Supporting Information for:

Development of the Intramolecular Prins Cyclization/Schmidt Reaction for the Synthesis of the Azaspiro[4,4]nonane: Application to the Formal Synthesis of (±)-Stemonamine

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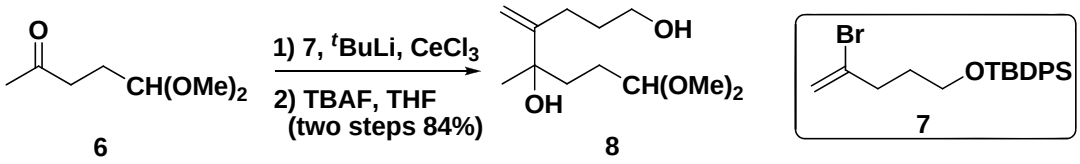
Supporting Information

Experimental Details

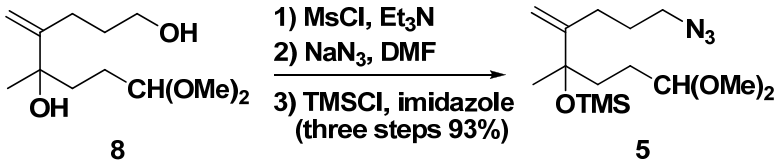
General information

For product purification by flash column chromatography, silica gel (200~300 mesh) and light petroleum ether (bp. 60~90 ^{o}C) and ethyl acetate are used. All solvents were purified and dried by standard techniques, and distilled prior to use. All organic extracts were dried over $MgSO_4$, unless otherwise noted. IR spectra were recorded on a fourier transform infrared spectrometer. ^{1}H and ^{13}C NMR spectra were taken on a *Bruker*, AM-400 spectrometer with TMS as an internal standard and $CDCl_3$ (or Acetone-d6) as solvent. The MS data were obtained with EI (70 eV). HRMS data were determined on a *Bruker Daltonics* APEXII 47e FT-ICR spectrometer. Melting point was measured on a melting point apparatus and was uncorrected. Starting material **7** is known compound.



Procedure 1): To a solution of 174.0 mg (0.43 mmol) of **7** in THF (2 mL) at -78 ^{o}C under argon was added tert-butyllithium (1.6 M, 540 μL, 0.86 mmol). After being stirred at -78 ^{o}C for 20 min, $CeCl_3$ (106.4 mg, 0.43 mmol) was added and the reaction mixture was stirred at -78 ^{o}C for another 20 min. Then, a solution of ketone **6** (63.0 mg. 0.43 mmol) in THF (2 mL) was added. The resulting mixture was stirred for 10 min and then quenched with water (1 mL). After being warmed up to room temperature, the reaction mixture was diluted with CH_2Cl_2 (5 mL) and water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to afford the crude product as a yellow oil.

Procedure 2): The above crude product was dissolved in THF (5 mL) at room temperature under argon, and then TBAF (225.0 mg, 0.86 mmol) was added. After being stirred at room temperature for 3.5 h, the reaction mixture was concentrated to give a yellow oil which was then purified via column chromatography (20% EtOAc/petroleum ether to 50% EtOAc/petroleum ether) to give compound **8** (84.2 mg, 84% yield, two steps) as a light yellow oil; ^{1}H NMR (400 MHz, Acetone-d6) δ 1.28 (s, 3H), 1.45-1.64 (m, 4H), 1.66-1.73 (m, 2H), 2.08-2.12 (t, J = 8.0 Hz, 2H), 3.22 (s, 6H), 3.53 (s, 1H), 3.57 (s, 2H), 4.29-4.31 (m, 1H), 4.81-4.82 (d, J = 1.6 Hz, 1H), 5.13 (s, 1H); ^{13}C NMR (100 MHz, Acetone-d6) δ 28.1, 28.2, 28.7, 28.8, 32.9, 36.4, 36.5, 52.8, 62.3, 62.4, 75.0, 75.2, 105.8, 108.0, 155.9.

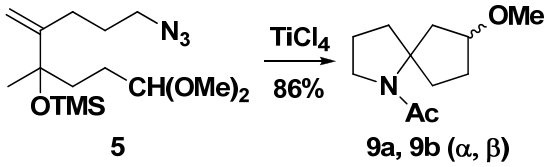


8 5

Procedure 1): A solution of **8** (80.0 mg, 0.34 mmol) in anhydrous CH_2Cl_2 (2 mL) under argon was treated with Et_3N (101 μL, 0.73 mmol) and methanesulfonyl chloride (32 μL, 0.41 mmol) at 0 °C. The reaction mixture was stirred for 2 min and then quenched with water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 3 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give the crude product as a yellow oil.

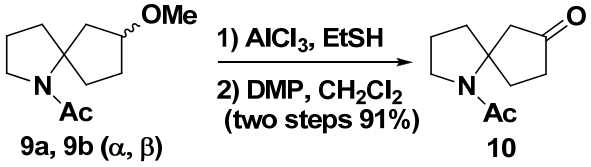
Procedure 2): The above crude product was dissolved DMF (2 mL) under argon, and then NaN_3 (71.0 mg, 1.09 mmol) was added. After being stirred at 40 °C for 4 h, the solution was allowed to cool on ice-water bath. Then, the reaction mixture was diluted with Et_2O (10 mL) and quenched with water (5 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phase was washed with water (2 x 5 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated to yield a yellow oil which was purified via column chromatography (10% EtOAc/ petroleum ether to 20% EtOAc/petroleum ether) to give the desired azide compound **5'** (83.1 mg, 94% yield, two steps) as a light yellow oil; ^{1}H NMR (400 MHz, Acetone-d6) δ 1.30 (s, 3H), 1.49-1.65 (m, 4H), 1.77-1.85 (dt, *J* = 7.2Hz, 7.2 Hz, 2H), 2.13-2.16 (m, 2H), 3.24 (s, 6H), 3.38-3.41 (t, *J* = 6.8 Hz, 2H), 3.55 (s, 1H), 4.31 (s, 1H), 4.85-4.86 (d, *J* = 1.2 Hz, 1H), 5.16 (s, 1H); ^{13}C NMR (100 MHz, Acetone-d6) δ 28.1, 28.7, 28.8, 29.0, 36.4, 36.5, 52.0, 52.8, 74.9, 75.0, 105.7, 108.6, 155.2.

Procedure 3): A solution of **5'** (83.1 mg, 0.32 mmol) in DMF (2 mL) under argon was treated with imidazole (440.0 mg, 6.47 mmol) and chlorotrimethylsilane (408 μL, 3.23 mmol) at room temperature. The reaction mixture was stirred for 10 h and then was diluted with Et_2O (5 mL) and water (1 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phase was washed with water (2 x 5 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated. The residue was purified via silica gel chromatography (2% EtOAc/petroleum ether to 4% EtOAc/petroleum ether) to give **5** (106.0 mg, 99% yield) as a light yellow oil; ^{1}H NMR (400 MHz, Acetone-d6) δ 0.13 (s, 9H), 1.41 (s, 3H), 1.44-1.69 (m, 4H), 1.72-1.87 (m, 2H), 2.10-2.19 (m, 2H), 3.23 (s, 3H), 3.24 (s, 3H), 3.38-3.41 (t, *J* = 6.8 Hz, 2H), 4.29-4.31 (t, *J* = 5.6 Hz, 1H), 4.86-4.87 (d, *J* = 1.2 Hz, 1H), 5.08 (s, 1H); ^{13}C NMR (100 MHz, Acetone-d6) δ 2.6, 28.3, 28.4, 28.8, 28.9, 37.5, 52.1, 52.8, 53.0, 79.3, 105.6, 109.3, 154.5; IR (neat) 840, 1251, 1640, 2096 cm^{-1}; MS (EI) *m/z* 329, 286, 254, 212, 198, 129, 75; HRMS (ESI) Calcd. for $C_{15}H_{31}N_3O_3SiNa$ $(M+Na)^+$: 352.2027, Found 352.2034.



5 **9a, 9b (α, β)**

To a solution of **5** (112.3 mg, 0.34 mmol) in CH_2Cl_2 (3 mL) at -78 ^oC under argon was added $TiCl_4$ (751 μL, 1M in CH_2Cl_2). The result mixture was stirred at -78 ºC for 15 minutes. After being warmed slowly to 10 ºC for additional times (about 3 h), it was quenched with water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give a yellow oil. Chromatography (60% EtOAc/petroleum ether to 80% EtOAc/petroleum ether) afforded **9a** (24.7 mg, 37% yield) and **9b** (33.2 mg, 49% yield) as light yellow oil, respectively; **9a**: ^1H NMR (400 MHz, $CDCl_3$) δ 1.49-1.68 (m, 3H), 1.79-1.99 (m, 4H), 2.01 (s, 3H), 2.17-2.26 (m, 1H), 2.31-2.39 (m, 1H), 2.62-2.67 (q, *J* = 6.8 Hz, 1H), 3.27 (s, 3H), 3.41-3.44 (t, *J* = 6.8 Hz, 2H), 4.05-4.10 (ddd, *J* = 4.2 Hz, 4.2 Hz, 4.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 23.4, 24.4, 31.8, 34.8, 42.0, 43.1, 49.2, 56.4, 69.5, 82.3, 168.5; IR (neat) 1101, 1411, 1645, 2930 cm^{-1}; MS (EI) *m/z* 197, 182, 165, 138, 126, 106, 83; HRMS (ESI) Calcd. for $C_{11}H_{19}NO_2Na$ $(M+Na)^+$: 220.1308, Found 220.1312. **9b**: ^1H NMR (400 MHz, $CDCl_3$) δ 1.34-1.41 (dt, *J* = 7.6 Hz, 12.8 Hz, 1H), 1.65-1.70 (q, *J* = 6.4 Hz, 1H), 1.74-1.82 (m, 4H), 1.84-2.00 (m, 2H), 2.01 (s, 3H), 2.58-2.70 (m, 2H), 3.28 (s, 3H), 3.37-3.46 (m, 2H), 3.67-3.74 (ddd, *J* = 15.6 Hz, 7.2 Hz, 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 23.1, 24.6, 30.1, 33.2, 40.8, 42.2, 49.2, 56.5, 68.5, 80.9, 168.5; IR (neat) 1101, 1411, 1645, 2930 cm^{-1}; MS (EI) *m/z* 197, 182, 165, 149, 124, 112, 96; HRMS (ESI) Calcd. for $C_{11}H_{19}NO_2Na$ $(M+Na)^+$: 220.1308, Found 220.1310.

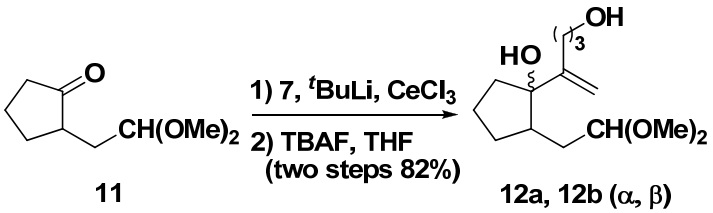


9a, 9b (α, β) **10**

Procedure 1): To a solution of the mixture of **9a** and **9b** (21.6 mg, 0.11 mmol) in EtSH (3 mL) at room temperature under argon was added $AlCl_3$ (73.1 mg, 0.55 mmol). The reaction mixture was stirred for 3 h and then was diluted with $CHCl_3$ (5 mL) and water (1 mL). The aqueous phase was extracted with $CHCl_3$ (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give the crude product as a yellow oil.

Procedure 2): To a CH_2Cl_2 (3 mL) solution of the above crude product under argon at 0 ^oC was added Dess-Martin periodinane (140.0 mg, 0.33 mmol) followed by slow warming of the reaction mixture to room temperature. After being stirred for 3 h, the reaction was quenched via addition of

saturated aqueous $NaHCO_3$ (3 mL) and $Na_2S_2O_3$ (3 mL), and diluted with CH_2Cl_2 (5 mL). The biphasic mixture was vigorously stirred at room temperature for 30 min and then the aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL). The combined organic extracts were dried over $MgSO_4$, filtered and concentrated to yield a yellow oil. Chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) afforded **10** (18.1 mg, 91% yield, two steps) as light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.83-2.00 (m, 5H), 2.04 (s, 3H), 2.08-2.12 (d, *J* = 18 Hz, 1H), 2.18-2.27 (ddd, *J* = 9.2 Hz, 9.2 Hz, 9.2 Hz, 1H), 2.57-2.66 (m, 1H), 2.73-2.81 (m, 1H), 3.29-3.35 (m, 1H), 3.47-3.58 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 23.0, 24.1, 33.2, 37.9, 40.9, 48.4, 49.3, 67.2, 169.4, 216.4; IR (neat) 1160, 1635, 1739, 2925 cm^{-1}; MS (EI) *m/z* 181, 153, 138, 122, 110, 96, 83; HRMS (ESI) Calcd. for $C_{10}H_{15}NO_2Na$ $(M+Na)^+$: 204.0995, Found 204.0990.

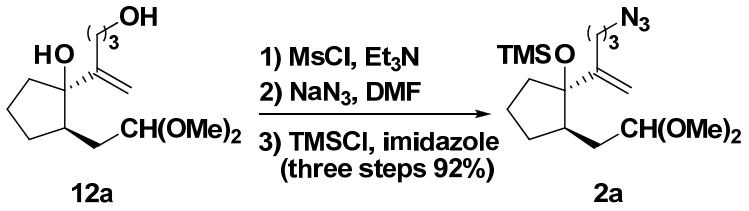


11 12a, 12b (α, β)

Procedure 1): To a solution of 489.0 mg (1.22 mmol) of **7** in THF (3 mL) at -78 °C under argon was added tert-butyllithium (1.6 M, 1.52 mL, 2.43 mmol). After being stirred at -78 °C for 20 min, $CeCl_3$ (300.0 mg, 1.22 mmol) was added and the reaction mixture was stirred at -78 °C for another 20 min. Then, a solution of ketone **11** (209.0 mg. 1.22 mmol) in THF (2 mL) was added. The resulting mixture was stirred for 10 min and then quenched with water (1 mL). After being warmed up to room temperature, the reaction mixture was diluted with CH_2Cl_2 (5 mL) and water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to afford the crude product as a yellow oil.

Procedure 2): The above crude product was dissolved in THF (5 mL) at room temperature under argon, and then TBAF (635.0 mg, 2.43 mmol) was added. After being stirred at room temperature for 2.5 h, the reaction mixture was concentrated to give a yellow oil which was then purified via column chromatography (20% EtOAc/petroleum ether to 35% EtOAc/petroleum ether) to give compound **12a** (216.0 mg) and **12b** (40.4 mg, 82% combined yield, two steps) as light yellow oil, respectively; **12a:** ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.47-1.68 (m, 4H), 1.70-1.97 (m, 8H), 2.02-2.14 (m, 3H), 3.28 (s, 3H), 3.29 (s, 3H), 3.66-3.69 (t, *J* = 6.0 Hz, 2H), 4.37-4.40 (dd, *J* = 4.0 Hz, 7.2 Hz, 1H), 4.94 (s, 1H), 5.21 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.9, 27.3, 30.1, 31.7, 31.8, 39.9, 42.4, 52.4, 53.1, 62.1, 85.0, 104.0, 108.7, 152.3; **12b:** ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.06-1.13 (dt, *J* = 14.4 Hz, 3.6 Hz, 1H), 1.49-1.56 (m, 2H), 1.62-1.68 (m, 1H), 1.72-1.86 (m, 4H), 1.99-2.19 (m, 6H), 2.28-2.36 (ddd, *J* = 16 Hz, 8 Hz, 8 Hz, 1H), 3.29 (s, 3H), 3.31 (s, 3H), 3.66-3.70 (dt, *J* = 8 Hz, 2 Hz, 2H), 4.34-4.36 (dd, *J* = 8

Hz, 3.6 Hz, 1H), 4.94 (s, 1H), 5.05 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.6, 27.4, 28.8, 31.5, 34.8, 35.8, 44.1, 52.9, 53.1, 62.0, 87.3, 104.0, 110.8, 150.8.



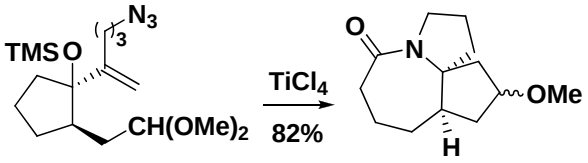
12a 2a

Procedure 1): A solution of **12a** (220.2 mg, 0.85 mmol) in anhydrous CH_2Cl_2 (5 mL) under argon was treated with Et_3N (238 μL, 1.71 mmol) and methanesulfonyl chloride (80 μL, 1.03 mmol) at 0 °C. The reaction mixture was stirred for 2 min and then quenched with water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (5 x 3 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give the crude product as a yellow oil.

Procedure 2): The above crude product was dissolved DMF (3 mL) under argon, and then NaN_3 (166.4 mg, 2.56 mmol) was added. After being stirred at 40 °C for 3.5 h, the solution was allowed to cool on ice-water bath. Then, the reaction mixture was diluted with Et_2O (10 mL) and quenched with water (5 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phase was washed with water (2 x 5 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated to yield a yellow oil which was purified via column chromatography (10% EtOAc/ petroleum ether to 20% EtOAc/petroleum ether) to give the desired azide compound **12a'** (221.3 mg, 92% yield, two steps) as a light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.45-1.53 (m, 2H), 1.55-1.62 (m, 2H), 1.64-1.73 (m, 1H), 1.74-1.93 (m, 6H), 1.95-2.05 (m, 1H), 2.06-2.10 (dd, J = 8.8 Hz, 6.8 Hz, 2H), 3.26 (s, 3H), 3.28 (s, 3H), 3.29-3.33 (t, J = 6.8 Hz, 2H), 4.35-4.38 (dd, J = 7.2 Hz, 4.0 Hz, 1H), 4.90 (s, 1H), 5.20 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 21.9, 28.1, 28.6, 30.1, 31.7, 40.0, 42.6, 51.2, 52.5, 52.8, 84.7, 103.8, 109.0, 151.8.

