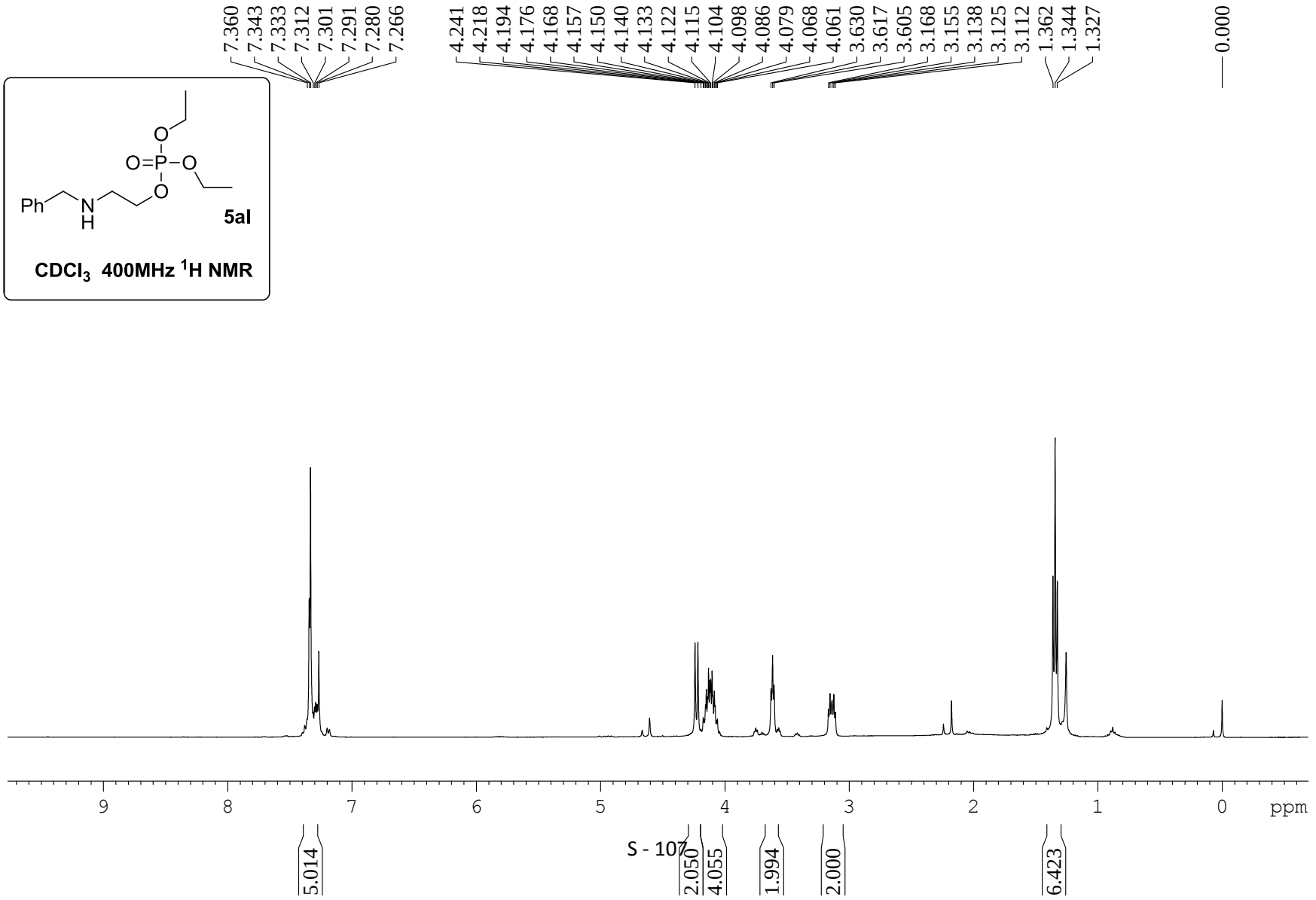


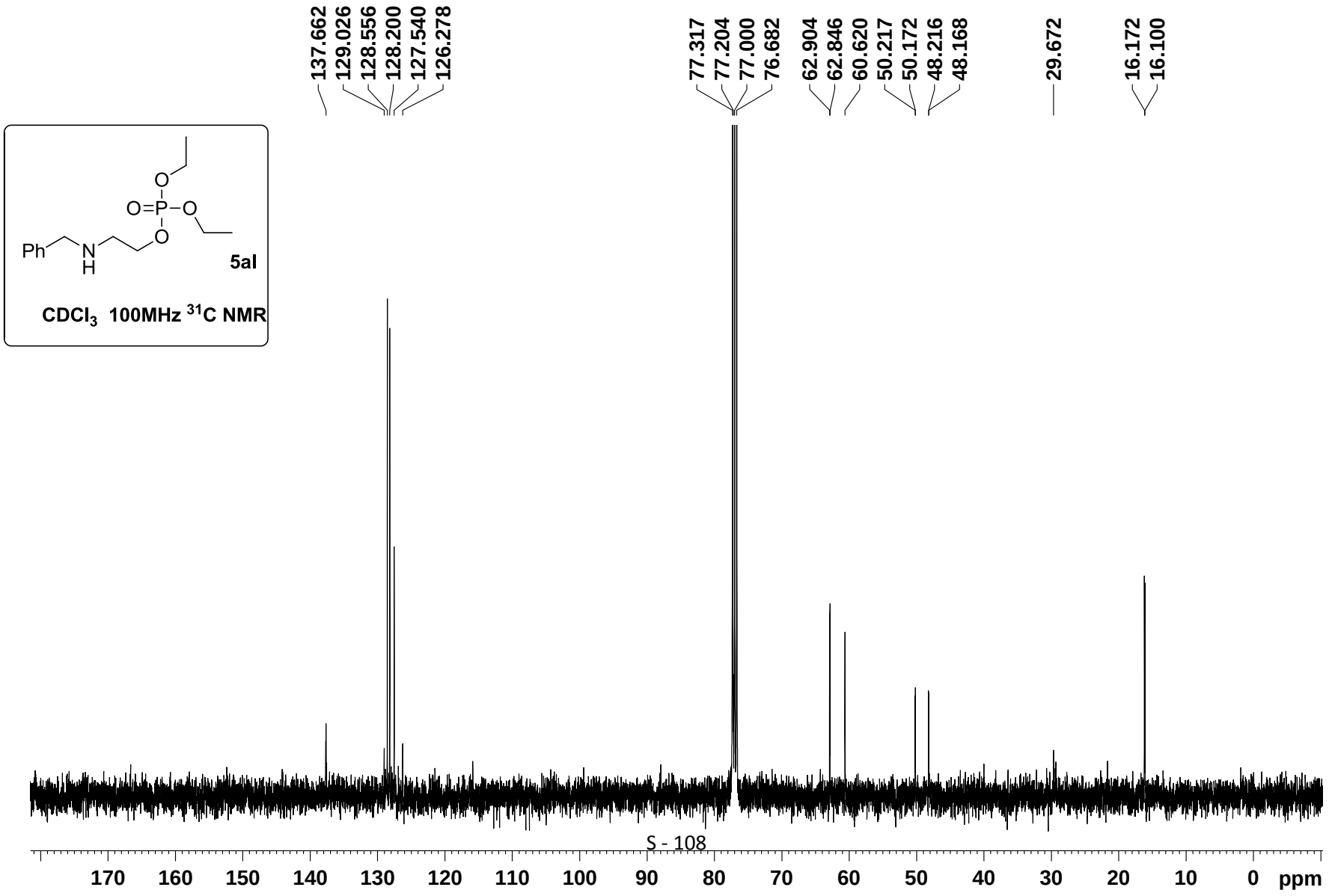
$CDCl_3$ 162MHz ^{31}P NMR

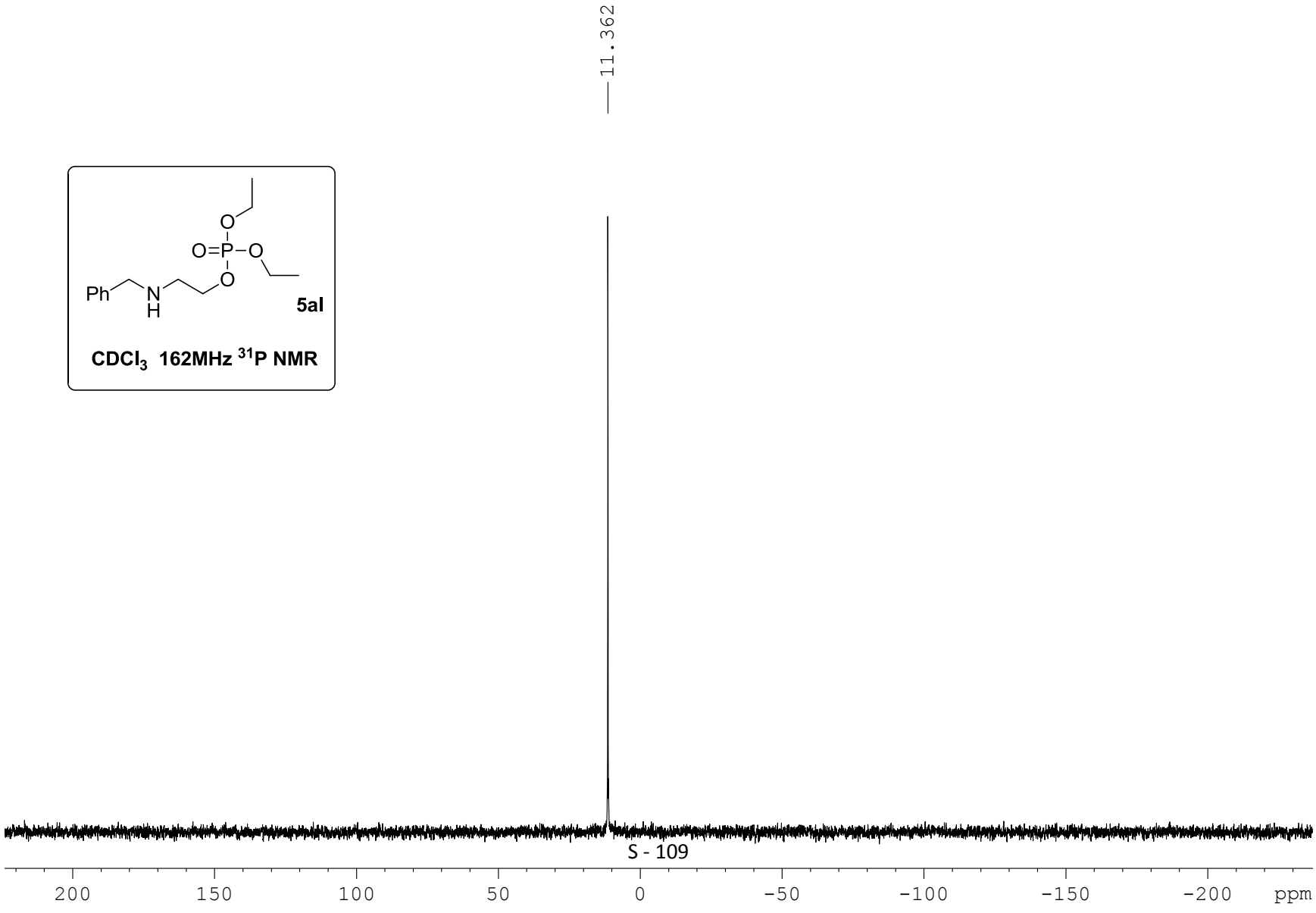

7.321
7.319
7.315
7.301
7.283
7.274
7.240
7.231
7.225
4.262
4.244
4.226
4.208
4.073
4.065
4.060
4.047
4.046
4.043
4.030
4.028
4.025
4.010
4.008
4.005
3.997
3.992
3.987
3.980
3.015
2.997
2.979
1.305
1.303
1.287
1.285
1.269
1.267
0.002
0.000
O
O=P–O
O
Ph
5ak
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.094
