Supporting Information

Cobalt-Catalyzed Highly α-Selective Hydrostannylation of Terminal Alkynes

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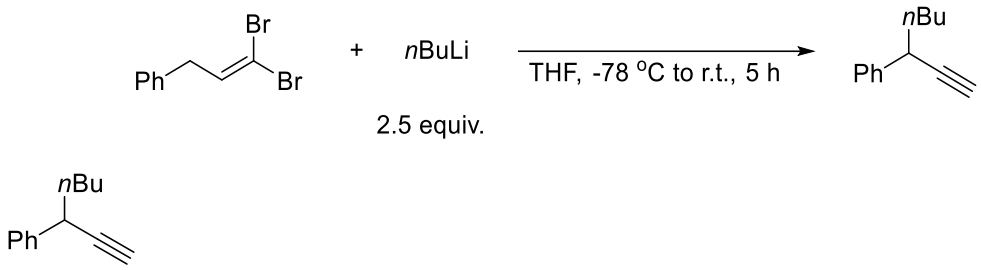
I. General Information

THF was distilled from sodium benzophenone ketyl prior to use. $Pd_2(dba)_3$ (98%) was purchased from Zhejiang Metallurgical Research Institute and used as received. 1,1'-Bis(diphenylphosphino)ferrocene (dppf) (98%) was purchased from Energy Chemical and used as received. $HSnBu_3$ (97%) and $Co(OAc)_2$ (99.99%) was purchased from Aladdin and used as received. The other commercially available chemicals were used as received. NMR spectra were recorded on a Bruker-400 instrument, a Bruker-500 instrument and a Wuhan Zhongke-Niujin-400 instrument. ^1H NMR chemical shifts were referenced to tetramethylsilane signal (0.0 ppm), ^{13}C NMR chemical shifts were referenced to the solvent resonance (77.0 ppm, $CDCl_3$). ^2H NMR chemical shifts were referenced to $CDCl_3$ signal (7.26 ppm). The following abbreviations (or combinations) were used to explain multiplicities: s = singlet, d = doublet, t = triplet, m= multiplet, brs = broad singlet, q = quadruplet. Melting points were obtained using a

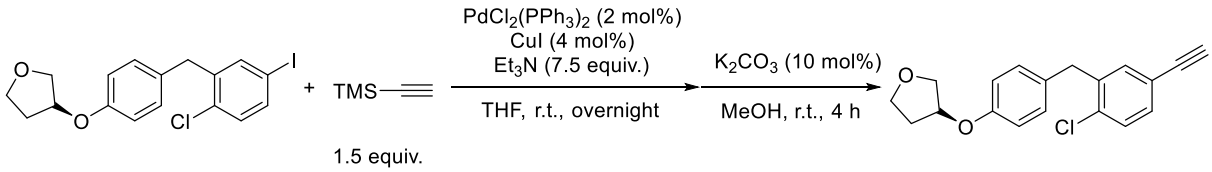
WRR melting point apparatus (Laboratory Devices, Shanghai Precision & Scientific Instrument Co., Ltd.). High-resolution mass spectra (HRMS) were recorded on ESI-TOF or EI. IR spectra were recorded on a Perkin-Elmer Spectrum One FTIR spectrometer with diamond ATR accessory.

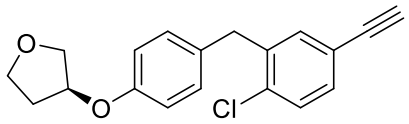
II. Synthesis of Substrates and Ligands.

Alkynes were prepared according to Sonogashira-Coupling reaction or the previously reported procedures.[1-15] **L1**[7], **L2-L4**[4], **L5**[16], **L7**[4], **L8**[17], **L10**[17] were prepared according to the previously reported procedures.

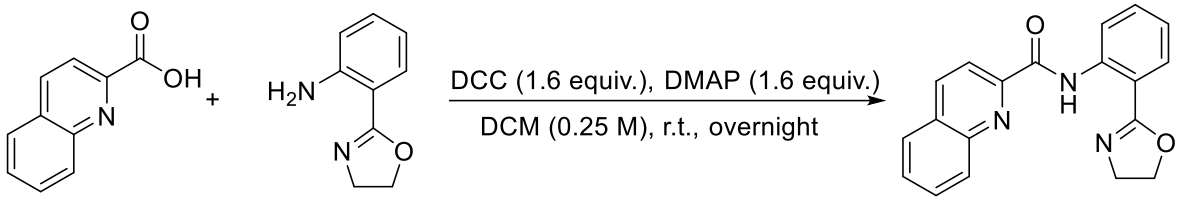


Hept-1-yn-3-ylbenzene (1aw). To a 500 mL flame-dried three-necked Schlenk flask, 24.84 g (90.0 mmol) of (3,3-dibromoallyl)benzene, 250 mL (0.36 M) of THF were added in sequence under the atmosphere of nitrogen. The solution was stirred at -78 °C for a while, and then 90 mL (2.5 M in hexane, 90 mmol, 2.5 equiv.) of *n*BuLi was added into the mixture by dropwise at -78 °C. The solution was stirred at -78 °C for 5 h. After that the mixture was warmed to 0 °C slowly and quenched by saturated NH_4Cl solution at 0 °C. Then, 50 mL H_2O and 50 mL Et_2O were added into the mixture and the organic layer was separated. The aqueous layer was extracted with Et_2O (3 × 150 mL). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. And the residue was purified by flash column chromatography using PE as the eluent to give 4.60 g (26.7 mmol, 30% yield) of the title compound as a yellow oil. IR (cm^{-1}): 3304, 3063, 2957, 2862, 1494, 1455. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.40-7.28 (m, 4H), 7.26-7.18 (m, 1H), 3.65-3.58 (m, 1H), 2.26 (d, $J_{H\text{-}H}$ = 2.4 Hz, 1H), 1.80-1.70 (m, 2H), 1.45-1.25 (m, 4H), 0.89 (t, $J_{H\text{-}H}$ = 7.2 Hz, 3H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 141.7, 128.5, 127.3, 126.7, 86.2, 70.7, 38.1, 37.5, 29.4, 22.4, 13.9; HRMS (EI) calculated for $[C_{13}H_{16}]^+$ $[M]^+$ requires m/z 172.1252, found m/z 172.1253.

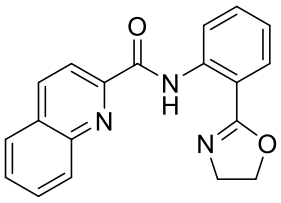




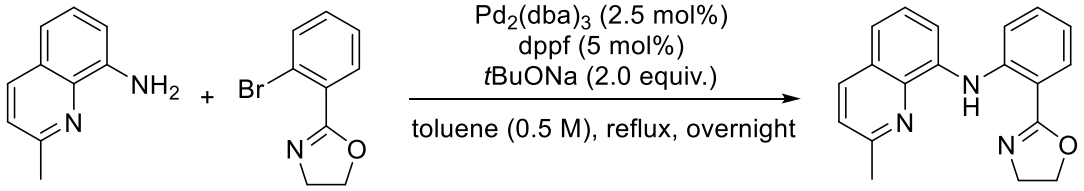
(*S*)-3-(4-(2-chloro-5-ethynylbenzyl)phenoxy)tetrahydrofuran (1ay). To a 50 mL flame-dried Schlenk flask, 0.0337 g (0.048 mmol, 2 mol%) of $PdCl_2(PPh_3)_2$, 0.0183 g (0.096 mmol, 4 mol%) of CuI, 5 mL (0.48 M) of THF, 1.00 g (2.4 mmol) of (*S*)-3-(4-(2-chloro-5-iodobenzyl)phenoxy)tetrahydrofuran, 2.5 mL (0.73 g/mL, 18 mmol，7.5 equiv.) of Et_3N and 0.36 g (3.6 mmol, 1.5 equiv.) ethynyltrimethylsilane were added in sequence under the atmosphere of nitrogen. The solution was stirred at room temperature overnight, quenched by PE and filtered through a pad of silica gel. The schlenk flask and silica gel were washed by PE/EtOAc = 5/1 (30 mL × 3). The combined filtrates were concentrated *in vacuo*. Then 20 mL (0.12 M) of MeOH and 0.0332 g (0.24 mmol, 10 mol%) of K_2CO_3 were added into the residue and the solution was stirred at room temperature for 5 h. The solution was filtered through a pad of silica gel and washed by PE/EtOAc = 20/1 (30 mL × 3). All volatiles were removed from the solution *via* rotary evaporation to give an orange sticky oil. And the residue was purified by flash column chromatography using PE/EtOAc = 20/1 as the eluent to give 0.7232 g (2.3 mmol, 96% yield) of the title compound as a yellow oil. IR (cm^{-1}): 3290, 2925, 2864, 1611, 1509, 1470. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.35-7.24 (m, 3H), 7.09 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 6.79 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 4.93-4.85 (m, 1H), 4.03-3.85 (m, 6H), 3.06 (s, 1H), 2.25-2.10 (m, 2H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 156.0, 139.3, 134.9, 134.3, 131.1, 130.0, 129.5, 120.8, 115.4, 82.7, 77.9, 77.3, 73.1, 67.1, 38.1, 33.0; HRMS (EI) calculated for $[C_{19}H_{17}O_2Cl]^+$ $[M]^+$ requires m/z 312.0917, found m/z 312.0915.

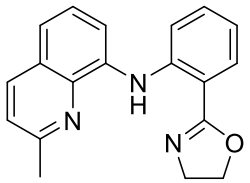


1.6 equiv.



***N*-(2-(4,5-dihydrooxazol-2-yl)phenyl)quinoline-2-carboxamide (L6).** To a 50 mL round-bottom flask, 1.40 g (8.0 mmol, 1.6 equiv.) of quinoline-2-carboxylic acid, 0.81 g (5.0 mmol) of 2-(4,5-dihydrooxazol-2-yl)aniline, and 20 ml (0.25 M) of DCM were added in sequence under air. The solution was stirred for 10 mins. 1.67 g (8.0 mmol, 1.6 equiv.) of DCC (dicyclohexylmethanediimine) was added in portion and 0.99 g (8.0 mmol, 1.6 equiv.) of DMAP (4-Dimethylaminopyridine) was added in sequence. The solution was stirred overnight. After that, 50 mL H_2O and 50 mL DCM were added into the mixture and the organic layer was separated. The aqueous layer was extracted with DCM (50 mL × 3). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by flash column chromatography using PE/EtOAc = 5/1 as the eluent to give 0.95 g (3.0 mmol, 60% yield) of the title compound as a white solid. M.p. 176.5-177.8 ^oC. IR (cm^{-1}): 2931, 2877, 1679, 1641, 1582, 1533. ^1H NMR: (400 MHz, $CDCl_3$) δ 14.09 (brs, 1H), 9.09 (d, J_{H-H} = 8.4 Hz, 1H), 8.43-8.32 (m, 2H), 8.22 (d, J_{H-H} = 8.8 Hz, 1H), 7.95 (dd, J_{H-H} = 7.6, 1.2 Hz, 1H), 7.92 (d, J_{H-H} = 8.0 Hz, 1H), 7.84-7.78 (m, 1H), 7.68-7.62 (m, 1H), 7.58-7.52 (m, 1H), 7.18-7.13 (m, 1H), 4.55-4.38 (m, 4H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 164.3, 164.1, 150.7, 146.6, 139.5, 137.4, 132.4, 130.0, 129.9, 129.4, 129.2, 128.0, 127.7, 122.6, 119.9, 119.1, 114.6, 66.3, 55.0; HRMS (ESI) calculated for $[C_{19}H_{16}N_3O_2]^+$ $[M+H]^+$ requires m/z 318.1237, found m/z 318.1236.

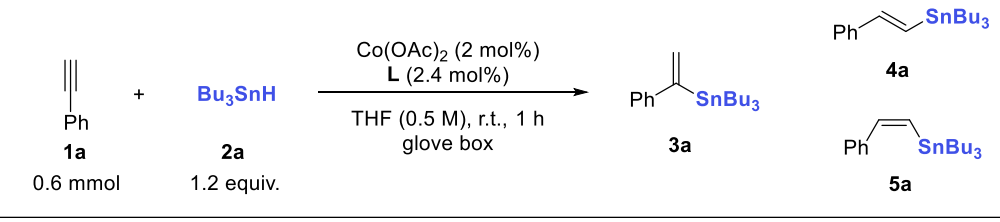


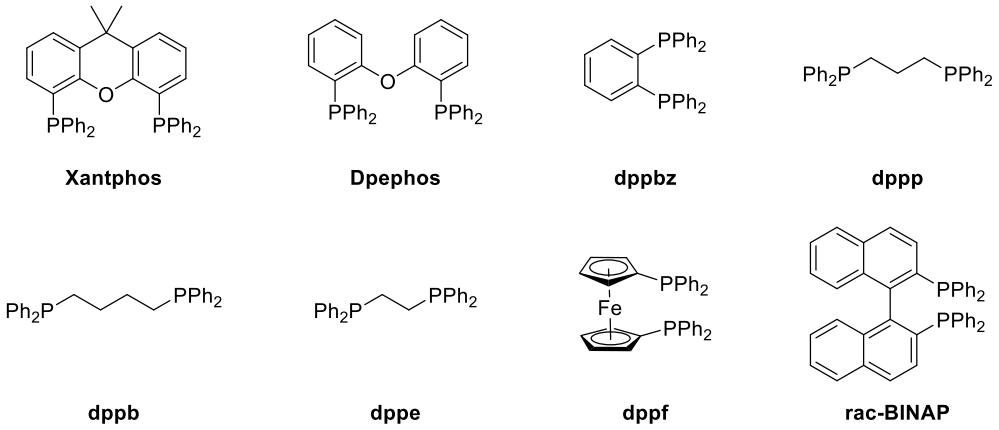


***N*-(2-(4,5-dihydrooxazol-2-yl)phenyl)-2-methylquinolin-8-amine (L9).** To a 50 mL flame-dried Schlenk flask, 0.0830 g of $Pd_2(dba)_3$ (0.091 mmol, 2.5 mol%), 0.0998 g (0.180 mmol, 5 mol%) of dppf and 10 mL (0.36 M) of toluene were added in sequence under the atmosphere of nitrogen. The solution was stirred for 10 mins. 0.81 g (3.6 mmol) of 2-(2-bromophenyl)-4,5-dihydrooxazole, 0.57 g (3.6 mmol, 1.0 equiv.) of 2-methylquinolin-8-amine, 0.70 g (7.2 mmol, 2.0 equiv.) of sodium *tert*-butoxide were added in sequence under the atmosphere of nitrogen. The solution was refluxed overnight, thereafter, cooled down to room temperature. The solution was filtered through a pad of silica gel. All volatiles were removed from the solution *via* rotary evaporation to give a brown sticky oil. And the residue was purified by flash column chromatography using PE/EtOAc = 10/1 as the eluent to give 0.72 g (2.4 mmol, 67% yield) of the title compound as a pale yellow solid. M.p. 133.2-135.4 ^oC. IR (cm^{-1}): 2925, 1638, 1578, 1531, 1500, 1452. ^1H NMR: (400 MHz, $CDCl_3$) δ 11.71 (brs, 1H), 8.00 (d, $J_{H\text{-}H}$ = 8.4 Hz, 1H), 7.90 (dd, $J_{H\text{-}H}$ = 8.0, 1.6 Hz, 1H), 7.85 (d, $J_{H\text{-}H}$ = 8.4 Hz, 1H), 7.78 (d, $J_{H\text{-}H}$ = 7.6 Hz, 1H), 7.40-7.34 (m, 2H), 7.32-7.26 (m, 2H), 6.90-6.83 (m, 1H), 4.43-4.35 (m, 2H), 4.29-4.21 (m, 2H), 2.79 (s, 3H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 164.4, 156.8, 143.6, 138.5, 136.1, 131.6, 130.3, 127.2, 125.8, 122.2, 118.4, 118.2, 115.2, 113.4, 111.7, 66.0, 55.2, 25.5; HRMS (ESI) calculated for $[C_{19}H_{18}N_3O]^+$ $[M+H]^+$ requires m/z 304.1444, found m/z 304.1445.

III. Cobalt-Catalyzed Highly α-Selective Hydrostannylation of Terminal Alkynes

Table S1. Some Phosphine Ligands for Hydrostannylation of Phenylacetylene





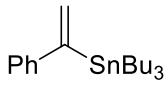
Entry	Changes of conditions	Yield (%)[b]	Ratio[c] (α/β)
1	**Xanphos**	22	0/100
2	**Dpephos**	17	0/100
3	**dppbz**	46	7/93
4	**dppp**	27	7/93
5	**dppb**	17	0/100
6	**dppe**	42	10/90
7	**dppf**	52	6/94
8	**rac-BINAP**	19	0/100

[a] Reaction conditions: **1a** (0.6 mmol), **2a** (1.2 equiv.), $Co(OAc)_2$ (2 mol%), **L** (2.4 mol%) in THF (1.2 ml) at room temperature in glovebox for 1 h. [b] Yield was determined by ^1H NMR using TMSPh as an internal standard. [c] Ratio was determined by ^1H NMR of the crude reaction mixture.

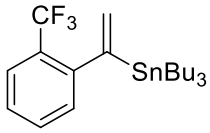
General procedure:

In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with $Co(OAc)_2$ (0.012 mmol, 2 mol%), **L7** (0.0144 mmol, 2.4 mol %), and THF (1.2 mL, 0.5 M). The mixture was stirred for 30 mins. Then $HSnBu_3$ (0.72 mmol, 1.2 equiv.) and alkynes (0.60 mmol, 1.0 equiv.) were added sequentially. The mixture was stirred at ambient temperature

for several hours, and quenched by 5 mL of petroleum ether (PE) and stirred for 5 mins until catalyst precipitated. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (15 mL × 3) (or other suitable solvent). The combined filtrates were concentrated *in vacuo.* NMR yield was monitored by ^1H NMR analysis using TMSPh as internal standard. The crude mixture was purified by short flash column chromatography to give the corresponding product.

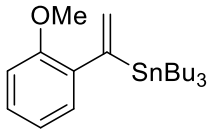


Tributyl(1-phenylvinyl)stannane (3a). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 66 μL (0.93 g/mL, 0.60 mmol) of phenylacetylene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2130 g (0.54 mmol, 90% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^1H NMR analysis of the isolated mixture. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.23-7.33 (m, 2H), 7.13-7.23 (m, 3H), 6.03 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 128 Hz, 1H), 5.42 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.60-1.40 (m, 6H), 1.35-1.23 (m, 6H), 1.07-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.7, 146.4, 128.2, 126.7, 126.3, 126.2, 29.0, 27.3, 13.6, 10.3; The spectroscopic data are in accordance with the literature.[18]

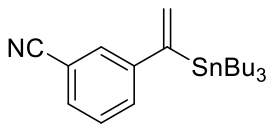


Tributyl(1-(2-(trifluoromethyl)phenyl)vinyl)stannane (3b). Prepared according to the general procedure using 0.0024 g (0.014 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1022 g (0.60 mmol) of 1-ethynyl-2-(trifluoromethyl)benzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2684 g (0.58 mmol, 97% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the

^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2926, 2853, 1604, 1572, 1485, 1451. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.58 (d, $J_{H\text{-}H}$ = 8.0 Hz, 1H), 7.40 (dd, $J_{H\text{-}H}$ = 7.6, 7.2 Hz, 1H), 7.21 (dd, $J_{H\text{-}H}$ = 7.6, 7.2 Hz, 1H), 6.97 (d, $J_{H\text{-}H}$ = 8.0 Hz, 1H), 5.78 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 121 Hz, 1H), 5.54 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.50-1.35 (m, 6H), 1.32-1.20 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 153.5, 147.2, 131.1, 128.5 (q, J = 5.9 Hz), 128.4, 125.9 (q, J = 29.2 Hz), 125.8 (q, J = 5.1 Hz), 125.1, 124.1 (q, J = 274.8 Hz), 28.7, 27.3, 13.6, 10.3; ^{19}F NMR: (376 MHz) δ -57.6; HRMS (EI) calculated for $[C_{17}H_{24}F_3Sn]^+$[M-Bu]$^+$ requires m/z 405.0852, found m/z 405.0851.

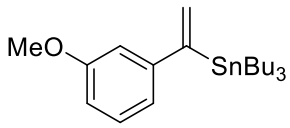


Tributyl(1-(2-methoxyphenyl)vinyl)stannane (3c). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0793 g (0.60 mmol) of 1-ethynyl-2-methoxybenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2324 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.21-7.14 (m, 1H), 7.13-7.08 (m, 1H), 6.91 (dd, $J_{H\text{-}H}$ = 7.6, 7.2 Hz, 1H), 6.78 (d, $J_{H\text{-}H}$ = 8.0 Hz, 1H), 5.95 (d, $J_{H\text{-}H}$ = 3.2 Hz, $J_{Sn\text{-}H}$ = 131 Hz, 1H), 5.39 (d, $J_{H\text{-}H}$ = 3.2 Hz, $J_{Sn\text{-}H}$ = 62 Hz, 1H), 3.78 (s, 3H), 1.53-1.38 (m, 6H), 1.34-1.21 (m, 6H), 0.98-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.0, 149.2, 143.1, 126.1, 126.0, 125.2, 34.4, 31.4, 29.1, 29.0, 27.3, 13.7, 10.3; The spectroscopic data are in accordance with the literature.[19]

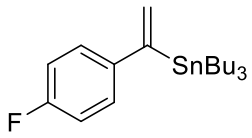


3-(1-(Tributylstannyl)vinyl)benzonitrile (3d). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%,

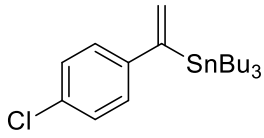
0.72 mmol) of $HSnBu_3$, 0.0762 g (0.60 mmol) of 3-ethynylbenzonitrile and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2334 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2925, 2852, 1593, 1462. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.50-7.45 (m, 1H), 7.45-7.32 (m, 3H), 6.01 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 119 Hz, 1H), 5.52 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 57 Hz, 1H), 1.60-1.40 (m, 6H), 1.35-1.22 (m, 6H), 1.05-0.90 (m, 6H), 0.87 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 153.1, 148.0, 130.7, 129.6, 129.5, 129.03, 129.00, 119.0, 112.3, 28.9, 27.2, 13.6, 10.3; HRMS (ESI) calculated for $[C_{21}H_{33}NNaSn]^+$[M+Na]$^+$ requires m/z 442.1527, found m/z 442.1529.



Tributyl(1-(3-methoxyphenyl)vinyl)stannane (3e). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0793 g (0.60 mmol) of 1-ethynyl-3-methoxybenzene and 1.2 mL (0.5 M) of THF. After 24 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2227g (0.53 mmol, 88% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2926, 2852, 1596, 1574, 1461. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.20 (dd, $J_{H\text{-}H}$ = 8.0, 7.6 Hz, 1H), 6.80-6.70 (m, 3H), 6.03 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 127 Hz, 1H), 5.41 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 3.81 (s, 3H), 1.55-1.43 (m, 6H), 1.35-1.24 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 159.5, 154.6, 148.0, 129.2, 126.8, 118.9, 111.8, 111.5, 55.1, 29.0, 27.3, 13.7, 10.3; HRMS (ESI) calculated for $[C_{21}H_{37}OSn]^+$[M+H]$^+$ requires m/z 425.1861, found m/z 425.1860.

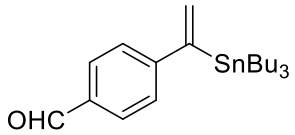


Tributyl(1-(4-fluorophenyl)vinyl)stannane (3f). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0719 g (0.60 mmol) of 1-ethynyl-4-fluorobenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2319 g (0.56 mmol, 94% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98.5/1.5 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2925, 2853, 1598, 1503, 1461, 1416. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.15-7.08 (m, 2H), 6.97 (dd, $J_{H\text{-}H}$ = 8.8, 8.4 Hz, 2H), 5.98 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 126 Hz, 1H), 5.40 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.55-1.42 (m, 6H), 1.35-1.23 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 161.7 (d, J = 244.0 Hz), 153.5, 142.5 (d, J = 2.9 Hz), 127.7 (d, J = 7.2 Hz), 126.8, 115.0 (d, J = 21.2 Hz), 29.0, 27.3, 13.6, 10.2; ^{19}F NMR: (376 MHz) δ -117.1; HRMS (EI) calculated for $[C_{16}H_{24}FSn]^+[M\text{-}Bu]^+$ requires m/z 355.0884, found m/z 355.0890.

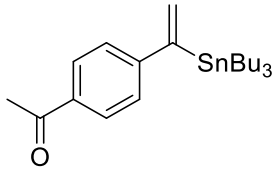


Tributyl(1-(4-chlorophenyl)vinyl)stannane (3g). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0819 g (0.60 mmol) of 1-chloro-4-ethynylbenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2463 g (0.58 mmol, 96% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97.5/2.5 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2924, 2852, 1589, 1460, 1416. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30-7.22 (m, 2H), 7.13-7.03 (m, 2H), 6.00 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 125 Hz, 1H), 5.42 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 59 Hz, 1H), 1.55-1.40 (m, 6H), 1.35-1.23 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C

NMR: (100 MHz, $CDCl_3$) δ 153.5, 145.0, 131.9, 128.4, 127.5, 127.4, 29.0, 27.3, 13.6, 10.2; HRMS (EI) calculated for $[C_{16}H_{24}ClSn]^+[M\text{-}Bu]^+$ requires m/z 371.0589, found m/z 371.0593.

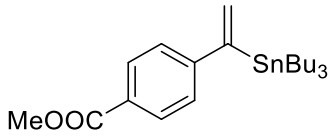


4-(1-(Tributylstannyl)vinyl)benzaldehyde (3h). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0781 g (0.60 mmol) of 4-ethynylbenzaldehyde and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2446 g (0.58 mmol, 97% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 9.98 (s, 1H), 7.81 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 7.28 (d, $J_{H\text{-}H}$ = 8.0 Hz, 2H), 6.07 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 120 Hz, 1H), 5.54 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 1.55-1.40 (m, 6H), 1.35-1.23 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 191.8, 154.3, 153.5, 134.3, 129.9, 128.9, 126.8, 28.9, 27.2, 13.6, 10.3; The spectroscopic data are in accordance with the literature.[18]

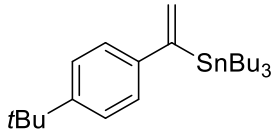


1-(4-(1-(Tributylstannyl)vinyl)phenyl)ethan-1-one (3i). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0866 g (0.60 mmol) of 1-(4-ethynylphenyl)ethan-1-one and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2545 g (0.58 mmol, 97% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be

99.5/0.5 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2925, 2871, 1684, 1600, 1557, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.90 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 7.22 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 6.06 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 122 Hz, 1H), 5.52 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 2.59 (s, 3H), 1.55-1.43 (m, 6H), 1.35-1.23 (m, 6H), 1.05-0.95 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 197.6, 154.2, 151.8, 134.9, 128.5, 128.4, 126.3, 28.9, 27.2, 26.5, 13.6, 10.3; HRMS (ESI) calculated for $[C_{22}H_{37}OSn]^+$[M+H]$^+$ requires m/z 437.1861, found m/z 437.1862.

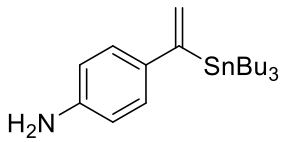


Methyl 4-(1-(tributylstannyl)vinyl)benzoate (3j). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0962 g (0.60 mmol) of methyl 4-ethynylbenzoate and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2500 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.97 (d, $J_{H\text{-}H}$ = 9.2 Hz, 2H), 7.19 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.05 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 123 Hz, 1H), 5.50 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 3.90 (s, 3H), 1.55-1.40 (m, 6H), 1.35-1.23 (m, 6H), 1.07-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 167.1, 154.3, 151.6, 129.7, 128.3, 127.7, 126.2, 51.9, 28.9, 27.2, 13.6, 10.3; The spectroscopic data are in accordance with the literature.[19]

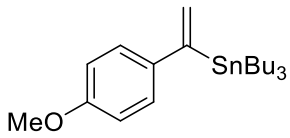


Tributyl(1-(4-(*tert*-butyl)phenyl)vinyl)stannane (3k). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0949 g (0.60 mmol) of

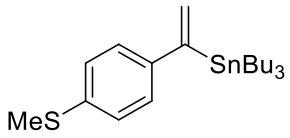
1-(*tert*-butyl)-4-ethynylbenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2480 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2958, 2927, 2853, 1506, 1462. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.31 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 7.12 (d, $J_{H\text{-}H}$ = 8.0 Hz, 2H), 6.05 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 130 Hz, 1H), 5.38 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 62 Hz, 1H), 1.55-1.43 (m, 6H), 1.35-1.23 (m, 15H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.0, 149.2, 143.1, 126.1, 126.0, 125.2, 34.4, 31.4, 29.0, 27.3, 13.7, 10.3; HRMS (ESI) calculated for $[C_{24}H_{43}Sn]^{+}$[M+H]$^{+}$ requires m/z 451.2381, found m/z 451.2379.



4-(1-(Tributylstannyl)vinyl)aniline (3l). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7,** 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0351 g (0.30 mmol) of 4-ethynylaniline and 1.2 mL (0.25 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 5/1 as the eluent to give 0.1163 g (0.29 mmol, 95% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3377, 2956, 2925, 2850, 1619, 1510, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.03 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 6.62 (d, $J_{H\text{-}H}$ = 8.4 Hz, $J_{Sn\text{-}H}$ = 132 Hz, 2H), 5.98 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 62 Hz, 1H), 5.26 (d, $J_{H\text{-}H}$ = 2.0 Hz, 1H), 3.61 (brs, 2H), 1.58-1.42 (m, 6H), 1.37-1.24 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 153.6, 145.0, 136.4, 127.4, 123.9, 115.0, 29.0, 27.3, 13.6, 10.2; HRMS (ESI) calculated for $[C_{20}H_{36}NSn]^{+}$[M+H]$^{+}$ requires m/z 410.1864, found m/z 410.1866.

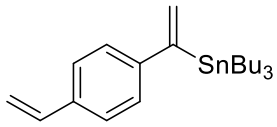


Tributyl(1-(4-methoxyphenyl)vinyl)stannane (3m). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0794 g (0.60 mmol) of 1-ethynyl-4-methoxybenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2481 g (0.59 mmol, 98% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.13 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.84 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.00 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 130 Hz, 1H), 5.33 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 61 Hz, 1H), 3.79 (s, 3H), 1.57-1.43 (m, 6H), 1.37-1.23 (m, 6H), 1.05-0.90 (m, 6H), 0.86 (m, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 158.3, 153.5, 138.7, 127.4, 125.2, 113.7, 55.2, 29.0, 27.3, 13.7, 10.2; The spectroscopic data are in accordance with the literature.[18]

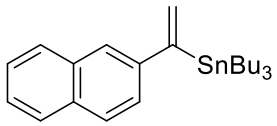


Tributyl(1-(4-(methylthio)phenyl)vinyl)stannane (3n). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0063 g (0.0180 mmol) of **L7,** 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0443 g (0.30 mmol) of (4-ethynylphenyl)(methyl)sulfane and 1.2 mL (0.25 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1194 g (0.27 mmol, 91% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99.5/0.5 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2923, 2851, 1592, 1548, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.20 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 7.10 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.02 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 128 Hz, 1H), 5.39 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 2.48 (s, 3H), 1.54-1.42 (m, 6H), 1.35-1.23 (m, 6H), 1.05-0.92 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 153.8, 143.4, 136.0, 126.8, 126.4, 29.0,

27.3, 16.1, 13.6, 10.3; HRMS (ESI) calculated for $[C_{21}H_{37}SSn]^+[M+H]^+$ requires m/z 441.1632, found m/z 441.1633.

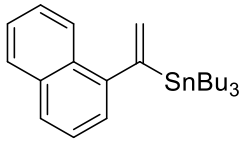


Tributyl(1-(4-vinylphenyl)vinyl)stannane (3o). Prepared according to the general procedure using 0.0021 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0773 g (0.60 mmol) of 1-ethynyl-4-vinylbenzene and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1786 g (0.43 mmol, 71% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97/3 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2925, 2852, 1597, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.34 (d, $J_{H\text{-}H}$ = 8.0 Hz, 2H), 7.13 (d, $J_{H\text{-}H}$ = 7.6 Hz, 2H), 6.70 (dd, $J_{H\text{-}H}$ = 19.6, 10.8 Hz, 1H), 6.04 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 128 Hz, 1H), 5.72 (d, $J_{H\text{-}H}$ = 19.6 Hz, 1H), 5.41 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 5.20 (d, $J_{H\text{-}H}$ = 10.8 Hz, 1H), 1.53-1.40 (m, 6H), 1.34-1.25 (m, 6H), 1.05-0.95 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.2, 145.9, 136.6, 135.6, 126.7, 126.5, 126.2, 113.1, 29.0, 27.3, 13.7, 10.3; HRMS (EI) calculated for $[C_{18}H_{27}Sn]^+[M\text{-}Bu]^+$ requires m/z 363.1135, found m/z 363.1132.

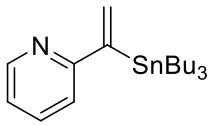


Tributyl(1-(naphthalen-2-yl)vinyl)stannane (3p). Prepared according to the general procedure using 0.0024 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0900 g (0.59 mmol) of 2-ethynylnaphthalene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2473 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz,

$CDCl_3$) δ 7.83-7.72 (m, 3H), 7.60-7.54 (m, 1H), 7.47-7.34 (m, 3H), 6.16 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 127 Hz, 1H), 5.51 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.58-1.46 (m, 6H), 1.37-1.25 (m, 6H), 1.10-0.95 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.6, 143.8, 133.6, 132.2, 127.9, 127.8, 127.6, 127.2, 126.0, 125.3, 125.1, 124.9, 29.0, 27.3, 13.7, 10.4; The spectroscopic data are in accordance with the literature.[18]

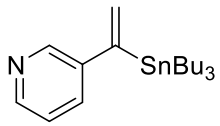


Tributyl(1-(naphthalen-1-yl)vinyl)stannane (3q). Prepared according to the general procedure using 0.0024 g (0.013 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0913 g (0.60 mmol) of 1-ethynylnaphthalene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2207 g (0.50 mmol, 83% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2926, 2851, 1576, 1460, 1419. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.97-7.90 (m, 1H), 7.85-7.78 (m, 1H), 7.65 (d, $J_{H\text{-}H}$ = 8.4 Hz, 1H), 7.48-7.30 (m, 3H), 7.08-7.02 (m, 1H), 5.95 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 124 Hz, 1H), 5.72 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.48-1.30 (m, 6H), 1.28-1.15 (m, 6H), 0.95-0.72 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.9, 145.6, 133.6, 130.5, 128.8, 128.2, 125.9, 125.7, 125.6, 125.4, 125.1, 122.7, 28.9, 27.3, 13.6, 10.4; HRMS (EI) calculated for $[C_{20}H_{28}Sn]^+$[M-C_4H_8]$^+$ requires m/z 388.1213, found m/z 388.1208.

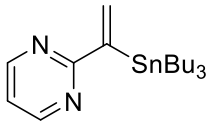


2-(1-(Tributylstannyl)vinyl)pyridine (3r). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0616 g (0.60 mmol) of 2-ethynylpyridine and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the

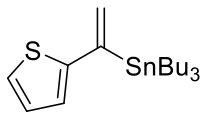
crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.1438 g (0.37 mmol, 61% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2955, 2924, 2851, 1583, 1461, 1429. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.52-8.43 (m, 1H), 7.63-7.54 (m, 1H), 7.50-7.43 (m, 1H), 7.10-7.00 (m, 1H), 6.46 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 132 Hz, 1H), 5.67 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 1.60-1.40 (m, 6H), 1.35-1.23 (m, 6H), 1.08-0.90 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 161.9, 157.0, 148.7, 136.0, 127.0, 121.2, 117.9, 29.1, 27.3, 13.7, 10.6; HRMS (ESI) calculated for $[C_{19}H_{34}NSn]^+$[M+H]$^+$ requires m/z 396.1708, found m/z 396.1709.



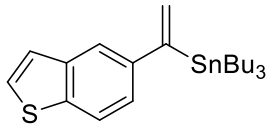
3-(1-(Tributylstannyl)vinyl)pyridine (3s). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0619 g (0.60 mmol) of 3-ethynylpyridine and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2223 g (0.56 mmol, 94% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2926, 2851, 1561, 1464, 1406. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.48-8.38 (m, 2H), 7.50-7.40 (m, 1H), 7.21 (dd, $J_{H\text{-}H}$ = 7.6, 4.8 Hz, 1H), 6.06 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 121 Hz, 1H), 5.53 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 1.58-1.40 (m, 6H), 1.37-1.24 (m, 6H), 1.08-0.95 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 151.1, 147.6, 147.4, 133.2, 128.9, 123.1, 28.9, 27.2, 13.6, 10.2; HRMS (ESI) calculated for $[C_{19}H_{34}NSn]^+$[M+H]$^+$ requires m/z 396.1708, found m/z 396.1710.



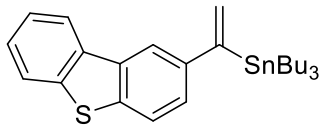
2-(1-(Tributylstannyl)vinyl)pyrimidine (3t). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0622 g (0.60 mmol) of 2-ethynylpyrimidine and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE/EtOAc = 5/1 as the eluent to give 0.1216 g (0.31 mmol, 52% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2924, 2851, 1564, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.66 (d, $J_{H\text{-}H}$ = 4.8 Hz, 2H), 7.13 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 123 Hz, 1H), 7.05 (t, $J_{H\text{-}H}$ = 4.8 Hz, 1H), 5.90 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 1.59-1.41 (m, 6H), 1.35-1.25 (m, 6H), 1.08-0.91 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.6 Hz, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.7, 154.7, 133.3, 118.2, 29.1, 27.3, 13.7, 10.4; HRMS (ESI) calculated for $[C_{14}H_{23}N_2Sn]^+$[M-Bu]$^+$ requires m/z 339.0883, found m/z 339.0877.



Tributyl(1-(thiophen-2-yl)vinyl)stannane (3u). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7,** 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0328 g (0.30 mmol) of 2-ethynylthiophene and 1.2 mL (0.25 M) of THF. After 12 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1104 g (0.28 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.12 (dd, $J_{H\text{-}H}$ = 4.8, 0.8 Hz, 1H), 6.94 (dd, $J_{H\text{-}H}$ = 5.2, 3.6 Hz, 1H), 6.79 (dd, $J_{H\text{-}H}$ = 3.6, 1.2 Hz, 1H), 6.15 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 132 Hz, 1H), 5.28 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 58 Hz, 1H), 1.58-1.45 (m, 6H), 1.38-1.25 (m, 6H), 1.12-0.95 (m, 6H), 0.88 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 150.2, 145.0, 127.1, 125.1, 124.7, 123.7, 29.0, 27.3, 13.6, 10.3; The spectroscopic data are in accordance with the literature.[18]

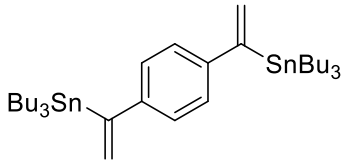


(1-(Benzo[*b*]thiophen-5-yl)vinyl)tributylstannane (3v). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0950 g (0.60 mmol) of 5-ethynylbenzo[*b*]thiophene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2468 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2924, 2850, 1583, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.78 (d, $J_{H\text{-}H}$ = 8.4 Hz, 1H), 7.59 (d, $J_{H\text{-}H}$ = 5.6 Hz, 1H), 7.39 (d, $J_{H\text{-}H}$ = 5.2 Hz, 1H), 7.29 (d, $J_{H\text{-}H}$ = 5.2 Hz, 1H), 7.19 (dd, $J_{H\text{-}H}$ = 8.0, 1.6 Hz, 1H), 6.09 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 128 Hz, 1H), 5.46 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 1.58-1.43 (m, 6H), 1.35-1.25 (m, 6H), 1.10-0.94 (m, 6H), 0.86 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.6, 142.9, 139.9, 137.7, 126.8, 126.5, 123.9, 123.3, 122.1, 120.9, 29.0, 27.3, 13.7, 10.3; HRMS (EI) calculated for $[C_{22}H_{34}SSn]^+[M]^+$ requires m/z 450.1403, found m/z 450.1404.

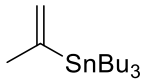


Tributyl(1-(dibenzo[*b,d*]thiophen-2-yl)vinyl)stannane (3w). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1250 g (0.60 mmol) of 2-ethynyldibenzo[*b,d*]thiophene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2756 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99.5/0.5 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2955, 2924, 2851, 1544, 1462. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.16-8.08 (m, 1H), 7.94 (d, $J_{H\text{-}H}$ = 1.6 Hz, 1H), 7.86-7.80 (m, 1H), 7.76 (d, $J_{H\text{-}H}$ =

8.4 Hz, 1H), 7.48-7.40 (m, 2H), 7.30 (dd, J_{H-H} = 8.4, 1.6 Hz, 1H), 6.15 (d, J_{H-H} = 2.4 Hz, J_{Sn-H} = 127 Hz, 1H), 5.51 (d, J_{H-H} = 2.0 Hz, J_{Sn-H} = 60 Hz, 1H), 1.63-1.48 (m, 6H), 1.38-1.25 (m, 6H), 1.10-0.95 (m, 6H), 0.87 (t, J_{H-H} = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.5, 143.1, 139.9, 137.3, 135.7, 135.6, 127.0, 126.6, 125.4, 124.3, 122.9, 122.5, 121.4, 119.1, 29.1, 27.3, 13.7, 10.4; HRMS (EI) calculated for $[C_{26}H_{36}SSn]^+$[M]$^+$ requires m/z 500.1560, found m/z 500.1557.

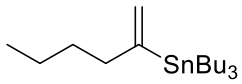


1,4-Bis(1-(tributylstannyl)vinyl)benzene (3x). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 396 μL (1.08 g/mL, 97%, 1.44 mmol) of $HSnBu_3$, 0.0757 g (0.60 mmol) of 1,4-diethynylbenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.3954 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2926, 2852, 1599, 1500, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.11 (s, 4H), 6.05 (d, J_{H-H} = 2.4 Hz, J_{Sn-H} = 129 Hz, 2H), 5.39 (d, J_{H-H} = 2.4 Hz, J_{Sn-H} = 61 Hz, 2H), 1.55-1.43 (m, 12H), 1.35-1.24 (m, 12H), 1.05-0.94 (m, 12H), 0.86 (t, J_{H-H} = 7.2 Hz, 18H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.2, 144.3, 126.3, 126.2, 29.0, 27.3, 13.7, 10.3; HRMS (ESI) calculated for $[C_{34}H_{63}Sn_2]^+$[M+H]$^+$ requires m/z 711.2968, found m/z 711.2977.

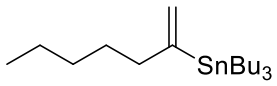


Tributyl(prop-1-en-2-yl)stannane (3y). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 600 μL (1 M in THF, 0.60 mmol) of prop-1-yne and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1917 g (0.58 mmol, 96% yield) of the title compound as a colorless oil. The ratio of α/β

was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2927, 2851, 1458. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.73-5.63 (m, J_{Sn-H} = 138 Hz, 1H), 5.12-5.03 (m, J_{Sn-H} = 62 Hz, 1H), 2.05-1.88 (m, J_{Sn-H} = 42 Hz, 3H), 1.58-1.40 (m, 6H), 1.38-1.25 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 150.4, 125.5, 29.1, 27.4, 27.3, 13.7, 9.1; HRMS (EI) calculated for $[C_{11}H_{24}Sn]^{+}[M\text{-}C_4H_8]^{+}$ requires m/z 276.0900, found m/z 276.0900.

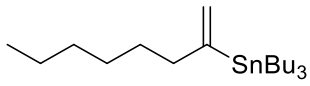


Tributyl(hex-1-en-2-yl)stannane (3z). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 70 μL (0.72 g/mL, 0.60 mmol) of hex-1-yne and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2239 g (0.60 mmol, >99% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.86-5.45 (m, J_{Sn-H} = 141 Hz, 1H), 5.20-4.98 (m, J_{Sn-H} = 64 Hz, 1H), 2.24 (t, J_{H-H} = 7.2 Hz, J_{Sn-H} = 48 Hz, 2H), 1.60-1.40 (m, 6H), 1.38-1.25 (m, 10H), 0.95-0.80 (m, 18H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 155.7, 124.5, 41.1, 31.9, 29.1, 27.4, 22.3, 13.9, 13.7, 9.5; The spectroscopic data are in accordance with the literature.[18]

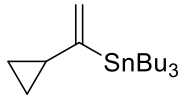


Tributyl(hept-1-en-2-yl)stannane (3aa). Prepared according to the general procedure using 0.0021 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0578 g (0.60 mmol) of 1-heptyne and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1915 g (0.49 mmol, 82% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2958, 2926, 2853, 1461. ^{1}H

NMR: (400 MHz, $CDCl_3$) δ 5.65 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 142 Hz, 1H), 5.09 (d, $J_{H\text{-}H}$ = 2.8 Hz, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 2.23 (t, $J_{H\text{-}H}$ = 6.4 Hz, $J_{Sn\text{-}H}$ = 48 Hz, 2H), 1.54-1.45 (m, 6H), 1.38-1.25 (m, 12H), 0.96-0.80 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.8, 124.5, 41.4, 31.6, 29.4, 29.2, 27.4, 22.6, 14.1, 13.7, 9.6; HRMS (EI) calculated for $[C_{15}H_{31}Sn]^+$[M-Bu]$^+$ requires m/z 331.1448, found m/z 331.1449.

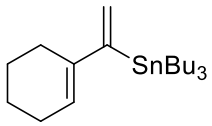


Tributyl(oct-1-en-2-yl)stannane (3ab). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0661 g (0.60 mmol) of oct-1-yne and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2251 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.85-5.45 (m, $J_{Sn\text{-}H}$ = 141 Hz, 1H), 5.20-4.98 (m, $J_{Sn\text{-}H}$ = 64 Hz, 1H), 2.23 (t, $J_{H\text{-}H}$ = 7.2 Hz, $J_{Sn\text{-}H}$ = 48 Hz, 2H), 1.55-1.43 (m, 6H), 1.38-1.23 (m, 14H), 1.00-0.80 (m, 18H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 155.8, 124.5, 41.5, 31.8, 29.7, 29.2, 29.0, 27.4, 22.7, 14.1, 13.7, 9.6; The spectroscopic data are in accordance with the literature.[20]

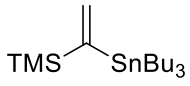


Tributyl(1-cyclopropylvinyl)stannane (3ac). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 51 μL (0.78 g/mL, 0.60 mmol) of ethynylcyclopropane and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2143 g (0.60 mmol, >99% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz,

$CDCl_3$) δ 5.84-5.42 (m, J_{Sn-H} = 136 Hz, 1H), 5.13-4.92 (m, J_{Sn-H} = 62 Hz, 1H), 1.60-1.40 (m, 7H), 1.38-1.28 (m, 6H), 1.00-0.80 (m, 15H), 0.70-0.60 (m, 2H), 0.50-0.35 (m, 2H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 157.0, 121.6, 29.1, 27.4, 20.3, 13.7, 9.7, 6.9; The spectroscopic data are in accordance with the literature.[21]

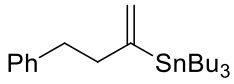


Tributyl(1-(cyclohex-1-en-1-yl)vinyl)stannane (3ad). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0620 g (0.58 mmol) of 1-ethynylcyclohex-1-ene and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1359 g (0.34 mmol, 59% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.81 (d, J_{H-H} = 2.0 Hz, J_{Sn-H} = 140 Hz, 1H), 5.56 (t, J_{H-H} = 4.0 Hz, 1H), 5.12 (d, J_{H-H} = 2.0 Hz, J_{Sn-H} = 67 Hz, 1H), 2.22-2.07 (m, 4H), 1.72-1.63 (m, 2H), 1.62-1.53 (m, 2H), 1.52-1.42 (m, 6H), 1.37-1.24 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 155.7, 141.0, 128.5, 121.4, 29.1, 27.3, 26.2, 26.0, 22.9, 22.5, 13.7, 10.3; The spectroscopic data are in accordance with the literature.[18]

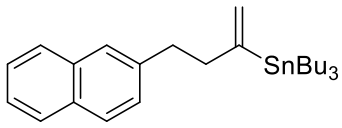


Trimethyl(1-(tributylstannyl)vinyl)silane (3ae). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 87 μL (0.695 g/mL, 0.60 mmol) of ethynyltrimethylsilane and 1.2 mL (0.5 M) of THF. After 24 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1873 g (0.48 mmol, 80% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97/3 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}):

2956, 2925, 2853, 1461. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 6.57 (d, $J_{H\text{-}H}$ = 4.4 Hz, $J_{Sn\text{-}H}$ = 178 Hz, 1H), 6.30 (d, $J_{H\text{-}H}$ = 4.8 Hz, $J_{Sn\text{-}H}$ = 107 Hz, 1H), 1.62-1.50 (m, 6H), 1.45-1.35 (m, 6H), 1.05-0.90 (m, 15H), 0.15 (s, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 156.7, 140.5, 29.1, 27.4, 13.7, 9.8, -0.8; HRMS (EI) calculated for $[C_{13}H_{31}SiSn]^{+}[M\text{-}C_4H_7]^{+}$ requires m/z 335.1217, found m/z 335.1221.

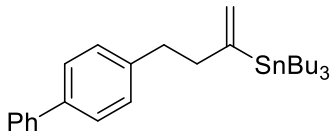


Tributyl(4-phenylbut-1-en-2-yl)stannane (3af). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0781 g (0.60 mmol) of but-3-yn-1-ylbenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2376 g (0.56 mmol, 94% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.32-7.24 (m, 2H), 7.22-7.13 (m, 3H), 5.95-5.53 (m, $J_{Sn\text{-}H}$ = 139 Hz, 1H), 5.26-5.05 (m, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 2.73-2.63 (m, 2H), 2.60-2.43 (m, 2H), 1.58-1.43 (m, 6H), 1.38-1.28 (m, 6H), 0.98-0.85 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.7, 142.2, 128.4, 128.3, 125.8, 125.2, 43.2, 36.2, 29.2, 27.4, 13.7, 9.6; The spectroscopic data are in accordance with the literature.[22]

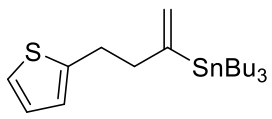


Tributyl(4-(naphthalen-2-yl)but-1-en-2-yl)stannane (3ag). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1082 g (0.60 mmol) of 2-(but-3-yn-1-yl)naphthalene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2432 g (0.52 mmol, 86% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3051, 2956, 2924, 2850, 1600, 1458. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.82-7.72 (m, 3H),

7.61 (s, 1H), 7.47-7.37 (m, 2H), 7.33 (dd, J_{H-H} = 8.4, 1.6 Hz, 1H), 5.95-5.55 (m, J_{Sn-H} = 138 Hz, 1H), 5.28-5.08 (m, J_{Sn-H} = 64 Hz, 1H), 2.90-2.80 (m, 2H), 2.72-2.55 (m, 2H), 1.63-1.40 (m, 6H), 1.40-1.28 (m, 6H), 1.05-0.85 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.6, 139.7, 133.6, 132.0, 127.8, 127.6, 127.4, 127.3, 126.3, 125.9, 125.3, 125.1, 43.1, 36.4, 29.2, 27.4, 13.7, 9.6; HRMS (EI) calculated for $[C_{26}H_{40}Sn]^+[M]^+$ requires m/z 472.2152, found m/z 472.2156.

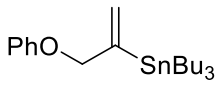


(4-([1,1'-Biphenyl]-4-yl)but-1-en-2-yl)tributylstannane (3ah). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1240 g (0.60 mmol) of 4-(but-3-yn-1-yl)-1,1'-biphenyl and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2577 g (0.52 mmol, 86% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3029, 2956, 2925, 2850, 1601, 1456. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.60-7.55 (m, 2H), 7.52 (d, J_{H-H} = 8.0 Hz, 2H), 7.45-7.38 (m, 2H), 7.34-7.28 (m, 1H), 7.26 (d, J_{H-H} = 8.0 Hz, 2H), 5.96-5.55 (m, J_{Sn-H} = 138 Hz, 1H), 5.30-5.05 (m, J_{Sn-H} = 63 Hz, 1H), 2.78-2.68 (m, 2H), 2.65-2.50 (m, 2H), 1.60-1.45 (m, 6H), 1.40-1.28 (m, 6H), 1.05-0.85 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 154.6, 141.4, 141.1, 138.7, 128.8, 128.7, 127.05, 126.98, 125.2, 43.1, 35.8, 29.2, 27.4, 13.7, 9.6; HRMS (EI) calculated for $[C_{28}H_{42}Sn]^+[M]^+$ requires m/z 498.2308, found m/z 498.2307.

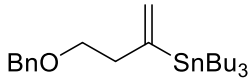


Tributyl(4-(thiophen-2-yl)but-1-en-2-yl)stannane (3ai). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0052 g (0.0150 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0817 g (0.60 mmol) of 2-(but-3-yn-1-yl)thiophene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate

was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2393 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2926, 2849, 1456. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.10 (dd, $J_{H\text{-}H}$ = 5.2, 1.2 Hz, 1H), 6.91 (dd, $J_{H\text{-}H}$ = 5.2, 3.6 Hz, 1H), 6.83-6.78 (m, 1H), 5.95-5.55 (m, $J_{Sn\text{-}H}$ = 137 Hz, 1H), 5.28-5.08 (m, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 2.95-2.85 (m, 2H), 2.70-2.55 (m, 2H), 1.60-1.40 (m, 6H), 1.38-1.28 (m, 6H), 1.05-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 153.9, 145.0, 126.6, 125.6, 124.0, 122.9, 43.2, 30.1, 29.1, 27.4, 13.7, 9.6; HRMS (EI) calculated for $[C_{20}H_{37}SSn]^{+}$[M+H]$^{+}$ requires m/z 429.1632, found m/z 429.1635.

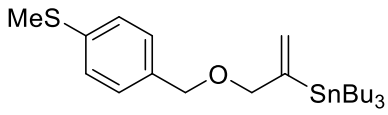


Tributyl(3-phenoxyprop-1-en-2-yl)stannane (3aj). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0794 g (0.60 mmol) of (prop-2-yn-1-yloxy)benzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2470 g (0.58 mmol, 97% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30-7.20 (m, 2H), 6.95-6.85 (m, 3H), 5.97 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 126 Hz, 1H), 5.35 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 4.65 (t, $J_{H\text{-}H}$ = 1.6 Hz, 2H), 1.60-1.40 (m, 6H), 1.36-1.24 (m, 6H), 1.05-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 158.7, 151.6, 129.3, 125.1, 120.5, 114.6, 74.8, 29.1, 27.3, 13.7, 9.7; The spectroscopic data are in accordance with the literature.[23]

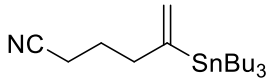


(4-(Benzyloxy)but-1-en-2-yl)tributylstannane (3ak). Prepared according to the general procedure using 0.0020 g (0.011 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL

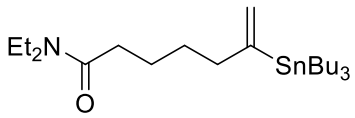
(1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0878 g (0.60 mmol) of ((but-3-yn-1-yloxy)methyl)benzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2282 g (0.52 mmol, 87% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.38-7.31 (m, 4H), 7.30-7.23 (m, 1H), 5.95-5.55 (m, J_{Sn-H} = 136 Hz, 1H), 5.19 (d, J_{H-H} = 2.4 Hz, J_{Sn-H} = 61 Hz, 1H), 4.51 (s, 2H), 3.48 (t, J_{H-H} = 7.2 Hz, 2H), 2.57 (t, J_{H-H} = 7.2 Hz, J_{Sn-H} = 45 Hz, 2H), 1.55-1.40 (m, 6H), 1.35-1.24 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 151.5, 138.4, 128.3, 127.7, 127.5, 126.9, 73.0, 70.2, 41.3, 29.1, 27.4, 13.7, 9.6; The spectroscopic data are in accordance with the literature.[24]



Tributyl(3-(4-(methylthio)benzyl)oxy)prop-1-en-2-yl)stannane (3al). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1154 g (0.60 mmol) of methyl(4-(prop-2-yn-1-yloxy)phenyl)sulfane and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2697 g (0.56 mmol, 93% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2955, 2923, 2848, 1602, 1494, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30-7.20 (m, 4H), 6.05-5.68 (m, J_{Sn-H} = 130 Hz, 1H), 5.40-5.15 (m, J_{Sn-H} = 62 Hz, 1H), 4.43 (s, 2H), 4.13 (s, 2H), 2.47 (s, 3H), 1.55-1.35 (m, 6H), 1.35-1.23 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 152.8, 137.4, 135.4, 128.3, 126.6, 124.8, 76.7, 71.6, 29.1, 27.3, 16.0, 13.7, 9.5; HRMS (ESI) calculated for $[C_{23}H_{40}NaOSSn]^+$[M+Na]$^+$ requires m/z 507.1714, found m/z 507.1717.

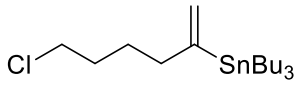


5-(Tributylstannyl)hex-5-enenitrile (3am). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0560 g (0.60 mmol) of hex-5-ynenitrile and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2167 g (0.56 mmol, 94% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.95-5.53 (m, $J_{Sn\text{-}H}$ = 134 Hz, 1H), 5.31-5.12 (m, $J_{Sn\text{-}H}$ = 61 Hz, 1H), 2.39 (t, $J_{H\text{-}H}$ = 7.2 Hz, $J_{Sn\text{-}H}$ = 45 Hz, 2H), 2.32 (t, $J_{H\text{-}H}$ = 7.2 Hz, 2H), 1.80-1.70 (m, 2H), 1.55-1.43 (m, 6H), 1.36-1.26 (m, 6H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 152.7, 126.9, 119.6, 39.6, 29.0, 27.3, 24.8, 16.3, 13.6, 9.5; The spectroscopic data are in accordance with the literature.[21]

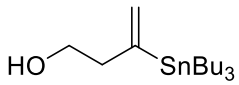


***N,N*-diethyl-6-(tributylstannyl)hept-6-enamide (3an).** Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0910 g (0.59 mmol) of *N*,*N*-diethylhept-6-ynamide and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.2078 g (0.47 mmol, 79% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2958, 2928, 2873, 1648, 1458, 1426. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.90-5.45 (m, $J_{Sn\text{-}H}$ = 140 Hz, 1H), 5.10 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 3.37 (q, $J_{H\text{-}H}$ = 7.2 Hz, 2H), 3.30 (q, $J_{H\text{-}H}$ = 7.2 Hz, 2H), 2.35-2.20 (m, 4H), 1.70-1.59 (m, 2H), 1.56-1.40 (m, 8H), 1.35-1.25 (m, 6H), 1.17 (t, $J_{H\text{-}H}$ = 7.2 Hz, 3H), 1.11 (t, $J_{H\text{-}H}$ = 7.2 Hz, 3H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 172.1, 155.1, 124.8, 41.9, 41.0, 40.0, 32.9, 29.3, 29.1, 27.3,

25.1, 14.4, 13.6, 13.1, 9.5; HRMS (ESI) calculated for $[C_{23}H_{48}NOSn]^+[M+H]^+$ requires m/z 474.2752, found m/z 474.2760.

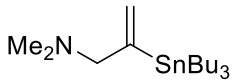


Tributyl(6-chlorohex-1-en-2-yl)stannane (3ao). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0049 g (0.0142 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0695 g (0.60 mmol) of 6-chlorohex-1-yne and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2299 g (0.56 mmol, 94% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.67 (d, $J_{H\text{-}H}$ = 1.2 Hz, $J_{Sn\text{-}H}$ = 138 Hz, 1H), 5.12 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 3.54 (t, $J_{H\text{-}H}$ = 6.8 Hz, 2H), 2.27 (t, $J_{H\text{-}H}$ = 7.2 Hz, $J_{Sn\text{-}H}$ = 46 Hz, 2H), 1.80-1.73 (m, 2H), 1.54-1.45 (m, 8H), 1.34-1.29 (m, 6H), 0.98-0.87 (m, 15H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.8, 125.3, 44.9, 40.4, 32.1, 30.6, 29.1, 27.4, 26.7, 13.7, 9.6; The spectroscopic data are in accordance with the literature.[21]

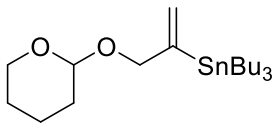


3-(Tributylstannyl)but-3-en-1-ol (3ap). Prepared according to the general procedure using 0.0019 g (0.011 mmol) of $Co(OAc)_2$, 0.0049 g (0.0142 mmol) of **L7**, 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0417 g (0.59 mmol) of but-3-yn-1-ol and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE/EtOAc = 40/1 as the eluent to give 0.1693 g (0.47 mmol, 80% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.80 (d, $J_{H\text{-}H}$ = 0.8 Hz, $J_{Sn\text{-}H}$ = 134 Hz, 1H), 5.29 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 61 Hz, 1H), 3.63 (t, $J_{H\text{-}H}$ = 6.4 Hz, 2H), 2.52 (t, $J_{H\text{-}H}$ = 6.4 Hz, $J_{Sn\text{-}H}$ = 47 Hz, 2H), 1.58-1.43 (m, 7H),

1.36-1.27 (m, 6H), 1.00-0.85 (m, 15H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.5, 128.4, 61.3, 44.2, 29.0, 27.3, 13.6, 9.6; The spectroscopic data are in accordance with the literature.[25]

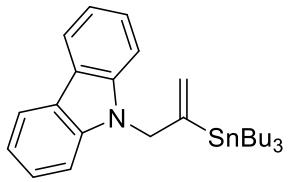


***N*,*N*-dimethyl-2-(tributylstannyl)prop-2-en-1-amine (3aq).** Prepared according to the general procedure using 0.0020 g (0.011 mmol) of $Co(OAc)_2$, 0.0053 g (0.0154 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0500 g (0.60 mmol) of *N*,*N*-dimethylprop-2-yn-1-amine and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE/EtOAc = 20/1 as the eluent to give 0.1841 g (0.50 mmol, 82% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2926, 2852, 2815, 2769, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.79-5.77 (m, J_{Sn-H} = 134 Hz, 1H), 5.19-5.18 (m, J_{Sn-H} = 61 Hz, 1H), 2.96 (s, J_{Sn-H} = 46 Hz, 2H), 2.12 (s, 6H), 1.53-1.45 (m, 6H), 1.36-1.27 (m, 6H), 0.97-0.80 (m, 15H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 124.8, 70.0, 45.4, 29.2, 27.5, 13.7, 9.6; The spectroscopic data are in accordance with the literature.[23]

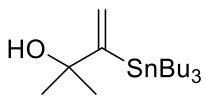


Tributyl(3-((tetrahydro-2*H*-pyran-2-yl)oxy)prop-1-en-2-yl)stannane (3ar). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0049 g (0.0142 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0851 g (0.61 mmol) of 2-(prop-2-yn-1-yloxy)tetrahydro-2*H*-pyran and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1585 g (0.37 mmol, 61% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97/3 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2954, 2927, 2872, 2850, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.88-5.86 (m, J_{Sn-H} = 131 Hz, 1H), 5.25 (d, J_{H-H} = 2.4 Hz, J_{Sn-H} = 63

Hz, 1H), 4.65-4.63 (m, 1H), 4.58-4.34 (m, J_{Sn-H} = 46 Hz, 1H), 4.11-3.99 (m, J_{Sn-H} = 46 Hz, 1H), 3.89-3.83 (m, 1H), 3.53-3.49 (m, 1H), 1.89-1.82 (m, 1H), 1.75-1.68 (m, 1H), 1.55-1.48 (m, 8H), 1.35-1.29 (m, 6H), 0.97-0.80 (m, 17H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.5, 1242, 97.9, 74.2, 61.7, 30.5, 29.1, 27.4, 25.5, 19.2, 13.7, 9.6; HRMS (ESI) calculated for $[C_{20}H_{40}NaO_2Sn]^+$[M+Na]$^+$ requires m/z 455.1942, found m/z 455.1946.

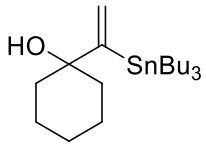


9-(2-(Tributylstannyl)allyl)-9*H*-carbazole (3as). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0052 g (0.0150 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1231 g (0.60 mmol) of 9-(prop-2-yn-1-yl)-9*H*-carbazole and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2838 g (0.57 mmol, 95% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2955, 2925, 2850, 1628, 1599, 1486. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.09 (d, J_{H-H} = 7.6 Hz, 2H), 7.45-7.38 (m, 2H), 7.30 (d, J_{H-H} = 8.0 Hz, 2H), 7.25-1.17 (m, 2H), 5.51 (d, J_{H-H} = 2.0 Hz, J_{Sn-H} = 124 Hz, 1H), 5.25 (d, J_{H-H} = 2.0 Hz, J_{Sn-H} = 59 Hz, 1H), 5.00 (s, J_{Sn-H} = 22 Hz, 2H), 1.45-1.32 (m, 6H), 1.30-1.18 (m, 6H), 0.85 (t, J_{H-H} = 7.2 Hz, 9H), 0.81-0.70 (m, 6H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 148.8, 140.6, 125.5, 122.8, 120.2, 118.9, 109.1, 51.4, 29.0, 27.3, 13.7, 9.2; HRMS (EI) calculated for $[C_{27}H_{39}NSn]^+$[M]$^+$ requires m/z 497.2104, found m/z 497.2098.

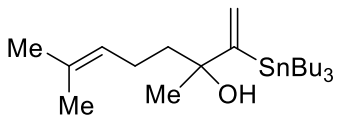


2-Methyl-3-(tributylstannyl)but-3-en-2-ol (3at). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0506 g (0.60 mmol) of 2-methylbut-3-yn-2-ol and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated

and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.1975 g (0.53 mmol, 88% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3609, 3479, 2958, 2926, 2870, 1599, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.72 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 138 Hz, 1H), 5.14 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 68 Hz, 1H), 1.55-1.45 (m, 6H), 1.35-1.25 (m, 12H), 0.95-0.85 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 164.9, 120.8, 75.7, 30.6, 29.1, 27.4, 13.7, 10.6; HRMS (EI) calculated for $[C_{13}H_{25}Sn]^+$[M-Bu-H_2O]$^+$ requires m/z 301.0978, found m/z 301.0974.

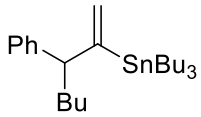


1-(1-(Tributylstannyl)vinyl)cyclohexan-1-ol (3au). Prepared according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0745 g (0.60 mmol) of 1-ethynylcyclohexan-1-ol and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.2292 g (0.55 mmol, 92% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3608, 3479, 2927, 2853, 1457. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.76 (d, $J_{H\text{-}H}$ = 1.2 Hz, $J_{Sn\text{-}H}$ = 141 Hz, 1H), 5.17 (d, $J_{H\text{-}H}$ = 1.2 Hz, $J_{Sn\text{-}H}$ = 71 Hz, 1H), 1.70-1.65 (m, 1H), 1.62-1.52 (m, 7H), 1.52-1.40 (m, 8H), 1.35-1.27 (m, 6H), 1.24-1.10 (m, 1H), 1.00-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 165.6, 120.9, 76.2, 37.8, 29.2, 27.4, 25.5, 22.1, 13.7, 10.8; HRMS (EI) calculated for $[C_{16}H_{29}Sn]^+$[M-Bu-H_2O]$^+$ requires m/z 341.1291, found m/z 341.1290.

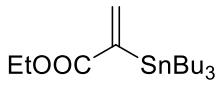


3,7-Dimethyl-2-(tributylstannyl)octa-1,6-dien-3-ol (3av). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0052 g (0.0150 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0913 g (0.60 mmol) of

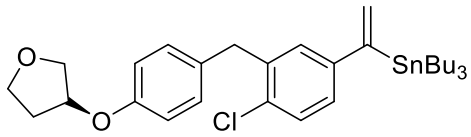
3,7-dimethyloct-6-en-1-yn-3-ol and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 50/1 as the eluent to give 0.1942 g (0.44 mmol, 73% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3609, 3477, 2957, 2924, 2854, 1457. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.68 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 140 Hz, 1H), 5.21 (d, $J_{H\text{-}H}$ = 1.6 Hz, $J_{Sn\text{-}H}$ = 67 Hz, 1H), 5.15-5.07 (m, 1H), 2.10-1.90 (m, 2H), 1.68 (s, 3H), 1.63 (s, 1H), 1.60 (s, 3H), 1.55-1.43 (m, 8H), 1.38-1.28 (m, 6H), 1.26 (s, 3H), 1.00-0.85 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 164.0, 131.8, 124.4, 121.5, 77.9, 42.3, 29.1, 29.0, 27.4, 25.7, 22.8, 17.7, 13.7, 10.6; HRMS (EI) calculated for $[C_{18}H_{33}Sn]^{+}$[M-Bu-H_2O]$^{+}$ requires m/z 369.1604, found m/z 369.1602.



Tributyl(3-phenylhept-1-en-2-yl)stannane (3aw). Prepared according to the general procedure using 0.0020 g (0.011 mmol) of $Co(OAc)_2$, 0.0049 g (0.0141 mmol) of **L7**, 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0517 g (0.60 mmol) of hept-1-yn-3-ylbenzene and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1223 g (0.26 mmol, 44% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2926, 2857, 1599, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30-7.22 (m, 2H), 7.20-7.10 (m, 3H), 6.00-5.55 (m, $J_{Sn\text{-}H}$ = 139 Hz, 1H), 5.32-5.10 (m, $J_{Sn\text{-}H}$ = 65 Hz, 1H), 3.42 (t, $J_{H\text{-}H}$ = 7.6 Hz, $J_{Sn\text{-}H}$ = 48 Hz, 1H), 1.85-1.65 (m, 2H), 1.38-1.15 (m, 16H), 0.90-0.80 (m, 12H), 0.75-0.55 (m, 6H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 159.0, 144.1, 128.2, 128.1, 126.0, 123.5, 55.2, 33.6, 30.2, 28.9, 27.4, 22.8, 14.1, 13.7, 9.8; HRMS (EI) calculated for $[C_{25}H_{44}Sn]^{+}$[M]$^{+}$ requires m/z 464.2465, found m/z 464.2469.

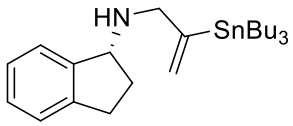


Ethyl 2-(tributylstannyl)acrylate (3ax). Prepared according to the general procedure using 0.0055 g (0.031 mmol) of $Co(OAc)_2$, 0.0126 g (0.037 mmol) of **L7,** 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.0575 g (0.59 mmol) of ethyl propiolate and 1.2 mL (0.5 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE/EtOAc = 50/1 as the eluent to give 0.1761 g (0.45 mmol, 76% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97/3 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2957, 2926, 2871, 1716, 1591, 1460. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 6.91 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 110 Hz, 1H), 5.92 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 53 Hz, 1H), 4.19 (q, $J_{H\text{-}H}$ = 6.8 Hz, 2H), 1.59-1.41 (m, 6H), 1.35-1.26 (m, 9H), 1.06-0.85 (m, 15H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.5, 146.1, 139.7, 60.5, 28.9, 27.2, 14.2, 13.6, 10.0; HRMS (ESI) calculated for $[C_{17}H_{34}NaO_2Na]^+$ $[M+Na]^+$ requires m/z 413.1473, found m/z 413.1475.

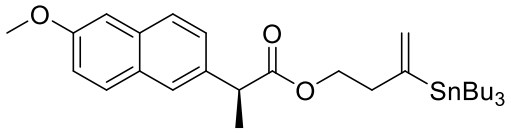


(*R*)-tributyl(1-(4-chloro-3-(4-((tetrahydrofuran-3-yl)oxy)benzyl)phenyl)vinyl)stannane (3ay). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7**, 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0920 g (0.30 mmol) of (*R*)-3-(4-(2-chloro-5-ethynylbenzyl)phenoxy)tetrahydrofuran and 1.2 mL (0.25 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.0807 g (0.14 mmol, 45% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2925, 2856, 1613, 1509, 1466. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30-7.23 (m, 1H), 7.10 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.99 (dd, $J_{H\text{-}H}$ = 8.4, 2.4 Hz, 1H), 6.86 (d, $J_{H\text{-}H}$ = 2.0 Hz, 1H), 6.79 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 5.98 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 126 Hz, 1H), 5.38 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 59 Hz, 1H), 4.92-4.85 (m, 1H), 4.05-3.85 (m, 6H), 2.24-2.08 (m, 2H), 1.47-1.35 (m, 6H), 1.32-1.20 (m, 6H),

0.95-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 155.9, 153.5, 145.0, 138.6, 131.9, 131.8, 130.1, 129.3, 129.0, 127.1, 125.0, 115.3, 77.2, 73.1, 67.2, 38.3, 33.0, 28.9, 27.2, 13.6, 10.2; HRMS (ESI) calculated for $[C_{31}H_{46}ClO_2Sn]^+$[M+H]$^+$ requires m/z 605.2203, found m/z 605.2206.

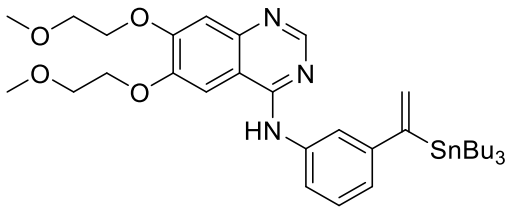


(*R*)-*N*-(2-(tributylstannyl)allyl)-2,3-dihydro-1*H*-inden-1-amine (3az). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7**, 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0514 g (0.30 mmol) of (*R*)-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-inden-1-amine and 1.2 mL (0.25 M) of THF. After 3 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.1234 g (0.27 mmol, 89% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2955, 2925, 2851, 1458. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.40-7.30 (m, 1H), 7.25-7.15 (m, 3H), 6.05-5.65 (m, J_{Sn-H} = 136 Hz, 1H), 5.30-5.10 (m, J_{Sn-H} = 63 Hz, 1H), 4.20 (t, J_{H-H} = 6.4 Hz, 1H), 3.65-3.35 (m, 2H), 3.05-2.90 (m, 1H), 2.85-2.72 (m, 1H), 2.50-2.38 (m, 1H), 1.83-1.70 (m, 1H), 1.55-1.40 (m, 6H), 1.35-1.23 (m, 6H), 0.95-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 155.4, 145.7, 143.5, 127.2, 126.1, 124.6, 124.2, 63.0, 57.1, 34.2, 30.3, 29.2, 27.4, 13.7, 9.8; HRMS (EI) calculated for $[C_{20}H_{30}NSn]^+$[M-C_4H_{11}]$^+$ requires m/z 404.1400, found m/z 404.1405.



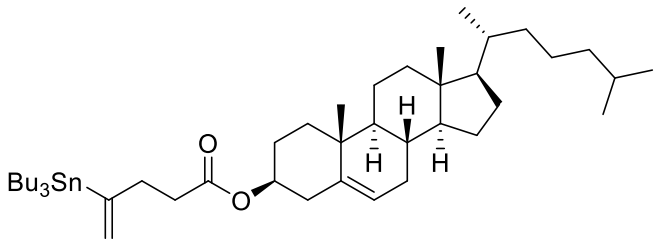
3-(Tributylstannyl)but-3-en-1-yl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate (3aaa). Prepared according to the general procedure using 0.0023 g (0.013 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7**, 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, 0.1697 g (0.60 mmol) of but-3-yn-1-yl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate and 1.2 mL (0.5 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude

mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.3440 g (0.60 mmol, >99% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2956, 2927, 2850, 1735, 1607, 1484, 1459. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.72-7.64 (m, 3H), 7.40 (dd, $J_{H\text{-}H}$ = 8.4, 1.6 Hz, 1H), 7.16-7.07 (m, 2H), 5.85-5.45 (m, $J_{Sn\text{-}H}$ = 133 Hz, 1H), 5.25-5.03 (m, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 4.18-4.03 (m, 2H), 3.89 (s, 3H), 3.82 (q, $J_{H\text{-}H}$ = 7.2 Hz, 1H), 2.49 (t, $J_{H\text{-}H}$ = 7.2 Hz, $J_{Sn\text{-}H}$ = 44 Hz, 2H), 1.56 (d, $J_{H\text{-}H}$ = 7.2 Hz, 3H), 1.50-1.40 (m, 6H), 1.34-1.23 (m, 6H), 0.95-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 174.5, 157.5, 150.0, 135.7, 133.6, 129.2, 128.9, 127.7, 127.0, 126.3, 125.9, 118.9, 105.5, 64.0, 55.2, 45.4, 39.8, 29.0, 27.3, 18.5, 13.6, 9.5; HRMS (ESI) calculated for $[C_{30}H_{46}NaO_3Sn]^+$[M+Na]$^+$ requires m/z 597.2361, found m/z 597.2366.

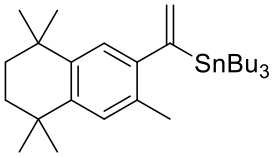


6,7-Bis(2-methoxyethoxy)-*N*-(3-(1-(tributylstannyl)vinyl)phenyl)quinazolin-4-amine (3aab). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7**, 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.1170 g (0.30 mmol) of *N*-(3-ethynylphenyl)-6,7-bis(2-methoxyethoxy)quinazolin-4-amine and 1.2 mL (0.25 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using EtOAc as the eluent to give 0.1547 g (0.23 mmol, 76% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 3390, 2955, 2925, 1622, 1576, 1507, 1433. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 8.65 (s, 1H), 7.75-7.60 (m, 2H), 7.51 (d, $J_{H\text{-}H}$ = 8.0 Hz, 1H), 7.32-7.25 (m, 2H), 7.19 (s, 1H), 6.95 (d, $J_{H\text{-}H}$ = 7.6 Hz, 1H), 6.06 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 126 Hz, 1H), 5.44 (d, $J_{H\text{-}H}$ = 2.4 Hz, $J_{Sn\text{-}H}$ = 60 Hz, 1H), 4.25-4.15 (m, 4H), 3.85-3.70 (m, 4H), 3.41 (d, $J_{H\text{-}H}$ = 1.6 Hz, 6H), 1.60-1.45 (m, 6H), 1.35-1.22 (m, 6H), 1.10-0.95 (m, 6H), 0.90 (t, $J_{H\text{-}H}$ = 7.2 Hz, 9H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 156.4, 154.33,

154.31, 153.7, 148.6, 147.2, 138.7, 128.7, 127.0, 122.2, 119.45, 119.41, 109.2, 108.6, 102.7, 70.8, 70.3, 69.0, 68.2, 59.2, 59.1, 29.0, 27.2, 13.6, 10.2; HRMS (ESI) calculated for $[C_{34}H_{52}N_3O_4Sn]^+$[M+H]$^+$ requires m/z 686.2974, found m/z 686.2984.



(3*S*,8*S*,9*S*,10*R*,13*R*,14*S*,17*R*)-10,13-dimethyl-17-((*R*)-6-methylheptan-2-yl)-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthren-3-yl 4-(tributylstannyl)pent-4-enoate (3aac). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7**, 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.1410 g (0.30 mmol) of (3*S*,8*S*,9*S*,10*R*,13*R*,14*S*,17*R*)-10,13-dimethyl-17-((*R*)-6-methylheptan-2-yl)-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthren-3-yl pent-4-ynoate and 1.2 mL (0.25 M) of THF. After 1 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 20/1 as the eluent to give 0.2273 g (0.30 mmol, >99% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^{1}H NMR analysis of the isolated mixture. IR (cm^{-1}): 2953, 2869, 1735, 1463. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 5.70 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 136 Hz, 1H), 5.37 (d, $J_{H\text{-}H}$ = 4.0 Hz, 1H), 5.25-5.05 (m, $J_{Sn\text{-}H}$ = 55 Hz, 1H), 4.70-4.55 (m, 1H), 2.65-2.45 (m, 2H), 2.42-2.25 (m, 4H), 2.05-1.92 (m, 2H), 1.90-1.78 (m, 3H), 1.65-1.40 (m, 12H), 1.38-1.25 (m, 11H), 1.20-1.06 (m, 6H), 1.05-0.95 (m, 6H), 0.94-0.80 (m, 25H), 0.68 (s, 3H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 172.6, 153.1, 139.7, 125.3, 122.6, 73.8, 56.7, 56.1, 50.0, 42.3, 39.7, 39.5, 38.1, 37.0, 36.6, 36.2, 35.8, 34.2, 31.9, 31.8, 29.1, 28.2, 28.0, 27.8, 27.4, 24.3, 23.8, 22.8, 22.5, 21.0, 19.3, 18.7, 13.7, 11.8, 9.5; HRMS (ESI) calculated for $[C_{44}H_{78}NaO_2Sn]^+$[M+Na]$^+$ requires m/z 781.4916, found m/z 781.4924.



Tributyl(1-(3,5,5,8,8-pentamethyl-5,6,7,8-tetrahydronaphthalen-2-yl)vinyl)stannane (3aad). Prepared according to the general procedure using 0.0027 g (0.015 mmol) of $Co(OAc)_2$, 0.0062 g (0.0180 mmol) of **L7**, 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$, 0.0679 g (0.30 mmol) of 6-ethynyl-1,1,4,4,7-pentamethyl-1,2,3,4-tetrahydronaphthalene and 1.2 mL (0.25 M) of THF. After 24 h, the resulting solution was quenched. The combined filtrate was concentrated and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1390 g (0.27 mmol, 90% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be >99/1 by the ^1H NMR analysis of the isolated mixture. IR (cm^{-1}): 2958, 2927, 2868, 1493, 1460. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.02 (s, 1H), 6.77 (s, 1H), 5.78 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 136 Hz, 1H), 5.50 (d, $J_{H\text{-}H}$ = 2.0 Hz, $J_{Sn\text{-}H}$ = 63 Hz, 1H), 2.16 (s, 3H), 1.65 (s, 4H), 1.48-1.35 (m, 6H), 1.30-1.20 (m, 18H), 0.95-0.80 (m, 15H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ156.0, 144.0, 141.73, 141.68, 130.0, 127.6, 127.5, 124.7, 35.3, 33.78, 33.76, 31.9, 28.9, 27.3, 20.1, 13.7, 10.3; HRMS (EI) calculated for $[C_{29}H_{50}Sn]^+[M]^+$ requires m/z 518.2934, found m/z 518.2932.

IV. Gram-Scale Reaction and Efficinecy Tests

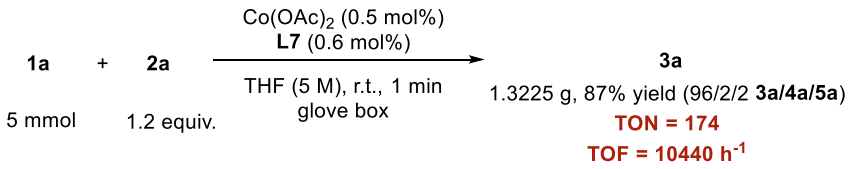


Figure S1. Gram-Scale Reaction.

In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 0.0045 g (0.025 mmol, 0.5 mol%) of $Co(OAc)_2$, 0.0103 g (0.030 mmol, 0.6 mol %) of **L7**, and 1 mL (5 M) of THF. The mixture was stirred for 1 hour. Then 1650 μL (1.08 g/mL, 97%, 6.0 mmol, 1.2 equiv.) of $HSnBu_3$ and 550 μL (0.93 g/mL, 5.0 mmol) alkynes were added sequentially. The mixture was stirred at ambient temperature for 1 minute, and quenched by 5 mL of petroleum ether (PE) and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates

were concentrated *in vacuo*. The residue was purified by short flash column chromatography using PE as the eluent to give 1.7104 g (4.35 mmol, 87% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 96/4 by the ^{1}H NMR analysis of the isolated mixture.

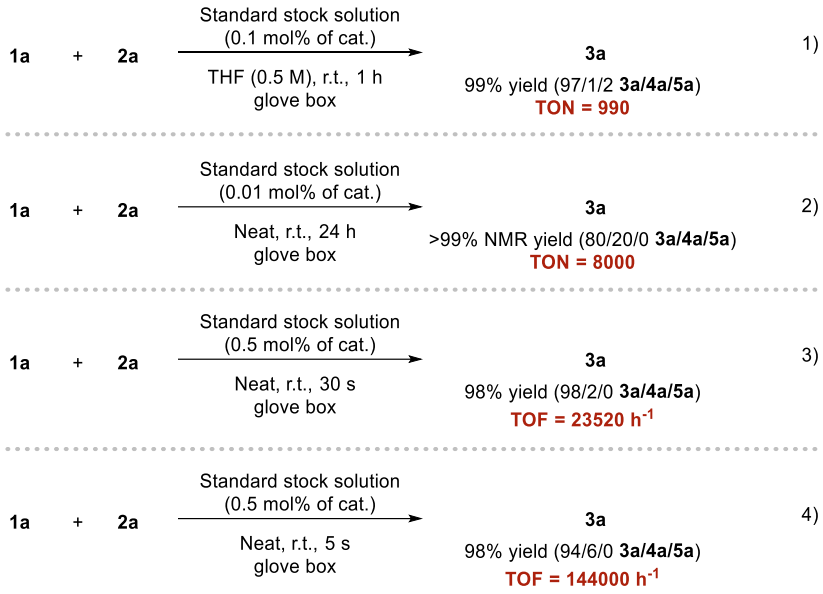


Figure S2. Efficiency Tests of Cobalt-Catalyzed Hydrostannylation of Alkynes.

Preparation of standard stock solution: $Co(OAc)_2$ (0.1 mmol), **L7** (0.12 mmol) in THF (4 mL) in glove box at room temperature for 4 h until no precipitate remains. The standard stock solution can be used according to the need (0.025 M).

Figure S2, Eq. 1. In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 24 μL of standard stock solution (0.1 mol% catalyst loading) and 1.2 mL (0.5 M) of THF. Then 198 μL (1.08 g/mL, 97%, 0.72 mmol, 1.2 equiv.) of $HSnBu_3$ and 66 μL (0.93 g/mL, 0.60 mmol) of phenylacetylene were added sequentially. The mixture was stirred at ambient temperature for 1 h, and quenched by 5 mL of petroleum ether (PE) and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates were concentrated *in vacuo*. The residue was purified by short flash column chromatography using PE as the eluent to give 0.2336 g (0.594 mmol, 99% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 97/3 by the ^{1}H NMR analysis of the isolated mixture.

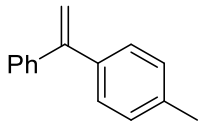
Figure S2, Eq. 2. In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 24 μL of standard stock solution (0.01 mol% catalyst loading).

Then 1980 μL (1.08 g/mL, 97%, 7.2 mmol, 1.2 equiv.) of $HSnBu_3$ and 660 μL (0.93 g/mL, 6.0 mmol) of phenylacetylene were added sequentially. The mixture was stirred at ambient temperature for 24 h, and quenched by 5 mL of petroleum ether (PE) and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates were concentrated *in vacuo*. The NMR yield and the ratio of α/β were determined to be >99% and 80/20 by the ^1H NMR analysis of the mixture, respectively.

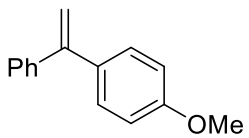
Figure S2, Eq. 3. In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 120 μL of standard stock solution (0.5 mol% catalyst loading). Then 1980 μL (1.08 g/mL, 97%, 7.2 mmol, 1.2 equiv.) of $HSnBu_3$ and 660 μL (0.93 g/mL, 0.60 mmol) of phenylacetylene were added sequentially. The mixture was stirred at ambient temperature for 30 s, and quenched by 10 mL of quenching solution (the quenching solution was consisted of 10 ml of THF, 3 ml of DCM, and 0.6 ml of H_2O) and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates were concentrated *in vacuo*. The combined filtrates were concentrated *in vacuo*. The residue was purified by short flash column chromatography using PE as the eluent to give 0.2312 g (0.588 mmol, 98% yield) of the title compound as a colorless oil. The ratio of α/β was determined to be 98/2 by the ^1H NMR analysis of the isolated mixture.

Figure S2, Eq. 4. In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 300 μL of standard stock solution (0.5 mol% catalyst loading). Then 395 μL (1.08 g/mL, 97%, 1.8 mmol, 1.2 equiv.) of $HSnBu_3$ and 165 μL (0.93 g/mL, 1.5 mmol) of phenylacetylene were added sequentially. The mixture was stirred at ambient temperature for 5 s, and quenched by 10 mL of quenching solution (the quenching solution was consisted of 10 ml of THF, 3 ml of DCM, and 0.6 ml of H_2O) and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates were concentrated *in vacuo*. The combined filtrates were concentrated *in vacuo*. The ratio of α/β was determined to be 94/6 by the ^1H NMR analysis of the isolated mixture.

V. Further Derivatizations

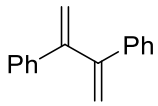


1-Methyl-4-(1-phenylvinyl)benzene (6). Prepared according to the previously reported procedure.[26] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried Schlenk flask, 0.0119 g (0.01 mmol, 10 mol%) of $Pd(PPh_3)_4$, 0.0504 g (0.51 mmol, 5.0 equiv.) of CuCl, 0.0265 g of LiCl (0.63 mmol, 6.0 equiv.), 0.5 mL (0.2 M) of DMSO, 0.0218 g (0.10 mmol) of 1-iodo-4-methylbenzene, and 0.0471 g (0.12 mmol, 1.2 equiv.) of **3a** were added in sequence. The resulting mixture was stirred at 60 °C for 24 h. After that, the reaction was quenched by addition of H_2O (10 mL) and Et_2O (10 mL). The mixture was washed with $NH_3•H_2O$ (30 mL) and the organic layer was separated. The aqueous layer was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by short flash column chromatography using PE as the eluent to give 0.0131 g (0.07 mmol, 67% yield) of the title compound as a colorless oil. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.35-7.30 (m, 5H), 7.24 (d, J_{H-H} = 8.0 Hz, 2H), 7.14 (d, J_{H-H} = 8.0 Hz, 2H), 5.43-5.40 (m, 2H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.8, 141.6, 138.6, 137.5, 128.8, 128.3, 128.12, 128.08, 127.6, 113.6, 21.2; The spectroscopic data are in accordance with the literature.[27]

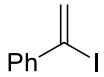


1-Methoxy-4-(1-phenylvinyl)benzene (7). Prepared according to the previously reported procedure.[26] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried

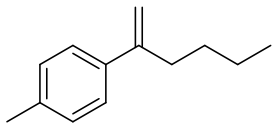
Schlenk flask, 0.0108 g (0.01 mmol, 10 mol%) of $Pd(PPh_3)_4$, 0.0496 g (0.50 mmol, 5.0 equiv.) of CuCl, 0.0257 g of LiCl (0.60 mmol, 6.0 equiv.), 0.5 mL (0.2 M) of DMSO, 0.0228 g (0.10 mmol) of 1-iodo-4-methoxybenzene, and 0.0470 g (0.12 mmol, 1.2 equiv.) of **3a** were added in sequence. The resulting mixture was stirred at 60 °C for 24 h. After that, the reaction was quenched by addition of H_2O (10 mL) and Et_2O (10 mL). The mixture was washed with $NH_3•H_2O$ (30 mL) and the organic layer was separated. The aqueous layer was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by short flash column chromatography using PE as the eluent to give 0.0191 g (0.09 mmol, 91% yield) of the title compound as a colorless oil. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.34-7.30 (m, 5H), 7.27 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 6.86 (d, $J_{H\text{-}H}$ = 8.8 Hz, 2H), 5.40-5.35 (m, 2H), 3.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 149.5, 141.8, 139.9, 129.4, 128.3, 128.1, 127.6, 113.4, 113.0, 55.3; The spectroscopic data are in accordance with the literature.[27]



Buta-1,3-diene-2,3-diyldibenzene (8). Prepared according to the previously reported procedure.[28] To a 25 mL Schlenk flask covered with aluminum foil to exclude light and equipped with a magnetic stirrer, 0.0495 g (0.5 mmol, 2.5 equiv.) of CuCl and 0.5 mL of DMF were added in sequence, and then 0.0786 g (0.2 mmol, 1.0 equiv.) of **3a** in 0.5 mL of DMF were added. The resulting mixture was stirred at ambient temperature for 2 h. After that, the reaction was quenched by addition of H_2O (10 mL) and Et_2O (10 mL) and stirred for an additional hour. The mixture was then washed with $NH_3•H_2O$ (30 mL) and the organic layer was separated. The aqueous layer was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with H_2O, brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by short flash column chromatography using PE as the eluent to give 0.0127 g (0.12 mmol, 62% yield) of the title compound as a white solid. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.39 (s, $J_{H\text{-}H}$ = 7.6 Hz, 4H), 7.30-7.18 (m, 6H), 5.54 (s, 2H), 5.31 (s, 2H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 149.8, 140.1, 128.2, 127.5, 116.4. The spectroscopic data are in accordance with the literature.[29]

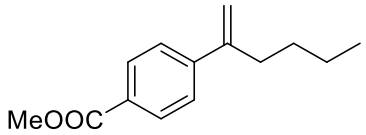


(1-Iodovinyl)benzene (9). Prepared according to the previously reported procedure.[30] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried Schlenk flask, 0.0786 g (0.20 mmol) of **3a**, 1 mL (0.2 M) of DCM, and 0.0507 g (0.20 mmol, 1.0 equiv.) of I_2 were added in sequence. The resulting mixture was stirred at ambient temperature for 4 h. After that, the reaction was quenched by addition of Et_2O. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.0423 (0.18 mmol, 92% yield) of the title compound as a faint yellow oil. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.55-7.45 (m, 2H), 7.35-7.25 (m, 3H), 6.46 (s, 1H), 6.08 (s, 1H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 141.6, 128.8, 128.2, 128.1, 127.3, 107.4. The spectroscopic data are in accordance with the literature.[31]

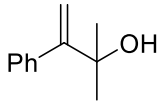


1-(Hex-1-en-2-yl)-4-methylbenzene (10). Prepared according to the previously reported procedure.[26] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried Schlenk flask, 0.0230 g (0.02 mmol, 10 mol%) of $Pd(PPh_3)_4$, 0.0990 g (1.00 mmol, 5.0 equiv.) of CuCl, 0.0256 g of LiCl (0.60 mmol, 3.0 equiv.), 1.0 mL (0.2 M) of DMSO, 0.0441 g (0.20 mmol) of 1-iodo-4-methylbenzene, and 0.0895 g (0.24 mmol, 1.2 equiv.) of **3z** were added in sequence. The resulting mixture was stirred at 80 ^{o}C for 24 h. After that, the reaction was quenched by addition of H_2O (10 mL) and Et_2O (10 mL). The mixture was washed with NH_3•H_2O (30 mL) and the organic layer was separated. The aqueous layer was extracted with Et_2O (20 mL × 3). The

combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by short flash column chromatography using PE as the eluent to give 0.0255 g (0.14 mmol, 72% yield) of the title compound as a colorless oil. IR (cm^{-1}): 2957, 2928, 2865, 1626, 1513, 1461. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.30 (d, $J_{H\text{-}H}$ = 8.0 Hz, 2H), 7.13 (d, $J_{H\text{-}H}$ = 8.0 Hz, 2H), 5.22 (s, 1H), 5.00 (s, 1H), 2.48 (t, $J_{H\text{-}H}$ = 6.8 Hz, 2H), 2.34 (s, 3H), 1.48-1.38 (m, 2H), 1.37-1.27 (m, 2H), 0.89 (t, $J_{H\text{-}H}$ = 7.2 Hz, 3H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 148.5, 138.5, 137.2, 136.9, 131.2, 128.9, 126.0, 111.2, 35.1, 30.5, 22.4, 21.1, 13.9; HRMS (EI) calculated for $[C_{13}H_{18}]^+$ $[M]^+$ requires m/z 174.1409, found m/z 174.1409.



Methyl 4-(hex-1-en-2-yl)benzoate (11). Prepared according to the previously reported procedure.[26] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried Schlenk flask, 0.0231 g (0.02 mmol, 10 mol%) of $Pd(PPh_3)_4$, 0.0992 g (1.00 mmol, 5.0 equiv.) of CuCl, 0.0257 g of LiCl (0.60 mmol, 3.0 equiv.), 1.0 mL (0.2 M) of DMSO, 0.0524 g (0.20 mmol) of methyl 4-iodobenzoate, and 0.0895 g (0.24 mmol, 1.2 equiv.) of **3z** were added in sequence. The resulting mixture was stirred at 80 °C for 24 h. After that, the reaction was quenched by addition of H_2O (10 mL) and Et_2O (10 mL). The mixture was washed with $NH_3 \bullet H_2O$ (30 mL) and the organic layer was separated. The aqueous layer was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo* to give a crude oil. The residue was purified by short flash column chromatography using PE to PE/EtOAc = 100/1 as the eluent to give 0.0349 g (0.16 mmol, 80% yield) of the title compound as a colorless oil. IR (cm^{-1}): 2956, 2866, 1725, 1609, 1436. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.91 (d, J = 8.4 Hz, 2H), 7.38 (d, $J_{H\text{-}H}$ = 8.4 Hz, 2H), 5.27 (s, 1H), 5.07 (s, 1H), 3.83 (s, 3H), 2.43 (t, $J_{H\text{-}H}$ = 7.2 Hz, 2H), 1.40-1.22 (m, 4H), 0.82 (t, $J_{H\text{-}H}$ = 7.2 Hz, 3H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 167.0, 147.9, 146.0, 129.6, 128.8, 126.1, 113.9, 52.0, 34.8, 30.3, 22.3, 13.9; HRMS (EI) calculated for $[C_{14}H_{18}O_2]^+$ $[M]^+$ requires m/z 218.1307, found m/z 218.1308.



2-Methyl-3-phenylbut-3-en-2-ol (12). Prepared according to the previously reported procedure.[32] A 25 mL Schlenk flask equipped with a magnetic stirrer and a flanging rubber plug was dried with flame under vacuum. When cooled to ambient temperature, it was vacuumed and flushed with N_2. This degassing procedure was repeated for three times. To the flame-dried Schlenk flask, 0.0786 g (0.20 mmol) of **3a**, 2 mL (0.1 M) of anhydrous THF were added, and 125 μL (1.6 M in diethoxymethane, 0.20 mmol, 1.0 equiv.) of MeLi were added dropwise at 0 °C. The resulting mixture was stirred at 0 °C for 0.5 h, and the color of mixture would intensify gradually. Then, 0.0120 g (0.20 mmol) of acetone was added dropwise at 0 °C. The mixture was taken back to ambient temperature and stirred for 16 hrs. The reaction was quenched by addition of Et_2O. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE to PE/EtOAc = 10/1 as the eluent to give 0.0171 (0.11 mmol, 53% yield) of the title compound as a colorless oil. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.30 (m, 5H), 5.43 (s, 1H), 4.97 (s, 1H), 1.42 (s, 6H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 157.0, 141.5, 128.8, 127.8, 127.0, 112.5, 73.0, 29.6. The spectroscopic data are in accordance with the literature.[33]

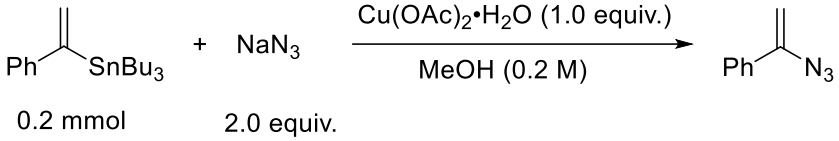
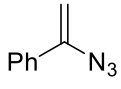


Figure S3. Azidation of Tributyl(1-phenylvinyl)stannane



(1-Azidovinyl)benzene (13). To a 25 mL Schlenk flask equipped with a magnetic stirrer, 0.0786 g (0.20 mmol) of **3a**, 2 mL (0.1 M) of MeOH, 0.0399 g (0.20 mmol, 1.0 equiv.) of $Cu(OAc)_2$•H_2O, and 0.0262 g (0.40 mmol, 2.0 equiv.) of sodium azide were added in sequence. The resulting mixture was stirred at ambient temperature for 16 h. After that, the reaction was quenched with Et_2O. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL ×

3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.0264 g (0.18 mmol, 91% yield) of the title compound as a colorless oil. ^{1}H NMR: (400 MHz, $CDCl_3$) δ 7.60-7.52 (m, 2H), 7.40-7.30 (m, 3H), 5.43 (d, $J_{H\text{-}H}$ = 2.0 Hz, 1H), 4.96 (d, $J_{H\text{-}H}$ = 2.0 Hz, 1H); ^{13}C NMR: (100 MHz, $CDCl_3$) δ 145.0, 134.2, 129.1, 128.4, 125.5, 98.0. The spectroscopic data are in accordance with those of the literature.[34]

VI. Mechanistic Studies and Control Experiments

A) Radical Trapping Experiment

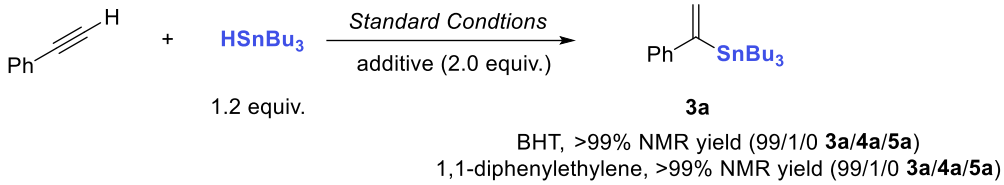


Figure S4. Radical Trapping Experiments.

The experiment was conducted according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** 1.2 mL (0.5 M) of THF, 0.2680 g (1.20 mmol, 2.0 equiv.) of BHT or 0.2163 g (1.20 mmol, 2.0 equiv.) of 1,1-diphenylethylene, 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$, and 66 μL (0.93 g/mL, 0.60 mmol) of phenylacetylene were added in sequence. (The radical scavengers were added before $HSnBu_3$, considering the reaction could finish with in 1min) After 1 h, the reaction was quenched with Et_2O. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated in *vacuo* and TMSPh was added as the internal standard. The aiming product tributyl(1-phenylvinyl)stannane was observed by ^{1}H NMR in high yield indicating that radical mechanism may be ruled out.

B) H-D Exchange Experiment

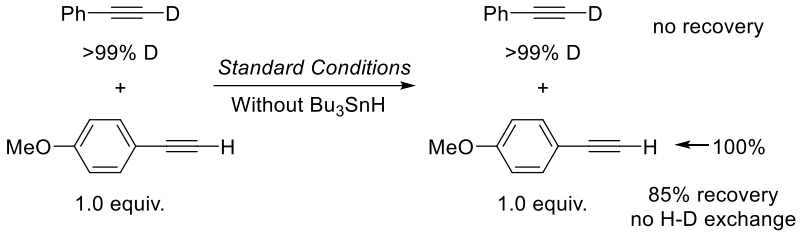


Figure S5. H-D Exchange Experiment.

The experiment was conducted according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** and 1.2 mL (0.5 M) of THF were added in sequence. The mixture was stirred for 30 mins at ambient temperature. Then 0.0309 g (0.30 mmol) of deuterium-phenylacetylene and 39 μL (1.02 g/mL, 0.30 mmol) of 1-ethynyl-4-methoxybenzene were added sequentially. After 1 h, the reaction was quenched. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.0337 g (0.25 mmol, 85% recovery) of 1-ethynyl-4-methoxybenzene as a colorless oil. There is no hydrogen-hdeuterium exchange in 1-ethynyl-4-methoxybenzene indicating that alkynyl cobalt mechanism may be ruled out.

C) Isotopic Labeling Experiment

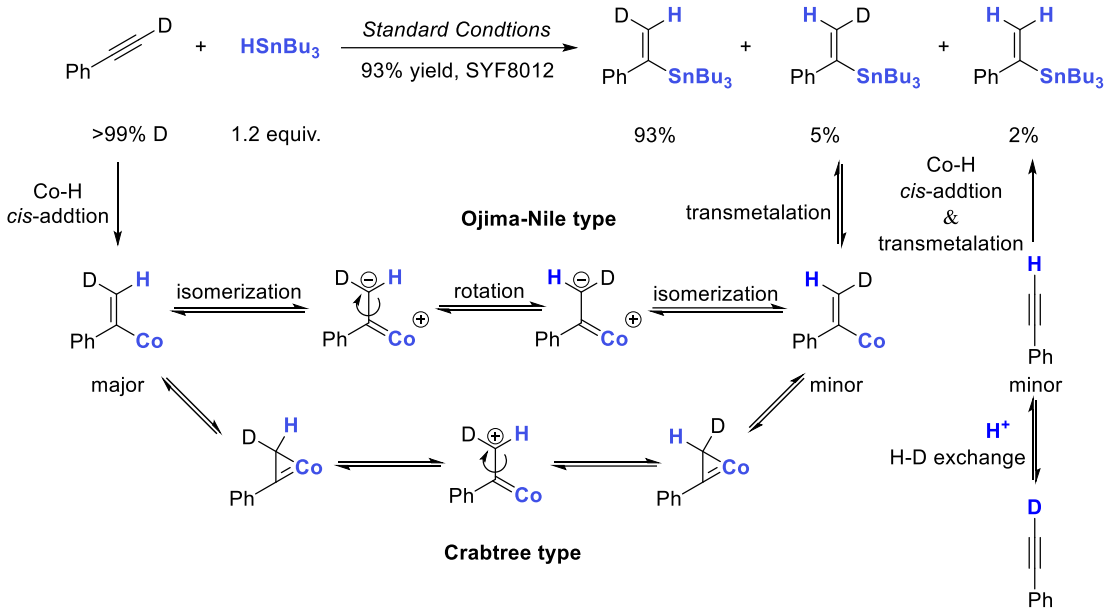


Figure S6. Isotopic Labeling Experiments using Deuterium-phenylacetylene.

The experiment was conducted according to the general procedure using 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0050 g (0.0144 mmol) of **L7,** and 1.2 mL (0.5 M) of THF were added in sequence. The mixture was stirred for 30 mins at ambient temperature. Then 198 μL (1.08 g/mL, 97%, 0.72 mmol) of $HSnBu_3$ and 0.0619 g (0.60 mmol) of deuterium-phenylacetylene were added in sequence. After 1 h, the reaction was quenched. The resulting solution was filtered through a pad

of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.2200 g (0.56 mmol, 93% yield) of title compound as a colorless oil. Quantitative deuterium spectrum was prepared with 0.0701 g title compound, 15 μL (1.50 g/mL) $CDCl_3$ as internal standard (integral: 1.05), and 0.5 mL $CHCl_3$ as solvent. IR (cm^{-1}): 2957, 2927, 2852, 1597, 1461. ^1H NMR: (400 MHz, $CDCl_3$) δ 7.35-7.25 (m, 2H), 7.22-7.13 (m, 3H), 6.03 (d, J_{H-H} = 1.6 Hz, J_{Sn-H} = 128 Hz, 0.02H), 6.02 (s, J_{Sn-H} = 127 Hz, 0.05H), 5.40 (s, J_{Sn-H} = 60 Hz, 1H), 1.55-1.40 (m, 6H), 1.35-1.22 (m, 6H), 0.97 (t, J_{H-H} = 8.4 Hz, 6H), 0.86 (t, J_{H-H} = 8.4 Hz, 9H); ^2H NMR: (77 MHz, $CDCl_3$) δ 6.09 (s, 0.93H), 5.49 (s, 0.05H).

D) M-H Species Observation Experiments

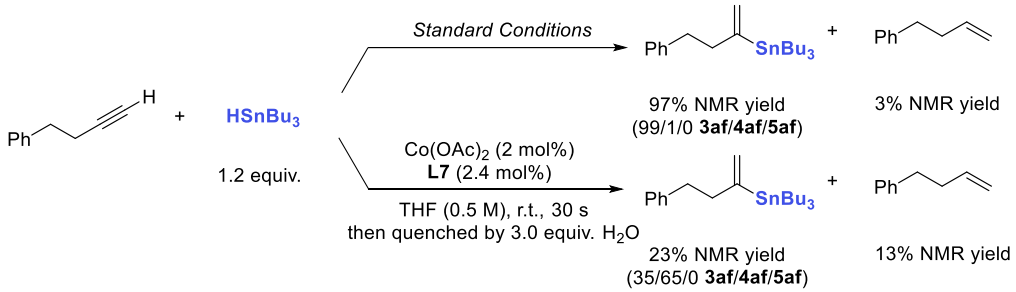
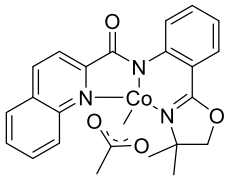
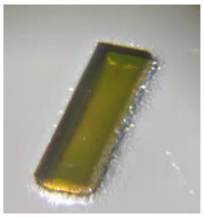


Figure S7. Quench Experiment Using 4-Phenyl-1-Butyne as the Substrate.

In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 0.0022 g (0.012 mmol) of $Co(OAc)_2$, 0.0051 g (0.0147 mmol) of **L7**, and THF (1.2 mL, 0.5 M). The mixture was stirred for 30 mins. Then 198 μL (1.08 g/mL, 97%, 0.72 mmol, 1.2 equiv.) of $HSnBu_3$ and 84 μL (0.93 g/mL, 0.60 mmol) of 4-phenyl-1-butyne were added sequentially. The mixture was stirred at ambient temperature for 30 s, and immediately quenched by 32.4 μL of H_2O and stirred for 5 minutes. The resulting solution was filtered through a pad of silica gel and the vial and silica gel were washed by Et_2O (20 mL × 3). The combined filtrates were concentrated *in vacuo* and 5 μL of TMSPh was added as an internal standard. The NMR yield and ratio of α/β were determined to be 23% NMR yield and 35/65 by the ^1H NMR analysis of the mixture, respectively. 13% of 4-phenyl-1-butene was observed, indicating that Co-H species might exist in the catalytic system.

E) Preparation and X-ray Diffraction of L7•Co(OAc), $(L7)_2$•Co, and L7•Co(OAc)(Py)





L7•Co(OAc). In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 0.0177 g (0.10 mmol) of $Co(OAc)_2$, 0.0351 g (0.10 mmol, 1.0 equiv.) of **L7**, and 1 mL (0.1 M) of THF. The mixture was stirred for 30 mins. After that, 27.5 μL of $HSnBu_3$ (0.10 mmol, 1.0 equiv.) were added. The mixture was stirred at ambient temperature for 4 h and then filtered through a syringe filter with 0.45 μm Nylon membrane. 1 mL of hexane was then added into the solution sequentially. The dark green crystals were obtained in 0.0120 g (0.026 mmol, 26% yield) by using THF/hexane (1/1, 0.05 M) as the solvents in the vial. The vial was sealed with a parafilm with small holes. The solvent evaporates naturally and the green crystals were separated out after about three days. IR (cm^{-1}): 2959, 2925, 1678, 1618, 1555, 1485, 1434. HRMS (ESI) calculated for $[C_{23}H_{21}CoN_3NaO_4]^+$[M+Na]$^+$ requires m/z 485.0756, found m/z 485.0758.

CCDC Number: 2042974

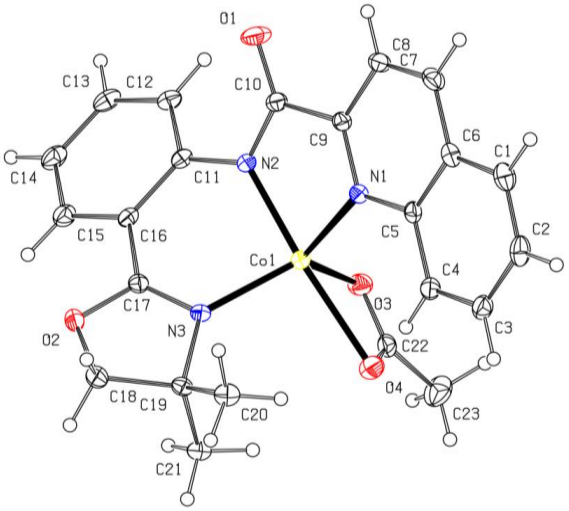
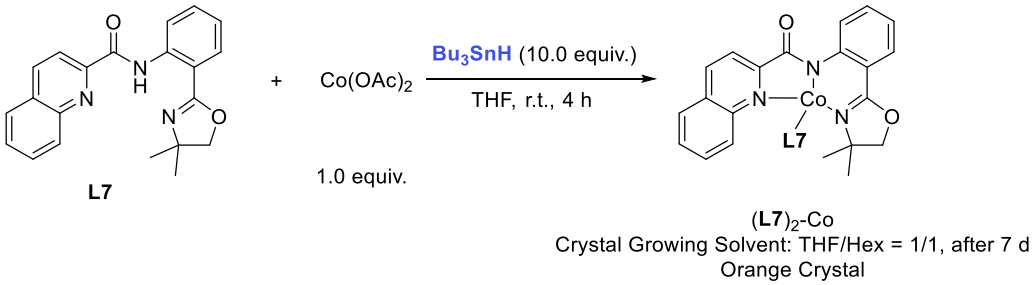


Figure S8. X-ray Diffraction of **L7•**Co(OAc)

Table S2. Crystal data and structure refinement for L7•Co(OAc).

Identification code	mo_201030_SYF7121_hex_0m
Empirical formula	$C_{23}H_{21}CoN_3O_4$
Formula weight	462.36
Temperature/K	170.0

Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	9.9487(6)
b/Å	21.9186(12)
c/Å	10.2914(6)
α/°	90
β/°	114.546(2)
γ/°	90
Volume/Å^3	2041.3(2)
Z	4
ρ_{calc}g/cm^3	1.504
μ/mm^{-1}	0.877
F(000)	956.0
Crystal size/mm^3	0.23 × 0.07 × 0.05
Radiation	MoKα (λ = 0.71073)
2θ range for data collection/°	3.716 to 54.254
Index ranges	-12 ≤ h ≤ 12, -28 ≤ k ≤ 27, -13 ≤ l ≤ 13
Reflections collected	32929
Independent reflections	4501 [R_{int} = 0.0471, R_{sigma} = 0.0246]
Data/restraints/parameters	4501/1/283
Goodness-of-fit on F^2	1.041
Final R indexes [I>=2σ (I)]	R_1 = 0.0316, wR_2 = 0.0868
Final R indexes [all data]	R_1 = 0.0402, wR_2 = 0.0914
Largest diff. peak/hole / e Å^{-3}	0.43/-0.40



(L7)$_2$•Co. In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 0.0180 g (0.10 mmol) of $Co(OAc)_2$, 0.0350 g (0.10 mmol, 1.0 equiv.) of **L7**, and 2 mL (0.05 M) of THF. The mixture was stirred for 30 mins. After that, 275 μL of $HSnBu_3$ (0.10 mmol, 1.0 equiv.) were added. The mixture was stirred at ambient temperature for 4 h and then filtered through a syringe filter with 0.45 μm Nylon membrane. 1 mL of hexane was then added into the solution sequentially. The orange solid were obtained by using THF/hexane (1/1,

0.05 M) as the solvents in the vial. The vial was sealed with a parafilm with small holes. The solvent evaporates naturally and the orange crystals were separated out after about seven days. HRMS (ESI) calculated for $[C_{42}H_{37}CoN_6O_4]^+$[M+H]$^+$ requires m/z 748.2203, found m/z 748.2198.

CCDC Number: 2095773

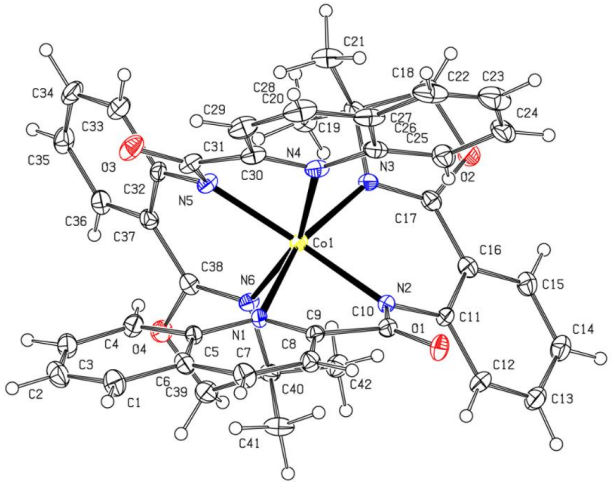
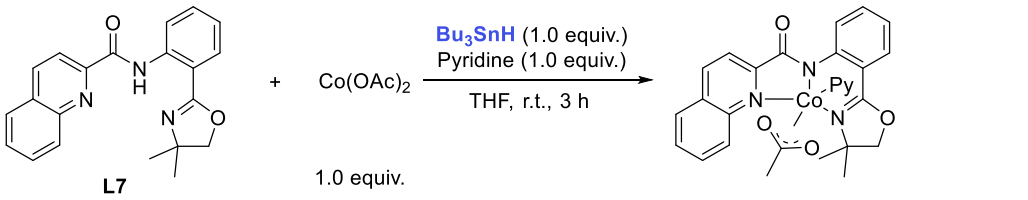


Figure S9. X-ray Diffraction of **(L7)**$_2$•Co

Table S3. Crystal data and structure refinement for (L7)$_2$•Co

Identification code	mo_210524_SYF9163_0m_tw
Empirical formula	$C_{42}H_{36}CoN_6O_4$
Formula weight	747.70
Temperature/K	170.0
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	10.4657(19)
b/Å	19.413(3)
c/Å	18.184(3)
α/°	90
β/°	106.225(6)
γ/°	90
Volume/Å^3	3547.2(10)
Z	4
ρ_{calc}g/cm^3	1.400
μ/mm^{-1}	0.537
F(000)	1556.0
Crystal size/mm^3	0.09 × 0.06 × 0.05
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	4.196 to 54.454

Index ranges	$-13 \leq h \leq 13, -24 \leq k \leq 24, -11 \leq l \leq 23$
Reflections collected	7759
Independent reflections	7759 [R_{int} = ?, R_{sigma} = 0.0499]
Data/restraints/parameters	7759/0/483
Goodness-of-fit on F^2	1.157
Final R indexes [I>=2σ (I)]	R_1 = 0.0971, wR_2 = 0.2812
Final R indexes [all data]	R_1 = 0.1041, wR_2 = 0.2870
Largest diff. peak/hole / e $Å^{-3}$	0.78/-1.00



L7•Co(OAc)(Py)
Crystal Growing Solvent: THF/Hex = 1/1, after 2 d
Red Crystal

L7•Co(OAc)(Py) In a nitrogen-filled glovebox, an oven-dried 25 mL vial that contained a magnetic stir bar was charged with 0.0088 g (0.05 mmol) of $Co(OAc)_2$, 0.0172 g (0.05 mmol, 1.0 equiv.) of **L7**, and 2 mL (0.025 M) of THF. The mixture was stirred for 30 mins. After that, 27.5 μL of $HSnBu_3$ (0.10 mmol, 1.0 equiv.) and 42 μL of pyridine (0.0525 mmol, 1.05 equiv.) were added in sequence. The mixture was stirred at ambient temperature for 4 h and then filtered through a syringe filter with 0.45 μm Nylon membrane. 1 mL of hexane was then added into the solution sequentially. The red crystals were obtained by using THF/hexane (1/1, 0.05 M) as the solvents in the vial. The vial was sealed with a parafilm with small holes. The solvent evaporates naturally and the red crystals were separated out after about two days.

CCDC Number: 2165238

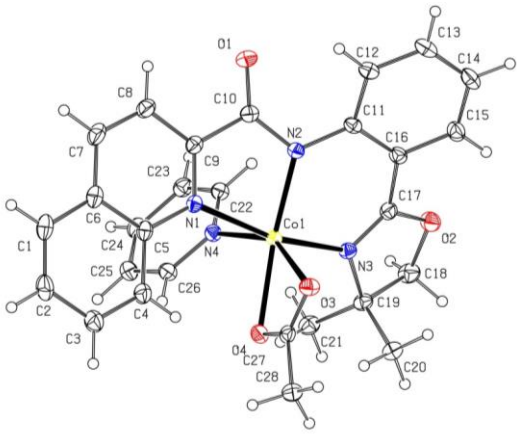


Figure S10. X-ray Diffraction of **L7•**Co(OAc)(Py)

Table S4. Crystal data and structure refinement for L7•Co(OAc)(Py)

Identification code	mo_220304_SYF12101_0m
Empirical formula	$C_{28}H_{26}CoN_4O_4$
Formula weight	541.46
Temperature/K	170.0
Crystal system	triclinic
Space group	P-1
a/Å	9.6488(5)
b/Å	11.3292(6)
c/Å	11.5795(6)
α/°	90.599(2)
β/°	97.306(2)
γ/°	101.688(2)
Volume/Å^3	1228.63(11)
Z	2
ρ_{calc}g/cm^3	1.464
μ/mm^{-1}	0.742
F(000)	562.0
Crystal size/mm^3	0.4 × 0.29 × 0.23
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	4.348 to 54.334
Index ranges	-12 ≤ h ≤ 12, -14 ≤ k ≤ 14, -14 ≤ l ≤ 14
Reflections collected	51954
Independent reflections	5431 [R_{int} = 0.0245, R_{sigma} = 0.0128]
Data/restraints/parameters	5431/0/337
Goodness-of-fit on F^2	1.039
Final R indexes [I>=2σ (I)]	R_1 = 0.0234, wR_2 = 0.0605

Final R indexes [all data]	R_1 = 0.0255, wR_2 = 0.0617
Largest diff. peak/hole / e Å^{-3}	0.30/-0.27

F) L7•Co(OAc) Catalyzed Hydrostannylation of alkyne.

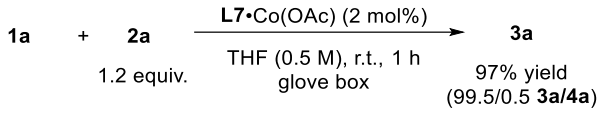


Figure S11. L7•Co(OAc) Catalyzed Hydrostannylation of alkyne.

The experiment was conducted according to the general procedure using 0.0028 g (0.006 mmol) of **L7•**Co(OAc)**,** and 0.6 mL (0.5 M) of THF were added in sequence. The mixture was stirred for 30 mins at ambient temperature. Then 99 μL (1.08 g/mL, 97%, 0.36 mmol) of $HSnBu_3$ and 33 μL (0.93 g/mL, 0.30 mmol) of phenylacetylene were added in sequence. After 1 h, the reaction was quenched. The resulting solution was filtered through a pad of silica gel and washed by Et_2O (20 mL × 3). The combined filtrate was concentrated *in vacuo* and the crude mixture was purified by short flash column chromatography using PE as the eluent to give 0.1144 g (0.29 mmol, 97% yield) of title compound as a colorless oil. The ratio of α/β was determined to be 99.5/0.5 by the ^1H NMR analysis of the isolated mixture.

G) Proposed Detailed Mechanism

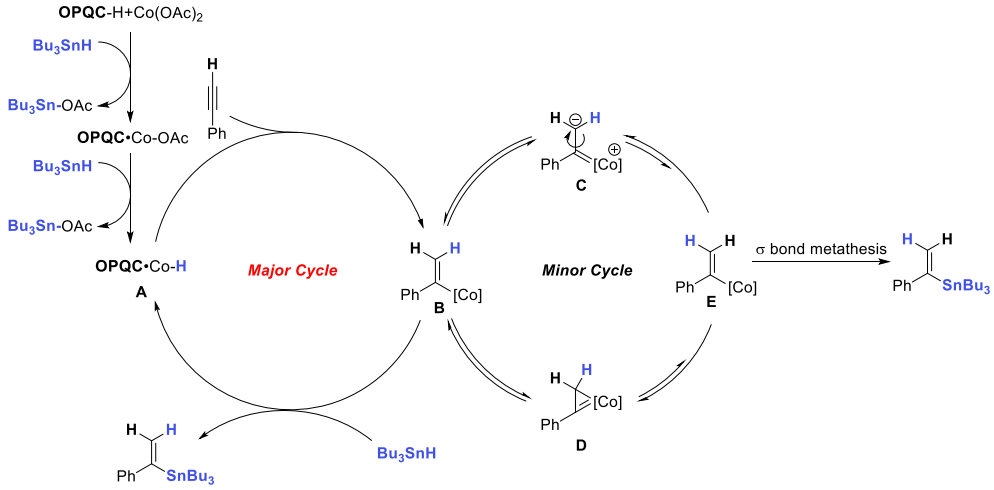


Figure S12. Proposed Detailed Mechanism of Cobalt-Catalyzed Hydrostannylation of Alkynes.

H) DFT Details

All density functional theory (DFT) calculation results are obtained with Gaussian 16 program.[35] Default G16 SCF convergence criteria (scf=tight), optimization convergence criteria and integral grid parameters (int=(ultrafine, acc2e=12)) for Gaussian 16 are applied unless

otherwise stated. Geometry optimizations are conducted with B3LYP functional,[36-37] employing the D3 version of Grimme's dispersion corrections[38] with Becke-Johnson damping[39] and def2-SVP [40]basis set was used for all atoms basis set for all atoms. The solvation effects were induced with a self-consistent reaction field (SCRF) using the PCM solvent model in THF[41-42]. MECP (minimum energy crossing point) was acquired using Gaussian 16 and sobMECP[43-44] software. Single-point energies and solvent effects at THF are also evaluated with the same functional as optimization and def2-TZVPP[45] basis set for all atoms, in a self-consistent reaction field (SCRF) using the SMD implicit solvent model[46]. Frequency analysis is also performed at the same level of theory as geometry optimization using harmonic oscillator model to confirm whether optimized stationary points are either local minimum or transition state, as well as to evaluate zero-point vibrational energies and thermal corrections for enthalpies and free energies at 298.15 K.

To correct the Gibbs free energies under 1 atm to the standard state in solution (1 mol/L), a correction of $RT\ln(c_s/c_g)$ is added to energies of all species. c_s stands for the standard molar concentration in solution (1 mol/L), c_g stands for the standard molar concentration in gas phase (about 0.040876 mol/L), and R is the gas constant. For calculated intermediates at the standard state of 1 mol/L at 298.15 K, the correction value equaling to 1.89 kcal/mol is used.

Energy decomposition analysis (EDA) was conducted with sobEDA[47] and Multiwfn[48] software. The 3D diagrams of optimized structures shown in this supplementary information for computations are generated with CYLview software.[49]

Discussion on Spin Multiplicity

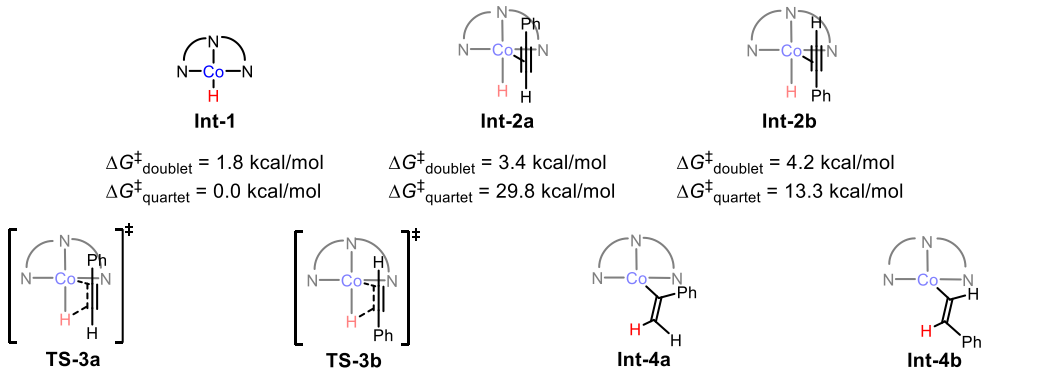


Fig S13. Gibbs free energy of spices in the free energy diagram at doublet state and quartet state.

Energy Decomposition Analysis

Energy decomposition analysis (Figure S12.) suggested that distortion of ligand dominated the regioselectivity of the reaction, consistent with the results obtained from distortion/interaction analysis. The corresponding decomposition equations are as follows:

$$\Delta E^{\ddagger} = \Delta E_{dist} + \Delta E_{int}$$

$$\Delta E_{int} = \Delta E_{els} + \Delta E_{xrep} + \Delta E_{orb} + \Delta E_{disp}$$

$$\Delta E_{xrep} = \Delta E_{ex} + \Delta E_{rep}$$

ΔE_{dist}: distortion energy. ΔE_{int}: interaction energy. ΔE_{els}: electrostatic interaction energy. ΔE_{orb}: orbital interaction energy. ΔE_{disp}: dispersion energy. ΔE_{ex}: exchange energy. ΔE_{rep}: Pauli repulsion energy.

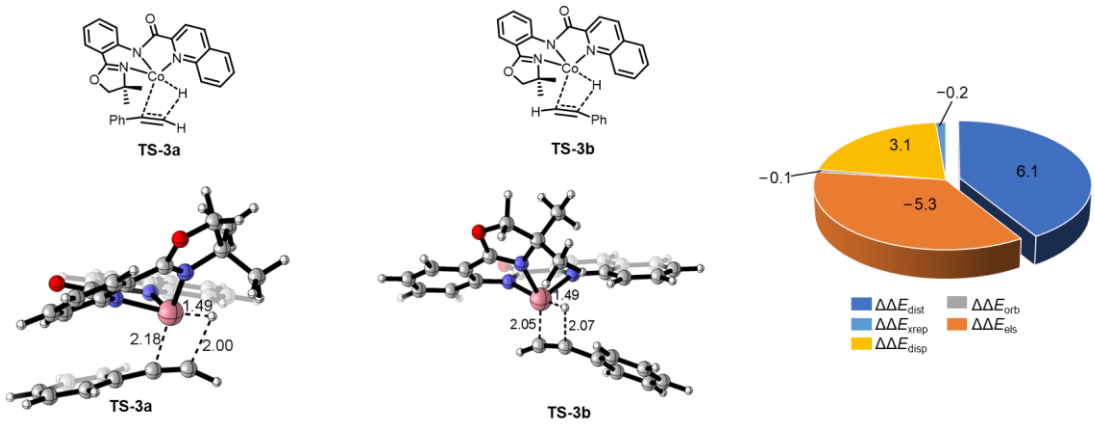


Fig S14. Energy Decomposition Analysis. EDA of $\Delta\Delta E^{\ddagger}$(TS-3b-TS-3a) with optimized key structures of TS-3a and TS-3b

Table of Energies

Table S5 Energies in Fig S13 and Fig S14. Zero-point correction (*ZPE*), thermal correction to enthalpy (*TCH*), thermal correction to Gibbs free energy (*TCG*), energies (*E*), enthalpies (*H*), and Gibbs free energies (*G*) (in Hartree) of the structures calculated at B3LYP-D3(BJ)/def2-TZVPP-SMD(THF)//B3LYP-D3(BJ)/def2SVP-PCM(THF) level of theory.

Structure	*ZPE*	*TCH*	*TCG*	*E*	*H*	*G*	Imaginary Frequency
1a	0.109758	0.117072	0.079347	−308.547202	−308.430130	−308.467855	

2a	0.369624	0.391311	0.315489	−688.782568	−688.391257	−688.467079	
3a	0.486228	0.515309	0.419695	−997.394469	−996.879160	−996.974774	
Int-1(quartet)	0.357677	0.381400	0.304597	−2509.856865	−2509.475465	−2509.552268	
Int-1	0.360211	0.383359	0.308197	−2509.857673	−2509.474314	−2509.549476	
Int1(MECP)				−2509.846289			
Int-2a(quartet)	0.469528	0.500780	0.407245	−2818.376902	−2817.876122	−2817.969657	
Int-2a	0.471848	0.502910	0.410560	−2818.422308	−2817.919398	−2818.011748	
Int-2b(quartet)	0.468065	0.500371	0.400701	−2818.396600	−2817.896229	−2817.995899	
Int-2b	0.471706	0.502902	0.409318	−2818.419700	−2817.916798	−2818.010382	
TS-3a(quartet)	0.467499	0.498810	0.403853	−2818.389117	−2817.890307	−2817.985264	557.3*i*
TS-3a	0.471749	0.502044	0.410469	−2818.411725	−2817.909681	−2818.001256	47.9*i*
TS-3b(quartet)	0.467798	0.498946	0.404214	−2818.383486	−2817.884540	−2817.979272	427.8*i*
TS-3b	0.471600	0.501767	0.410994	−2818.406755	−2817.904988	−2817.995761	23.4*i*
Int-4a(MECP)				−2818.458773			
Int-4a(quartet)	0.474453	0.505528	0.411409	−2818.476652	−2817.971124	−2818.065243	
Int-4a	0.476061	0.506338	0.415860	−2818.463633	−2817.957295	−2818.047773	
Int-4b(quartet)	0.474964	0.506114	0.409303	−2818.472794	−2817.96668	−2818.063491	
Int-4b	0.476500	0.506880	0.414623	−2818.461944	−2817.955064	−2818.047321	

Cartesian Coordinates of Computed Species

1a

Charge = 0, Multiplicity = 1

C	2.02698000	-0.00007900	-0.00004700
C	0.59431500	-0.00003600	-0.00001600
C	-0.12056200	-1.21546500	0.00002300
C	-0.12049100	1.21543500	-0.00002300
C	-1.51526000	-1.21063500	0.00005200
H	0.42892700	-2.15865700	0.00003000
C	-1.51519000	1.21068700	0.00000500

H	0.42905200	2.15859600	-0.00005300
C	-2.21632900	0.00004700	0.00004300
H	-2.05900500	-2.15811000	0.00008200
H	-2.05887900	2.15819400	-0.00000200
H	-3.30873400	0.00007800	0.00006600
C	3.24187200	-0.00004400	-0.00006100
H	4.31663500	0.00044000	0.00001700

2a

Charge = 0, Multiplicity = 1

Sn	0.00000300	-0.91912500	-0.47667600
H	0.00008100	-1.99805100	-1.83961200
C	-1.80162800	-1.22727400	0.71571200
H	-1.90308300	-2.30674800	0.91638600
H	-1.62487300	-0.73953300	1.68941800
C	-3.06739700	-0.67274400	0.05838100
H	-3.22392700	-1.15243300	-0.92554700
H	-2.93907000	0.40444700	-0.15486100
C	-4.33140200	-0.85860200	0.90484900
H	-4.17796300	-0.37733600	1.88779400
H	-4.46873700	-1.93491700	1.11416500
C	-5.58969500	-0.29566500	0.24543900
H	-5.78306100	-0.78352900	-0.72471500
H	-6.48084100	-0.44233100	0.87642800
H	-5.48909500	0.78618400	0.05519300
C	1.80160400	-1.22714300	0.71578800
H	1.90301100	-2.30658400	0.91666200
H	1.62485900	-0.73921400	1.68940200

C	3.06740200	-0.67278600	0.05836700
H	2.93911700	0.40436800	-0.15508400
H	3.22392700	-1.15267200	-0.92546600
C	4.33139000	-0.85852600	0.90488700
H	4.46868600	-1.93480600	1.11441000
H	4.17795400	-0.37706700	1.88773800
C	5.58971100	-0.29575700	0.24538600
H	5.48914800	0.78605900	0.05492900
H	6.48084300	-0.44232800	0.87641600
H	5.78307500	-0.78381600	-0.72467000
C	-0.00004700	1.14952000	-1.16915800
H	0.88500900	1.29654000	-1.81028600
H	-0.88517600	1.29652100	-1.81019000
C	0.00000100	2.14502600	-0.00660000
H	-0.88020500	1.96948000	0.63954300
H	0.88027200	1.96948900	0.63945600
C	-0.00002800	3.61188100	-0.44985200
H	-0.88172100	3.79224600	-1.09110900
H	0.88157700	3.79224200	-1.09122800
C	0.00005700	4.59737100	0.71790800
H	0.00004800	5.64249700	0.36935700
H	-0.88855300	4.45788600	1.35635700
H	0.88874300	4.45786600	1.35624800

3a

Charge = 0, Multiplicity = 1

C	-0.95042100	0.57463300	1.34092300
C	-2.32458400	0.77474100	0.82693500

C	-2.54434200	1.38018100	-0.42608000
C	-3.45028400	0.33575900	1.55250100
C	-3.83564000	1.56204800	-0.92456000
H	-1.68980200	1.72626500	-1.01239000
C	-4.74192400	0.50915100	1.05148200
H	-3.30216400	-0.16777600	2.51029500
C	-4.94171000	1.12530400	-0.18849100
H	-3.97839600	2.04334100	-1.89521600
H	-5.59867100	0.15261300	1.62902200
H	-5.95231700	1.25621900	-0.58241900
C	-0.64116600	0.71715700	2.64135200
H	-1.38355500	1.04037600	3.38367100
H	0.36758500	0.53015200	3.02297000
Sn	0.57514500	-0.07057000	-0.08208800
C	2.22159700	-0.92719400	1.05846400
H	1.80259400	-1.70961700	1.71280200
H	2.61630600	-0.13737500	1.71968300
C	3.33326100	-1.49408900	0.17266800
H	3.72261800	-0.70417000	-0.49619000
H	2.92183300	-2.27234500	-0.49647600
C	4.50370100	-2.09135900	0.96126300
H	4.92034400	-1.31419700	1.62731000
H	4.11888900	-2.88469400	1.62734000
C	5.60952600	-2.65567700	0.07047300
H	6.43582200	-3.07745000	0.66468300
H	5.22454700	-3.45685700	-0.58262300
H	6.03251500	-1.87380100	-0.58252300
C	-0.39744100	-1.55588900	-1.34579100
H	-1.04300300	-1.00681600	-2.05115100

H	0.37472000	-2.06446900	-1.94684300
C	-1.21737300	-2.56294000	-0.53682600
H	-1.95109900	-2.02678800	0.09119400
H	-0.56004500	-3.10417200	0.16887500
C	-1.96538300	-3.58410600	-1.39996700
H	-1.23745000	-4.13319800	-2.02447600
H	-2.62086500	-3.04193900	-2.10535200
C	-2.79537800	-4.57203300	-0.58134700
H	-3.55103800	-4.04624800	0.02619600
H	-3.32555700	-5.29185900	-1.22528900
H	-2.15933900	-5.14840700	0.11146900
C	1.27632900	1.65625400	-1.21962400
H	0.57079900	1.82710900	-2.05003300
H	2.24056000	1.37786000	-1.67745800
C	1.42392600	2.91393000	-0.36166600
H	2.11727900	2.71831500	0.47737000
H	0.45560400	3.16038800	0.11082200
C	1.92210200	4.13630800	-1.13971800
H	2.89468100	3.89488000	-1.60557600
H	1.22811200	4.33509700	-1.97649400
C	2.05981200	5.38845300	-0.27472600
H	2.41790200	6.25067400	-0.85966900
H	1.09298200	5.66830900	0.17632300
H	2.77270200	5.22527000	0.55099000

Int-1(MECP)

Charge = 0, Multiplicity = 2

O	-0.04362500	-3.44202000	0.49733000
O	3.67219700	1.69342400	0.53014800

N	-1.85853900	-0.47235000	-0.14608000
N	0.69824100	-1.30203400	-0.10327200
N	1.51494800	1.43629700	0.03487100
C	-5.54718300	-0.22020800	0.23923400
H	-6.38864800	-0.84725900	0.54203900
C	-5.74245500	1.09440800	-0.12729500
H	-6.74724100	1.52174600	-0.12246300
C	-4.64081900	1.89630200	-0.51934500
H	-4.81120100	2.93261300	-0.82020700
C	-3.36058500	1.38264600	-0.53090500
H	-2.50193400	1.97436300	-0.84896100
C	-3.13200000	0.03416100	-0.15252500
C	-4.24404600	-0.78569000	0.22774400
C	-3.98796800	-2.13738200	0.57660900
H	-4.82035100	-2.78394400	0.86525600
C	-2.69891200	-2.61653600	0.54532300
H	-2.44180600	-3.64397200	0.79761100
C	-1.64853700	-1.74123900	0.18655800
C	-0.22107600	-2.25823800	0.19857100
C	2.05991900	-1.58360800	-0.15419700
C	2.56840100	-2.89568700	-0.33767600
H	1.86070300	-3.71313900	-0.42349400
C	3.93232100	-3.15574500	-0.39389500
H	4.27042700	-4.18453200	-0.54445100
C	4.86831600	-2.12313400	-0.26147600
H	5.93975200	-2.32805800	-0.29960000
C	4.40658400	-0.82736900	-0.08467500
H	5.11425100	-0.00479700	0.01432000
C	3.02685700	-0.53252900	-0.03505300

C	2.67072200	0.86936100	0.17003900
C	3.10481300	2.98826500	0.80625000
H	3.70387200	3.74680600	0.28546400
H	3.16340000	3.15841600	1.89200800
C	1.64407700	2.89317400	0.29291500
C	0.62949000	3.32828200	1.35186900
H	-0.39781600	3.16747100	0.99098900
H	0.74651200	4.39955900	1.57971500
H	0.76492000	2.75450800	2.28118700
C	1.45000000	3.66827000	-1.01354900
H	2.18135100	3.34350200	-1.76911600
H	1.58470800	4.74637700	-0.83533700
H	0.44312900	3.48595300	-1.41284100
Co	-0.12655500	0.50135100	-0.48548500
H	-0.58568400	1.42826100	-1.68959700

Int-1(quartet)

Charge = 0, Multiplicity = 4

O	0.23295200	-3.38766600	0.59988000
O	3.34752900	1.87596200	0.89678600
N	-1.76526900	-0.57247000	-0.20663900
N	0.81480800	-1.27963700	-0.22239500
N	1.37688900	1.47871400	-0.06400700
C	-5.42189000	-0.40366300	0.42353100
H	-6.22208700	-1.03583000	0.81526800
C	-5.68091600	0.88363400	0.00231100
H	-6.69520700	1.28467400	0.05640300
C	-4.63372500	1.69268600	-0.50811800
H	-4.85419100	2.70744200	-0.84675300

C	-3.34421400	1.21013100	-0.58776800
H	-2.53427900	1.81351900	-0.99891800
C	-3.04911500	-0.10812700	-0.15139300
C	-4.10468000	-0.93155400	0.35720500
C	-3.77458400	-2.24621100	0.78058500
H	-4.56272100	-2.89644700	1.16815700
C	-2.47183700	-2.68028800	0.70593600
H	-2.15924300	-3.67383600	1.02420000
C	-1.48073700	-1.79857800	0.21076500
C	-0.03148100	-2.25117800	0.19460800
C	2.19180400	-1.45504400	-0.19625700
C	2.81071100	-2.71359800	-0.39016000
H	2.17566400	-3.57918500	-0.55594700
C	4.19356800	-2.85592800	-0.36193400
H	4.62996500	-3.84429500	-0.52850400
C	5.02798600	-1.75535200	-0.12312600
H	6.11310200	-1.87195500	-0.09806700
C	4.45053300	-0.50929500	0.08004100
H	5.07606800	0.36331100	0.27003100
C	3.05220000	-0.33595000	0.03763400
C	2.53385100	1.00895800	0.27385400
C	2.67206900	3.15050100	0.97172000
H	3.24801900	3.87654500	0.37982100
H	2.65850000	3.46774000	2.02331200
C	1.25713400	2.88265000	0.38800100
C	0.15292000	2.96021000	1.44695000
H	-0.80442900	2.62830500	1.01455200
H	0.03145300	3.99250800	1.80971400
H	0.38613900	2.30941000	2.30308300

C	0.94486400	3.79210100	-0.80122300
H	1.71398100	3.69142600	-1.58134900
H	0.90476100	4.84407100	-0.47875700
H	-0.02728600	3.52562800	-1.24053600
Co	-0.06534600	0.40971600	-1.00404000
H	-0.70947400	0.82536700	-2.46764300

Int-1

Charge = 0, Multiplicity = 2

O	0.13030600	-3.36826900	0.81621900
O	-3.79173700	1.58218800	0.02762600
N	1.84799100	-0.37486000	0.06445400
N	-0.63175400	-1.28401100	0.05540100
N	-1.56686400	1.39368000	0.09153000
C	5.55402300	-0.15502400	-0.21837500
H	6.42770200	-0.79492200	-0.07493300
C	5.69600500	1.15180300	-0.63216400
H	6.68973200	1.56433700	-0.81917200
C	4.54988500	1.96491900	-0.81896000
H	4.67118400	2.99793500	-1.15273800
C	3.28482000	1.47015800	-0.58128000
H	2.39228000	2.08167600	-0.70106300
C	3.10861500	0.12902700	-0.15270900
C	4.26451200	-0.70179600	0.02295500
C	4.07337400	-2.04894400	0.42384600
H	4.94349700	-2.69190500	0.57565500
C	2.79585100	-2.52944300	0.59360000
H	2.57952300	-3.55933800	0.87464900

C	1.70458300	-1.66040300	0.38357400
C	0.29547800	-2.20140900	0.45252900
C	-1.95661200	-1.63941800	-0.15565300
C	-2.36752300	-2.98046200	-0.37682400
H	-1.61715400	-3.76266500	-0.33013700
C	-3.69184400	-3.30898600	-0.63506400
H	-3.95410300	-4.35629800	-0.80716600
C	-4.68504200	-2.32143500	-0.67565600
H	-5.72711600	-2.58044300	-0.87271300
C	-4.31666700	-1.00162800	-0.46506000
H	-5.06687100	-0.21279400	-0.49859200
C	-2.97518600	-0.63723600	-0.21135700
C	-2.70769000	0.78410200	-0.02164500
C	-3.33974200	2.94589900	0.02672900
H	-3.88563700	3.49290400	0.80670700
H	-3.57457200	3.38432700	-0.95585600
C	-1.81737100	2.85260300	0.28760500
C	-1.02917800	3.68254200	-0.72302800
H	0.04767300	3.57829200	-0.53803900
H	-1.30675100	4.74497000	-0.63605100
H	-1.24378900	3.34887400	-1.74987100
C	-1.46894000	3.24132000	1.72688900
H	-2.06128000	2.65051900	2.44286600
H	-1.68307100	4.30875300	1.89354000
H	-0.40329600	3.05454200	1.91493900
Co	0.14417400	0.54915700	0.08927300
H	0.79708000	1.85186800	0.48743000

Int-2a(quartet)

Charge = 0, Multiplicity = 4

O	0.22595000	-3.36735500	-0.31088800
O	-3.00660400	2.13828600	-0.82352700
N	2.31478800	-0.45826100	-0.34142300
N	-0.22911800	-1.10109200	-0.75758900
N	-0.85488200	1.66126800	-0.51304700
C	5.99033300	-0.59340000	0.22782500
H	6.75348000	-1.34621900	0.44276000
C	6.34322800	0.74962600	0.10589900
H	7.38339300	1.06078500	0.22485400
C	5.34635500	1.69209700	-0.17511200
H	5.60426200	2.74870600	-0.28207100
C	4.01759900	1.29734900	-0.32673400
H	3.24922100	2.03595300	-0.55486400
C	3.63108900	-0.05383700	-0.19734500
C	4.65701600	-1.02197800	0.07996700
C	4.28451500	-2.40823200	0.19719100
H	5.05655500	-3.14898000	0.41581900
C	2.97137800	-2.77467900	0.02253400
H	2.63799200	-3.81065000	0.09311000
C	1.99319700	-1.80428500	-0.26125800
C	0.60151700	-2.19245800	-0.45217800
C	-1.53520100	-1.25532600	-1.14935600
C	-2.07193700	-2.50731700	-1.57549600
H	-1.41158300	-3.36689900	-1.57875700
C	-3.39605100	-2.64747400	-1.94761600
H	-3.75282500	-3.62995500	-2.26822600
C	-4.28401000	-1.55655000	-1.91467000

H	-5.33213000	-1.67742900	-2.19436000
C	-3.79735300	-0.32370500	-1.52945900
H	-4.45644500	0.54267300	-1.50633400
C	-2.43994100	-0.13891800	-1.16479100
C	-2.04459400	1.20240400	-0.81640400
C	-2.45169300	3.36518400	-0.32181100
H	-2.82763300	3.51555300	0.70201200
H	-2.79547600	4.18888900	-0.96013400
C	-0.92368400	3.14547400	-0.36401100
C	-0.28775800	3.79074300	-1.59891000
H	0.76613400	3.48787000	-1.68009800
H	-0.33285700	4.88795400	-1.52258900
H	-0.81170800	3.48046900	-2.51583300
C	-0.26229200	3.63579900	0.92090300
H	-0.63866900	3.08722500	1.79501100
H	-0.47495300	4.70726700	1.05790800
H	0.82719300	3.50343700	0.87784400
Co	0.69931300	0.57435200	-0.36392300
H	1.43989600	1.83505300	-0.15675900
C	-0.17518000	0.06375600	2.23768700
C	-1.54394300	-0.34395000	2.18681700
C	-2.56636700	0.61205100	2.35846200
C	-1.88706400	-1.67951000	1.89935300
C	-3.90208800	0.24266800	2.21997800
H	-2.30005900	1.64462000	2.58844900
C	-3.22687800	-2.03942700	1.76765100
H	-1.10337900	-2.41878500	1.73274300
C	-4.23461500	-1.08251500	1.91824100
H	-4.68678400	0.99274300	2.33888000

H	-3.48319200	-3.07071200	1.51864700
H	-5.28134900	-1.36824600	1.79447000
C	0.98061800	0.45313400	2.23250600
H	2.00198500	0.76997600	2.34399500

Int-2a

Charge = 0, Multiplicity = 2

O	0.30276300	-3.28380800	-0.12390600
O	-3.07519200	2.05147700	-0.84245800
N	2.36435300	-0.41483000	-0.26443500
N	-0.15507300	-1.07186900	-0.74970700
N	-0.90884200	1.65919700	-0.46522200
C	6.06296400	-0.55866900	0.17108600
H	6.83304900	-1.29842800	0.40154500
C	6.39477800	0.75923700	-0.05685700
H	7.43719900	1.08097900	-0.00597900
C	5.38058500	1.70044600	-0.36382500
H	5.65180300	2.74164600	-0.55311500
C	4.05635600	1.32032600	-0.42714600
H	3.25713100	2.02573200	-0.64848600
C	3.68275100	-0.02842800	-0.19090000
C	4.70964100	-0.98720900	0.10321200
C	4.33352600	-2.33879700	0.30975600
H	5.10084800	-3.07900600	0.54854800
C	3.01183000	-2.69659900	0.18883700
H	2.65685400	-3.71860800	0.31406900
C	2.05746700	-1.70265700	-0.11546500
C	0.61894000	-2.10602700	-0.33304200

C	-1.45540100	-1.27455200	-1.18578700
C	-1.91739400	-2.53492800	-1.64616600
H	-1.22804600	-3.37263700	-1.63027100
C	-3.22107300	-2.72391600	-2.08370900
H	-3.52613800	-3.71479200	-2.43085600
C	-4.14187500	-1.66809000	-2.07652600
H	-5.17225600	-1.81860800	-2.40452700
C	-3.71611300	-0.42051300	-1.64720700
H	-4.40921500	0.41911800	-1.63780800
C	-2.39052100	-0.19477400	-1.21760100
C	-2.05620300	1.16611500	-0.81595400
C	-2.59598100	3.28565000	-0.28789100
H	-3.01255200	3.39069500	0.72654900
H	-2.95418900	4.11349300	-0.91385600
C	-1.05898200	3.13344100	-0.28072300
C	-0.41079000	3.83710400	-1.47703100
H	0.65014700	3.55617600	-1.52873300
H	-0.49112400	4.93039500	-1.37192200
H	-0.90007100	3.53835600	-2.41729600
C	-0.46136500	3.62102200	1.03582200
H	-0.84321800	3.03497000	1.88301700
H	-0.72427500	4.67942000	1.19188100
H	0.63051900	3.51923500	1.01867000
Co	0.72809700	0.67329900	-0.34151700
H	1.46611800	1.95800900	-0.06170100
C	-0.25111300	-0.01017200	2.28918300
C	-1.62135400	-0.40219100	2.16731600
C	-2.64352800	0.55825500	2.30823200
C	-1.96717000	-1.73049500	1.85243900

C	-3.97609000	0.20331200	2.10990000
H	-2.37946800	1.58591200	2.55972300
C	-3.30350300	-2.07759500	1.66146500
H	-1.18429000	-2.47581200	1.71187000
C	-4.30936900	-1.11460400	1.78029200
H	-4.75739700	0.96074800	2.20384800
H	-3.55747400	-3.10416100	1.39033900
H	-5.35262000	-1.38918500	1.60974600
C	0.90601600	0.35828600	2.36957300
H	1.92424500	0.67057600	2.50447700

Int-2b(quartet)

Charge = 0, Multiplicity = 4

O	1.82649900	-3.79382600	-0.18253300
O	3.86218000	1.88841000	1.06910600
N	-1.10997500	-1.85949300	0.15371900
N	1.53406900	-1.47881500	-0.18846000
N	1.76599000	1.10976200	1.07640900
C	-4.48807900	-3.34433400	0.60200100
H	-4.94600600	-4.32603300	0.74382200
C	-5.26202300	-2.20420700	0.55051000
H	-6.34702600	-2.27276200	0.65467700
C	-4.65388500	-0.93734700	0.35769800
H	-5.27625500	-0.04072500	0.31212300
C	-3.28607500	-0.82355500	0.22942500
H	-2.80801300	0.14141800	0.09368400
C	-2.46490000	-1.97909300	0.28449100
C	-3.07612700	-3.26238600	0.46568000

C	-2.23012400	-4.40211600	0.49290200
H	-2.67045300	-5.39218100	0.63494100
C	-0.87362600	-4.24751600	0.32895200
H	-0.17863400	-5.08588800	0.32141200
C	-0.34950300	-2.94276300	0.15871700
C	1.13748800	-2.77514000	-0.08681600
C	2.78958900	-1.17880400	-0.70632100
C	3.41344700	-2.01429900	-1.66963300
H	2.90794400	-2.92881300	-1.96718900
C	4.64433900	-1.70190000	-2.22919300
H	5.07635600	-2.37441900	-2.97489300
C	5.33076900	-0.54037100	-1.84848900
H	6.30292100	-0.29607300	-2.28093900
C	4.74600400	0.30037800	-0.91454300
H	5.25426100	1.21353000	-0.60737800
C	3.48488300	0.01424600	-0.34435200
C	2.96827600	0.98362600	0.62066900
C	3.20858300	2.69990700	2.06028800
H	3.39963900	3.75612600	1.82638200
H	3.64713700	2.45982300	3.04120800
C	1.71270600	2.30482800	1.96025400
C	1.12946500	1.94878800	3.32639300
H	0.08985100	1.61533900	3.21097400
H	1.15983000	2.82683800	3.99100300
H	1.70763500	1.13695700	3.79382400
C	0.88895400	3.39359000	1.26724300
H	1.32824600	3.65287100	0.29133000
H	0.85596000	4.30200600	1.88900800
H	-0.13609800	3.04171400	1.10184800

Co	0.13792100	-0.10150800	0.52933700
H	-0.95736300	0.62636300	1.53673800
C	-0.92395900	1.44611600	-1.63320800
C	-1.90402700	2.46883100	-1.40807400
C	-2.45484800	2.70150500	-0.13237500
C	-2.34285800	3.24414900	-2.50188000
C	-3.42586500	3.68794200	0.03935000
H	-2.10347600	2.09597400	0.70711700
C	-3.31417700	4.22732700	-2.31829100
H	-1.91790400	3.06449300	-3.49102400
C	-3.85881800	4.45197000	-1.04894400
H	-3.84694200	3.86062300	1.03244100
H	-3.64886200	4.82145700	-3.17152400
H	-4.62028400	5.22272300	-0.90952500
C	-0.11576100	0.58514200	-1.93581000
H	0.58453800	-0.16458900	-2.25626000

Int-2b

Charge = 0, Multiplicity = 2

O	-0.98020800	-3.54737700	0.71426200
O	-4.11680700	2.01278900	-0.27007800
N	1.06543900	-0.99529700	-0.62969500
N	-1.51637500	-1.39836500	-0.06432400
N	-1.96593200	1.41685200	-0.35430300
C	4.66642700	-1.55363700	-1.42647300
H	5.40317600	-2.35783900	-1.36338000
C	5.01432500	-0.31225500	-1.91069300
H	6.03729600	-0.11538800	-2.23868700

C	4.04068700	0.71418500	-1.98080100
H	4.32225500	1.69820100	-2.36238700
C	2.74456300	0.49246700	-1.56872600
H	1.98289100	1.26937000	-1.59687500
C	2.35564800	-0.77209000	-1.05751300
C	3.34013500	-1.81477800	-0.98973500
C	2.95764300	-3.07343900	-0.46500400
H	3.69812100	-3.87363700	-0.39360600
C	1.66006700	-3.26548100	-0.05543900
H	1.29717500	-4.20812200	0.35113100
C	0.73863900	-2.20177800	-0.16814800
C	-0.70110300	-2.45118200	0.21735700
C	-2.89408700	-1.49042900	0.06968800
C	-3.57583600	-2.72750600	0.24281400
H	-2.98068700	-3.63101100	0.30795800
C	-4.95831100	-2.80337200	0.34267600
H	-5.42572300	-3.78371100	0.46917700
C	-5.75047100	-1.64960100	0.28833900
H	-6.83715300	-1.70651900	0.37633900
C	-5.12141200	-0.42694800	0.11606200
H	-5.71238900	0.48604400	0.06347400
C	-3.71671200	-0.31785300	-0.00212300
C	-3.19394200	1.02848400	-0.21024100
C	-3.41793400	3.26671800	-0.29659000
H	-3.52109500	3.73892900	0.69353200
H	-3.88285100	3.90988800	-1.05532200
C	-1.95547500	2.88601400	-0.61761700
C	-1.61855300	3.12010800	-2.09326700
H	-0.63455200	2.68475100	-2.31400600

H	-1.59717600	4.19846500	-2.31581500
H	-2.36808700	2.64329100	-2.74414700
C	-0.97957300	3.61575600	0.30048900
H	-1.16943700	3.35870200	1.35288600
H	-1.09137800	4.70446900	0.17525600
H	0.05010300	3.32792300	0.05566900
Co	-0.43337600	0.26322800	-0.40601800
H	0.40168400	1.45551700	-0.76320300
C	0.69584200	0.63912300	2.02789100
C	2.08428800	0.94017900	1.86569300
C	3.04138800	-0.09064300	1.93512900
C	2.50978700	2.25710300	1.60479600
C	4.39161300	0.19060200	1.73409000
H	2.71205900	-1.11315200	2.12672400
C	3.86209000	2.52977900	1.40718300
H	1.76936000	3.05535600	1.54710200
C	4.80566900	1.49842100	1.46603800
H	5.12289800	-0.61923900	1.77162000
H	4.18215800	3.55299200	1.19755600
H	5.86331000	1.71362300	1.29824100
C	-0.47924300	0.35570800	2.17670200
H	-1.50354100	0.11639100	2.39257000

Int-4a(MECP)

Charge = 0, Multiplicity = 2

O	0.02312800	-3.17913600	-1.23560000
O	-3.78359400	2.06992300	-0.49030000
N	1.75766300	-0.12050100	-0.88500800

N	-0.78433200	-0.99257700	-0.93540600
N	-1.62751900	1.66772800	-0.11797600
C	5.45171700	0.17046400	-1.07950100
H	6.32589700	-0.47448900	-1.19530600
C	5.59234400	1.53815800	-0.97020500
H	6.58563800	1.99042500	-0.99797300
C	4.44997800	2.36621600	-0.82592900
H	4.57644700	3.44823200	-0.74651200
C	3.18459400	1.81920500	-0.78594300
H	2.30127800	2.44882400	-0.67361800
C	3.01388700	0.41687600	-0.90372900
C	4.16177000	-0.42379300	-1.05441200
C	3.94861800	-1.82303200	-1.18081500
H	4.80957400	-2.48738500	-1.28584400
C	2.66697600	-2.32287300	-1.18065100
H	2.44355700	-3.38326000	-1.28776600
C	1.58194700	-1.42827900	-1.03456300
C	0.16223800	-1.96394500	-1.07404000
C	-2.14001400	-1.23697200	-1.08148600
C	-2.66223200	-2.50732800	-1.45307900
H	-1.95815300	-3.32227500	-1.57728400
C	-4.01891700	-2.72080500	-1.65497300
H	-4.36065300	-3.71954900	-1.94094900
C	-4.94496900	-1.68111700	-1.49841700
H	-6.01201900	-1.84641800	-1.65957500
C	-4.47560300	-0.43100900	-1.13120900
H	-5.17399700	0.39437500	-0.99963700
C	-3.10104500	-0.18054400	-0.90919100
C	-2.76770000	1.18073100	-0.50485600

C	-3.20917000	3.37171900	-0.26001600
H	-3.88475700	3.93842200	0.39226300
H	-3.11412400	3.88203800	-1.23261200
C	-1.84433600	3.05389000	0.37725600
C	-0.72582500	3.97591400	-0.09242800
H	0.22657500	3.67843900	0.37091400
H	-0.93426500	5.01549100	0.20346500
H	-0.61682500	3.93754600	-1.18639300
C	-1.94506000	3.02349000	1.90736500
H	-2.78434500	2.38617800	2.22649100
H	-2.11606400	4.04024000	2.29410900
H	-1.01874100	2.62236200	2.33767300
Co	0.05854600	0.69593100	-0.18792000
C	0.79212300	0.75520300	1.67007200
C	0.47108600	-0.56997400	2.22952300
C	1.48083600	-1.52894800	2.44819800
C	-0.86956100	-0.96830400	2.42372600
C	1.16375400	-2.83059500	2.84812400
H	2.52176400	-1.24464300	2.27663900
C	-1.18400800	-2.26351900	2.83066600
H	-1.66661500	-0.24773800	2.22876200
C	-0.16848800	-3.20529300	3.04177100
H	1.96361500	-3.55970800	3.00119500
H	-2.22985600	-2.54757700	2.97100300
H	-0.41684600	-4.22543100	3.34467900
C	1.56869300	1.64766100	2.30253700
H	1.85393200	2.60310500	1.84607900
H	1.95949800	1.47463800	3.31718500

Int-4a(quartet)

Charge = 0, Multiplicity = 4

O	-0.67365000	-3.20608600	-1.59524900
O	-4.27414700	1.63716300	-0.36246100
N	1.09615300	-0.19274100	-1.00274000
N	-1.25982600	-1.30736200	-0.36696800
N	-2.07837500	1.41083600	-0.06074200
C	4.66372500	0.33676900	-1.87097800
H	5.50337900	-0.21853700	-2.29507700
C	4.81422700	1.64821100	-1.47117100
H	5.78104500	2.14501100	-1.57579900
C	3.71866100	2.35923500	-0.91823700
H	3.85493300	3.39415100	-0.59725700
C	2.49074600	1.75154100	-0.76926400
H	1.64788100	2.27575100	-0.31824400
C	2.30995400	0.40517300	-1.17398500
C	3.41010400	-0.31688800	-1.73457200
C	3.18765700	-1.66449900	-2.12034500
H	4.01071700	-2.23924500	-2.55171100
C	1.94686400	-2.23266900	-1.94078600
H	1.72417600	-3.26250200	-2.21678300
C	0.91691600	-1.46071500	-1.35619400
C	-0.44355800	-2.09679500	-1.10744200
C	-2.57883600	-1.63459600	-0.09131000
C	-3.02665200	-2.96974800	0.04185100
H	-2.30665400	-3.76946700	-0.10952400
C	-4.34925500	-3.26347700	0.35440700
H	-4.65154200	-4.30818400	0.46464500

C	-5.29087700	-2.24067500	0.53062400
H	-6.32868000	-2.47394200	0.77614300
C	-4.88485100	-0.92089000	0.38487000
H	-5.60273000	-0.10951900	0.50576400
C	-3.54677600	-0.59363700	0.08243800
C	-3.23326400	0.82527000	-0.10435200
C	-3.77922100	2.99244000	-0.39752000
H	-4.14013400	3.51093200	0.50383800
H	-4.18689500	3.48385400	-1.29037600
C	-2.23723100	2.83968100	-0.41842200
C	-1.64706700	3.05247800	-1.81729800
H	-0.57935700	2.78623300	-1.82121300
H	-1.74778000	4.10497500	-2.12409600
H	-2.16057800	2.41953400	-2.55692800
C	-1.55360800	3.73316800	0.61313700
H	-1.95972500	3.55013200	1.61836500
H	-1.70574600	4.79376500	0.36077300
H	-0.47264600	3.53503800	0.64064400
Co	-0.40263600	0.37470000	0.32358800
C	0.61206700	0.66433700	2.04108600
C	1.86860400	-0.11632500	2.09999300
C	3.11862900	0.50577400	2.29374000
C	1.86286500	-1.50596100	1.85593400
C	4.30803400	-0.22540700	2.24037200
H	3.14867200	1.58544800	2.45628000
C	3.04824200	-2.24005700	1.81175100
H	0.90599400	-2.00730100	1.68848600
C	4.28061500	-1.60222500	1.99732600
H	5.26448800	0.28613500	2.37870900

H	3.01188000	-3.31558200	1.61938200
H	5.21108200	-2.17290500	1.94543600
C	0.28711400	1.51924000	3.02946000
H	-0.61783500	2.13583800	2.98874000
H	0.90096200	1.63724800	3.93705500

Int-4a

Charge = 0, Multiplicity = 2

O	-0.07149500	-3.24848100	-0.93716100
O	-3.67867700	2.11393000	-0.53158000
N	1.72297600	-0.22342400	-0.78067200
N	-0.79653400	-1.01298500	-0.95369200
N	-1.54924400	1.61684900	-0.10076500
C	5.41134600	0.04775000	-1.08876100
H	6.27790400	-0.60598300	-1.21072500
C	5.56331400	1.41553800	-1.01054100
H	6.55882000	1.86087900	-1.06573200
C	4.42790100	2.25365800	-0.86599600
H	4.56039300	3.33660600	-0.81768800
C	3.16125300	1.71587700	-0.78384200
H	2.28585100	2.35499000	-0.67690400
C	2.97940600	0.31149200	-0.85492600
C	4.11857000	-0.53930700	-1.02209400
C	3.89957200	-1.93825000	-1.12188400
H	4.75644100	-2.60629400	-1.23609600
C	2.61488300	-2.43190900	-1.08860500
H	2.38339800	-3.49250300	-1.17641100
C	1.54156600	-1.53070000	-0.92729600

C	0.11410700	-2.03027700	-0.93588700
C	-2.15799300	-1.24180500	-1.07643900
C	-2.70451800	-2.50015600	-1.44811900
H	-2.02102400	-3.33060300	-1.58457000
C	-4.06923700	-2.68762400	-1.62259500
H	-4.43420700	-3.67795500	-1.90791900
C	-4.97365200	-1.63364900	-1.43855900
H	-6.04667100	-1.78238100	-1.57364900
C	-4.47563200	-0.39136000	-1.07955000
H	-5.15504900	0.44709900	-0.93204300
C	-3.09289300	-0.17145800	-0.88568000
C	-2.70555500	1.17869900	-0.50053700
C	-3.04525400	3.39228800	-0.34017500
H	-3.70098200	4.01808200	0.27746900
H	-2.90858000	3.85980600	-1.32931400
C	-1.70710400	3.03678900	0.33335100
C	-0.55016100	3.89299100	-0.16779600
H	0.38541100	3.59689600	0.32493400
H	-0.73303600	4.95386000	0.06335400
H	-0.42757200	3.78880100	-1.25624600
C	-1.83775000	3.08588300	1.86024700
H	-2.70806400	2.49793600	2.19076000
H	-1.97773600	4.12734300	2.18981400
H	-0.93684200	2.67702300	2.33271900
Co	0.08278100	0.66330600	-0.27233300
C	0.77875100	0.86367600	1.52809200
C	0.42505600	-0.42924200	2.15473600
C	1.42600000	-1.37672000	2.44775800
C	-0.91910400	-0.80571200	2.35641500

C	1.09731300	-2.65233400	2.91476900
H	2.47096000	-1.10766200	2.27622400
C	-1.24653100	-2.07447400	2.83299200
H	-1.70991200	-0.09385000	2.11478000
C	-0.24033400	-3.00931700	3.10692000
H	1.89167100	-3.37474800	3.12081900
H	-2.29618500	-2.34310400	2.97760800
H	-0.49927500	-4.00989400	3.46139900
C	1.55502200	1.76570400	2.14664800
H	1.88091300	2.69584800	1.66989400
H	1.89921500	1.61756700	3.18046600

Int-4b(quartet)

Charge = 0, Multiplicity = 4

O	-2.25520300	2.74636000	-2.18441300
O	-3.71719500	-1.80075700	1.82893700
N	0.35195900	1.80863300	0.03566000
N	-1.88762700	0.75916500	-1.01118600
N	-1.75450600	-0.88597500	1.30425200
C	3.16042700	4.05123300	0.96866500
H	3.53989600	5.04574800	0.72331900
C	3.80768700	3.25595100	1.89058600
H	4.71157300	3.61604000	2.38632700
C	3.30614300	1.96567200	2.20030900
H	3.83105100	1.34464300	2.92931300
C	2.16827500	1.48585400	1.58691400
H	1.78867200	0.48710000	1.80251500
C	1.48216400	2.28550300	0.63579500

C	1.98399300	3.58884600	0.31976900
C	1.26976200	4.35931400	-0.63476400
H	1.63341900	5.35590400	-0.89669200
C	0.13033200	3.84842900	-1.21357800
H	-0.46062600	4.40109400	-1.94260100
C	-0.30548900	2.55376300	-0.84741200
C	-1.59867600	2.00999800	-1.44383700
C	-3.09085700	0.12468500	-1.28213600
C	-3.84474400	0.37338800	-2.45324100
H	-3.47034400	1.11320200	-3.15527600
C	-5.03365200	-0.30118900	-2.70856600
H	-5.57785100	-0.09101100	-3.63303100
C	-5.53471700	-1.24254600	-1.80020000
H	-6.46810500	-1.77154300	-2.00206000
C	-4.82641300	-1.49290600	-0.63222500
H	-5.20397900	-2.21374900	0.09271100
C	-3.61160200	-0.83330400	-0.35264100
C	-2.96550700	-1.14423900	0.92678600
C	-2.93125400	-1.98122100	3.02486100
H	-2.92366300	-3.05140600	3.27331500
H	-3.41776000	-1.42328900	3.83817200
C	-1.52669000	-1.42377300	2.66313900
C	-1.09146300	-0.29142300	3.59562900
H	-0.13055700	0.13071000	3.26585300
H	-0.96875300	-0.66523500	4.62397600
H	-1.83825600	0.51651700	3.60139600
C	-0.46717700	-2.52768200	2.59948500
H	-0.78872700	-3.33607200	1.92557100
H	-0.29626200	-2.95164900	3.60104600

H	0.48263500	-2.12679400	2.21727100
Co	-0.40585200	-0.12866300	0.01409800
C	3.47035800	-1.95567600	-1.06040000
C	3.35434400	-3.35628700	-1.17695300
C	4.74684100	-1.38873800	-1.24853600
C	4.46372700	-4.14924700	-1.46673100
H	2.37799600	-3.82592900	-1.03839000
C	5.86036100	-2.18033300	-1.53865000
H	4.85914100	-0.30407200	-1.16132600
C	5.72520700	-3.56734700	-1.64953300
H	4.34623000	-5.23281500	-1.55260400
H	6.83826700	-1.71222500	-1.67892800
H	6.59297400	-4.19124200	-1.87695000
C	1.04690700	-1.40771700	-0.48002900
H	0.82435000	-2.48956000	-0.51971900
C	2.33014800	-1.07189000	-0.74572400
H	2.61646700	-0.01076700	-0.72181800

Int-4b

Charge = 0, Multiplicity = 2

O	-1.96283000	2.78005300	-2.22407900
O	-3.40071400	-2.40696500	1.39625600
N	0.44960200	1.86832400	0.17497200
N	-1.96446600	1.10655300	-0.57204100
N	-1.52696500	-1.30277800	0.91086700
C	3.41434900	3.92003700	1.05561000
H	3.90791200	4.83785600	0.72829100
C	3.91800800	3.18346400	2.10640200

H	4.82406900	3.51026900	2.62076100
C	3.25673800	2.00361100	2.53381900
H	3.65584700	1.43758300	3.37815600
C	2.11714000	1.56438600	1.89416700
H	1.60191800	0.66065400	2.21895200
C	1.58677000	2.29719100	0.80201200
C	2.23177700	3.50552500	0.38500100
C	1.64443400	4.24569300	-0.67402200
H	2.12846500	5.16235800	-1.01872200
C	0.46225200	3.81447300	-1.23324700
H	-0.05194400	4.35724200	-2.02543200
C	-0.11862000	2.61763900	-0.76300200
C	-1.46503600	2.16239400	-1.28095700
C	-3.25228800	0.62513900	-0.76159700
C	-4.22977200	1.30630100	-1.53642000
H	-3.93171300	2.21602900	-2.04559600
C	-5.52969500	0.83391300	-1.66239700
H	-6.24016400	1.39858700	-2.27205600
C	-5.93535600	-0.34536300	-1.02477400
H	-6.95638200	-0.71795400	-1.12667500
C	-5.00937200	-1.03298700	-0.25629800
H	-5.29809300	-1.95056500	0.25461100
C	-3.67785800	-0.58143000	-0.11383600
C	-2.80837600	-1.39842300	0.72338800
C	-2.43351500	-2.92389100	2.32804200
H	-2.53755800	-4.01506500	2.37006300
H	-2.64826300	-2.49292800	3.31974300
C	-1.08183900	-2.44867100	1.75990100
C	-0.11886300	-1.98219600	2.84631200

H	0.82965700	-1.65647200	2.39683800
H	0.09874800	-2.80844700	3.54091800
H	-0.54828900	-1.14781600	3.42096100
C	-0.44836400	-3.53422500	0.88091300
H	-1.14984100	-3.85849200	0.09694700
H	-0.19293700	-4.40742600	1.50120800
H	0.46693800	-3.16397800	0.40437200
Co	-0.46575400	0.18634800	0.38937500
C	3.20072500	-1.84336700	-0.96869900
C	2.76906900	-2.79405200	-1.91793000
C	4.58595700	-1.75586900	-0.72058000
C	3.68004100	-3.61006400	-2.58747100
H	1.70260900	-2.89488600	-2.13029300
C	5.50035100	-2.57181200	-1.39018600
H	4.94431300	-1.02787800	0.01312100
C	5.05303600	-3.50560900	-2.32983400
H	3.31654800	-4.33839800	-3.31742300
H	6.56852600	-2.47829300	-1.17677300
H	5.76444000	-4.14729600	-2.85521700
C	0.94561500	-0.85270800	-0.38806800
H	0.50265600	-1.49282600	-1.17053800
C	2.28080200	-0.95825200	-0.22919700
H	2.79039000	-0.34775900	0.52432900

TS-3a(quartet)

Charge = 0, Multiplicity = 4

O	0.20285400	-2.38795600	-2.42481000
O	-3.16114600	2.62050600	-0.93475800

N	2.22064300	-0.24143300	-0.44473500
N	-0.41492500	-0.61994900	-1.03561100
N	-1.08291300	2.07897500	-0.32123000
C	5.90905400	-0.66985500	-0.18614600
H	6.68873100	-1.33542700	-0.56386200
C	6.21953600	0.37607000	0.65658900
H	7.25452700	0.54951000	0.95902900
C	5.19553400	1.23564400	1.12820100
H	5.45401600	2.06827100	1.78660100
C	3.88013900	1.03787500	0.76362600
H	3.07925600	1.69651300	1.09992300
C	3.52880200	-0.03825600	-0.09345200
C	4.56482600	-0.90054700	-0.58316000
C	4.19374800	-1.95495400	-1.45639800
H	4.96474700	-2.62478400	-1.84535200
C	2.87385600	-2.11891700	-1.80128400
H	2.52931300	-2.90774200	-2.46772900
C	1.90522000	-1.23621600	-1.26301700
C	0.44784400	-1.47133200	-1.63252900
C	-1.78767500	-0.81201700	-1.11493900
C	-2.36650000	-2.08949800	-1.31108900
H	-1.70477500	-2.93934900	-1.44144500
C	-3.74106500	-2.27649900	-1.32104200
H	-4.13889400	-3.28656800	-1.44860900
C	-4.61587500	-1.19409500	-1.15926600
H	-5.69769200	-1.34090900	-1.17112800
C	-4.08120600	0.07282000	-0.97959500
H	-4.73890400	0.93196000	-0.85035600
C	-2.68656300	0.28545400	-0.94184800

C	-2.23814200	1.66008200	-0.72569000
C	-2.50784600	3.89445600	-0.78304800
H	-3.13961500	4.53690000	-0.15550700
H	-2.40687100	4.34652500	-1.78209100
C	-1.13925300	3.55175500	-0.14176700
C	0.02274300	4.22536600	-0.86905100
H	0.97662400	3.91280800	-0.42071100
H	-0.06155500	5.32101400	-0.79374900
H	0.02829100	3.94660800	-1.93366200
C	-1.12537800	3.88189000	1.35483400
H	-1.95903900	3.38131400	1.87106000
H	-1.22341800	4.96873900	1.50310400
H	-0.18363400	3.54410700	1.80669000
Co	0.42031200	0.76482900	0.24028300
H	1.19783100	1.98382700	0.99093500
C	-0.10646200	-0.10537300	2.17854700
C	-0.99883000	-1.21236800	2.11483100
C	-0.51501100	-2.51437600	1.84929000
C	-2.39183900	-1.02409400	2.26496600
C	-1.39804600	-3.58734800	1.75810700
H	0.55680600	-2.66558700	1.70745600
C	-3.26308900	-2.10676200	2.17492900
H	-2.77681600	-0.01834100	2.44201900
C	-2.77440300	-3.39321000	1.92412500
H	-1.00849000	-4.58670700	1.54891200
H	-4.33713300	-1.94157900	2.28565900
H	-3.46274900	-4.23717000	1.84276400
C	0.67877600	0.85706300	2.35651500
H	1.27035400	1.42559000	3.06253300

TS-3a

Charge = 0, Multiplicity = 2

O	0.07902900	2.19245700	-2.15218300
O	3.85428200	-2.11243700	-0.61335400
N	-1.51256900	-0.48575200	-0.45351100
N	0.85563500	0.73110000	-0.51288000
N	1.76004100	-1.77725100	0.08962000
C	-5.08209000	-1.39996500	-0.95779600
H	-5.94485800	-1.07191300	-1.54259400
C	-5.18256800	-2.46937800	-0.09201800
H	-6.13091700	-3.00027600	0.01612500
C	-4.05619700	-2.88292600	0.66307900
H	-4.14835700	-3.72863600	1.34843100
C	-2.84860200	-2.22713800	0.54285700
H	-1.97054300	-2.51651400	1.12010000
C	-2.71549700	-1.12568500	-0.34283400
C	-3.85347800	-0.70245500	-1.10445700
C	-3.69333400	0.40778800	-1.97712100
H	-4.54492100	0.75010100	-2.57033500
C	-2.47528200	1.03698500	-2.05323700
H	-2.29112400	1.89962800	-2.69195600
C	-1.40082900	0.56125700	-1.26057800
C	-0.06524500	1.26673400	-1.34356700
C	2.17621500	1.14808100	-0.53148200
C	2.56545600	2.49396600	-0.71264400
H	1.78849100	3.23700700	-0.87020000
C	3.90793600	2.86130100	-0.68867300

H	4.17504100	3.91431500	-0.81138800
C	4.91580700	1.90305200	-0.51077800
H	5.96693900	2.19784600	-0.49558300
C	4.55978200	0.56656100	-0.36418600
H	5.32637400	-0.20059700	-0.24727300
C	3.20787600	0.17759700	-0.36347100
C	2.88158900	-1.24536800	-0.27836300
C	3.26254600	-3.42808500	-0.64168700
H	3.94530200	-4.12710500	-0.14184000
H	3.14363100	-3.72278900	-1.69602500
C	1.90361200	-3.25663900	0.08251100
C	0.74780400	-3.89295100	-0.68478900
H	-0.20193300	-3.69750400	-0.16797700
H	0.88890800	-4.98247300	-0.75999000
H	0.67959000	-3.47510000	-1.70021700
C	1.97499600	-3.77441300	1.52283700
H	2.81939200	-3.31474700	2.05958000
H	2.11248500	-4.86679700	1.52507000
H	1.04872000	-3.53193200	2.06116500
Co	0.26884000	-0.68241400	0.79913200
H	-0.14569100	-1.86949700	1.59197000
C	-0.56739800	0.83486800	2.11703200
C	-0.91184100	2.14010400	1.64464100
C	-2.20867500	2.39661100	1.15453500
C	0.05335800	3.16664300	1.59458100
C	-2.52738600	3.64865300	0.62953900
H	-2.95569700	1.60177100	1.17895200
C	-0.27477600	4.41406200	1.06840700
H	1.06419900	2.96675300	1.95252100

C	-1.56329400	4.65996300	0.57955500
H	-3.53373200	3.83053500	0.24544500
H	0.48495500	5.19812800	1.02746800
H	-1.81298300	5.63620100	0.15803800
C	-0.36945100	-0.24031100	2.72184500
H	-0.37637500	-0.85153700	3.61321400

TS-3b(quartet)

Charge = 0, Multiplicity = 4

O	-2.15507700	3.62804600	-0.19047400
O	-3.61557800	-2.06430600	1.36612700
N	0.91652000	1.88623500	0.14527000
N	-1.71189500	1.34225400	-0.24545000
N	-1.57729000	-1.22633900	0.98453400
C	4.15221900	3.64939000	0.68170400
H	4.51979500	4.66742500	0.83049400
C	5.02280600	2.58070200	0.65263700
H	6.09545300	2.74189100	0.77986200
C	4.52627700	1.26750100	0.45696900
H	5.22062100	0.42435100	0.43443700
C	3.17620800	1.03832000	0.29599900
H	2.78430900	0.03648100	0.15885000
C	2.25555600	2.11760300	0.31871900
C	2.75595700	3.44738100	0.51410400
C	1.82158900	4.51462400	0.52429400
H	2.17687900	5.53687600	0.67619300
C	0.48721500	4.24879400	0.33419100
H	-0.27565200	5.02546400	0.31701500

C	0.07207300	2.90819800	0.14066700
C	-1.40097900	2.65081200	-0.12292800
C	-2.98011100	0.95211500	-0.65434700
C	-3.76098000	1.72729000	-1.54733800
H	-3.36483900	2.68038300	-1.88748500
C	-5.00711900	1.29942700	-1.98770700
H	-5.56755100	1.92334100	-2.68899600
C	-5.54827000	0.08463000	-1.54389800
H	-6.53031300	-0.24827600	-1.88547400
C	-4.81152000	-0.69134600	-0.66016100
H	-5.21005700	-1.63880300	-0.29737800
C	-3.53433100	-0.28753200	-0.21744600
C	-2.84049800	-1.17064400	0.71941700
C	-2.78325800	-2.74197700	2.32561500
H	-2.98452100	-3.81949400	2.26266900
H	-3.05489600	-2.37780800	3.32885000
C	-1.33806200	-2.35506600	1.92117000
C	-0.51131200	-1.89890300	3.12134600
H	0.48735500	-1.58115100	2.79081700
H	-0.40245400	-2.72213500	3.84493800
H	-0.99670100	-1.05003500	3.62636500
C	-0.65092800	-3.49968900	1.16932800
H	-1.26091300	-3.82262700	0.31171400
H	-0.50857600	-4.36080700	1.84096800
H	0.32849200	-3.18120700	0.79580300
Co	-0.17360700	-0.01620500	-0.02245700
H	1.01006000	-0.84798400	0.70498900
C	0.99612900	-1.31488900	-1.20149300
C	2.12821300	-2.23029300	-1.14430900

C	2.81108600	-2.55967300	0.03688300
C	2.55797900	-2.80992000	-2.35695200
C	3.89422100	-3.43976800	0.01271900
H	2.47275600	-2.10785400	0.97137300
C	3.63909700	-3.68903100	-2.37928100
H	2.03202100	-2.55807600	-3.28009600
C	4.31289000	-4.00762600	-1.19389600
H	4.41309300	-3.68363300	0.94270800
H	3.95976400	-4.12830200	-3.32686500
H	5.16081600	-4.69626100	-1.21260800
C	0.11804400	-0.75264400	-1.91505700
H	-0.40479700	-0.52590700	-2.83421600

TS-3b

Charge = 0, Multiplicity = 2

O	1.86115600	3.42519500	-0.16195200
O	3.72924900	-2.04589200	-1.25736900
N	-0.73256000	1.07106800	-0.70569400
N	1.72140600	1.15484200	0.33189500
N	1.69491800	-1.41394800	-0.57844800
C	-4.08241000	1.93536600	-2.05729700
H	-4.64528600	2.81492800	-2.37917200
C	-4.65446100	0.68038300	-2.09223200
H	-5.68150600	0.55686400	-2.44285000
C	-3.91641200	-0.45583000	-1.67149900
H	-4.38449100	-1.44231200	-1.69413600
C	-2.62032600	-0.32341400	-1.22266800
H	-2.03711600	-1.17232400	-0.86999000

C	-2.00859300	0.95678800	-1.17036000
C	-2.74965000	2.10690600	-1.59558200
C	-2.10471900	3.37070600	-1.52257600
H	-2.64411500	4.26630900	-1.84119800
C	-0.81660300	3.45036100	-1.04685700
H	-0.27313300	4.39124200	-0.96623500
C	-0.16045400	2.26322300	-0.63349800
C	1.25821200	2.34529400	-0.10641600
C	3.04959100	0.97233000	0.68412400
C	3.81999300	1.93308300	1.37418700
H	3.35699000	2.88392400	1.62758300
C	5.14436400	1.67456700	1.71939600
H	5.70977800	2.43138300	2.26954900
C	5.75825100	0.46345600	1.37126600
H	6.79745300	0.26905700	1.64377800
C	5.02839500	-0.48699300	0.66436700
H	5.48992400	-1.42813800	0.36216100
C	3.68461800	-0.25280700	0.32379400
C	2.97377300	-1.23855300	-0.49037000
C	2.84155100	-2.99194600	-1.88696300
H	2.99070800	-3.97194900	-1.40734100
H	3.10694400	-3.06136400	-2.94990900
C	1.42265600	-2.42190500	-1.63667400
C	0.86684000	-1.68232700	-2.85899700
H	-0.05850000	-1.15518400	-2.58771600
H	0.64793100	-2.39084700	-3.67305600
H	1.58974200	-0.93756100	-3.22545800
C	0.46506900	-3.51513600	-1.17133600
H	0.80283400	-3.95190500	-0.22009500

H	0.42012500	-4.31358300	-1.92877200
H	-0.54725900	-3.11599500	-1.02696100
Co	0.42453100	-0.38017600	0.53998500
H	-0.47252500	-1.56941500	0.52135000
C	-1.08380700	-0.28316500	2.01791800
C	-2.44062300	-0.78633300	2.06022100
C	-2.76789200	-2.12077400	1.76392600
C	-3.47438200	0.11310000	2.38598700
C	-4.09486100	-2.54637100	1.79694400
H	-1.97010800	-2.81237300	1.48931300
C	-4.80270300	-0.31365200	2.40277500
H	-3.22439400	1.15280700	2.60482700
C	-5.11821300	-1.64382800	2.10862400
H	-4.33488300	-3.58703400	1.56656200
H	-5.59603400	0.39833800	2.64213400
H	-6.15883900	-1.97618900	2.11826600
C	-0.13544200	0.47418700	2.31670900
H	0.45325000	1.20760900	2.84658700

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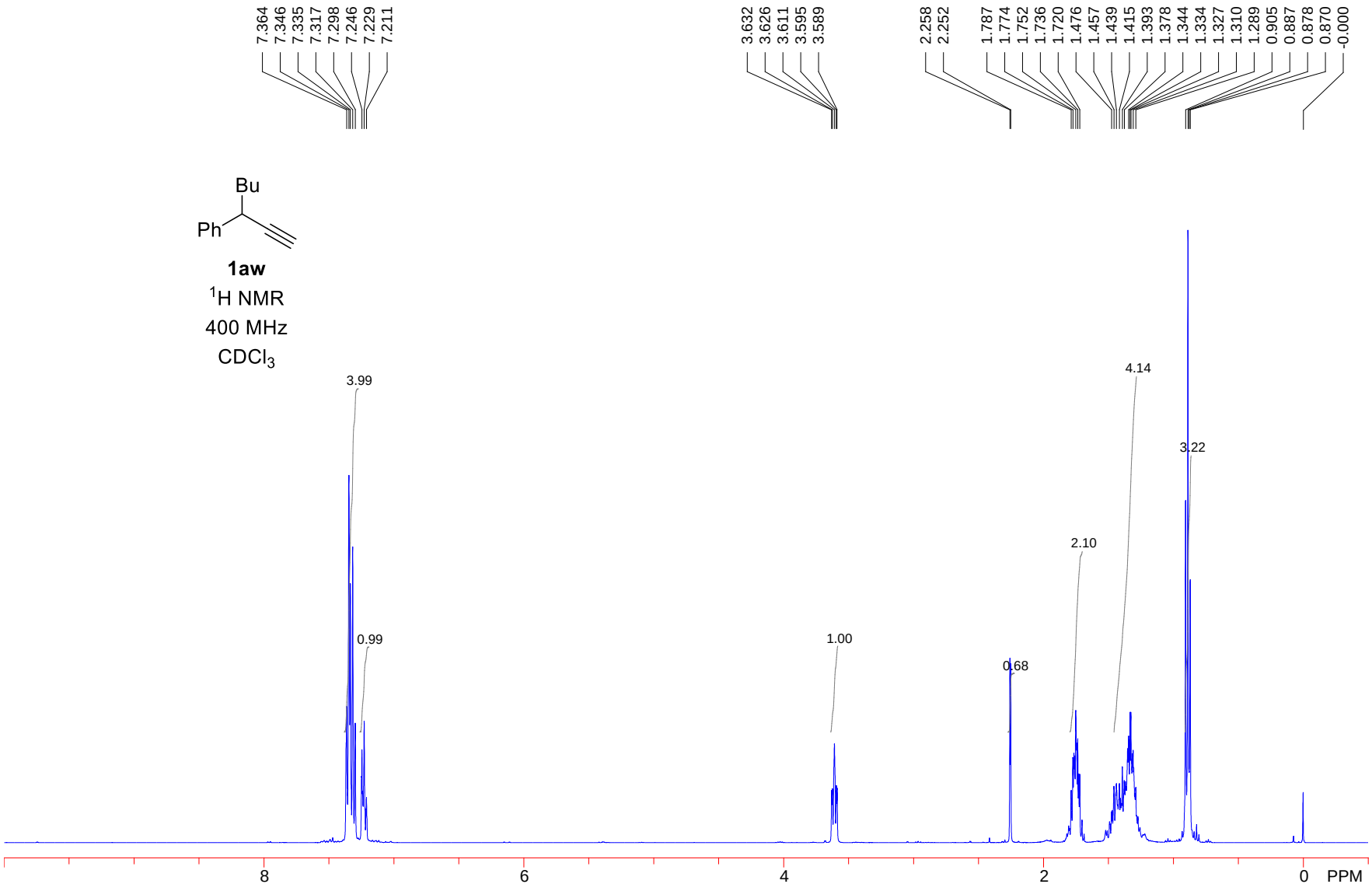
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3.589
2.258
2.252
1.787
1.774
1.752
1.736
1.720
1.476
1.457
1.439
1.415
1.393
1.378
1.344
1.334
1.327
1.310
1.289
0.905
0.887
0.878
0.870
-0.000
Bu
Ph
1aw
1H NMR
400 MHz
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8
6
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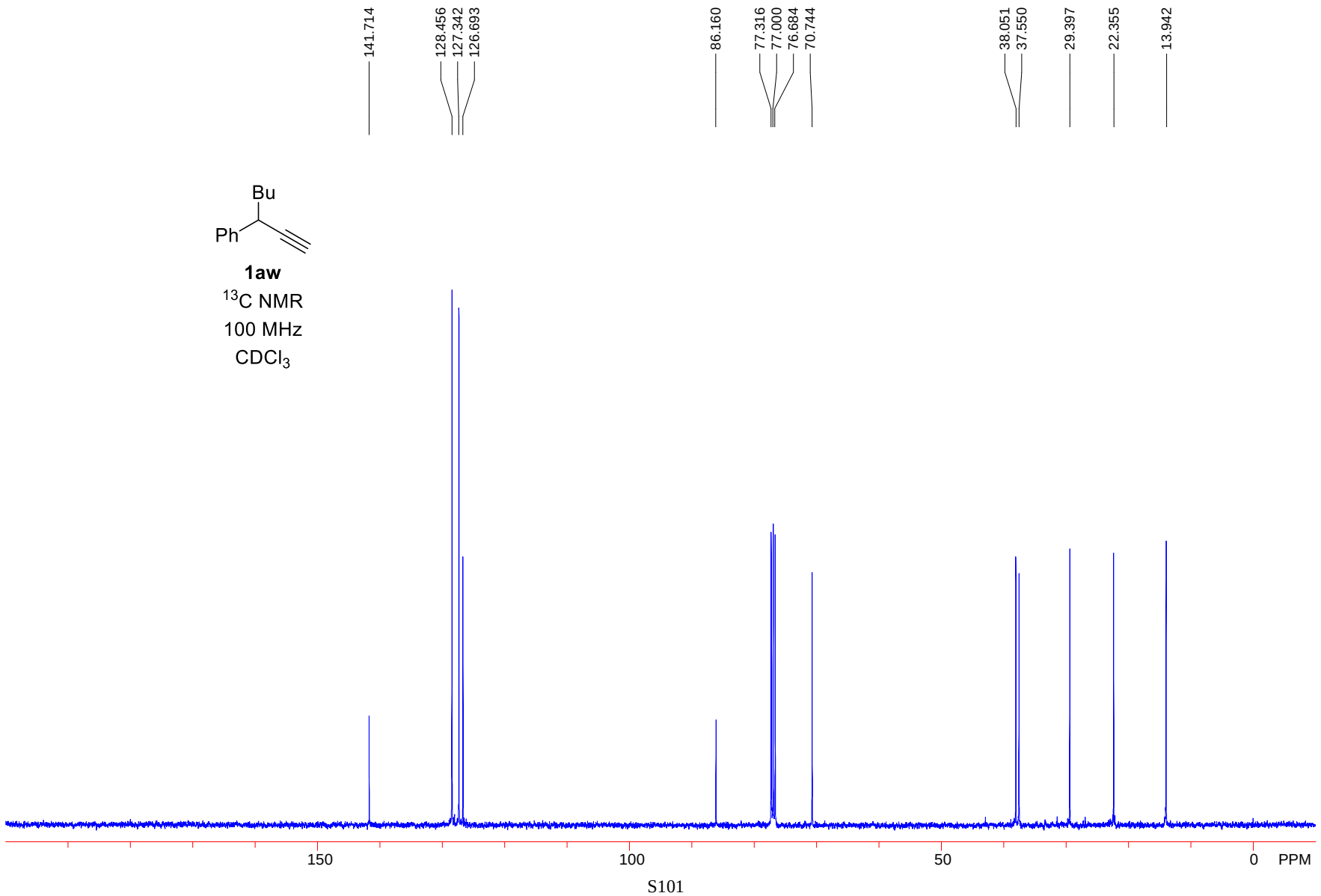
PPM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76.684
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Bu
Ph
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13C NMR
100 MHz
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100
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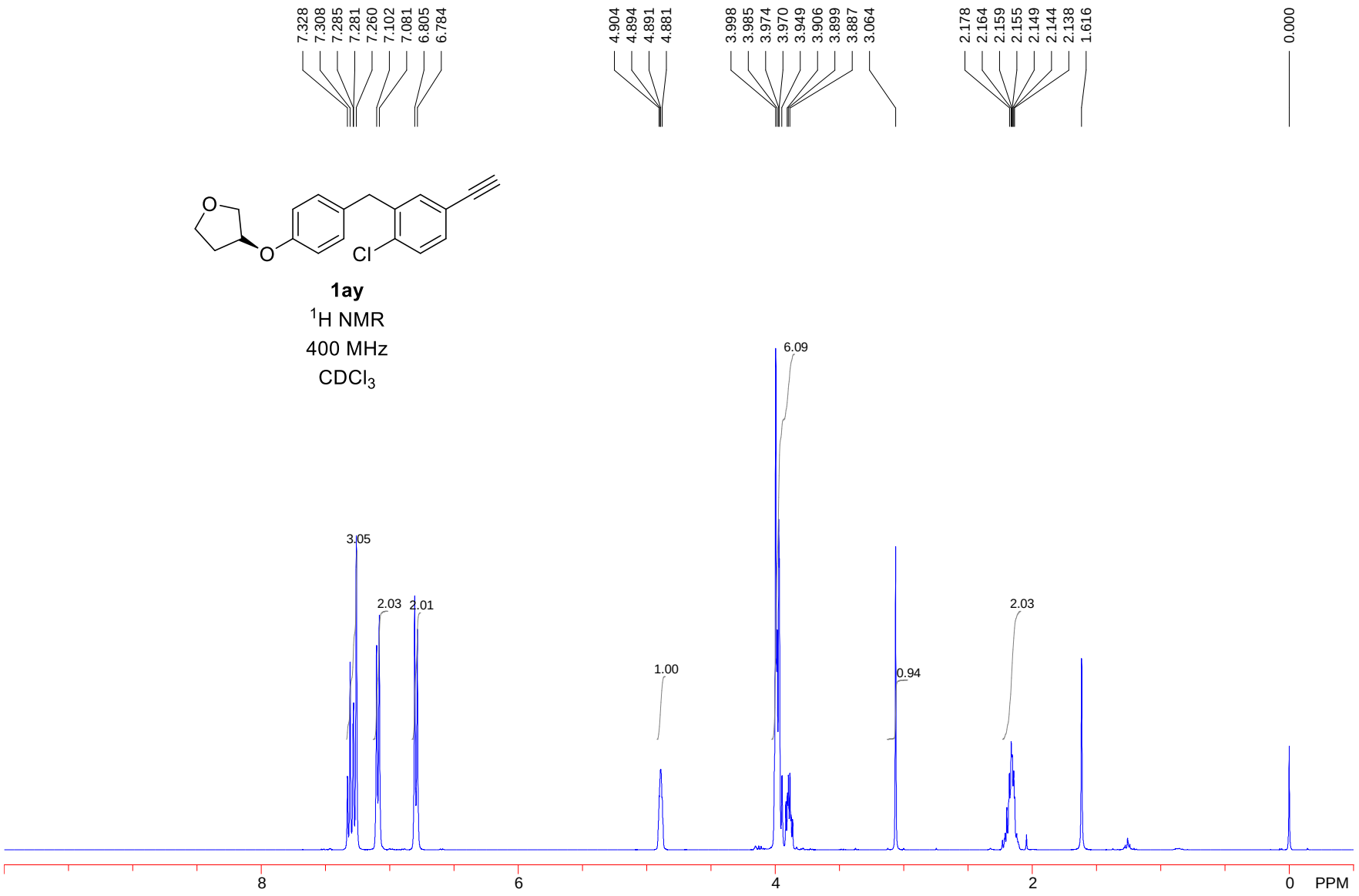
0
PPM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6.805
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4.881
3.998
3.985
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3.970
3.949
3.906
3.899
3.887
3.064
2.178
2.164
2.159
2.155
2.149
2.144
2.138
1.616
0.000
O
O
Cl
1ay
1H NMR
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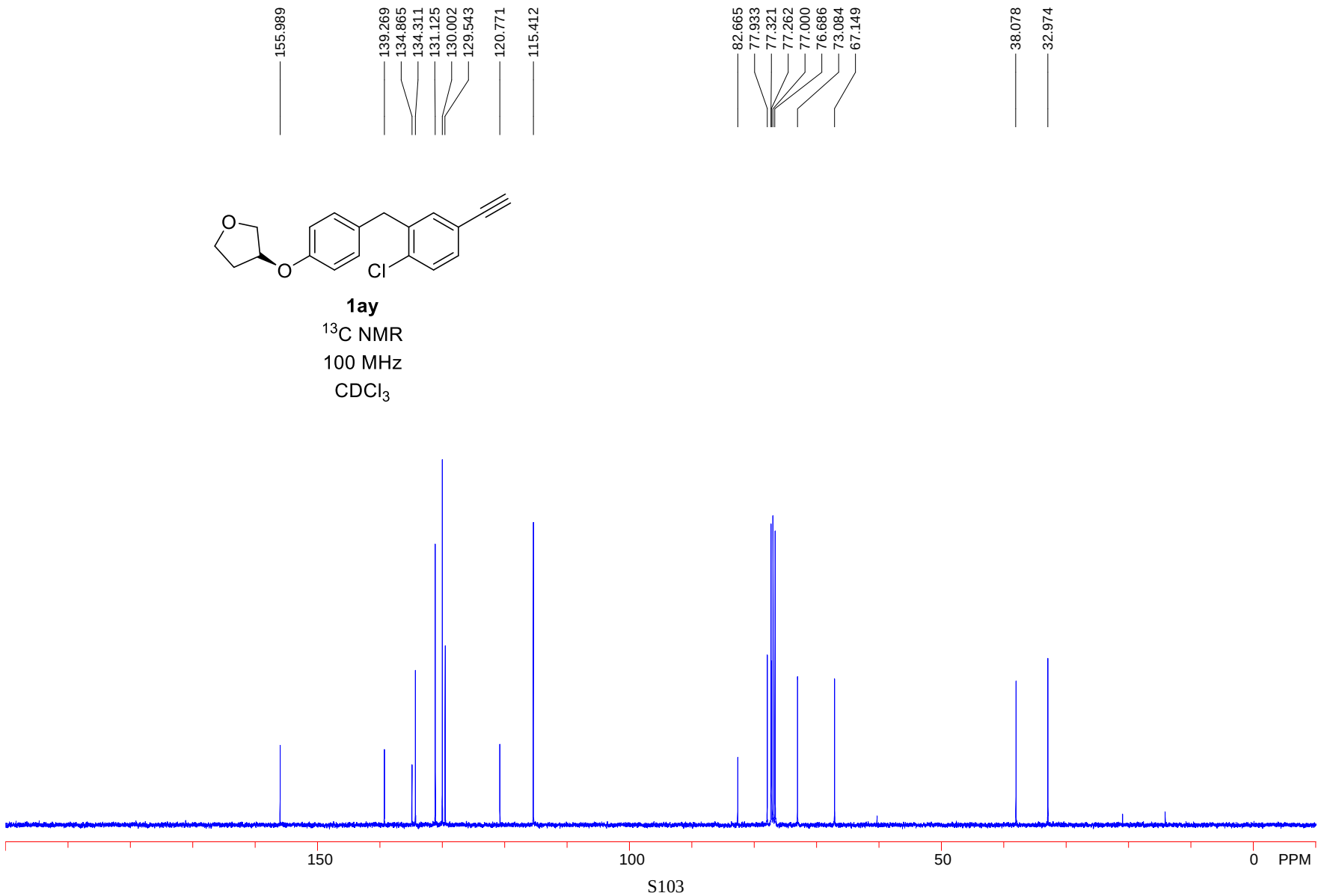
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77.000
76.686
73.084
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Cl
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100 MHz
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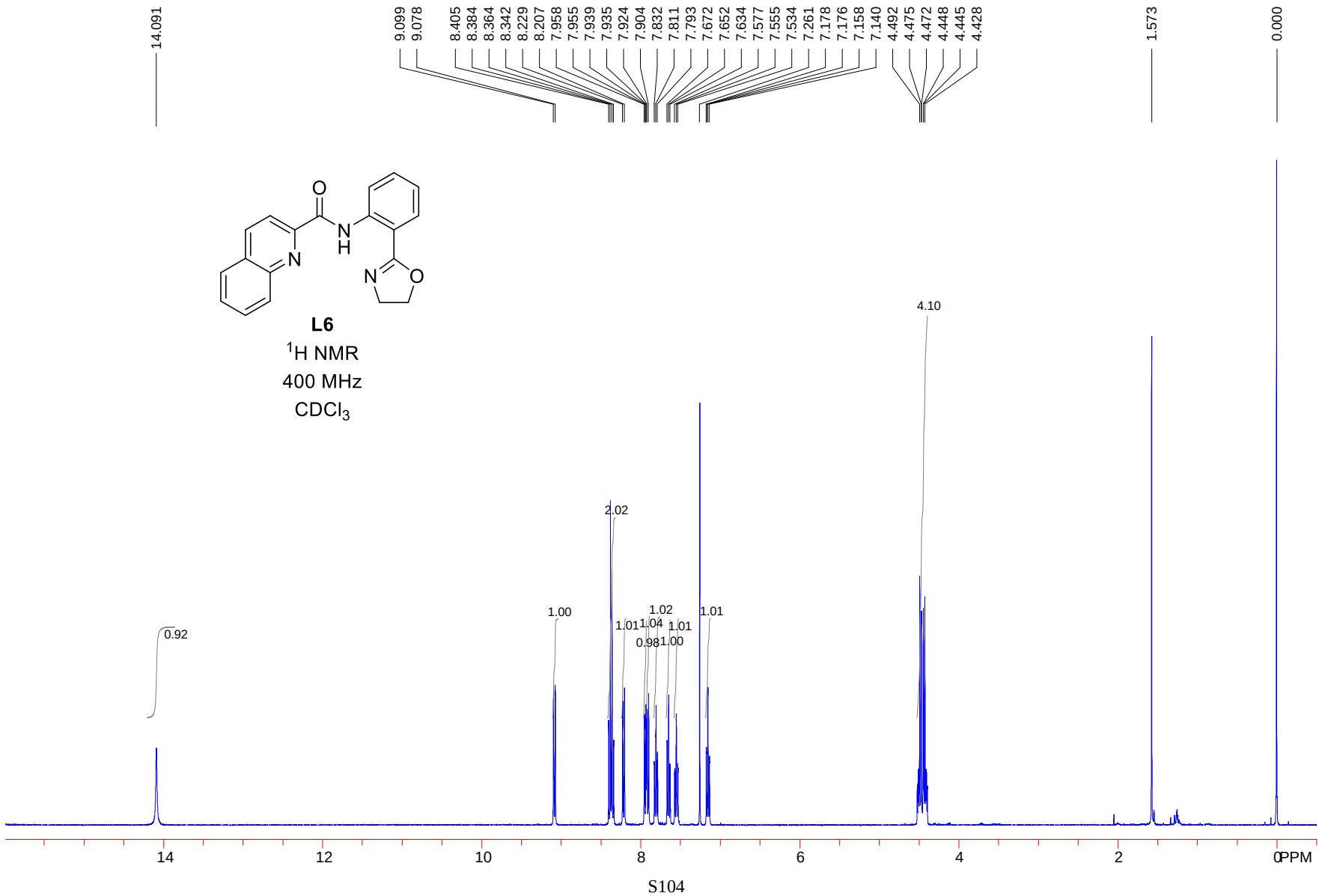
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7.935
7.924
7.904
7.832
7.811
7.793
7.672
7.652
7.634
7.577
7.555
7.534
7.261
7.178
7.176
7.158
7.140
4.492
4.475
4.472
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4.445
4.428
1.573
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O
N
H
N
N
O
L6
1H NMR
400 MHz
CDCl3
4.10
2.02
1.00
1.02
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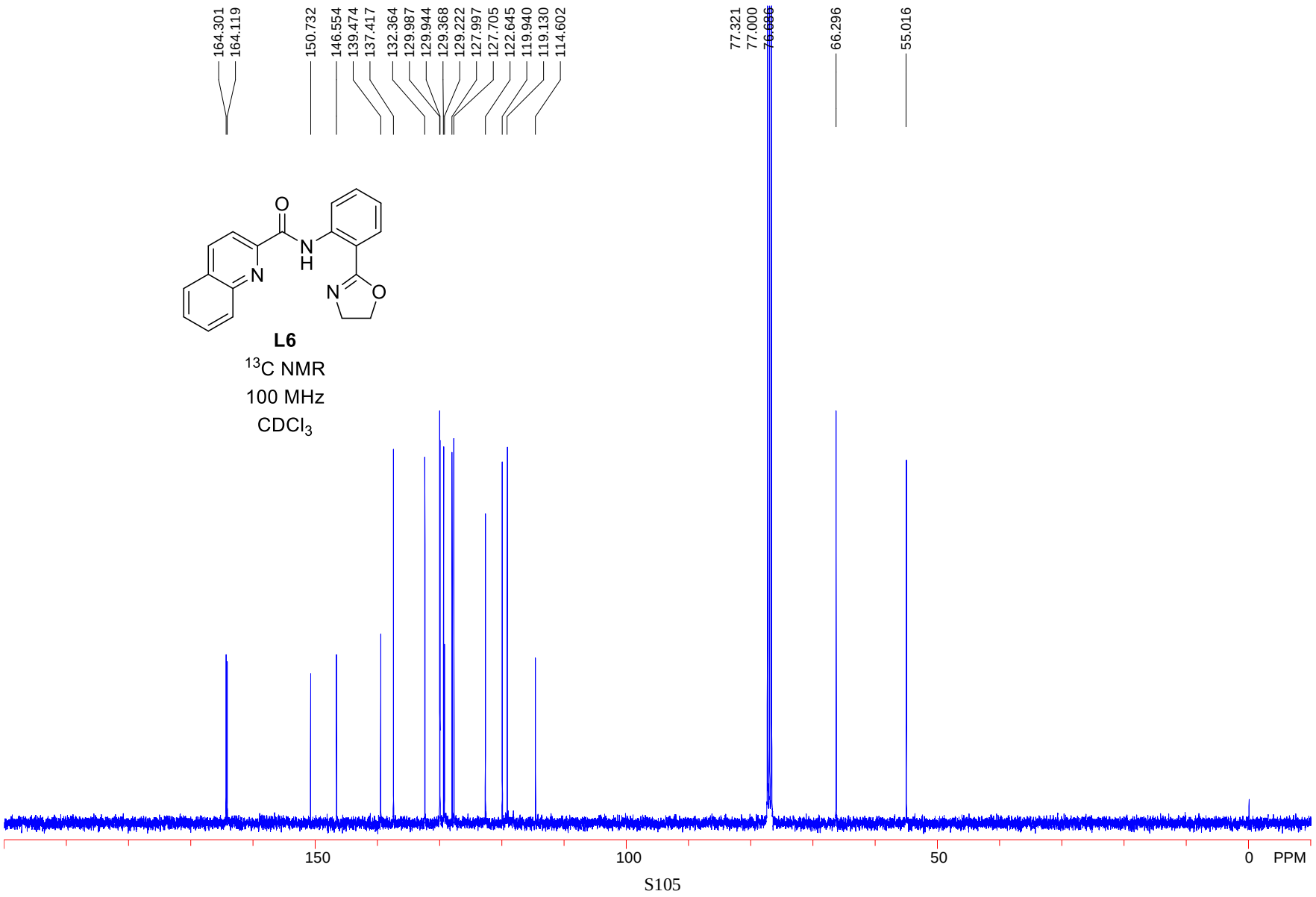
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127.705
122.645
119.940
119.130
114.602
77.321
77.000
76.686
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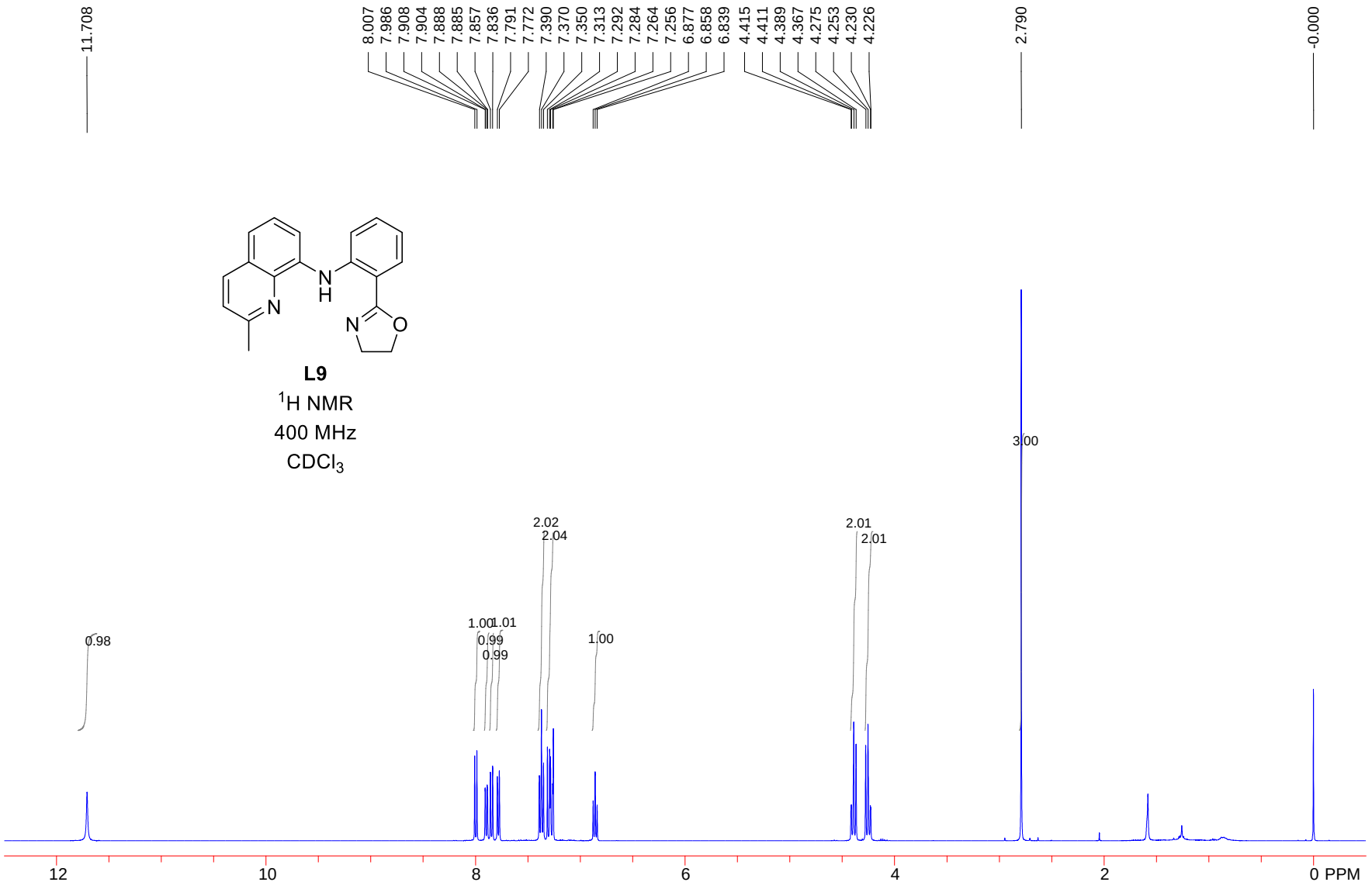
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7.904
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7.857
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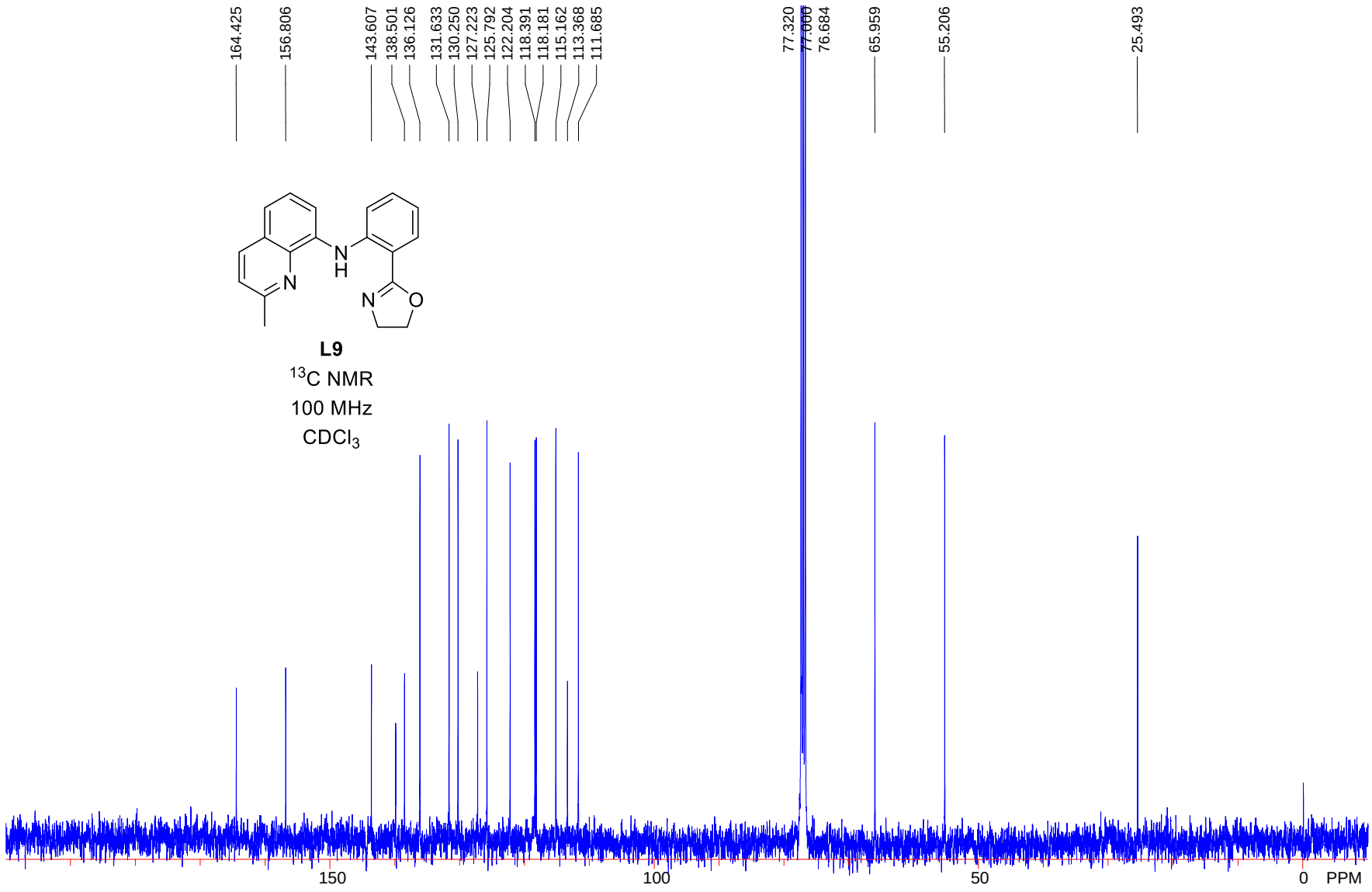
7.791
7.772
7.390
7.370
7.350
7.313
7.292
7.284
7.264
7.256
6.877
6.858
6.839
4.415
4.411
4.389
4.367
4.275
4.253
4.230
4.226
2.790
-0.000
L9
1H NMR
400 MHz
CDCl3
0.98
1.00
0.99
1.01
0.99
2.02
2.04
1.00
2.01
2.01
3.00
12
10
8
6
4
2
0 PPM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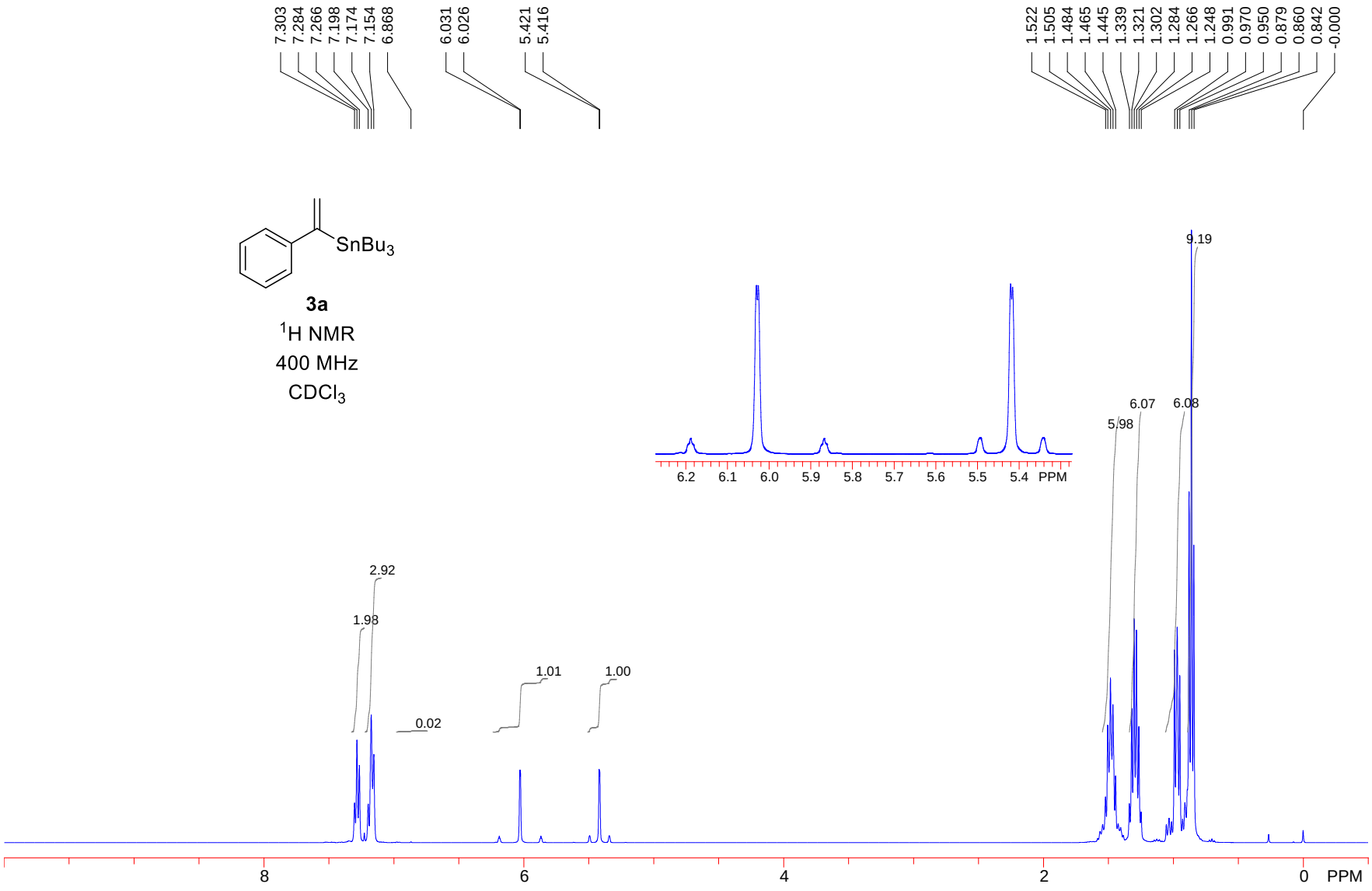
115.162
113.368
111.685
77.320
77.000
76.684
65.959
55.206
25.493
N
H
N
N
O
L9
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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6.031
6.026
5.421
5.416
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1.505
1.484
1.465
1.445
1.339
1.321
1.302
1.284
1.266
1.248
0.991
0.970
0.950
0.879
0.860
0.842
-0.000
SnBu3
3a
1H NMR
400 MHz
CDCl3
9.19
6.07
6.08
5.98
2.92
1.98
1.01
1.00
0.02
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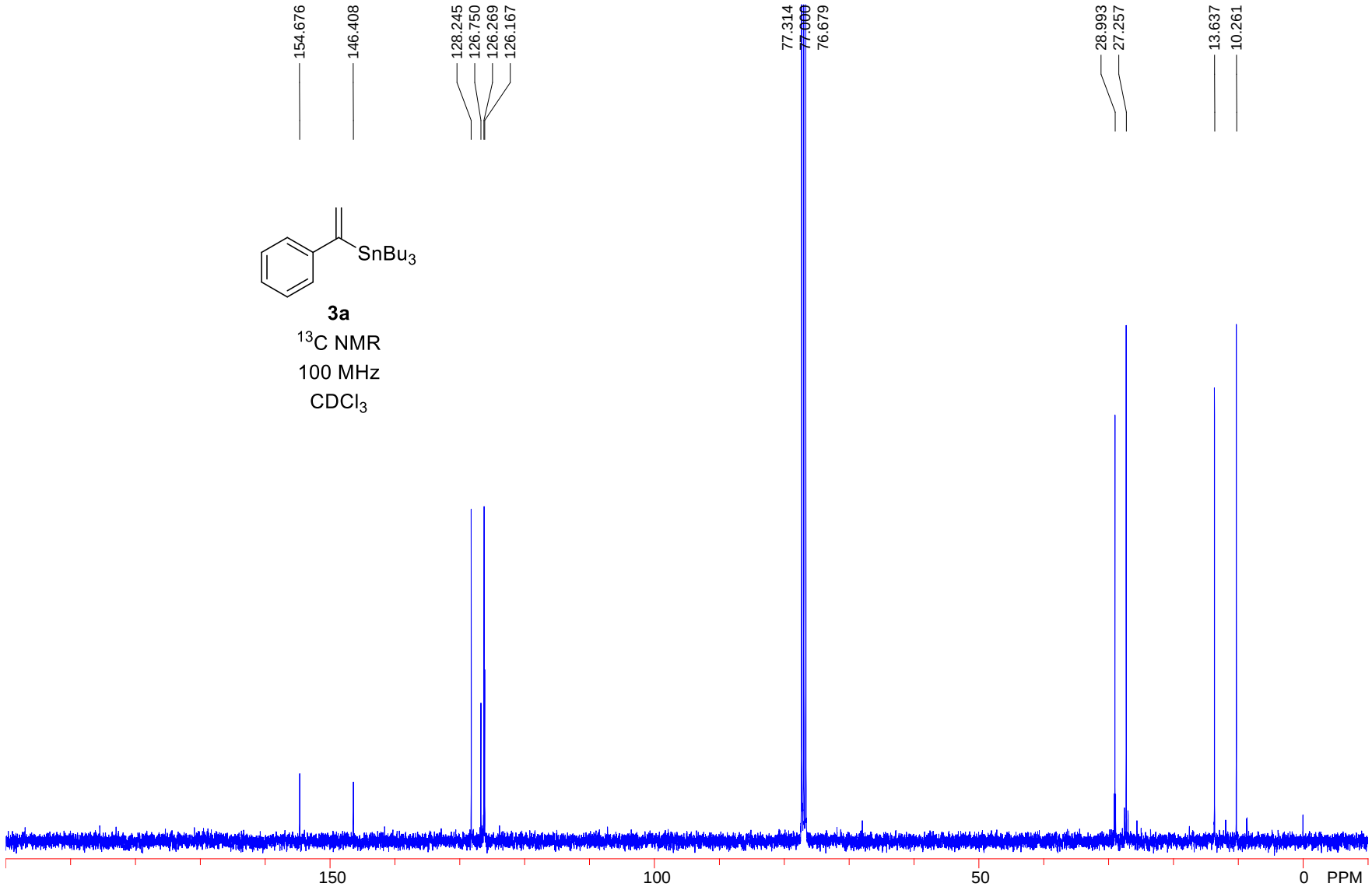
8 6 4 2 0 PPM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126.167
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77.000
76.679
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10.261
SnBu3
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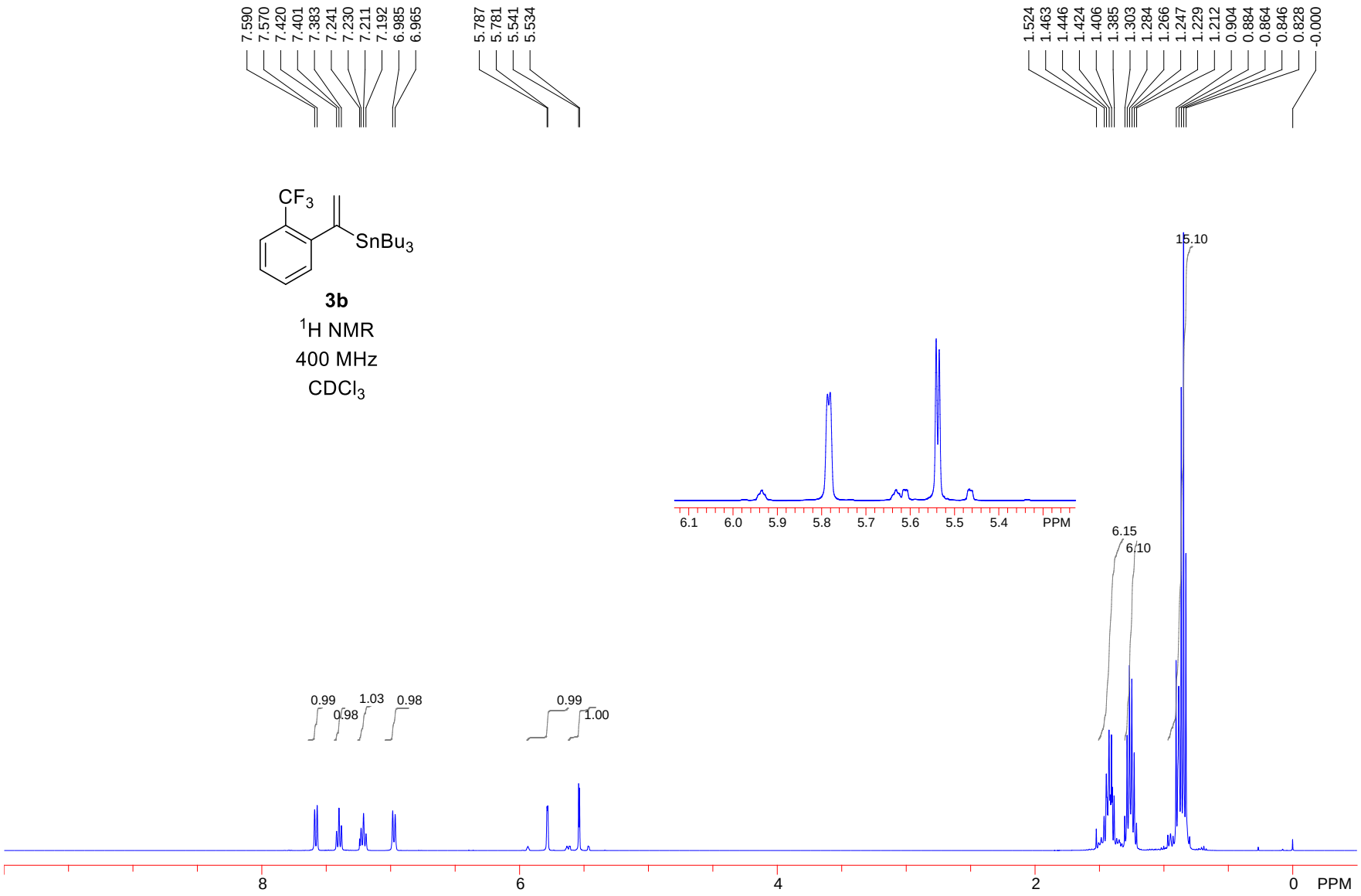
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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7.241
7.230
7.211
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5.781
5.541
5.534
1.524
1.463
1.446
1.424
1.406
1.385
1.303
1.284
1.266
1.247
1.229
1.212
0.904
0.884
0.864
0.846
0.828
-0.000
CF3
SnBu3
3b
1H NMR
400 MHz
CDCl3
15.10
6.15
6.10
0.99
0.98
1.03
0.98
0.99
1.00
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5.8
5.7
5.6
5.5
5.4
PPM
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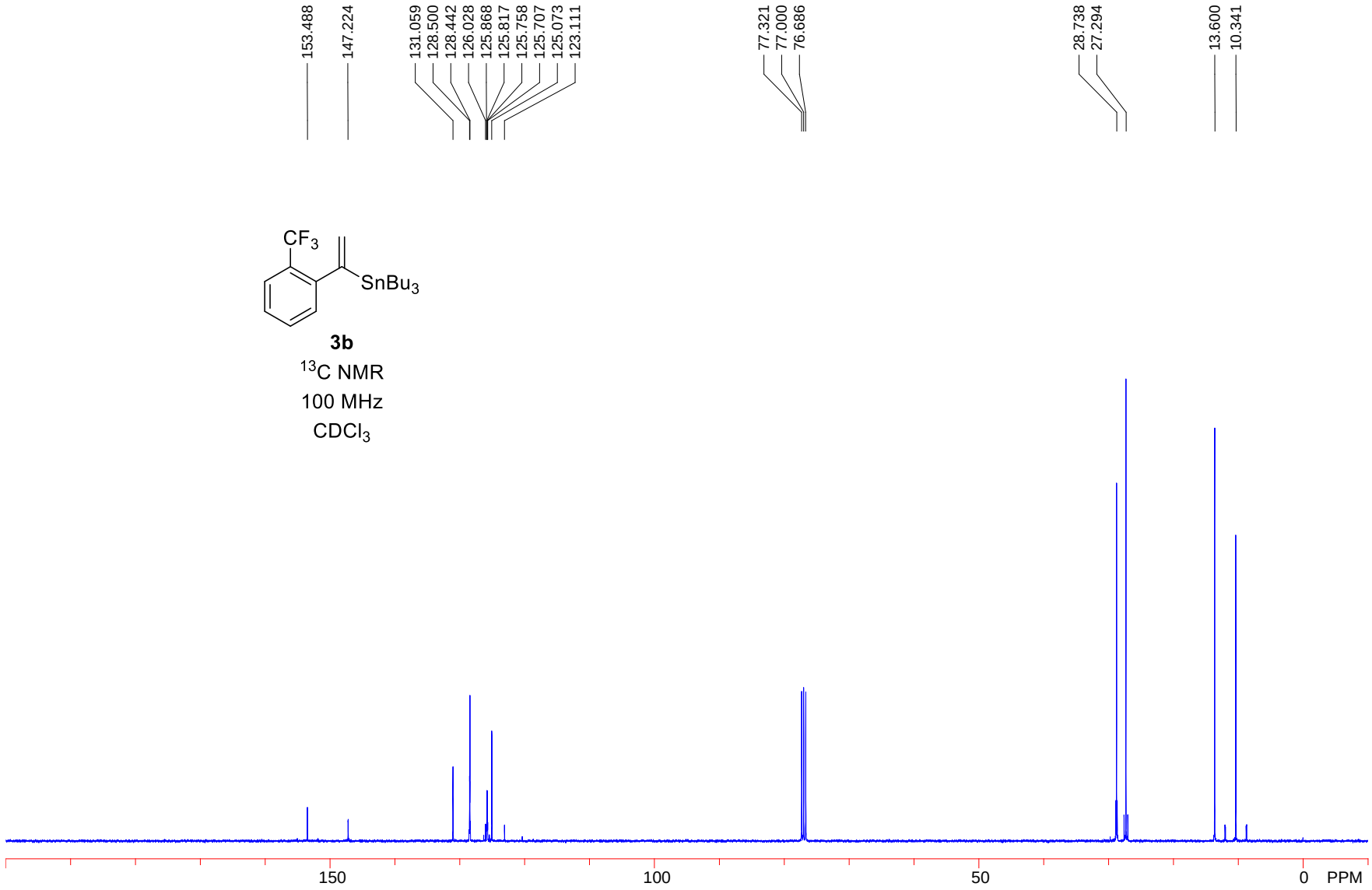
6
4
2
0
PPM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125.817
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125.707
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123.111
77.321
77.000
76.686
28.738
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10.341
CF3
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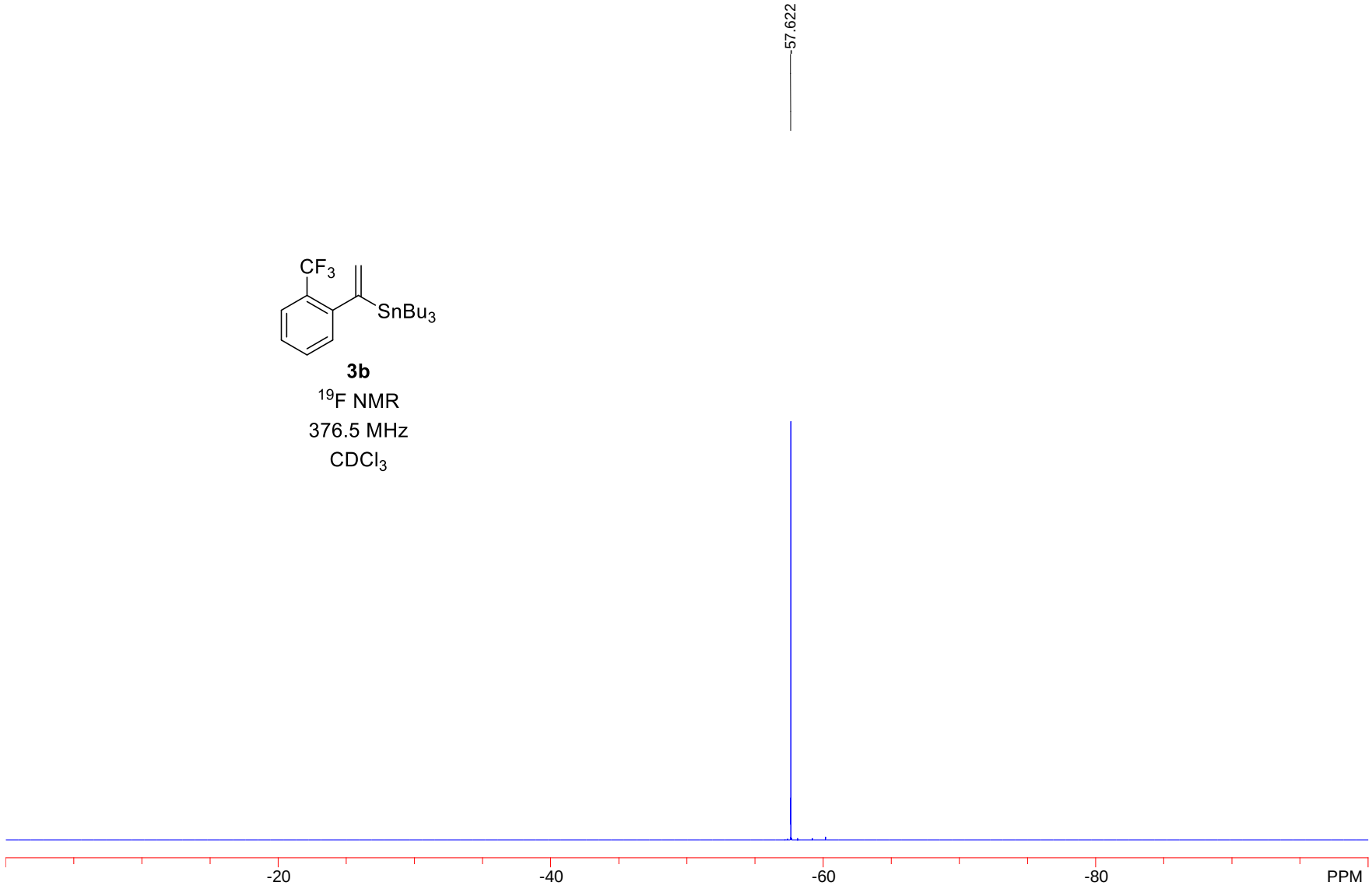
3b
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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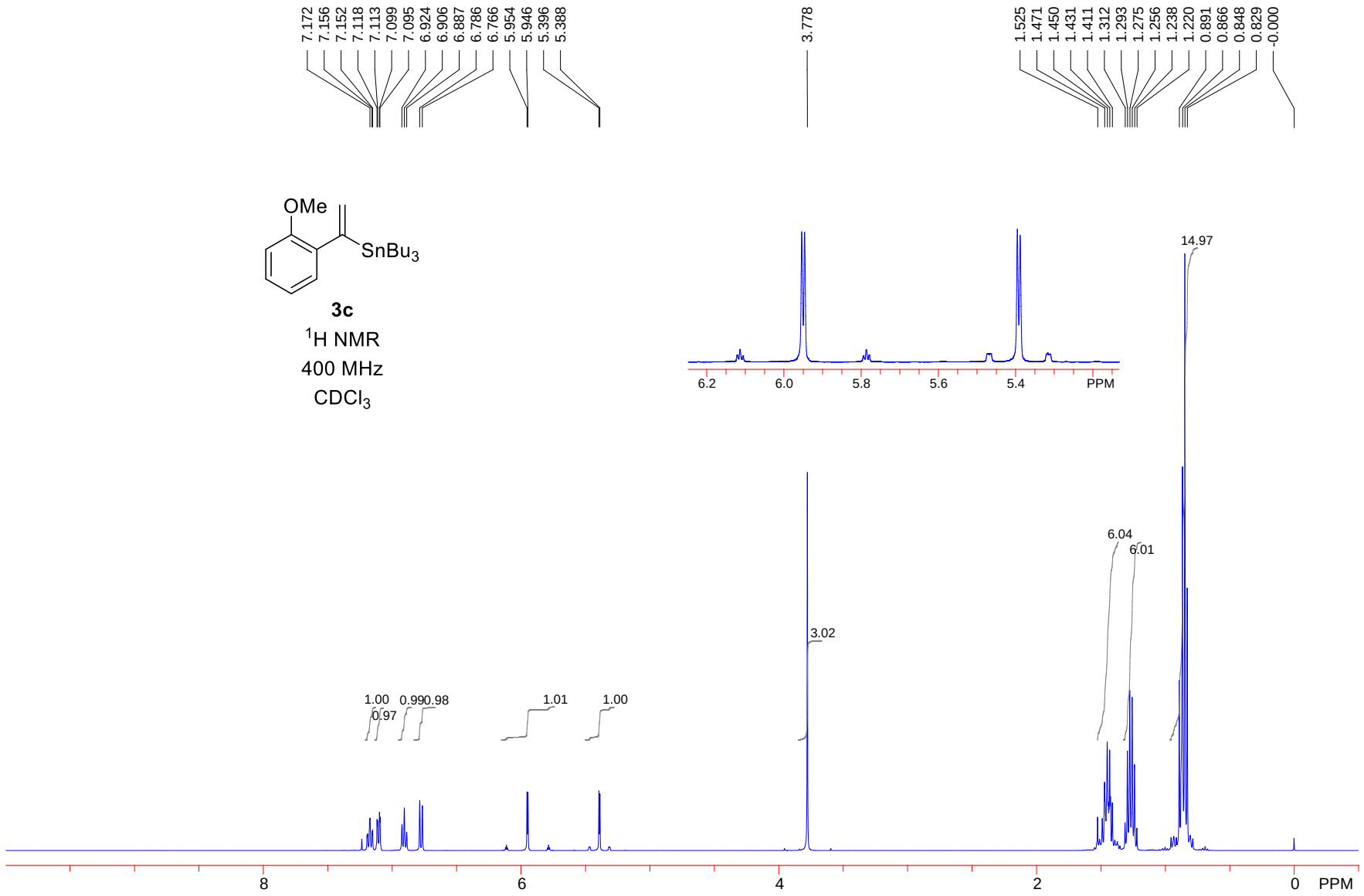
19F NMR
376.5 MHz
CDCl3
-20
-40
-60
-80
PPM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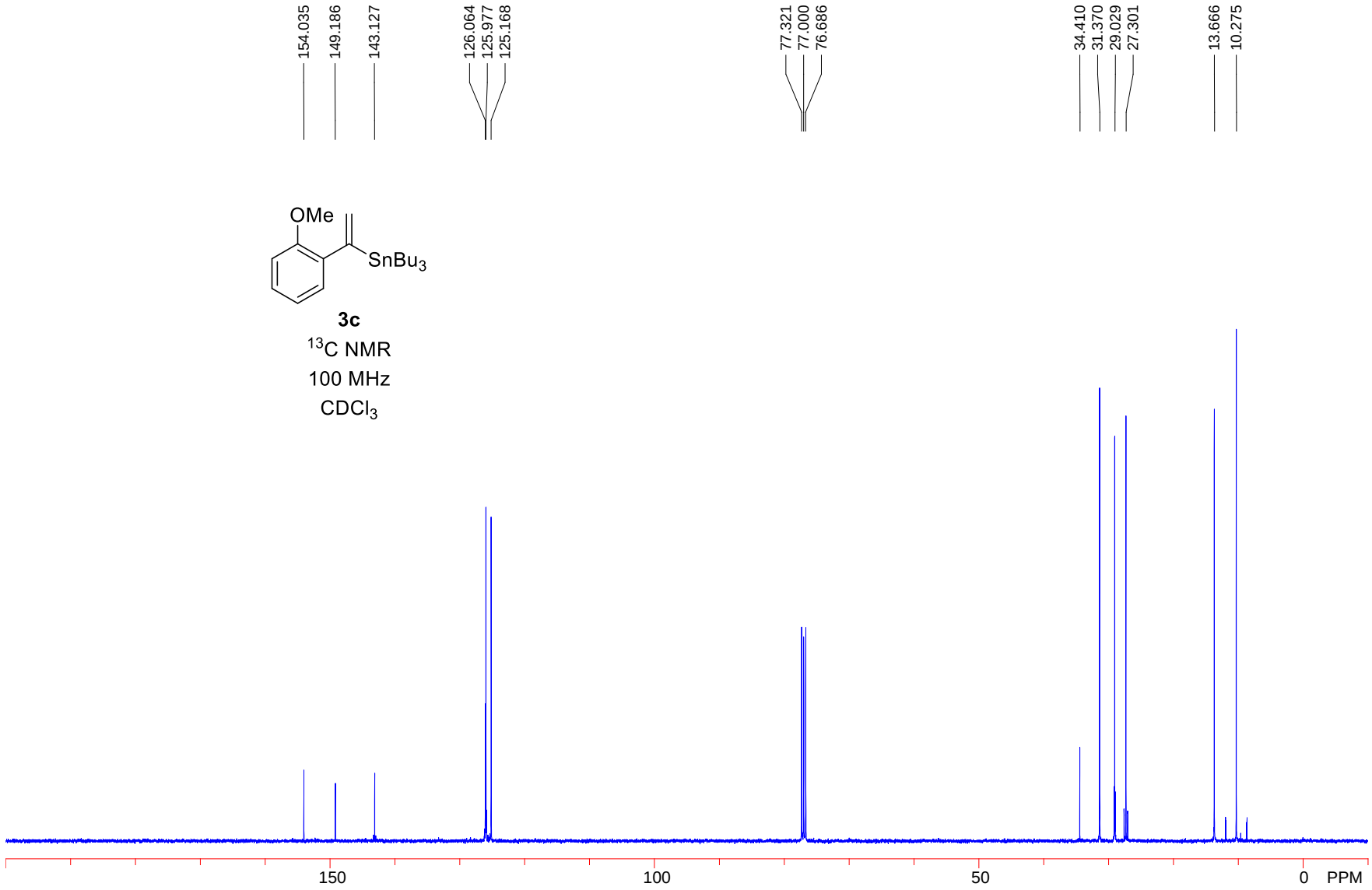
7.113
7.099
7.095
6.924
6.906
6.887
6.786
6.766
5.954
5.946
5.396
5.388
3.778
1.525
1.471
1.450
1.431
1.411
1.312
1.293
1.275
1.256
1.238
1.220
0.891
0.866
0.848
0.829
-0.000
OMe
SnBu3
3c
1H NMR
400 MHz
CDCl3
14.97
6.04
6.01
3.02
1.00
0.97
0.99
0.98
1.01
1.00
6.2
6.0
5.8
5.6
5.4
PPM
8
6
4
2
0
PPM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77.000
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31.370
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100 MHz
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150
100
50
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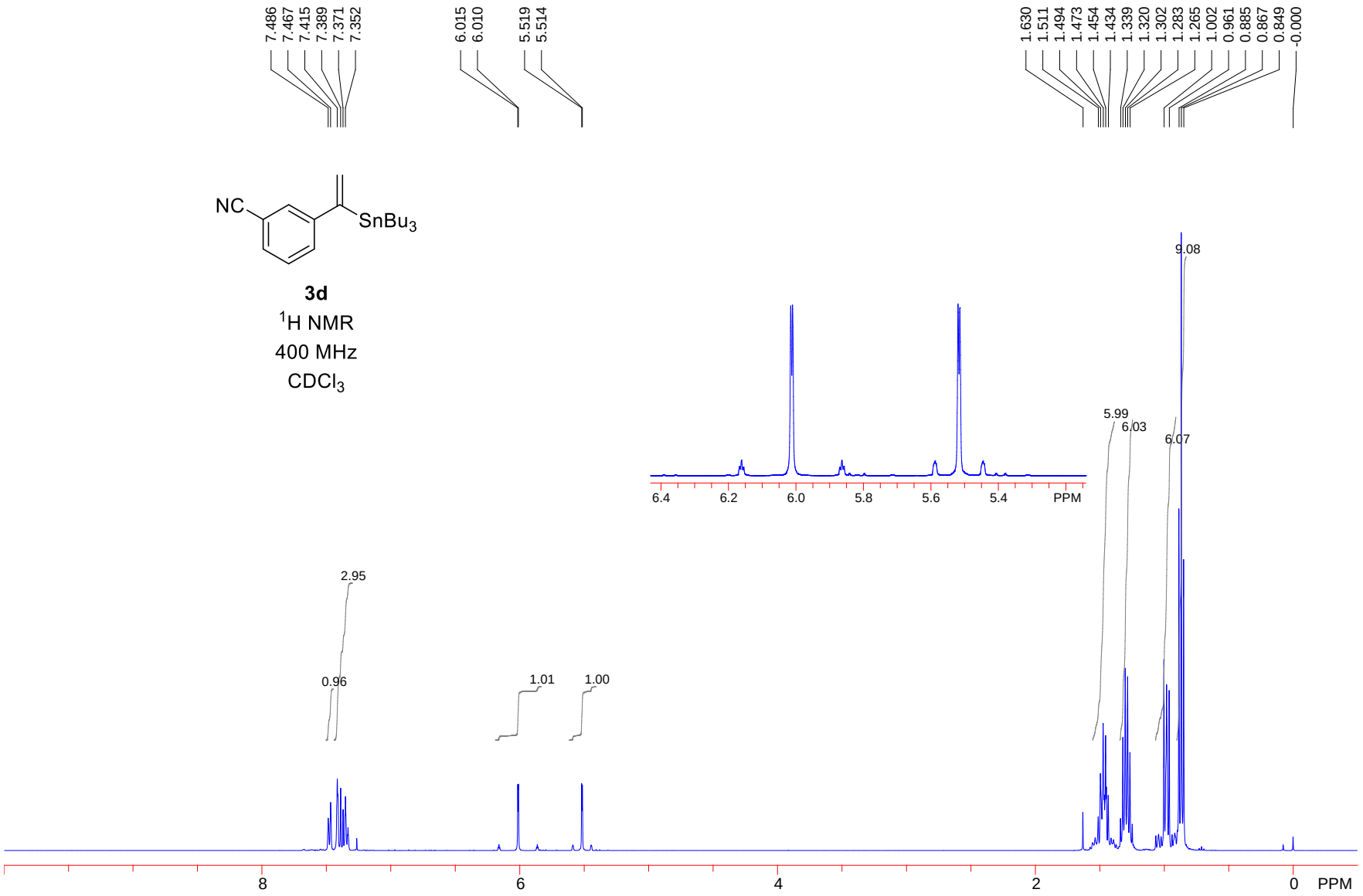
PPM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7.371
7.352
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6.010
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5.514
1.630
1.511
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1.473
1.454
1.434
1.339
1.320
1.302
1.283
1.265
1.002
0.961
0.885
0.867
0.849
-0.000
NC
SnBu3
3d
1H NMR
400 MHz
CDCl3
9.08
5.99
6.03
6.07
2.95
0.96
1.01
1.00
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6.2
6.0
5.8
5.6
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4
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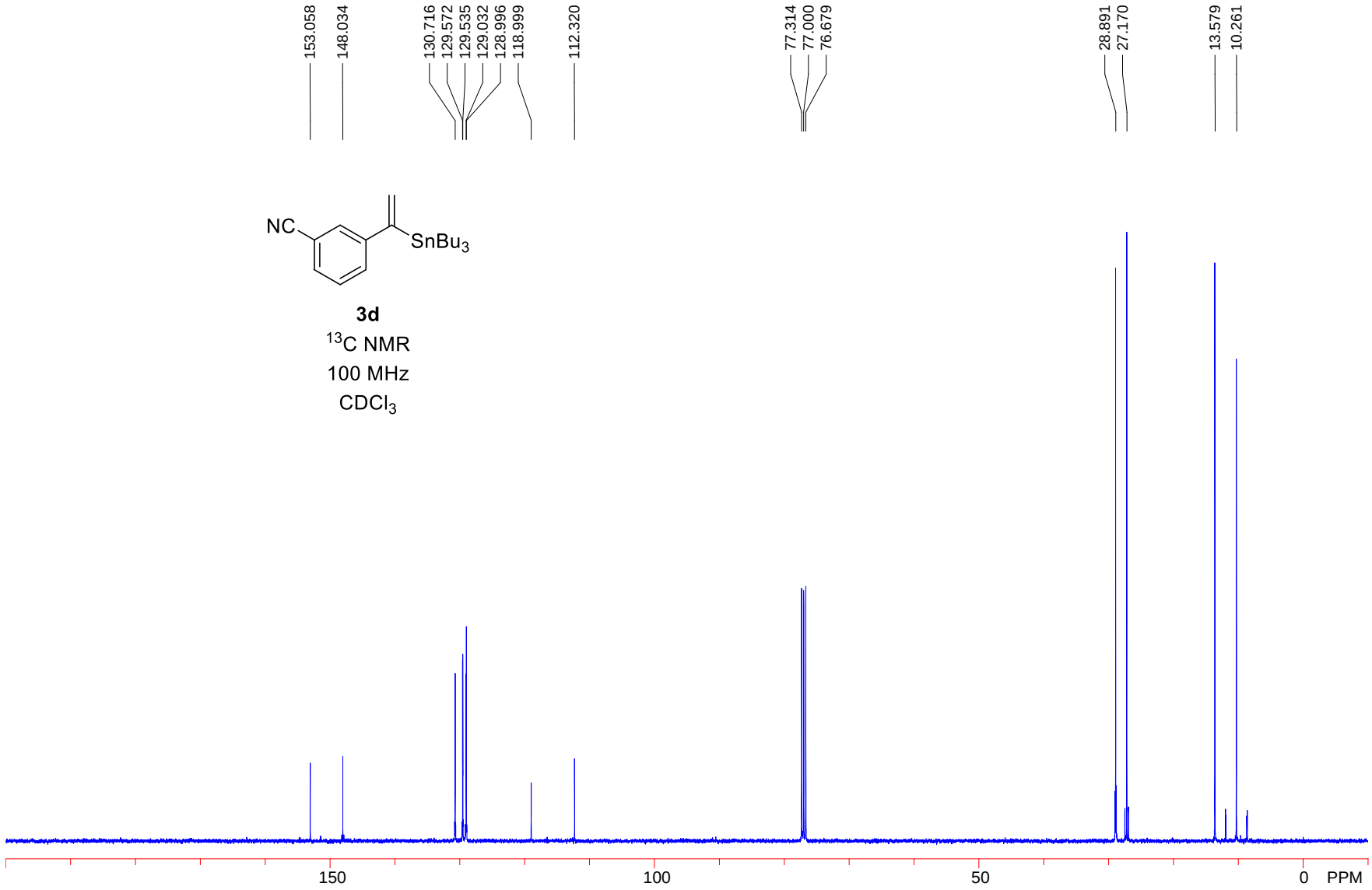
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118.999
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77.314
77.000
76.679
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27.170
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10.261
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13C NMR
100 MHz
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150
100
50
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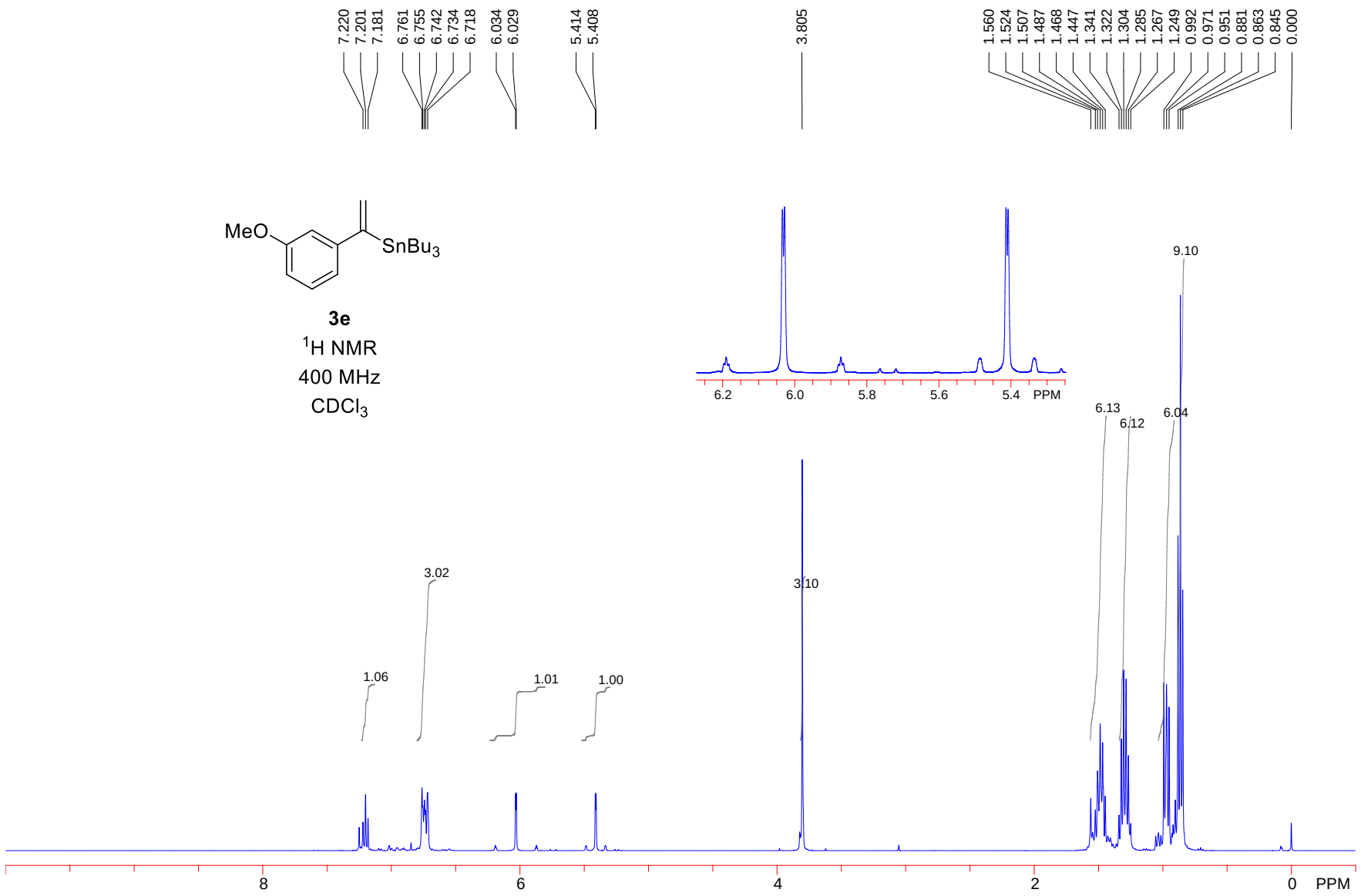
PPM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6.755
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6.734
6.718
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6.029
5.414
5.408
3.805
1.560
1.524
1.507
1.487
1.468
1.447
1.341
1.322
1.304
1.285
1.267
1.249
0.992
0.971
0.951
0.881
0.863
0.845
0.000
MeO
SnBu3
3e
1H NMR
400 MHz
CDCl3
6.2
6.0
5.8
5.6
5.4
PPM
9.10
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6.04
3.02
3.10
1.06
1.01
1.00
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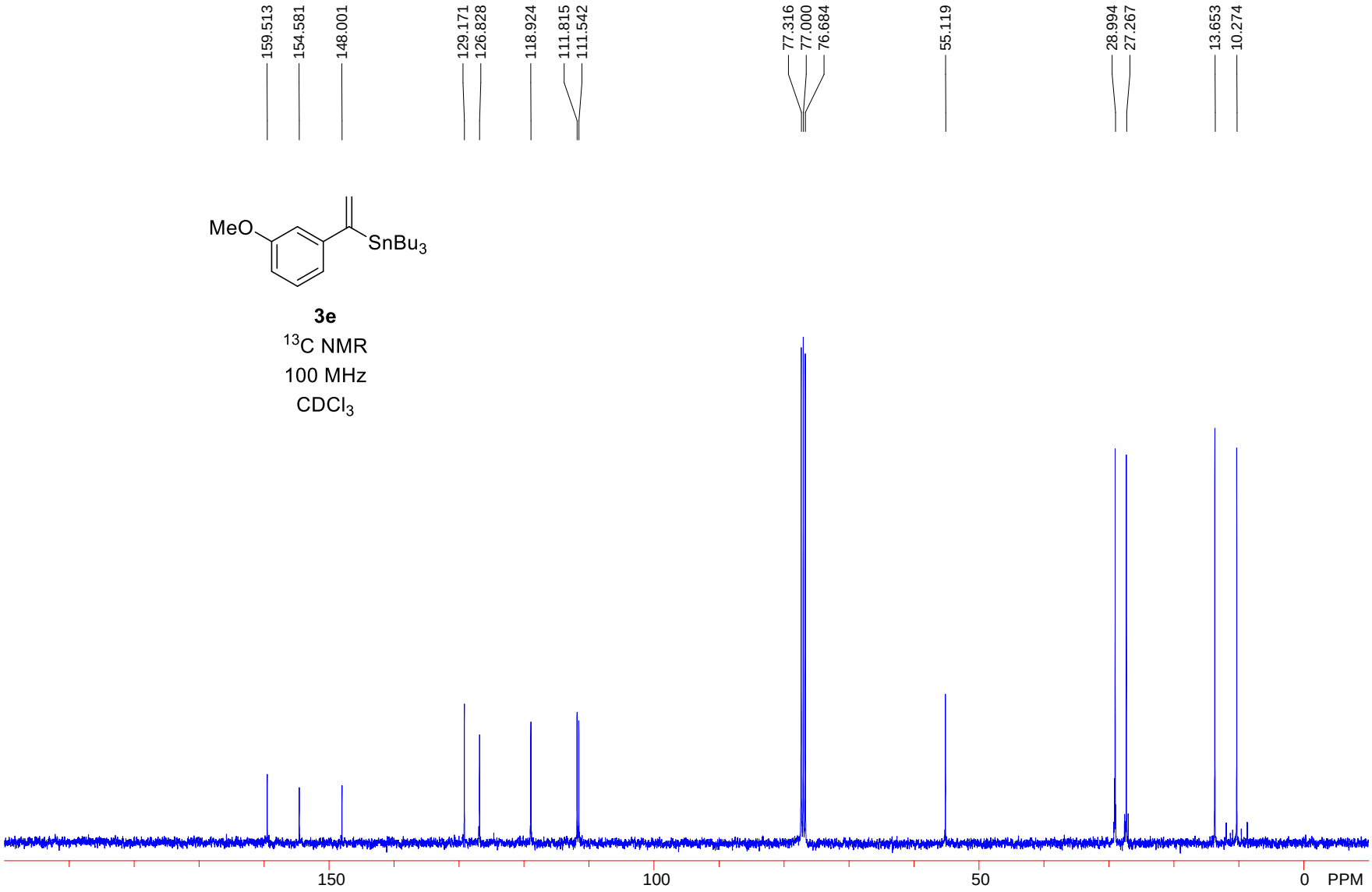
0
PPM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77.000
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55.119
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10.274
MeO
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13C NMR
100 MHz
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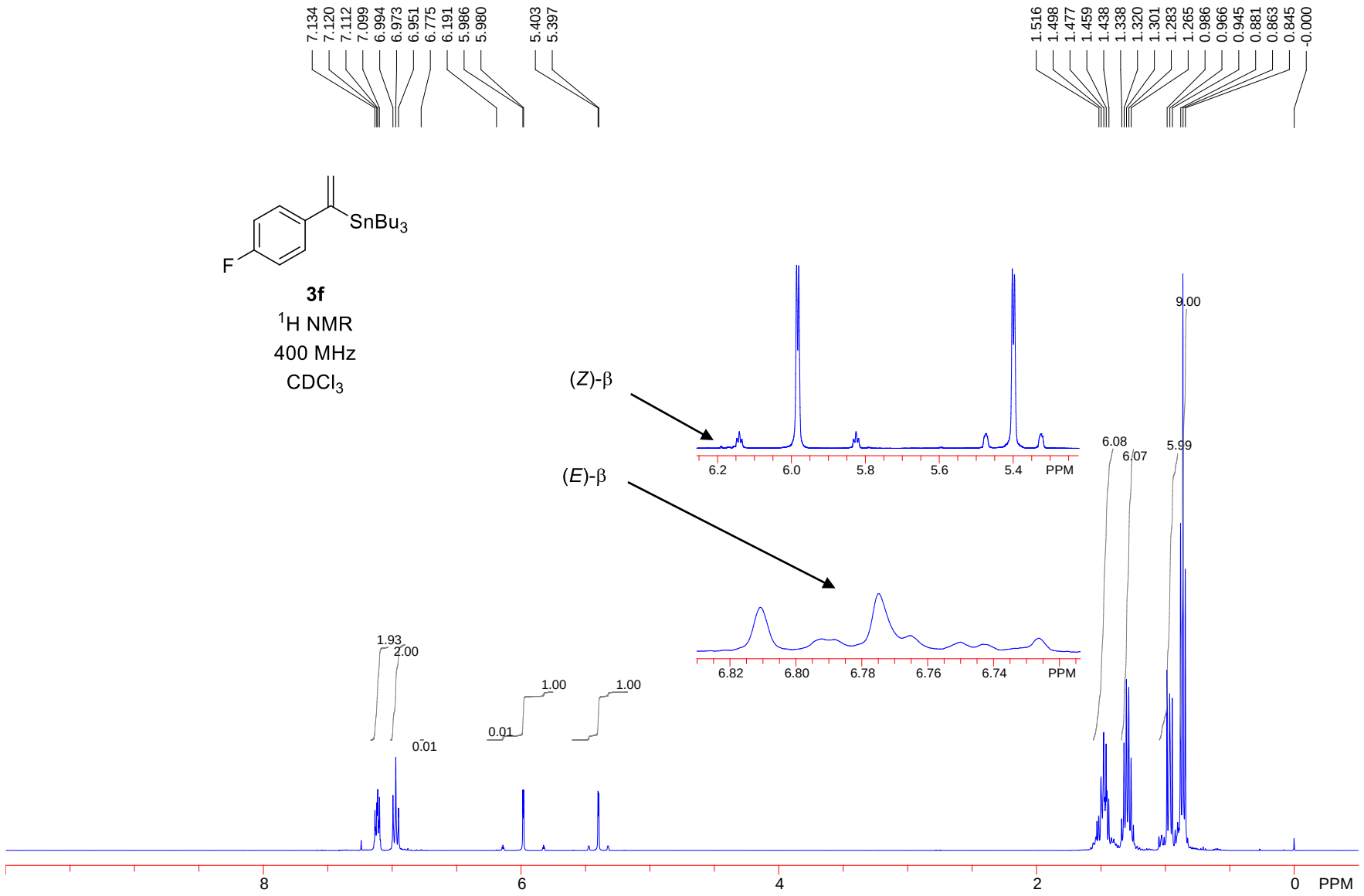
150
100
50
0
PPM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6.973
6.951
6.775
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5.986
5.980
5.403
5.397
1.516
1.498
1.477
1.459
1.438
1.338
1.320
1.301
1.283
1.265
0.986
0.966
0.945
0.881
0.863
0.845
-0.000
SnBu3
F
3f
1H NMR
400 MHz
CDCl3
(Z)-β
(E)-β
6.2
6.0
5.8
5.6
5.4
PPM
6.82
6.80
6.78
6.76
6.74
PPM
9.00
6.08
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1.00
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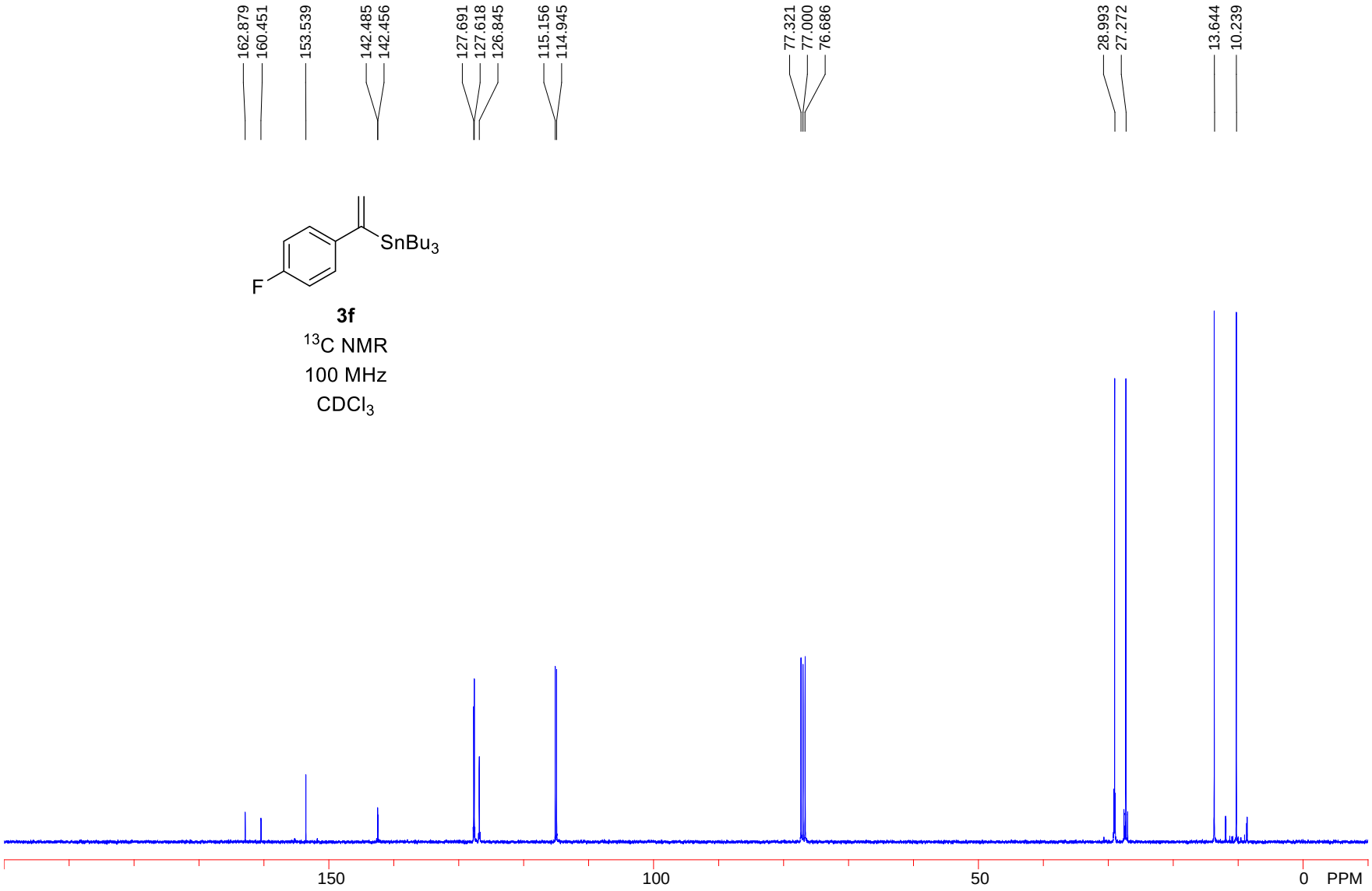
PPM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142.456
127.691
127.618
126.845
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114.945
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76.686
28.993
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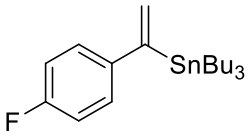
10.239
SnBu3
F
3f
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

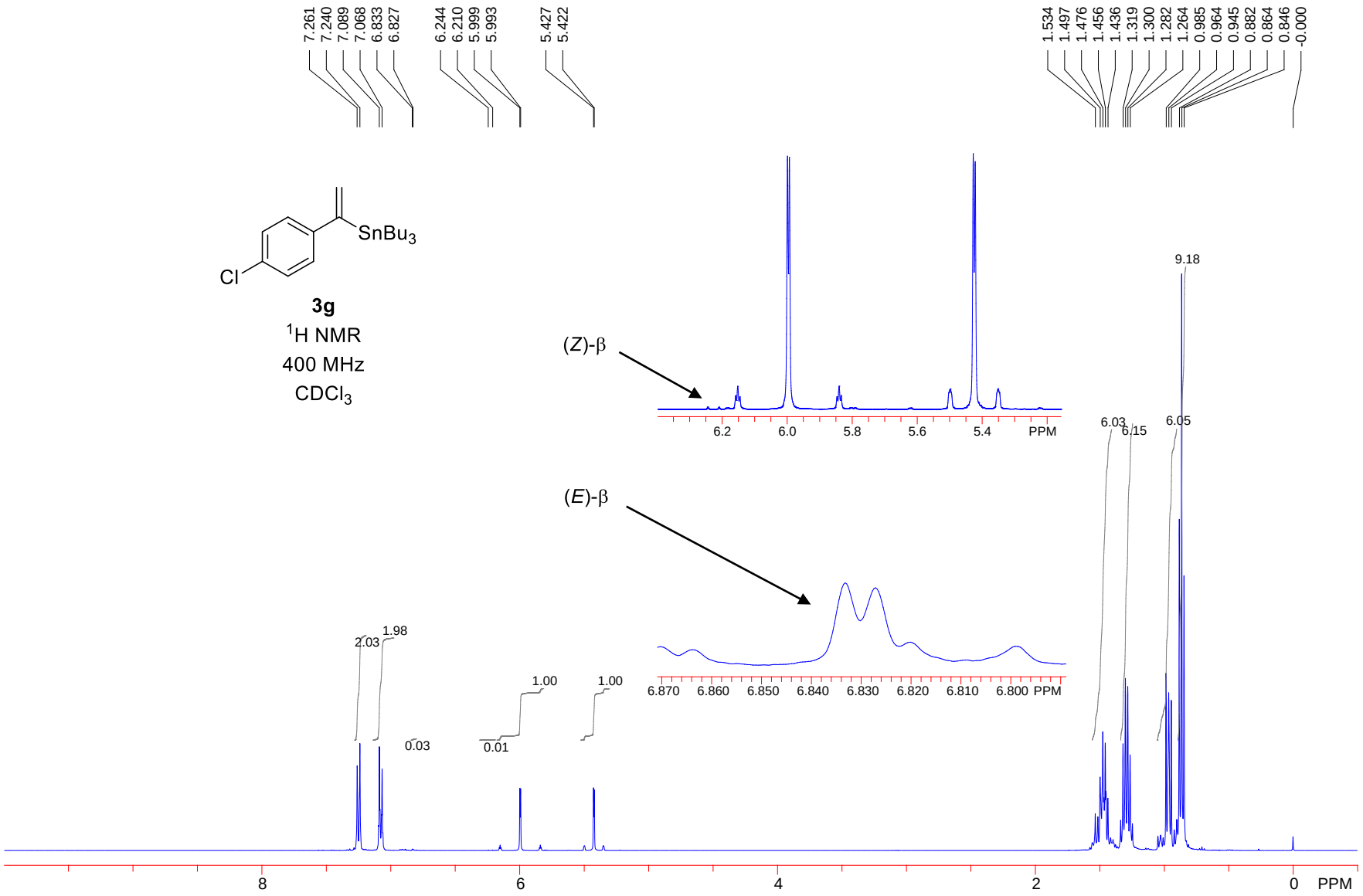


3f

^{19}F NMR

376.5 MHz

$CDCl_3$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6.827
6.244
6.210
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5.993
5.427
5.422
1.534
1.497
1.476
1.456
1.436
1.319
1.300
1.282
1.264
0.985
0.964
0.945
0.882
0.864
0.846
-0.000
SnBu3
Cl
3g
1H NMR
400 MHz
CDCl3
(Z)-β
(E)-β
9.18
6.03
6.15
6.05
2.03
1.98
0.03
0.01
1.00
1.00
6.2
6.0
5.8
5.6
5.4
PPM
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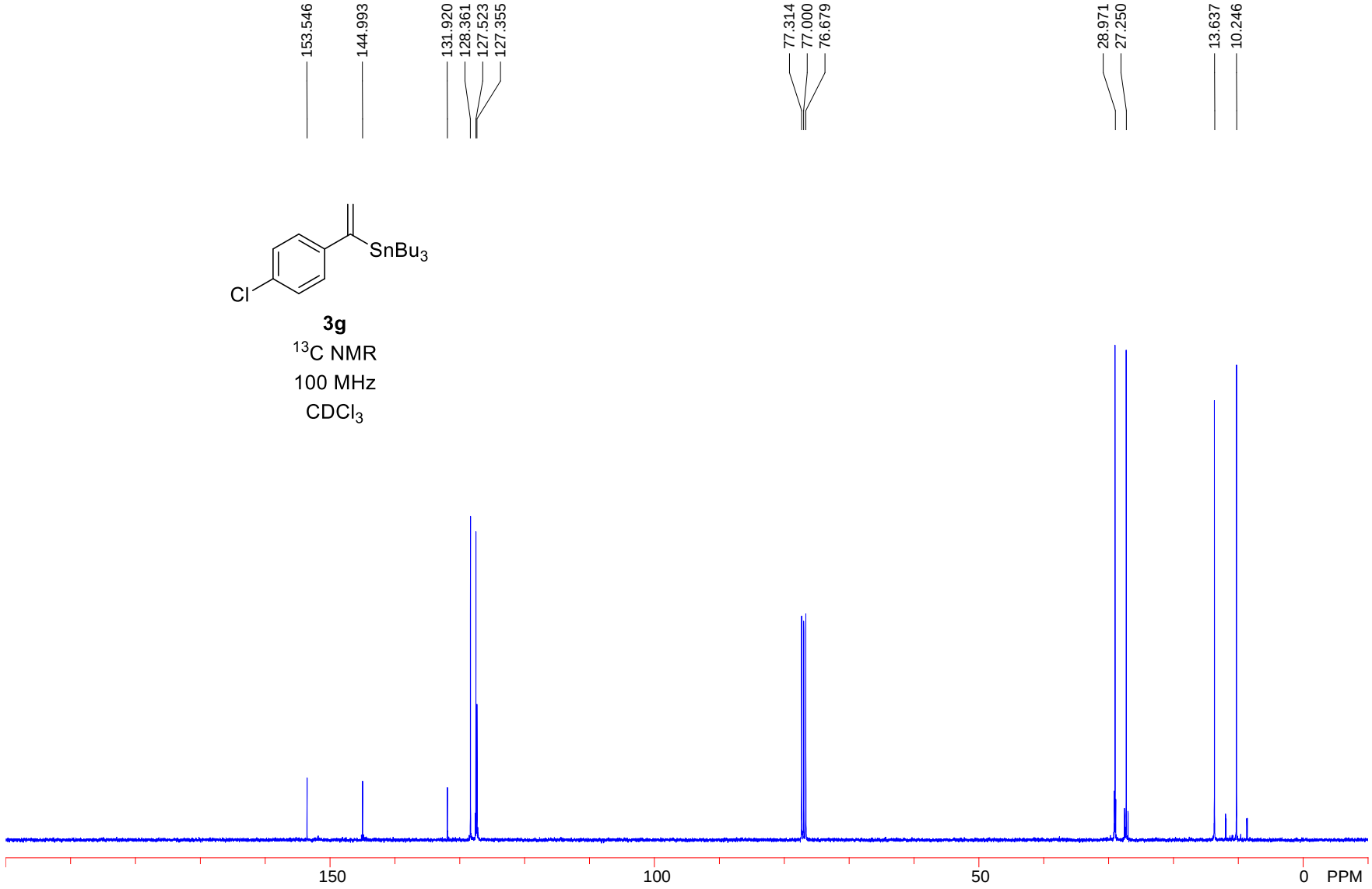
6.850
6.840
6.830
6.820
6.810
6.800 PPM
8
6
4
2
0
PPM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127.355
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77.000
76.679
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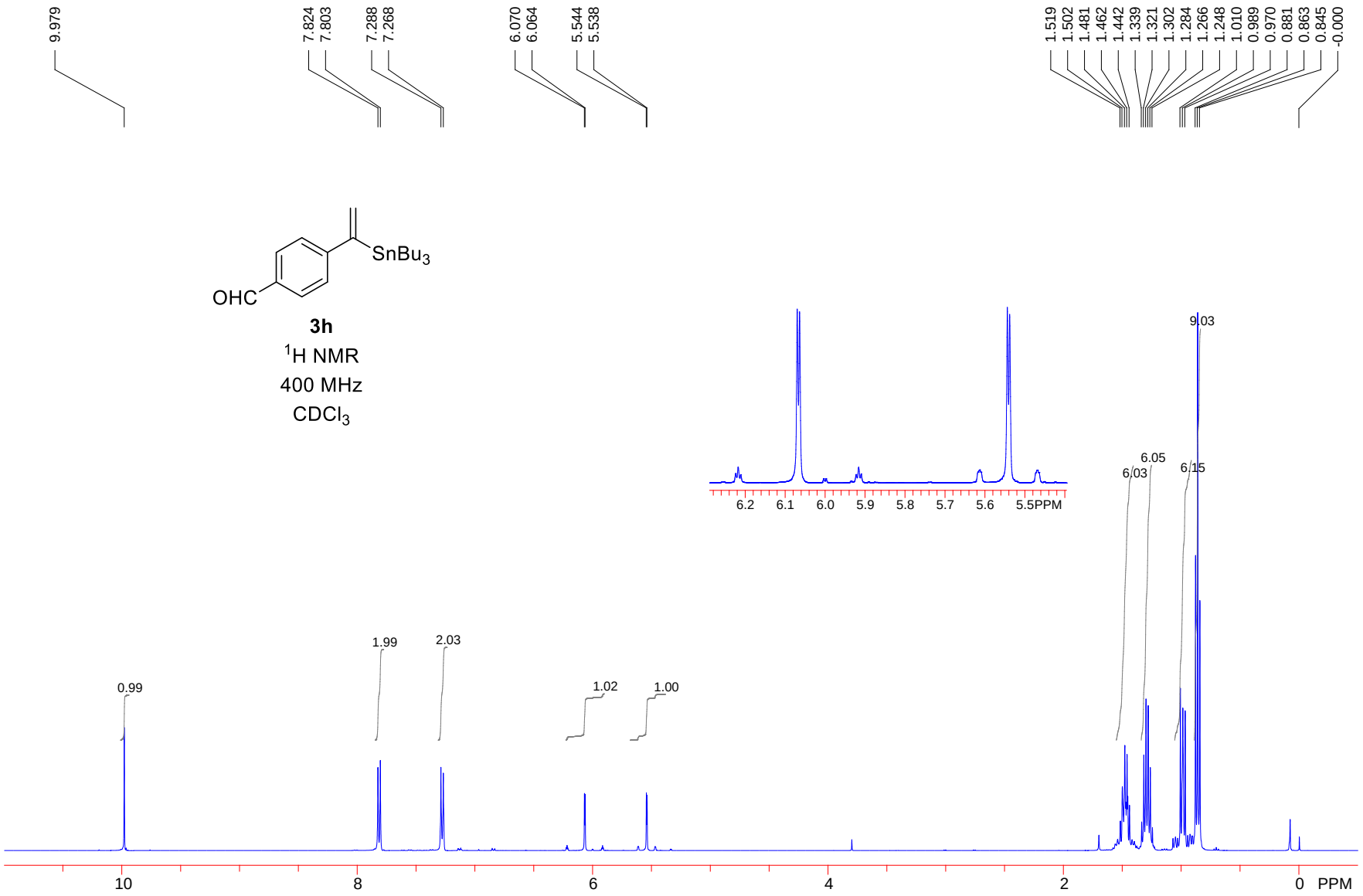
10.246
SnBu3
Cl
3g
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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6.070
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5.544
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1.519
1.502
1.481
1.462
1.442
1.339
1.321
1.302
1.284
1.266
1.248
1.010
0.989
0.970
0.881
0.863
0.845
-0.000
SnBu3
OHC
3h
1H NMR
400 MHz
CDCl3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5PPM
9.03
6.05
6.03
6.15
0.99
1.99
2.03
1.02
1.00
10
8
6
4
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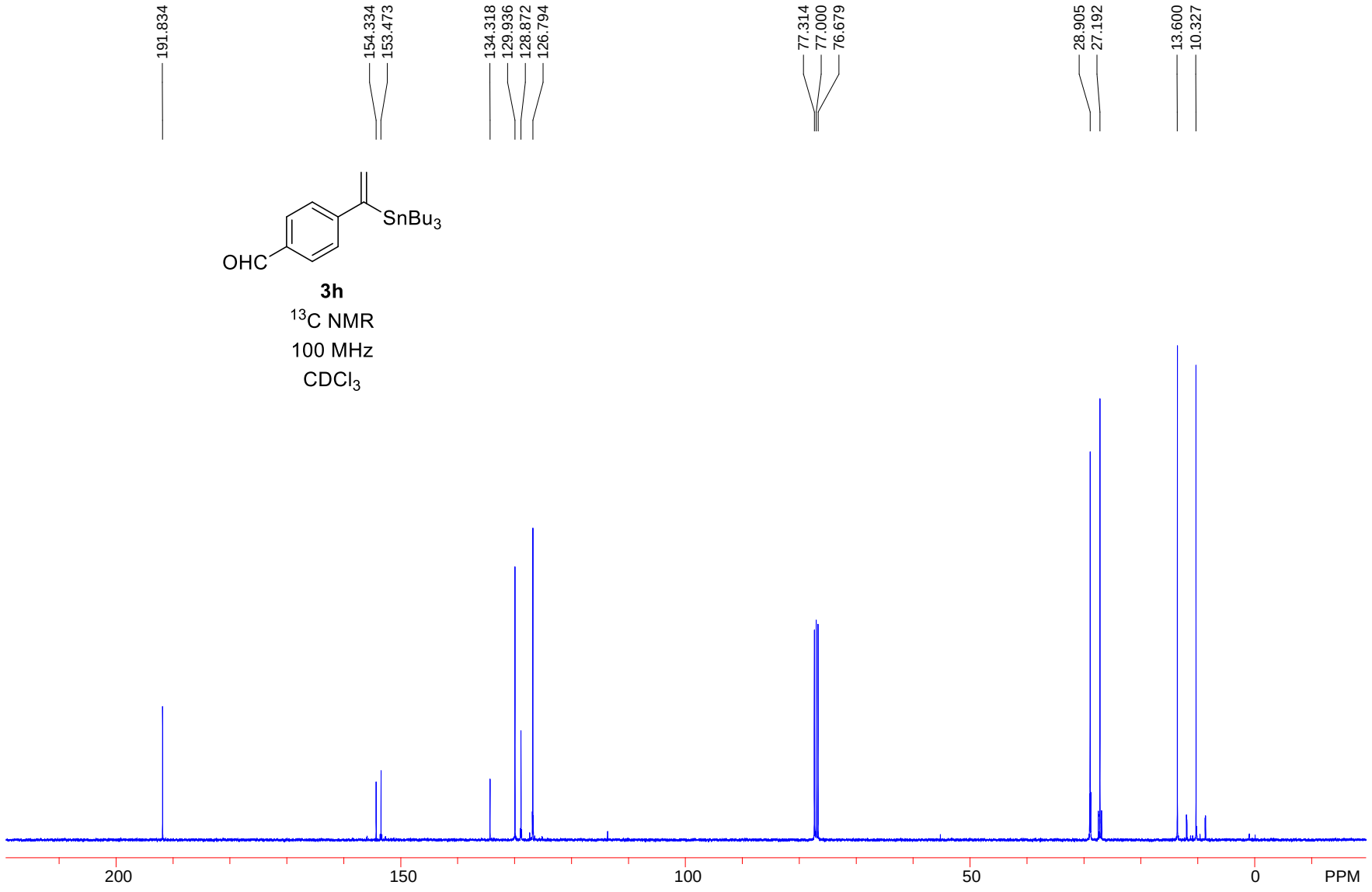
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3h
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CDCl3
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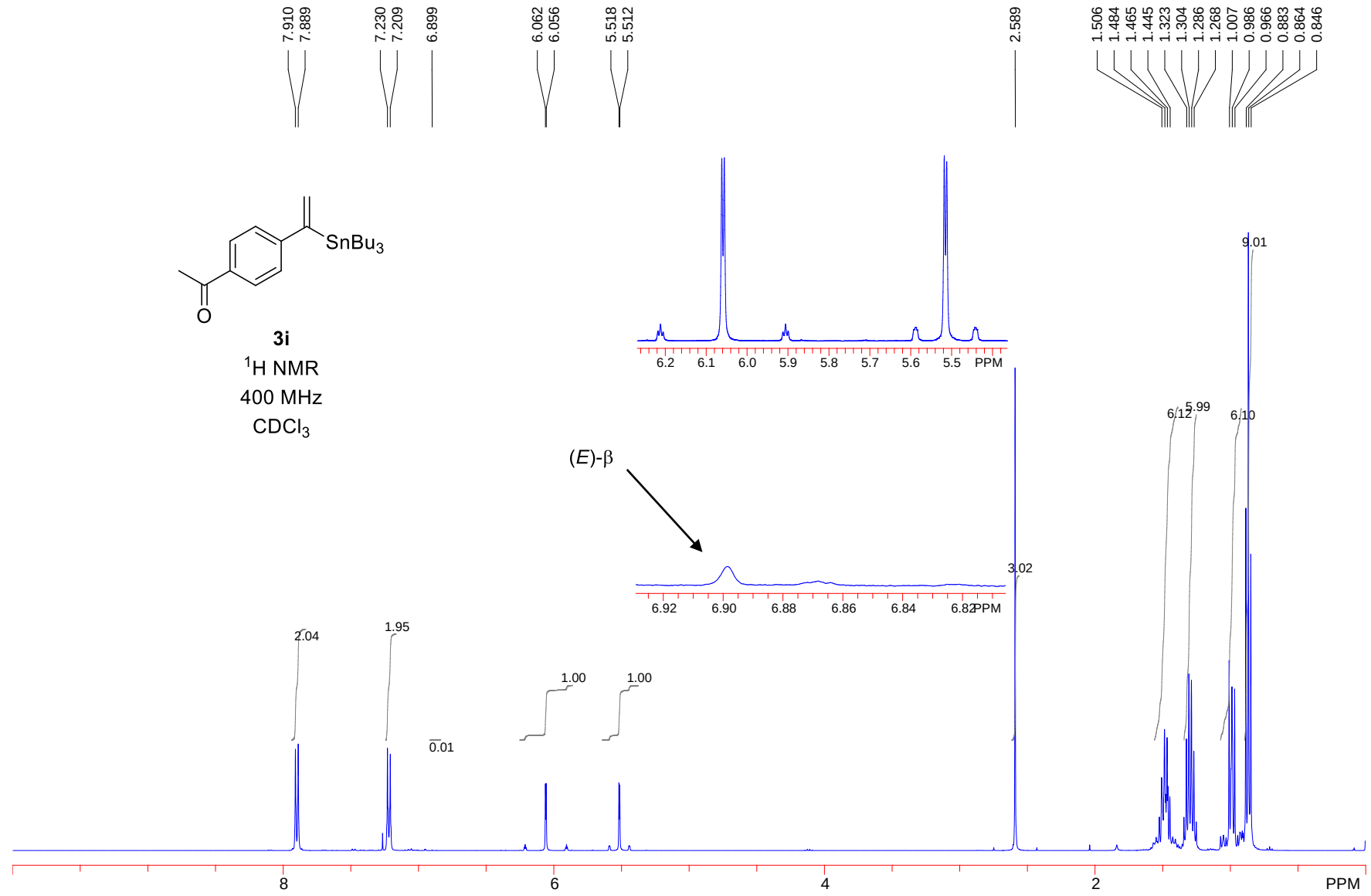
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7.209
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6.056
5.518
5.512
2.589
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1.465
1.445
1.323
1.304
1.286
1.268
1.007
0.986
0.966
0.883
0.864
0.846
SnBu3
O
3i
1H NMR
400 MHz
CDCl3
(E)-β
9.01
6.12
5.99
6.10
3.02
2.04
1.95
0.01
1.00
1.00
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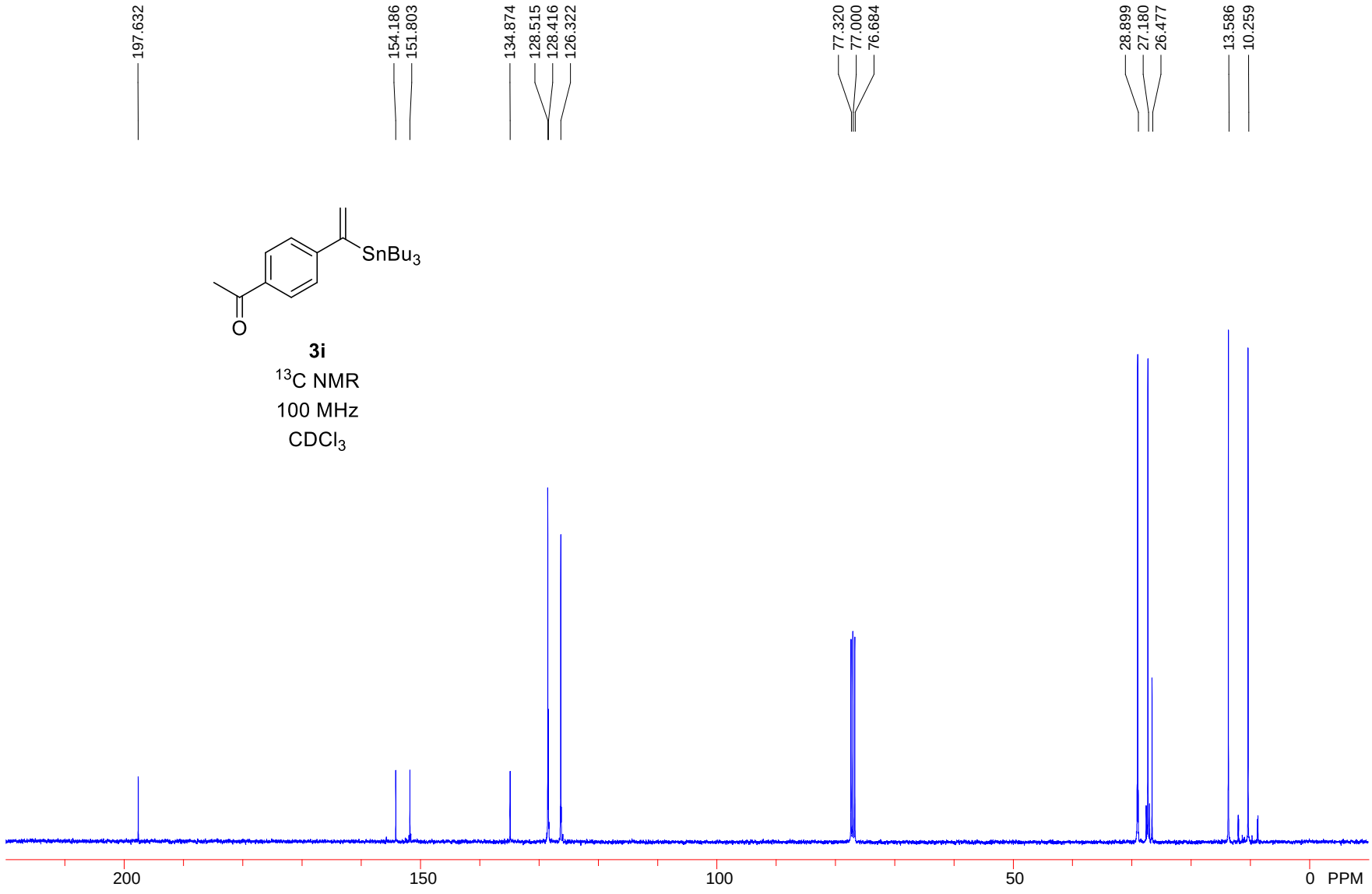
8 6 4 2 PPM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77.320
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SnBu3
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3i
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100 MHz
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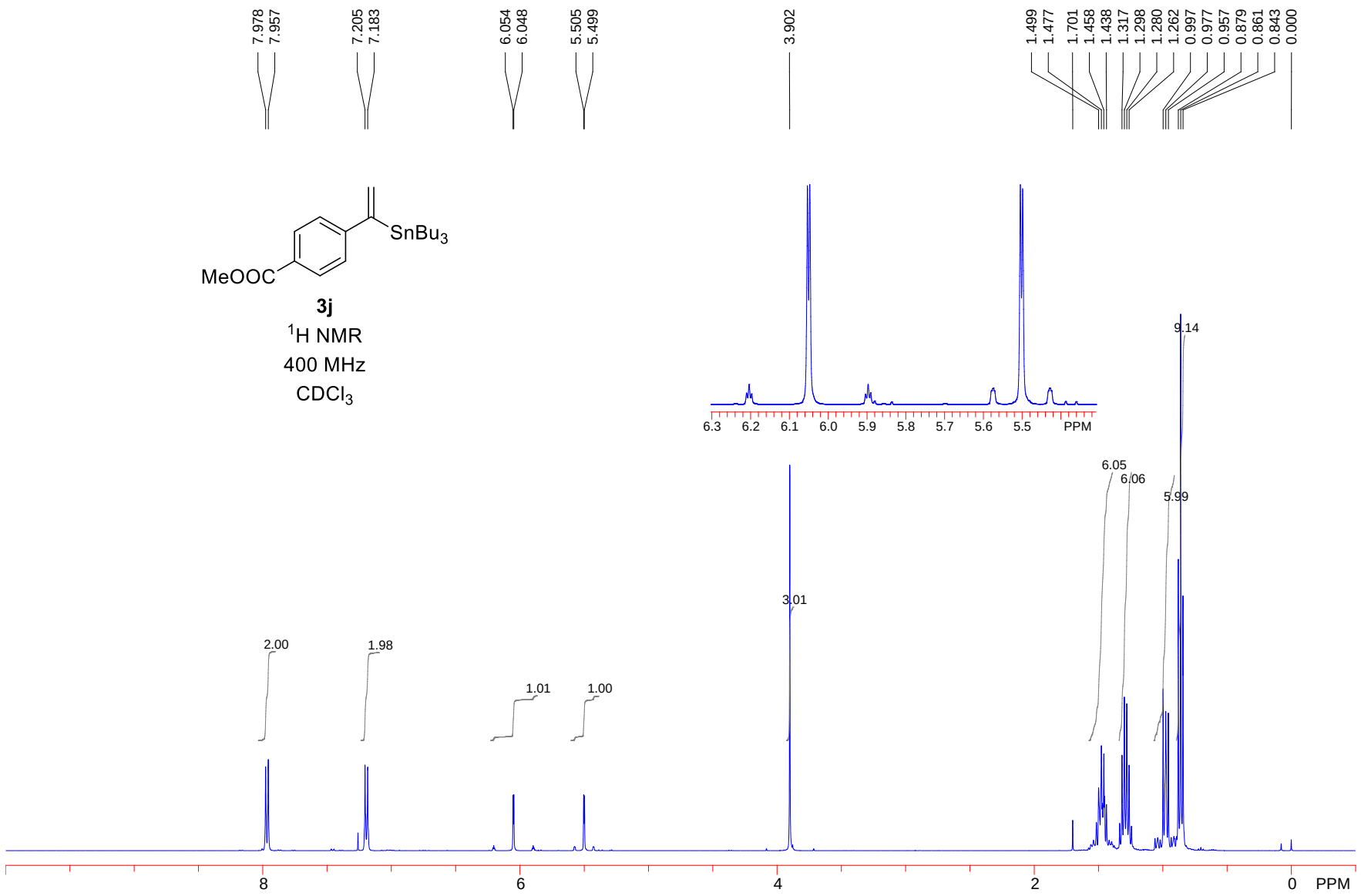
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7.957
7.205
7.183
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6.048
5.505
5.499
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1.499
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1.701
1.458
1.438
1.317
1.298
1.280
1.262
0.997
0.977
0.957
0.879
0.861
0.843
0.000
SnBu3
MeOOC
3j
1H NMR
400 MHz
CDCl3
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5
PPM
9.14
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5.99
3.01
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1.00
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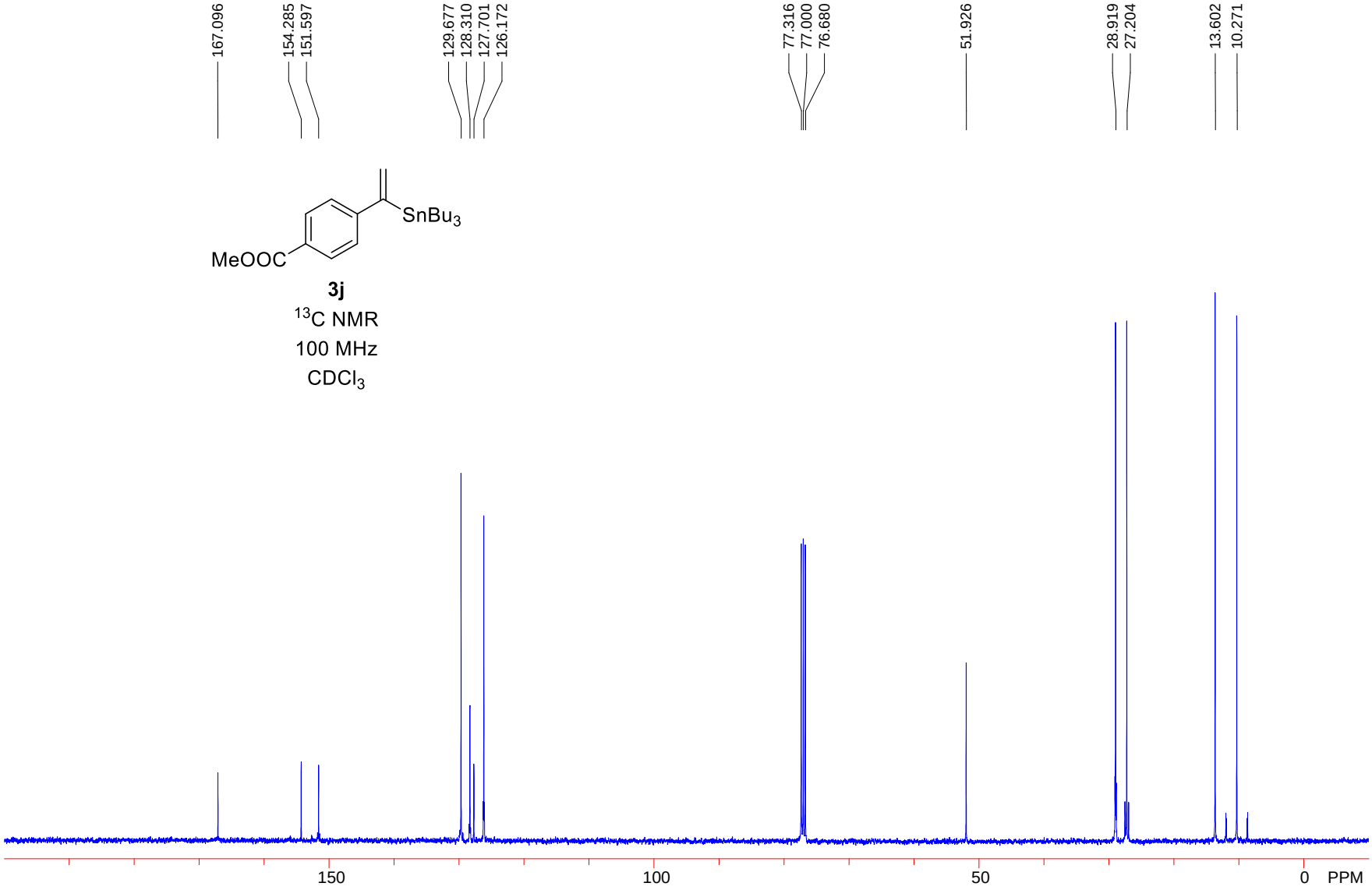
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151.597
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51.926
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10.271
SnBu3
MeOOC
3j
13C NMR
100 MHz
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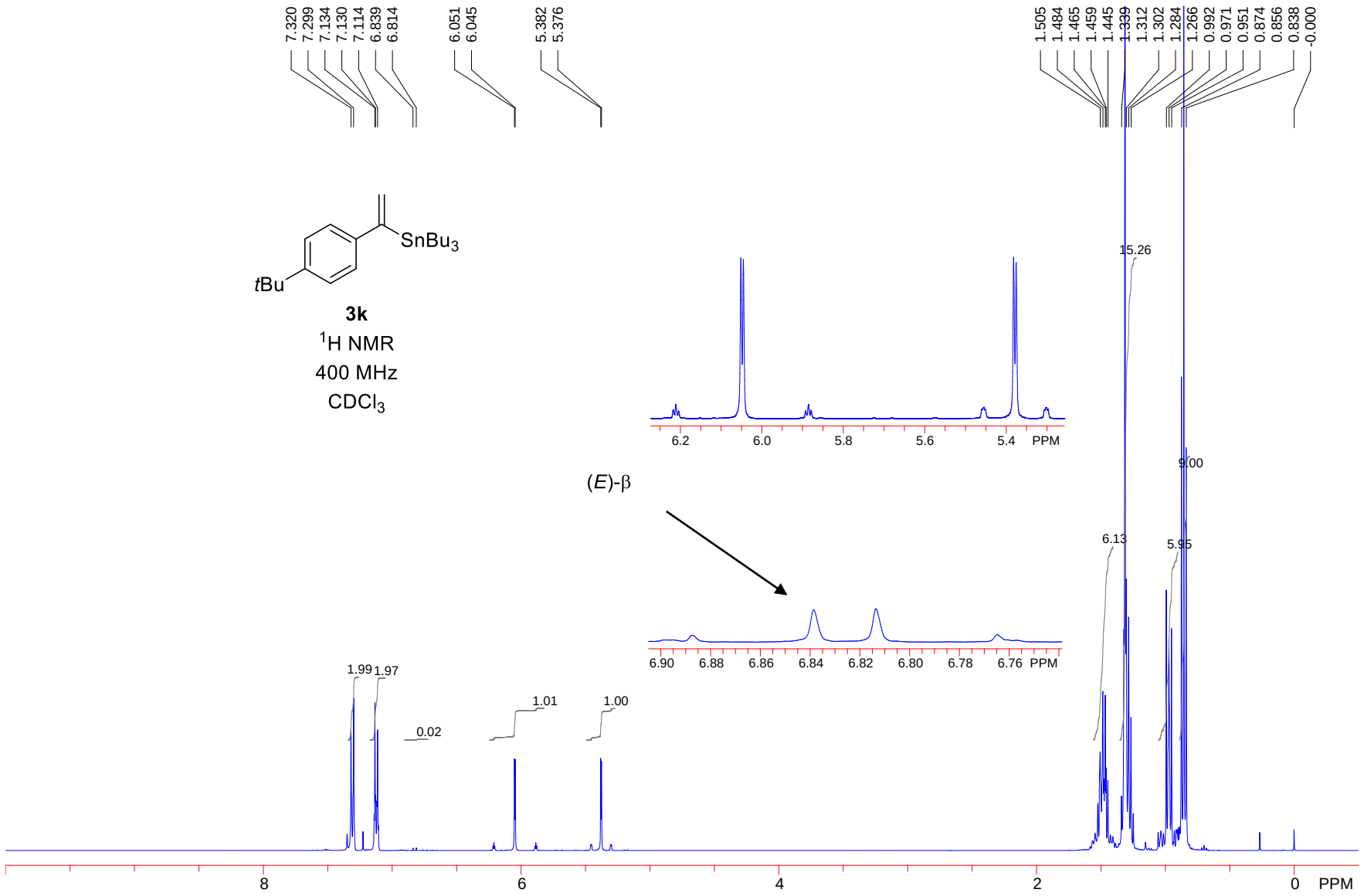
PPM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7.134
7.130
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6.814
6.051
6.045
5.382
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1.484
1.465
1.459
1.445
1.339
1.312
1.302
1.284
1.266
0.992
0.971
0.951
0.874
0.856
0.838
-0.000
SnBu3
tBu
3k
1H NMR
400 MHz
CDCl3
(E)-β
15.26
9.00
6.13
5.95
1.99
1.97
0.02
1.01
1.00
6.2
6.0
5.8
5.6
5.4
PPM
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6.84
6.82
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PPM
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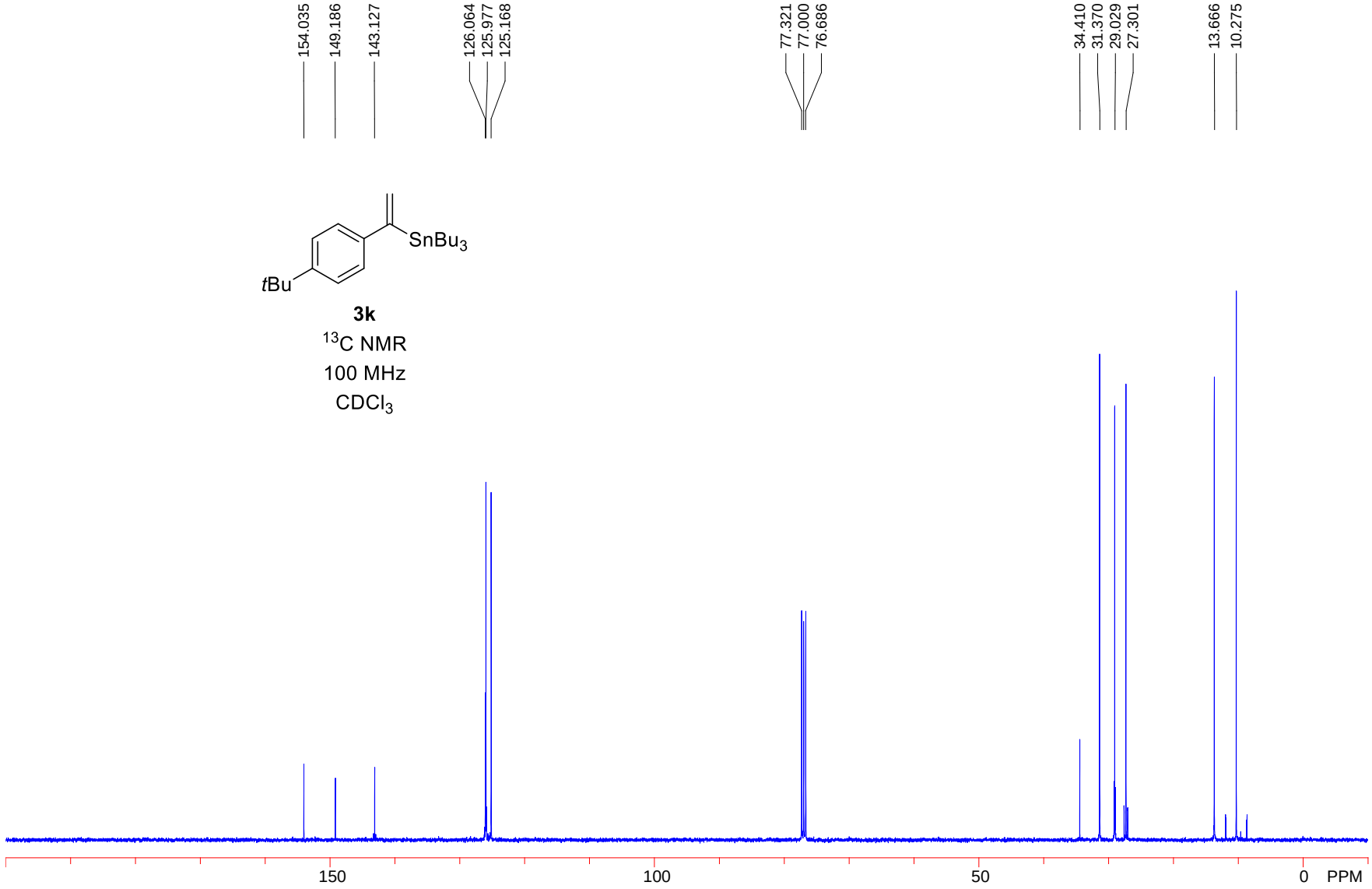
0
PPM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77.000
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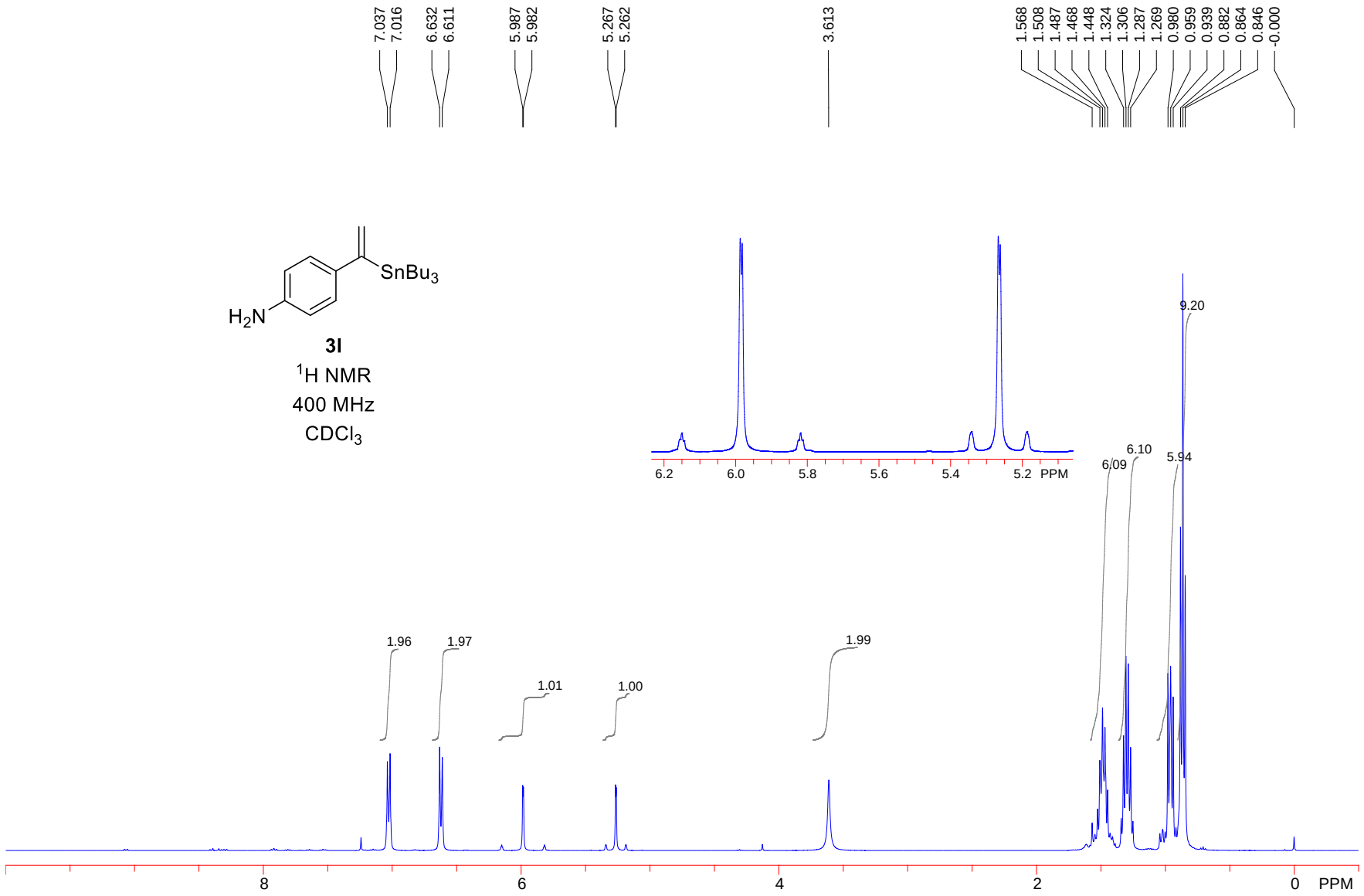
10.275
SnBu3
tBu
3k
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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6.632
6.611
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5.982
5.267
5.262
3.613
1.568
1.508
1.487
1.468
1.448
1.324
1.306
1.287
1.269
0.980
0.959
0.939
0.882
0.864
0.846
-0.000
SnBu3
H2N
3l
1H NMR
400 MHz
CDCl3
6.2
6.0
5.8
5.6
5.4
5.2 PPM
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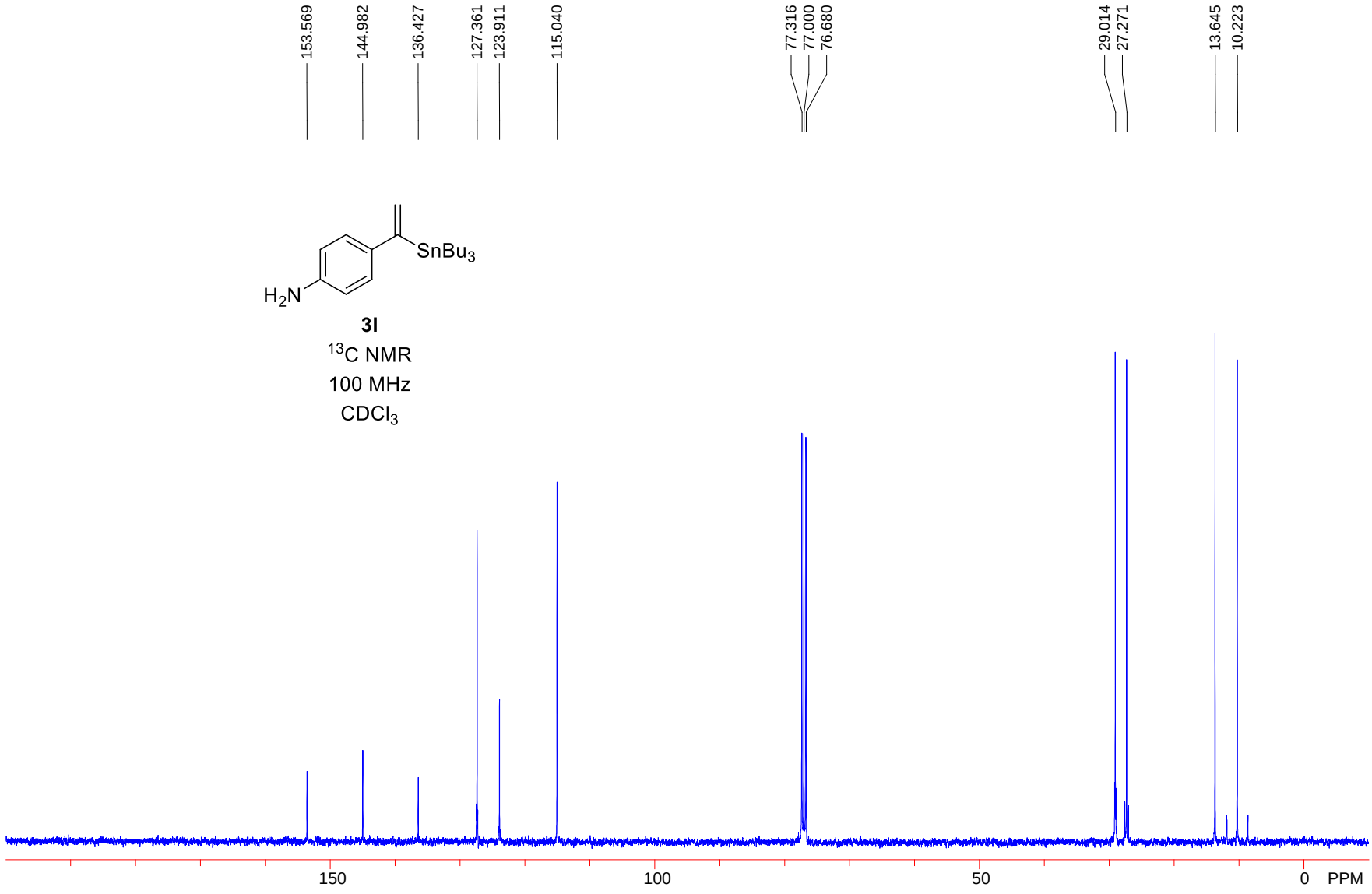
6.10
6.09
5.94
1.96
1.97
1.01
1.00
1.99
8
6
4
2
0 PPM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144.982
136.427
127.361
123.911
115.040
77.316
77.000
76.680
29.014
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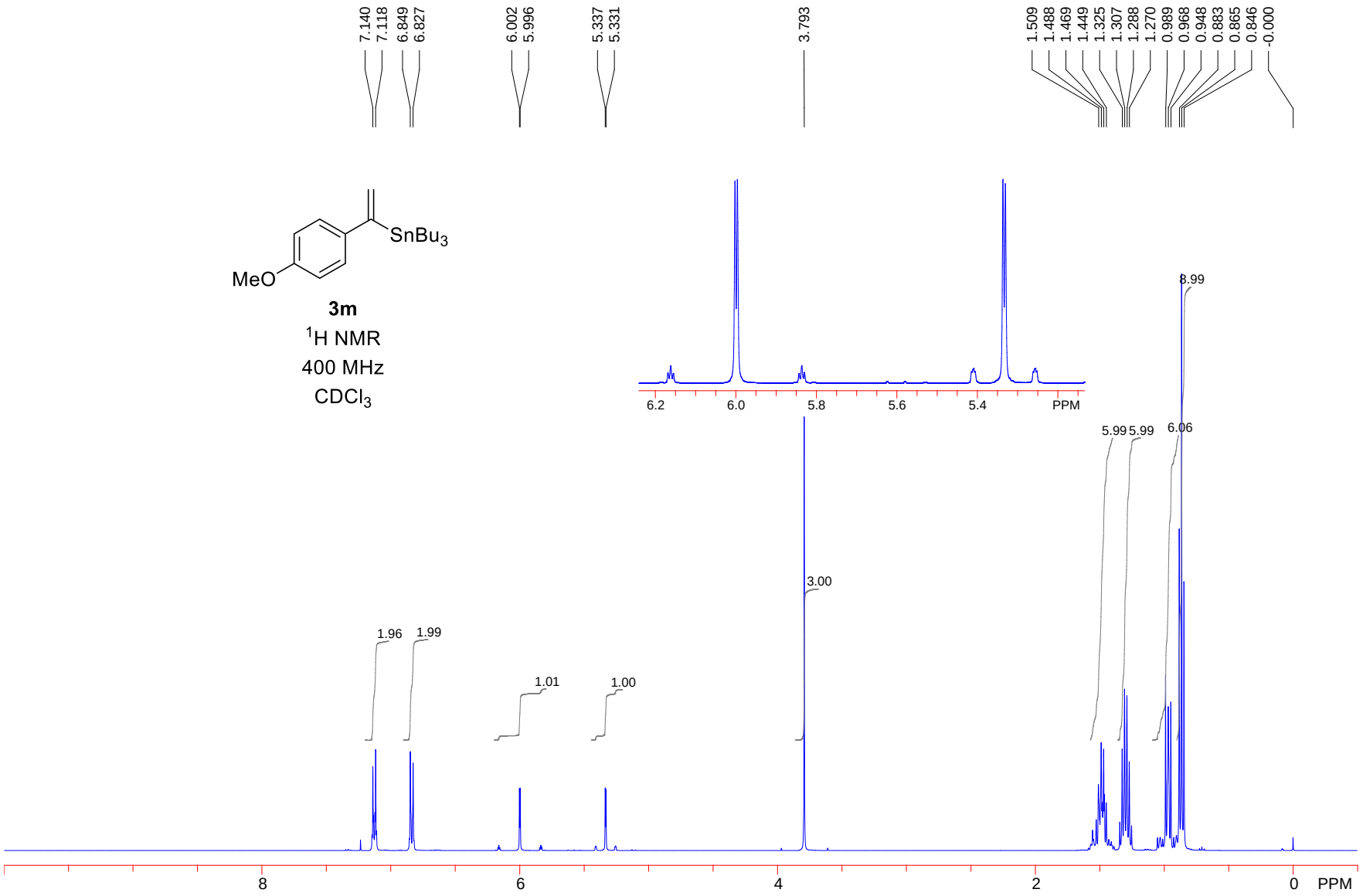
10.223
SnBu3
H2N
3l
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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6.002
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5.337
5.331
3.793
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1.469
1.449
1.325
1.307
1.288
1.270
0.989
0.968
0.948
0.883
0.865
0.846
-0.000
SnBu3
MeO
3m
1H NMR
400 MHz
CDCl3
8.99
6.2
6.0
5.8
5.6
5.4
PPM
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6.06
3.00
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1.00
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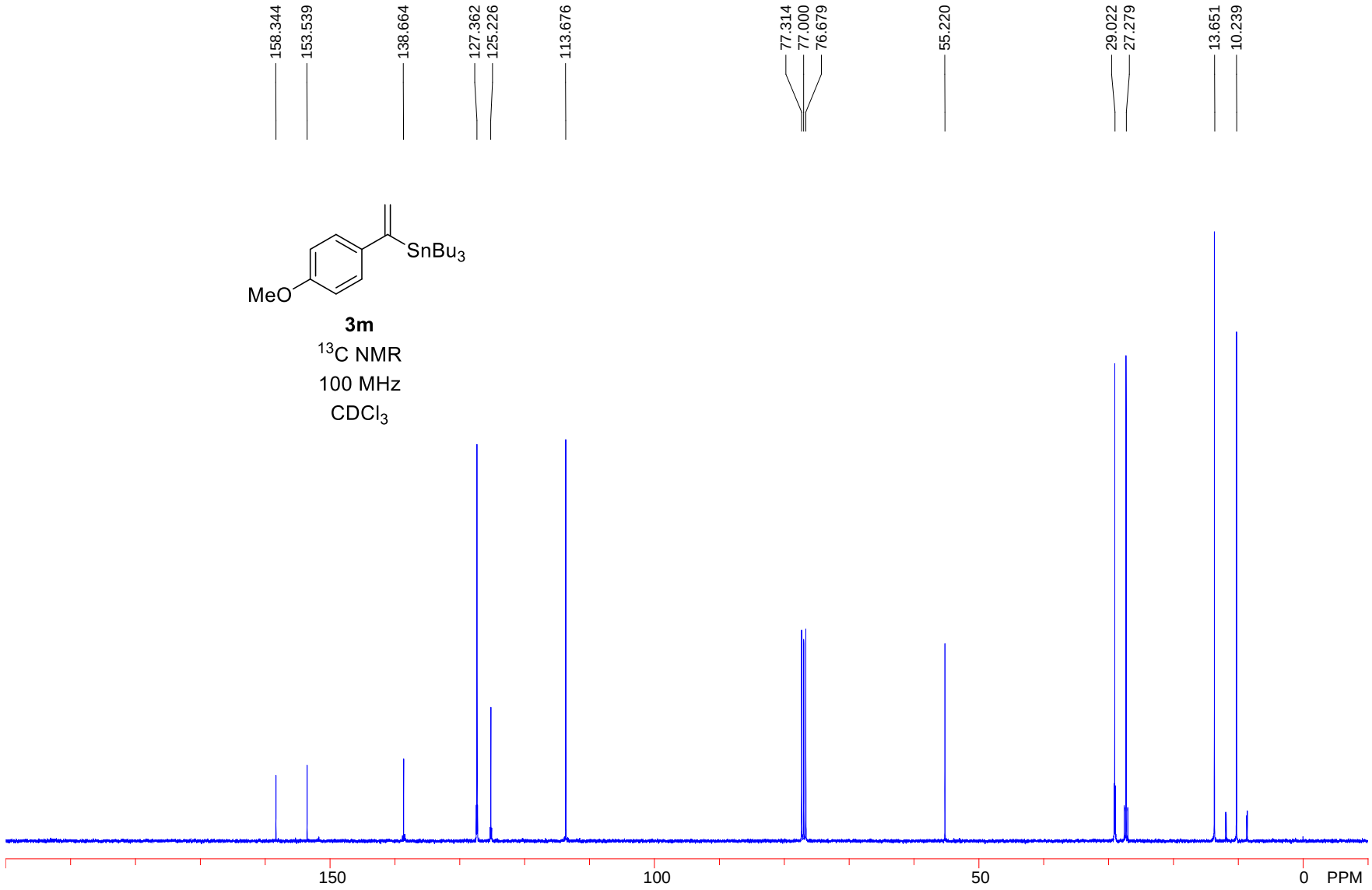
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77.000
76.679
55.220
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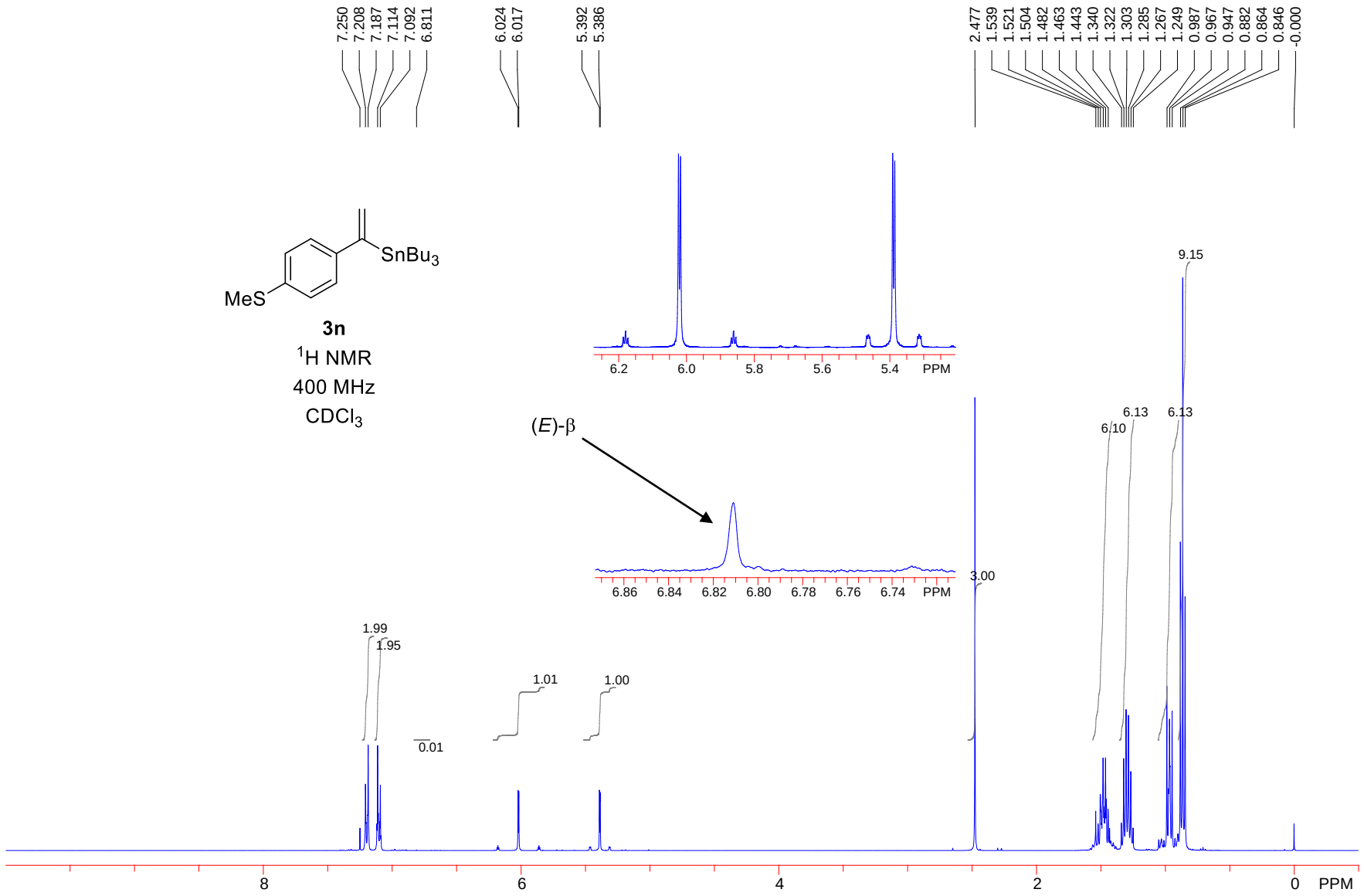
10.239
SnBu3
MeO
3m
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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7.208
7.187
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6.017
5.392
5.386
2.477
1.539
1.521
1.504
1.482
1.463
1.443
1.340
1.322
1.303
1.285
1.267
1.249
0.987
0.967
0.947
0.882
0.864
0.846
-0.000
SnBu3
MeS
3n
1H NMR
400 MHz
CDCl3
(E)-β
9.15
6.13
6.13
6.10
3.00
1.99
1.95
1.01
1.00
0.01
6.2
6.0
5.8
5.6
5.4
PPM
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6.82
6.80
6.78
6.76
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PPM
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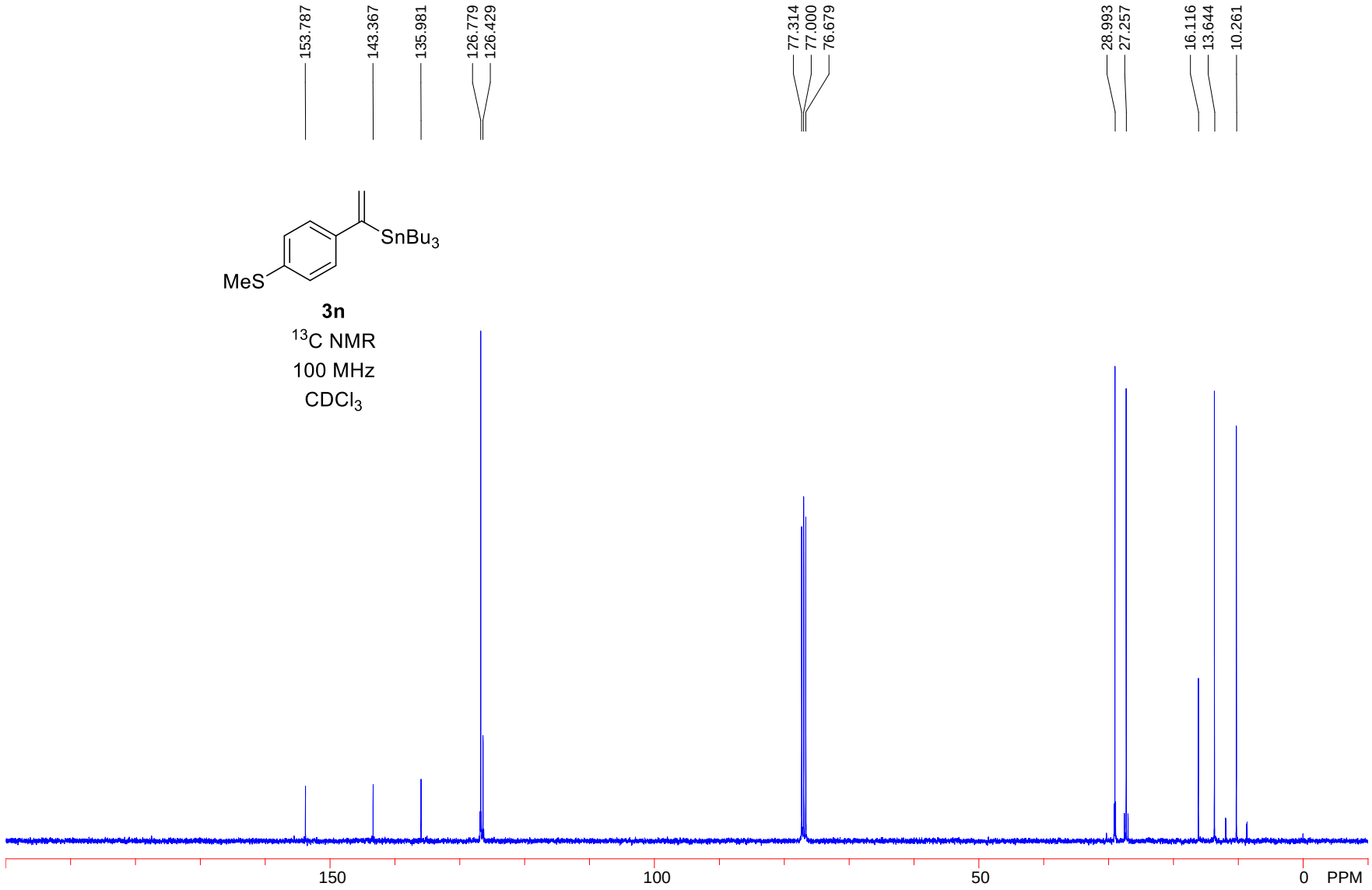
4
2
0
PPM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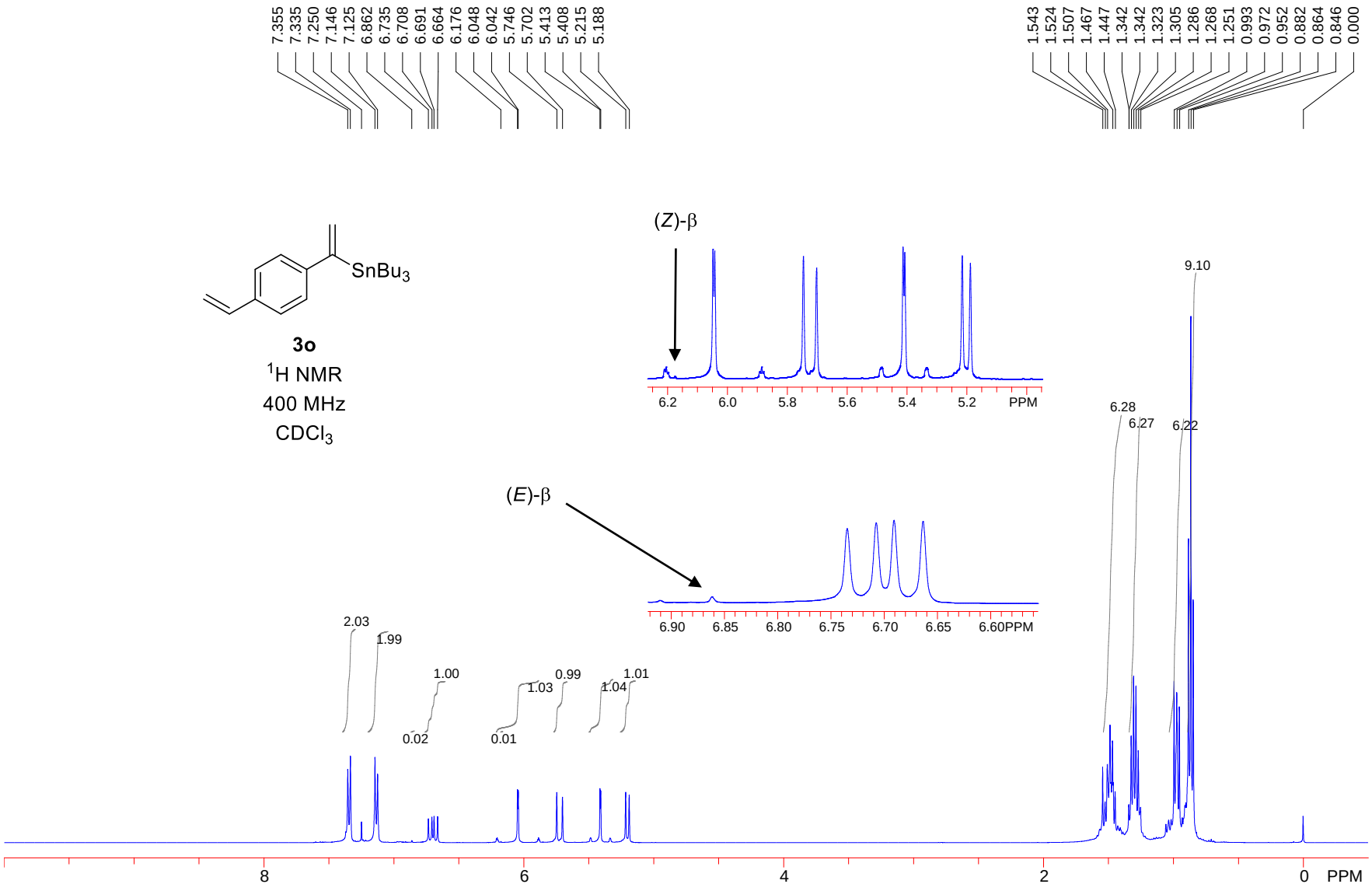
10.261
SnBu3
MeS
3n
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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7.125
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6.664
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6.042
5.746
5.702
5.413
5.408
5.215
5.188
1.543
1.524
1.507
1.467
1.447
1.342
1.342
1.323
1.305
1.286
1.268
1.251
0.993
0.972
0.952
0.882
0.864
0.846
0.000
SnBu3
3o
1H NMR
400 MHz
CDCl3
(Z)-β
6.2
6.0
5.8
5.6
5.4
5.2
PPM
(E)-β
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6.65
6.60PPM
9.10
6.28
6.27
6.22
2.03
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1.01
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6
4
2
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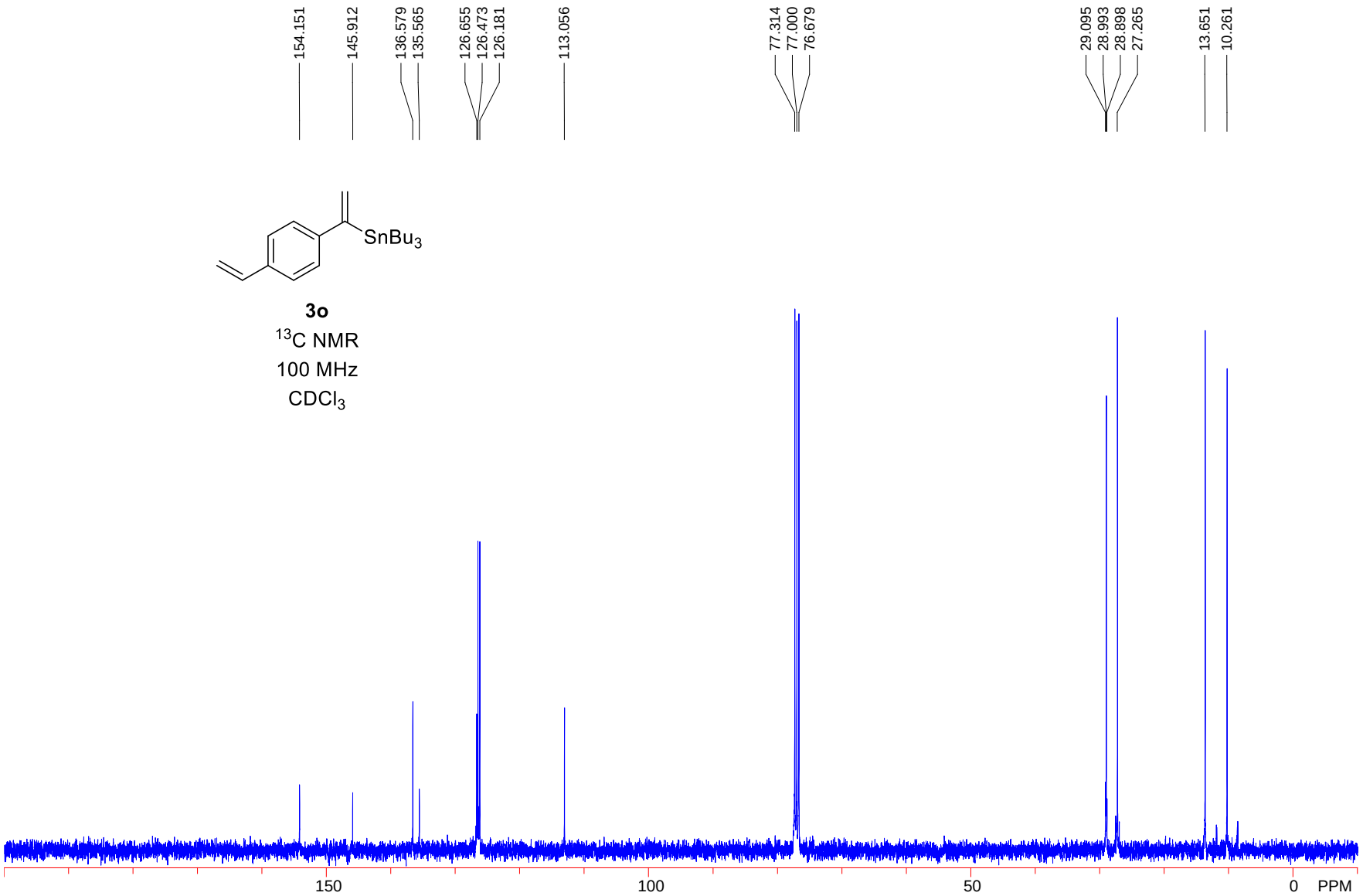
PPM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77.000
76.679
29.095
28.993
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27.265
13.651
10.261
SnBu3
3o
13C NMR
100 MHz
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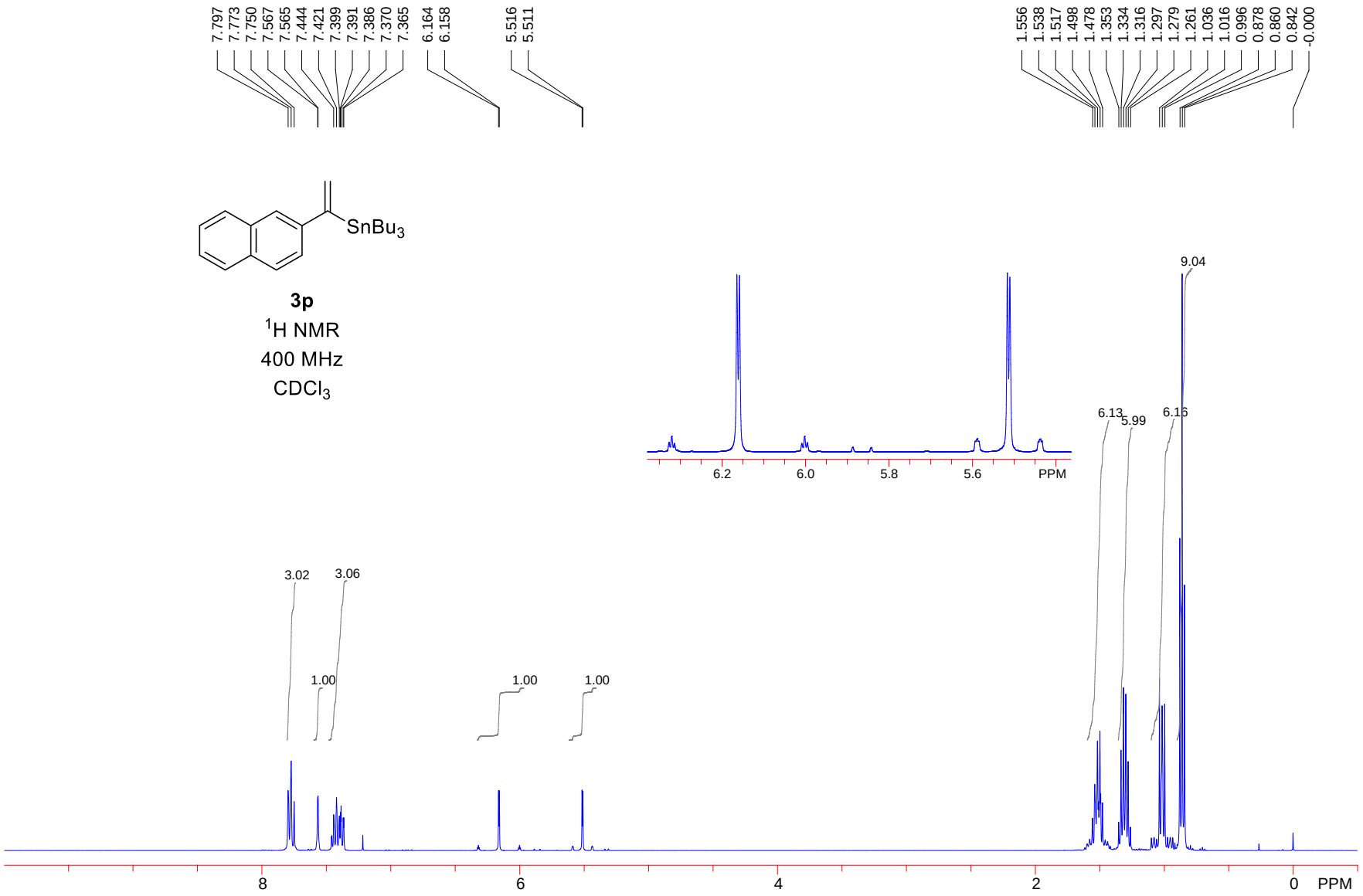
100
50
0
PPM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7.444
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7.399
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7.386
7.370
7.365
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6.158
5.516
5.511
1.556
1.538
1.517
1.498
1.478
1.353
1.334
1.316
1.297
1.279
1.261
1.036
1.016
0.996
0.878
0.860
0.842
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SnBu3
3p
1H NMR
400 MHz
CDCl3
9.04
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5.99
6.16
6.2
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PPM
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1.00
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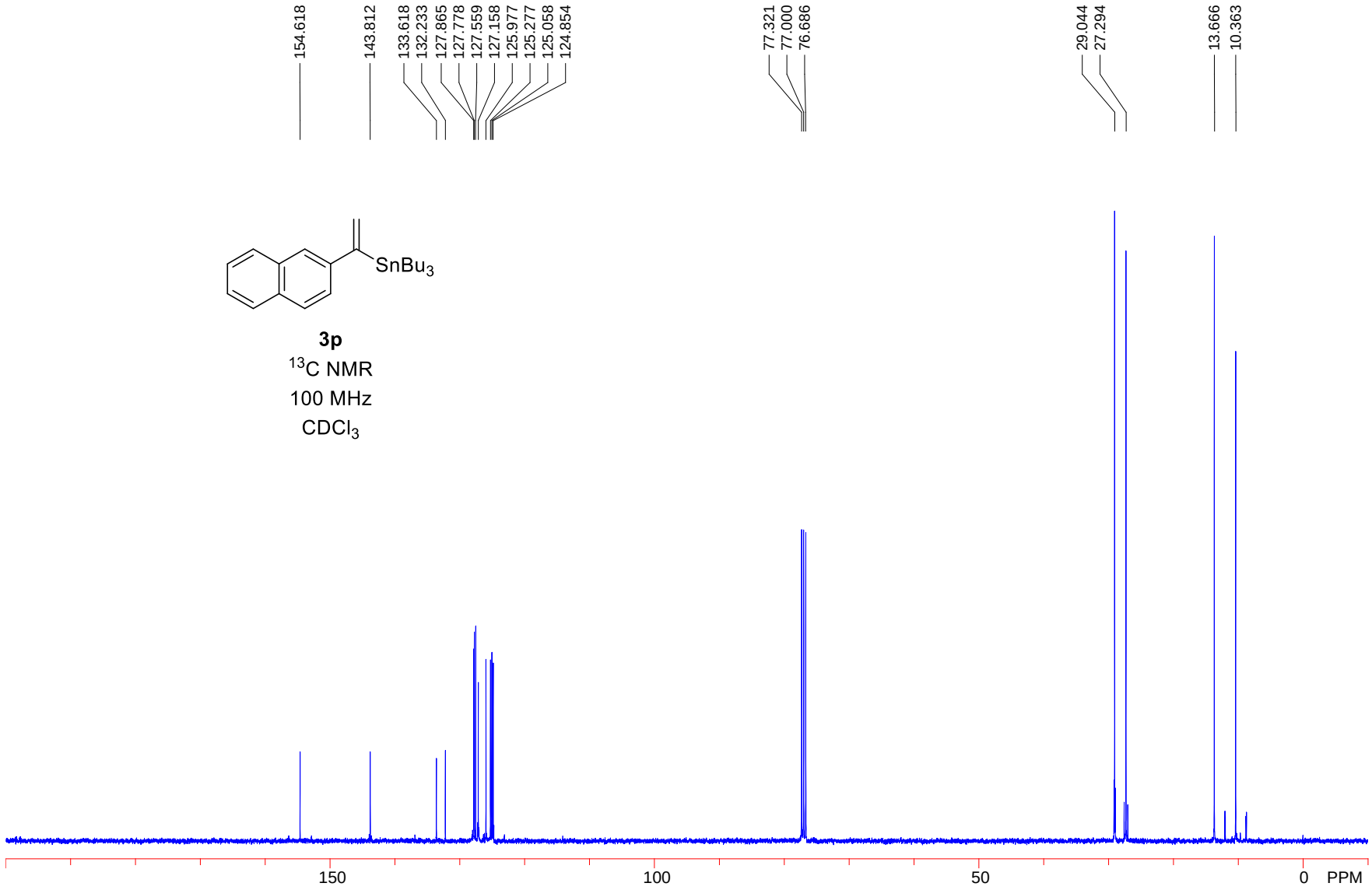
PPM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127.158
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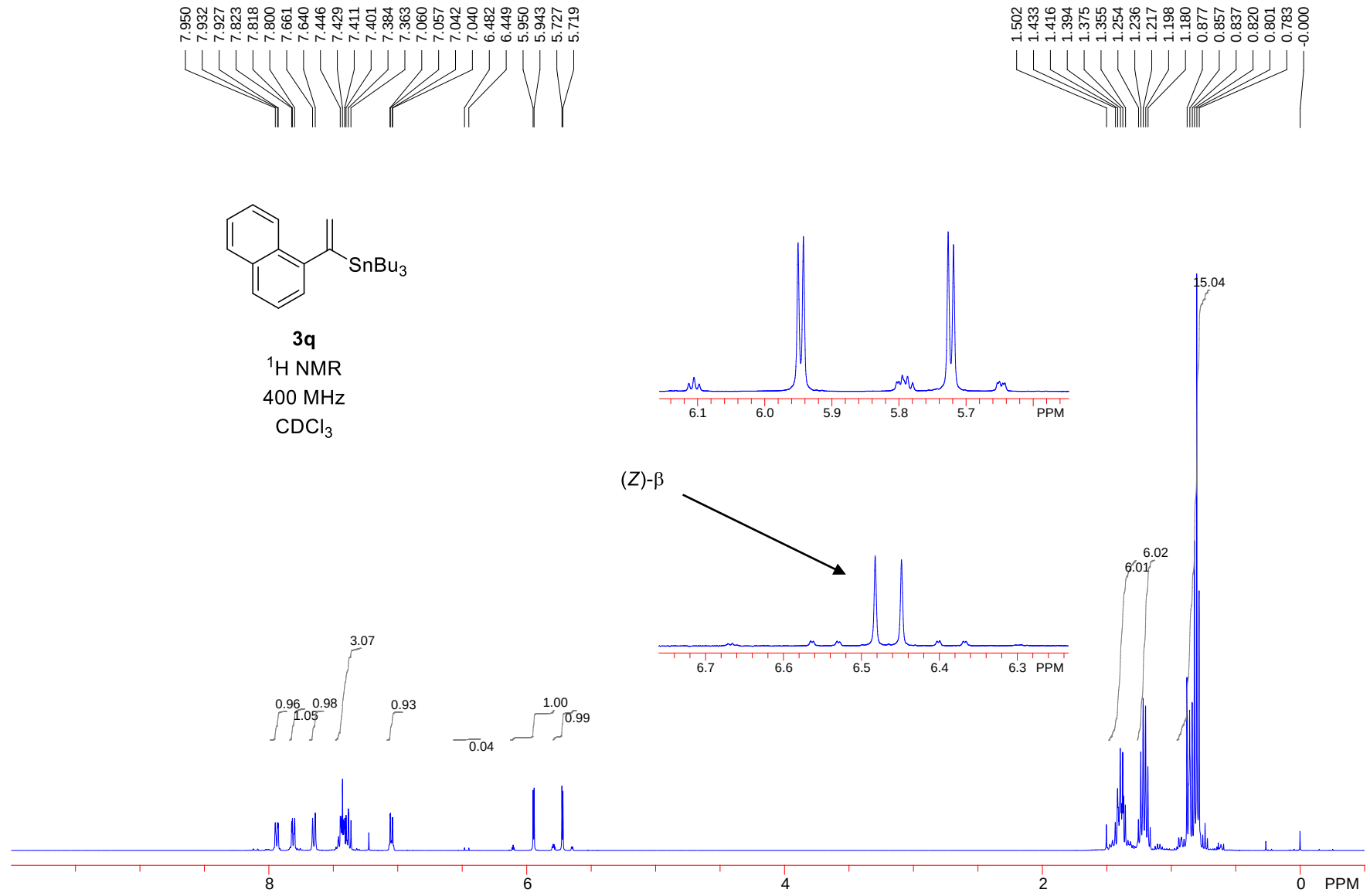
125.277
125.058
124.854
77.321
77.000
76.686
29.044
27.294
13.666
10.363
SnBu3
3p
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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7.640
7.446
7.429
7.411
7.401
7.384
7.363
7.060
7.057
7.042
7.040
6.482
6.449
5.950
5.943
5.727
5.719
1.502
1.433
1.416
1.394
1.375
1.355
1.254
1.236
1.217
1.198
1.180
0.877
0.857
0.837
0.820
0.801
0.783
-0.000
SnBu3
3q
1H NMR
400 MHz
CDCl3
(Z)-β
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6.01
3.07
0.96
1.05
0.98
0.93
0.04
1.00
0.99
6.1
6.0
5.9
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PPM
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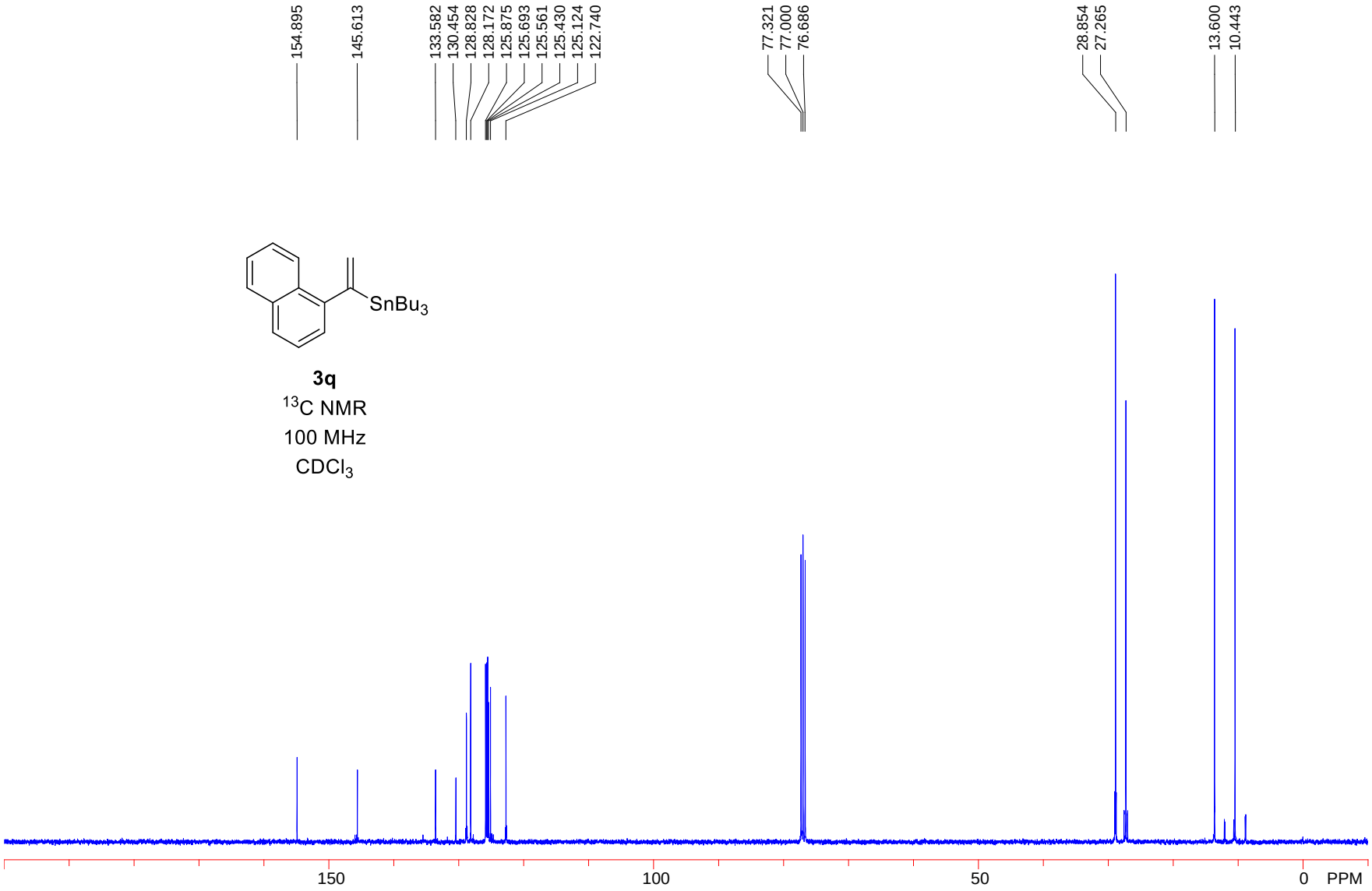
PPM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77.000
76.686
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13.600
10.443
SnBu3
3q
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100 MHz
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50
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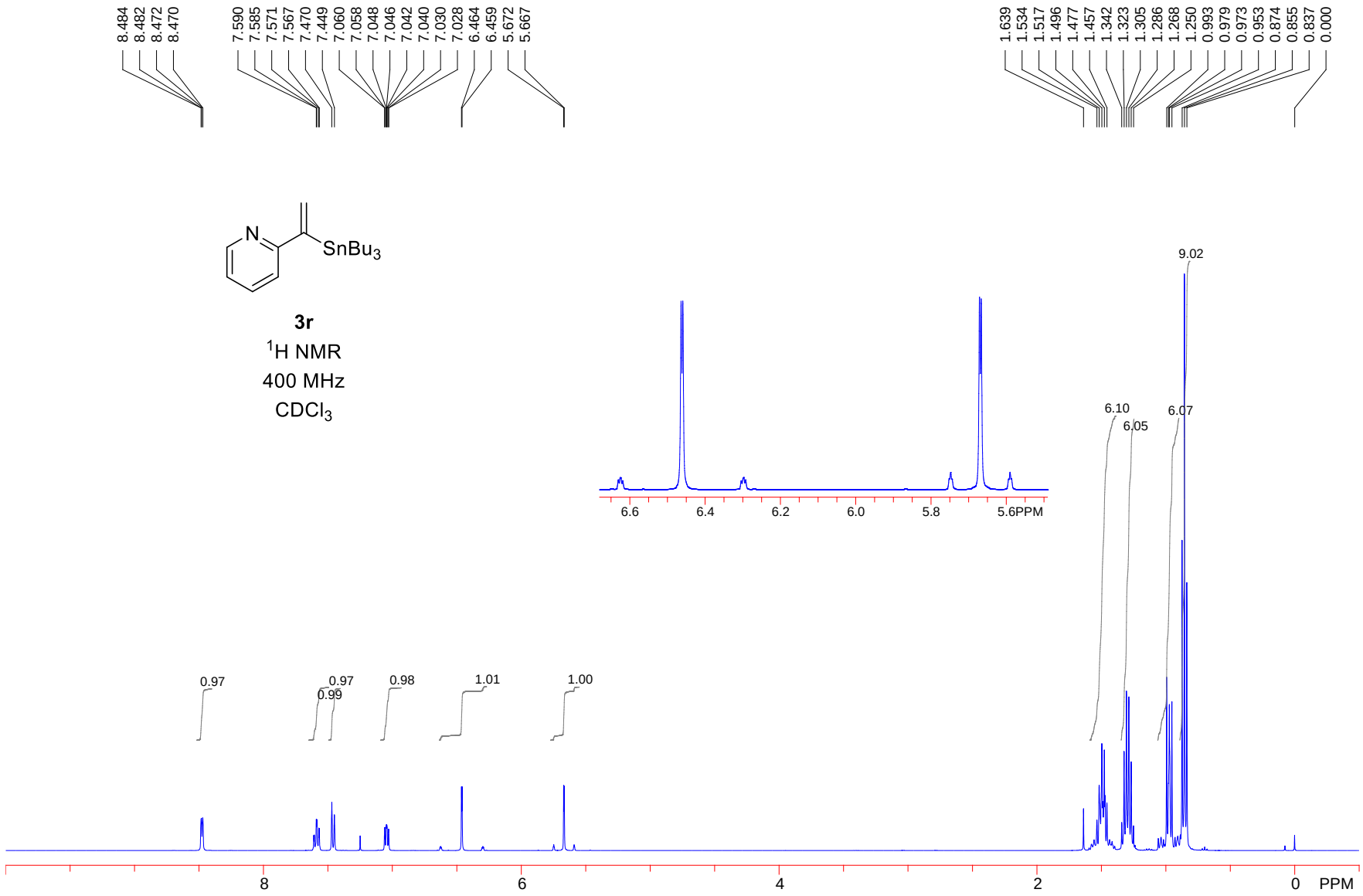
PPM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7.058
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7.046
7.042
7.040
7.030
7.028
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6.459
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5.667
1.639
1.534
1.517
1.496
1.477
1.457
1.342
1.323
1.305
1.286
1.268
1.250
0.993
0.979
0.973
0.953
0.874
0.855
0.837
0.000
N
SnBu3
3r
1H NMR
400 MHz
CDCl3
9.02
6.10
6.05
6.07
0.97
0.97
0.99
0.98
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6.4
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6.0
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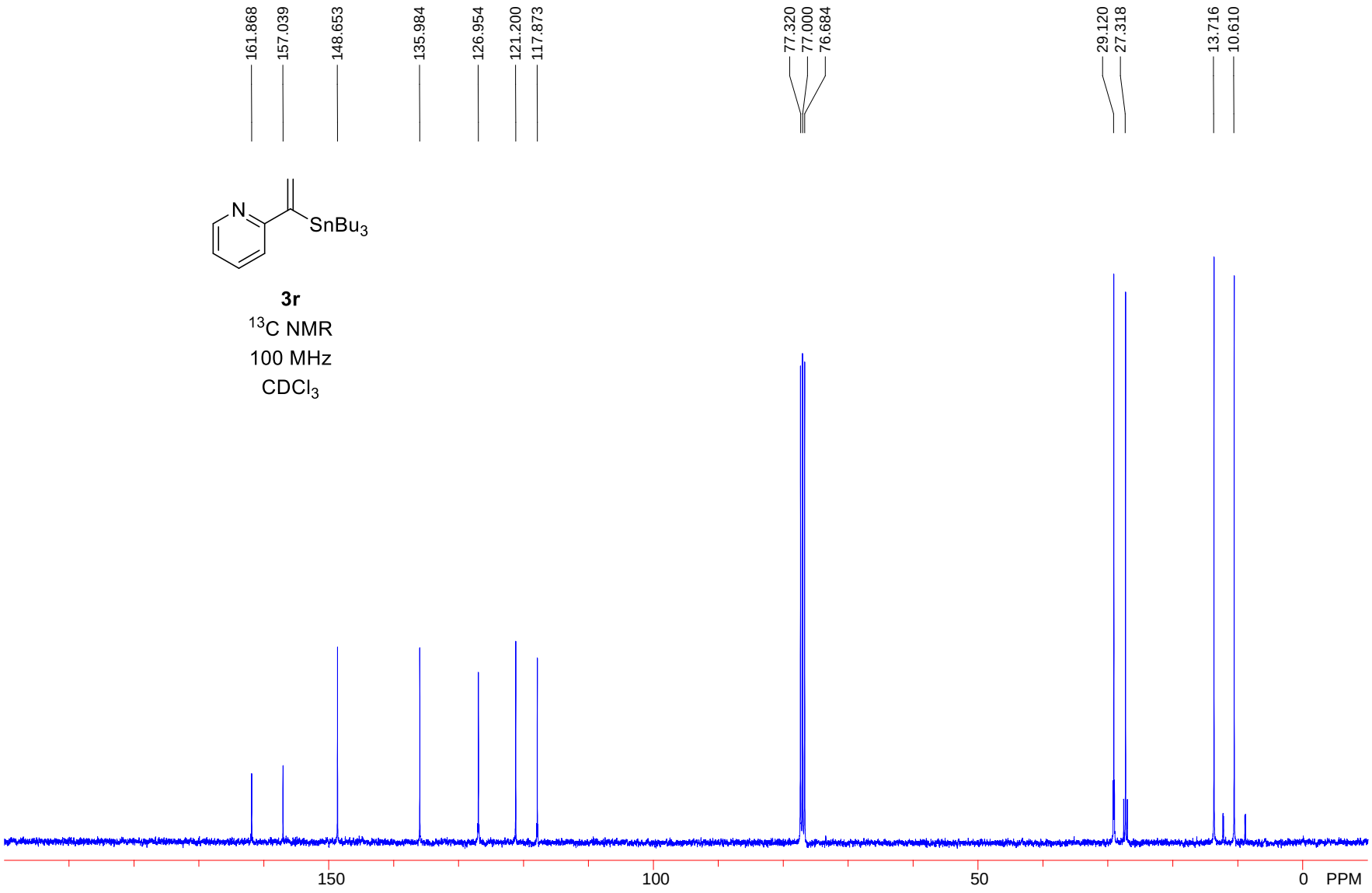
4
2
0
PPM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117.873
77.320
77.000
76.684
29.120
27.318
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100 MHz
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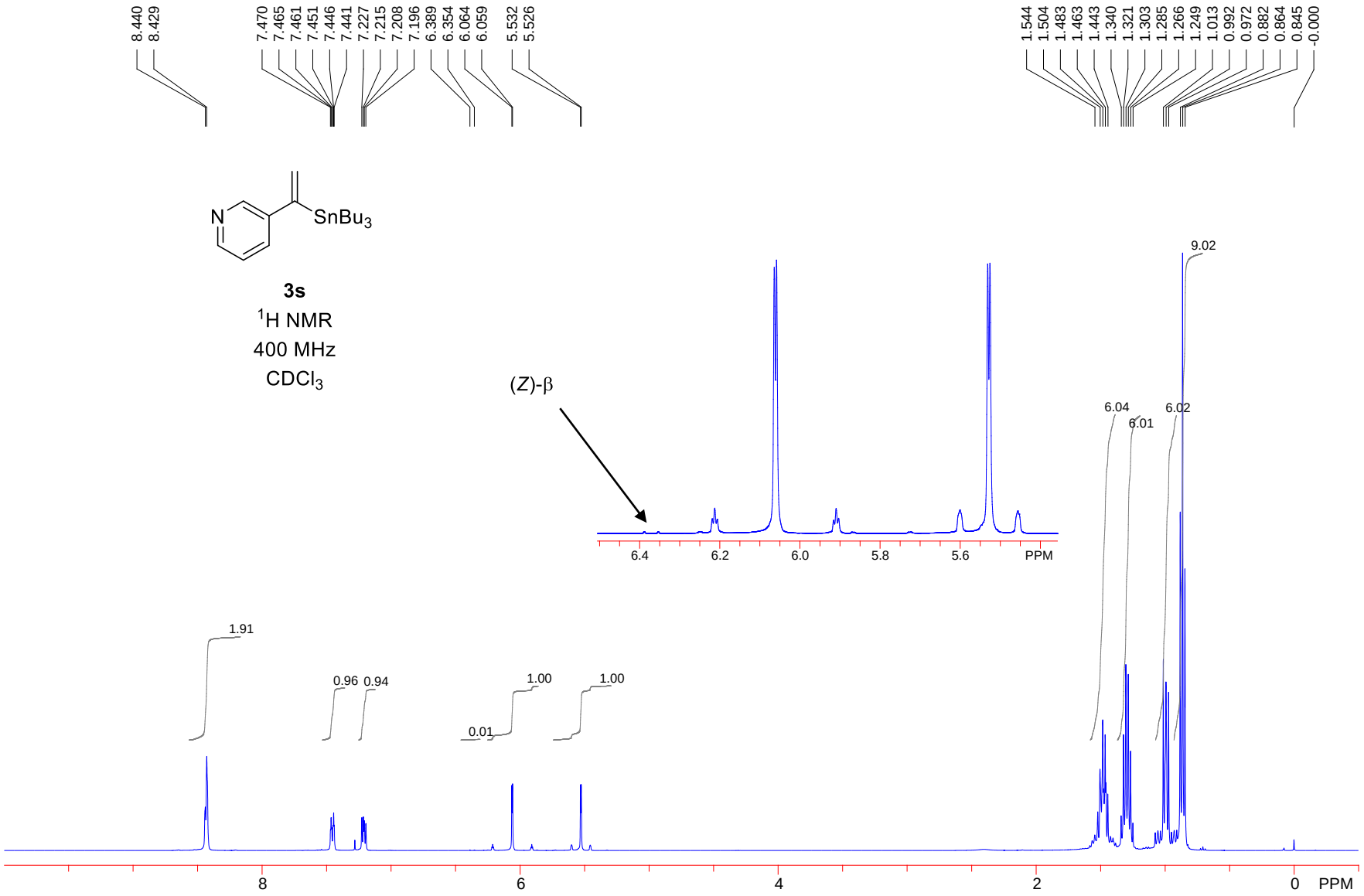
PPM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7.451
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7.208
7.196
6.389
6.354
6.064
6.059
5.532
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1.013
0.992
0.972
0.882
0.864
0.845
-0.000
N
SnBu3
3s
1H NMR
400 MHz
CDCl3
(Z)-β
6.4
6.2
6.0
5.8
5.6
PPM
9.02
6.04
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1.00
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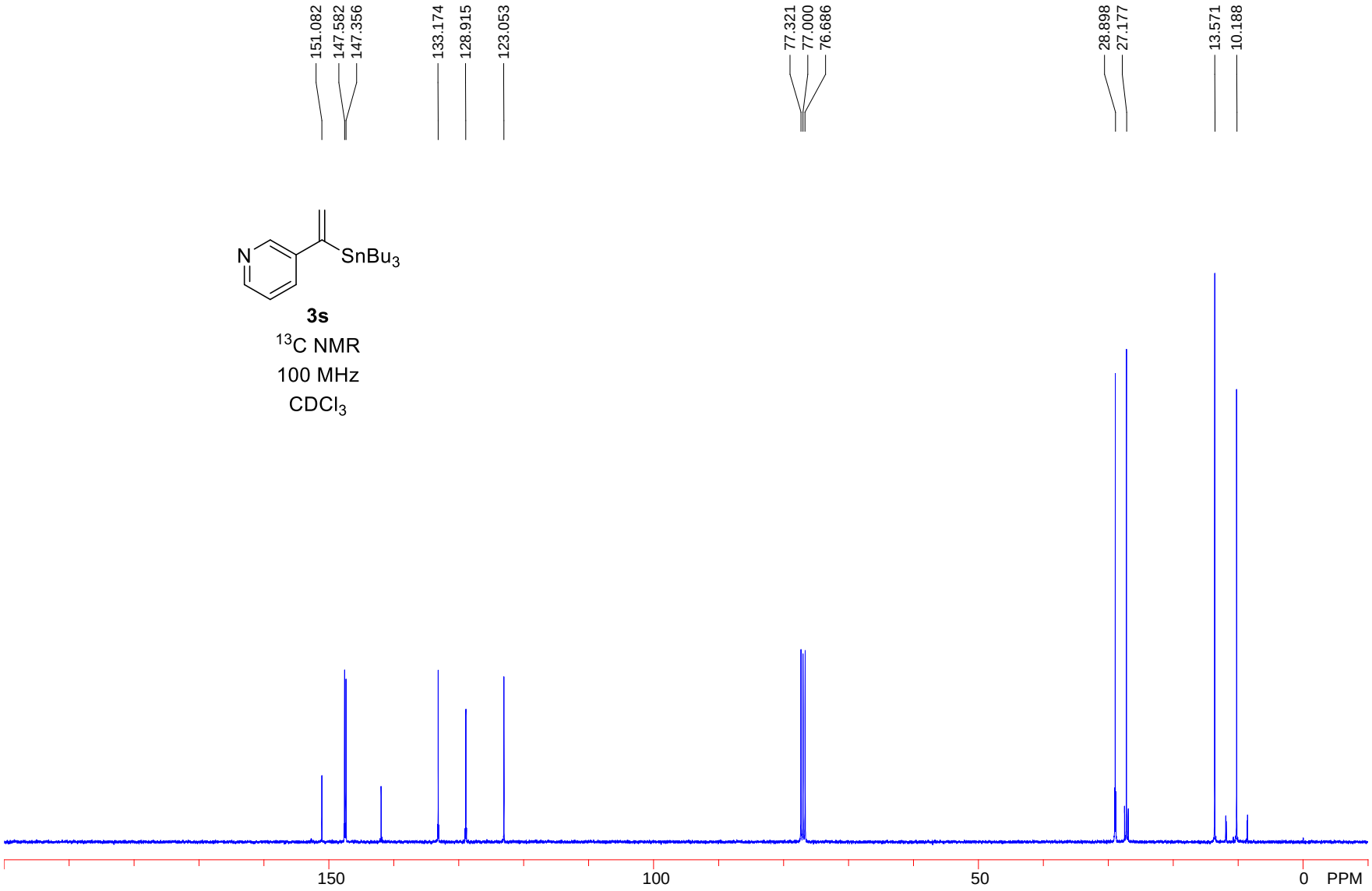
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77.000
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100 MHz
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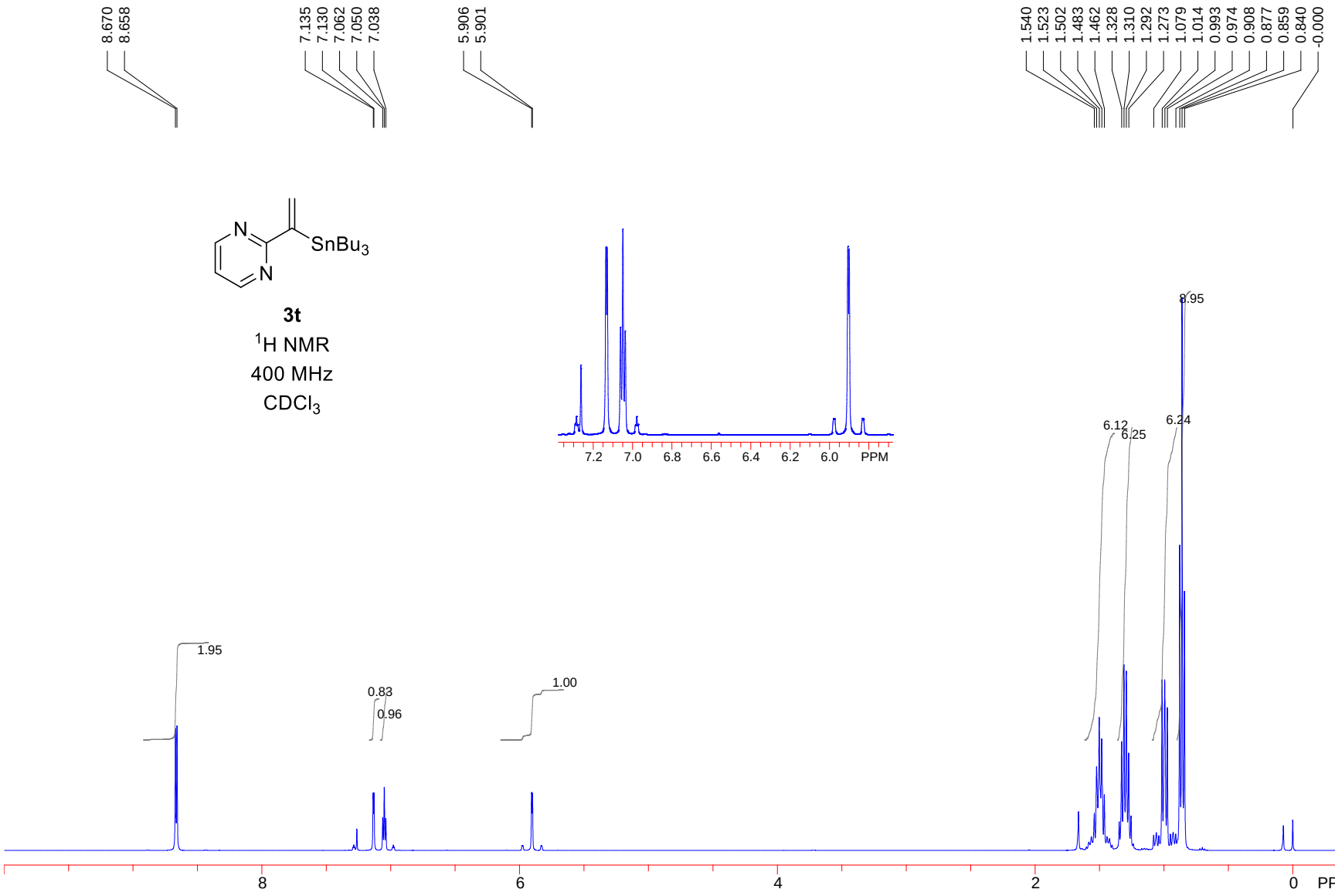
PPM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7.050
7.038
5.906
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1.540
1.523
1.502
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1.462
1.328
1.310
1.292
1.273
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1.014
0.993
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0.859
0.840
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N
N
SnBu3
3t
1H NMR
400 MHz
CDCl3
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6.8
6.6
6.4
6.2
6.0
PPM
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1.00
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6.25
6.24
8.95
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4
2
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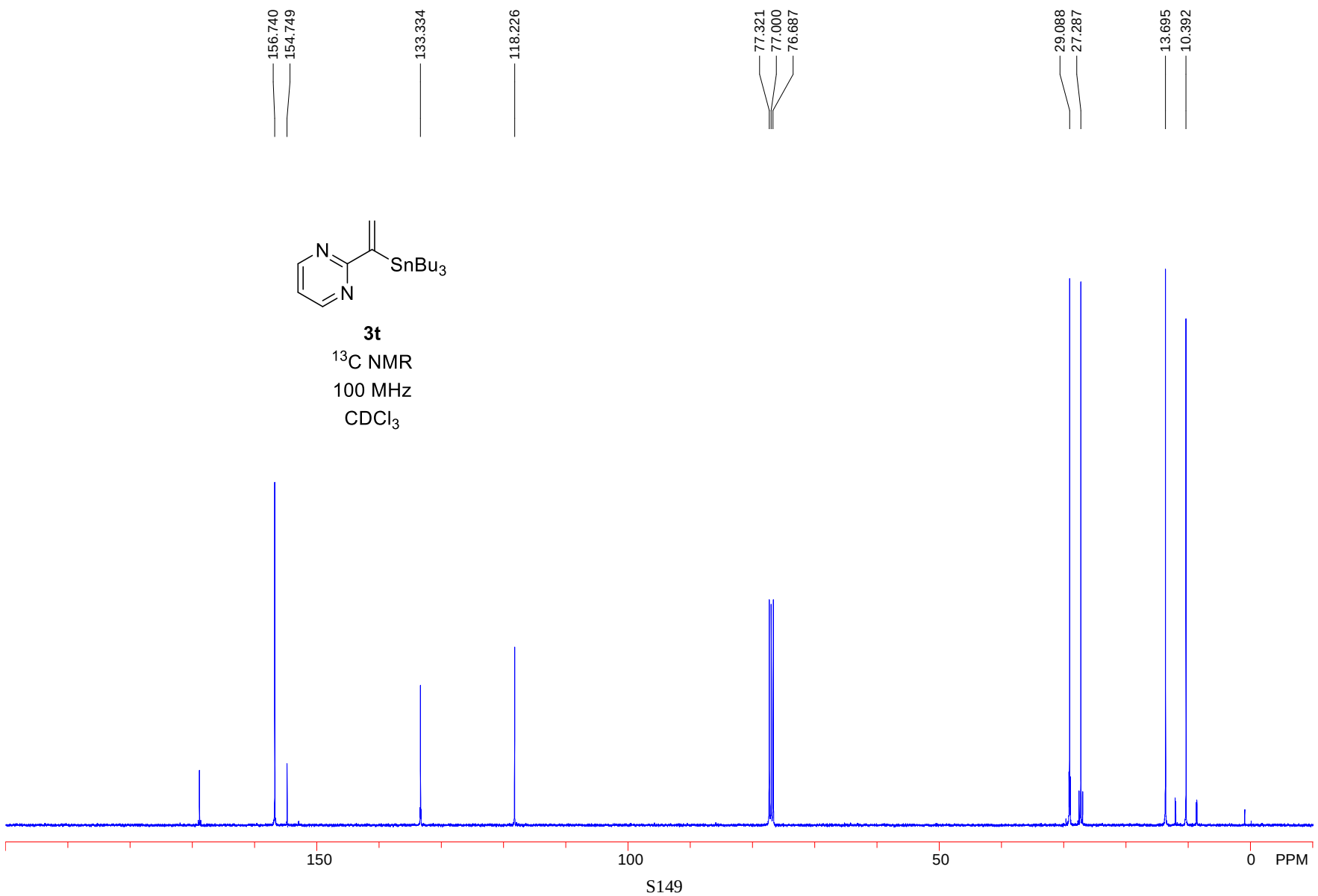
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N
N
SnBu3
3t
13C NMR
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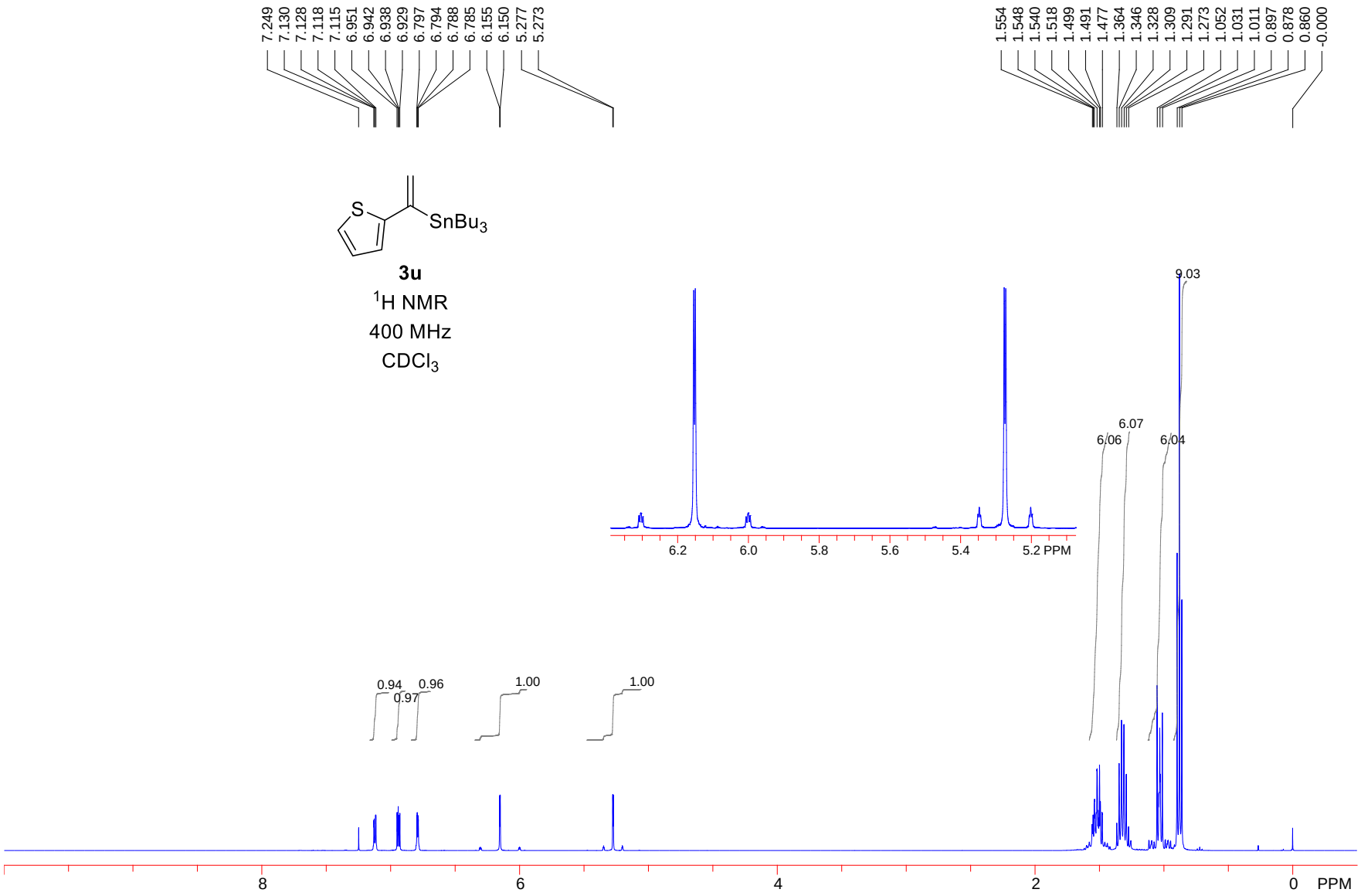
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6.788
6.785
6.155
6.150
5.277
5.273
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1.540
1.518
1.499
1.491
1.477
1.364
1.346
1.328
1.309
1.291
1.273
1.052
1.031
1.011
0.897
0.878
0.860
-0.000
S
SnBu3
3u
1H NMR
400 MHz
CDCl3
9.03
6.07
6.06
6.04
6.2
6.0
5.8
5.6
5.4
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1.00
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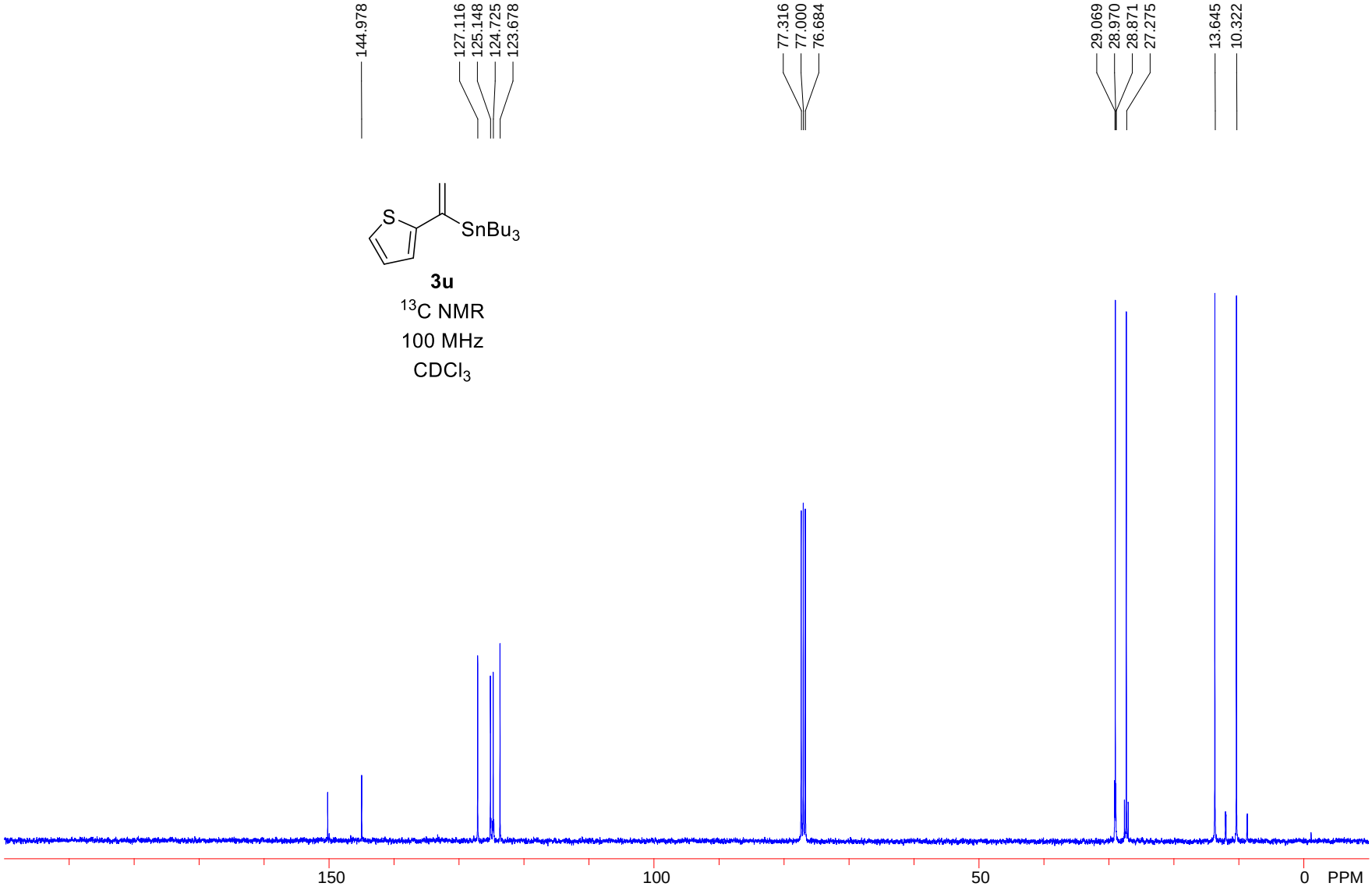
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S
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13C NMR
100 MHz
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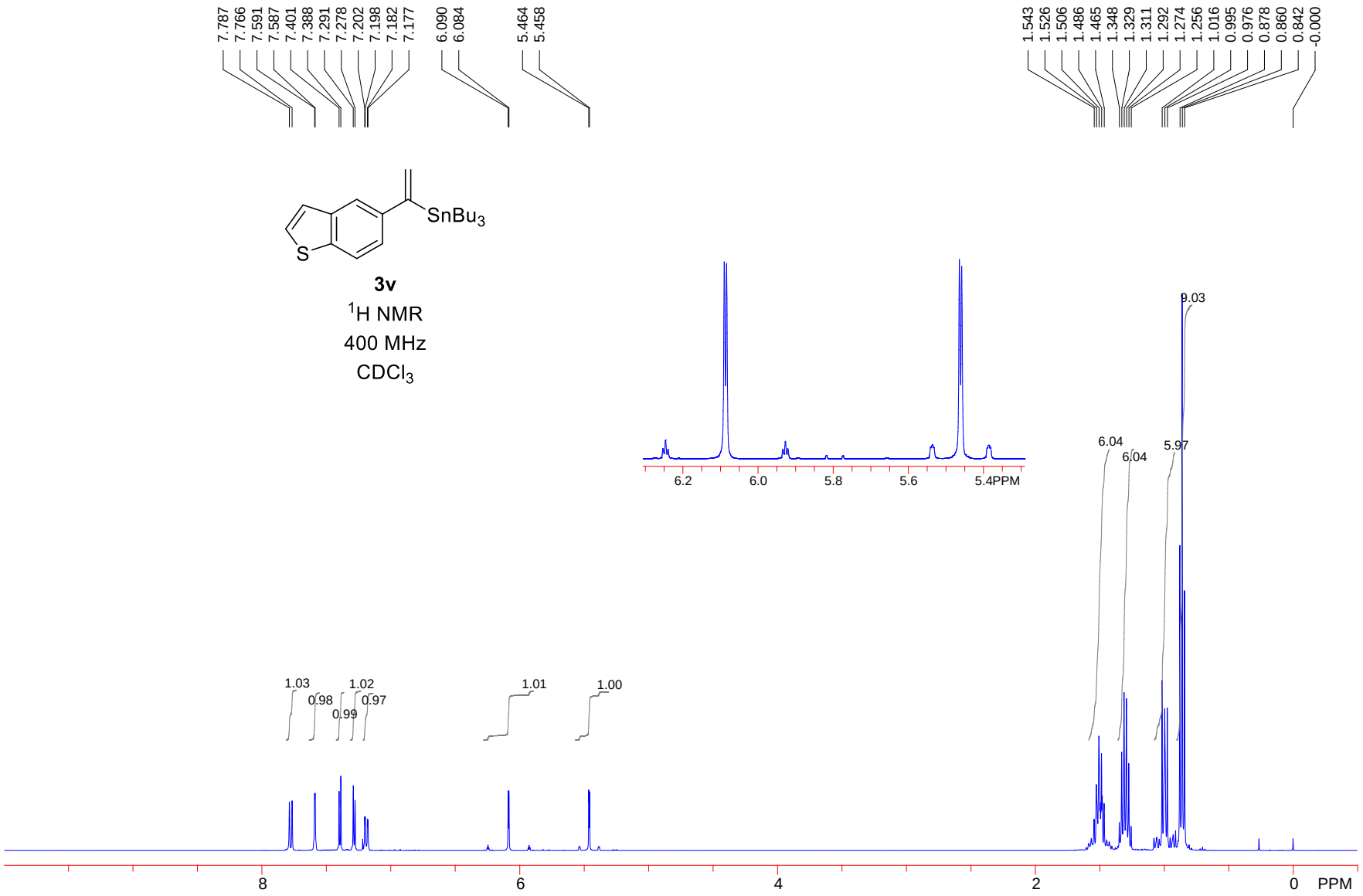
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6.090
6.084
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1.506
1.486
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1.329
1.311
1.292
1.274
1.256
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0.878
0.860
0.842
-0.000
SnBu3
S
3v
1H NMR
400 MHz
CDCl3
6.2
6.0
5.8
5.6
5.4PPM
9.03
6.04
6.04
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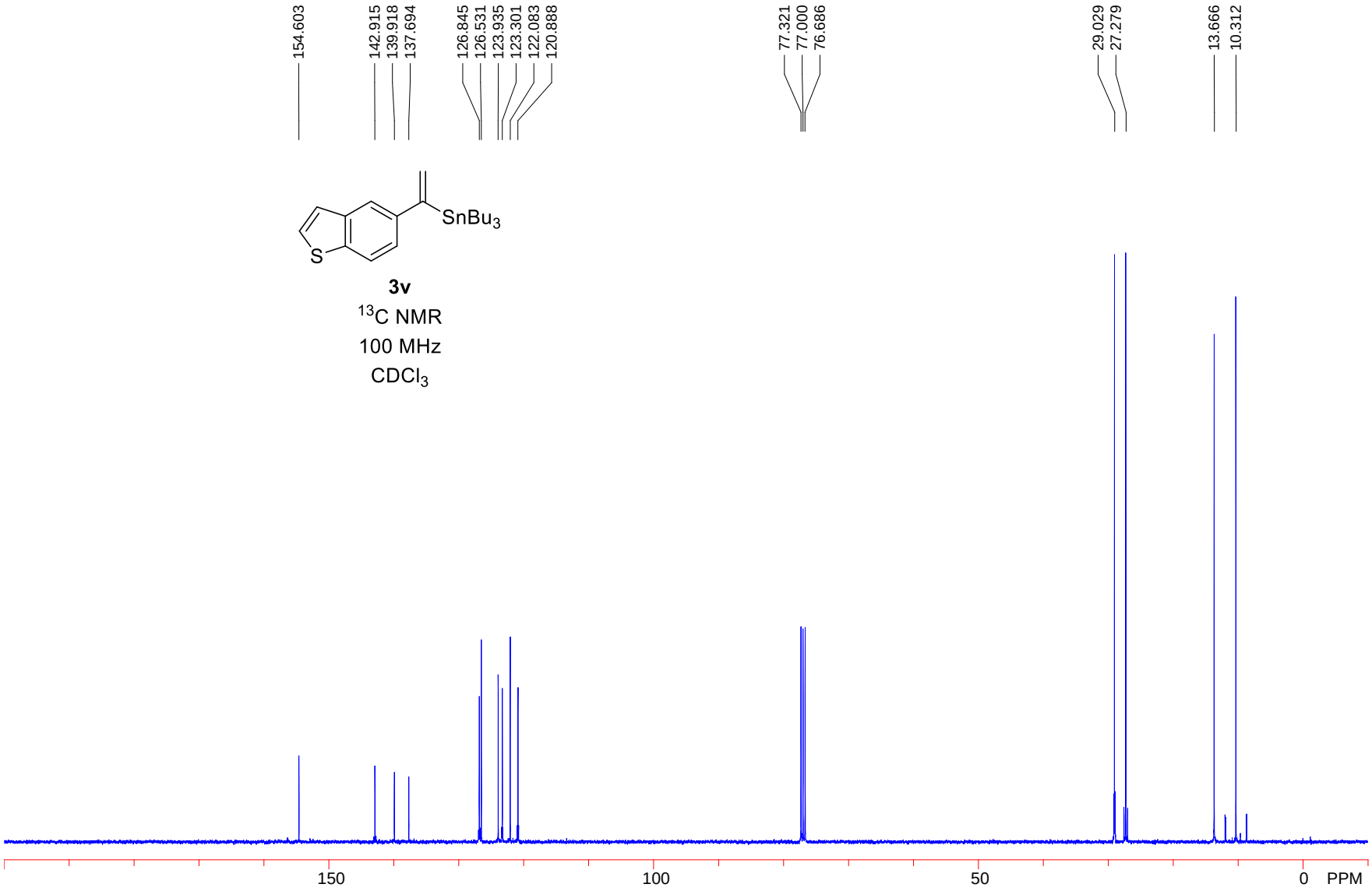
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S
3v
13C NMR
100 MHz
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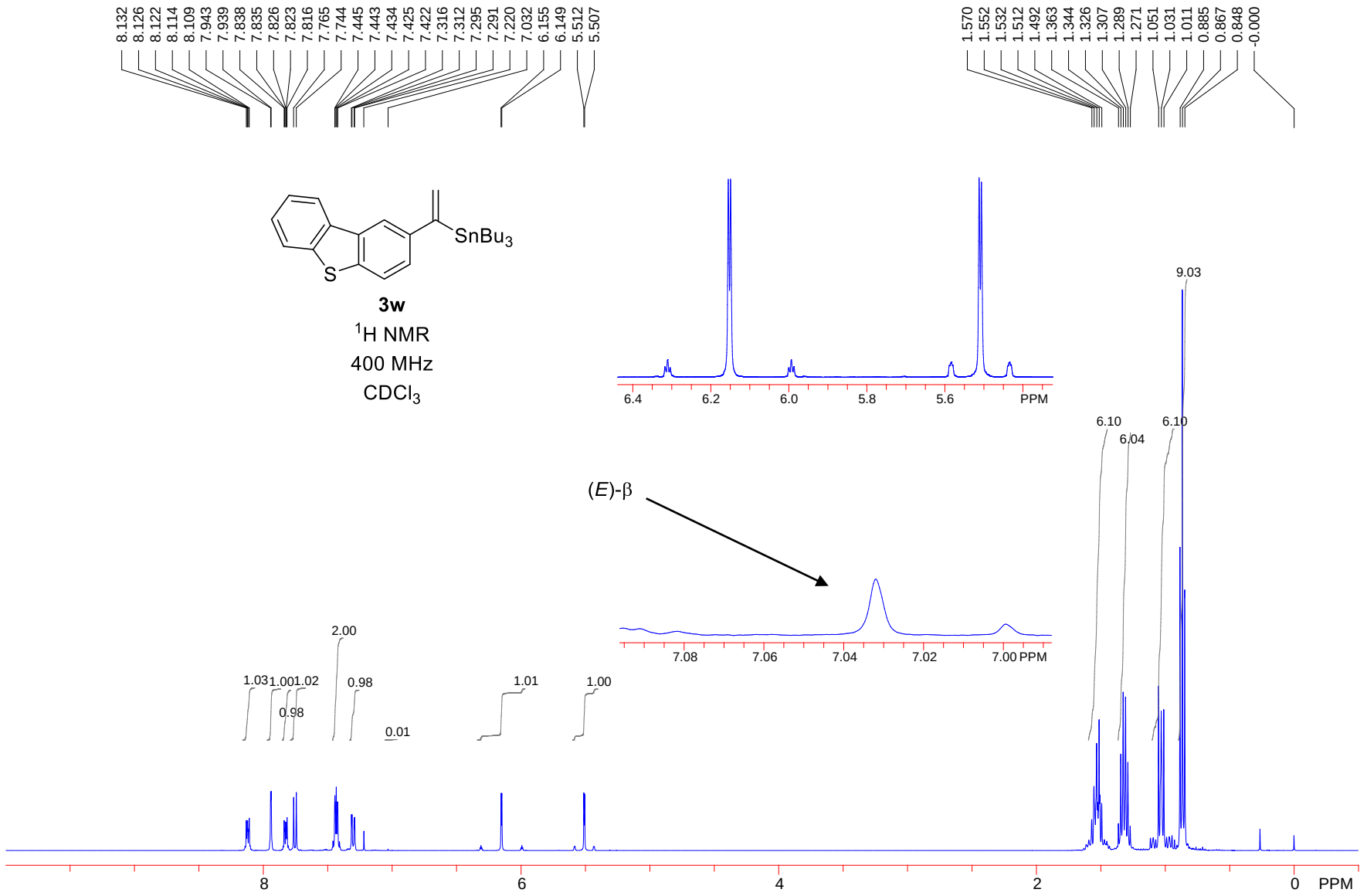
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8.122
8.114
8.109
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7.939
7.838
7.835
7.826
7.823
7.816
7.765
7.744
7.445
7.443
7.434
7.425
7.422
7.316
7.312
7.295
7.291
7.220
7.032
6.155
6.149
5.512
5.507
1.570
1.552
1.532
1.512
1.492
1.363
1.344
1.326
1.307
1.289
1.271
1.051
1.031
1.011
0.885
0.867
0.848
-0.000
SnBu3
S
3w
1H NMR
400 MHz
CDCl3
6.4
6.2
6.0
5.8
5.6
PPM
(E)-β
7.08
7.06
7.04
7.02
7.00 PPM
9.03
6.10
6.04
6.10
2.00
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1.00
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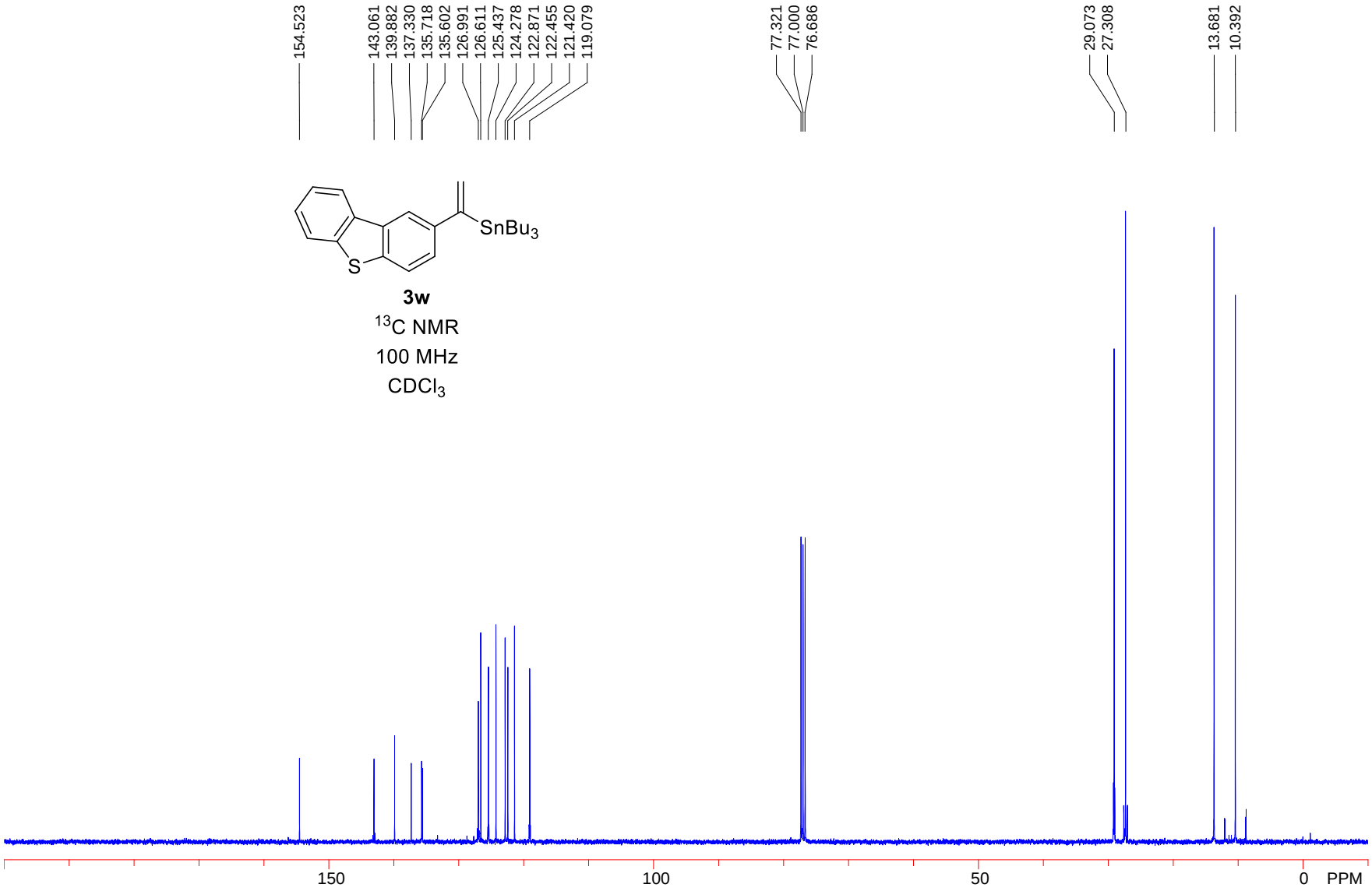
PPM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126.611
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121.420
119.079
77.321
77.000
76.686
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10.392
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S
3w
13C NMR
100 MHz
CDCl3
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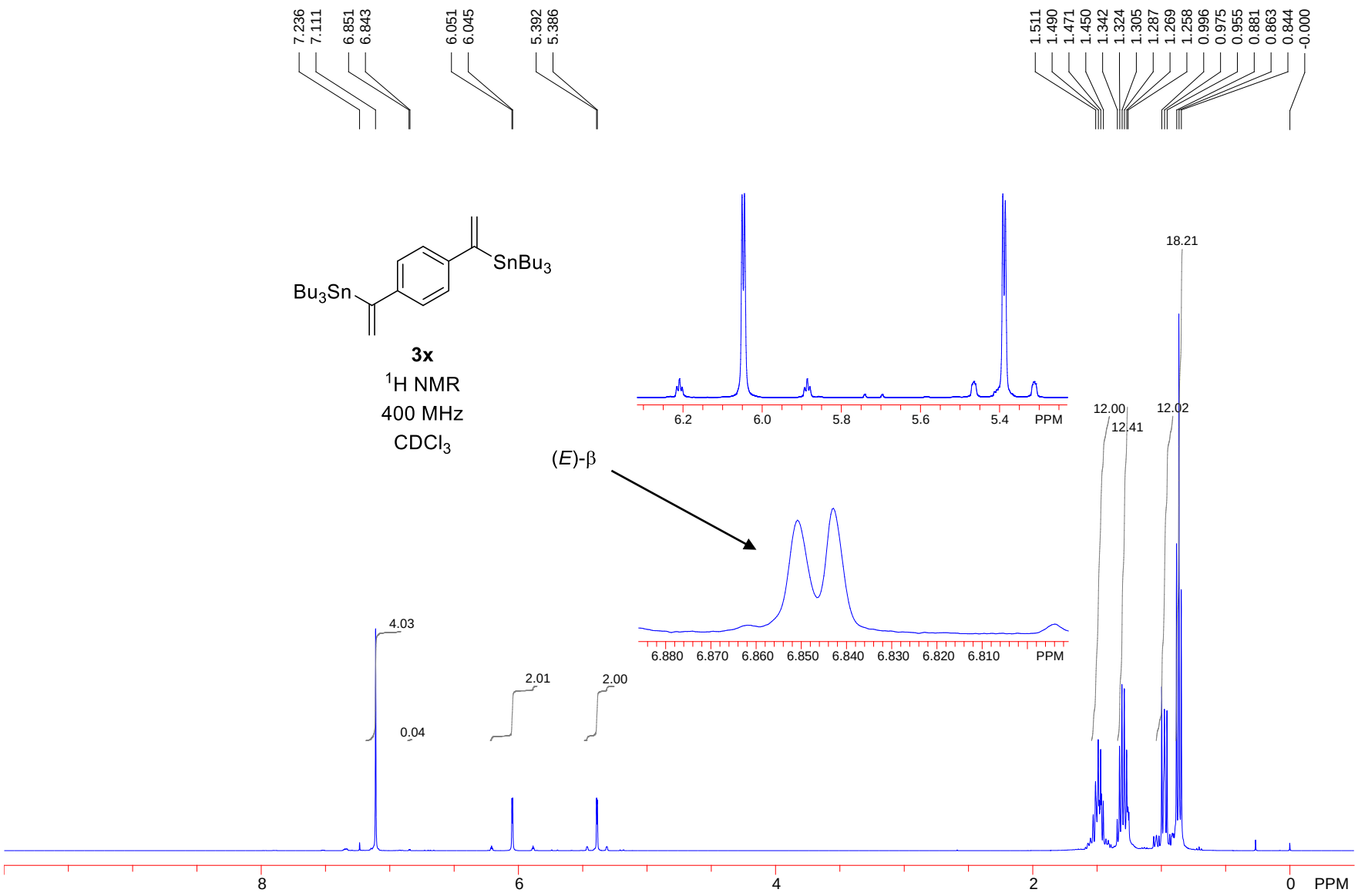
PPM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7.111
6.851
6.843
6.051
6.045
5.392
5.386
1.511
1.490
1.471
1.450
1.342
1.324
1.305
1.287
1.269
1.258
0.996
0.975
0.955
0.881
0.863
0.844
-0.000
Bu3Sn
SnBu3
3x
1H NMR
400 MHz
CDCl3
(E)-β
6.2
6.0
5.8
5.6
5.4
PPM
6.880
6.870
6.860
6.850
6.840
6.830
6.820
6.810
PPM
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12.41
12.02
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2.00
8
6
4
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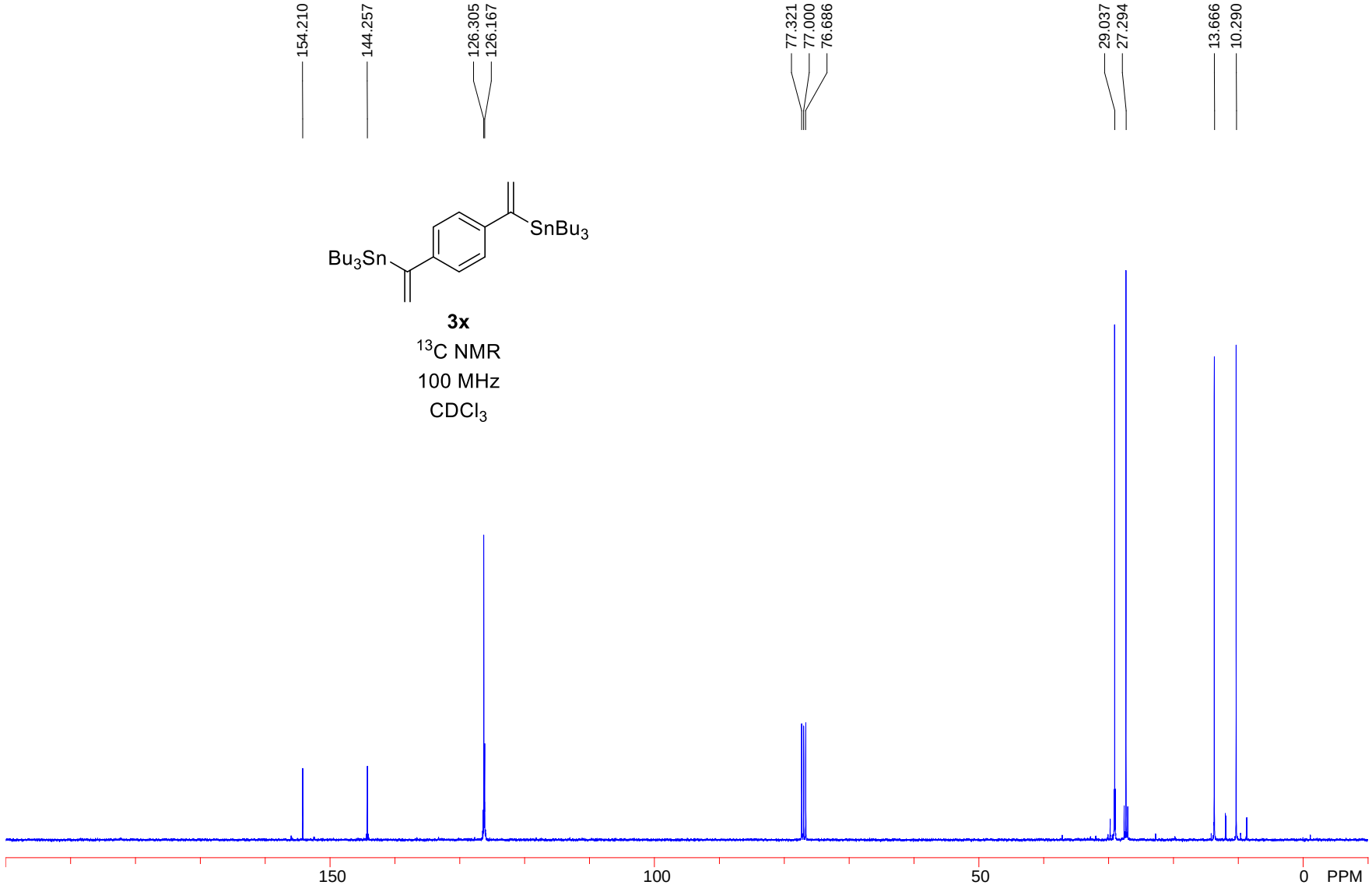
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SnBu3
3x
13C NMR
100 MHz
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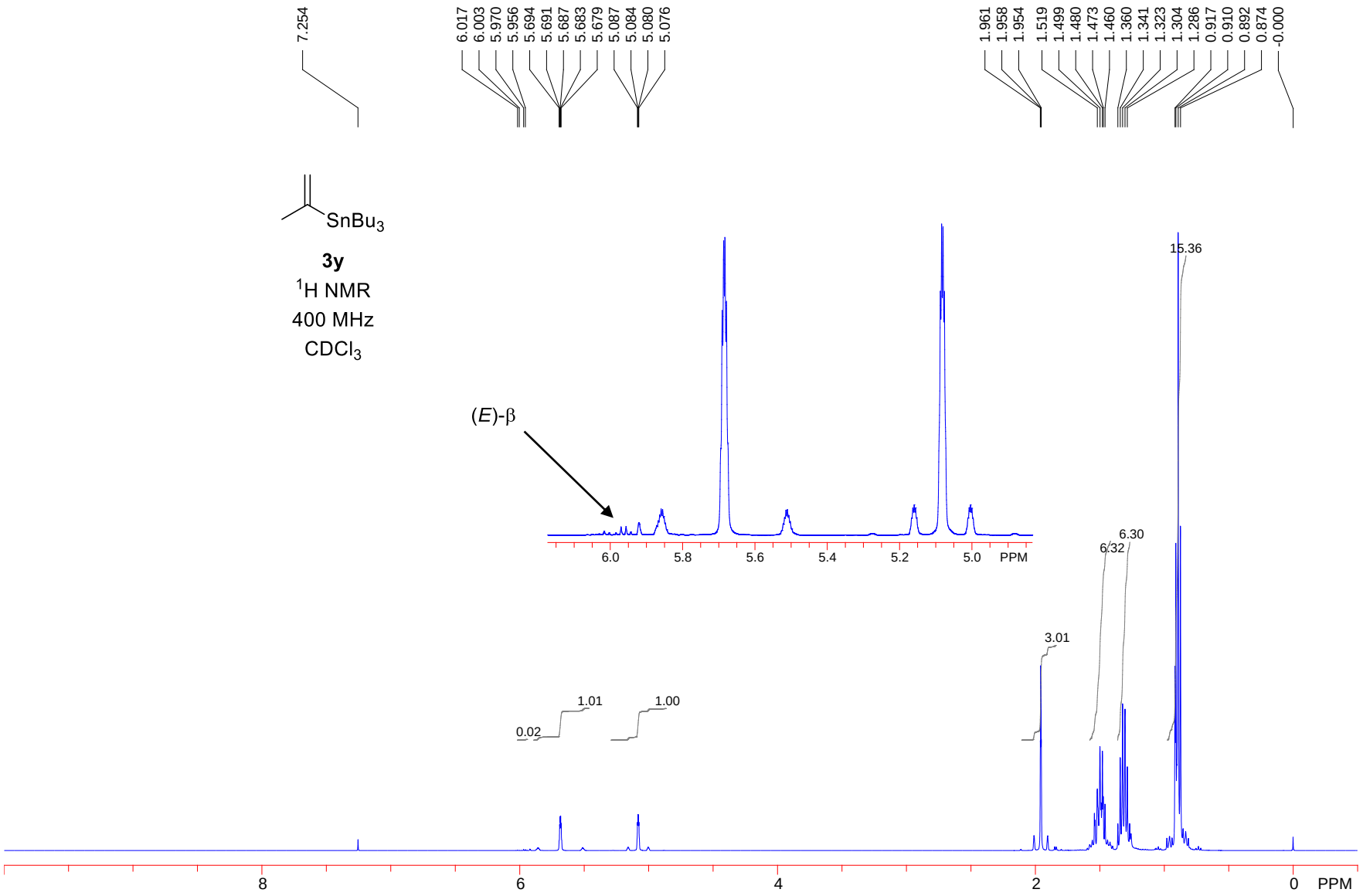
150
100
50
0
PPM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6.003
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5.694
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5.687
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5.679
5.087
5.084
5.080
5.076
1.961
1.958
1.954
1.519
1.499
1.480
1.473
1.460
1.360
1.341
1.323
1.304
1.286
0.917
0.910
0.892
0.874
-0.000
SnBu3
3y
1H NMR
400 MHz
CDCl3
(E)-β
15.36
6.30
6.32
3.01
1.01
1.00
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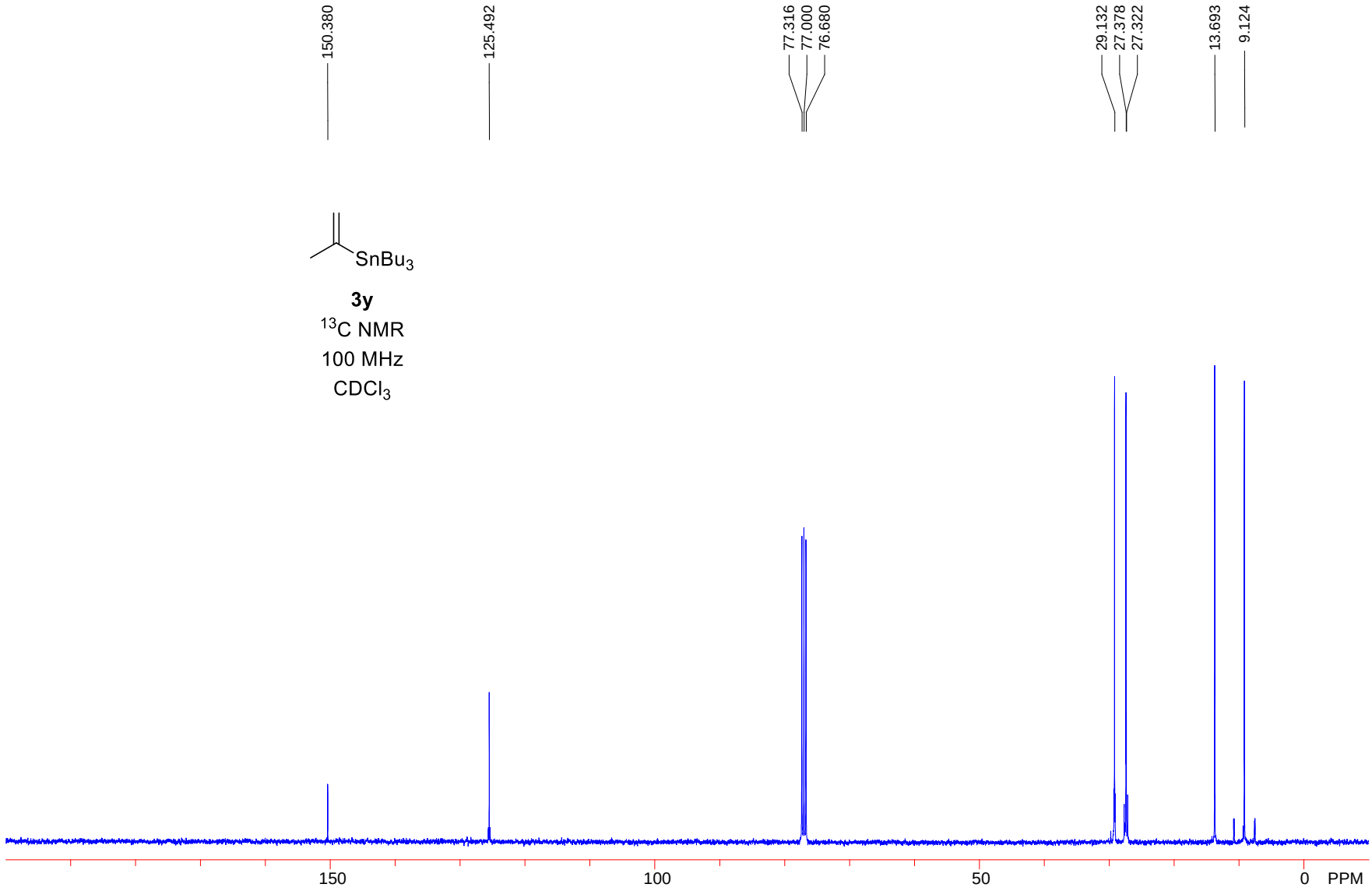
5.8
5.6
5.4
5.2
5.0
PPM
8
6
4
2
0
PPM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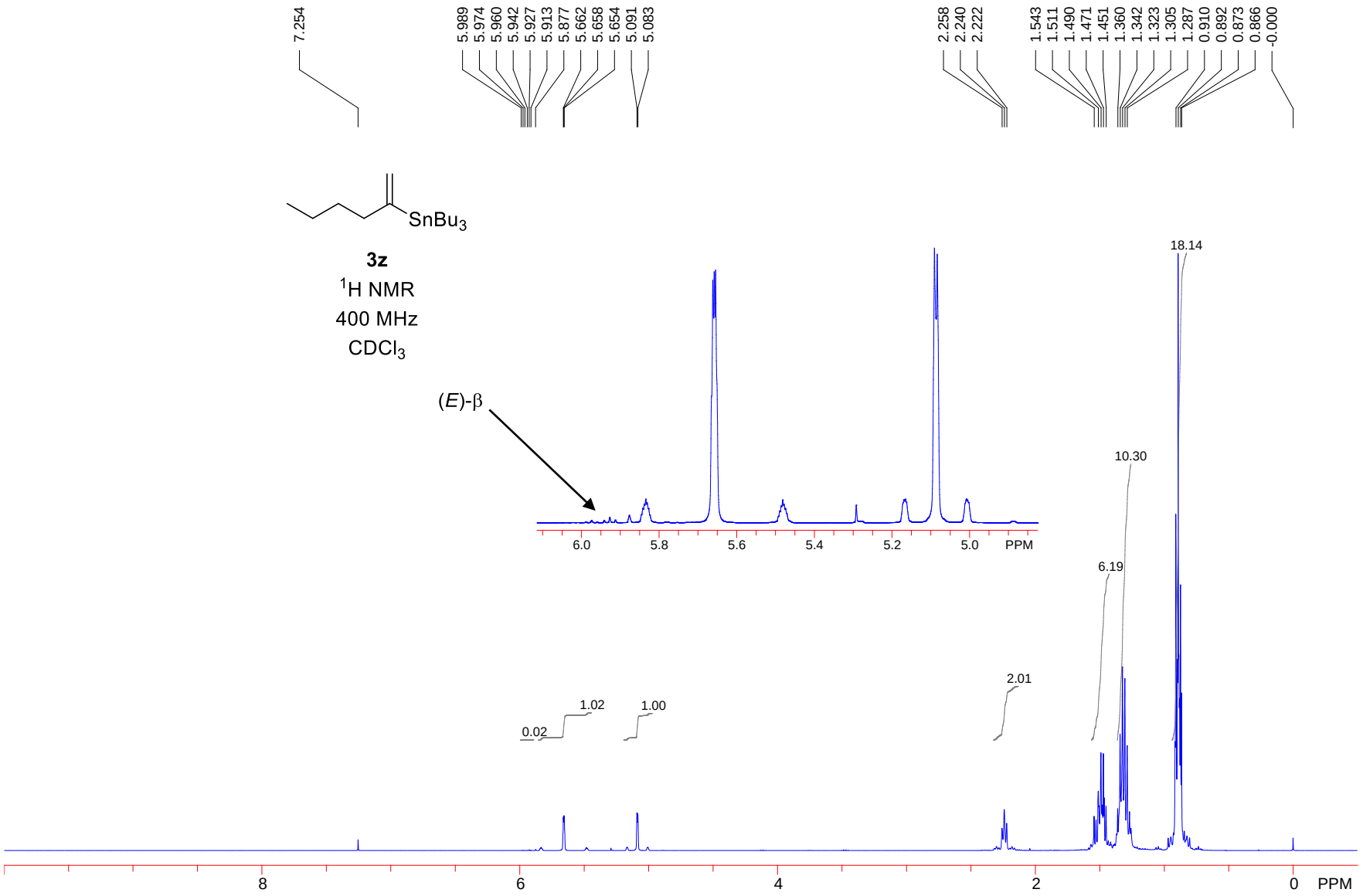
PPM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5.913
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5.662
5.658
5.654
5.091
5.083
2.258
2.240
2.222
1.543
1.511
1.490
1.471
1.451
1.360
1.342
1.323
1.305
1.287
0.910
0.892
0.873
0.866
-0.000
SnBu3
3z
1H NMR
400 MHz
CDCl3
(E)-β
18.14
10.30
6.19
2.01
1.02
1.00
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5.8
5.6
5.4
5.2
5.0
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4
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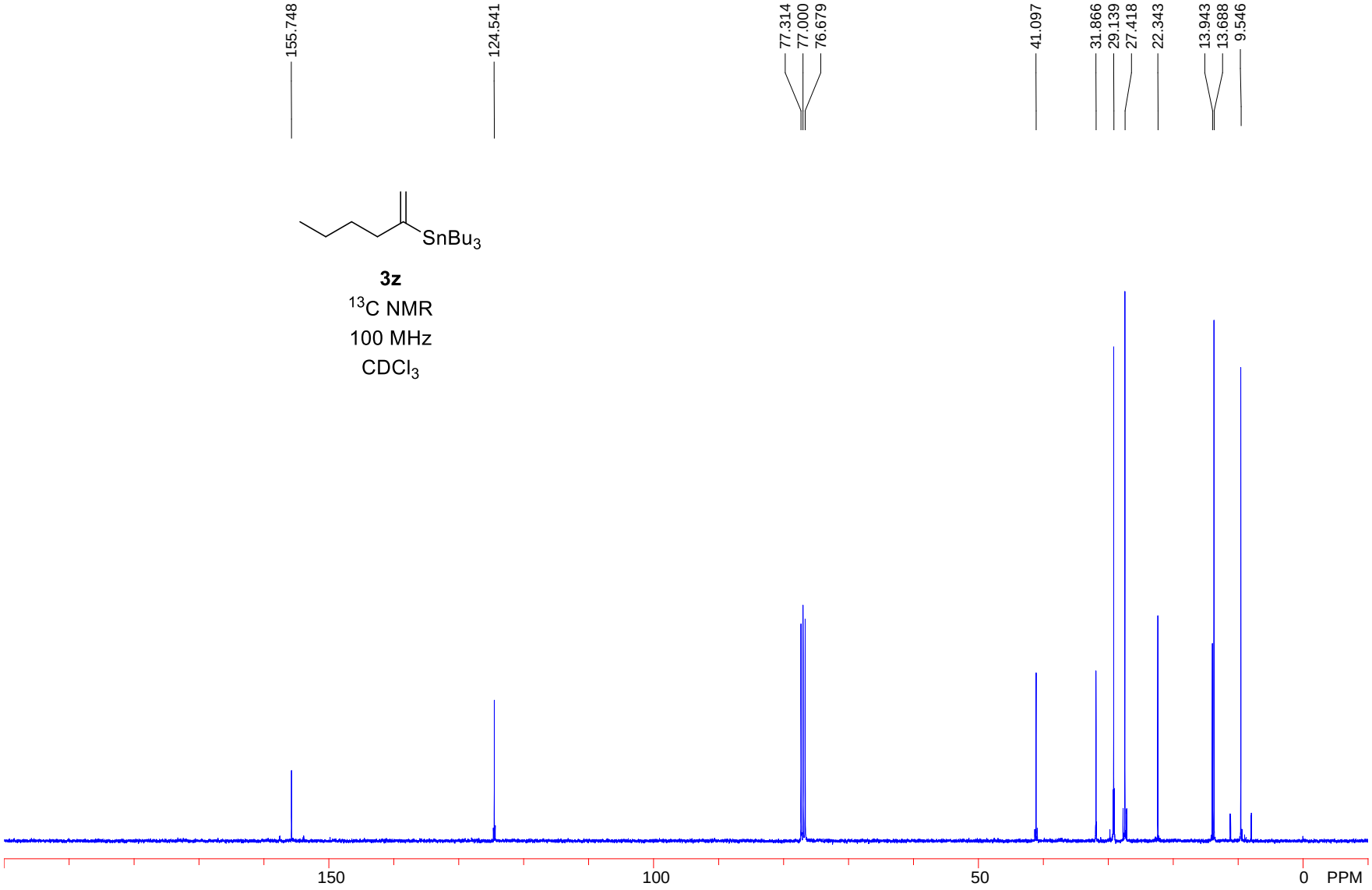
PPM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29.139
27.418
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9.546
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13C NMR
100 MHz
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50
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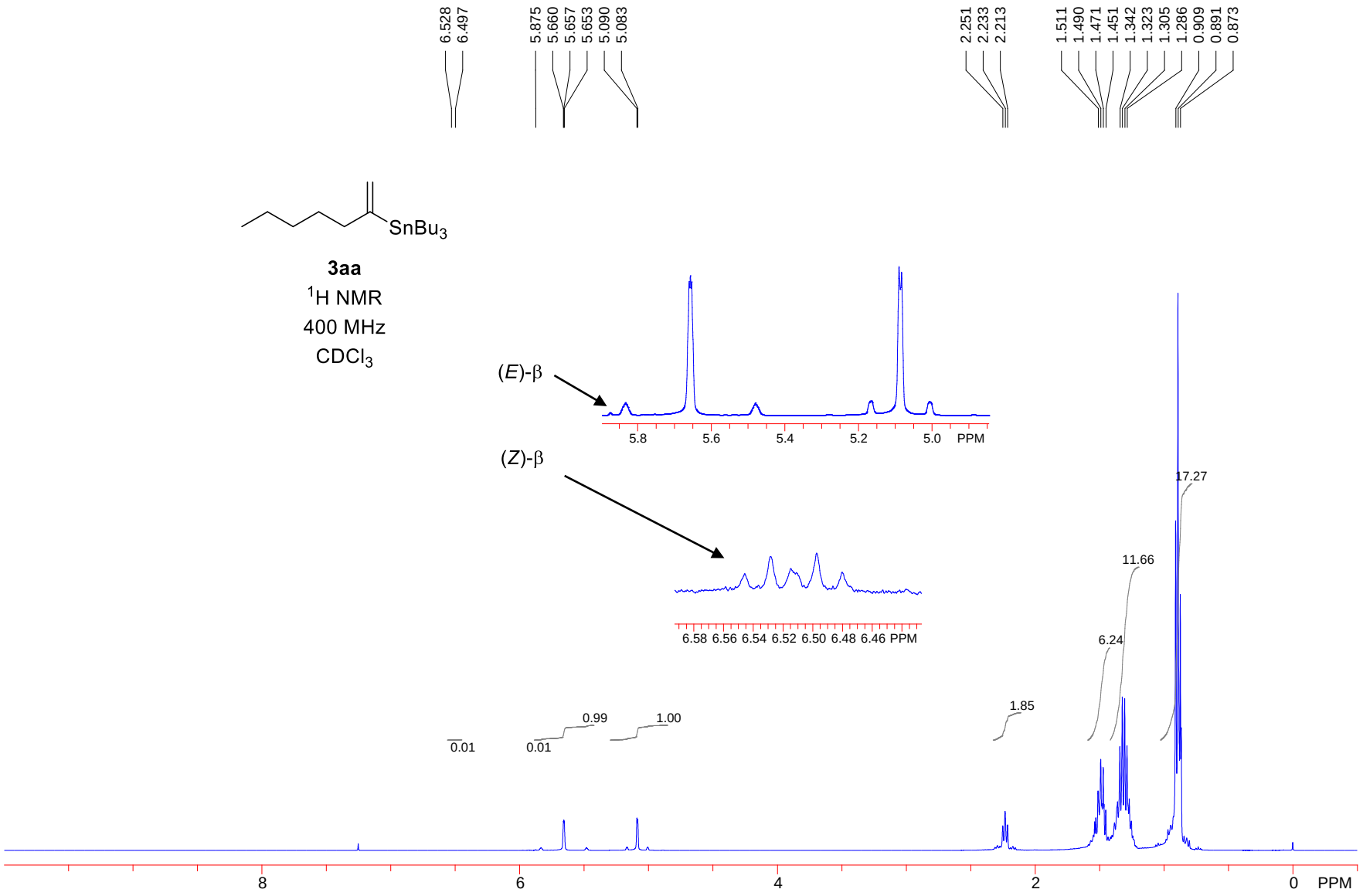
PPM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5.653
5.090
5.083
2.251
2.233
2.213
1.511
1.490
1.471
1.451
1.342
1.323
1.305
1.286
0.909
0.891
0.873
SnBu3
3aa
1H NMR
400 MHz
CDCl3
(E)-β
(Z)-β
5.8
5.6
5.4
5.2
5.0 PPM
6.58 6.56 6.54 6.52 6.50 6.48 6.46 PPM
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4
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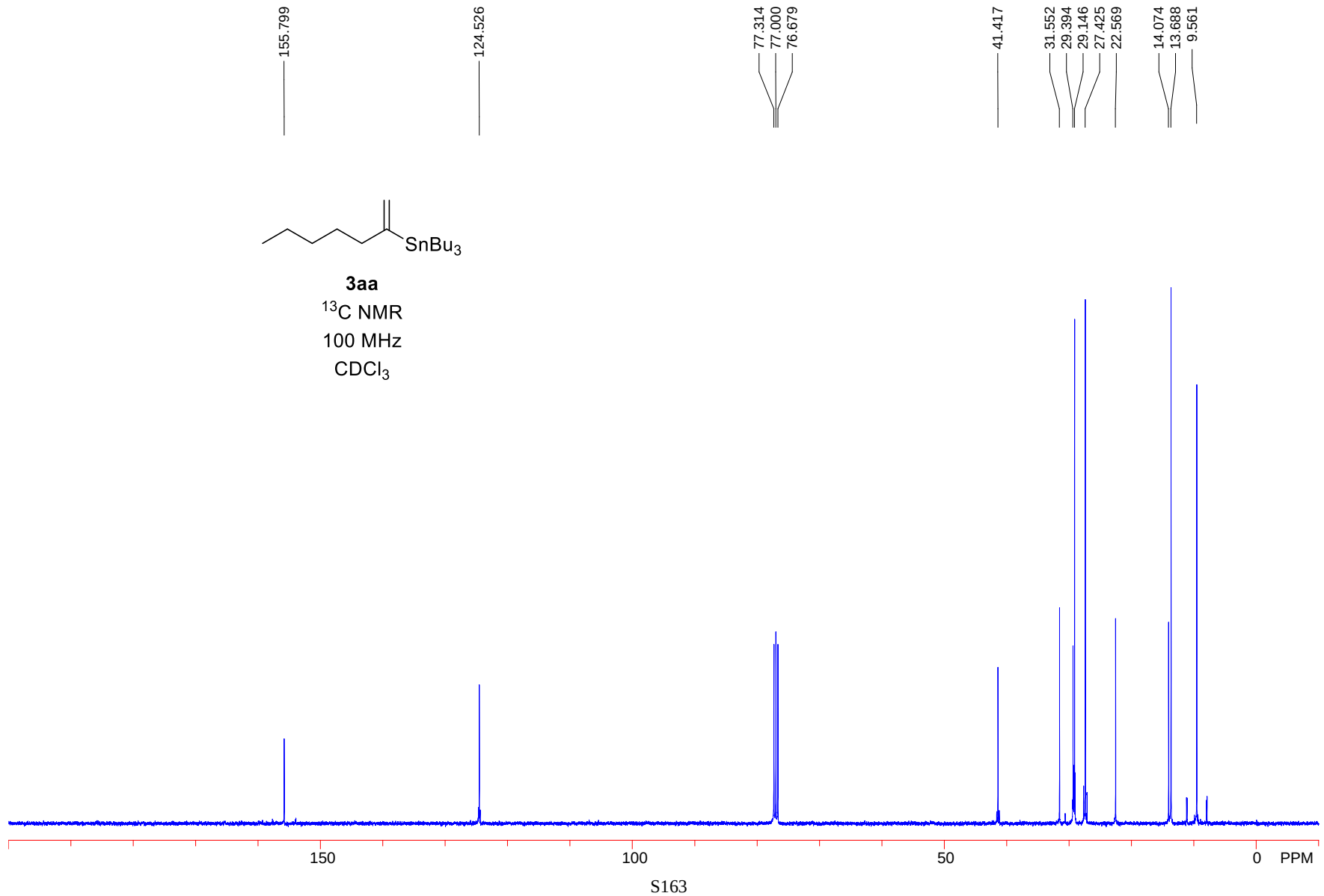
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27.425
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9.561
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50
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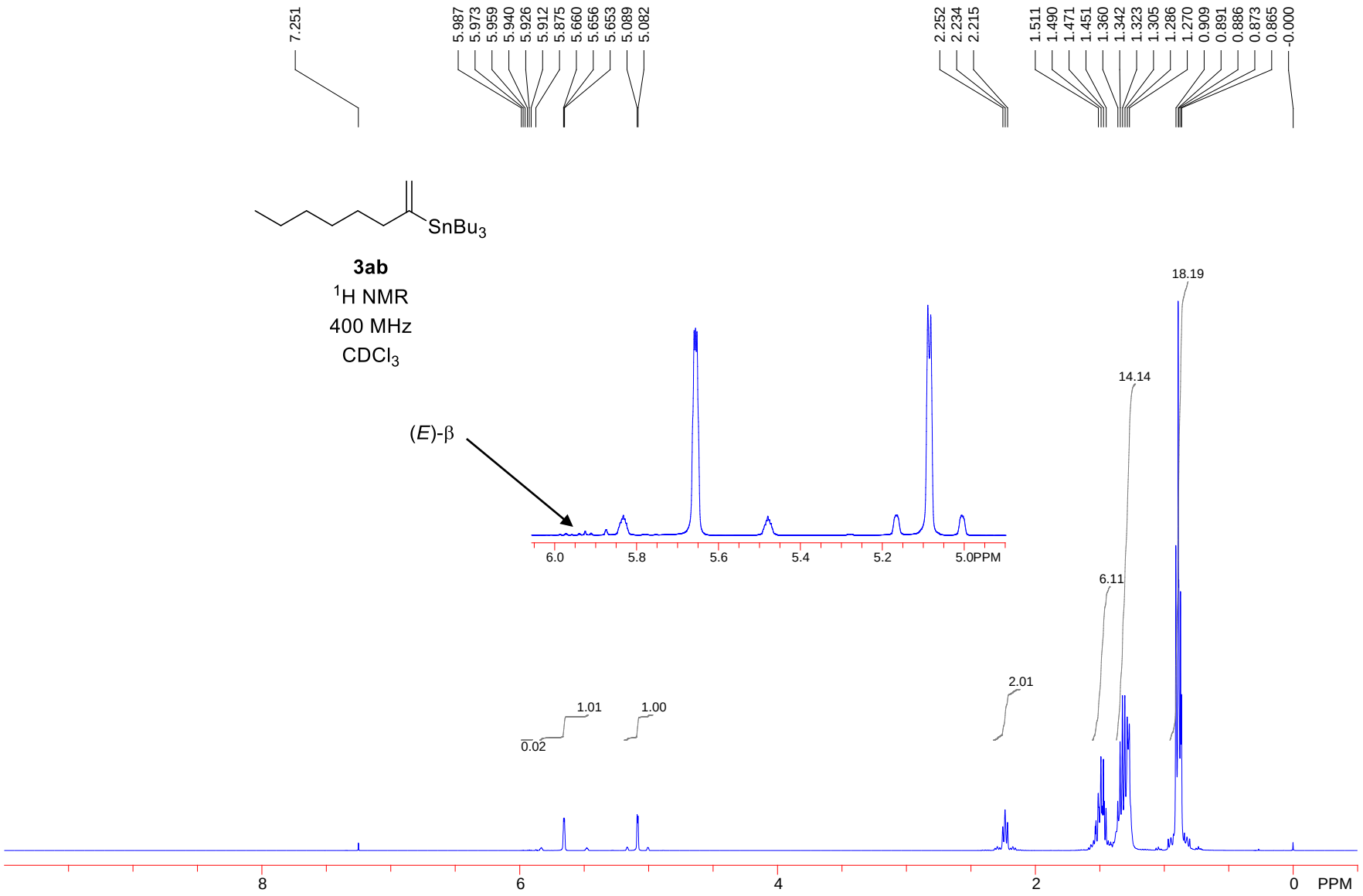
PPM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5.875
5.660
5.656
5.653
5.089
5.082
2.252
2.234
2.215
1.511
1.490
1.471
1.451
1.360
1.342
1.323
1.305
1.286
1.270
0.909
0.891
0.886
0.873
0.865
-0.000
SnBu3
3ab
1H NMR
400 MHz
CDCl3
(E)-β
6.0
5.8
5.6
5.4
5.2
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6.11
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0.02
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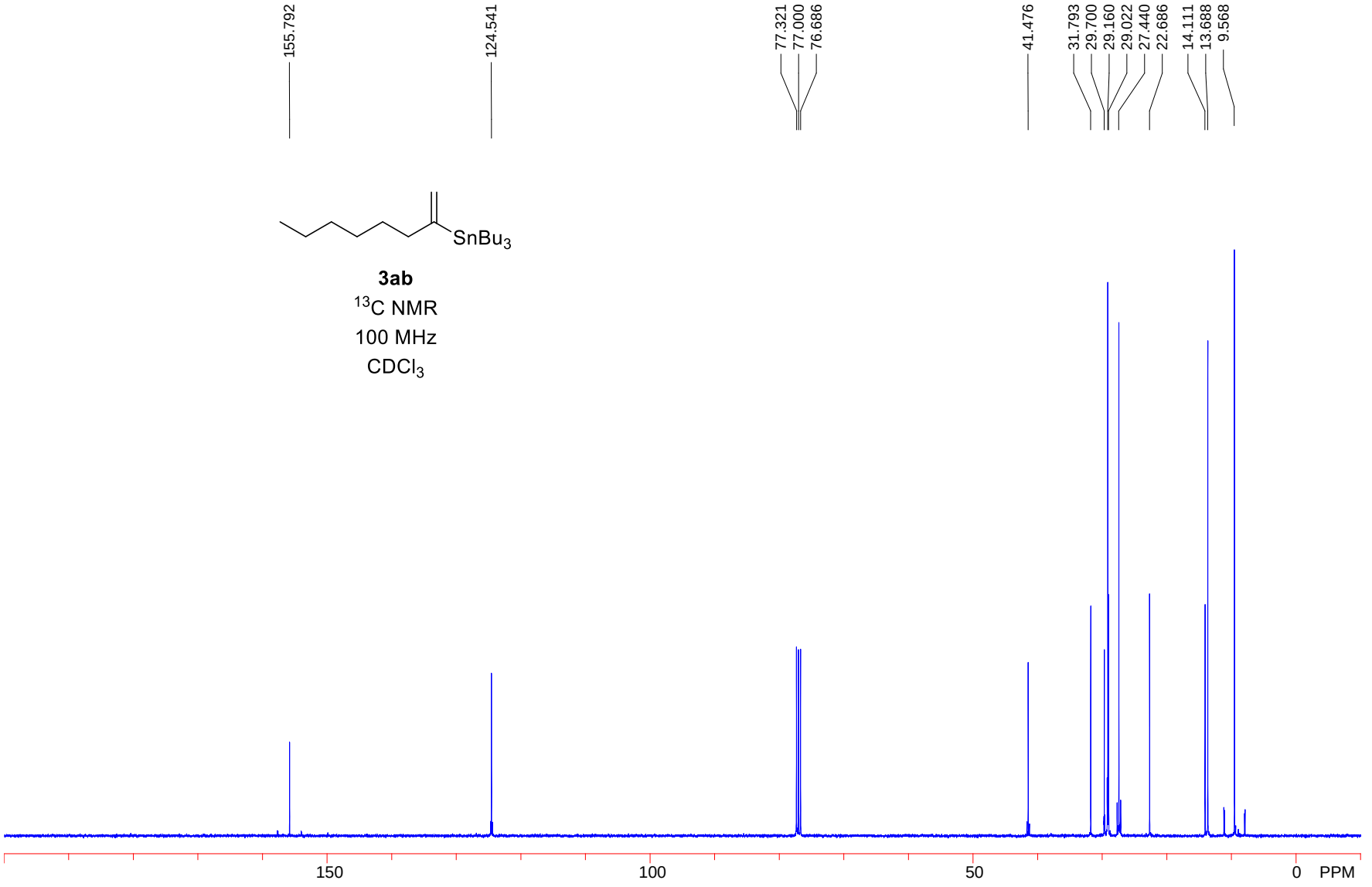
PPM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29.022
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9.568
SnBu3
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13C NMR
100 MHz
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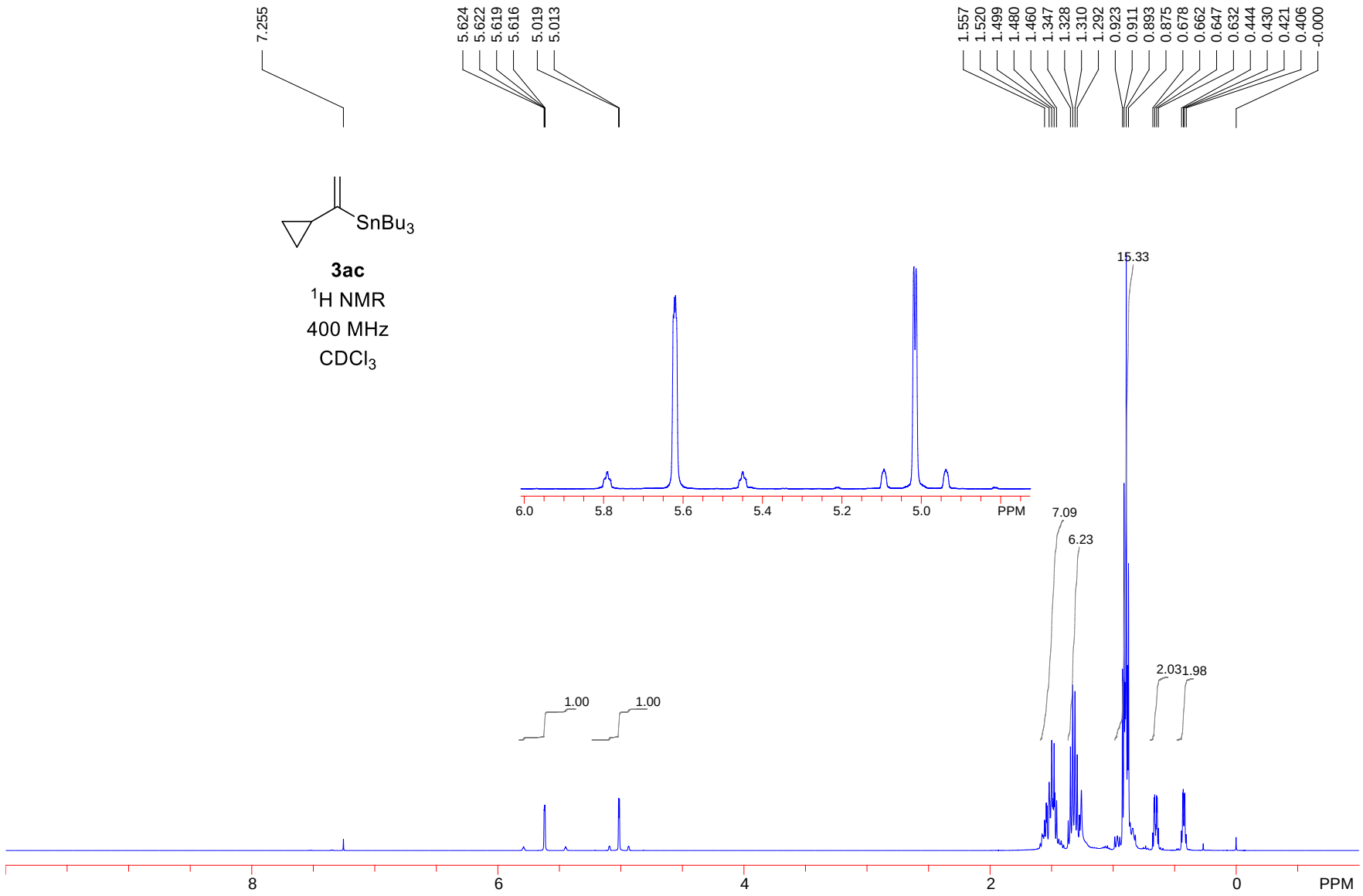
100
50
0
PPM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1.347
1.328
1.310
1.292
0.923
0.911
0.893
0.875
0.678
0.662
0.647
0.632
0.444
0.430
0.421
0.406
-0.000
SnBu3
3ac
1H NMR
400 MHz
CDCl3
15.33
7.09
6.23
2.03
1.98
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5.6
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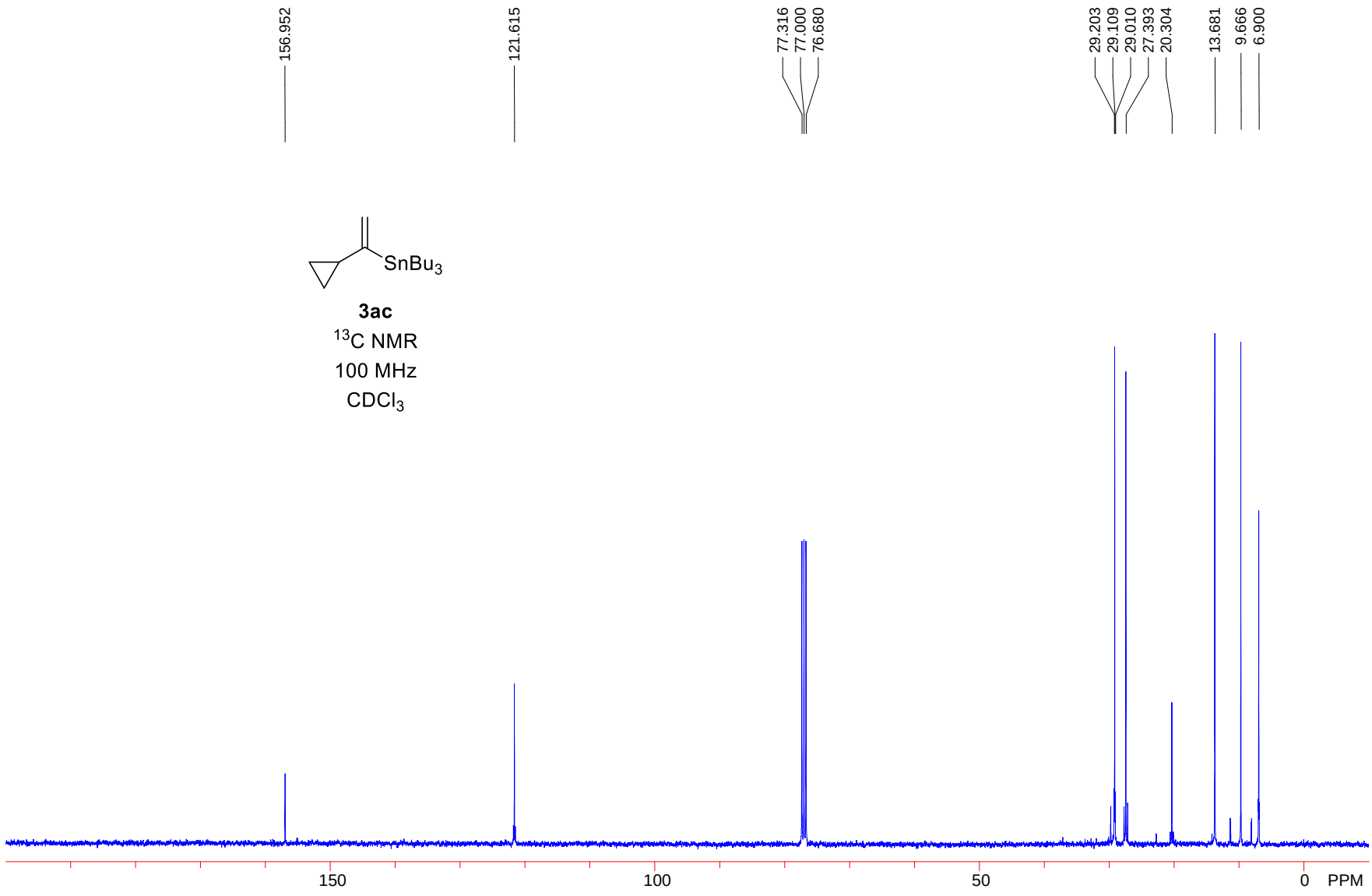
PPM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13C NMR
100 MHz
CDCl3
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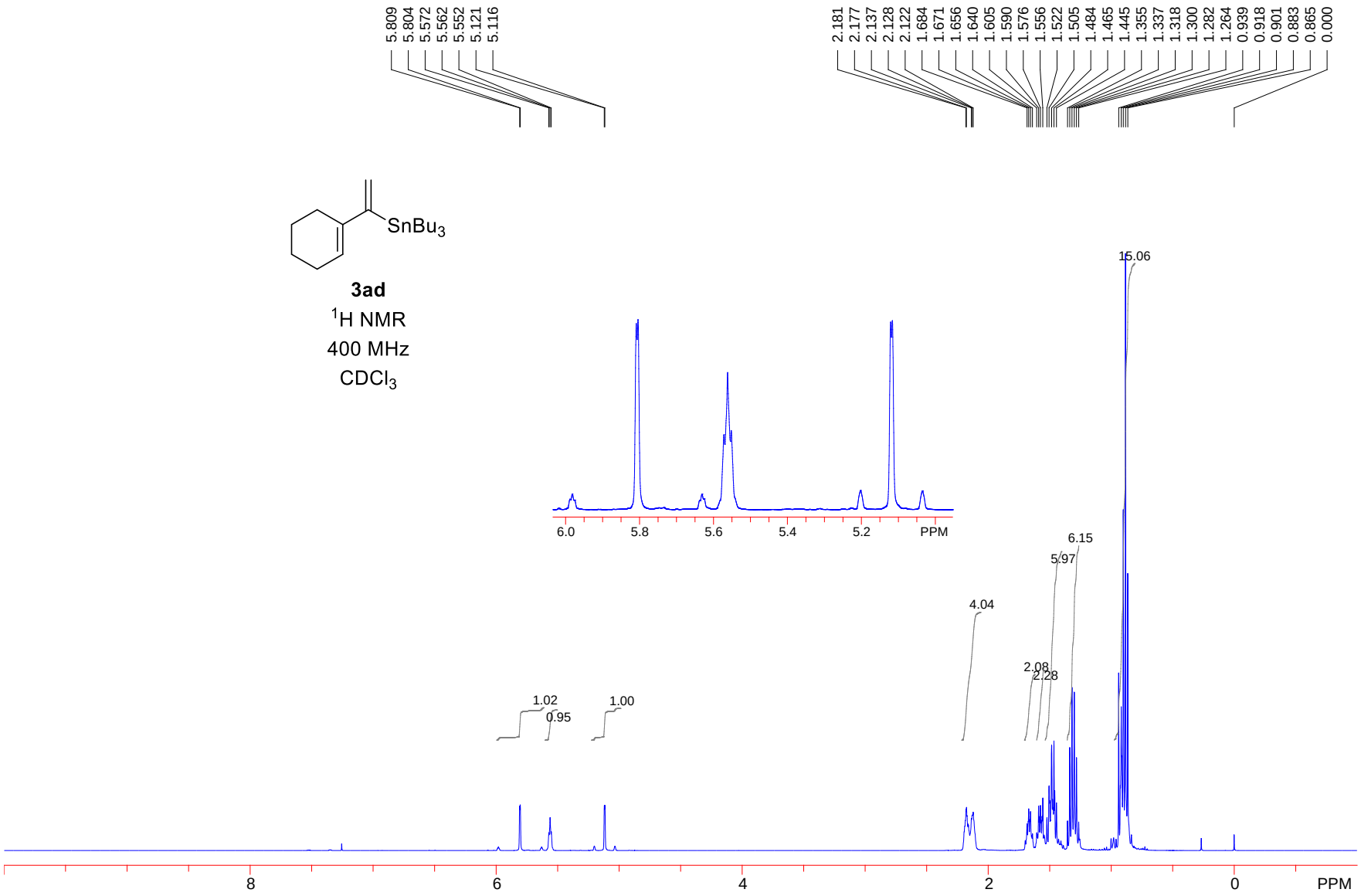
PPM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2.122
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1.671
1.656
1.640
1.605
1.590
1.576
1.556
1.522
1.505
1.484
1.465
1.445
1.355
1.337
1.318
1.300
1.282
1.264
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0.918
0.901
0.883
0.865
0.000
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3ad
1H NMR
400 MHz
CDCl3
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5.6
5.4
5.2
PPM
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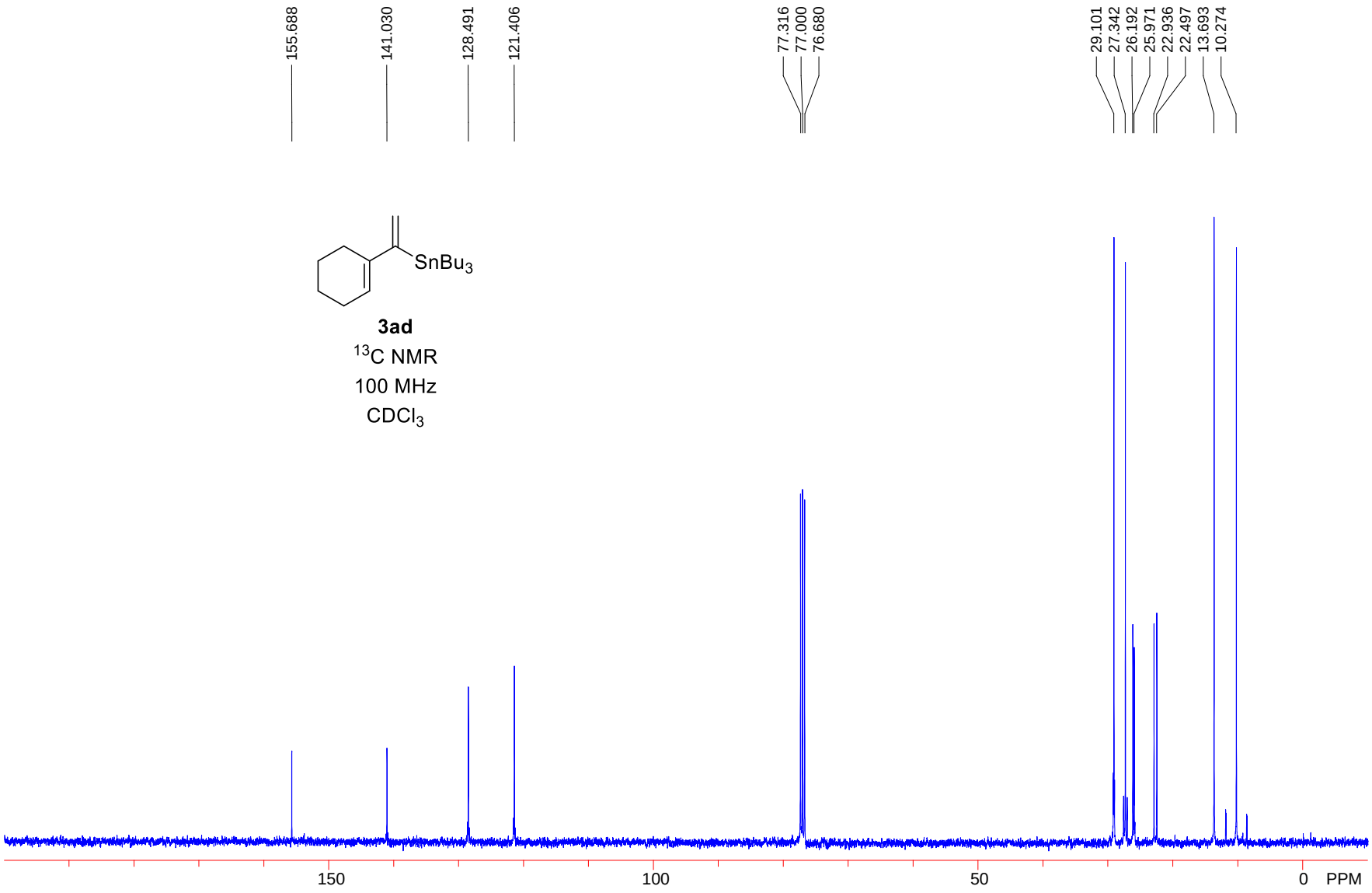
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25.971
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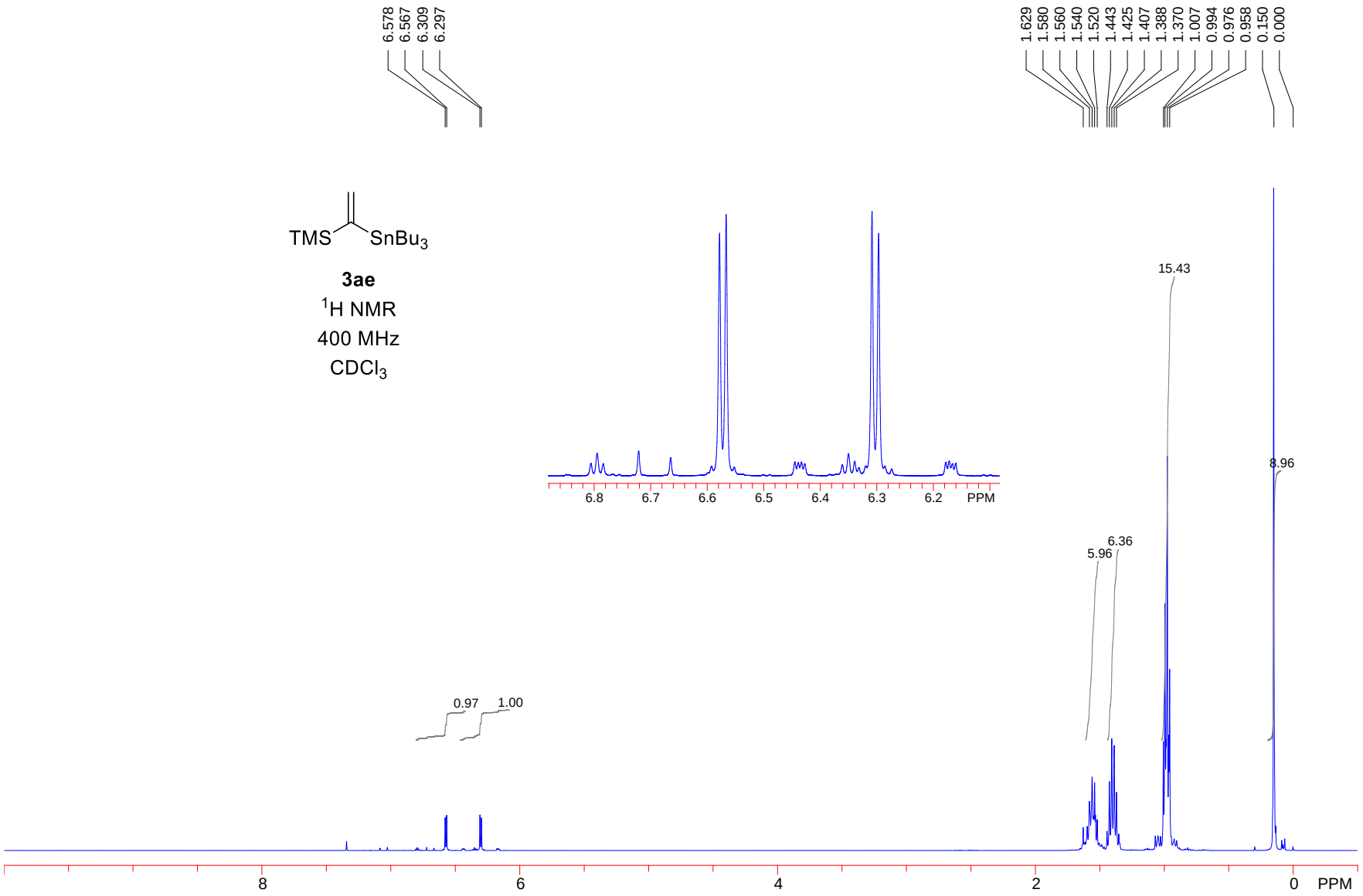
13.693
10.274
SnBu3
3ad
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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1.388
1.370
1.007
0.994
0.976
0.958
0.150
0.000
TMS
SnBu3
3ae
1H NMR
400 MHz
CDCl3
15.43
8.96
6.36
5.96
0.97
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6.6
6.5
6.4
6.3
6.2
PPM
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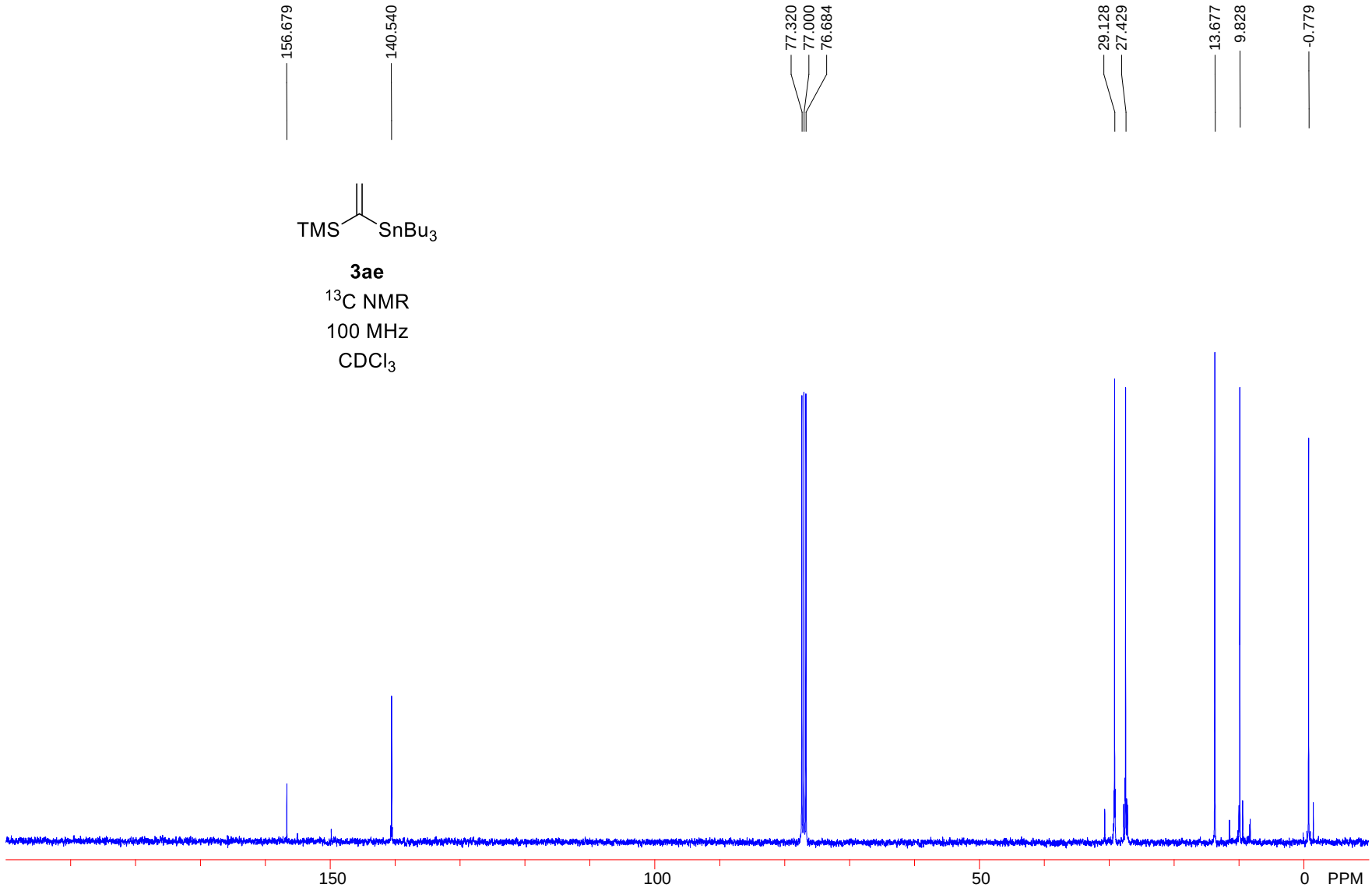
PPM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100 MHz
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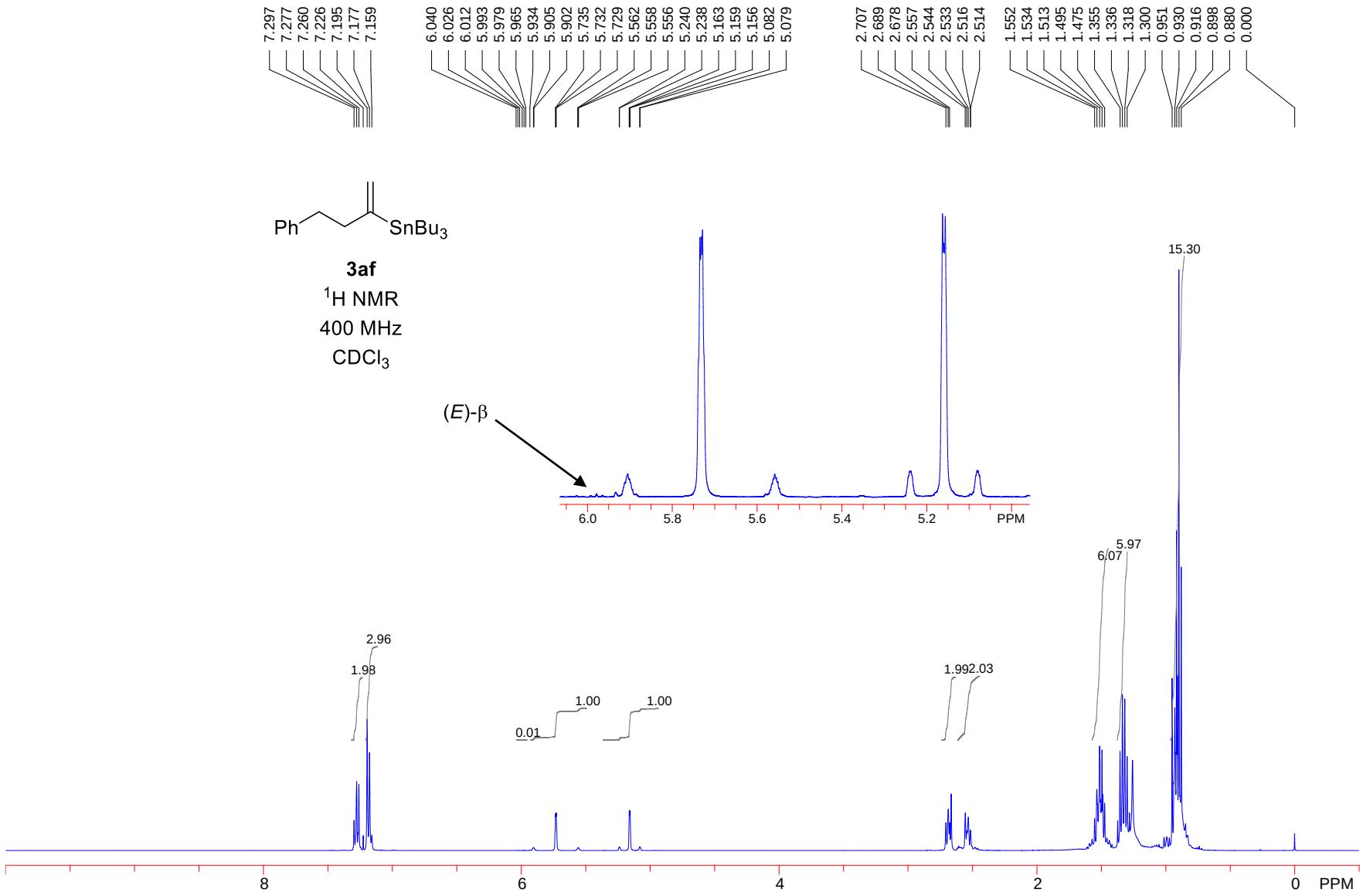
0
PPM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5.905
5.902
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5.732
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5.556
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5.238
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5.156
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2.533
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2.514
1.552
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1.513
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1.300
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0.930
0.916
0.898
0.880
0.000
Ph
SnBu3
3af
1H NMR
400 MHz
CDCl3
(E)-β
6.0
5.8
5.6
5.4
5.2
PPM
15.30
6.07
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1.00
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2.03
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4
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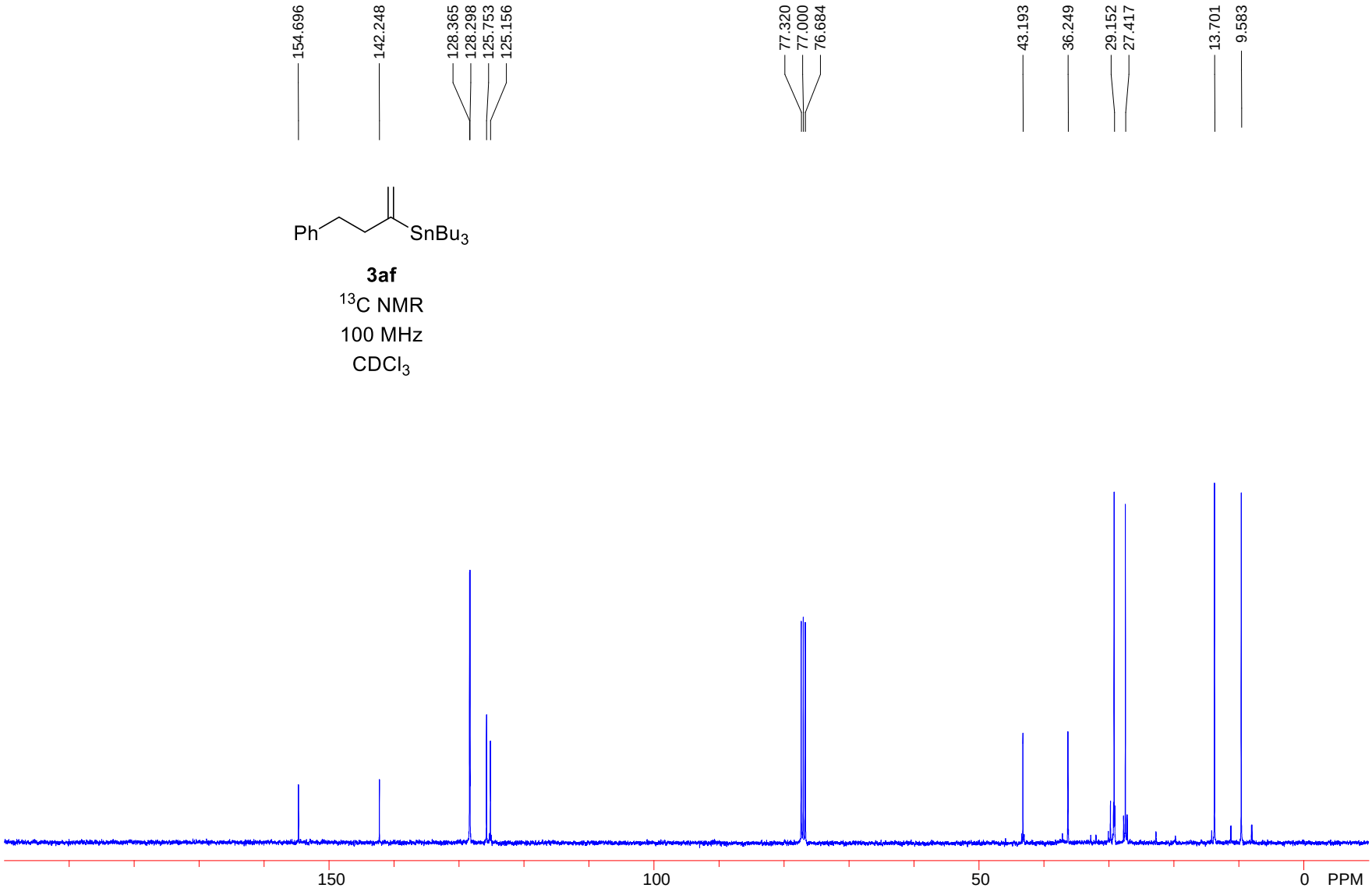
PPM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43.193
36.249
29.152
27.417
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9.583
Ph
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13C NMR
100 MHz
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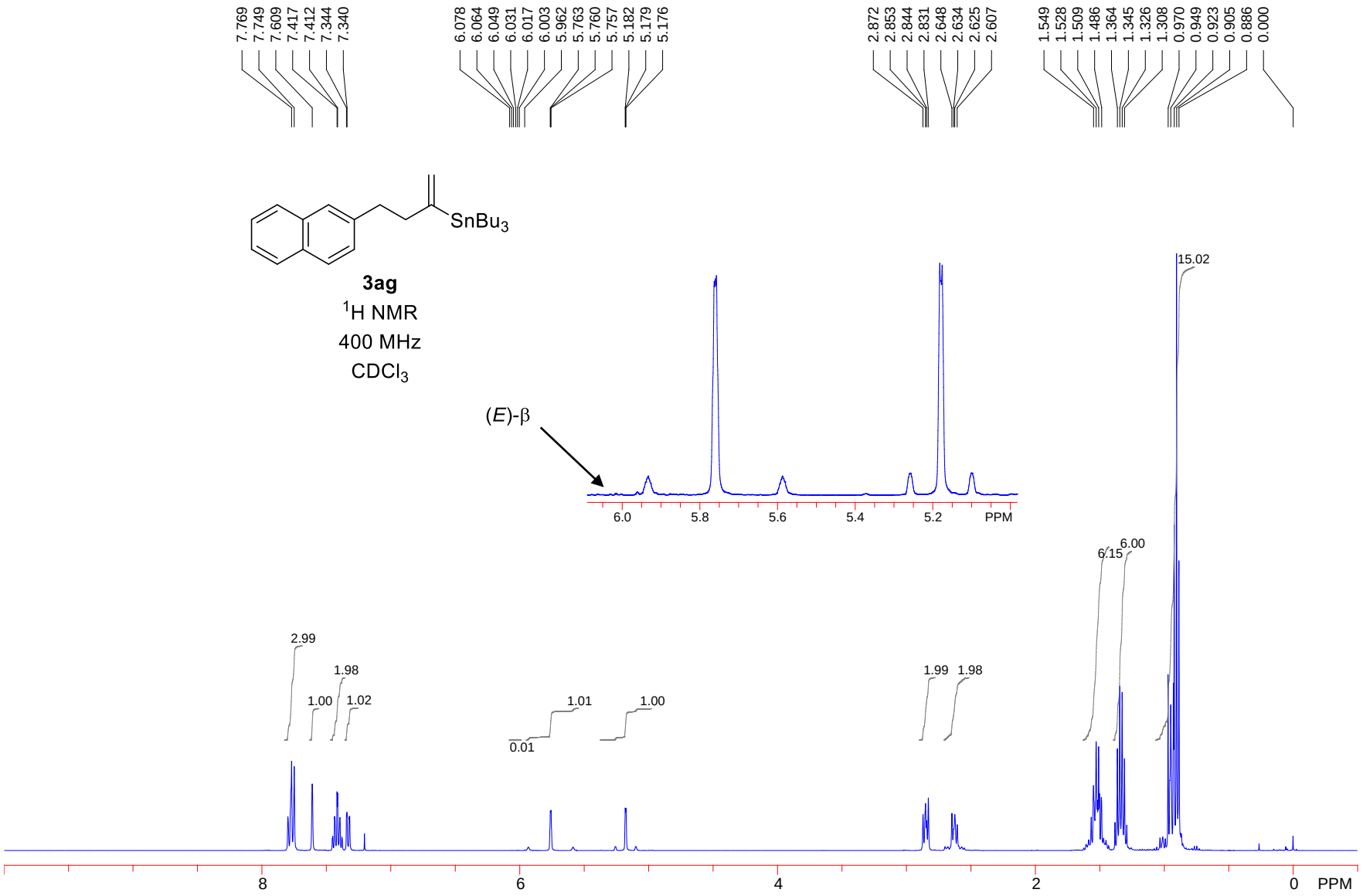
0
PPM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7.609
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7.412
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7.340
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6.049
6.031
6.017
6.003
5.962
5.763
5.760
5.757
5.182
5.179
5.176
2.872
2.853
2.844
2.831
2.648
2.634
2.625
2.607
1.549
1.528
1.509
1.486
1.364
1.345
1.326
1.308
0.970
0.949
0.923
0.905
0.886
0.000
SnBu3
3ag
1H NMR
400 MHz
CDCl3
(E)-β
6.0
5.8
5.6
5.4
5.2
PPM
15.02
6.15
6.00
2.99
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0.01
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1.98
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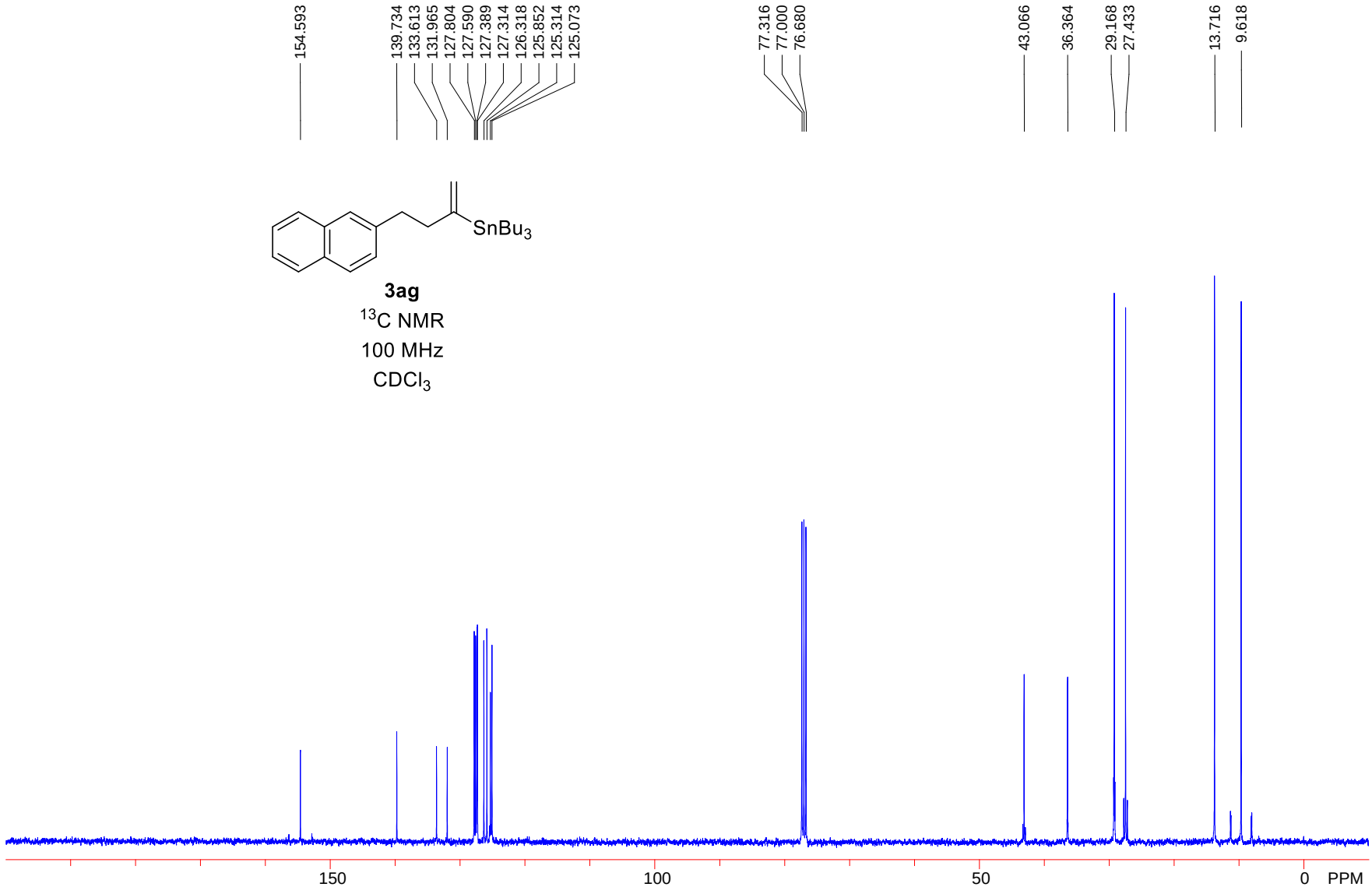
PPM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139.734
133.613
131.965
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127.389
127.314
126.318
125.852
125.314
125.073
77.316
77.000
76.680
43.066
36.364
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13.716
9.618
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100 MHz
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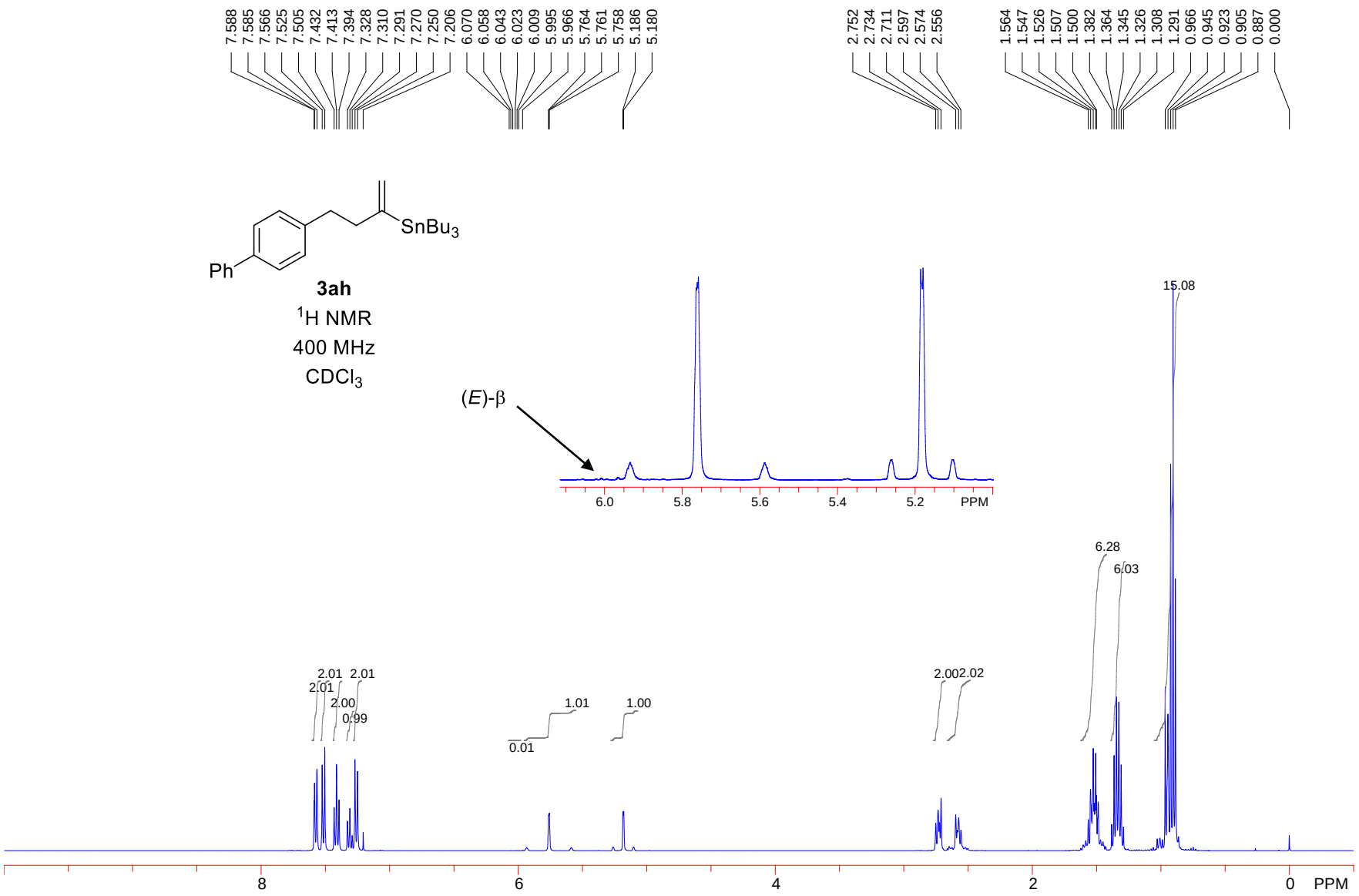
0
PPM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7.585
7.566
7.525
7.505
7.432
7.413
7.394
7.328
7.310
7.291
7.270
7.250
7.206
6.070
6.058
6.043
6.023
6.009
5.995
5.966
5.764
5.761
5.758
5.186
5.180
2.752
2.734
2.711
2.597
2.574
2.556
1.564
1.547
1.526
1.507
1.500
1.382
1.364
1.345
1.326
1.308
1.291
0.966
0.945
0.923
0.905
0.887
0.000
SnBu3
Ph
3ah
1H NMR
400 MHz
CDCl3
(E)-β
6.0
5.8
5.6
5.4
5.2
PPM
15.08
6.28
6.03
2.01
2.01
2.01
2.01
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0.99
1.01
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2.00
2.02
8
6
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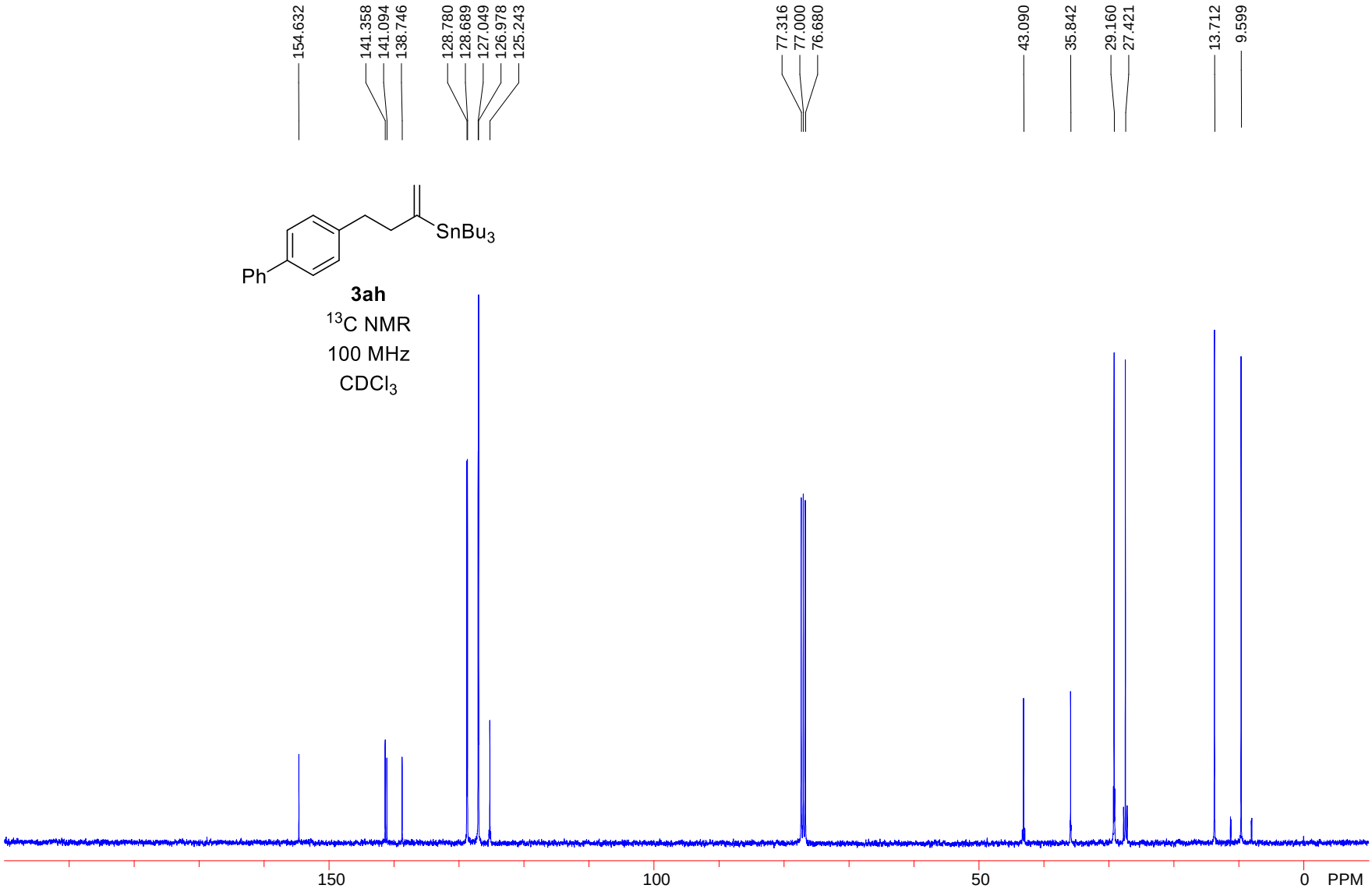
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141.358
141.094
138.746
128.780
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127.049
126.978
125.243
77.316
77.000
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43.090
35.842
29.160
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9.599
SnBu3
Ph
3ah
13C NMR
100 MHz
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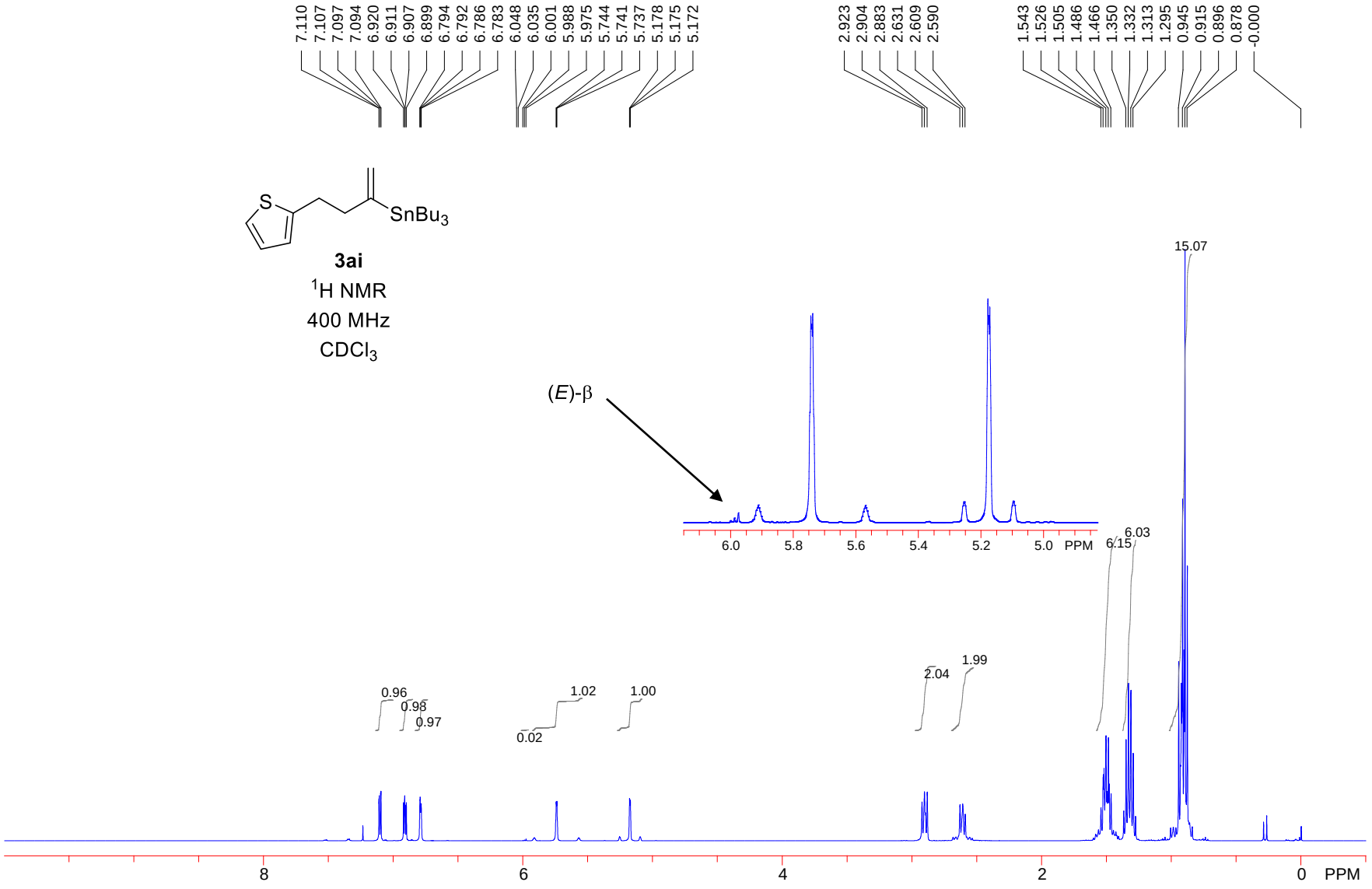
PPM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7.107
7.097
7.094
6.920
6.911
6.907
6.899
6.794
6.792
6.786
6.783
6.048
6.035
6.001
5.988
5.975
5.744
5.741
5.737
5.178
5.175
5.172
2.923
2.904
2.883
2.631
2.609
2.590
1.543
1.526
1.505
1.486
1.466
1.350
1.332
1.313
1.295
0.945
0.915
0.896
0.878
-0.000
S
SnBu3
3ai
1H NMR
400 MHz
CDCl3
(E)-β
15.07
6.03
6.15
1.99
2.04
1.02
1.00
0.96
0.98
0.97
0.02
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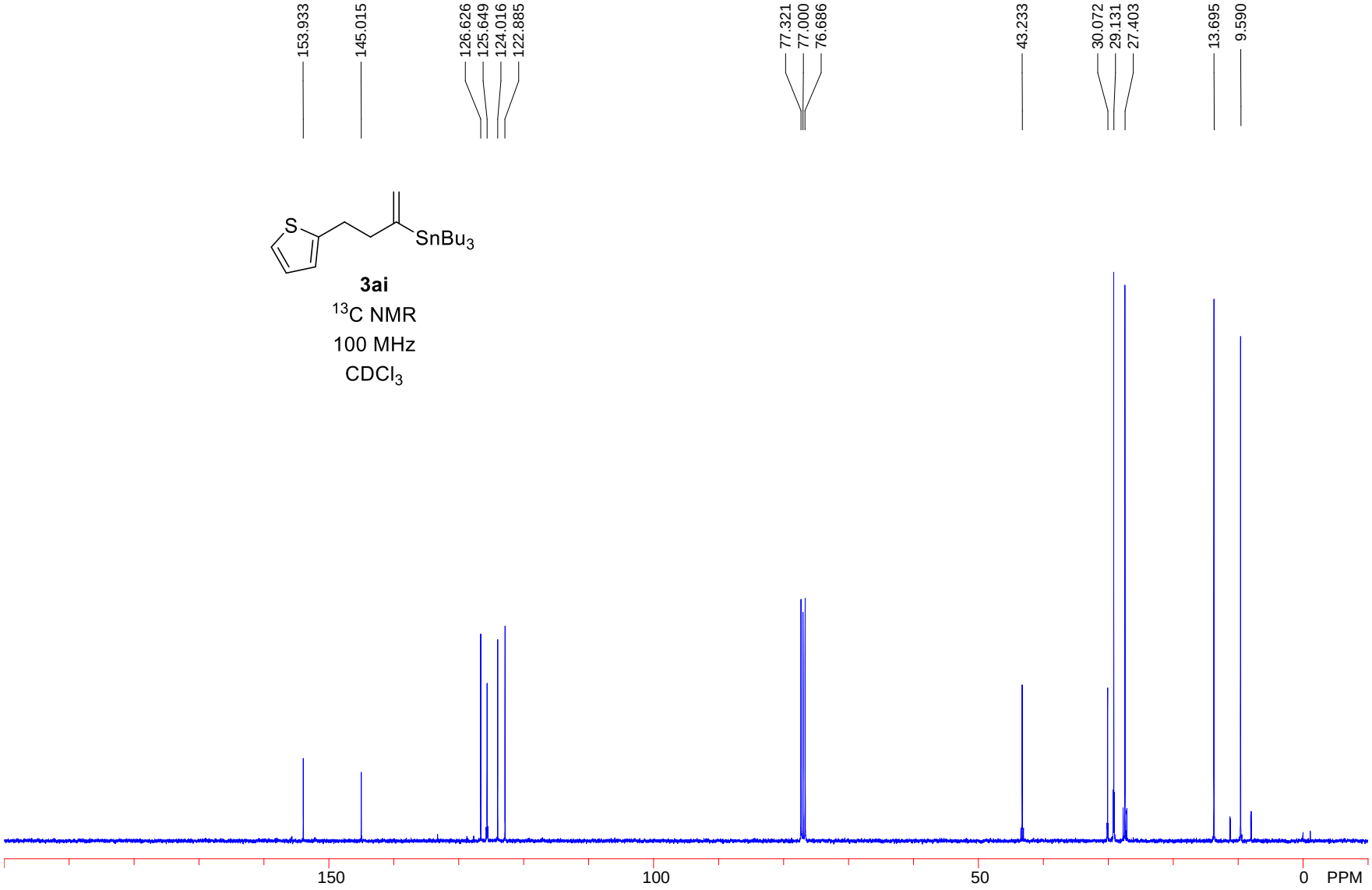
5.8
5.6
5.4
5.2
5.0
PPM
8
6
4
2
0
PPM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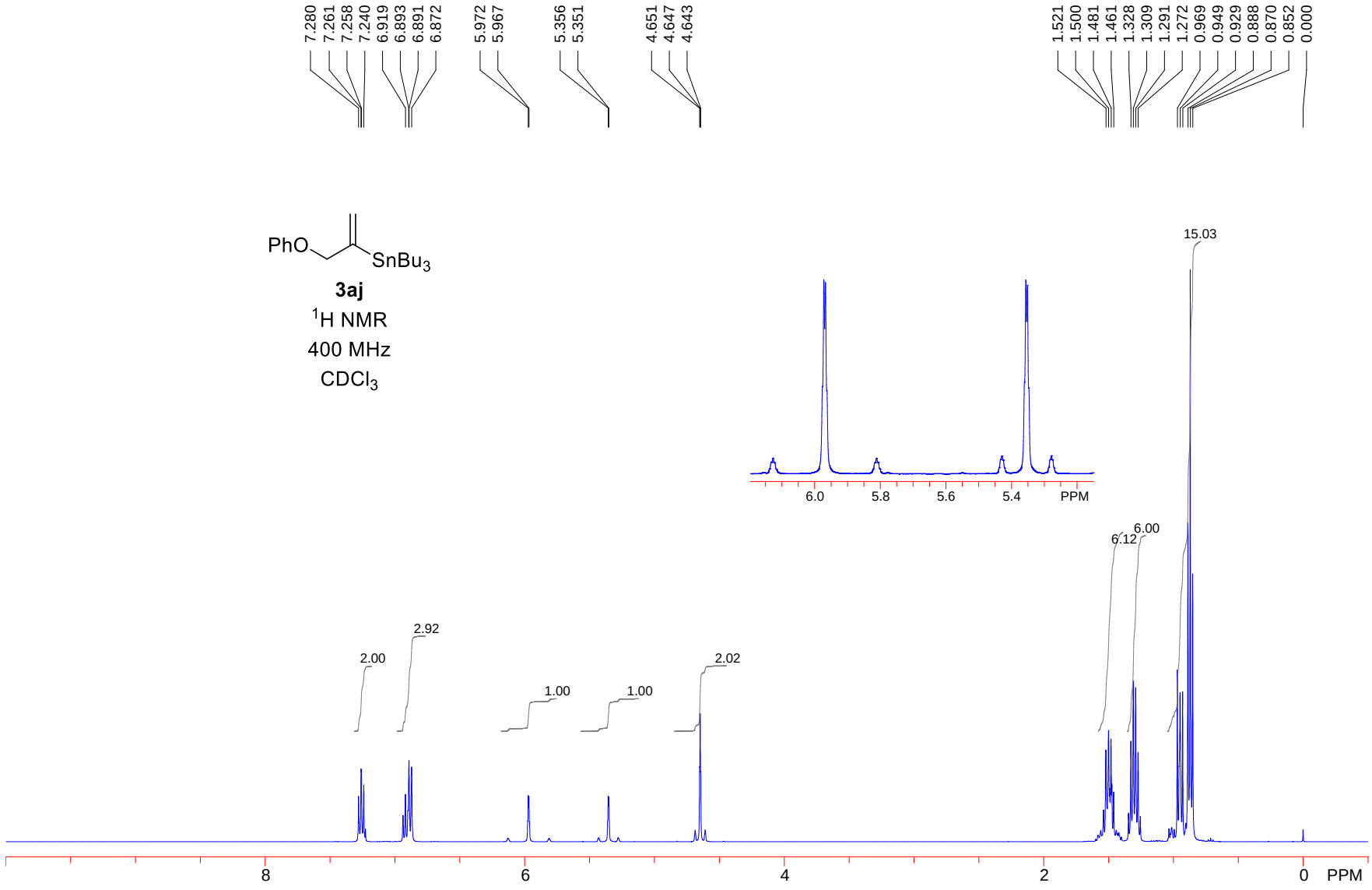
145.015
126.626
125.649
124.016
122.885
77.321
77.000
76.686
43.233
30.072
29.131
27.403
13.695
9.590
S
SnBu3
3ai
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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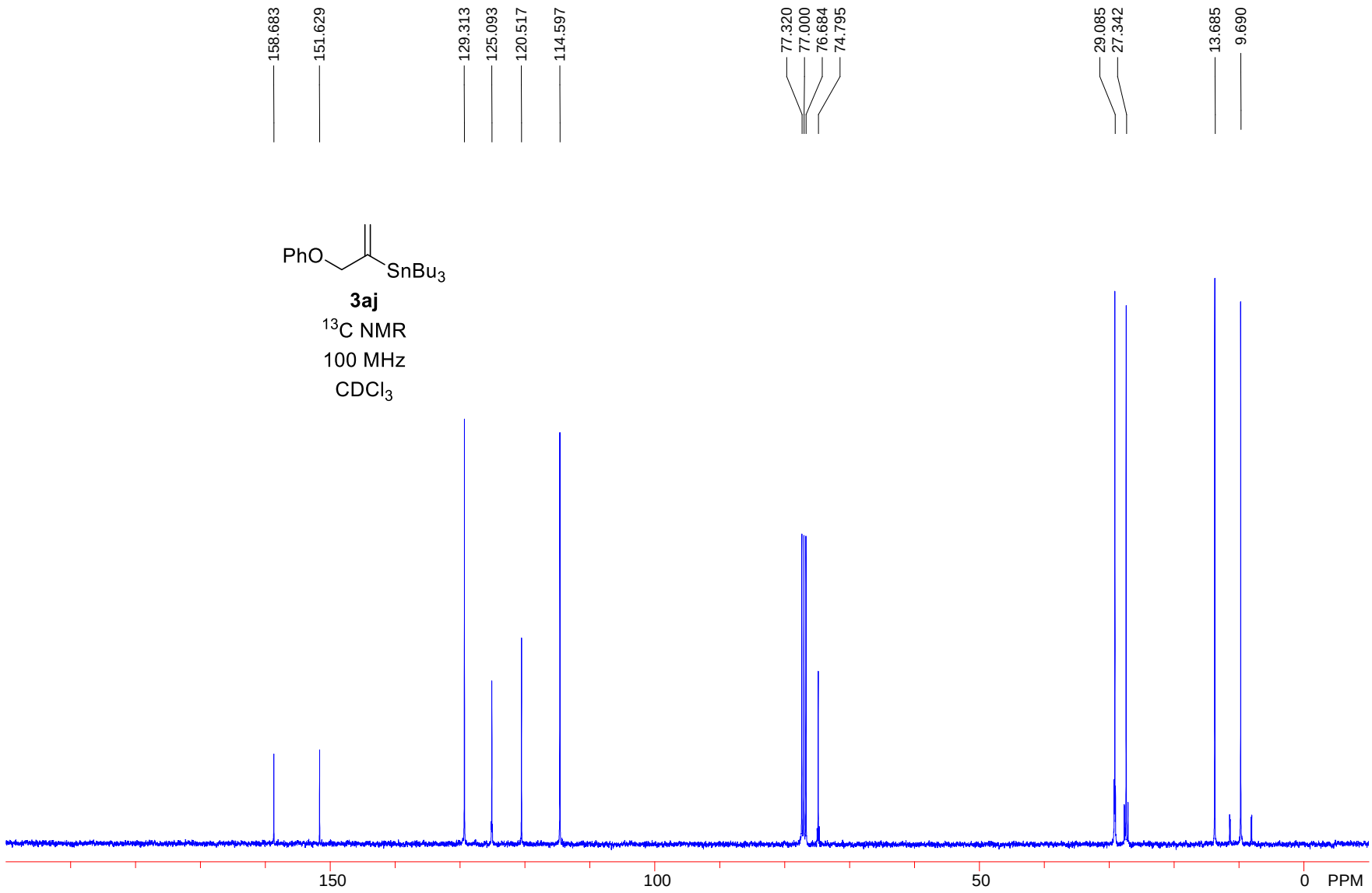
7.261
7.258
7.240
6.919
6.893
6.891
6.872
5.972
5.967
5.356
5.351
4.651
4.647
4.643
1.521
1.500
1.481
1.461
1.328
1.309
1.291
1.272
0.969
0.949
0.929
0.888
0.870
0.852
0.000
PhO
SnBu3
3aj
1H NMR
400 MHz
CDCl3
15.03
6.12
6.00
2.92
2.00
1.00
1.00
2.02
6.0
5.8
5.6
5.4
PPM
8
6
4
2
0
PPM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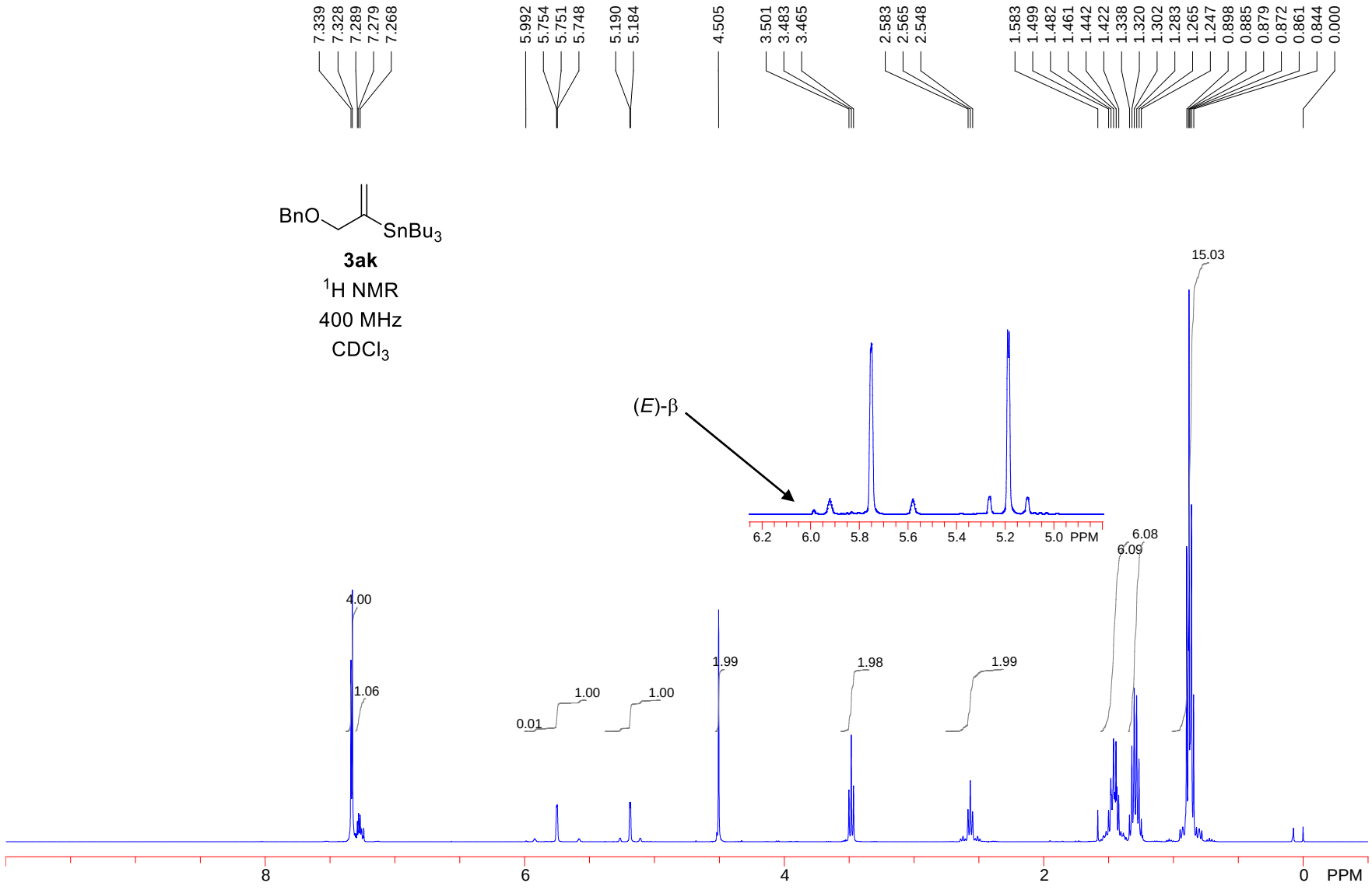
151.629
129.313
125.093
120.517
114.597
77.320
77.000
76.684
74.795
29.085
27.342
13.685
9.690
PhO
SnBu3
3aj
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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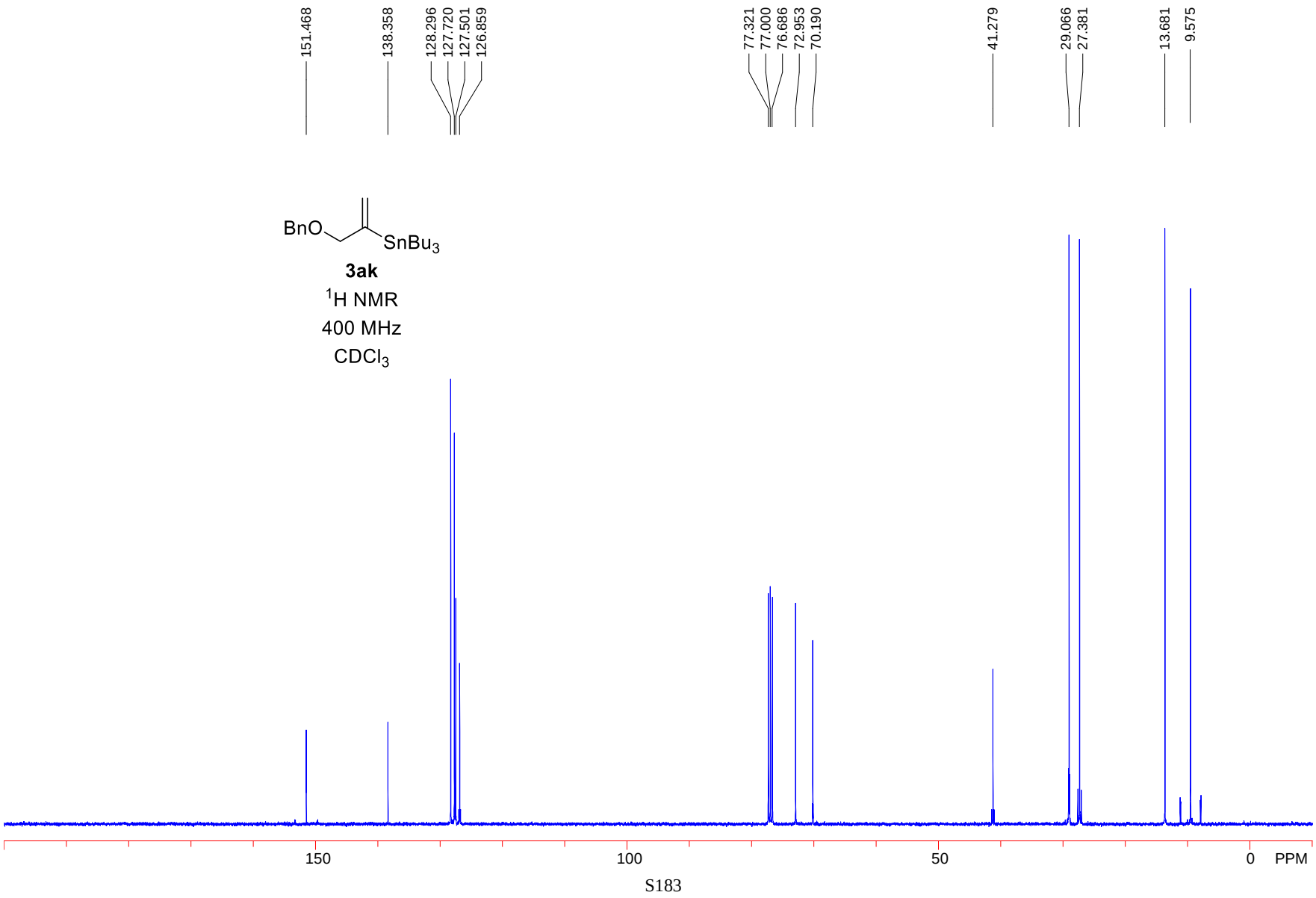
7.328
7.289
7.279
7.268
5.992
5.754
5.751
5.748
5.190
5.184
4.505
3.501
3.483
3.465
2.583
2.565
2.548
1.583
1.499
1.482
1.461
1.442
1.422
1.338
1.320
1.302
1.283
1.265
1.247
0.898
0.885
0.879
0.872
0.861
0.844
0.000
BnO
SnBu3
3ak
1H NMR
400 MHz
CDCl3
(E)-β
6.2
6.0
5.8
5.6
5.4
5.2
5.0 PPM
15.03
6.08
6.09
4.00
1.06
0.01
1.00
1.00
1.99
1.98
1.99
8
6
4
2
0 PPM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77.000
76.686
72.953
70.190
41.279
29.066
27.381
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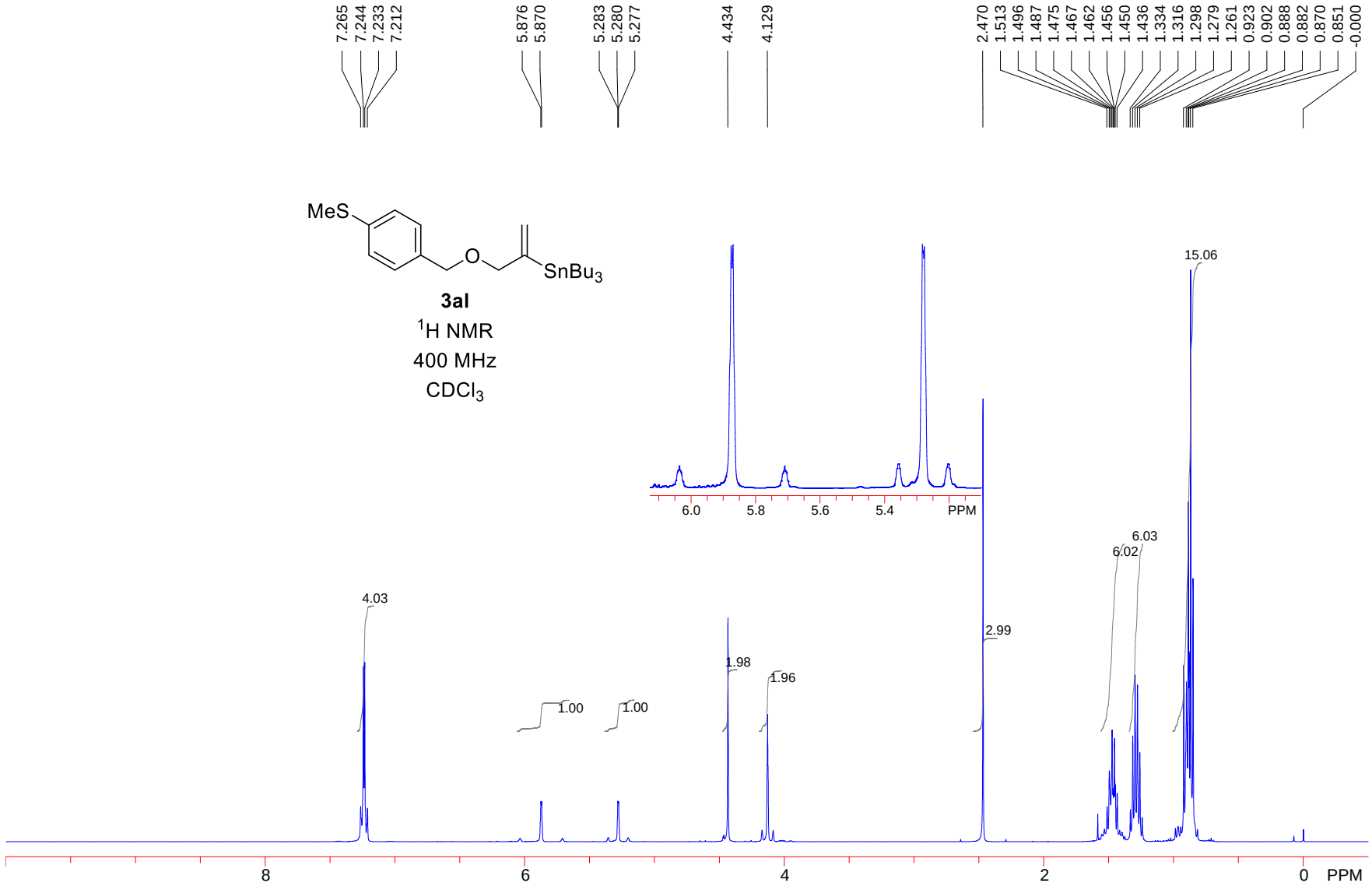
9.575
BnO
SnBu3
3ak
1H NMR
400 MHz
CDCl3
150
100
50
0
PPM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7.244
7.233
7.212
5.876
5.870
5.283
5.280
5.277
4.434
4.129
2.470
1.513
1.496
1.487
1.475
1.467
1.462
1.456
1.450
1.436
1.334
1.316
1.298
1.279
1.261
0.923
0.902
0.888
0.882
0.870
0.851
-0.000
MeS
O
SnBu3
3aI
1H NMR
400 MHz
CDCl3
15.06
6.03
6.02
4.03
2.99
1.98
1.96
1.00
1.00
6.0
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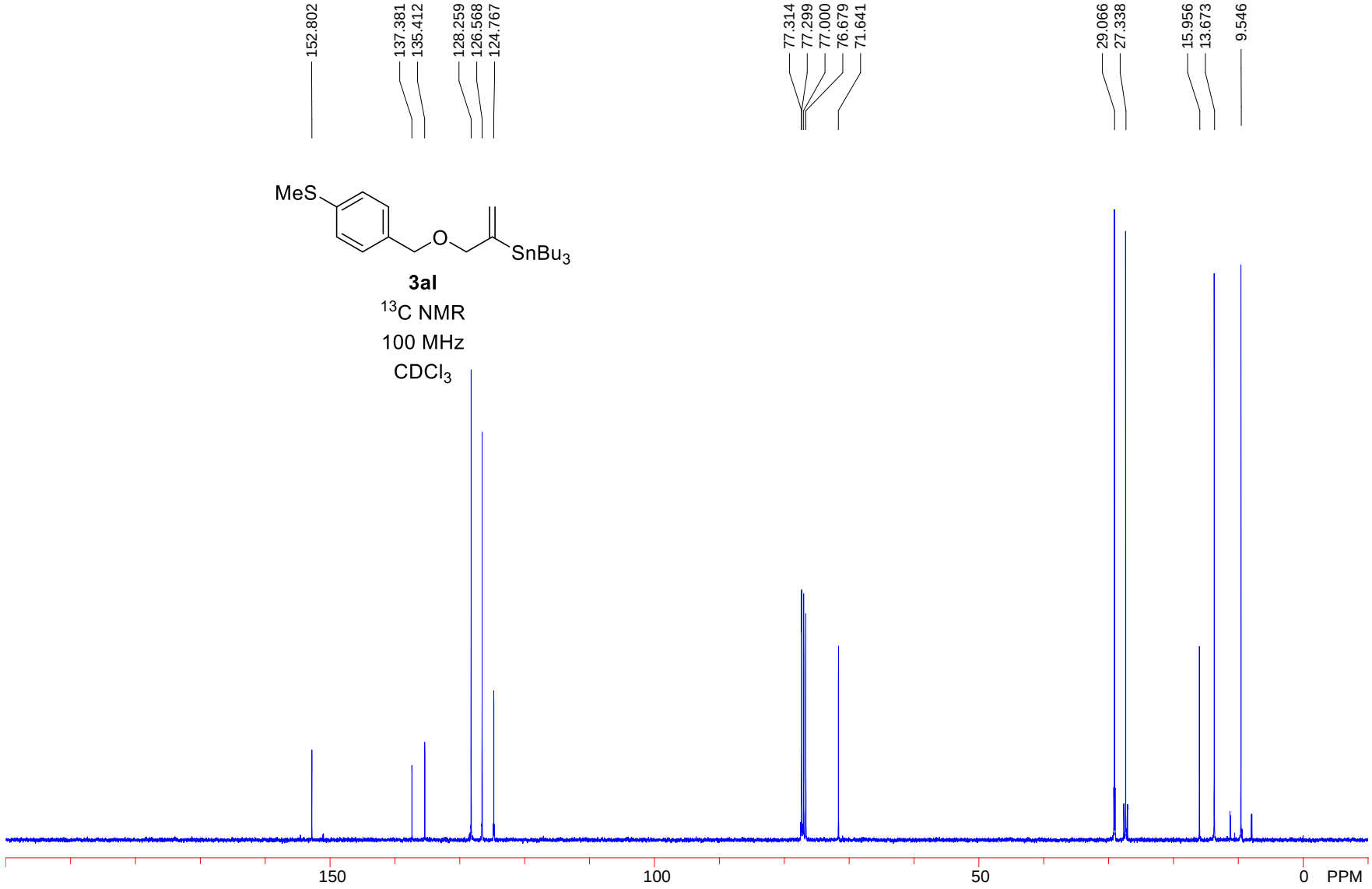
5.6
5.4
PPM
8
6
4
2
0
PPM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128.259
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124.767
77.314
77.299
77.000
76.679
71.641
29.066
27.338
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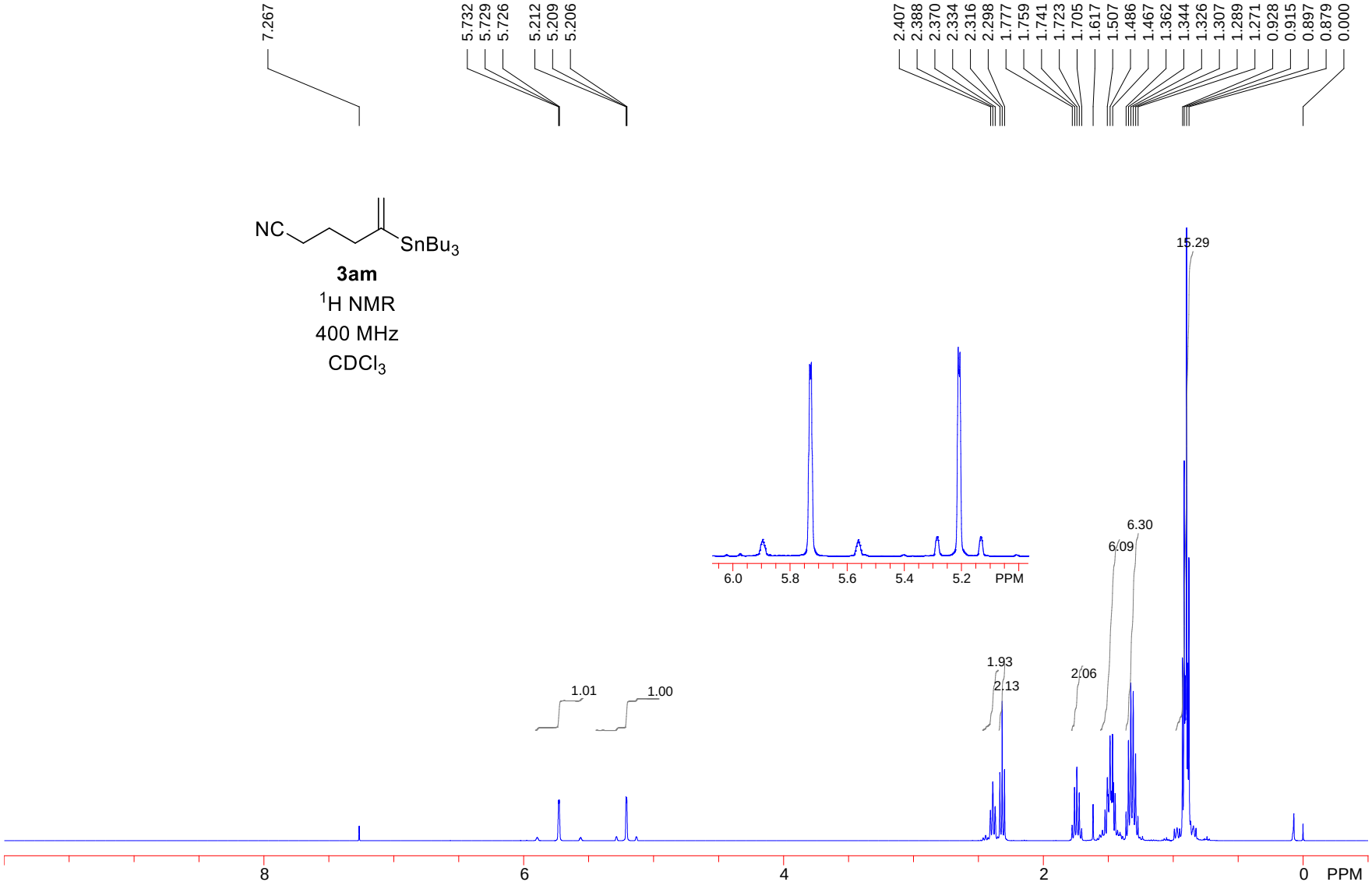
13.673
9.546
MeS
O
SnBu3
3al
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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5.732
5.729
5.726
5.212
5.209
5.206
2.407
2.388
2.370
2.334
2.316
2.298
1.777
1.759
1.741
1.723
1.705
1.617
1.507
1.486
1.467
1.362
1.344
1.326
1.307
1.289
1.271
0.928
0.915
0.897
0.879
0.000
NC
SnBu3
3am
1H NMR
400 MHz
CDCl3
15.29
6.30
6.09
2.06
1.93
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6.0
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PPM
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4
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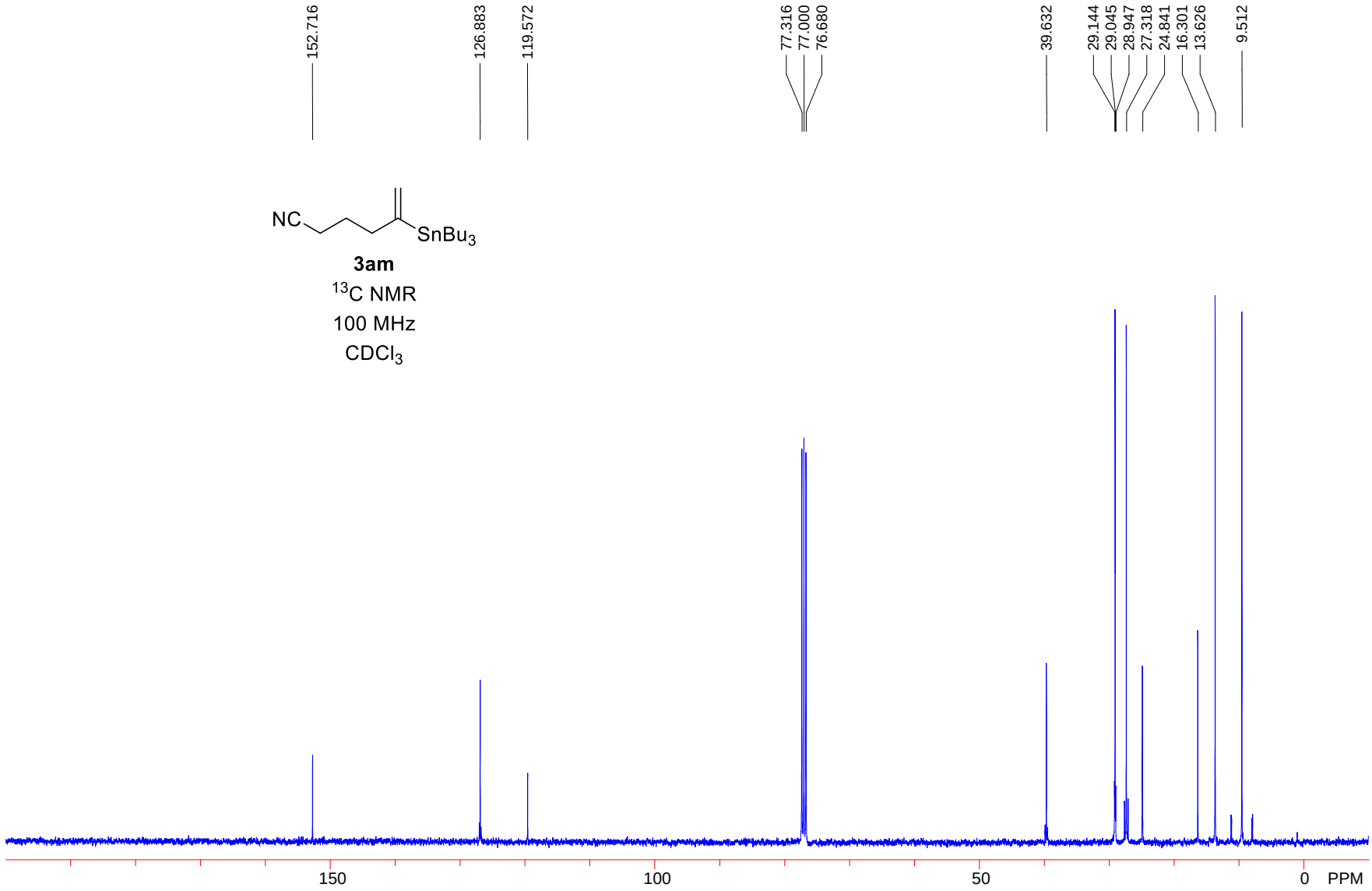
PPM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29.144
29.045
28.947
27.318
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9.512
NC
SnBu3
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13C NMR
100 MHz
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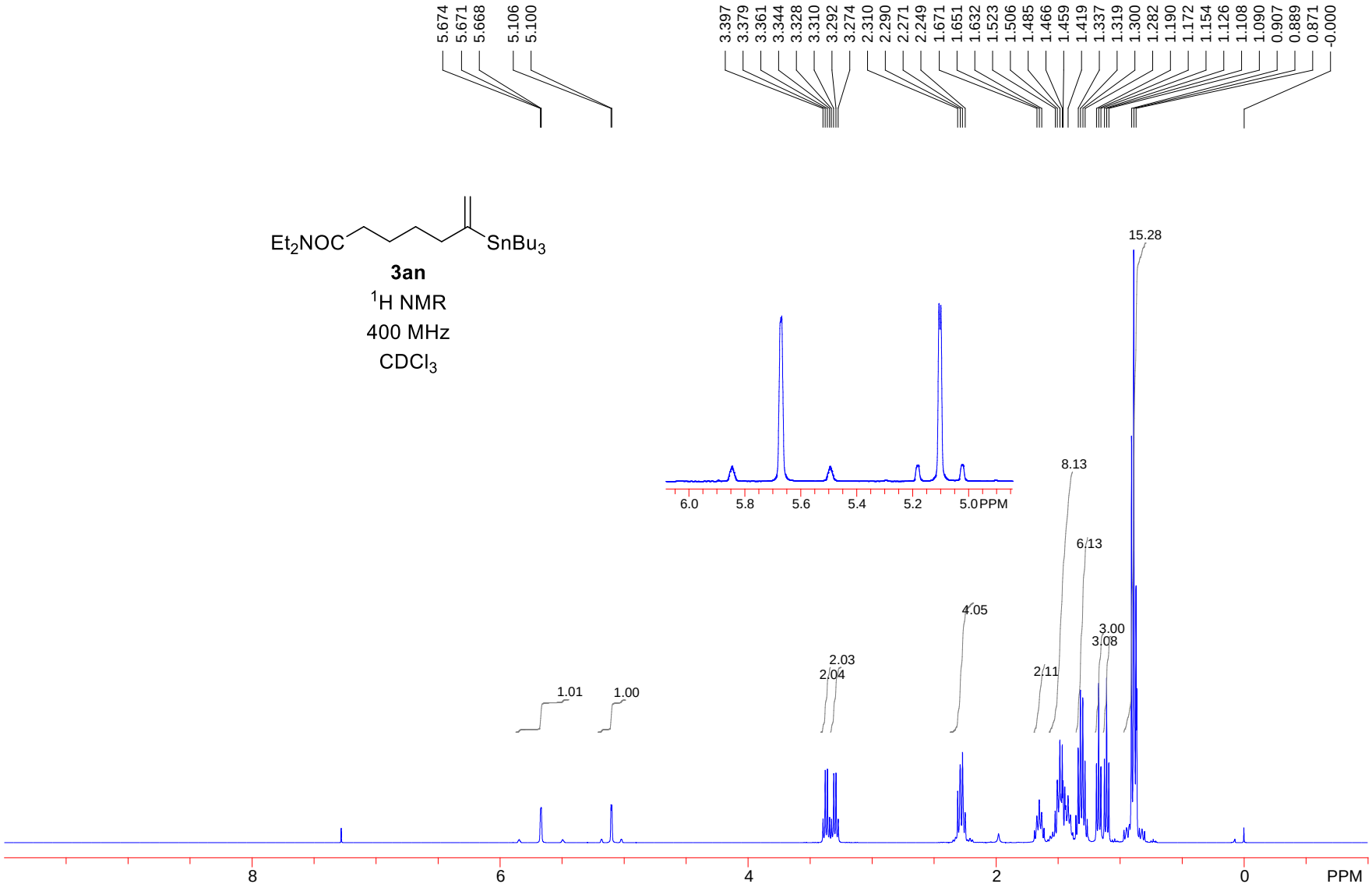
PPM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3.379
3.361
3.344
3.328
3.310
3.292
3.274
2.310
2.290
2.271
2.249
1.671
1.651
1.632
1.523
1.506
1.485
1.466
1.459
1.419
1.337
1.319
1.300
1.282
1.190
1.172
1.154
1.126
1.108
1.090
0.907
0.889
0.871
-0.000
Et2NOC
SnBu3
3an
1H NMR
400 MHz
CDCl3
15.28
8.13
6.13
4.05
3.00
3.08
2.03
2.04
2.11
1.01
1.00
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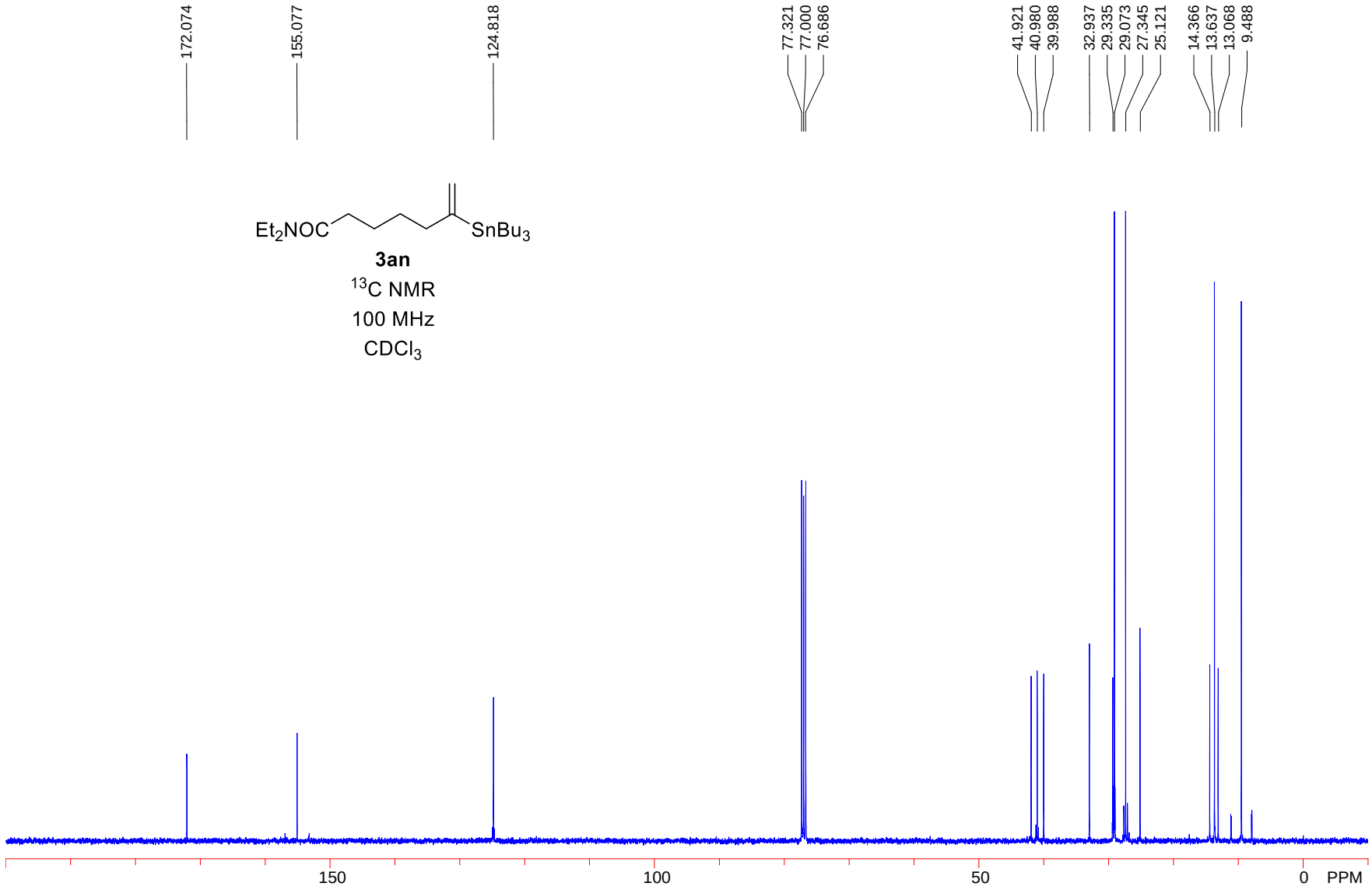
5.8
5.6
5.4
5.2
5.0 PPM
8
6
4
2
0
PPM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40.980
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32.937
29.335
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27.345
25.121
14.366
13.637
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Et2NOC
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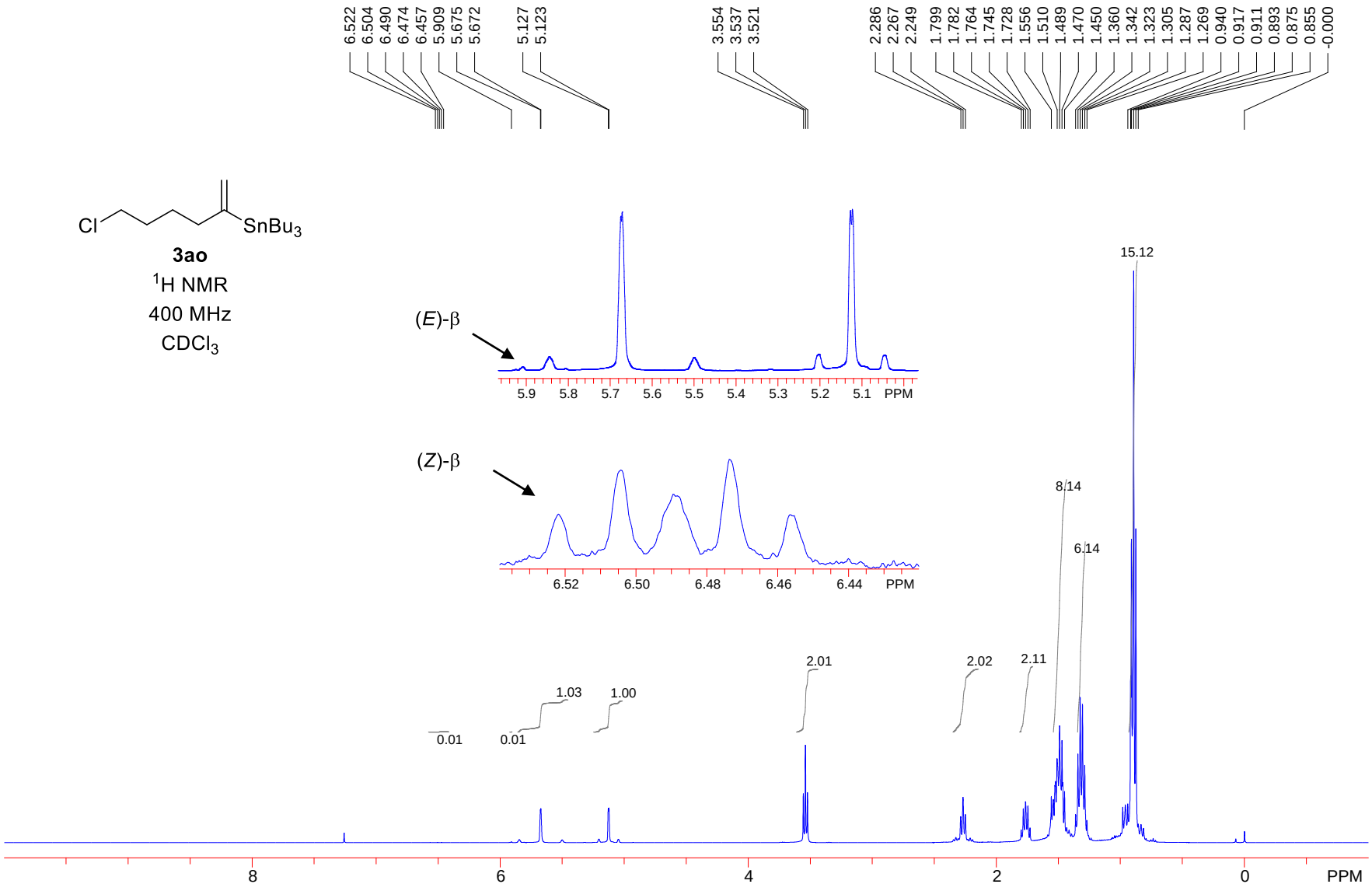
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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6.490
6.474
6.457
5.909
5.675
5.672
5.127
5.123
3.554
3.537
3.521
2.286
2.267
2.249
1.799
1.782
1.764
1.745
1.728
1.556
1.510
1.489
1.470
1.450
1.360
1.342
1.323
1.305
1.287
1.269
0.940
0.917
0.911
0.893
0.875
0.855
-0.000
Cl
SnBu3
3ao
1H NMR
400 MHz
CDCl3
(E)-β
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
PPM
(Z)-β
6.52
6.50
6.48
6.46
6.44
PPM
15.12
8.14
6.14
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2.02
2.11
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0.01
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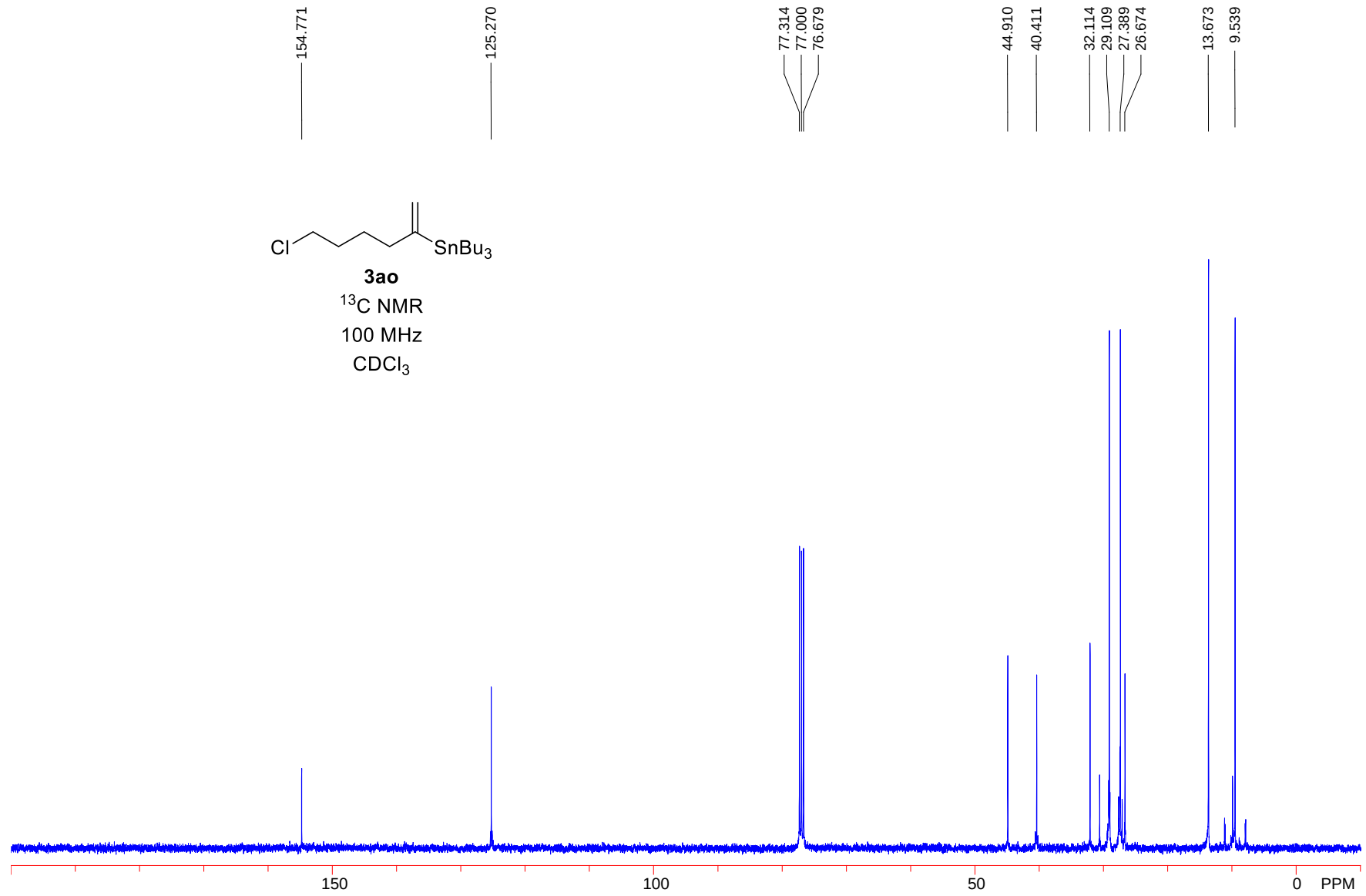
PPM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44.910
40.411
32.114
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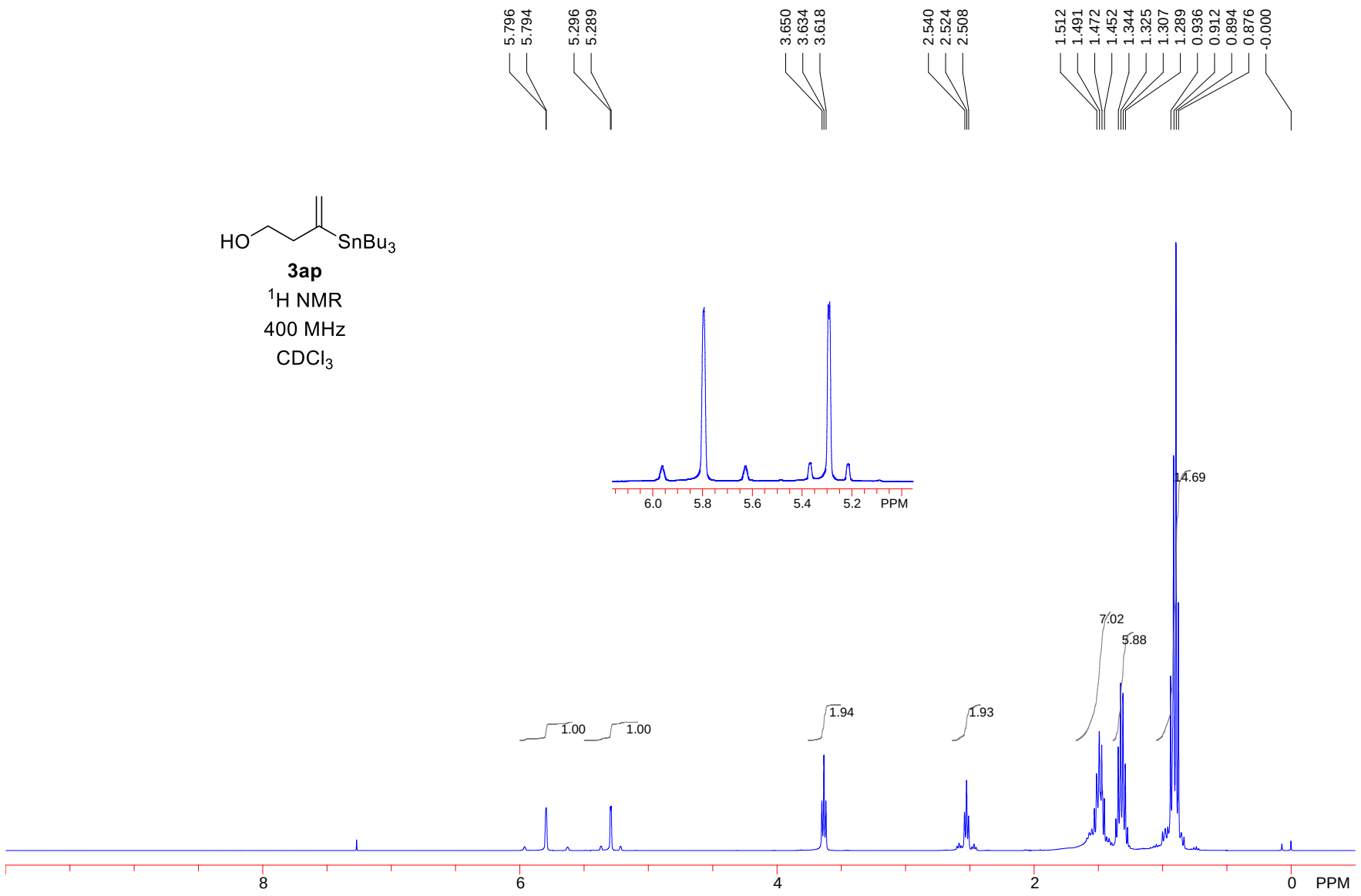
3ao
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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3.634
3.618
2.540
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2.508
1.512
1.491
1.472
1.452
1.344
1.325
1.307
1.289
0.936
0.912
0.894
0.876
-0.000
HO
SnBu3
3ap
1H NMR
400 MHz
CDCl3
6.0
5.8
5.6
5.4
5.2
PPM
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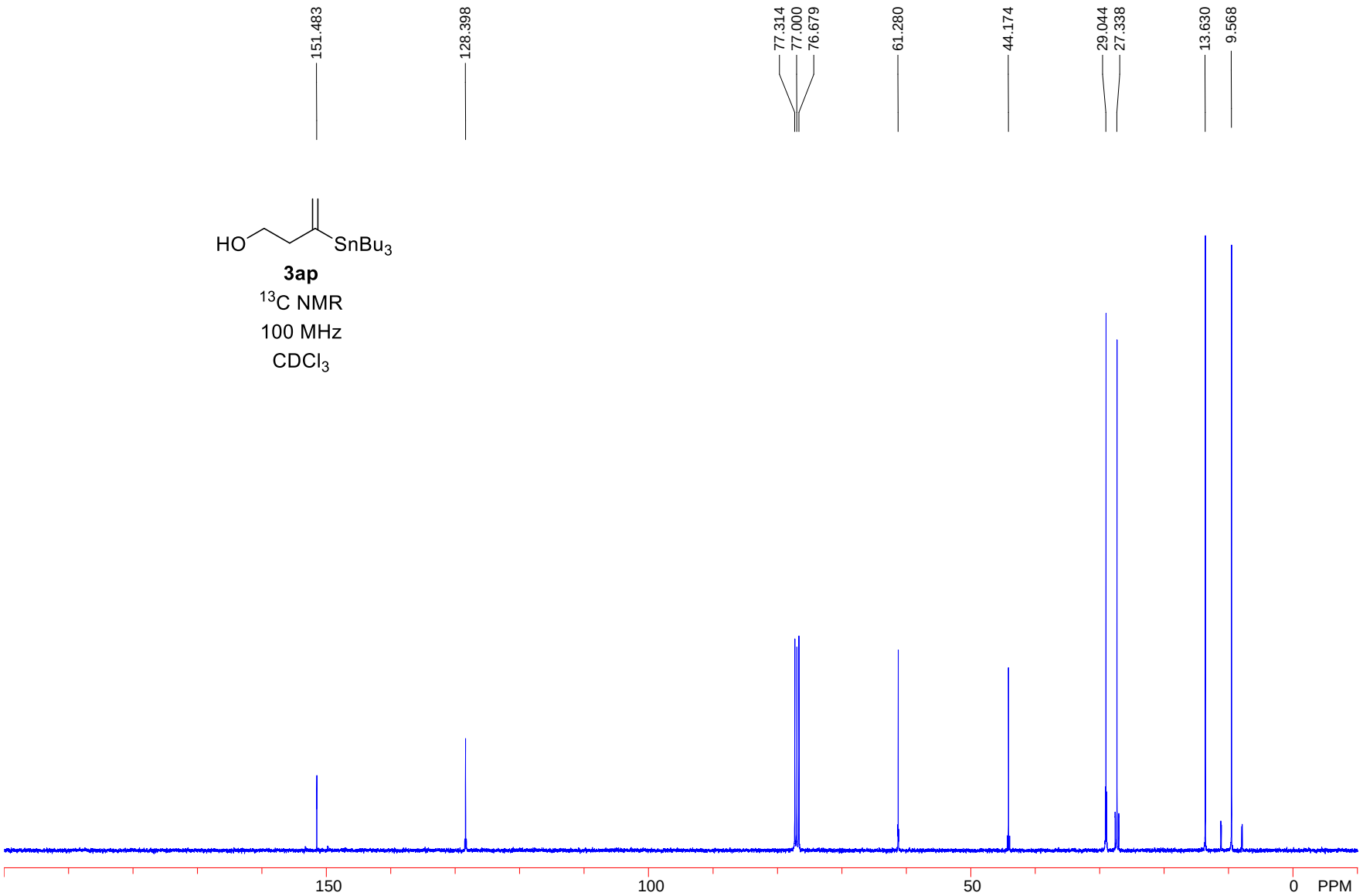
PPM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9.568
HO
SnBu3
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13C NMR
100 MHz
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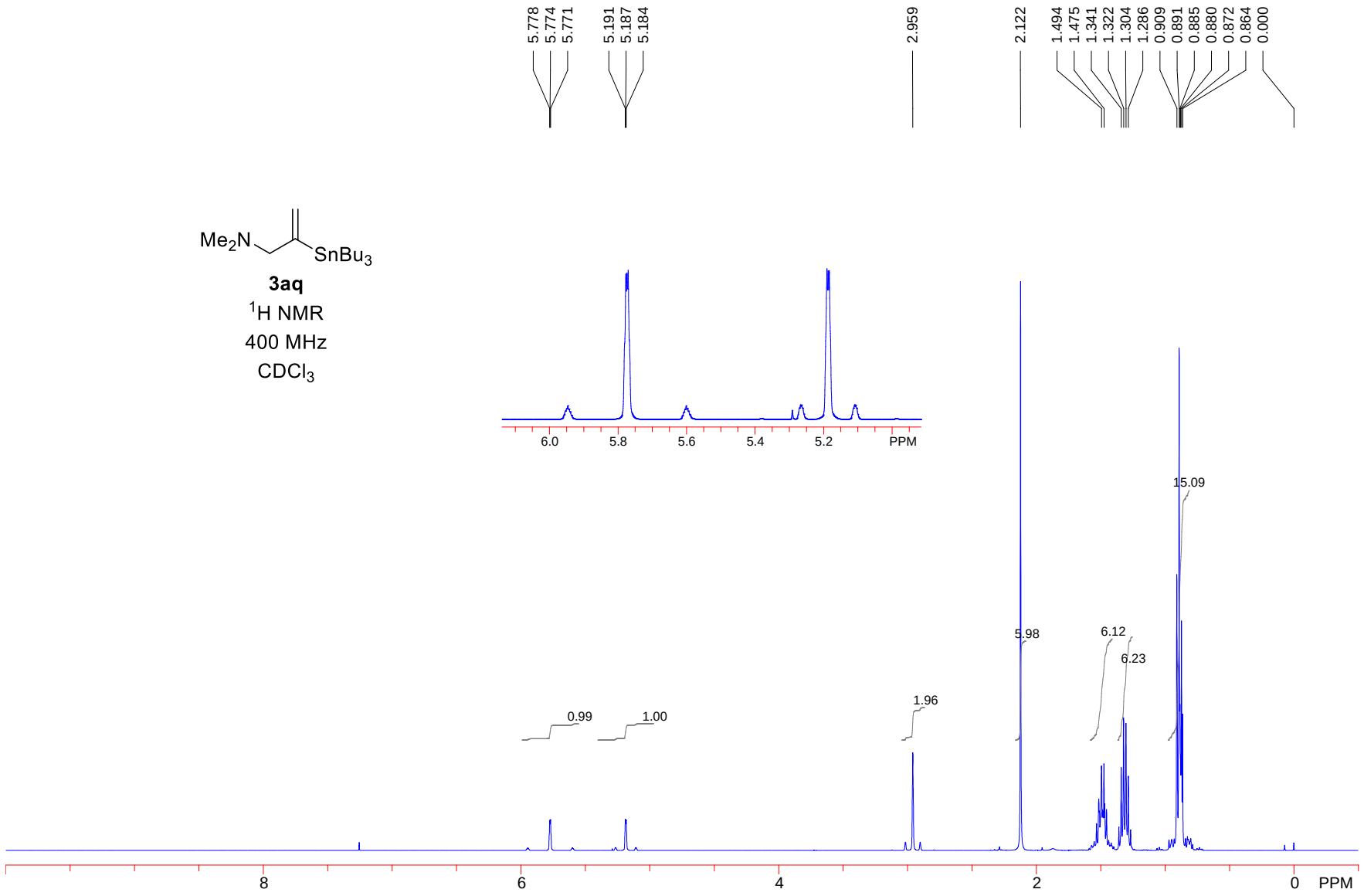
150
100
50
0
PPM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5.184
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2.122
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1.475
1.341
1.322
1.304
1.286
0.909
0.891
0.885
0.880
0.872
0.864
0.000
Me2N
SnBu3
3aq
1H NMR
400 MHz
CDCl3
6.0
5.8
5.6
5.4
5.2
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1.00
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6
4
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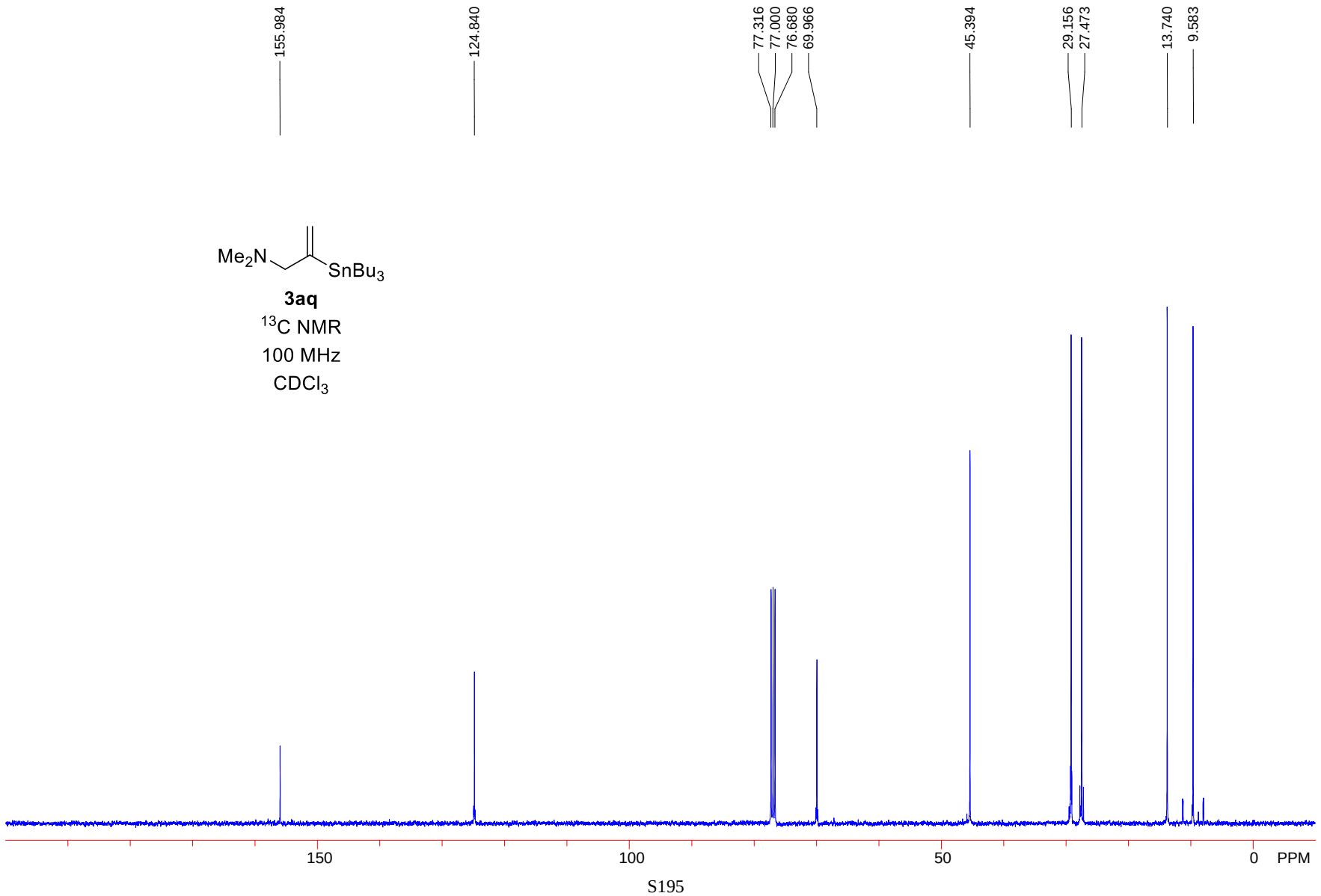
PPM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13C NMR
100 MHz
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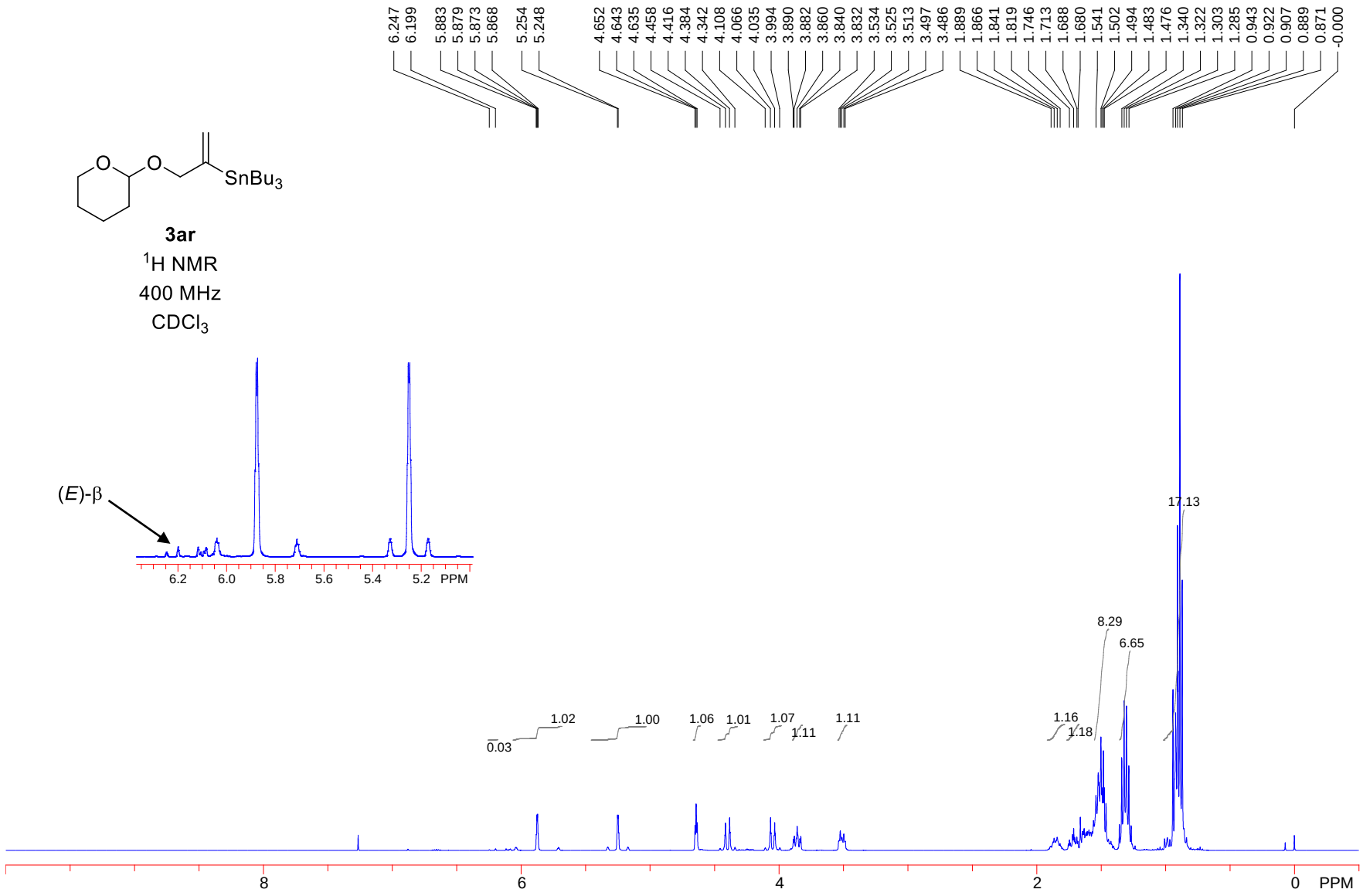
150
100
50
0
PPM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5.248
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4.416
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4.342
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4.066
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3.994
3.890
3.882
3.860
3.840
3.832
3.534
3.525
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3.497
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1.494
1.483
1.476
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1.322
1.303
1.285
0.943
0.922
0.907
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0.871
-0.000
O
O
SnBu3
3ar
1H NMR
400 MHz
CDCl3
(E)-β
6.2
6.0
5.8
5.6
5.4
5.2
PPM
17.13
8.29
6.65
1.02
1.00
1.06
1.01
1.07
1.11
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1.16
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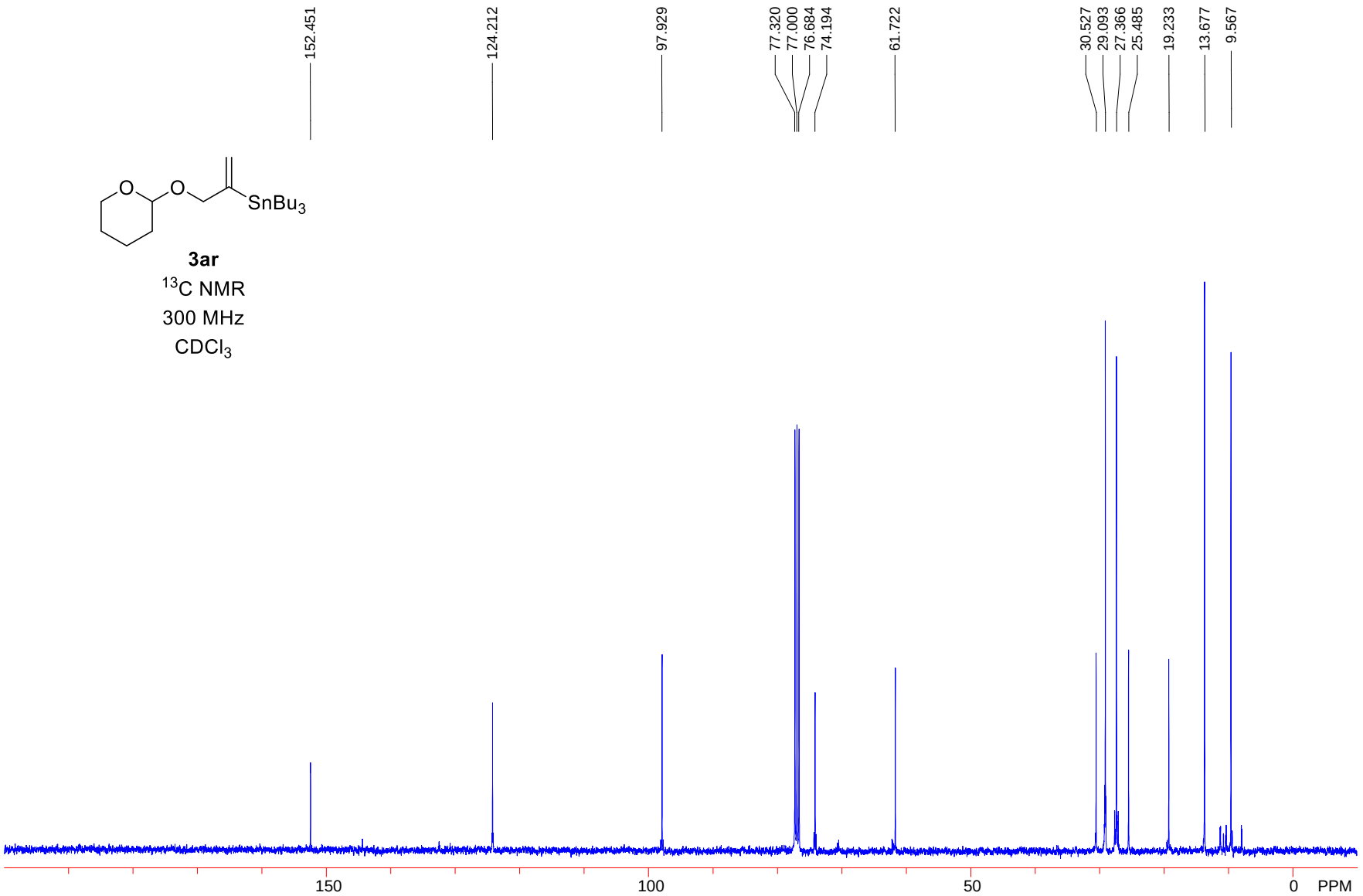
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61.722
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27.366
25.485
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O
O
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3ar
13C NMR
300 MHz
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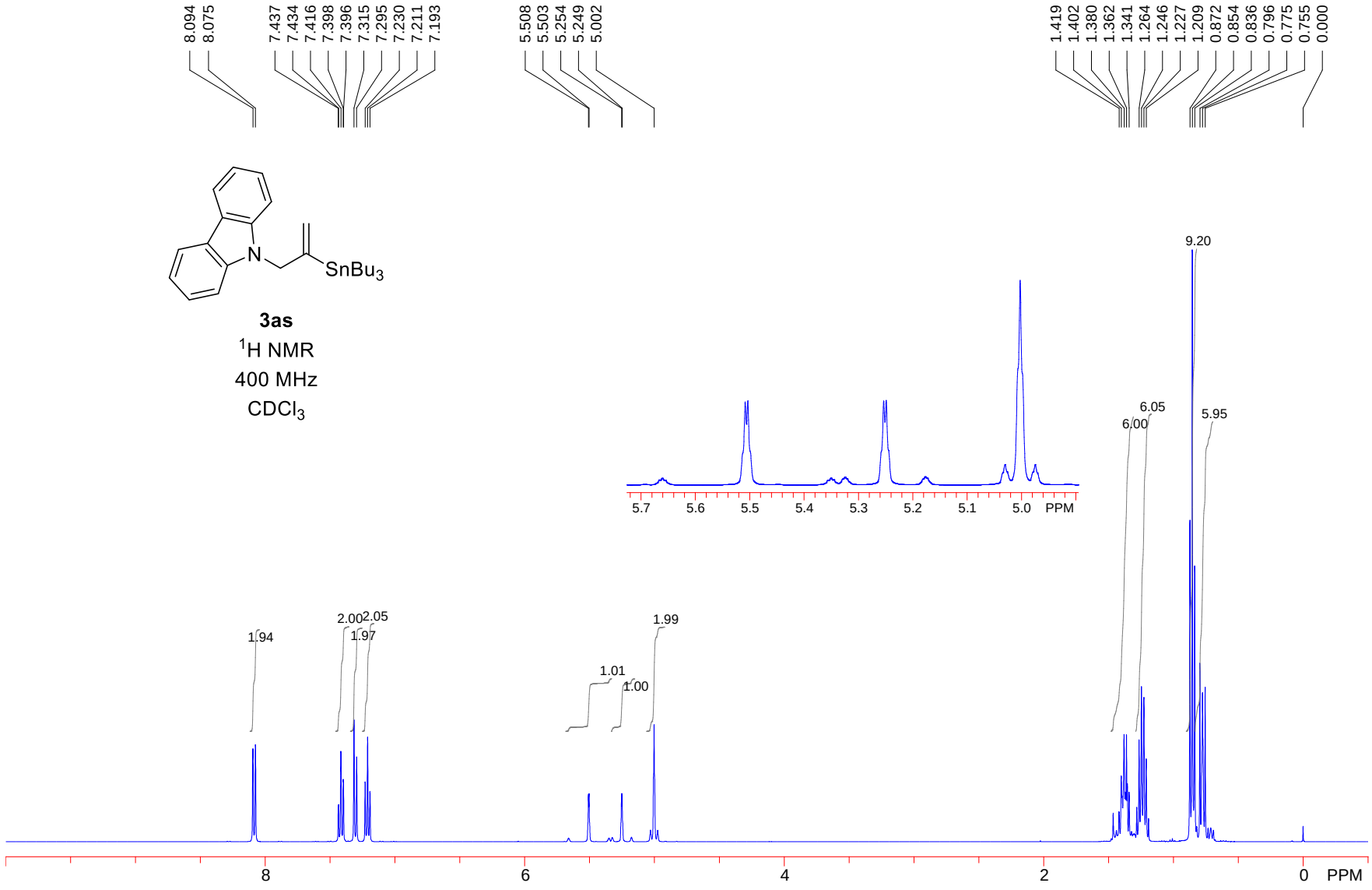
PPM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7.434
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7.396
7.315
7.295
7.230
7.211
7.193
5.508
5.503
5.254
5.249
5.002
1.419
1.402
1.380
1.362
1.341
1.264
1.246
1.227
1.209
0.872
0.854
0.836
0.796
0.775
0.755
0.000
N
SnBu3
3as
1H NMR
400 MHz
CDCl3
9.20
6.05
6.00
5.95
1.94
2.00
2.05
1.97
1.99
1.01
1.00
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5.4
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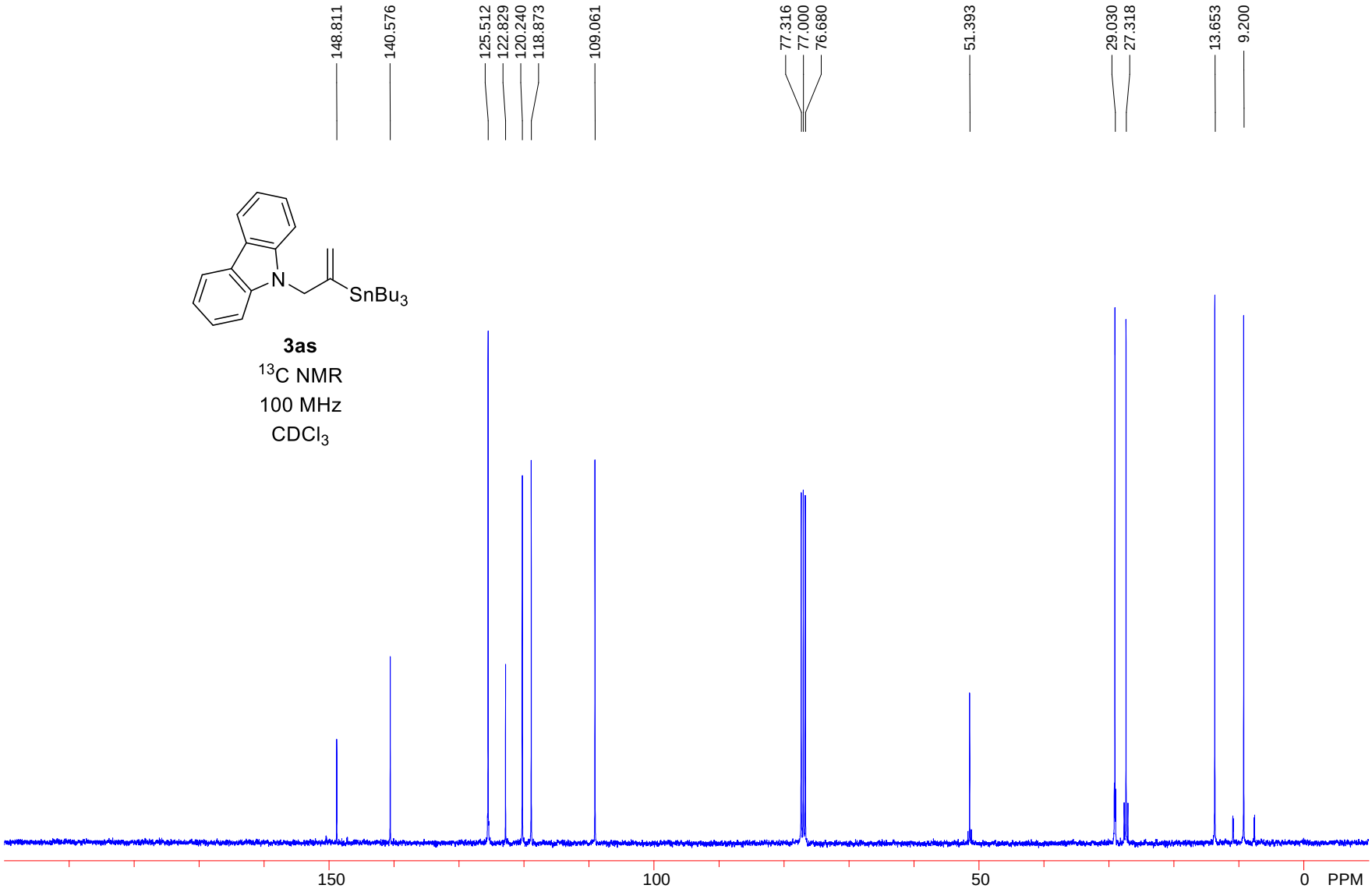
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125.512
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77.316
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9.200
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13C NMR
100 MHz
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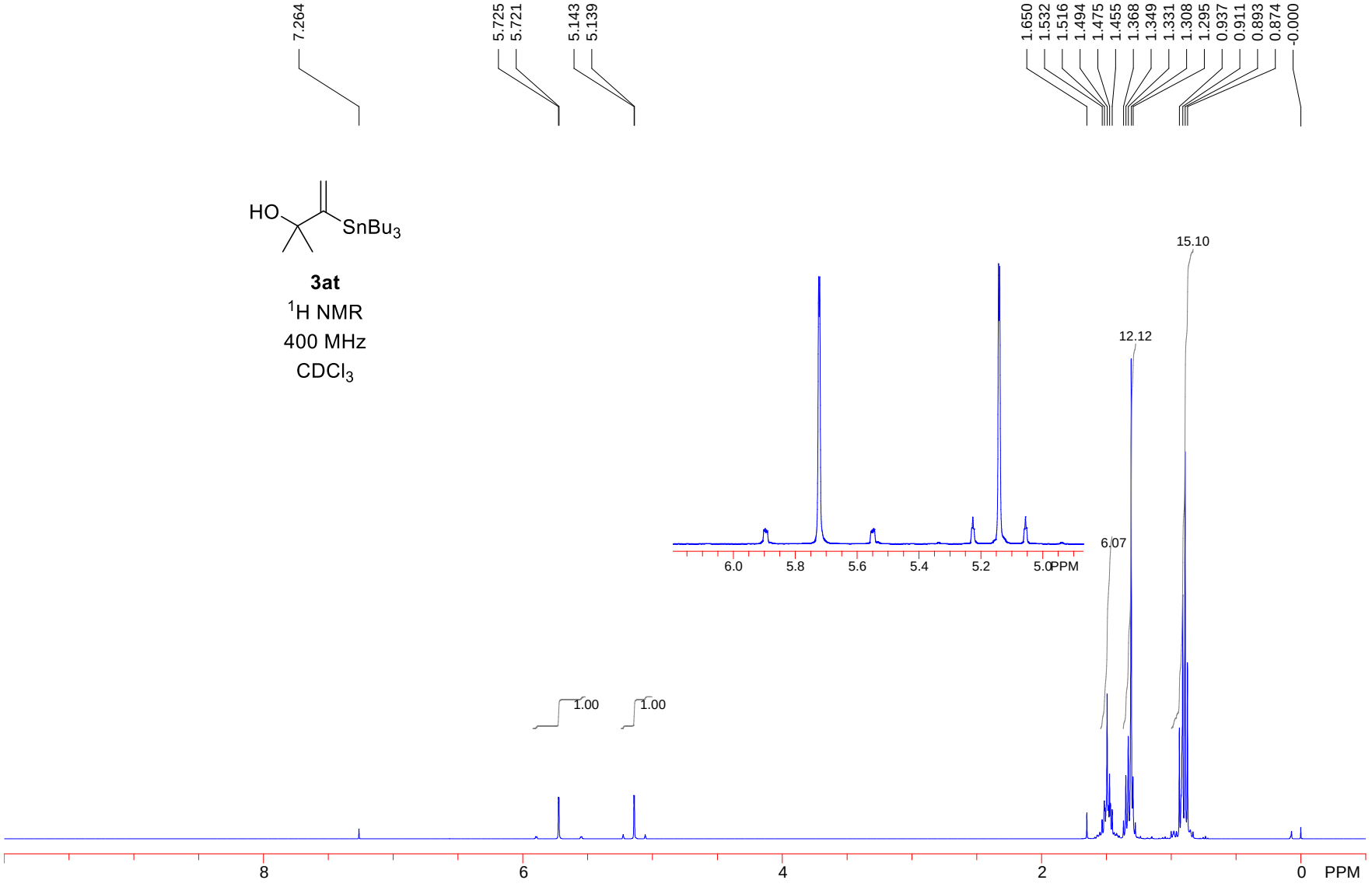
50
0
PPM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5.721
5.143
5.139
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1.532
1.516
1.494
1.475
1.455
1.368
1.349
1.331
1.308
1.295
0.937
0.911
0.893
0.874
-0.000
HO
SnBu3
3at
1H NMR
400 MHz
CDCl3
15.10
12.12
6.07
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1.00
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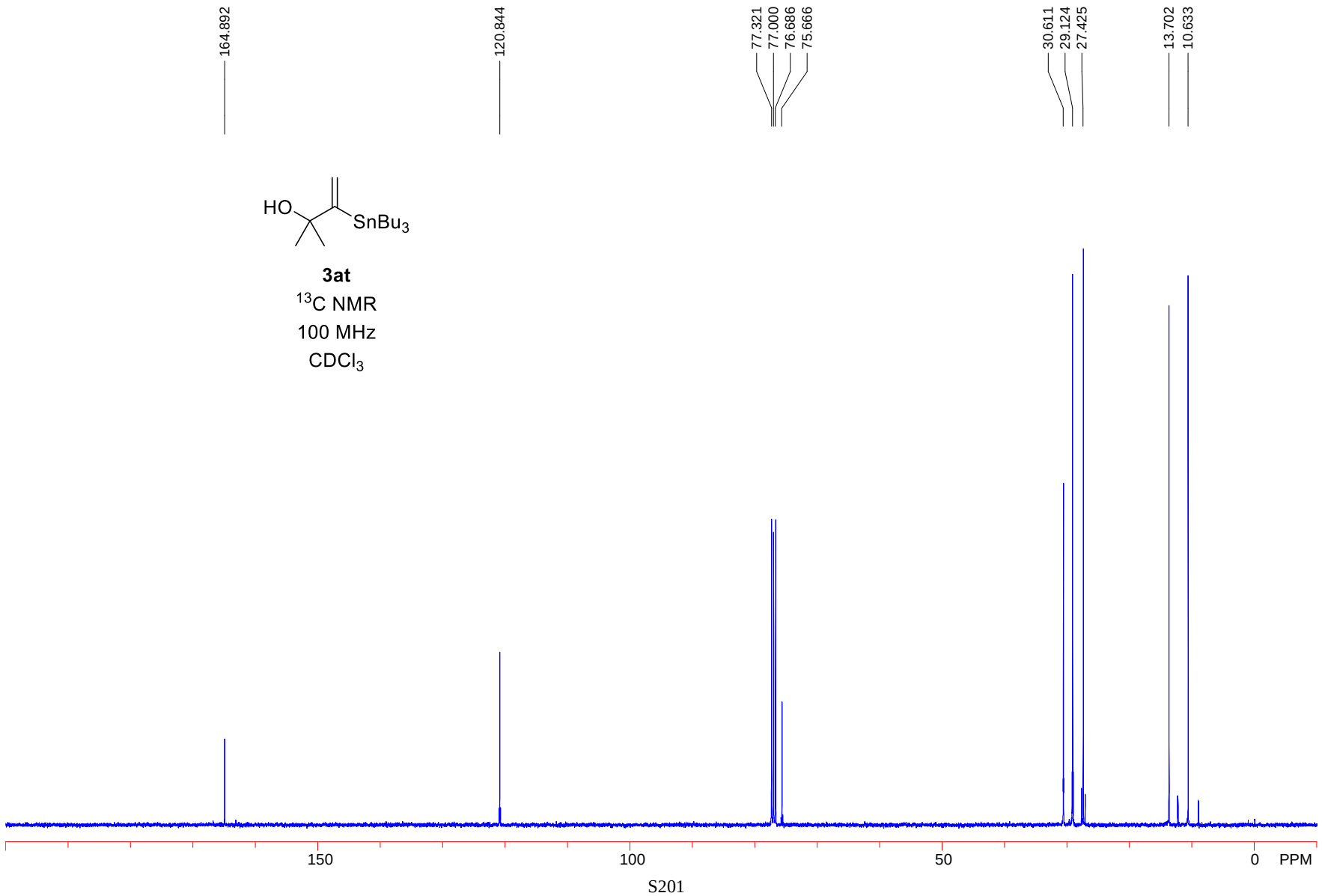
PPM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10.633
HO
SnBu3
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13C NMR
100 MHz
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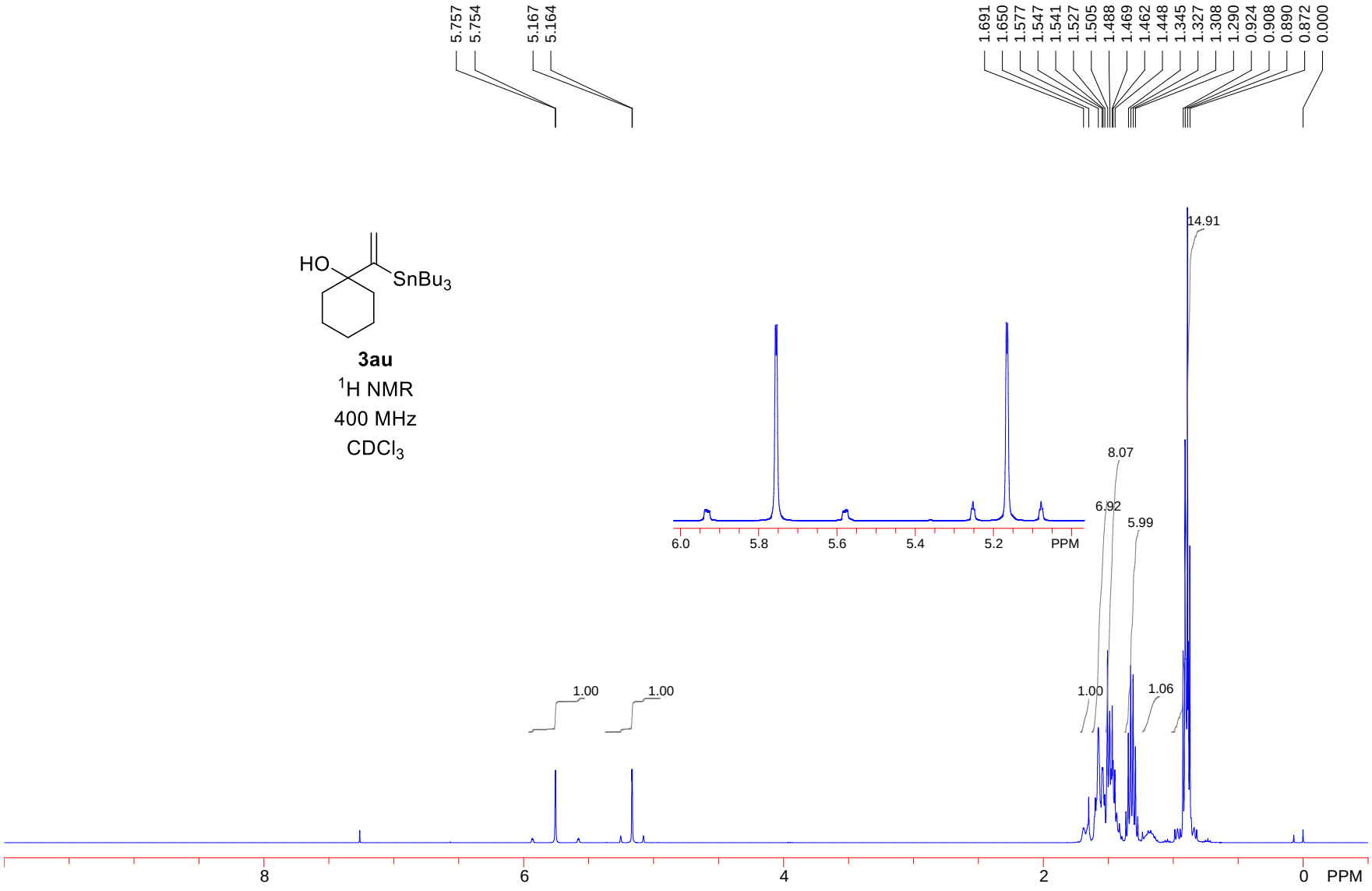
150
100
50
0
PPM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5.754
5.167
5.164
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1.650
1.577
1.547
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1.488
1.469
1.462
1.448
1.345
1.327
1.308
1.290
0.924
0.908
0.890
0.872
0.000
HO
SnBu3
3au
1H NMR
400 MHz
CDCl3
14.91
8.07
6.92
5.99
1.00
1.00
1.00
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6.0
5.8
5.6
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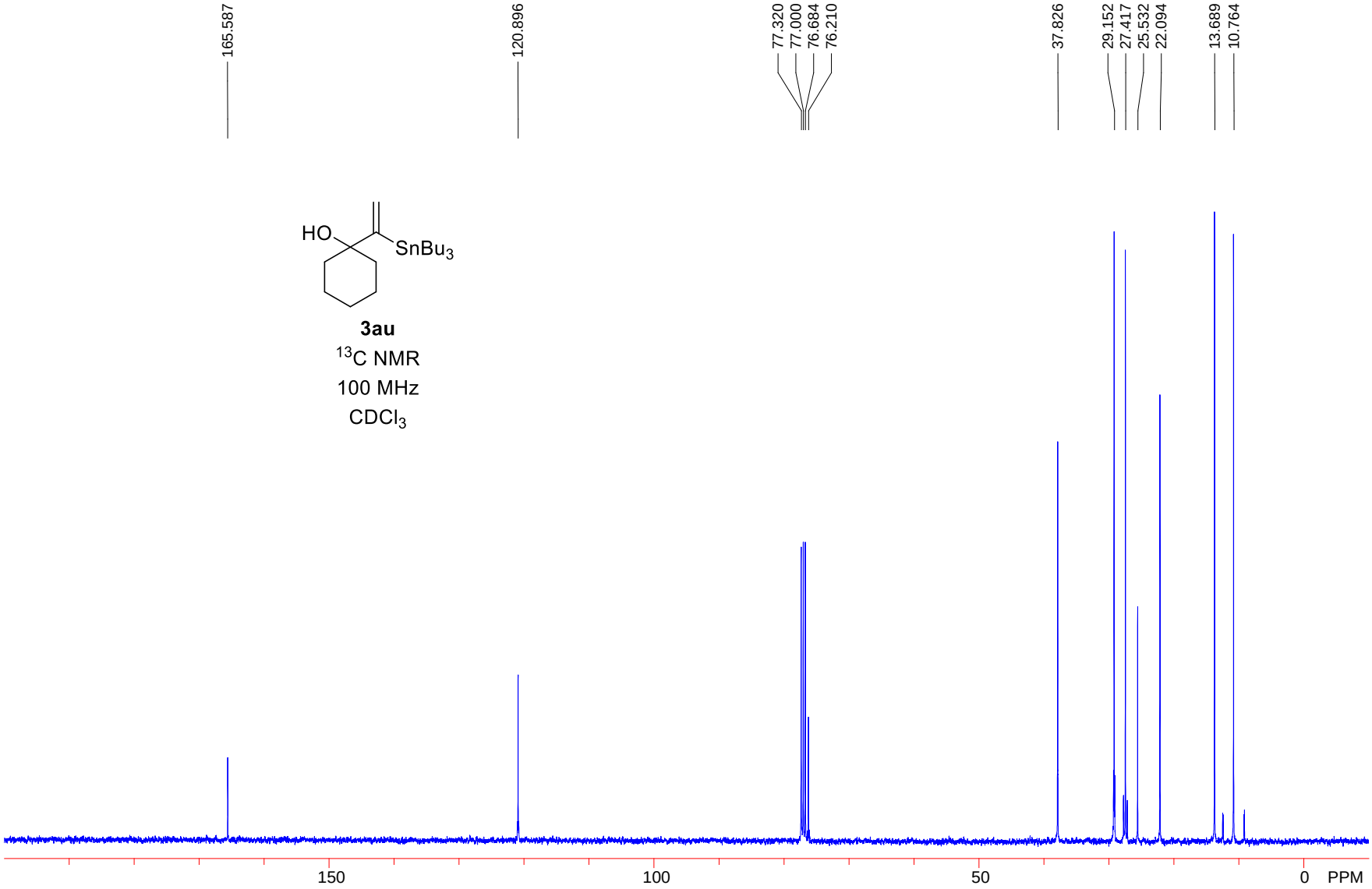
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120.896
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77.000
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76.210
37.826
29.152
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25.532
22.094
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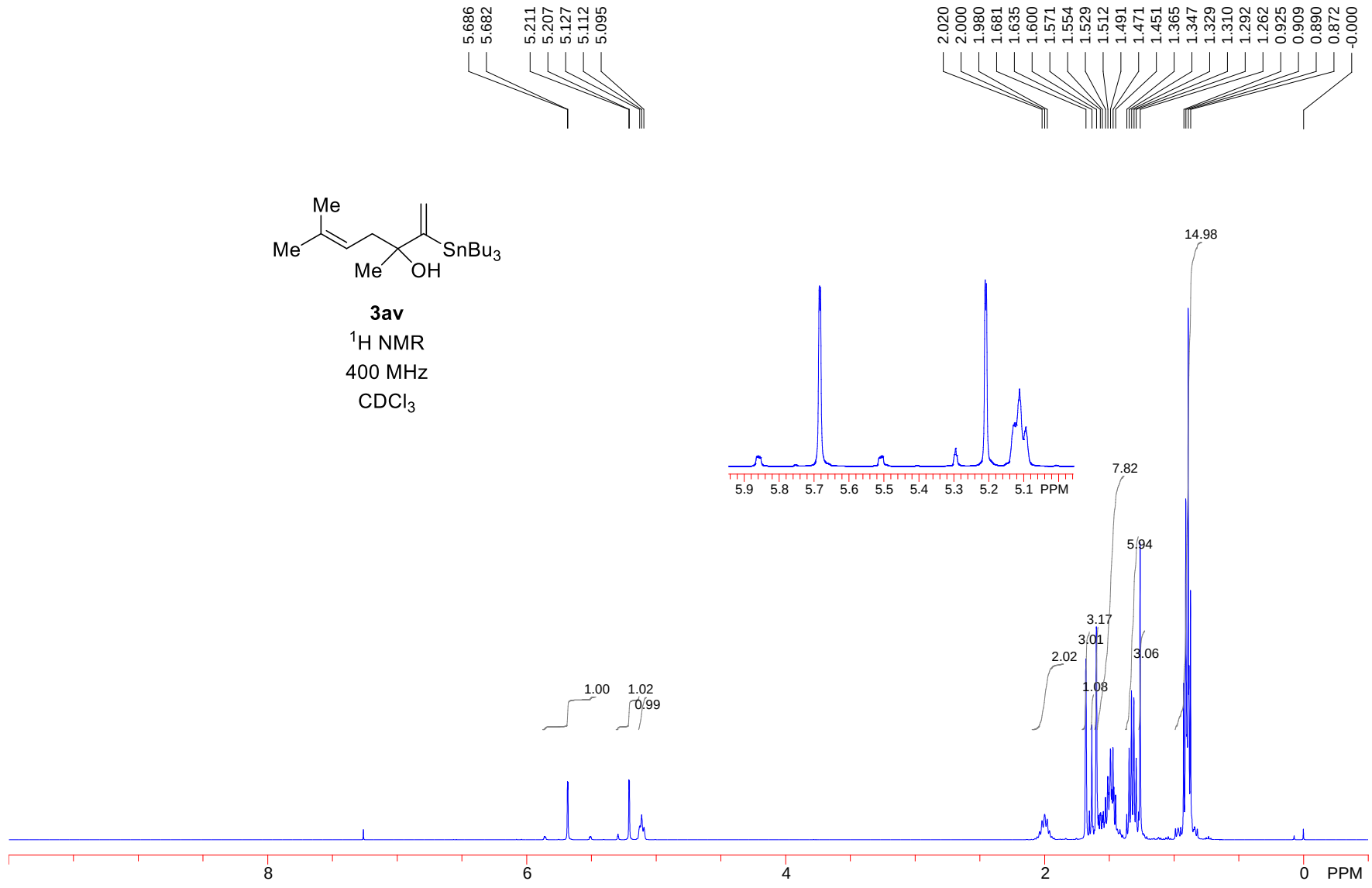
10.764
HO
SnBu3
3au
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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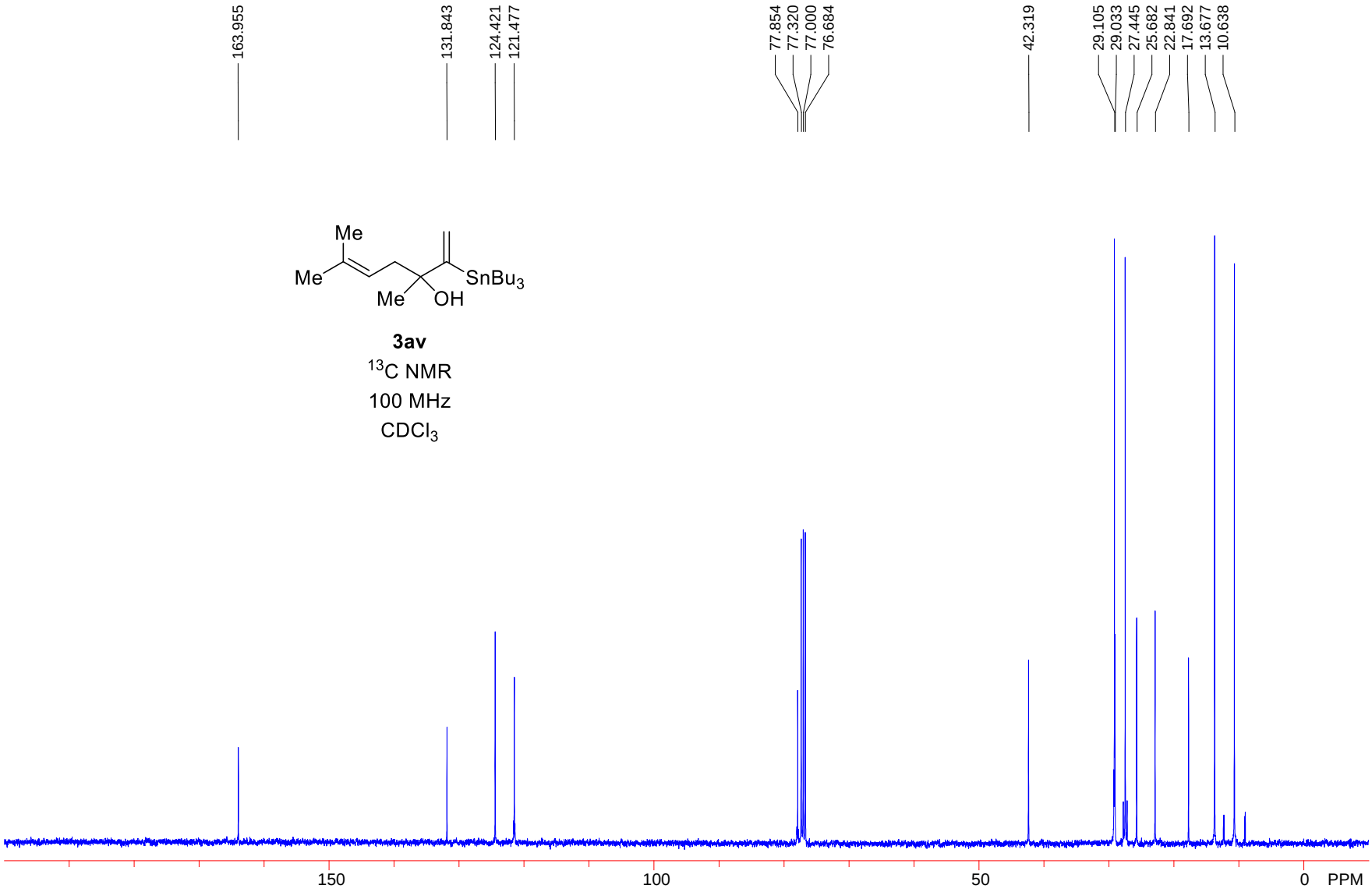
5.682
5.211
5.207
5.127
5.112
5.095
2.020
2.000
1.980
1.681
1.635
1.600
1.571
1.554
1.529
1.512
1.491
1.471
1.451
1.365
1.347
1.329
1.310
1.292
1.262
0.925
0.909
0.890
0.872
-0.000
Me
Me
Me
OH
SnBu3
3av
1H NMR
400 MHz
CDCl3
14.98
7.82
5.94
3.17
3.01
3.06
2.02
1.08
1.00
1.02
0.99
5.9 5.8 5.7 5.6 5.5 5.4 5.3 5.2 5.1 PPM
8
6
4
2
0 PPM

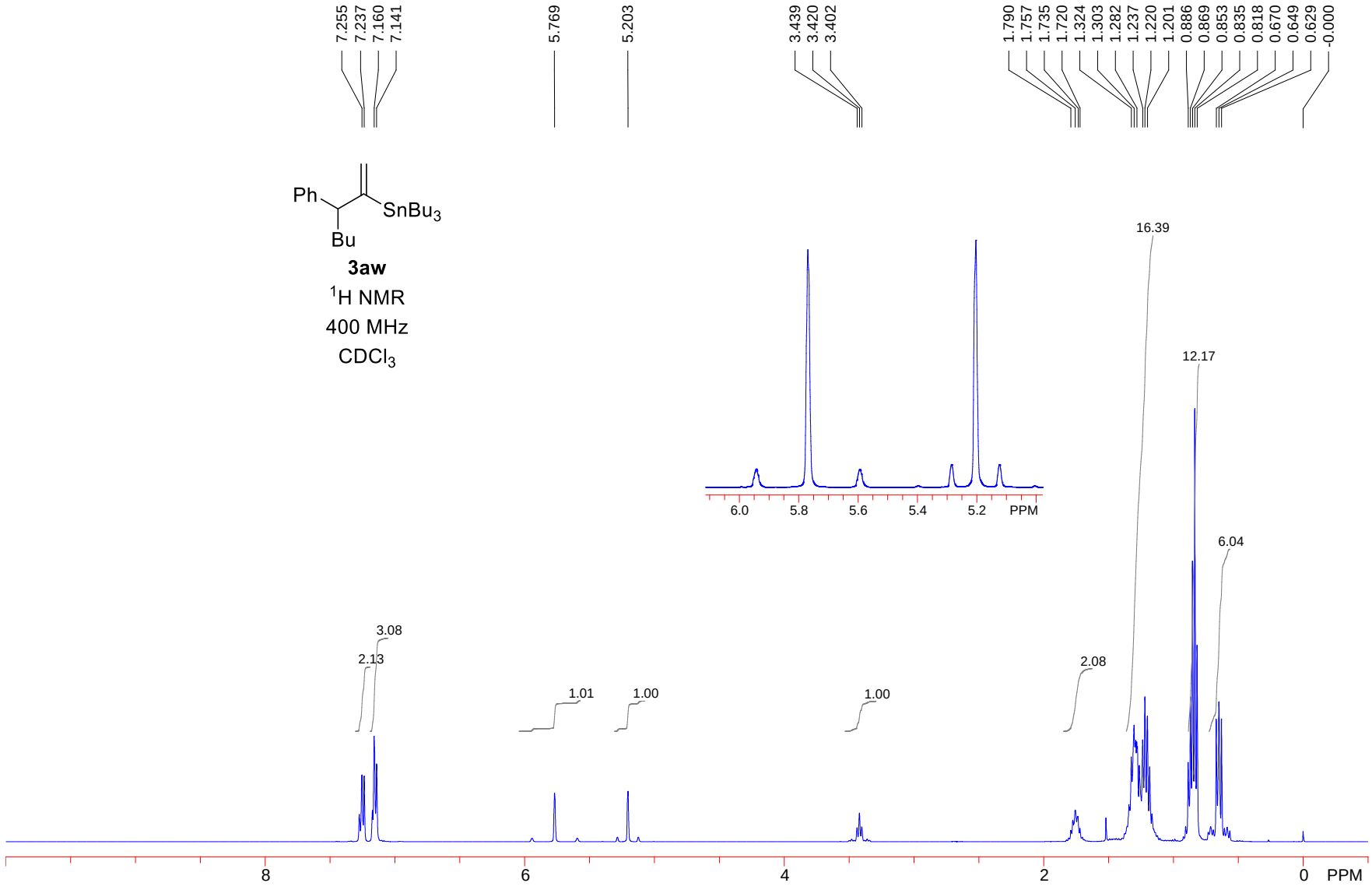


3av

^{13}C NMR

100 MHz

$CDCl_3$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7.237
7.160
7.141
5.769
5.203
3.439
3.420
3.402
1.790
1.757
1.735
1.720
1.324
1.303
1.282
1.237
1.220
1.201
0.886
0.869
0.853
0.835
0.818
0.670
0.649
0.629
-0.000
Ph
SnBu3
Bu
3aw
1H NMR
400 MHz
CDCl3
16.39
12.17
6.04
3.08
2.13
1.01
1.00
1.00
2.08
6.0
5.8
5.6
5.4
5.2
PPM
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6
4
2
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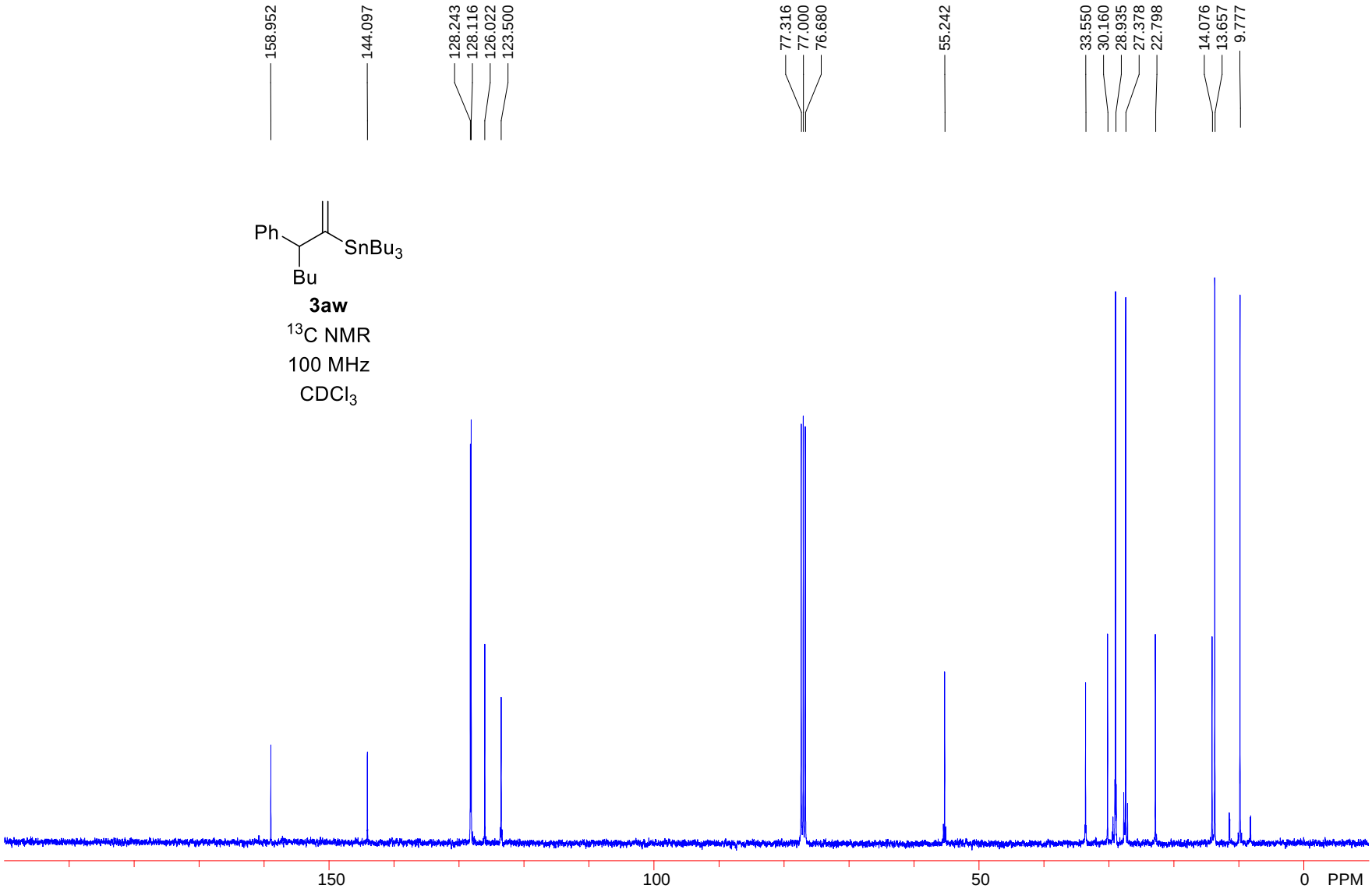
PPM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77.316
77.000
76.680
55.242
33.550
30.160
28.935
27.378
22.798
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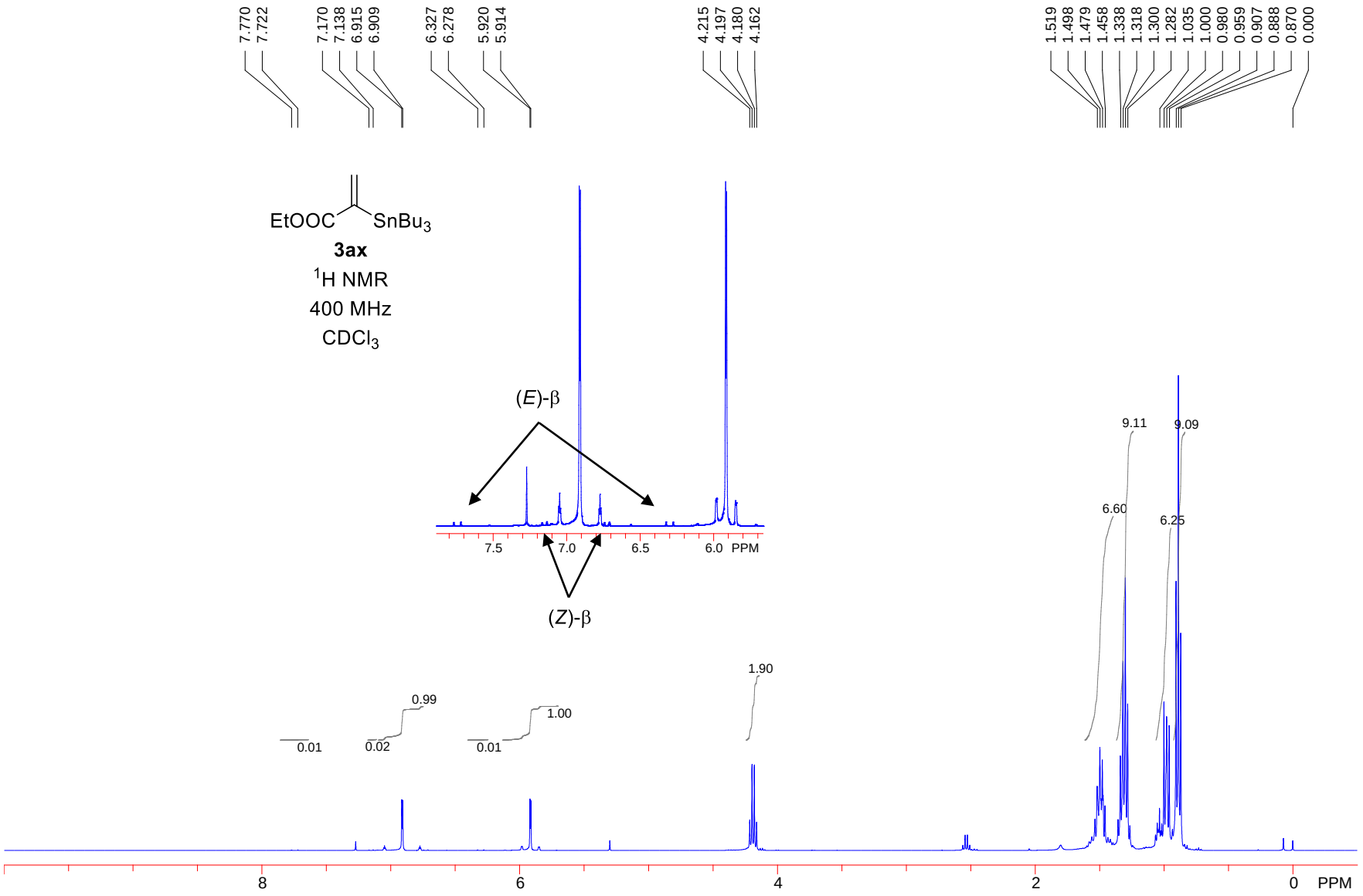
13.657
9.777
Ph
SnBu3
Bu
3aw
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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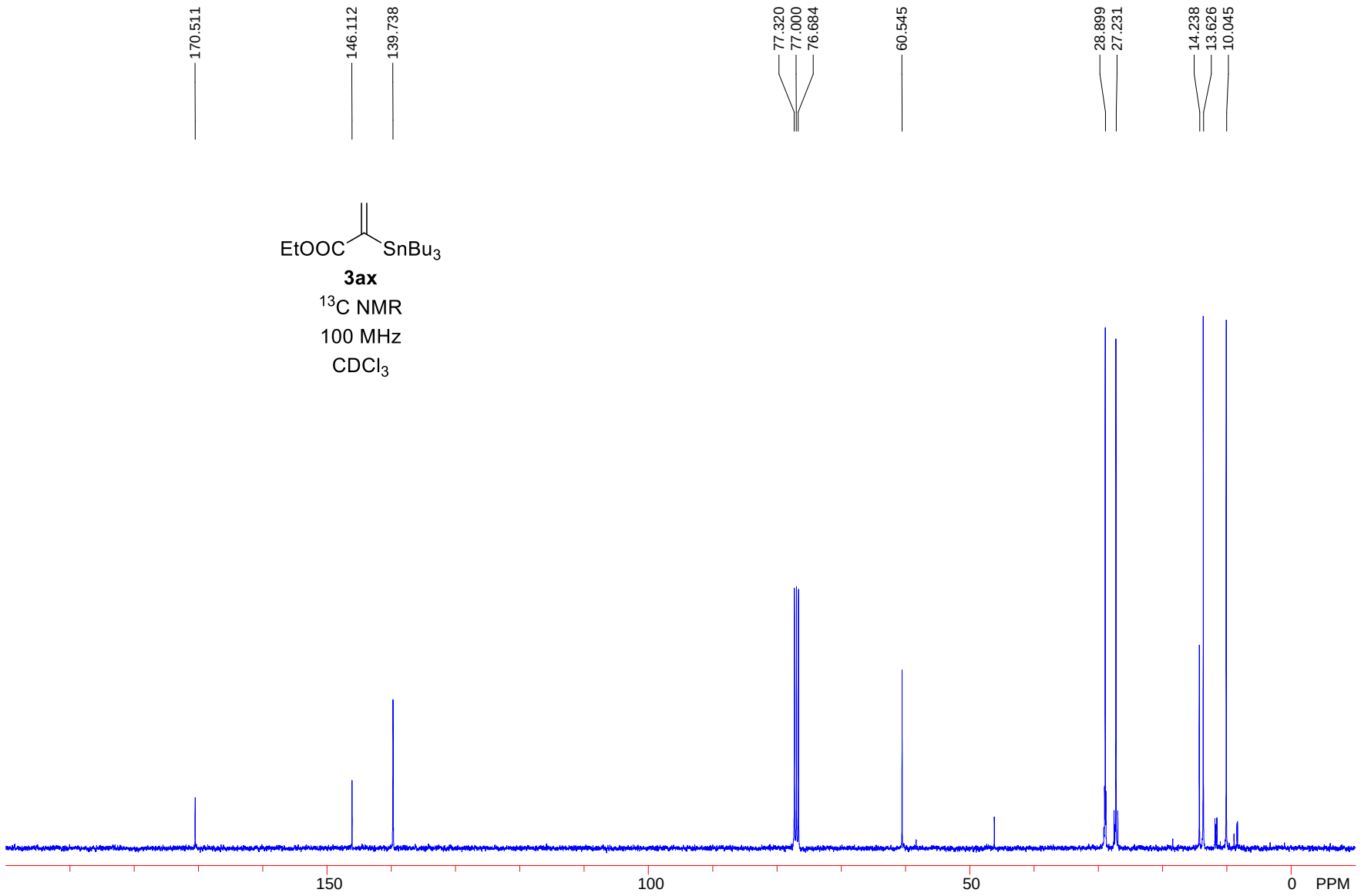
7.722
7.170
7.138
6.915
6.909
6.327
6.278
5.920
5.914
4.215
4.197
4.180
4.162
1.519
1.498
1.479
1.458
1.338
1.318
1.300
1.282
1.035
1.000
0.980
0.959
0.907
0.888
0.870
0.000
EtOOC
SnBu3
3ax
1H NMR
400 MHz
CDCl3
(E)-β
(Z)-β
7.5
7.0
6.5
6.0 PPM
9.11
9.09
6.60
6.25
1.90
0.99
1.00
0.01
0.02
0.01
8
6
4
2
0 PPM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146.112
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77.000
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60.545
28.899
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10.045
EtOOC
SnBu3
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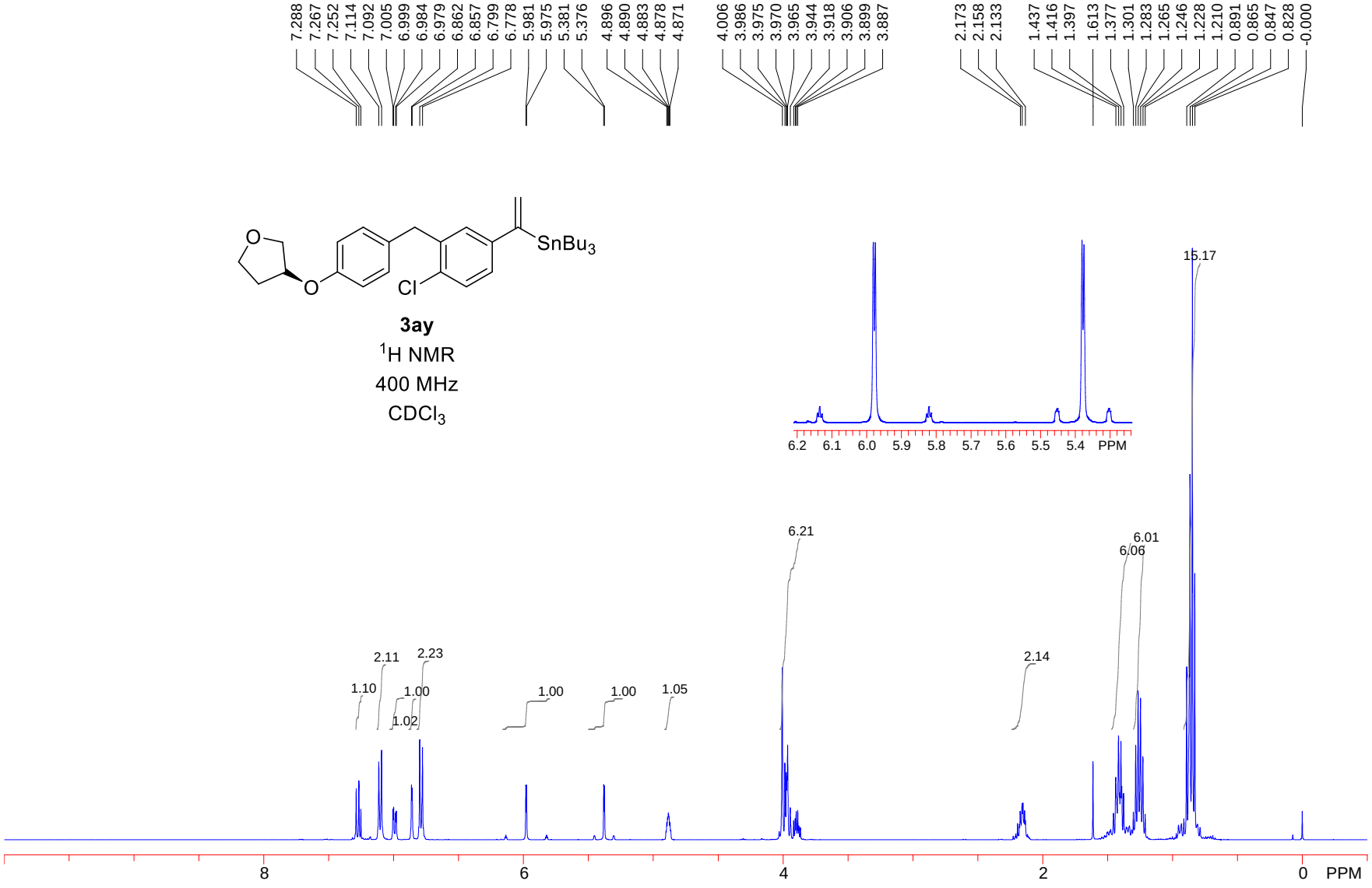
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM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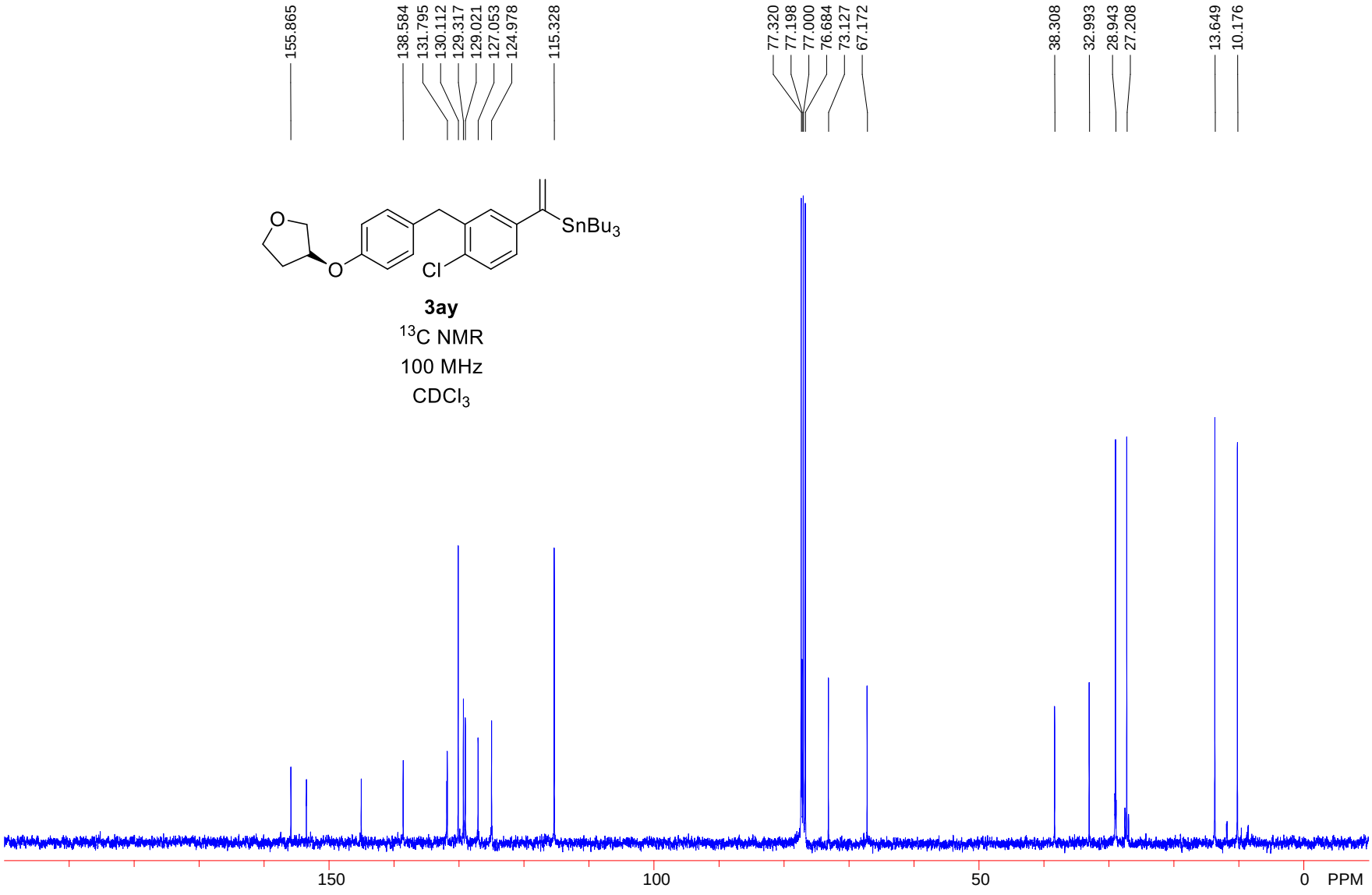
7.092
7.005
6.999
6.984
6.979
6.862
6.857
6.799
6.778
5.981
5.975
5.381
5.376
4.896
4.890
4.883
4.878
4.871
4.006
3.986
3.975
3.970
3.965
3.944
3.918
3.906
3.899
3.887
2.173
2.158
2.133
1.437
1.416
1.397
1.613
1.377
1.301
1.283
1.265
1.246
1.228
1.210
0.891
0.865
0.847
0.828
-0.000
O
O
Cl
SnBu3
3ay
1H NMR
400 MHz
CDCl3
15.17
6.21
6.01
6.06
2.14
2.11
2.23
1.10
1.00
1.02
1.00
1.00
1.05
6.2 6.1 6.0 5.9 5.8 5.7 5.6 5.5 5.4 PPM
8
6
4
2
0 PPM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77.000
76.684
73.127
67.172
38.308
32.993
28.943
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O
O
Cl
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13C NMR
100 MHz
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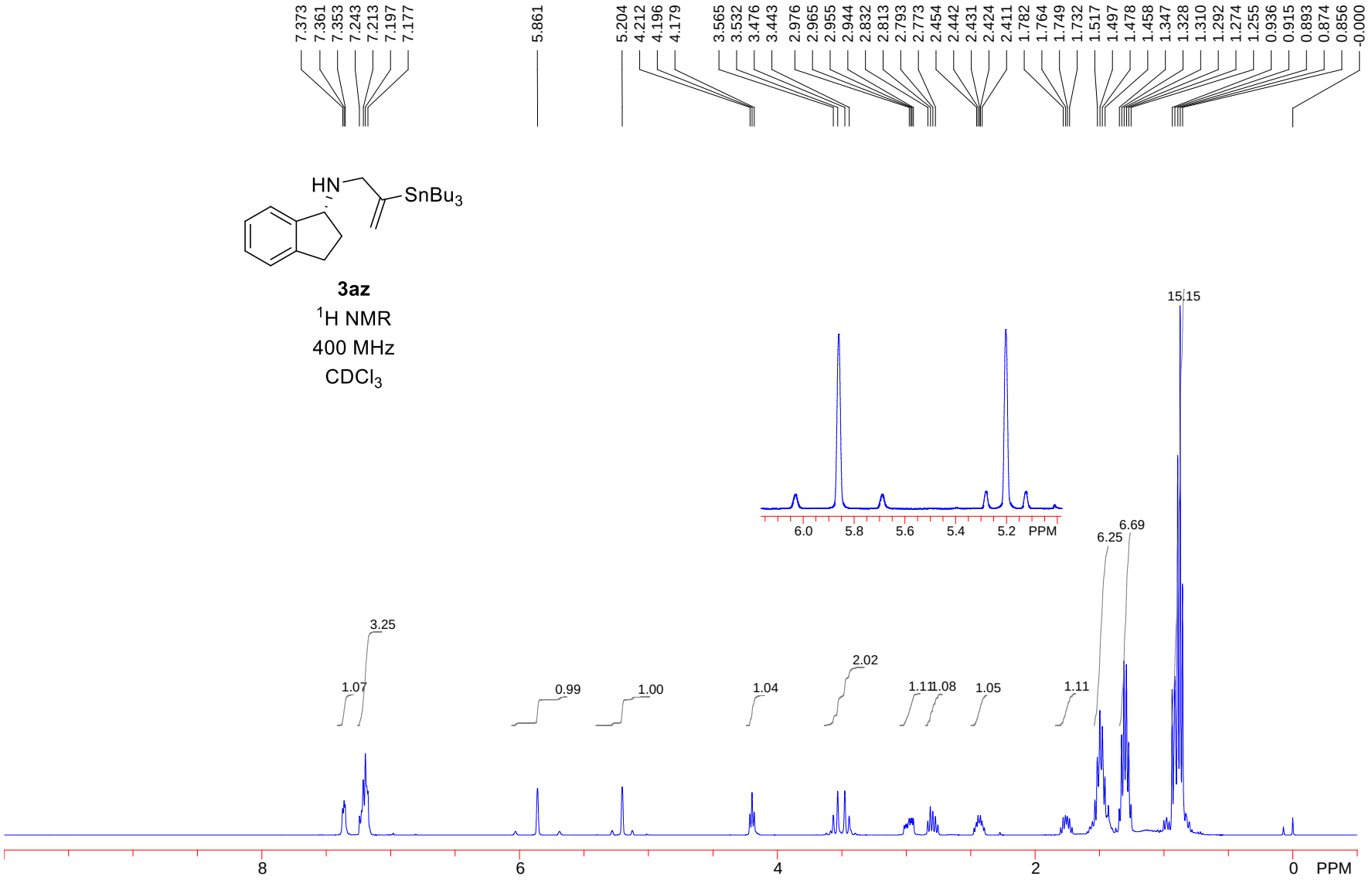
PPM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7.177
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4.196
4.179
3.565
3.532
3.476
3.443
2.976
2.965
2.955
2.944
2.832
2.813
2.793
2.773
2.454
2.442
2.431
2.424
2.411
1.782
1.764
1.749
1.732
1.517
1.497
1.478
1.458
1.347
1.328
1.310
1.292
1.274
1.255
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0.915
0.893
0.874
0.856
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HN
SnBu3
3az
1H NMR
400 MHz
CDCl3
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6.69
6.25
3.25
2.02
1.07
0.99
1.00
1.04
1.11
1.08
1.05
1.11
6.0
5.8
5.6
5.4
5.2
PPM
8
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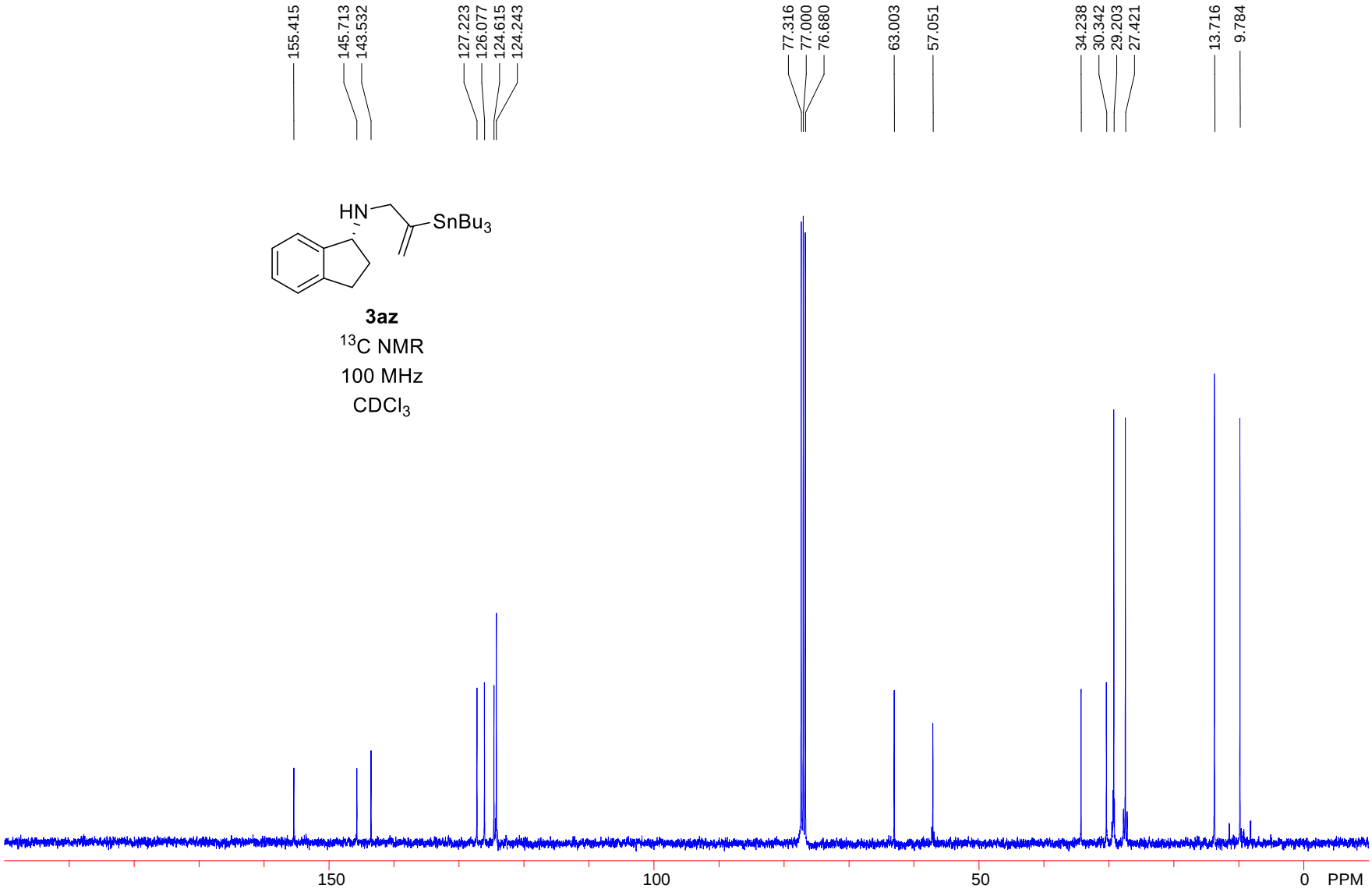
4
2
0
PPM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30.342
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9.784
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13C NMR
100 MHz
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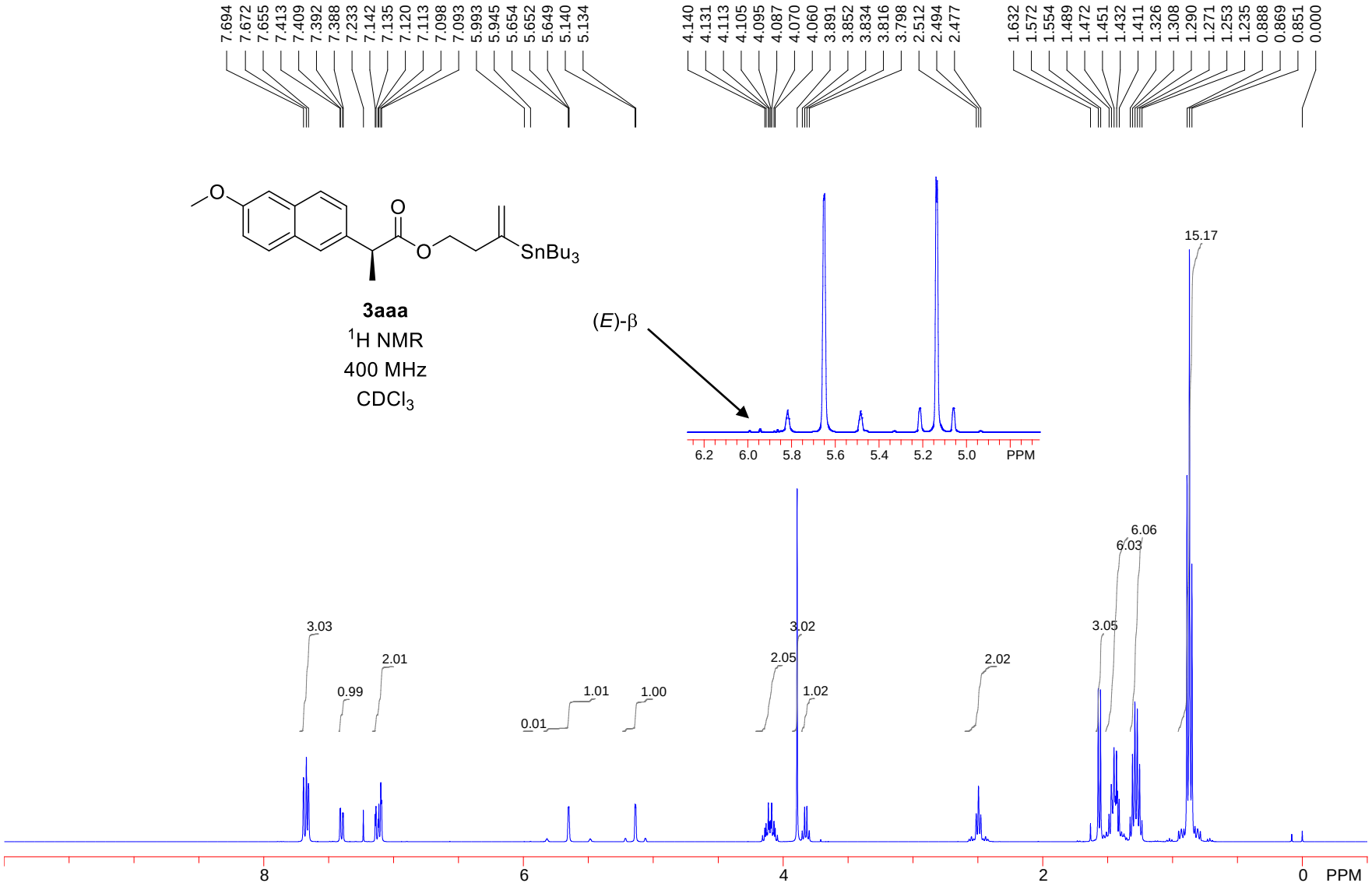
PPM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7.233
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7.120
7.113
7.098
7.093
5.993
5.945
5.654
5.652
5.649
5.140
5.134
4.140
4.131
4.113
4.105
4.095
4.087
4.070
4.060
3.891
3.852
3.834
3.816
3.798
2.512
2.494
2.477
1.632
1.572
1.554
1.489
1.472
1.451
1.432
1.411
1.326
1.308
1.290
1.271
1.253
1.235
0.888
0.869
0.851
0.000
O
O
O
SnBu3
3aaa
1H NMR
400 MHz
CDCl3
(E)-β
6.2
6.0
5.8
5.6
5.4
5.2
5.0
PPM
15.17
6.06
6.03
3.03
3.05
3.02
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2.01
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0.99
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1.00
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0.01
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6
4
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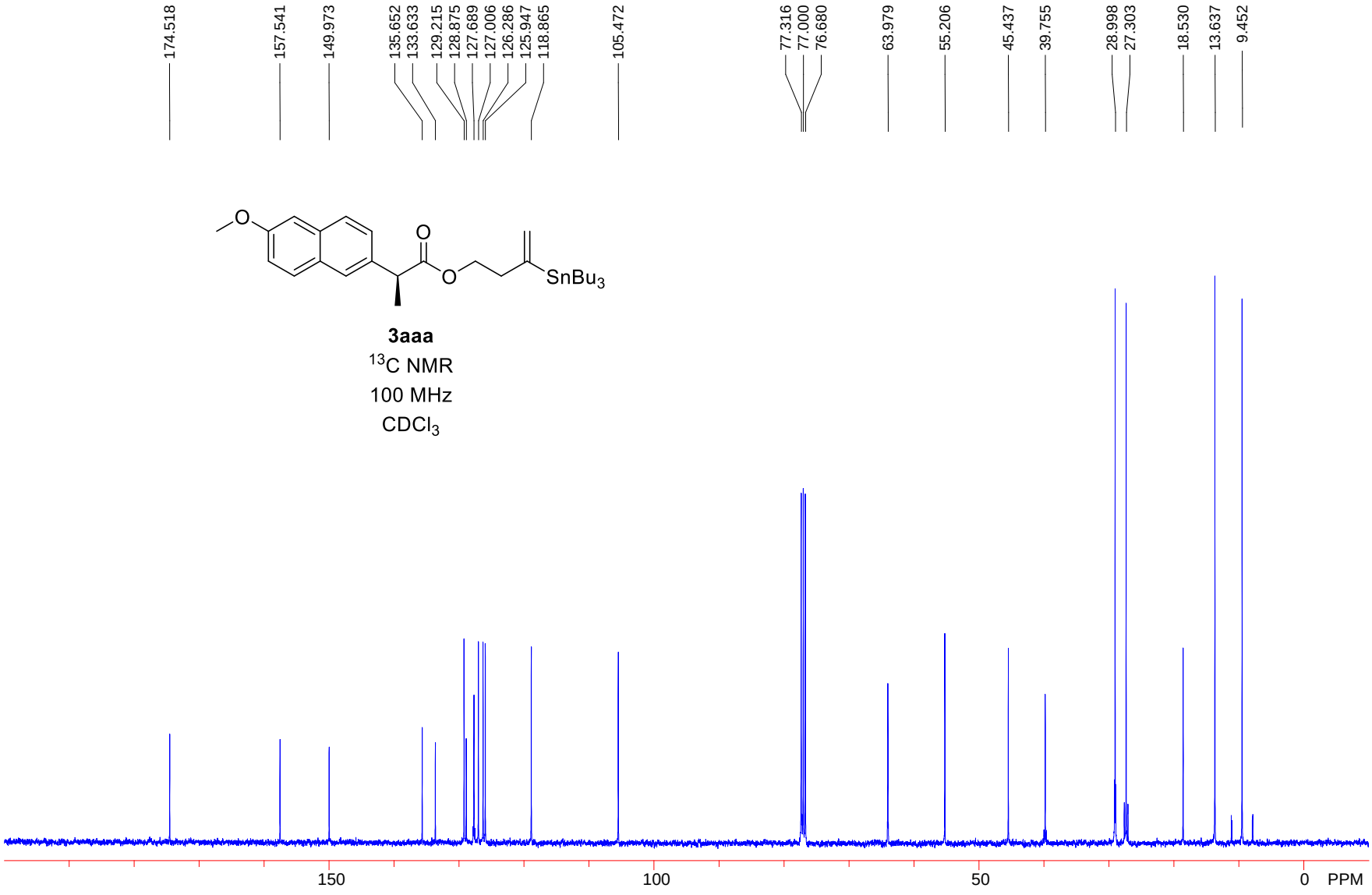
PPM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118.865
105.472
77.316
77.000
76.680
63.979
55.206
45.437
39.755
28.998
27.303
18.530
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O
O
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13C NMR
100 MHz
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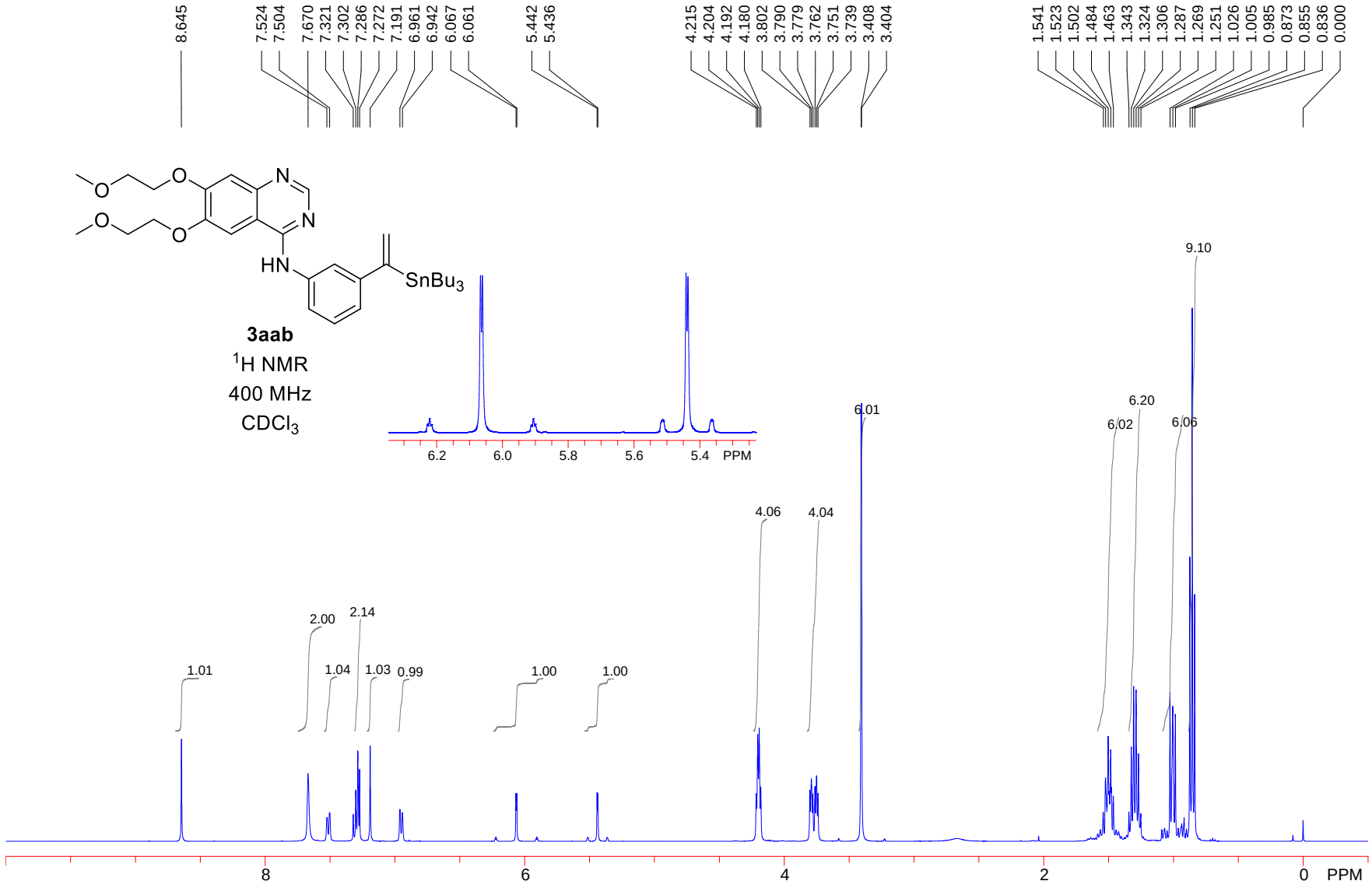
PPM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7.302
7.286
7.272
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6.942
6.067
6.061
5.442
5.436
4.215
4.204
4.192
4.180
3.802
3.790
3.779
3.762
3.751
3.739
3.408
3.404
1.541
1.523
1.502
1.484
1.463
1.343
1.324
1.306
1.287
1.269
1.251
1.026
1.005
0.985
0.873
0.855
0.836
0.000
O
O
O
O
N
N
HN
SnBu3
3aab
1H NMR
400 MHz
CDCl3
6.2
6.0
5.8
5.6
5.4
PPM
9.10
6.20
6.02
6.06
6.01
4.06
4.04
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1.04
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1.00
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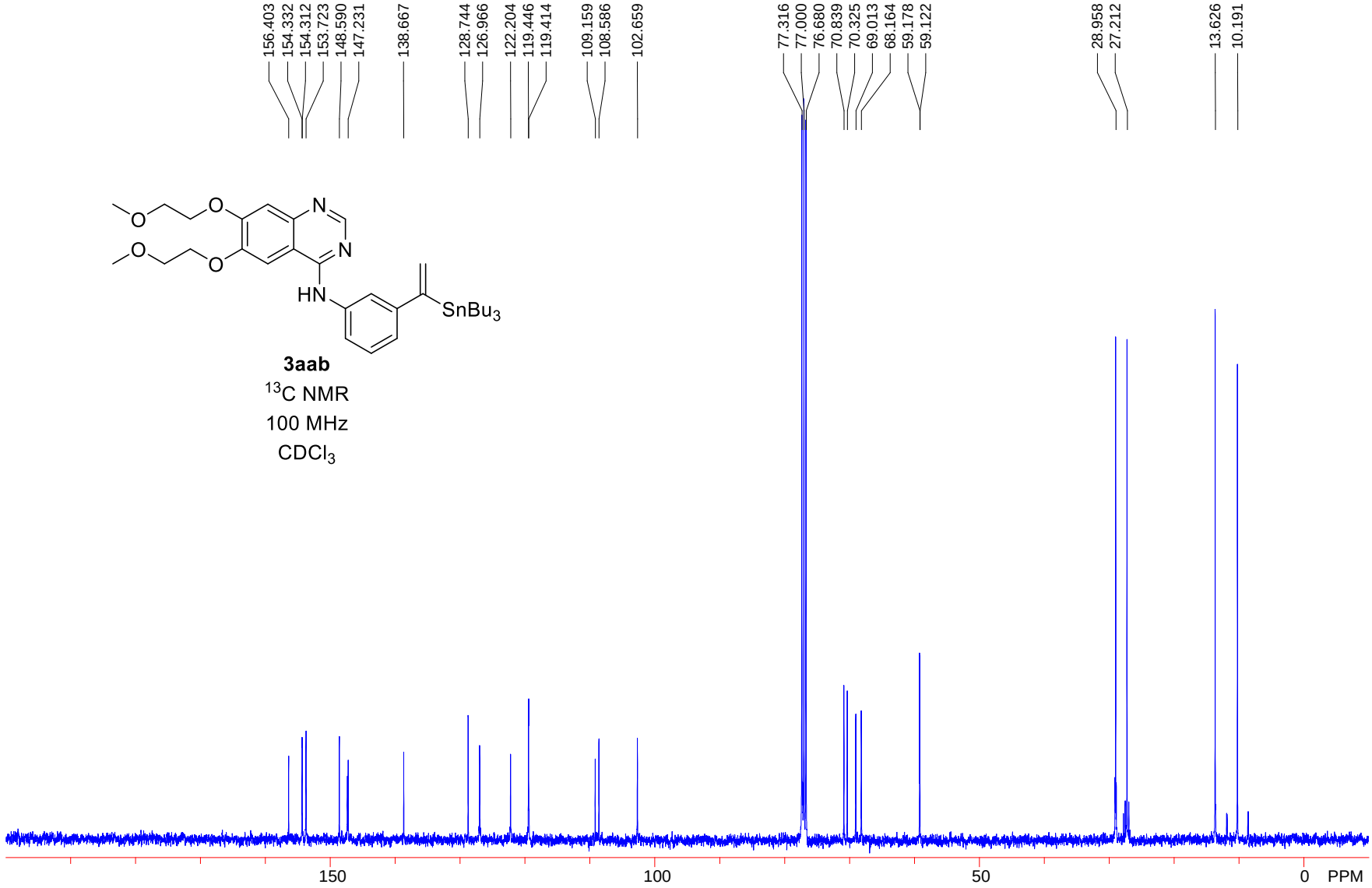
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108.586
102.659
77.316
77.000
76.680
70.839
70.325
69.013
68.164
59.178
59.122
28.958
27.212
13.626
10.191
O
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O
N
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HN
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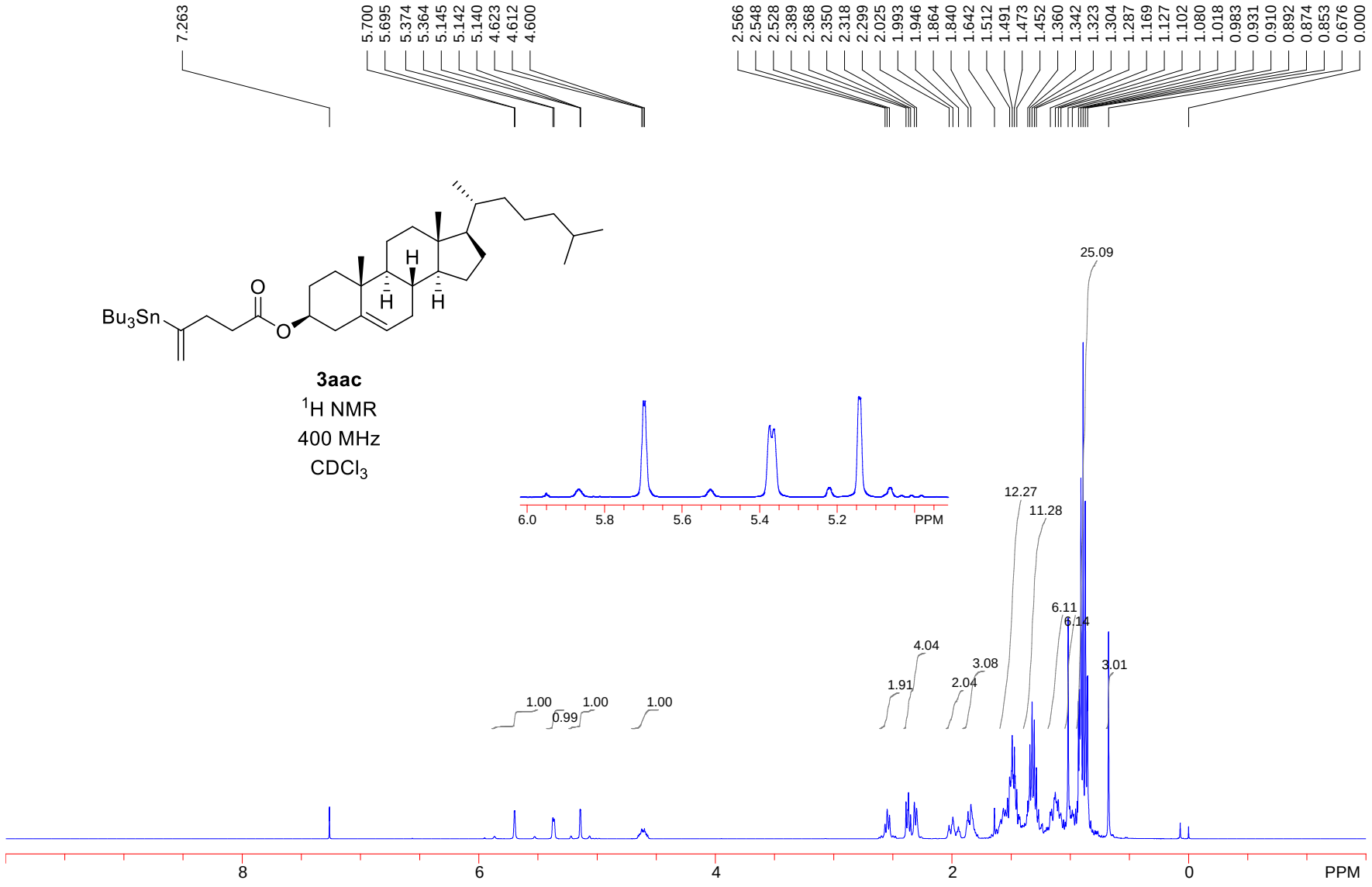
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2.318
2.299
2.025
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1.864
1.840
1.642
1.512
1.491
1.473
1.452
1.360
1.342
1.323
1.304
1.287
1.169
1.127
1.102
1.080
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0.910
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0.874
0.853
0.676
0.000
Bu3Sn
O
O
H
H
H
3aac
1H NMR
400 MHz
CDCl3
6.0
5.8
5.6
5.4
5.2
PPM
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12.27
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6.11
6.14
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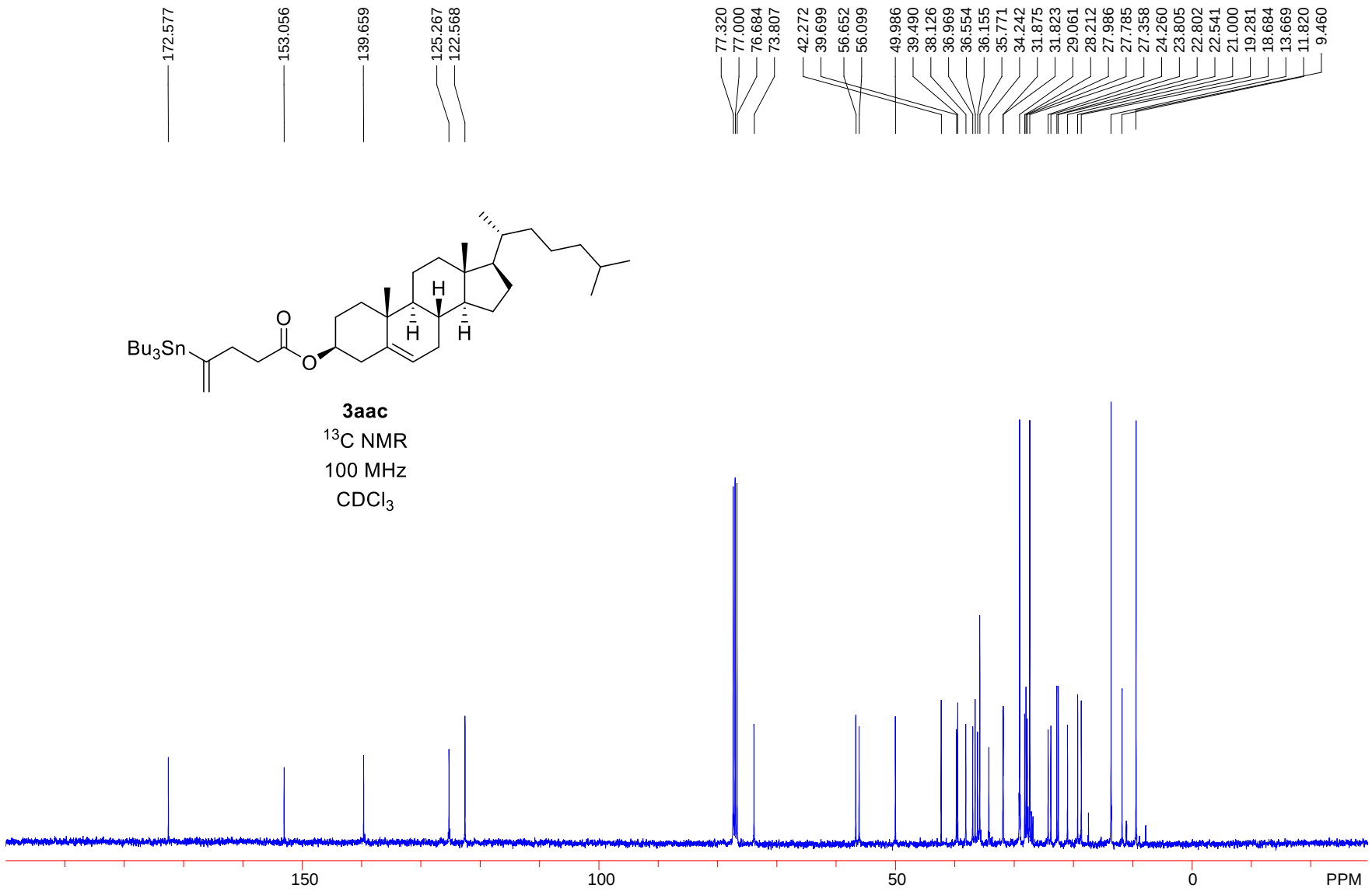
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49.986
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36.554
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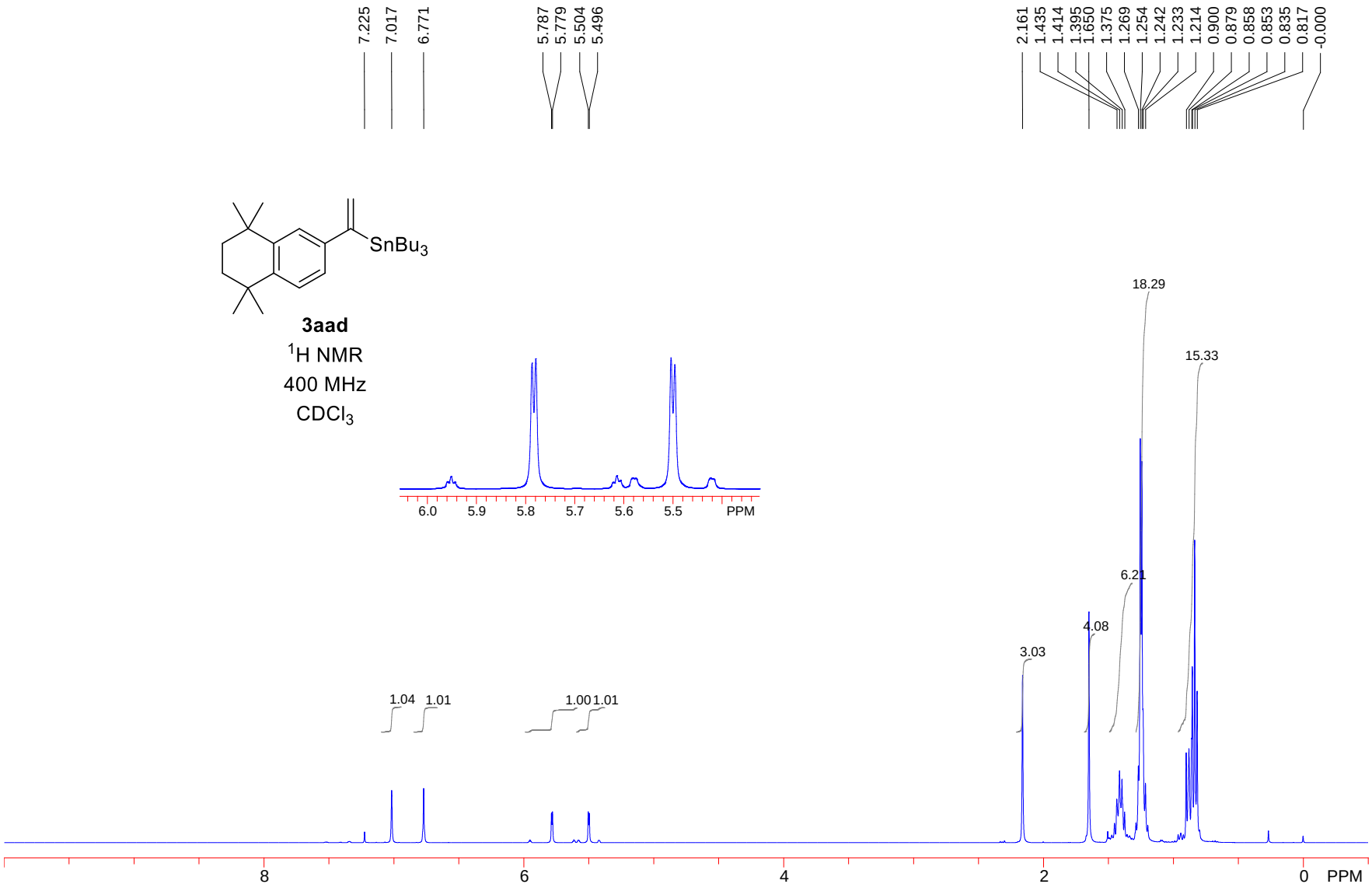
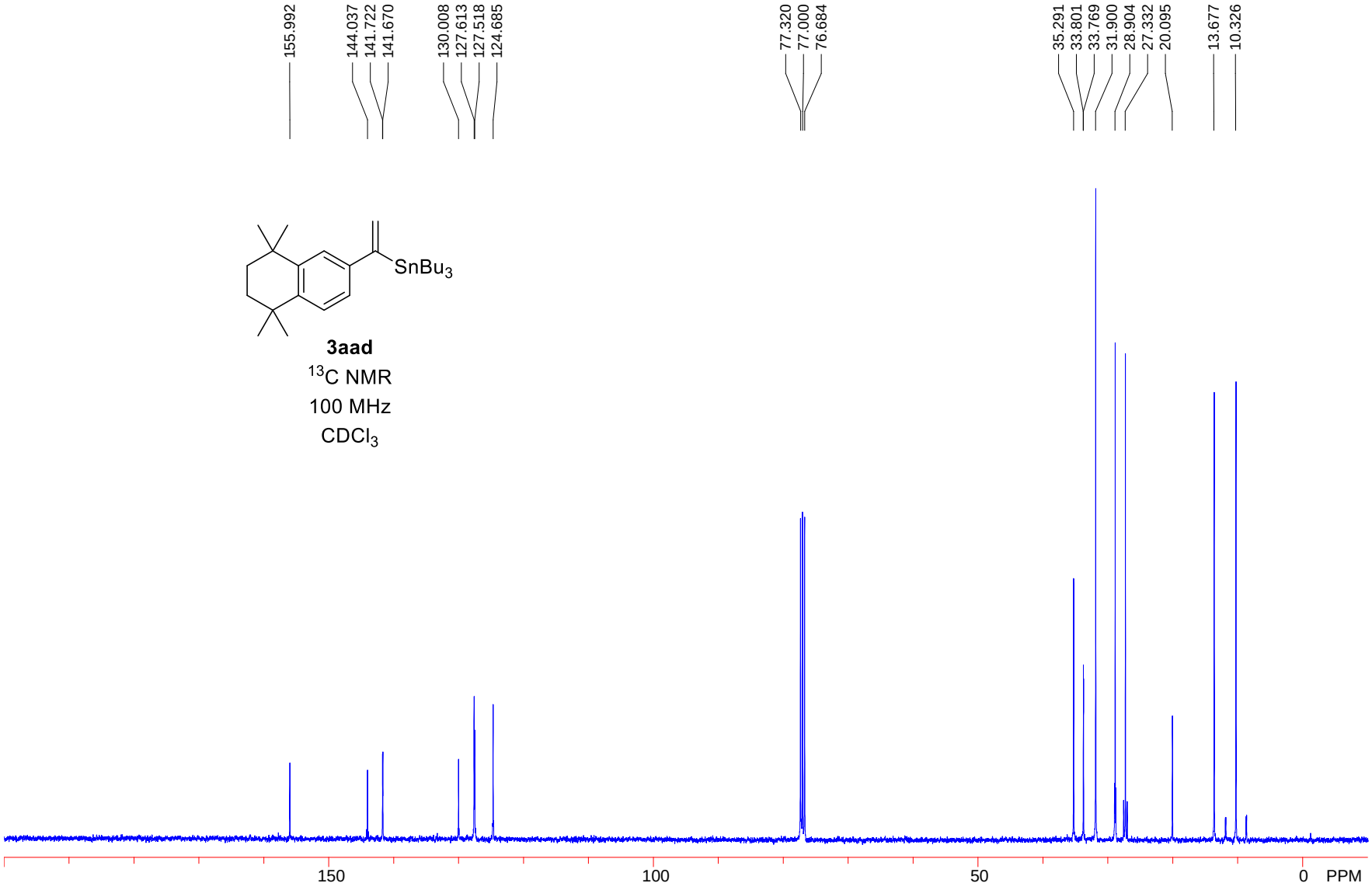
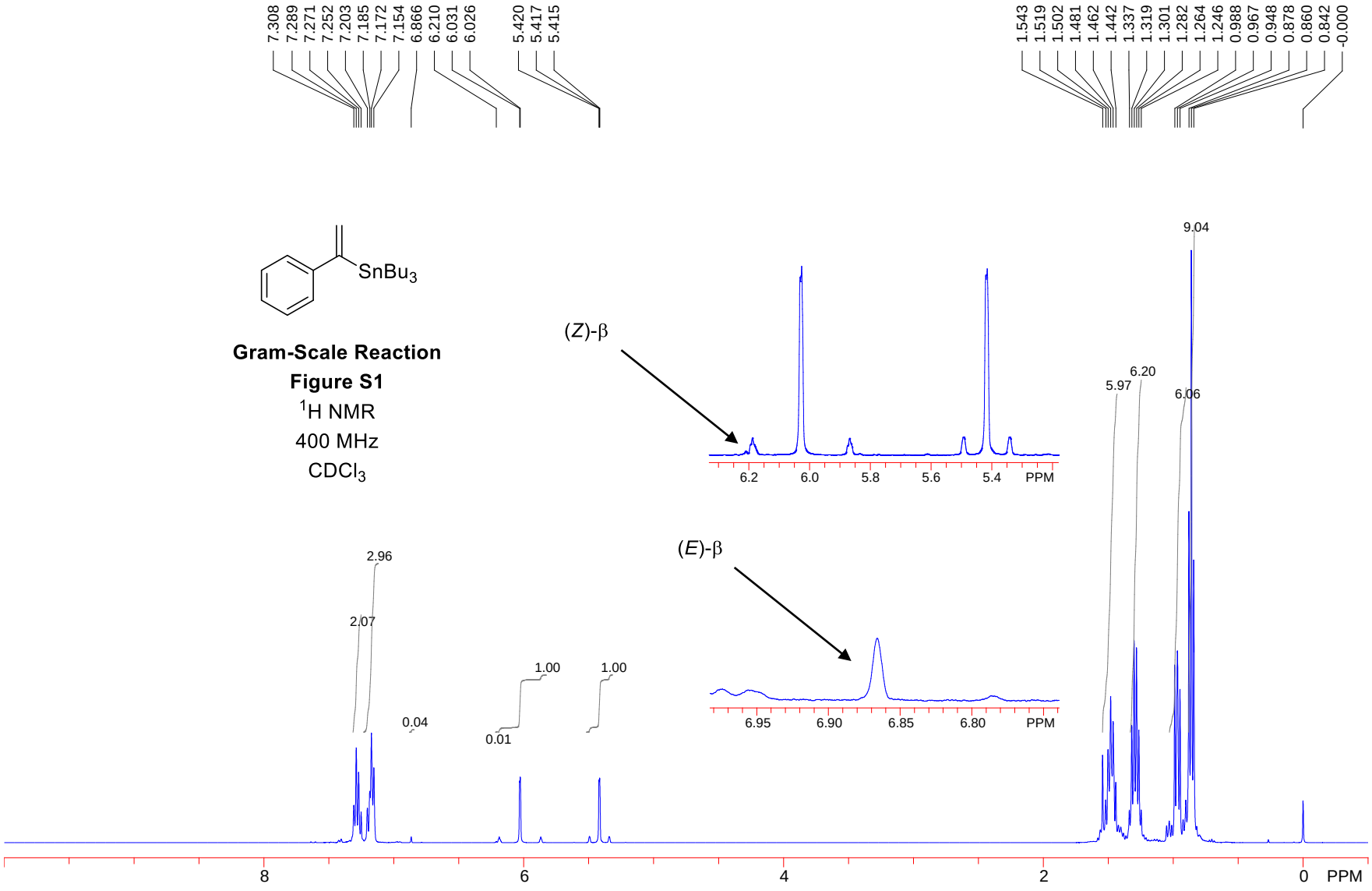
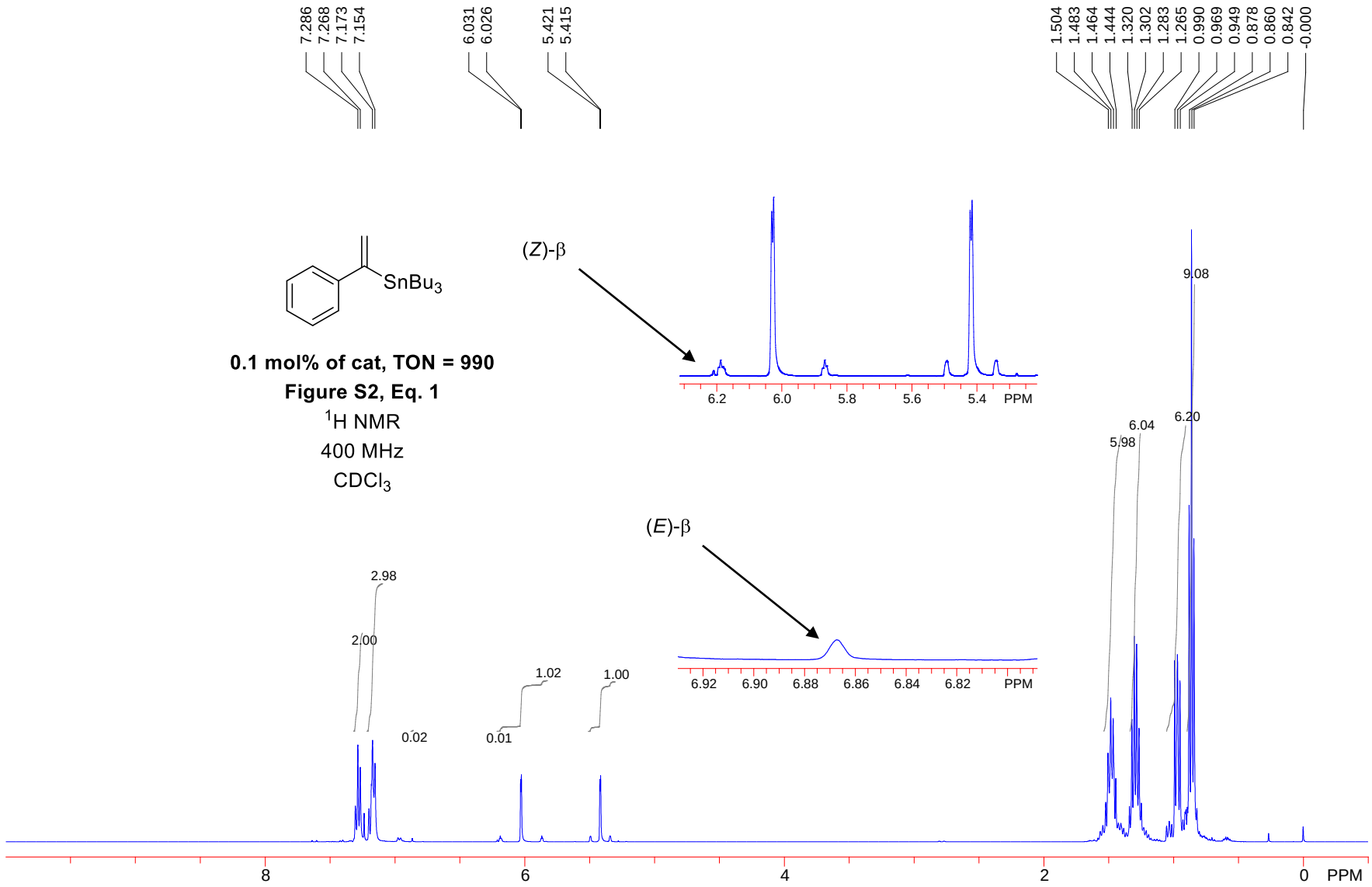
27.785
27.358
24.260
23.805
22.802
22.541
21.000
19.281
18.684
13.669
11.820
9.460
Bu3Sn
O
O
H
H
H
3aac
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM


7.225
7.017
6.771
5.787
5.779
5.504
5.496
2.161
1.435
1.414
1.395
1.650
1.375
1.269
1.254
1.242
1.233
1.214
0.900
0.879
0.858
0.853
0.835
0.817
-0.000
SnBu3
3aad
1H NMR
400 MHz
CDCl3
6.0
5.9
5.8
5.7
5.6
5.5
PPM
18.29
15.33
6.21
4.08
3.03
1.04
1.01
1.00
1.01
8
6
4
2
0
PPM


155.992
144.037
141.722
141.670
130.008
127.613
127.518
124.685
77.320
77.000
76.684
35.291
33.801
33.769
31.900
28.904
27.332
20.095
13.677
10.326
SnBu3
3aad
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM


7.308
7.289
7.271
7.252
7.203
7.185
7.172
7.154
6.866
6.210
6.031
6.026
5.420
5.417
5.415
1.543
1.519
1.502
1.481
1.462
1.442
1.337
1.319
1.301
1.282
1.264
1.246
0.988
0.967
0.948
0.878
0.860
0.842
-0.000
SnBu3
Gram-Scale Reaction
Figure S1
1H NMR
400 MHz
CDCl3
(Z)-β
(E)-β
9.04
6.20
5.97
6.06
2.96
2.07
0.04
0.01
1.00
1.00
6.2
6.0
5.8
5.6
5.4
PPM
6.95
6.90
6.85
6.80
PPM
8
6
4
2
0
PPM



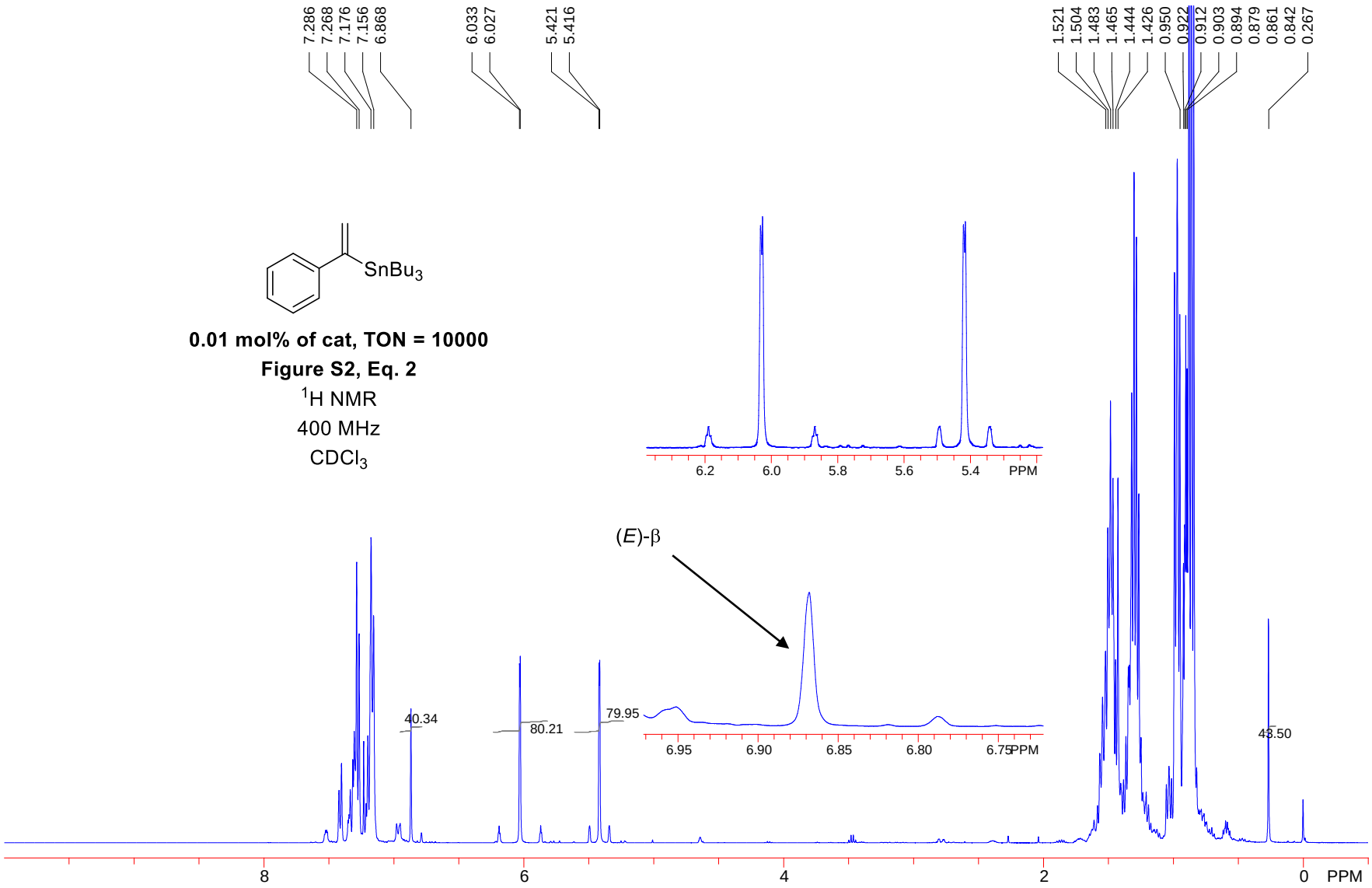
0.1 mol% of cat, TON = 990

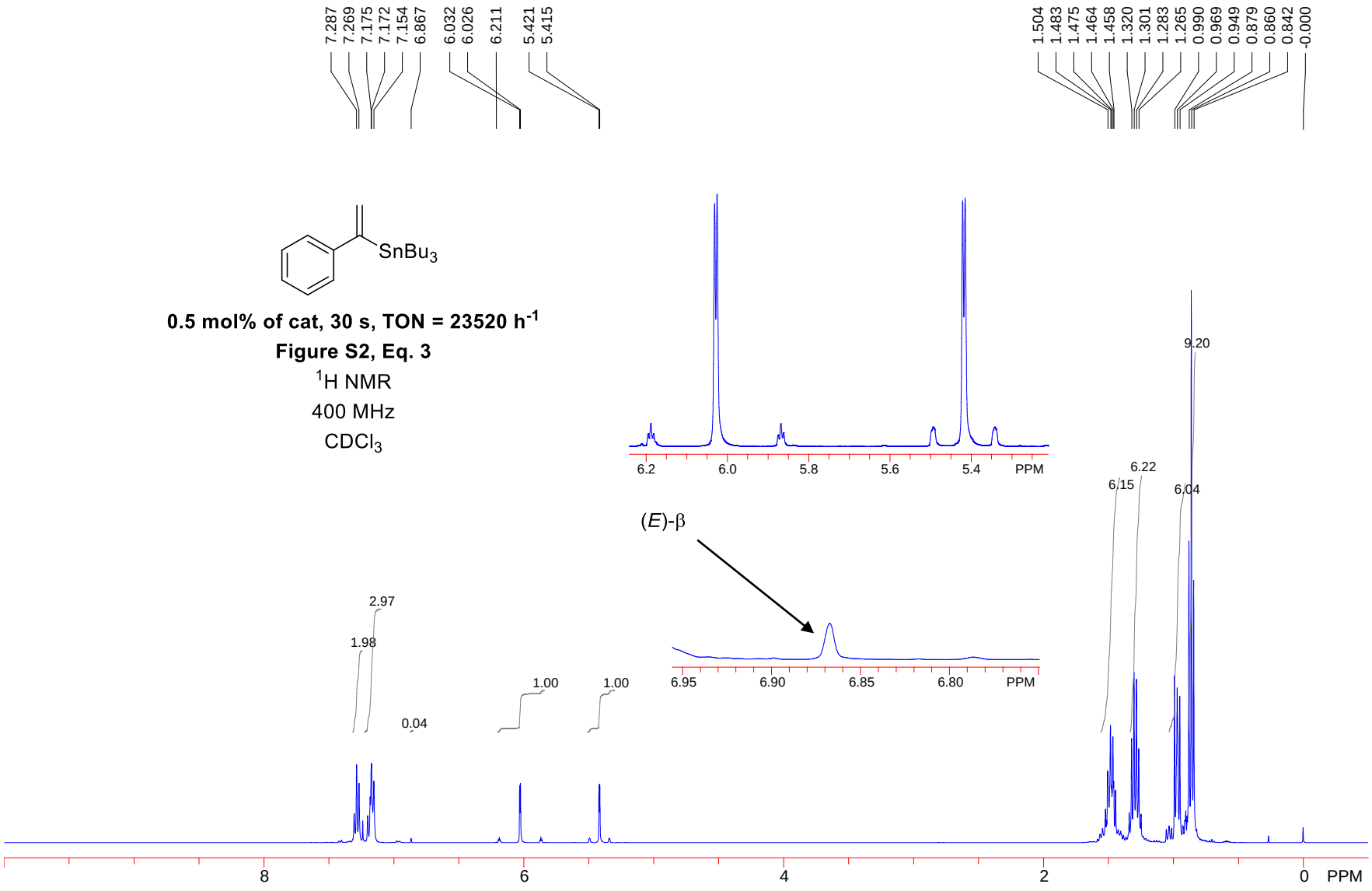
Figure S2, Eq. 1

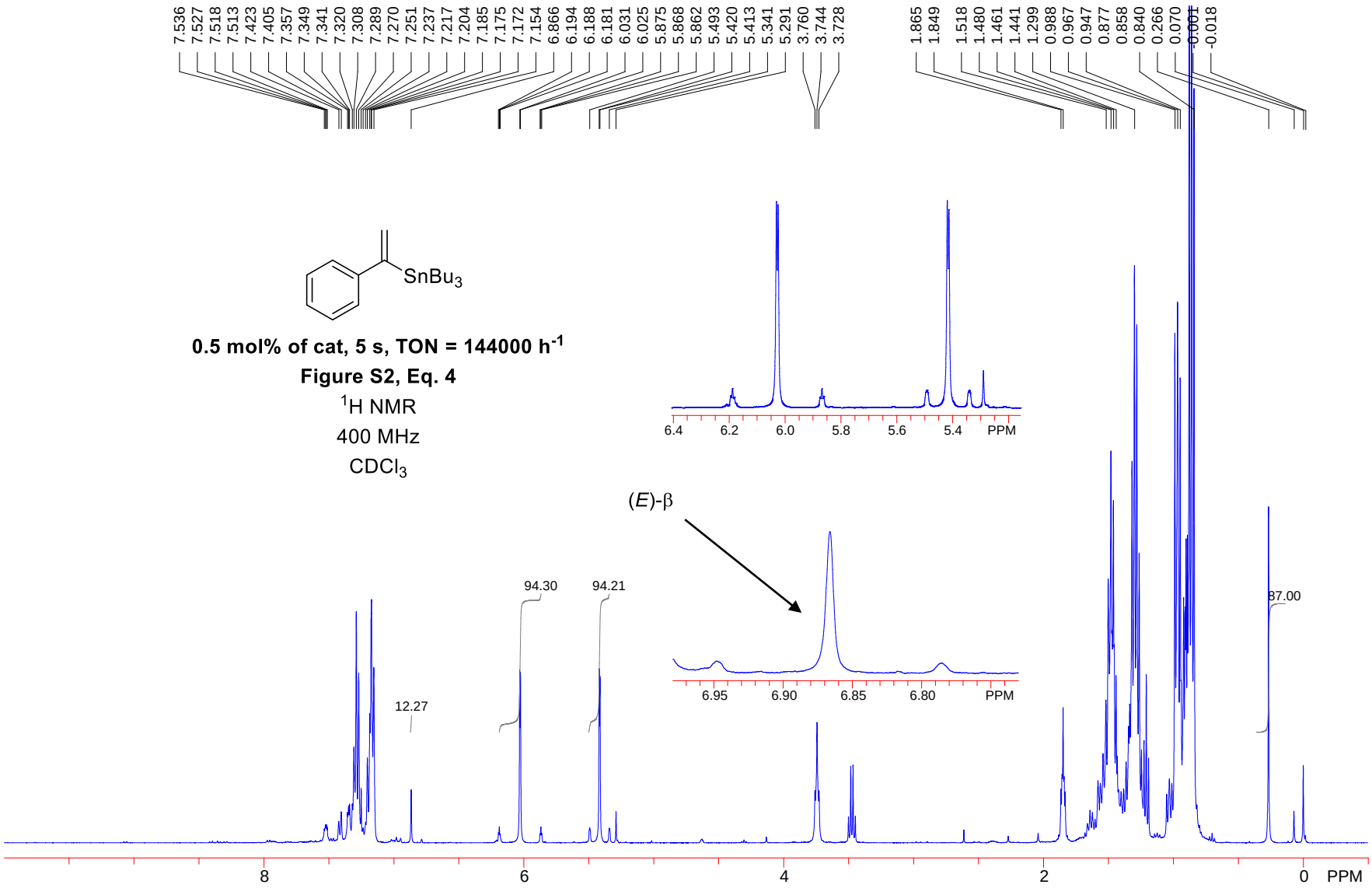
^{1}H NMR

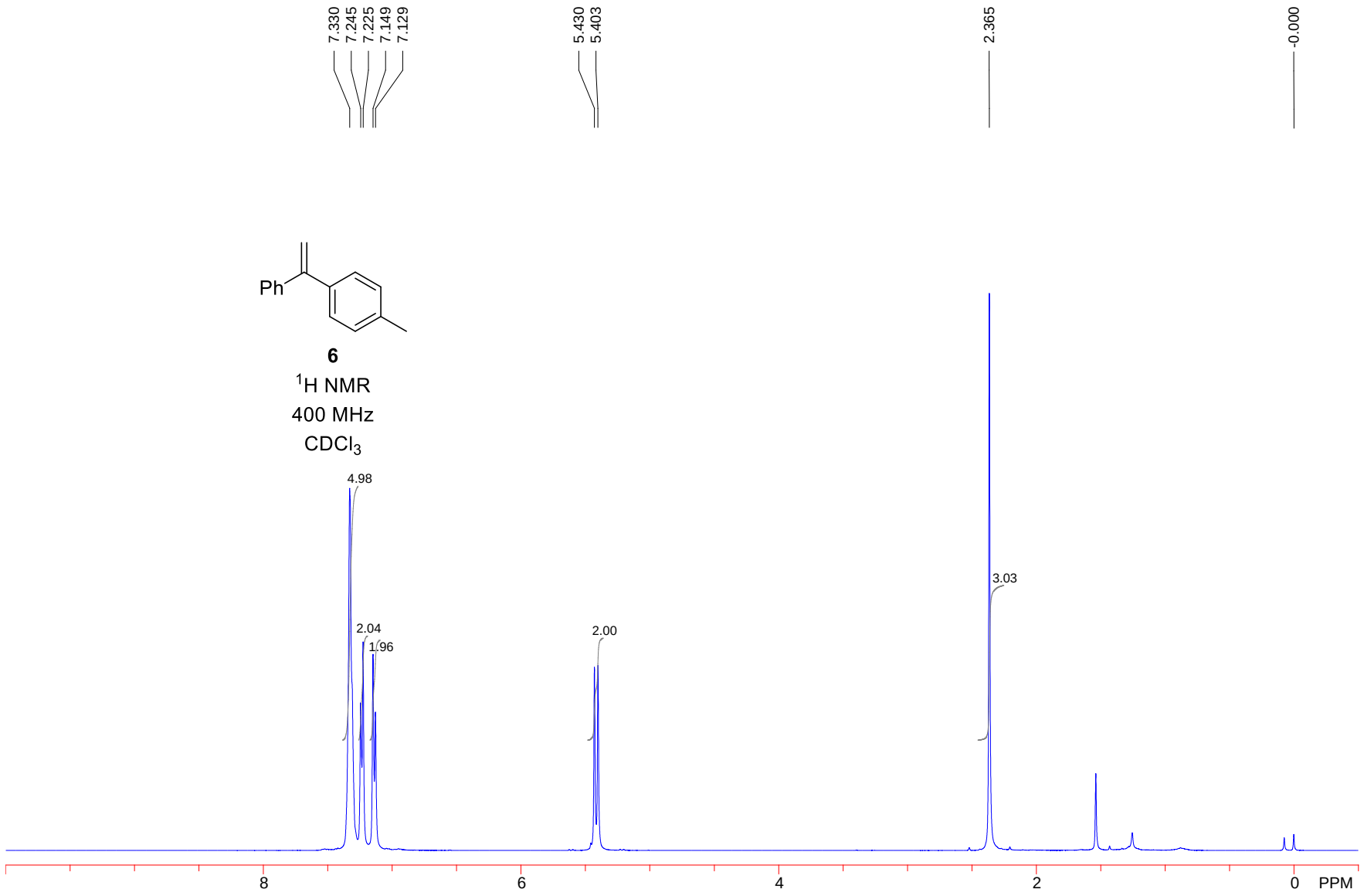
400 MHz

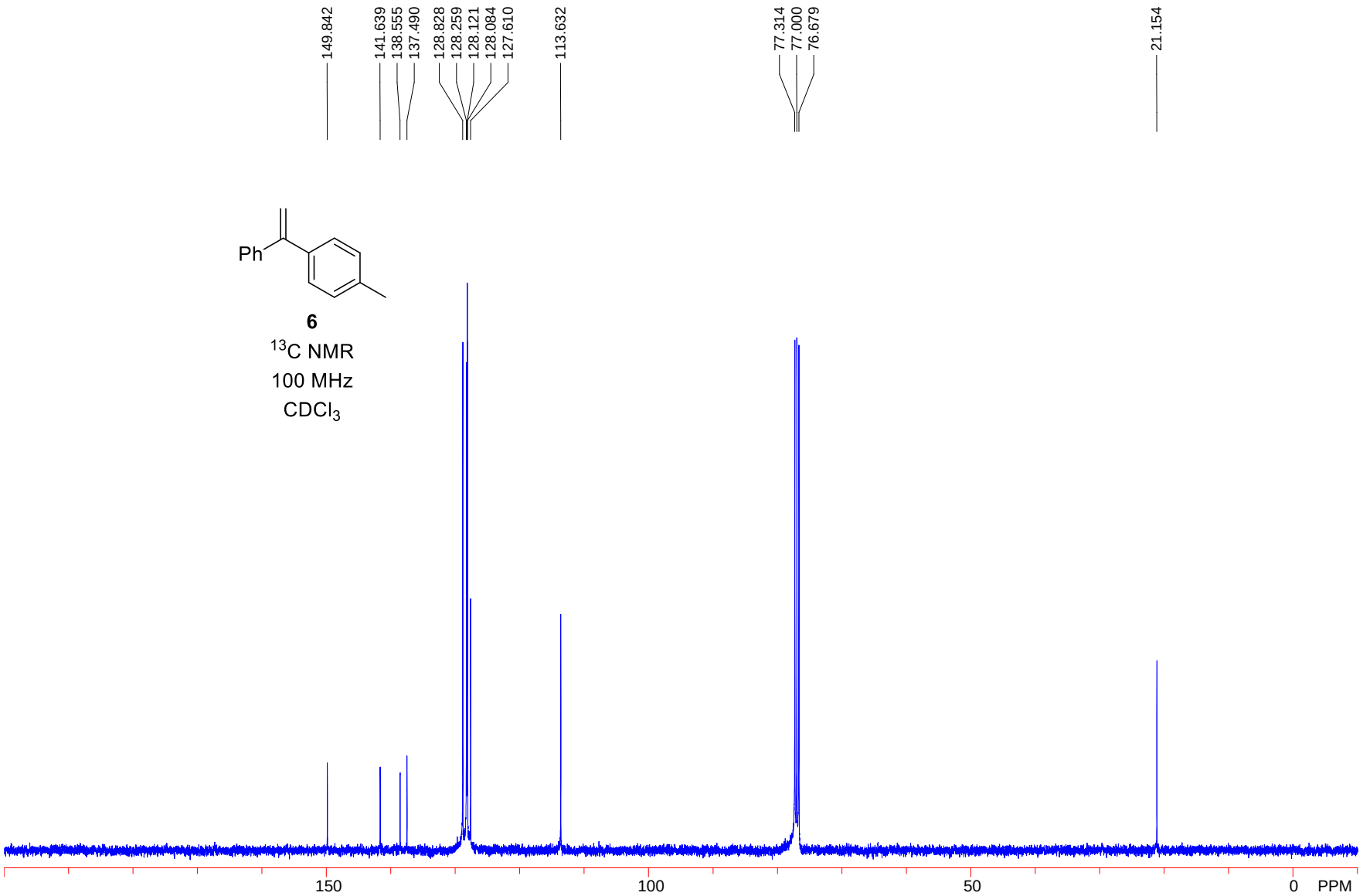
$CDCl_3$

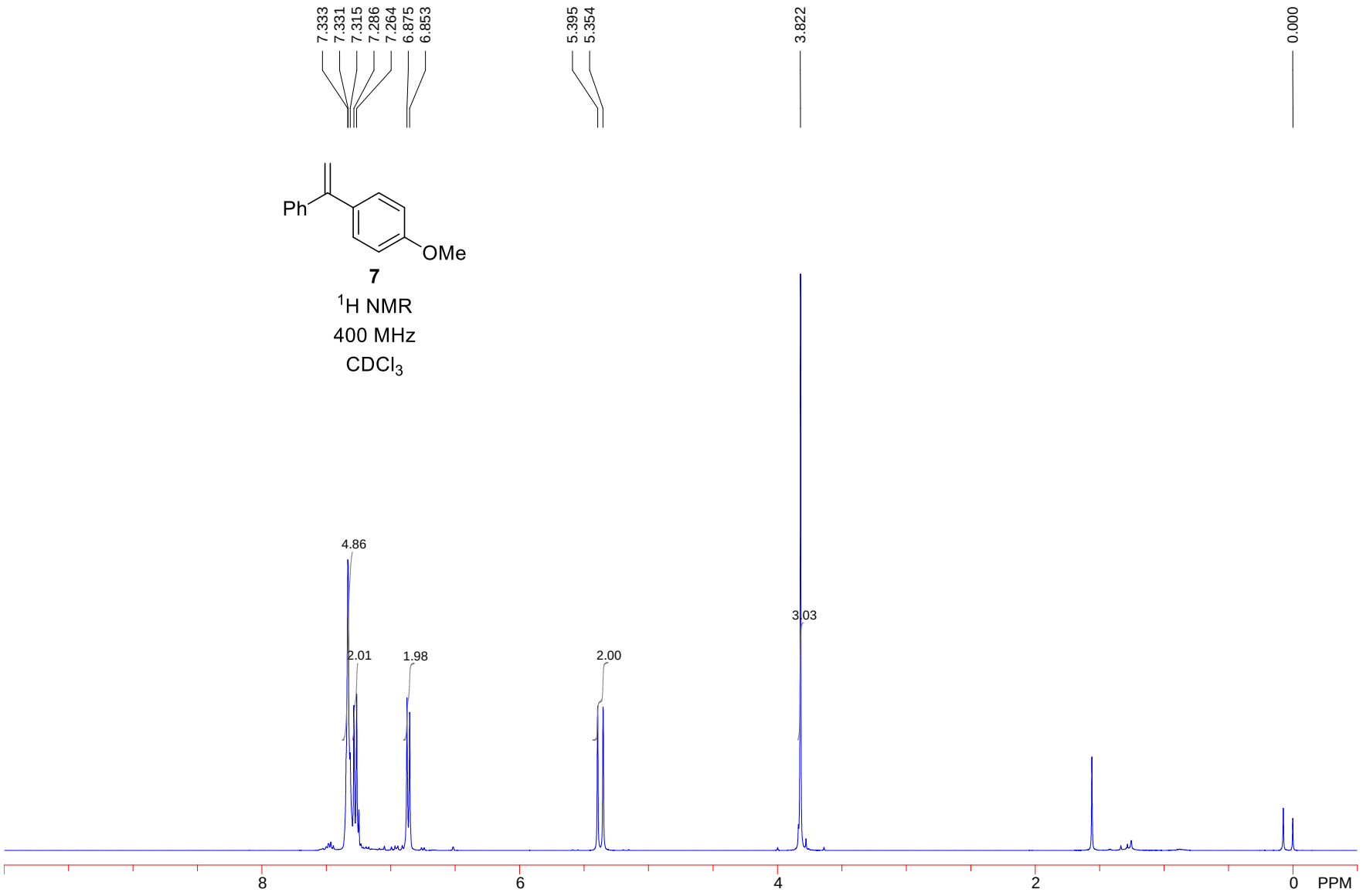

7.286
7.268
7.176
7.156
6.868
6.033
6.027
5.421
5.416
1.521
1.504
1.483
1.465
1.444
1.426
0.950
0.922
0.912
0.903
0.894
0.879
0.861
0.842
0.267
SnBu3
0.01 mol% of cat, TON = 10000
Figure S2, Eq. 2
1H NMR
400 MHz
CDCl3
(E)-β
40.34
80.21
79.95
43.50
6.2
6.0
5.8
5.6
5.4
PPM
6.95
6.90
6.85
6.80
6.75
PPM
8
6
4
2
0
PPM

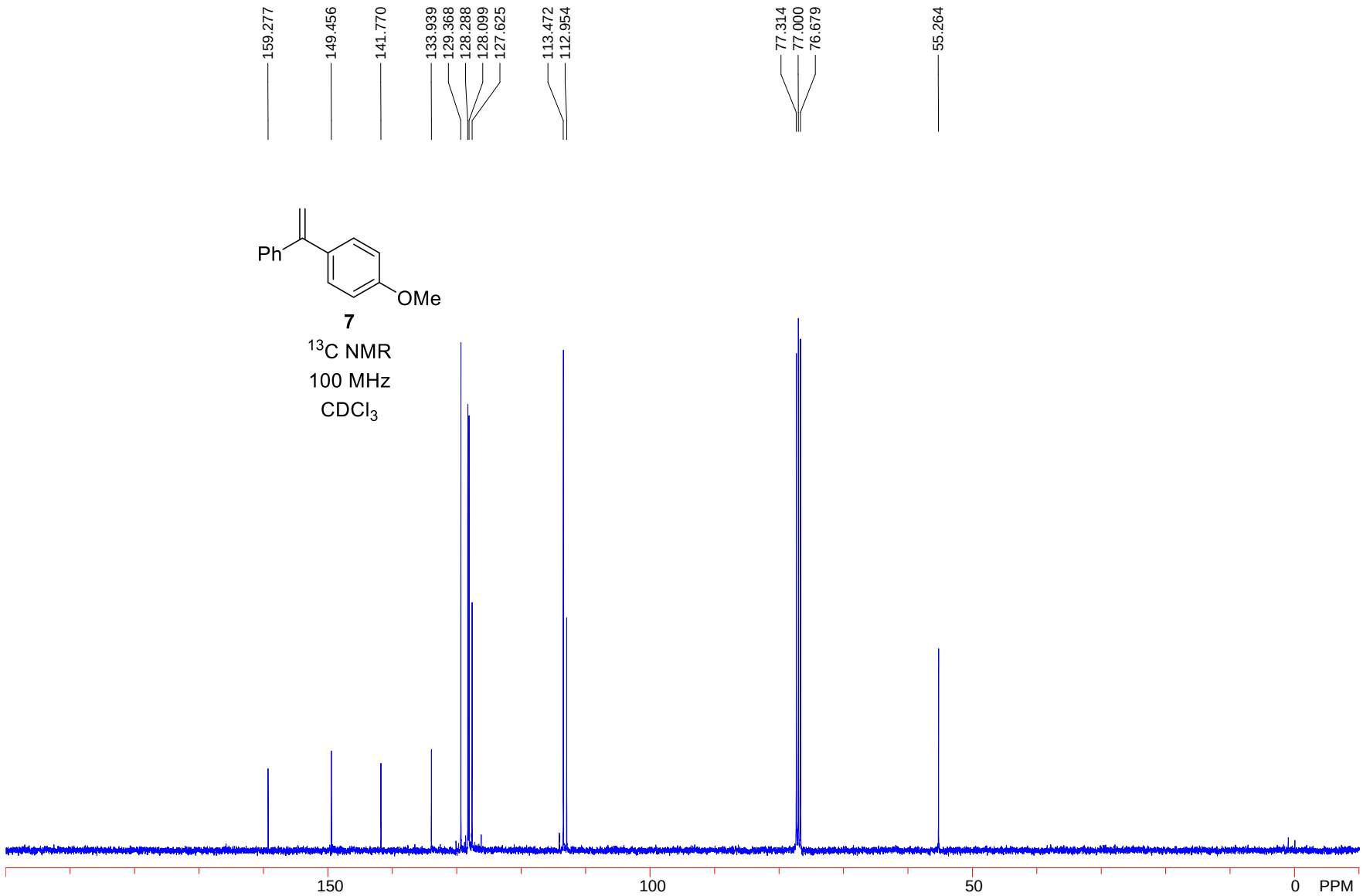

7.287
7.269
7.175
7.172
7.154
6.867
6.032
6.026
6.211
5.421
5.415
1.504
1.483
1.475
1.464
1.458
1.320
1.301
1.283
1.265
0.990
0.969
0.949
0.879
0.860
0.842
-0.000
SnBu3
0.5 mol% of cat, 30 s, TON = 23520 h-1
Figure S2, Eq. 3
1H NMR
400 MHz
CDCl3
(E)-β
9.20
6.22
6.15
6.04
2.97
1.98
0.04
1.00
1.00
6.2
6.0
5.8
5.6
5.4
PPM
6.95
6.90
6.85
6.80
PPM
8
6
4
2
0
PPM

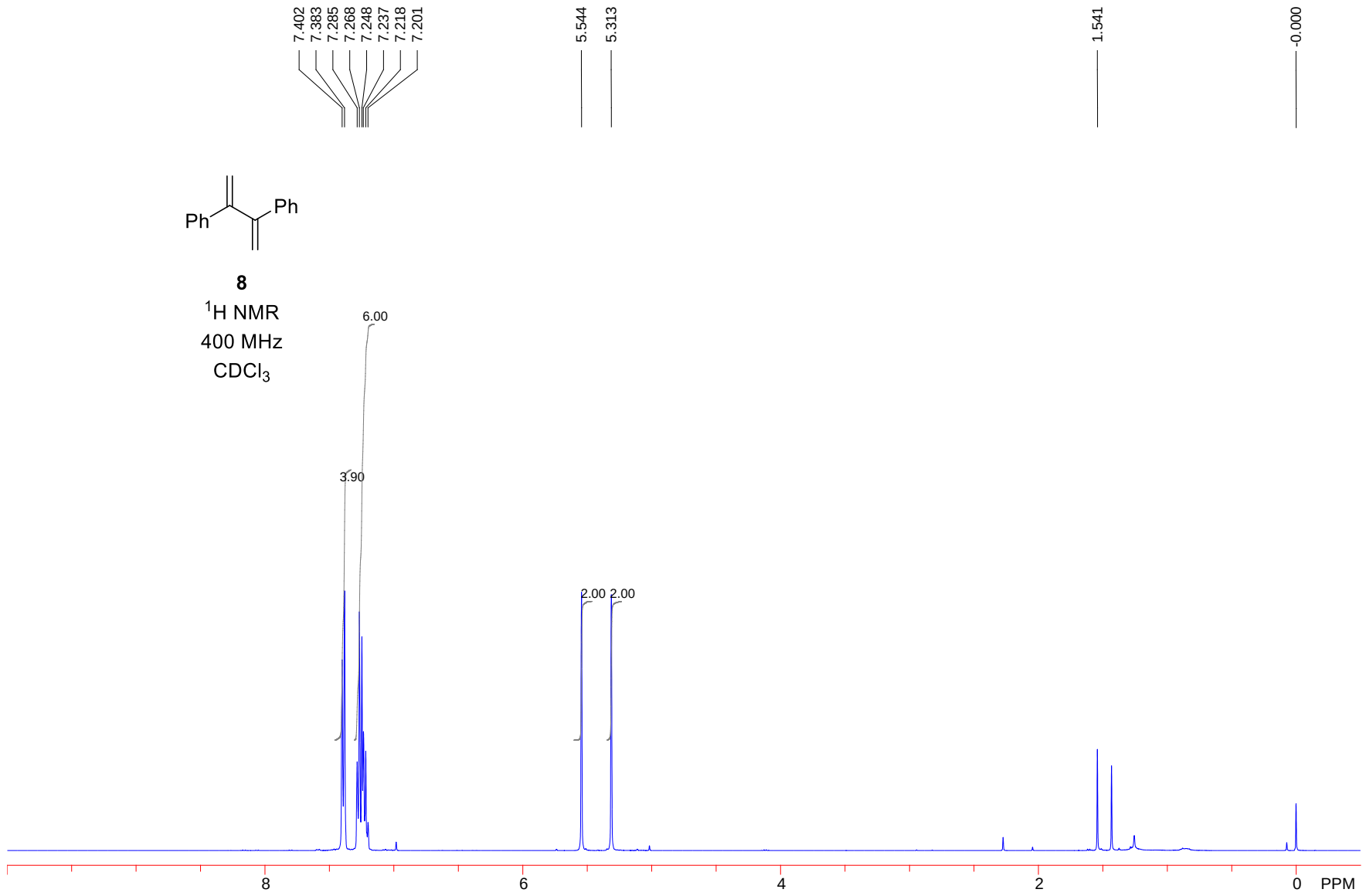

7.536
7.527
7.518
7.513
7.423
7.405
7.357
7.349
7.341
7.320
7.308
7.289
7.270
7.251
7.237
7.217
7.204
7.185
7.175
7.172
7.154
6.866
6.194
6.188
6.181
6.031
6.025
5.875
5.868
5.862
5.493
5.420
5.413
5.341
5.291
3.760
3.744
3.728
1.865
1.849
1.518
1.480
1.461
1.441
1.299
0.988
0.967
0.947
0.877
0.858
0.840
0.266
0.070
0.001
-0.018
SnBu3
0.5 mol% of cat, 5 s, TON = 144000 h-1
Figure S2, Eq. 4
1H NMR
400 MHz
CDCl3
(E)-β
94.30
94.21
12.27
87.00
6.4
6.2
6.0
5.8
5.6
5.4
PPM
6.95
6.90
6.85
6.80
PPM
8
6
4
2
0
PPM

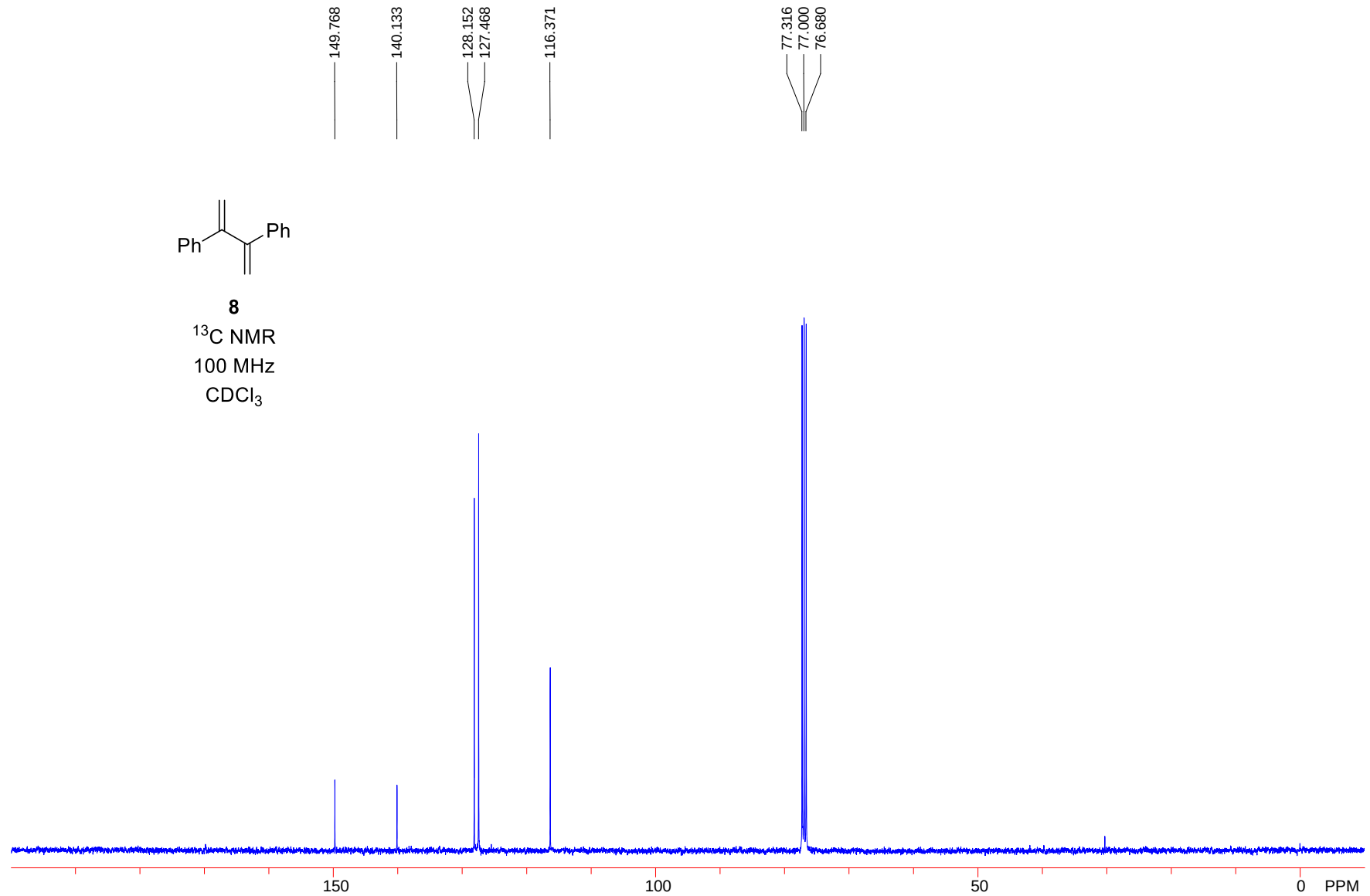

7.330
7.245
7.225
7.149
7.129
5.430
5.403
2.365
-0.000
Ph
6
1H NMR
400 MHz
CDCl3
4.98
2.04
1.96
2.00
3.03
8
6
4
2
0
PPM

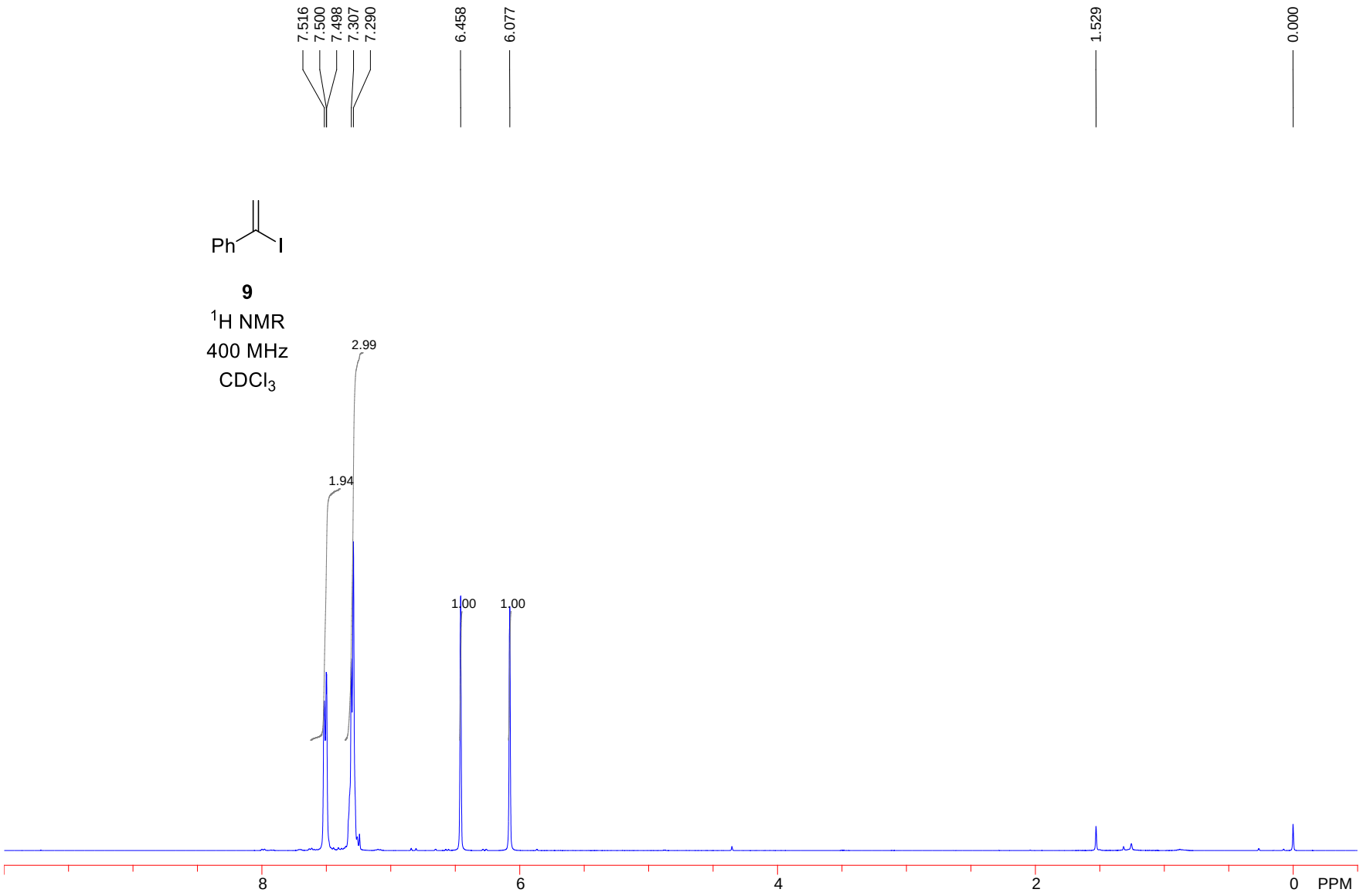

149.842
141.639
138.555
137.490
128.828
128.259
128.121
128.084
127.610
113.632
77.314
77.000
76.679
21.154
Ph
6
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

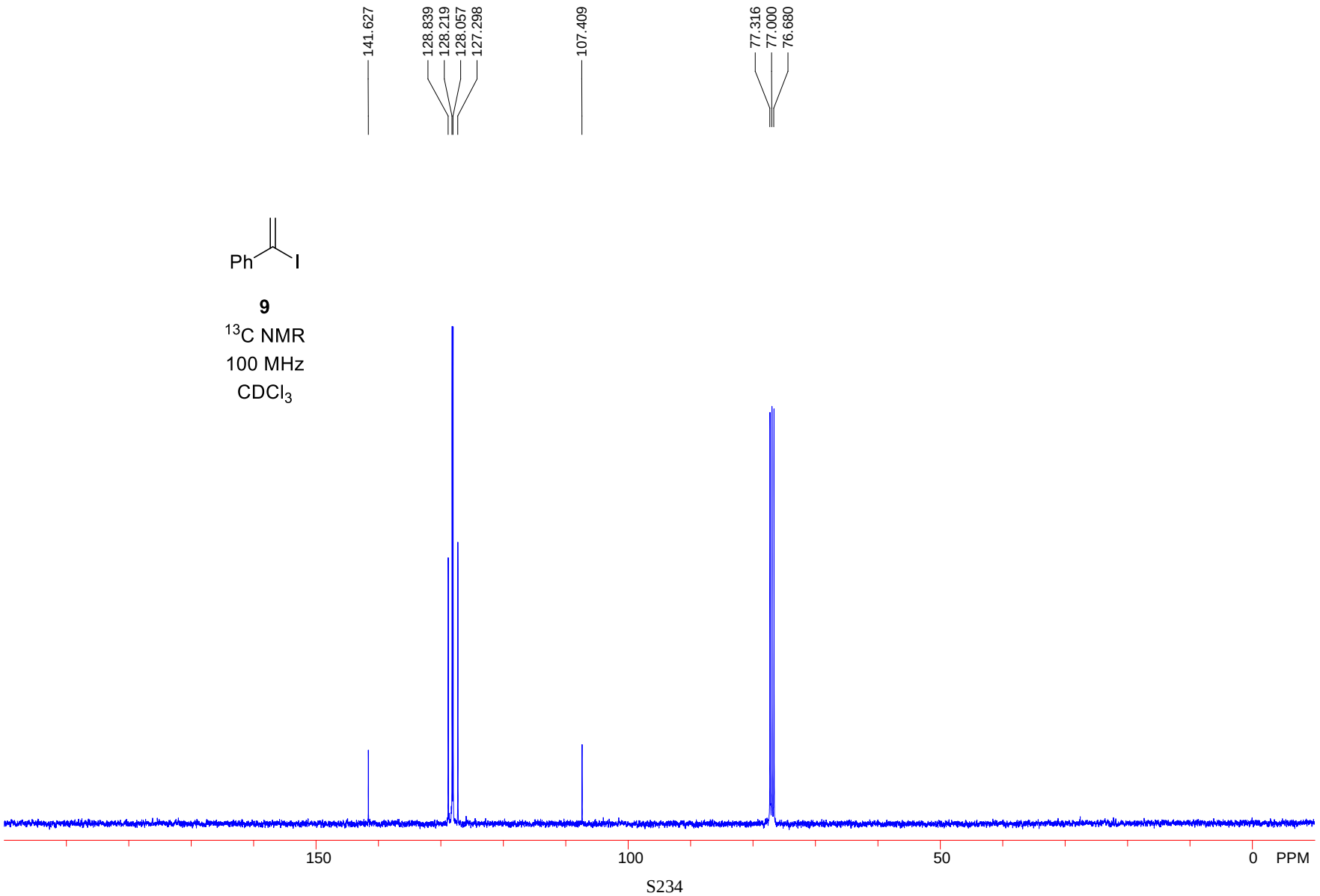

7.333
7.331
7.315
7.286
7.264
6.875
6.853
5.395
5.354
3.822
0.000
Ph
OMe
7
1H NMR
400 MHz
CDCl3
4.86
2.01
1.98
2.00
3.03
8
6
4
2
0
PPM

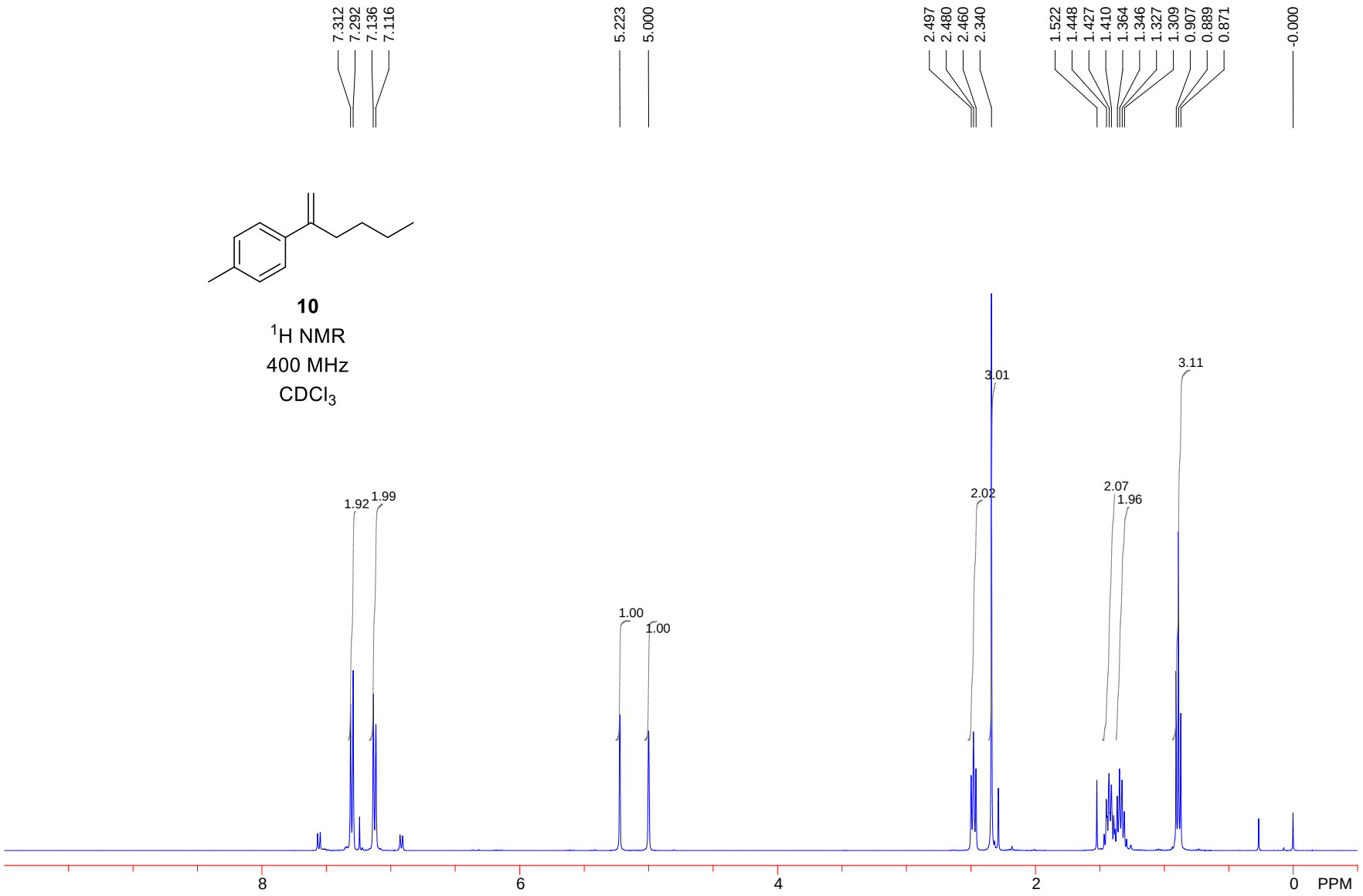

159.277
149.456
141.770
133.939
129.368
128.288
128.099
127.625
113.472
112.954
77.314
77.000
76.679
55.264
Ph
OMe
7
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

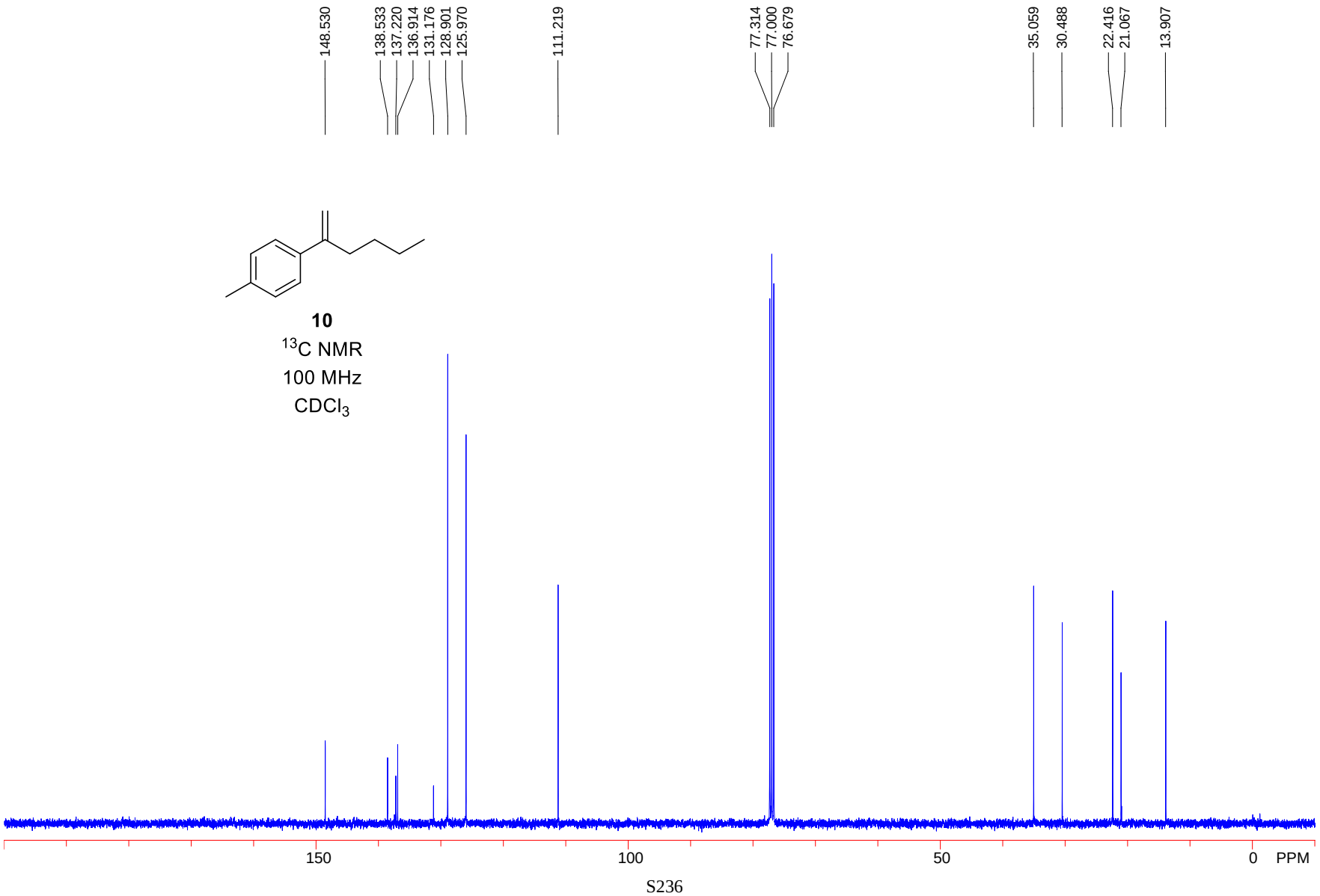

7.402
7.383
7.285
7.268
7.248
7.237
7.218
7.201
5.544
5.313
1.541
-0.000
Ph
Ph
8
1H NMR
400 MHz
CDCl3
6.00
3.90
2.00
2.00
8
6
4
2
0
PPM

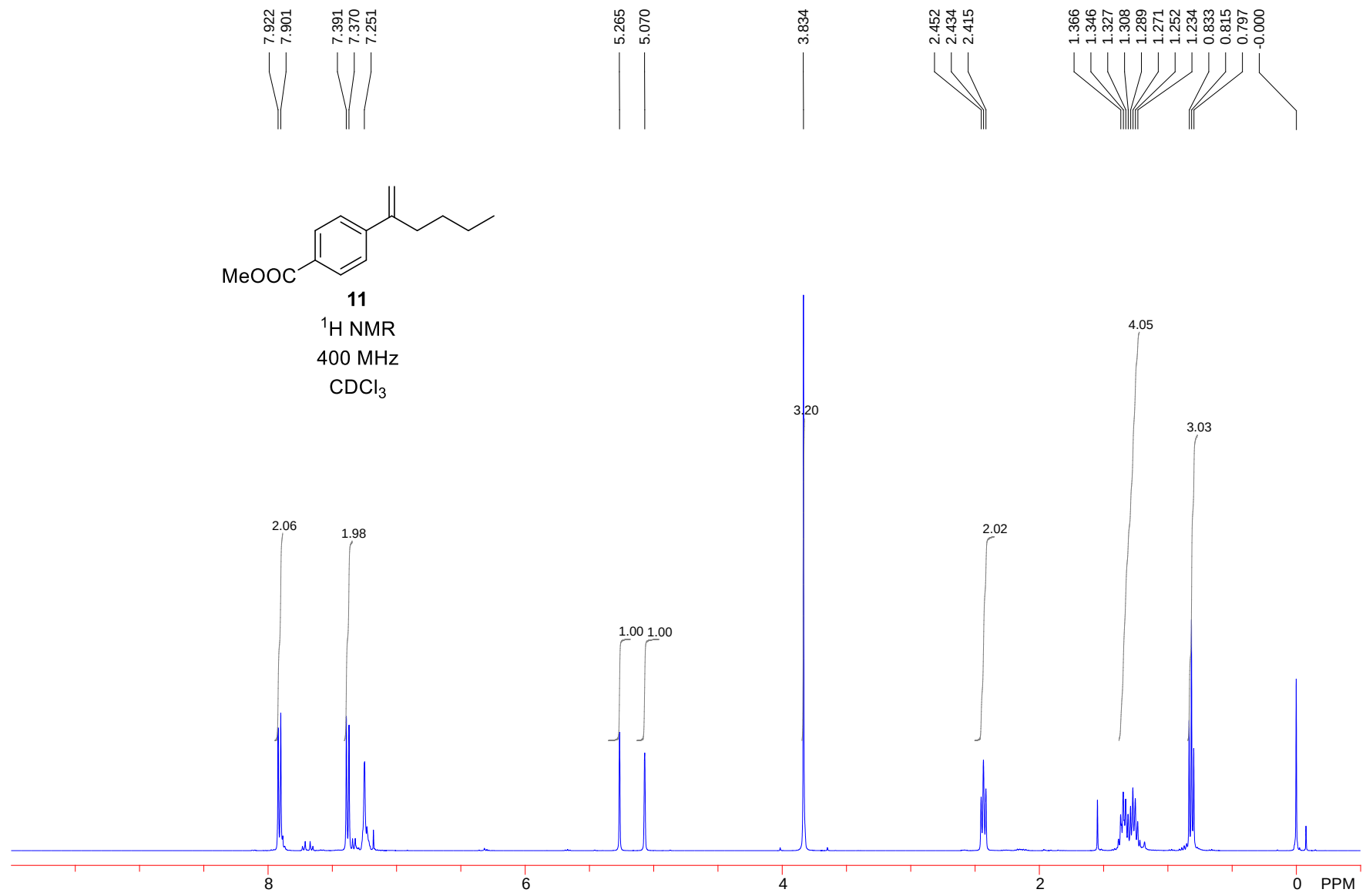

149.768
140.133
128.152
127.468
116.371
77.316
77.000
76.680
Ph
Ph
8
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

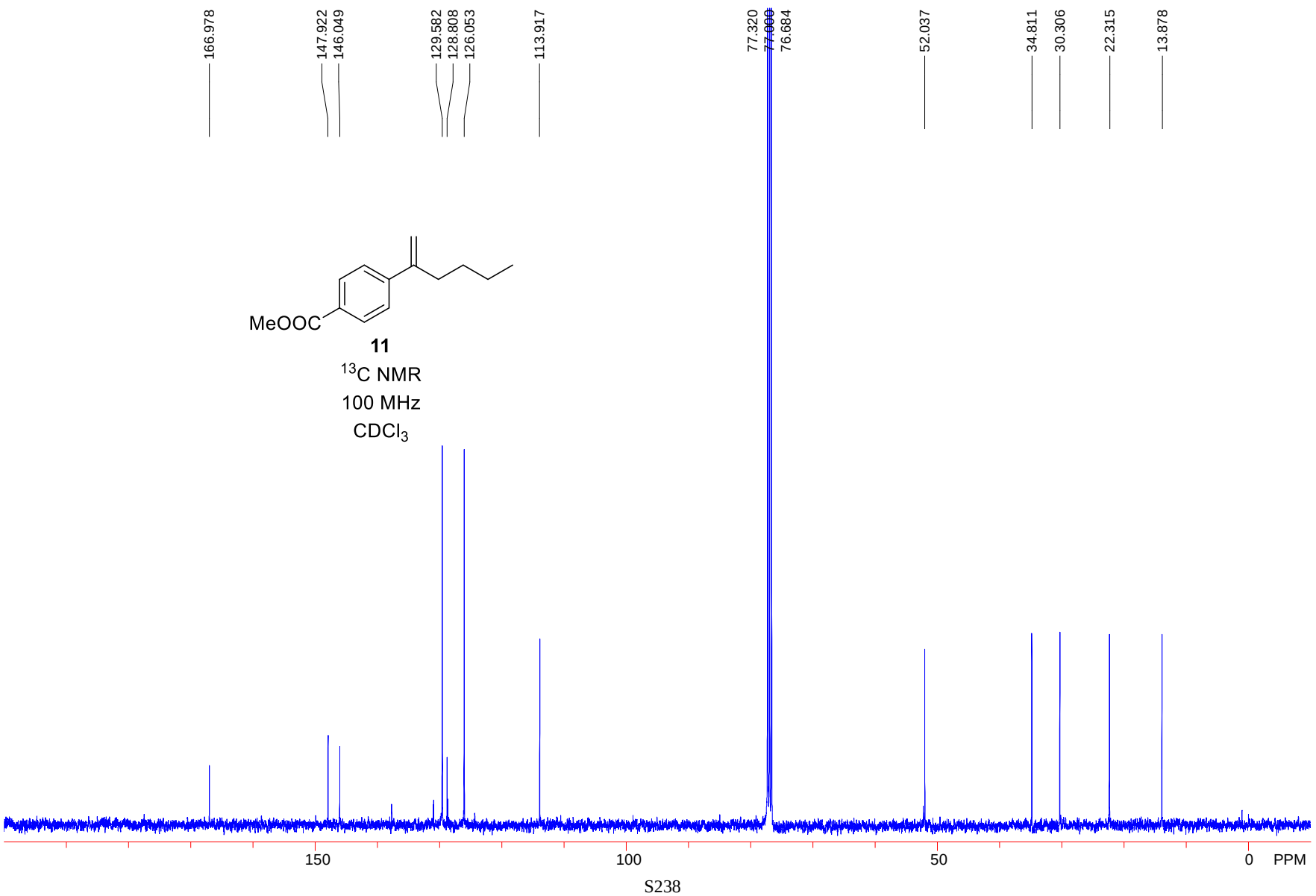

7.516
7.500
7.498
7.307
7.290
6.458
6.077
1.529
0.000
Ph
I
9
1H NMR
400 MHz
CDCl3
2.99
1.94
1.00
1.00
8
6
4
2
0
PPM

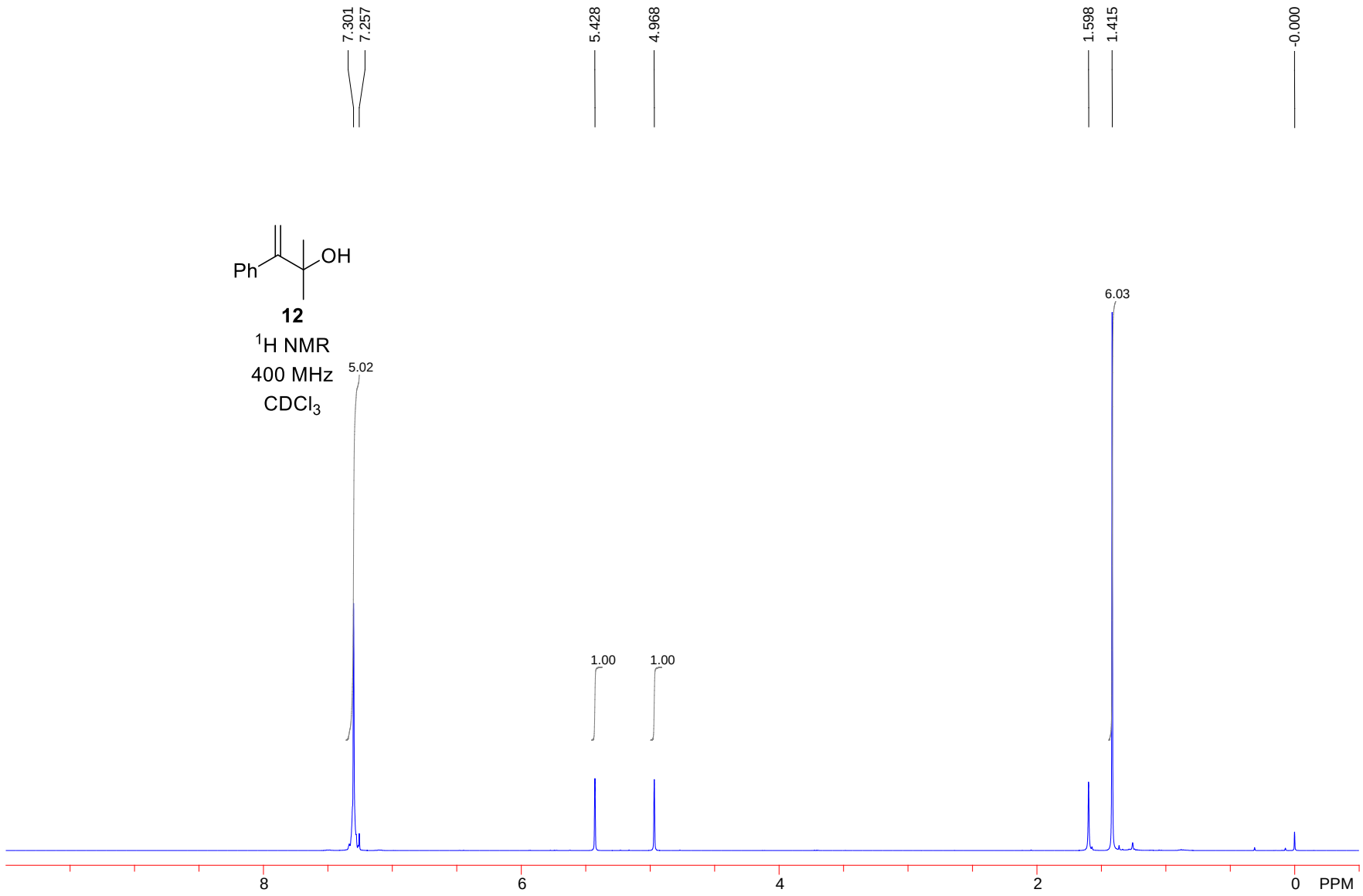

141.627
128.839
128.219
128.057
127.298
107.409
77.316
77.000
76.680
Ph
I
9
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

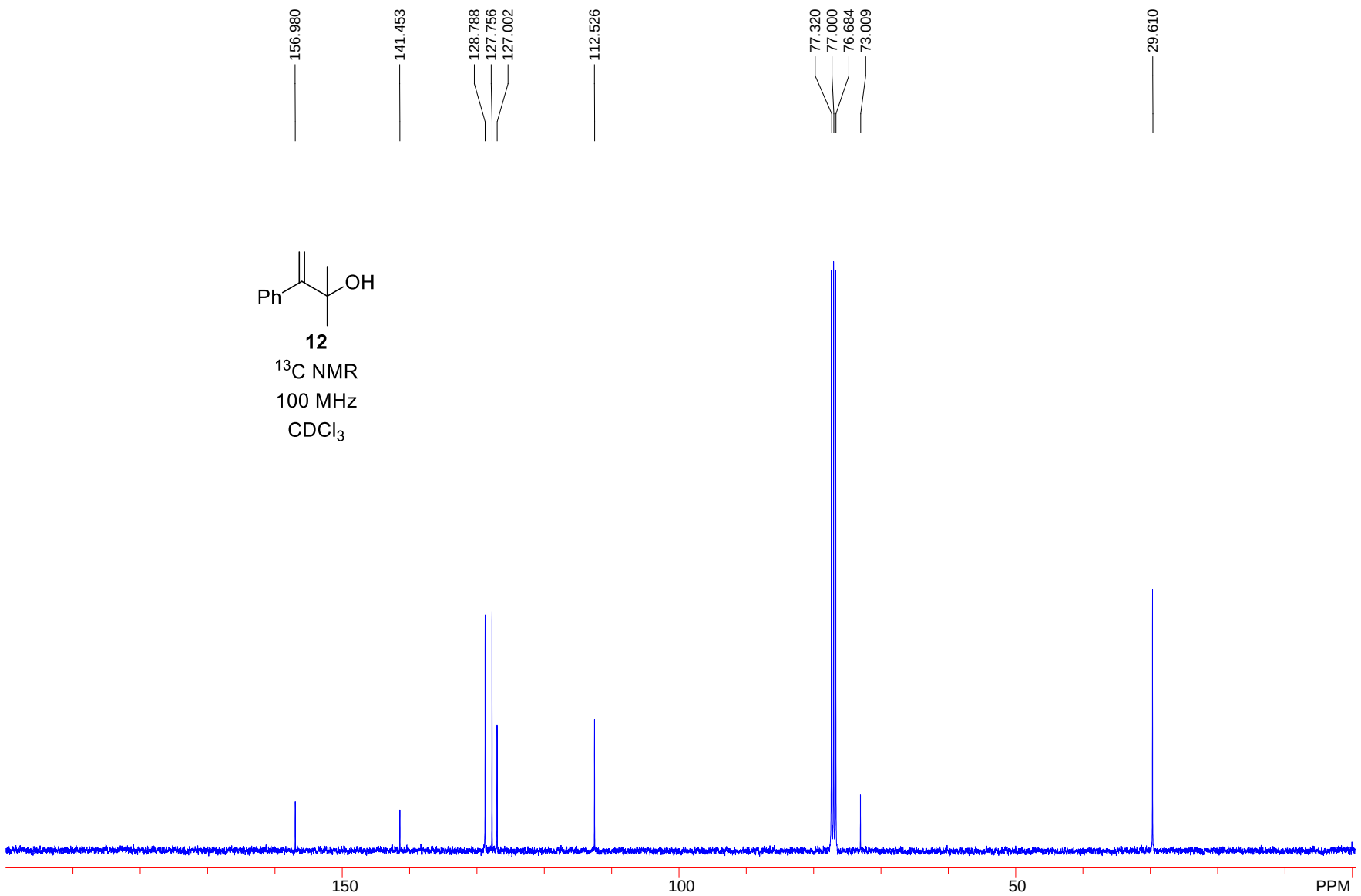

7.312
7.292
7.136
7.116
5.223
5.000
2.497
2.480
2.460
2.340
1.522
1.448
1.427
1.410
1.364
1.346
1.327
1.309
0.907
0.889
0.871
-0.000
10
1H NMR
400 MHz
CDCl3
1.92
1.99
1.00
1.00
3.01
2.02
2.07
1.96
3.11
8
6
4
2
0
PPM

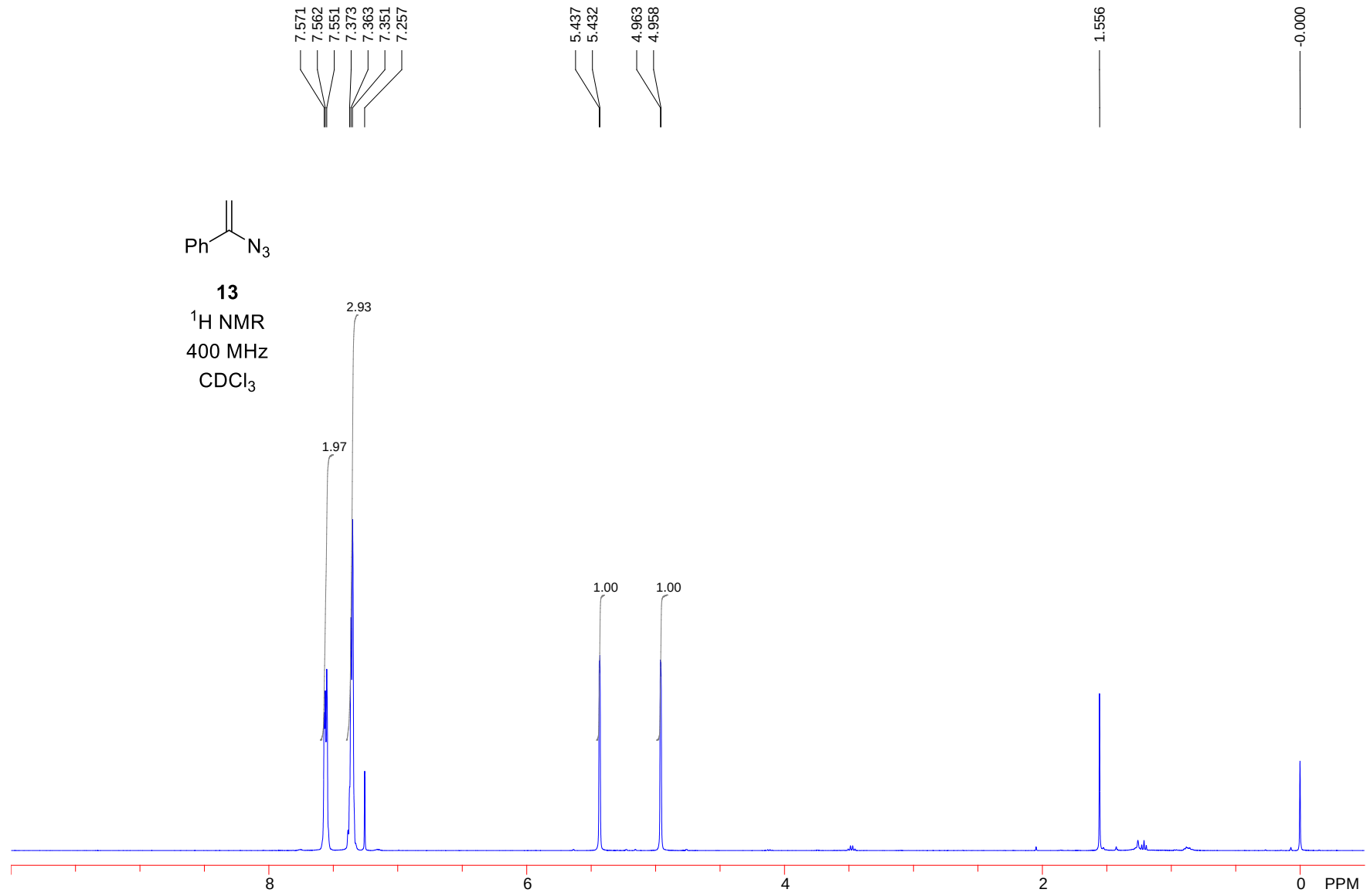

148.530
138.533
137.220
136.914
131.176
128.901
125.970
111.219
77.314
77.000
76.679
35.059
30.488
22.416
21.067
13.907
10
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM

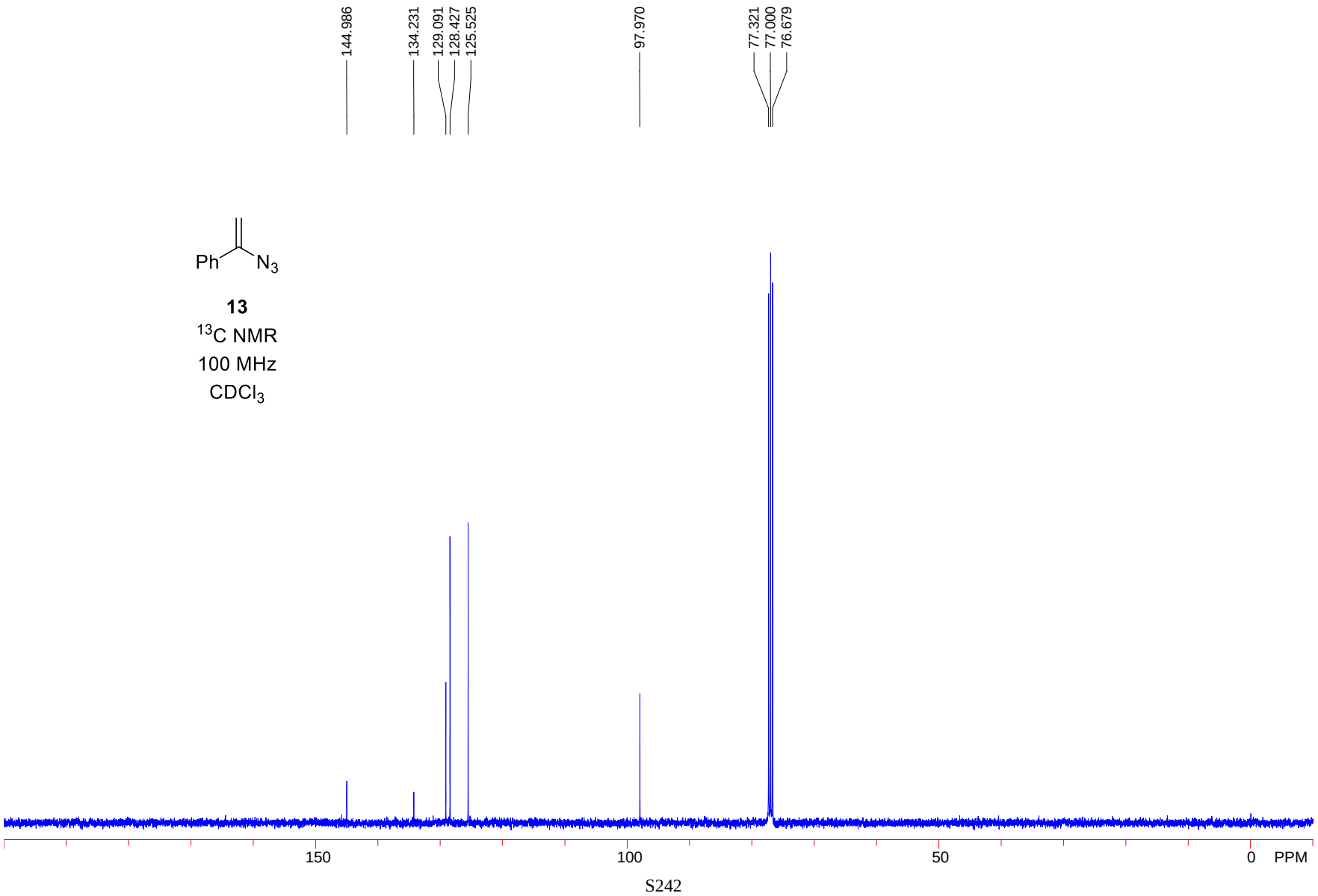

7.922
7.901
7.391
7.370
7.251
5.265
5.070
3.834
2.452
2.434
2.415
1.366
1.346
1.327
1.308
1.289
1.271
1.252
1.234
0.833
0.815
0.797
-0.000
MeOOC
11
1H NMR
400 MHz
CDCl3
2.06
1.98
1.00
1.00
3.20
2.02
4.05
3.03
8
6
4
2
0
PPM

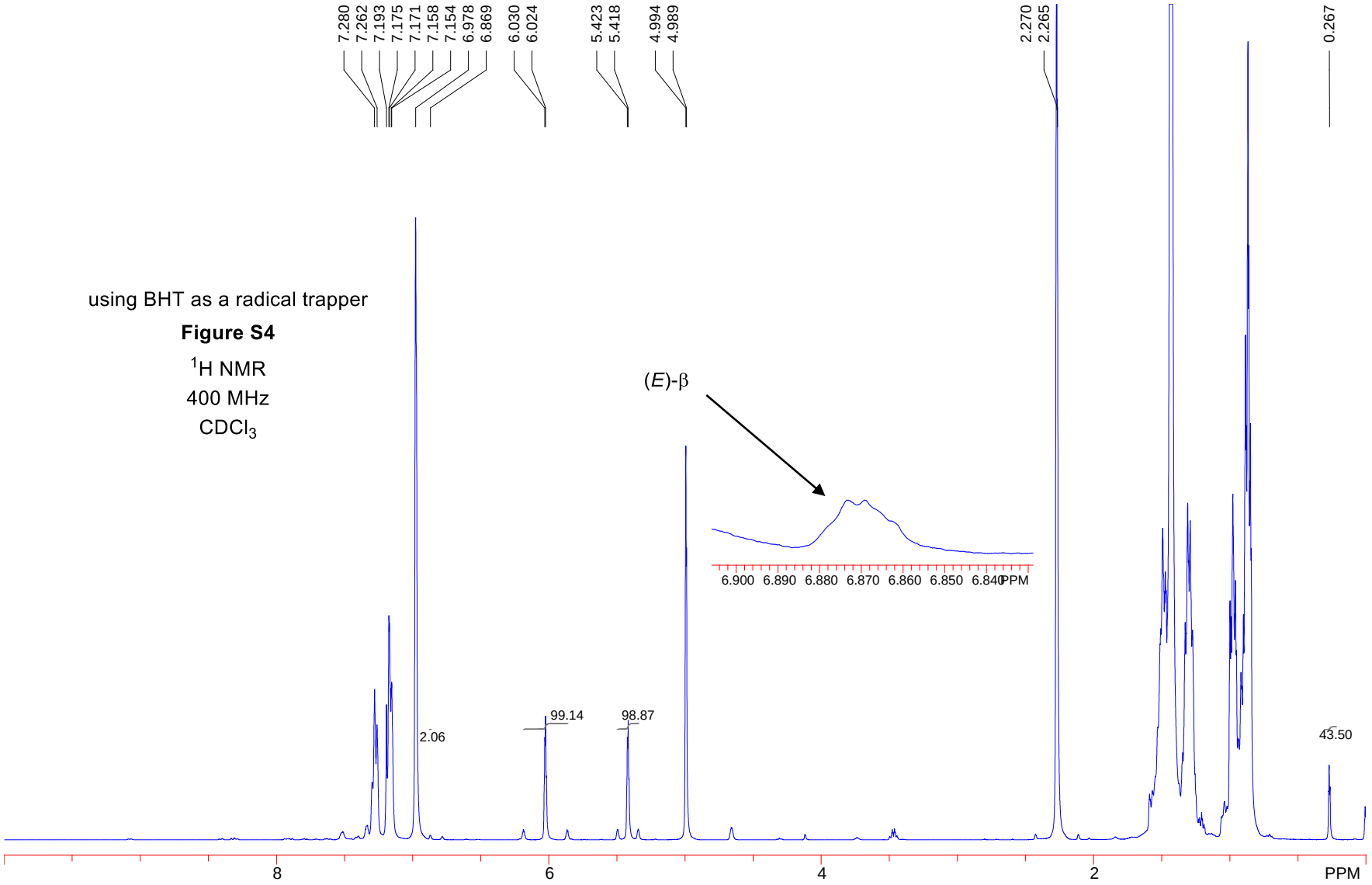

166.978
147.922
146.049
129.582
128.808
126.053
113.917
77.320
77.000
76.684
52.037
34.811
30.306
22.315
13.878
MeOOC
11
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM


7.301
7.257
5.428
4.968
1.598
1.415
-0.000
Ph
OH
12
1H NMR
400 MHz
CDCl3
5.02
1.00
1.00
6.03
8
6
4
2
0
PPM


156.980
141.453
128.788
127.756
127.002
112.526
77.320
77.000
76.684
73.009
29.610
Ph
OH
12
13C NMR
100 MHz
CDCl3
150
100
50
PPM


7.571
7.562
7.551
7.373
7.363
7.351
7.257
5.437
5.432
4.963
4.958
1.556
-0.000
Ph
N3
13
1H NMR
400 MHz
CDCl3
2.93
1.97
1.00
1.00
8
6
4
2
0
PPM

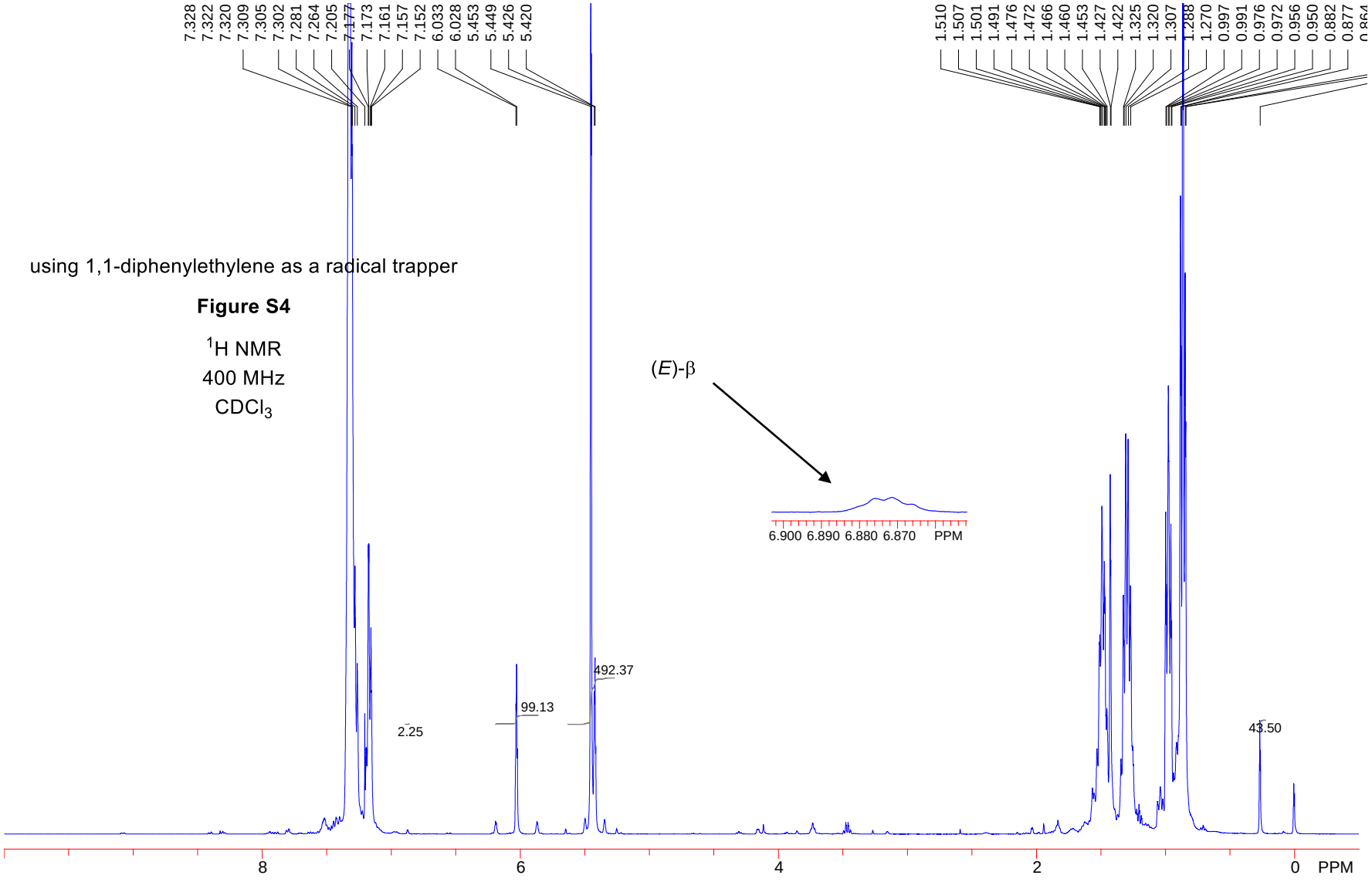

144.986
134.231
129.091
128.427
125.525
97.970
77.321
77.000
76.679
Ph
N3
13
13C NMR
100 MHz
CDCl3
150
100
50
0
PPM


7.280
7.262
7.193
7.175
7.171
7.158
7.154
6.978
6.869
6.030
6.024
5.423
5.418
4.994
4.989
2.270
2.265
0.267
using BHT as a radical trapper
Figure S4
1H NMR
400 MHz
CDCl3
(E)-β
6.900 6.890 6.880 6.870 6.860 6.850 6.840 PPM
2.06
99.14
98.87
43.50
8
6
4
2
PPM

using 1,1-diphenylethylene as a radical trapper

Figure S4

^{1}H NMR
400 MHz
$CDCl_3$



recovery of 4-Ethynylanisole
no H-D exchange was observed

Figure S5

^{1}H NMR

400 MHz

$CDCl_3$

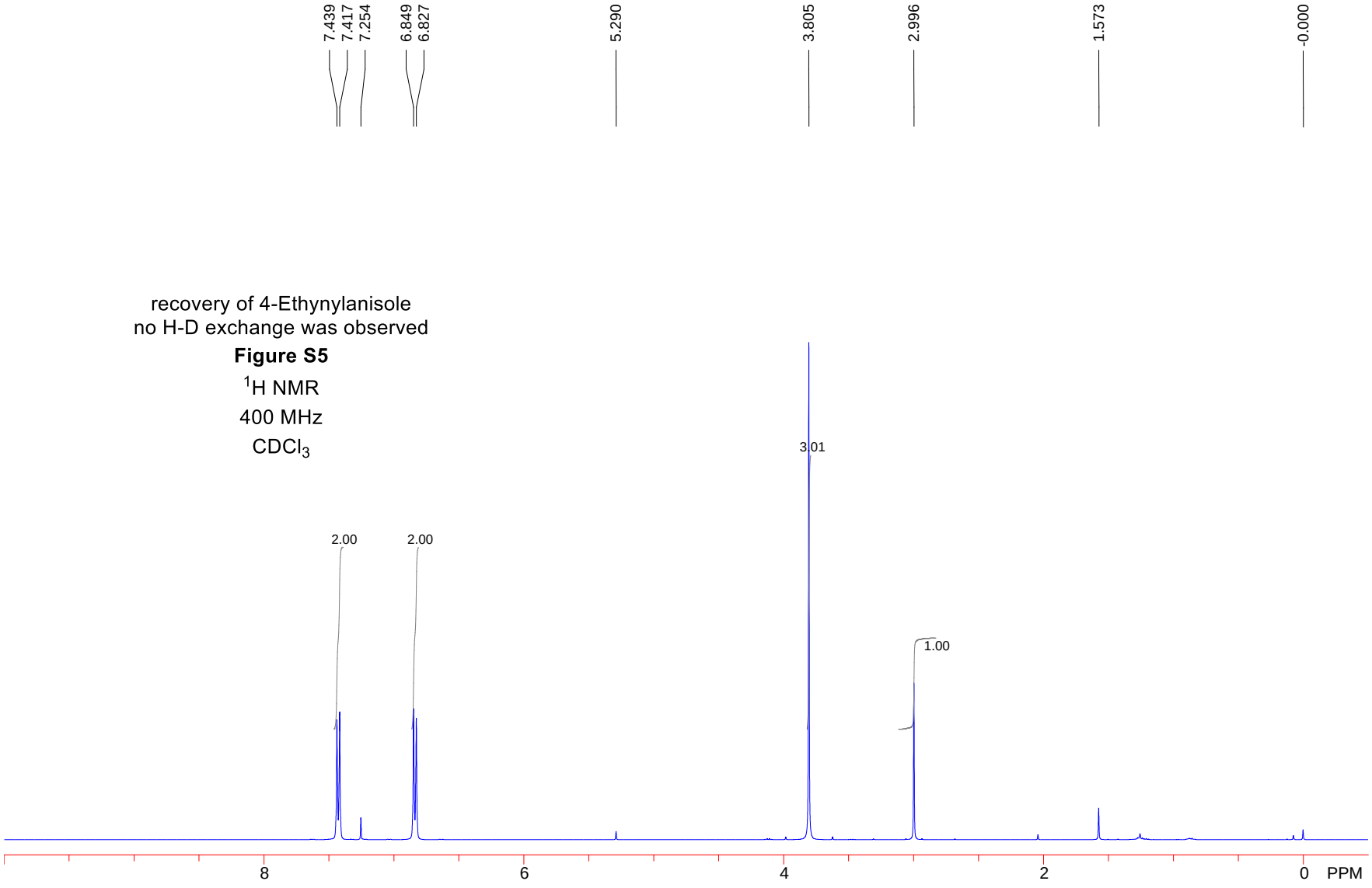


Figure S6
^{1}H NMR
400 MHz
$CDCl_3$

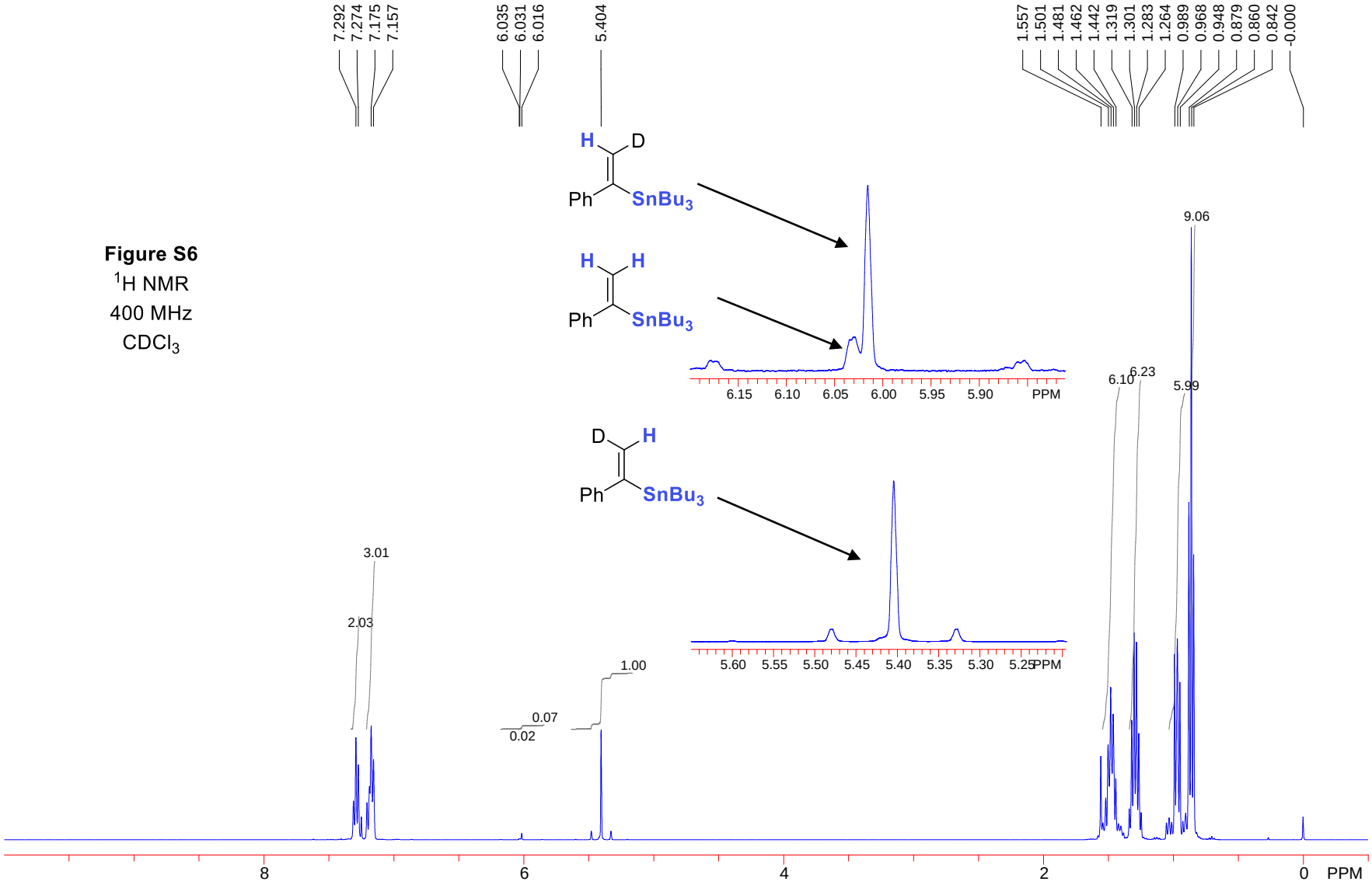


Figure S6
^{2}H NMR
77 MHz
$CHCl_3$

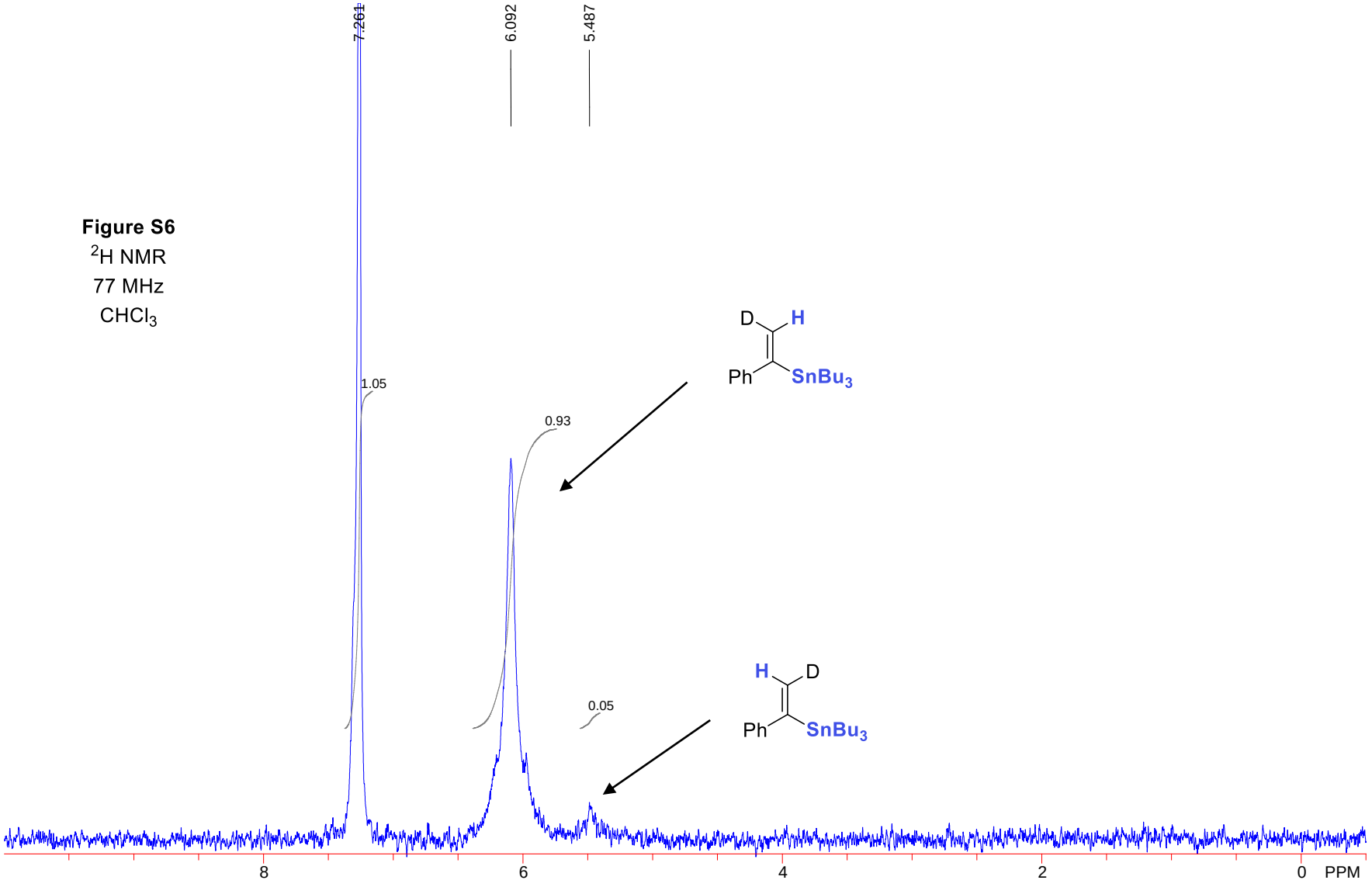
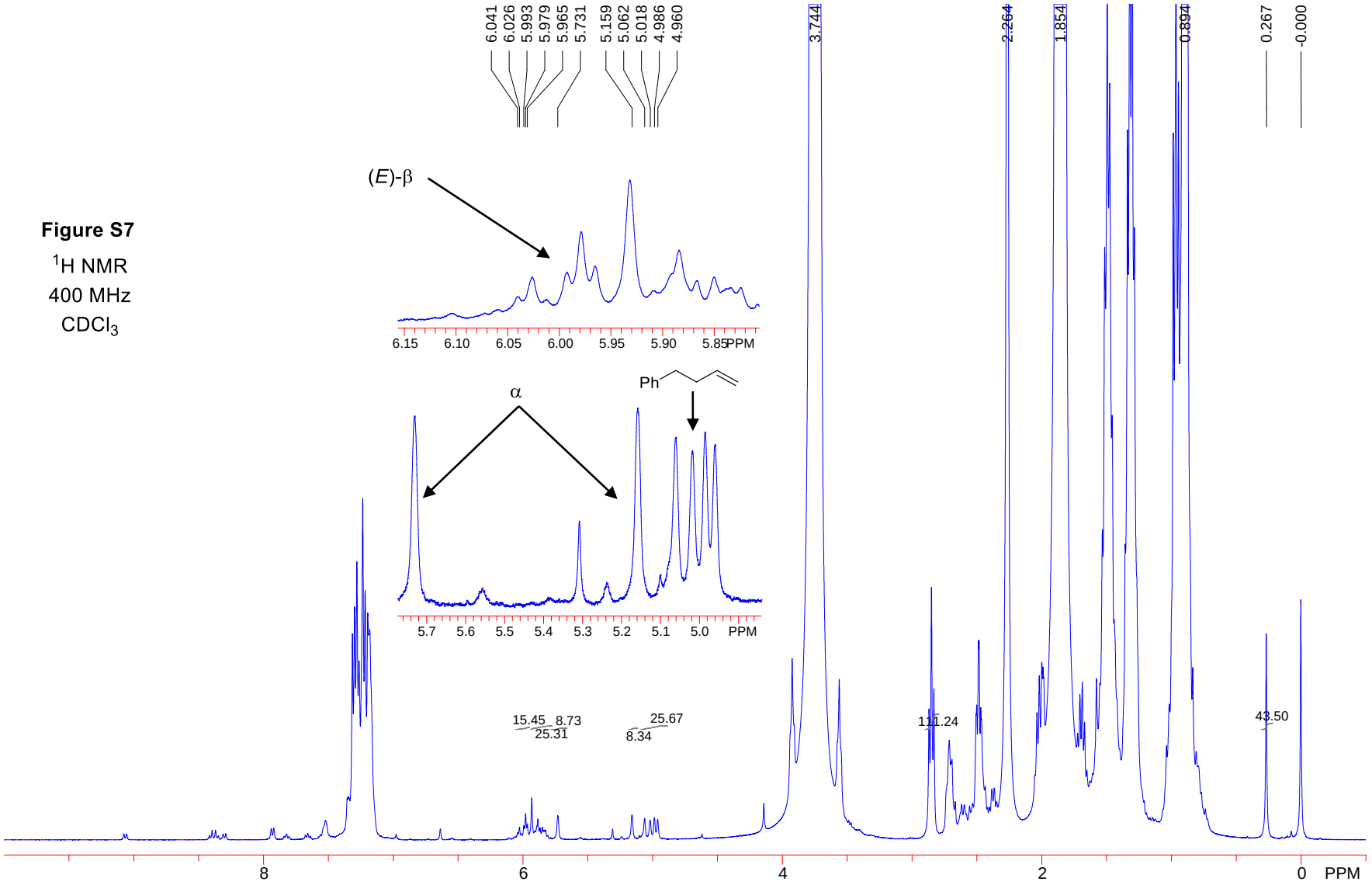


Figure S7

^{1}H NMR
400 MHz
$CDCl_3$



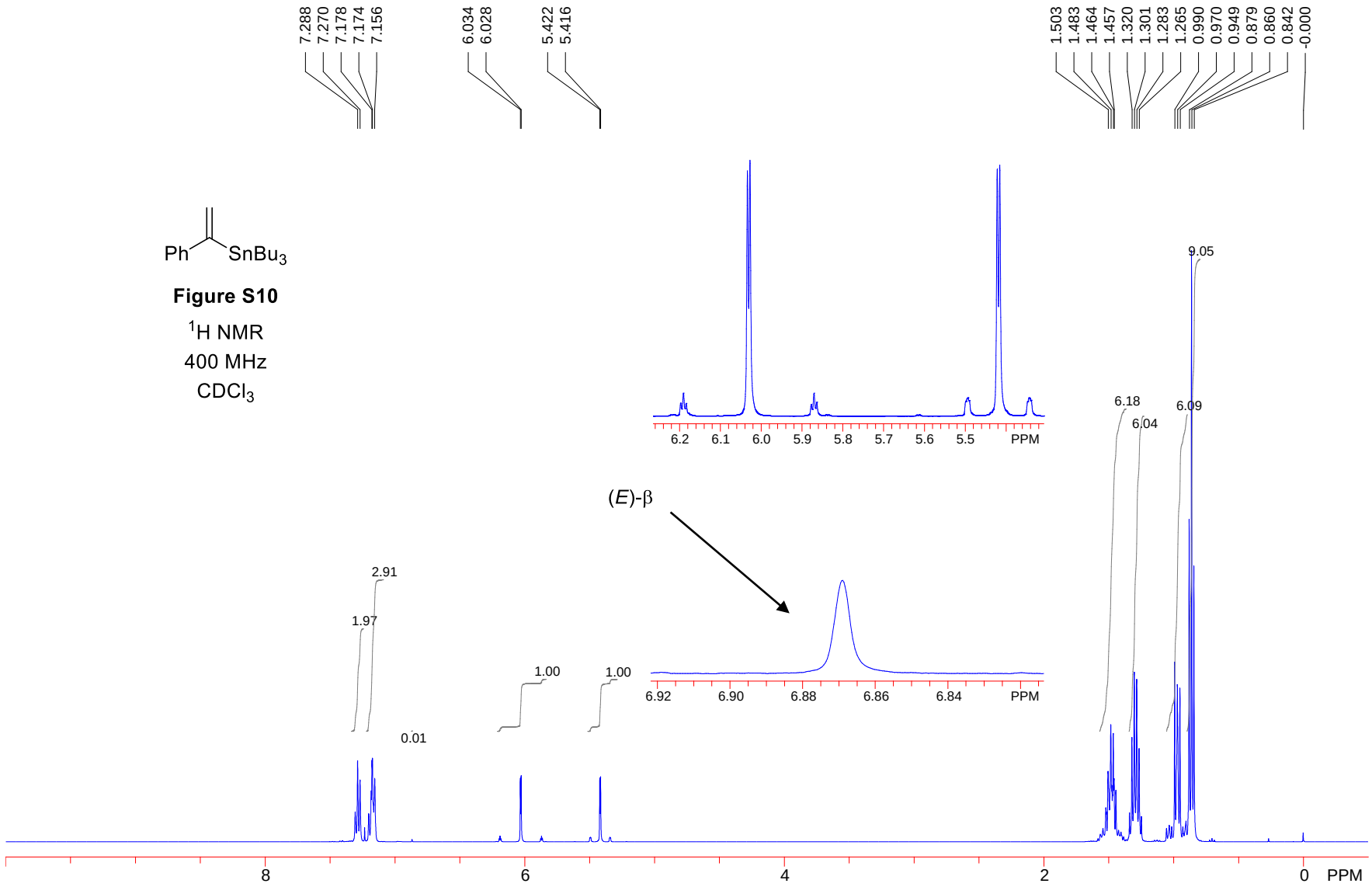


Figure S10

^{1}H NMR

400 MHz

$CDCl_3$