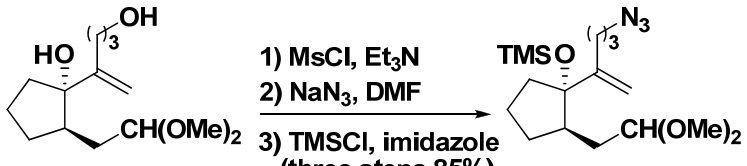
Procedure 3): A solution of **12a'** (190.0 mg, 0.67 mmol) in DMF (4 mL) under argon was treated with imidazole (915.0 mg, 13.4 mmol) and chlorotrimethylsilane (848 μL, 6.71 mmol) at room temperature. The reaction mixture was stirred for 10 h and then was diluted with Et_2O (10 mL) and water (5 mL). The aqueous phase was extracted with Et_2O (3 x 10 mL), and the combined organic phase was washed with water (2 x 5 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated. The residue was purified via silica gel chromatography (2% EtOAc/petroleum ether to 9% EtOAc/petroleum ether) to give **2a** (236.0 mg, 99% yield) as a light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.09 (s, 9H), 1.36-1.49 (m, 2H), 1.61-1.69 (m, 2H), 1.70-1.79 (m, 4H), 1.80-1.89 (m, 2H), 1.95-2.03 (m, 3H), 3.23 (s, 3H), 3.29-3.33 (m, 5H), 4.35-4.38 (dd, J = 7.6 Hz, 4.4 Hz, 1H), 4.90-4.91 (d, J = 1.2 Hz, 1H), 5.17 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 2.0, 22.0, 28.5, 28.7, 29.7,

31.1, 36.7, 44.4, 51.3, 51.7, 53.1, 88.0, 104.1, 110.6, 150.7; IR (neat) 840, 1063, 2096, 2927 cm^{-1}; MS (EI) *m/z* 355, 312, 252, 237, 208, 155, 109; HRMS (ESI) Calcd. for $C_{17}H_{33}N_3O_3SiNa$ $(M+Na)^+$: 378.2183, Found 378.2179.



2a **4 (dr = 1 : 0.84)**

To a solution of **2a** (242.1 mg, 0.68 mmol) in CH_2Cl_2 (7 mL) at -78 ^oC under argon was added $TiCl_4$ (1.50 mL, 1M in CH_2Cl_2). The result mixture was stirred at -78 ºC for 15 minutes. After being warmed slowly to 10 ºC for additional times (about 3 h), it was quenched with water (2 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give a yellow oil. Chromatography (50% EtOAc/petroleum ether to 80% EtOAc/petroleum ether) afforded **4** (a mixture of epimers in the ratio of 1:0.84, 125.2 mg, 82% yield) as light yellow oil; **4**: ^1H NMR (400 MHz, $CDCl_3$) δ 1.51-1.80 (m, 15H), 1.81-1.94 (m, 4H), 1.98-2.11 (m, 4H), 2.13-2.17 (m, 2H), 2.26-2.37 (m, 4H), 2.57-2.65 (dt, *J* = 13.2 Hz, 7.2 Hz, 1H), 3.22 (s, 3H), 3.29-3.36 (m, 5H), 3.60-3.68 (m, 3H), 3.85-3.87 (t, *J* = 4.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 17.9, 21.4, 21.5, 22.6, 23.2, 33.0, 33.7, 33.8, 41.3, 41.4, 43.0, 43.6, 45.0, 45.3, 47.7, 47.8, 55.8, 57.2, 68.1, 70.5, 78.5, 80.3, 171.1, 171.3; IR (neat) 1458, 1636, 2360, 2923 cm^{-1}; MS (EI) *m/z* 223, 208, 192, 151, 136, 123, 96; HRMS (ESI) Calcd. for $C_{13}H_{22}NO_2$ $(M+H)^+$: 224.1645, Found 224.1651.



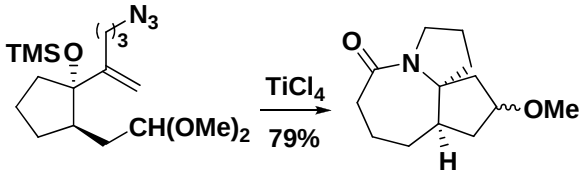
12b **2b**

Procedure 1): A solution of **12b** (81.3 mg, 0.32 mmol) in anhydrous CH_2Cl_2 (3 mL) under argon was treated with Et_3N (88 μL, 0.63 mmol) and methanesulfonyl chloride (29 μL, 0.38 mmol) at 0 ^oC. The reaction mixture was stirred for 2 min and then quenched with water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (5 x 3 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give the crude product as a yellow oil.

Procedure 2): The above crude product was dissolved DMF (2 mL) under argon, and then NaN_3

(62.0 mg, 0.95 mmol) was added. After being stirred at 40 °C for 3.5 h, the solution was allowed to cool on ice-water bath. Then, the reaction mixture was diluted with Et_2O (5 mL) and quenched with water (3 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phase was washed with water (2 x 3 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated to yield a yellow oil which was purified via column chromatography (10% EtOAc/ petroleum ether to 15% EtOAc/petroleum ether) to give the desired azide compound **12b'** (78.5 mg, 88% yield, two steps) as a light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.05-1.12 (m, 1H), 1.46-1.55 (m, 2H), 1.60-1.89 (m, 6H), 1.97-2.14 (m, 4H), 2.26-2.34 (m, 1H), 3.28-3.33 (m, 8H), 4.32-4.35 (dd, *J* = 8.0 Hz, 4.4 Hz, 1H), 4.90 (s, 1H), 5.03 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.6, 27.8, 28.9, 34.7, 36.0, 44.1, 51.3, 53.0, 53.1, 86.8, 103.9, 110.6, 150.5.

Procedure 3): A solution of **12b'** (61.0 mg, 0.22 mmol) in DMF (2 mL) under argon was treated with imidazole (294.0 mg, 4.32 mmol) and chlorotrimethylsilane (273 μL, 2.16 mmol) at room temperature. The reaction mixture was stirred for 1.5 h and then was diluted with Et_2O (5 mL) and water (3 mL). The aqueous phase was extracted with Et_2O (3 x 5 mL), and the combined organic phase was washed with water (2 x 3 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated. The residue was purified via silica gel chromatography (2% EtOAc/petroleum ether to 9% EtOAc/petroleum ether) to give **2b** (73.9 mg, 97% yield) as a light yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.07 (s, 9H), 0.94-1.01 (m, 1H), 1.36-1.42 (m, 1H), 1.45-1.51 (m, 1H), 1.66-1.84 (m, 5H), 1.91-2.09 (m, 4H), 2.27-2.35 (m, 1H), 3.29-3.35 (m, 8H), 4.30-4.33 (q, *J* = 3.6 Hz, 1H), 4.87 (s, 1H), 4.98 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 1.8, 20.3, 27.0, 27.8, 28.4, 33.8, 34.1, 45.4, 51.6, 53.0, 53.1, 89.6, 104.2, 110.1, 150.6; IR (neat) 839, 1063, 1251, 2096 cm^{-1}; MS (EI) *m/z* 355, 312, 296, 238, 210, 196, 155; HRMS (ESI) Calcd. for $C_{17}H_{33}N_3O_3SiNa$ $(M+Na)^+$: 378.2183, Found 378.2178.



2b **4 (dr = 1 : 0.53)**

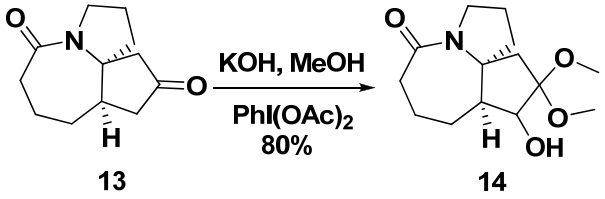
To a solution of **2b** (27.5 mg, 0.08 mmol) in CH_2Cl_2 (2 mL) at -78 °C under argon was added $TiCl_4$ (171 μL, 1M in CH_2Cl_2). The result mixture was stirred at -78 ºC for 15 minutes. After being warmed slowly to 10 ºC for additional times (about 3 h), it was quenched with water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give a yellow oil. Chromatography (50% EtOAc/petroleum ether to 80% EtOAc/petroleum ether) afforded **4** (a mixture of epimers in the ratio of 1:0.53, 13.7 mg, 79% yield) as light yellow oil; **4**: ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.53-1.84 (m, 25H), 1.88-1.96 (m,

6H), 2.01-2.09 (m, 3H), 2.10-2.16 (m, 2H), 2.17-2.20 (m, 2H), 2.30-2.40 (m, 7H), 2.60-2.68 (dt, J = 13.2 Hz, 7.2 Hz, 1H), 3.25 (s, 6H), 3.31-3.39 (m, 6H), 3.62-3.71 (m, 4H), 3.87-3.89 (t, J = 4.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.7, 17.9, 21.5, 21.6, 22.5, 23.1, 32.9, 33.0, 33.7, 33.8, 41.2, 41.3, 43.0, 43.6, 45.1, 45.3, 47.8, 47.9, 55.9, 57.3, 68.1, 70.6, 78.5, 80.3, 171.2, 171.4; IR (neat) 1458, 1636, 2360, 2923 cm^{-1}; MS (EI) *m/z* 223, 208, 192, 151, 136, 123, 96; HRMS (ESI) Calcd. for $C_{13}H_{22}NO_2$ $(M+H)^+$: 224.1645, Found 224.1651.

4 13

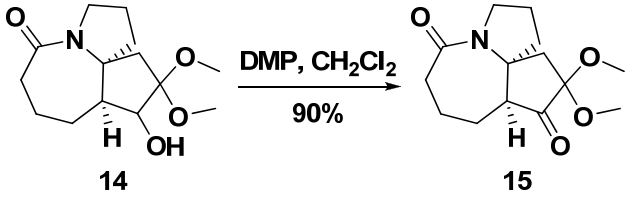
Procedure 1): To a solution of the mixture of epimers **4** (100.2 mg, 0.45 mmol) in EtSH (5 mL) at room temperature under argon was added $AlCl_3$ (300.0 mg, 2.25 mmol). The reaction mixture was stirred for 1.5 h and then was diluted with CH_2Cl_2 (10 mL) and water (3 mL). The aqueous phase was extracted with CH_2Cl (3 x 10 mL), then the combined organic extracts were dried over $MgSO_4$, filtered and concentrated to give the crude product as a yellow oil.

Procedure 2): To a CH_2Cl_2 (7 mL) solution of the above crude product under argon at 0 ^{o}C was added Dess-Martin periodinane (572.0 mg, 1.35 mmol) followed by slow warming of the reaction mixture to room temperature. After being stirred for 2.5 h, the reaction was quenched via addition of saturated aqueous $NaHCO_3$ (5 mL) and $Na_2S_2O_3$ (5 mL), and diluted with CH_2Cl_2 (10 mL). The biphasic mixture was vigorously stirred at room temperature for 30 min and then the aqueous phase was extracted with CH_2Cl_2 (3 x 10 mL). The combined organic extracts were dried over $MgSO_4$, filtered and concentrated to yield a yellow oil. Chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) afforded **13** (81.0 mg, 87% yield, two steps) as a white crystalline solid: mp 157-159 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.49-1.59 (m, 1H), 1.65-1.83 (m, 3H), 1.86-2.06 (m, 4H), 2.19-2.32 (m, 3H), 2.41-2.46 (m, 1H), 2.52-2.69 (m, 3H), 3.44-3.52 (dt, J = 11.6 Hz, 7.2 Hz, 1H), 3.78-3.84 (t, J = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.1, 20.5, 31.3, 36.5, 43.6, 44.7, 45.6, 47.4, 49.1, 67.1, 172.4, 214.3; IR (neat) 1456, 1625, 1743, 2925 cm^{-1}; MS (EI) *m/z* 207, 164, 150, 136, 127, 110, 83; HRMS (ESI) Calcd. for $C_{12}H_{18}NO_2$ $(M+H)^+$: 208.1332, Found 208.1326.



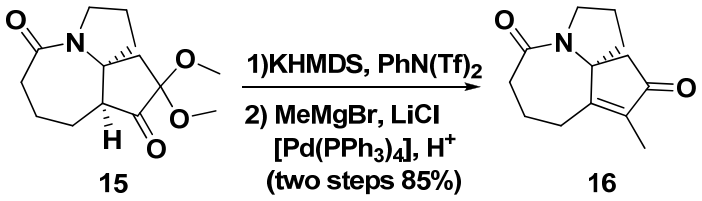
13 14

A solution of **13** (25.0 mg, 0.12 mmol) in anhydrous MeOH (2 mL) under argon was treated with $PhI(OAc)_2$ (47.0 mg, 0.15 mmol) and KOH (24.3 mg, 0.43 mmol) at 0 ^oC. The reaction mixture was stirred for 2 h and then concentrated. The residue was purified via silica gel chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) to give **14** (26.0 mg, 80% yield) as a light yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ 1.49-1.60 (m, 2H), 1.66-1.73 (m, 2H), 1.81-1.98 (m, 4H), 2.10-2.15 (ddd, *J* = 10.4 Hz, 5.2 Hz, 5.2 Hz, 1H), 2.22-2.25 (d, *J* = 13.2 Hz, 1H), 2.34-2.36 (m, 1H), 2.46-2.53 (m, 1H), 2.60-2.65 (m, 1H), 2.76 (brs, 1H), 3.24 (s, 3H), 3.32 (s, 3H), 3.33-3.39 (m, 1H), 3.73-3.77 (m, 1H), 4.16-4.17 (d, *J* = 6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 20.4, 21.1, 25.7, 38.1, 42.3, 42.5, 48.6, 49.3, 49.4, 50.4, 65.9, 76.1, 104.8, 173.6; IR (neat) 1129, 1457, 1616, 2360 cm^{-1}; MS (EI) *m/z* 269, 238, 191, 152, 122, 110, 89; HRMS (ESI) Calcd. for $C_{14}H_{24}NO_4$ $(M+H)^+$: 270.1700, Found 270.1700.



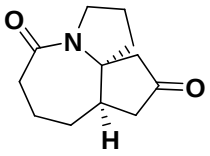
14 15

To a CH_2Cl_2 (2 mL) solution of alcohol **14** (18.5 mg, 0.07 mmol) under argon at 0 ^oC was added $NaHCO_3$ (57.8 mg, 0.69 mmol) and Dess-Martin periodinane (87.5 mg, 0.21 mmol) followed by slow warming of the reaction mixture to room temperature. After being stirred for 5.5 h, the reaction was quenched via addition of saturated aqueous $NaHCO_3$ (2 mL) and $Na_2S_2O_3$ (2 mL), and diluted with CH_2Cl_2 (5 mL). The biphasic mixture was vigorously stirred at room temperature for 30 min and then the aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL). The combined organic extracts were dried over $MgSO_4$, filtered and concentrated to yield a yellow oil. Chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) afforded ketone **15** (16.5 mg, 90% yield) as a light yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ 1.55-1.64 (m, 1H), 1.66-1.76 (m, 1H), 1.80-1.96 (m, 5H), 2.18-2.32 (m, 3H), 2.35-2.41 (m, 2H), 2.77-2.79 (dd, *J* = 5.2 Hz, 3.2 Hz, 1H), 3.19 (s, 3H), 3.34-3.3.42 (m, 4H), 3.74-3.79 (dd, *J* = 11.6 Hz, 8.4 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 17.2, 19.9, 21.0, 33.4, 44.6, 46.0, 47.4, 49.1, 50.5, 50.7, 62.6, 101.9, 170.7, 207.6; IR (neat) 1457, 1616, 2925 cm^{-1}; MS (EI) *m/z* 267, 239, 211, 169, 127, 99, 71; HRMS (ESI) Calcd. for $C_{14}H_{22}NO_4$ $(M+H)^+$: 268.1543, Found 268.1547.



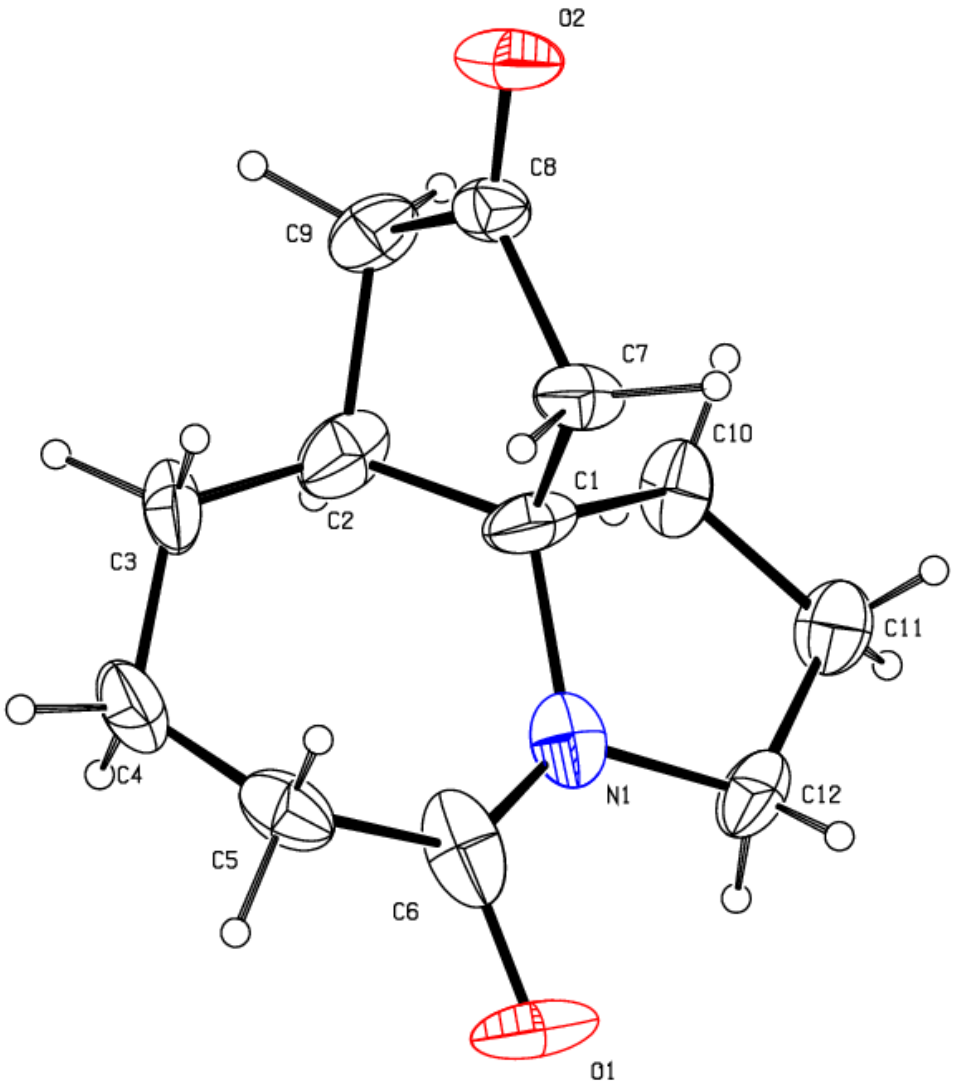
Procedure 1): To a solution of the ketone **15** (12.0 mg, 0.04 mmol) in THF (3 mL) at -78 ^{o}C under argon was added KHMDS (0.91 M, 99 μL, 0.09 mmol). After being stirred at -78 ^{o}C for 1 h, $PhN(Tf)_2$ (40.1 mg, 0.15 mmol) was added. The resulting mixture was stirred for 30 min and then quenched with water (1 mL). After being warmed up to room temperature, the reaction mixture was diluted with CH_2Cl_2 (5 mL) and water (1 mL). The aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL), then the combined organic extracts were dried over Na_2SO_4, filtered and concentrated. Flash column Chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) afforded crude product as a yellow oil.

