Supporting Information

A Redox Economical Synthesis of Bioactive 6,12-Guaianolides

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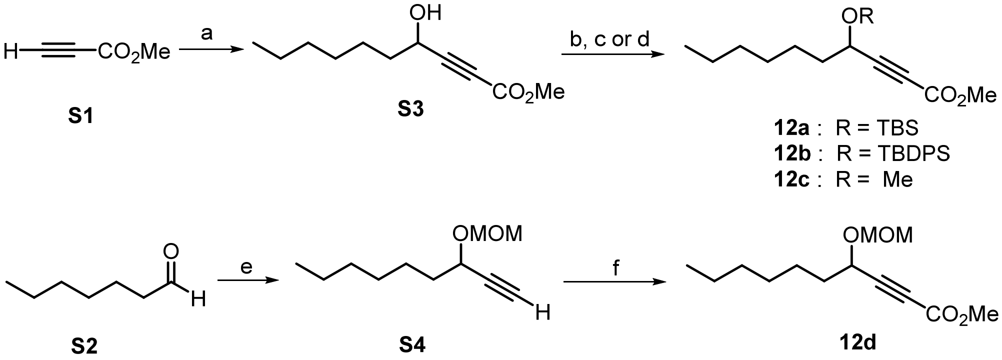
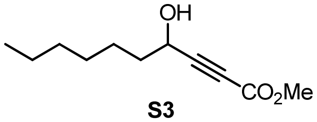
General Materials and Methods

Unless otherwise noted, all reactions were performed in flame-dried glassware sealed with rubber septa under a nitrogen atmosphere and the reaction mixture stirred with a Teflon-coated magnetic stir bar. Liquid reagents and solvents were transferred via syringe and cannula using standard techniques. The reaction solvents tetrahydrofuran (THF), dichloromethane (DCM), and diethyl ether (Et_2O) were dried by passage over a column of activated alumina using a solvent purification system; toluene was freshly distilled over calcium hydride prior to use. Chloroform and anhydrous *N*,*N*-dimethylformamide (DMF) were purchased and used as received from Aldrich Chemical Co. All other solvents and reagents were used as received unless otherwise noted. Reaction temperatures above 23 °C refer to oil bath temperature, which was controlled by a temperature modulator. Reaction progress was monitored by thin layer chromatography using EMD Chemicals Silica Gel 60 F254 glass plates (250 μm thickness) and visualized by UV irradiation (at 254 nm) and $KMnO_4$ stain. Purification of the compounds by flash column chromatography (FCC) was performed using silica gel (32-63 μm particle size, 60 Å pore size).

^{1}H NMR and ^{13}C NMR spectra were recorded on 300 MHz, 400 MHz, or 500 MHz spectrometers. ^{1}H and ^{13}C chemical shifts (δ) are reported relative to the solvent signal, $CHCl_3$ ($\delta = 7.24$ for ^{1}H NMR and $\delta = 77.00$ for ^{13}C NMR). Data are reported as follows: chemical shift (multiplicity, coupling constants where applicable, number of hydrogens). The following abbreviations are used to denote multiplicities: s, singlet; d, doublet; t, triplet; q, quartet; p, pentet; m, multiplet; b, broad. Coupling constants, J, are reported in hertz (Hz). All NMR spectra were obtained at rt unless otherwise specified. IR spectra were recorded on a 360 spectrometer and are reported in frequency of absorption (cm^{-1}). Only select IR peaks are reported. High resolution mass spectral data were obtained from the University of Pittsburgh, Department of Chemistry Mass Spectral Facility. References located after compound names refer to literature protocols for the preparation of these or similar compounds by comparable methods.



(a) $ZnEt_2$, *N*-methyl imidazole (NMI), CH_2Cl_2, heptanal **S2**, 79%; (b) TBSCl, imidazole, CH_2Cl_2, 94%; (c) TBDPSCl, imidazole, CH_2Cl_2, 90%; (d) MeI, Ag_2O, Et_2O, 78%; (e) 1: BrMgCCH, THF, 2: MOMCl, iPr_2NEt, CH_2Cl_2, 72%; (f) n-BuLi, $ClCO_2Me$, THF, 85%.



S3

Methyl 4-hydroxydec-2-ynoate S3: Under nitrogen, to a flame-dried 50 mL round-bottomed flask containing 30 mL of CH_2Cl_2 were sequentially added *N*-methyl imidazole (NMI, 0.25 mmol, 20 μL), methyl propiolate **S1** (6 mmol, 0.504 g) and diethylzinc ($ZnEt_2$, 6.0 mL of a 1.0 M solution in heptane, 6.0 mmol). The resulting mixture was stirred at rt for 3 h, followed by the addition of heptanal (5 mmol, 0.571 g). The resulting mixture was stirred for additional 12 h. Saturated NH_4Cl solution (20 mL) was added to quench the reaction, and the aqueous layer was extracted with CH_2Cl_2 (2 x 10 mL). The combined organic layers were dried over anhydrous sodium sulfate, filtered and then concentrated under reduced pressure. The residue was purified by flash column chromatography (silica gel, 50% diethyl ether in hexanes) to give the product as a yellow oil (0.787 g, 79%). ^{1}H and ^{13}C NMR spectra agreed with those previously reported.[1]

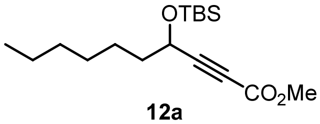
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.46 (app q, *J* = 6.5 Hz, 1H), 3.76 (s, 3H), 2.71 (d, *J* = 3.5 Hz, 1H), 1.77-1.71 (m, 2H), 1.47-1.40 (m, 2H), 1.33-1.22 (m, 6H), 0.86 (t, *J* = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.9, 88.5, 76.1, 62.0, 52.8, 36.8, 31.6, 28.8, 24.8, 22.5, 13.9 ppm;

IR (film): 3416, 2954, 2930, 2859, 2237, 1719, 1436, 1437, 1254, 1049, 752 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{11}H_{19}O_3$, 199.1334; found, 199.1330;

TLC: R_f = 0.42 (50% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain]



12a

Methyl 4-((*tert*-butyldimethylsilyl)oxy)dec-2-ynoate 12a: The methyl 4-hydroxydec-2-ynoate **S3** (1.85 mmol, 0.366 g) was dissolved in 10 mL CH_2Cl_2 and cooled to 0 °C under nitrogen. To this stirred solution was added imidazole (4.62 mmol, 0.314 g). After 15 min, *tert*-butyldimethylsilyl chloride (2.40 mmol, 0.361 g) was added at the same temperature. The reaction solution was allowed to stir overnight at rt. The reaction was then quenched by the addition of water and the organic phase was washed by brine and water. The combined organic layers were dried over anhydrous sodium sulfate, filtered and then concentrated under reduced pressure. The residue was purified by flash column chromatography (silica gel, 5% diethyl ether/hexanes) to give the product as a yellow oil (0.539 g, 94%).

^{1}H NMR (500 MHz, $CDCl_3$): δ 4.43 (t, *J* = 6.5 Hz, 1H), 3.76 (s, 3H), 1.72-1.67 (m, 2H),

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[1] *Journal of Agricultural and Food Chemistry*, **2004**, *52*, 7075-7083.

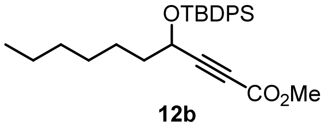
1.45-1.37 (m, 2H), 1.31-1.24 (m, 6H), 0.89 (s, 9H), 0.86 (t, J = 2.5 Hz, 3H), 0.13 (s, 3H), 0.1 (s, 3H)ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.9, 89.2, 75.6, 62.6, 52.6, 37.7, 31.7, 28.8, 25.7, 24.9, 22.5, 18.1, 14.0, -4.63, -5.18 ppm;

IR (film): 3425, 2931, 2859, 2236, 1722, 1464, 1435, 1252, 1094, 838, 779 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{17}H_{33}O_3Si$, 313.2199; found, 313.2201;

TLC: R_f = 0.43 (5% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



12b **Methyl 4-((*tert*-butyldiphenylsilyl)oxy)dec-2-ynoate 12b:** The methyl 4-hydroxydec-2-ynoate **S3** (3.03 mmol, 0.600 g) was dissolved in 15 mL CH_2Cl_2 and cooled to 0 °C under nitrogen. To this stirred solution was added imidazole (7.58 mmol, 0.520 g). After 15 min, *tert*-butyldiphenylsilyl chloride (4.55 mmol, 1.25 g) was added at same temperature. The reaction solution was allowed to stir overnight at rt. The reaction was then quenched by the addition of water and the organic phase was washed by brine and water. The combined organic layers were dried over anhydrous sodium sulfate, filtered and then concentrated under reduced pressure. The residue was purified by flash column chromatography (silica gel, 5% diethyl ether/hexanes) to give the product as a yellow oil (1.18 g, 90%).

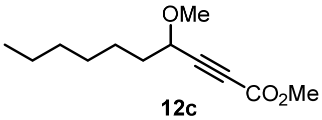
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.74 (dd, J = 6.5, 1.5 Hz, 2H), 7.68 (dd, J = 6.5, 1.5 Hz, 2H), 7.47−7.37 (m, 6H), 4.42 (t, J = 7.8 Hz, 1H), 3.75 (s, 3H), 1.76−1.66 (m, 2H), 1.44−1.37 (m, 2H), 1.27−1.21 (m, 6H), 1.10 (s, 9H), 0.88 (t, J = 7.5 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.8, 136.0, 135.8, 133.0, 132.9, 129.9, 129.8, 127.7, 127.5, 88.8, 76.1, 63.5, 52.5, 37.5, 31.6, 28.7, 26.8, 24.5, 22.5, 19.2, 14.0 ppm;

IR (film): 3072, 2954, 2931, 2858, 2236, 1720, 1463, 1430, 1251, 1110, 740 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{27}H_{37}O_3Si$, 437.2512; found, 437.2533;

TLC: R_f = 0.40 (5% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].



12c

Methyl 4-methoxydec-2-ynoate 12c: A mixture of methyl 4-hydroxydec-2-ynoate **S3** (0.77 g, 3.88 mmol), iodomethane (0.59 mL, 9.7 mmol), and silver oxide (2.25 g, 9.7 mmol) in ether (15 mL) was stirred for 48 h under a nitrogen atmosphere. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated. Purification of the residue by chromatography on silica gel (10% diethyl ether/hexanes) gave the product as a yellow oil (0.64 g, 78%).

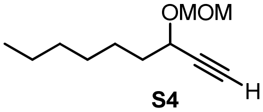
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.04 (t, *J* = 6.5 Hz, 1H), 3.78 (s, 3H), 3.41 (s, 3H), 1.80-1.68 (m, 2H), 1.45-1.42 (m, 2H), 1.33-1.25 (m, 6H), 0.87 (t, *J* = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.7, 86.6, 71.0, 56.9, 52.7, 34.9, 31.6, 28.9, 25.0, 22.5, 14.0 ppm;

IR (film): 3421, 2930, 2858, 2234, 1721, 1460, 1435, 1335, 1250, 1100, 947, 751 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{12}H_{21}O_3$, 213.1491; found, 213.1481;

TLC: R_f = 0.41 (10% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain]



S4

3-(Methoxymethoxy)non-1-yne S4:

N,N-diisopropylethylamine (1.29 g, 10 mmol) was added to a solution of non-1-yn-3-ol (0.720 g, 5.14 mmol) in CH_2Cl_2 (30 mL) at 0 °C. Then, chloromethoxymethane (1.2 g, 14.9 mmol) was added and after 1 h the reaction mixture was warmed to rt. After 24 h stirring, the resultant mixture was poured into saturated aqueous $NaHCO_3$. The extract with CH_2Cl_2 was dried over sodium sulfate and evaporated. Purification of the crude product by silica gel column chromatography gave the product as colorless oil (0.67g, 72%).

^{1}H NMR (400 MHz, $CDCl_3$): δ 4.93 (d, *J* = 6.8 Hz, 1H), 4.58 (d, *J* = 6.8 Hz, 1H), 4.31

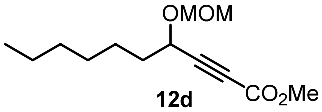
(td, *J* = 6.4 Hz, 2.0 Hz, 1H), 3.37 (s, 3H), 2.39 (d, *J* = 2.0 Hz, 1H), 1.77-1.69 (m, 2H), 1.49-1.30 (m, 2H), 1.38-1.24 (m, 6H), 0.88 (t, *J* = 6.8 Hz, 3H) ppm;

^{13}C NMR (100 MHz, $CDCl_3$): δ 94.1, 82.7, 73.4, 65.4, 55.7, 35.6, 31.2, 28.9, 25.2, 22.6, 14.1 ppm;

IR (film): 3309, 2928, 2859, 1732, 1689, 1464, 1154, 1099, 1030 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{11}H_{21}O_2$, 185.1542; found, 185.1541;

TLC: R_f = 0.55 (10% diethyl ether/hexanes) [silica gel, KMnO4 stain].



12d

Methyl 4-(methoxymethoxy)dec-2-ynoate 12d: To a solution of 3-(methoxymethoxy)non-1-yne **S4** (1.5 g, 8.15 mmol) in anhydrous THF (40 mL) under a nitrogen atmosphere, n-butyllithium (5.6 mL of a 1.6 M solution in hexanes, 8.96 mmol) was added dropwise at -78 °C. After stirring for 30 minutes at -78 °C, methyl chloroformate (1.00 g, 10.6 mmol) was added in one portion. The reaction was stirred at -78 °C for 30 min and was then allowed to reach rt over a period of 3 h. The reaction was quenched using saturated aqueous NH_4Cl (20 mL) and extracted with Et_2O (3x50 mL). The combined organic fractions were dried over sodium sulfate, filtered, and concentrated under reduced pressure. The crude product was purified by flash column chromatography on silica gel (10% diethyl ether/hexanes) gave the product as a yellow oil (1.67 g, 85%).

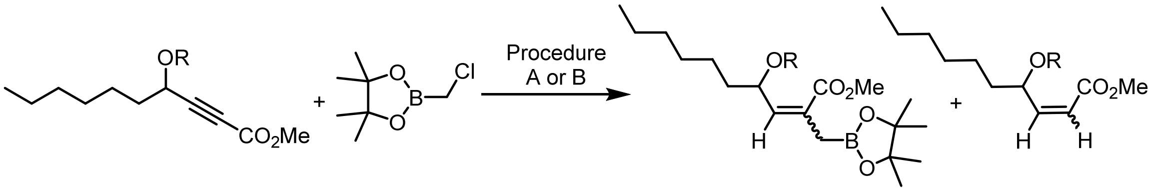
^{1}H NMR (500 MHz, $CDCl_3$): δ 4.86 (d, *J* = 7.0 Hz, 1H), 4.58 (d, *J* = 7.0 Hz, 1H), 4.40 (t, *J* = 7.0 Hz, 1H), 3.76 (s, 3H), 3.37 (s, 3H), 1.79-1.73 (m, 2H), 1.47-1.42 (m, 2H), 1.35-1.24 (m, 6H), 0.87 (t, *J* = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 153.7, 94.6, 86.6, 76.7, 65.3, 55.8, 52.7, 34.9, 31.6, 28.8, 25.1, 22.6, 14.0 ppm;

IR (film): 3421, 2931, 2860, 2236, 1722, 1460, 1435, 1253, 1154, 1027, 922, 752 cm^{-1};

<u>HRMS</u>: $[M + H]^+$ calcd for $C_{13}H_{23}O_4$, 243.1596; found, 243.1592;

<u>TLC</u>: R_f = 0.33 (10% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



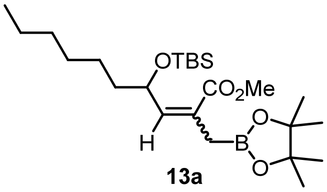
13a : R = TBS
13b : R = TBDPS
13c : R = Me
13d : R = MOM

(A) Hexamethylphosphoramide, diisobutylaluminum hydride, toluene, 0 °C (B) Methyl lithium, CuI, hexamethylphosphoramide, diisobutylaluminum hydride, toluene, -30 °C

General methods A and B for the synthesis of allylboronate compounds:

A: To a stirred solution of hexamethylphosphoramide (3 mmol, 3 equiv) in toluene (5 mL) was added dropwise at 0 °C a 1 M solution of diisobutylaluminum hydride (1.55 mmol, 1.55 equiv) in hexanes. After the mixture was stirred at 0 °C for 2 h, ynoate **12** (1 mmol, 1 equvi) in toluene (3 mL) was added dropwise and the reaction mixture was stirred at 0 °C overnight. Then, pinacol chloromethylboronate (1.2 mmol, 1.2 equiv) in toluene (2 mL) was introduced and stirring was maintained at rt for 48 h. After dilution 1M HCl (2 mL), the organic layer was then successively washed with 1M HCl (3x), saturated sodium bicarbonate and water (2x). The combined organic fractions were dried over sodium sulfate, filtered, and concentrated under reduced pressure. The crude product was purified by a short silica gel plug (5 g, 10% diethyl ether/hexanes) to afford **13** as a yellow oil contaminated with an alkene by-product.

B: To a stirred solution of CuI (0.1 mmol, 0.1 equiv) in THF (3 mL), cooled to -30 °C, was added a 1.6 M solution of methyllithium (0.1 mmol, 0.1 equiv) in ether. After 20 min stirring at this temperature, toluene (7 mL) and hexamethylphosphoramide (2 mmol, 2 equiv) were added to this mixture. Diisobutylaluminum hydride (1.5 mmol, 1M solution in toluene, 1.5 equiv) was then added dropwise and the reaction mixture was stirred at -30 °C for 2 h. Ynoate **12** (1 mmol, 1 equiv) in toluene (5 mL) was added and the reaction mixture was stirred at -20 °C for an additional 5 h. Then, a solution of pinacol chloromethylboronate (1.2 mmol, 1.2 equiv) in toluene (2 mL) was introduced and stirring was maintained at rt overnight. After dilution with ether, the reaction mixture was slowly quenched with 1M HCl (1 mL). The organic layer was then successively washed with 1 M HCl (3x), saturated sodium bicarbonate and water (2x). The combined organic fractions were dried over sodium sulfate, filtered, and concentrated under reduced pressure. The crude product was purified by short silica gel plug (5 g, 10% diethyl ether/hexanes) to afford the product as a yellow oil.



13a

Allylboronate 13a: Using general procedure A**,** ynoate **12a** (0.312 g, 1.0 mmol) was added to the solution of diisobutylaluminum hydride (1.55 mL of 1M solution in toluene, 1.55 mmol) and hexamethylphosphoramide (0.537 g, 3 mmol) in 5 mL toluene. After the addition of pinacol chloromethylboronate (0.264 g, 1.5 mmol), the desired allylboronate product was afforded as a mixture of two diastereomers (*Z/E* = 1.9/1, 91%) and alkene (*Z/E* = 2/1, 9%) based upon crude NMR.

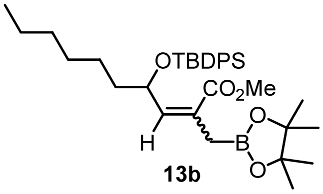
^{1}H NMR (500 MHz, $CDCl_3$): **Z-13a** δ 5.81 (d, *J* = 8.0 Hz, 1H), 5.03-4.98 (m, 1H), 3.69 (s, 3H), 1.83 (d, *J* = 15.8 Hz, 1H), 1.77 (d, *J* = 15.8 Hz, 1H), 1.51-1.35 (m, 4H), 1.32-1.22 (m, 6H), 1.21 (s, 12H), 0.85-0.81 (m, 12H), 0.02 (s, 3H), 0.01 (s, 3H) ppm, **E-13a** δ 6.59 (d, *J* = 8.5 Hz, 1H), 4.38-4.33 (m, 1H), 3.71 (s, 3H), 1.84 (d, *J* = 15.5 Hz, 1H), 1.78 (d, *J* = 16.0 Hz, 1H), 1.58-1.51 (m, 1H), 1.49-1.30 (m, 2H), 1.30-1.20 (m, 7H), 0.91-0.79 (m, 12H), 0.023 (s, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): **Z-13a** δ 167.8, 146.6, 126.3, 83.2, 69.6, 51.2, 37.6, 31.9, 29.3, 25.9, 25.2, 24.7, 22.6, 18.2, 14.1, -4.46, -4.99 ppm, **E-13a** δ 168.5, 143.6, 127.3, 83.3, 69.9, 51.7, 37.4, 31.8, 29.3, 25.8, 25.1, 24.7, 24.6, 22.6, 18.1, 14.1, -4.38, -4.94 ppm;

IR (film): 2954, 2930, 2857, 1721, 1649, 1464, 1352, 1254, 1146, 1073, 837, 777cm^{-1};

HRMS: [M + Na]$^{+}$calcd for $C_{24}H_{47}BO_5SiNa$, 477.3184; found, 477.3206;

TLC: R_f= 0.33 (10% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



13b

Allylboronate 13b: Using general procedure B**,** ynoate **12b** (1.18 g, 2.72 mmol) was added to the solution of CuI (0.052 g, 0.272 mmol), methyl lithium (0.17 mL, 0.272 mmol), diisobutylaluminum hydride (4.08 mL of 1M solution in toluene, 4.08 mmol) and hexamethylphosphoramide (0.97 g, 5.44 mmol) in 6 mL THF and 8 mL toluene. After the addition of pinacol chloromethylboronate (0.57 g, 1.2 mmol), the desired allylboronate product was afforded as a mixture of two diastereomers (*Z/E* = 3/1, 90%) and alkene (*Z/E* = 2/1, 10%) based upon crude NMR.

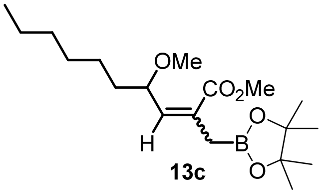
^{1}H NMR (500 MHz, $CDCl_3$): **Z-13b** δ 7.67 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.63 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.45-7.29 (m, 6H), 5.90 (d, *J* = 8.5 Hz, 1H), 5.05-5.00 (m, 1H), 3.43 (s, 3H), 1.68 (d, *J* = 8.5 Hz, 1H), 1.63 (d, *J* = 8.5 Hz, 1H), 1.63-1.55 (m, 1H), 1.50-1.43 (m, 1H), 1.35-1.15 (m, 8H), 1.22 (s, 6H), 1.20 (s, 6H), 1.05 (s, 9H), 0.85 (t, *J* = 7.0 Hz, 3H) ppm, **E-13b** δ 7.67 (dd, *J* = 7.5, 1.5 Hz, 2H), 7.62 (dd, *J* = 7.5, 1.5 Hz, 2H), 7.44-7.29 (m, 6H), 6.63 (d, *J* = 8.5 Hz, 1H), 4.42-4.37 (m, 1H), 3.69 (s, 3H), 1.63-1.54 (m, 1H), 1.49-1.45 (m, 1H), 1.47 (d, *J* = 15.5 Hz, 1H), 1.35 (d, *J* = 16 Hz, 1H),1.30-1.12 (m, 8H), 1.18 (s, 6H), 1.17 (s, 6H), 1.05 (s, 9H), 0.84 (t, *J* = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): **Z-13b** δ 167.4, 145.45, 135.9, 135.8, 134.5, 134.4, 129.3, 129.2, 127.3, 127.2, 126.6, 83.1, 70.6, 50.8, 37.6, 31.8, 31.5, 29.2, 27.1, 24.6, 22.5, 19.3, 14.1 ppm, **E-13b** δ 168.3, 142.6, 135.88, 135.8, 134.2, 133.9, 129.5, 129.4, 127.8, 127.5, 127.4, 83.1, 70.6, 51.6, 37.5, 34.6, 31.7, 29.3, 27.0, 24.7, 22.6, 19.2, 14.0 ppm;

IR (film): *Z/E* mixture 3070, 3048, 2930, 2857, 1716, 1649, 1467, 1429, 1352, 1326, 1145, 1109, 1063, 1003, 823cm^{-1};

HRMS: [M + H]$^{+}$ calcd for $C_{34}H_{52}BO_5Si$, 579.3677; found, 579.3656;

TLC: R_f = 0.29 (10% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



13c

Allylboronate 13c: Using general procedure A**,** ynoate **12c** (0.80 g, 3.77 mmol) was added diisobutylaluminum hydride (5.84 mL of 1M solution in toluene, 5.84 mmol) and hexamethylphosphoramide (2.02 g, 11.31 mmol) in toluene. After the addition of pinacol chloromethylboronate (0.99 g, 5.65 mmol), the desired allylboronate product was afforded as two diastereomers (Z/E = 9/1, 95%) and alkenes (Z/E = 1/1, 5%) based upon crude NMR.

Using general procedure B**,** ynoate **12c** (0.78 g, 3.68 mmol) was added to the solution of CuI (0.071 g, 0.37 mmol), methyl lithium (0.23 mL, 0.37 mmol), diisobutylaluminum hydride (5.52 mL of a 1M solution in toluene, 5.52 mmol) and hexamethylphosphoramide (1.32 g, 7.36 mmol) in 6 mL THF and 8 mL toluene. After the addition of pinacol chloromethylboronate (0.77 g, 4.41 mmol), the desired allylboronate product was afforded as a mixture of diastereomers (Z/E = 2/1, 88%) and alkene (Z/E = 1.5/1) based upon crude NMR.

^{1}H NMR (500 MHz, $CDCl_3$): δ 6.50 (d, *J* = 9.0 Hz, 1H)*, 5.70 (d, *J* = 9.0 Hz, 1H)**, 4.51-4.46 (m, 1H)**, 3.92-3.89 (m, 1H)*, 3.71 (s, 3H)*, 3.69 (s, 3H)**, 3.25 (s, 3H)**, 3.24 (s, 3H)*, 1.91-1.81 (m, 2H), 1.64-1.52 (m, 1H), 1.49-1.40 (m, 1H), 1.37-1.22 (m, 8H), 1.20 (s, 12H)**, 1.19 (s, 12H)*, 0.84 (t, *J* = 7.0 Hz, 3H) ppm;

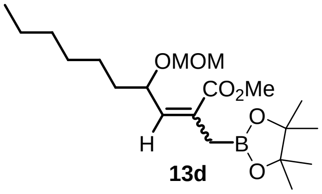
^{13}C NMR (125 MHz, CDCl$_3$): δ 168.1*, 167.9**, 143.5**, 140.7*, 131.4*, 130.6**, 83.3*, 83.25**, 77.8*, 77.6**, 56.6*, 56.5**, 51.8*, 51.3**, 35.2**, 34.85*, 31.8**, 31.7*, 29.3*, 29.28**, 25.1**, 25.08*, 24.67**, 24.62**, 24.59*, 22.5*, 14.03**, 14.0*ppm;

(E-diastereomer *, Z-diastereomer**)

IR (film): **Z/E** mixture 2978, 2930, 2859, 2820, 1720, 1648, 1464, 1351, 1202, 1146, 1096, 968, 848 cm^{-1};

HRMS: [M + H]$^+$ calcd for $C_{19}H_{36}BO_5$, 355.2650; found, 355.2682;

TLC: R_f = 0.25 (20% diethyl ether/hexanes) [silica gel, KMnO$_4$ stain].



13d

Allylboronate 13d: using general procedure A, ynoate **12d** (0.57 g, 2.36 mmol) was added to the solution of diisobutylaluminum hydride (3.65 mL of a 1M solution in toluene, 3.65 mmol) and hexamethylphosphoramide (1.27 g, 7.06 mmol) in toluene. After the addition of pinacol chloromethylboronate (0.83 g, 4.71 mmol), the desired allylboronate product was afforded as mixture of two diastereomers (*Z/E* = 4/1, 93%) and alkene (*Z/E* = 2.3/1, 7%) based upon crude NMR.

Using general procedure B, ynoate **12d** (1.00 g, 4.13 mmol) was added to the solution of CuI (0.079 g, 0.41 mmol), methyl lithium (0.26 mL, 0.41 mmol), diisobutylaluminum hydride (6.20 mL of a 1M solution in toluene, 6.20 mmol) and hexamethylphosphoramide (1.48 g, 8.26 mmol) in THF (7 mL) and toluene (9 mL). After the addition of pinacol chloromethylboronate (0.87 g, 4.96 mmol), the desired allylboronate product was afforded as a mixture of two diastereomers (*Z/E* = 2.8/1, 71%) and alkene (*Z/E* = 2.5/1, 29%) based upon crude NMR.

^{1}H NMR (500 MHz, $CDCl_3$): δ 6.49 (d, J = 9.0 Hz, 1H)*, 5.73 (d, J = 9.0 Hz, 1H)**, 4.92-4.88 (m, 1H)**, 4.66 (d, J = 7.0 Hz, 1H)**, 4.62 (d, J = 7.0 Hz, 1H)*, 4.50 (d, J = 7.0 Hz, 1H)**, 4.47 (d, J = 7.0 Hz, 1H)*, 4.37-4.32 (m, 1H)*, 3.70 (s, 3H)*, 3.69 (s, 3H)**, 3.33 (s, 3H)**, 3.32 (s, 3H)*, 1.88-1.80 (m, 2H), 1.48-1.40 (m, 2H), 1.63-1.56 (m, 1H), 1.53-1.45 (m, 1H), 1.43-1.22 (m, 8H), 1.20 (s, 12H), 0.84 (t, J = 7.0 Hz, 3H) ppm;

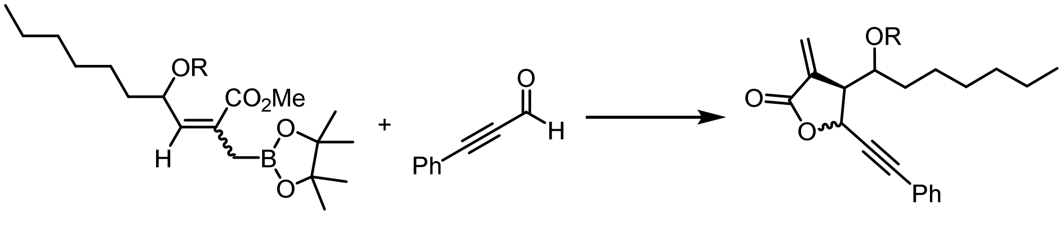
^{13}C NMR (125 MHz, $CDCl_3$): δ 168.1*, 167.7**, 142.6**, 139.8*, 131.4*, 130.1**, 94.6**, 94.1*, 83.3*, 83.26**, 73.1**, 72.1*, 55.4*, 55.3*, 51.8*, 51.3**, 35.3*, 34.8*, 31.8**, 31.7*, 29.23*, 29.2**, 25.23**, 25.2*, 24.7*, 24.6**, 24.57*, 22.56*, 14.03**, 14.0* ppm;

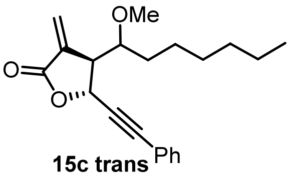
(E-diastereomer*, Z-diastereomer**)

IR (film): **Z/E** mixture 2930, 2858, 1721, 1647, 1465, 1437, 1352, 1272, 1213, 1148, 1098, 1036, 968, 848 cm^{-1};

HRMS: $[M - C_2H_5O_2]^+$ calcd for $C_{18}H_{32}BO_4$, 323.2394; found, 323.2361;

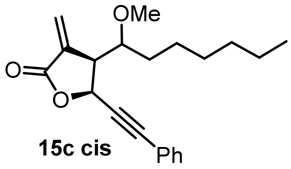
TLC: R_f = 0.30 (20% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].





15c trans

and



15c cis

***cis* and *trans*-Lactone 15c**: (Method **A**) Allylboronate **13c** (0.245 g, 0.69 mmol, Z/E=9:1) and 3-phenylpropiolaldehyde (0.20 g, 1.54 mmol) were dissolved in toluene (5 mL) under nitrogen and cooled to 0 °C. To this stirred solution was added boron trifluoride etherate (BF_3•Et_2O, 4 μl) and the reaction was stirred for 48 h. The reaction was quenched with a solution of NH_4Cl(aq)/NH_4OH (9 : 1) and extracted with diethyl ether (3x). The combined extracts were washed with brine and water. The organics phase were dried over sodium sulfate, filtered and concentrated in vacuo. The crude product was purified by flash chromatography (20% diethyl ether/ hexanes) to give *trans*-lactone (0.03 g, 13 %) as a yellow oil.

Method **B**: Allylboronate **13c** (0.30 g, 0.83 mmol, *Z/E*=2:1) and 3-phenylpropiolaldehyde (0.215 g, 1.66 mmol) were dissolved in toluene (5 mL) under nitrogen and cooled to 0 °C. To this stirred solution was added trifluoromethanesulfonic acid (TfOH, 10 μl) and the reaction was stirred at 0 °C for 24 h. The reaction was quenched with a solution of NH_4Cl(aq)/NH_4OH (9:1) and extracted with diethyl ether (3x). The combined extracts were washed with brine and water. The organic phase were dried over sodium sulfate, filtered and concentrated in vacuo. The crude product was purified by flash chromatography (20% diethyl ether/ hexanes) to afford lactone **15c** (0.205 g, 76%, *trans* : *cis* = 3 : 1) as a yellow oil. The *trans*-lactone **15c** was afforded as a 1.3:1 mixture of diastereomers and the *cis*-lactone **15c** was afforded as a 3.3:1 mixture of diastereomers.

Method **C**: Allylboronate **13c** (0.30 g, 0.83 mmol, *Z/E*=2:1) and 3-phenylpropiolaldehyde (0.215 g, 1.66 mmol) were dissolved in toluene (5 mL) under nitrogen and cooled to 0 °C. To this stirred solution was added scandium triflate ($Sc(OTf)_3$, 41 mg, 0.083 mmol) and the reaction was stirred at rt for 24 h. The reaction was quenched with a solution of NH_4Cl(aq)/NH_4OH (9 : 1) and extracted with diethyl ether (3x). The combined extracts were washed with brine and water. The organics phase were dried over sodium sulfate, filtered and concentrated in vacuo. The crude product was purified by flash chromatography (20% diethyl ether/ hexanes) to give lactone product (0.20 g, 74%, *trans* : *cis* = 4 : 1) as a yellow oil.

^{1}H NMR (500 MHz, $CDCl_3$): *trans*-lactone **15c** δ 7.43 (dd, *J* =1.5, 6.5 Hz, 2H), 7.38−7.29 (m, 3H), 6.39 (d, *J* = 2.5 Hz, 1H), 5.76 (d, *J* = 2.0 Hz, 1H), 5.22 (d, *J* = 4.0 Hz, 1H), 3.54−3.49 (m, 1H), 3.42 (s, 3H), 3.37−3.34 (m, 1H), 1.54−1.41 (m, 3H), 1.37−1.23 (m, 7H), 0.87 (t, J = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): *trans*-lactone **15c** δ 169.4, 134.5, 131.8, 129.0, 128.3, 124.6, 121.6, 87.3, 85.5, 82.5, 68.7, 57.7, 48.9, 31.7, 29.7, 29.2, 25.4, 22.5, 14.0 ppm;

IR (film): 3523, 2930, 2857, 2230, 1772, 1491, 1443, 1273, 1104, 1015, 758 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{21}H_{27}O_3$, 327.1960; found, 327.1963;

TLC: R_f = 0.43 (35% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].

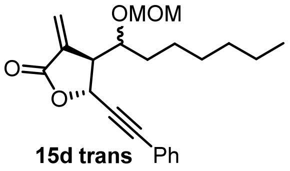
^{1}H NMR (500 MHz, $CDCl_3$): *cis*-lactone **15c** δ 7.46−7.44 (m, 2H), 7.38−7.32 (m, 3H), 6.38 (d, J = 2.5 Hz, 1H), 5.76 (d, J = 1.5 Hz, 1H), 5.51 (d, J = 8.0 Hz, 1H), 3.68−3.64 (m, 1H), 3.57−3.53 (m, 1H), 3.45 (s, 3H), 1.74−1.69 (m, 1H), 1.55−1.47 (m, 1H), 1.42−1.33 (m, 2H), 1.27 −1.19 (m, 6H), 0.83 (t, J = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): *cis*-lactone **15c** δ 169.3, 133.9, 131.8, 129.2, 128.4, 125.0, 121.5, 89.9, 82.1, 81.6, 69.4, 57.5, 43.6, 31.8, 30.6, 29.3, 25.7, 22.5, 14.0 ppm;

IR (film): 3432, 3034, 2930, 2857, 1769, 1458, 1274, 1104, 999, 762 cm^{-1};

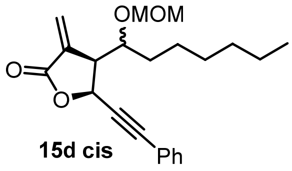
HRMS: $[M – H]^+$ calcd for $C_{21}H_{25}O_3$, 325.1804; found, 325.1779;

TLC: R_f = 0.27(35% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



15d trans

and



15d cis

***Cis*- and *trans*-Lactones 15d**: A solution of allylboronate **13d** (0.80 g, 2.08 mmol, *Z/E*=2.8:1) and 3-phenylpropiolaldehyde (0.215 g, 1.66 mmol) in toluene (10 mL) were heated to 100 °C in sealed tube under a nitrogen atmosphere for 48 h. The reaction was quenched with saturated NH_4Cl solution (3 mL) and extracted with Et_2O (3x10 mL). The combined extracts were washed with brine, dried over anhydrous sodium sulfate, filtered, and concentrated in vacuo. The crude product was purified by flash chromatography (20%

diethyl ether/ hexanes) to give lactone **15d** (0.606 g, 82% yield, *trans* : *cis* = 2.7 : 1) as a yellow oil. The *trans*-lactone was afforded as 1.7:1 mixtures of diastereomers and the *cis*-lactone as 1.4 :1 diastereomeric mixture.

^{1}H NMR (500 MHz, $CDCl_3$): *trans*-lactone **15d** δ 7.43−7.41 (m, 2H), 7.35−7.29 (m, 3H), 6.42 (d, *J* = 2.5 Hz, 1H), 5.74 (d, *J* = 1.5 Hz, 1H), 5.36 (d, *J* = 3.0 Hz, 1H), 4.71 (d, *J* = 7.0 Hz, 1H), 4.69 (d, *J* = 7.0 Hz, 1H), 3.76−3.72 (m, 1H), 3.55−3.53 (m, 1H), 3.42 (s, 3H), 1.56−1.51 (m, 1H), 1.49−1.41 (m, 2H), 1.33 −1.24 (m, 7H), 0.88 (t, *J* = 7.0 Hz, 3H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): *trans*-lactone **15d** δ 169.4, 134.2, 131.7, 129.0, 128.3, 124.7, 121.5, 96.4, 87.3, 85.7, 79.7, 68.9, 56.1, 50.1, 31.6, 30.1, 29.1, 25.6, 22.5, 14.0 ppm;

IR (film): 3468, 2930, 2857, 2230, 1770, 1491, 1445, 1273, 1119, 1028, 758 cm^{-1};

HRMS: $[M + Na]^+$ calcd for $C_{22}H_{28}O_4Na$, 379.1885; found, 379.1872;

TLC: R_f= 0.31 (35% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].