3.024
2.087
4.000
2.054
6.358

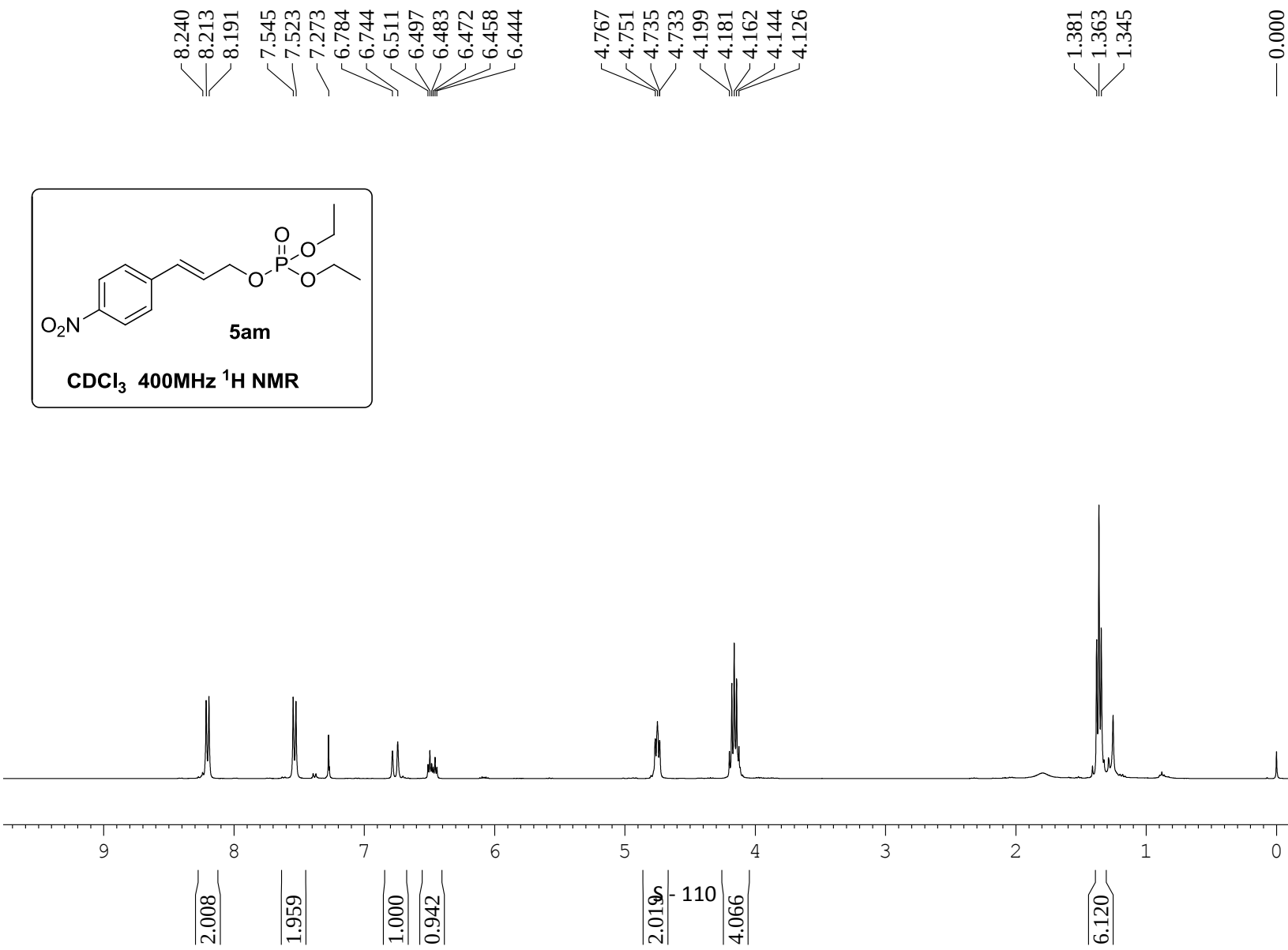

137.130
128.940
128.413
126.587
77.319
77.001
76.683
67.822
67.763
63.629
63.571
36.710
36.640
16.048
15.980
O
O=P–O
O
Ph
5ak
CDCl3 100MHz 13C NMR
S - 105
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

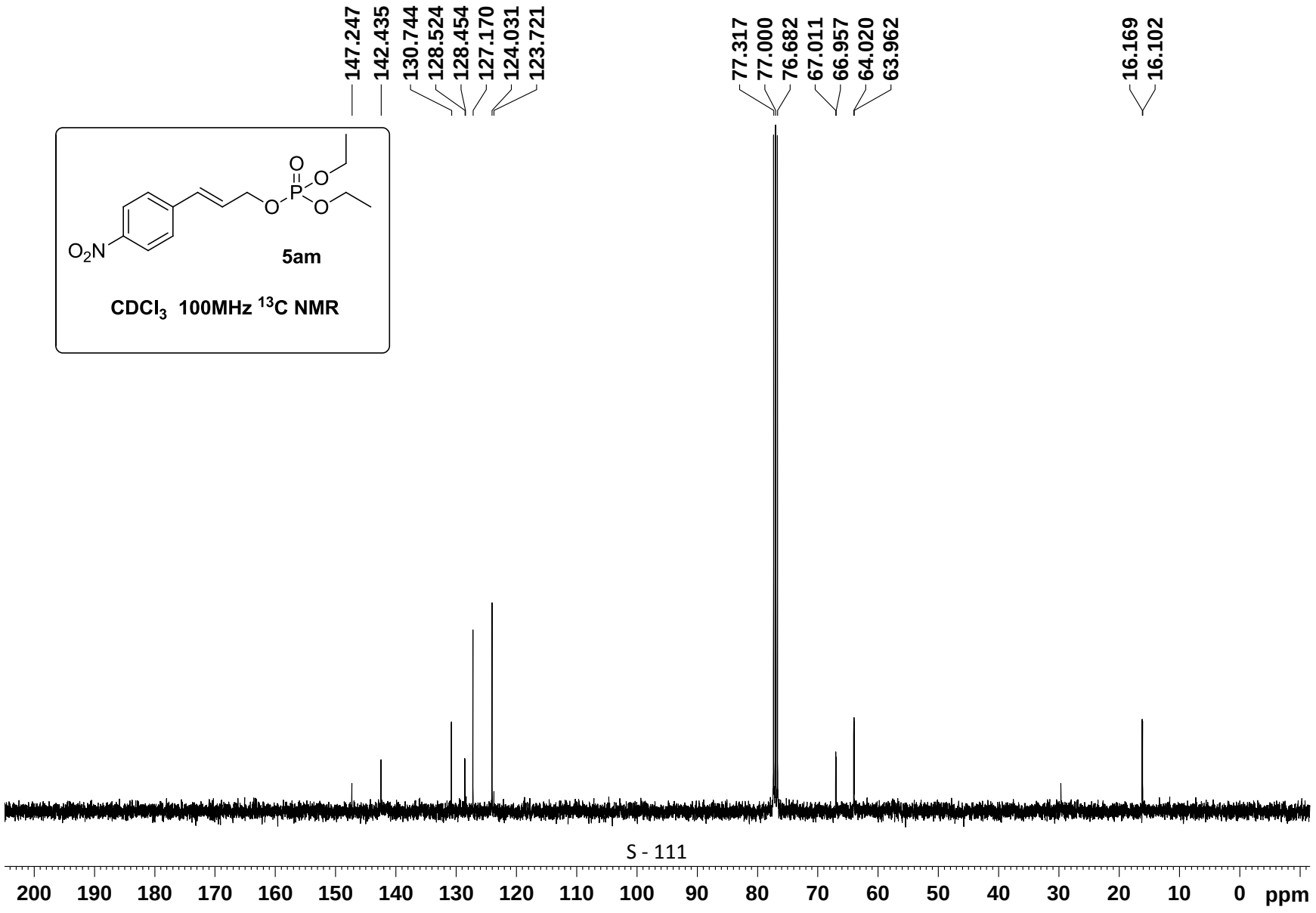

-1.141
O
O=P–O
O
Ph
5ak
CDCl3 162MHz 31P NMR
S - 106
200
150
100
50
0
-50
-100
-150
-200
ppm