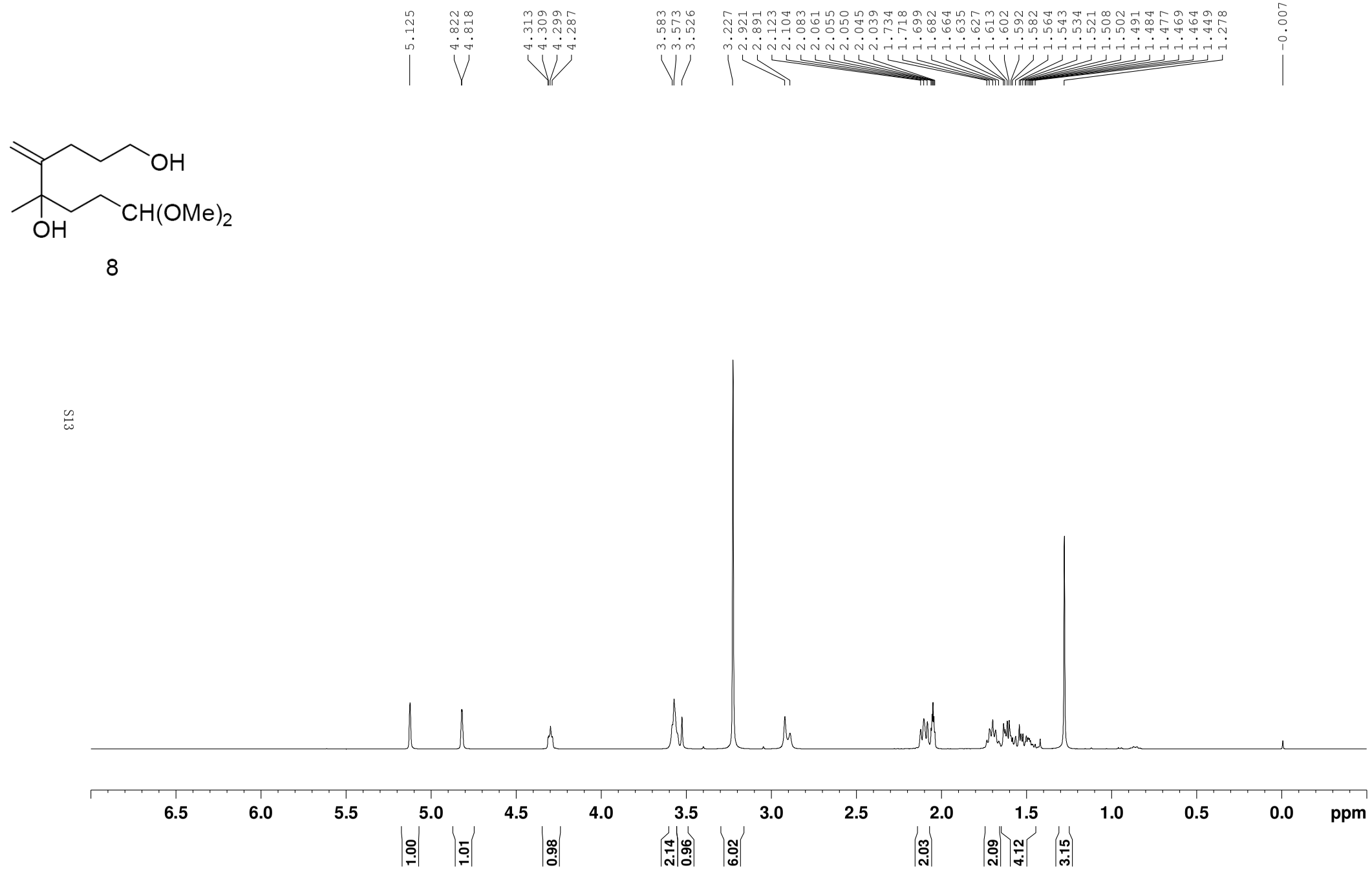
Procedure 2): The above crude product was dissolved in THF (3 mL) under argon, followed by addition of LiCl (9.6 mg, 0.23 mmol) and $Pd(PPh_3)_4$ (5.3 mg, 0.005mmol). After being stirred at room temperature for 30 min, CH_3MgBr (1M, 225 μL, 0.23 mmol) was added. The reaction mixture was stirred for 30 min and then quenched with water (1 mL). The resulting mixture was diluted with CH_2Cl_2 (5 mL) and treated with 1N HCl to PH = 2. The biphasic mixture was vigorously stirred at room temperature for 30 min and then the aqueous phase was extracted with CH_2Cl_2 (3 x 5 mL). The combined organic extracts were dried over $MgSO_4$, filtered and concentrated to yield a yellow oil. Chromatography (50% EtOAc/petroleum ether to 70% EtOAc/petroleum ether) afforded enone **16** (8.4 mg, 85% yield, two steps) as a white amorphous solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.55-1.59 (m, 1H), 1.78 (s, 3H), 1.87-1.95 (m, 2H), 1.96- 2.08 (m, 2H), 2.14-2.23 (m, 1H), 2.26-2.37 (m, 3H), 2.56-2.66 (m, 2H), 2.80-2.85 (dd, *J* = 12.8 Hz, 8.8 Hz, 1H), 3.56-3.71 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 8.0, 21.5, 22.3, 23.7, 32.8, 40.6, 47.0, 49.7, 69.7, 136.3, 171.0, 171.2, 203.5; IR (neat) 1629, 1700 cm^{-1}; MS (EI) *m/z* 219, 204, 191, 176, 163, 148, 135; HRMS (ESI) Calcd. for $C_{13}H_{18}NO_2$ $(M+H)^+$: 220.1332, Found 220.1332.



13

The structure of our synthetic tricyclic compound **13** was corroborated by single-crystal. The crystal structure has been deposited at the Cambridge Crystallographic Data Centre and allocated the deposition number: 801019.

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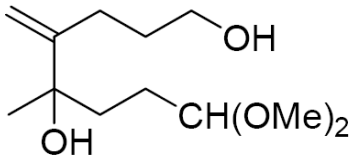

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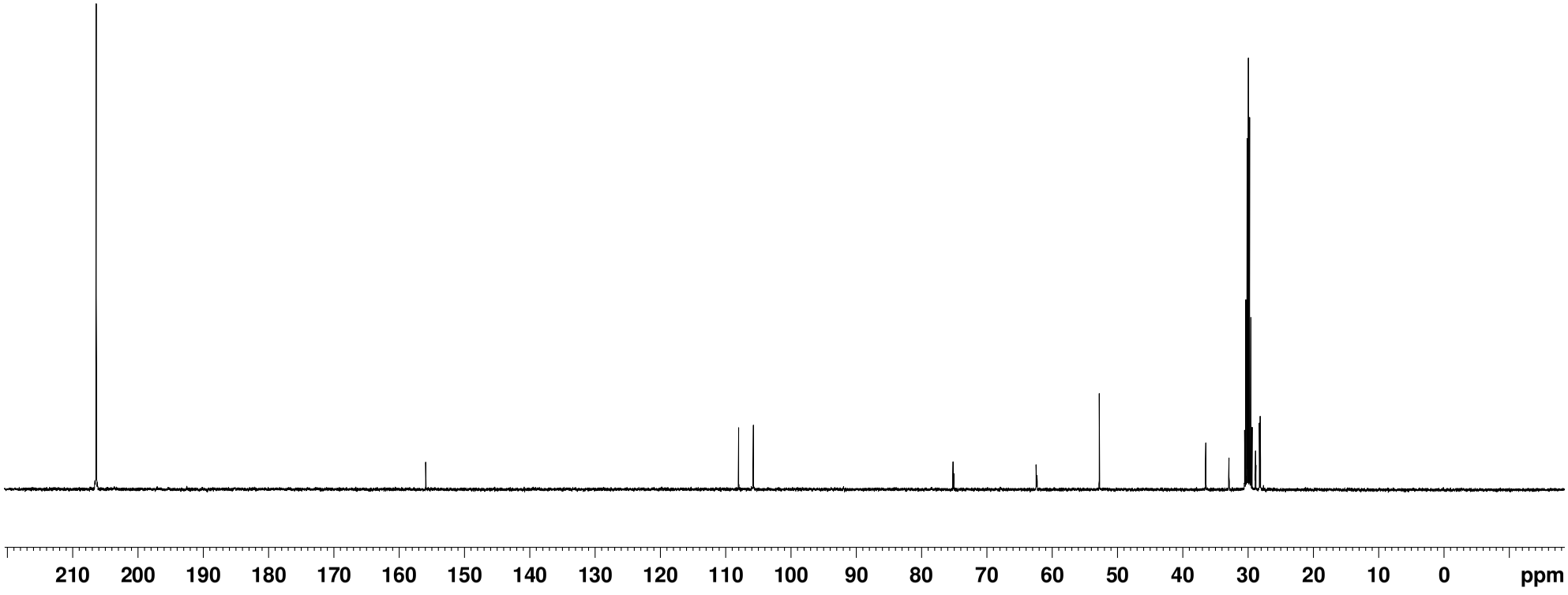

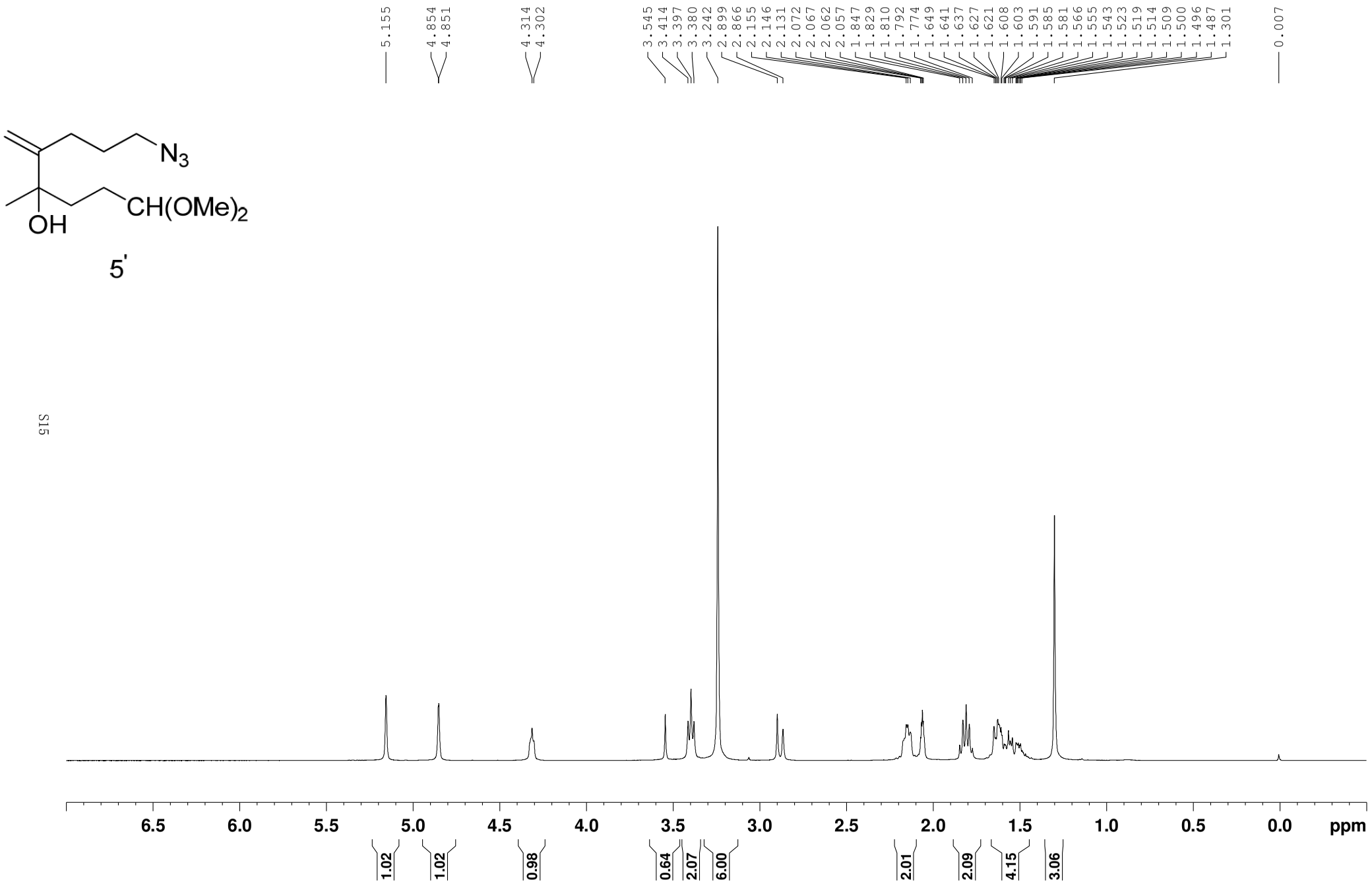
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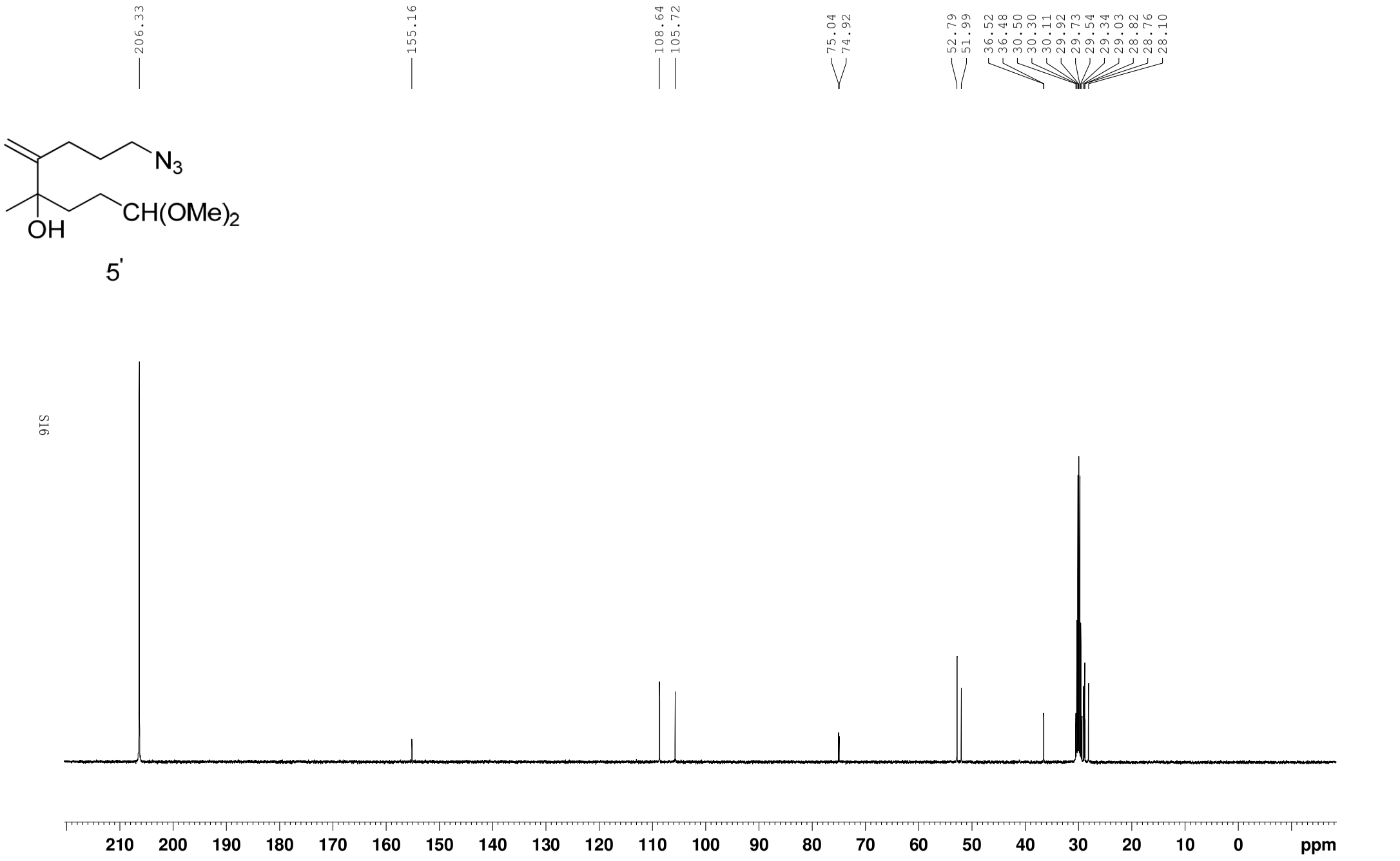
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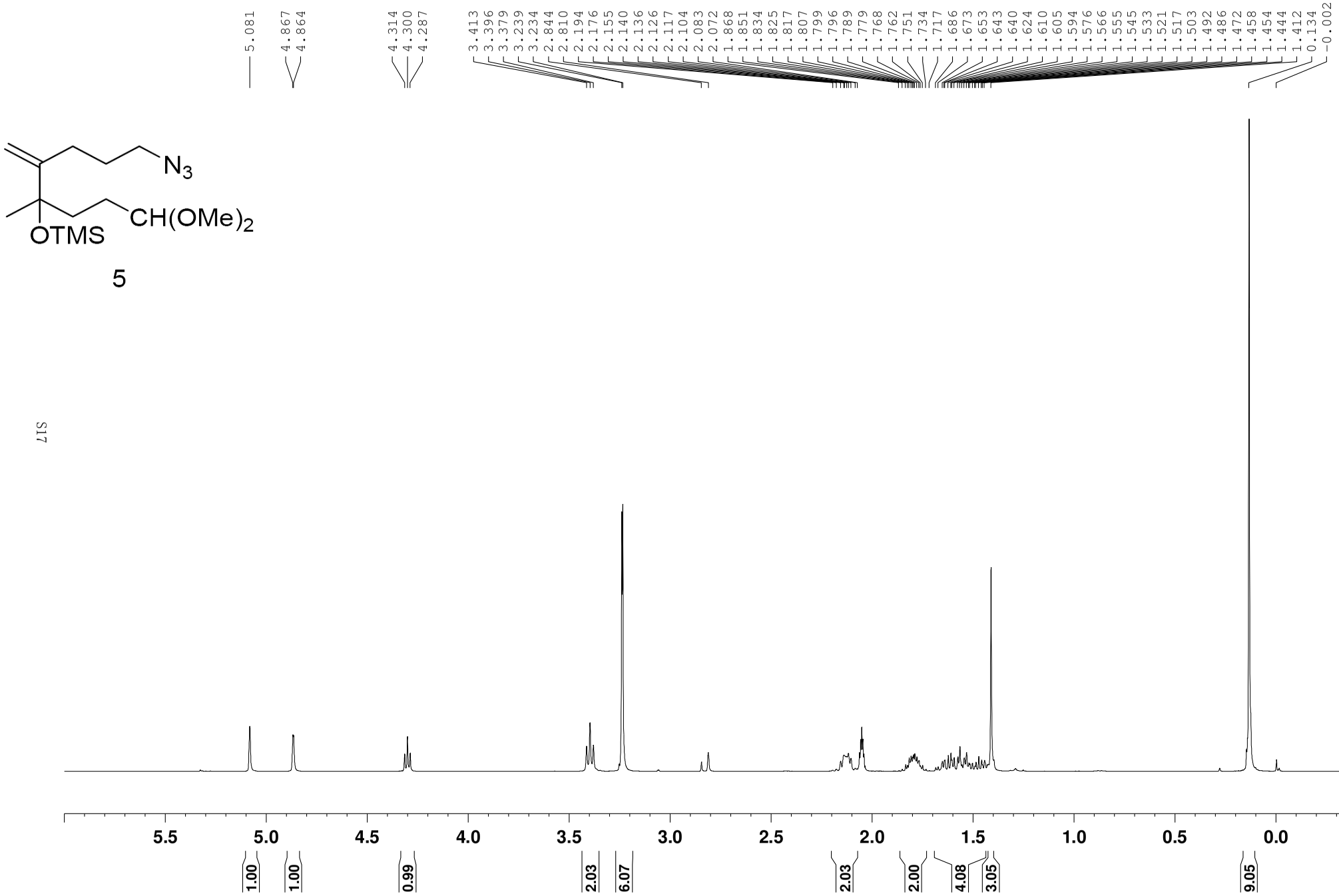
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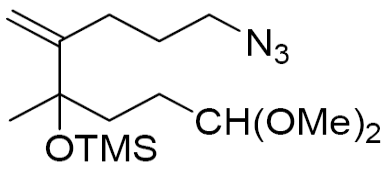

