Supporting Information

Catalyst-Free Three-Component Reaction to Synthesize Chiral *α*-Amino Phosphine Oxides

Xi-An Li,[a] Jia-Yuan Li, [a] Bin Yang, [a] and Shang-Dong Yang [a,b]*

[a] State Key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, P. R. China.

[b] State Key Laboratory for Oxo Synthesis and Selective Oxidation, Lanzhou Institute of Chemical Physics, Lanzhou, 730000, P. R. China

E-mail: yangshd@lzu.edu.cn

Contents:

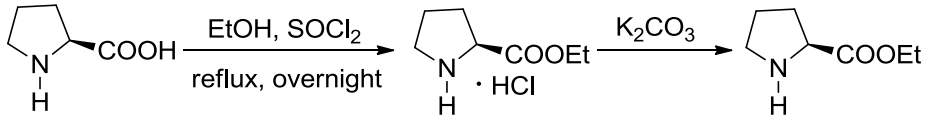
1. General Information

All reactions involving air- and moisture-sensitive reagent were carried out under argon atmosphere. All chemicals were purchased from Aldrich and used without further purification. Thin-layer chromatography (TLC) was performed using 60 mesh silica gel plates visualized with short-wavelength UV light (254 nm). Silica gel 60 (230~400 mesh) was used for column chromatography. IR spectra were recorded with an FT-IR spectrometer as KBr plates or as thin films and peaks are reported in cm^{-1}. ^{1}H NMR, ^{13}C NMR and ^{31}P NMR spectra spectra were recorded on a Bruker INOVA-400 and a Bruker AC-250. NMR spectras were

on a Bruker INOVA-400 and a Bruker AC-250. NMR spectras were recorded on a 400 instrument (400 MHz for ^{1}H, 100 MHz for ^{13}C and 162 MHz for ^{31}P). Chemical shifts (δ) were measured in ppm relative to TMS δ = 0 for ^{1}H or to chloroform δ = 77.0 for ^{13}C as internal standard. Data are reported as follows: Chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), Coupling constants, *J*, are reported in hertz. Mass spectrometry were measured with MICRO-TOF Q Ⅱ (ESI).

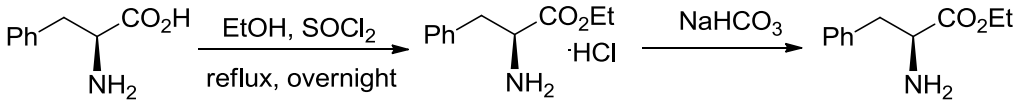
2. General Synthesis of Substrstes

2.1. Preparation of (*S*)-ethyl pyrrolidine-2-carboxylate[1]



To dissolve L-proline (10 g, 86.9 mmol) in 100 mL ethanol, cooled to 0 ℃, (12.9 mL, 173.9 mmol) $SOCl_2$ was added dropwise and stirred at 0 ℃ for 1 h. Then, further stirred for 12 h at reflux. After cooling to room temperature and neutralizing the ester hydrochloride with saturated K_2CO_3 solution, extracted with ethyl acetate, and concentrated under reduced pressure. The residue was purified by column chromatography, affording a yellow liquid 10 g, yield 80.6%.

2.2. Preparation of (*S*)-ethyl 2-amino-3-phenylpropanoate[2]



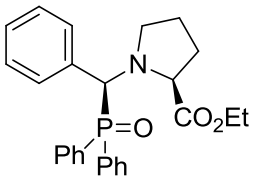
To dissolve (*S*)-2-amino-3-phenylpropanoic acid (10 g, 60.0 mmol) in 100 mL ethanol, cooled to 0 ℃, thionyl chloride (6.5 mL, 90.0 mmol) was added dropwise and stirred at 0 ℃ for 1 h. Then, further stirred for 12 h at reflux. After cooling to room temperature and neutralizing the ester hydrochloride with saturated $NaHCO_3$ to pH = 8, extracted with ethyl acetate, and concentrated under reduced pressure. The residue was purified by column chromatography, affording a yellow liquid 11.6 g, yield 90.0%.

3. General procedures for Three-Component System of Chiral Amino Acid Ester to Construct Chiral Phosphorus Compounds.

(*L*)-ethyl pyrrolidine-2-carboxylate (0.45 mmol, 64 mg), diphenylphosphine oxide (0.3 mmol, 60.6 mg) were added to Schlenk tube, then, the tube was charged with

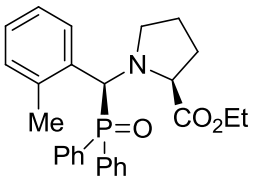
argon. Benzaldehyde (0.45 mmol, 46 μL) and toluene (2 mL) was added using a syringe respectively. The reaction mixture was stirred at 110^{o}C until substrate disappeared as determined by TLC. After cooling to room temperature, the reaction system was purified by silica gel flash chromatography to afford pure **2a** as a yellow oil (101.0 mg, 78%).

4. Characterization of products (2a-v and 3):



2a

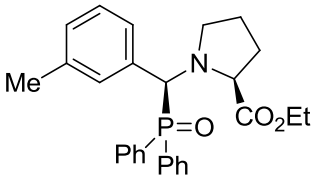
(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(phenyl) methyl) pyrrolidine-2-carboxylate（2a）: Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.13-8.08 (m, 2H), 7.53-7.41 (m, 7H), 7.28-7.26 (m, 1H), 7.22-7.17 (m, 5H), 4.98 (d, *J* = 9.6 Hz, 1H), 4.10-4.02 (m, 2H), 3.51-3.47 (m, 1H), 3.23-3.19 (m, 1H), 3.05-2.98 (m, 1H), 1.82-1.76 (m, 2H), 1.70-1.62 (m, 2H), 1.20 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.6, 132.5 (dd, $J_{C\text{-}P}$ = 4.0 Hz, $J_{C\text{-}P}$ = 97.5 Hz), 131.83, 131.5 (dd, $J_{C\text{-}P}$ = 8.0 Hz, $J_{C\text{-}P}$ = 47.0 Hz), 131.4 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.1, 131.0, 128.0 (dd, $J_{C\text{-}P}$ = 11.0 Hz, $J_{C\text{-}P}$ = 25.0 Hz), 128.0, 63.0 (d, $J_{C\text{-}P}$ = 82.0 Hz), 61.8 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.3, 49.6, 27.9, 23.7, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.80. **IR** (neat): 3373, 2976, 1738, 1438, 1216, 1183, 1119, 755, 697, 549 cm^{-1}. **MS (ESI):** $(M+H)^+$ 434.1736.



2b

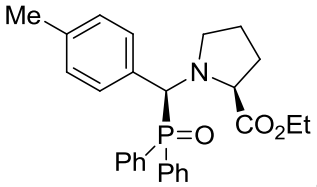
(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(o-tolyl) methyl) pyrrolidine-2-carboxylate (2b): Light yellow solid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.27-8.15 (m, 2H), 8.07 (d, *J* = 8.0 Hz, 1H), 7.59-7.51 (m, 3H), 7.35-7.27 (m, 3H), 7.24-7.10 (m, 4H), 6.91 (d, *J* = 8.0 Hz, 1H), 5.29 (d, *J* = 8.0 Hz, 1H), 4.10-4.04 (m, 2H), 3.40 (s, 1H), 3.29-3.22 (m, 2H), 1.89-1.76 (m, 2H), 1.85 (s, 3H), 1.71-1.66 (m, 2H), 1.20 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 174.2, 137.6, 133.3, 132.6, 132.3, 132.1 (d, $J_{C\text{-}P}$ = 9.0 Hz), 131.8 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.68, 131.6 (d, $J_{C\text{-}P}$ = 3.0 Hz,), 131.3, 131.1 (d, $J_{C\text{-}P}$ = 9.0 Hz), 131.0, 130.0, 128.2 (d, $J_{C\text{-}P}$ = 11.0 Hz), 127.7, 127.6 (d, $J_{C\text{-}P}$ = 11.0 Hz), 125.8, 63.4 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.22, 57.7 (d, $J_{C\text{-}P}$ = 81.0 Hz), 50.4, 28.6, 23.9, 19.3, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.77. **IR** (neat): 3395, 2975, 1735, 1438, 1186,

1118, 1027, 753, 696, 555 cm^{-1}. **MS (ESI):** $(M+H)^+$ 448.2234.



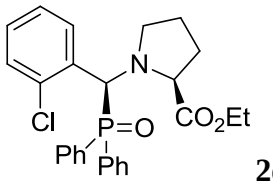
2c

(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(m-tolyl) methyl) pyrrolidine-2-carboxylate (2c): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.13-8.08 (m, 2H), 7.54-7.44 (m, 5H), 7.29-7.27 (m, 1H), 7.24-7.19 (m, 4H), 7.11 (t, *J* = 8.0 Hz, 1H), 7.02 (d, *J* = 8.0 Hz, 1H), 4.96 (d, *J* = 8.0 Hz, 1H), 4.12-4.02 (m, 2H), 3.50-3.46 (m, 1H), 3.25 (t, *J* = 8.0 Hz, 1H), 3.03 (d, *J* = 8.0 Hz, 1H), 2.26 (s, 3H), 1.83-1.78 (m, 2H), 1.71-1.63 (m, 2H), 1.22 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.6, 137.5, 132.4 (dd, J_{C-P} = 32.0 Hz, J_{C-P} = 67.5 Hz), 131.8, 131.7, 131.4 (d, J_{C-P} = 9.0 Hz, J_{C-P} = 66.5 Hz), 131.1 (dd, J_{C-P} = 3 Hz, J_{C-P} = 42 Hz), 128.6, 128.3 (d, J_{C-P} = 6.0 Hz), 128.1 (d, J_{C-P} = 12.0 Hz), 127.8 (t, J_{C-P} = 5.5 Hz), 63.1 (d, J_{C-P} = 83 Hz), 61.8 (d, J_{C-P} = 12 Hz), 60.3, 49.6, 27.9, 23.9, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.69. **IR** (neat): 3397, 2974, 1737, 1438, 1185, 1118, 1031, 701, 560, 518 cm^{-1}. **MS (ESI):** $(M+H)^+$ 448.1971.



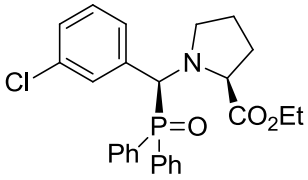
2d

(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(p-tolyl) methyl) pyrrolidine-2-carboxylate (2d): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.12-8.08 (m, 2H), 7.52-7.46 (m, 5H), 7.34-7.27 (m, 3H), 7.23-7.19 (m, 2H), 7.04-7.02 (m, 2H), 4.97 (d, *J* = 8.0 Hz, 1H), 4.12-4.02 (m, 2H), 3.53-3.48 (m, 1H), 3.23-3.19 (m, 1H), 3.02-2.96 (m, 1H), 2.27 (s, 3H), 1.82-1.74 (m, 2H), 1.72-1.59 (m, 2H), 1.22 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.5, 137.5, 132.8 (dd, J_{C-P} = 5.0 Hz, J_{C-P} = 97.0 Hz), 131.7 (d, J_{C-P} = 9.0 Hz), 131.6 (dd, J_{C-P} = 3 Hz, J_{C-P} = 40 Hz), 131.1 (dd, J_{C-P} = 7.0 Hz, J_{C-P} = 17.0 Hz), 128.7, 128.5, 128.0 (d, J_{C-P} = 12.0 Hz), 127.9 (d, J_{C-P} = 11.0 Hz), 62.6 (d, J_{C-P} = 84.0 Hz), 61.8 (d, J_{C-P} = 12.0 Hz), 60.3, 49.4, 27.9, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.87. **IR** (neat): 3404, 2975, 1736, 1438, 1186, 1118, 1030, 752, 698, 562, 542 cm^{-1}. **MS (ESI):** $(M+H)^+$ 448.2336.



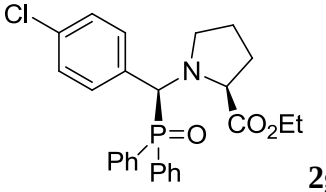
2e

(*S*)-ethyl 1-((*S*)-(2-chlorophenyl)(diphenylphosphoryl) methyl)pyrrolidine-2-carb oxylate (2e): Light yellow solid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.23-8.18 (m, 3H), 7.53-7.48 (m, 5H), 7.28-7.11 (m, 6H), 5.73 (d, *J* = 10.8 Hz, 1H), 4.09-4.04 (m, 2H), 3.60-3.57 (m, 1H), 3.24-3.20 (m, 1H), 2.99-2.97 (m, 1H), 1.88-1.62 (m, 4H), 1.20 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.6, 135.4 (d, $J_{C\text{-}P}$ = 9.0 Hz), 133.2 (d, $J_{C\text{-}P}$ = 4.0 Hz), 131.5, 131.4 (dd, $J_{C\text{-}P}$ = 9 Hz, $J_{C\text{-}P}$ = 99.0 Hz), 131.4 (dd, $J_{C\text{-}P}$ = 3.0 Hz, $J_{C\text{-}P}$ = 39.0 Hz), 130.2 (d, $J_{C\text{-}P}$ = 2.0 Hz), 129.1, 128.0 (dd, $J_{C\text{-}P}$ = 12.0 Hz, $J_{C\text{-}P}$ = 29.0 Hz), 61.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 60.24, 57.4 (d, $J_{C\text{-}P}$ = 83.0 Hz), 49.5, 28.4, 23.4, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 31.52. **IR** (neat): 3411, 2977, 1740, 1438, 1191, 1118, 1032, 755, 694, 552, 521 cm^{-1}. **MS (ESI):** $(M+H)^+$ 468.1679.



2f

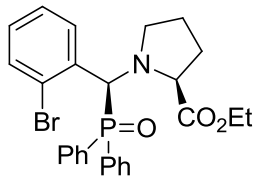
(*S*)-ethyl 1-((*S*)-(3-chlorophenyl)(diphenylphosphoryl)methyl)pyrrolidine-2-Carb oxylate (2f): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.11-8.05 (m, 2H), 7.53-7.44 (m, 5H), 7.38-7.28 (m, 3H), 7.25-7.15 (m, 4H), 4.98 (d, *J* = 10.4 Hz, 1H), 4.13-4.02 (m, 2H), 3.47-3.42 (m, 1H), 3.20 (t, *J* = 8.0 Hz, 1H), 2.99-2.95 (m, 1H), 1.84-1.78 (m, 2H), 1.76-1.58 (m, 2H), 1.21 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.3, 134.0 (d, $J_{C\text{-}P}$ = 28.0 Hz), 133.7 (d, $J_{C\text{-}P}$ = 6.0 Hz), 131.7, 131.3 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 68.5 Hz), 131.6, 131.2 (d, $J_{C\text{-}P}$ = 2.0 Hz), 130.9 (d, $J_{C\text{-}P}$ = 7.0 Hz), 129.3, 129.2, 128.1 (dd, $J_{C\text{-}P}$ = 11 Hz, $J_{C\text{-}P}$ = 17.5 Hz), 62.6 (d, $J_{C\text{-}P}$ = 81.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.4, 49.6, 27.9, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.27. **IR** (neat): 3399, 2977, 1735, 1438, 1188, 1118, 1026, 752, 724, 700, 564, 516 cm^{-1}. **MS (ESI):** $(M+H)^+$ 468.1139.



2g

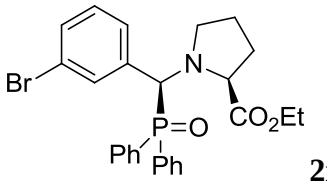
(*S*)-ethyl 1-((*S*)-(4-chlorophenyl)(diphenylphosphoryl) methyl)pyrrolidine-2-carb oxylate (2g): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.10-8.07 (m, 2H),

7.52-7.45 (m, 5H), 7.44-7.43 (m, 2H), 7.38-7.36 (m, 1H), 7.30-7.18 (m, 4H), 4.99 (d, J = 9.6 Hz, 1H), 4.10-4.03 (m, 2H), 3.49-3.43 (m, 1H), 3.18-3.14 (m, 1H), 2.98-2.92 (m, 1H), 1.82-1.76 (m, 2H), 1.68-1.61 (m, 2H), 1.20 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.3, 133.9 (d, $J_{C\text{-}P}$ = 1.0 Hz), 132.3 (dd, $J_{C\text{-}P}$ = 11.0 Hz, $J_{C\text{-}P}$ = 140.0 Hz), 131.7 (dd, $J_{C\text{-}P}$ = 6.0 Hz, $J_{C\text{-}P}$ = 150.0 Hz), 131.6 (d, $J_{C\text{-}P}$ = 8.0 Hz), 131.4 (dd, $J_{C\text{-}P}$ = 3.0 Hz, $J_{C\text{-}P}$ = 30.0 Hz), 130.4, 128.2, 128.1 (d, $J_{C\text{-}P}$ = 2.0 Hz), 128.0, 62.2 (d, $J_{C\text{-}P}$ = 82.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.4, 49.4, 27.8, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.42. **IR** (neat): 3412, 2978, 1735, 1488, 1438, 1187, 1118, 1092, 1017, 754, 723, 695, 553, 526 cm^{-1}. **MS (ESI):** $(M+H)^+$ 468.1794.



2h

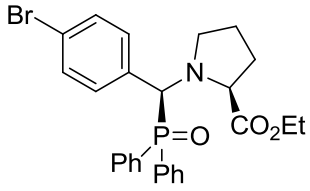
(*S*)-ethyl 1-((*S*)-(2-bromophenyl)(diphenylphosphoryl)methyl)pyrrolidine-2-carb oxylate (2h): White solid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.25-8.20 (m, 3H), 7.54-7.46 (m, 5H), 7.34-7.27 (m, 3H), 7.22-7.17 (m, 2H), 7.04 (t, J = 8.0 Hz, 1H), 5.68 (d, J = 12.0 Hz, 1H), 4.10-4.04 (m, 2H), 3.58-3.55 (m, 1H), 3.29-3.25 (m, 1H), 3.06-3.00 (m, 1H), 1.85-1.62 (m, 4H), 1.21 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.8, 133.2 (d, $J_{C\text{-}P}$ = 16.0 Hz), 132.5, 132.0 (d, $J_{C\text{-}P}$ = 130.0 Hz), 132.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 132.0 (d, $J_{C\text{-}P}$ = 66.0 Hz), 131.4 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 88.5 Hz), 131.4 (dd, $J_{C\text{-}P}$ = 3.0 Hz, $J_{C\text{-}P}$ = 41.5 Hz), 128.2 (d, $J_{C\text{-}P}$ = 224.0 Hz), 127.9 (dd, $J_{C\text{-}P}$ = 11.0 Hz, $J_{C\text{-}P}$ = 37.5 Hz), 126.7 (d, $J_{C\text{-}P}$ = 9.0 Hz), 61.4 (d, $J_{C\text{-}P}$ = 12.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 82.0 Hz), 60.3, 49.7, 28.6, 23.5, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.25. **IR** (neat): 3415, 2977, 1739, 1464, 1437, 1189, 1118, 1022, 754, 695, 551, 520 cm^{-1}. **MS (ESI):** $(M+H)^+$ 512.1246.



2i

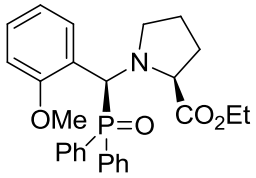
(*S*)-ethyl 1-((*S*)-(3-bromophenyl)(diphenylphosphoryl)methyl)pyrrolidine-2-carb oxylate (2i): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.09-8.07 (m, 2H), 7.54-7.43 (m,7H), 7.34-7.29 (m, 2H), 7.25-7.21(m, 2H), 7.09 (t, J = 7.6 Hz, 1H), 4.96 (d, J = 9.2 Hz, 1H), 4.13-4.02 (m, 2H), 3.45-3.41 (m, 1H), 3.22-3.18 (m, 1H), 3.01-2.95 (m, 1H), 1.84-1.76 (m, 2H), 1.69-1.63 (m, 2H), 1.22 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.3, 134.5, 133.8 (d, $J_{C\text{-}P}$ = 7.0 Hz), 132.6 (d, $J_{C\text{-}P}$ = 6.0

Hz), 131.6, 131.3 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 68.5 Hz,), 131.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 129.7 (d, $J_{C\text{-}P}$ = 3.0 Hz), 129.5, 128.1 (dd, $J_{C\text{-}P}$ = 12.0 Hz, $J_{C\text{-}P}$ = 17.0 Hz), 122.1, 62.6 (d, $J_{C\text{-}P}$ = 81.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.4, 49.6, 27.9, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.25. **IR** (neat): 3391, 3058, 2372, 1735, 1438, 1187, 1118, 751, 700, 560, 516 cm^{-1}. **MS (ESI):** $(M+H)^+$ 514.0572.



2j

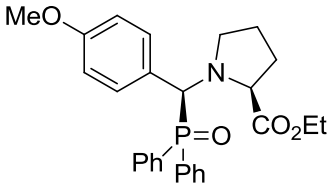
(*S*)-ethyl 1-((*S*)-(4-bromophenyl)(diphenylphosphoryl)methyl)pyrrolidine-2-carb oxylate (2j): Yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.16-8.04 (m, 2H), 7.53-7.48 (m, 5H), 7.46-7.28 (m, 6H), 7.24-7.22 (m, 2H), 4.98 (d, *J* = 9.6 Hz, 1H), 4.10-4.03 (m, 2H), 3.45-3.42 (m, 1H), 3.16 (t, *J* = 8.0 Hz, 1H), 2.88-2.98 (m, 1H), 1.82-1.76 (m, 2H), 1.68-1.61 (m, 2H), 1.20 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.2, 132.7 (d, $J_{C\text{-}P}$ = 6.0 Hz), 132.6 (d, $J_{C\text{-}P}$ = 11.0 Hz), 131.2 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 71.0 Hz), 131.3, 131.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.1, 128.1 (d, $J_{C\text{-}P}$ = 24.0 Hz), 128.1, 122.2 (d, $J_{C\text{-}P}$ = 2.0 Hz), 62.1 (d, $J_{C\text{-}P}$ = 94.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 23.0 Hz), 60.3, 49.4, 27.8, 23.5, 14.1. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.59, 29.26. **IR** (neat): 3396, 2970, 2374, 1731, 1438, 1187, 1118, 699, 550, 521 cm^{-1}. **MS (ESI):** $(M+H)^+$ 512.0805.



2k

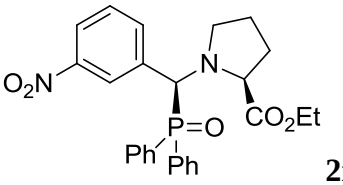
(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(2-methoxyphenyl) methyl) pyrrolidine-2-Carboxylate (2k): Light yellow solid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.19-8.14 (m, 2H), 8.09 (d, *J* = 7.6 Hz, 1H), 7.54-7.45 (m, 5H), 7.28-7.13 (m, 4H), 6.90 (t, *J* = 7.2 Hz, 1H), 6.67 (d, *J* = 8.4 Hz, 1H), 5.71 (d, *J* = 10.2 Hz, 1H), 4.14-4.01 (m, 2H), 3.60 (s, 3H), 3.10-3.06 (m, 1H), 2.90-2.83 (m, 1H), 1.81-1.56 (m, 4H), 1.21 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.7, 157.5 (d, $J_{C\text{-}P}$ = 8.0 Hz), 133.0 (dd, $J_{C\text{-}P}$ = 26.0 Hz, $J_{C\text{-}P}$ = 97.5 Hz), 132.0 (dd, $J_{C\text{-}P}$ = 4.0 Hz, $J_{C\text{-}P}$ = 155.5 Hz), 131.3 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 107.5 Hz), 130.8, 129.0, 127.8 (dd, $J_{C\text{-}P}$ = 12.0 Hz, $J_{C\text{-}P}$ = 28.0 Hz), 120.1, 119.9 (d, $J_{C\text{-}P}$ = 2.0 Hz), 109.8, 62.1 (d, $J_{C\text{-}P}$ = 12.0 Hz), 59.9, 55.0, 52.8 (d, $J_{C\text{-}P}$ = 86.0 Hz), 49.1, 28.2, 23.1, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 32.23. **IR** (neat): 3418, 2973, 1741, 1487, 1438, 1243, 1179, 1118, 1027, 755, 696, 555, 515

cm^{-1}. **MS (ESI):** $(M+H)^+$ 464.1631.



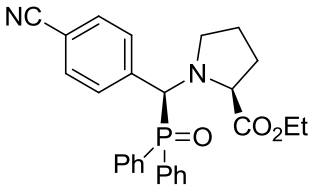
2l

(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(2-methoxyphenyl) methyl) pyrrolidine-2-carboxylate (2l): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.07-8.06 (m, 2H), 7.52-7.46 (m, 5H), 7.44-7.35 (m, 2H), 7.28-7.26 (m, 1H), 7.22-7.20 (m, 2H), 6.75 (d, J = 8.8 Hz, 2H), 4.94 (d, J = 10.4 Hz, 1H), 4.08-4.05 (m, 2H), 3.74 (s, 3H), 3.49-3.44 (m, 1H), 3.22-3.19 (m, 1H), 2.99-2.93 (m, 1H), 1.82-1.75 (m, 2H), 1.69-1.58 (m, 2H), 1.21 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.5, 159.1, 132.8 (dd, $J_{C\text{-}P}$ = 16.0 Hz, $J_{C\text{-}P}$ = 97.0 Hz), 132.1 (dd, $J_{C\text{-}P}$ = 7.0 Hz, $J_{C\text{-}P}$ = 77.5 Hz), 131.32, 131.6 (d, $J_{C\text{-}P}$ = 9.0 Hz), 128.0 (dd, $J_{C\text{-}P}$ = 11.0 Hz, $J_{C\text{-}P}$ = 16.5 Hz), 123.7, 113.4, 62.2 (d, $J_{C\text{-}P}$ = 95.0 Hz), 61.8, 60.3, 55.0, 49.4, 27.9, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 31.00. **IR** (neat): 3400, 2971, 1736, 1606, 1510, 1438, 1254, 1182, 1117, 1031, 751, 698, 550, 519 cm^{-1}. **MS (ESI):** $(M+H)^+$ 464.2101.



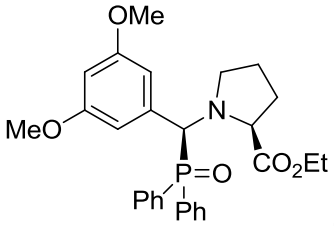
2n

(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(3-nitrophenyl) methyl) pyrrolidine-2-carb oxylate (2n): Yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.16-8.11 (m, 2H), 8.07-8.03 (m, 2H), 7.98-7.96 (m, 1H), 7.57-7.51 (m, 3H), 7.48-7.42 (m, 3H), 7.32-7.28 (m, 1H), 7.24-7.20 (m, 1H), 5..17 (d, J = 8.0 Hz, 1H), 4.16-4.06 (m, 2H), 3.45-3.40 (m, 1H), 3.17 (t, J = 8.0, 1H), 3.01 (q, J = 8.0, 1H), 1.85-1.81 (m, 2H), 1.71-1.67 (m, 2H), 1.22 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.1, 147.7, 136.8 (d, $J_{C\text{-}P}$ = 5.0 Hz), 134.7, 132.3, 131.8 (d, $J_{C\text{-}P}$ = 2.0 Hz), 131.6, 131.2, 131.1 (d, $J_{C\text{-}P}$ = 24.0 Hz), 130.8 (d, $J_{C\text{-}P}$ = 9.0 Hz), 129.0, 128.3 (dd, $J_{C\text{-}P}$ = 12.0 Hz, $J_{C\text{-}P}$ = 15.5 Hz), 125.4 (d, $J_{C\text{-}P}$ = 8.0 Hz), 122.8, 62.5 (d, $J_{C\text{-}P}$ = 80.0 Hz), 61.8 (d, $J_{C\text{-}P}$ = 10.0 Hz), 60.5, 49.6, 27.9, 23.5, 14.1. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.07. **IR** (neat): 3240, 2927, 1740, 1705, 1531, 1439, 1351, 1196, 1130, 753, 727, 697, 551 cm^{-1}. **MS (ESI):** $(M+H)^+$ 479.1876.



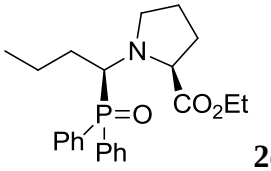
2o

(*S*)-ethyl 1-((*S*)-(4-cyanophenyl)(diphenylphosphoryl) methyl) pyrrolidine-2-carb oxylate (2o): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.18-8.04 (m, 2H), 7.55-7.53 (m, 7H), 7.52-7.48 (m, 2H), 7.48-7.30 (m, 1H), 7.28-7.21 (m, 2H), 5.08 (s, 1H), 4.11-4.05 (m, 2H), 3.45-3.41 (m, 1H), 3.16-3.12 (m, 1H), 3.04-2.94 (m, 1H), 1.84-1.80 (m, 2H), 1.72-1.64 (m, 2H), 1.21 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.2, 138.0, 132.3 (d, $J_{C\text{-}P}$ = 14.0 Hz), 131.6 (dd, $J_{C\text{-}P}$ = 3.0 Hz, $J_{C\text{-}P}$ = 39.5 Hz,), 131.7 (d, $J_{C\text{-}P}$ = 4.0 Hz), 131.4 (d, $J_{C\text{-}P}$ = 1.0 Hz), 131.3 (d, $J_{C\text{-}P}$ = 15.0 Hz), 130.9 (d, $J_{C\text{-}P}$ = 9.0 Hz), 128.3 (dd, $J_{C\text{-}P}$ = 12.0 Hz, $J_{C\text{-}P}$ = 17.5 Hz), 118.5, 111.7, 62.8 (d, $J_{C\text{-}P}$ = 80.0 Hz), 61.7 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.5, 49.7, 28.0, 23.6, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 29.93. **IR** (neat): 3402, 2978, 2229, 1732, 1438, 1189, 1117, 1023, 754, 730, 697, 566, 529 cm^{-1}. **MS (ESI):** $(M+H)^+$ 495.1957.



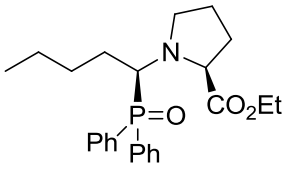
2p

(*S*)-ethyl 1-((*S*)-(3,5-dimethoxyphenyl)(diphenylphosphoryl) methyl) pyrrolidine -2-carboxylate (2p): Yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.14-8.04 (m, 2H), 7.52-7.47 (m, 5H), 7.31-7.21 (m, 3H), 6.59 (s, 2H), 6.31 (s, 1H), 4.92 (d, J = 9.2 Hz, 2H), 4.04-4.08 (m, 2H), 3.70 (s, 6H), 3.46-3.41 (m, 1H), 3.32 (t, J = 7.2 Hz, 1H), 3.08-3.02 (m, 1H), 1.83-1.79 (m, 2H), 1.68-1.65 (m, 2H), 1.20 (t, J = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.6, 160.2, 134.2, 132.7 (d, $J_{C\text{-}P}$ = 97.0 Hz), 132.5 (d, $J_{C\text{-}P}$ = 97.0 Hz), 131.4 (dd, $J_{C\text{-}P}$ = 9.0 Hz, $J_{C\text{-}P}$ = 63.0 Hz), 131.4 (d, $J_{C\text{-}P}$ = 2.0 Hz), 131.0, 128.0 (dd, $J_{C\text{-}P}$ = 11.0 Hz, $J_{C\text{-}P}$ = 21.0 Hz), 109.1 (d, $J_{C\text{-}P}$ = 7.0 Hz), 100.4, 63.1 (d, $J_{C\text{-}P}$ = 82.0 Hz), 61.8 (d, $J_{C\text{-}P}$ = 11.0 Hz), 60.3, 55.3, 49.8, 28.0, 23.7, 14.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 30.41. **IR** (neat): 3298, 2935, 1736, 1594, 1461, 1436, 1202, 1157, 1117, 1064, 723, 700, 530, 516 cm^{-1}. **MS (ESI):** $(M+H)^+$ 494.2084.



2q

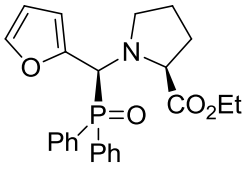
(*S*)-ethyl 1-((*S*)-1-(diphenylphosphoryl) butyl) pyrrolidine-2-carboxylate (2q): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.94-7.82 (m, 4H), 7.49-7.29 (m, 6H), 4.12-4.07 (m, 1H), 4.01-3.96 (m, 1H), 3.93-3.87 (m, 1 H), 3.67 (t, J = 6.4 Hz, 0.5H), 3.38-3.35 (m, 1H), 3.12-3.11 (m, 1H), 2.84-2.82 (m, 0.5H),1.93-1.80 (m, 2H), 1.78-1.57 (m, 2H), 1.54-1.51 (m, 2H), 1.29-1.22 (m, 3H), 1.18-1.14 (m, 2H), 0.89-0.78 (m, 3H), **^{13}C NMR** (100 MHz, $CDCl_3$): δ 174.5 (d, $J_{C\text{-}P}$ = 3.0 Hz), 173.6, 134.1 (d, $J_{C\text{-}P}$ = 128.0 Hz), 133.8, 133.7, 132.9 (d, $J_{C\text{-}P}$ = 6.0 Hz), 132.4, 131.6, 131.5, 131.4 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.3 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.1, 131.0 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.0 (d, $J_{C\text{-}P}$ = 2.0 Hz), 130.9, 130.8, 130.6 (d, $J_{C\text{-}P}$ = 11.0 Hz), 128.8 (d, $J_{C\text{-}P}$ = 13.0 Hz), 128.5 (d, $J_{C\text{-}P}$ = 14.0 Hz), 128.4, 128.3 (d, $J_{C\text{-}P}$ = 4.0 Hz), 127.8 (d, $J_{C\text{-}P}$ = 12.0 Hz), 63.6 (d, $J_{C\text{-}P}$ = 12.0 Hz), 63.2, 60.2 (d, $J_{C\text{-}P}$ = 7.0 Hz), 59.0 (d, $J_{C\text{-}P}$ = 36.0 Hz), 58.2 (d, $J_{C\text{-}P}$ = 21.0 Hz), 48.4, 47.3, 30.0 (d, $J_{C\text{-}P}$ = 7.0 Hz), 29.2 (d, $J_{C\text{-}P}$ = 68.0 Hz), 26.5 (d, $J_{C\text{-}P}$ = 4.0 Hz), 24.4 (d, $J_{C\text{-}P}$ = 32.0 Hz), 21.6 (d, $J_{C\text{-}P}$ = 9.0 Hz), 20.0 (d, $J_{C\text{-}P}$ = 12.0 Hz), 14.1 (d, $J_{C\text{-}P}$ = 11.0 Hz), 14.0 (d, $J_{C\text{-}P}$ = 26.0 Hz). **^{31}P NMR** (162 MHz, $CDCl_3$): δ 32.20, 31.25. **IR** (neat): 3395, 2962, 1739, 1655, 1438, 1184, 1117, 1097, 1028, 750, 722, 698, 545 cm^{-1}. **MS (ESI):** $(M+H)^+$ 400.1971.



2r

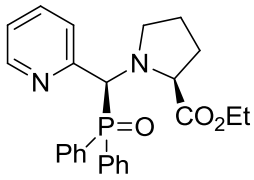
(*S*)-ethyl 1-((*S*)-1-(diphenylphosphoryl) pentyl) pyrrolidine-2-carboxylate (2r): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.94-7.81 (m, 4H), 7.49-7.39 (m, 6H), 4.11-4.07 (m, 1H), 3.96-3.86 (m, 2H), 3.69-3.65 (m, 0.5 H), 3.36-3.34 (m, 1H), 3.15-3.12 (m, 1H), 2.85-2.83 (m, 0.5H), 1.92-1.87 (m, 2H), 1.81-1.52 (m, 4H), 1.27-1.13 (m, 7H), 0.83-0.74 (m, 3H), **^{13}C NMR** (100 MHz, $CDCl_3$): δ 174.4 (d, $J_{C\text{-}P}$ = 3.0 Hz), 173.6, 134.3 (d, $J_{C\text{-}P}$ = 87.0 Hz), 133.8 (d, $J_{C\text{-}P}$ = 4.0 Hz), 133.2 (d, $J_{C\text{-}P}$ = 48.0 Hz), 132.7 (d, $J_{C\text{-}P}$ = 39.0 Hz), 131.6, 131.51, 131.48, 131.4 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.3 (d, $J_{C\text{-}P}$ = 2.0 Hz), 131.14, 131.10, 131.0, 130.9 (d, $J_{C\text{-}P}$ = 5.0 Hz), 130.8, 130.7 (d, $J_{C\text{-}P}$ = 8.0 Hz), 128.9 (d, $J_{C\text{-}P}$ = 13.0 Hz), 128.6, 128.5 (d, $J_{C\text{-}P}$ = 4.0 Hz), 128.3 (d, $J_{C\text{-}P}$ = 3.0 Hz), 127.9 (d, $J_{C\text{-}P}$ = 11.0 Hz), 63.7 (d, $J_{C\text{-}P}$ = 11.0 Hz), 63.2, 60.3 (d, $J_{C\text{-}P}$ = 7.0 Hz), 59.2 (d, $J_{C\text{-}P}$ = 33.0 Hz), 58.5 (d, $J_{C\text{-}P}$ = 18.0 Hz), 48.4, 47.4, 30.7 (d, $J_{C\text{-}P}$ = 10.0 Hz), 29.6, 29.1, 29.0 (d, $J_{C\text{-}P}$ = 2.0 Hz), 27.5 (d, $J_{C\text{-}P}$ = 6.0 Hz), 24.4 (d, $J_{C\text{-}P}$ = 32.0 Hz), 24.1 (d, $J_{C\text{-}P}$ = 5.0 Hz), 22.4 (d, $J_{C\text{-}P}$ = 28.0 Hz), 14.1 (d, $J_{C\text{-}P}$ = 12.0 Hz), 13.8 (d, $J_{C\text{-}P}$ = 14.0 Hz). **^{31}P NMR** (162 MHz, $CDCl_3$): δ 32.24, 31.25. **IR** (neat):

3399, 2956, 2931, 2866, 1738, 1438, 1271, 1186, 1115, 1028, 720, 699, 552, 531 cm^{-1}. **MS (ESI):** $(M+H)^+$ 414.2137.