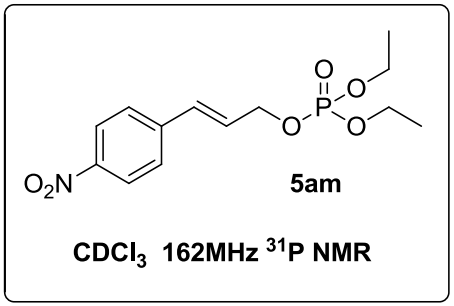

7.360
7.343
7.333
7.312
7.301
7.291
7.280
7.266
4.241
4.218
4.194
4.176
4.168
4.157
4.150
4.140
4.133
4.122
4.115
4.104
4.098
4.086
4.079
4.068
4.061
3.630
3.617
3.605
3.168
3.155
3.138
3.125
3.112
1.362
1.344
1.327
0.000
O
O=P–O
O
Ph
N
H
5aI
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
5.014
2.050
4.055
1.994
2.000
6.423


137.662
129.026
128.556
128.200
127.540
126.278
77.317
77.204
77.000
76.682
62.904
62.846
60.620
50.217
50.172
48.216
48.168
29.672
16.172
16.100
Ph
N
H
O
O=P−O
O
5al
CDCl3 100MHz 31C NMR
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


11.362
O
O=P–O
O
Ph
N
H
5al
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

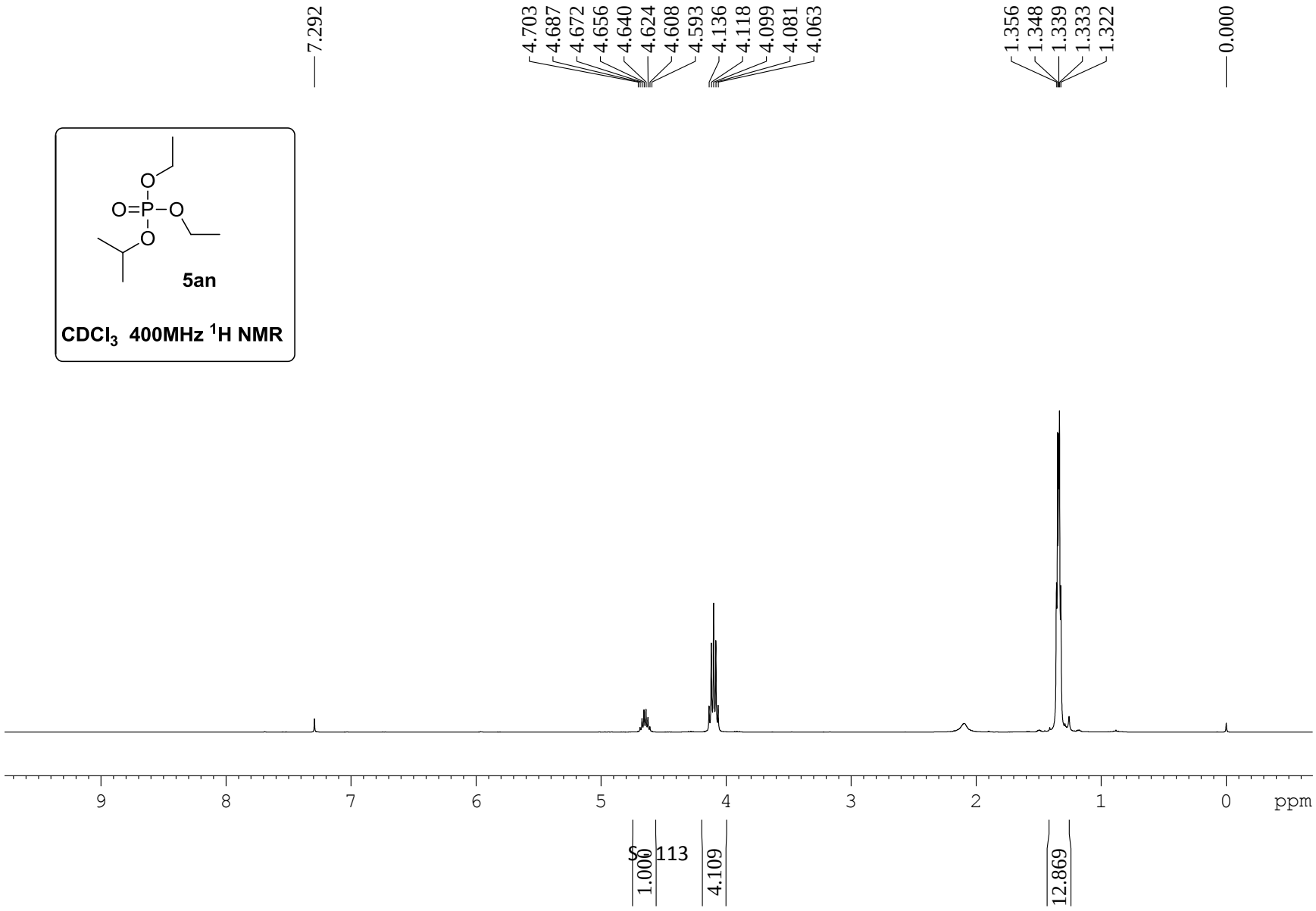

8.240
8.213
8.191
7.545
7.523
7.273
6.784
6.744
6.511
6.497
6.483
6.472
6.458
6.444
4.767
4.751
4.735
4.733
4.199
4.181
4.162
4.144
4.126
1.381
1.363
1.345
0.000
O2N
5am
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.008
1.959
1.000
0.942
2.019
4.066
6.120