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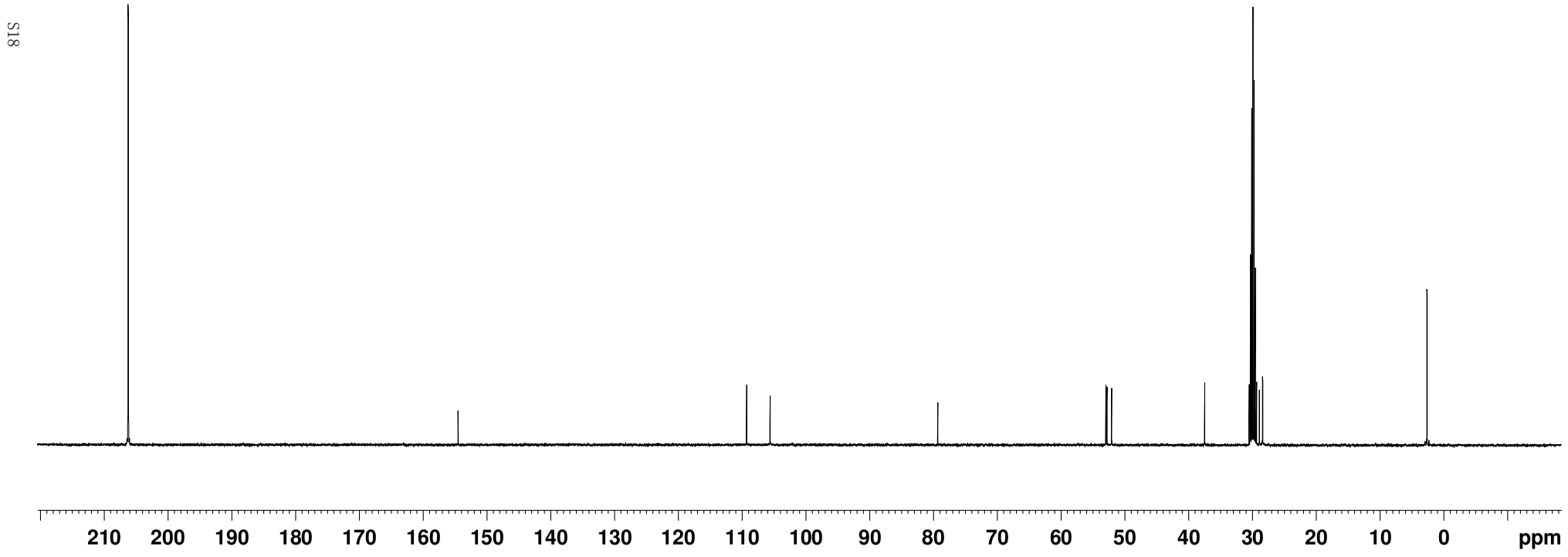

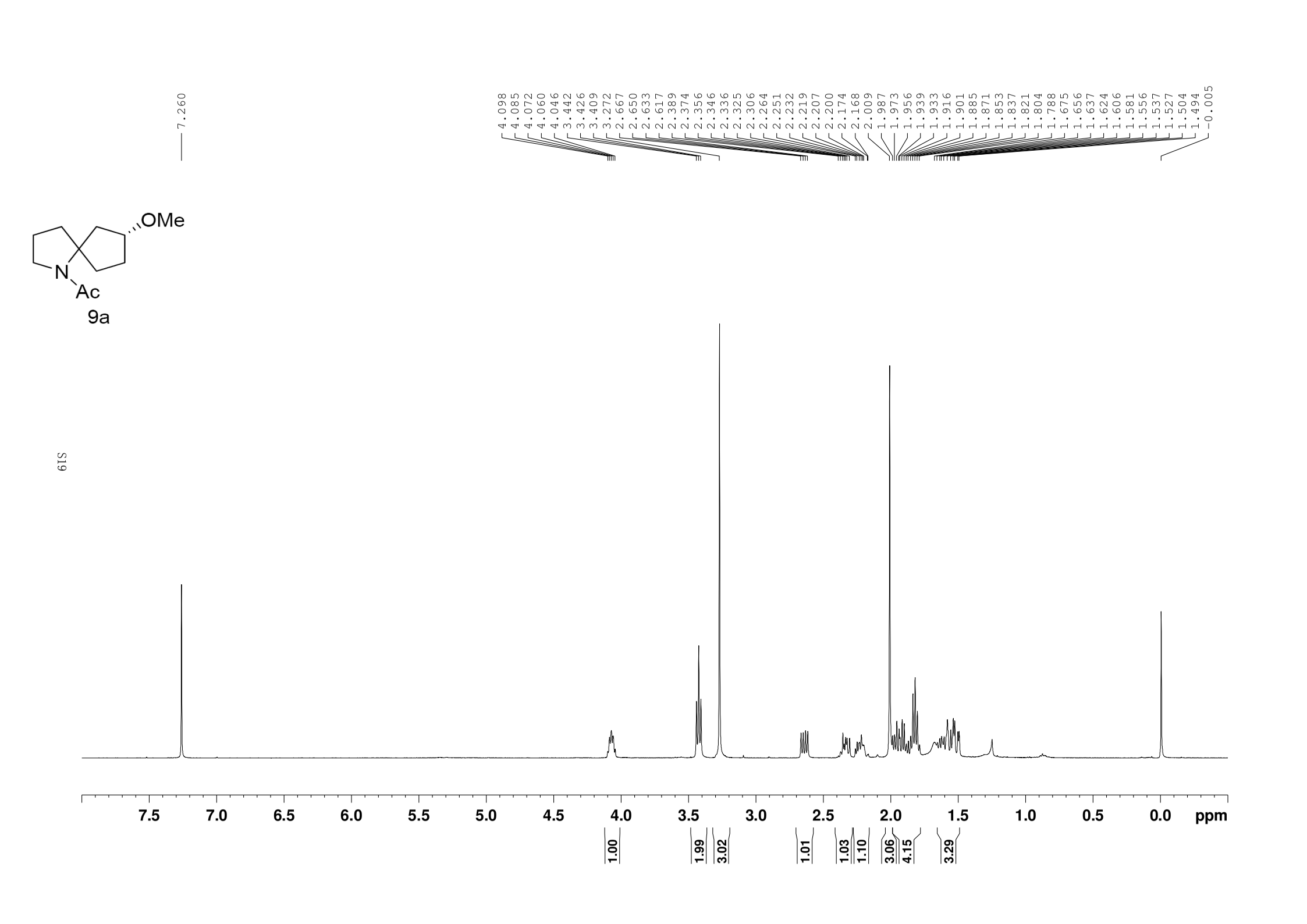
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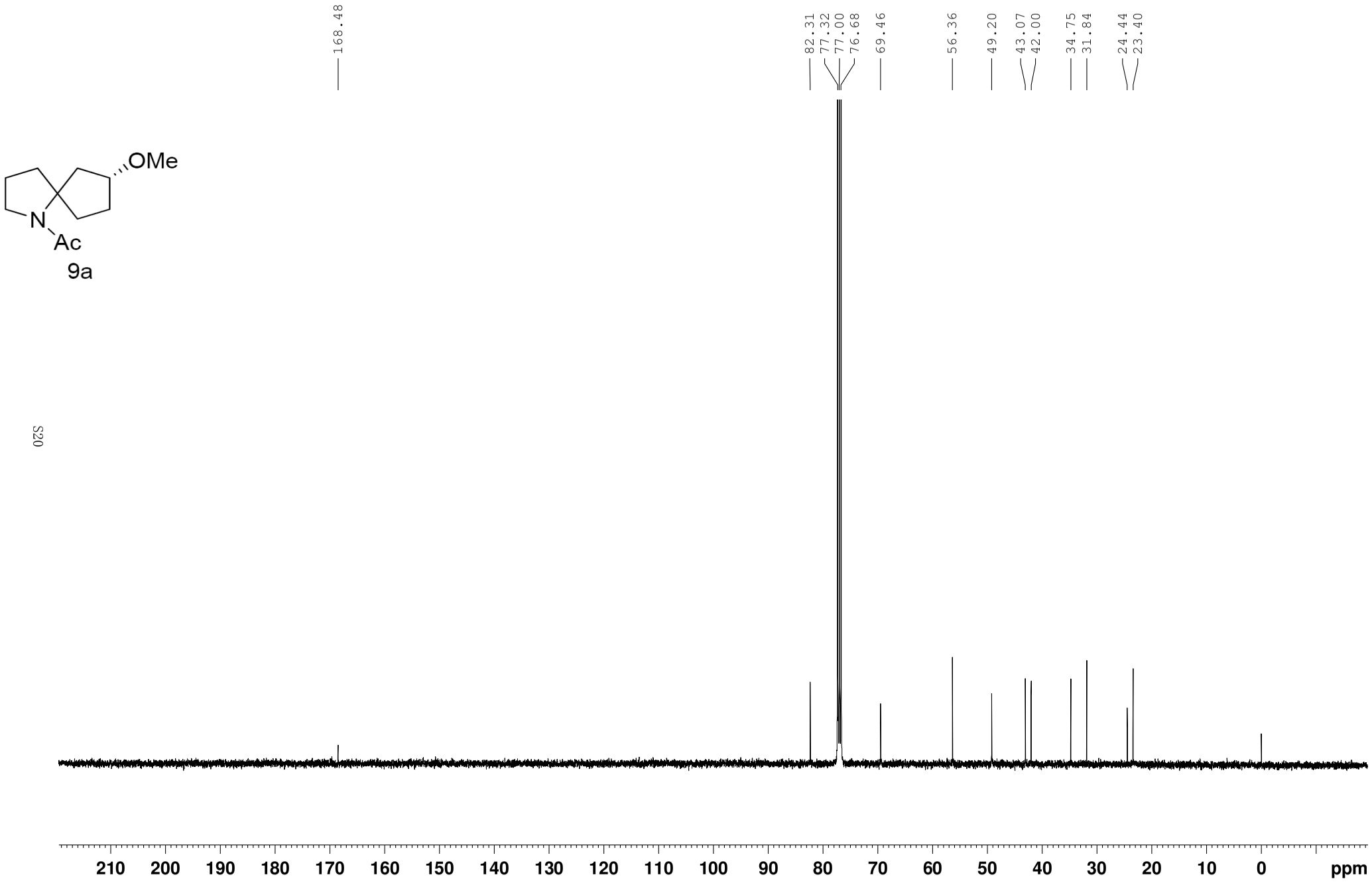
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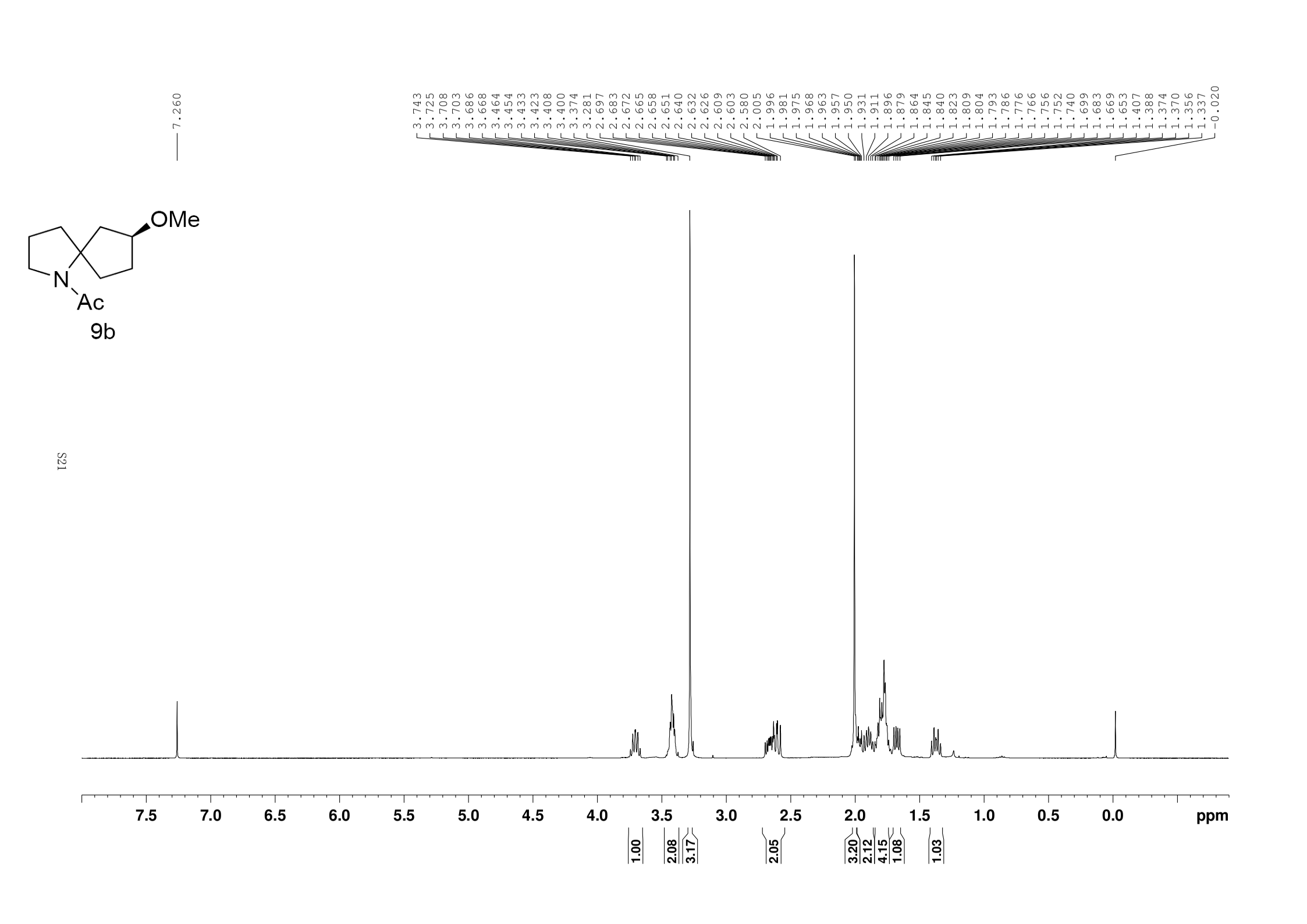
82.31
77.32
77.00
76.68
69.46
56.36
49.20
43.07
42.00
34.75
31.84
24.44
23.40
OMe
N
Ac
9a
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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3.423
3.408
3.400
3.374
3.281
2.697
2.683
2.672
2.665
2.658
2.651
2.640
2.632
2.626
2.609
2.603
2.580
2.005
1.996
1.981
1.975
1.968
1.963
1.957
1.950
1.931
1.911
1.896
1.879
1.864
1.845
1.840
1.823
1.809
1.804
1.793
1.786
1.776
1.766
1.756
1.752
1.740
1.699
1.683
1.669
1.653
1.407
1.388
1.374
1.370
1.356
1.337
-0.020
OMe
N
Ac
9b
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
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ppm
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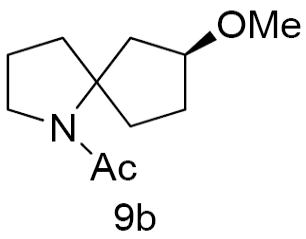
3.17
2.05
3.20
2.12
4.15
1.08
1.03