2s

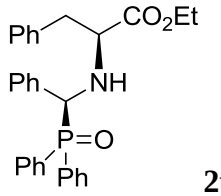
(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(furan-2-yl) methyl) pyrrolidine-2-carboxy late (2s): Yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.10-8.05 (m, 2H), 7.59-7.45 (m, 5H), 7.37-7.27 (m, 4H), 6.68 (d, *J* = 3.0 Hz, 1H), 6.27-6.26 (m, 1H), 5.21 (d, *J* = 32.0 Hz, 1H), 4.11-4.06 (m, 2H), 3.43-3.39 (m, 1H), 3.28 (t, *J* = 8.0 Hz, 1H), 2.96-2.88 (m, 1H), 1.84-1.80 (m, 2H), 1.74-1.53 (m, 4H), 1.22 (t, *J* = 8.0 Hz, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.3, 146.5 (d, J_{C-P} = 6.0 Hz), 142.5 (d, J_{C-P} = 1.0 Hz), 132.6 (d, J_{C-P} = 60.0 Hz), 131.9, 131.84, 131.75, 131.5 (d, J_{C-P} = 3.0 Hz), 131.3, 131.2, 130.9 (d, J_{C-P} = 9.0 Hz), 128.1, 128.0, 63.2 (d, J_{C-P} = 12.0 Hz), 60.4, 57.6 (d, J_{C-P} = 86.0 Hz), 49.4, 28.0, 23.6, 14.1. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 29.54. **IR** (neat): 3427, 2976, 2372, 1736, 1438, 1199, 1118, 1012, 749, 724, 698, 541, 522 cm^{-1}. **MS (ESI):** $(M+H)^+$ 424.1829.



2t

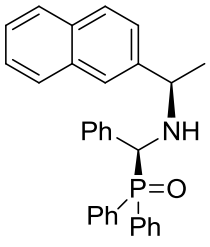
(*S*)-ethyl 1-((*S*)-(diphenylphosphoryl)(pyridin-2-yl) methyl) pyrrolidine-2-carb oxylate (2t): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 8.40-8.39 (m, 1H), 8.11-8.09 (m, 2H), 8.07-8.06 (m, 1H), 7.85-7.82 (m, 0.25H), 7.71-7.63 (m, 0.5H), 7.59-7.45 (m, 7H), 7.31-7.21 (m, 4H), 7.09-7.06 (m, 1H), 5.31 (d, *J* = 9.6 Hz, 1H), 5.21 (d, *J* = 7.6 Hz, 0.25H), 4.06-3.96 (m, 2H), 3.89-3.86 (m, 0.5H), 3.52-3.42 (m, 2H), 3.22-3.18 (m, 0.5H), 3.13-3.07 (m, 1H), 1.82-1.60 (m, 5H), 1.19-1.15 (m, 3H), 1.07 (t, *J* = 7.2 Hz, 1H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 174.4, 173.3, 155.2 (d, J_{C-P} = 3.0 Hz), 153.4 (d, J_{C-P} = 4.0 Hz), 149.0, 148.6, 135.9, 135.7, 133.6, 132.9, 132.6 (d, J_{C-P} = 14.0 Hz), 131.9, 131.7, 131.6, 131.54, 131.48, 131.41, 131.38, 131.3 (d, J_{C-P} = 9.0 Hz), 131.2, 131.1, 131.0, 130.9, 128.1 (d, J_{C-P} = 11.0 Hz), 128.0 (d, J_{C-P} = 25.0 Hz), 127.9, 127.8, 125.7 (d, J_{C-P} = 3.0 Hz), 125.2 (d, J_{C-P} = 3.0 Hz), 122.5, 122.3, 67.4 (d, J_{C-P} = 77.0 Hz), 65.2 (d, J_{C-P} = 80.0 Hz), 63.3 (d, J_{C-P} = 4.0 Hz), 62.2 (d, J_{C-P} = 11.0 Hz), 60.8, 60.2, 60.0, 58.4, 50.7 (d, J_{C-P} = 6.0 Hz), 49.5, 47.6, 30.2, 29.5, 29.3, 28.3, 24.6, 23.9, 23.3, 22.1, 14.0, 13.8. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 33.19, 29.56.

IR (neat): 3424, 3056, 2977, 2873, 1737, 1586, 1467, 1436, 1189, 1118, 1028, 752, 722, 696, 551, 521 cm^{-1}. **MS (ESI):** $(M+H)^+$ 435.1947.



2u

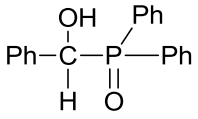
(S)-ethyl 2-(((S)-(diphenylphosphoryl)(phenyl) methyl) amino)-3-phenylpropan oate (2u): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.89-7.84 (m, 2H), 7.76-7.71 (m, 1H), 7.60-7.49 (m, 4H), 7.47-7.40 (m, 5H), 7.35-7.28 (m, 8H), 7.26-7.01 (m, 8H), 6.76 (d, *J* = 7.6 Hz, 1H), 4.69 (d, *J* = 10.0 Hz, 1H), 4.28-4.38 (d, *J* = 9.6 Hz, 0.5H), 4.13-4.08 (m, 2H), 3.70-3.67 (m, 1H), 3.42-3.38 (m, 0.5H), 3.37-3.32 (m, 1H), 3.00-2.87 (m, 1H), 2.82-2.74 (m, 2H), 2.36 (s, 1H), 1.16 (t, *J* = 7.2 Hz, 3H), 0.96 (t, *J* = 8.0 Hz, 1.5H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 173.6, 173.3, 137.5, 136.9, 135.1, 133.5 (d, $J_{C\text{-}P}$ = 4.0 Hz), 132.4 (d, $J_{C\text{-}P}$ = 8.0 Hz), 131.9 (d, $J_{C\text{-}P}$ = 3.0 Hz), 131.7, 131.6, 131.4 (d, $J_{C\text{-}P}$ = 11.0 Hz), 131.35 (d, $J_{C\text{-}P}$ = 8.0 Hz), 130.7, 130.6 (d, $J_{C\text{-}P}$ = 95.0 Hz), 130.2 (d, $J_{C\text{-}P}$ = 50.0 Hz), 129.3, 129.2, 129.1, 129.0, 128.9, 128.2 (d, $J_{C\text{-}P}$ = 4.0 Hz), 128.1, 127.83 (d, $J_{C\text{-}P}$ = 11.0 Hz), 127.82 (d, $J_{C\text{-}P}$ = 1.0 Hz), 127.8, 127.6 (d, $J_{C\text{-}P}$ = 2.0 Hz), 127.5 (d, $J_{C\text{-}P}$ = 2.0 Hz), 126.6, 126.4, 62.8 (d, $J_{C\text{-}P}$ = 80.0 Hz), 62.2 (d, $J_{C\text{-}P}$ = 13.0 Hz), 61.4 (d, $J_{C\text{-}P}$ = 77.0 Hz), 60.59, 60.55, 59.4 (d, $J_{C\text{-}P}$ = 14.0 Hz), 39.5, 39.3, 14.1, 13.7. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 31.35, 30.05. **IR** (neat): 3331, 1731, 1438, 1187, 1119, 1028, 752, 722, 699, 552, 501 cm^{-1}. **MS (ESI):** $(M+H)^+$ 484.1971.



2v

((S)-(((R)-1-(naphthalen-2-yl) ethyl) amino)(phenyl) methyl) diphenylphosphine oxide (2v): Light yellow liquid, **^{1}H NMR** (400 MHz, $CDCl_3$): δ 7.97-7.92 (m, 0.5H), 7.82-7.70 (m, 4H), 7.65 (d, *J* = 8.0 Hz, 0.5H), 7.56-7.49 (m, 2H), 7.43-7.34 (m, 3H), 7.32-7.14 (m, 10H), 7.07-7.04 (m, 2H), 4.72 (d, *J* = 10.0 Hz, 0.25H), 4.48-4.42 (m, 1H), 4.14-4.08 (m, 0.75H), 2.76 (s, 1H), 1.40-1.34 (m, 3H). **^{13}C NMR** (100 MHz, $CDCl_3$): δ 140.6, 139.5, 135.9, 135.5, 133.7, 133.6, 132.0 (d, $J_{C\text{-}P}$ = 10.0 Hz), 131.8, 131.73, 131.69, 131.6, 131.51, 131.47, 131.30, 131.26, 131.2, 131.1, 131.0, 130.9, 130.8, 130.6 (d, $J_{C\text{-}P}$ = 5.0 Hz), 128.9 (d, $J_{C\text{-}P}$ = 6.0 Hz), 128.7 (d, $J_{C\text{-}P}$ = 5.0 Hz),

128.5, 128.1, 128.0, 128.0 (d, $J_{C\text{-}P}$ = 40.0 Hz), 127.74, 127.69, 127.6, 127.5, 127.3, 127.2, 125.4 (d, $J_{C\text{-}P}$ = 4.0 Hz), 125.1, 124.6, 123.2 (d, $J_{C\text{-}P}$ = 42.0 Hz), 60.4, 60.3, 59.6, 59.5, 24.2, 21.2. **^{31}P NMR** (162 MHz, $CDCl_3$): δ 31.87, 31.13. **IR** (neat): 3328, 3058, 2969, 1595, 1438, 1187, 1120, 801, 780, 753, 722, 699, 551, 527, 502 cm^{-1}. **MS (ESI):** $(M+H)^+$ 462.1884.



3

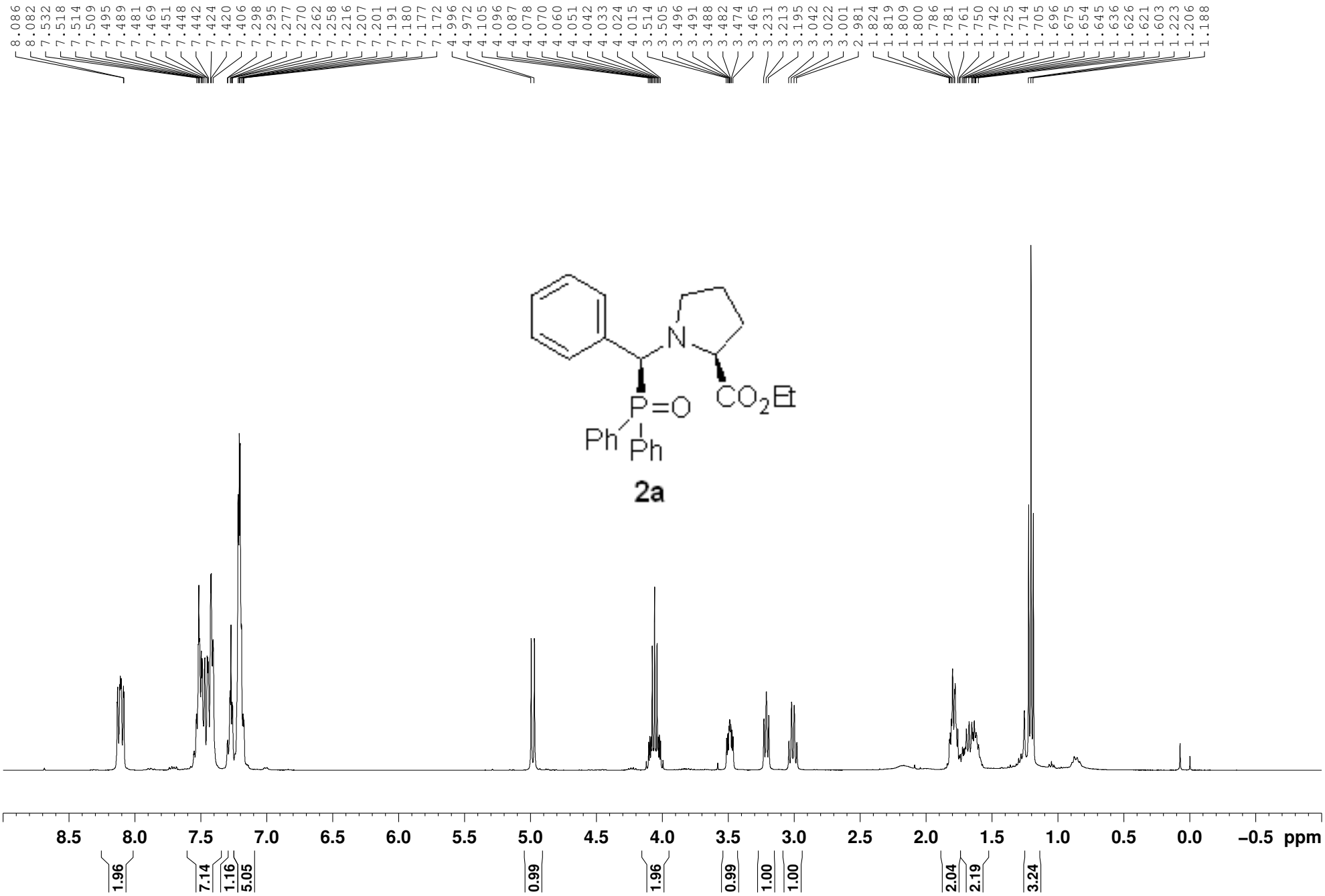
(hydroxyl (phenyl) methyl) diphenylphosphine oxide (3): Light yellow liquid, **^{1}H NMR** (400 MHz, CD_3OD): δ 7.89-7.75 (m, 4H), 7.61-7.56 (m, 2H), 7.51-7.45 (m, 4H), 7.24-7.18 (m, 5H), 5.62 (d, *J* = 7.2 Hz, 1H). **^{13}C NMR** (100 MHz, CD_3OD): δ 138.4, 133.8 (d, $J_{C\text{-}P}$ = 9.0 Hz), 133.5 (d, $J_{C\text{-}P}$ = 8.0 Hz), 133.0 (d, $J_{C\text{-}P}$ = 9.0 Hz), 132.7 (d, $J_{C\text{-}P}$ = 96.0 Hz), 130.1 (d, $J_{C\text{-}P}$ = 96.0 Hz), 129.8 (d, $J_{C\text{-}P}$ = 11.0 Hz), 129.4 (d, $J_{C\text{-}P}$ = 11.0 Hz), 129.1, 129.0, 128.9, 74.6, 73.8. **^{31}P NMR** (162 MHz, CD_3OD): δ 33.04. **IR** (neat): 3274, 2923, 1593, 1436, 1161, 1119, 1027, 722, 695, 546,502 cm^{-1}. **MS (ESI):** $(M+H)^+$ 309.0854.

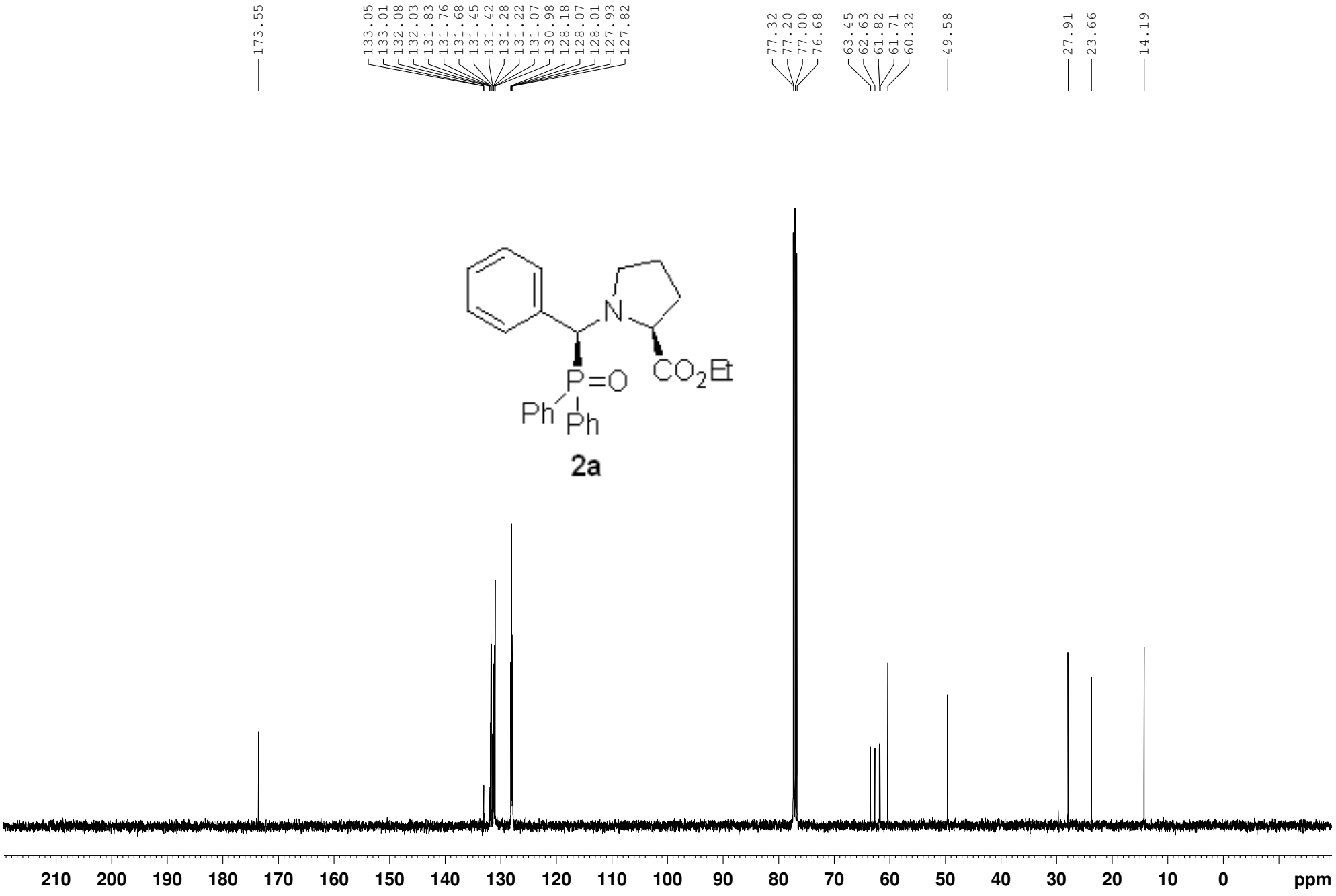
References:

1. G. J. Wang, N. Goyal and B. Hopkinson, *Bioorg. Med. Chem. Lett*, 2009, **19**, 3798.

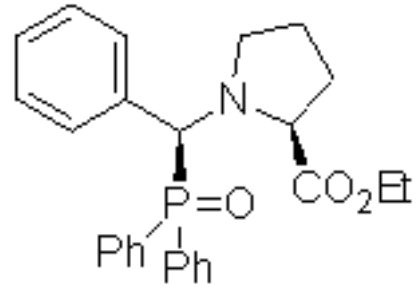
2. S. Stella and A. Chadha, *Tetrahedron: Asymmetry*, 2010, **21**, 457.

5. NMR Spectra

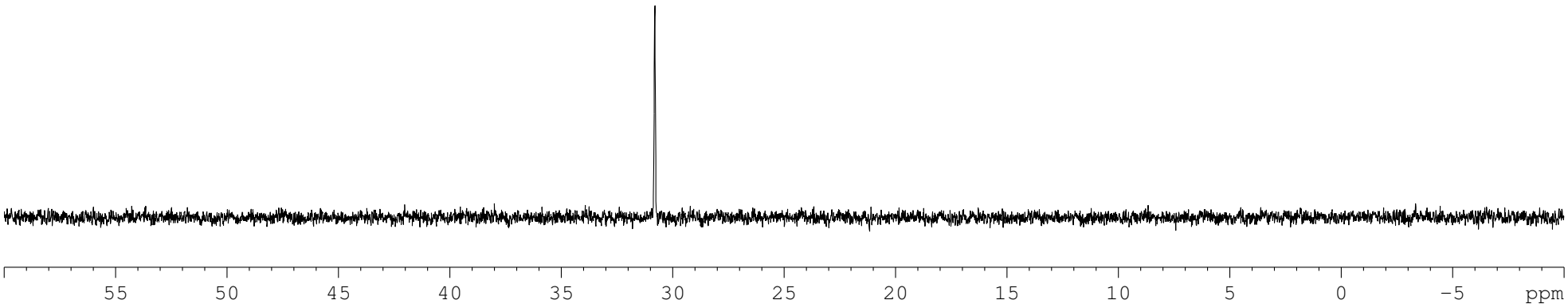

8.086
8.082
7.532
7.518
7.514
7.509
7.495
7.489
7.481
7.469
7.451
7.448
7.442
7.424
7.420
7.406
7.298
7.295
7.277
7.270
7.262
7.258
7.216
7.207
7.201
7.191
7.180
7.177
7.172
4.996
4.972
4.105
4.096
4.087
4.078
4.070
4.060
4.051
4.042
4.033
4.024
4.015
3.514
3.505
3.496
3.491
3.488
3.482
3.474
3.465
3.231
3.213
3.195
3.042
3.022
3.001
2.981
1.824
1.819
1.809
1.800
1.786
1.781
1.761
1.750
1.742
1.725
1.714
1.705
1.696
1.675
1.654
1.645
1.636
1.626
1.621
1.603
1.223
1.206
1.188
N
CO2Et
P=O
Ph
Ph
2a
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
1.96
7.14
1.16
5.05
0.99
1.96
0.99
1.00
1.00
2.04
2.19
3.24

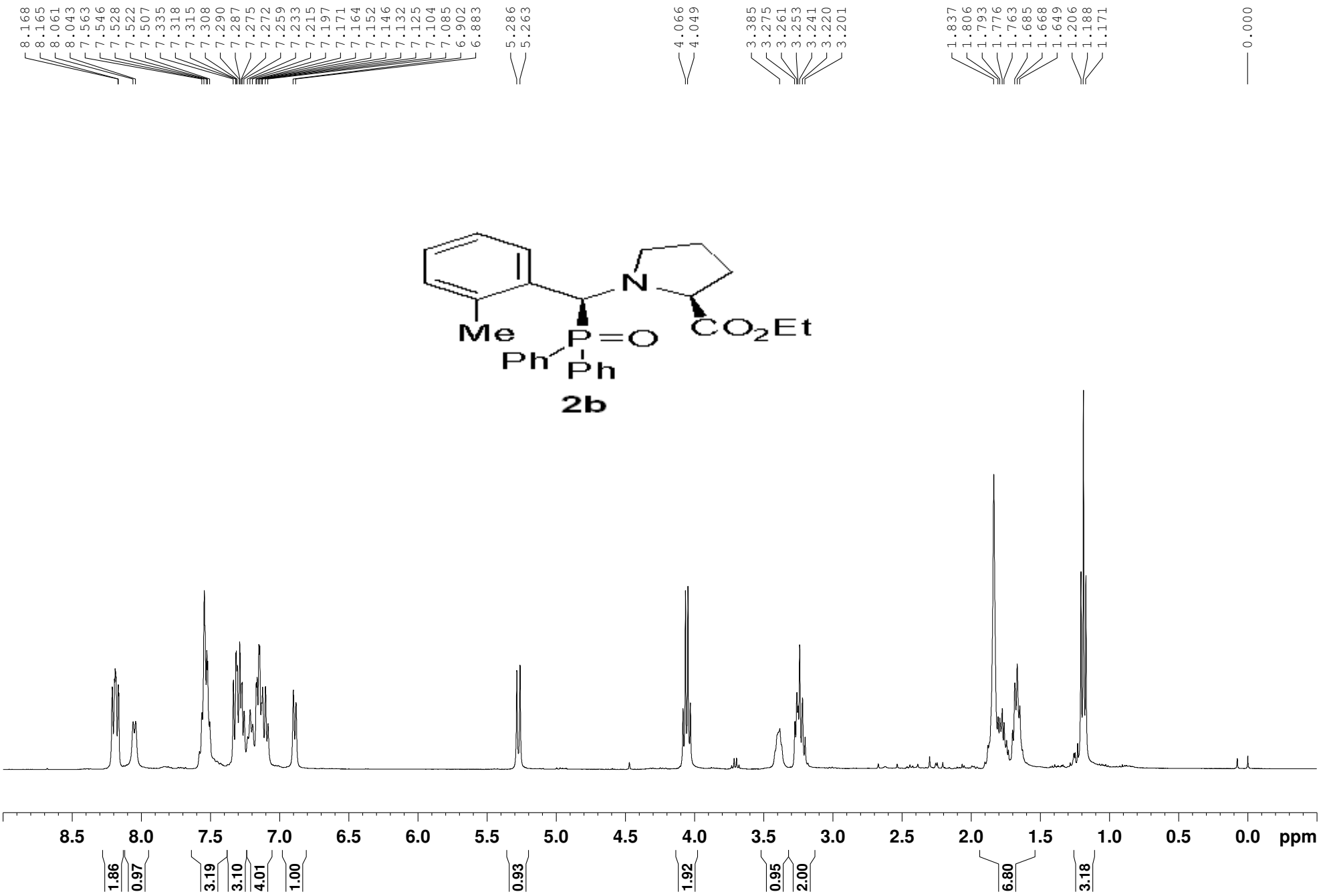

173.55
133.05
133.01
132.08
132.03
131.83
131.76
131.68
131.45
131.42
131.28
131.22
131.07
130.98
128.18
128.07
128.01
127.93
127.82
77.32
77.20
77.00
76.68
63.45
62.63
61.82
61.71
60.32
49.58
27.91
23.66
14.19
N
P=O
Ph
Ph
CO2Et
2a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

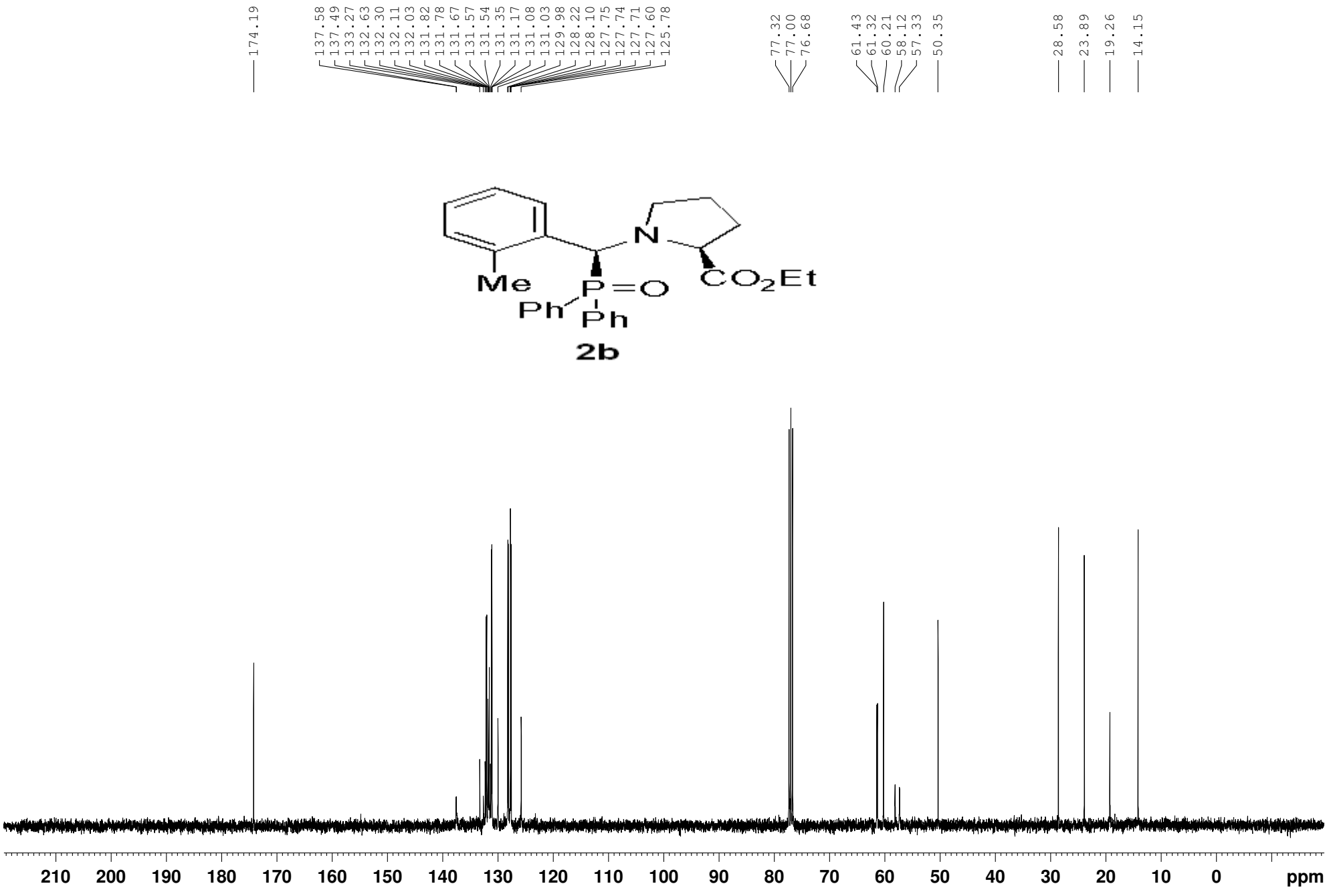
30.80



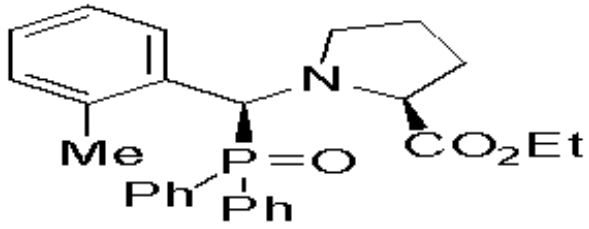
2a



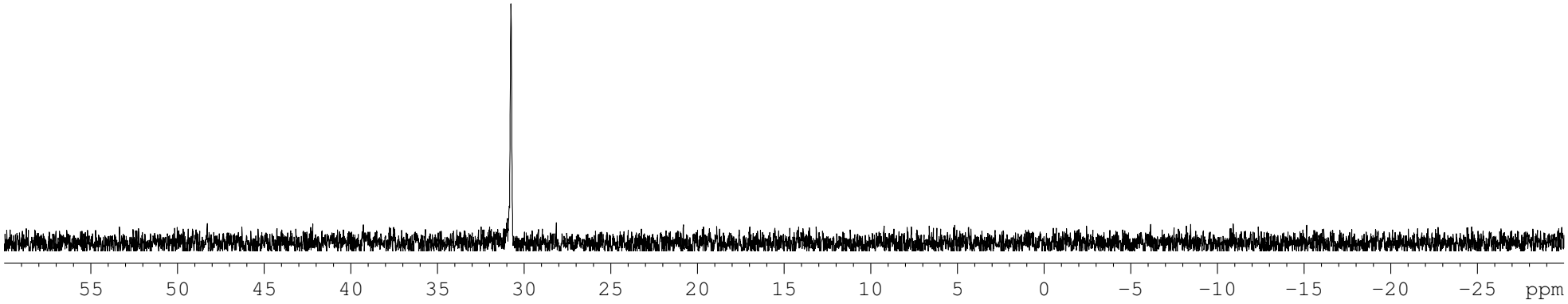

8.168
8.165
8.061
8.043
7.563
7.546
7.528
7.522
7.507
7.335
7.318
7.315
7.308
7.290
7.287
7.275
7.272
7.259
7.233
7.215
7.197
7.171
7.164
7.152
7.146
7.132
7.125
7.104
7.085
6.902
6.883
5.286
5.263
4.066
4.049
3.385
3.275
3.261
3.253
3.241
3.220
3.201
1.837
1.806
1.793
1.776
1.763
1.685
1.668
1.649
1.206
1.188
1.171
0.000
Me
P=O
Ph
Ph
N
CO2Et
2b
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.86
0.97
3.19
3.10
4.01
1.00
0.93
1.92
0.95
2.00
6.80
3.18

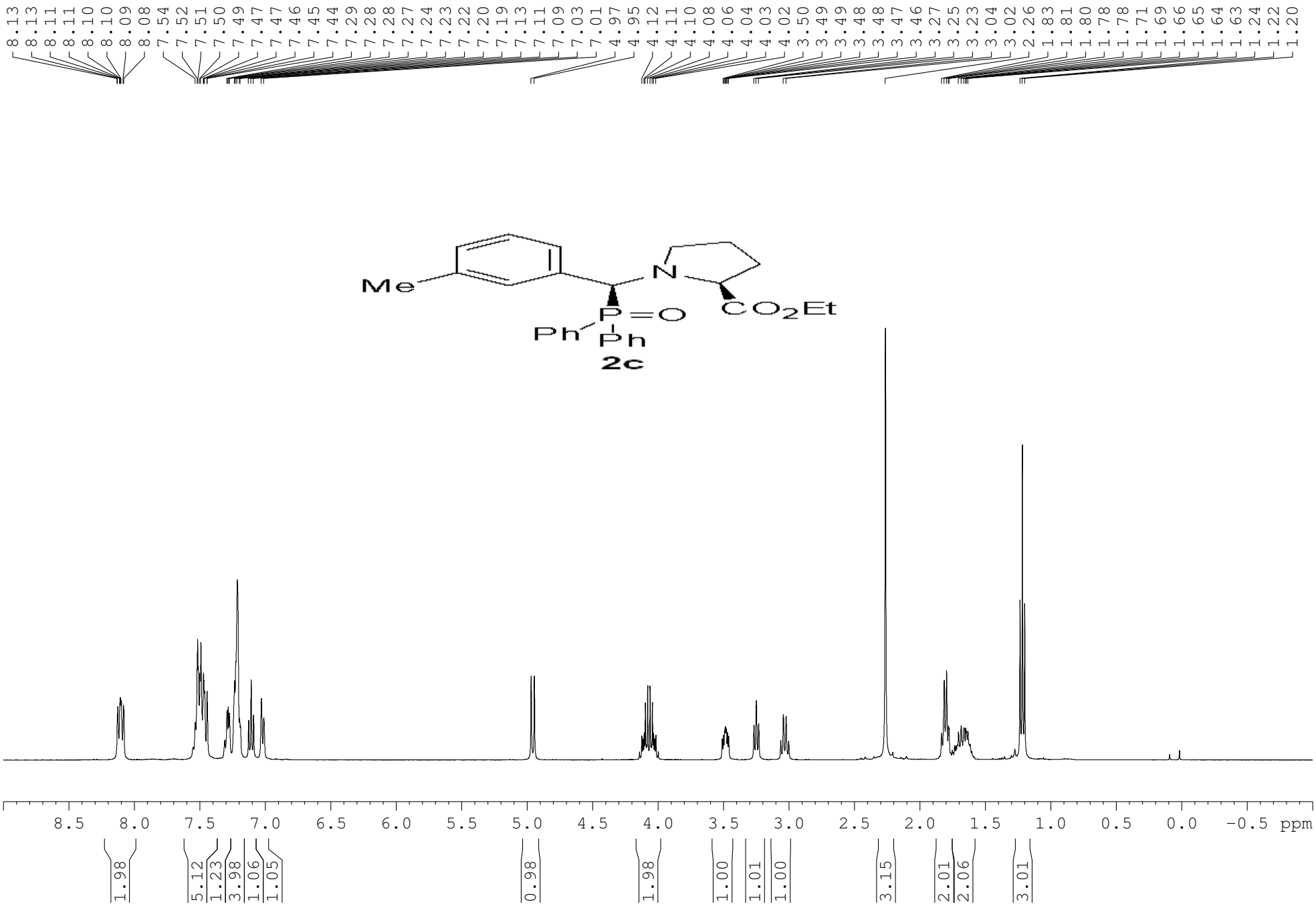

174.19
137.58
137.49
133.27
132.63
132.30
132.11
132.03
131.82
131.78
131.67
131.57
131.54
131.35
131.17
131.08
131.03
129.98
128.22
128.10
127.75
127.74
127.71
127.60
125.78
77.32
77.00
76.68
61.43
61.32
60.21
58.12
57.33
50.35
28.58
23.89
19.26
14.15
N
Me
P=O
Ph
Ph
CO2Et
2b
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