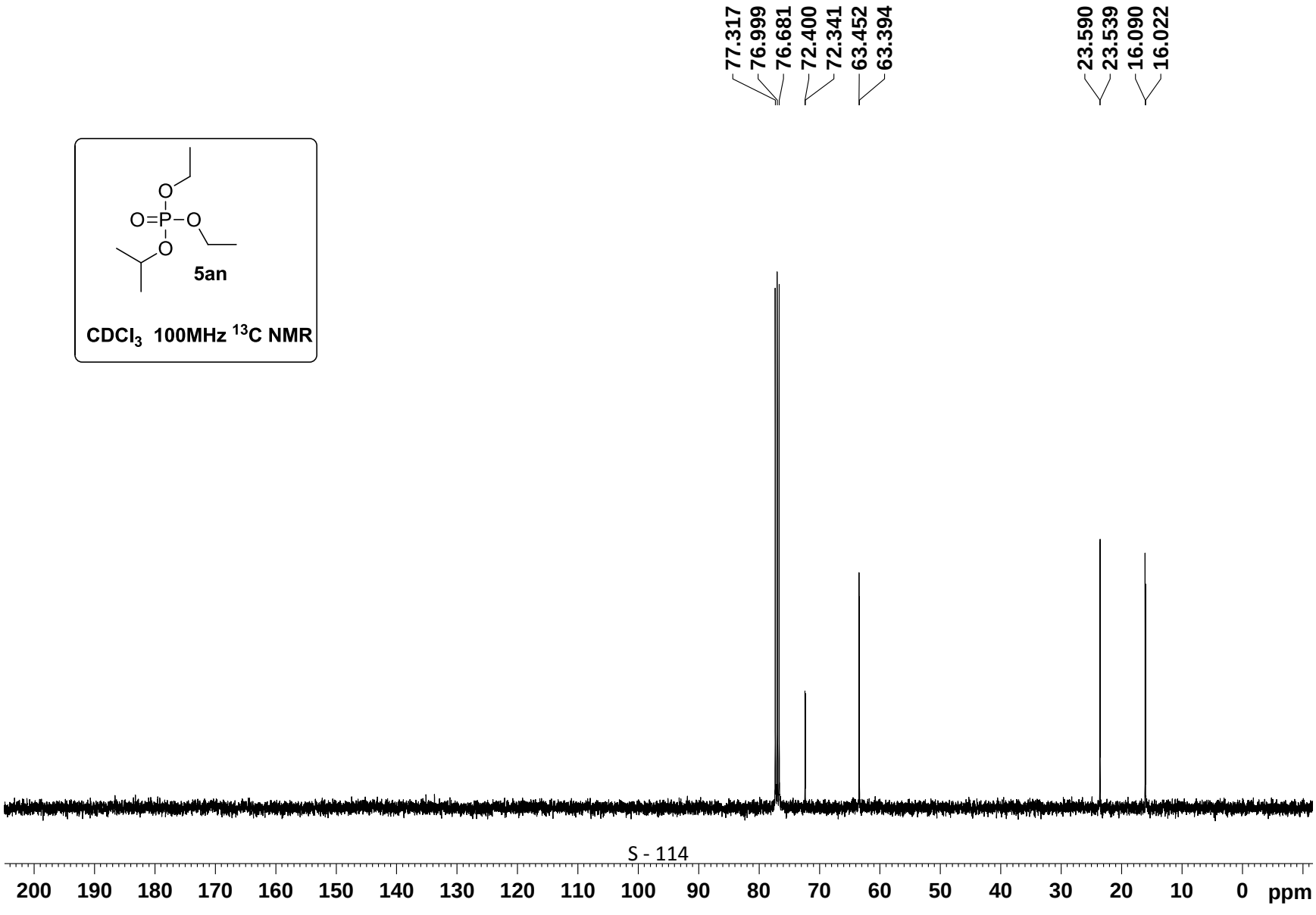

147.247
142.435
130.744
128.524
128.454
127.170
124.031
123.721
77.317
77.000
76.682
67.011
66.957
64.020
63.962
16.169
16.102
O2N
5am
CDCl3 100MHz 13C NMR
S - 111
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

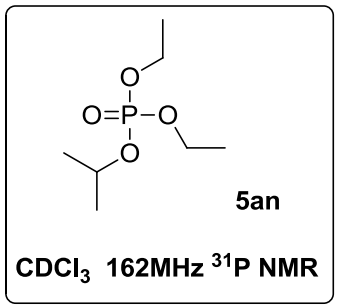


5am

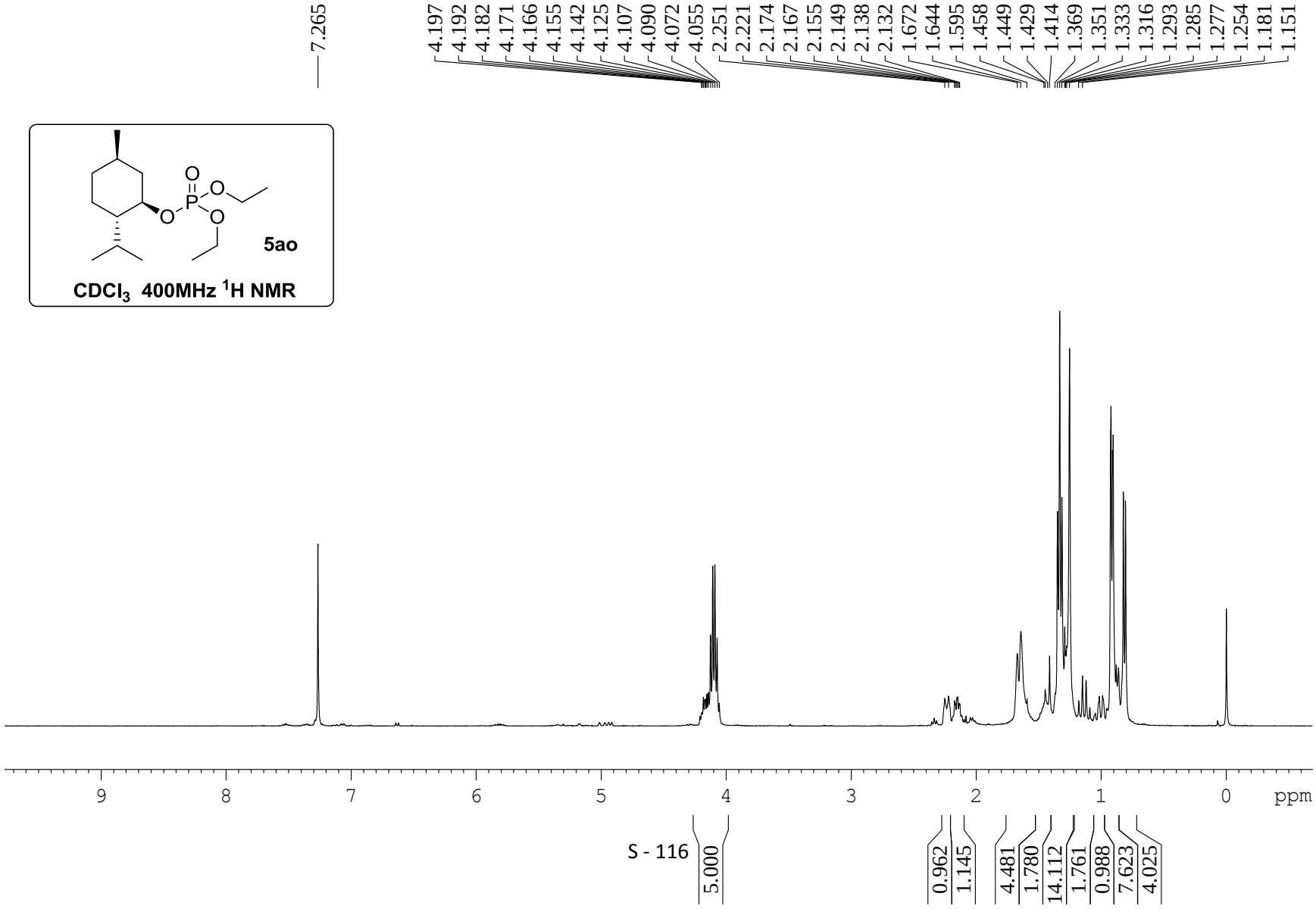
$CDCl_3$ 162MHz ^{31}P NMR

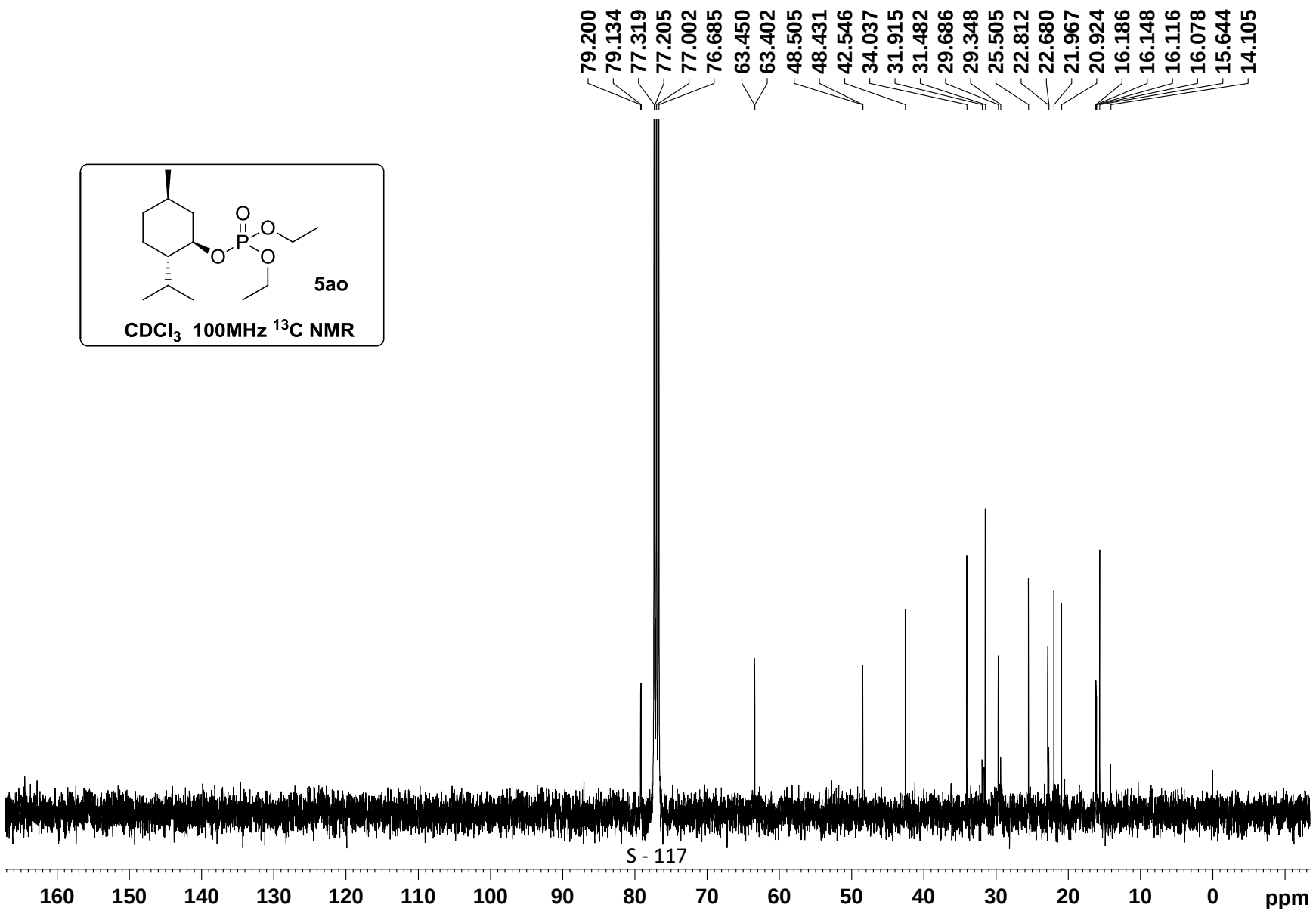

7.292
4.703
4.687
4.672
4.656
4.640
4.624
4.608
4.593
4.136
4.118
4.099
4.081
4.063
1.356
1.348
1.339
1.333
1.322
0.000
5an
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
1.000
4.109
12.869