OMe
N
Ac

9b

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76.69
68.54
56.53
49.18
42.20
40.77
33.16
30.10
24.62
23.09
210
200
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140
130
120
110
100
90
80
70
60
50
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30
20
10
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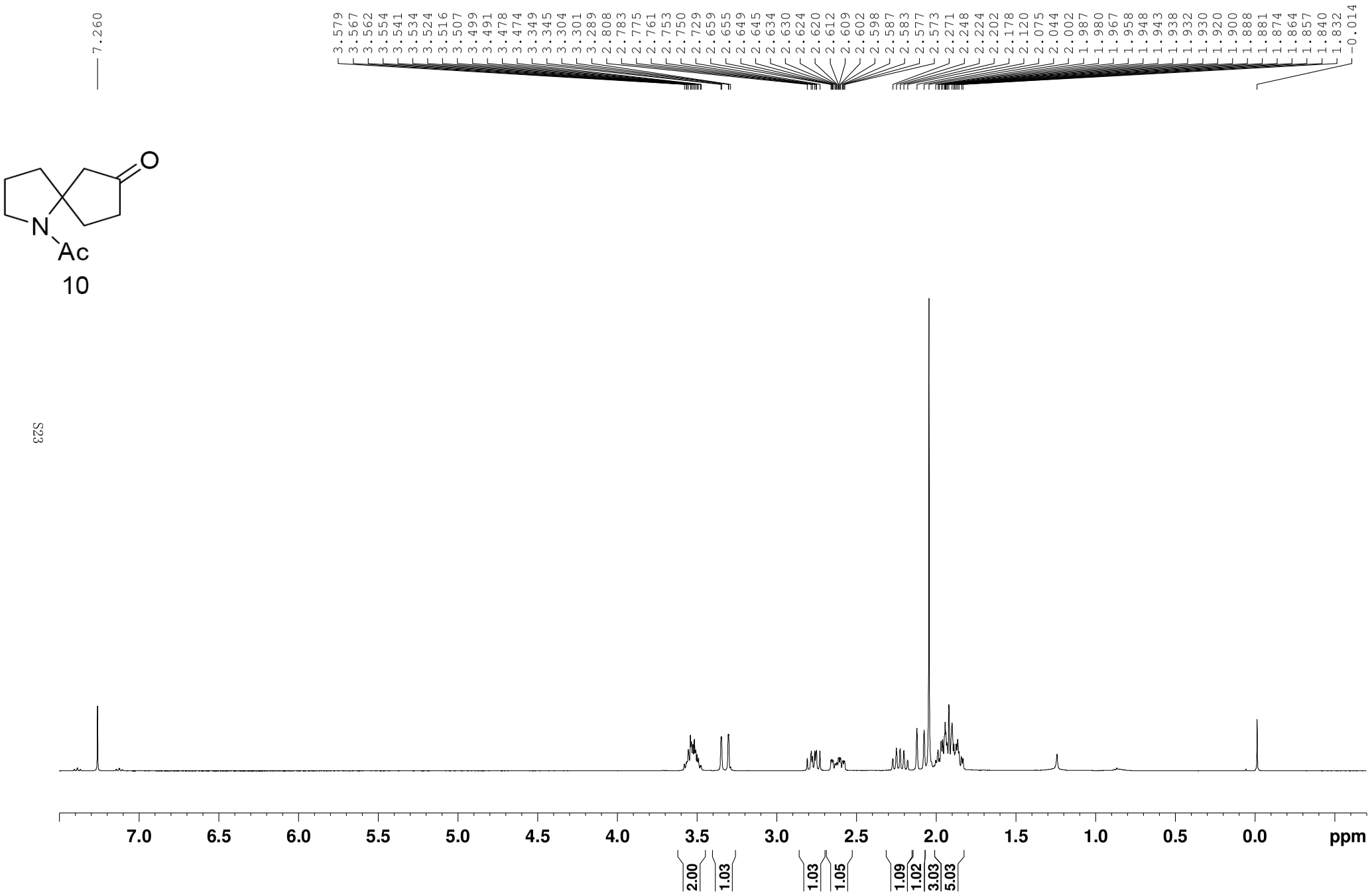
ppm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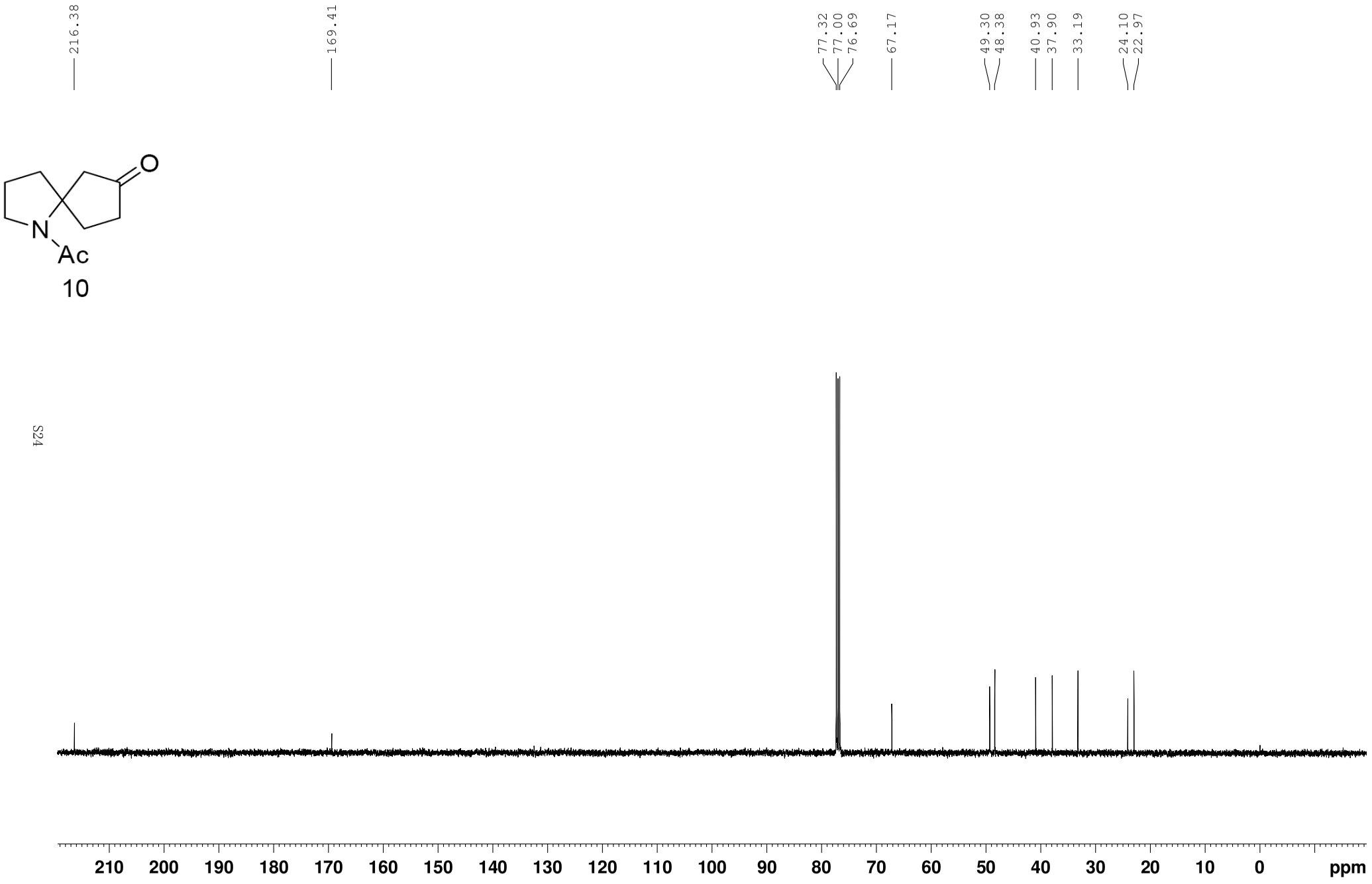
3.567
3.562
3.554
3.541
3.534
3.524
3.516
3.507
3.499
3.491
3.478
3.474
3.349
3.345
3.304
3.301
3.289
2.808
2.783
2.775
2.761
2.753
2.750
2.729
2.659
2.655
2.649
2.645
2.634
2.630
2.624
2.620
2.612
2.609
2.602
2.598
2.587
2.583
2.577
2.573
2.271
2.248
2.224
2.202
2.178
2.120
2.075
2.044
2.002
1.987
1.980
1.967
1.958
1.948
1.943
1.938
1.932
1.930
1.920
1.900
1.888
1.881
1.874
1.864
1.857
1.840
1.832
-0.014
O
N
Ac
10
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.00
1.03
1.03
1.05
1.09
1.02
3.03
5.03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77.32
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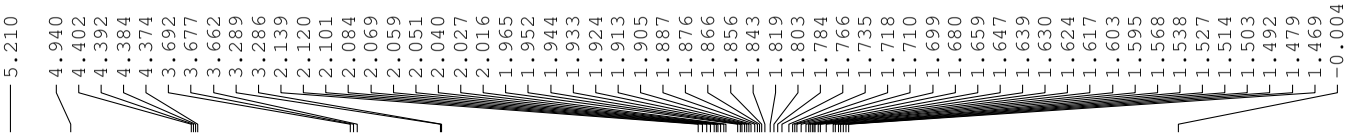
76.69
67.17
49.30
48.38
40.93
37.90
33.19
24.10
22.97
O
N
Ac
10
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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4.940
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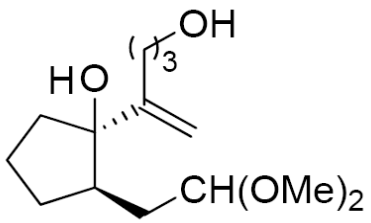
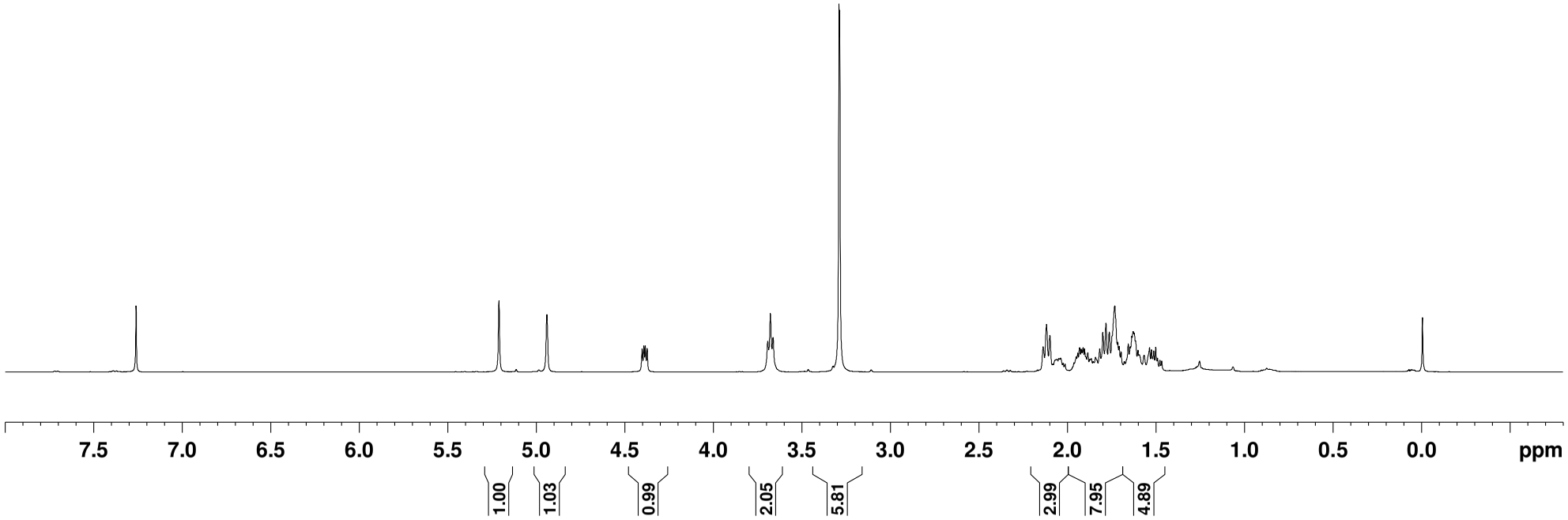
4.392
4.384
4.374
3.692
3.677
3.662
3.289
3.286
2.139
2.120
2.101
2.084
2.069
2.059
2.051
2.040
2.027
2.016
1.965
1.952
1.944
1.933
1.924
1.913
1.905
1.887
1.876
1.866
1.856
1.843
1.819
1.803
1.784
1.766
1.735
1.718
1.710
1.699
1.680
1.659
1.647
1.639
1.630
1.624
1.617
1.603
1.595
1.568
1.538
1.527
1.514
1.503
1.492
1.479
1.469
-0.004


OH
HO
3
CH(OMe)2

12a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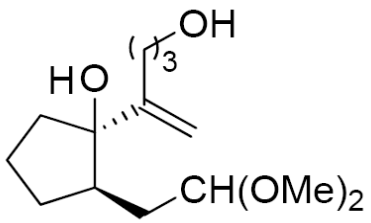
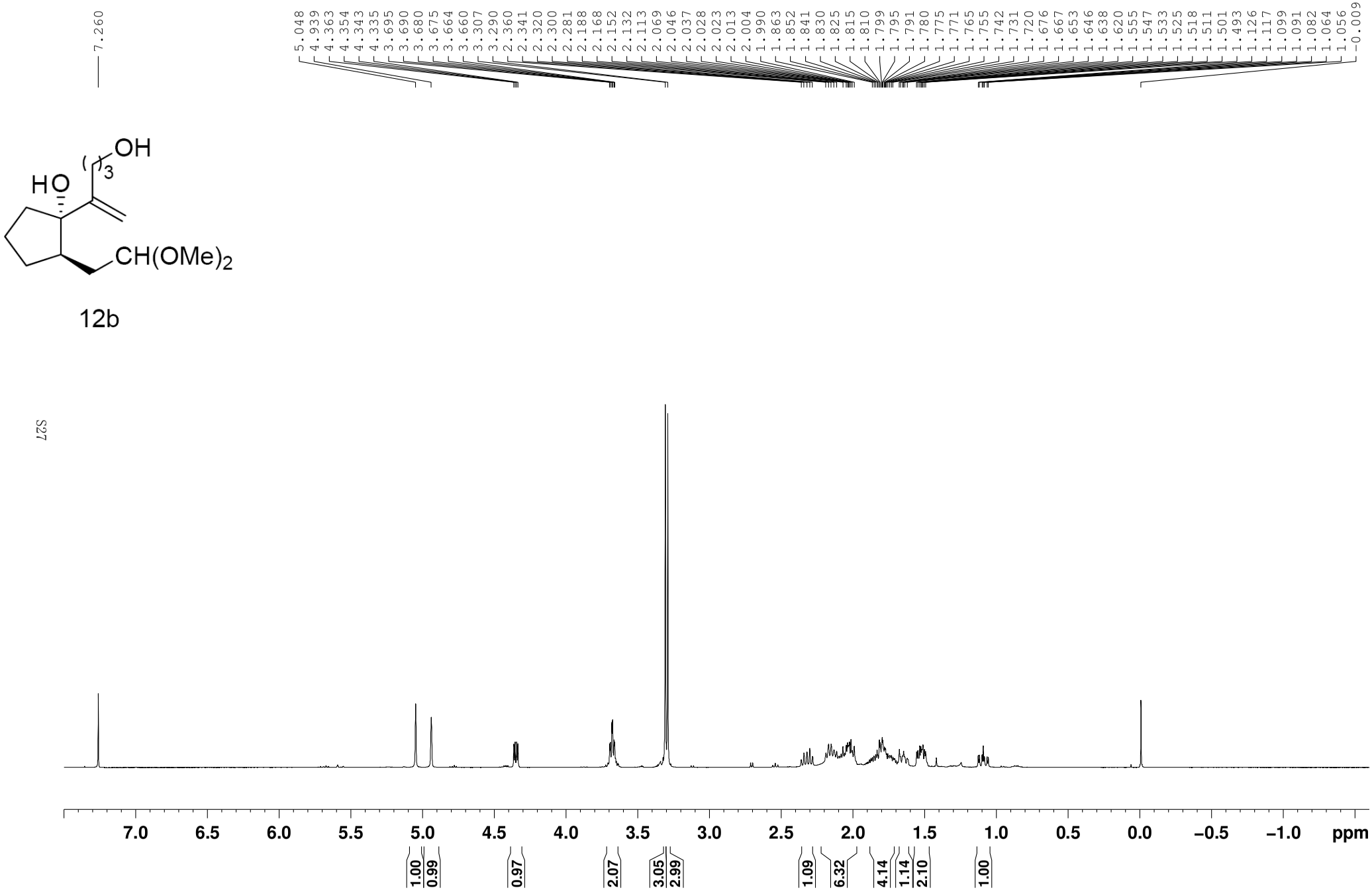
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.03
0.99
2.05
5.81
2.99
7.95
4.89


OH
HO
3
CH(OMe)2

12a

152.28
108.72
103.96
85.03
77.32
77.00
76.68
62.12
53.10
52.40
42.42
39.89
31.79
31.75
30.11
27.29
21.92
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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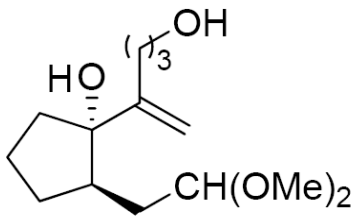
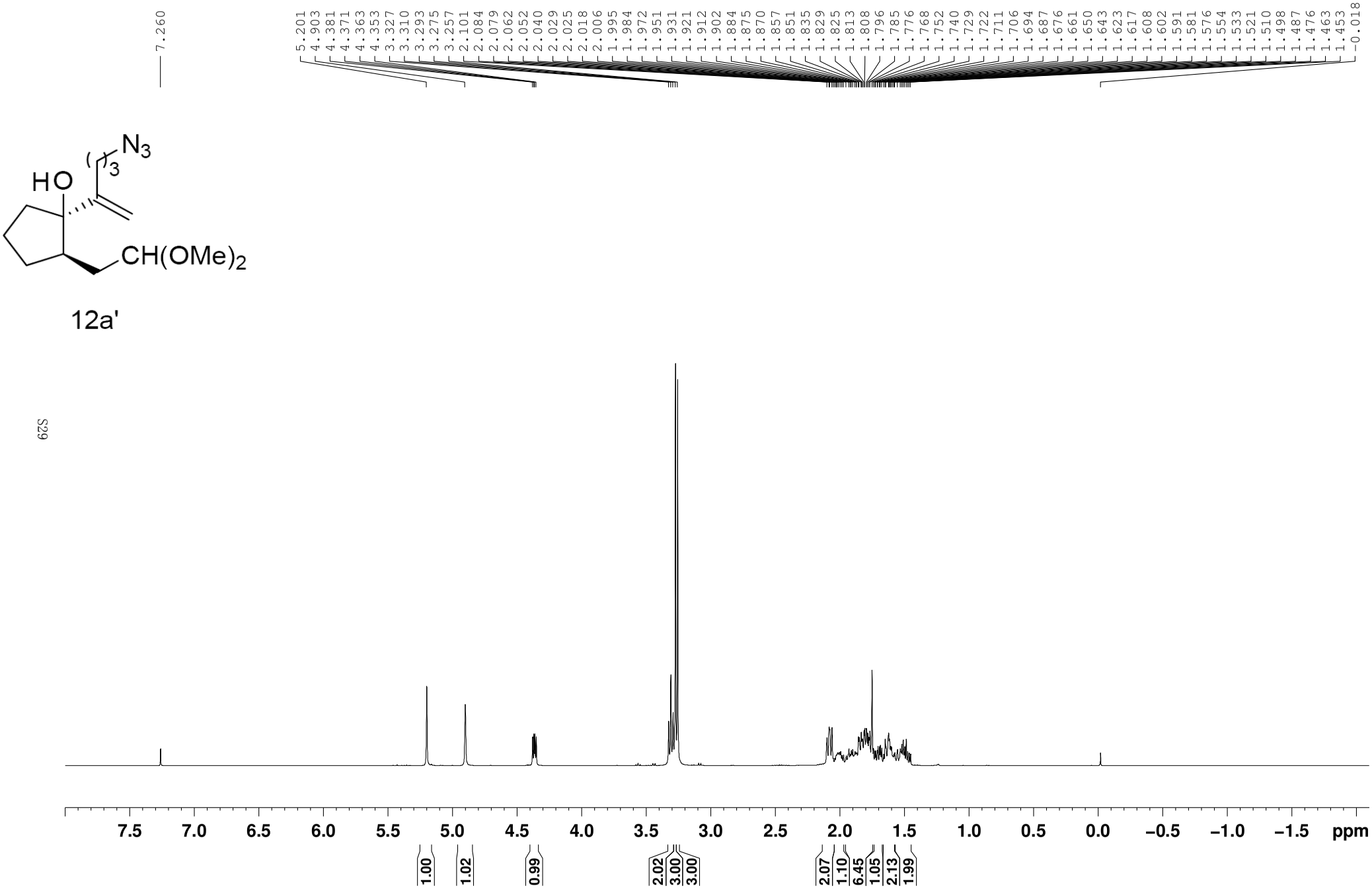
5.048
4.939
4.363
4.354
4.343
4.335
3.695
3.690
3.680
3.675
3.664
3.660
3.307
3.290
2.360
2.341
2.320
2.300
2.281
2.188
2.168
2.152
2.132
2.113
2.069
2.046
2.037
2.028
2.023
2.013
2.004
1.990
1.863
1.852
1.841
1.830
1.825
1.815
1.810
1.799
1.795
1.791
1.780
1.775
1.771
1.765
1.755
1.742
1.731
1.720
1.676
1.667
1.653
1.646
1.638
1.620
1.555
1.547
1.533
1.525
1.518
1.511
1.501
1.493
1.126
1.117
1.099
1.091
1.082
1.064
1.056
-0.009
OH
HO
3
CH(OMe)2
12b
S27
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
−1.0
ppm
1.00
0.99
0.97
2.07
3.05
2.99
1.09
6.32
4.14
1.14
2.10
1.00