^{1}H NMR (500 MHz, $CDCl_3$): *cis*-lactone **15d** δ 7.46−7.28 (m, 5H), 6.44 (s, 1H)*, 6.41 (d, *J* = 2.0 Hz, 1H)**, 5.86 (d, *J* = 1.5 Hz, 1H)**, 5.84 (s, 1H)*, 5.47 (d, *J* = 8.0 Hz, 1H)**, 5.11 (d, *J* = 6.5 Hz, 1H)*, 4.79 (d, *J* = 7.0 Hz, 1H)**, 4.76 (d, *J* = 7.0 Hz, 1H)*, 4.74 (d, *J* = 7.0 Hz, 1H)*, 4.71 (d, *J* = 7.0 Hz, 1H)**, 4.14−4.09 (m, 1H)*, 4.07−4.01 (m, 1H)**, 3.61−3.56 (m, 1H)**, 3.45 (s, 3H)*, 3.44 (s, 3H)*, 3.36−3.31 (m, 1H)*, 1.73−1.63 (m, 1H), 1.53−1.22 (m, 9H), 0.86 (t, *J* = 7.0 Hz, 3H)*, 0.81 (t, *J* = 7.0 Hz, 3H)**ppm;

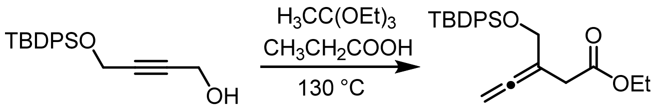
^{13}C NMR (125 MHz, $CDCl_3$): *cis*-lactone **15d** δ 169.2, 167.7, 138.1, 133.9, 131.8, 131.6, 129.3, 128.4, 128.3, 128.2, 125.2, 122.6, 121.4, 96.9, 96.0, 90.3, 88.1, 86.7, 81.8, 79.2, 79.16, 69.1, 65.4, 56.2, 56.1, 52.2, 45.3, 31.8, 31.7, 31.67, 30.9, 29.5, 29.2, 26.0, 23.4, 22.5, 22.49, 14.0, 13.97 ppm;

Major diastereomer **, minor diastereomer *

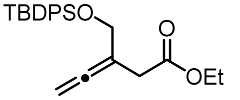
IR (film): 3448, 2929, 2857, 2237, 1773, 1720, 1442, 1268, 1146, 1100, 1034, 758 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{22}H_{29}O_4$, 357.2066; found, 357.2084;

TLC: R_f = 0.14 (35% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



S5 **16**, 82%



16

Ethyl (3-(*t*-Butyldiphenylsilyl)oxymethyl)penta-3,4-dienoate 16: To a flame dried two neck flask were added monoprotected propargyl alcohol **S5** (6.8 g, 21 mmol), triethyl orthoacetate (10.2 g, 11.5 ml, 63 mmol) and propionic acid (0.47 g, 6.29 mmol) under nitrogen. The mixture was heated at 130 °C for 5 h as the resulting ethanol was removed by a Dean-Stark trap. After the starting material was completely consumed as monitored by TLC, the mixture was cooled to rt. The cooled mixture was diluted with diethyl ether (100 mL) and washed with 1M HCl (3x30 mL). The aqueous layer was extracted with diethyl ether and the combined organic layer was washed with saturated sodium bicarbonate and brine and dried over anhydrous sodium sulfate. Concentration afforded a brown oil. Flash chromatography on silica gel (hexanes: diethyl ether = 3:1) gave 6.8 g of product (82% yield) as a colorless oil.

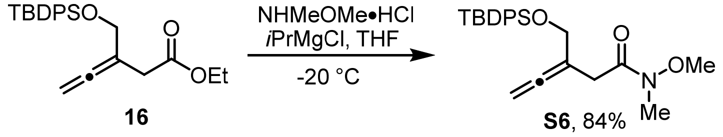
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.70-7.67 (m, 4H), 7.45-7.37 (m, 6H), 4.77 (m, 2H), 4.29 (t, *J* = 3.0 Hz, 2H), 4.14 (q, *J* = 7.0 Hz, 2H), 3.14 (t, *J* = 2.5 Hz, 2H), 1.25 (t, *J* = 2.0 Hz, 3H), 1.07 (s, 9H) ppm;

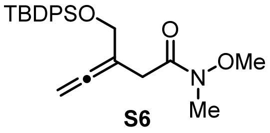
^{13}C NMR (125 MHz, $CDCl_3$): δ 206.7, 171.1, 135.5 (4), 133.4 (2), 129.6 (2), 127.6 (4), 97.1, 76.6, 64.1, 60.6, 34.9, 26.7, 19.3, 14.2 ppm;

IR (film): 3071, 2933, 2858, 2360, 1964, 1738, 1428, 1391, 1111, 823, 740 cm^{-1};

HRMS: $[M + Na]^+$ calcd for $C_{24}H_{30}O_3SiNa$, 417.1862; found, 417.1898;

TLC: R_f = 0.71 (35% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].





S6

3-(*t*-Butyldiphenylsilyl)oxymethyl-N-methoxy-N-methylpena-3,4-dienamide S6 : To a slurry of dienoate **16** (5.80 g, 14.7 mmol), *N,O*-dimethylhydroxylamine hydrochloride (1.86 g, 19.1 mmol) in THF (125 mL) at -20 °C was added 2M isopropylmagnesium chloride (18.4 mL, 36.8 mmol) under a nitrogen atmosphere. The reaction mixture was stirred at -10 °C for another 2 h until the starting material was completely consumed as monitored by TLC. The mixture was quenched with saturated NH_4Cl solution, diluted with water and extracted with ether (100 mL x 3). The combined organic layer was washed with brine and dried over anhydrous sodium sulfate. Removal of the solvent under vacuum and flash chromatography on silica gel (hexanes:diethyl ether = 2 : 1) gave 5.06 g of the product (84% yield) as a colorless oil.

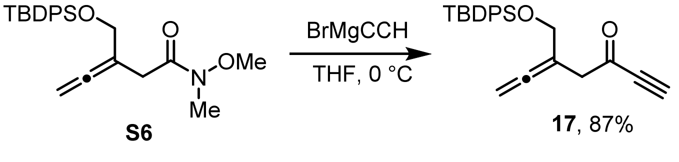
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.71-7.68 (m, 4H), 7.44-7.36 (m, 6H), 4.76 (t, J = 2.5 Hz, 2H), 4.31 (t, J = 2.5 Hz, 2H), 3.67 (s, 3H), 3.28 (b, s, 2H), 3.18 (s, 3H), 1.10 (s, 9H) ppm;

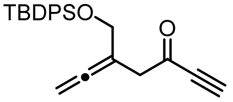
^{13}C NMR (125 MHz, $CDCl_3$): δ 206.6, 171.8, 135.5 (4), 133.5 (2), 129.6 (2), 127.6 (4), 97.9, 76.6, 64.4, 61.2, 32.9, 32.1, 26.8, 19.3 ppm;

IR (film): 3070, 2932, 2857, 1964, 1670, 1463, 1427, 1380, 1110, 1068, 824, 741 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{24}H_{32}NO_3Si$, 410.2151; found, 410.2131;

TLC: R_f = 0.23 (35% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].





17 **5-((*t*-Butyldiphenylsilyl)oxymethyl)hepta-5,6-dien-1-yn-3-one 17**: To a solution of the dienamide **S6** (4.20 g, 10.27 mmol) in THF (100 mL) was added ethynylmagnesium bromide (41.0 mL of 0.5 M solution in THF, 20.5 mmol) dropwise at 0 °C under a nitrogen atmosphere. Then, the reacting mixture was stirred for another 5 h at 0 °C as monitored by TLC. The reaction was quenched with saturated NH_4Cl solution. After the temperature rise to rt, the organic layer was transferred to a separation funnel and washed by water. The aqueous layer was extracted with diethyl ether and the combined organic layer was washed with brine and dried over anhydrous sodium sulfate. Concentration and purification by a short silica gel plug (hexanes : diethyl ether = 4 : 1) gave 3.34 g of the product (87%) as a pale yellow oil.

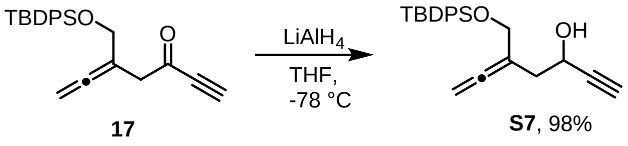
<u>^{1}H NMR</u> (500 MHz, $CDCl_3$): δ 7.70-7.68 (m, 4H), 7.46-7.38 (m, 6H), 4.81−4.75 (m, 2H), 4.25 (t, *J* = 2.5 Hz, 2H), 4.31 (t, *J* = 2.5 Hz, 2H), 3.21 (s, 1H), 1.07 (s, 9H);

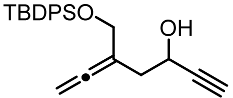
<u>^{13}C NMR</u> (125 MHz, $CDCl_3$): δ 207.2, 184.1, 135.6 (4), 133.2 (2), 129.7 (2), 127.7 (4), 95.9, 81.4, 79.0, 76.9, 64.1, 45.4, 26.7, 19.2;

<u>IR</u> (film): 3272, 3070, 2932, 2857, 2094, 1961, 1685, 1470, 1428, 1111, 824, 741 cm^{-1};

<u>HRMS</u>: $[M + H]^+$ calcd for $C_{24}H_{27}O_2Si$, 375.1780; found, 375.1809;

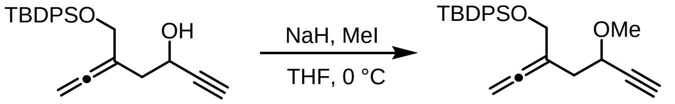
<u>TLC</u>: R_f = 0.51 (20% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].



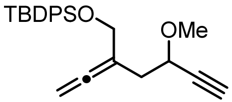


S7 **5-((*t*-Butyldiphenylsilyl)oxymethyl)hepta-5,6-dien-1-yn-3-ol S7**: A flame dried 100 mL round bottomed flask was charged with 1M lithium aluminum hydride (6.5 mL, 6.50 mmol) and diethyl ether (30 mL) under a nitrogen atmosphere. After cooling to -78 °C, a solution of alkynone **17** (2.70g, 7.22 mmol) in diethyl ether (20 mL) was added dropwise under nitrogen over 10 min. The resulting mixture was stirred at -78 °C for another 1 h and quenched with water. The aqueous layer was extracted with ether. The combined organic layers were dried over anhydrous sodium sulfate, filtered, evaporated, and purified by flash chromatography on silica gel (hexanes:diethyl ether = 2 : 1) to afford 2.64 g (98%) of the product as a colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$): δ 7.73-7.70 (m, 4H), 7.47-7.38 (m, 6H), 4.76 (p, *J* = 2.5 Hz, 2H), 4.60-4.55 (m, 1H), 4.27-4.20 (m, 2H), 3.04 (d, *J* = 6.0 Hz, 1H), 2.61-2.50 (m, 2H), 2.44 (d, *J* = 2.0 Hz, 1H), 1.10 (s, 9H) ppm;
^{13}C NMR (125 MHz, CDCl$_3$): δ 207.6, 135.7 (2), 135.6 (2), 133.13, 133.10, 129.8 (2), 127.7, 98.5, 84.55, 76.4, 72.8, 65.4, 61.3, 38.6, 26.8, 19.2 ppm;
IR (film): 3337, 3301, 3070, 2932, 2858, 1959, 1471, 1428, 1110, 1059, 823, 741 cm^{-1};
HRMS: [M + H]$^+$ calcd for $C_{24}H_{29}O_2Si$, 377.1937; found, 377.1946;
TLC: R_f = 0.23 (20% diethyl ether/hexanes) [silica gel, UV, KMnO$_4$ stain].



S7 **S8**, 90%



S8

5-methoxy-3-((*t*-Butyldiphenylsilyl)oxymethyl)hepta-1,2-dien-6-yne S8: A solution of propargylic alcohol **S7** (1.6 g, 4.26 mmol) in anhydrous THF (5 mL) was added dropwise to a solution of sodium hydride (0.122 g, 5.08 mmol) in THF (25 mL) at 0 °C under a nitrogen atmosphere. After being stirred for 15 min, iodomethane was slowly added to the solution. The resulting solution was then slowly warmed to rt and stirred for 3 h. The mixture was quenched with saturated NH_4Cl solution and extracted with diethyl ether (3 x 10 mL). The combined organic layers were washed by water, dried over anhydrous sodium sulfate, filtered, evaporated, and purified by flash chromatography on silica gel (hexanes:diethyl ether = 4 : 1) to afford 1.49 g (90%) of the product as a colorless oil.

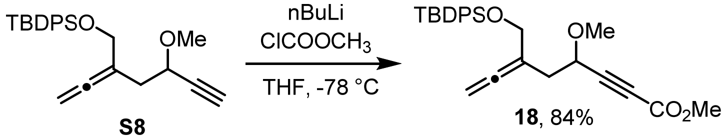
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.72-7.70 (m, 4H), 7.46-7.38 (m, 6H), 4.77 (p, *J* = 2.5 Hz, 2H), 4.25-4.24 (t, *J* = 2.5 Hz, 2H), 4.13-4.10 (dt, *J* = 2.0, 7.0 Hz, 1H), 3.40 (s, 1H), 2.58-2.47 (m, 2H), 2.43 (d, *J* = 2.0 Hz, 1H), 1.08 (s, 9H) ppm;

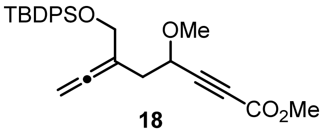
^{13}C NMR (125 MHz, $CDCl_3$): δ 206.4, 135.6 (4), 133.5 (2), 129.6 (2), 127.6 (4), 99.1, 82.5, 76.8, 73.7, 69.7, 64.7, 56.3, 35.1, 26.8, 19.3 ppm;

IR (film): 3291, 3071, 2932, 2857, 1961, 1589, 1469, 1428, 1109, 824, 740 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{25}H_{31}O_2Si$, 391.2093; found, 391.2089;

TLC: R_f = 0.61 (35% diethyl ether/hexanes) [silica gel, UV, KMnO4 stain].





18

Methyl 4-methoxy-6-((*t*-Butyldiphenylsilyloxy)methyl) octa-6,7-dien-2-ynoate 18: To a solution of alkyne **S8** (0.580 g, 1.49 mmol) in THF (5 mL) was added n-butyllithium (0.93 mL of a 1.6M solution in hexanes, 1.49 mmol) dropwise over a period of 5 min at -78 °C under a nitrogen atmosphere. After stirring for 30 min at -78 °C, this solution was added by cannula to a cold (-35 °C external temperature) mixture of methyl chloroformate (0.419 g, 4.46 mmol) in THF (5 mL). The temperature was maintained between -35 °C to -25 °C for another 30 min and the cooling bath removed. After stirring for another hour at rt, the reaction mixture was poured on to a 10 mL of saturated aqueous NH_4Cl solution. The product was extracted with ether (3 x 15 mL), washed with brine and dried over anhydrous sodium sulfate. Solvent was removed under vacuum and the residue was purified by flash chromatography on silica gel (hexanes:diethyl ether = 4 : 1) to afford 0.560 g (84%) of the product as a colorless oil.

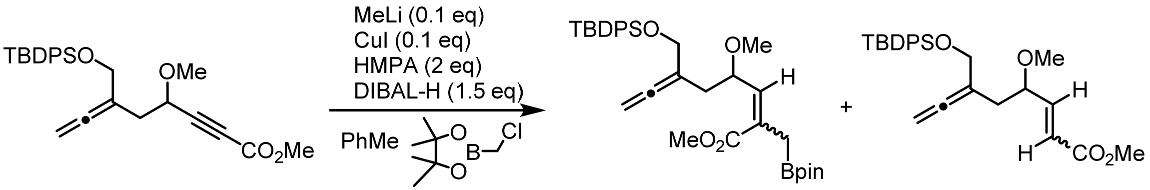
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.69-7.66 (m, 4H), 7.44-7.36 (m, 6H), 4.78-4.76 (m, 2H), 4.23-4.21 (m, 2H), 4.20 (t, *J* = 2.5 Hz, 2H), 3.78 (s, 3H), 3.39 (s, 3H), 2.55-2.50 (m, 2H), 1.06 (s, 9H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 206.4, 153.7, 135.6 (4), 133.4 (2), 129.7 (2), 127.7 (4), 98.4, 86.2, 77.3, 77.1, 69.8, 64.8, 56.9, 52.7, 34.4, 26.8, 19.3 ppm;

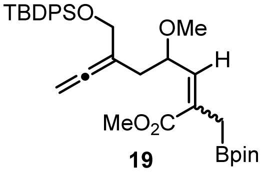
IR (film): 3534, 3071, 2932, 2857, 2236, 1961, 1719, 1431, 1253, 1109, 824, 742 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{27}H_{33}O_4Si$, 449.2148; found, 449.2153;

TLC: R_f = 0.45 (20% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain].



18 **19**, 78% *Z/E* = 1.2 :1 **S9**



19

Allylboronate 19: (Method A) To a stirred solution of hexamethylphosphoramide (0.268 g, 1.5 mmol) in toluene (3 mL) was added diisobutylaluminum hydride (0.78 mL of 1M solution in toluene, 0.78 mmol) dropwise at 0 °C. After the mixture was stirred at 0 °C for 2 h, ynoate **18** (0.224 g, 0.5 mmol) in toluene (1 mL) was added dropwise and the reaction mixture was stirred at 0 °C overnight. Then, freshly distilled pinacol chloromethylboronate (0.132 g, 1.5 mmol) in toluene (1 mL) was introduced and stirring was maintained at rt for 48 h. After dilution with 1M HCl (1 mL), the organic layer was then successively washed with 1M HCl (3x), saturated sodium bicarbonate and water (2x). The combined organic fractions were dried over sodium sulfate, filtered, and concentrated under reduced pressure. Crude NMR analysis shows 80% allylboronate **19** (*Z/E* = 2.2 : 1) and 20% alkene **S9** (*Z/E* = 3 : 1).

(Method B) To a stirred solution of CuI (0.15 g, 0.78 mmol) in dry THF (21 mL), cooled to -30 °C was added methyllithium (0.49 mL of 1M solution in ether, 0.78 mmol) under a nitrogen atmosphere. After 20 min stirring at this temperature, toluene (30 mL) and hexamethylphosphoramide (2.80 g, 15.6 mmol) were added to this mixture. Diisobutylaluminum hydride (11.7 mL of a 1 M solution in toluene, 11.7 mmol) was then added dropwise and the reaction mixture was stirred at -30 °C for 2 h. Ynoate **18** (3.50 g, 7.81mmol) in toluene (10 mL) was added dropwise and the reaction mixture was stirred at -20 °C for an additional 5 h. Freshly distilled pinacol chloromethyl boronate (1.65 g, 9.37 mmol) in toluene (3 mL) was introduced and stirring was maintained at rt overnight. After dilution with 100 mL of ether, the reaction mixture was slowly quenched with 1M HCl (5 mL). The organic layer was successively washed with 1M HCl (3x), saturated sodium bicarbonate and water (2x). The combined organic fractions were dried over sodium sulfate, filtered, and concentrated under reduced pressure. The crude NMR analysis shows allylboronate **19** (*Z/E* = 1.2 : 1, 89%) and alkene **S9** (*Z/E* = 2 : 1, 11%). Purification of crude products was accomplished on a short silica gel plug (40 g, 50% diethyl ether in hexanes) to provide 3.6 g (78%) of allyboronate as a mixture of two diastereomers.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.72-7.70 (m, 4H), 7.46-7.38 (m, 6H), 6.55 (d, *J* = 9.0 Hz, 1H)*, 5.76 (d, *J* = 9.0 Hz, 1H)**, 4.75−4.71 (m, 2H), 4.73−4.67 (m,1H)**, 4.24−4.17

(m,2H), 4.15−4.09 (m,1H)*, 3.73 (s, 1H)*, 3.67 (s, 1H)**, 3.27 (s, 1H)**, 3.25 (s, 1H)*, 2.42−2.24 (m, 2H), 1.95−1.87 (m, 2H), 1.22 (s, 12H)**, 1.21 (s, 12H)*, 1.06 (s, 9H) ppm;

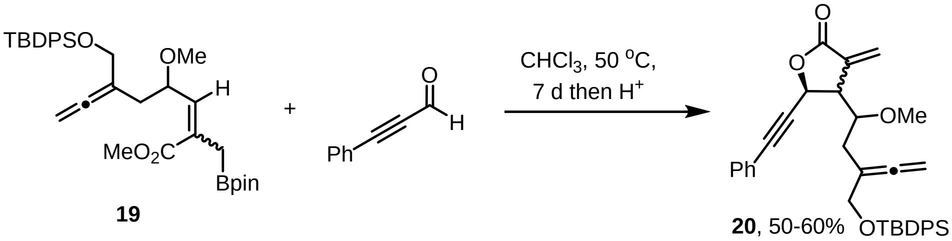
^{13}C NMR (125 MHz, $CDCl_3$): δ 206.5, 206.3, 168.1, 167.7, 142.4, 139.8, 135.6, 135.53, 133.7, 133.52, 133.50, 132.0, 131.1, 129.5, 129.46, 127.6, 127.5, 99.9, 99.6, 83.3, 83.2, 76.5, 76.3, 76.2, 76.17, 64.9, 64.8, 56.5, 56.47, 51.8, 51.3, 34.6, 34.2, 26.8, 24.7, 24.65, 24.6, 24.58, 19.24, 19.21 ppm;

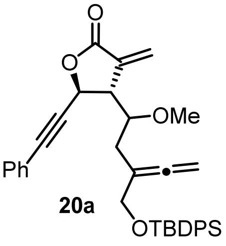
(E-diastereomer *, Z-diastereomer**)

IR (film): 3433, 3070, 2931, 2857, 1960, 1718, 1429, 1351, 1144, 1109, 824, 741 cm^{-1};

HRMS: [M] calcd for $C_{34}H_{45}BO_6Si$, 590.3235; found, 590.3298;

TLC: R_f = 0.38 (35% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].





20a

***Trans*-Lactone 20a and *Cis*-Lactone 20b:** A solution of *Z/E* (1.2 : 1) allylboronate **19** (3.15 g, 5.34 mmol) and 3-phenyl-propiolaldehyde (1.54 g, 11.9 mmol) in $CHCl_3$ (50 mL) was heated to 60 °C in a sealed tube under an nitrogen atmosphere for 7 d. After this time, no starting material was evident by tlc and *p*-toluenesulfonic acid monohydrate (0.103g, 0.53 mmol) was added, and the mixture was stirred overnight at rt. The reaction was quenched with $NaHCO_3$ (10 ml) and extracted with CH_2Cl_2 (3x20 mL). The combined extracts were washed with brine (20 mL), dried over anhydrous sodium sulfate, filtered, and concentrated. The crude product was purified by flash chromatography on silica gel (hexanes:diethyl ether = 3 : 1) to afford 1.2 g (40%) of the *trans*-lactone **20a** as two diastereomers as a yellow oil. The *cis*-lactone **20b** and unlactonized intermediates were collected as a mixture after purification. To 0.8 g of this mixture was added with sodium hydride (46 mg, 2 equiv) in THF (20 mL) at 0 °C for 3 h and then quenched with saturated NH_4Cl solution, extracted with Et_2O (3x20 mL). The combined extracts were washed with brine, dried over anhydrous sodium sulfate, filtered, and concentrated. Flash chromatography on silica gel gave 0.42 g (14%) *cis*-lactone **20b** as a single diastereomer as a yellow oil. The ^{13}C NMR shows evidence of an impurity that has not been characterized.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.71-7.66 (m, 5H), 7.46-7.36 (m, 10H), 6.40 (d, *J* = 2.0 Hz, 1H)*, 6.37 (d, *J* = 3.0 Hz, 1H)**, 5.75 (d, *J* = 2.0 Hz, 1H)*, 5.68 (d, *J* = 3.0 Hz, 1H)**, 5.40 (d, *J* = 4.0 Hz, 1H)**, 5.22 (d, *J* = 3.5 Hz, 1H)*, 4.81−4.77 (m, 2H), 4.27−4.20 (m, 2H), 3.64−3.60 (m, 1H), 3.51−3.48 (m, 1H)*, 3.43−3.40 (m, 1H)**, 3.38 (s, 3H)*, 3.34 (s, 3H)**, 2.52−2.45 (m, 1H)**, 2.42−2.36 (m, 1H)*, 2.32−2.24 (m, 1H), 1.08 (s, 9H)*, 1.07 (s, 9H)** ppm;

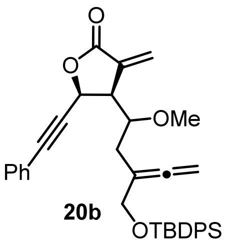
^{13}C NMR (125 MHz, $CDCl_3$): δ 206.3, 169.4, 169.3, 136.2, 135.6, 135.55, 135.53, 135.2, 134.8, 133.9, 133.3, 133.26, 131.8, 129.8, 129.6, 129.0, 128.9, 128.33, 128.29, 127.7, 127.67, 125.0, 123.4, 121.7, 121.6, 99.4, 87.4, 87.3, 85.9, 85.6, 80.9, 80.7, 77.2, 77.1, 69.5, 67.6, 65.0, 64.9, 58.3, 57.7, 49.9, 49.3, 30.1, 29.1, 26.8, 26.5, 19.3, 19.0 ppm;

Major diastereomer*, minor diastereomer**

IR (film): 3520, 3070, 2931, 2857, 1959, 1774, 1735, 1428, 1360, 1272, 1110, 823, 742 cm^{-1};

HRMS: $[M + Na]^+$ calcd for $C_{36}H_{38}O_4NaSi$, 585.2437; found, 585.2457;

TLC: R_f = 0.37 (35% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].



20b

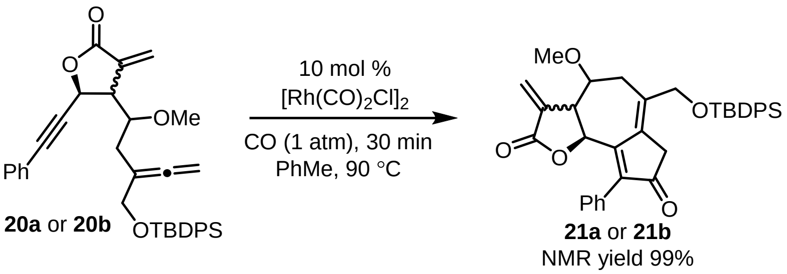
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.66-7.64 (m, 5H), 7.46-7.34 (m, 10H), 6.37 (d, J = 2.5 Hz, 1H), 5.79 (d, J = 2.0 Hz, 1H), 5.49 (d, J = 8.0 Hz, 1H), 4.76−4.73 (m, 1H), 4.69−4.65 (m, 1H), 4.22−4.14 (m, 2H), 3.93−3.89 (m, 1H), 3.53−3.49 (m, 1H), 3.38 (s, 3H), 2.60 (d, J = 2.5 Hz, 1H), 6.37 (d, J = 2.5 Hz, 1H), 2.16−2.11 (m, 1H), 1.03 (s, 9H) ppm;

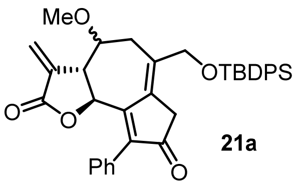
^{13}C NMR (125 MHz, $CDCl_3$): δ 205.9, 169.2, 135.6, 135.5, 131.9, 129.6, 129.6, 129.1, 128.3, 127.6, 125.0, 121.5, 100.7, 89.8, 82.3, 79.8, 77.5, 69.3, 64.9, 57.1, 44.2, 30.3, 26.8, 19.2 ppm; The 13C NMR

IR (film): 3437, 3070, 2931, 2857, 1960, 1773, 1721, 1428, 1268, 1110, 823, 742 cm^{-1};

HRMS: $[M + Na]^+$ calcd for $C_{36}H_{38}O_4NaSi$, 585.2437; found, 585.2501;

TLC: R_f = 0.18 (35% diethyl ether/hexanes) [silica gel, $KMnO_4$ stain]





21a

Trans [5-7-5] ring system 21a: A flame dried vial (25 x 70 mm) equipped with a teflon-coated stir-bar and a septa cap was charged with trans allene-yne **20a** (0.30 g, 0.53 mmol) and toluene (5 mL, degassed by bubbling with nitrogen for (5 min). The tube was evacuated for 3-5 sec and refilled with carbon monoxide (g) (3 x). To the allene-yne solution was added $[Rh(CO)_2Cl]_2$ (0.021g, 0.10 equiv) in one portion, and the vial was evacuated and refilled with carbon monoxide (g) (3 x). The vial was placed in a preheated 90 °C oil bath and stirred under carbon monoxide (g) for 30 min. After the reaction was complete in 30 min, the mixture was cooled to rt and triphenylphosphine polymer bound (0.177 g, 200-400 mesh, extent of labeling: ~3.0 mmol/g loading, 1 equiv) was added. The mixture was stirred overnight and eluted through a short plug of Celite using Et_2O, and concentrated in vacuo to give 0.32 g of product as a mixture of two diastereomers (2.4 : 1). The product was not stable during silica gel chromatography so it was directly used for the next step. The crude NMR analysis shows a quantitative yield for this reaction when compared against the internal standard, mesitylene. A small amount was purified by column chromatography for characterization purposes.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.72−7.69 (m, 1H), 7.68−7.65 (m, 2H), 7.48−7.32 (m, 10H), 7.25−7.22 (m, 1H), 6.35 (d, *J* = 4.0 Hz, 1H)*, 6.23 (d, *J* = 3.5 Hz, 1H)**, 5.86 (d, *J* = 3.0 Hz, 1H)**, 5.72 (d, *J* = 9.5 Hz, 1H)*, 5.49 (d, *J* = 3.5 Hz, 1H)*, 5.32 (d, *J* = 10.0 Hz, 1H)**, 4.32 (d, *J* = 13.0 Hz, 1H)**, 4.30 (d, *J* = 12.8 Hz, 1H)*, 4.27 (d, *J* = 12.8 Hz, 1H)*, 4.22 (d, *J* = 12.5 Hz, 1H)**, 4.00−3.95 (m, 1H)*, 3.86−3.83 (m, 1H)**, 3.424 (s, 3H)**, 3.42 (s, 3H)*, 3.30−3.38 (m, 1H), 3.15−3.08 (m, 1H), 2.86 (d, *J* = 21.0 Hz, 1H)**, 2.82 (d, *J* = 18.5 Hz, 1H)*, 2.76 (d, *J* = 18.5 Hz, 1H)*, 2.75 (d, *J* = 21.0 Hz, 1H)**, 2.43−2.38 (m, 1H) , 1.11 (s, 9H)*, 1.10 (s, 9H)** ppm;

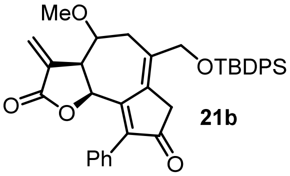
^{13}C NMR (125 MHz, $CDCl_3$): δ 201.5**, 201.1*, 168.2*, 167.9**, 162.0*, 161.5**, 143.1*, 142.1**, 137.2, 135.6, 135.56, 135.54, 135.50, 134.8, 133.5, 133.47, 133.0, 132.9, 132.88, 132.8, m132.76, 132.3, 132.26, 130.7, 130.2, 130.1, 130.0, 129.8, 129.7, 128.5, 128.4, 127.9, 127.8, 127.5, 122.6*, 121.9**, 81.7**, 75.6**, 74.7*, 73.8*, 66.4**, 66.0*, 57.2*, 56.3**, 49.61**, 49.56*, 39.3*, 39.2**, 32.9, 30.3, 29.1, 26.9, 26.88, 19.30 ppm;

Major diastereomer**, minor diastereomer*

IR (film): 3392, 3070, 2931, 2857, 1774, 1704, 1428, 1267, 1110, 822, 736 cm^{-1};

HRMS: $[M + H]^+$ calcd for $C_{37}H_{39}O_5Si$, 591.2567; found, 591.2567;

TLC: R_f = 0.48 (75% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].

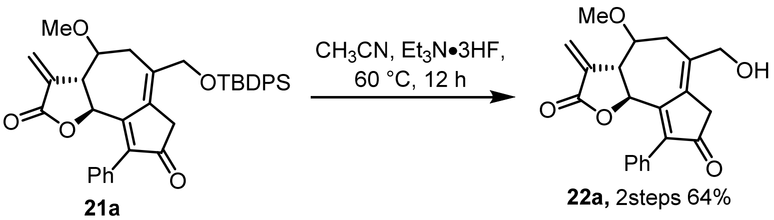

21b

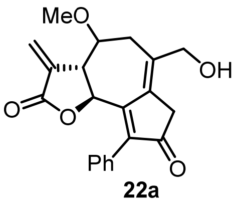
***Cis*-[5-7-5] ring system 21b**: Following the same procedure for the $[Rh(CO)_2Cl]_2$ catalyzed cyclocarbonylation reaction of trans lactone. *Cis*-allene-yne **20b** (0.20 g, 0.038 mmol) and $[Rh(CO)_2Cl]_2$ (0.014 g, 0.0356 mmol) were reacted in toluene (3 mL) for 30 min. Triphenylphosphine polymer bound (0.118 g) was added to the reaction mixture. The mixture was stirred overnight and then passed through a short plug of Celite using Et_2O, and concentrated in vacuo to give 0.23 g of product. The product was not stable during silica gel chromatography so it was directly used for the next step. A small amount was purified by column chromatography for characterization purposes.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.68-7.65 (m, 3H), 7.48-7.38 (m, 10H), 7.28−7.25 (m, 2H), 6.52 (d, J = 1.0 Hz, 1H), 5.93 (d, J = 0.5 Hz, 1H), 5.57 (d, J = 7.5 Hz, 1H), 4.27 (d, J = 13.5 Hz, 1H), 4.27 (d, J = 13.0 Hz, 1H), 3.75-3.70 (m, 1H), 3.61-3.51 (m, 1H), 3.44 (s, 3H), 2.96 (d, J = 18.5 Hz, 1H), 2.90 (d, J = 20.5 Hz, 1H), 2.80 (dd, J =1 Hz, 20.5 Hz, 1H), 2.36 (dd, J =10.0 Hz, 18.5 Hz, 1H), 1.06 (s, 9H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 201.6, 169.5, 156.7, 147.7, 136.9, 135.6, 135.5, 133.0, 132.98, 132.65, 130.2, 130.0, 129.8, 129.5, 129.2, 128.7, 128.2, 127.9, 127.88, 79.9, 72.8, 65.5, 56.8, 44.7, 40.3, 31.2, 26.8, 19.2 ppm;

TLC: R_f = 0.60 (75% diethyl ether/hexanes) [silica gel, UV, $KMnO_4$ stain].





22a ***Trans*-[5-7-5] ring system 22a**: A solution of TBDPS ether **21a** (0.32 g, 0.533) and triethylamine trihydrofluoride (0.174g, 1.08 mmol) in acetonitrile (4 mL) was heated at 60 °C for 12 h. The solution was allowed to cool to rt then partitioned between Et_2O (100 mL) and H_2O (15 mL). The organic phase was washed with $NaHCO_3$ 10 mL and H_2O 20 mL, dried over anhydrous sodium sulfate, filtered, and concentrated affording a yellow oil. Purification of the crude product by flash chromatography on neutral aluminum oxide (20 g, 10% methanol/ Et_2O) afforded the desired alcohol (0.12 g, 64% yield, two steps) as a mixture of diastereomers (3.9 : 1) as a yellow oil.

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41−7.34 (m, 3H), 7.32-7.25 (m, 2H), 6.35 (d, *J* = 3.5 Hz, 1H)*, 6.25 (d, *J* = 3.5 Hz, 1H)**, 5.86 (d, *J* = 3.0 Hz, 1H)**, 5.78 (d, *J* = 9.5 Hz, 1H)*, 5.52 (d, *J* = 3.0 Hz, 1H)*, 5.39 (d, *J* = 10.5 Hz, 1H)**, 4.28 (d, *J* = 12.5 Hz, 1H)**, 4.25 (d, *J* = 12.5 Hz, 1H)*, 4.22 (d, *J* = 12.5 Hz, 1H)*, 4.19 (d, *J* = 12.5 Hz, 1H)**, 4.11−4.00 (m, 1H)*, 3.88−3.84 (m, 1H)**, 3.54 (s, 3H)**, 3.44 (s, 3H)*, 3.29 (d, *J* = 21.0 Hz, 1H)**, 3.18 (d, *J* = 21.0 Hz, 1H)**, 3.12 −3.20 (m, 1H), 2.57 −2.50 (m, 1H)**, 2.49−2.45 (m, 1H)*, 1.99 (b s, 1H) ppm;

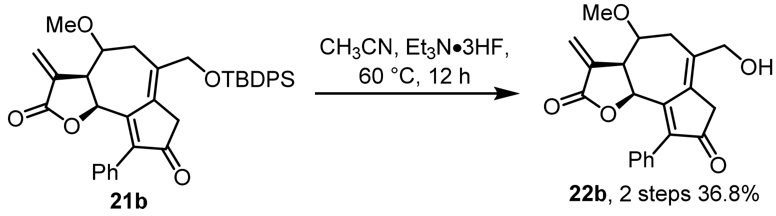
^{13}C NMR (125 MHz, $CDCl_3$): δ 201.4**, 201.35*, 168.2*, 167.7**, 162.2*, 161.6**, 143.4*, 142.8**, 137.0**, 134.8*, 133.5*, 133.45**, 133.2**, 132.5*, 130.6*, 130.5**, 129.8**, 129.7*, 128.6*, 128.55**, 127.6*, 127.5**, 122.7*, 121.9*, 81.5**, 75.6**, 74.7*, 73.7*, 65.2*, 65.1**, 57.2*, 56.6**, 49.8**, 49.5*, 39.6*, 39.3**, 33.5*, 30.3** ppm;

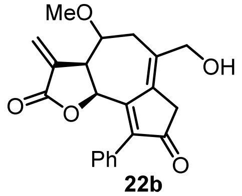
Major diastereomer**, minor diastereomer*

IR (film): 3432, 2931, 1768, 1698, 1393, 1270, 1134, 1094, 732 cm^{-1};

HRMS: $[M + Na]^+$ calcd for $C_{21}H_{20}O_5Na$, 375.1208; found, 375.1212;

TLC: R_f = 0.47 (10% methanol/EtOAc) [silica gel, $KMnO_4$ stain].





22b

Cis [5-7-5] ring system 22b: A solution of TBDPS ether **21b** (0.23 g) and triethylamine trihydrofluoride (0.114g, 0.71 mmol) in acetonitrile (4 mL) was heated at 60 °C for 12 h. The solution was allowed to cool to rt then partitioned between Et_2O (100 mL) and H_2O (15 mL). The organic phase was washed with $NaHCO_3$ (10 mL) and H_2O (20 mL), dried over anhydrous sodium sulfate, filtered, and concentrated affording a yellow oil. Purification of the crude product by flash chromatography on neutral aluminum oxide (15 g, 5% methanol/Et_2O) afforded the desired alcohol (0.046 g, 37% two steps) as a single diastereomer (yellow oil).