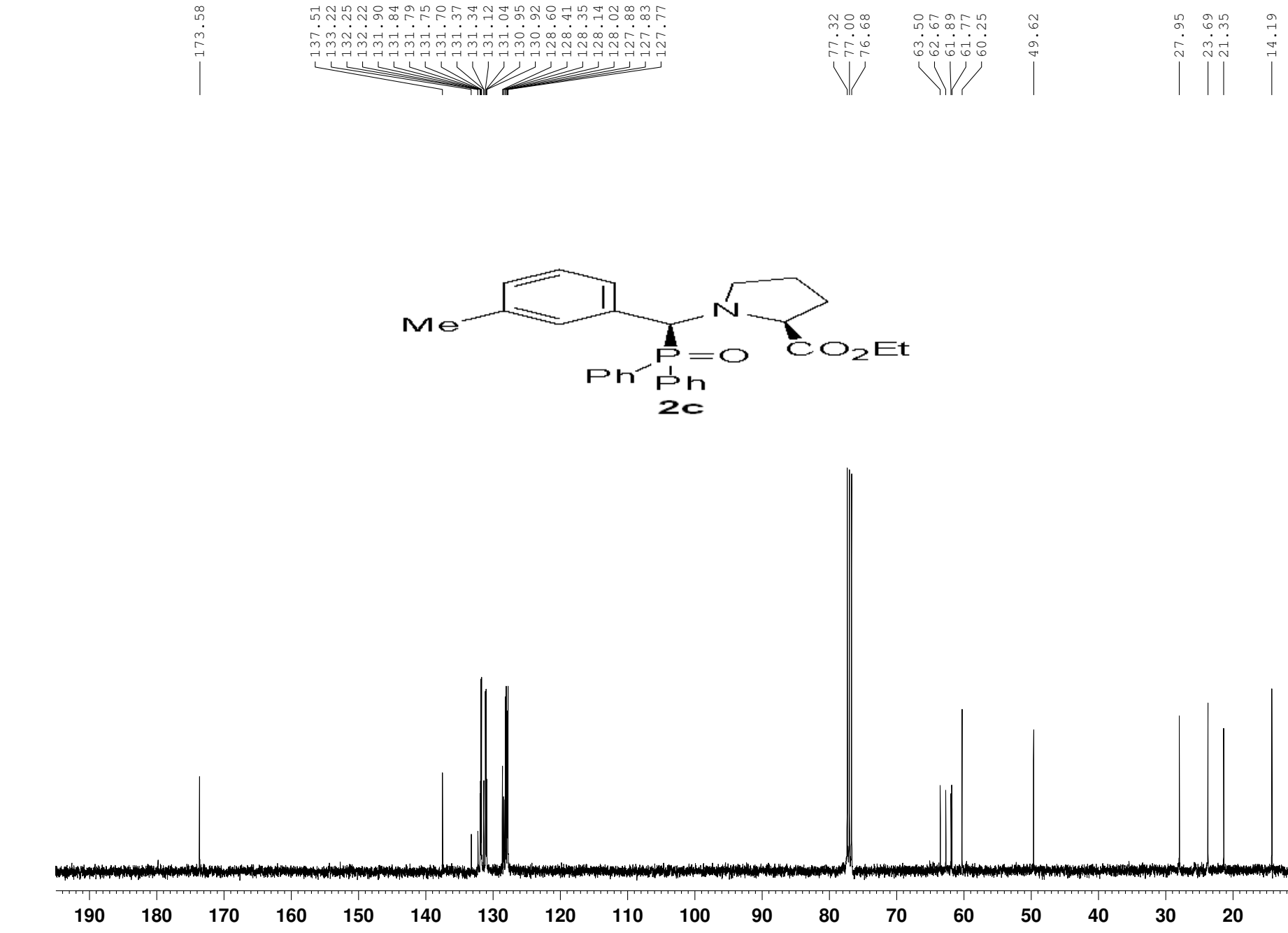
30.77



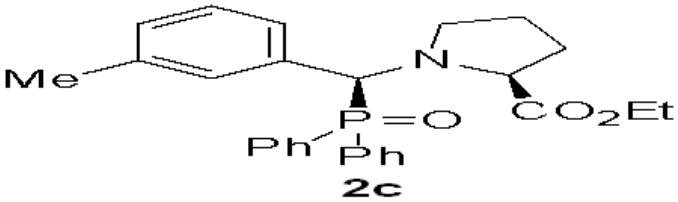
2b



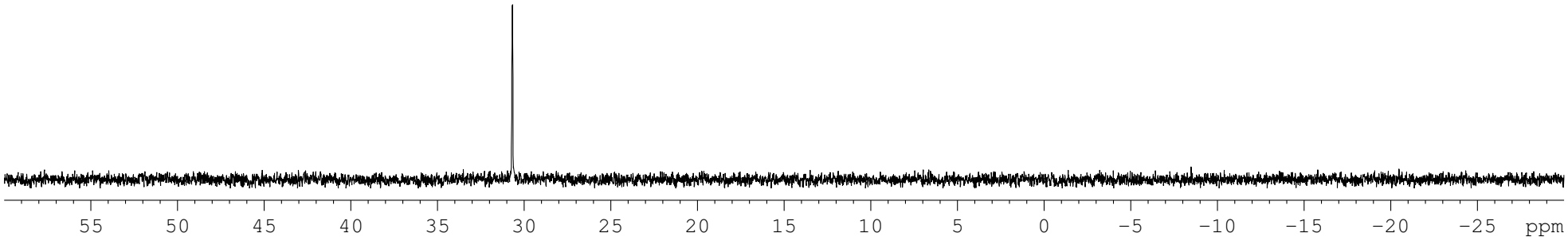

8.13 8.13 8.11 8.11 8.10 8.10 8.09 8.08 7.54 7.52 7.51 7.50 7.49 7.47 7.47 7.46 7.45 7.44 7.29 7.28 7.28 7.27 7.24 7.23 7.22 7.20 7.19 7.13 7.11 7.09 7.03 7.01 4.97 4.95 4.12 4.11 4.10 4.08 4.06 4.04 4.03 4.02 3.50 3.49 3.49 3.48 3.48 3.47 3.46 3.27 3.25 3.23 3.04 3.02 2.26 1.83 1.81 1.80 1.78 1.78 1.71 1.69 1.66 1.65 1.64 1.63 1.24 1.22 1.20
Me
N
P=O
CO2Et
Ph
Ph
2c
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 ppm
1.98 5.12 1.23 3.98 1.06 1.05 0.98 1.98 1.00 1.01 1.00 3.15 2.01 2.06 3.01

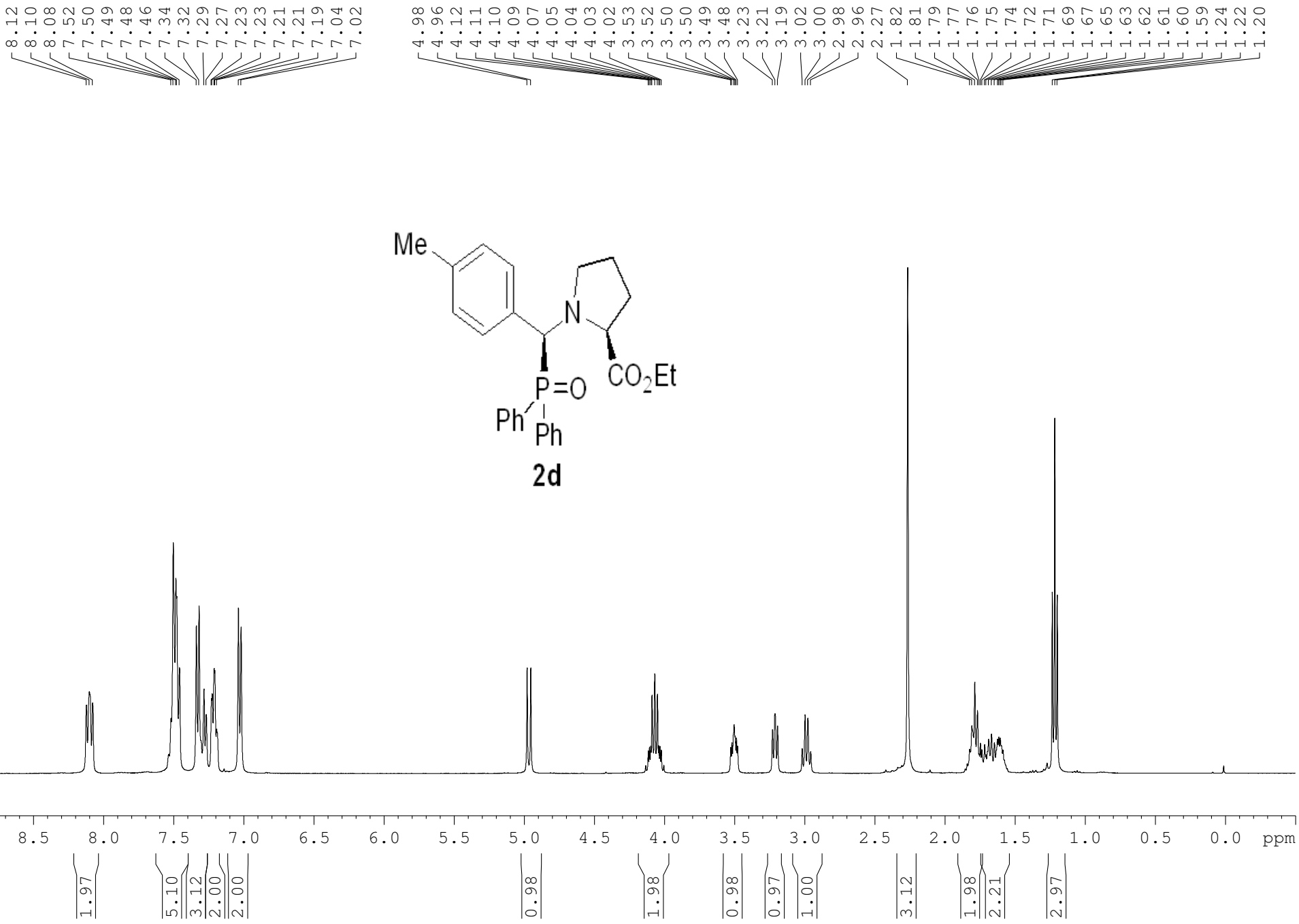

173.58
137.51
133.22
132.25
132.22
131.90
131.84
131.79
131.75
131.70
131.37
131.34
131.12
131.04
130.95
130.92
128.60
128.41
128.35
128.14
128.02
127.88
127.83
127.77
77.32
77.00
76.68
63.50
62.67
61.89
61.77
60.25
49.62
27.95
23.69
21.35
14.19
Me
N
P=O
Ph
Ph
CO2Et
2c
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

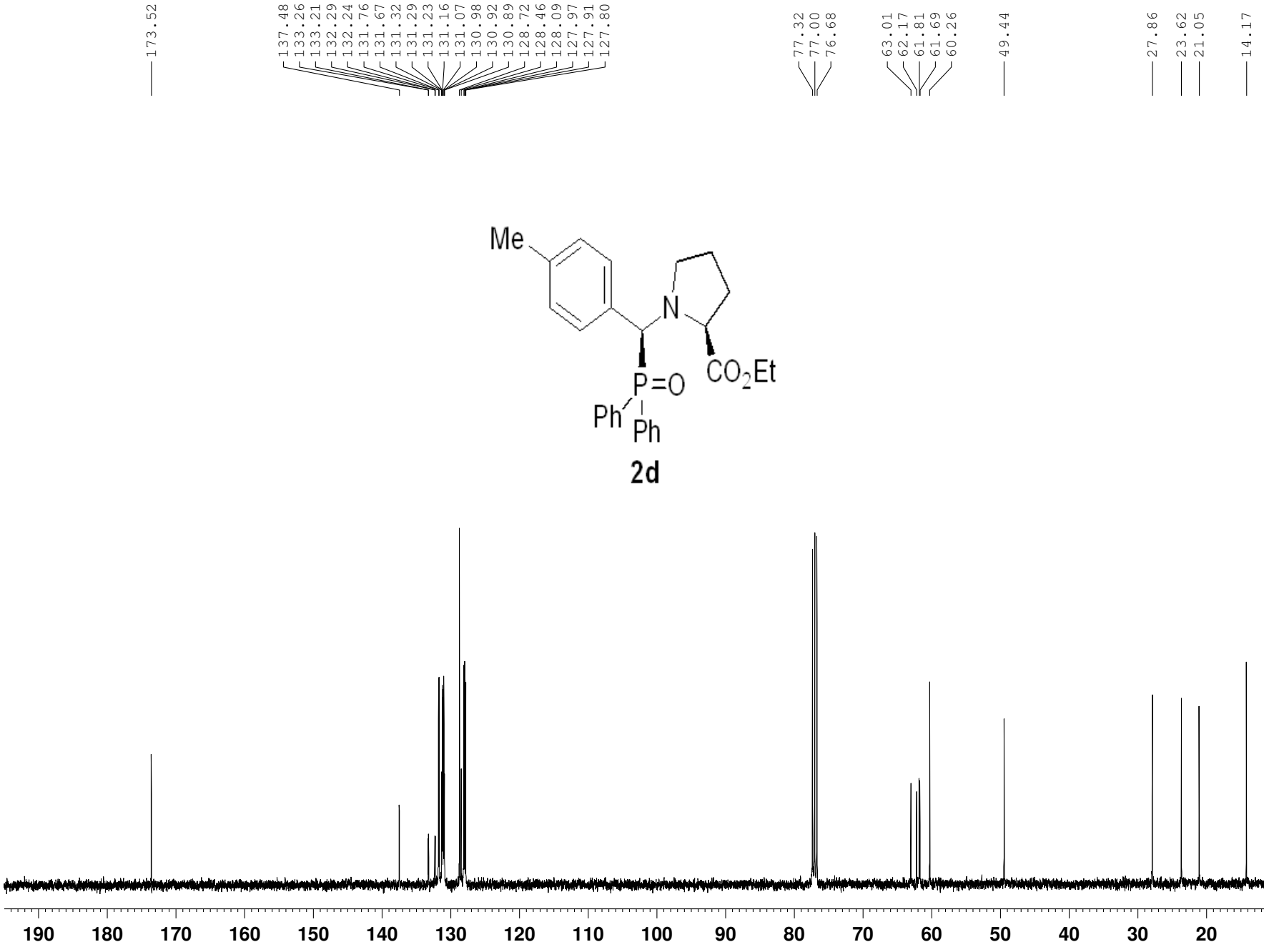
30.69

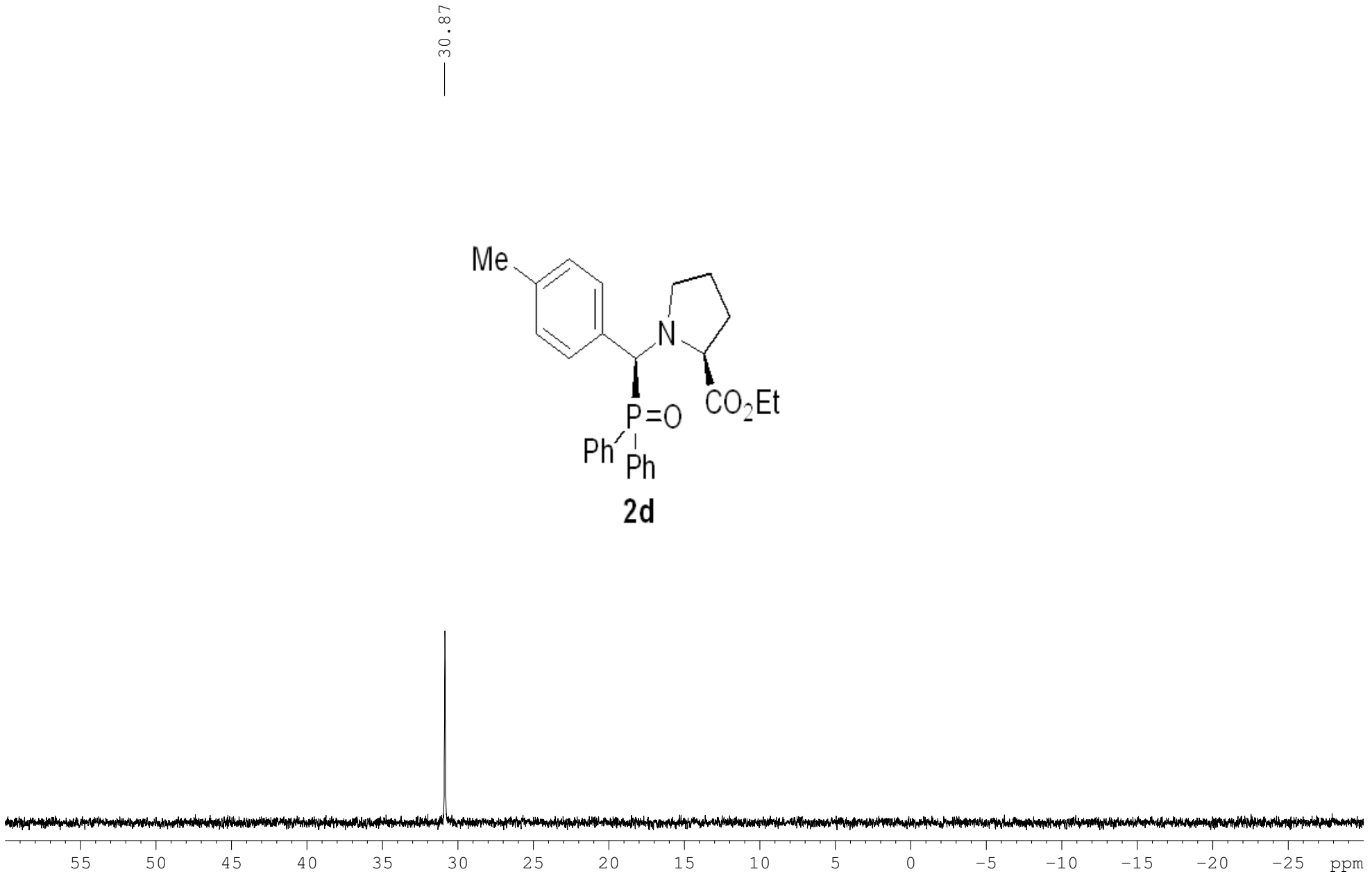


2c

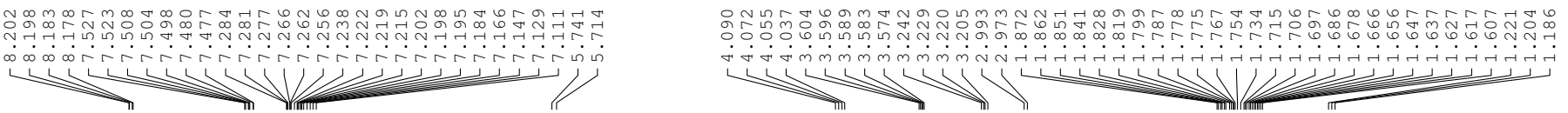


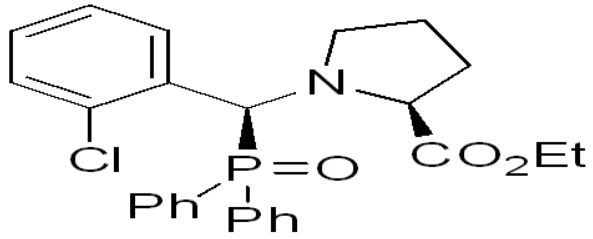

8.12
8.10
8.08
7.52
7.50
7.49
7.48
7.46
7.34
7.32
7.29
7.27
7.23
7.23
7.21
7.21
7.19
7.04
7.02
4.98
4.96
4.12
4.11
4.10
4.09
4.07
4.05
4.04
4.03
4.02
3.53
3.52
3.50
3.50
3.49
3.48
3.23
3.21
3.19
3.02
3.00
2.98
2.96
2.27
1.82
1.81
1.79
1.77
1.76
1.75
1.74
1.72
1.71
1.69
1.67
1.65
1.63
1.62
1.61
1.60
1.59
1.24
1.22
1.20
Me
N
CO2Et
P=O
Ph
Ph
2d
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.97
5.10
3.12
2.00
2.00
0.98
1.98
0.98
0.97
1.00
3.12
1.98
2.21
2.97


173.52
137.48
133.26
133.21
132.29
132.24
131.76
131.67
131.32
131.29
131.23
131.16
131.07
130.98
130.92
130.89
128.72
128.46
128.09
127.97
127.91
127.80
77.32
77.00
76.68
63.01
62.17
61.81
61.69
60.26
49.44
27.86
23.62
21.05
14.17
Me
N
P=O
Ph
Ph
CO2Et
2d
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

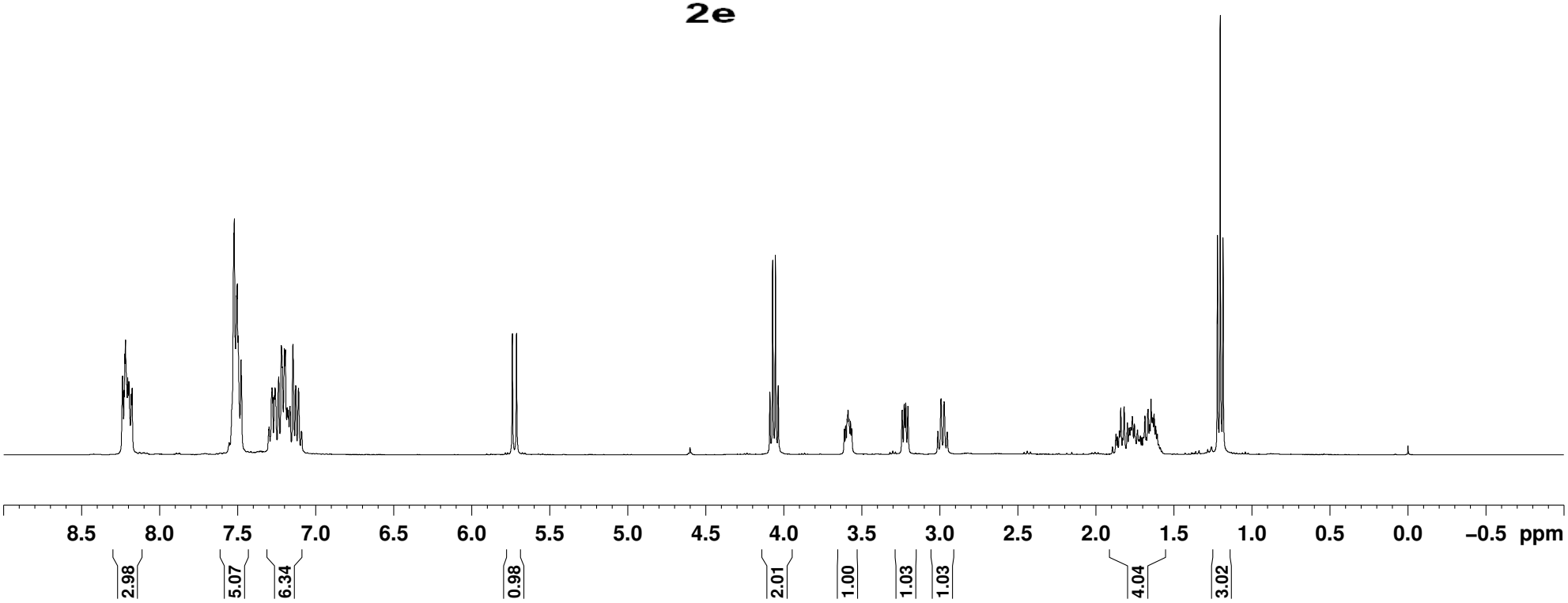

30.87
Me
N
CO2Et
P=O
Ph
Ph
55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
ppm

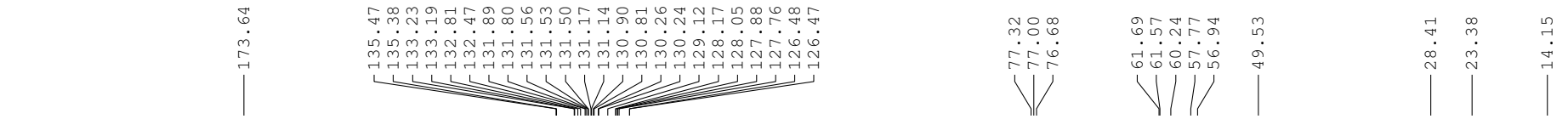
2d

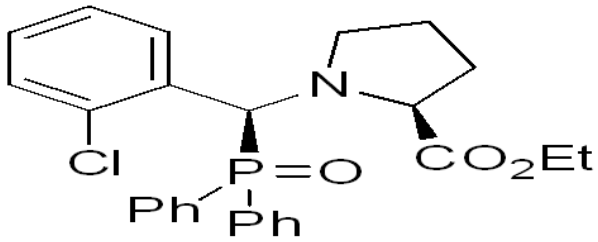

8.202
8.198
8.183
8.178
7.527
7.523
7.508
7.504
7.498
7.480
7.477
7.284
7.281
7.277
7.266
7.262
7.256
7.238
7.222
7.219
7.215
7.202
7.198
7.195
7.184
7.166
7.147
7.129
7.111
5.741
5.714
4.090
4.072
4.055
4.037
3.604
3.596
3.589
3.583
3.574
3.242
3.229
3.220
3.205
2.993
2.973
1.872
1.862
1.851
1.841
1.828
1.819
1.799
1.787
1.778
1.775
1.767
1.754
1.734
1.715
1.706
1.697
1.686
1.678
1.666
1.656
1.647
1.637
1.627
1.617
1.607
1.221
1.204
1.186


Cl
P=O
N
CO2Et
Ph
Ph

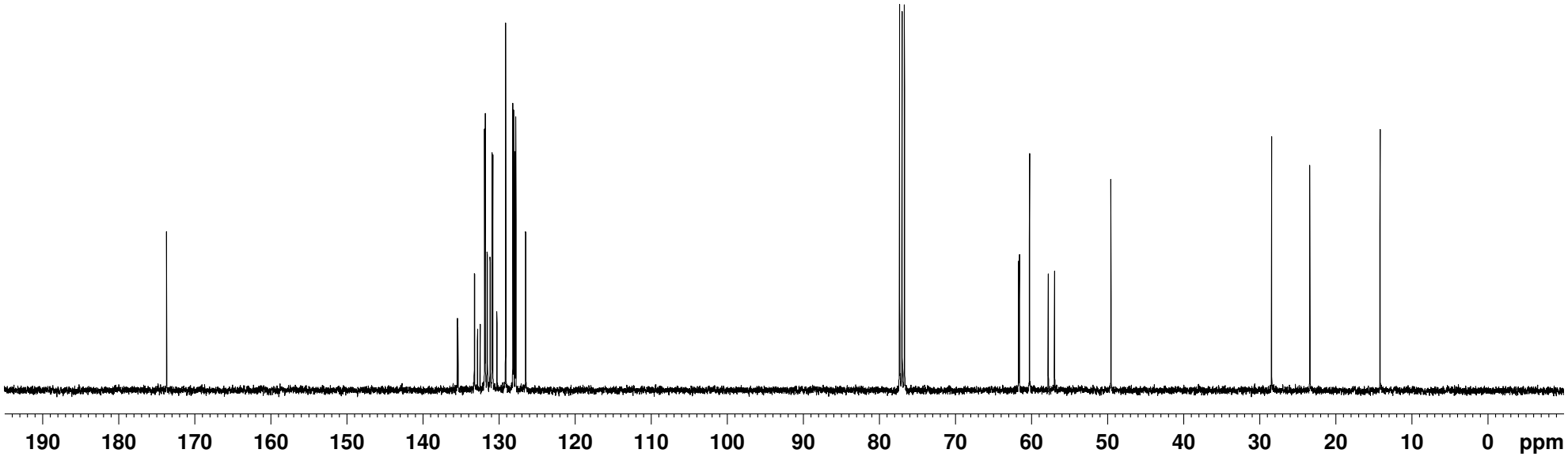
2e


8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
2.98
5.07
6.34
0.98
2.01
1.00
1.03
1.03
4.04
3.02

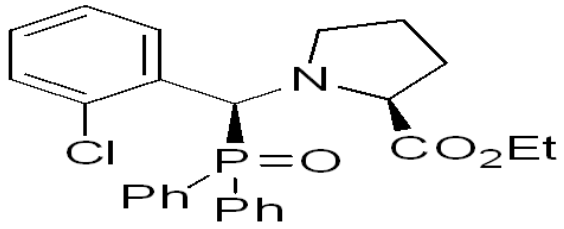

173.64
135.47
135.38
133.23
133.19
132.81
132.47
131.89
131.80
131.56
131.53
131.50
131.17
131.14
130.90
130.81
130.26
130.24
129.12
128.17
128.05
127.88
127.76
126.48
126.47
77.32
77.00
76.68
61.69
61.57
60.24
57.77
56.94
49.53
28.41
23.38
14.15


N
Cl
P=O
CO2Et
Ph
Ph

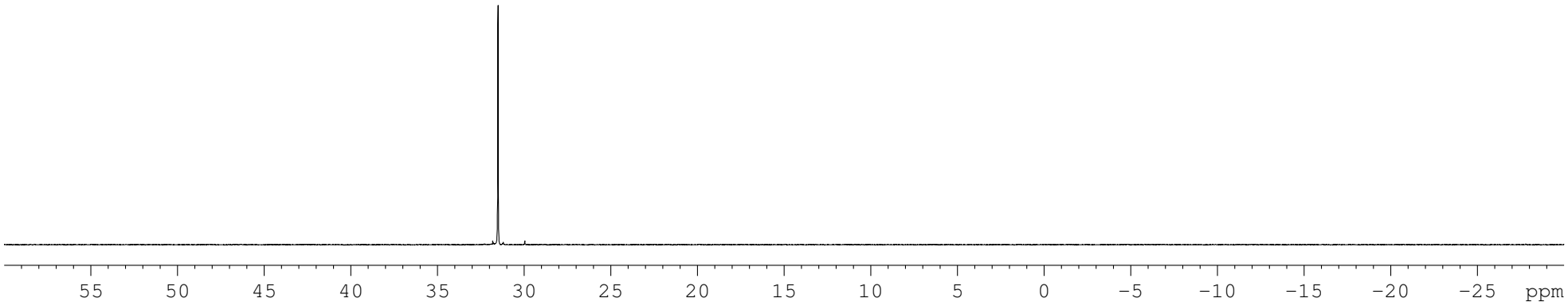
2e

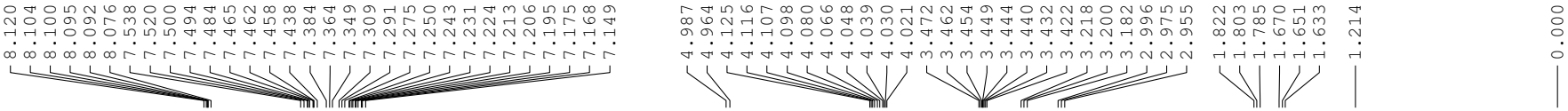

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

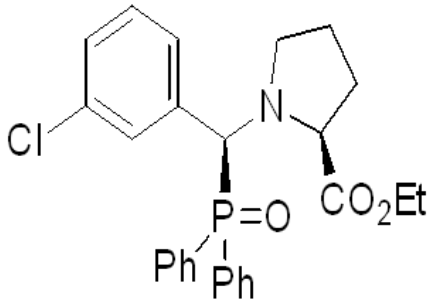
31.52



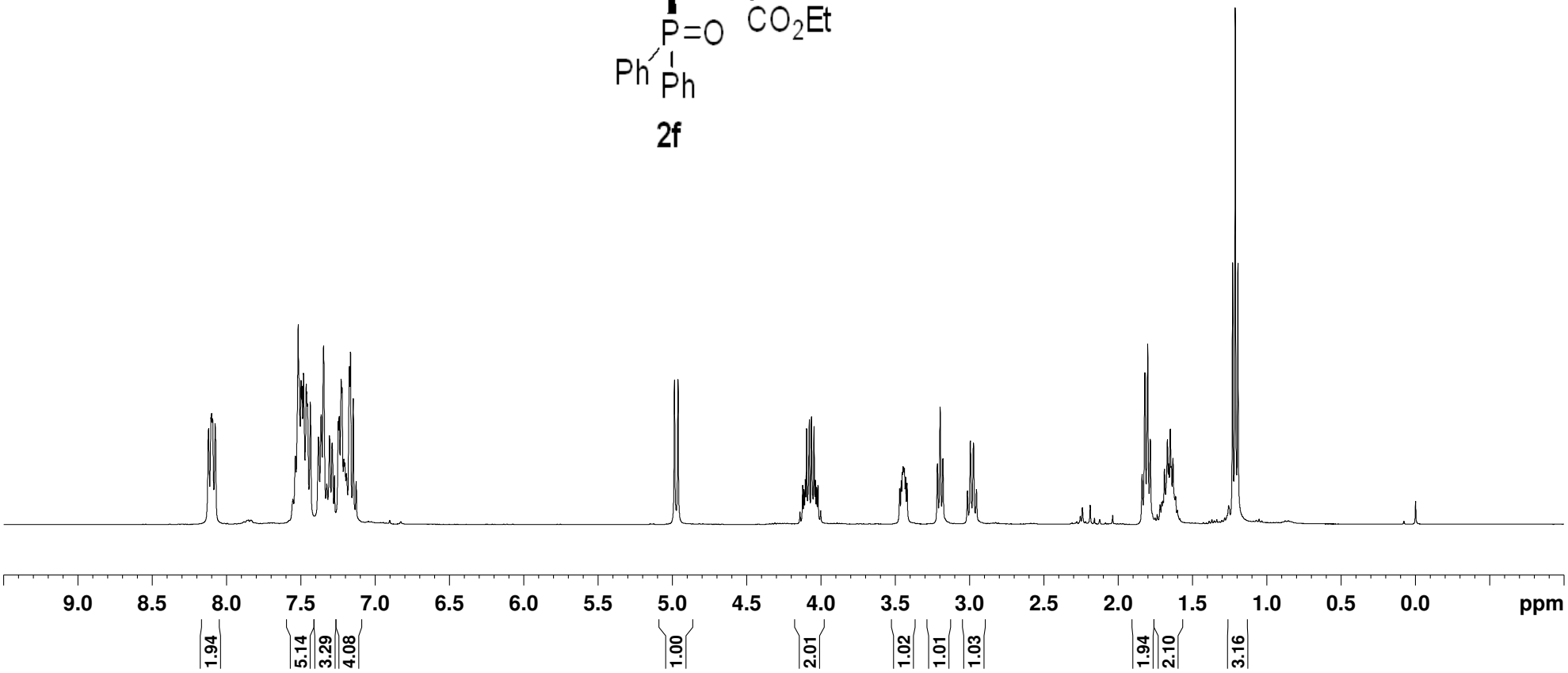
2e

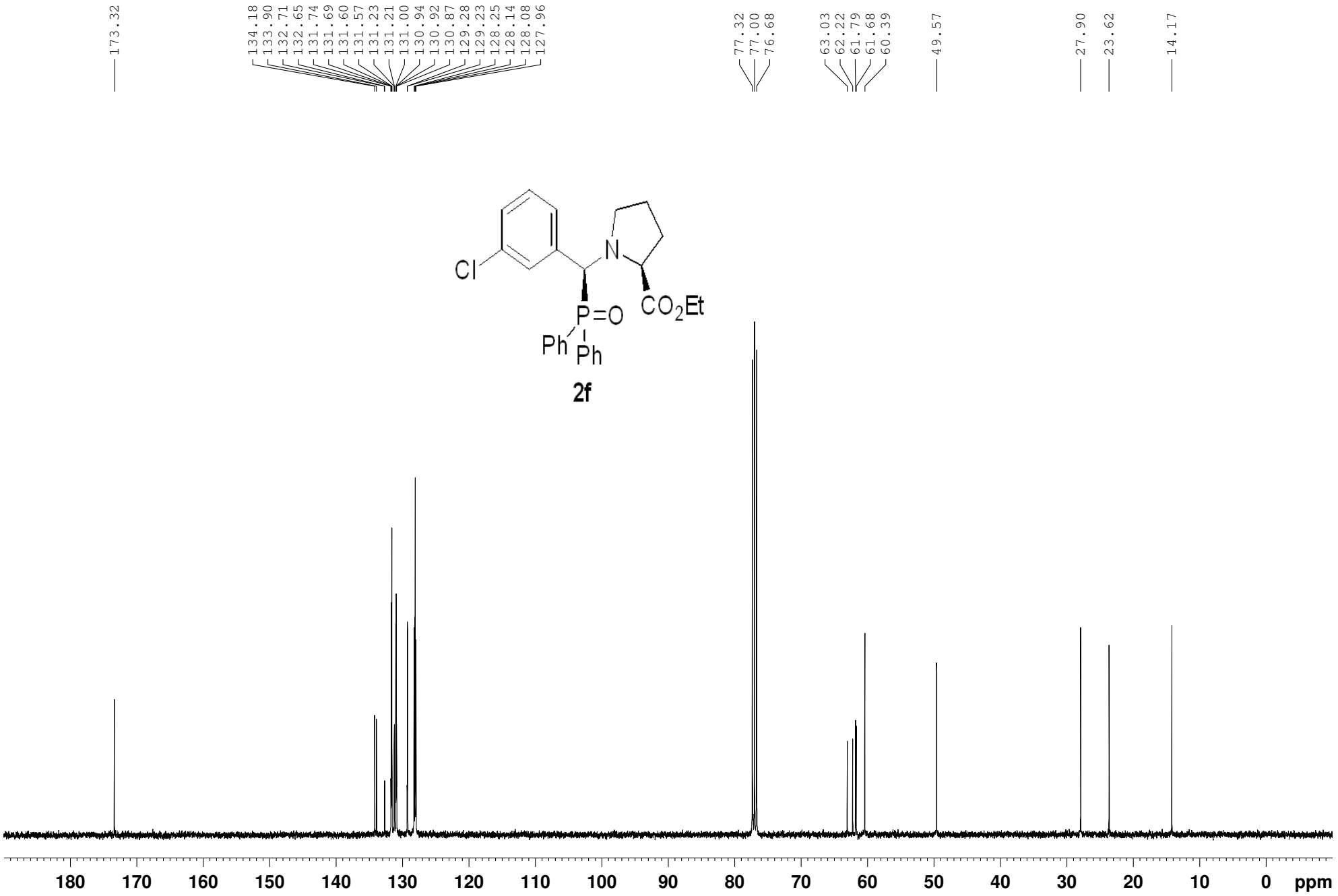



8.120
8.104
8.100
8.095
8.092
8.076
7.538
7.520
7.500
7.494
7.484
7.465
7.462
7.458
7.438
7.384
7.364
7.349
7.309
7.291
7.275
7.250
7.243
7.231
7.224
7.213
7.206
7.195
7.175
7.168
7.149
4.987
4.964
4.125
4.116
4.107
4.098
4.080
4.066
4.048
4.039
4.030
4.021
3.472
3.462
3.454
3.449
3.444
3.440
3.432
3.422
3.218
3.200
3.182
2.996
2.975
2.955
1.822
1.803
1.785
1.670
1.651
1.633
1.214
0.000

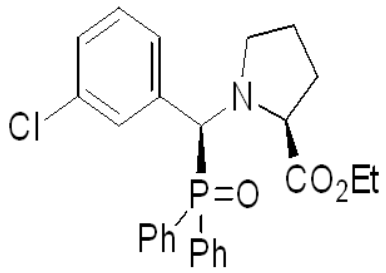

Cl
N
CO2Et
P=O
Ph
Ph

2f

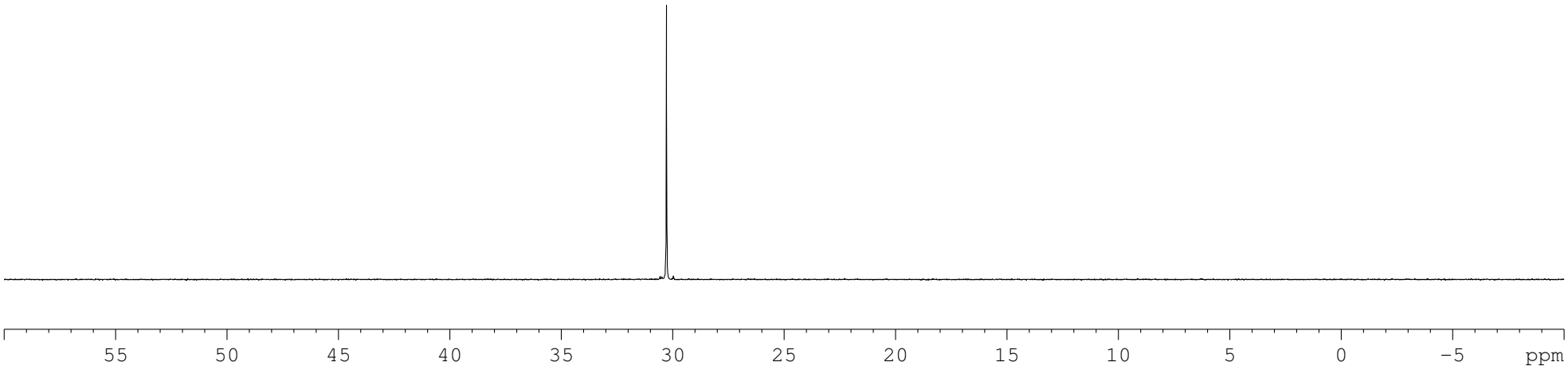

9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.94
5.14
3.29
4.08
1.00
2.01
1.02
1.01
1.03
1.94
2.10
3.16