OH
3
HO
CH(OMe)2

12b

150.79
110.76
103.95
87.27
77.32
77.00
76.68
61.97
53.09
52.94
44.11
35.80
34.82
31.53
28.78
27.40
20.60
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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4.381
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4.363
4.353
3.327
3.310
3.293
3.275
3.257
2.101
2.084
2.079
2.062
2.052
2.040
2.029
2.025
2.018
2.006
1.995
1.984
1.972
1.951
1.931
1.921
1.912
1.902
1.884
1.875
1.870
1.857
1.851
1.835
1.829
1.825
1.813
1.808
1.796
1.785
1.776
1.768
1.752
1.740
1.729
1.722
1.711
1.706
1.694
1.687
1.676
1.661
1.650
1.643
1.623
1.617
1.608
1.602
1.591
1.581
1.576
1.554
1.533
1.521
1.510
1.498
1.487
1.476
1.463
1.453
-0.018
N3
3
HO
CH(OMe)2
12a'
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
−1.0
−1.5
ppm
1.00
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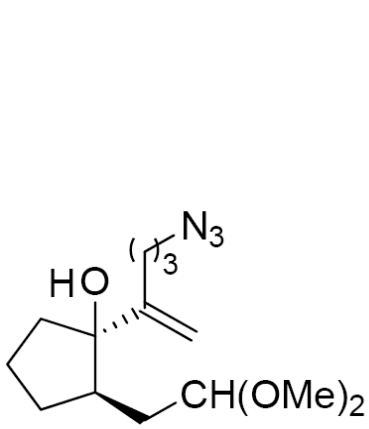
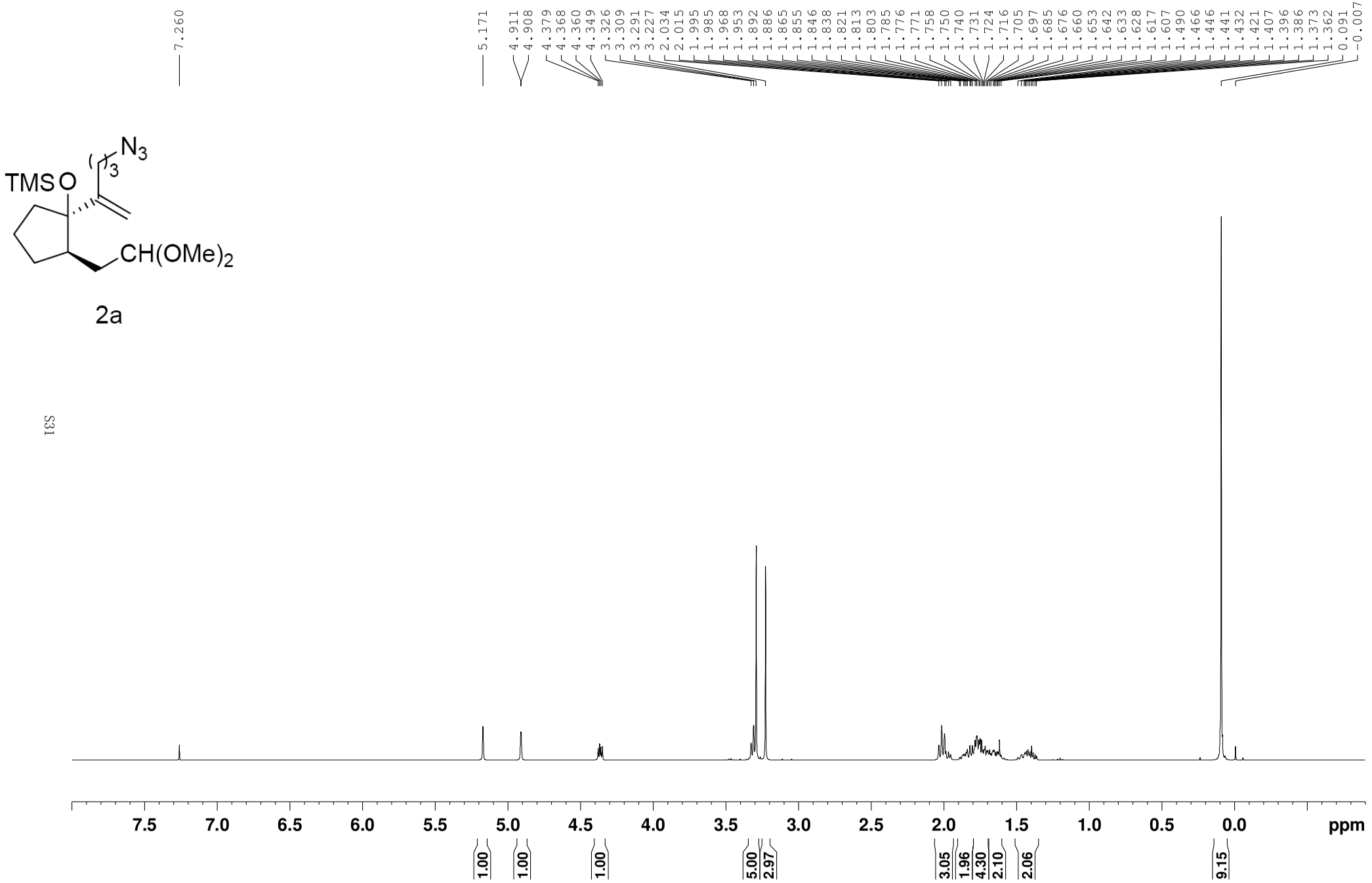
0.99
2.02
3.00
3.00
2.07
1.10
6.45
1.05
2.13
1.99


N3
3
HO
CH(OMe)2

12a'

151.78
108.99
103.81
84.73
77.32
77.00
76.68
52.77
52.46
51.18
42.57
39.95
31.67
30.07
28.56
28.09
21.90
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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4.911
4.908
4.379
4.368
4.360
4.349
3.326
3.309
3.291
3.227
2.034
2.015
1.995
1.985
1.968
1.953
1.892
1.886
1.865
1.855
1.846
1.838
1.821
1.813
1.803
1.785
1.776
1.771
1.758
1.750
1.740
1.731
1.724
1.716
1.705
1.697
1.685
1.676
1.660
1.653
1.642
1.633
1.628
1.617
1.607
1.490
1.466
1.446
1.441
1.432
1.421
1.407
1.396
1.386
1.373
1.362
0.091
-0.007
TMS O
N3
3
CH(OMe)2
2a
S31
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
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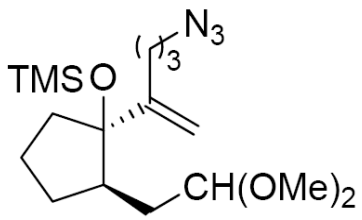
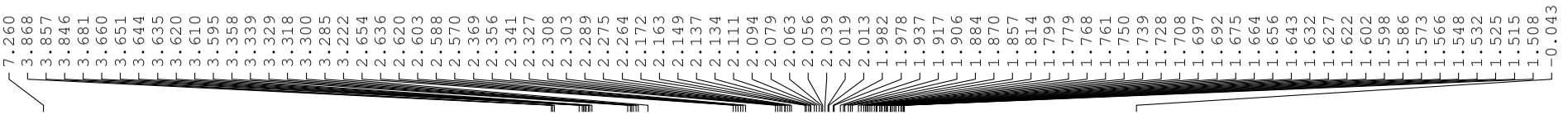
1.00
1.00
5.00
2.97
3.05
1.96
4.30
2.10
2.06
9.15


TMS O
N3
3
CH(OMe)2

2a

150.72
110.60
104.08
88.02
77.32
77.00
76.68
53.05
51.74
51.27
44.44
36.70
31.09
29.68
28.67
28.47
22.04
2.02
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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3.644
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3.620
3.610
3.595
3.358
3.339
3.329
3.318
3.300
3.285
3.222
2.654
2.636
2.620
2.603
2.588
2.570
2.369
2.356
2.341
2.327
2.308
2.303
2.289
2.275
2.264
2.172
2.163
2.149
2.137
2.134
2.111
2.094
2.079
2.063
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2.039
2.019
2.013
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1.978
1.937
1.917
1.906
1.884
1.870
1.857
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1.799
1.779
1.768
1.761
1.750
1.739
1.728
1.708
1.697
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1.675
1.664
1.656
1.643
1.632
1.627
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1.602
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1.586
1.573
1.566
1.548
1.532
1.525
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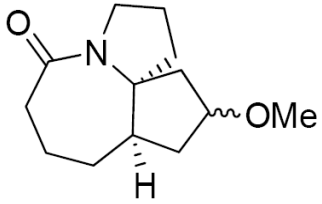
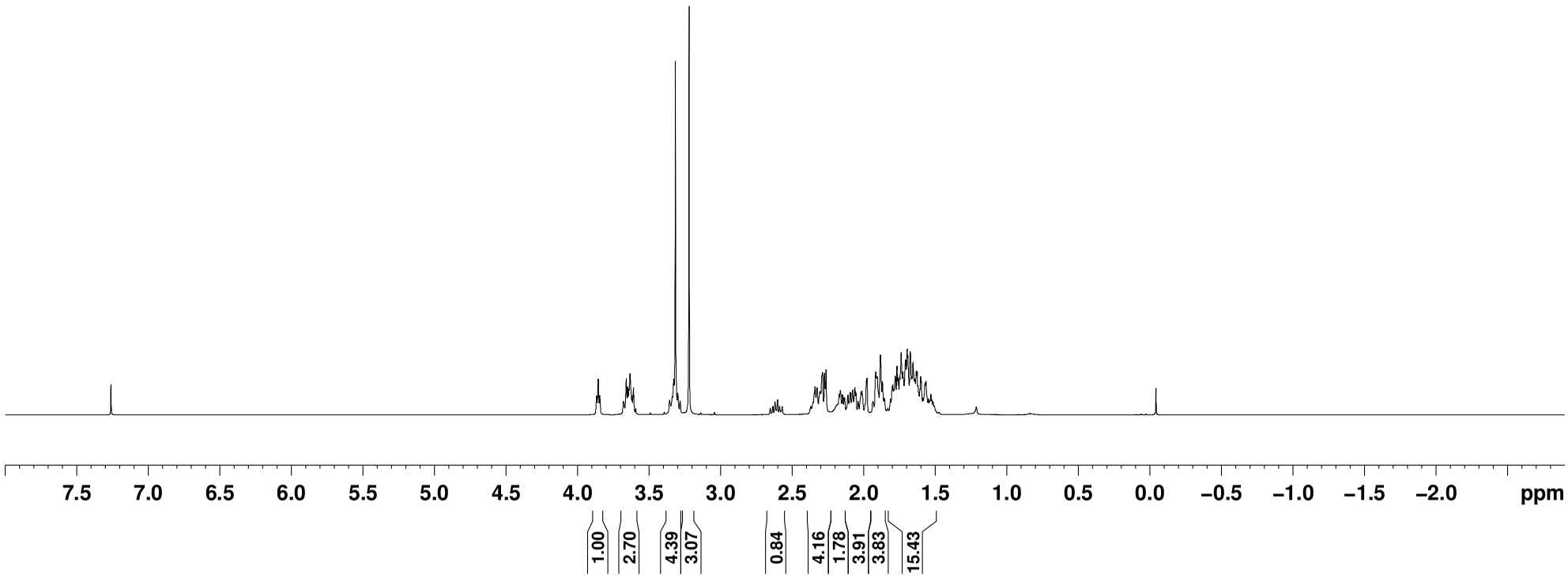
1.508
-0.043


O
N
OMe
H

4 (dr = 1 : 0.84)


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
−1.0
−1.5
−2.0
ppm
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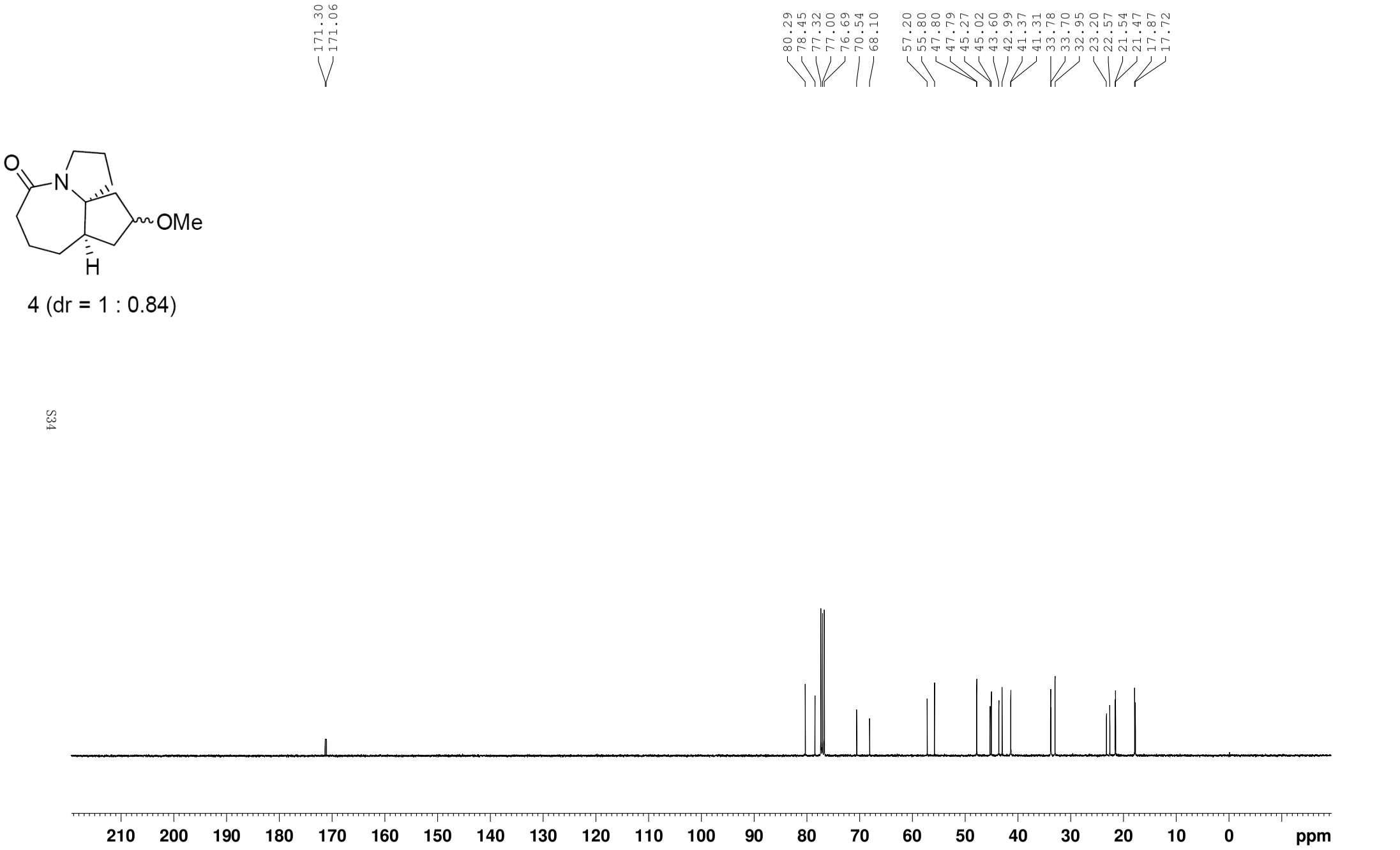
2.70
4.39
3.07
0.84
4.16
1.78
3.91
3.83
15.43


171.30
171.06
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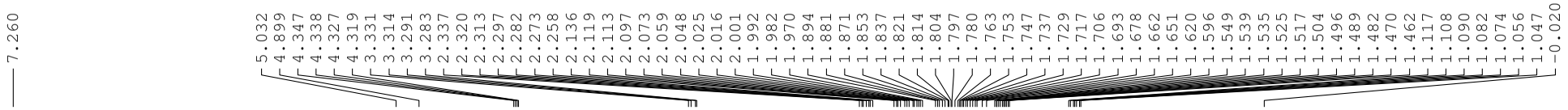
78.45
77.32
77.00
76.69
70.54
68.10
57.20
55.80
47.80
47.79
45.27
45.02
43.60
42.99
41.37
41.31
33.78
33.70
32.95
23.20
22.57
21.54
21.47
17.87
17.72
O
N
OMe
H
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

4 (dr = 1 : 0.84)