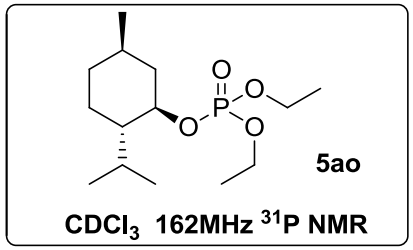

77.317
76.999
76.681
72.400
72.341
63.452
63.394
23.590
23.539
16.090
16.022
5an
CDCl3 100MHz 13C NMR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


5an
CDCl3 162MHz 31P NMR

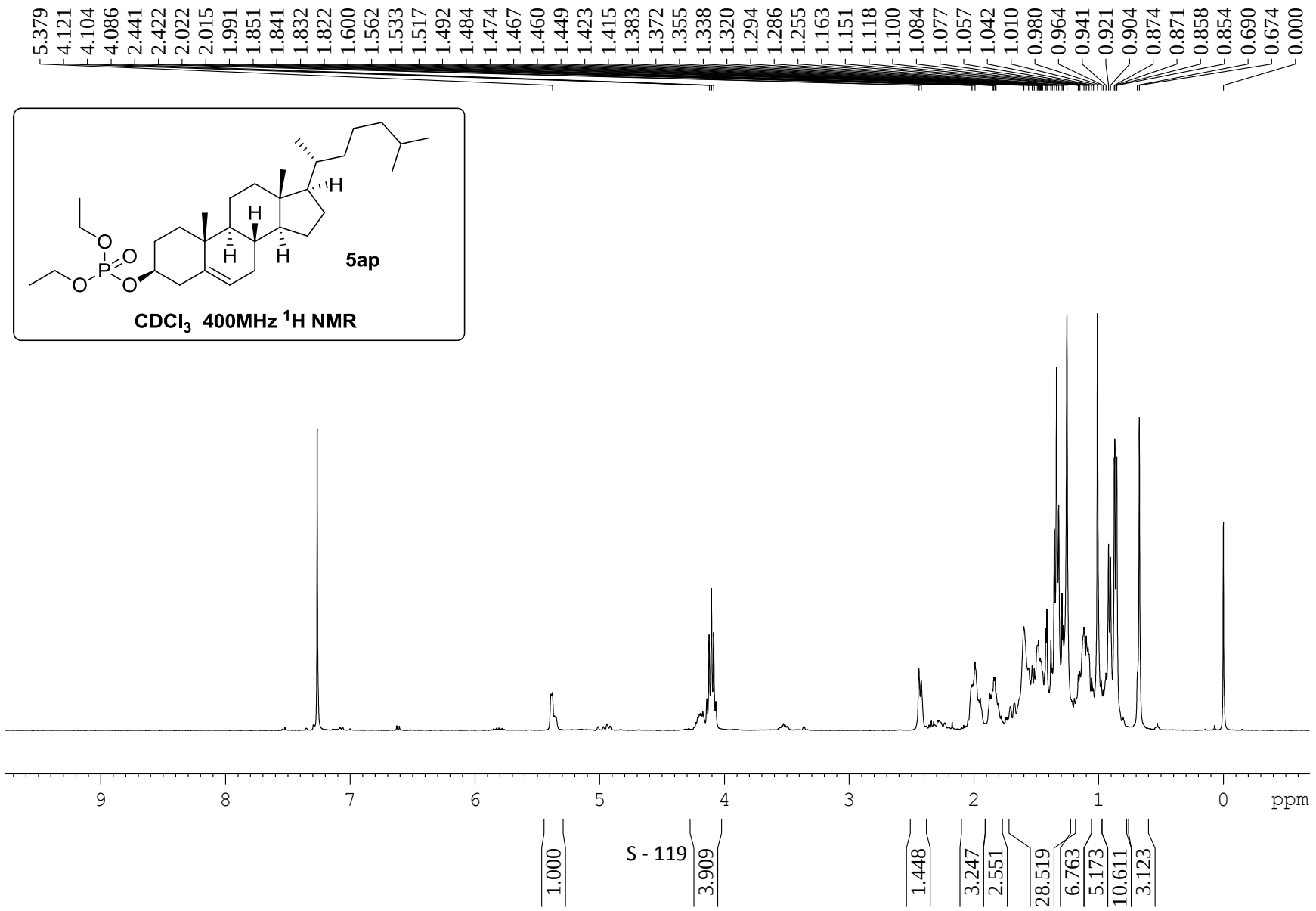
-1.858
S - 115
200
150
100
50
0
-50
-100
-150
-200
ppm

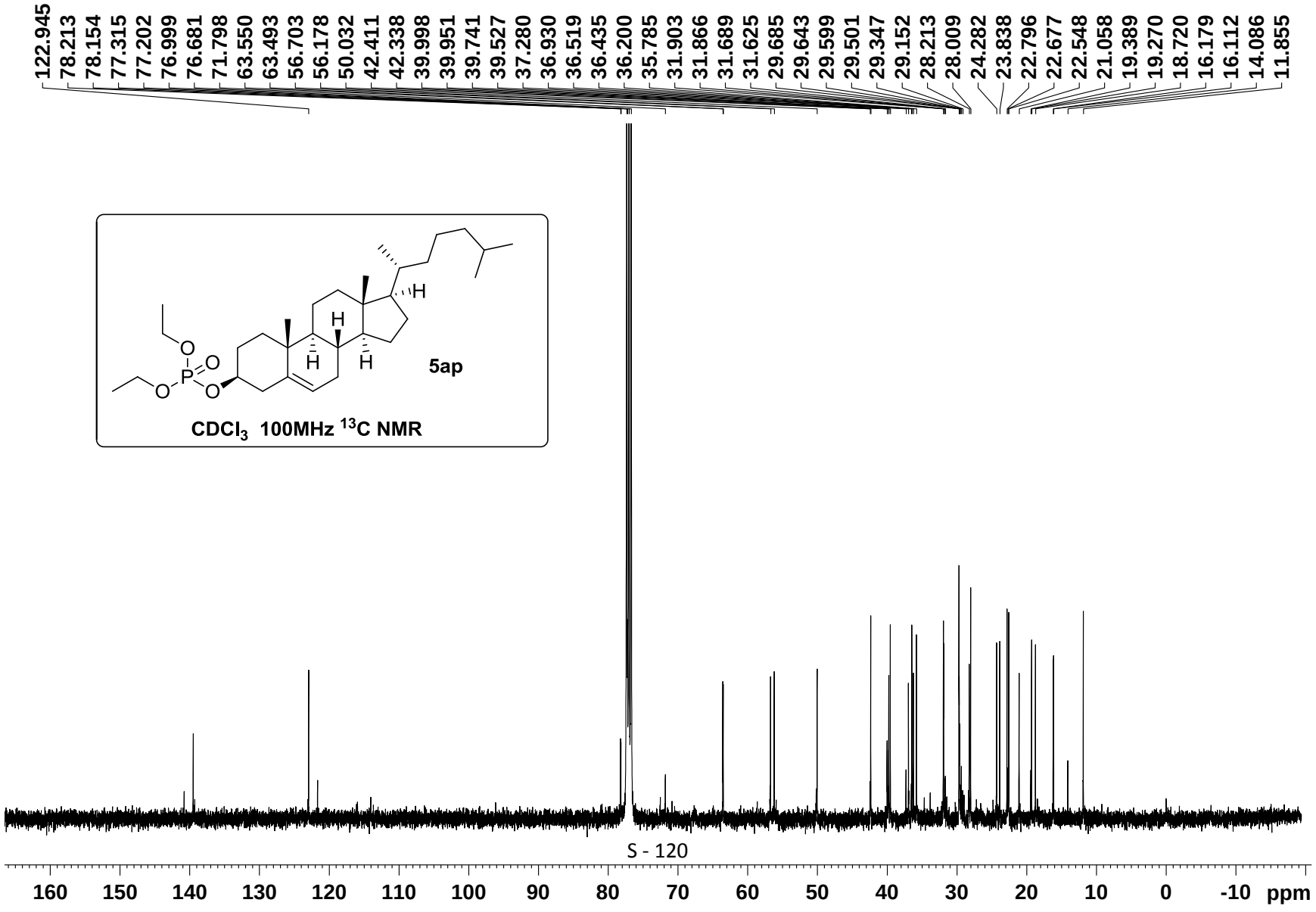

7.265
4.197
4.192
4.182
4.171
4.166
4.155
4.142
4.125
4.107
4.090
4.072
4.055
2.251
2.221
2.174
2.167
2.155
2.149
2.138
2.132
1.672
1.644
1.595
1.458
1.449
1.429
1.414
1.369
1.351
1.333
1.316
1.293
1.285
1.277
1.254
1.181
1.151
5ao
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
S - 116
5.000
0.962
1.145
4.481
1.780
14.112
1.761
0.988
7.623
4.025

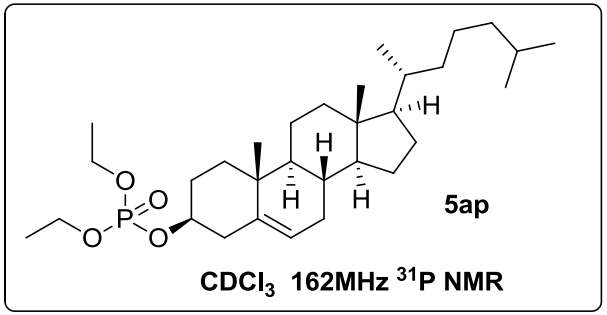

79.200
79.134
77.319
77.205
77.002
76.685
63.450
63.402
48.505
48.431
42.546
34.037
31.915
31.482
29.686
29.348
25.505
22.812
22.680
21.967
20.924
16.186
16.148
16.116
16.078
15.644
14.105
5ao
CDCl3 100MHz 13C NMR
S - 117
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



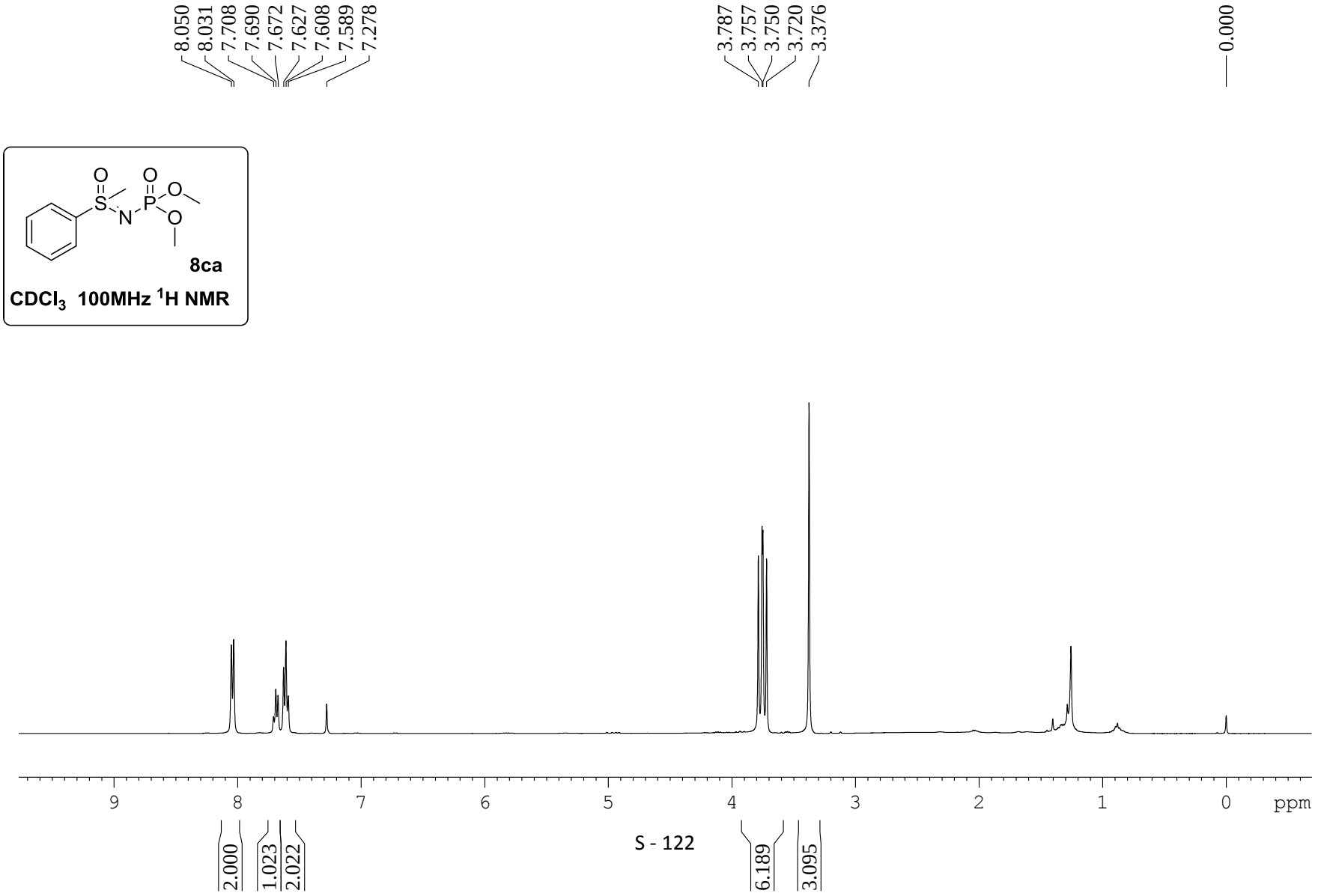
$CDCl_3$ 162MHz ^{31}P NMR

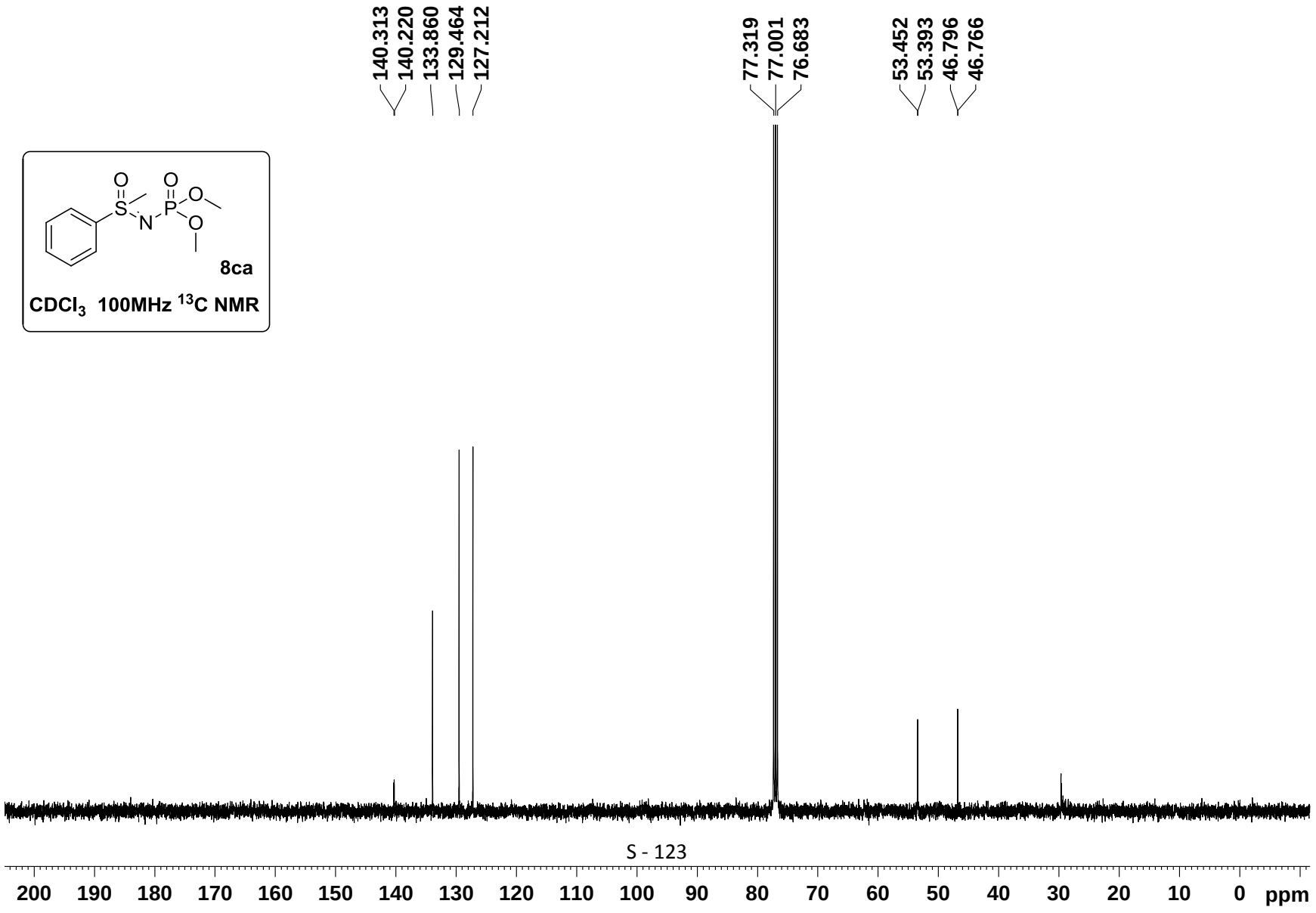

5.379
4.121
4.104
4.086
2.441
2.422
2.022
2.015
1.991
1.851
1.841
1.832
1.822
1.600
1.562
1.533
1.517
1.492
1.484
1.474
1.467
1.460
1.449
1.423
1.415
1.383
1.372
1.355
1.338
1.320
1.294
1.286
1.255
1.163
1.151
1.118
1.100
1.084
1.077
1.057
1.042
1.010
0.980
0.964
0.941
0.921
0.904
0.874
0.871
0.858
0.854
0.690
0.674
0.000
5ap
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
1.000
3.909
1.448
3.247
2.551
28.519
6.763
5.173
10.611
3.123
S - 119

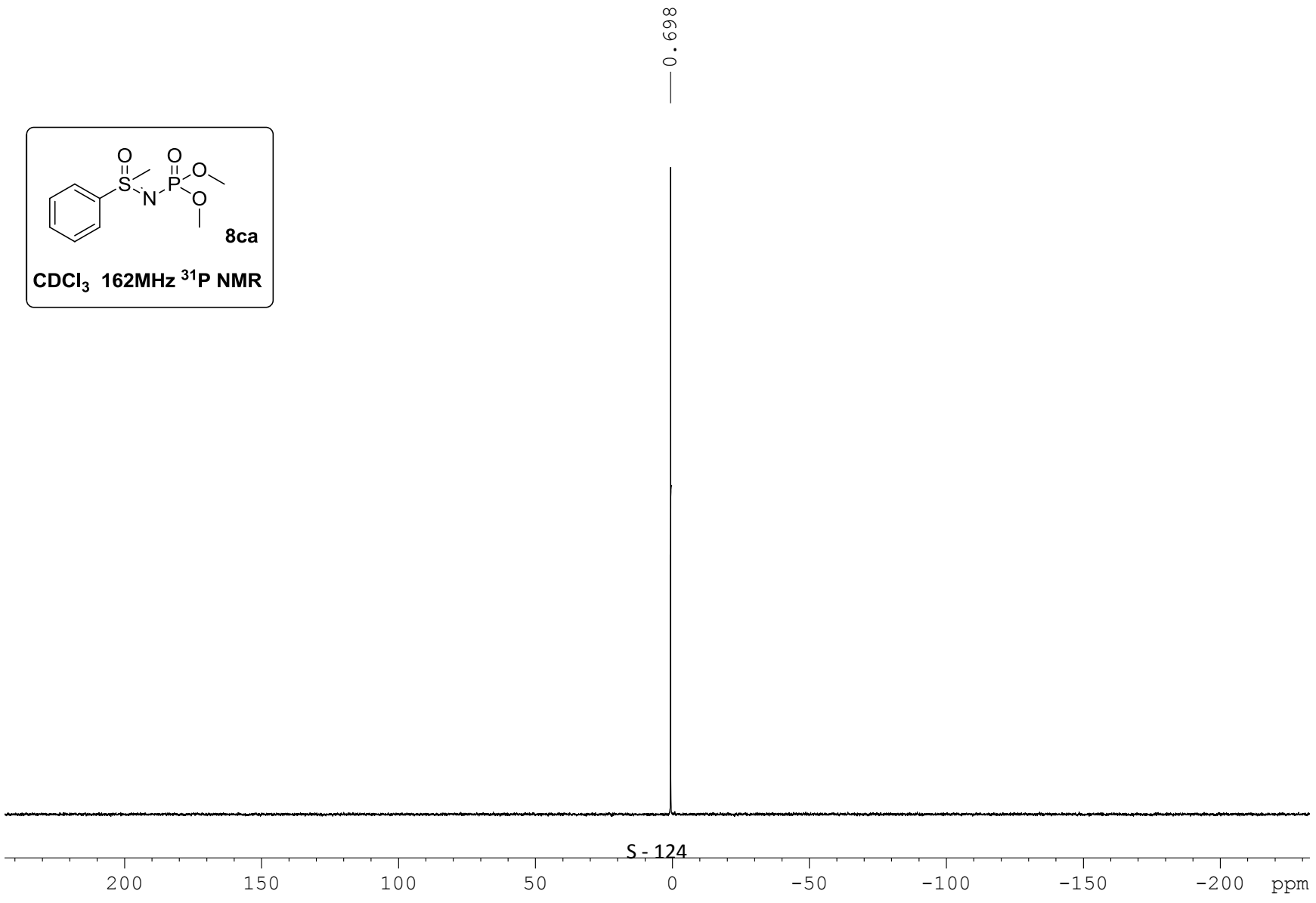

122.945
78.213
78.154
77.315
77.202
76.999
76.681
71.798
63.550
63.493
56.703
56.178
50.032
42.411
42.338
39.998
39.951
39.741
39.527
37.280
36.930
36.519
36.435
36.200
35.785
31.903
31.866
31.689
31.625
29.685
29.643
29.599
29.501
29.347
29.152
28.213
28.009
24.282
23.838
22.796
22.677
22.548
21.058
19.389
19.270
18.720
16.179
16.112
14.086
11.855
5ap
CDCl3 100MHz 13C NMR
S - 120
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
ppm

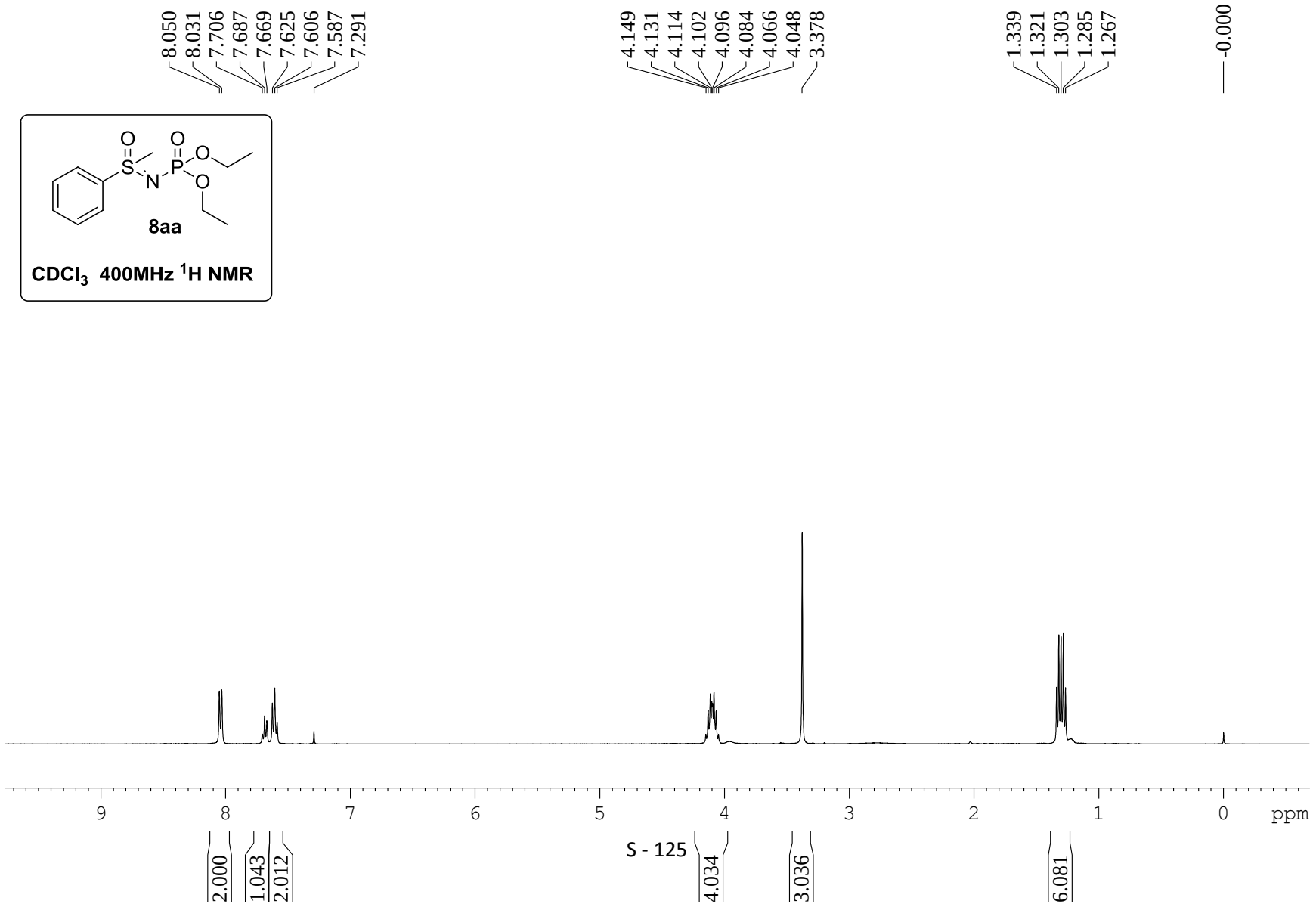

5ap
CDCl3 162MHz 31P NMR

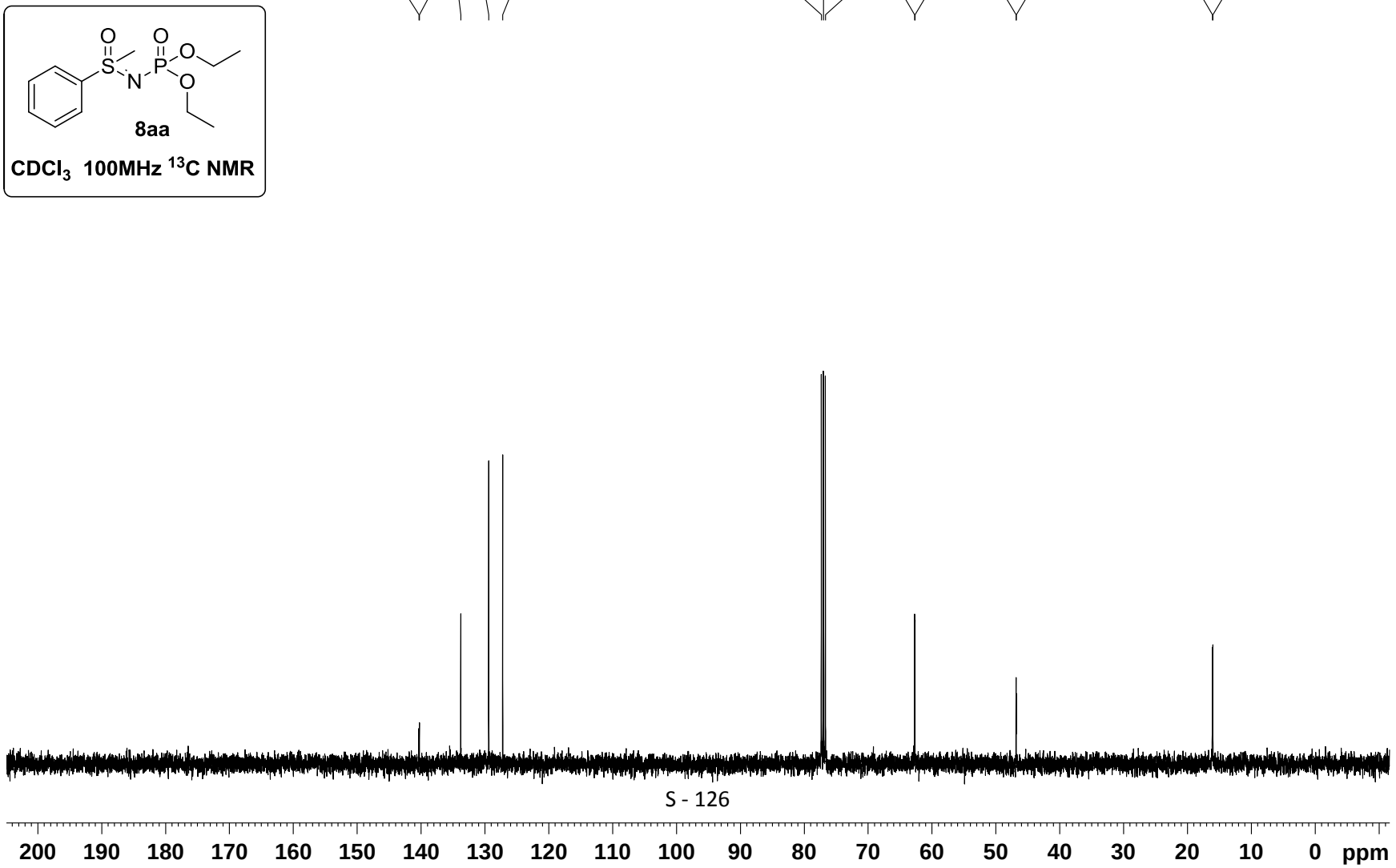
-1.860
S - 121
200
150
100
50
0
-50
-100
-150
-200
ppm

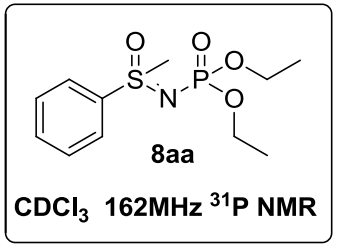

8.050
8.031
7.708
7.690
7.672
7.627
7.608
7.589
7.278
3.787
3.757
3.750
3.720
3.376
0.000
8ca
CDCl3 100MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.000
1.023
2.022
6.189
3.095


140.313
140.220
133.860
129.464
127.212
77.319
77.001
76.683
53.452
53.393
46.796
46.766
8ca
CDCl3 100MHz 13C NMR
S - 123
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


0.698
8ca
CDCl3 162MHz 31P NMR
200
150
100
50
0
-50
-100
-150
-200
ppm

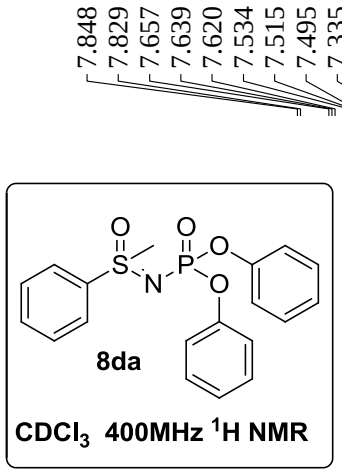

8.050
8.031
7.706
7.687
7.669
7.625
7.606
7.587
7.291
4.149
4.131
4.114
4.102
4.096
4.084
4.066
4.048
3.378
1.339
1.321
1.303
1.285
1.267
-0.000
8aa
CDCl3 400MHz 1H NMR
9
8
7
6
5
4
3
2
1
0
ppm
2.000
1.043
2.012
4.034
3.036
6.081


140.335
140.247
133.767
129.391
127.202
77.318
77.000
76.682
62.711
62.651
46.830
46.795
16.088
16.010
8aa
CDCl3 100MHz 13C NMR
S - 126
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

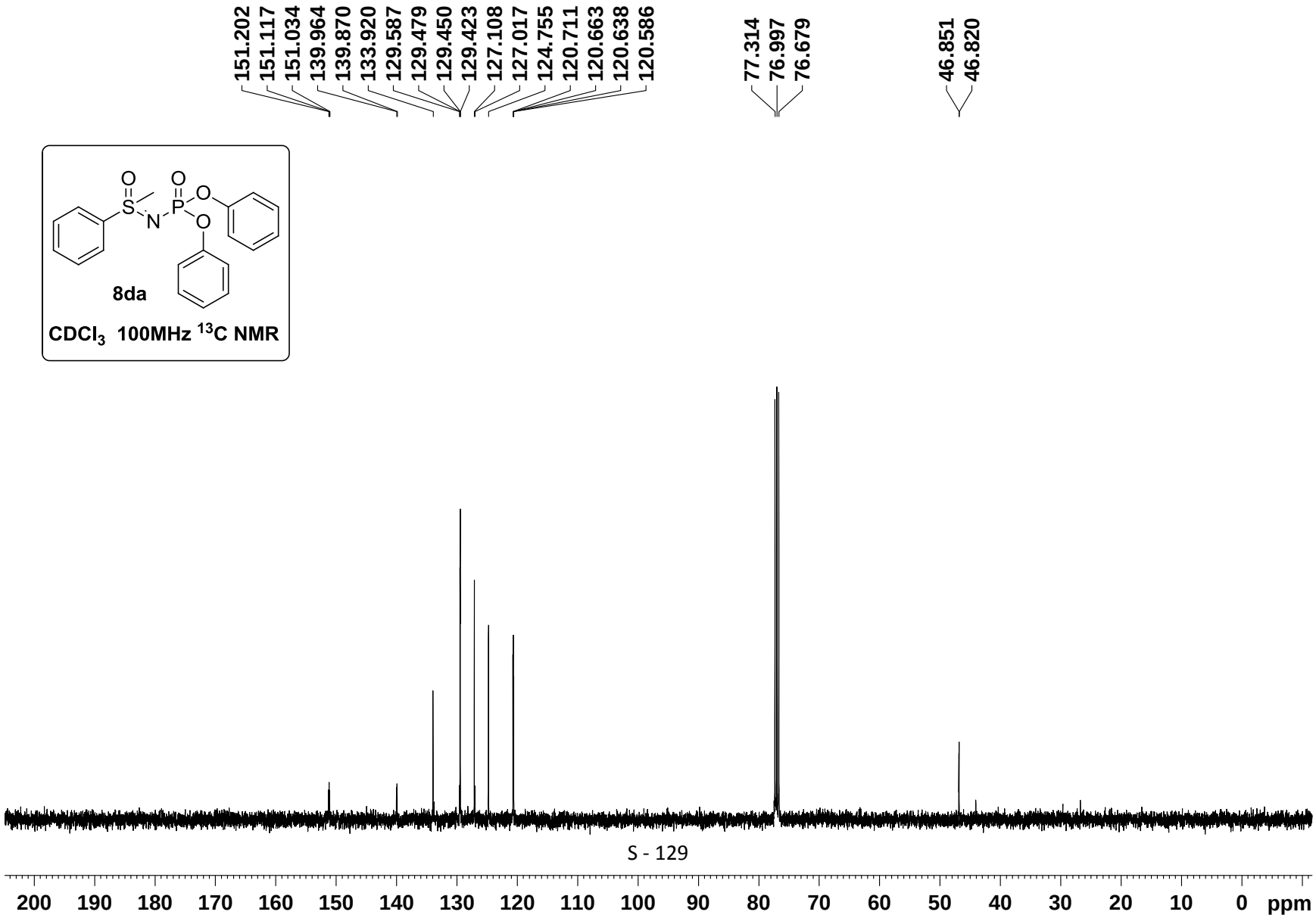


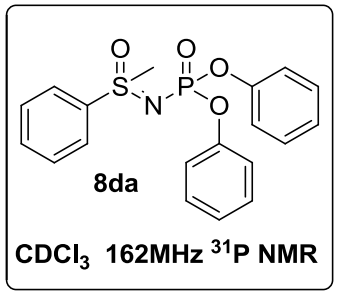
8aa

$CDCl_3$ 162MHz ^{31}P NMR


8da
CDCl3 400MHz 1H NMR

7.848
7.829
7.657
7.639
7.620
7.534
7.515
7.495
7.335
7.328
7.314
7.308
7.298
7.265
7.253
7.232
7.169
7.151
7.134
3.317
0.000
9
8
7
6
5
4
3
2
1
0
ppm
1.790
1.205
1.898
7.369
1.809
3.000


151.202
151.117
151.034
139.964
139.870
133.920
129.587
129.479
129.450
129.423
127.108
127.017
124.755
120.711
120.663
120.638
120.586
77.314
76.997
76.679
46.851
46.820
8da
CDCl3 100MHz 13C NMR
S - 129
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


8da
CDCl3 162MHz 31P NMR

-12.172
S - 130
200
150
100
50
0
-50
-100
-150
-200
ppm