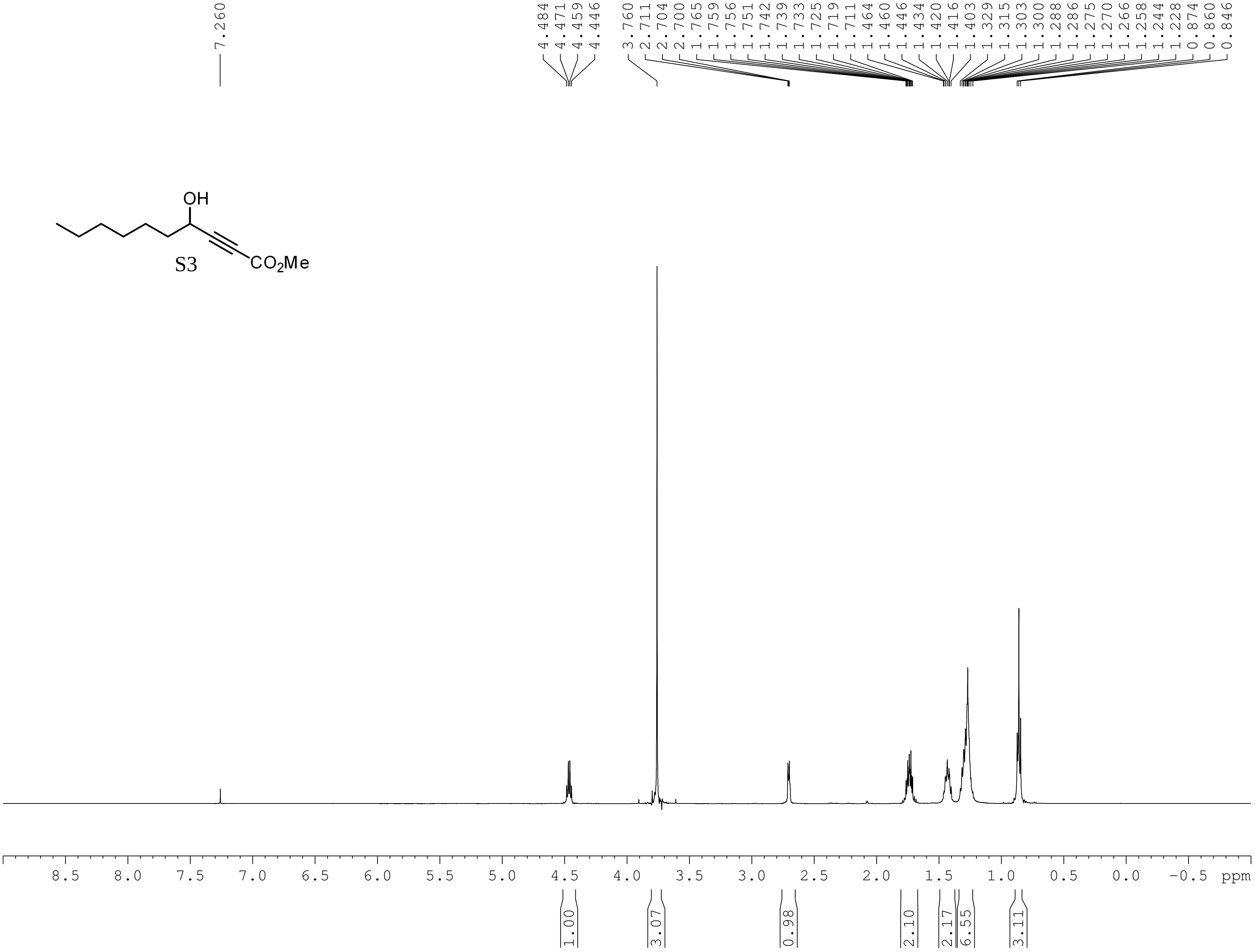
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.48-7.40 (m, 3H), 7.28-7.23 (m, 2H), 6.49 (d, J = 1.0 Hz, 1H), 5.91 (s, 1H), 5.58 (d, J = 7.5 Hz, 1H), 4.28 (d, J = 13.0 Hz, 1H), 4.17 (d, J = 13.0 Hz, 1H), 3.76-3.70 (m, 1H), 3.61-3.57 (m, 1H), 3.42 (s, 3H), 3.33 (d, J = 21.0 Hz, 1H), 3.23 (d, J = 21.0 Hz, 1H), 2.75 (d, J = 18.5 Hz, 1H), 2.39–2.32 (m, 1H) ppm;

^{13}C NMR (125 MHz, $CDCl_3$): δ 201.7, 169.6, 156.8, 147.8, 136.9, 132.8, 130.8, 129.6, 129.5, 129.2, 128.7, 128.3, 79.7, 72.9, 64.6, 56.7, 44.4, 40.5, 31.8;

IR (film): 3410, 2934, 1765, 1702, 1382, 1272, 1153, 1111, 994, 733 cm^{-1};

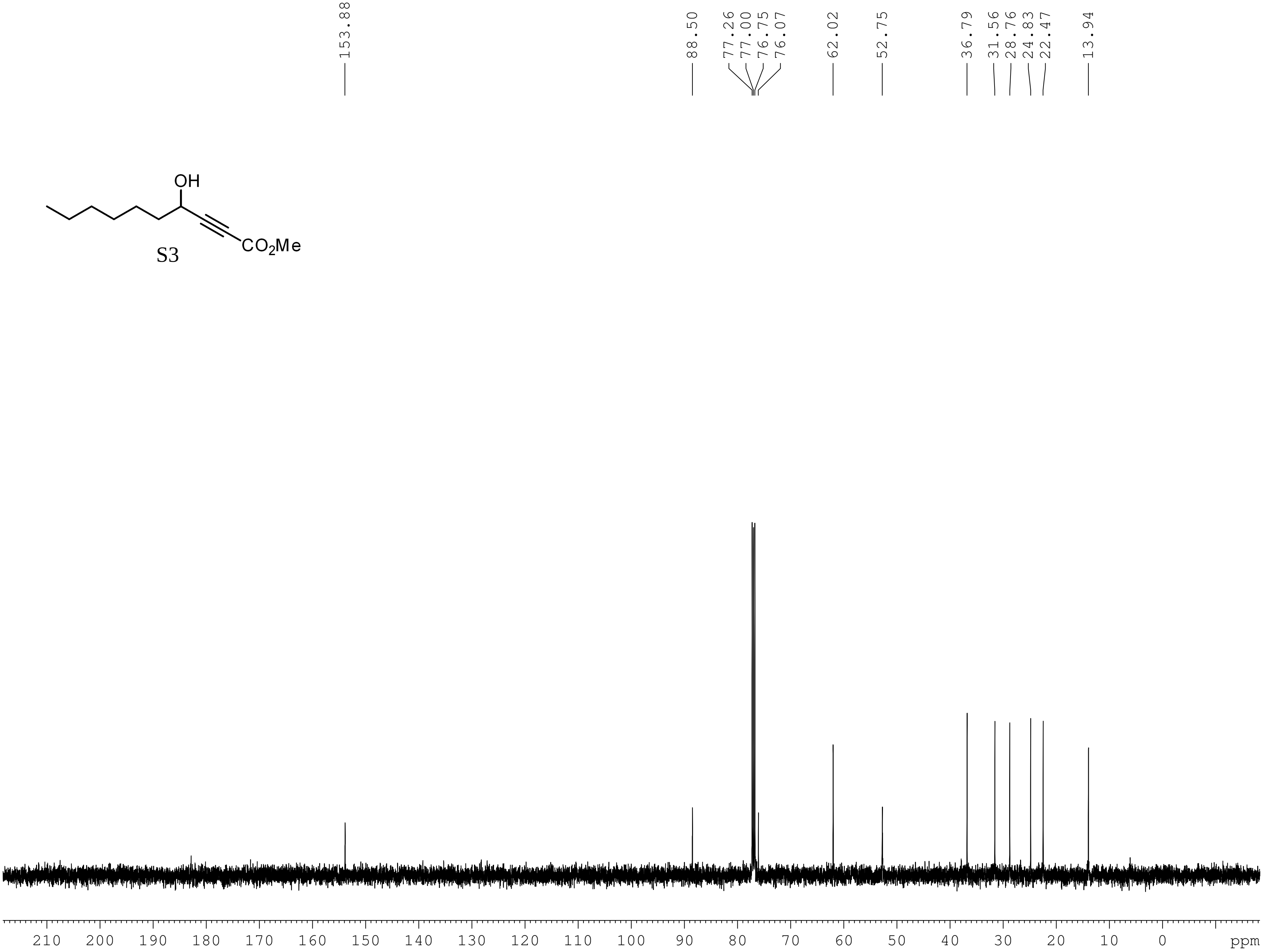
HRMS: $[M + H]^+$ calcd for $C_{21}H_{21}O_5$, 353.1389; found, 353.1396;

TLC: R_f = 0.62 (5% methanol/diethyl ether) [silica gel, UV, $KMnO_4$ stain].



S3

7.260
4.484
4.471
4.459
4.446
3.760
2.711
2.704
2.700
1.765
1.759
1.756
1.751
1.742
1.739
1.733
1.725
1.719
1.711
1.464
1.460
1.446
1.434
1.420
1.416
1.403
1.329
1.315
1.303
1.300
1.288
1.286
1.275
1.270
1.266
1.258
1.244
1.228
0.874
0.860
0.846
OH
CO2Me
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
1.00
3.07
0.98
2.10
2.17
6.55
3.11


S3

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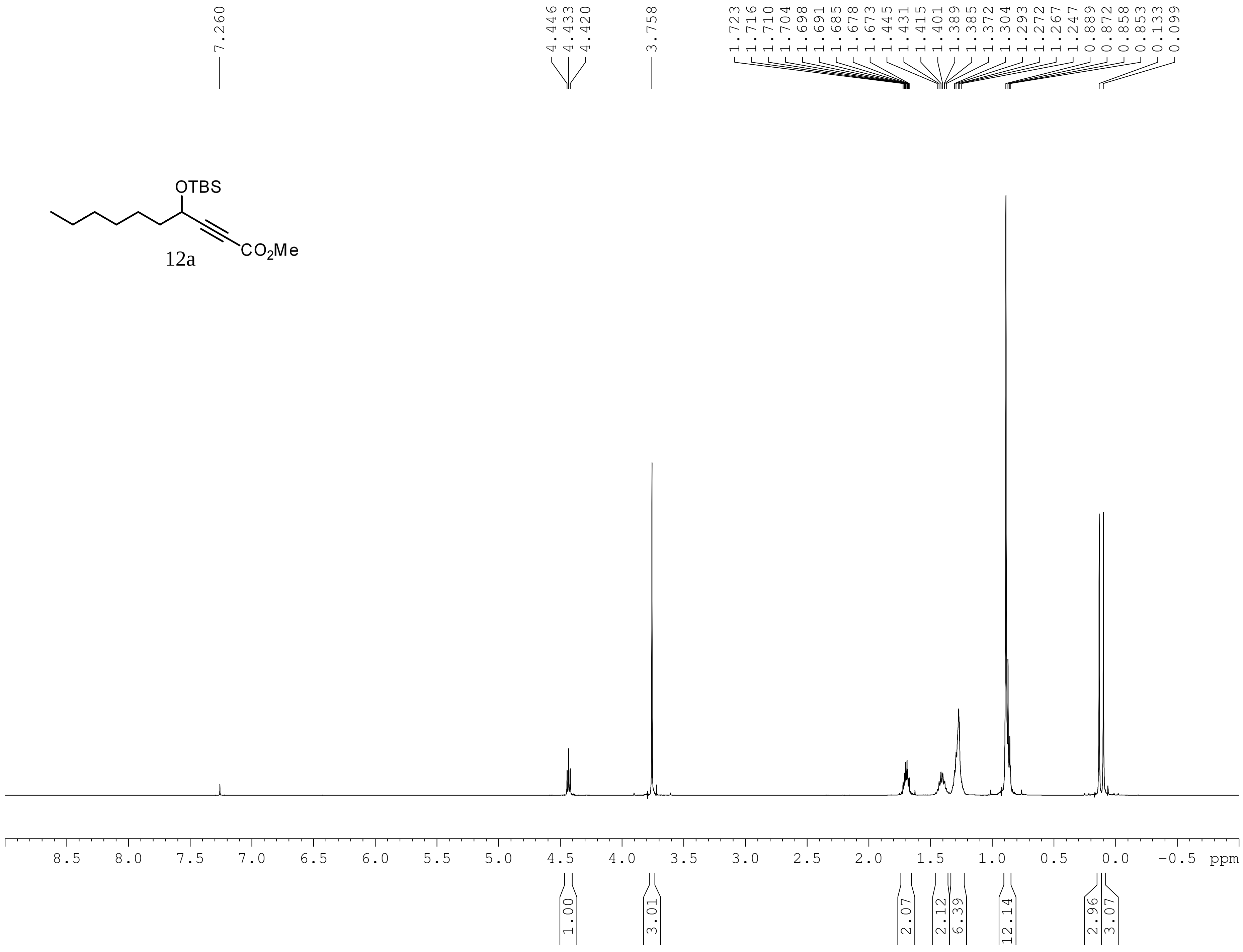
88.50
77.26
77.00
76.75
76.07
62.02
52.75
36.79
31.56
28.76
24.83
22.47
13.94
OH
CO2Me
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



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4.420
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1.723
1.716
1.710
1.704
1.698
1.691
1.685
1.678
1.673
1.445
1.431
1.415
1.401
1.389
1.385
1.372
1.304
1.293
1.272
1.267
1.247
0.889
0.872
0.858
0.853
0.133
0.099
OTBS
CO_2Me
12a
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
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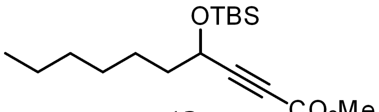
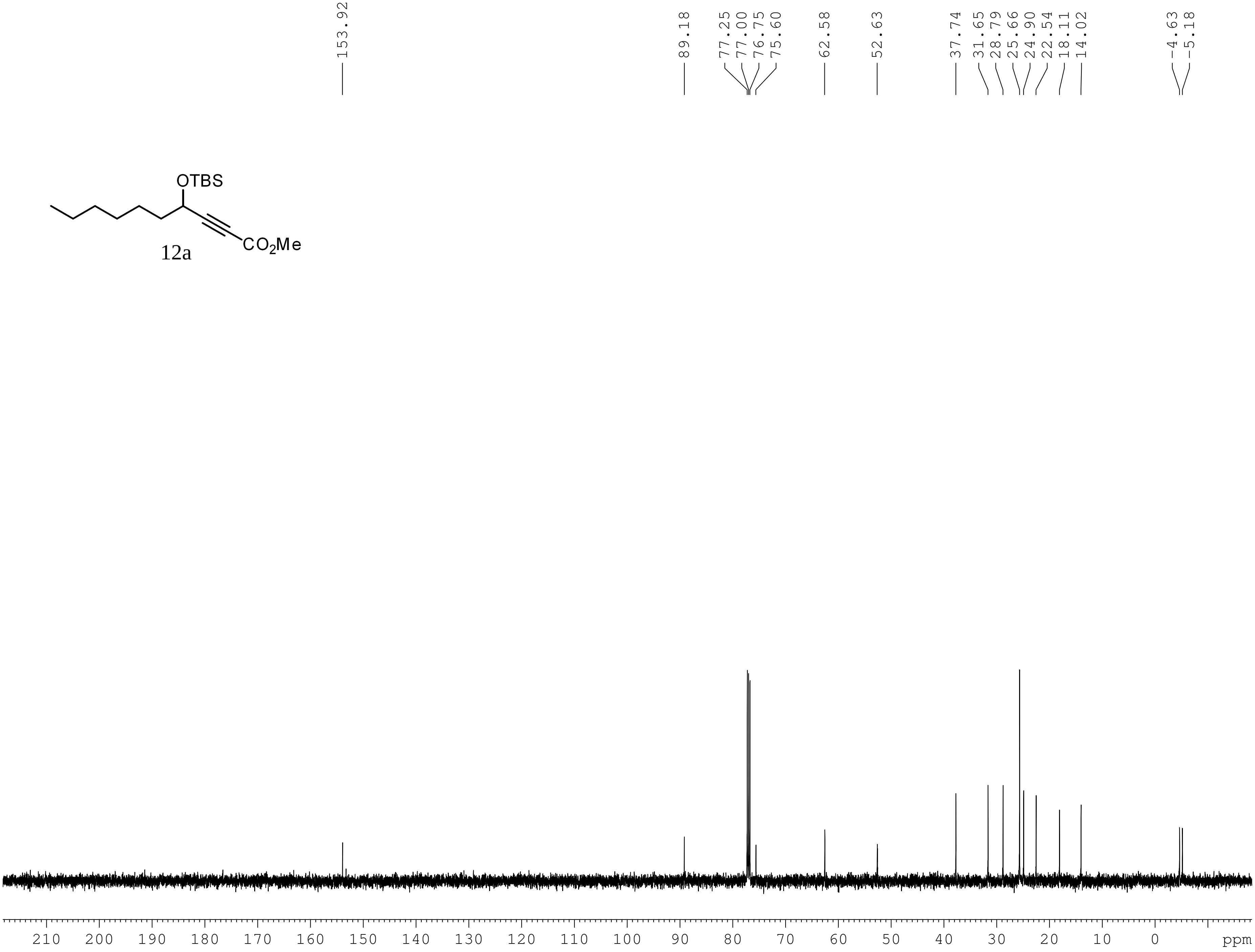
3.01
2.07
2.12
6.39
12.14
2.96
3.07


OTBS
CO_2Me

12a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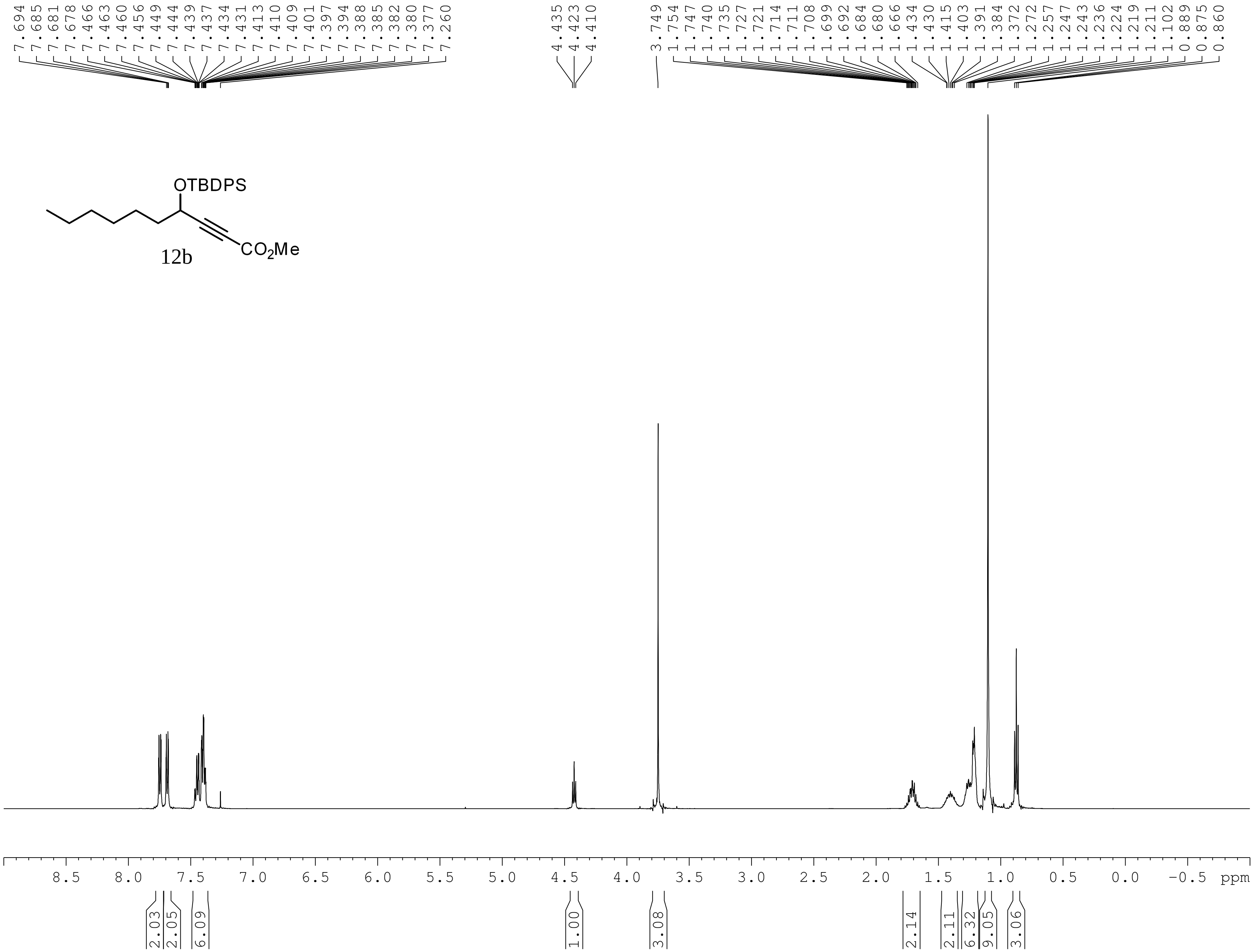
77.00
76.75
75.60
62.58
52.63
37.74
31.65
28.79
25.66
24.90
22.54
18.11
14.02
-4.63
-5.18
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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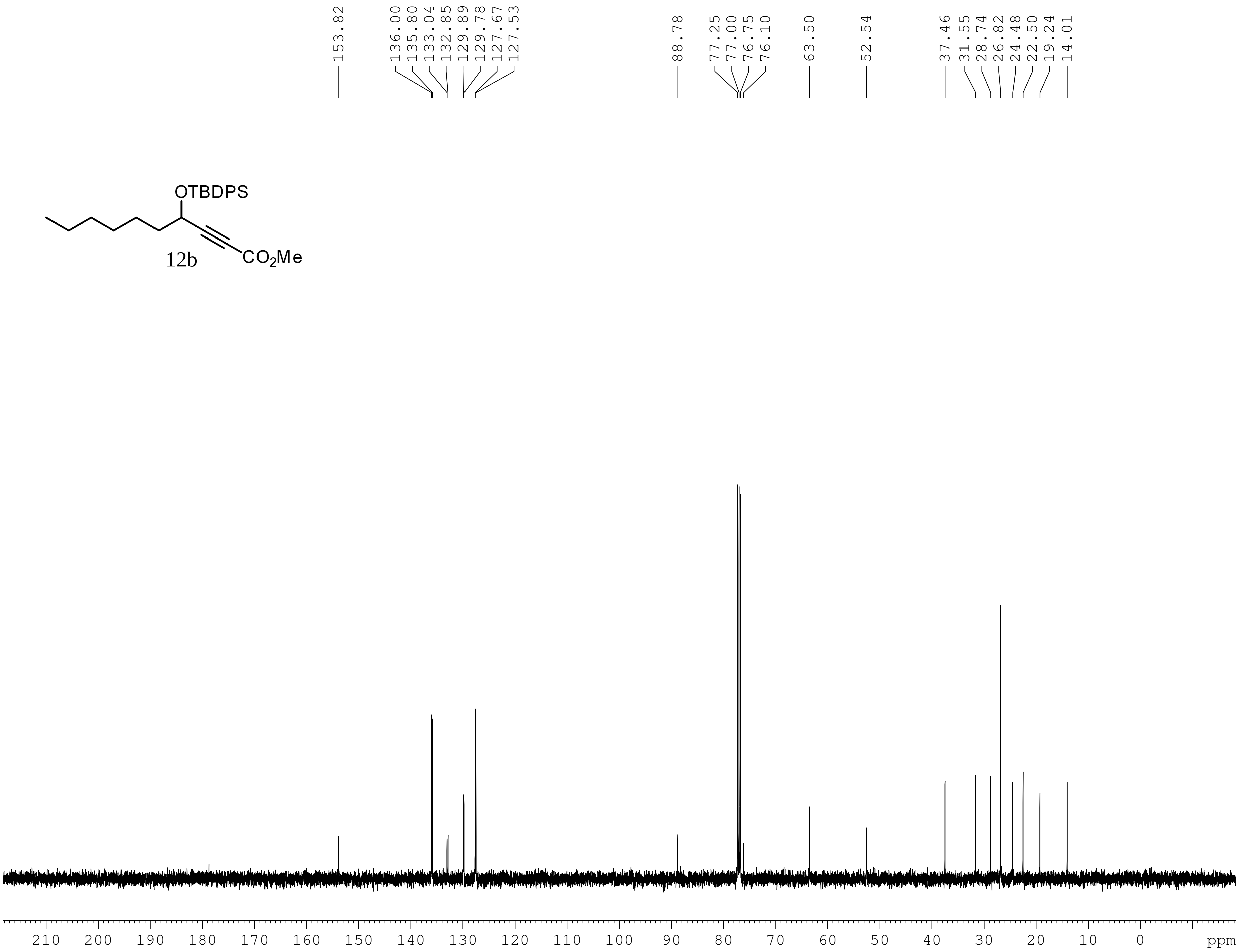
7.456
7.449
7.444
7.439
7.437
7.434
7.431
7.413
7.410
7.409
7.401
7.397
7.394
7.388
7.385
7.382
7.380
7.377
7.260
4.435
4.423
4.410
3.749
1.754
1.747
1.740
1.735
1.727
1.721
1.714
1.711
1.708
1.699
1.692
1.684
1.680
1.666
1.434
1.430
1.415
1.403
1.391
1.384
1.372
1.272
1.257
1.247
1.243
1.236
1.224
1.219
1.211
1.102
0.889
0.875
0.860
OTBDPS
CO2Me
12b
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
2.03
2.05
6.09
1.00
3.08
2.14
2.11
6.32
9.05
3.06

OTBDPS
CO2Me

12b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132.85
129.89
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127.67
127.53
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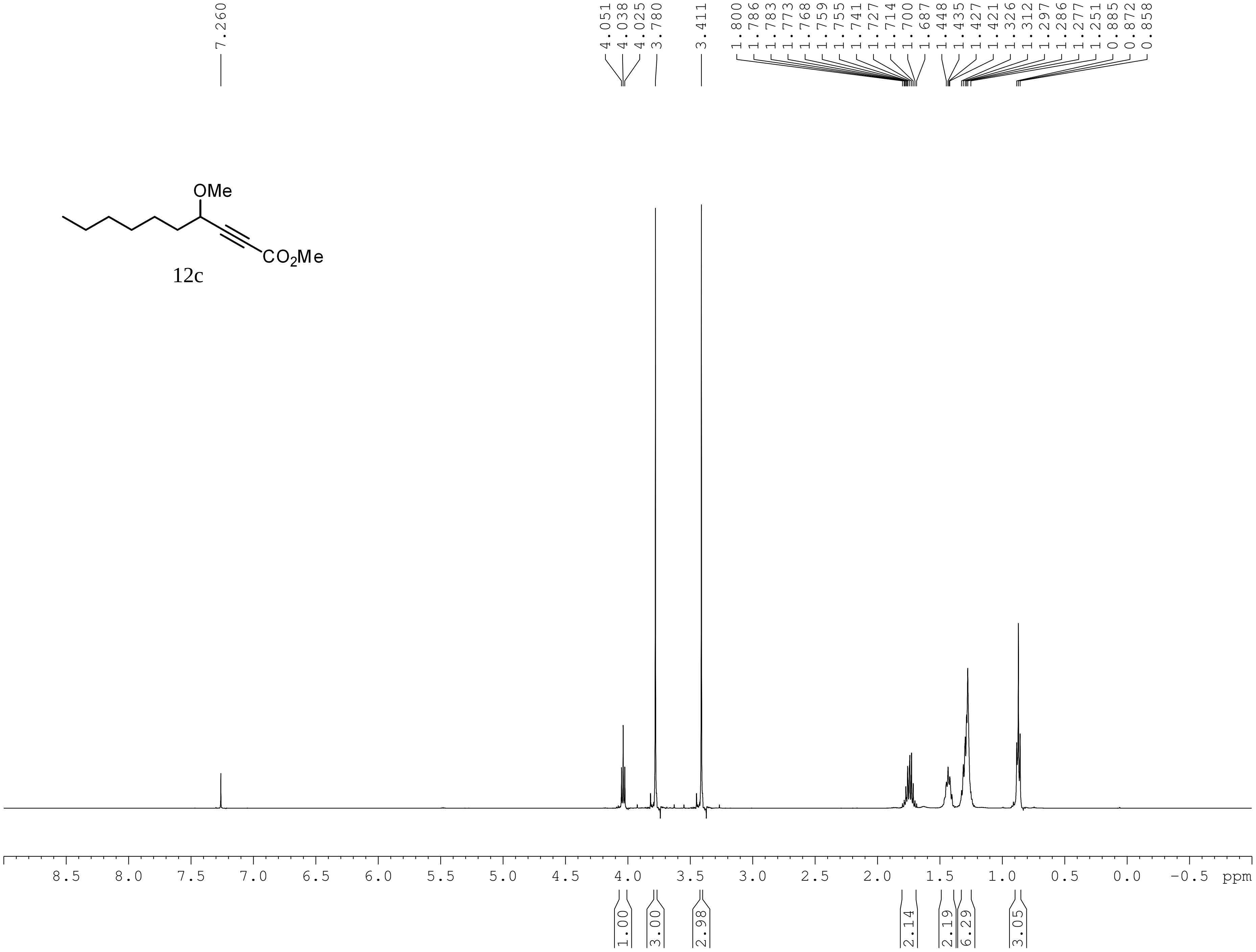
77.25
77.00
76.75
76.10
63.50
52.54
37.46
31.55
28.74
26.82
24.48
22.50
19.24
14.01
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

OMe
CO$_2$Me

12c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1.755
1.741
1.727
1.714
1.700
1.687
1.448
1.435
1.427
1.421
1.326
1.312
1.297
1.286
1.277
1.251
0.885
0.872
0.858
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
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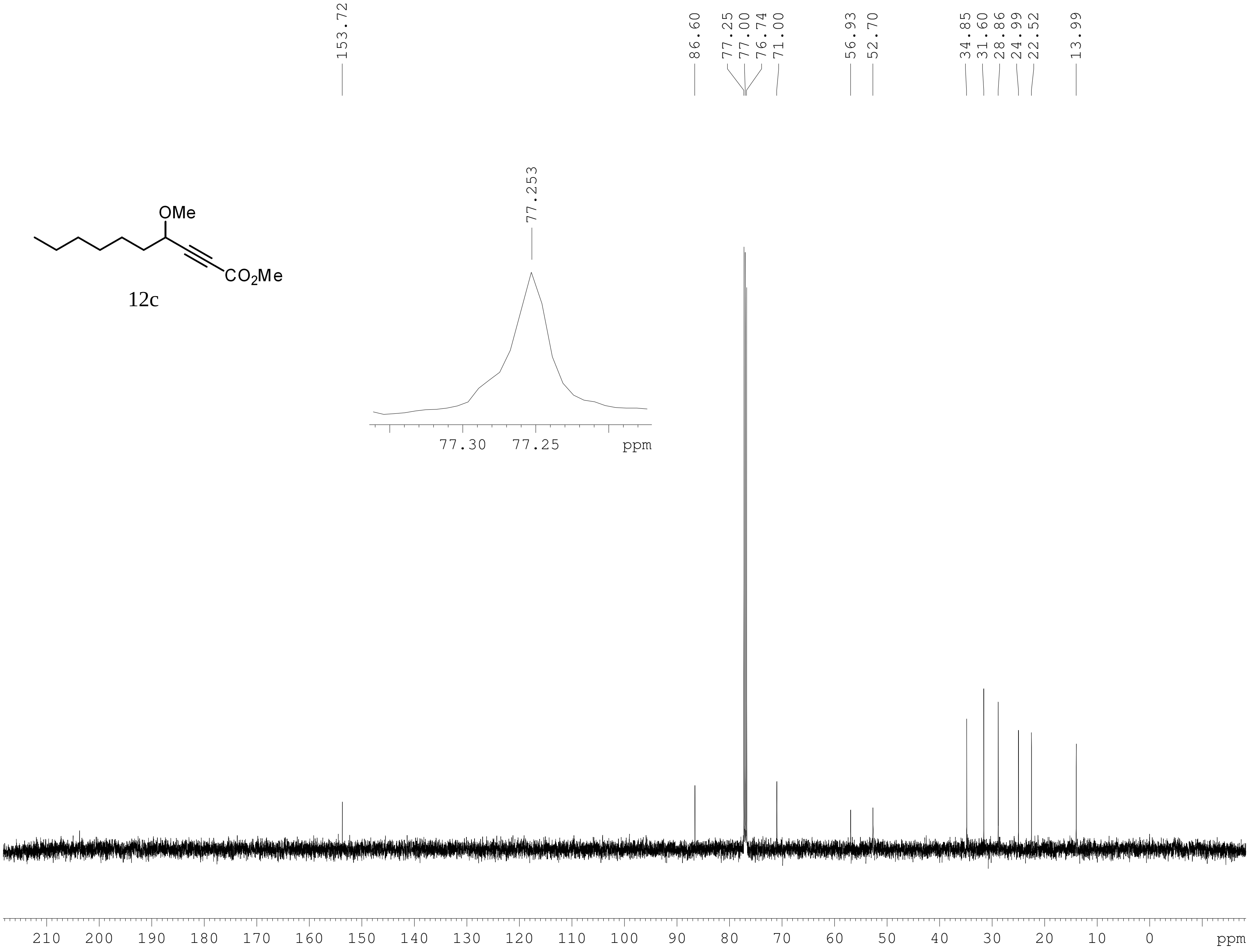
3.00
2.98
2.14
2.19
6.29
3.05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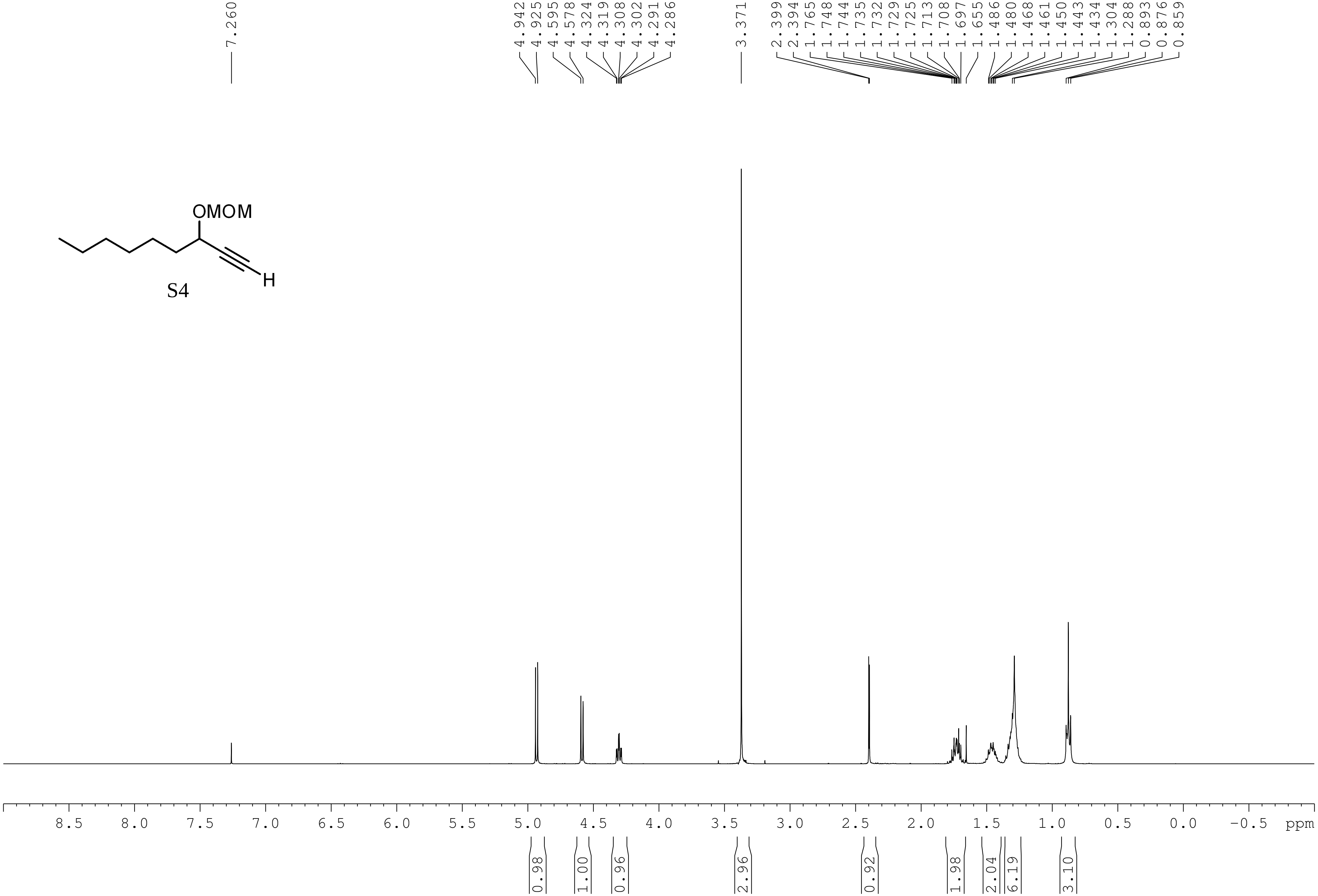
77.00
76.74
71.00
56.93
52.70
34.85
31.60
28.86
24.99
22.52
13.99
OMe
CO$_2$Me
12c
77.253
77.30
77.25
ppm
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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4.291
4.286
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2.399
2.394
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1.748
1.744
1.735
1.732
1.729
1.725
1.713
1.708
1.697
1.655
1.486
1.480
1.468
1.461
1.450
1.443
1.434
1.304
1.288
0.893
0.876
0.859
OMOM
H
S4
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
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ppm
0.98
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0.96
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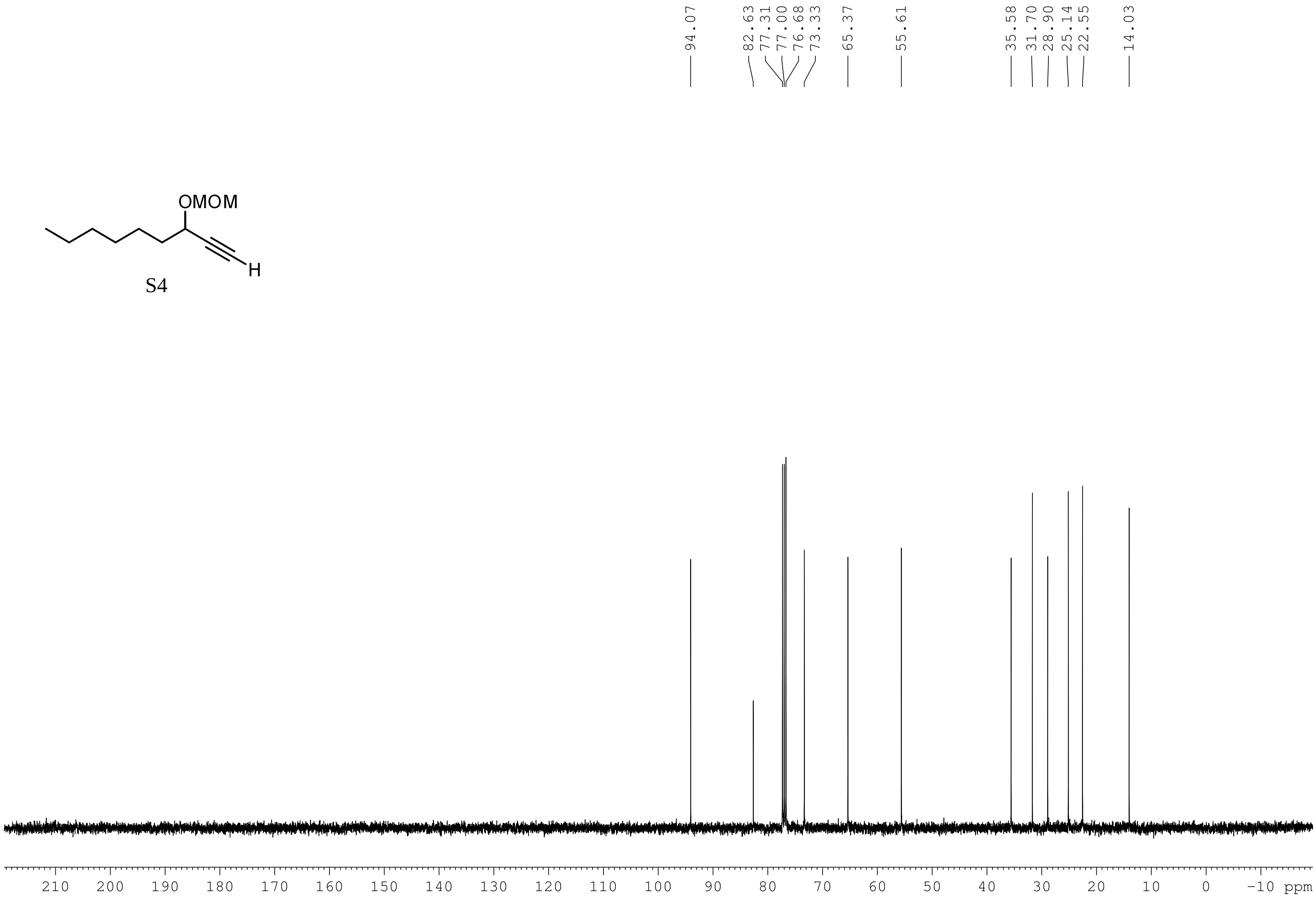
1.98
2.04
6.19
3.10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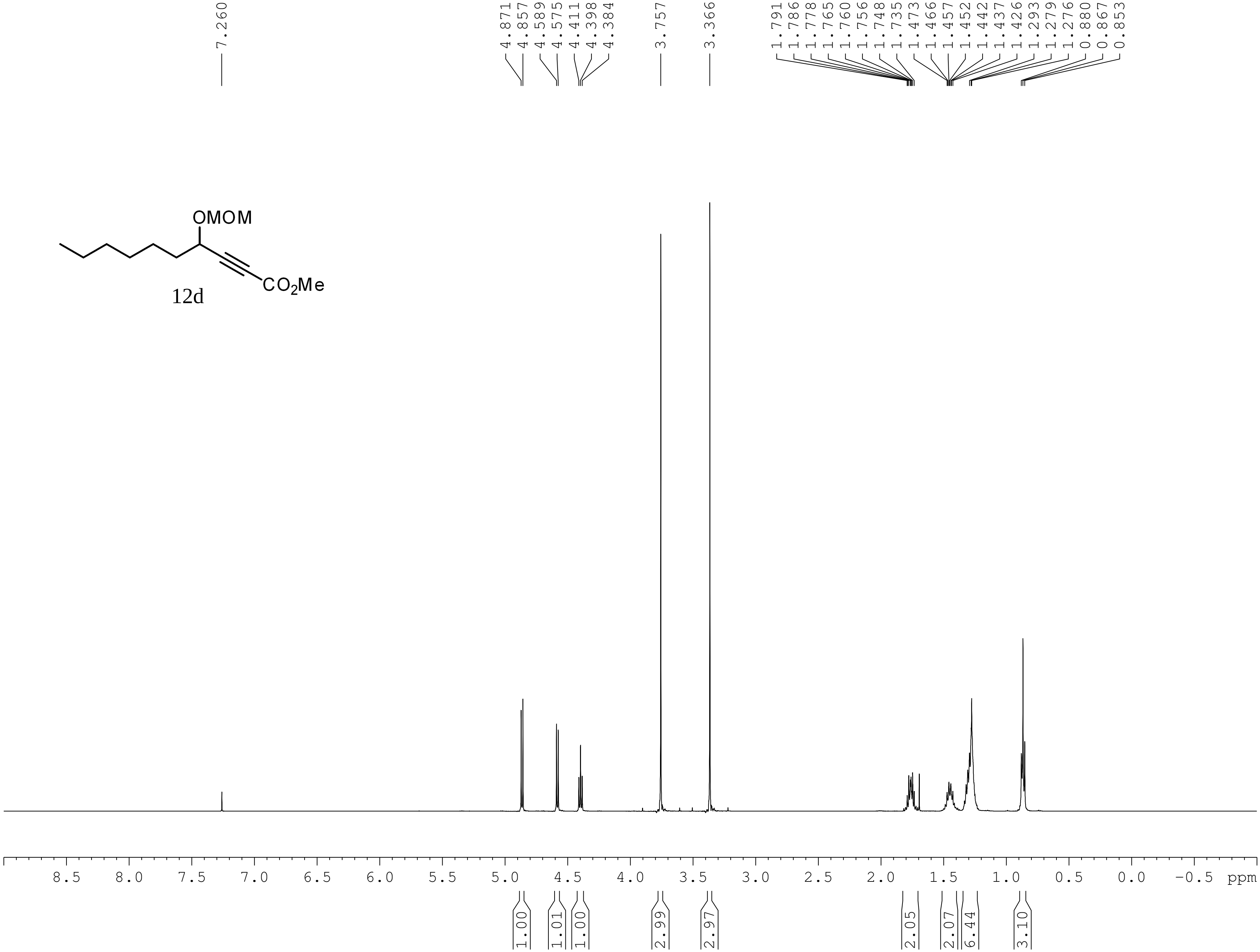
76.68
73.33
65.37
55.61
35.58
31.70
28.90
25.14
22.55
14.03
OMOM
H
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10 ppm