7.260
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4.338
4.327
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3.331
3.314
3.291
3.283
2.337
2.320
2.313
2.297
2.282
2.273
2.258
2.136
2.119
2.113
2.097
2.073
2.059
2.048
2.025
2.016
2.001
1.992
1.982
1.970
1.894
1.881
1.871
1.853
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1.814
1.804
1.797
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1.747
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1.678
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1.651
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1.549
1.539
1.535
1.525
1.517
1.504
1.496
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1.462
1.117
1.108
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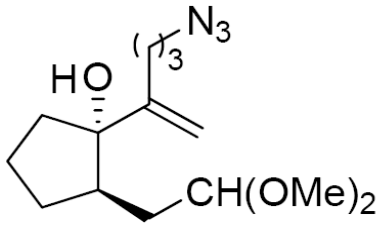
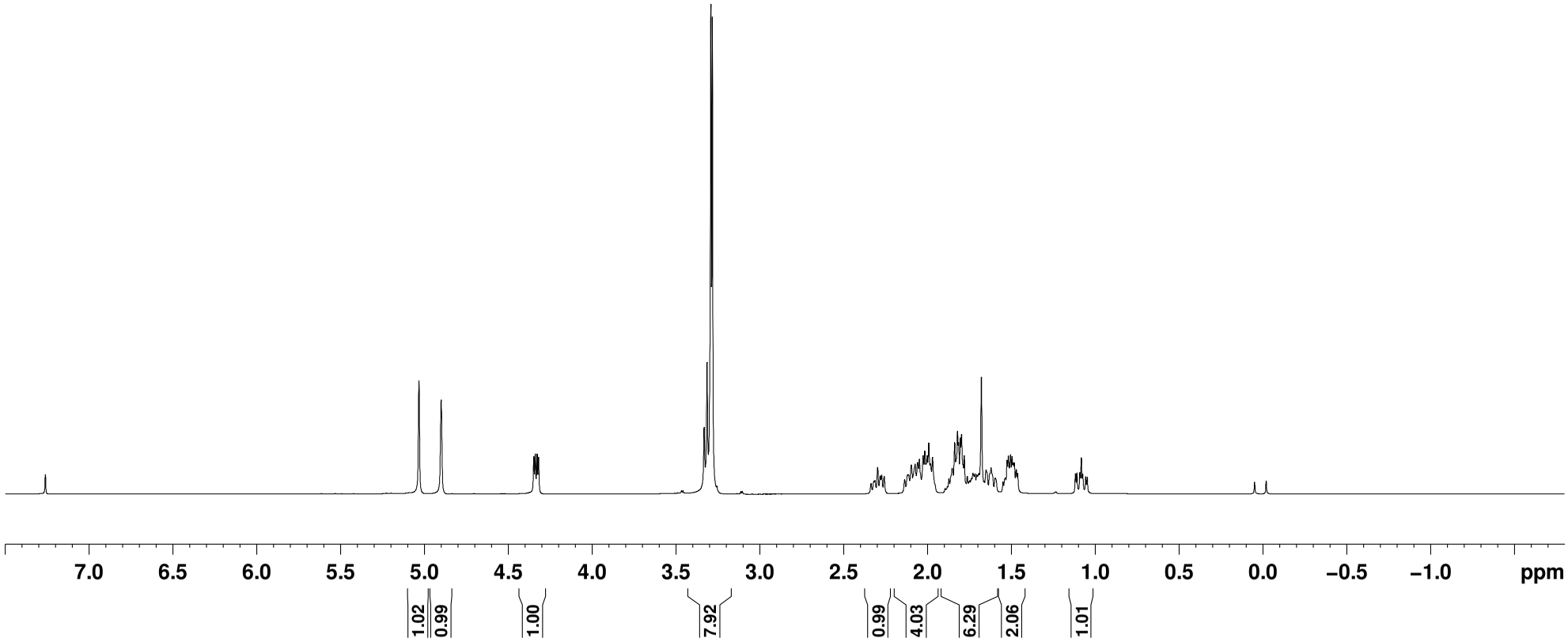

N3
3
HO
CH(OMe)2

12b'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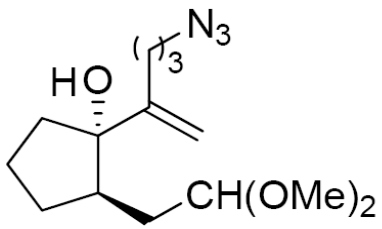
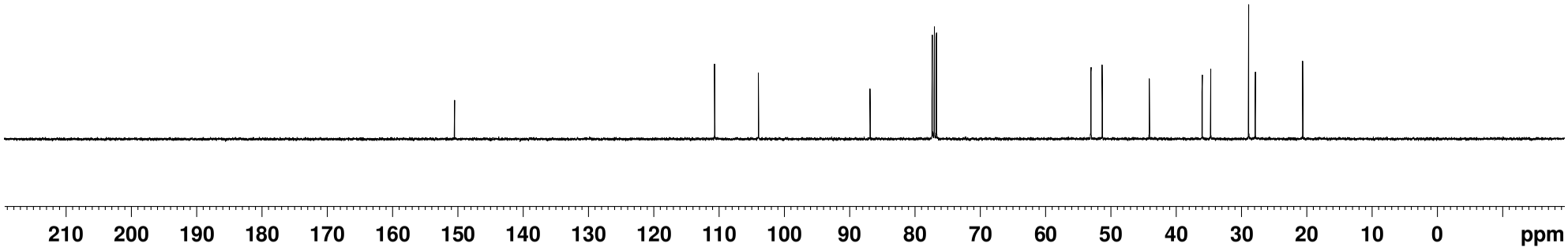
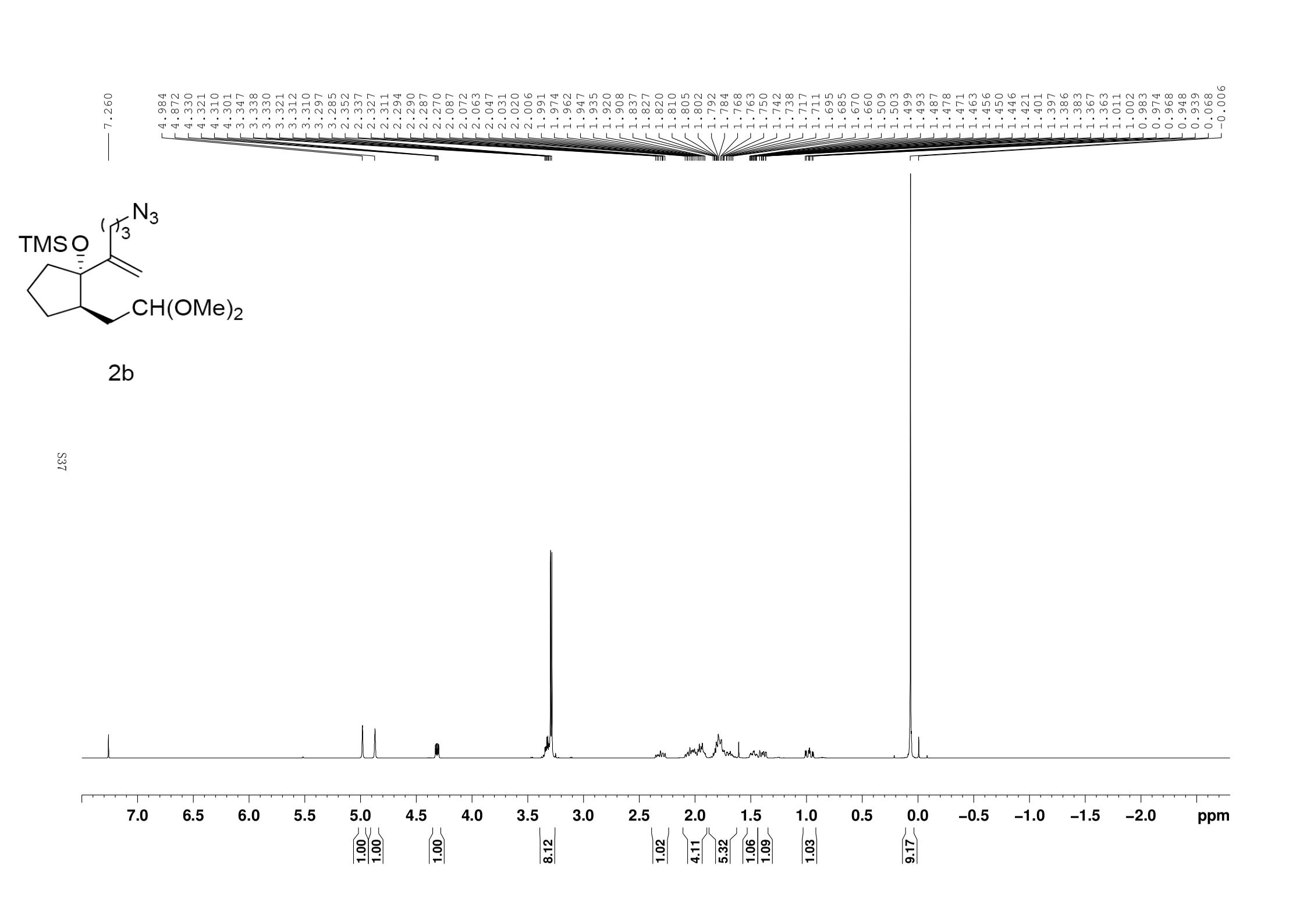
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
ppm
1.02
0.99
1.00
7.92
0.99
4.03
6.29
2.06
1.01



12b'

150.48
110.64
103.93
86.83
77.32
77.00
76.68
53.04
52.98
51.27
44.07
35.97
34.66
28.86
27.83
20.56

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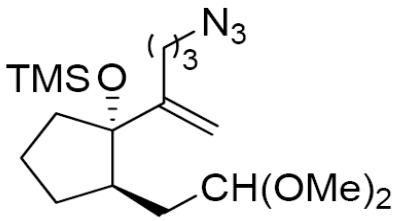
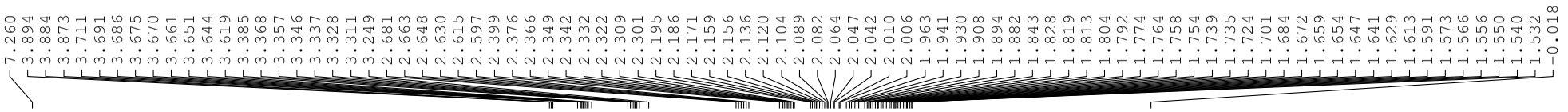
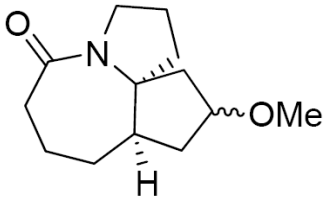
4.984
4.872
4.330
4.321
4.310
4.301
3.347
3.338
3.330
3.321
3.312
3.310
3.297
3.285
2.352
2.337
2.327
2.311
2.294
2.290
2.287
2.270
2.087
2.072
2.063
2.047
2.031
2.020
2.006
1.991
1.974
1.962
1.947
1.935
1.920
1.908
1.837
1.827
1.820
1.810
1.805
1.802
1.792
1.784
1.768
1.763
1.750
1.742
1.738
1.717
1.711
1.695
1.685
1.670
1.660
1.509
1.503
1.499
1.493
1.487
1.478
1.471
1.463
1.456
1.450
1.446
1.421
1.401
1.397
1.386
1.383
1.367
1.363
1.011
1.002
0.983
0.974
0.968
0.948
0.939
0.068
-0.006
TMS
O
N3
3
CH(OMe)2
2b
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
-1.0
-1.5
-2.0
ppm
1.00
1.00
1.00
8.12
1.02
4.11
5.32
1.06
1.09
1.03
9.17


TMS
O
N3
3
CH(OMe)2

2b

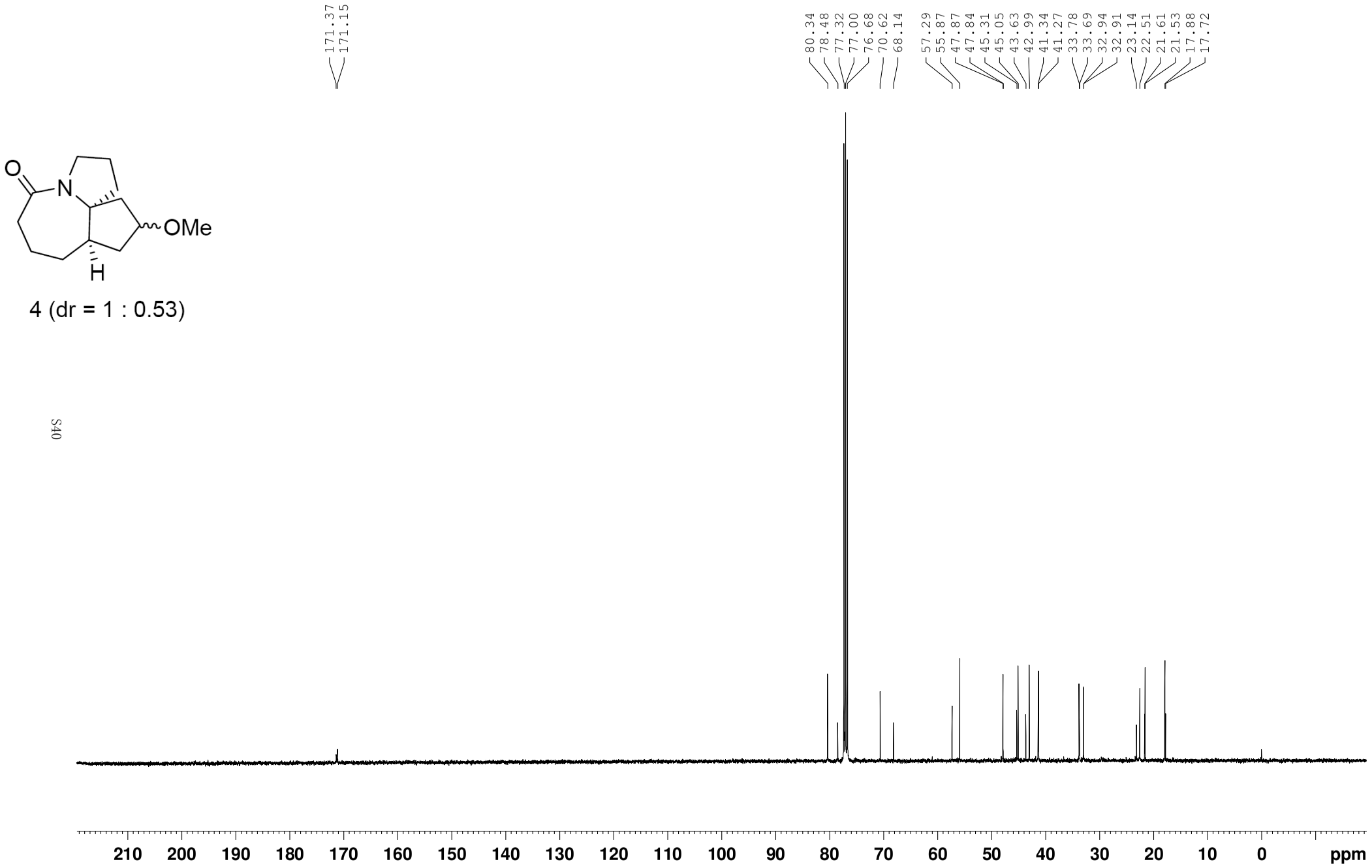
150.57
110.14
104.23
89.58
77.32
77.00
76.69
53.08
53.05
51.56
45.38
34.08
33.78
28.39
27.81
26.98
20.29
1.82
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.260
3.894
3.884
3.873
3.711
3.691
3.686
3.675
3.670
3.661
3.651
3.644
3.619
3.385
3.368
3.357
3.346
3.337
3.328
3.311
3.249
2.681
2.663
2.648
2.630
2.615
2.597
2.399
2.376
2.366
2.349
2.342
2.332
2.322
2.309
2.301
2.195
2.186
2.171
2.159
2.156
2.136
2.120
2.104
2.089
2.082
2.064
2.047
2.042
2.010
2.006
1.963
1.941
1.930
1.908
1.894
1.882
1.843
1.828
1.819
1.813
1.804
1.792
1.774
1.764
1.758
1.754
1.739
1.735
1.724
1.701
1.684
1.672
1.659
1.654
1.647
1.641
1.629
1.613
1.591
1.573
1.566
1.556
1.550
1.540
1.532
-0.018

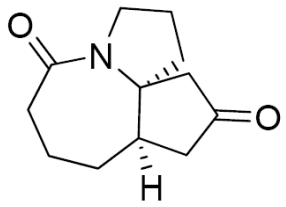

O
N
OMe
H

4 (dr = 1 : 0.53)

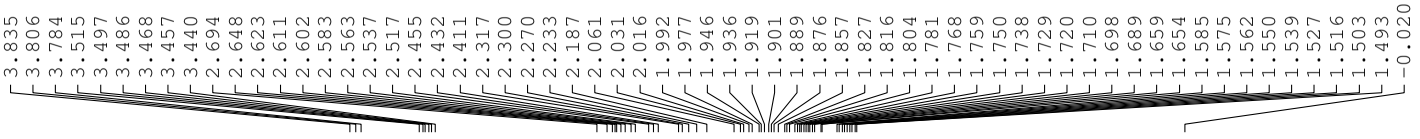
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
ppm
2.00
3.93
5.99
5.95
1.06
7.35
2.13
2.22
3.03
6.35
24.84

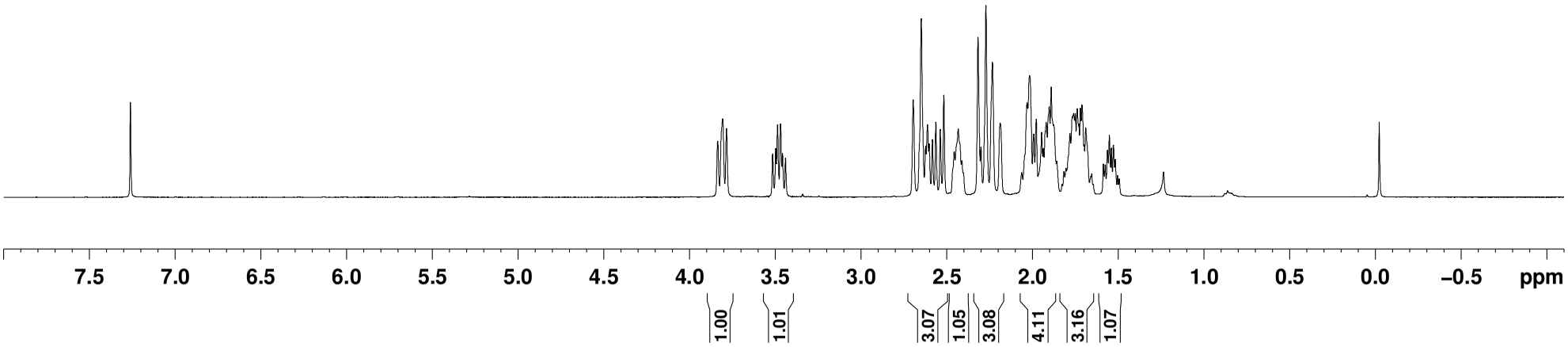

171.37
171.15
80.34
78.48
77.32
77.00
76.68
70.62
68.14
57.29
55.87
47.87
47.84
45.31
45.05
43.63
42.99
41.34
41.27
33.78
33.69
32.94
32.91
23.14
22.51
21.61
21.53
17.88
17.72
O
N
OMe
H
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

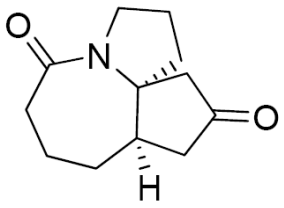
4 (dr = 1 : 0.53)