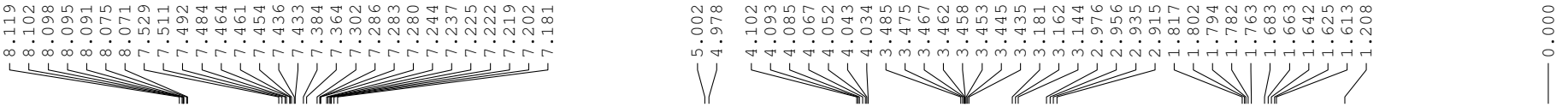

173.32
134.18
133.90
132.71
132.65
131.74
131.69
131.60
131.57
131.23
131.21
131.00
130.94
130.92
130.87
129.28
129.23
128.25
128.14
128.08
127.96
77.32
77.00
76.68
63.03
62.22
61.79
61.68
60.39
49.57
27.90
23.62
14.17
Cl
N
P=O
Ph
Ph
CO2Et
2f
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

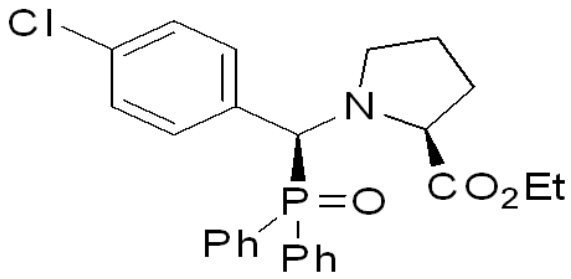
30.27



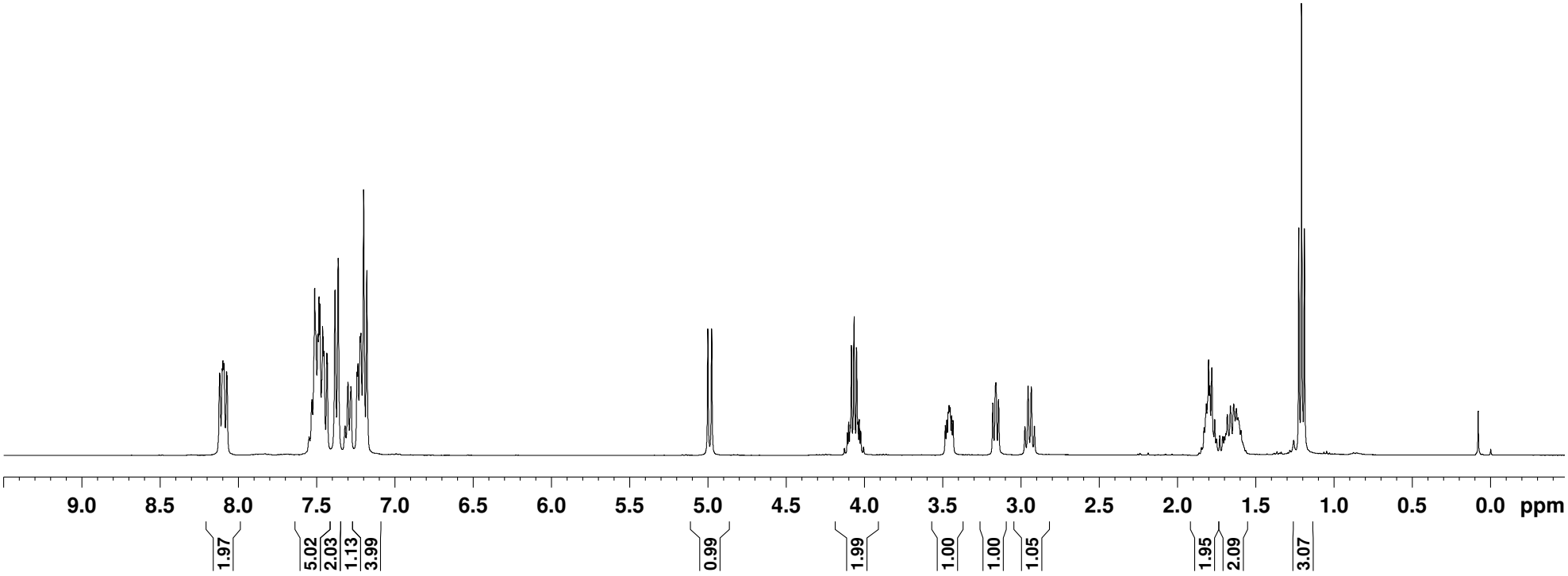
2f

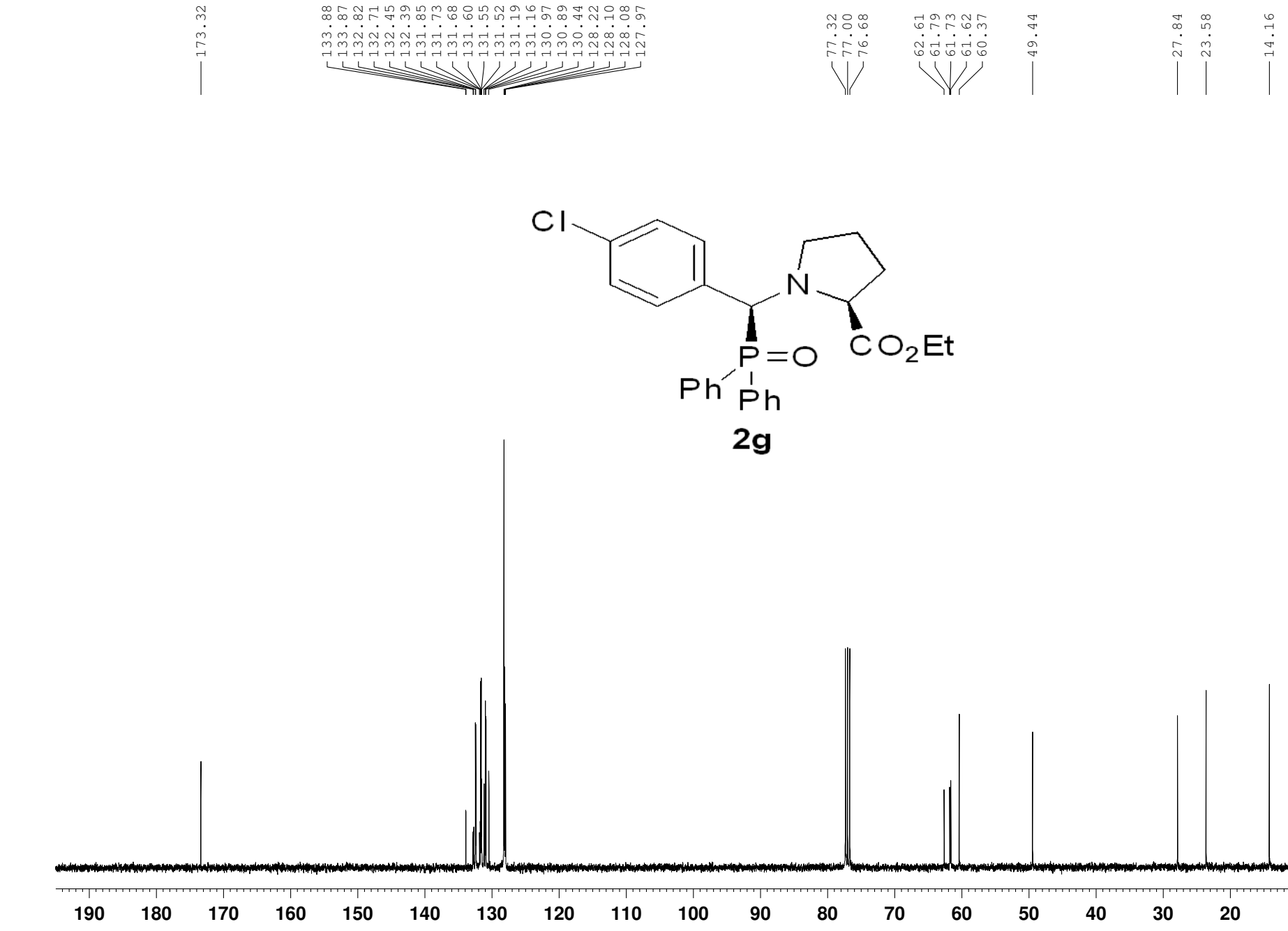


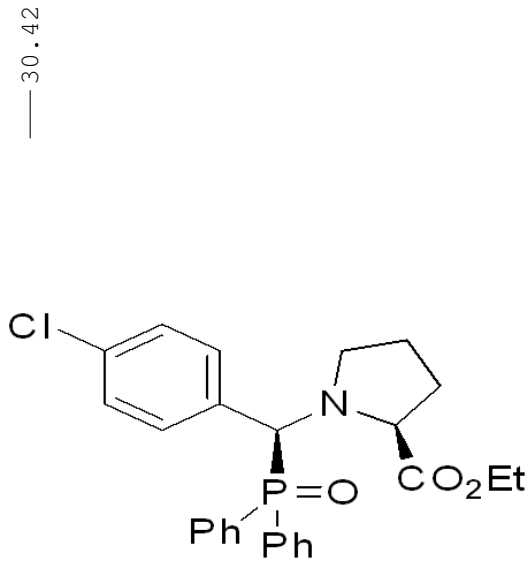

8.119
8.102
8.098
8.095
8.091
8.075
8.071
7.529
7.511
7.492
7.484
7.464
7.461
7.454
7.436
7.433
7.384
7.364
7.302
7.286
7.283
7.280
7.244
7.237
7.225
7.222
7.219
7.202
7.181
5.002
4.978
4.102
4.093
4.085
4.067
4.052
4.043
4.034
3.485
3.475
3.467
3.462
3.458
3.453
3.445
3.435
3.181
3.162
3.144
2.976
2.956
2.935
2.915
1.817
1.802
1.794
1.782
1.763
1.683
1.663
1.642
1.625
1.613
1.208
0.000


Cl
N
CO2Et
P=O
Ph
Ph

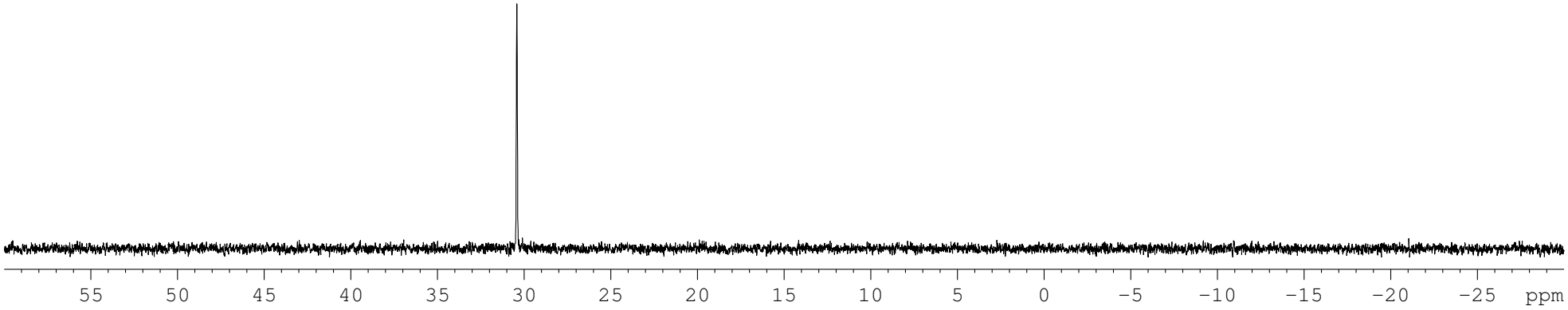
2g

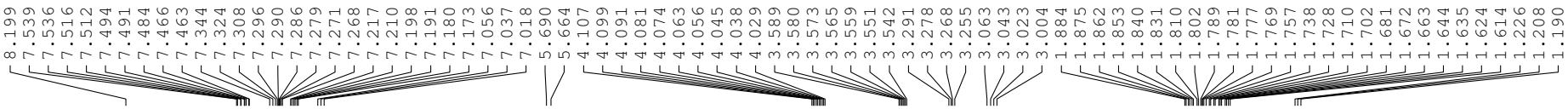

9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.97
5.02
2.03
1.13
3.99
0.99
1.99
1.00
1.00
1.05
1.95
2.09
3.07

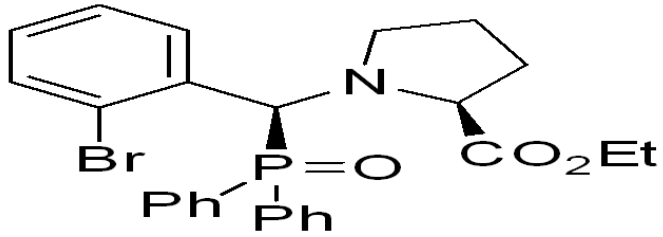

173.32
133.88
133.87
132.82
132.71
132.45
132.39
131.85
131.73
131.68
131.60
131.55
131.52
131.19
131.16
130.97
130.89
130.44
128.22
128.10
128.08
127.97
77.32
77.00
76.68
62.61
61.79
61.73
61.62
60.37
49.44
27.84
23.58
14.16
Cl
N
P=O
Ph
Ph
CO2Et
2g
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


30.42
Cl
N
P=O
CO2Et
Ph
Ph

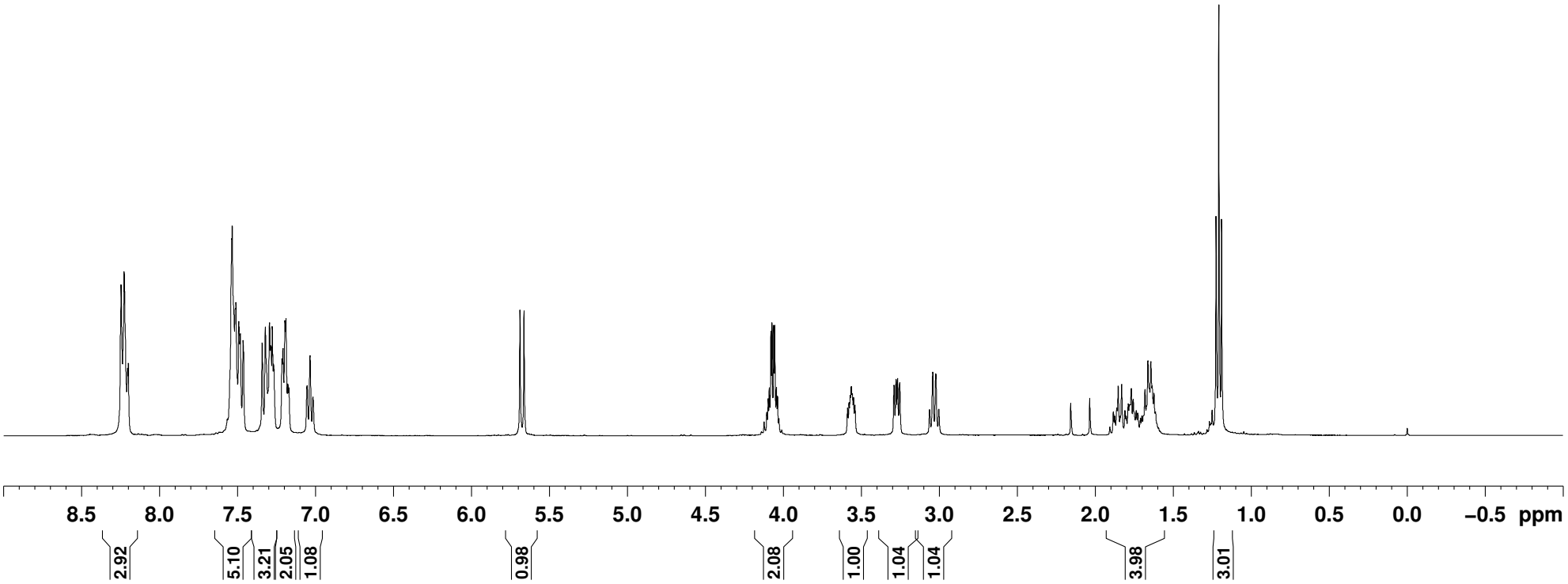
2g

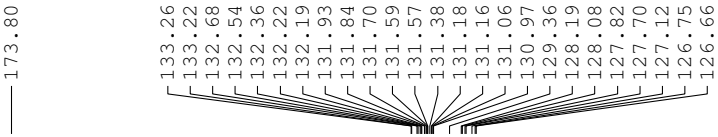

55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
ppm

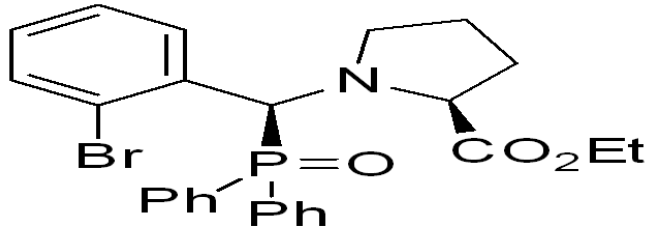

8.199
7.539
7.536
7.516
7.512
7.494
7.491
7.484
7.466
7.463
7.344
7.324
7.308
7.296
7.290
7.286
7.279
7.271
7.268
7.217
7.210
7.198
7.191
7.180
7.173
7.056
7.037
7.018
5.690
5.664
4.107
4.099
4.091
4.081
4.074
4.063
4.056
4.045
4.038
4.029
3.589
3.580
3.573
3.565
3.559
3.551
3.542
3.291
3.278
3.268
3.255
3.063
3.043
3.023
3.004
1.884
1.875
1.862
1.853
1.840
1.831
1.810
1.802
1.789
1.781
1.777
1.769
1.757
1.738
1.728
1.710
1.702
1.681
1.672
1.663
1.644
1.635
1.624
1.614
1.226
1.208
1.190


Br
P=O
Ph
Ph
N
CO2Et

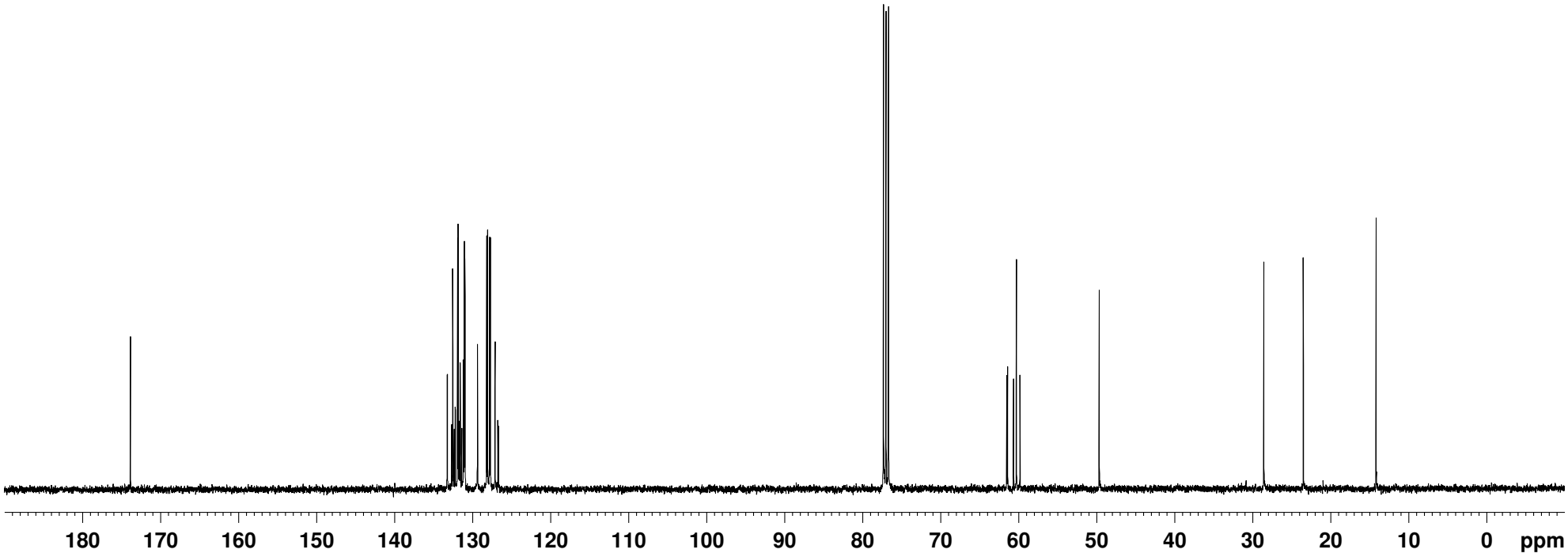
2h

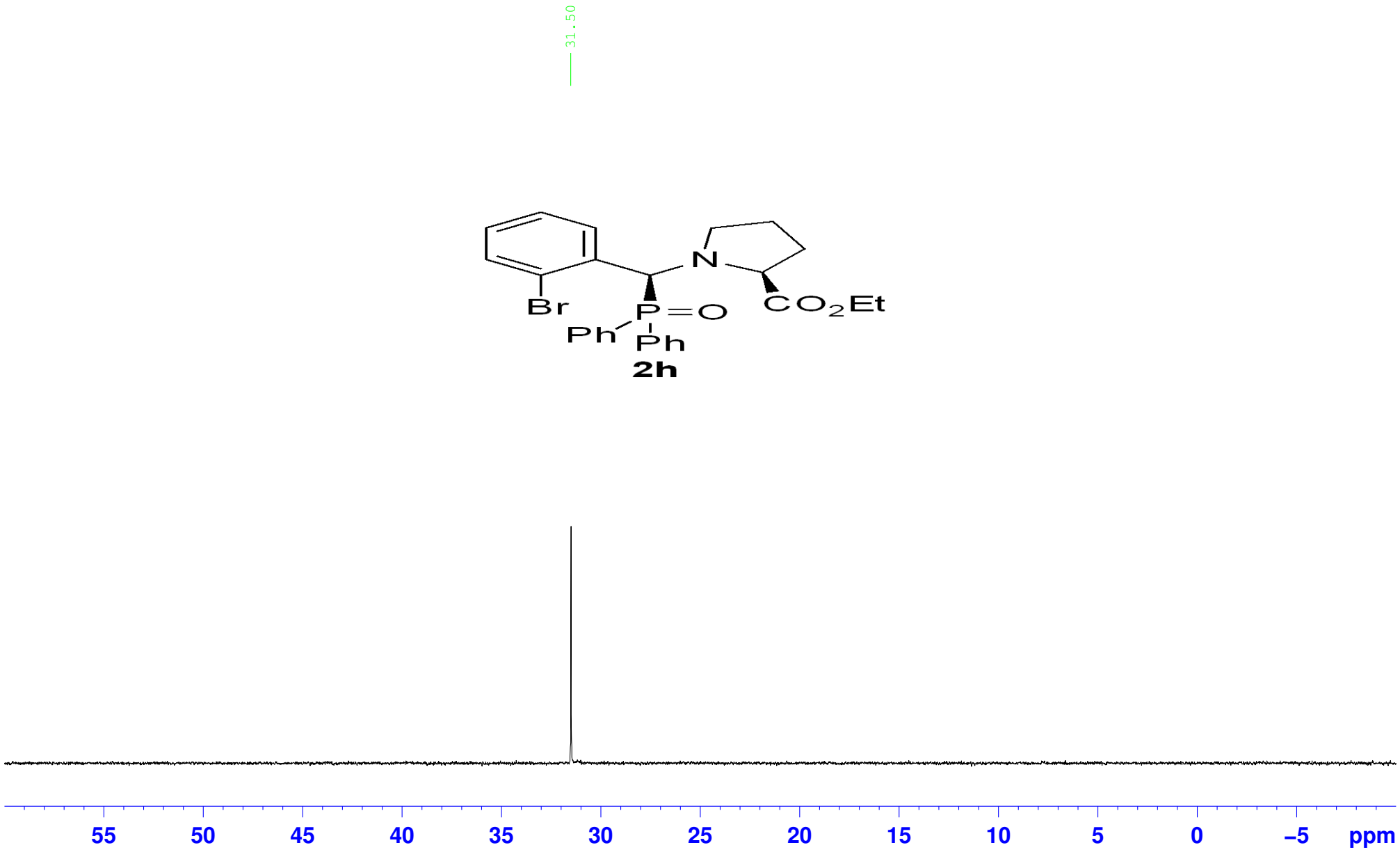

8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
2.92
5.10
3.21
2.05
1.08
0.98
2.08
1.00
1.04
1.04
3.98
3.01


173.80
133.26
133.22
132.68
132.54
132.36
132.22
132.19
131.93
131.84
131.70
131.59
131.57
131.38
131.18
131.16
131.06
130.97
129.36
128.19
128.08
127.82
127.70
127.12
126.75
126.66
77.32
77.00
76.68
61.52
61.40
60.64
60.28
59.82
49.67
28.56
23.50
14.18

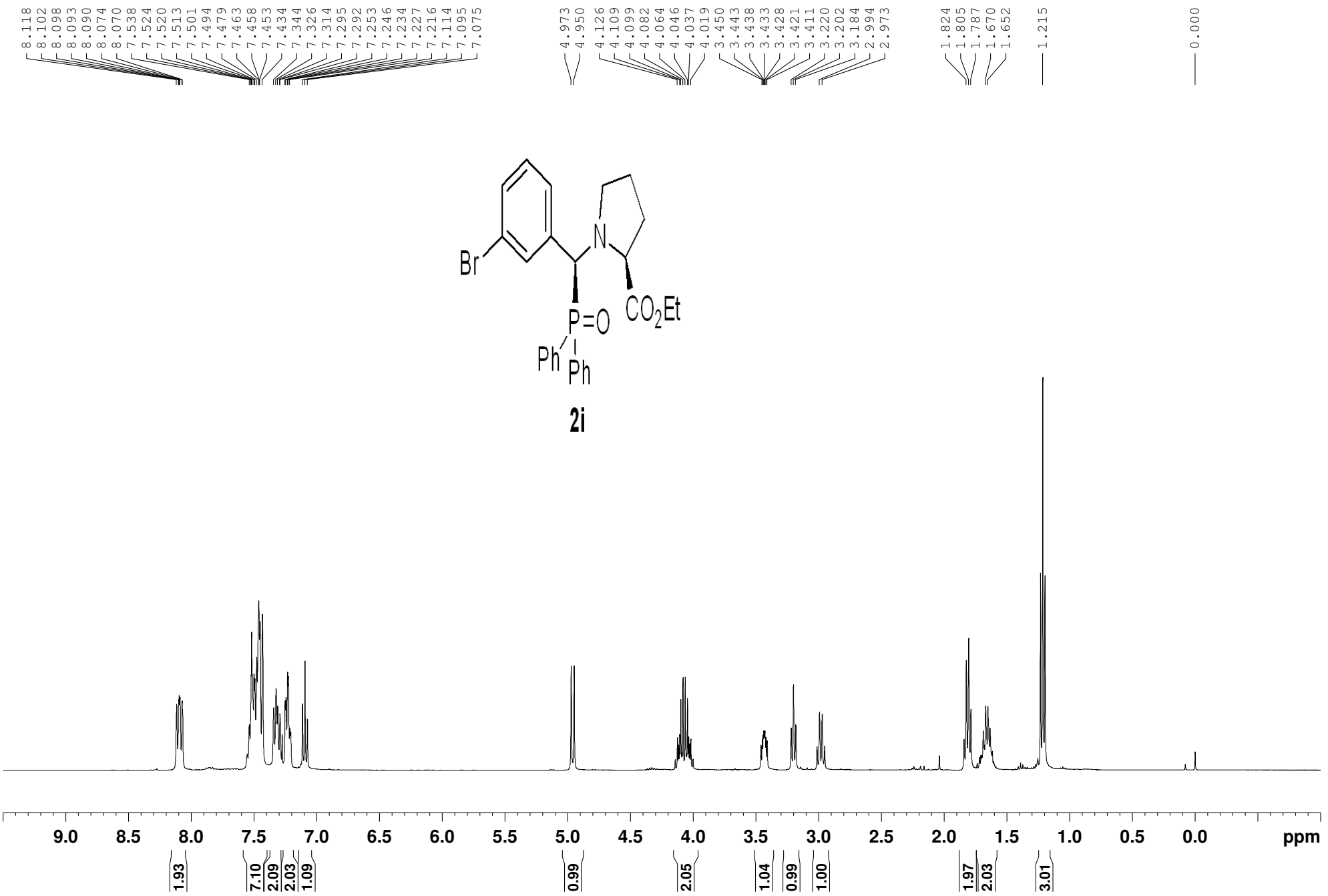

Br
P=O
Ph
Ph
N
CO2Et

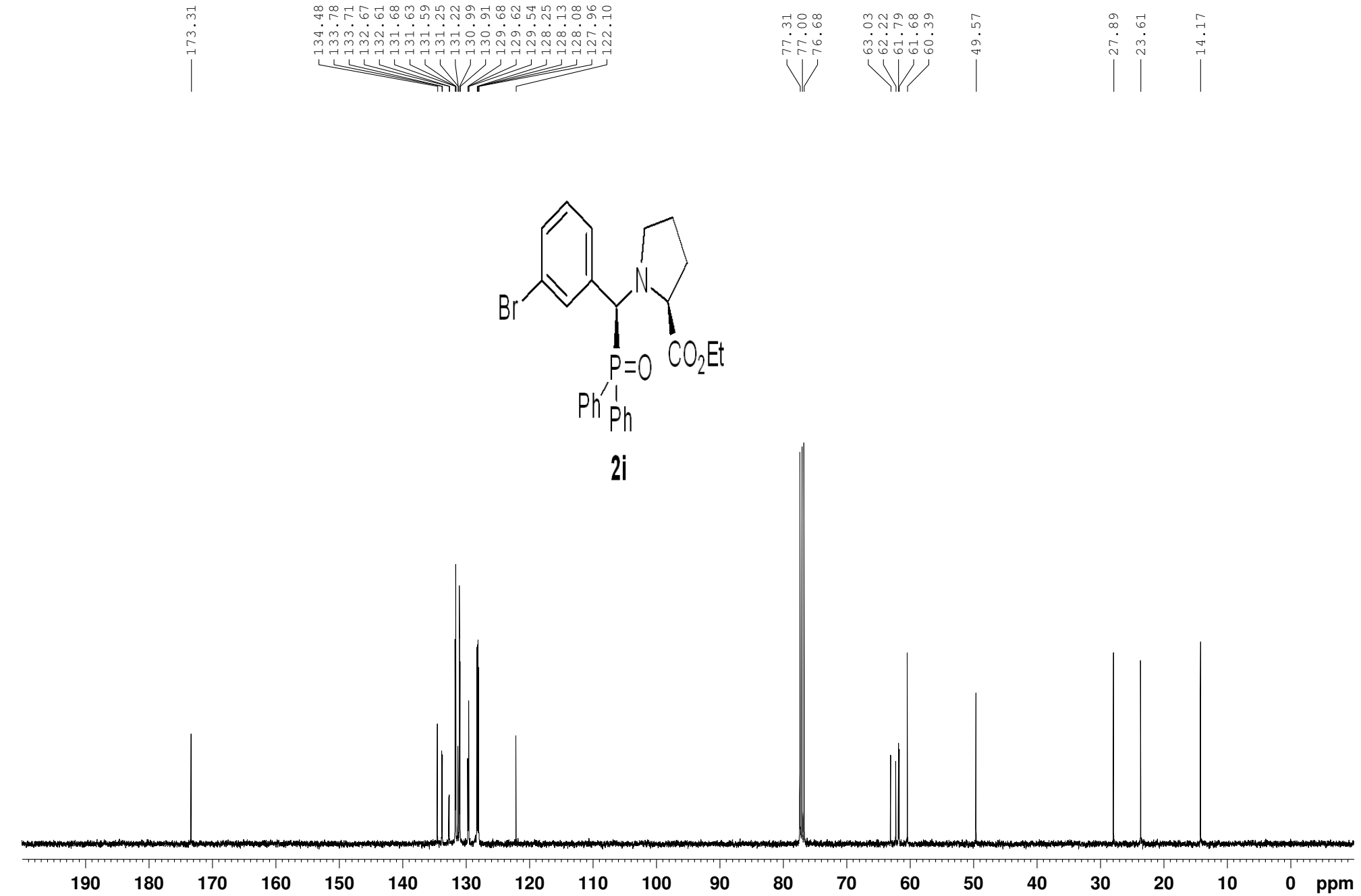
2h


180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

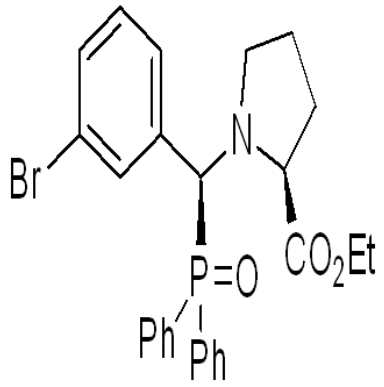


2h

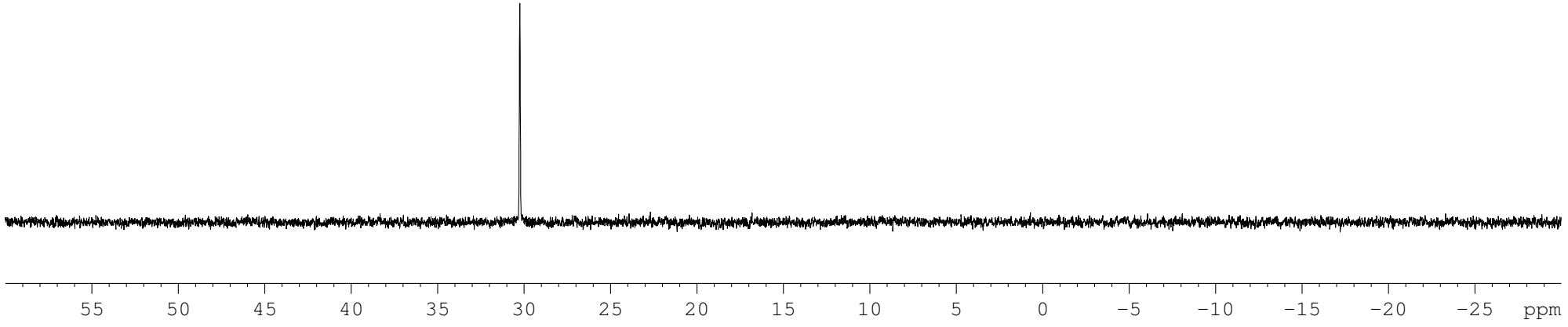

8.118
8.102
8.098
8.093
8.090
8.074
8.070
7.538
7.524
7.520
7.513
7.501
7.494
7.479
7.463
7.458
7.453
7.434
7.344
7.326
7.314
7.295
7.292
7.253
7.246
7.234
7.227
7.216
7.114
7.095
7.075
4.973
4.950
4.126
4.109
4.099
4.082
4.064
4.046
4.037
4.019
3.450
3.443
3.438
3.433
3.428
3.421
3.411
3.220
3.202
3.184
2.994
2.973
1.824
1.805
1.787
1.670
1.652
1.215
0.000
Br
N
P=O
Ph
Ph
CO2Et
2i
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.93
7.10
2.09
2.03
1.09
0.99
2.05
1.04
0.99
1.00
1.97
2.03
3.01

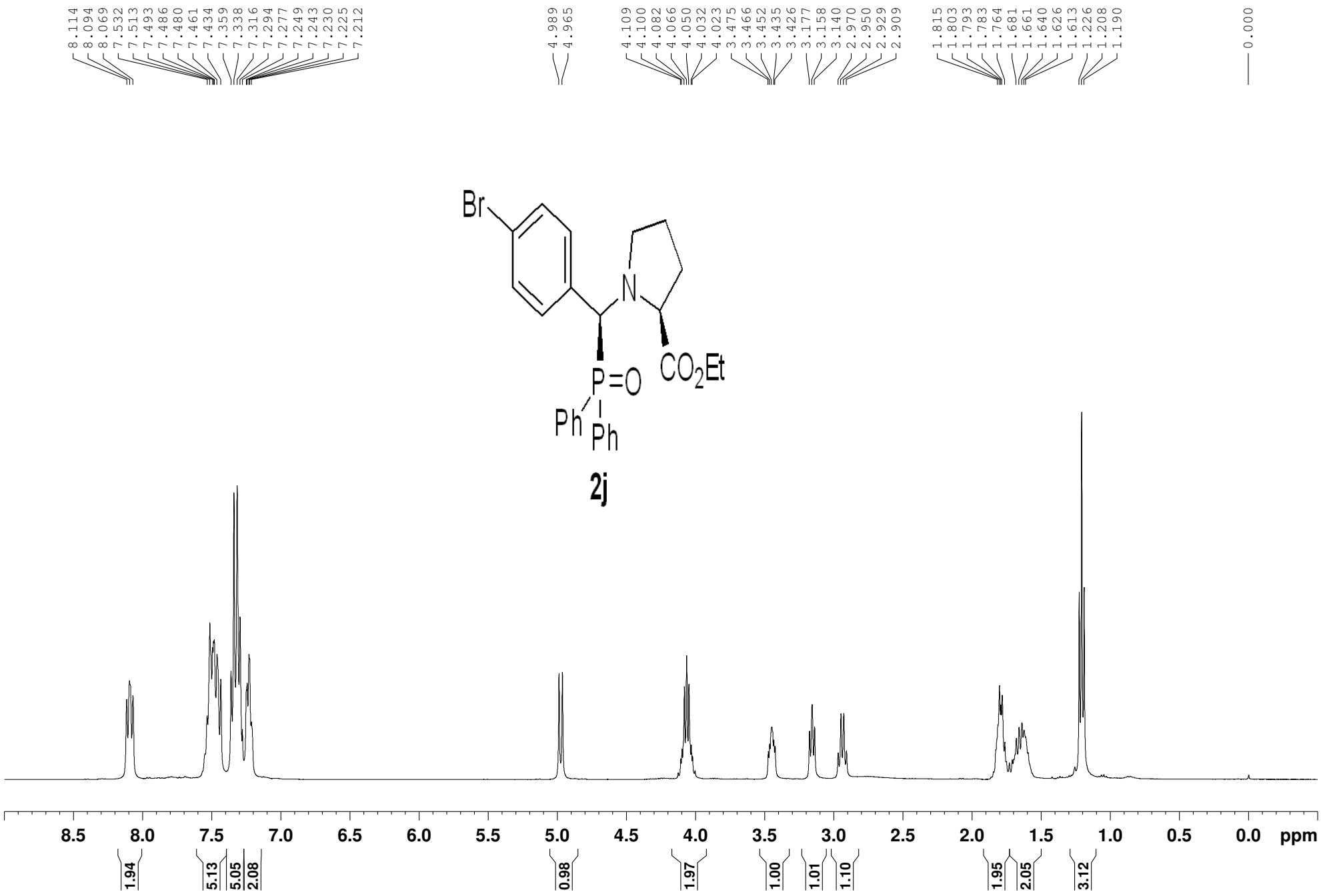

173.31
134.48
133.78
133.71
132.67
132.61
131.68
131.63
131.59
131.25
131.22
130.99
130.91
129.68
129.62
129.54
128.25
128.13
128.08
127.96
122.10
77.31
77.00
76.68
63.03
62.22
61.79
61.68
60.39
49.57
27.89
23.61
14.17
Br
N
P=O
CO2Et
Ph
Ph
2i
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

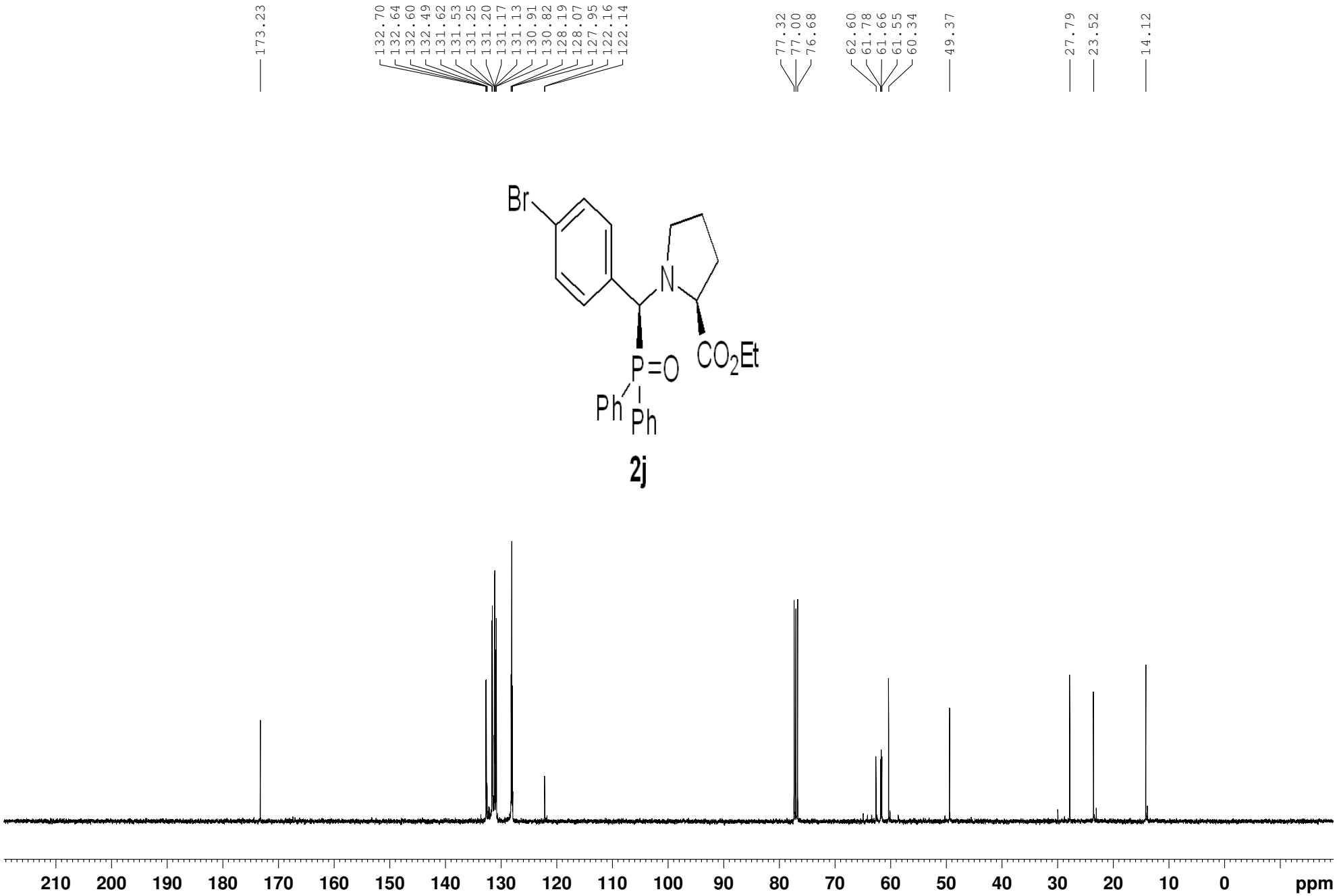
30.25

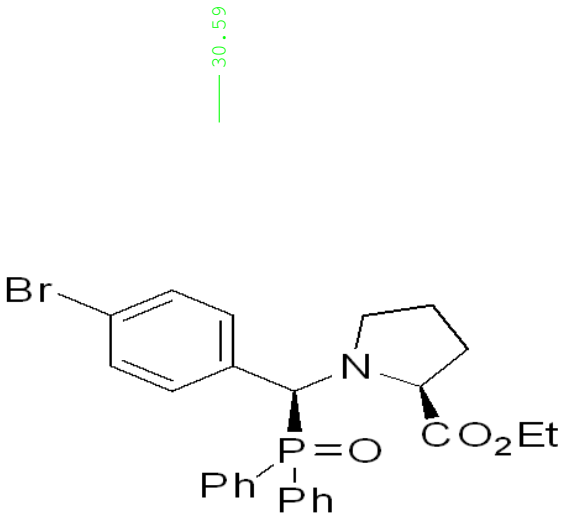


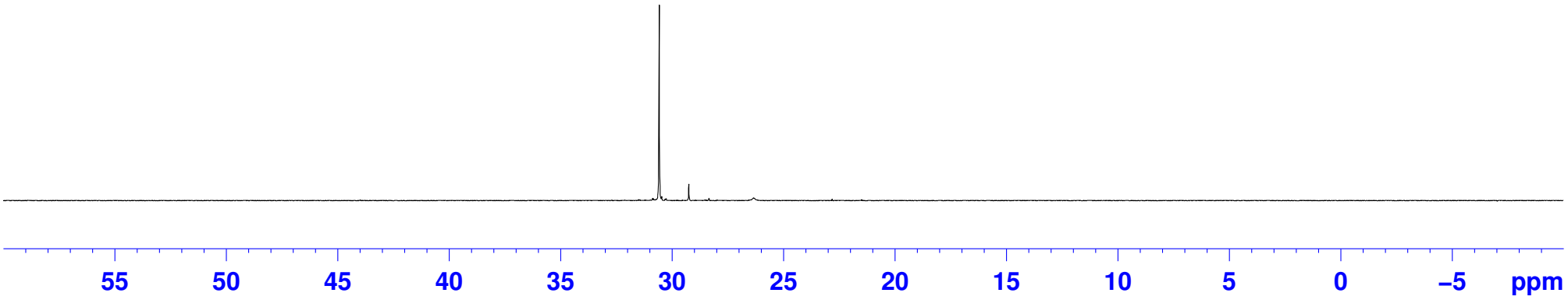
2i

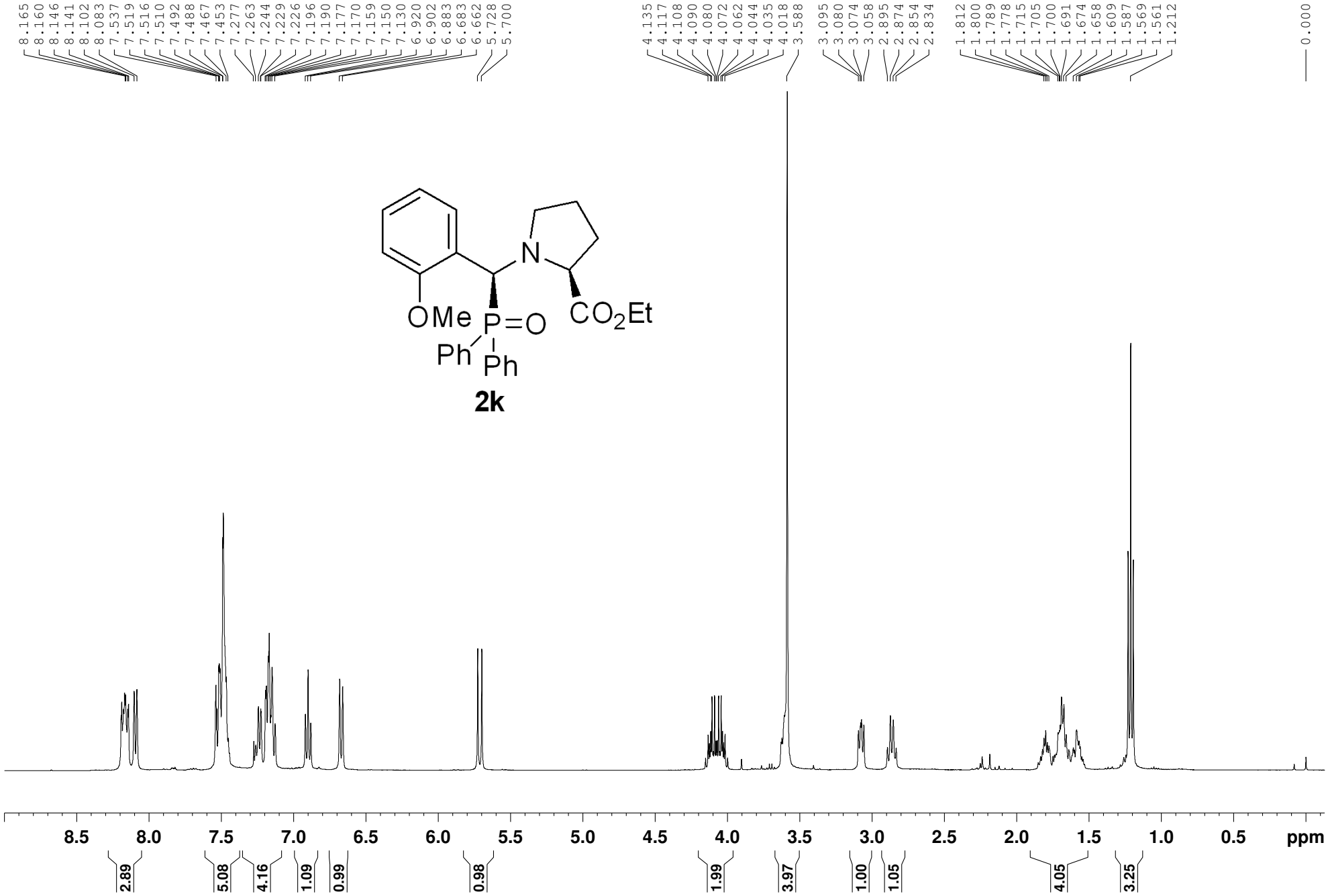


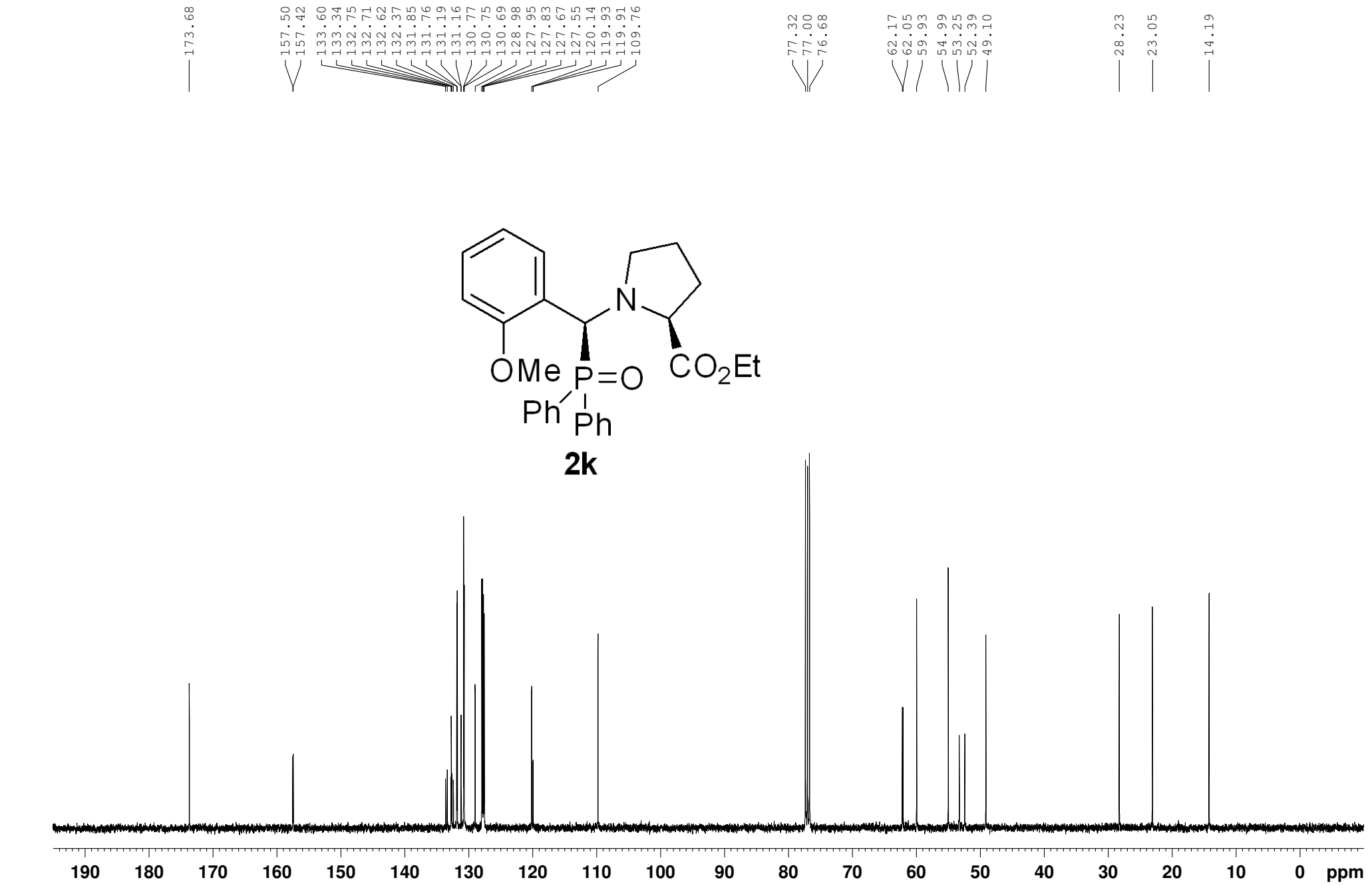

8.114
8.094
8.069
7.532
7.513
7.493
7.486
7.480
7.461
7.434
7.359
7.338
7.316
7.294
7.277
7.249
7.243
7.230
7.225
7.212
4.989
4.965
4.109
4.100
4.082
4.066
4.050
4.032
4.023
3.475
3.466
3.452
3.435
3.426
3.177
3.158
3.140
2.970
2.950
2.929
2.909
1.815
1.803
1.793
1.783
1.764
1.681
1.661
1.640
1.626
1.613
1.226
1.208
1.190
0.000
Br
N
CO2Et
P=O
Ph
Ph
2j
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.94
5.13
5.05
2.08
0.98
1.97
1.00
1.01
1.10
1.95
2.05
3.12

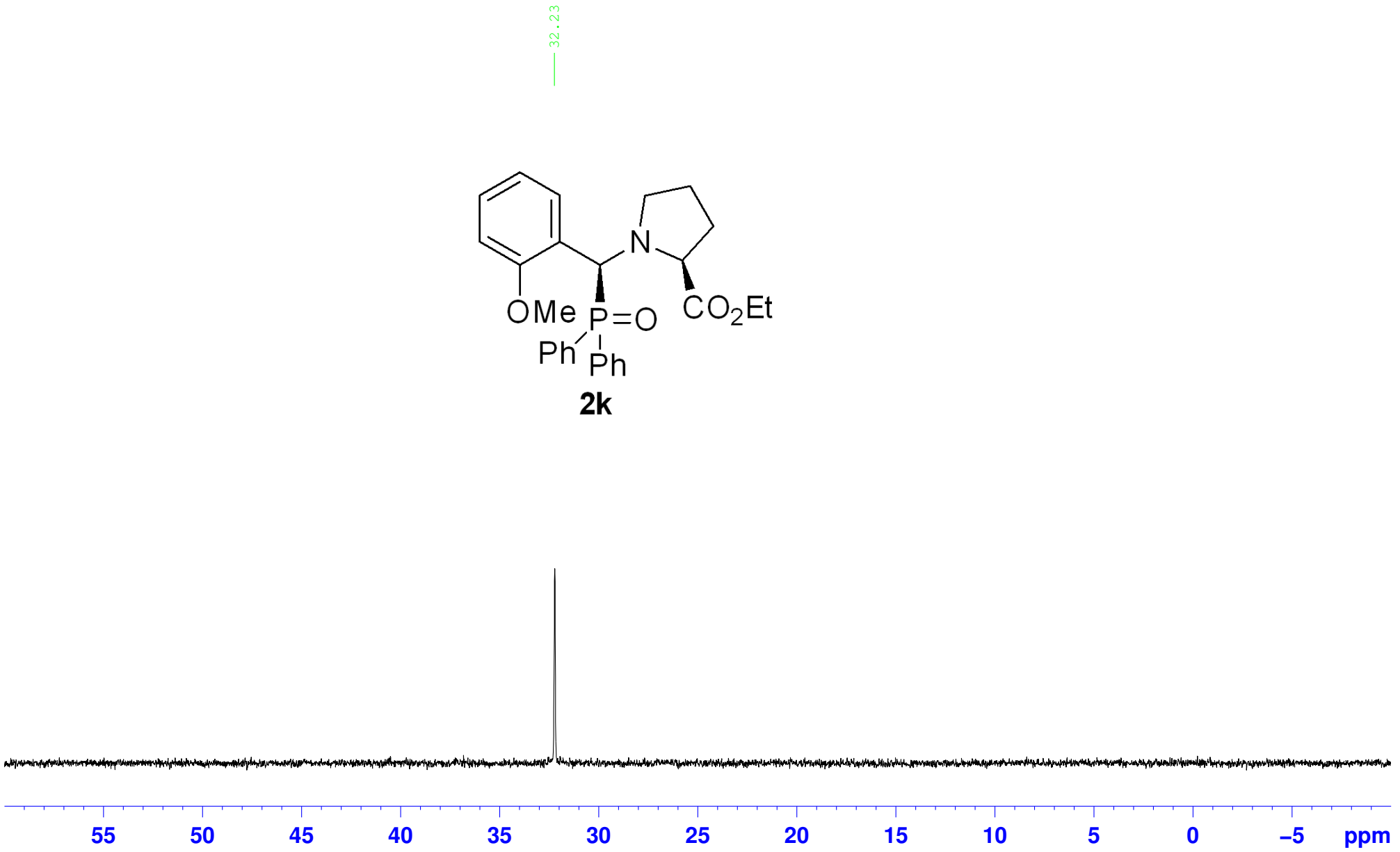

173.23
132.70
132.64
132.60
132.49
131.62
131.53
131.25
131.20
131.17
131.13
130.91
130.82
128.19
128.07
127.95
122.16
122.14
77.32
77.00
76.68
62.60
61.78
61.66
61.55
60.34
49.37
27.79
23.52
14.12
Br
N
P=O
Ph
Ph
CO2Et
2j
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


30.59
Br
N
CO2Et
P=O
Ph
Ph
2j

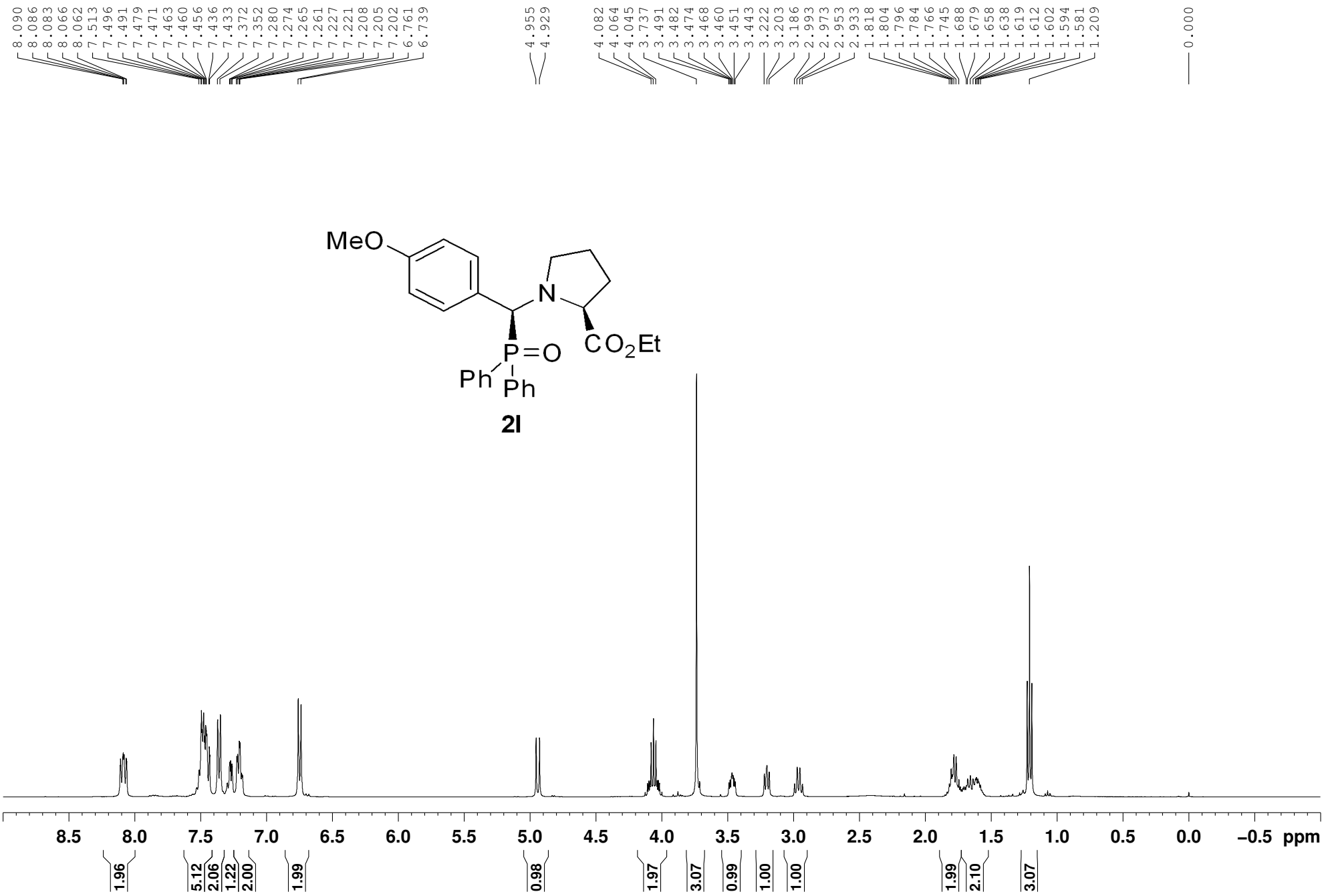

55
50
45
40
35
30
25
20
15
10
5
0
–5
ppm

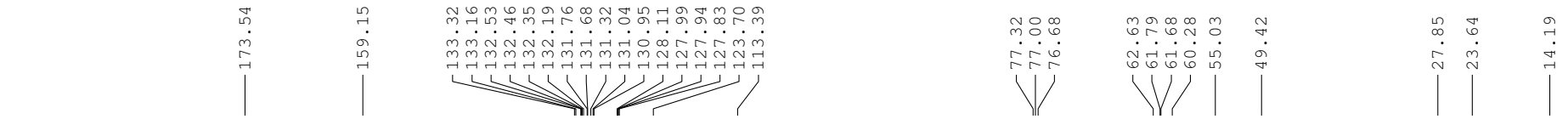

8.165
8.160
8.146
8.141
8.102
8.083
7.537
7.519
7.516
7.510
7.492
7.488
7.467
7.453
7.277
7.263
7.244
7.229
7.226
7.196
7.190
7.177
7.170
7.159
7.150
7.130
6.920
6.902
6.883
6.683
6.662
5.728
5.700
4.135
4.117
4.108
4.090
4.080
4.072
4.062
4.044
4.035
4.018
3.588
3.095
3.080
3.074
3.058
2.895
2.874
2.854
2.834
1.812
1.800
1.789
1.778
1.715
1.705
1.700
1.691
1.674
1.658
1.609
1.587
1.569
1.561
1.212
0.000
OMe
P=O
CO2Et
Ph
Ph
N
2k
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
2.89
5.08
4.16
1.09
0.99
0.98
1.99
3.97
1.00
1.05
4.05
3.25

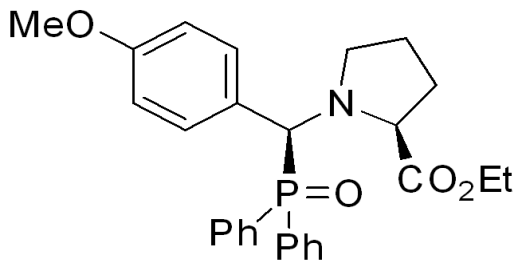

173.68
157.50
157.42
133.60
133.34
132.75
132.71
132.62
132.37
131.85
131.76
131.19
131.16
130.77
130.75
130.69
128.98
127.95
127.83
127.67
127.55
120.14
119.93
119.91
109.76
77.32
77.00
76.68
62.17
62.05
59.93
54.99
53.25
52.39
49.10
28.23
23.05
14.19
OMe
P=O
Ph
Ph
N
CO2Et
2k
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



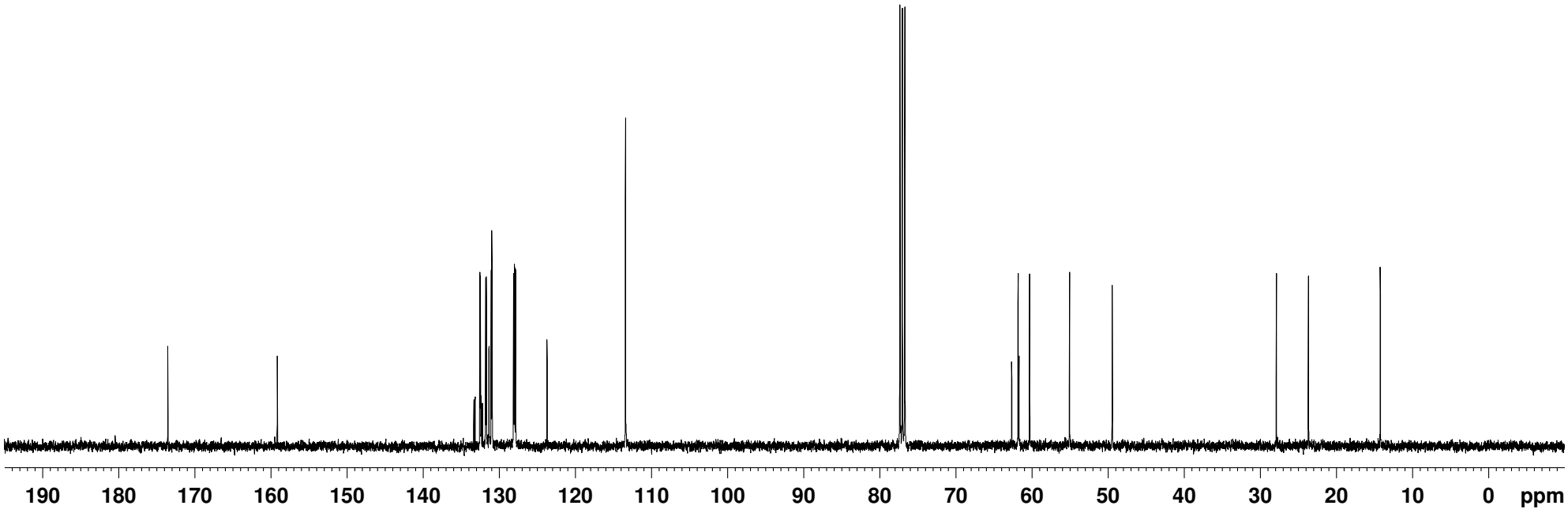
2k

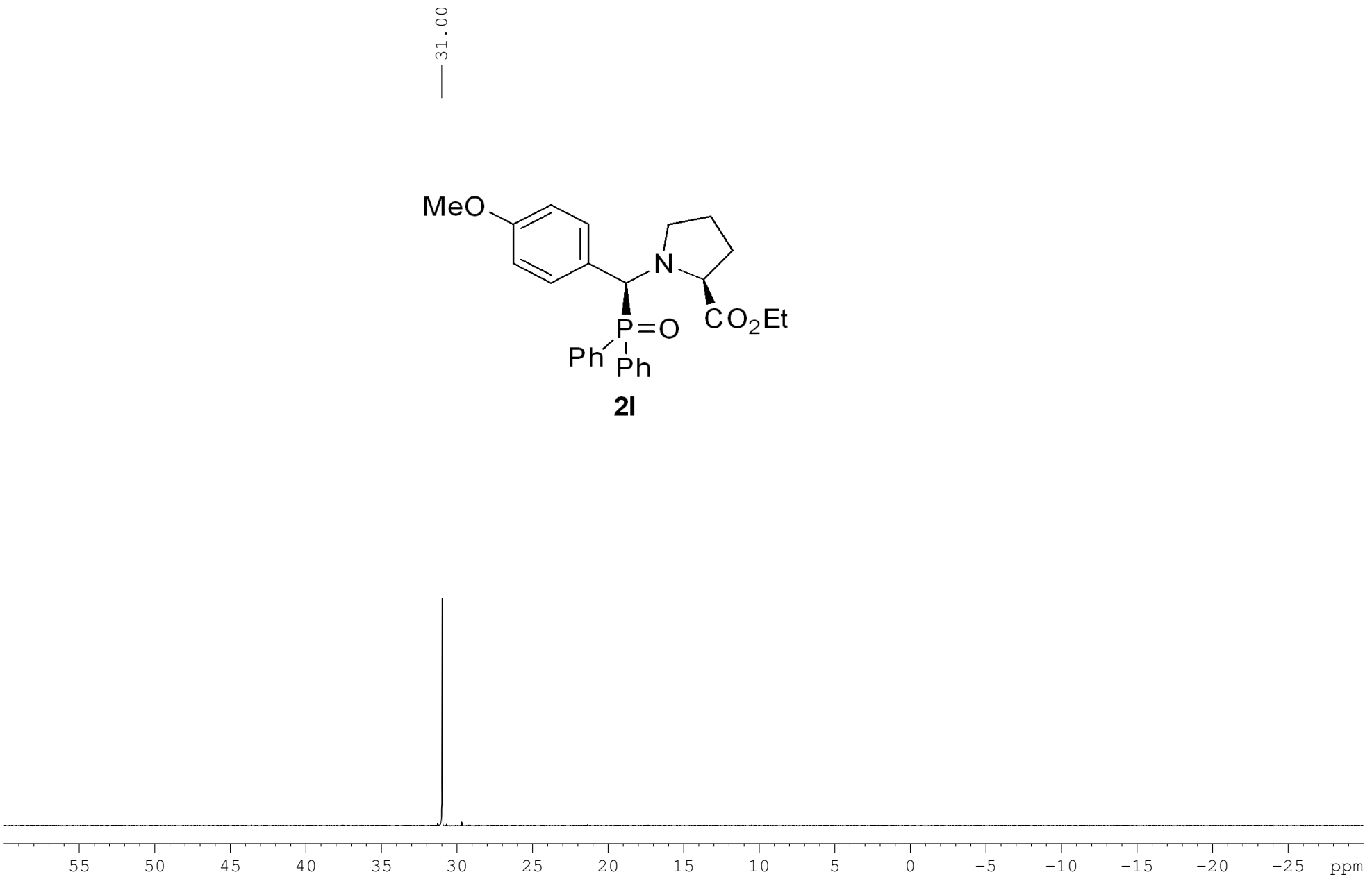

8.090
8.086
8.083
8.066
8.062
7.513
7.496
7.491
7.479
7.471
7.463
7.460
7.456
7.436
7.433
7.372
7.352
7.280
7.274
7.265
7.261
7.227
7.221
7.208
7.205
7.202
6.761
6.739
4.955
4.929
4.082
4.064
4.045
3.737
3.491
3.482
3.474
3.468
3.460
3.451
3.443
3.222
3.203
3.186
2.993
2.973
2.953
2.933
1.818
1.804
1.796
1.784
1.766
1.745
1.688
1.679
1.658
1.638
1.619
1.612
1.602
1.594
1.581
1.209
0.000
MeO
N
P=O
CO2Et
Ph
Ph
2l
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
1.96
5.12
2.06
1.22
2.00
1.99
0.98
1.97
3.07
0.99
1.00
1.00
1.99
2.10
3.07


173.54
159.15
133.32
133.16
132.53
132.46
132.35
132.19
131.76
131.68
131.32
131.04
130.95
128.11
127.99
127.94
127.83
123.70
113.39
77.32
77.00
76.68
62.63
61.79
61.68
60.28
55.03
49.42
27.85
23.64
14.19

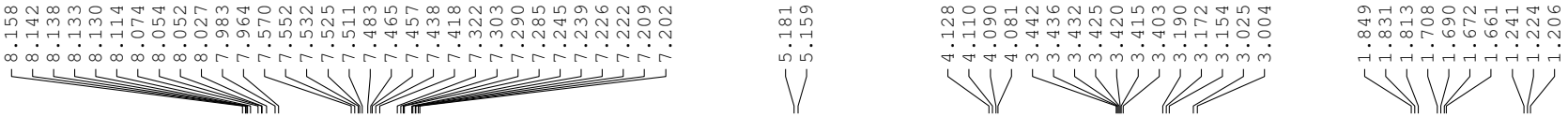

MeO
N
CO2Et
P=O
Ph
Ph

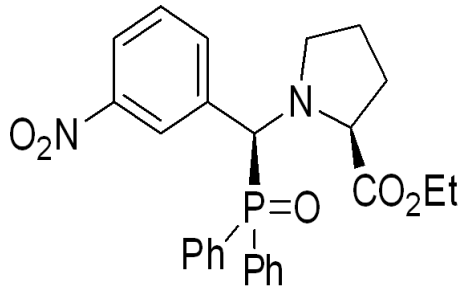
2l


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

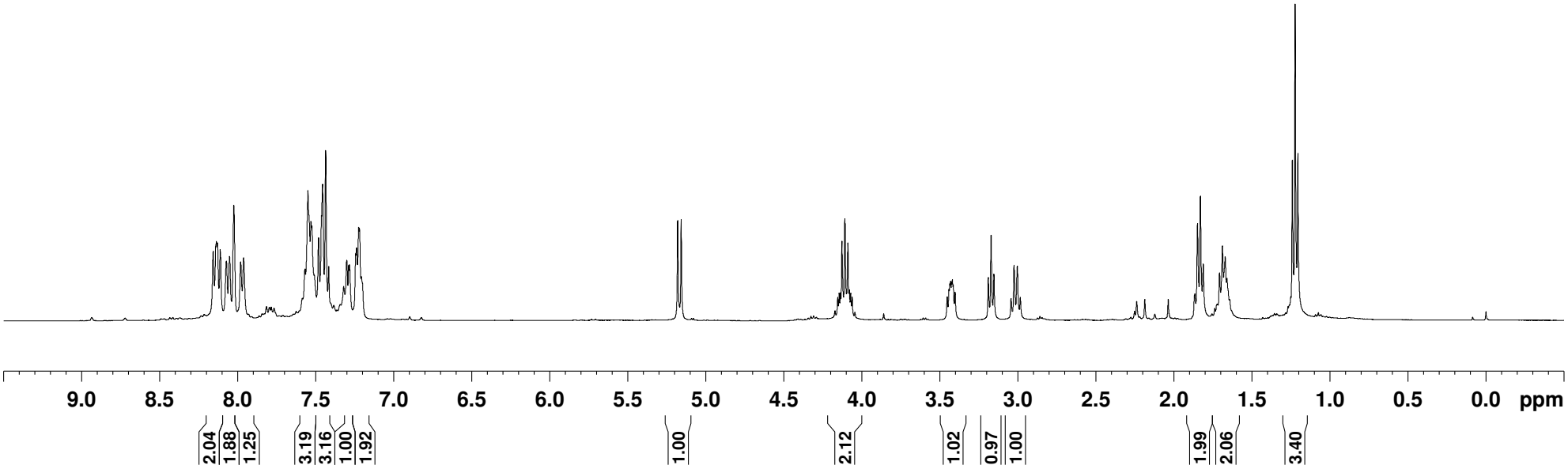

31.00
MeO
N
CO2Et
P=O
Ph
Ph
55
50
45
40
35
30
25
20
15
10
5
0
−5
−10
−15
−20
−25
ppm

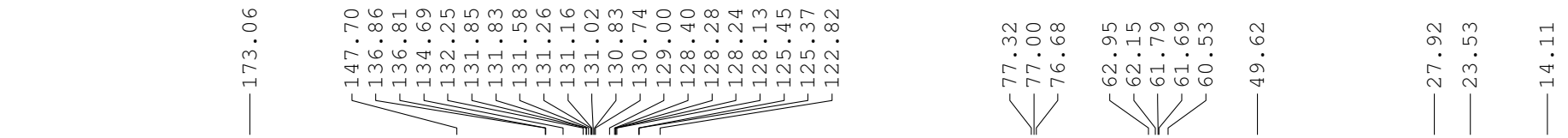
2l

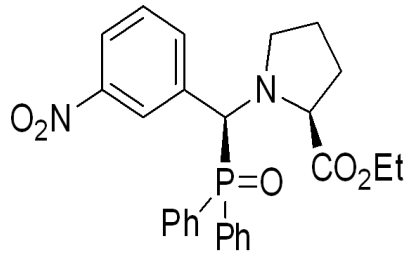

8.158
8.142
8.138
8.133
8.130
8.114
8.074
8.054
8.052
8.027
7.983
7.964
7.570
7.552
7.532
7.525
7.511
7.483
7.465
7.457
7.438
7.418
7.322
7.303
7.290
7.285
7.245
7.239
7.226
7.222
7.209
7.202
5.181
5.159
4.128
4.110
4.090
4.081
3.442
3.436
3.432
3.425
3.420
3.415
3.403
3.190
3.172
3.154
3.025
3.004
1.849
1.831
1.813
1.708
1.690
1.672
1.661
1.241
1.224
1.206


O2N
N
P=O
CO2Et
Ph
Ph

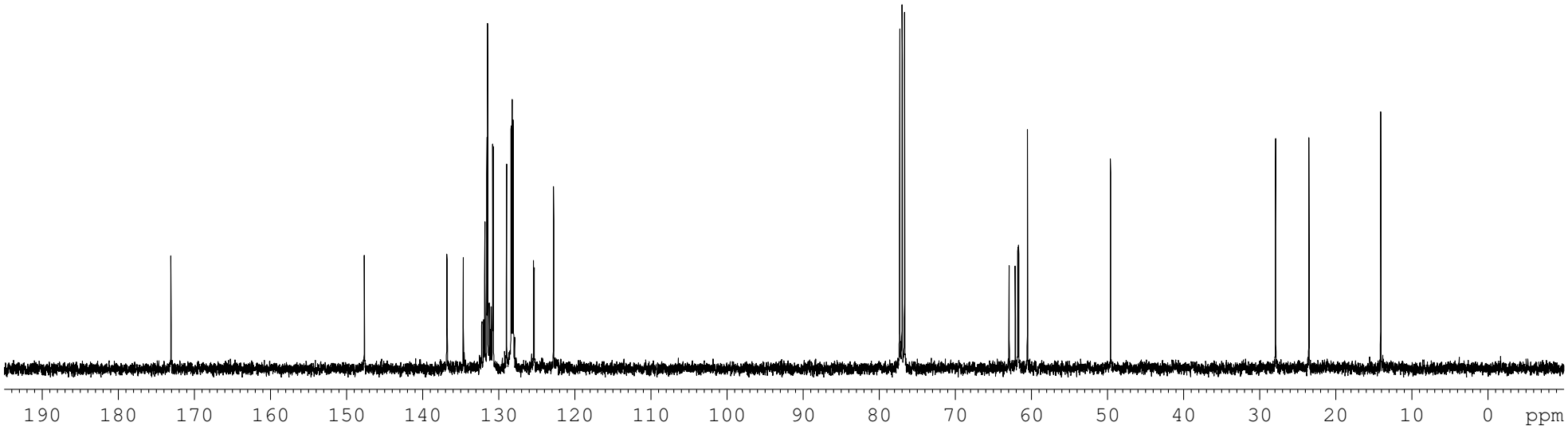
2n


9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.04
1.88
1.25
3.19
3.16
1.00
1.92
1.00
2.12
1.02
0.97
1.00
1.99
2.06
3.40

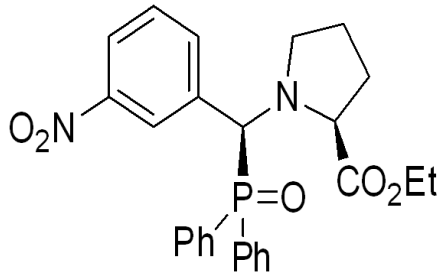

173.06
147.70
136.86
136.81
134.69
132.25
131.85
131.83
131.58
131.26
131.16
131.02
130.83
130.74
129.00
128.40
128.28
128.24
128.13
125.45
125.37
122.82
77.32
77.00
76.68
62.95
62.15
61.79
61.69
60.53
49.62
27.92
23.53
14.11


O2N
N
CO2Et
P=O
Ph
Ph

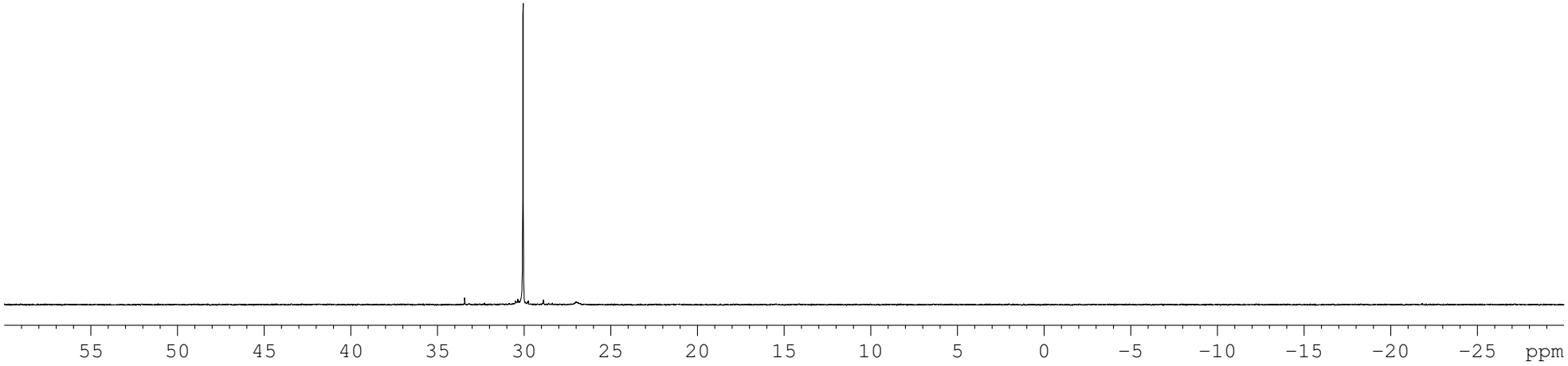
2n

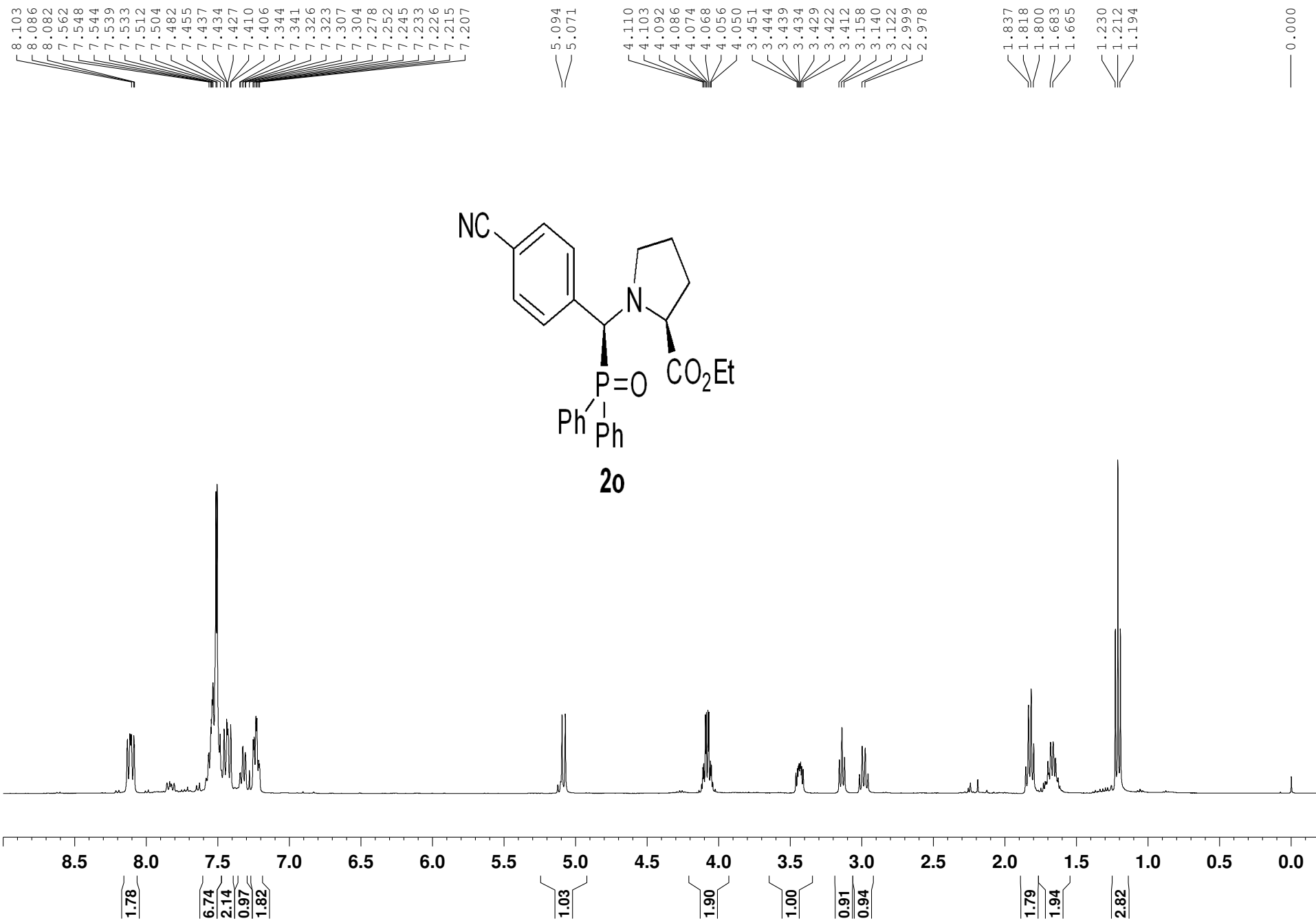

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

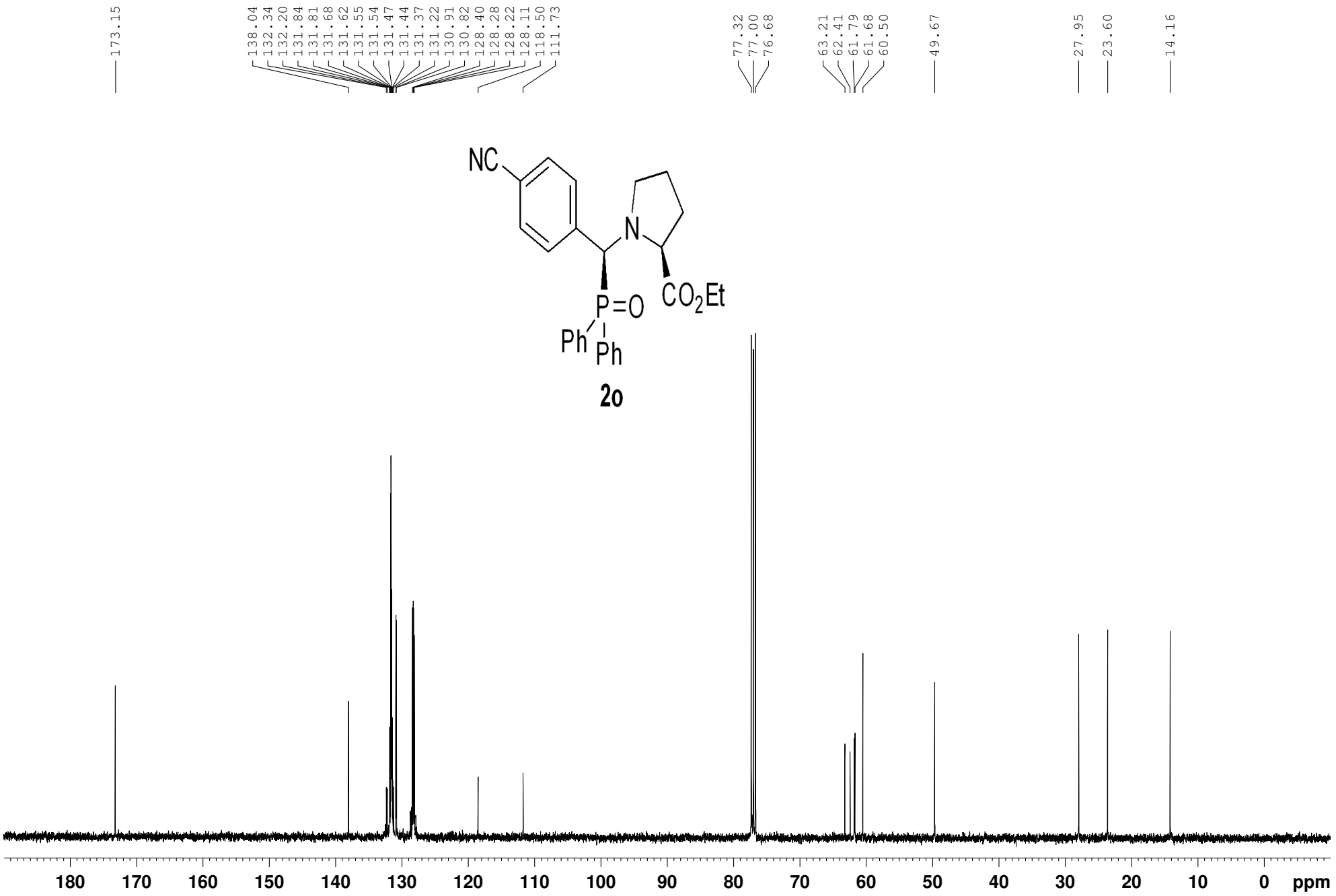
30.07

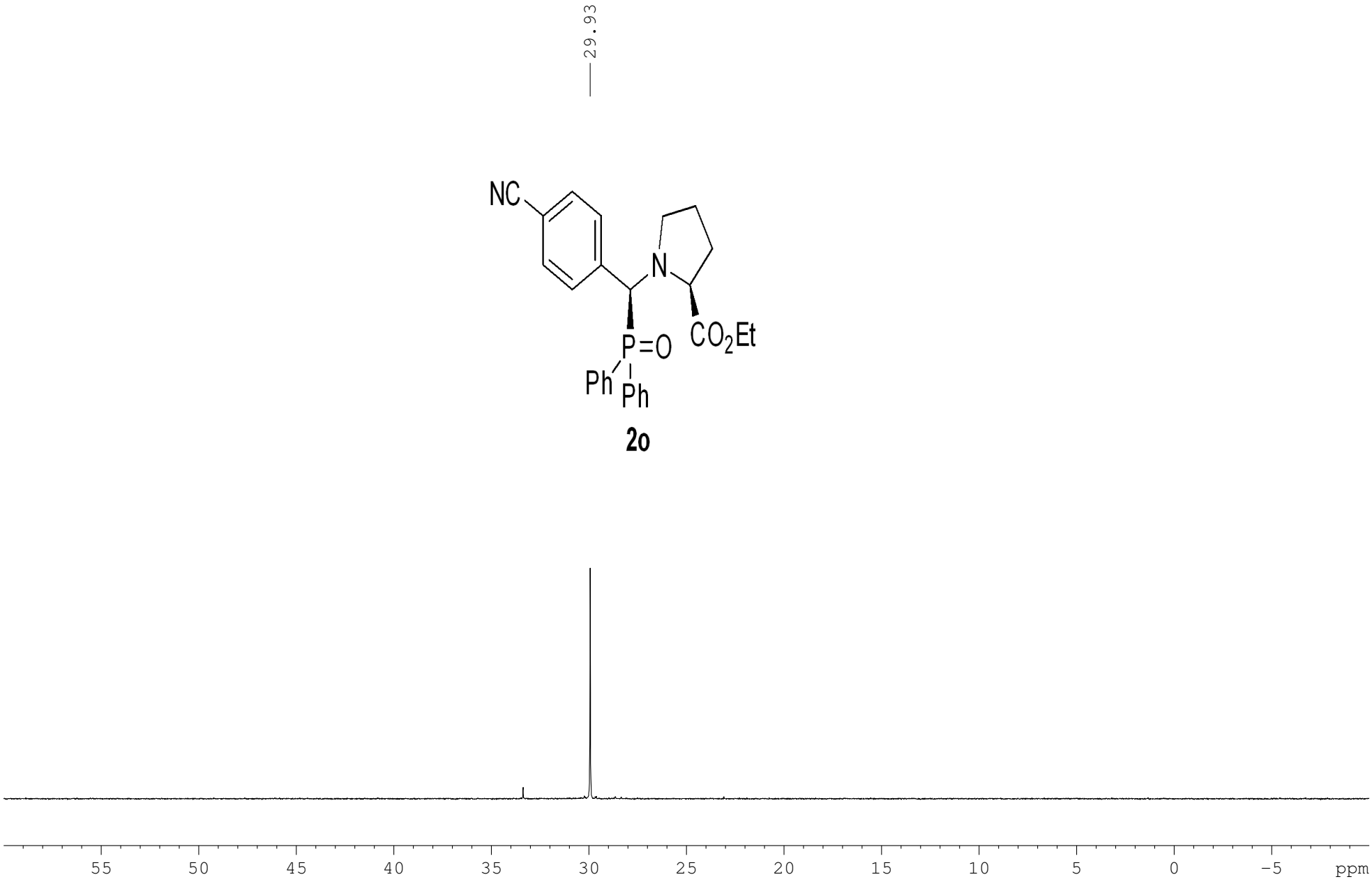


2n

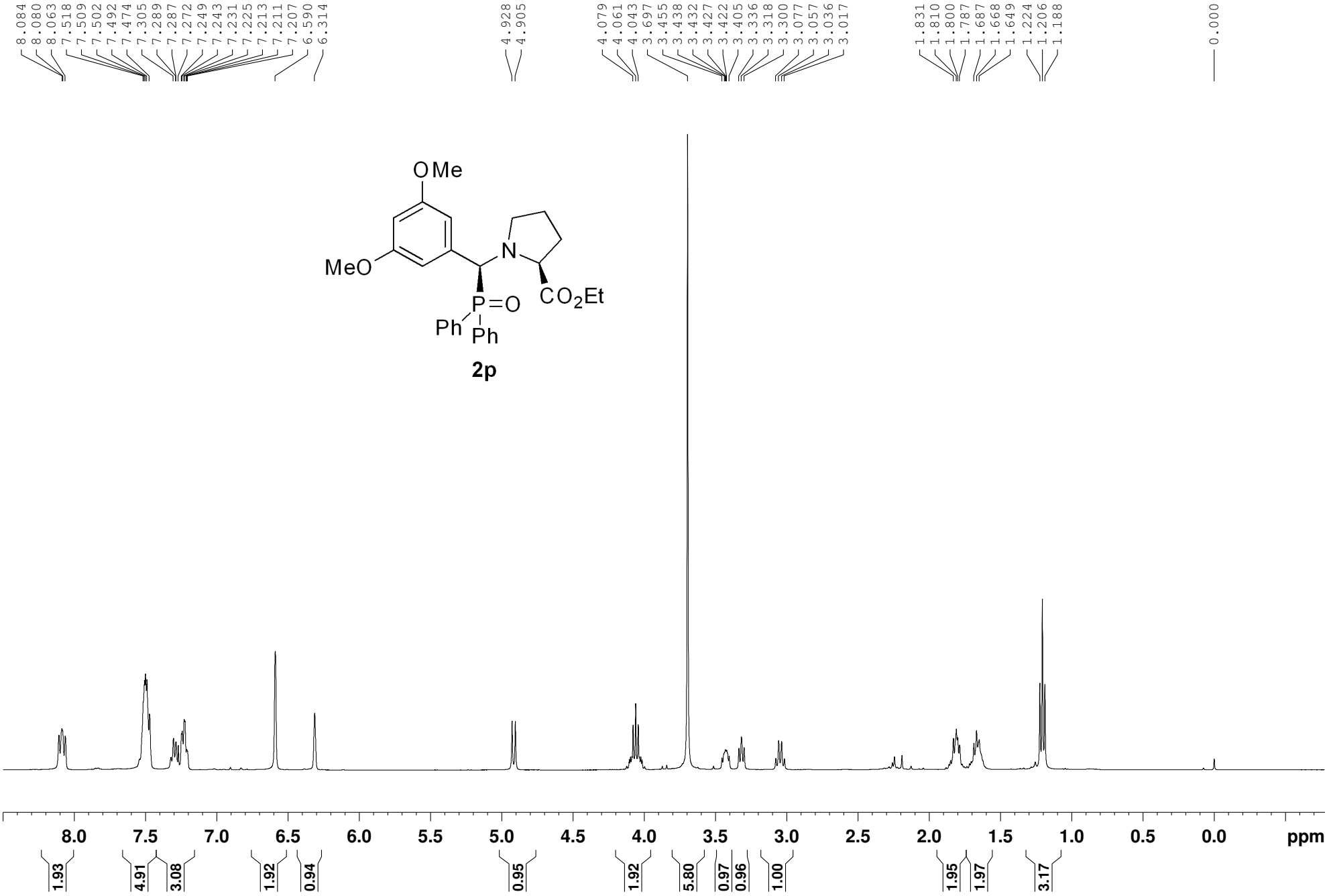


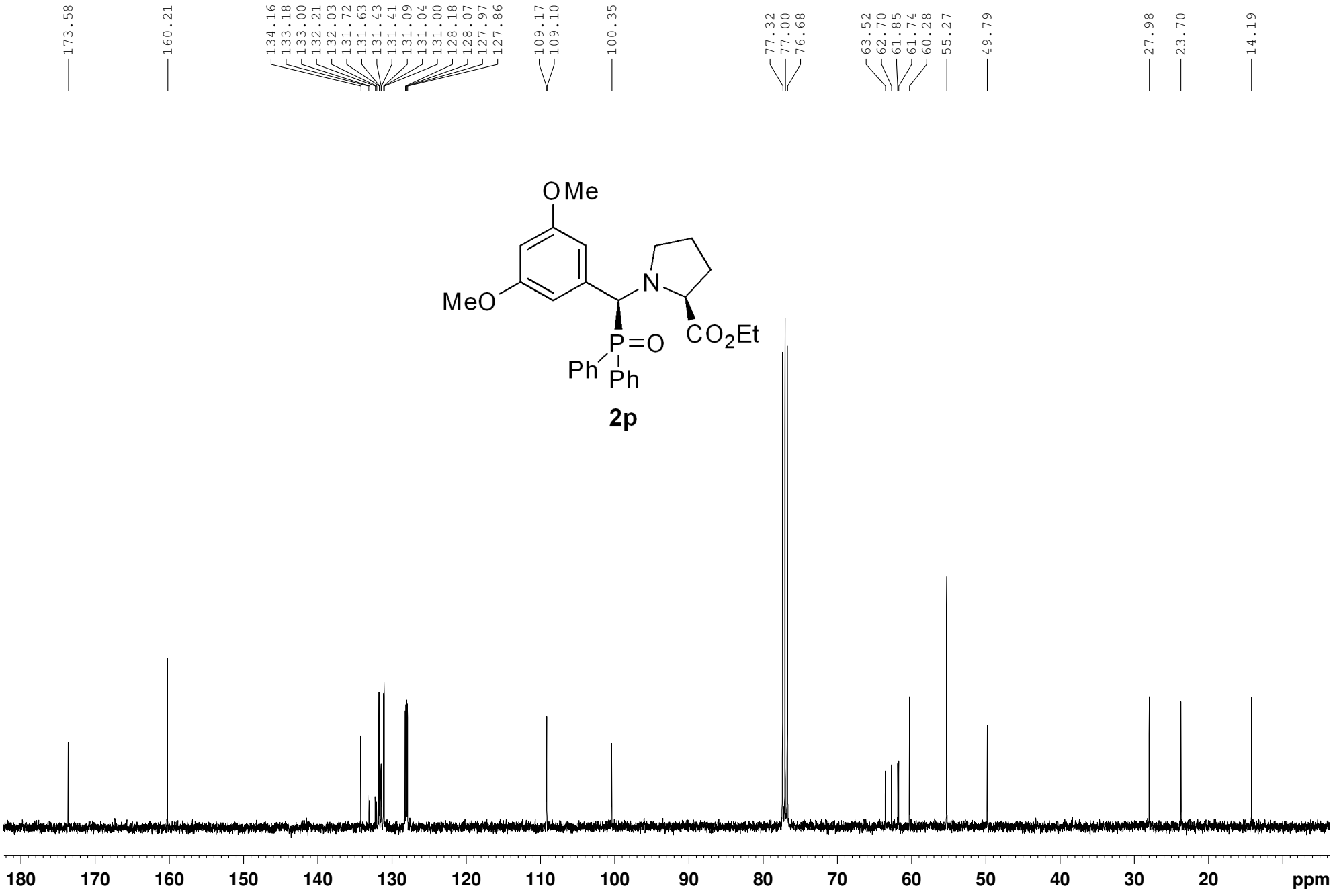

8.103
8.086
8.082
7.562
7.548
7.544
7.539
7.533
7.512
7.504
7.482
7.455
7.437
7.434
7.427
7.410
7.406
7.344
7.341
7.326
7.323
7.307
7.304
7.278
7.252
7.245
7.233
7.226
7.215
7.207
5.094
5.071
4.110
4.103
4.092
4.086
4.074
4.068
4.056
4.050
3.451
3.444
3.439
3.434
3.429
3.422
3.412
3.158
3.140
3.122
2.999
2.978
1.837
1.818
1.800
1.683
1.665
1.230
1.212
1.194
0.000
NC
N
P=O
CO2Et
Ph
Ph
2o
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.78
6.74
2.14
0.97
1.82
1.03
1.90
1.00
0.91
0.94
1.79
1.94
2.82


173.15
138.04
132.34
132.20
131.84
131.81
131.68
131.62
131.55
131.54
131.47
131.44
131.37
131.22
130.91
130.82
128.40
128.28
128.22
128.11
118.50
111.73
77.32
77.00
76.68
63.21
62.41
61.79
61.68
60.50
49.67
27.95
23.60
14.16
NC
N
P=O
CO2Et
Ph
Ph
2o
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

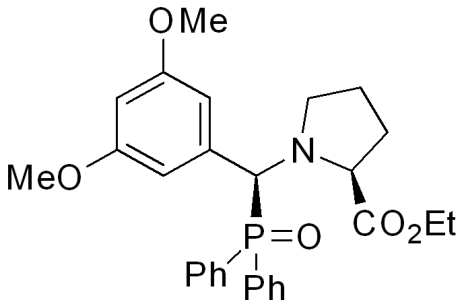


2o

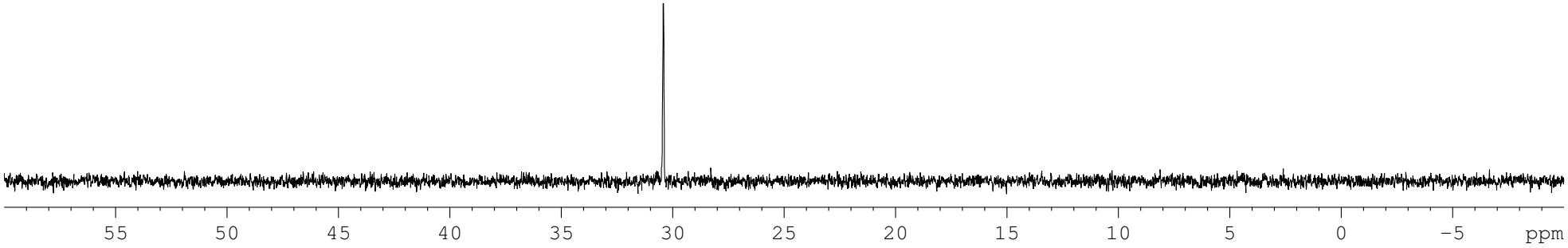

8.084
8.080
8.063
7.518
7.509
7.502
7.492
7.474
7.305
7.289
7.287
7.272
7.249
7.243
7.231
7.225
7.213
7.211
7.207
6.590
6.314
4.928
4.905
4.079
4.061
4.043
3.697
3.455
3.438
3.432
3.427
3.422
3.405
3.336
3.318
3.300
3.077
3.057
3.036
3.017
1.831
1.810
1.800
1.787
1.687
1.668
1.649
1.224
1.206
1.188
0.000
OMe
MeO
N
P=O
CO2Et
Ph
Ph
2p
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.93
4.91
3.08
1.92
0.94
0.95
1.92
5.80
0.97
0.96
1.00
1.95
1.97
3.17

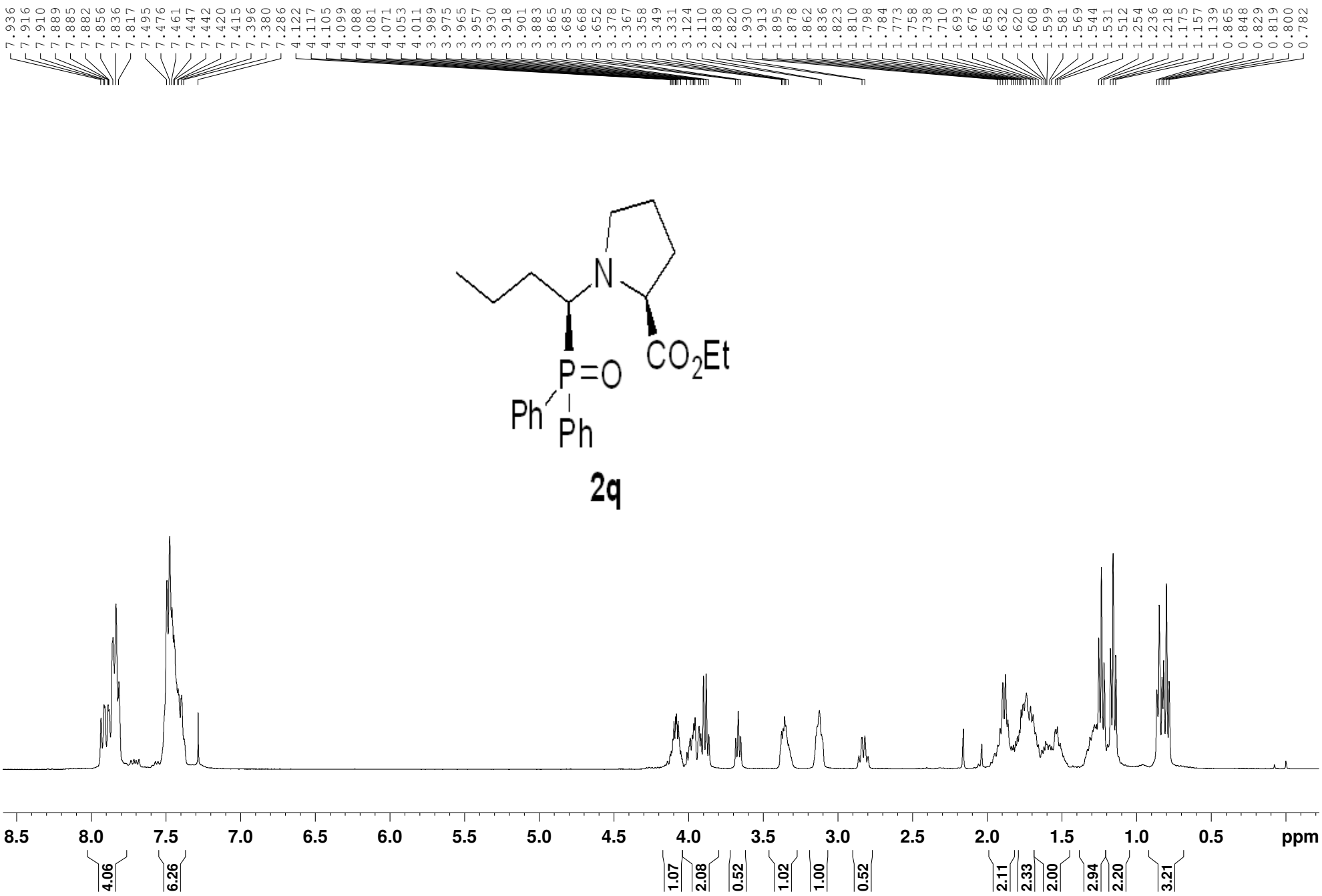

173.58
160.21
134.16
133.18
133.00
132.21
132.03
131.72
131.63
131.43
131.41
131.09
131.04
131.00
128.18
128.07
127.97
127.86
109.17
109.10
100.35
77.32
77.00
76.68
63.52
62.70
61.85
61.74
60.28
55.27
49.79
27.98
23.70
14.19
OMe
MeO
N
CO2Et
P=O
Ph
Ph
2p
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

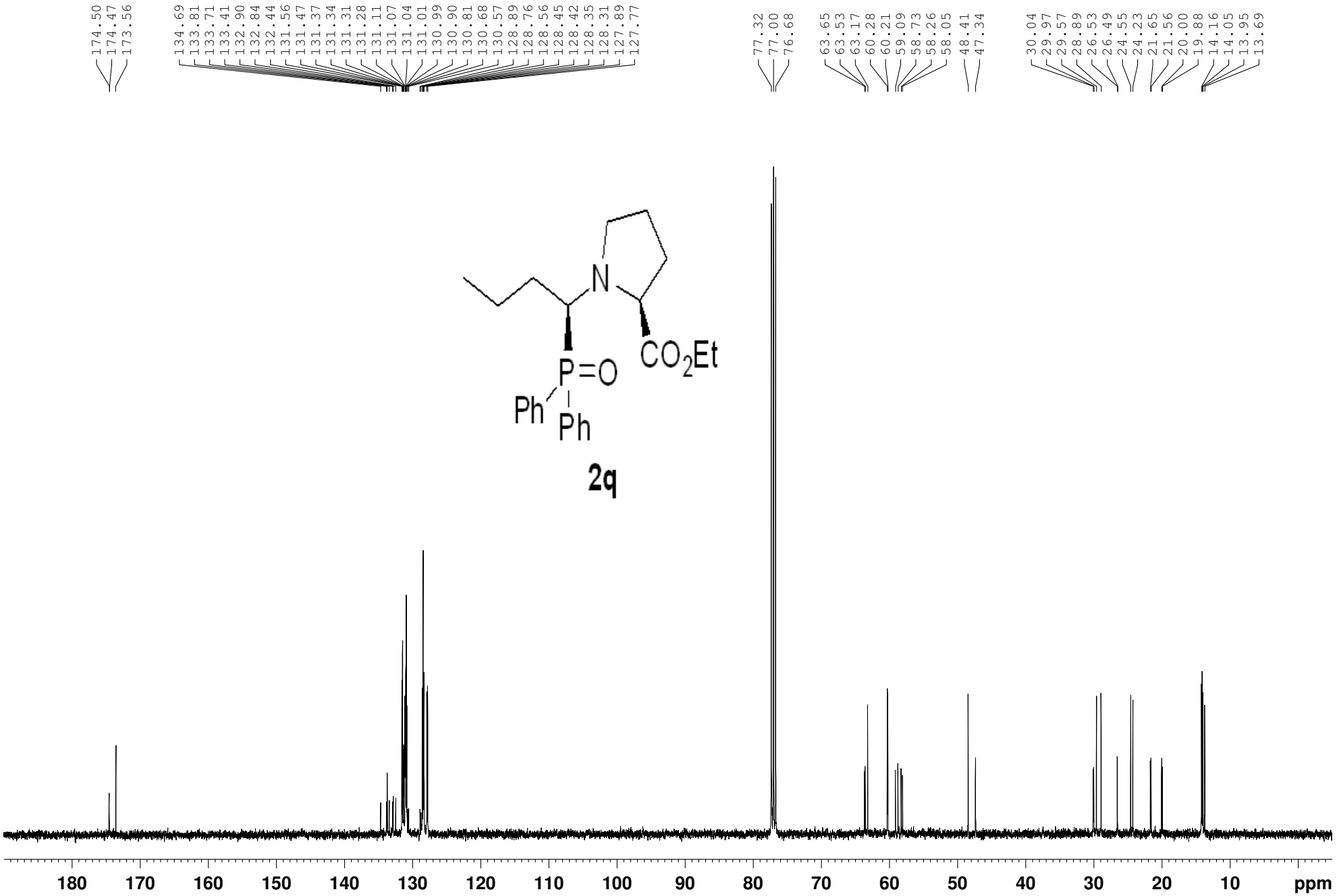
30.41

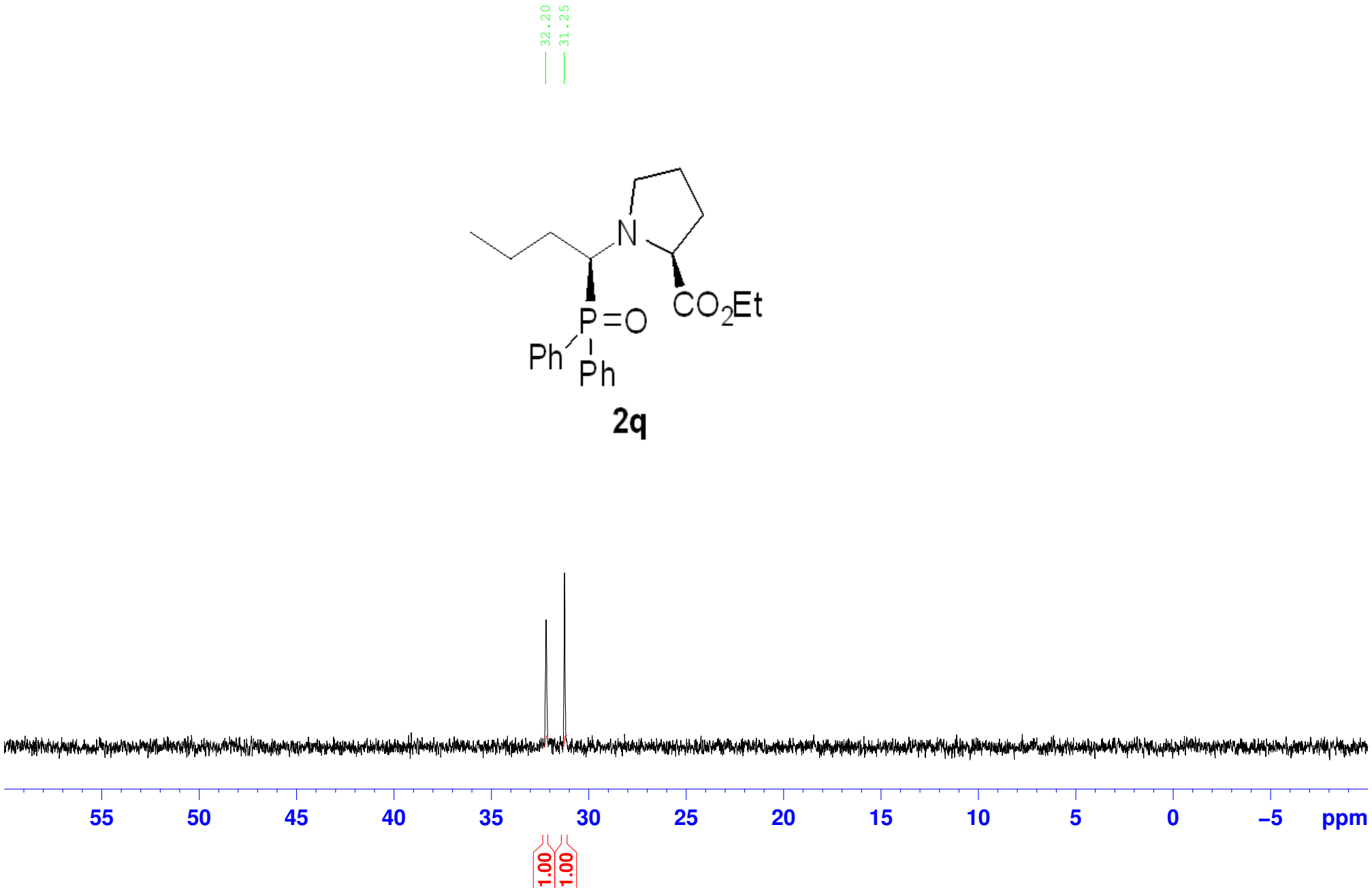


2p

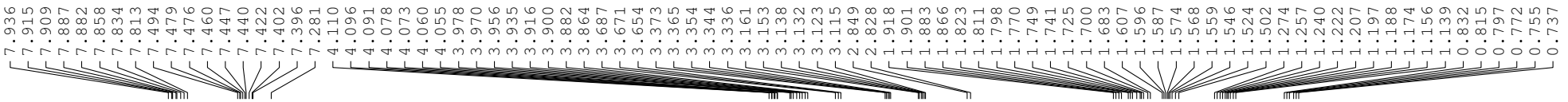


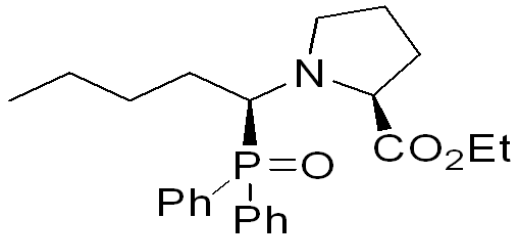

7.936
7.916
7.910
7.889
7.885
7.882
7.856
7.836
7.817
7.495
7.476
7.461
7.447
7.442
7.420
7.415
7.396
7.380
7.286
4.122
4.117
4.105
4.099
4.088
4.081
4.071
4.053
4.011
3.989
3.975
3.965
3.957
3.930
3.918
3.901
3.883
3.865
3.685
3.668
3.652
3.378
3.367
3.358
3.349
3.331
3.124
3.110
2.838
2.820
1.930
1.913
1.895
1.878
1.862
1.836
1.823
1.810
1.798
1.784
1.773
1.758
1.738
1.710
1.693
1.676
1.658
1.632
1.620
1.608
1.599
1.581
1.569
1.544
1.531
1.512
1.254
1.236
1.218
1.175
1.157
1.139
0.865
0.848
0.829
0.819
0.800
0.782
N
CO2Et
P=O
Ph
Ph
2q
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
4.06
6.26
1.07
2.08
0.52
1.02
1.00
0.52
2.11
2.33
2.00
2.94
2.20
3.21


174.50
174.47
173.56
134.69
133.81
133.71
133.41
132.90
132.84
132.44
131.56
131.47
131.37
131.34
131.31
131.28
131.11
131.07
131.04
131.01
130.99
130.90
130.81
130.68
130.57
128.89
128.76
128.56
128.45
128.42
128.35
128.31
127.89
127.77
77.32
77.00
76.68
63.65
63.53
63.17
60.28
60.21
59.09
58.73
58.26
58.05
48.41
47.34
30.04
29.97
29.57
28.89
26.53
26.49
24.55
24.23
21.65
21.56
20.00
19.88
14.16
14.05
13.95
13.69
N
P=O
Ph
Ph
CO2Et
2q
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

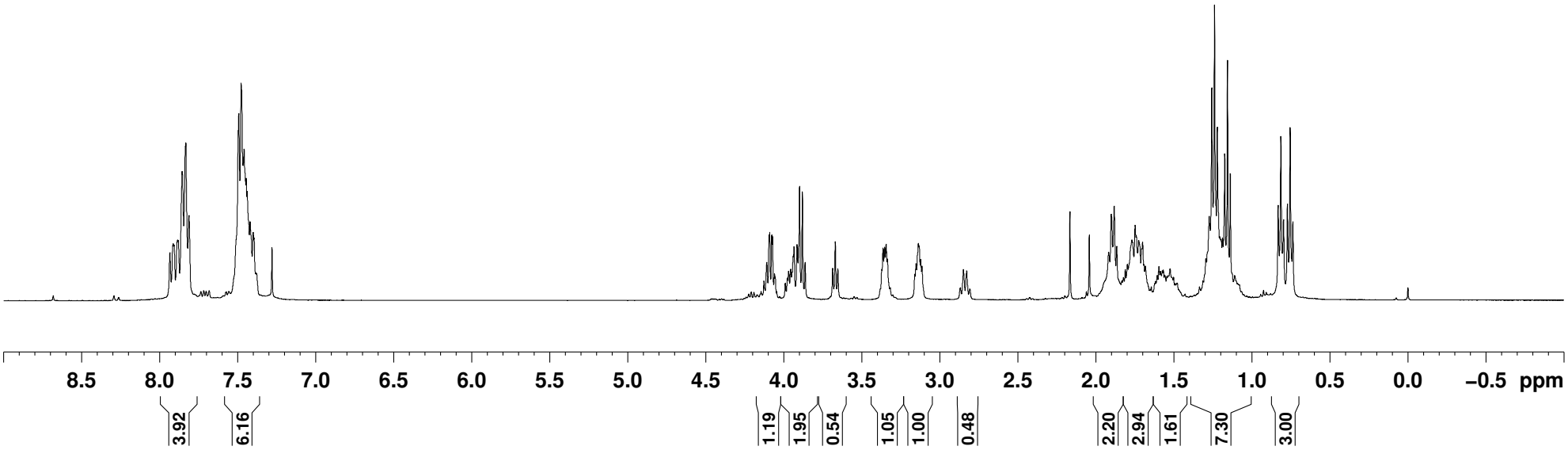

32.20
31.25
N
CO2Et
P=O
Ph
Ph
55
50
45
40
35
30
25
20
15
10
5
0
–5
ppm
1.00
1.00

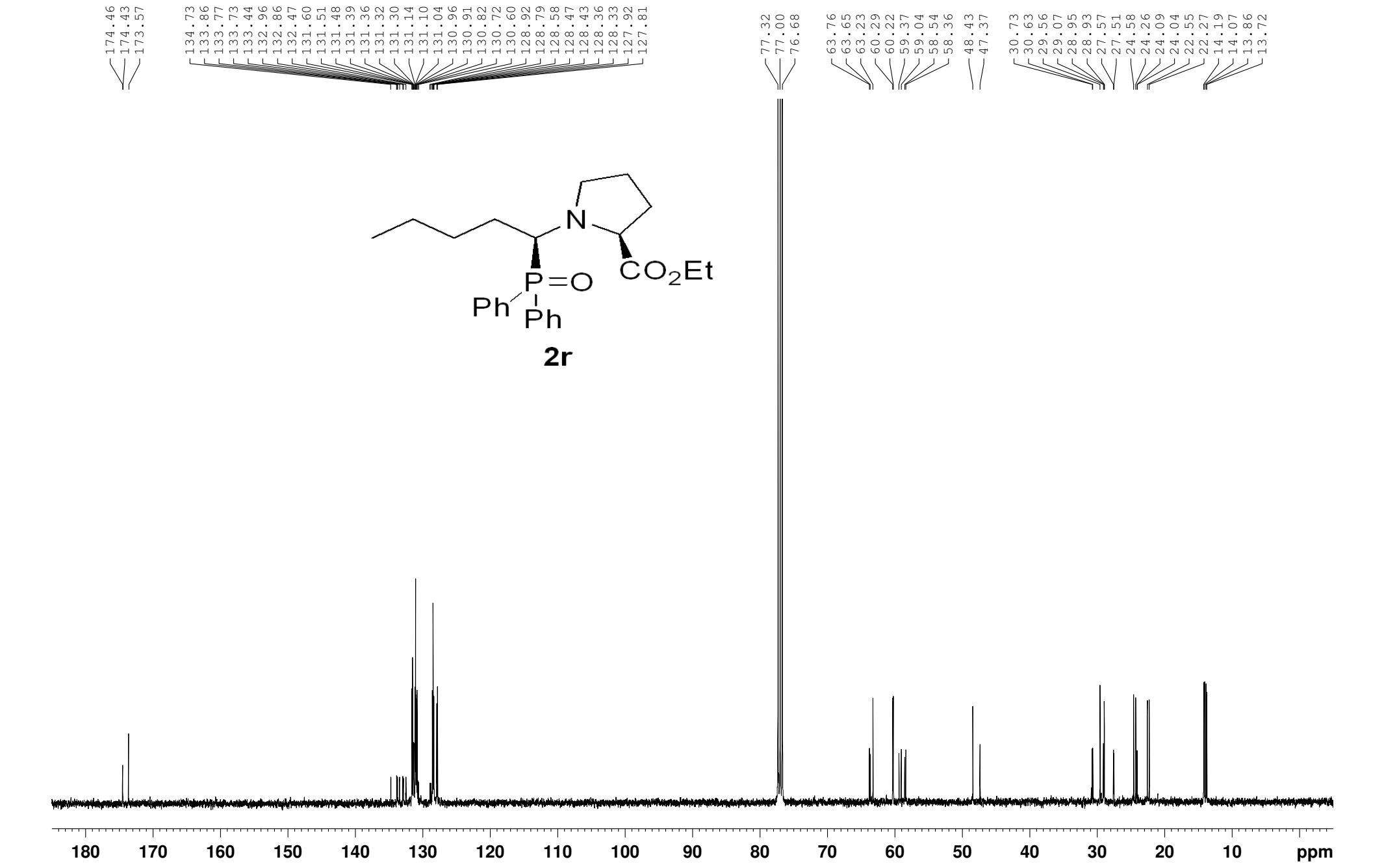
2q

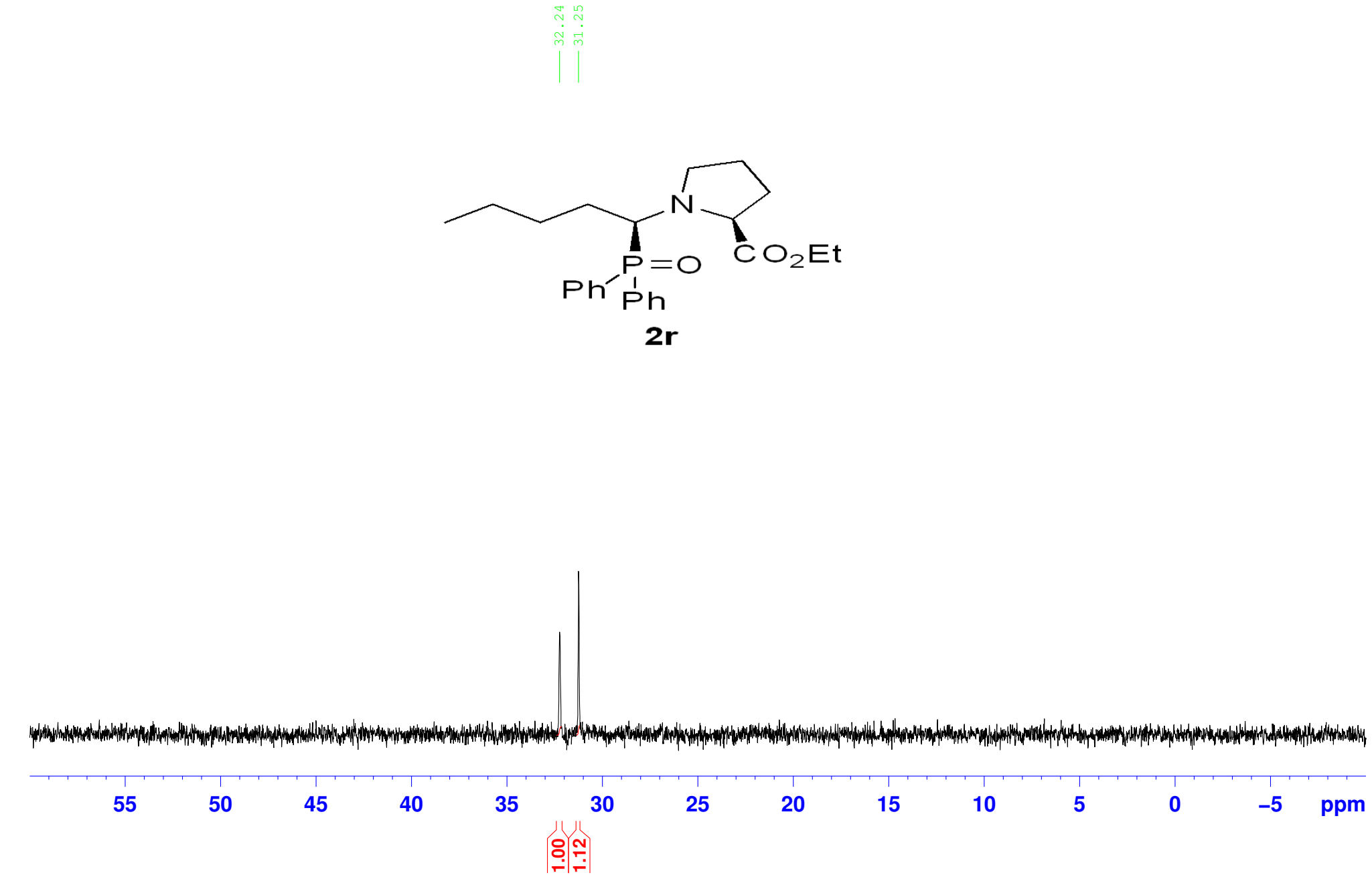

7.936
7.915
7.909
7.887
7.882
7.858
7.834
7.813
7.494
7.479
7.476
7.460
7.447
7.440
7.422
7.402
7.396
7.281
4.110
4.096
4.091
4.078
4.073
4.060
4.055
3.978
3.970
3.956
3.935
3.916
3.900
3.882
3.864
3.687
3.671
3.654
3.373
3.365
3.354
3.344
3.336
3.161
3.153
3.138
3.132
3.123
3.115
2.849
2.828
1.918
1.901
1.883
1.866
1.823
1.811
1.798
1.770
1.749
1.741
1.725
1.700
1.683
1.607
1.596
1.587
1.574
1.568
1.559
1.546
1.524
1.502
1.274
1.257
1.240
1.222
1.207
1.197
1.188
1.174
1.156
1.139
0.832
0.815
0.797
0.772
0.755
0.737

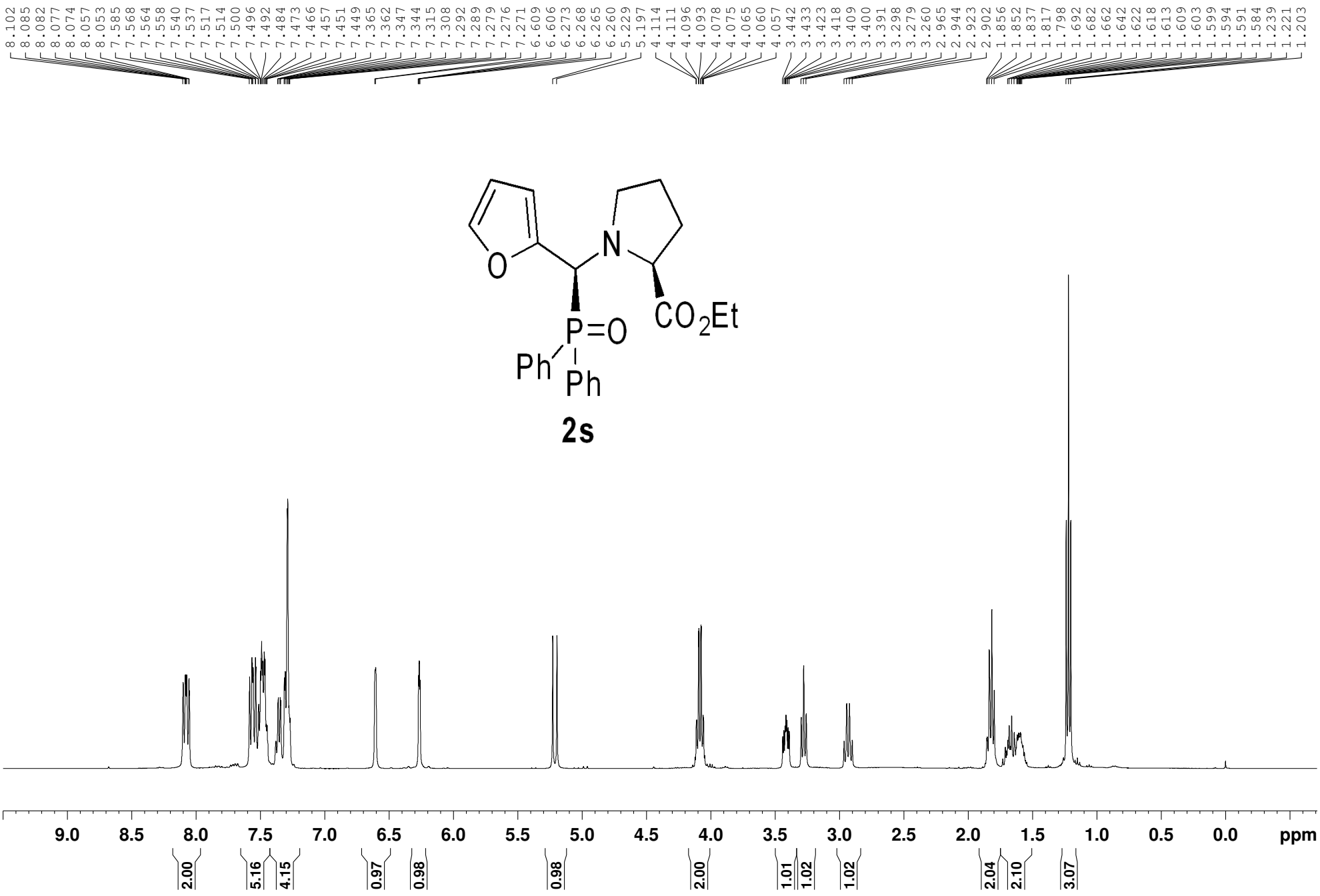

N
CO2Et
P=O
Ph
Ph

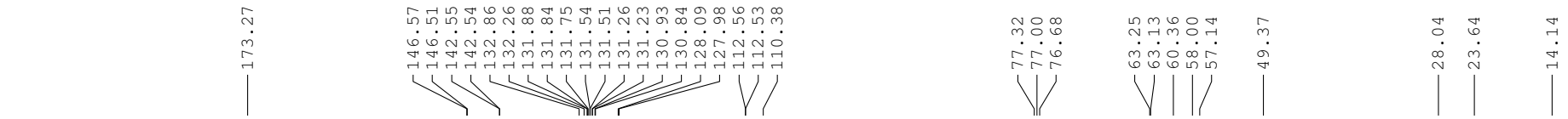
2r

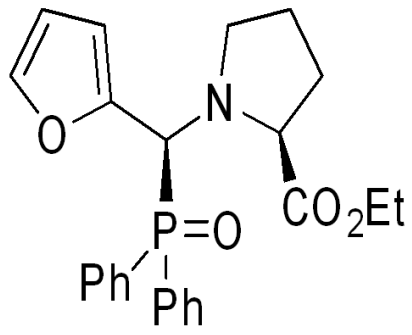

8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
3.92
6.16
1.19
1.95
0.54
1.05
1.00
0.48
2.20
2.94
1.61
7.30
3.00


174.46
174.43
173.57
134.73
133.86
133.77
133.73
133.44
132.96
132.86
132.47
131.60
131.51
131.48
131.39
131.36
131.32
131.30
131.14
131.10
131.04
130.96
130.91
130.82
130.72
130.60
128.92
128.79
128.58
128.47
128.43
128.36
128.33
127.92
127.81
77.32
77.00
76.68
63.76
63.65
63.23
60.29
60.22
59.37
59.04
58.54
58.36
48.43
47.37
30.73
30.63
29.56
29.07
28.95
28.93
27.57
27.51
24.58
24.26
24.09
24.04
22.55
22.27
14.19
14.07
13.86
13.72
N
CO2Et
P=O
Ph
Ph
2r
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

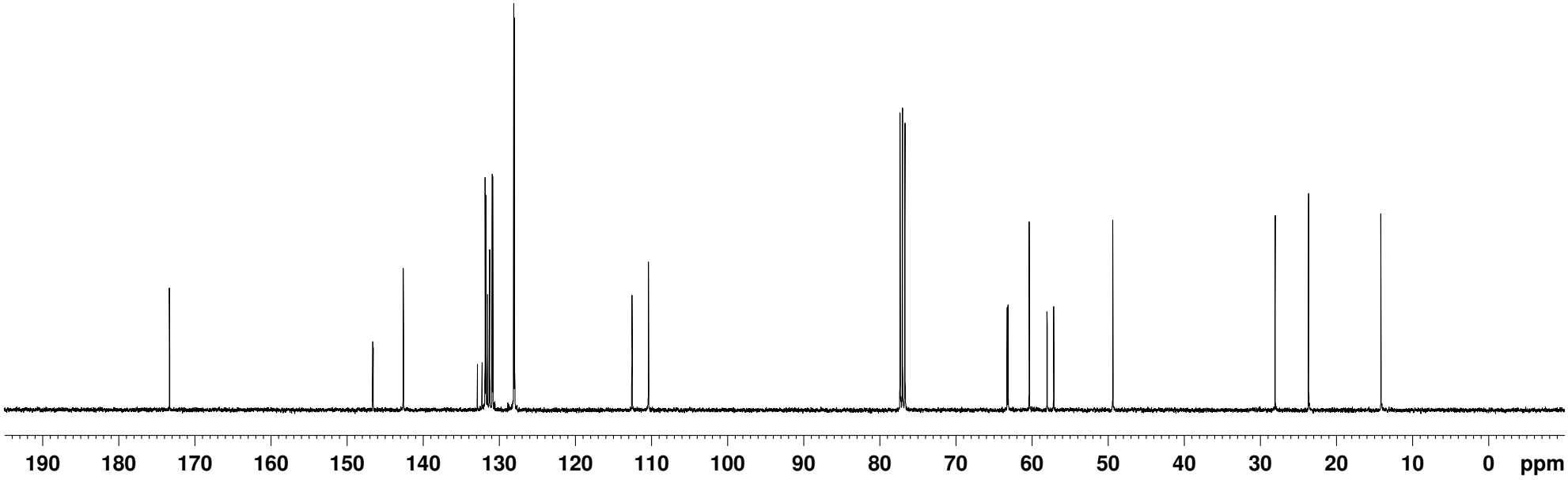

32.24
31.25
N
CO2Et
P=O
Ph
Ph
2r
55
50
45
40
35
30
25
20
15
10
5
0
–5
ppm
1.00
1.12

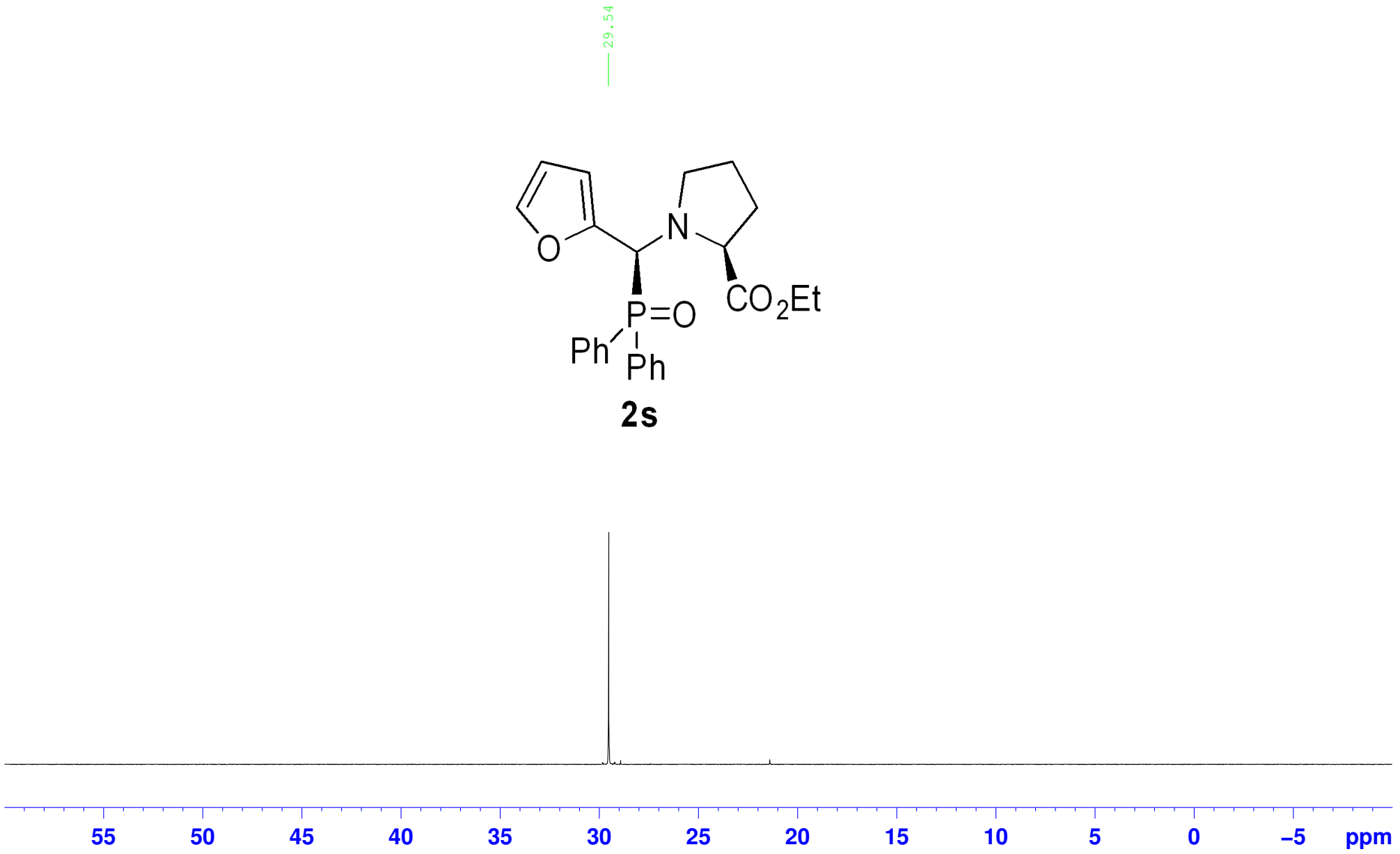

8.102
8.085
8.082
8.077
8.074
8.057
8.053
7.585
7.568
7.564
7.558
7.540
7.537
7.517
7.514
7.500
7.496
7.492
7.484
7.473
7.466
7.457
7.451
7.449
7.365
7.362
7.347
7.344
7.315
7.308
7.292
7.289
7.279
7.276
7.271
6.609
6.606
6.273
6.268
6.265
6.260
5.229
5.197
4.114
4.111
4.096
4.093
4.078
4.075
4.065
4.060
4.057
3.442
3.433
3.423
3.418
3.409
3.400
3.391
3.298
3.279
3.260
2.965
2.944
2.923
2.902
1.856
1.852
1.837
1.817
1.798
1.692
1.682
1.662
1.642
1.622
1.618
1.613
1.609
1.603
1.599
1.594
1.591
1.584
1.239
1.221
1.203
O
N
P=O
Ph
Ph
CO2Et
2s
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.00
5.16
4.15
0.97
0.98
0.98
2.00
1.01
1.02
1.02
2.04
2.10
3.07


173.27
146.57
146.51
142.55
142.54
132.86
132.26
131.88
131.84
131.75
131.54
131.51
131.26
131.23
130.93
130.84
128.09
127.98
112.56
112.53
110.38
77.32
77.00
76.68
63.25
63.13
60.36
58.00
57.14
49.37
28.04
23.64
14.14

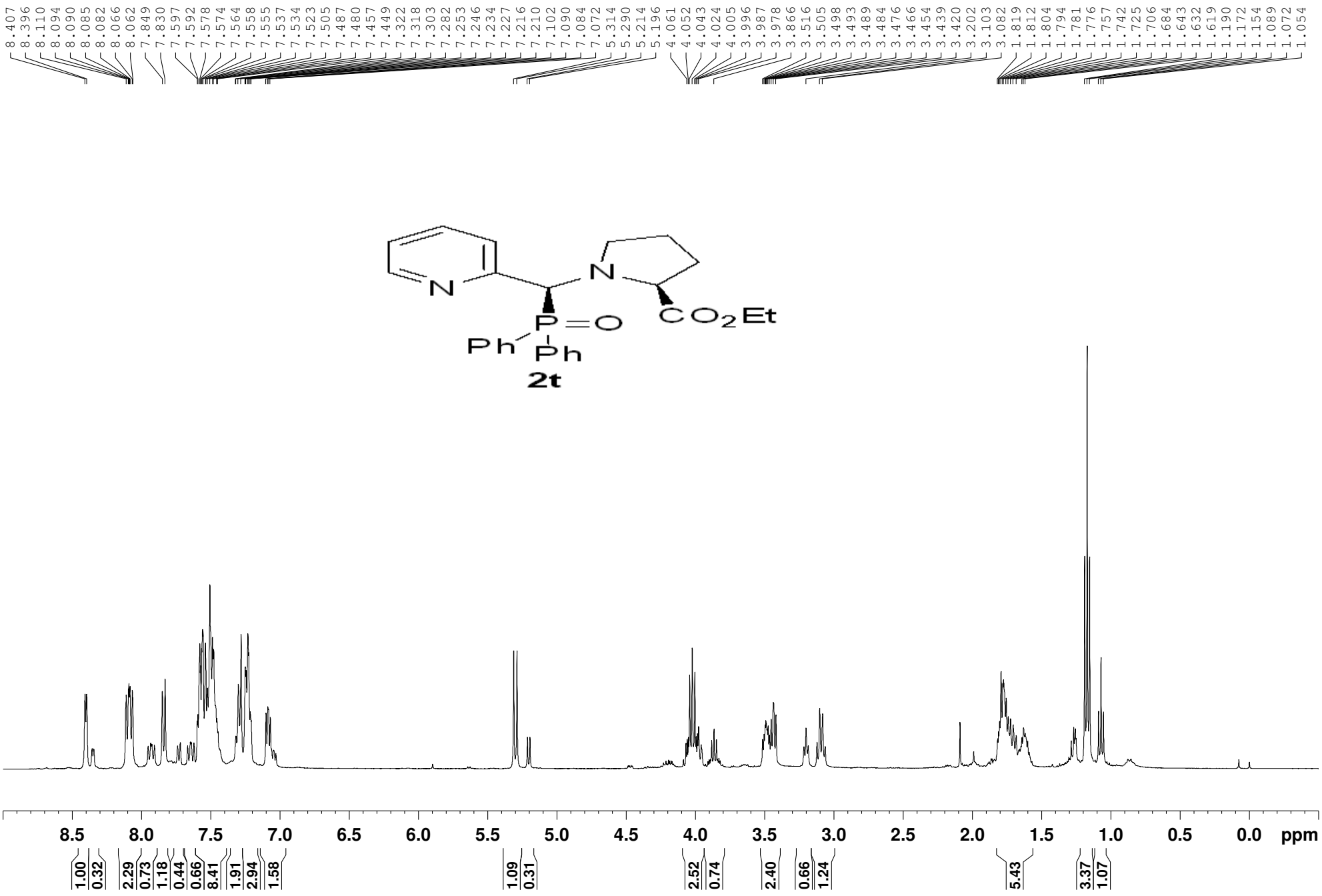

O
N
CO2Et
P=O
Ph
Ph

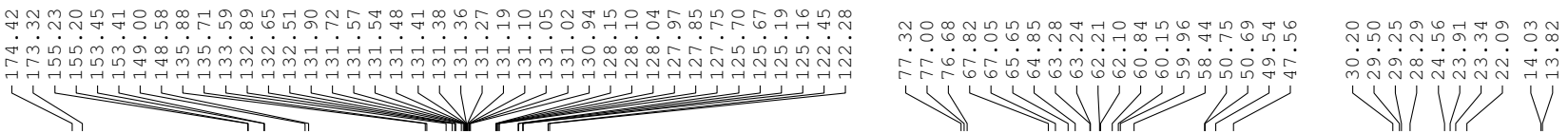
2s

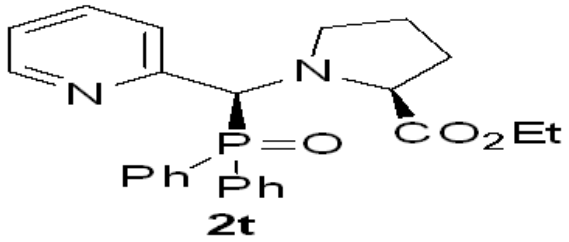

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



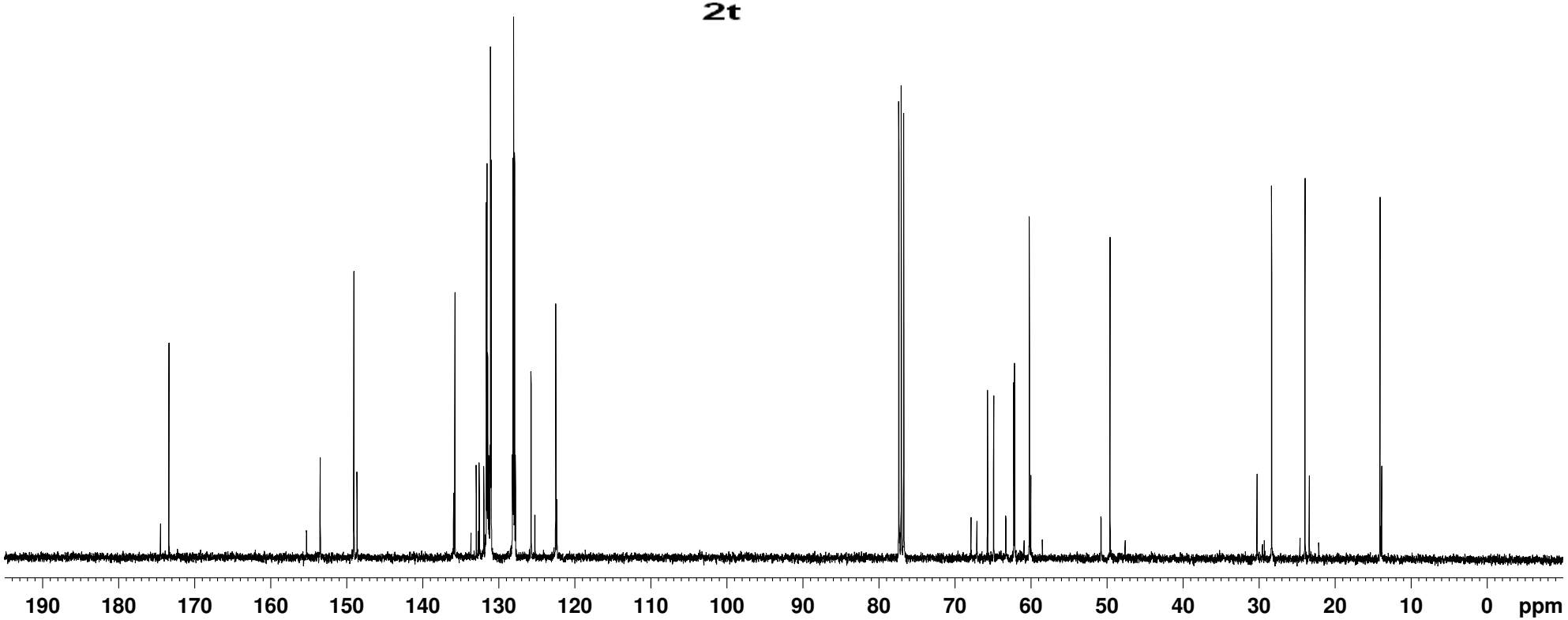
2s


8.407
8.396
8.110
8.094
8.090
8.085
8.082
8.066
8.062
7.849
7.830
7.597
7.592
7.578
7.574
7.564
7.558
7.555
7.537
7.534
7.523
7.505
7.487
7.480
7.457
7.449
7.322
7.318
7.303
7.282
7.253
7.246
7.234
7.227
7.216
7.210
7.102
7.090
7.084
7.072
5.314
5.290
5.214
5.196
4.061
4.052
4.043
4.024
4.005
3.996
3.987
3.978
3.866
3.516
3.505
3.498
3.493
3.489
3.484
3.476
3.466
3.454
3.439
3.420
3.202
3.103
3.082
1.819
1.812
1.804
1.794
1.781
1.776
1.757
1.742
1.725
1.706
1.684
1.643
1.632
1.619
1.190
1.172
1.154
1.089
1.072
1.054
N
N
P=O
Ph
Ph
CO2Et
2t
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
0.32
2.29
0.73
1.18
0.44
0.66
8.41
1.91
2.94
1.58
1.09
0.31
2.52
0.74
2.40
0.66
1.24
5.43
3.37
1.07

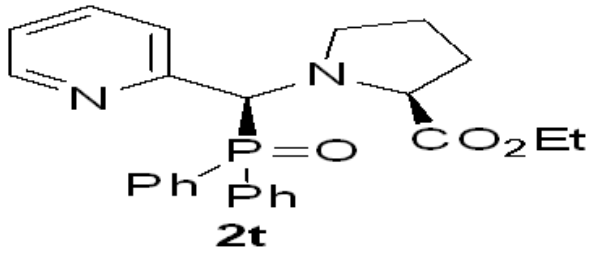

174.42
173.32
155.23
155.20
153.45
153.41
149.00
148.58
148.88
135.71
133.59
132.89
132.65
132.51
131.90
131.72
131.57
131.54
131.48
131.41
131.38
131.36
131.27
131.19
131.10
131.05
131.02
130.94
128.15
128.10
128.04
127.97
127.85
127.75
125.70
125.67
125.19
125.16
122.45
122.28
77.32
77.00
76.68
67.82
67.05
65.65
64.85
63.28
63.24
62.21
62.10
60.84
60.15
59.96
58.44
50.75
50.69
49.54
47.56
30.20
29.50
29.25
28.29
24.56
23.91
23.34
22.09
14.03
13.82


N
N
P=O
CO2Et
Ph
Ph

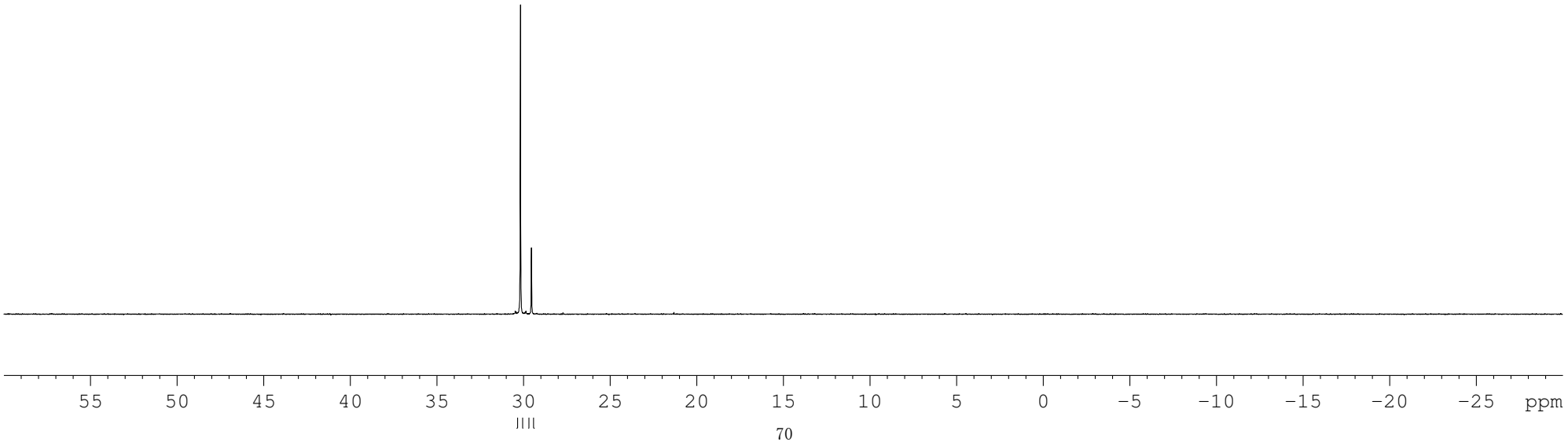
2t

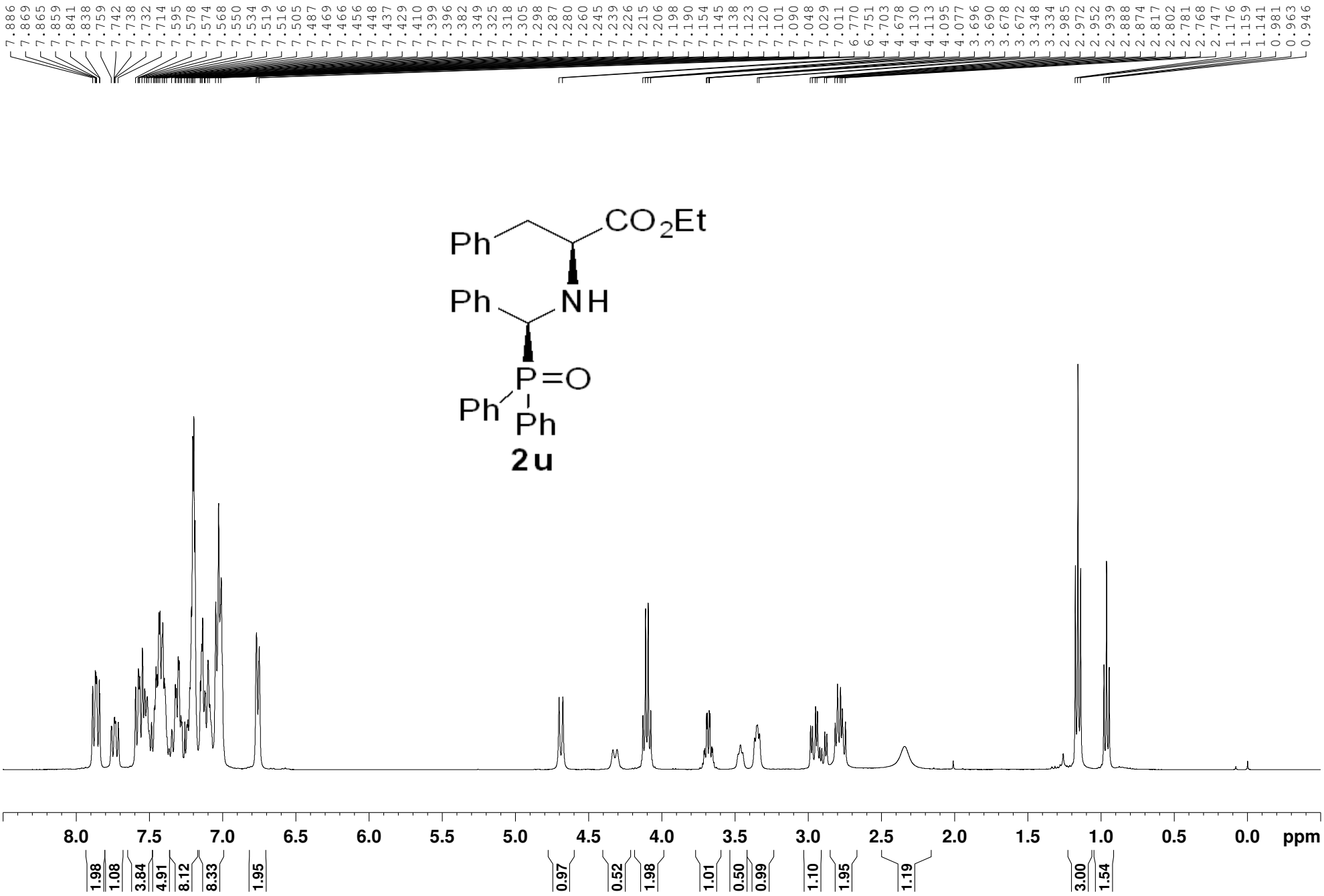

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

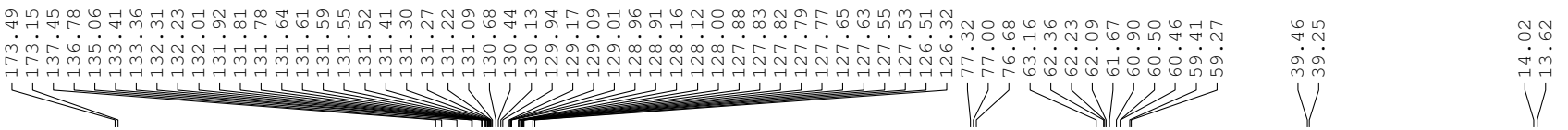
30.19
29.56

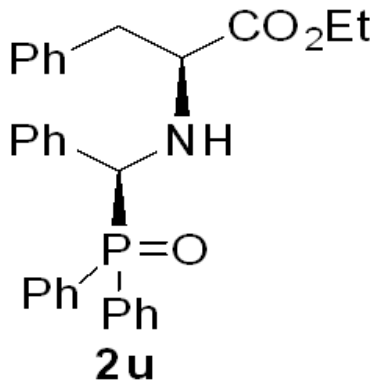


2t

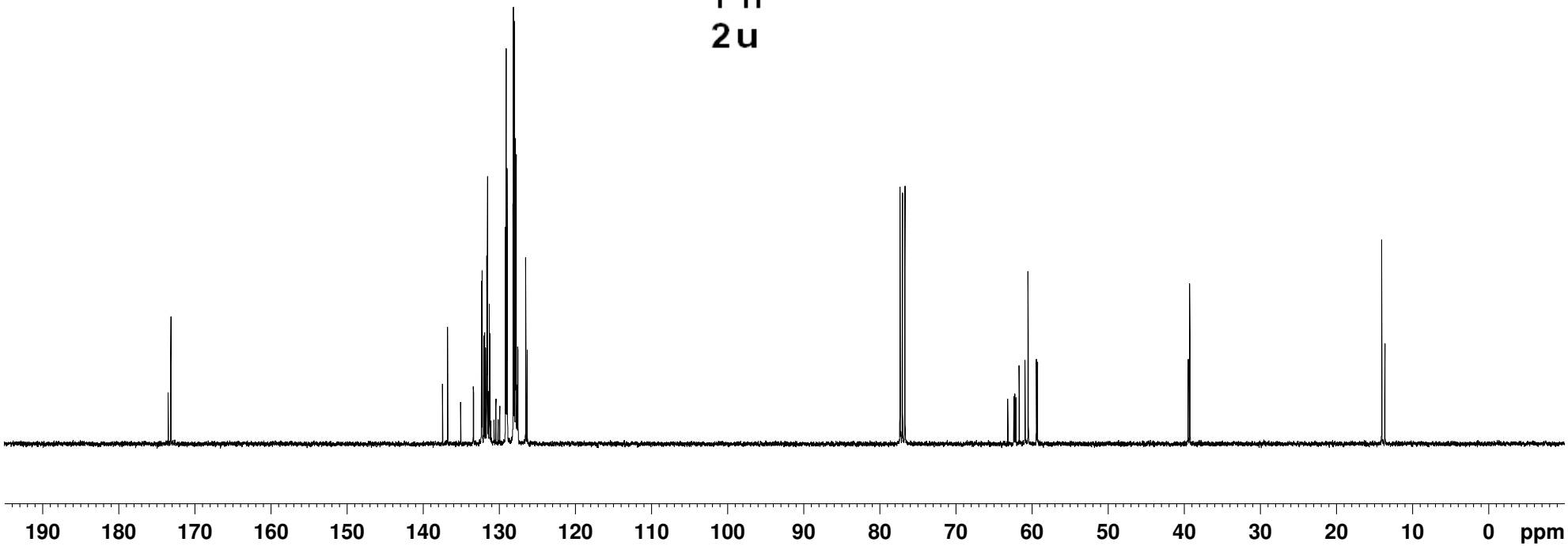


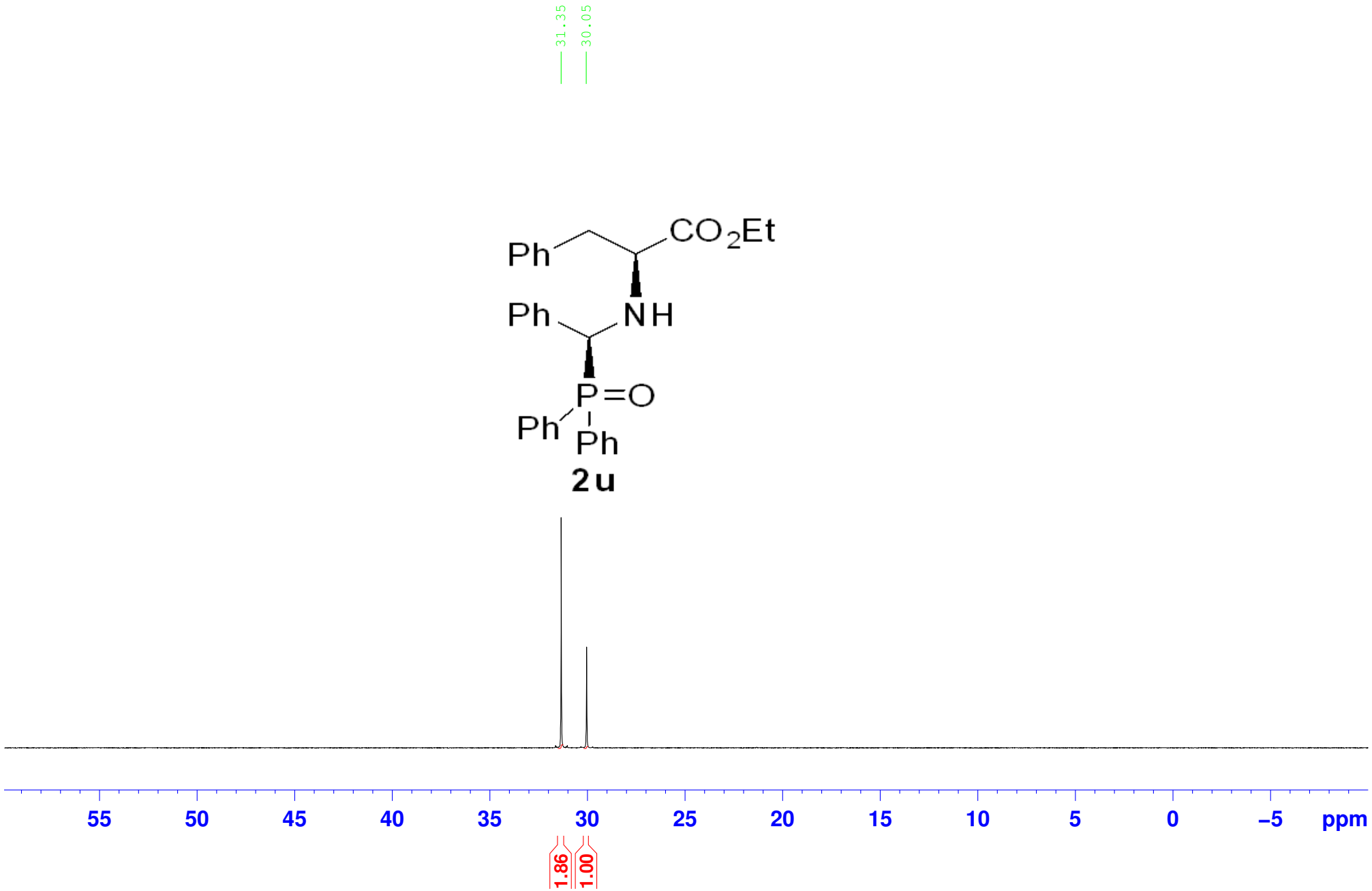

7.886 7.869 7.865 7.859 7.841 7.838 7.759 7.742 7.738 7.732 7.714 7.595 7.578 7.574 7.568 7.550 7.534 7.519 7.516 7.505 7.487 7.469 7.466 7.456 7.448 7.437 7.429 7.410 7.399 7.396 7.382 7.349 7.325 7.318 7.305 7.298 7.287 7.280 7.260 7.245 7.239 7.226 7.215 7.206 7.198 7.190 7.154 7.145 7.138 7.123 7.120 7.101 7.090 7.048 7.029 7.011 6.770 6.751 4.703 4.678 4.130 4.113 4.095 4.077 3.696 3.690 3.678 3.672 3.348 3.334 2.985 2.972 2.952 2.939 2.888 2.874 2.817 2.802 2.781 2.768 2.747 1.176 1.159 1.141 0.981 0.963 0.946
Ph
CO2Et
Ph
NH
P=O
Ph
Ph
2u
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
1.98 1.08 3.84 4.91 8.12 8.33 1.95 0.97 0.52 1.98 1.01 0.50 0.99 1.10 1.95 1.19 3.00 1.54

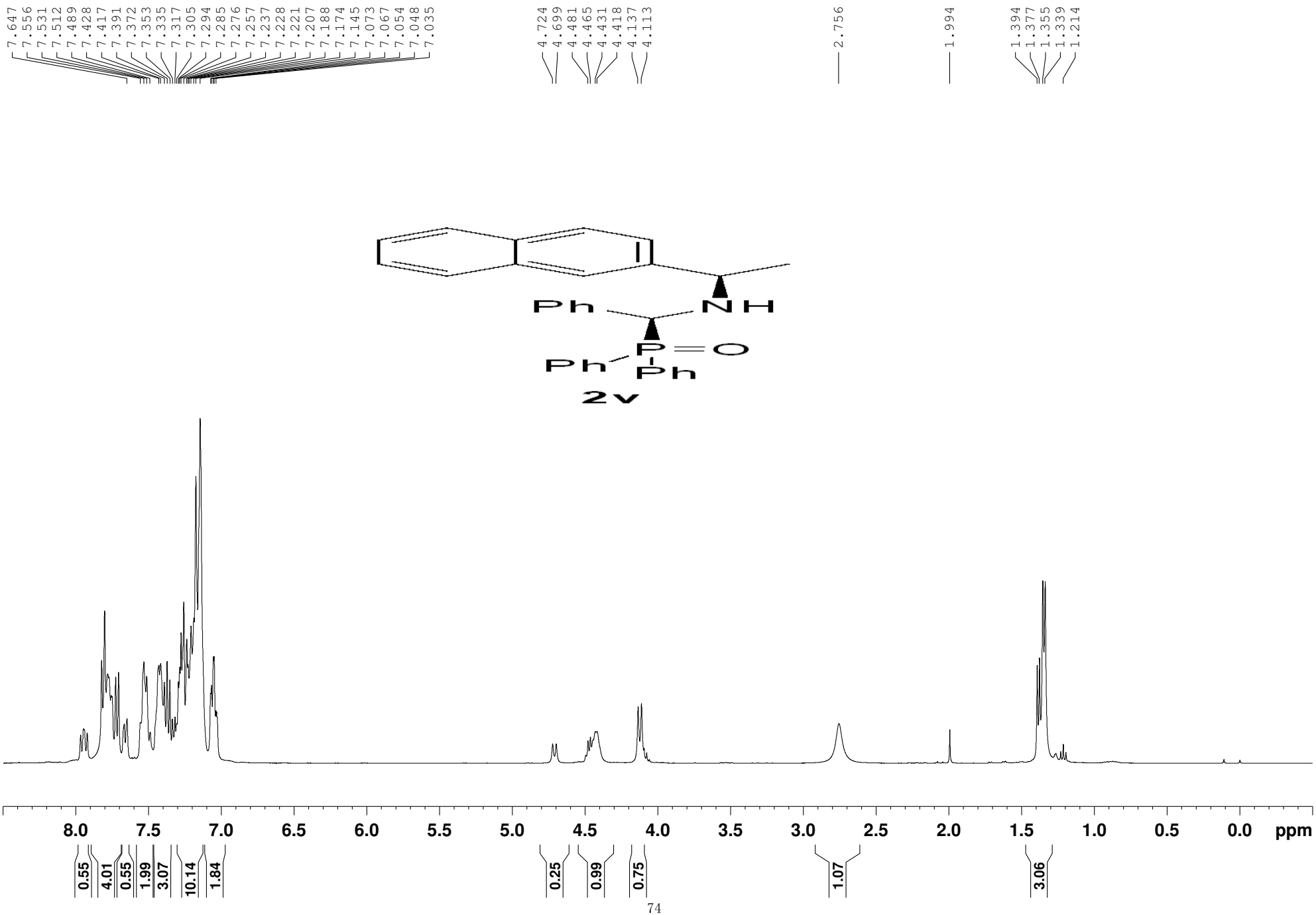

173.49
173.15
137.45
136.78
135.06
133.41
133.36
132.31
132.23
132.01
131.92
131.81
131.78
131.64
131.61
131.59
131.55
131.52
131.41
131.30
131.27
131.22
131.09
130.68
130.44
130.13
129.94
129.17
129.09
129.01
128.96
128.91
128.16
128.12
128.00
127.88
127.83
127.82
127.79
127.77
127.65
127.63
127.55
127.53
126.51
126.32
77.32
77.00
76.68
63.16
62.36
62.23
62.09
61.67
60.90
60.50
60.46
59.41
59.27
39.46
39.25
14.02
13.62

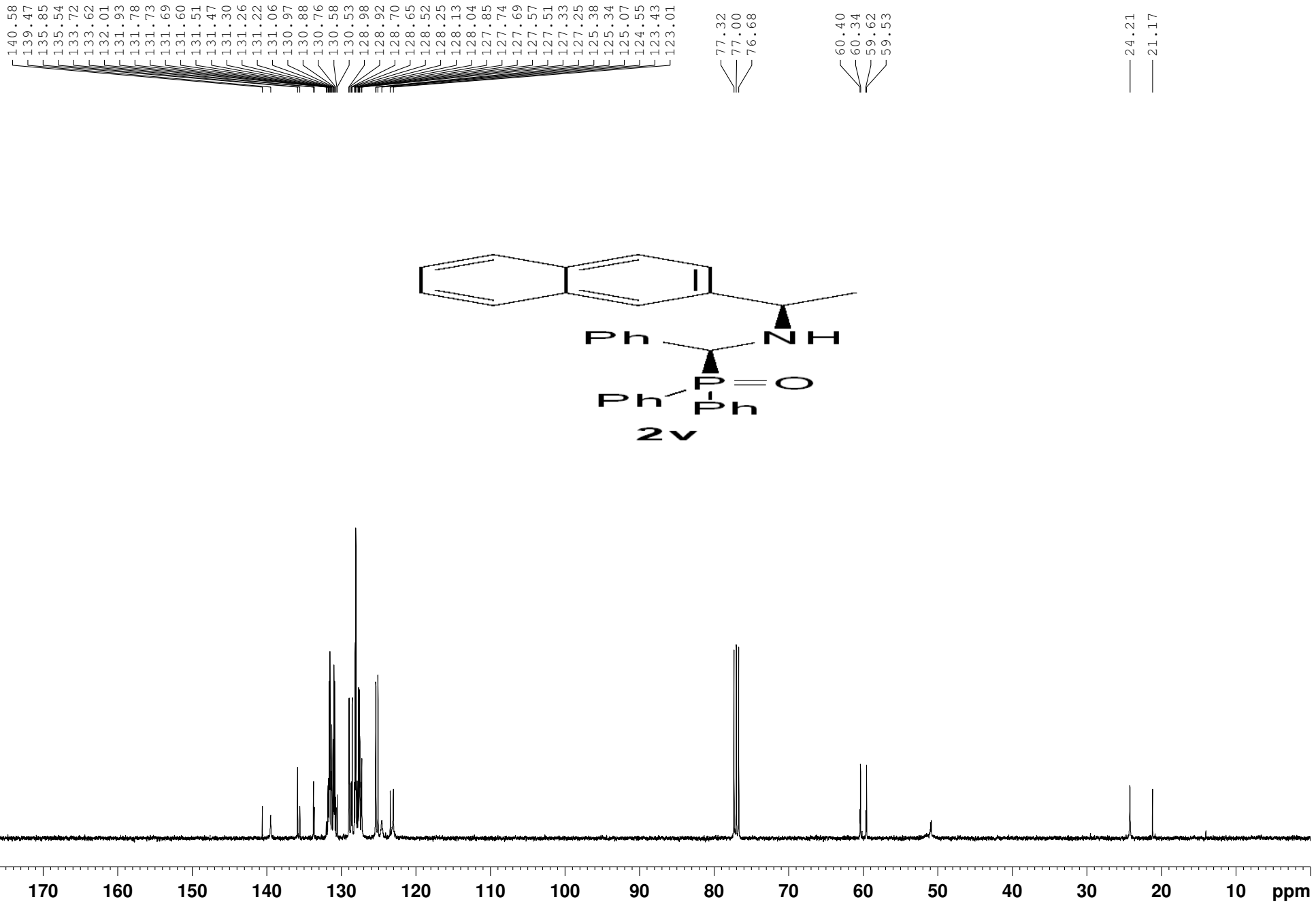

Ph
CO2Et
Ph
NH
P=O
Ph
Ph

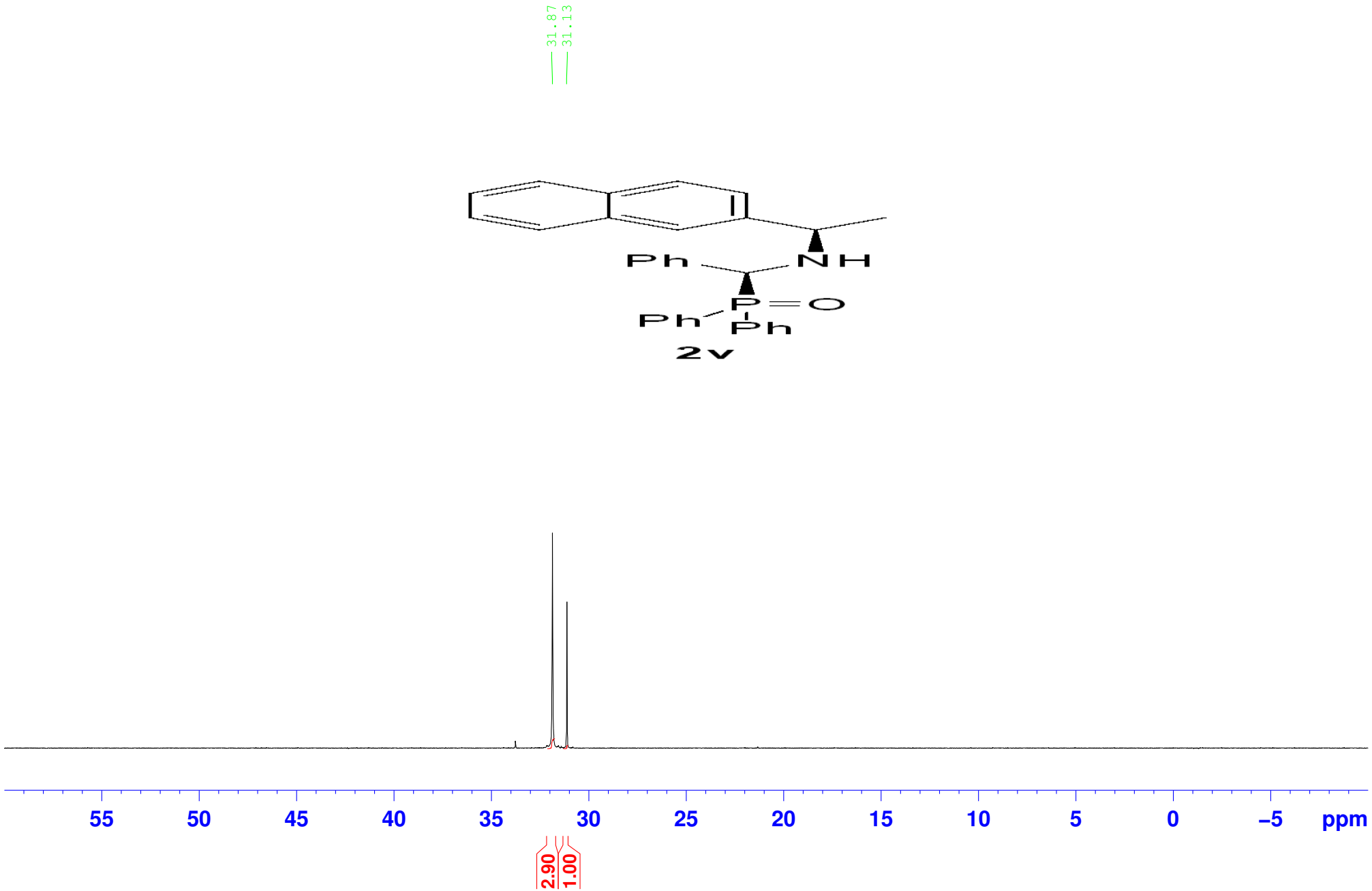
2u

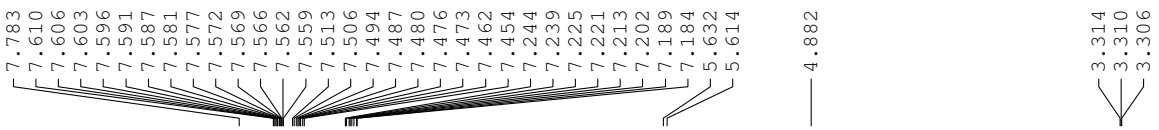

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

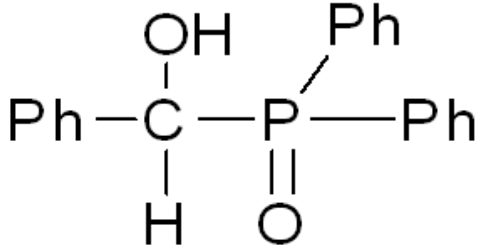

31.35
30.05
CO2Et
Ph
Ph
NH
P=O
Ph
Ph
2u
55
50
45
40
35
30
25
20
15
10
5
0
−5
ppm
1.86
1.00


7.647
7.556
7.531
7.512
7.489
7.428
7.417
7.391
7.372
7.353
7.335
7.317
7.305
7.294
7.285
7.276
7.257
7.237
7.228
7.221
7.207
7.188
7.174
7.145
7.073
7.067
7.054
7.048
7.035
4.724
4.699
4.481
4.465
4.431
4.418
4.137
4.113
2.756
1.994
1.394
1.377
1.355
1.339
1.214
Ph
NH
P
O
Ph
Ph
2v
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
0.55
4.01
0.55
1.99
3.07
10.14
1.84
0.25
0.99
0.75
1.07
3.06

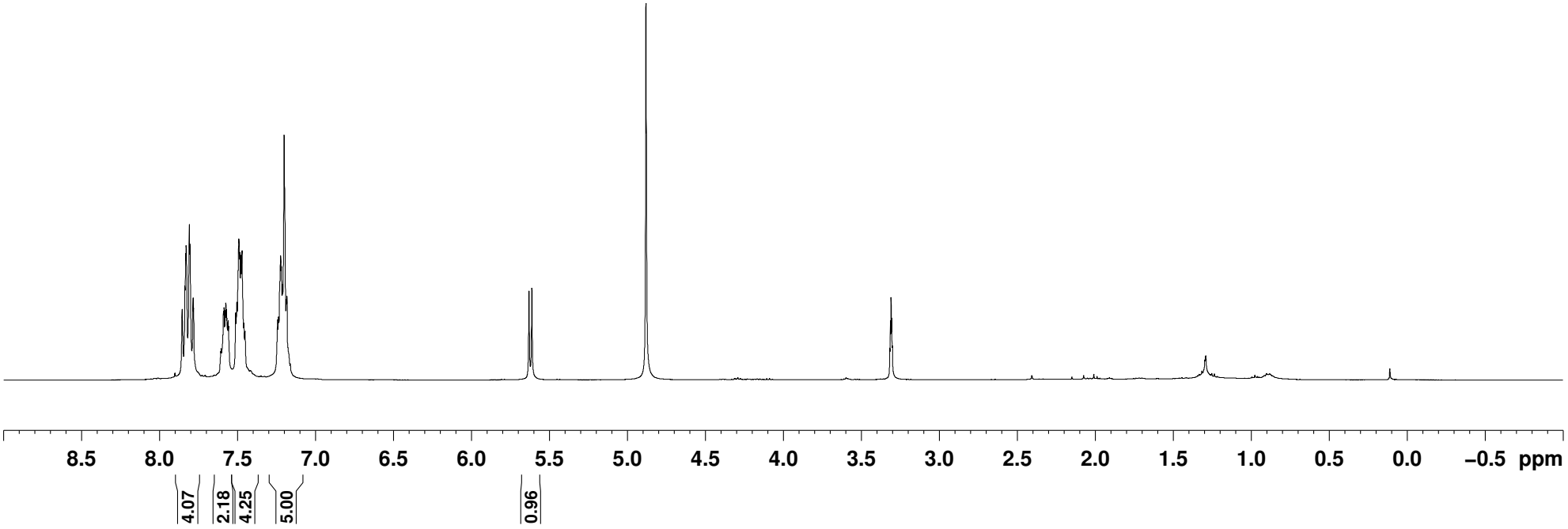

140.58
139.47
135.85
135.54
133.72
133.62
132.01
131.93
131.78
131.73
131.69
131.60
131.51
131.47
131.30
131.26
131.22
131.06
130.97
130.88
130.76
130.58
130.53
128.98
128.92
128.70
128.65
128.52
128.25
128.13
128.04
127.85
127.74
127.69
127.57
127.51
127.33
127.25
125.38
125.34
125.07
124.55
123.43
123.01
77.32
77.00
76.68
60.40
60.34
59.62
59.53
24.21
21.17
Ph
NH
P
O
Ph
Ph
2v
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

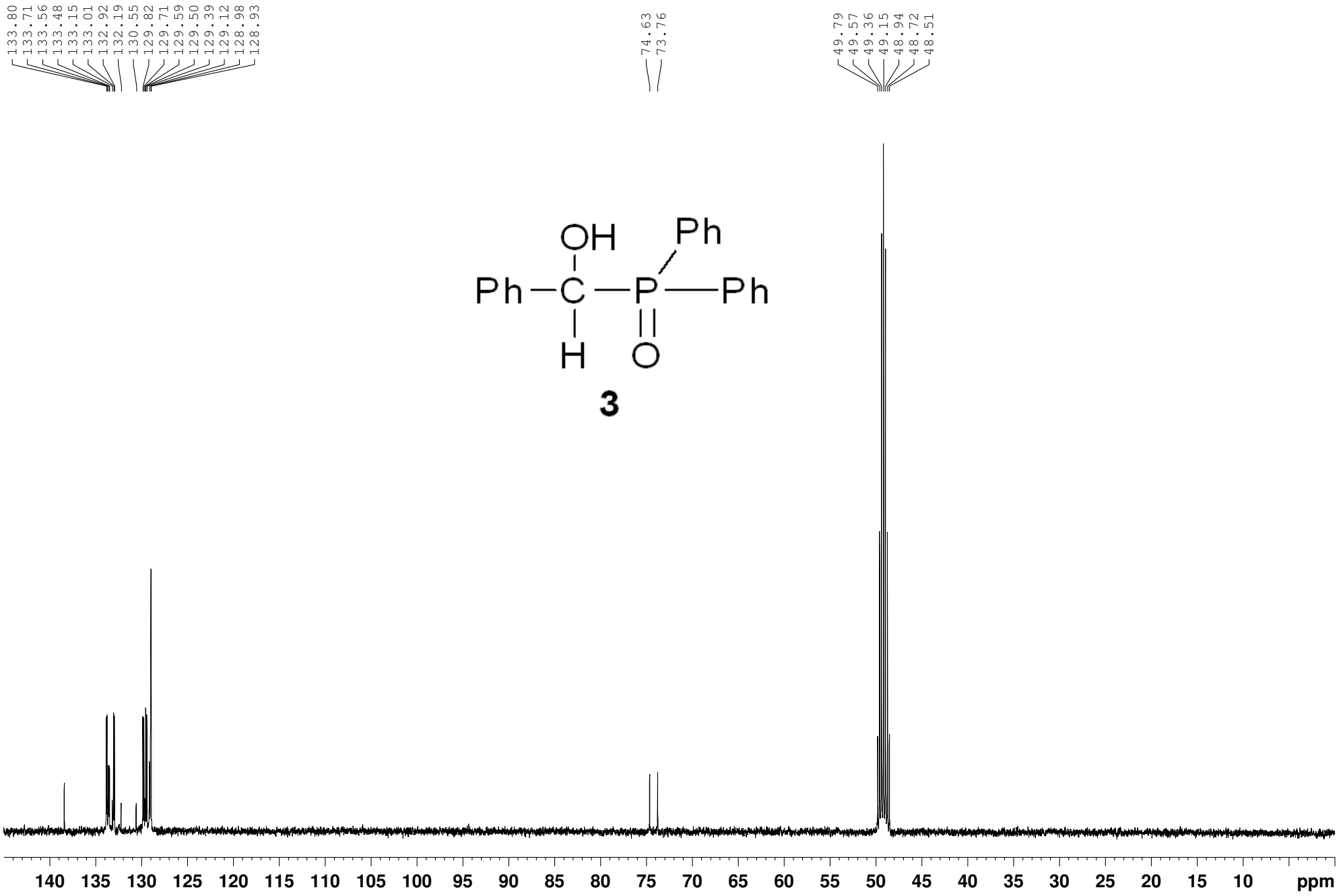

31.87
31.13
Ph
NH
P
O
Ph
Ph
2v
55
50
45
40
35
30
25
20
15
10
5
0
−5
ppm
2.90
1.00


7.783
7.610
7.606
7.603
7.596
7.591
7.587
7.581
7.577
7.572
7.569
7.566
7.562
7.559
7.513
7.506
7.494
7.487
7.480
7.476
7.473
7.462
7.454
7.244
7.239
7.225
7.221
7.213
7.202
7.189
7.184
5.632
5.614
4.882
3.314
3.310
3.306

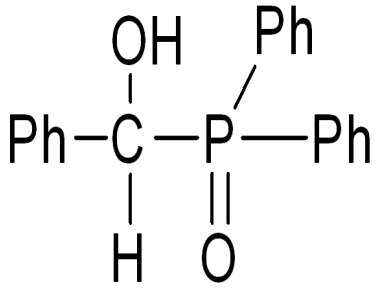

OH
Ph
Ph
C
P
Ph
H
O

3


8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
4.07
2.18
4.25
5.00
0.96


133.80
133.71
133.56
133.48
133.15
133.01
132.92
132.19
130.55
129.82
129.71
129.59
129.50
129.39
129.12
128.98
128.93
74.63
73.76
49.79
49.57
49.36
49.15
48.94
48.72
48.51
OH
Ph
Ph
C
P
Ph
H
O
3
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
ppm

33.04



3