S4



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4.575
4.411
4.398
4.384
3.757
3.366
1.791
1.786
1.778
1.765
1.760
1.756
1.748
1.735
1.473
1.466
1.457
1.452
1.442
1.437
1.426
1.293
1.279
1.276
0.880
0.867
0.853
OMOM
CO_2Me
12d
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
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ppm
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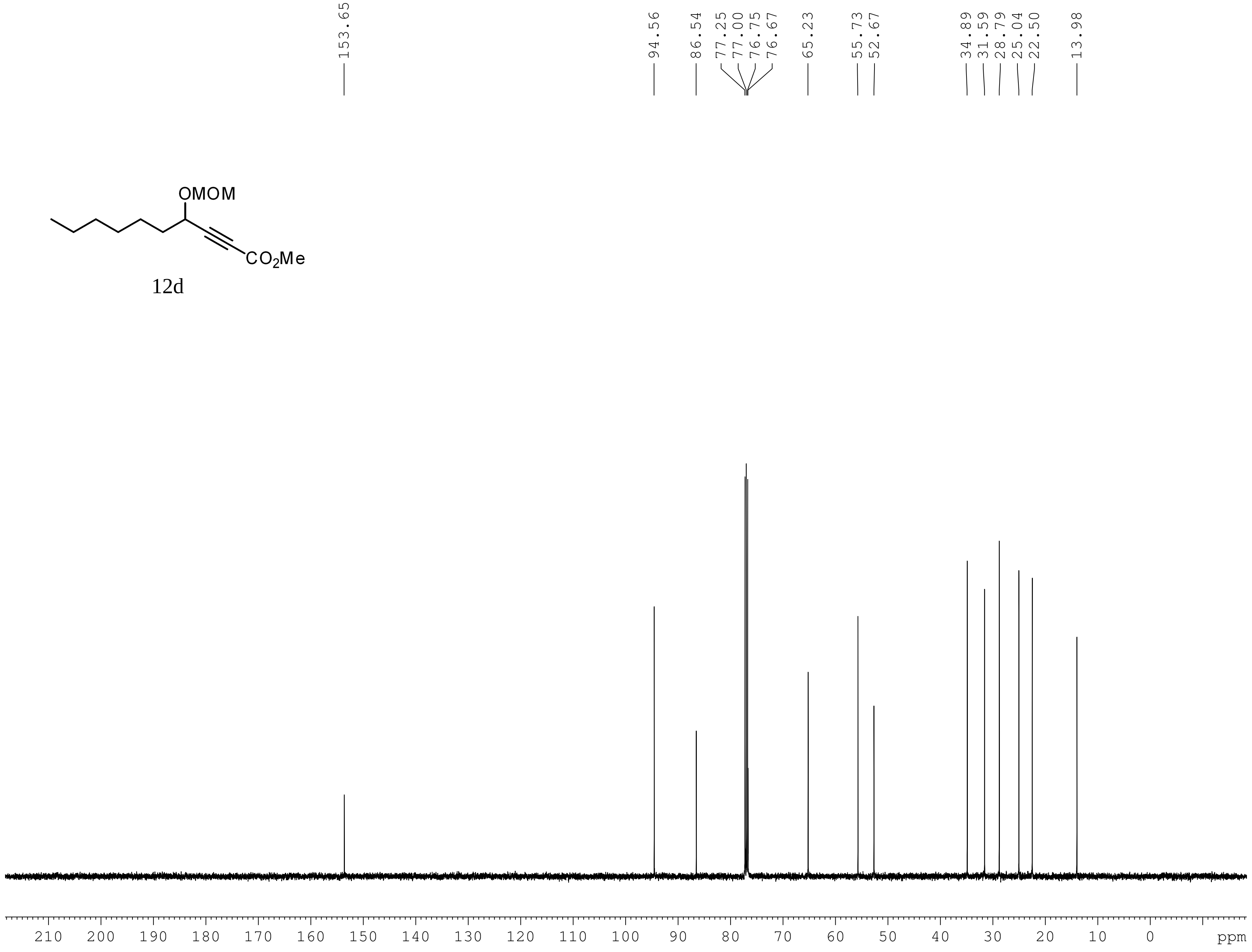
2.97
2.05
2.07
6.44
3.10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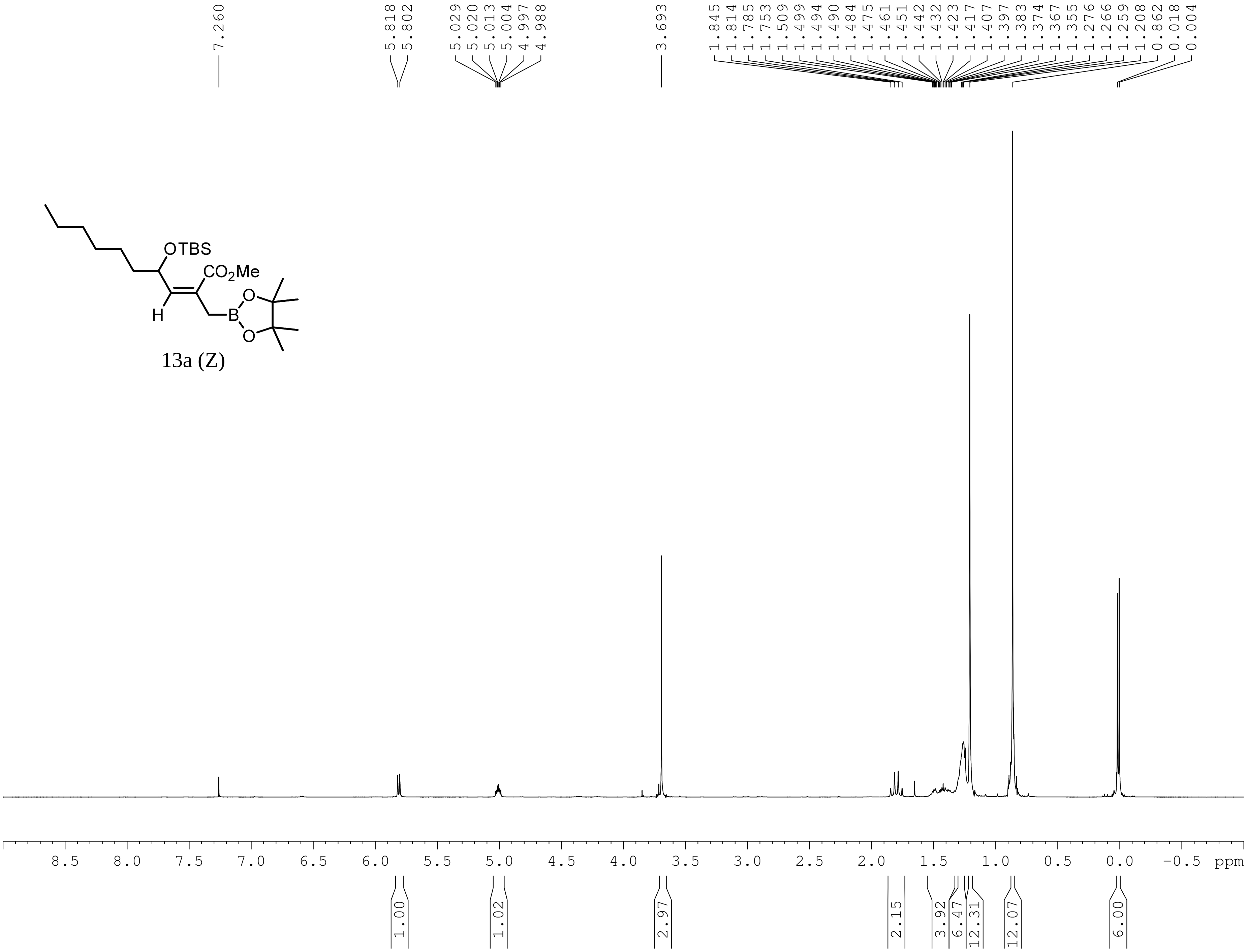
76.67
65.23
55.73
52.67
34.89
31.59
28.79
25.04
22.50
13.98
OMOM
CO_2Me
12d
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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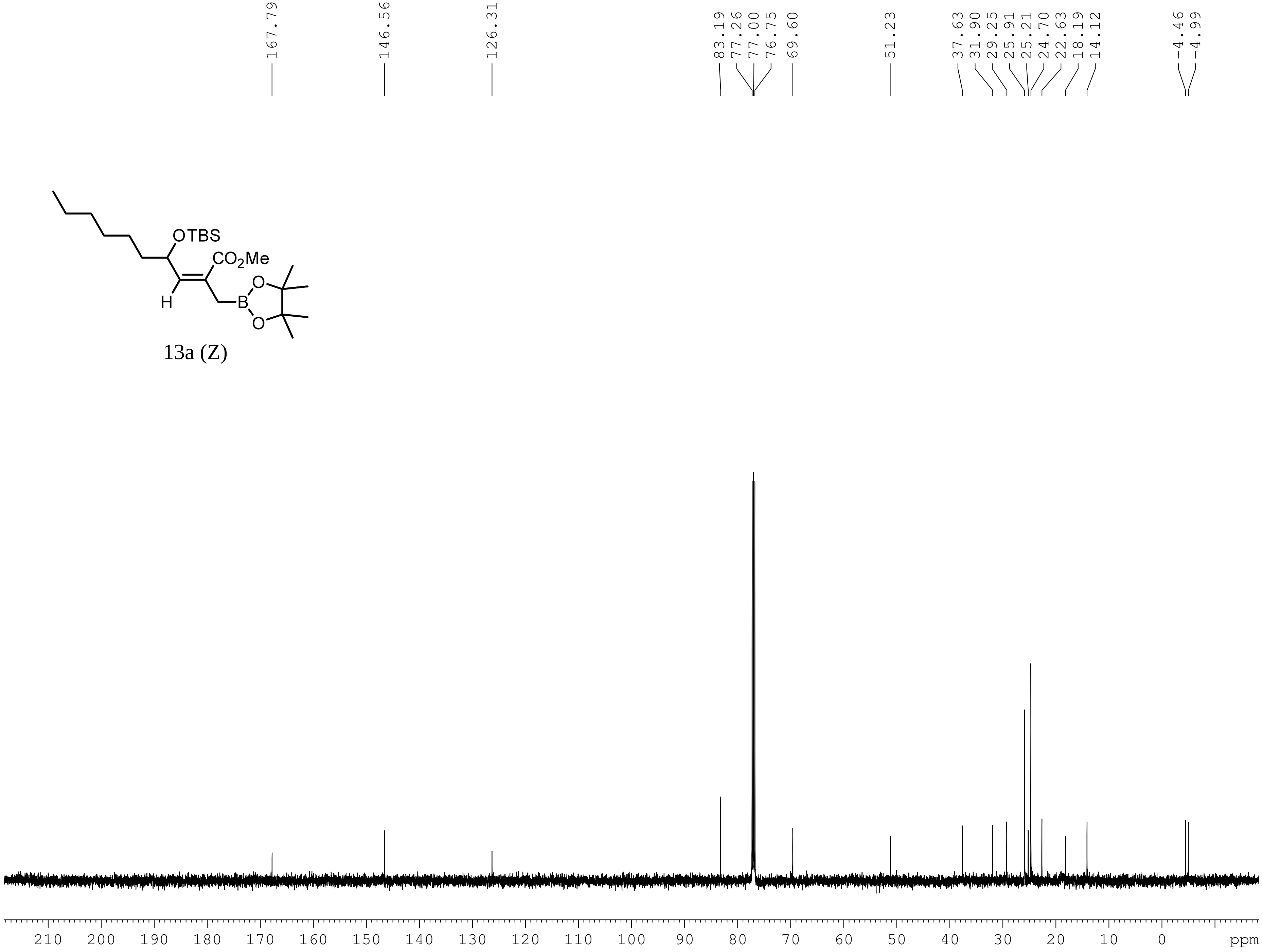
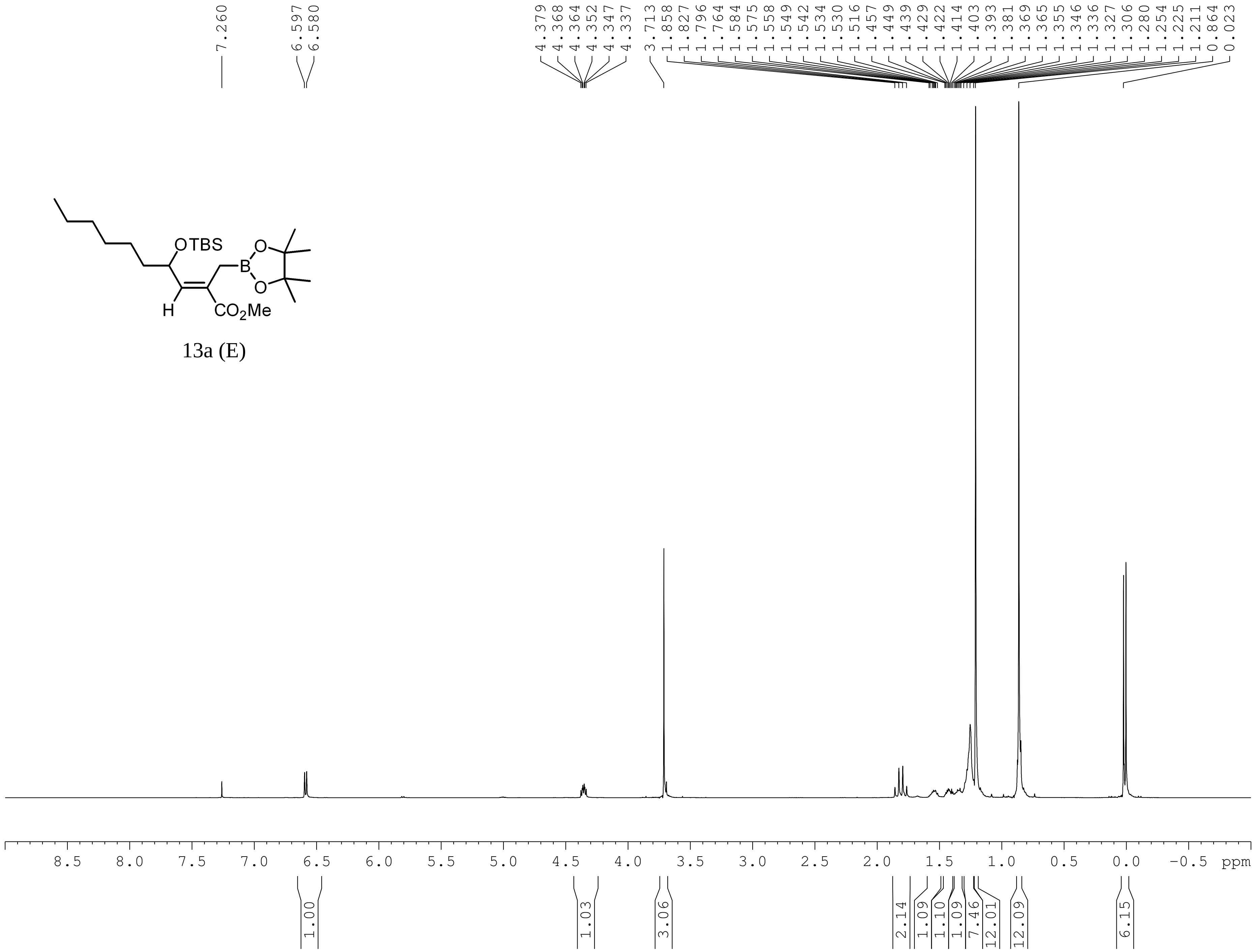
5.029
5.020
5.013
5.004
4.997
4.988
3.693
1.845
1.814
1.785
1.753
1.509
1.499
1.494
1.490
1.484
1.475
1.461
1.451
1.442
1.432
1.423
1.417
1.407
1.397
1.383
1.374
1.367
1.355
1.276
1.266
1.259
1.208
0.862
0.018
0.004
OTBS
CO2Me
H
B
O
O
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
1.00
1.02
2.97
2.15
3.92
6.47
12.31
12.07
6.00

13a (Z)


167.79
146.56
126.31
83.19
77.26
77.00
76.75
69.60
51.23
37.63
31.90
29.25
25.91
25.21
24.70
22.63
18.19
14.12
-4.46
-4.99
OTBS
CO_2Me
H
B
O
O
13a (Z)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



13a (E)

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6.580
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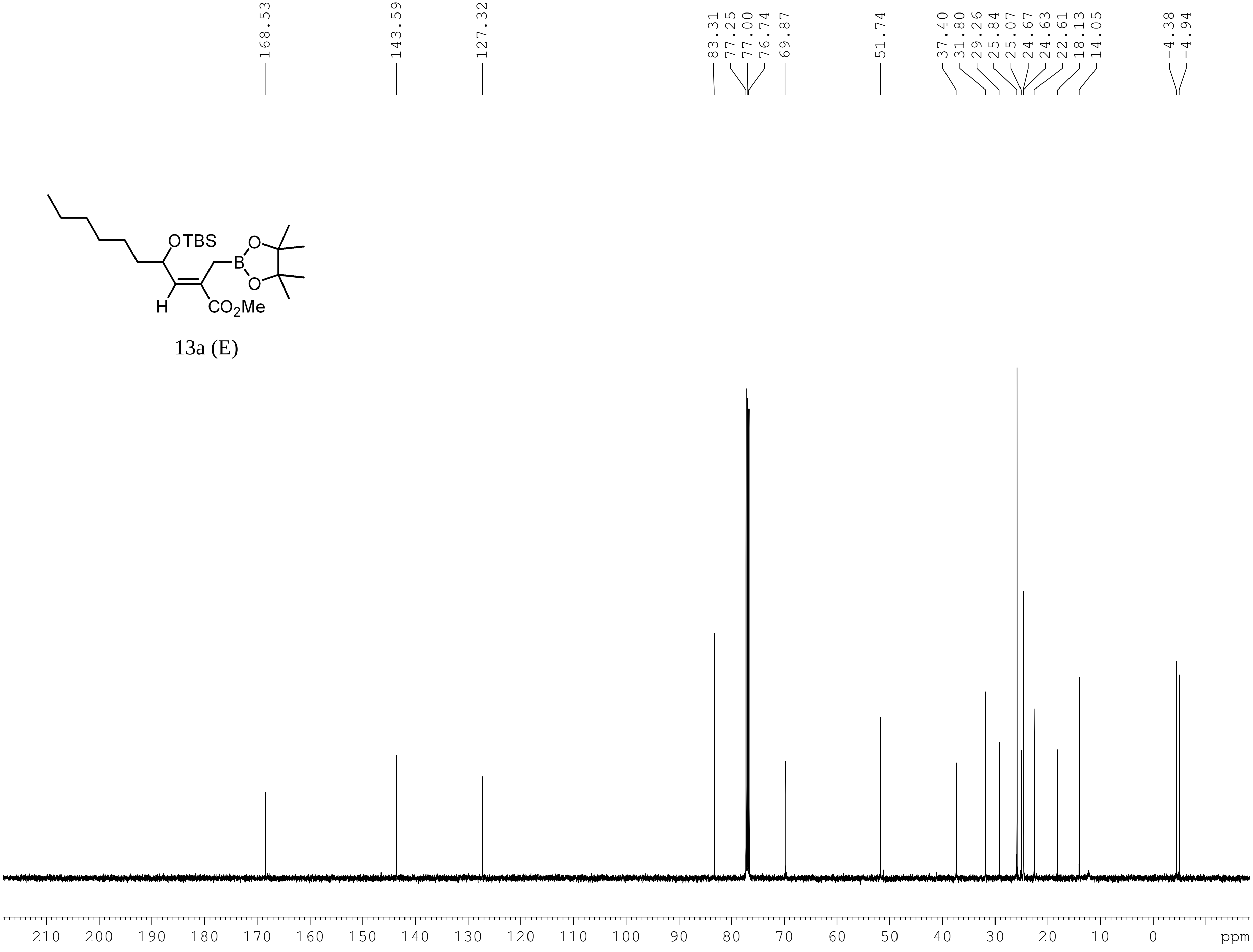
4.368
4.364
4.352
4.347
4.337
3.713
1.858
1.827
1.796
1.764
1.584
1.575
1.558
1.549
1.542
1.534
1.530
1.516
1.457
1.449
1.439
1.429
1.422
1.414
1.403
1.393
1.381
1.369
1.365
1.355
1.346
1.336
1.327
1.306
1.280
1.254
1.225
1.211
0.864
0.023
OTBS
B
O
O
H
CO2Me
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
1.00
1.03
3.06
2.14
1.09
1.10
1.09
7.46
12.01
12.09
6.15



13a (E)

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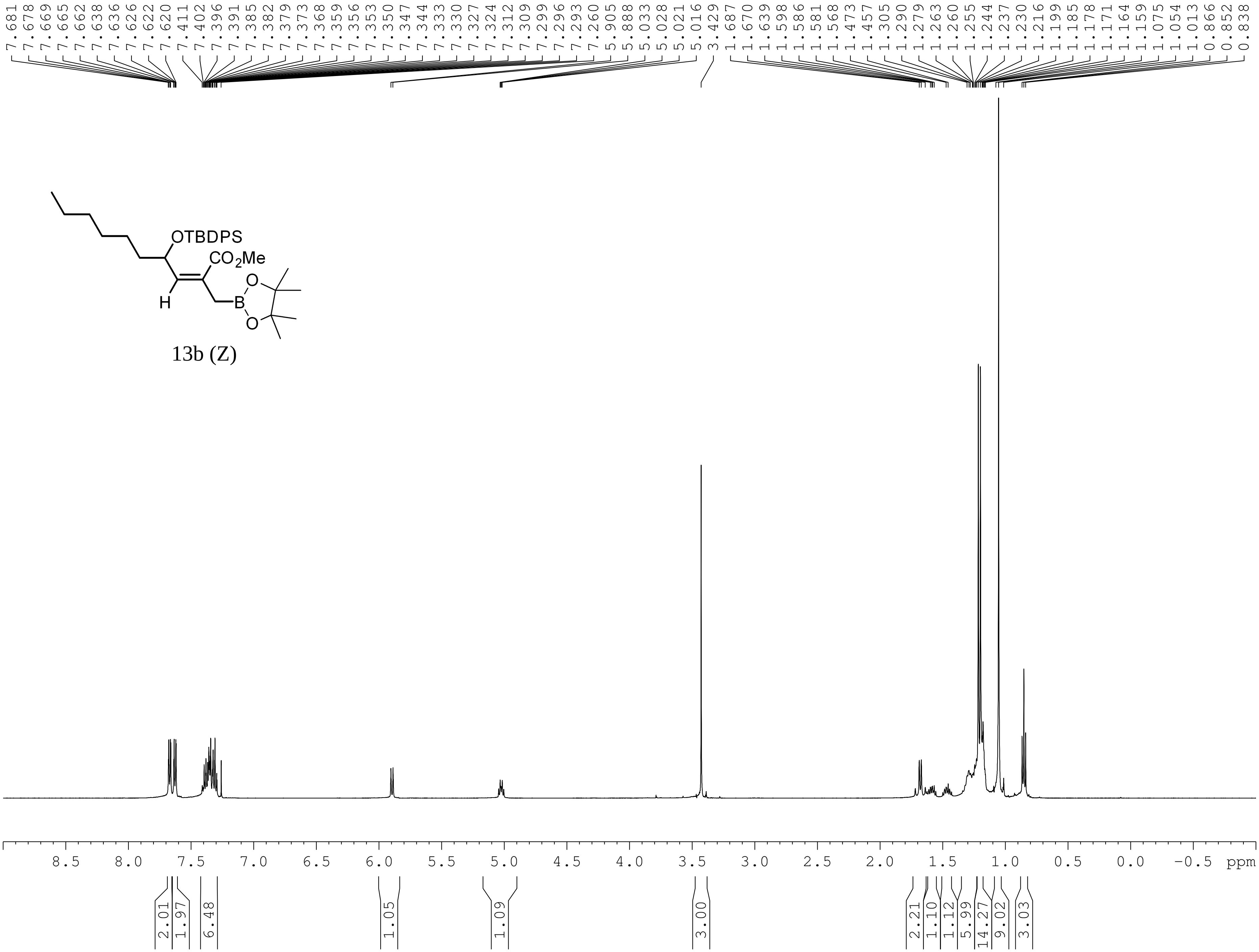
143.59
127.32
83.31
77.25
77.00
76.74
69.87
51.74
37.40
31.80
29.26
25.84
25.07
24.67
24.63
22.61
18.13
14.05
-4.38
-4.94
OTBS
B
O
O
H
CO2Me
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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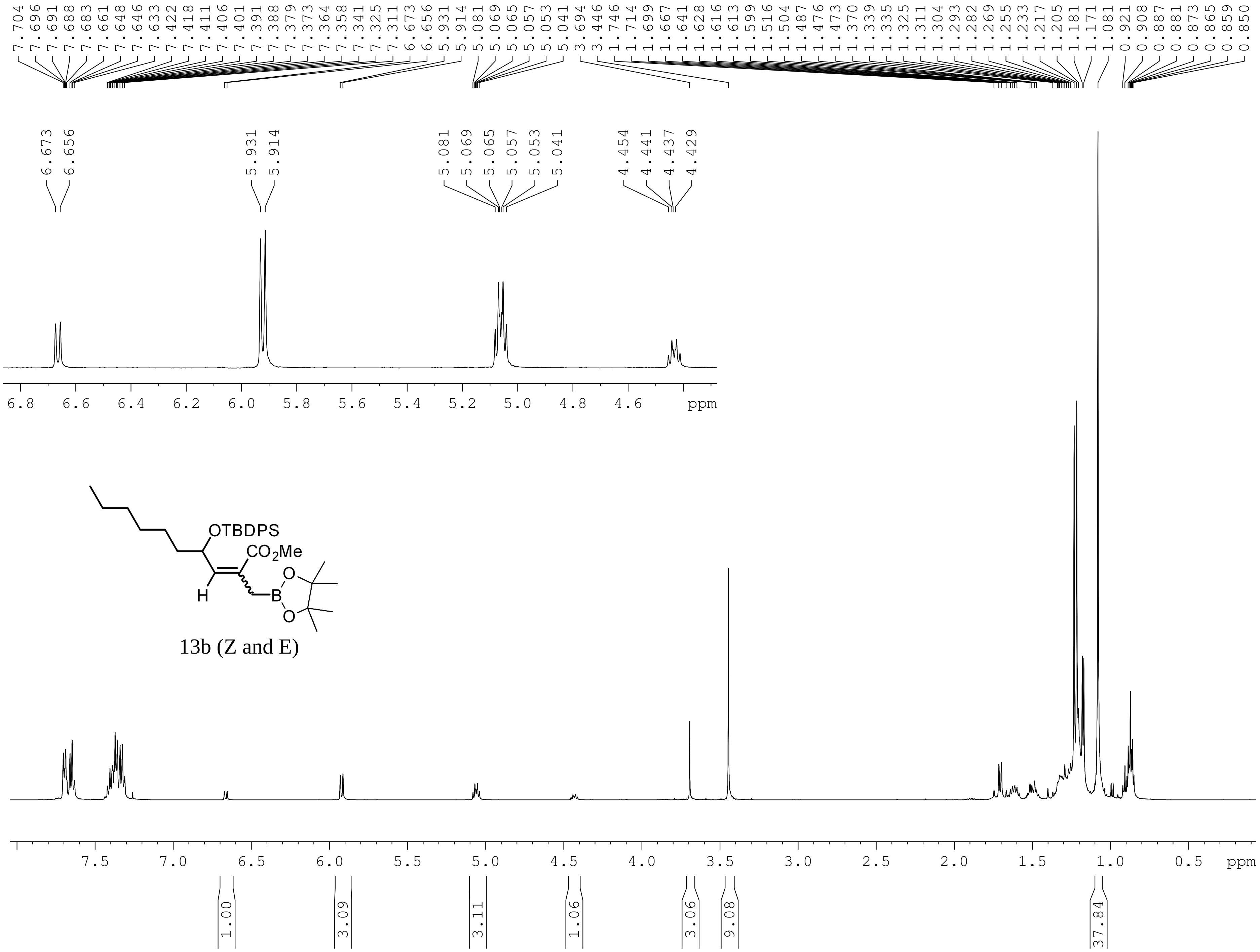
7.662
7.638
7.636
7.626
7.622
7.620
7.411
7.402
7.396
7.391
7.385
7.382
7.379
7.373
7.368
7.359
7.356
7.353
7.350
7.347
7.344
7.333
7.330
7.327
7.324
7.312
7.309
7.299
7.296
7.293
7.260
5.905
5.888
5.033
5.028
5.021
5.016
3.429
1.687
1.670
1.639
1.598
1.586
1.581
1.568
1.473
1.457
1.305
1.290
1.279
1.263
1.260
1.255
1.244
1.237
1.230
1.216
1.199
1.185
1.178
1.171
1.164
1.159
1.075
1.054
1.013
0.866
0.852
0.838
OTBDPS
CO2Me
H
B
O
O
13b (Z)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
2.01
1.97
6.48
1.05
1.09
3.00
2.21
1.10
1.12
5.99
14.27
9.02
3.03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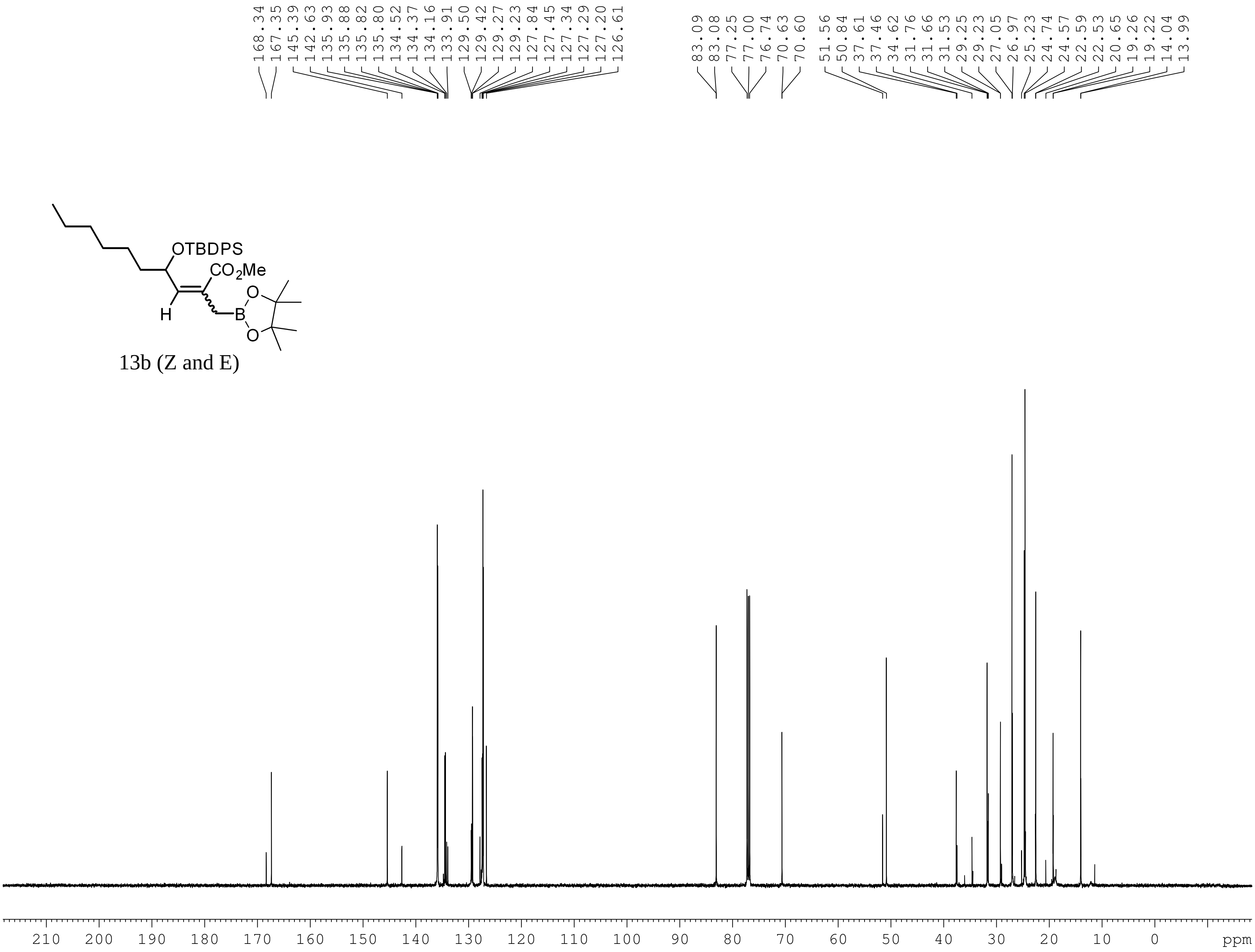
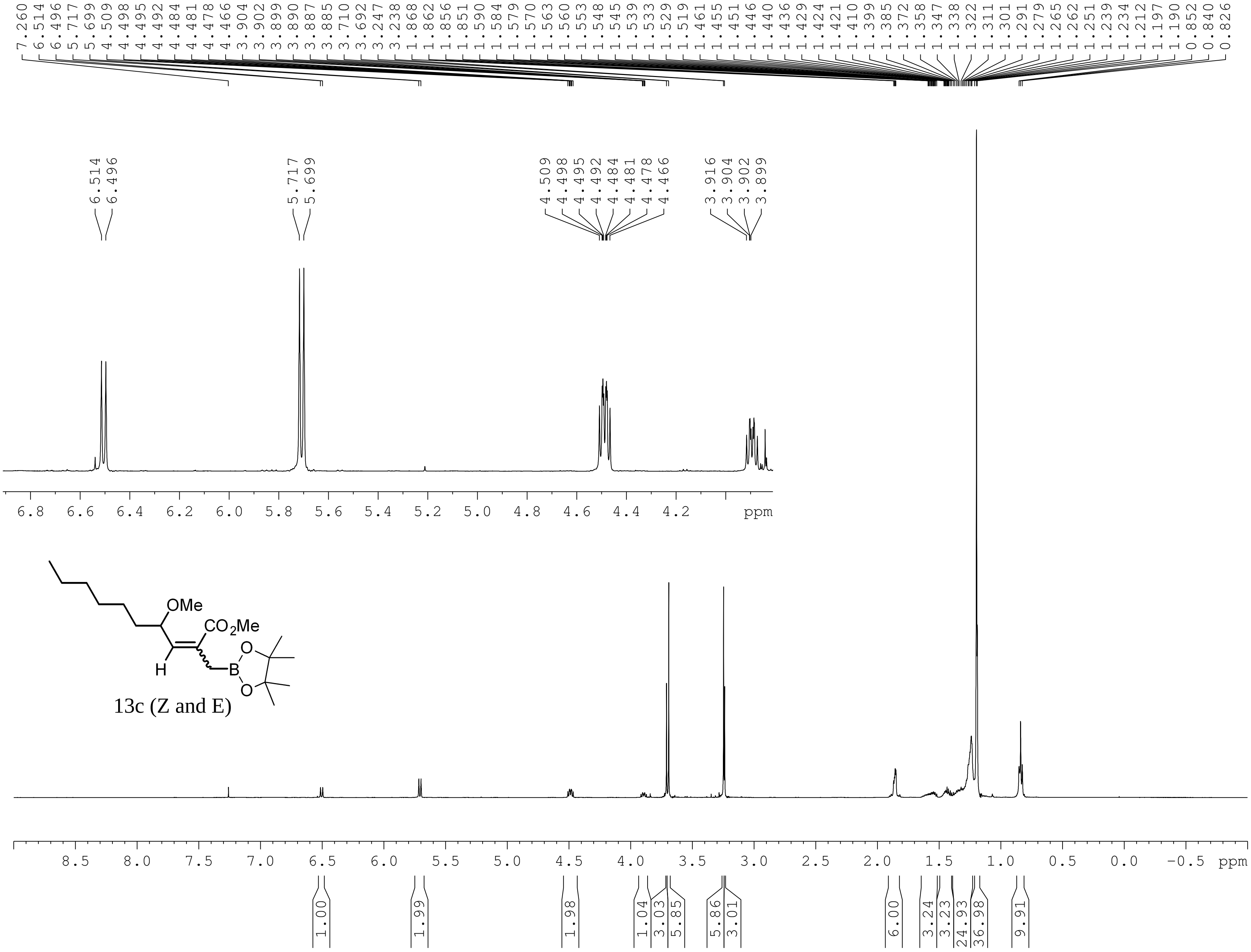
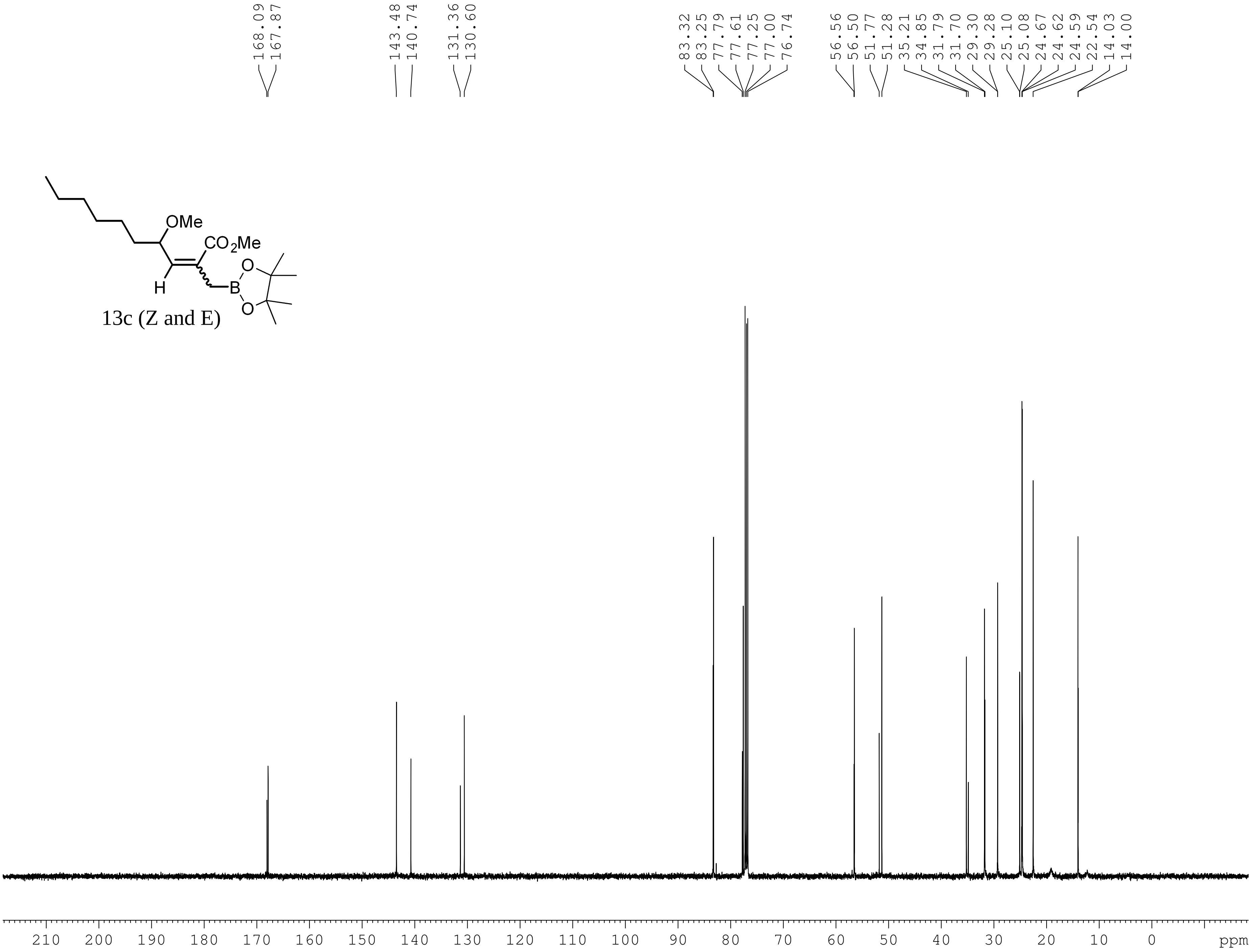
7.696
7.691
7.688
7.683
7.661
7.648
7.646
7.633
7.422
7.418
7.411
7.406
7.401
7.391
7.388
7.379
7.373
7.364
7.358
7.341
7.325
7.311
6.673
6.656
5.931
5.914
5.081
5.069
5.065
5.057
5.053
5.041
3.694
3.446
1.746
1.714
1.699
1.667
1.641
1.628
1.616
1.613
1.599
1.516
1.504
1.487
1.476
1.473
1.370
1.339
1.335
1.325
1.311
1.304
1.293
1.282
1.269
1.255
1.233
1.217
1.205
1.181
1.171
1.081
0.921
0.908
0.887
0.881
0.873
0.865
0.859
0.850
6.673
6.656
5.931
5.914
5.081
5.069
5.065
5.057
5.053
5.041
4.454
4.441
4.437
4.429
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
ppm
OTBDPS
CO2Me
H
O
B
O
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.00
3.09
3.11
1.06
3.06
9.08
37.84

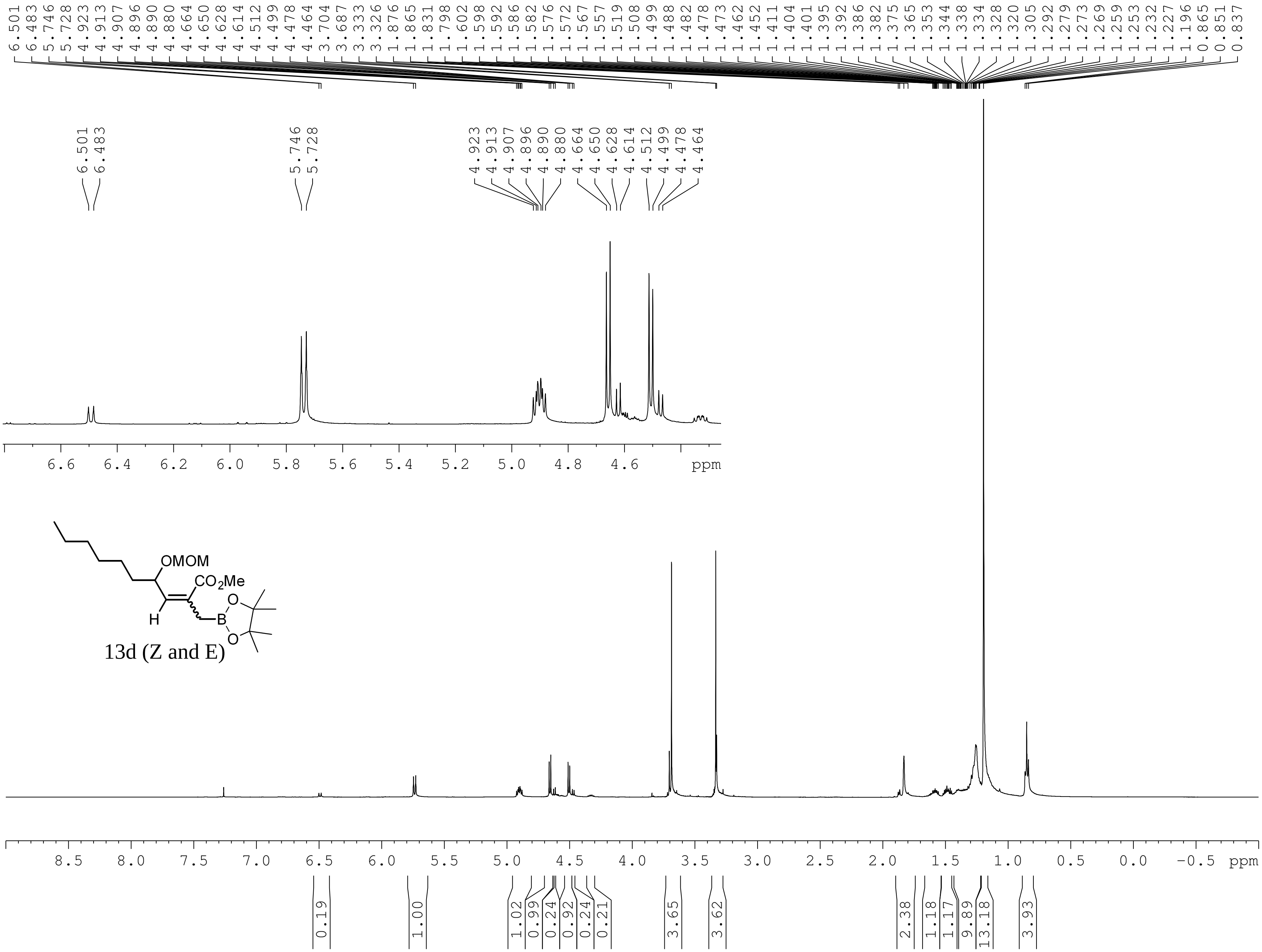
13b (Z and E)


168.34
167.35
145.39
142.63
135.93
135.88
135.82
135.80
134.52
134.37
134.16
133.91
129.50
129.42
129.27
129.23
127.84
127.45
127.34
127.29
127.20
126.61
83.09
83.08
77.25
77.00
76.74
70.63
70.60
51.56
50.84
37.61
37.46
34.62
31.76
31.66
31.53
29.25
29.23
27.05
26.97
25.23
24.74
24.57
22.59
22.53
20.65
19.26
19.22
14.04
13.99
OTBDPS
CO_2Me
H
B
O
O
13b (Z and E)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

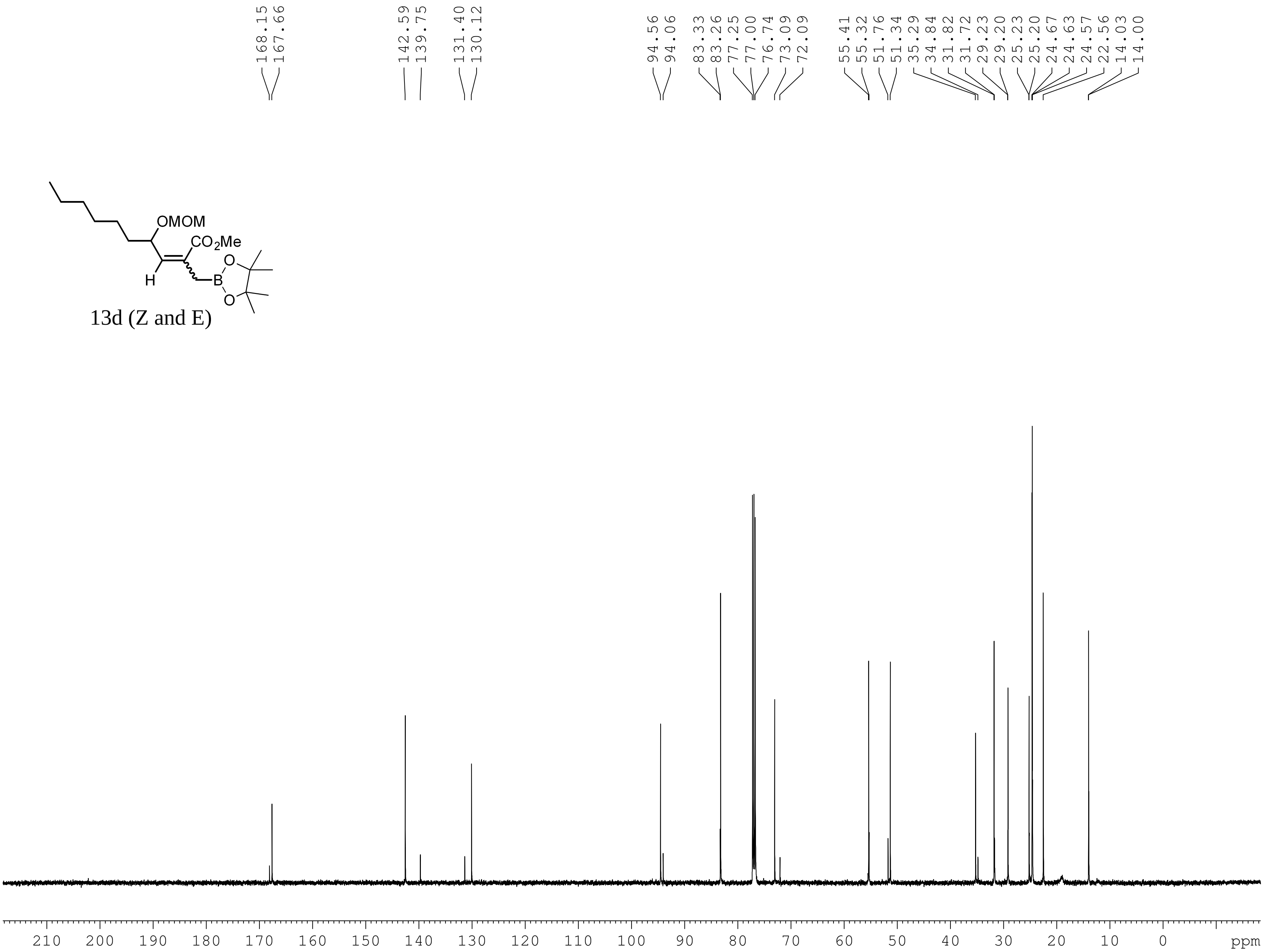

7.260
6.514
6.496
5.717
5.699
4.509
4.498
4.495
4.492
4.484
4.481
4.478
4.466
3.904
3.902
3.899
3.890
3.887
3.885
3.710
3.692
3.247
3.238
1.868
1.862
1.856
1.851
1.590
1.584
1.579
1.570
1.563
1.560
1.553
1.548
1.545
1.539
1.533
1.529
1.519
1.461
1.455
1.451
1.446
1.440
1.436
1.429
1.424
1.421
1.410
1.399
1.385
1.372
1.358
1.347
1.338
1.322
1.311
1.301
1.291
1.279
1.265
1.262
1.251
1.239
1.234
1.212
1.197
1.190
0.852
0.840
0.826
6.514
6.496
5.717
5.699
4.509
4.498
4.495
4.492
4.484
4.481
4.478
4.466
3.916
3.904
3.902
3.899
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
ppm
OMe
CO2Me
H
B
O
O
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
1.00
1.99
1.98
1.04
3.03
5.85
5.86
3.01
6.00
3.24
3.23
24.93
36.98
9.91

13c (Z and E)


13c (Z and E)
168.09
167.87
143.48
140.74
131.36
130.60
83.32
83.25
77.79
77.61
77.25
77.00
76.74
56.56
56.50
51.77
51.28
35.21
34.85
31.79
31.70
29.30
29.28
25.10
25.08
24.67
24.62
24.59
22.54
14.03
14.00
OMe
CO2Me
H
O
B
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

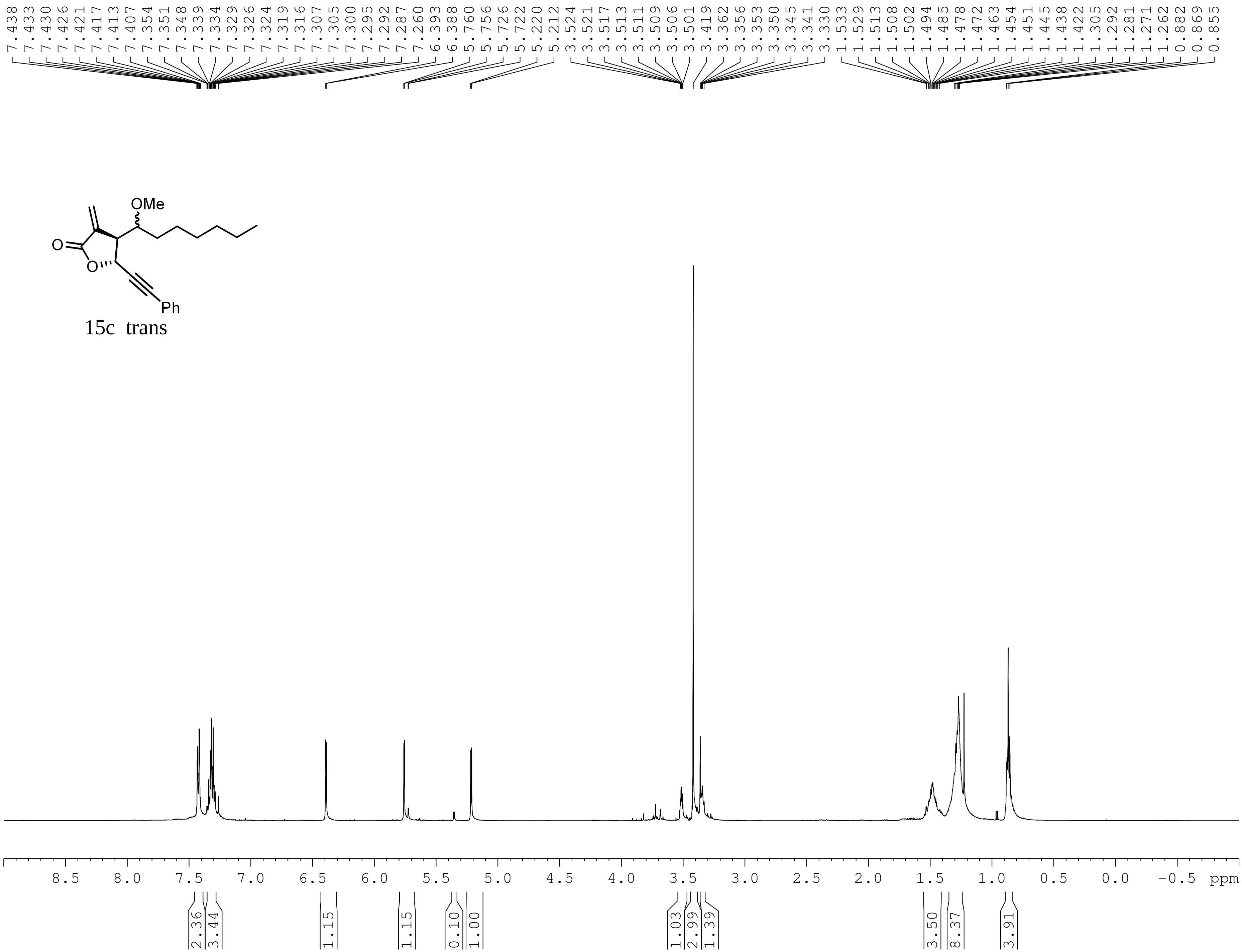
6.501
6.483
5.746
5.728
4.923
4.913
4.907
4.896
4.890
4.880
4.664
4.650
4.628
4.614
4.512
4.499
4.478
4.464
3.704
3.687
3.333
3.326
1.876
1.865
1.831
1.798
1.602
1.598
1.592
1.586
1.582
1.576
1.572
1.567
1.557
1.519
1.508
1.499
1.488
1.482
1.478
1.473
1.462
1.452
1.411
1.404
1.401
1.395
1.392
1.386
1.382
1.375
1.365
1.353
1.344
1.338
1.334
1.328
1.320
1.305
1.292
1.279
1.273
1.269
1.259
1.253
1.232
1.227
1.196
0.865
0.851
0.837
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
ppm
OMOM
CO2Me
H
B
O
O
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
0.19
1.00
1.02
0.99
0.24
0.92
0.24
0.21
3.65
3.62
2.38
1.18
1.17
9.89
13.18
3.93

13d (Z and E)



13d (Z and E)

OMOM
CO2Me
H
B
O
O
168.15
167.66
142.59
139.75
131.40
130.12
94.56
94.06
83.33
83.26
77.25
77.00
76.74
73.09
72.09
55.41
55.32
51.76
51.34
35.29
34.84
31.82
31.72
29.23
29.20
25.23
25.20
24.67
24.63
24.57
22.56
14.03
14.00
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.438
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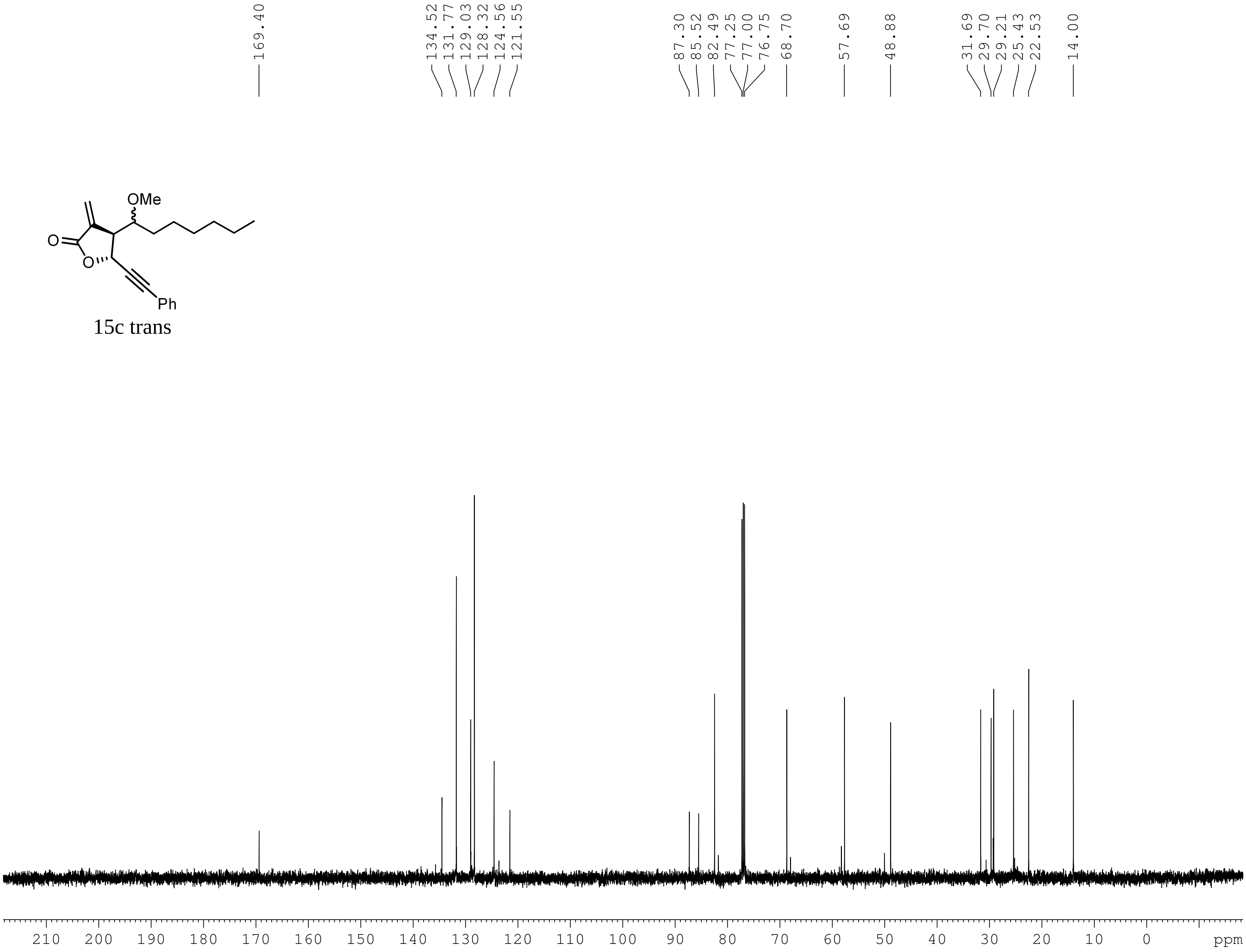
7.430
7.426
7.421
7.417
7.413
7.407
7.354
7.351
7.348
7.339
7.334
7.329
7.326
7.324
7.319
7.316
7.307
7.305
7.300
7.295
7.292
7.287
7.260
6.393
6.388
5.760
5.756
5.726
5.722
5.220
5.212
3.524
3.521
3.517
3.513
3.511
3.509
3.506
3.501
3.419
3.362
3.356
3.353
3.350
3.345
3.341
3.330
1.533
1.529
1.513
1.508
1.502
1.494
1.485
1.478
1.472
1.463
1.454
1.451
1.445
1.438
1.422
1.305
1.292
1.281
1.271
1.262
0.882
0.869
0.855
OMe
O
O
Ph
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
2.36
3.44
1.15
1.15
0.10
1.00
1.03
2.99
1.39
3.50
8.37
3.91

15c trans

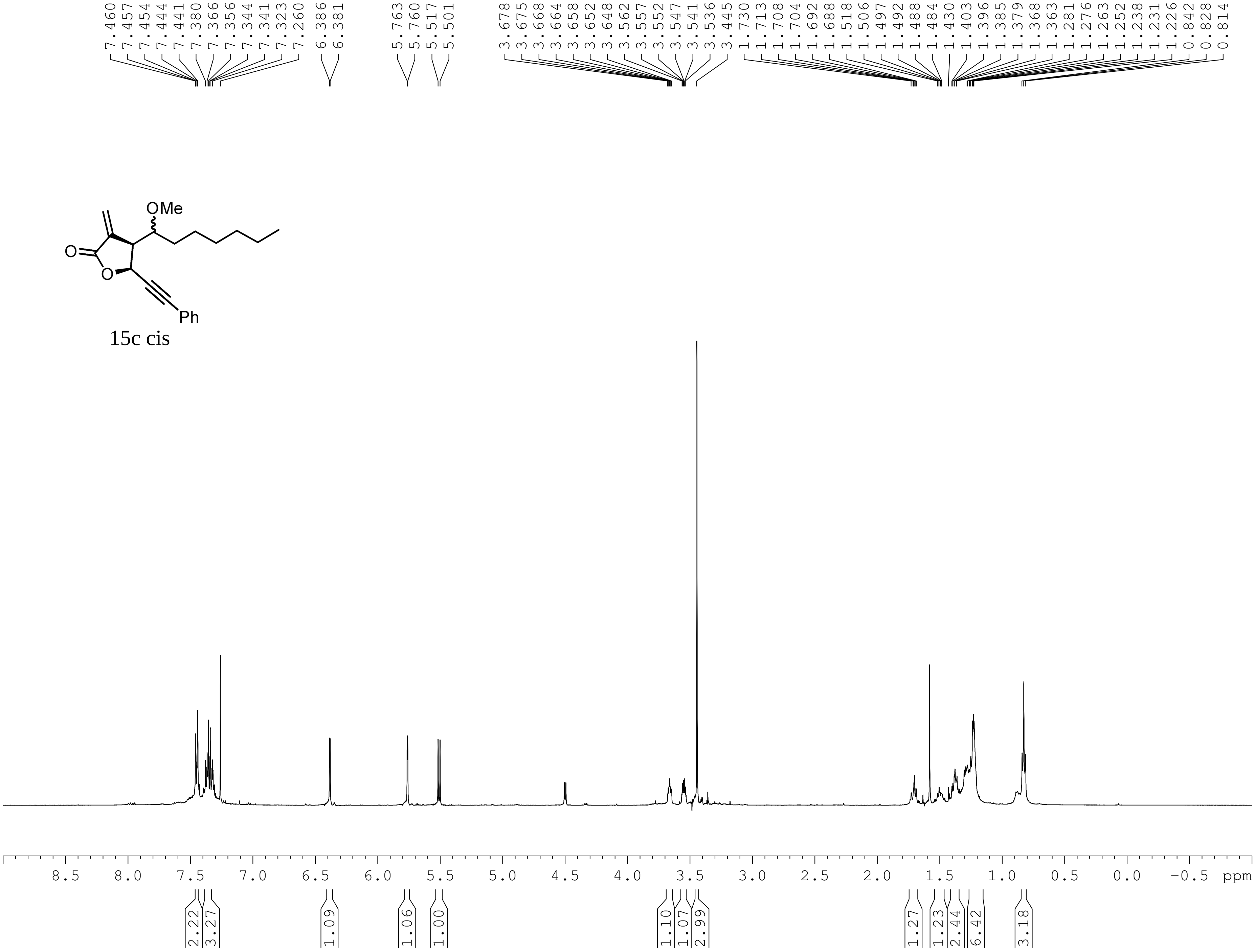


15c trans

169.40
134.52
131.77
129.03
128.32
124.56
121.55
87.30
85.52
82.49
77.25
77.00
76.75
68.70
57.69
48.88
31.69
29.70
29.21
25.43
22.53
14.00
OMe
O
O
Ph
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

OMe
O
O
Ph

15c cis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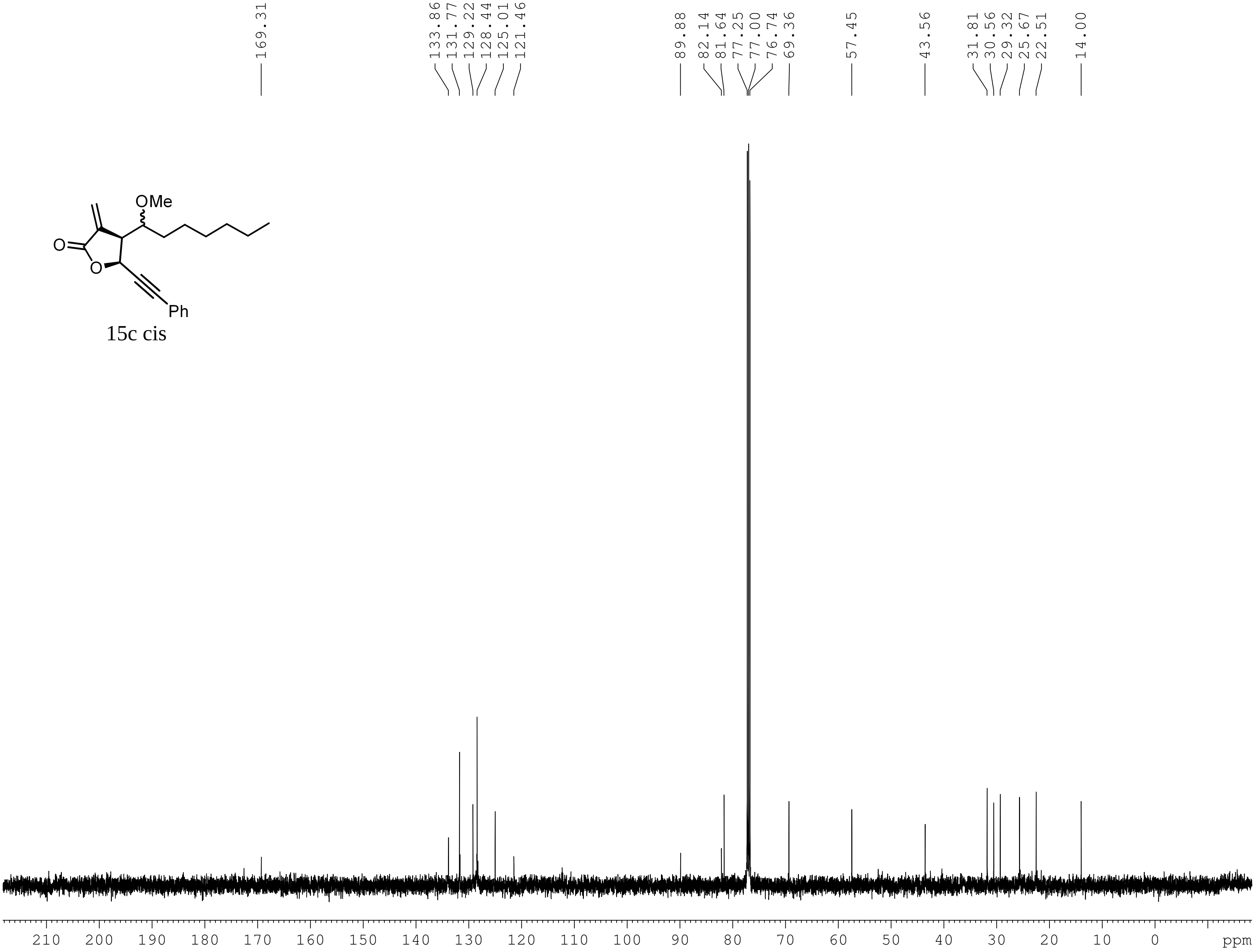
7.454
7.444
7.441
7.380
7.366
7.356
7.344
7.341
7.323
7.260
6.386
6.381
5.763
5.760
5.517
5.501
3.678
3.675
3.668
3.664
3.658
3.652
3.648
3.562
3.557
3.552
3.547
3.541
3.536
3.445
1.730
1.713
1.708
1.704
1.692
1.688
1.518
1.506
1.497
1.492
1.488
1.484
1.430
1.403
1.396
1.385
1.379
1.368
1.363
1.281
1.276
1.263
1.252
1.238
1.231
1.226
0.842
0.828
0.814
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
ppm
2.22
3.27
1.09
1.06
1.00
1.10
1.07
2.99
1.27
1.23
2.44
6.42
3.18


15c cis
169.31
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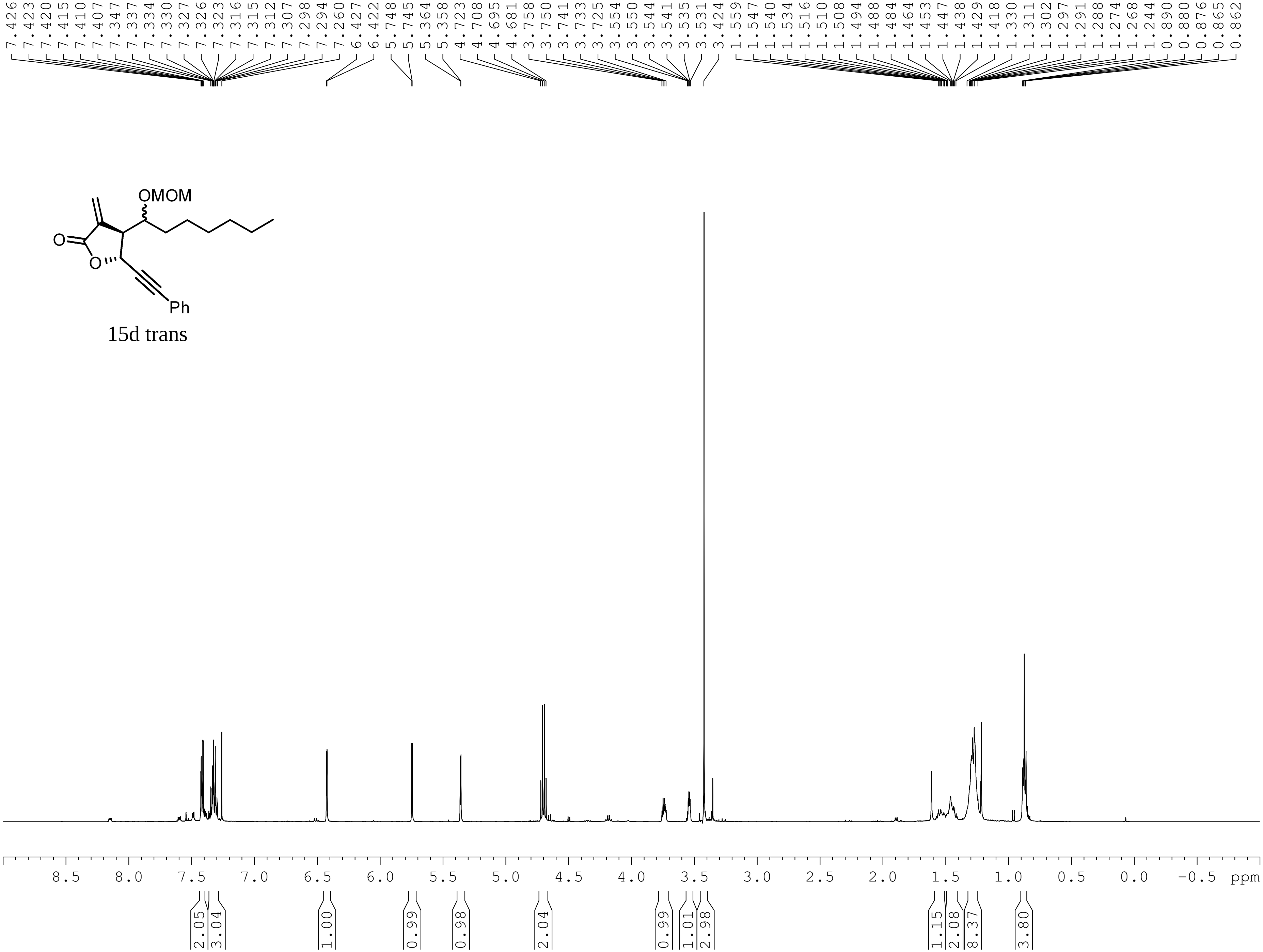
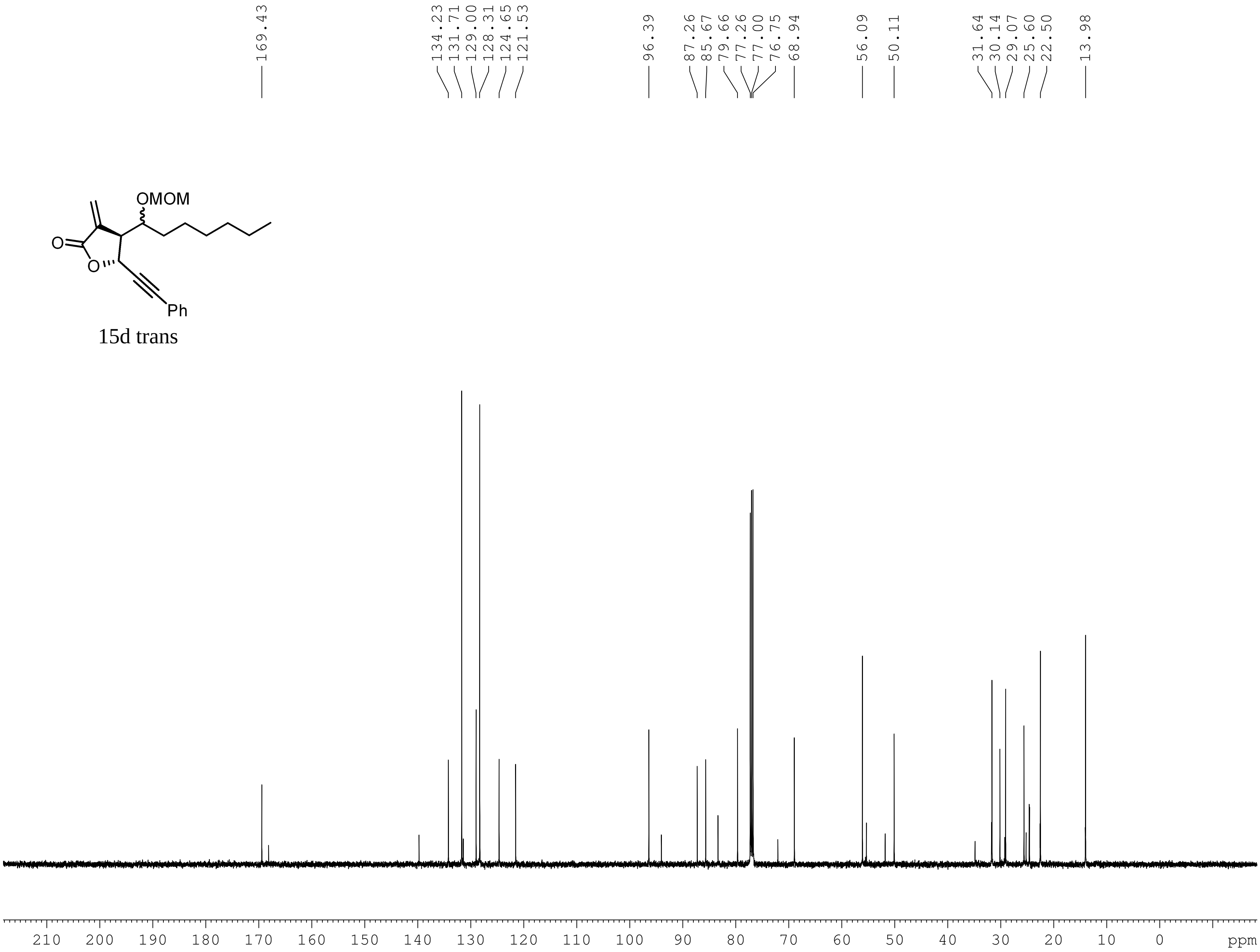
129.22
128.44
125.01
121.46
89.88
82.14
81.64
77.25
77.00
76.74
69.36
57.45
43.56
31.81
30.56
29.32
25.67
22.51
14.00
OMe
O
O
Ph
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.426
7.423
7.420
7.415
7.410
7.407
7.347
7.337
7.334
7.330
7.327
7.326
7.323
7.316
7.315
7.312
7.307
7.298
7.294
7.260
6.427
6.422
5.748
5.745
5.364
5.358
4.723
4.708
4.695
4.681
3.758
3.750
3.741
3.733
3.725
3.554
3.550
3.544
3.541
3.535
3.531
3.424
1.559
1.547
1.540
1.534
1.516
1.510
1.508
1.494
1.488
1.484
1.464
1.453
1.447
1.438
1.429
1.418
1.330
1.311
1.302
1.297
1.291
1.288
1.274
1.268
1.244
0.890
0.880
0.876
0.865
0.862
OMOM
O
O
Ph
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
ppm
2.05
3.04
1.00
0.99
0.98
2.04
0.99
1.01
2.98
1.15
2.08
8.37
3.80

15d trans

OMOM
O
O
Ph

15d trans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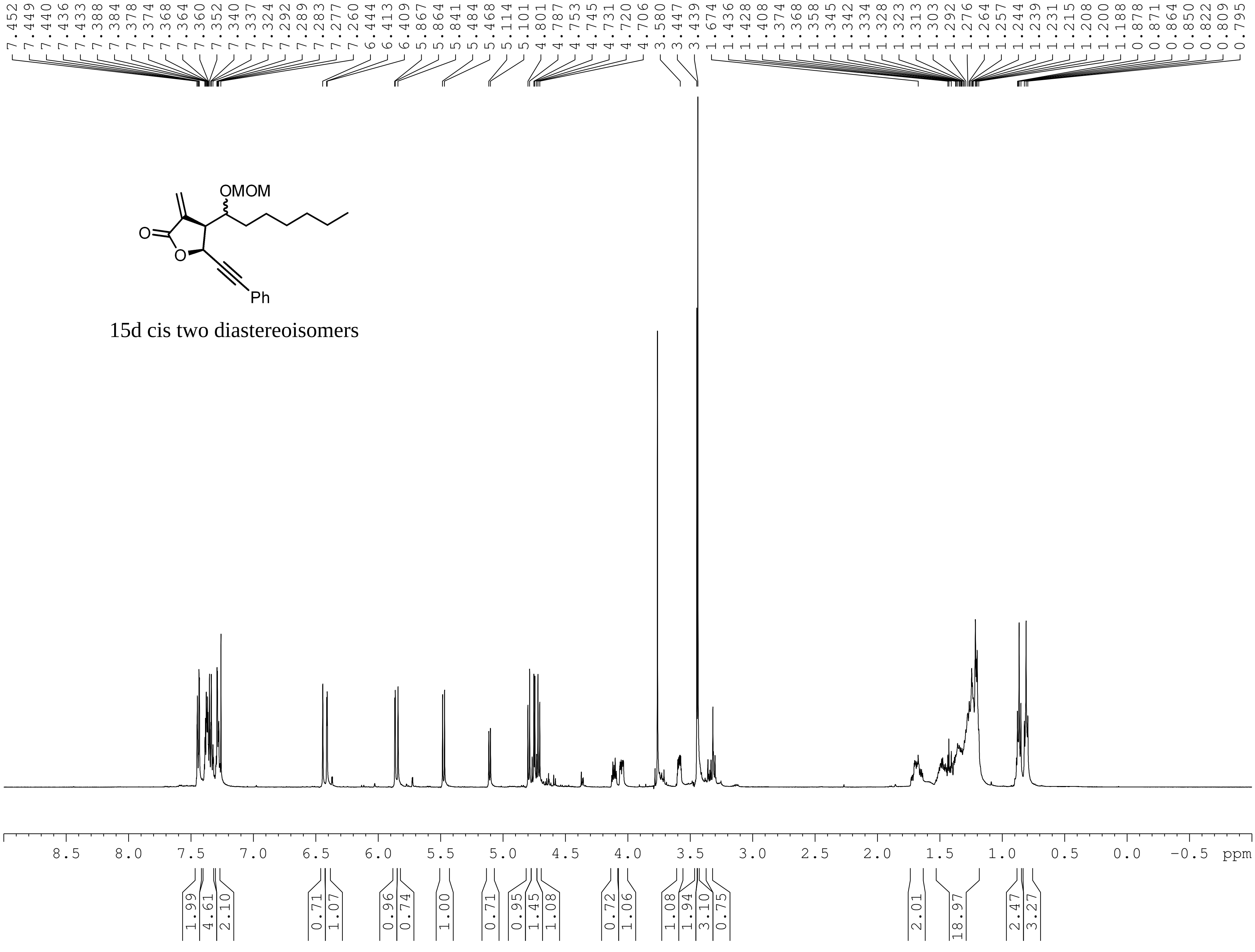
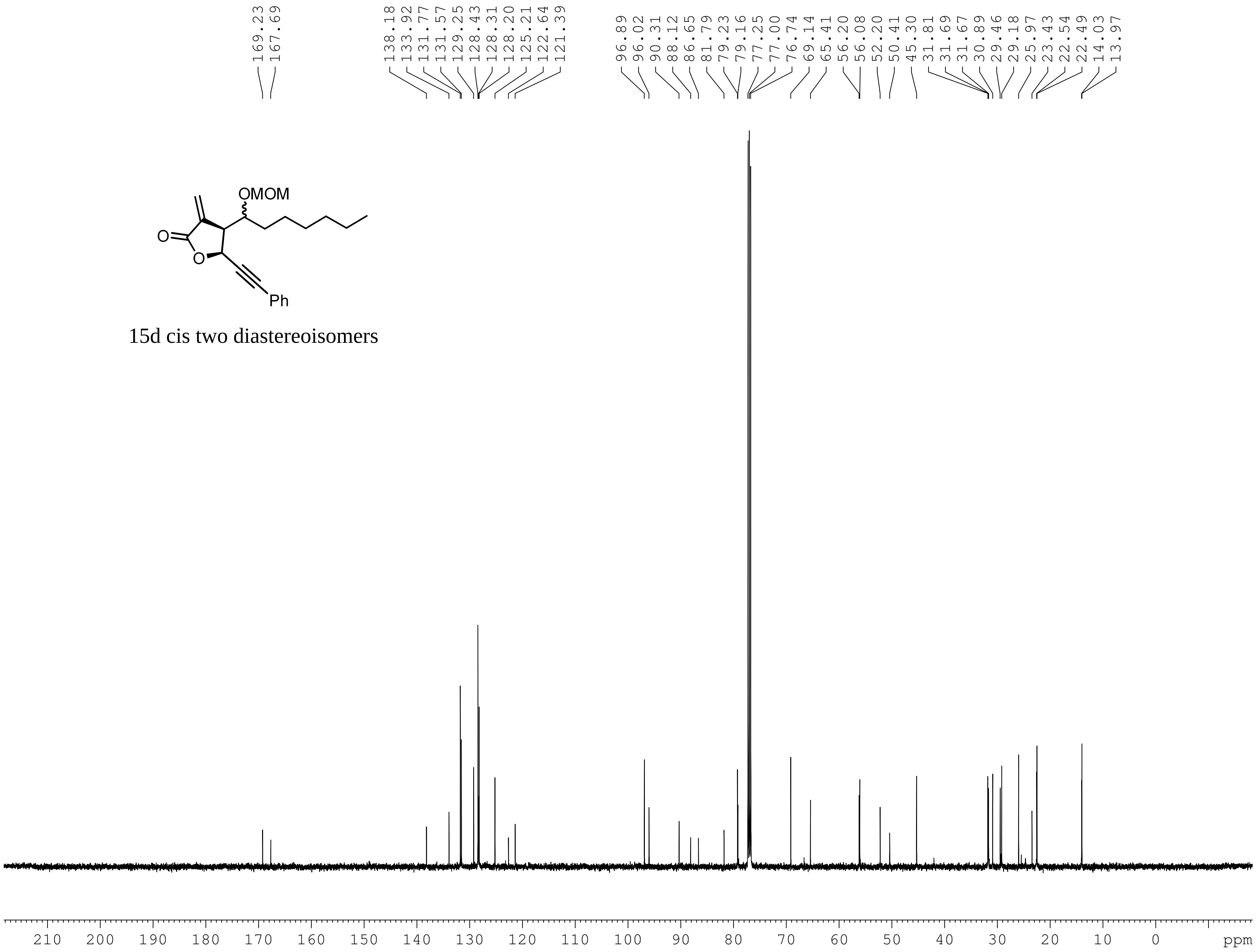
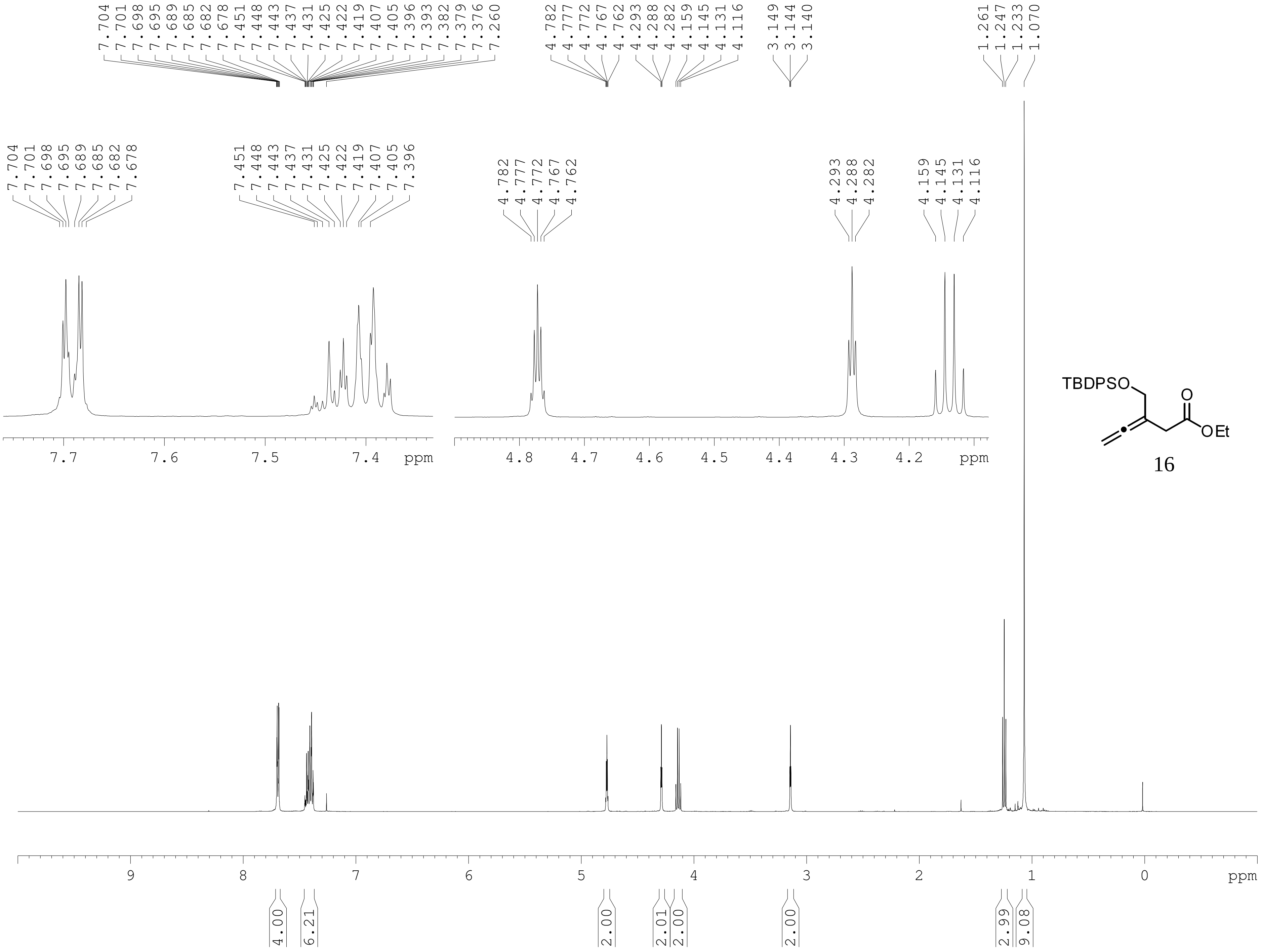
131.71
129.00
128.31
124.65
121.53
96.39
87.26
85.67
79.66
77.26
77.00
76.75
68.94
56.09
50.11
31.64
30.14
29.07
25.60
22.50
13.98
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



15d cis two diastereoisomers


15d cis two diastereoisomers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7.685
7.682
7.678
7.451
7.448
7.443
7.437
7.431
7.425
7.422
7.419
7.407
7.405
7.396
7.393
7.382
7.379
7.376
7.260
4.782
4.777
4.772
4.767
4.762
4.293
4.288
4.282
4.159
4.145
4.131
4.116
3.149
3.144
3.140
1.261
1.247
1.233
1.070
7.7
7.6
7.5
7.4
ppm
4.8
4.7
4.6
4.5
4.4
4.3
4.2
ppm
TBDPSO
O
OEt
9
8
7
6
5
4
3
2
1
0
ppm
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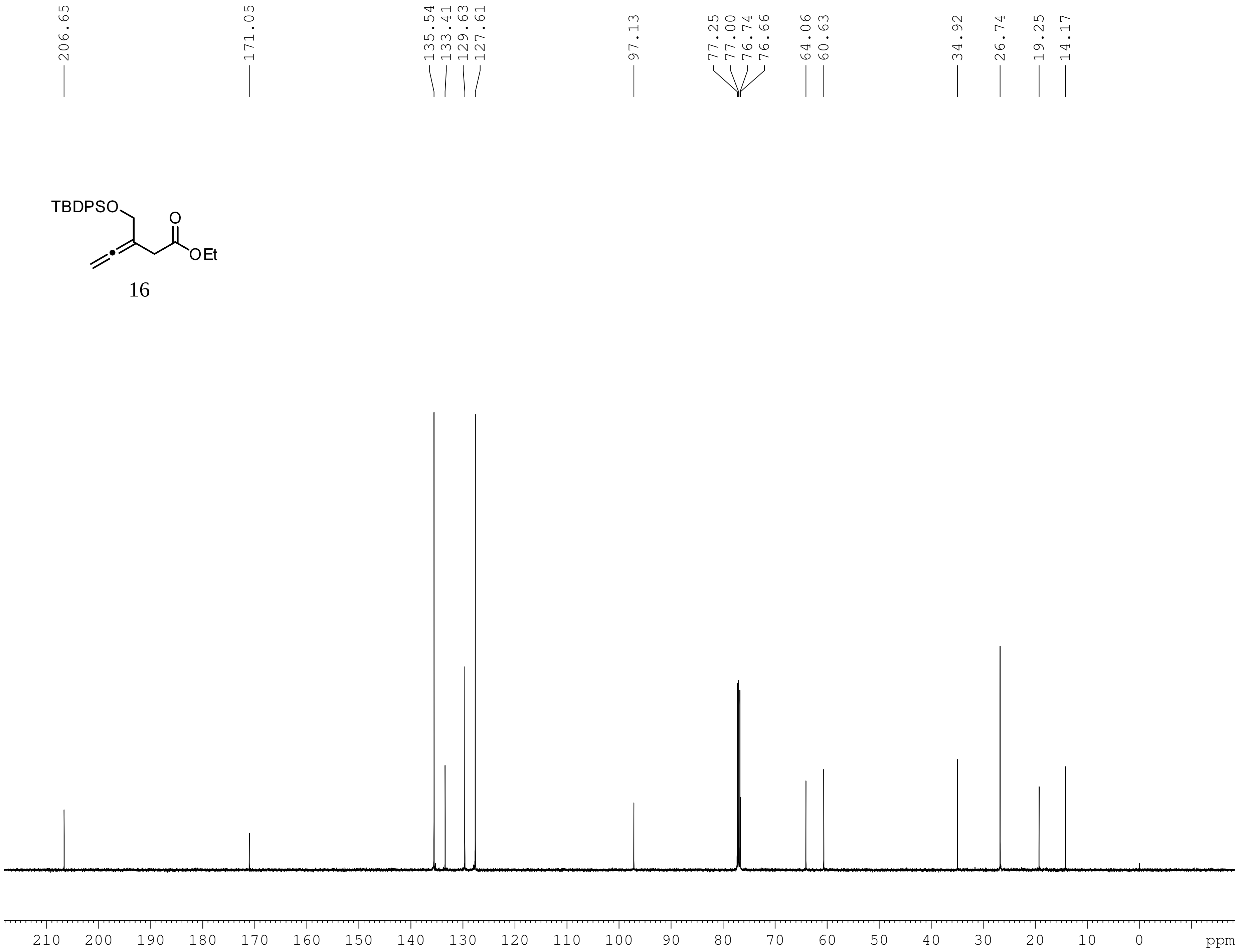
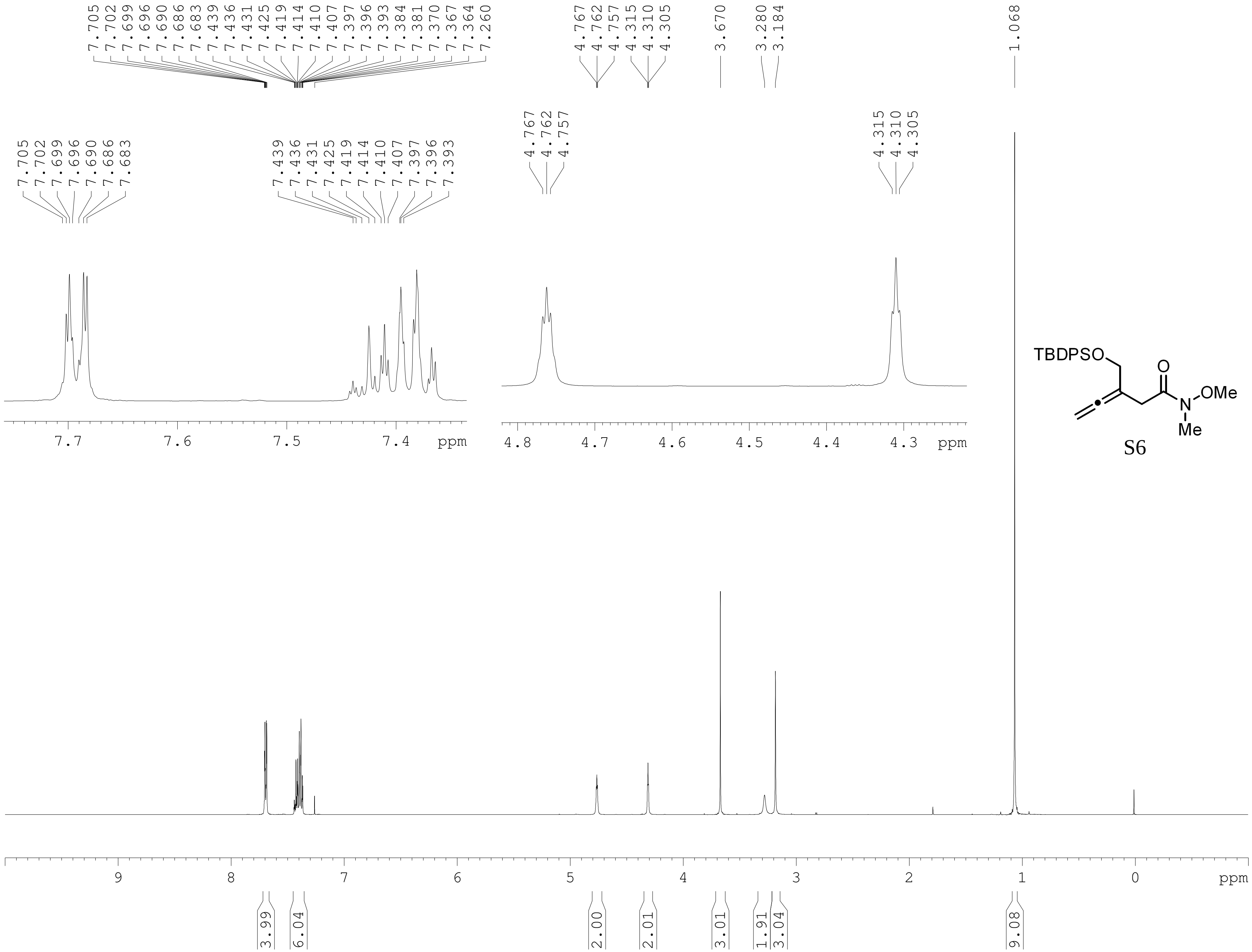
2.00
2.01
2.00
2.00
2.99
9.08

16


206.65
171.05
135.54
133.41
129.63
127.61
97.13
77.25
77.00
76.74
76.66
64.06
60.63
34.92
26.74
19.25
14.17
TBDPSO
O
OEt
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

16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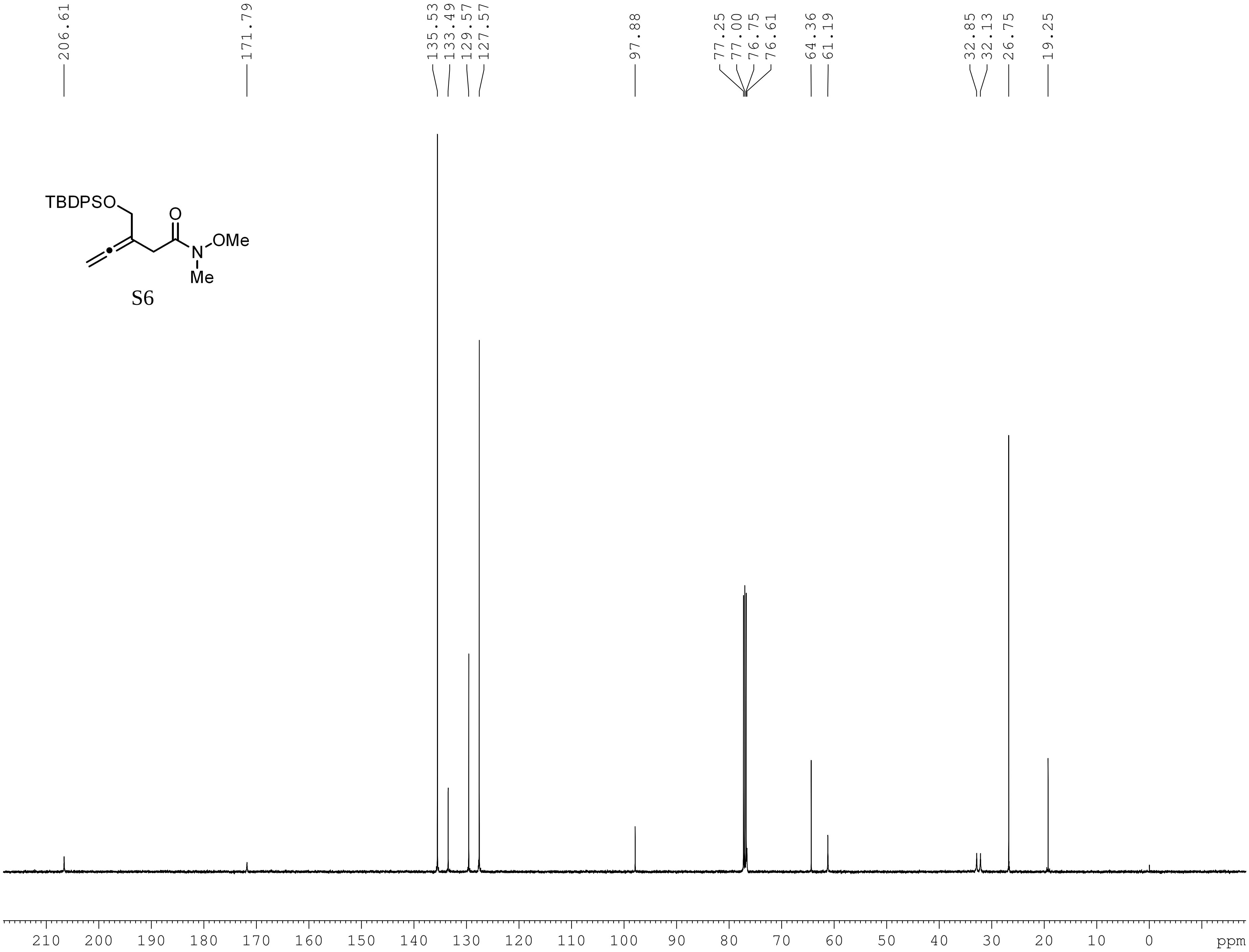
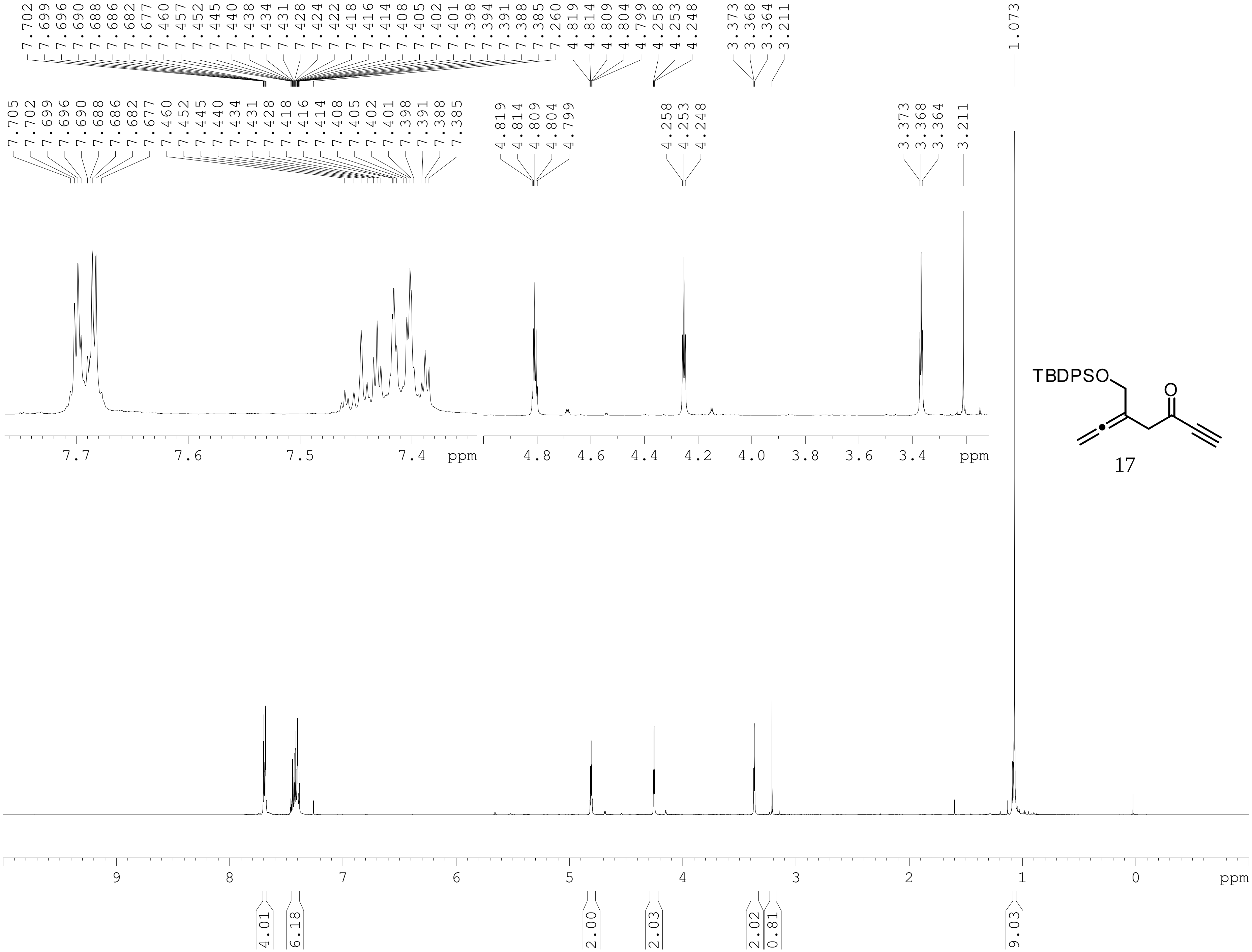
7.431
7.425
7.419
7.414
7.410
7.407
7.397
7.396
7.393
7.384
7.381
7.370
7.367
7.364
7.260
4.767
4.762
4.757
4.315
4.310
4.305
3.670
3.280
3.184
1.068
7.7
7.6
7.5
7.4
ppm
4.8
4.7
4.6
4.5
4.4
4.3
ppm
TBDPSO
O
N
OMe
Me
9
8
7
6
5
4
3
2
1
0
ppm
3.99
6.04
2.00
2.01
3.01
1.91
3.04
9.08

S6

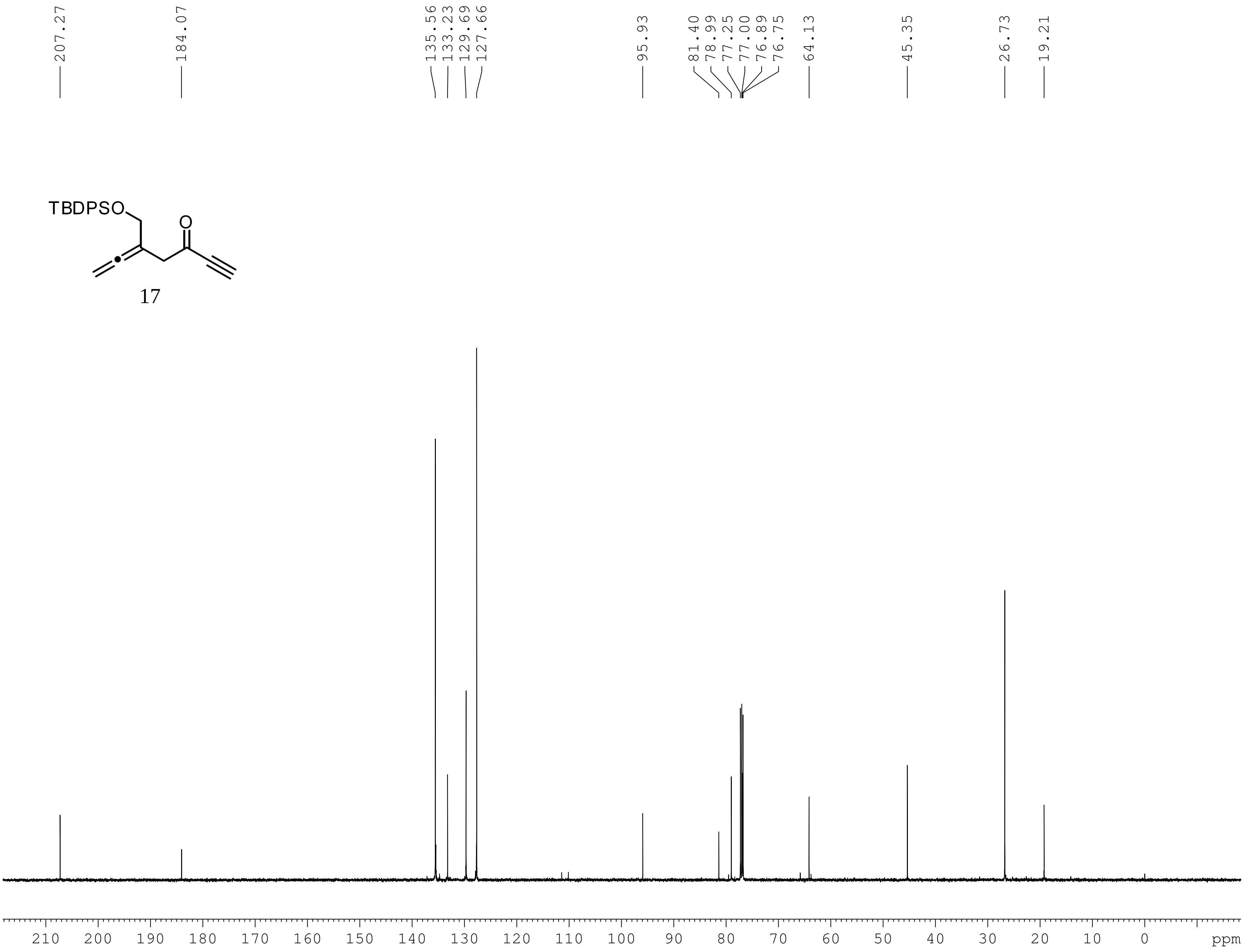


S6

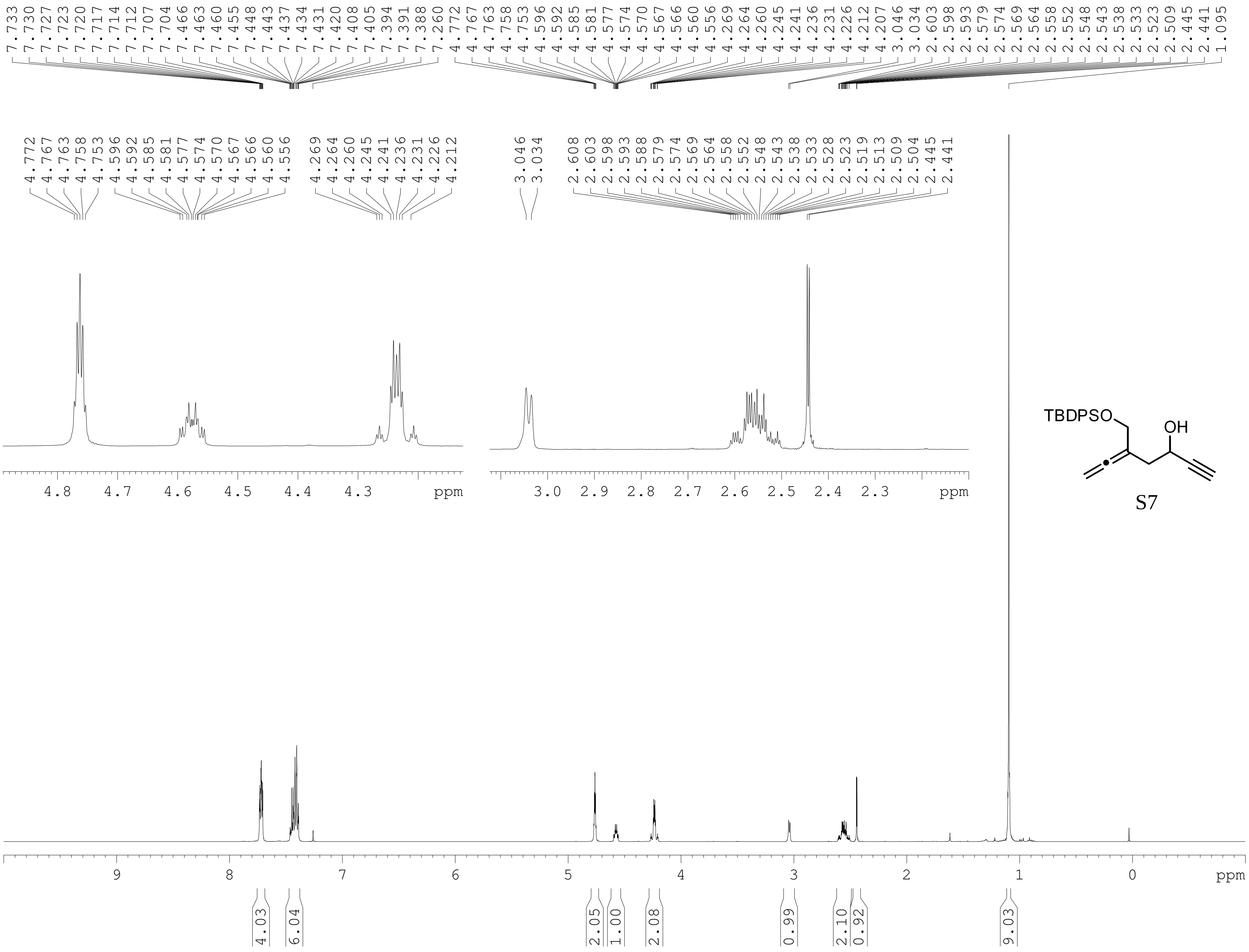
206.61
171.79
135.53
133.49
129.57
127.57
97.88
77.25
77.00
76.75
76.61
64.36
61.19
32.85
32.13
26.75
19.25
TBDPSO
O
N
OMe
Me
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.702 7.699 7.696 7.690 7.688 7.686 7.682 7.677 7.460 7.457 7.452 7.445 7.440 7.438 7.434 7.431 7.428 7.424 7.422 7.418 7.416 7.414 7.408 7.405 7.402 7.401 7.398 7.394 7.391 7.388 7.385 7.260
4.819 4.814 4.809 4.804 4.799
4.258 4.253 4.248
3.373 3.368 3.364 3.211
1.073
7.705 7.702 7.699 7.696 7.690 7.688 7.686 7.682 7.677
7.460 7.452 7.445 7.440 7.434 7.431 7.428 7.418 7.416 7.414 7.408 7.405 7.402 7.401 7.398 7.391 7.388 7.385
4.819 4.814 4.809 4.804 4.799
4.258 4.253 4.248
3.373 3.368 3.364
3.211
7.7
7.6
7.5
7.4
ppm
4.8
4.6
4.4
4.2
4.0
3.8
3.6
3.4
ppm
TBDPSO
O
9
8
7
6
5
4
3
2
1
0
ppm
4.01
6.18
2.00
2.03
2.02
0.81
9.03

17

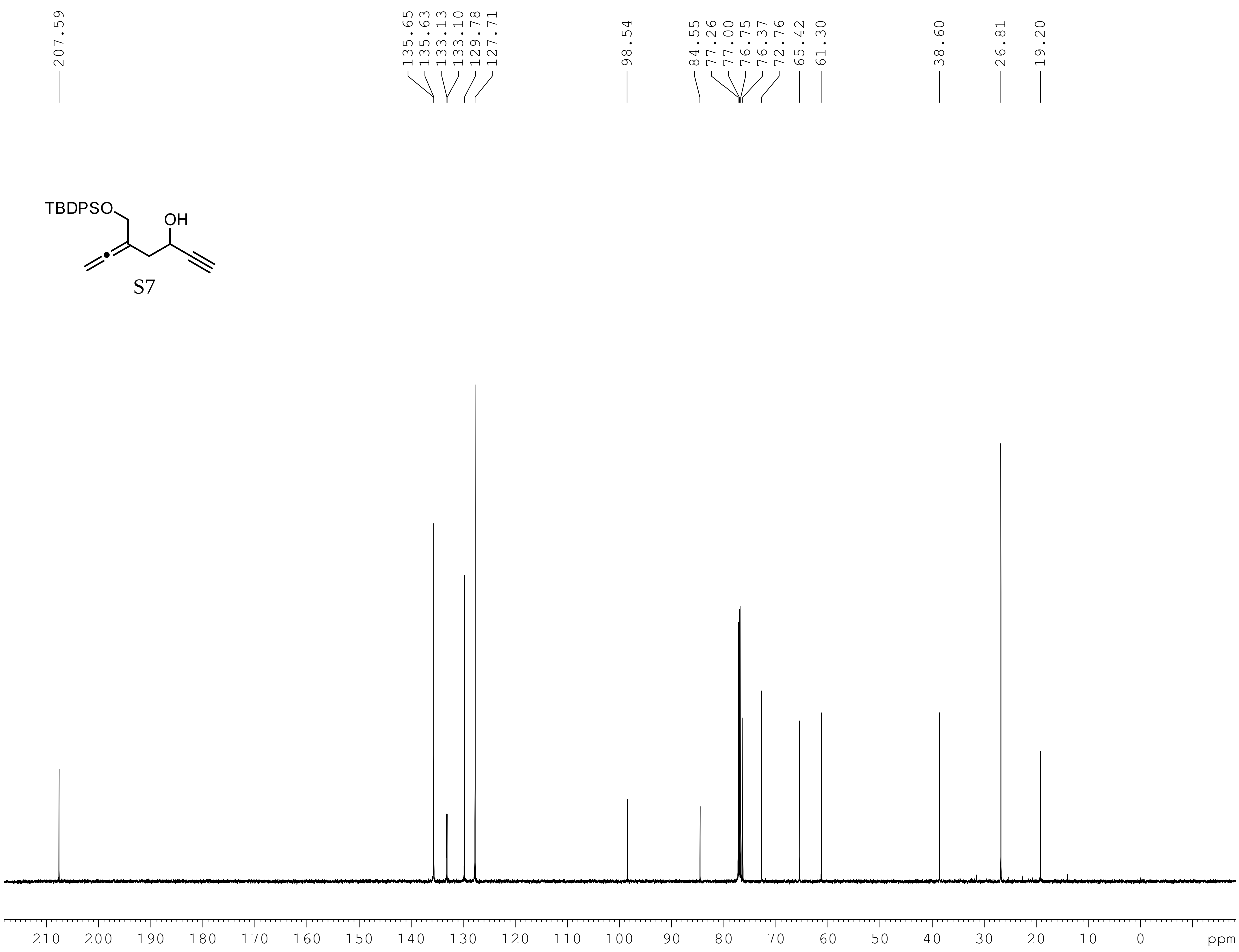

17

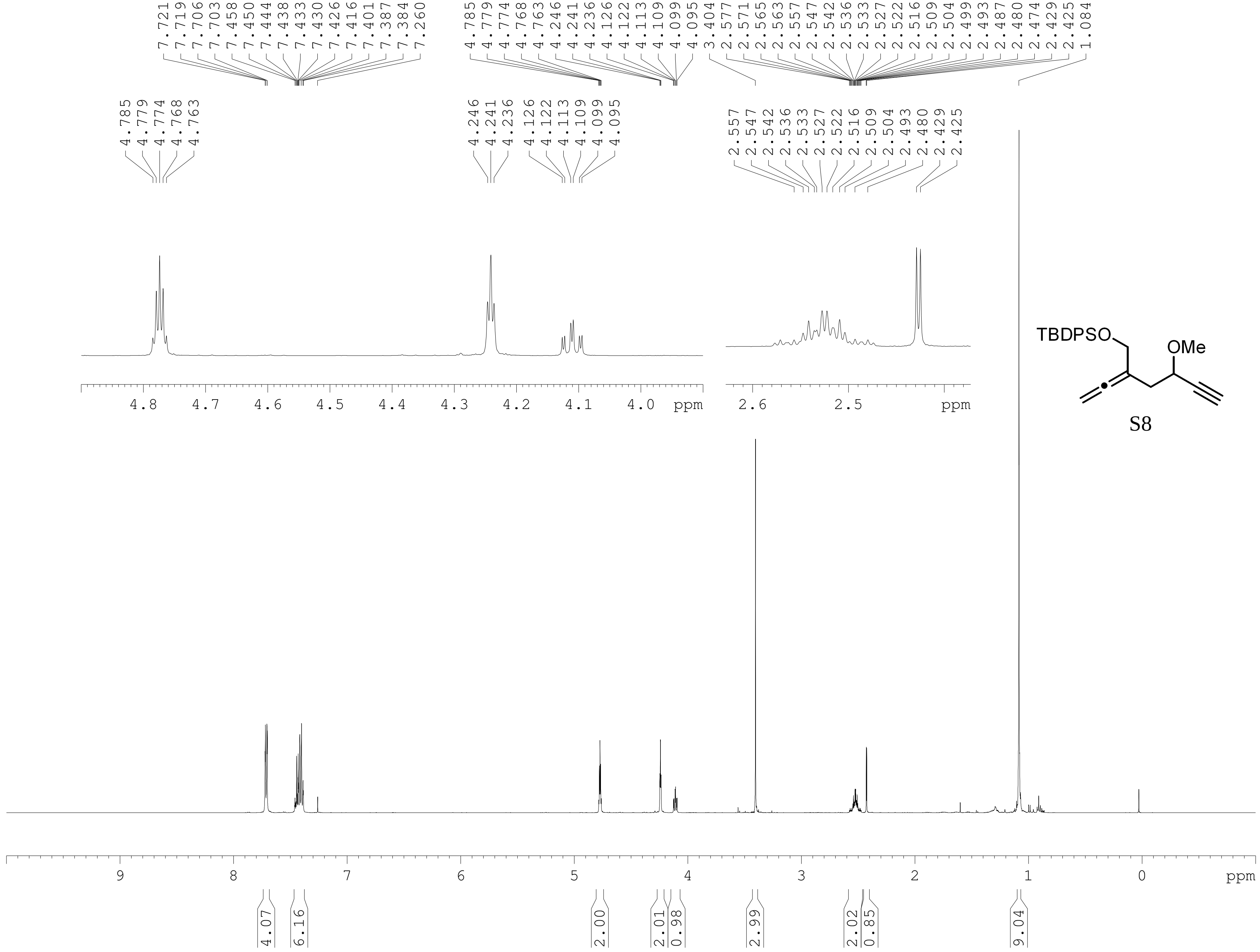
207.27
184.07
135.56
133.23
129.69
127.66
95.93
81.40
78.99
77.25
77.00
76.89
76.75
64.13
45.35
26.73
19.21
TBDPSO
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.733 7.730 7.727 7.723 7.720 7.717 7.714 7.712 7.707 7.704 7.466 7.463 7.460 7.455 7.448 7.443 7.437 7.434 7.431 7.420 7.408 7.405 7.394 7.391 7.388 7.260 4.772 4.767 4.763 4.758 4.753 4.596 4.592 4.585 4.581 4.577 4.574 4.570 4.567 4.566 4.560 4.556 4.269 4.264 4.260 4.245 4.241 4.236 4.231 4.226 4.212 4.207 3.046 3.034 2.603 2.598 2.593 2.579 2.574 2.569 2.564 2.558 2.552 2.548 2.543 2.538 2.533 2.523 2.509 2.445 2.441 1.095
4.772 4.767 4.763 4.758 4.753 4.596 4.592 4.585 4.581 4.577 4.574 4.570 4.567 4.566 4.560 4.556 4.269 4.264 4.260 4.245 4.241 4.236 4.231 4.226 4.212
4.8 4.7 4.6 4.5 4.4 4.3 ppm
3.046 3.034
2.608 2.603 2.598 2.593 2.588 2.579 2.574 2.569 2.564 2.558 2.552 2.548 2.543 2.538 2.533 2.528 2.523 2.519 2.513 2.509 2.504 2.445 2.441
3.0 2.9 2.8 2.7 2.6 2.5 2.4 2.3 ppm
TBDPSO
OH
S7
9 8 7 6 5 4 3 2 1 0 ppm
4.03 6.04 2.05 1.00 2.08 0.99 2.10 0.92 9.03

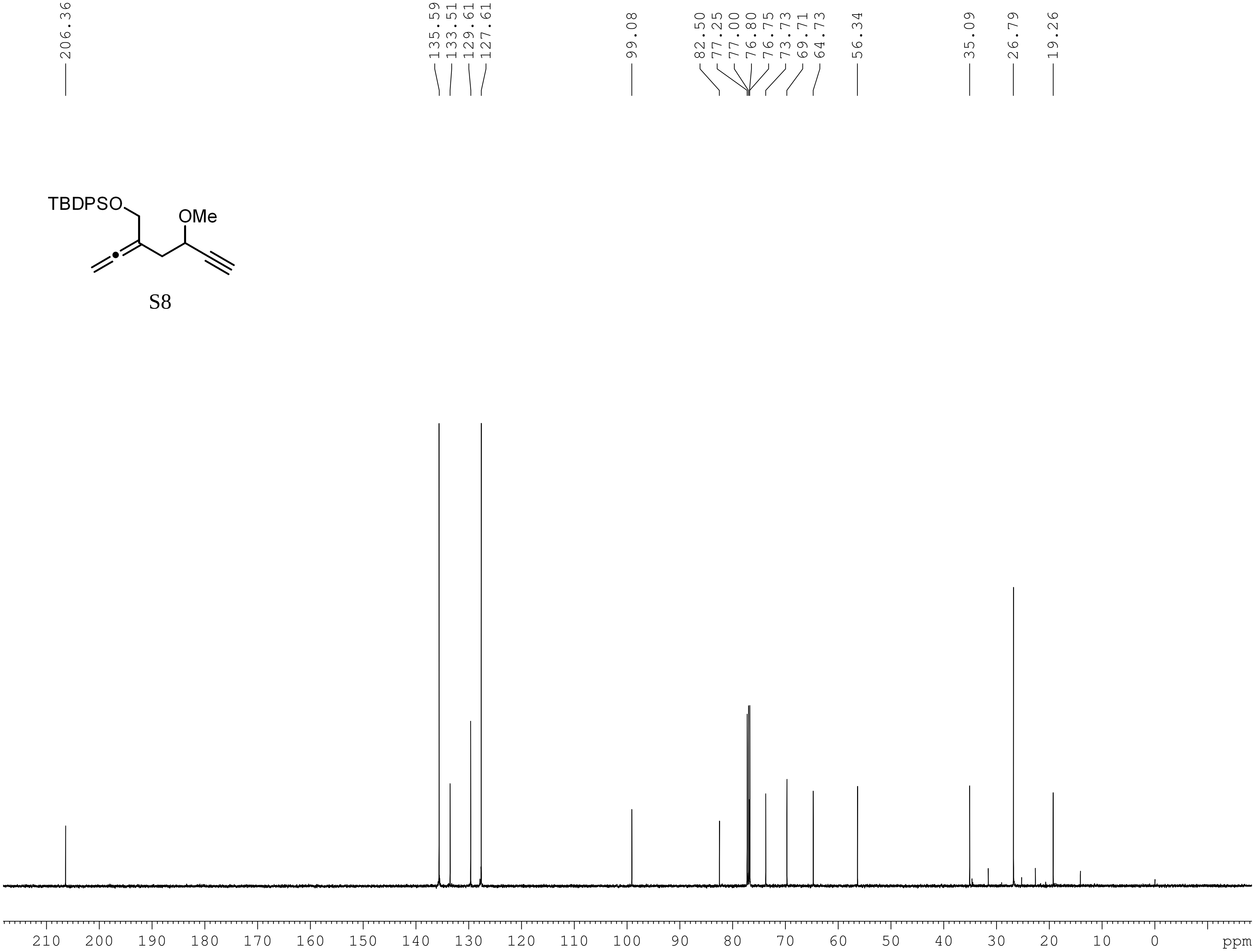
TBDPSO
OH

S7

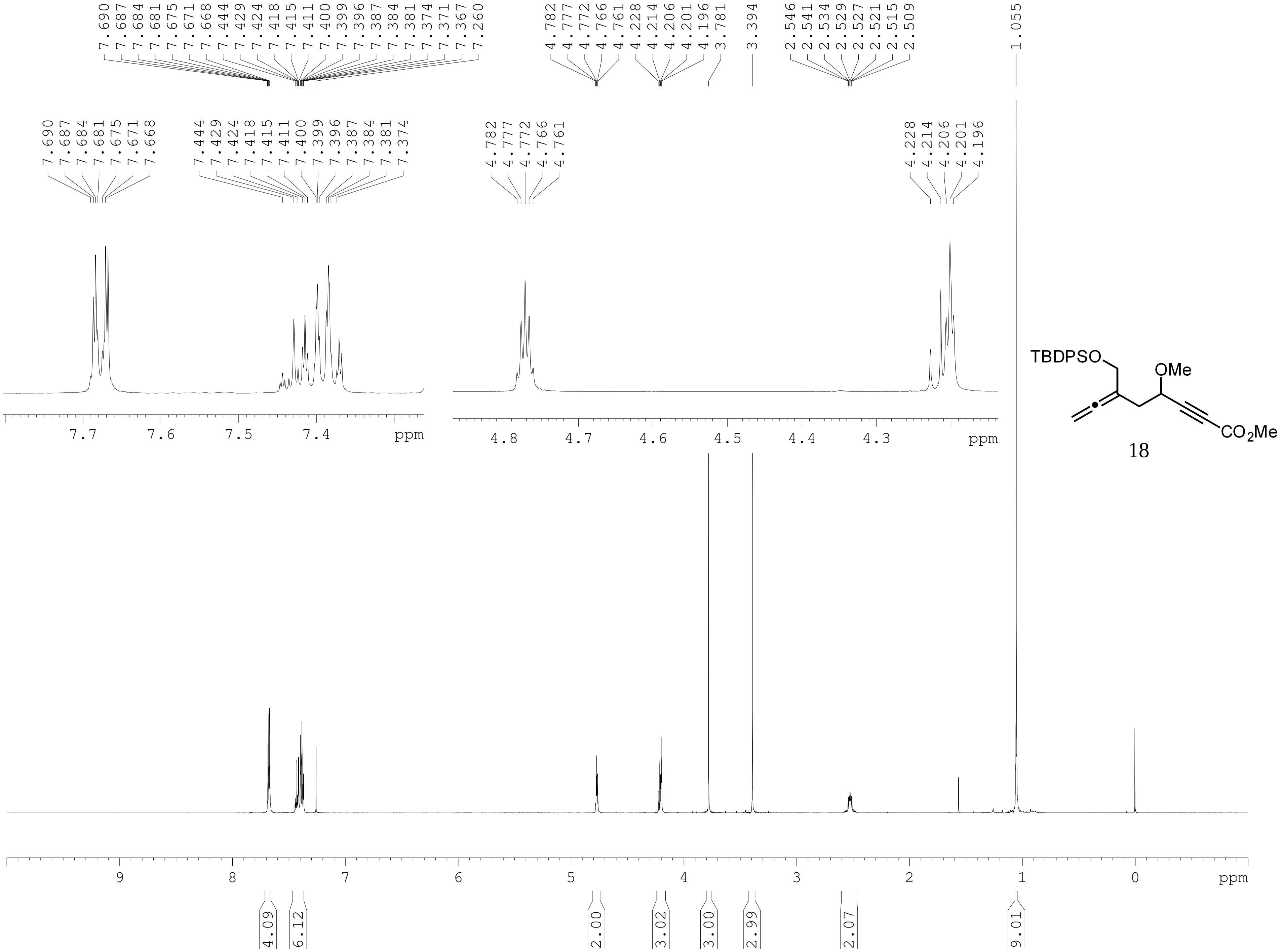

207.59
135.65
135.63
133.13
133.10
129.78
127.71
98.54
84.55
77.26
77.00
76.75
76.37
72.76
65.42
61.30
38.60
26.81
19.20
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.721
7.719
7.706
7.703
7.458
7.450
7.444
7.438
7.433
7.430
7.426
7.416
7.401
7.387
7.384
7.260
4.785
4.779
4.774
4.768
4.763
4.246
4.241
4.236
4.126
4.122
4.113
4.109
4.099
4.095
3.404
2.577
2.571
2.565
2.563
2.557
2.547
2.542
2.536
2.533
2.527
2.522
2.516
2.509
2.504
2.499
2.493
2.487
2.480
2.474
2.429
2.425
1.084
4.785
4.779
4.774
4.768
4.763
4.246
4.241
4.236
4.126
4.122
4.113
4.109
4.099
4.095
2.557
2.547
2.542
2.536
2.533
2.527
2.522
2.516
2.509
2.504
2.493
2.480
2.429
2.425
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
ppm
2.6
2.5
ppm
TBDPSO
OMe
9
8
7
6
5
4
3
2
1
0
ppm
4.07
6.16
2.00
2.01
0.98
2.99
2.02
0.85
9.04

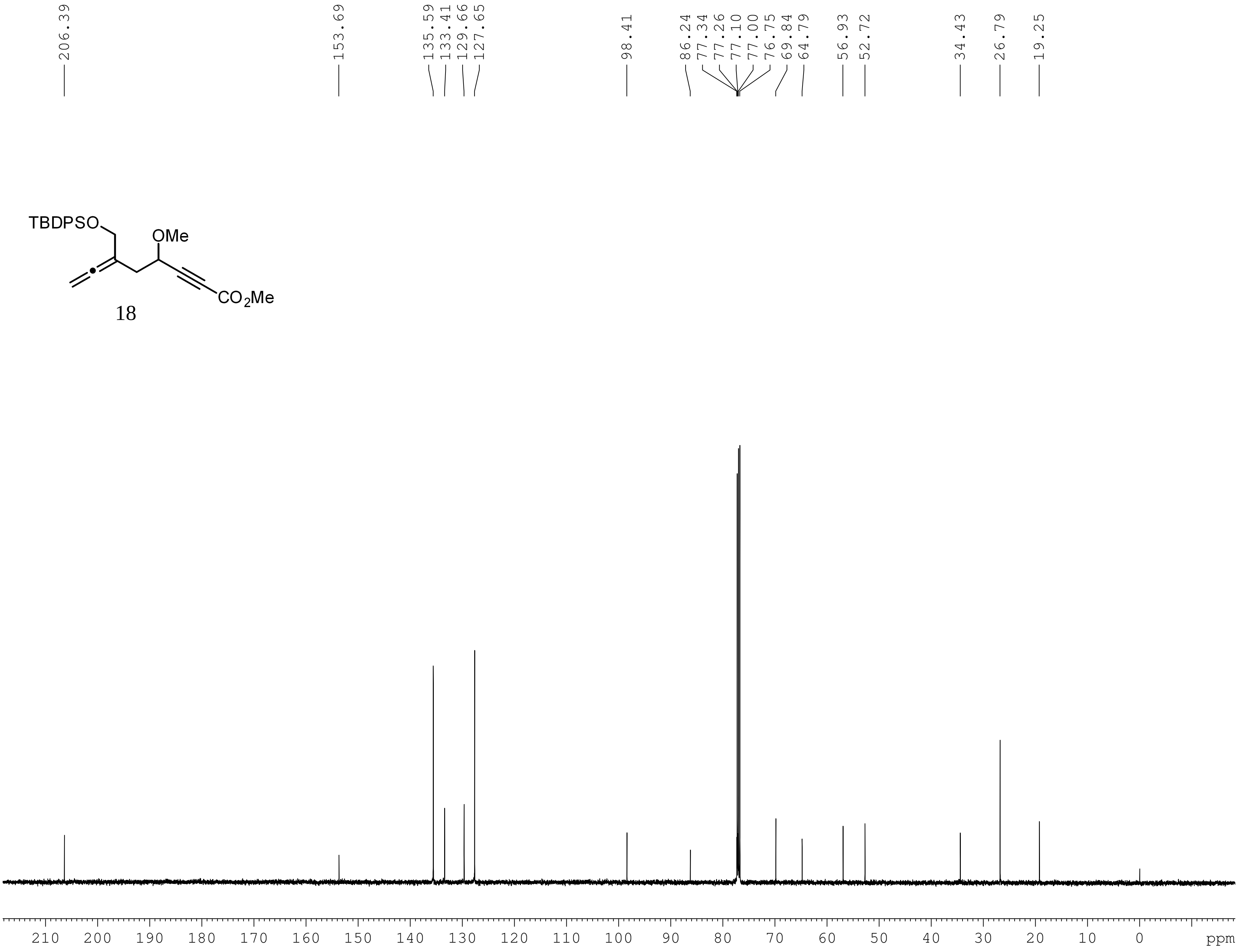
S8

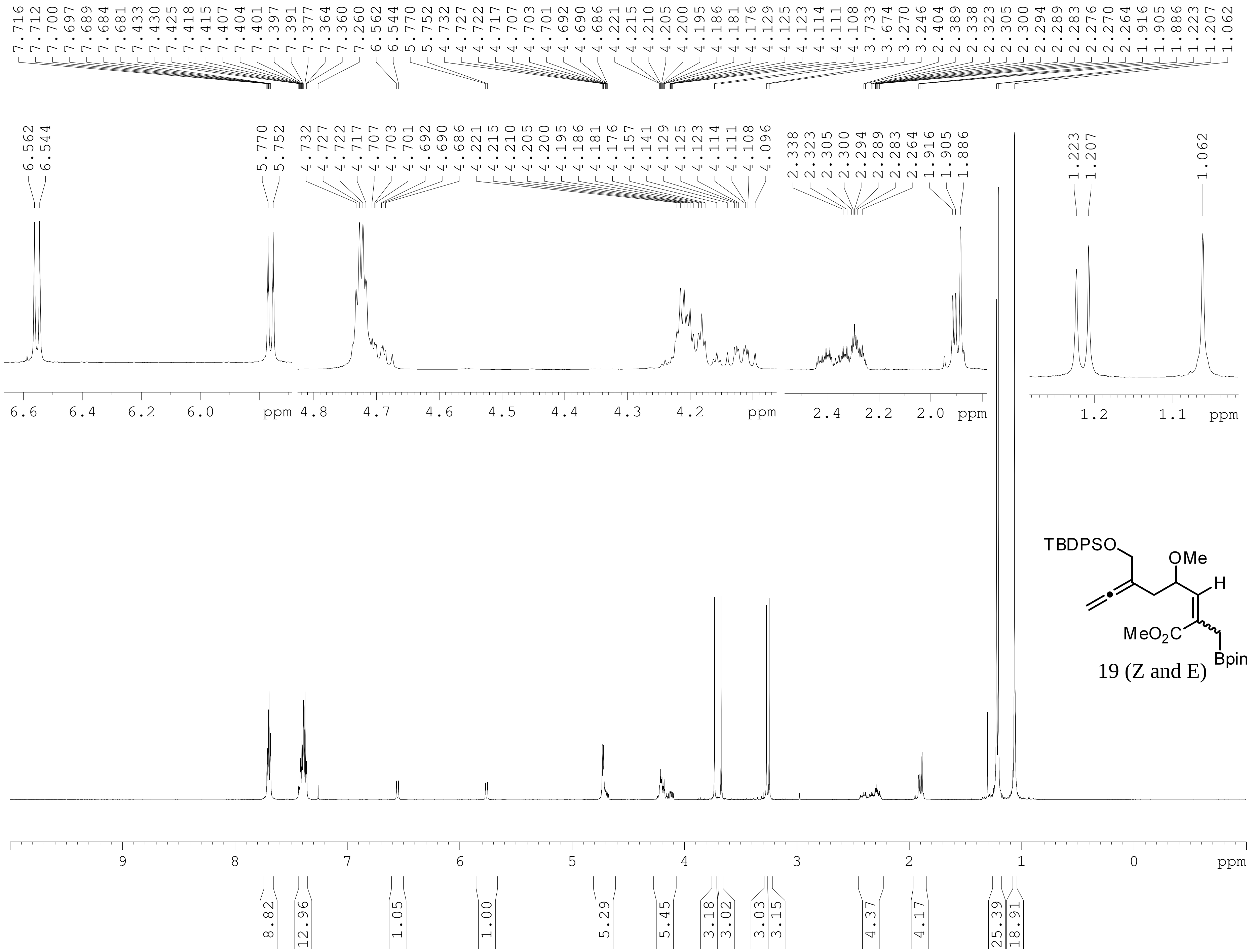

206.36
135.59
133.51
129.61
127.61
99.08
82.50
77.25
77.00
76.80
76.75
73.73
69.71
64.73
56.34
35.09
26.79
19.26
TBDPSO
OMe
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

S8

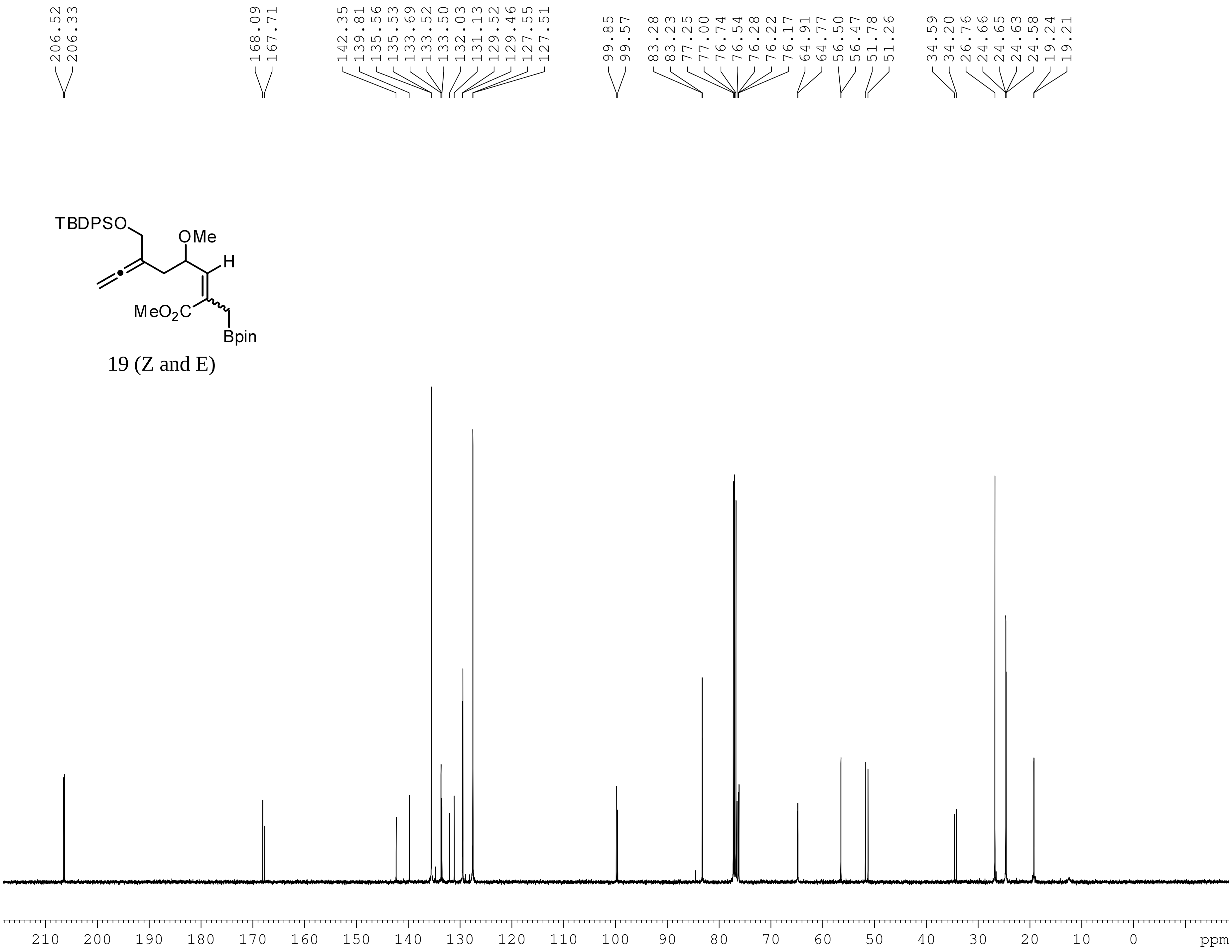

7.690 7.687 7.684 7.681 7.675 7.671 7.668 7.444 7.429 7.424 7.418 7.415 7.411 7.400 7.399 7.396 7.387 7.384 7.381 7.374 7.371 7.367 7.260
4.782 4.777 4.772 4.766 4.761 4.228 4.214 4.206 4.201 4.196 3.781
3.394
2.546 2.541 2.534 2.529 2.527 2.521 2.515 2.509
1.055
7.690 7.687 7.684 7.681 7.675 7.671 7.668
7.444 7.429 7.424 7.418 7.415 7.411 7.400 7.399 7.396 7.387 7.384 7.381 7.374
4.782 4.777 4.772 4.766 4.761
4.228 4.214 4.206 4.201 4.196
7.7 7.6 7.5 7.4 ppm
4.8 4.7 4.6 4.5 4.4 4.3 ppm
TBDPSO
OMe
CO2Me
9 8 7 6 5 4 3 2 1 0 ppm
4.09 6.12 2.00 3.02 3.00 2.99 2.07 9.01

18

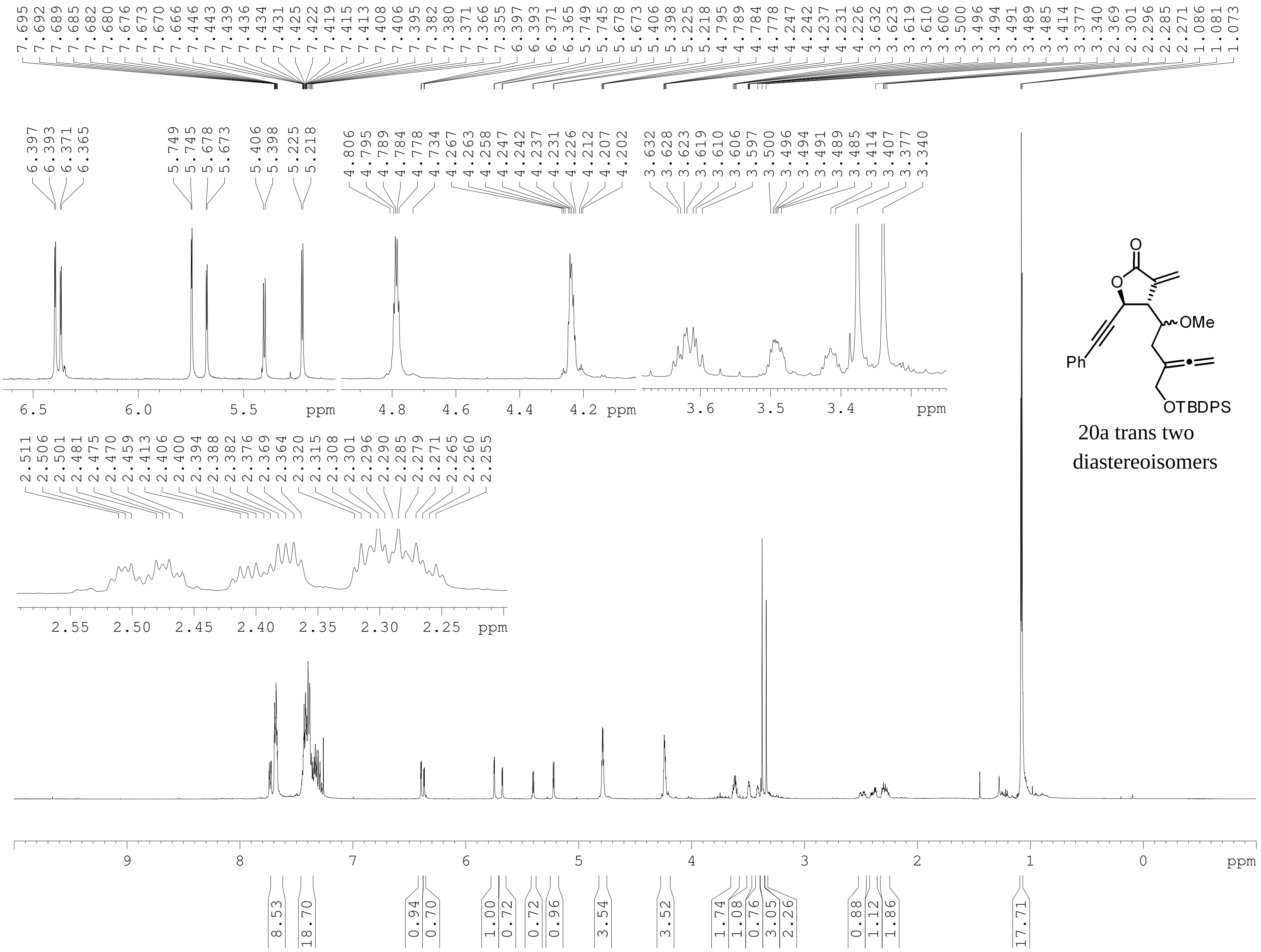

206.39
153.69
135.59
133.41
129.66
127.65
98.41
86.24
77.34
77.26
77.10
77.00
76.75
69.84
64.79
56.93
52.72
34.43
26.79
19.25
TBDPSO
OMe
CO2Me
18
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.716 7.712 7.700 7.697 7.689 7.684 7.681 7.433 7.430 7.425 7.418 7.415 7.407 7.404 7.401 7.397 7.391 7.377 7.364 7.360 7.260 6.562 6.544 5.770 5.752 4.732 4.727 4.722 4.717 4.707 4.703 4.701 4.692 4.690 4.686 4.221 4.215 4.210 4.205 4.200 4.195 4.186 4.181 4.176 4.129 4.125 4.123 4.114 4.111 4.108 3.733 3.674 3.270 3.246 2.404 2.389 2.338 2.323 2.305 2.300 2.294 2.289 2.283 2.276 2.270 2.264 1.916 1.905 1.886 1.223 1.207 1.062
6.562 6.544 5.770 5.752
4.732 4.727 4.722 4.717 4.707 4.703 4.701 4.692 4.690 4.686 4.221 4.215 4.210 4.205 4.200 4.195 4.186 4.181 4.176 4.157 4.141 4.129 4.125 4.123 4.114 4.111 4.108 4.096
2.338 2.323 2.305 2.300 2.294 2.289 2.283 2.264 1.916 1.905 1.886
1.223 1.207 1.062
6.6 6.4 6.2 6.0 ppm
4.8 4.7 4.6 4.5 4.4 4.3 4.2 ppm
2.4 2.2 2.0 ppm
1.2 1.1 ppm
TBDPSO
OMe
H
MeO2C
Bpin
9 8 7 6 5 4 3 2 1 0 ppm
8.82 12.96 1.05 1.00 5.29 5.45 3.18 3.02 3.03 3.15 4.37 4.17 25.39 18.91

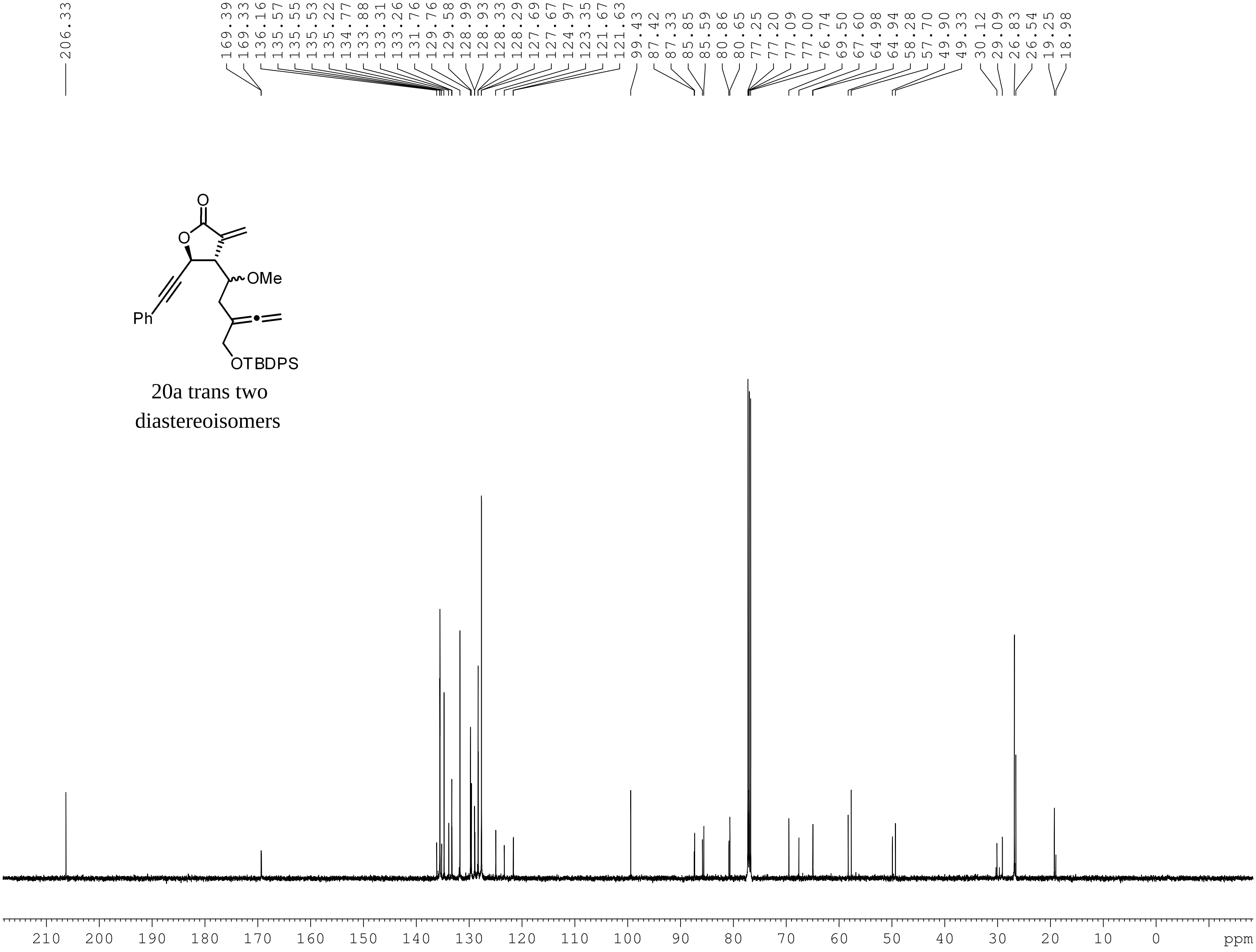
19 (Z and E)

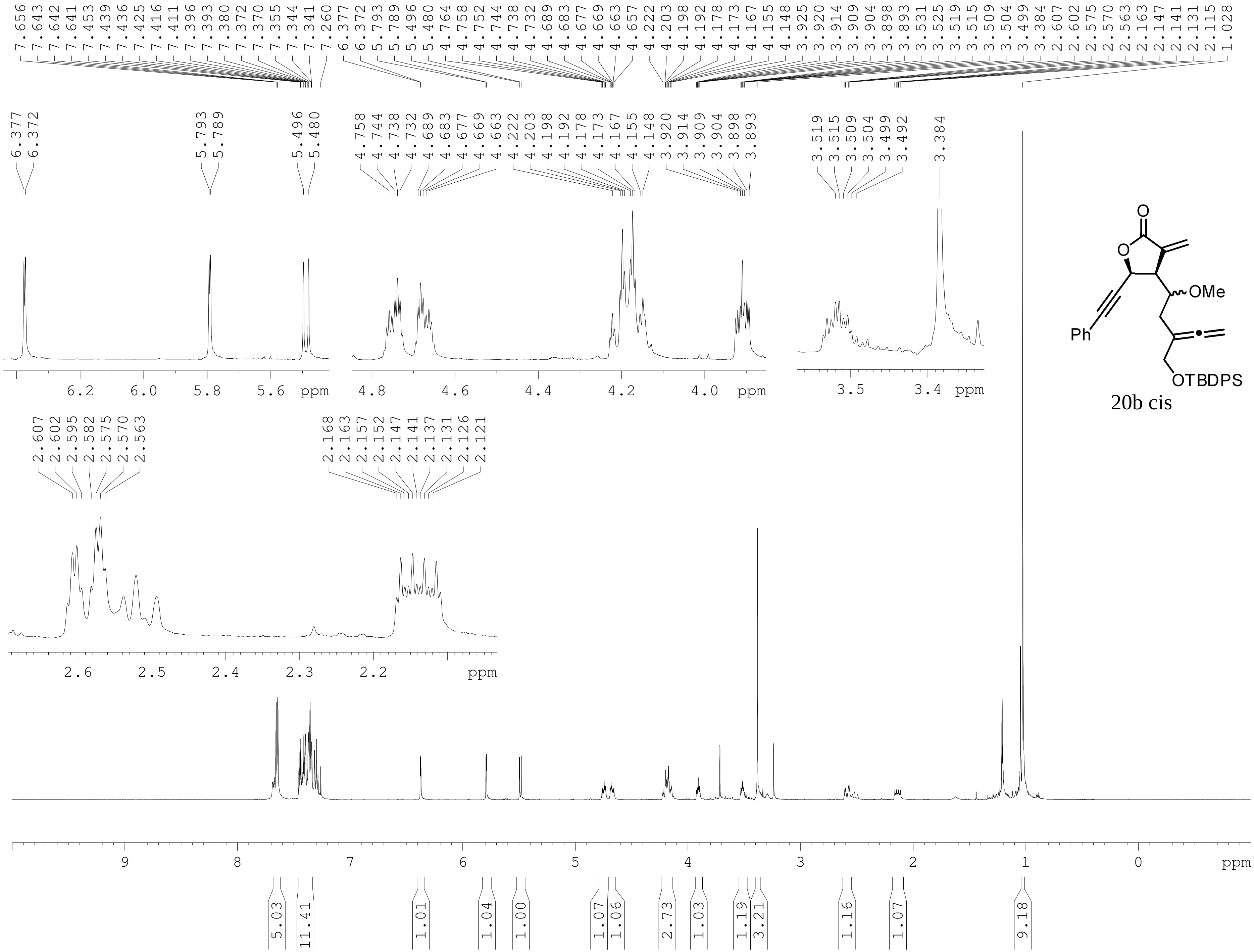

206.52
206.33
168.09
167.71
142.35
139.81
135.56
135.53
133.69
133.52
133.50
132.03
131.13
129.52
129.46
127.55
127.51
99.85
99.57
83.28
83.23
77.25
77.00
76.74
76.54
76.28
76.22
76.17
64.91
64.77
56.50
56.47
51.78
51.26
34.59
34.20
26.76
24.66
24.65
24.63
24.58
19.24
19.21
TBDPSO
OMe
H
MeO_2C
Bpin
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

19 (Z and E)

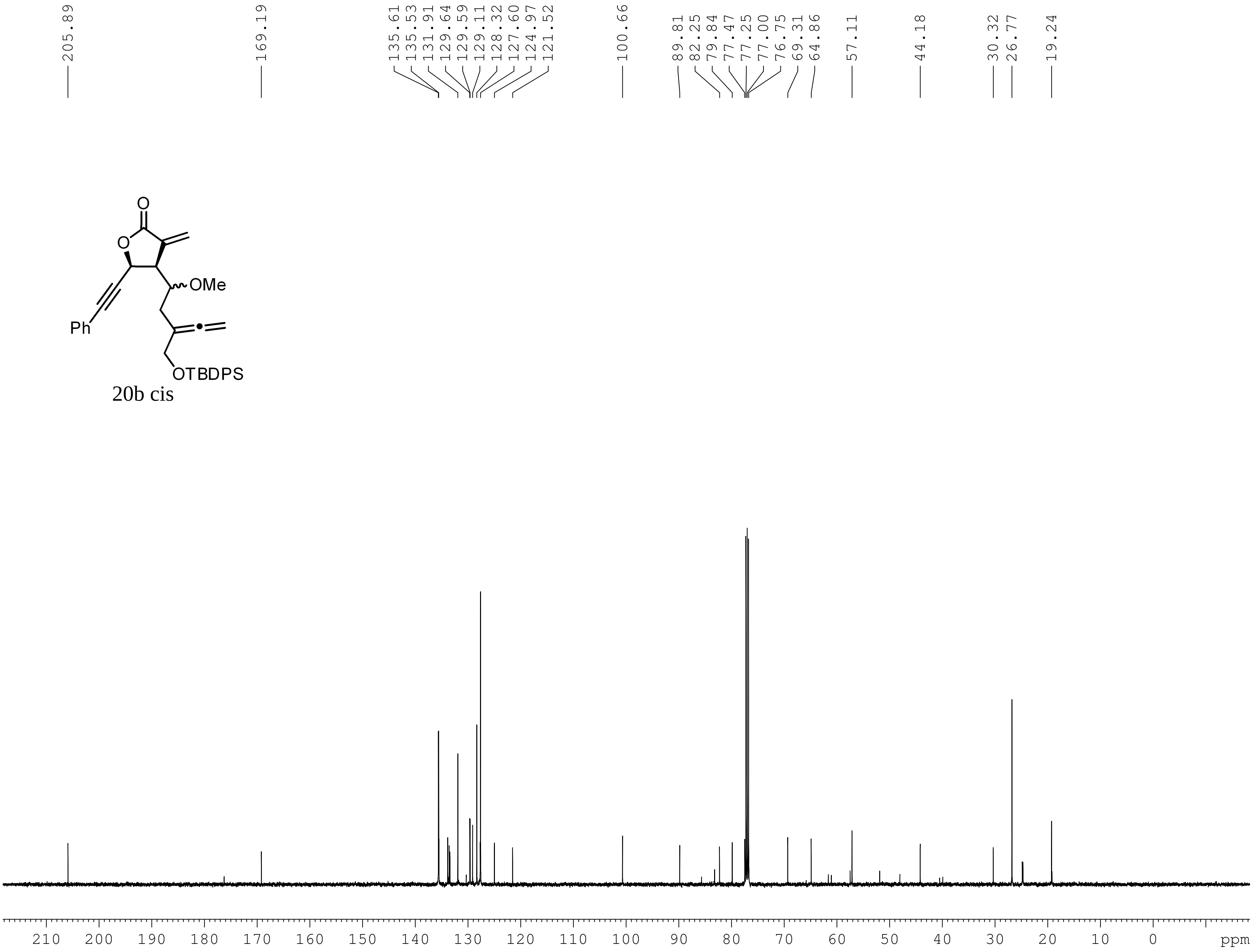


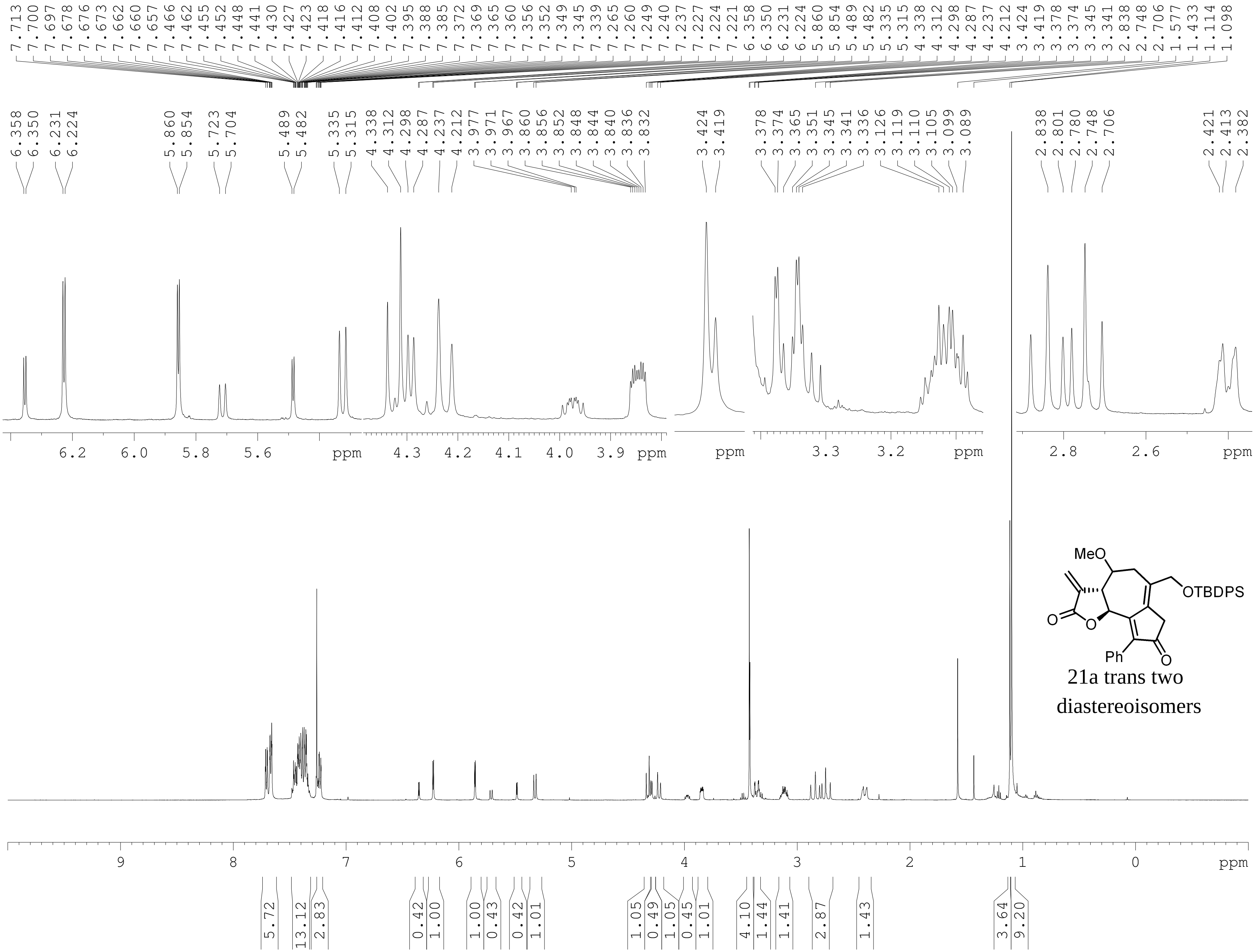
20a trans two
diastereoisomers


20a trans two diastereoisomers

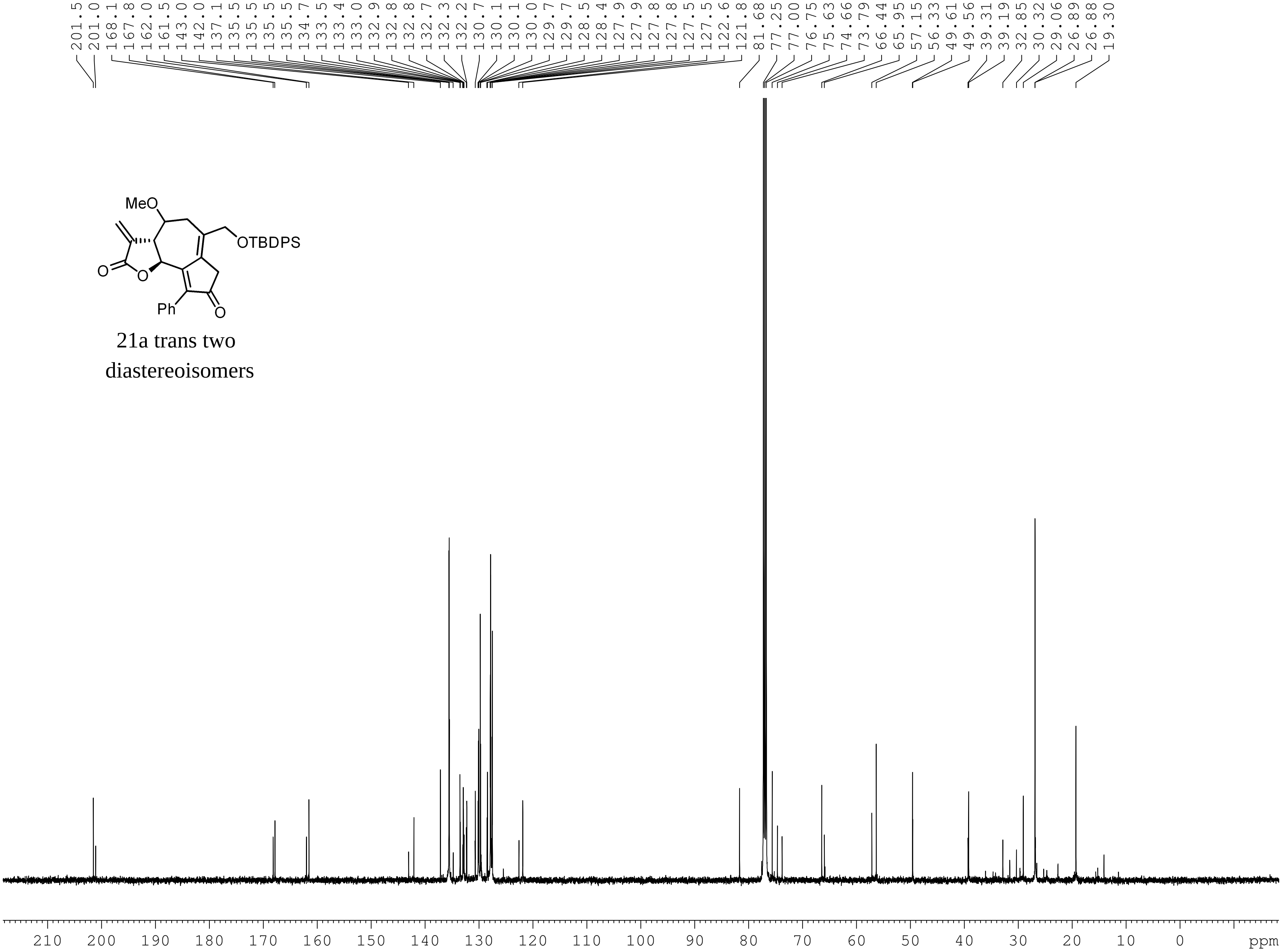

7.656
7.643
7.642
7.641
7.453
7.439
7.436
7.425
7.416
7.411
7.396
7.393
7.380
7.372
7.370
7.355
7.344
7.341
7.260
6.377
6.372
5.793
5.789
5.496
5.480
4.764
4.758
4.752
4.744
4.738
4.732
4.689
4.683
4.677
4.669
4.663
4.657
4.222
4.203
4.198
4.192
4.178
4.173
4.167
4.155
4.148
3.925
3.920
3.914
3.909
3.904
3.898
3.893
3.531
3.525
3.519
3.515
3.509
3.504
3.499
3.384
2.607
2.602
2.575
2.570
2.563
2.163
2.147
2.141
2.131
2.115
1.028
6.377
6.372
5.793
5.789
5.496
5.480
6.2
6.0
5.8
5.6
ppm
4.758
4.744
4.738
4.732
4.689
4.683
4.677
4.669
4.663
4.222
4.203
4.198
4.192
4.178
4.173
4.167
4.155
4.148
3.920
3.914
3.909
3.904
3.898
3.893
4.8
4.6
4.4
4.2
4.0
ppm
3.519
3.515
3.509
3.504
3.499
3.492
3.384
3.5
3.4
ppm
2.607
2.602
2.595
2.582
2.575
2.570
2.563
2.168
2.163
2.157
2.152
2.147
2.141
2.137
2.131
2.126
2.121
2.6
2.5
2.4
2.3
2.2
ppm
O
O
OMe
Ph
OTBDPS
9
8
7
6
5
4
3
2
1
0
ppm
5.03
11.41
1.01
1.04
1.00
1.07
1.06
2.73
1.03
1.19
3.21
1.16
1.07
9.18

20b cis

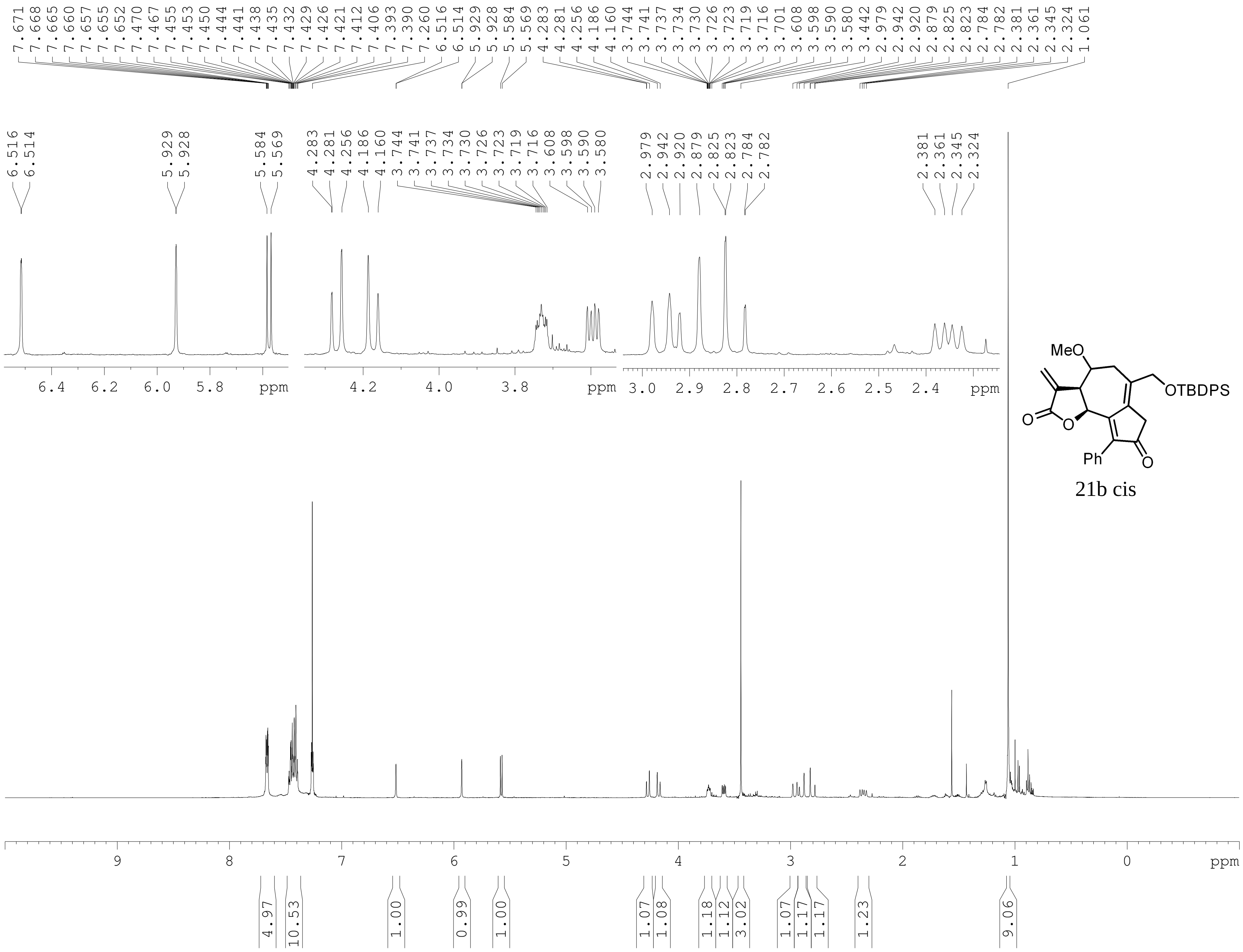

20b cis
205.89
169.19
135.61
135.53
131.91
129.64
129.59
129.11
128.32
127.60
124.97
121.52
100.66
89.81
82.25
79.84
77.47
77.25
77.00
76.75
69.31
64.86
57.11
44.18
30.32
26.77
19.24
O
O
OMe
Ph
OTBDPS
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm



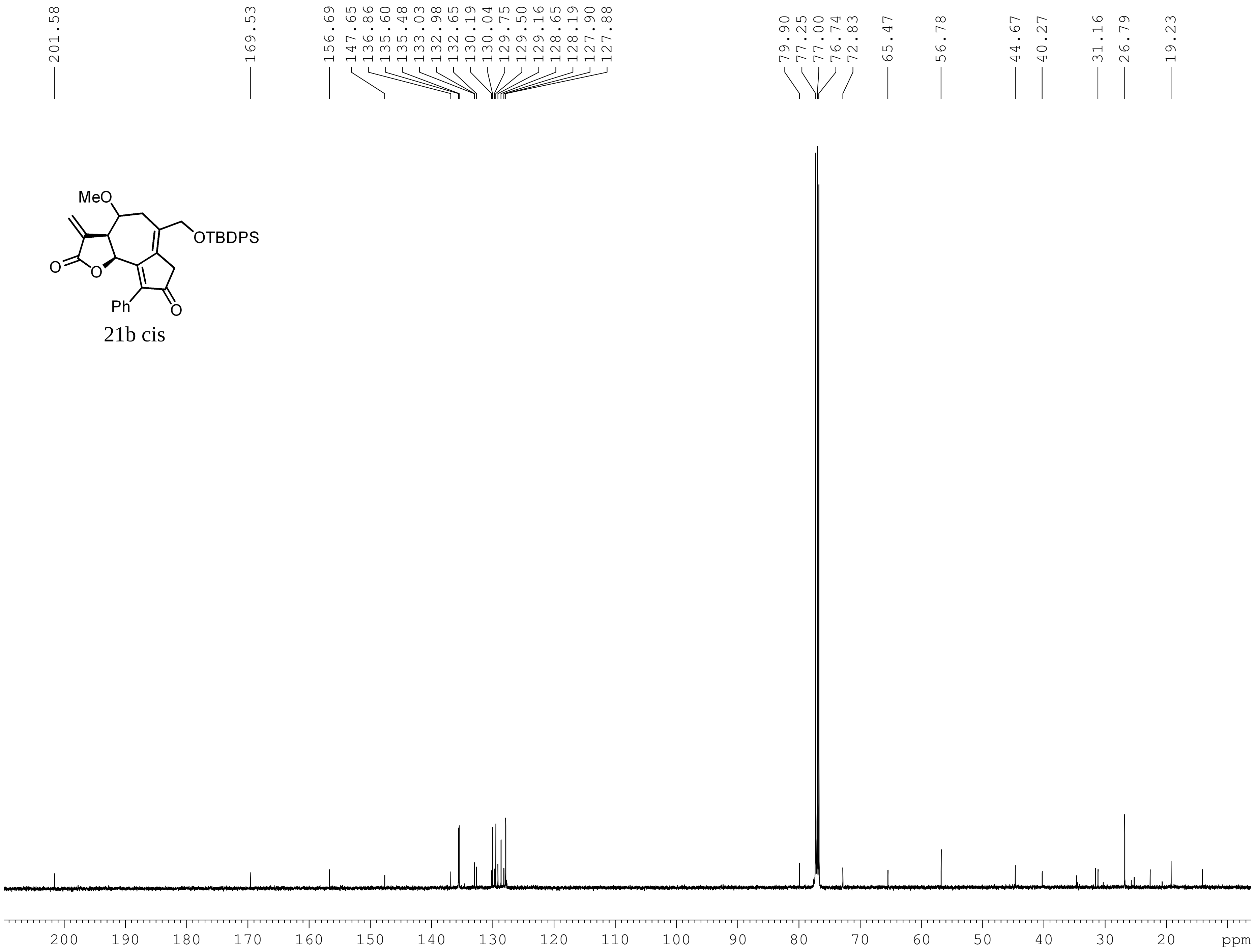
21a trans two diastereoisomers



21a trans two diastereoisomers

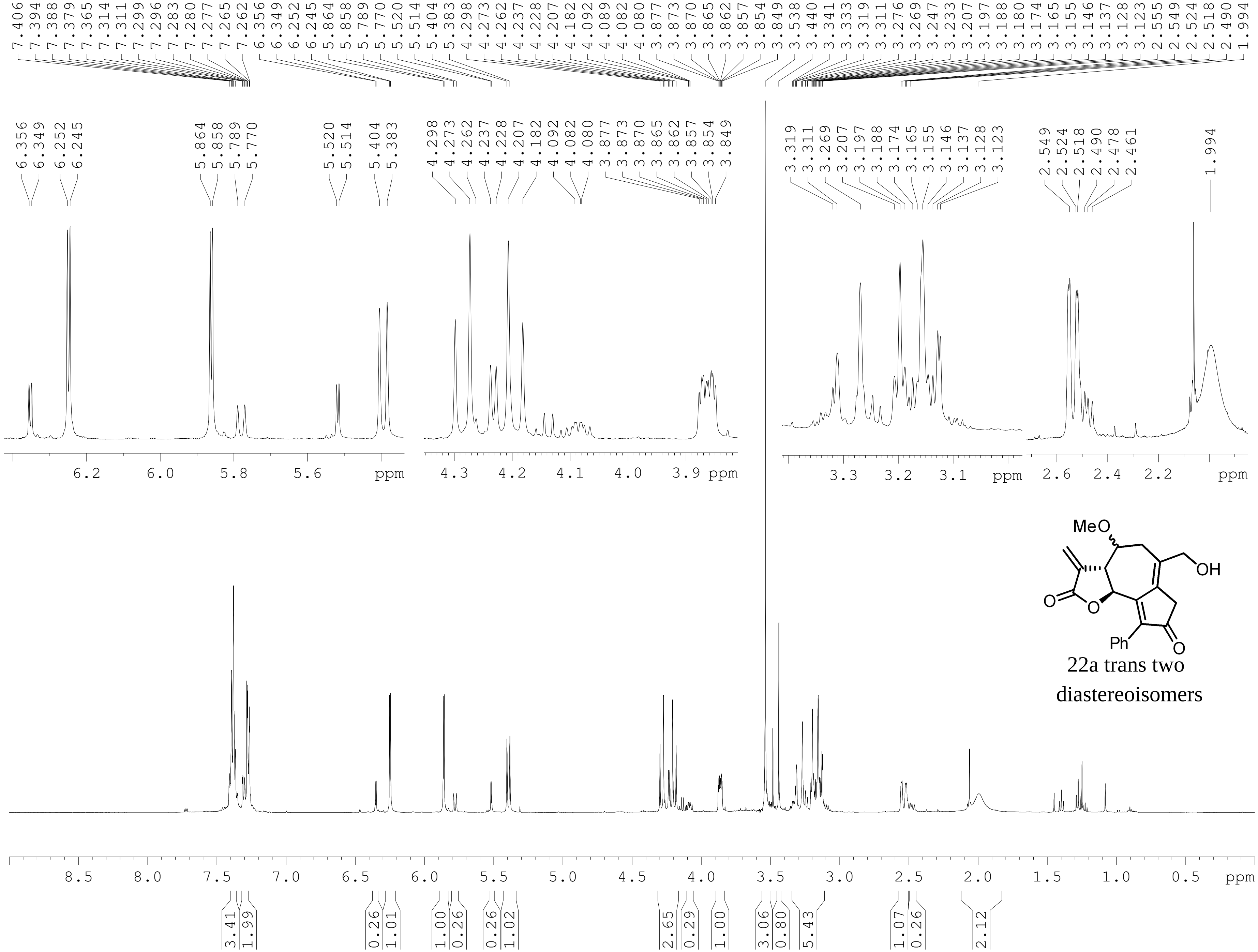

7.671
7.668
7.665
7.660
7.657
7.655
7.652
7.470
7.467
7.455
7.453
7.450
7.444
7.441
7.438
7.435
7.432
7.429
7.426
7.421
7.412
7.406
7.393
7.390
7.260
6.516
6.514
5.929
5.928
5.584
5.569
4.283
4.281
4.256
4.186
4.160
3.744
3.741
3.737
3.734
3.730
3.726
3.723
3.719
3.716
3.701
3.608
3.598
3.590
3.580
3.442
2.979
2.942
2.920
2.879
2.825
2.823
2.784
2.782
2.381
2.361
2.345
2.324
1.061
6.4
6.2
6.0
5.8
ppm
4.2
4.0
3.8
ppm
3.0
2.9
2.8
2.7
2.6
2.5
2.4
ppm
MeO
OTBDPS
O
O
Ph
O
9
8
7
6
5
4
3
2
1
0
ppm
4.97
10.53
1.00
0.99
1.00
1.07
1.08
1.18
1.12
3.02
1.07
1.17
1.17
1.23
9.06

21b cis

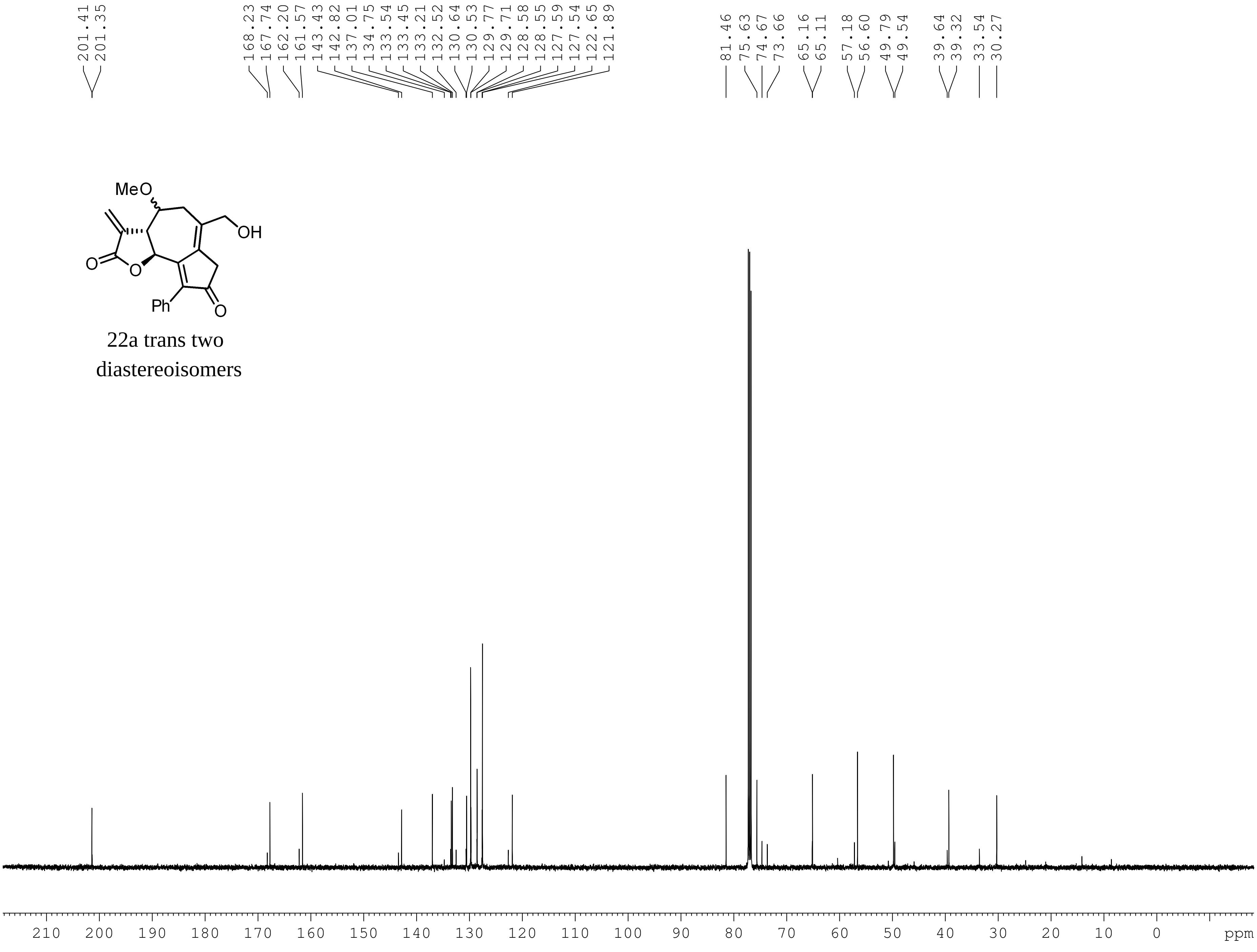


201.58
169.53
156.69
147.65
136.86
135.60
135.48
133.03
132.98
132.65
130.19
130.04
129.75
129.50
129.16
128.65
128.19
127.90
127.88
79.90
77.25
77.00
76.74
72.83
65.47
56.78
44.67
40.27
31.16
26.79
19.23
MeO
OTBDPS
O
O
Ph
O
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

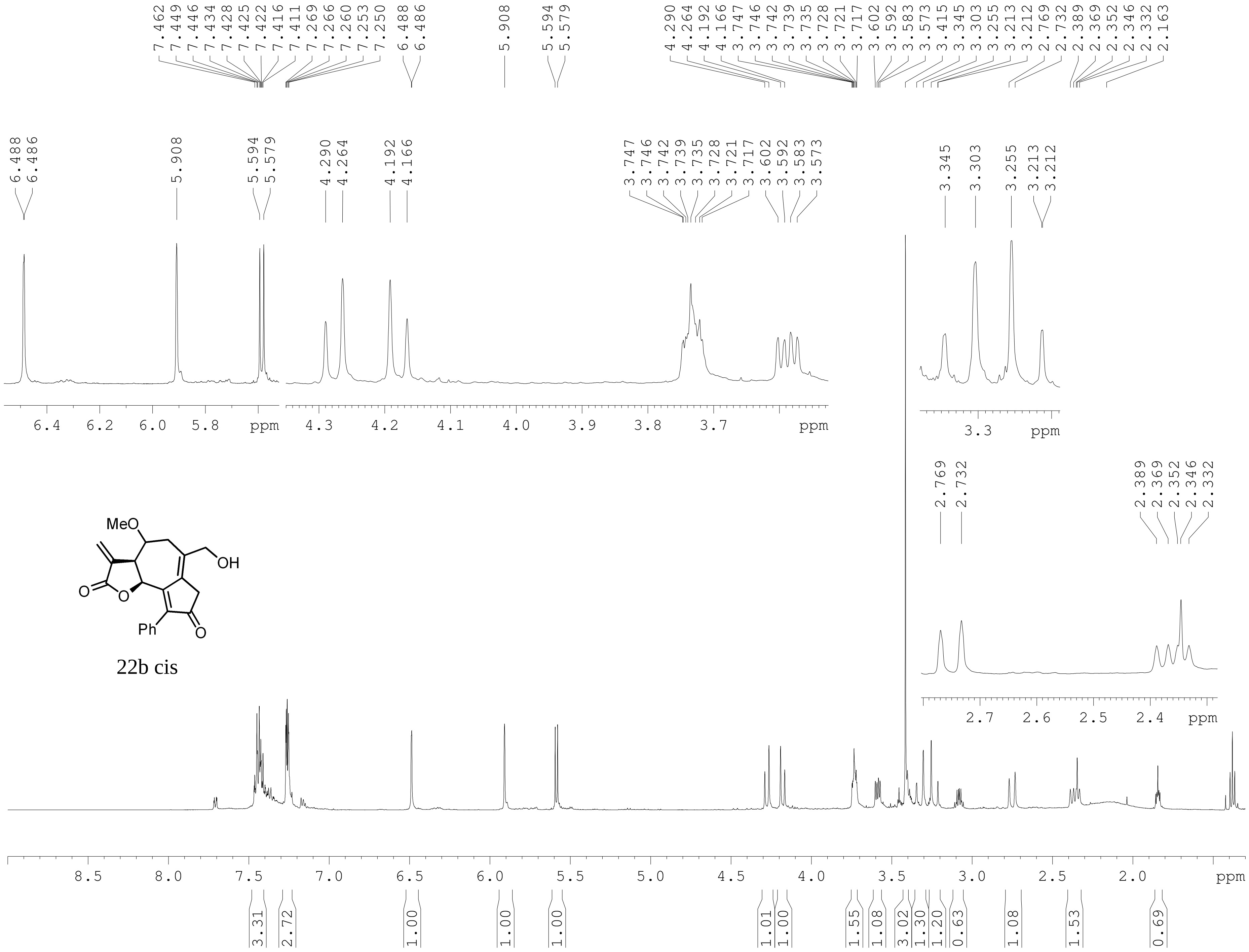
21b cis



22a trans two diastereoisomers



22a trans two diastereoisomers


7.462
7.449
7.446
7.434
7.428
7.425
7.422
7.416
7.411
7.269
7.266
7.260
7.253
7.250
6.488
6.486
5.908
5.594
5.579
4.290
4.264
4.192
4.166
3.747
3.746
3.742
3.739
3.735
3.728
3.721
3.717
3.602
3.592
3.583
3.573
3.415
3.345
3.303
3.255
3.213
3.212
2.769
2.732
2.389
2.369
2.352
2.346
2.332
2.163
MeO
OH
O
O
Ph
O
6.4
6.2
6.0
5.8
ppm
4.3
4.2
4.1
4.0
3.9
3.8
3.7
ppm
3.3
ppm
2.7
2.6
2.5
2.4
ppm
8.5
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7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
ppm
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2.72
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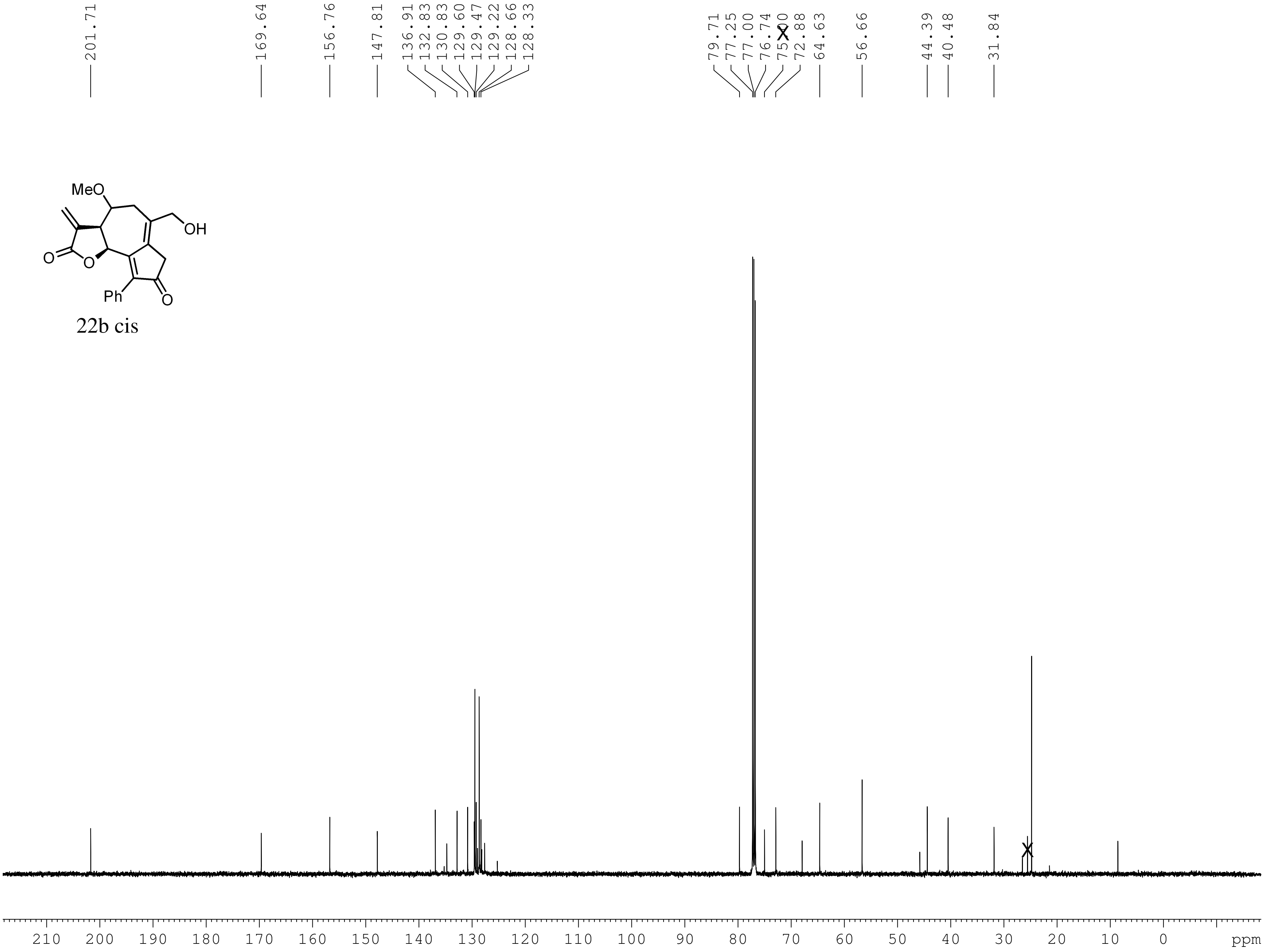
1.00
1.00
1.01
1.00
1.55
1.08
3.02
1.30
1.20
0.63
1.08
1.53
0.69

22b cis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77.25
77.00
76.74
75.00
72.88
64.63
56.66
44.39
40.48
31.84
MeO
OH
O
O
Ph
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

22b cis