O
N
O
H

13

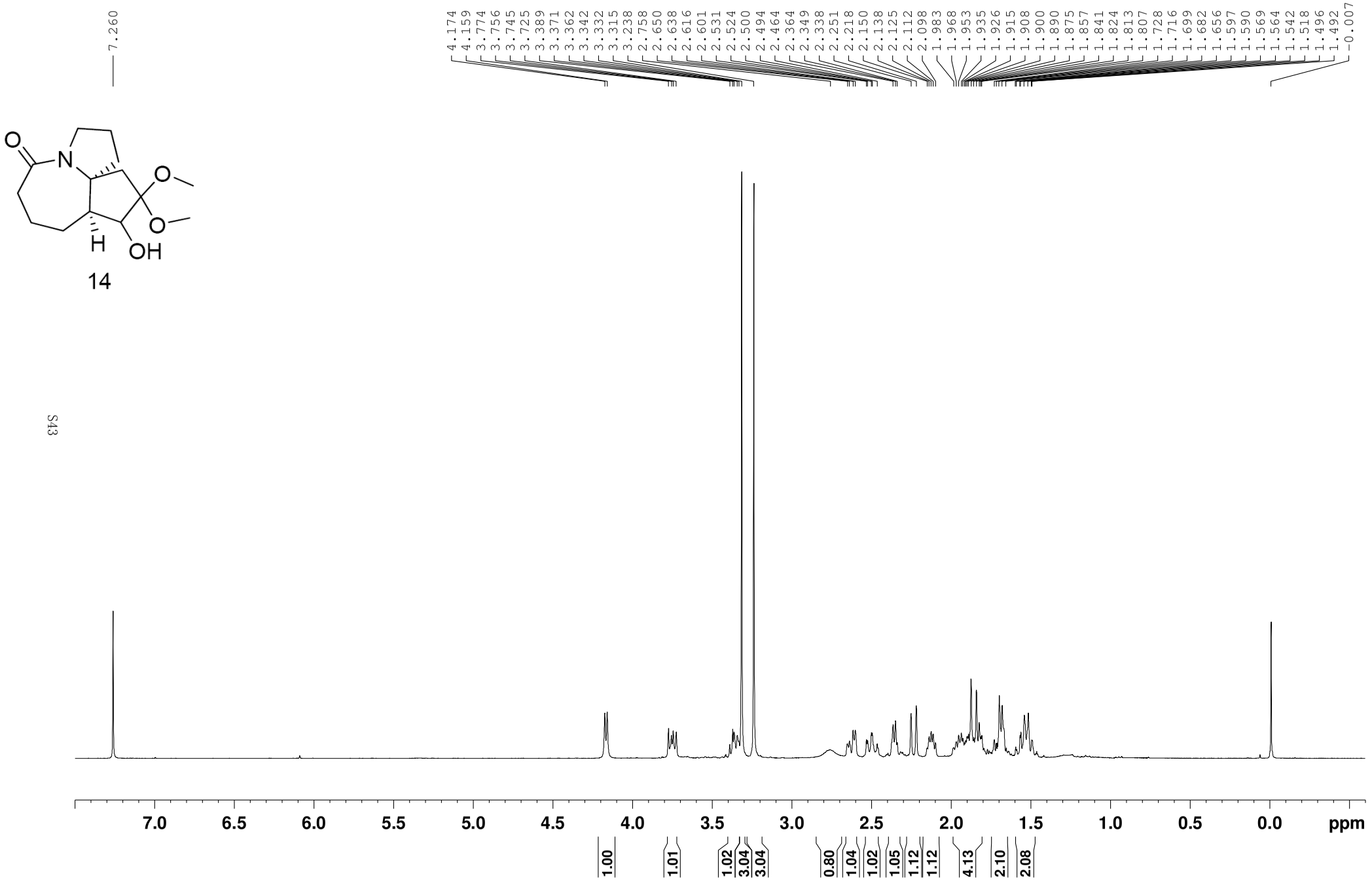

7.260
3.835
3.806
3.784
3.515
3.497
3.486
3.468
3.457
3.440
2.694
2.648
2.623
2.611
2.602
2.583
2.563
2.537
2.517
2.455
2.432
2.411
2.317
2.300
2.270
2.233
2.187
2.061
2.031
2.016
1.992
1.977
1.946
1.936
1.919
1.901
1.889
1.876
1.857
1.827
1.816
1.804
1.781
1.768
1.759
1.750
1.738
1.729
1.720
1.710
1.698
1.689
1.659
1.654
1.585
1.575
1.562
1.550
1.539
1.527
1.516
1.503
1.493
-0.020

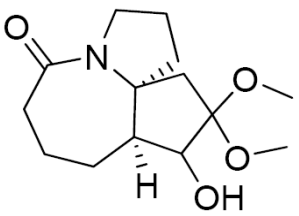

7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
–0.5
ppm
1.00
1.01
3.07
1.05
3.08
4.11
3.16
1.07


O
N
O
H

13

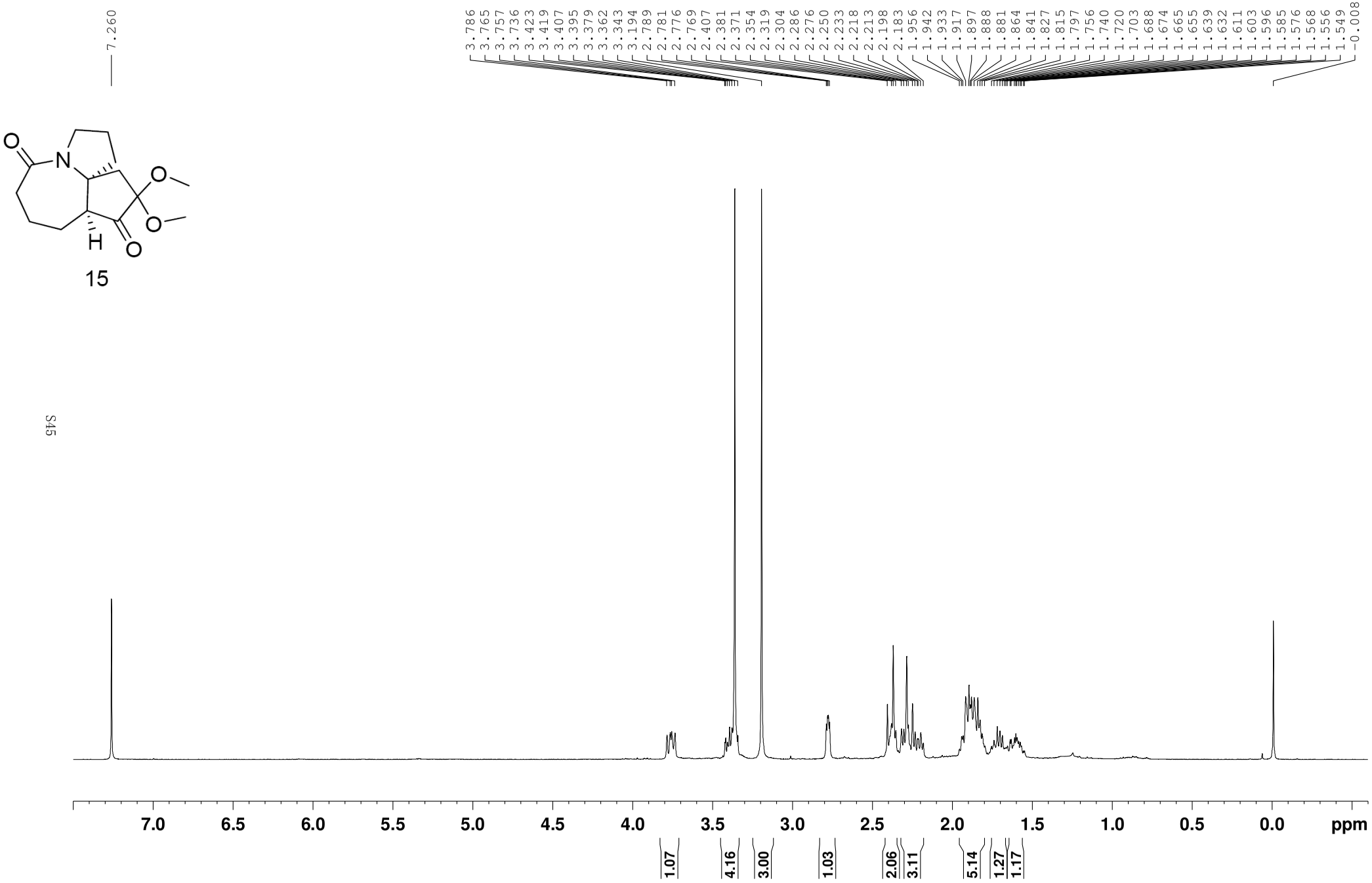
214.29
172.42
77.32
77.00
76.68
67.07
49.07
47.43
45.60
44.65
43.57
36.47
31.34
20.51
20.10
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

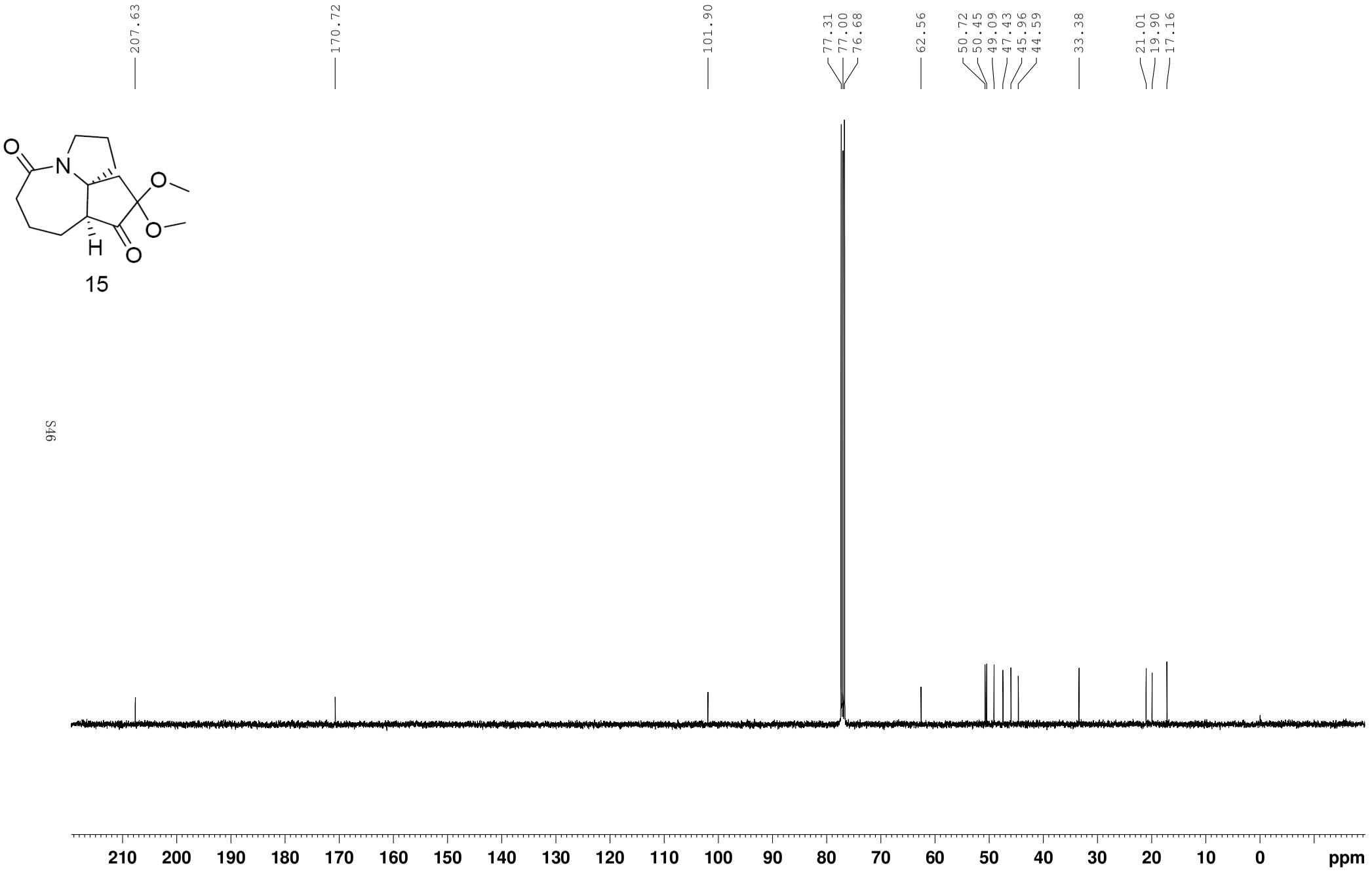

7.260
4.174
4.159
3.774
3.756
3.745
3.725
3.389
3.371
3.362
3.342
3.332
3.315
3.238
2.758
2.650
2.638
2.616
2.601
2.531
2.524
2.500
2.494
2.464
2.364
2.349
2.338
2.251
2.218
2.150
2.138
2.125
2.112
2.098
1.983
1.968
1.953
1.935
1.926
1.915
1.908
1.900
1.890
1.875
1.857
1.841
1.824
1.813
1.807
1.728
1.716
1.699
1.682
1.656
1.597
1.590
1.569
1.564
1.542
1.518
1.496
1.492
-0.007
O
N
O
O
H
OH
14
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.00
1.01
1.02
3.04
3.04
0.80
1.04
1.02
1.05
1.12
1.12
4.13
2.10
2.08


O
N
O
O
H
OH

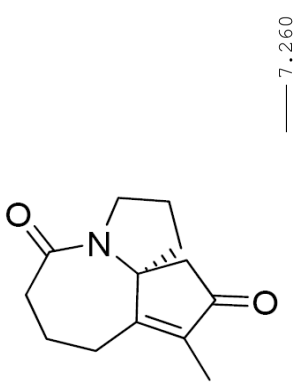
14

173.56
104.76
77.32
77.00
76.68
76.11
65.89
50.42
49.37
49.31
48.62
42.53
42.28
38.05
25.71
21.14
20.38
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
3.786
3.765
3.757
3.736
3.423
3.419
3.407
3.395
3.379
3.362
3.343
3.194
2.789
2.781
2.776
2.769
2.407
2.381
2.371
2.354
2.319
2.304
2.286
2.276
2.250
2.233
2.218
2.213
2.198
2.183
1.956
1.942
1.933
1.917
1.897
1.888
1.881
1.864
1.841
1.827
1.815
1.797
1.756
1.740
1.720
1.703
1.688
1.674
1.665
1.655
1.639
1.632
1.611
1.603
1.596
1.585
1.576
1.568
1.556
1.549
-0.008
O
N
O
O
H
O
15
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.07
4.16
3.00
1.03
2.06
3.11
5.14
1.27
1.17

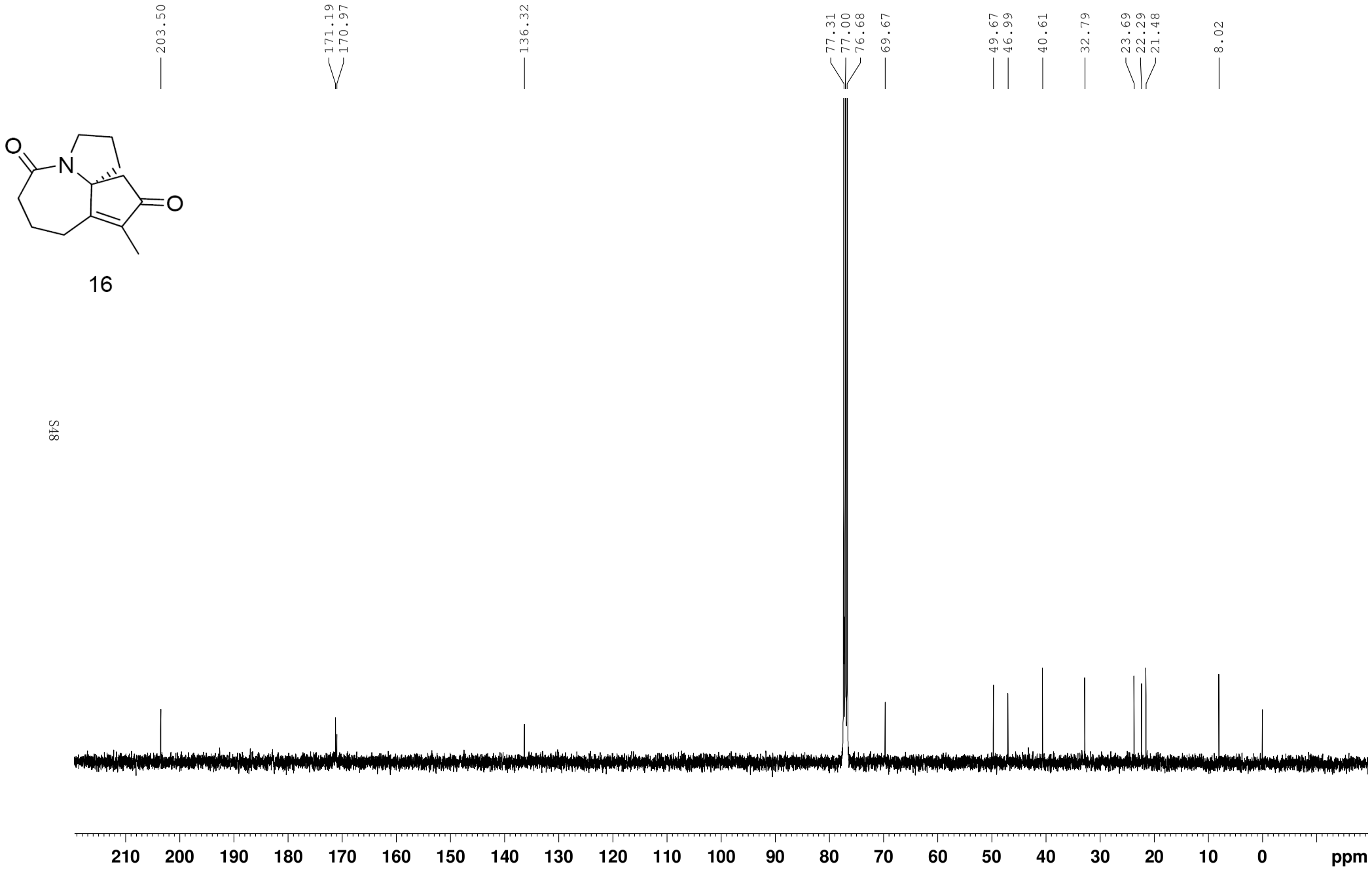

207.63
170.72
101.90
77.31
77.00
76.68
62.56
50.72
50.45
49.09
47.43
45.96
44.59
33.38
21.01
19.90
17.16
O
N
O
O
H
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

15



16

7.260
3.708
3.678
3.665
3.660
3.652
3.634
3.615
3.593
3.564
2.853
2.831
2.821
2.800
2.660
2.618
2.601
2.558
2.371
2.342
2.321
2.299
2.289
2.276
2.270
2.262
2.230
2.217
2.196
2.187
2.171
2.164
2.142
2.077
2.052
2.039
2.025
2.008
1.994
1.982
1.964
1.947
1.936
1.923
1.909
1.902
1.895
1.883
1.874
1.867
1.780
1.589
1.580
1.567
1.552
-0.005
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
2.09
1.07
2.00
3.08
1.12
2.26
2.12
3.11
1.09


203.50
171.19
170.97
136.32
77.31
77.00
76.68
69.67
49.67
46.99
40.61
32.79
23.69
22.29
21.48
8.02
O
N
O
16
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm