Electronic Supplementary Material (ESI) for ChemComm.

Supporting information

Iron Catalyzed Oxidative Assembly of N-heteroaryl and Aryl Metal Reagents Using Oxygen as an Oxidant

Kun Ming Liu, Lian Yan Liao, and Xin Fang Duan*

College of Chemistry, Beijing Normal University, Beijing, 100875, China

xinfangduan@vip.163.com

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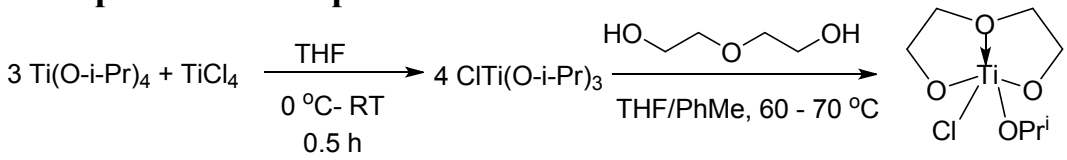
1. General Experimental Details

^{1}H (400 MHz) and ^{13}C (100 MHz) spectra were recorded on a Bruke spectrometer unless otherwise noted. The chemical shifts (δ) were quoted in parts per million from tetramethylsilane for ^{1}H and $CDCl_3$ for ^{13}C spectroscopy. ESI mass spectra were recorded on TRACE MS spectrometer. High resolution mass spectra (HRMS) were obtained with a Bruker microTOF (ESI). Infrared data were acquired using an AVATAR 360 FT-IR spectrophotometer. Elemental analysis was carried out with an Elementear Vario instrument. Melting points were recorded on a TECH X-4 microscopic instrument and uncorrected.

2. Preparation of tbepc



Under Ar atmosphere, $TiCl_4$ (19 g, 0.1 mol) was added slowly to a solution of Ti(O-i-Pr)$_4$ (85.2 g, 0.3 mol) in THF(100 ml) at 0 °C and stirred 0.5 h at room temperature. To the mixture of ethylene diglycol (42.4 g, 0.4 mol) in THF (50 ml) was added dropwise at room temperature and stirred 2 h at 60 °C. After THF was removed under reduced pressure, 100 mL toluene was added to the mixture and distilled under vaccum at 60–70 °C. After the distillation completed, another 100 mL toluene was added and distilled again under vaccum at 60–70 °C. When 50 mL distillate was collected, the mixture was cooled to room temperature, and pale yellow crystals were precipitated. The crystals were filtered and washed by 3 × 50 ml hexane under an argon atmosphere in a glove box, and dried under vaccum to give **tbepc** as a whitish solid (90.5 g, 92% yield). IR (neat): 2935, 1459, 1365, 1237, 1126, 1068, 937, 815, 635; ^{1}H NMR (DMSO-d_6, 400 MHz) δ (ppm) 3.81–3.74 (m, 5H), 3.50 (t, J = 9.0 Hz, 4H), 1.04 (d, J = 6.1 Hz, 6H); ^{13}C NMR (DMSO-d_6, 100 MHz) δ (ppm) 86.52, 67.14, 51.58, 26.23. HRMS (ESI) calcd for $C_7H_{15}ClO_4Ti$ $[M+H]^+$ 247.0138, found 247.0136.

3. General Procedure for the oxidative cross coupling reactions between aryl and N-heteroaryl metal reagents

3.1 General remarks for the preparation of aryl and N-heteroaryl metal reagents

All reagents and solvents used for aryl magnesium reagents or lithium reagents and reactions were freshly dehydrated before use. The corresponding glassware was oven dried (120 °C) and cooled under a stream of argon gas.

Aryl Grignard reagents such as phenyl magnesium or 4-methoxyphenyl magnesium were prepared according to standard procedure. Functionalized aryl Grignard reagents such as 2-cyanophenyl

magnesium chloride or 4-(ethoxycarbonyl)phenyl magnesium chloride were prepared via iodine - magnesium exchange using *i*-PrMgCl·LiCl according to Knochel's method.[1] All the Grignard reagents were titrated before use.[2]

The preparation of *N*-heteroaryl metal reagents was illustrated in specific examples.

3.2 Typical procedure for the oxidative cross couplings of aryl or *N*-heteroaryl metal reagents (5ac)

Under Ar atmosphere, a solution of *i*-PrMgCl·LiCl (2.5 mmol, 1.0 M in THF) was added dropwise to a solution of ethyl 4-iodobenzoate (690 mg, 2.5 mmol) in 5 ml THF at –40 °C and stirred for 1h at that temperature. A solution of **tbepc** (615 mg, 2.5 mmol) in 10 mL THF added dropwise to that mixture. The stirring was continued for 2 h and then the temperature was allowed to come to 0 °C (Note 1). To this mixture was added dropwise 2-pyridylMgCl (prepared from 2-bromopyridine via bromine-magnesium exchange using *i*-PrMgCl, 2.5 mmol) (Note 2). The resulting mixture stirred at 0 °C for 0.5–1h. The solution of $FeCl_3$ (32.5 mg, 0.2 mmol), TMEDA (58 mg, 0.5 mmol) in THF (5 ml) was added in at one portion. The Ar atmosphere was changed into O_2 atmosphere (applied by an oxygen bag). The thus-obtained mixture was stirred at room temperature until the completion of the reaction (monitored by TLC). The reaction was quenched with saturated aqueous Na_2CO_3 and diluted with CH_2Cl_2. After being filtered, the mixture was extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4 and concentrated to yield the crude compound, which was purified by column chromatography to yield the desired product **5ac** (494 mg, 87% yield).

Note 1: For the reactions where the metal reagents were stable at room temperature (for example, **5aa**, **5ab** and *etc*.), all operations were performed at room temperature.

Note 2: For the reactions where the *N*-heteroaryl metal reagents were prepared at –30 or –40 °C (for example, **5hb**, **5la** and etc.), the combination of the *N*-heteroaryl metal reagents with the aryl titanium reagents was also conducted at –30 or –40 °C. The following operations were conducted as described in typical procedure.

4. Total synthesis of caboxamycin(Scheme 4)

To a solution of benzyl benzo[d]oxazole-7-carboxylate (2.5 g, 10.0 mmol, 1.0 equiv) in THF (40 mL) was added dropwise TMPLi (12.0 mmol, 1.2 equiv) at –40 °C. The mixture was stirred at that temperature for 1h.

At the same time, to a solution of **tbepc** (10.0 mmol) in 10 mL THF was added dropwise 2-$BnOC_6H_4MgBr$ (10.0 mmol, 1.0M) at room temperature and stirred for 2 h. This mixture was cooled to –40 °C, and the solution of above-prepared metal reagent of benzyl benzo[d]- oxazole-7-

carboxylate was added in at that temperature. The stirring was continued for 1h, and the temperature was allowed to warm to 0 °C. The solution of $FeCl_3$ (163 mg, 1 mmol), TMEDA (232 mg, 2 mmol) in THF (10 ml) was added in. The Ar atmosphere was changed into O_2 atmosphere (applied by an oxygen bag). The mixture was stirred at room temperature until the completion of the reaction (monitored by TLC). The reaction was quenched with saturated aqueous Na_2CO_3 and diluted with CH_2Cl_2. After being filtered, the mixture was extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4 and concentrated to yield the crude compound, which was purified by column chromatography to yield the desired product **7** as a whitish solid (3.57 g, 82% yield).

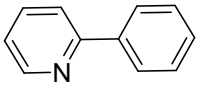
The solution of **7** (3.5 g, 16 mmol) in 60 ml EtOH was hydrogenation under the catalysis of 10% Pd/C (0.35 g) at atmosphere at room temperature for 6 h. After filtration to remove Pd/C, the filtrate was concentrated under pressure to give a pale white solid, which was recrystallization in *i*-PrOH to obtain caboxamycin as a whitish solid (2.0 g, 97% yield).

5. Direct arylation of (s)-nicotine(Scheme 5)

Following the reported procedure[3], (S)-nicotine (0.81 g, 5.0 mmol) in dry THF (5 ml) was cooled to 0°C. $BF_3{\cdot}Et_2O$ (0.78 g, 5.5 mmol) was added dropwise and stirred for 15min at that temperature. TMPMgCl·LiCl (7.5 ml, 7.5 mmol, 1 M in THF) was added to this solution and stirred at room temperature for 2.5 h.

At the same time, to a solution of **tbepc** (5.0 mmol) in 5 mL THF was added dropwise 1-naphthyl-magnesium bromide (5.0 mmol) at room temperature and stirred for 2 h. The solution of above-prepared metal reagent of (S)-nicotine was added in dropwise and stirred for 1h. The solution of $FeCl_3$ (65 mg, 0.4 mmol), TMEDA (116 mg, 1 mmol) in THF (5 ml) was added in. The Ar atmosphere was changed into O_2 atmosphere (applied by an oxygen bag). The resulting mixture was stirred at room temperature for 6 h (monitored by TLC). The reaction was quenched with saturated aqueous Na_2CO_3 and diluted with CH_2Cl_2. After being filtered, the mixture was extracted with CH_2Cl_2. The organic layer was dried over Na_2SO_4 and concentrated to yield the crude compound, which was purified by column chromatography to yield the desired product as a yellow viscous liquid (1.32 g, 92% yield).

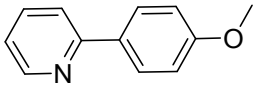
6. Characterization data for products



2-Phenylpyridine (5aa) [4]

Yield 96%, yellow oil.

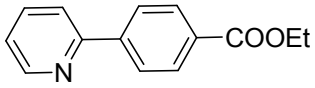
The Grignard reagent of 2-bromopyridine was prepared via bromo-magnesium exchange using *i*-PrMgCl according to the reported method[5] and all operations were conducted at room temperature. IR (neat): 1592, 1565, 693; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.67 (d, J = 4.8 Hz, 1H), 7.98 (d, J = 7.2 Hz, 2H), 7.67–7.66 (m, 2H), 7.46–7.40 (m, 2H), 7.38–7.36 (m, 1H), 7.17–7.13 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 157.4, 149.7, 139.4, 136.7, 129.0, 128.8, 127.0, 122.1, 120.5.



2-(4-Methoxyphenyl)pyridine (5ab) [6]

Yield 96%, whitish solid, m.p. = 52.5–53.5 °C（lit. 53.2－53.5 °C).

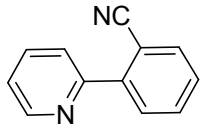
The product was prepared as described in **5aa**. IR (neat): 2926, 1609, 1587, 1516, 1462, 1040, 782, 744; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.65 (dd, J = 5.0 Hz, 0.6 Hz, 1H), 7.95 (d, J = 8.9 Hz, 2H), 7.73–7.66 (m, 2H), 7.19–7.15 (m, 1H), 7.00 (d, J = 8.9Hz, 2H), 3.86 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 160.5, 157.1, 149.5, 136.7, 132.0, 128.2, 121.4, 119.8, 114.1, 55.3.



Ethyl 4-(pyridin-2-yl)benzoate (5ac) [7]

Yield 87%, whitish solid, m.p. = 50.5–51.5 °C（lit. 50.5–52.0 °C).

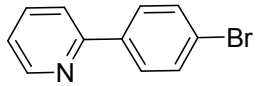
The product was prepared as described in typical procedure. IR (neat): 3055, 2983, 1710, 1608, 1586, 1467, 1364, 1280, 1017, 869; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.73 (d, J = 4.6 Hz, 1H), 8.16–8.13 (m, 2H), 8.07 (d, J = 8.4 Hz, 2H), 7.79 (d, J = 3.8 Hz, 2H), 7.31–7.27 (m, 1H), 4.41 (q, J = 7.1 Hz, 2H), 1.42 (t, J = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 166.4, 156.2, 149.8, 143.4, 136.9, 130.7, 130.0, 126.8, 122.8, 121.0, 61.0, 14.3.



2-(Pyridine-2-yl)benzonitrile (5ad) [8]

yield 81%, yellow oil.

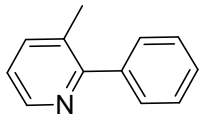
The product was prepared as described in **5ac**. IR (neat): 3064, 2225, 1586, 1463, 1149, 761; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.79 (d, J = 4.8 Hz, 1H), 7.90–7.72 (m, 4H), 7.54 (d, J = 7.7 Hz, 1H), 7.49 (d, J = 7.7 Hz, 1H), 7.30–7.20 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 155.4, 150.0, 143.5, 136.4, 134.7, 132.9, 130.0, 128.7, 123.4, 123.3, 118.2, 111.4.



2-(4-Bromophenyl)pyridine (5ae) [9]

Yield 76%, whitish solid, m.p.= 60.8–62.0 °C（lit. 60–62 °C).

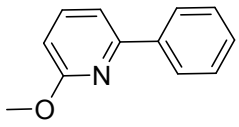
The product was prepared as described in **5aa**. IR (neat): 3052, 1586, 1432, 1152, 838; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.69 (d, J = 4.7 Hz, 1H), 7.87 (d, J = 8.6 Hz, 2H), 7.78–7.74 (m, 1H), 7.70 (d, J = 7.9 Hz, 1H), 7.60 (d, J = 8.6 Hz, 2H), 7.27–7.24 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.2, 149.7, 138.2, 137.0, 131.9, 128.5, 123.5, 122.4, 120.3.



3-Methyl-2-Phenylpyridine (5ba) [10]

Yield 78%, colorless oil.

The product was prepared as described in **5aa**. IR (neat): 3052, 2980, 1582, 1427, 1117, 747; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.50 (dd, J = 4.7 Hz, 0.9 Hz, 1H), 7.53–7.49 (m, 3H), 7.43–7.40 (m, 2H), 7.37–7.33 (m, 1H), 7.12 (dd, J = 7.7 Hz, 4.8 Hz, 1H), 2.31 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.7, 146.9, 140.6, 138.5, 130.8, 128.9, 128.1, 127.9, 122.1, 20.0.

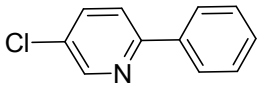


2-Methoxy-6-phenylpyridine (5ca) [11]

Yield 87%, colorless oil.

The product was prepared as described in **5aa**. IR (neat): 3060, 2952, 2926, 1576, 1452, 1255, 766; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.02 (d, J = 7.1 Hz, 2H), 7.52 (t, J = 7.6 Hz, 1H), 7.43–

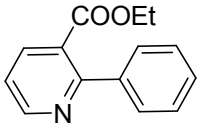
7.34 (m, 3H), 7.26 (d, J = 7.4 Hz, 1H), 6.64 (d, J = 8.1 Hz, 1H), 4.00 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.9, 154.7, 139.2, 139.1, 128.9, 128.7, 126.8, 112.8, 109.3, 53.2.



3-chrolo-6-phenylpyridine (5da)

Yield 87%, whitish solid, m.p.= 63.7–64.8℃.

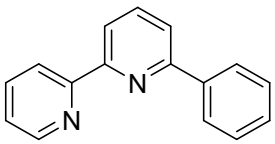
The product was prepared as described in **5aa**. IR (neat): 3057, 1574, 1554, 1460, 1110, 834, 729, 691; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.64 (d, J = 2.0 Hz, 1H), 7.95 (d, J = 7.0 Hz, 2H), 7.73–7.66 (m, 2H), 7.50–7.41 (m, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 155.5, 148.5, 138.1, 136.5, 130.6, 129.3, 128.9, 126.8, 121.1; Anal. Calcd for $C_{11}H_8ClN$: C, 69.67; H, 4.24; N, 7.39; Found: C, 69.78; H, 4.28; N, 7.24. MS(ESI): $[M+H]^+$ (m/z), 190 (100%), 191 (30%).



Ethyl 2-phenyl-3-pyridinecarboxylate (5ea) [12]

Yield 91%, yellow oil.

The metal reagent of ethyl nicotinate was prepared using TMPMgCl·LiCl at –30 °C and combined with phenyl titanium reagent at that temperature. IR (neat): 3058, 2982, 1720, 1582, 1432, 1281, 1133, 757, 698; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.79 (dd, J = 4.8 Hz, 1.6 Hz, 1H), 8.13 (dd, J = 7.8 Hz, 1.6 Hz, 1H), 7.56–7.53 (m, 2H), 7.45–7.43 (m, 3H), 7.38–7.35 (m, 1H), 4.16 (q, J = 7.2 Hz, 2H), 1.05 (t, J = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm)168.1, 158.8, 151.0, 140.0, 138.0, 128.7, 128.6, 128.1, 127.5, 121.7, 61.5, 13.6.

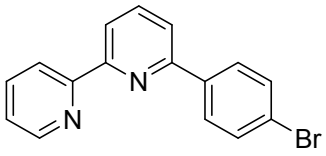


6-Phenyl-2,2'-bipyridine (5fa) [13]

Yield 82%, whitish solid, m.p.= 84.3–85.2 °C（lit. 85 °C).

2,2'-Bipyridin-6-yllithium was prepare from 6-bromo-2,2'-bipyridine using n-BuLi according to the reported procedure[14], and combined with titanium reagent at –40 °C. IR (neat): 3056, 1576, 1453, 1423, 757; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.71 (d, J = 4.8 Hz, 1H), 8.66 (d, J = 8.0 Hz, 1H), 8.40 (d, J = 7.8 Hz, 1H), 8.16 (d, J = 7.2 Hz, 2H), 7.92–7.86 (m, 2H), 7.79 (d, J = 7.8

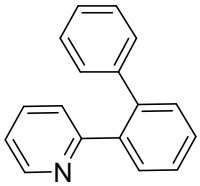
Hz, 1H), 7.52 (t, *J* = 7.1 Hz, 2H), 7.47–7.43 (m, 1H), 7.36–7.33 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.5, 156.2, 155.5, 148.9, 139.3, 137.7, 137.1, 129.0, 128.7, 127.0, 123.8, 121.4, 120.4, 119.4.



6-(4-Bromophenyl)-2,2'-bipyridine (5fe) [15]

Yield 61%, whitish solid, m.p. = 96.6–97.3 °C.

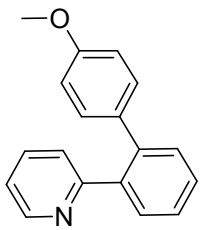
The product was prepared as described in **5fa**. IR (neat): 3010, 1582, 1560, 1489, 1431, 1009, 771; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.70 (d, *J* = 4.8 Hz, 1H), 8.60 (d, *J* = 8.0 Hz, 1H), 8.39 (d, *J* = 7.8 Hz, 1H), 8.03 (d, *J* = 8.5 Hz, 2H), 7.90–7.84 (m, 2H), 7.74 (d, *J* = 7.8 Hz, 1H), 7.63 (d, *J* = 8.6 Hz, 2H), 7.35–7.32 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 156.1, 155.7, 155.3, 149.0, 138.2, 137.9, 137.0, 131.9, 128.5, 123.9, 123.5, 121.3, 120.0, 119.7.



2-(Biphenyl-2-yl)pyridine (5ga) [16]

Yield 82%, whitish solid, m.p. = 80.7–82.2 °C（lit. 84–85 °C）.

2-(Pyridin-2-yl)phenyl magnesium reagent was prepared from 2-phenylpyridine using TMPMgCl·LiCl[17], and combined with titanium reagent at room temperature. IR (neat): 3057, 3019, 1587, 1470, 1428, 1172, 751; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.64 (dt, *J* = 4.9 Hz, 0.6 Hz, 1H), 7.72–7.70 (m, 1H), 7.49–7.44 (m, 3H), 7.43–7.38 (m, 1H), 7.24–7.23 (m, 3H), 7.17–7.11 (m, 3H), 7.13–7.11 (m, 1H), 6.90 (d, *J* = 7.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 159.2, 149.3, 141.3, 140.6, 139.3, 135.4, 130.5, 129.7, 128.6, 128.0, 127.7, 126.7, 125.5, 122.4, 121.4.

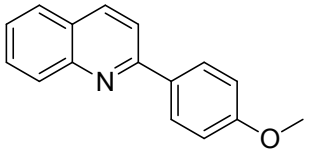


2-(4'-Methoxybiphenyl-2-yl)pyridine (5gb) [18]

Yield 76%, whitish solid, m.p. = 69.2–71.2 °C（lit. 69–71 °C).

The product was prepared as described in **5ga**. IR (neat): 3059, 2957, 2835, 1605, 1511, 1465,

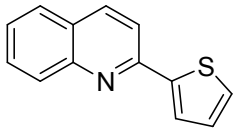
1246, 1178, 1032, 781; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.65 (dd, *J* = 5.0 Hz, 0.8 Hz, 1H), 7.70–7.68 (m, 1H), 7.60–7.40 (m, 4H), 7.14–7.11 (m, 1H), 7.07 (d, *J* = 8.8 Hz, 2H), 6.92 (d, *J* = 7.9 Hz, 1H), 6.77 (d, *J* = 8.8 Hz, 2H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 159.1, 158.6, 148.9, 140.3, 138.7, 135.7, 133.6, 130.8, 130.6, 130.5, 128.7, 127.4, 125.6, 121.4, 113.6, 55.2.



2-(4-Methoxyphenyl)quinoline (5hb)

Yield 80%, pale yellow solid, m.p. = 123.3–124.0 °C（lit. 123°C [13]).

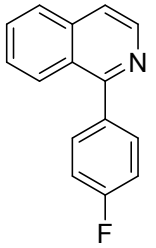
2-Quinoline metal reagent was prepared from quinoline using BF_3·Et_2O and TMPMgCl·LiCl according to Knochel's method[19] and combined with the titanium reagent at –40 °C. IR (neat): 2962, 1601, 1583, 1496, 1432, 1250, 1178, 820, 790; ^{1}H NMR ($CDCl_3$, 400MHz) δ (ppm) 8.20-8.14 (m, 4H), 7.85–7.79 (m, 2H), 7.73–7.69 (m, 1H), 7.50–7.48 (m, 1H), 7.05 (d, *J* = 8.8 Hz, 2H), 3.89 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 160.9, 156.9, 148.1, 136.8, 132.1, 129.7, 129.4, 128.9, 127.4, 126.9, 126.0, 118.6, 114.2, 55.4.



2-(2-thienyl)quinoline (5hf) [20]

Yield 86%, pale yellow solid, m.p. = 131.2–132.0 °C（lit. 131–133 °C).

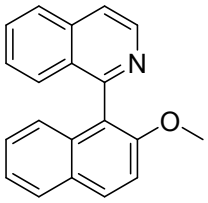
The product was prepared as described in **5hb**. IR (neat): 3076, 1617, 1593, 1562, 1502, 1033, 834; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.14–8.09 (m, 2H), 7.80–7.67 (m, 4H), 7.50–7.46 (m,2H), 7.16 (dd, *J* = 4.8 Hz, 3.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 152.3, 147.9, 145.4, 136.7, 129.9, 129.2, 128.6, 128.1, 127.5, 127.2, 126.1, 126.0, 117.7.



1(4-Fluorophenyl)isoquinoline (5ig) [21]

Yield 89%, whitish solid, m.p. = 83.7–84.4 °C.

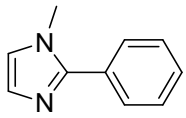
1-Isoquinoline metal reagent was prepared from isoquinoline using TMPMgCl·LiCl according to the reported method[19] and combined with the titanium reagent at 0 °C. IR (neat): ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.59 (d, *J* = 5.7 Hz, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.88 (d, *J* = 8.2 Hz, 1H), 7.70–7.63 (m, 4H), 7.56–7.52 (m, 1H), 7.22 (t, *J* = 8.6 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 164.3, 161.9, 159.6, 142.1, 137.0, 135.6(d, 135.61, 135.58), 131.7(d, 131.77, 131.70), 130.1, 127.3–127.2(d, 127.34, 127.27), 127.1, 126.6, 120.1, 115.5–115.3(d, 115.5, 115.3).



1-(2-Methoxynaphthalen-1-yl)-isoquinoline (5ih) [22]

Yield 91%, whitish solid, m.p. = 127.3–128.5 °C（lit. 125–126 °C).

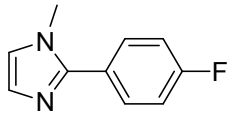
The product was prepared as described in **5ig**. IR (neat): 3050, 2935, 2837, 1621, 1510, 1257, 1084, 808, 747; ^{1}H NMR ($CDCl_3$, 400MHz) δ (ppm) 8.74 (d, *J* = 5.8 Hz, 1H), 8.01 (d, *J* = 9.1 Hz, 1H), 7.92 (d, *J* = 8.3 Hz, 1H), 7.87 (d, *J* = 8.1 Hz, 1H), 7.76 (d, J = 5.8 Hz, 1 H), 7.67 (t, *J* = 7.1 Hz, 1H), 7.51 (d, *J* = 8.4 Hz, 1H), 7.44 (d, *J* = 9.1 Hz, 1H), 7.39 (t, *J* = 7.8 Hz, 1H), 7.34–7.30 (m, 1H), 7.26–7.22 (m, 1H), 7.02 (d, *J* = 8.5 Hz, 1H), 3.77 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.1, 154.8, 142.6, 136.3, 133.8, 130.5, 130.2, 129.0, 128.8, 127.9, 127.5, 127.2, 126.9, 126.8, 124.8, 123.7, 121.8, 120.2, 113.4, 56.6.



1-Methyl-2-phenyl-1*H*-imidazole (5ja) [23]

Yield 92%, yellow oil.

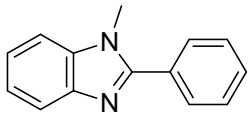
(1-Methyl-1*H*-imidazole-2-yl)lithium was prepared from N-methyl imidazole using TMPLi according to the reported literature[24] and combined with the titanium reagent at –40 °C. IR (neat): 3259, 3106, 2928, 1476, 1405, 1280, 773, 702; ^{1}H NMR ($CDCl_3$, 400MHz) δ (ppm) 7.65 (dd, *J* = 8.2 Hz, 1.6 Hz, 2H), 7.50–7.41 (m, 3H), 7.16 (s, 1H), 7.01 (d, *J* = 0.7 Hz, 1H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 147.4, 129.4, 129.1, 128.8, 128.7, 127.3, 122.4, 34.7.



2-(4-Fluorophenyl)-1-methyl-1*H*-imidazole (5jg)

Yield 83%, yellow oil.

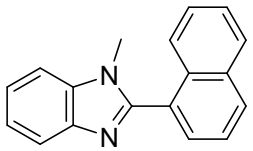
The product was prepared as described in **5ja**. IR (neat): 3245, 3058, 2928,1483, 1277, 1153, 796; ^{1}H NMR ($CDCl_3$, 400MHz) δ (ppm) 7.76–7.72 (m, 2H), 7.21–7.16 (m, 4H), 3.86 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 165.4, 162.9, 144.8, 131.6–131.5 (d, 131.63, 131.54), 123.2–122.5 (d, 123.18, 122.46), 121.0(d, 121.02, 120.98), 116.6–116.4 (d, 116.58, 116.36), 35.5. Anal. Calcd for $C_{10}H_9FN_2$: C, 68.17; H, 5.15; N, 15.90; Found: C, 68.38; H, 5.28; N, 15.56. MS (ESI): $[M+H]^+$ (m/z 177).



1-Methyl-2-phenyl-1*H*-benzo[*d*]imidazole (5ka) [25]

Yield 92%, pale yellow solid, m.p. = 94.4–95.2 °C（lit. 94.7 °C）.

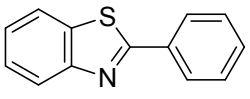
(1-Methyl-1*H*-benzo[*d*]imidazole-2-yl)lithium was prepared from N-methyl benzoimidazole using TMPLi at 0 °C according to reported literature[26] and combined with the titanium reagent at 0°C. IR (neat): 3242, 3050, 1467, 1383, 1276, 773, 754; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.84 (dd, *J* = 4.8 Hz, 1.5 Hz, 1H), 7.76 (dd, *J* = 7.9 Hz, 2.1 Hz, 2H), 7.54–7.50 (m, 3H), 7.40–7.38 (m, 1H), 7.34–7.29 (m, 2H), 3.86 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 153.8, 142.9, 136.6, 130.2, 129.7, 129.5, 128.7, 122.8, 122.4, 119.8, 109.6, 31.7.



1-Methyl-2-(naphthalen-1-yl)-1*H*-benzo[*d*]imidazole (5ki)

Yield 92%, whitish solid, m.p. = 137.8–139.0 °C.

The product was prepared as described in **5ka**. IR (neat): 3045, 2935, 1496, 1456, 1324, 1281, 838, 763; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.02 (d, *J* = 8.2 Hz, 1H), 7.95 (d, *J* = 7.7 Hz, 1H), 7.92–7.89 (m, 1H), 7.73 (d, *J* = 8.2 Hz, 1H), 7.69 (dd, *J* = 7.0 Hz, 1.1 Hz, 1H), 7.62–7.59 (m, 1H), 7.54 (dt, *J* = 8.0 Hz, 1.2 Hz, 1H), 7.51–7.45 (m, 2H), 7.41–7.35 (m, 2H), 3.62 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 152.9, 143.1, 135.9, 133.5, 132.1, 130.4, 128.9, 128.5, 127.7, 127.2, 126.4, 125.4, 125.0, 122.9, 122.4, 120.0, 109.6, 31.1. Anal. Calcd for $C_{18}H_{14}N_2$: C, 83.69; H, 5.46; N, 10.84; Found: C, 83.29; H, 5.88; N, 10.83. MS(ESI): $[M+H]^+$ (m/z 259).

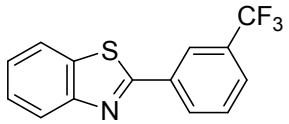


2-Phenylbenzothiazole (5la) [27]

Yield 94%, whitish solid, m.p. = 113.7–114.5 °C（lit. 114 °C）.

The lithium reagent of benzothiazole was prepared from benzothiazole using TMPLi at –40 °C and combined with the titanium reagent at room temperature. IR (neat): 3054, 1587, 1477, 1432, 756; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.09–8.06 (m, 3H), 7.87 (d, *J* = 8.0 Hz, 1H), 7.49–7.45 (m, 4H), 7.35 (t, *J* = 8.0 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 168.1, 154.1, 135.1, 133.6, 131.0, 129.0, 127.6, 126.3, 125.2, 123.3, 121.6.

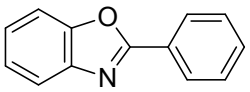
Note: this compound was also prepared in the same yield using benzo[d]thiazol-2-ylmagnesium bromide, which was prepared from benzothiazole using EtMgBr at 10–15 °C according to reported literature[28].



2-(3-Trifluoromethylphenyl)benzothiazole (5lj) [29]

Yield 92%, pale yellow solid, m.p. = 87.7–88.4 °C（lit. 87–88 °C）.

The product was prepared as described in **5la**. IR (neat): 3058, 1617, 1552, 1446, 1052, 743; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (pp m) 8.38 (s, 1H), 8.24 (d, *J* = 7.8 Hz, 1H), 8.10 (d, *J* = 8.1 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.74 (d, *J* = 7.8 Hz, 1H), 7.62 (t, *J* = 7.8 Hz, 1H), 7.52 (t, *J* = 7.2 Hz, 1H), 7.42 (t, *J* = 7.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 166.1, 154.1, 135.2, 134.5, 132.2–131.2(q), 130.7, 129.6, 127.4–127.3(q), 126.6, 125.2, 124.4–124.2 (q), 123.0, 121.8, 127.9–119.8 (q, 127.9, 125.7, 122.5, 119.8).



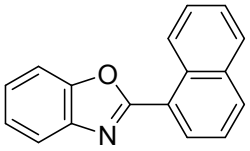
2-Phenylbenzoxazole (5ma) [30]

Yield 88%, pale yellow solid, m.p. = 102.4–103.4 °C（lit. 103.1–104.4 °C）.

The lithium reagent of benzoxazole was prepared from benzoxazole using TMPLi at –40 °C and combined with the titanium reagent at room temperature. IR (neat): 3052, 3004, 1614, 1248, 1040, 793; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.26 (dd, *J* = 5.4 Hz, 2.0 Hz, 1H), 7.80 (d, *J* = 7.2 Hz, 2H), 7.60–7.51 (m, 3H), 7.47 (t, *J* = 7.2 Hz, 2H), 7.36–7.34 (m, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 163.0, 150.8, 142.2, 131.5, 128.9, 127.6, 127.2, 125.1, 124.6, 120.0, 110.6.

Note: this compound was also prepared in the same yield using the Benzo[d]oxazol -2-ylmagnesium chloride, which was prepared from benzoxazole using *i*-PrMgCl at –10 °C

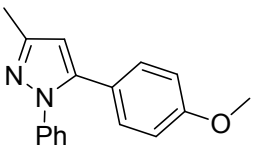
according to reported literature[31].



2-(naphthalen-1-yl)benzoxazole (5mi) [32]

Yield 81%, whitish solid, m.p. = 102.8–104.2 °C（lit. 101–104 °C）.

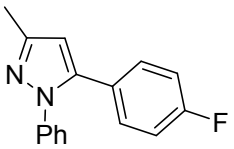
The product was prepared as described in **5ma**. IR (neat): 3046, 1538, 1452, 1243, 1120, 969, 776; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 9.46 (d, J = 8.7 Hz, 1H), 8.43 (dd, J = 6.4 Hz, 0.9 Hz, 1H), 8.03 (d, J = 8.2 Hz, 1H), 7.93 (d, J = 8.1 Hz, 1H), 7.89 (t, J = 3.4 Hz, 1H), 7.73–7.69 (m, 1H), 7.65–7.57 (m, 3H), 7.41–7.39 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 162.8, 150.2, 142.3, 134.0, 132.3, 130.7, 129.4, 128.7, 128.0, 126.5, 126.3, 125.3, 125.0, 124.5, 123.6, 120.3, 110.5.



1-Phenyl-3-methyl-5(4-methoxyphenyl)pyrazole (5nb) [33]

Yield 78%, whitish solid, m.p. = 86.7–87.8 °C（lit. 86–88 °C）.

(3-Methyl-1-phenyl-1H-pyrazol-5-yl)magnesium chloride was prepared using 5-chloro-3-methyl -1-phenyl-1H-pyrazole and Mg/LiCl according to reported literature[34] and combined with the titanium reagent at room temperature. IR (neat): 3435, 3061, 2925, 1604, 1506, 1434, 1248, 1180, 1030, 837, 760, 694; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.33–7.23 (m, 5H), 7.13 (d, J = 8.8 Hz, 2H), 6.80 (d, J = 8.8 Hz, 2H), 6.25 (s, 1H), 3.78 (s, 3H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 159.4, 149.3, 143.5, 140.3, 129.9, 128.8, 127.0, 125.1, 123.2, 113.9, 107.2, 55.2, 13.6. Data was consistent with that reported in the literature.[35]

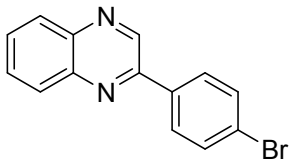


1-Phenyl-3-methyl-5(4-fluorophenyl)pyrazole (5ng)

Yield 87%, whitish solid, m.p. = 83.4–84.6 °C.

The product was prepared as described in **5nb**. IR (neat): 3325, 3043, 2961, 1604, 1502, 1462, 1290, 1111, 793, 666; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.79 (d, J = 9.8 Hz, 2H), 7.51–7.41 (m, 5H), 7.08 (d, J = 9.2 Hz, 2H), 6.35 (s, 1H), 2.40 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm)

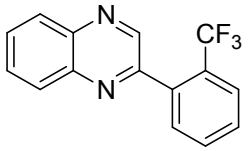
162.4, 150.1, 144.5, 141.5, 131.0, 130.8, 127.0, 126.5, 123.7, 117.2, 108.3, 17.5. Anal. Calcd for $C_{18}H_{14}N_2$: C, 76.17; H, 5.19; N, 11.10; Found: C, 76.19; H, 5.18; N, 11.07. MS(ESI): $[M+H]^+$ (m/z 253).



2-(4-Bromophenyl)quinoxaline (5oe) [35]

Yield 77%, whitish solid, m.p. = 128.4–130.0 °C (lit. 128 °C).

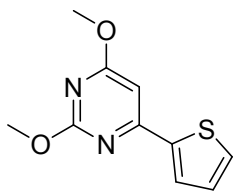
Quinoxalin-2-ylmagnesium chloride was prepared from quinoxaline using $TMP_2Mg{\cdot}2LiCl$ according to the reported literature[36] and combined with the titanium reagent at 0 °C. IR (neat): 3059, 1586, 1484, 1072, 1007, 956, 761; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 9.30 (s, 1H), 8.16–8.08 (m, 4H), 7.82–7.75 (m, 2H), 7.70 (d, J = 8.6 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 150.7, 142.7, 142.2, 141.6, 135.6, 132.4, 130.5, 129.9, 129.6, 129.1, 129.0, 125.0.



2-(2-Trifluoromethylphenyl)quinoxaline(5oj)

Yield 87%, yellow oil.

The product was prepared as described in **5oe**. IR (neat): 3063, 1605, 1486, 1312, 1168, 1118, 959, 762; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 9.00 (s, 1H), 8.20–8.16 (m, 2H), 7.87–7.81 (m, 3H), 7.69 (d, J = 7.5 Hz, 1H), 7.65–7.62 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 153.0, 145.1–145.0(q), 141.7, 141.5, 136.8(d, 136.84, 136.83), 131.9, 131.8, 130.5, 130.2, 129.7, 129.4, 129.3, 129.36–128.44 (q, 129.36, 129.05, 128.75, 128.44), 126.77–126.62 (q, 126.77, 126.72, 126.67, 126.62), 128.0–119.9 (q, 128.0, 125.3, 122.6, 119.9). Anal. Calcd for $C_{15}H_9F_3N_2$: C, 65.69; H, 3.31; N, 10.21; Found: C, 65.81; H, 3.23; N, 10.17. MS(ESI): $[M+H]^+$ (m/z 275).

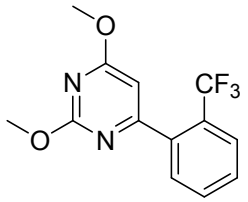


2,4-Dimethoxy-6-(thiophen-2-yl)-pyrimidine(5pf)

Yield 80%, pale yellow solid, m.p. = 43.7– 44.5 °C.

(2,6-Dimethoxypyrimidin-4-yl)magnesium chloride was prepared from 2,4-dimethoxy pyrimidine

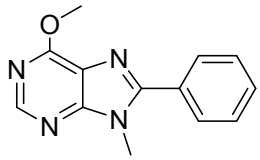
using TMPMgCl·LiCl according to the reported literature[37] and combined with the titanium reagent at room temperature. IR (neat): 3097, 2950, 1585, 1477, 1455, 1356, 1209, 1102, 822, 713; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.71 (dd, *J* = 3.7 Hz, 0.8 Hz, 1H), 7.46 (dd, *J* = 5.0 Hz, 0.7 Hz, 1H), 7.12 (dd, *J* = 4.8 Hz, 3.8 Hz, 1H), 6.65 (s, 1H), 4.05 (s, 3H), 4.00 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 172.4, 165.3, 160.7, 142.2, 129.2, 128.1, 126.9, 95.2, 54.8, 54.0. Anal. Calcd for $C_{10}H_{10}N_2O_2S$: C, 54.04; H, 4.53; N, 12.60; Found: C, 54.12; H, 4.54; N, 12. 51. MS (ESI): $[M+H]^+$ (m/z 223).



2,4-Dimethoxy-6-(2- Trifluoromethylphenyl)pyrimidine(5pj)

Yield 80%, whitish solid, m.p. = 38.2–40.0 °C.

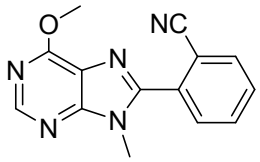
The product was prepared as described in **5pf**. IR (neat): 2956, 2870, 1602, 1513, 1477, 1247. 1026, 827; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.77 (d, J = 7.3 Hz, 1H), 7.63–7.52 (m, 2H), 7.50 (d, J = 7.5 Hz, 1H), 6.50 (s, 1H), 4.02(s, 3H), 4.01(s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 171.8, 167.1, 165.0, 137.8 (d, 137.84, 137.82), 131.7, 130.9, 129.1, 128.8–127.9 (q, 128.8, 128.5, 128.2, 127.9), 126.8–126.6 (q, 126.76, 126.71, 126.65, 126.60), 128.0–119.8 (q, 127.98, 125.26, 122.54, 119.82), 101.7(d, 101.66, 101.65), 65.0, 54.0. Anal. Calcd for $C_{13}H_{11}F_3N_2O_2$: C, 54.93; H, 3.90; N, 20.05; Found: C, 54.82; H, 4.04; N, 20.02. MS (ESI): $[M+H]^+$ (m/z 285).



6-Methoxy-9-methyl-8-phenyl-9*H*-purine (5qa) [38]

Yield 80%, whitish solid, m.p. = 118.3–119.2 °C（lit. 118–119°C）.

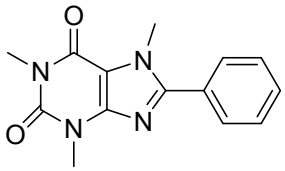
(6-Methoxy-9-methyl-9H-purin-8-yl)magnesium chloride was prepared from 6-methoxy-9-methyl purine using TMPMgCl·LiCl according to the reported literature[39] and combined with the titanium reagent at 0 °C. IR (neat): 3212, 2924, 2853, 1618, 1477, 1344, 1131, 1060, 768; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.57 (s, 1H), 7.84 (d, *J* = 3.1 Hz, 2H), 7.53 (t, *J* = 3.0 Hz, 3H), 4.22 (s, 3H), 3.96 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 160.7, 154.0, 152.9, 151.6, 130.3, 129.3, 129.2, 128.7, 121.3, 54.2, 31.0.



2(6-Methoxy-9-methyl-9*H*-purin -8-yl)benzonitrile (5qd)

Yield 80%, whitish solid, m.p. = 114.3–115.2 °C.

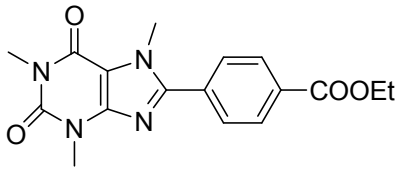
The product was prepared as described in **5qa**. IR (neat): 3218, 3033, 2939, 2227, 1600, 1592, 1479, 1345, 1070, 775; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.62 (s, 1H), 7.88 (d, *J* = 7.6 Hz, 1H), 7.81–7.76 (m, 2H), 7.71–7.66 (m, 1H), 4.23 (s, 3H), 3.87 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 161.2, 153.5, 152.5, 149.3, 133.6, 133.0, 131.5, 130.7, 121.4, 117.0, 113.3, 54.4, 30.6. Anal. Calcd for $C_{14}H_{11}N_5O$: C, 63.39; H, 4.18; N, 26.40; Found: C, 63.42; H, 4.14; N, 26.41. MS (ESI): $[M+H]^+$ (m/z 266).



1,3,7-Trimethyl-8-Phenyl-xanthine (5ra) [40]

Yield 80%, whitish solid, m.p. = 179.8–181.0 °C (lit. 180–181 °C).

The Grignard reagent of caffeine was prepared as follows: to a solution of caffeine (400 mg, 2.5 mmol, 1 equiv) in THF (5 ml) was added dropwise TMPMgCl·LiCl (3 mmol, 1.2 equiv) at –10 °C and stirred for 2 h at this temperature. The Grignard reagent of caffeine was combined with the titanium reagent at 0 °C. IR (neat): 2944, 1691, 1659, 1541, 1458, 1379, 1037, 753; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 7.71–7.68 (m, 2H), 7.54–7.52 (m, 3H), 4.06 (s, 3H), 3.63 (s, 3H), 3.43 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm)155.6, 152.1, 151.7, 148.3, 130.4, 129.2, 128.9, 128.4, 108.5, 33.9, 29.8, 28.0.

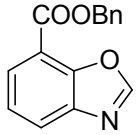


Ethyl-4-(1,3,7-trimethyl-2,6-dioxo-2,3,6,7-tetrahydro-1*H*-purin-8-yl)benzonate (5rk)

Yield 80%, whitish solid, m.p. = 173.5–174.6 °C.

The product was prepared as described in **5ra**. IR (neat): 2919, 2851, 1714, 1659, 1284, 1102, 744; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.18 (d, *J* = 8.4 Hz, 2H), 7.78 (d, *J* = 8.4 Hz, 2H), 4.62

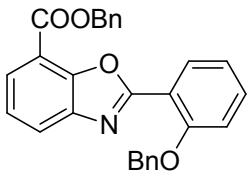
(q, J = 7.1 Hz, 2H), 4.09 (s, 3H), 3.64 (s, 3H), 3.44 (s, 3H), 1.23 (t, J = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 165.2, 155.6, 151.7, 150.9, 148.4, 132.5, 130.0, 129.1, 109.0, 60.9, 34.0, 29.8, 28.0, 14.0. Anal. Calcd for $C_{17}H_{18}N_4O_4$: C, 59.64; H, 5.30; N, 16.37; Found: C, 59.82; H, 5.14; N, 16.35. MS (ESI): $[M+H]^+$ (m/z 343).



Benzyl benzo[d]oxazole-7-carboxylate (6)

Yield 90%, whitish solid, m.p. = 118.6–119.4 °C.

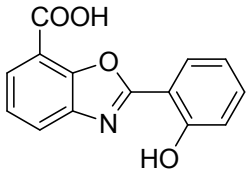
Benzyl benzo[d]oxazole-7-carboxylate was prepared from benzo[d]oxazole-7-carboxylic acid according to reported literature.[41] IR (neat): 3052, 3022, 2926, 1721, 1601, 1387, 1154, 748, 722; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.28 (d, J = 2.4 Hz, 1H), 7.69 (dd, J = 7.8 Hz, 1.5 Hz, 1H), 7.45–7.26 (m, 6H), 7.18 (t, J = 8.0 Hz, 1H), 5.36 (s, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 168.2, 160.6, 149.7, 135.1, 128.8, 128.7, 128.3, 127.9, 126.4, 126.0, 123.2, 119.4, 67.6. Anal. Calcd for $C_{15}H_{11}NO_3$: C, 71.14; H, 4.38; N, 5.53; Found: C, 71.03; H, 4.44; N, 5.58. MS(ESI): $[M+H]^+$ (m/z 254).



Benzyl 2-(2-(benzyloxy)phenyl)benzo[d]oxazole-7-carboxylate (7)

Yield 82%, whitish solid, m.p. = 143.4–145.0 °C.

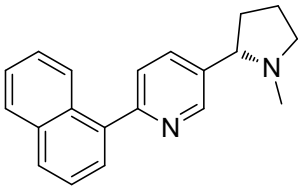
IR (neat): 3058, 3025, 2926, 1721, 1599, 1498, 1318, 1239, 1180, 751, 729; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.34 (dd, J = 8.0 Hz, 1.8 Hz, 1H), 8.05 (dd, J = 7.8 Hz, 0.9 Hz, 1H), 7.76 (dd, J = 8.1 Hz, 0.9 Hz, 1H), 7.62 (t, J = 7.2 Hz, 4H), 7.53–7.48 (m, 1H), 7.43–7.38 (m, 5H), 7.34–7.32 (m, 2H), 7.15–7.12 (m, 2H), 5.52 (s, 2H), 5.30 (s, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 165.0, 164.0, 157.8, 151.5, 141.8, 136.7, 136.3, 133.2, 132.2, 128.53, 128.49, 128.0, 127.7, 126.8, 126.7, 124.1, 122.0, 121.1, 116.5, 114.8, 113.9, 70.7, 66.7. Anal. Calcd for $C_{28}H_{21}NO_4$: C, 77.23; H, 4.86; N, 3.22; Found: C, 77.28; H, 4.84; N, 3.19. MS(ESI): $[M+H]^+$ (m/z 436).



2-(2-Hydroxyphenyl)benzo[d]oxazole-7-carboxylate (Carboxamycin) [42]

Yield 97%, whitish solid, m.p. = 238.3–240.1 °C（lit. 237–239 °C).

IR (neat): 3400, 3010, 2851, 1705, 1628, 1483, 1298, 1059, 754; ^{1}H NMR (CD_3SOCD_3, 400 MHz) δ (ppm) 13.34 (br s, 1H), 11.85 (s, 1H), 8.12 (d, *J* = 8.1 Hz, 1H), 8.04 (d, *J* = 7.8 Hz, 1H), 8.02 (d, *J* = 8.8 Hz, 1H), 7.61–7.55 (m, 2H), 7.17–7.09 (m, 2H); ^{13}C NMR (CD_3SOCD_3, 100 MHz) δ (ppm) 165.5, 163.5, 158.3, 149.4, 138.7, 134.4, 127.4, 127.1, 125.3, 121.7, 119.9, 117.3, 115.3, 109.6.

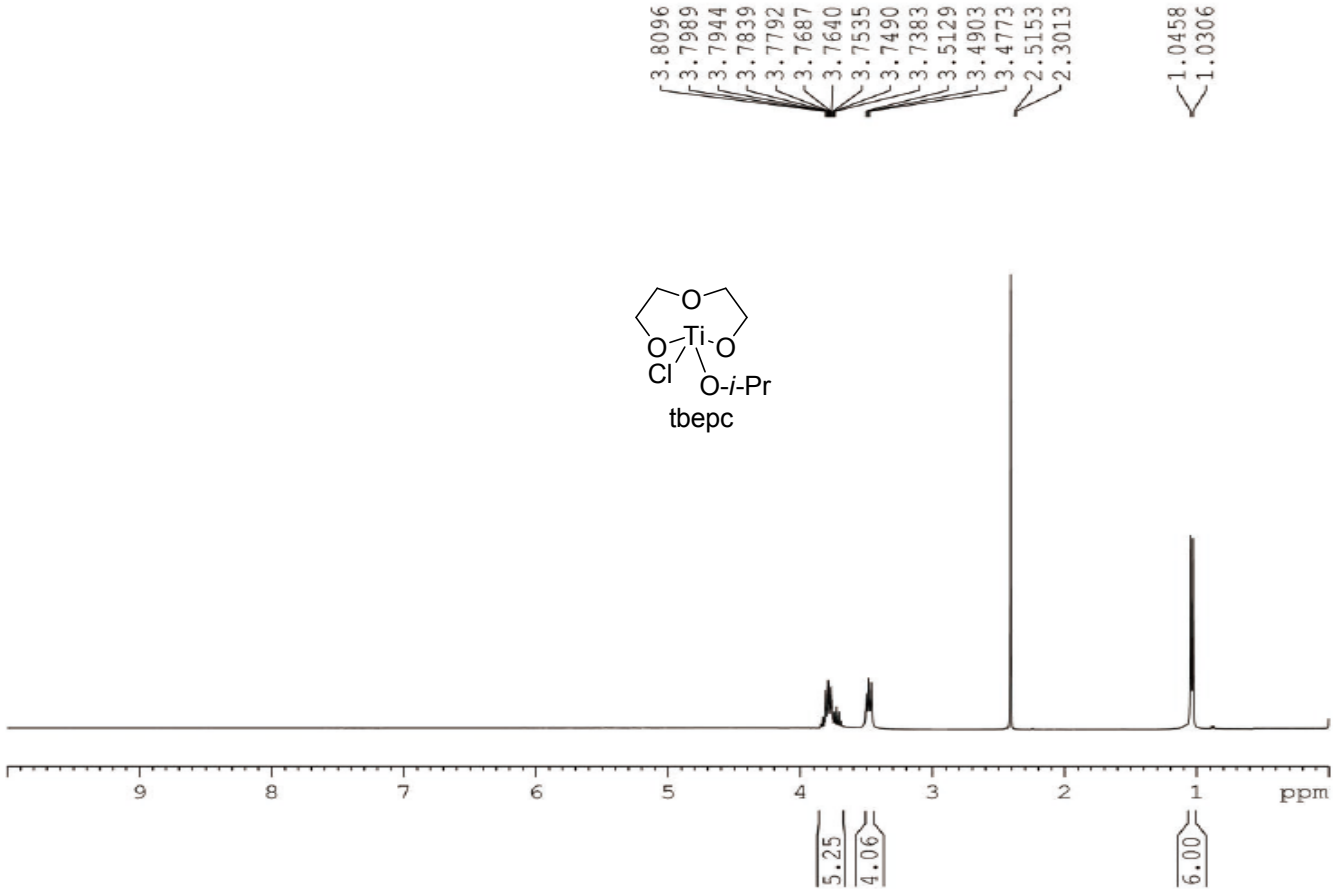


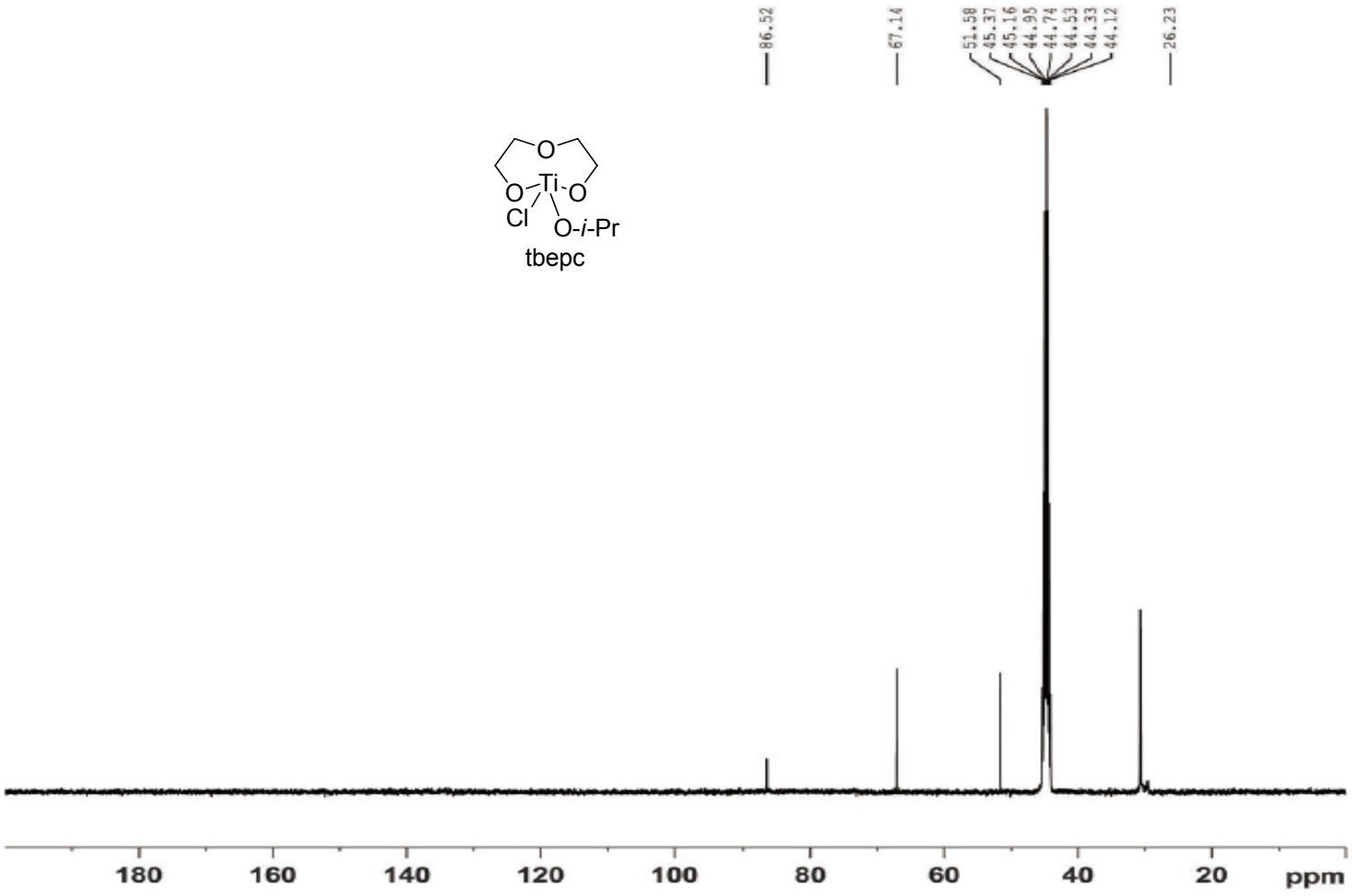
(S)-5-(N-methylpyrrolidin-2-yl)-2-(naphthalen-1-yl)pyridine (9)

Yield 92%, yellow viscous liquid

IR (neat): 3045, 2967, 2776, 1593, 1481, 1044, 802, 781; ^{1}H NMR ($CDCl_3$, 400 MHz) δ (ppm) 8.70 (d, J = 1.9 Hz, 1H), 8.12-8.09 (m, 1H), 7.89 (d, J = 7.5 Hz, 2H), 7.84 (dd, J = 8.0 Hz, 2.0 Hz, 1H), 7.60 (d, J = 6.1 Hz, 1H), 7.55 (dd, J = 8.0 Hz, 4.1 Hz, 2H), 7.49–7.45 (m, 2H), 3.31–3.27 (m, 1H), 3.20 (t, J = 8.4 Hz, 1H), 2.36 (q, J = 9.1 Hz, 1H), 2.30–2.24 (m, 4H), 2.05–1.98 (m, 1H), 1.89–1.83 (m, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ (ppm) 158.2, 149.3, 138.5, 135.3, 134.0, 131.3, 128.8, 128.3, 127.5, 126.4, 125.8, 125.7, 125.3, 125.0, 120.8, 68.8, 57.1, 40.5, 35.3, 22.7; Anal. Calcd for $C_{20}H_{20}N_2$: C, 83.30; H, 6.49; N, 9.71; Found: C,83.36; H, 6.44; N, 9.70. MS(ESI): $[M+H]^+$ (m/z 288).

7. ^{1}H and ^{13}C NMR spectra for products

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44.95
44.74
44.53
44.33
44.12
26.23
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O
Ti
O
Cl
O-i-Pr
tbepc
180
160
140
120
100
80
60
40
20
ppm


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8.6599
7.9889
7.9708
7.6667
7.6643
7.6562
7.4614
7.4437
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7.3769
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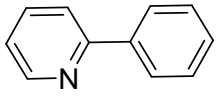
7.3587
7.2247
7.1682
7.1565
7.1476
7.1349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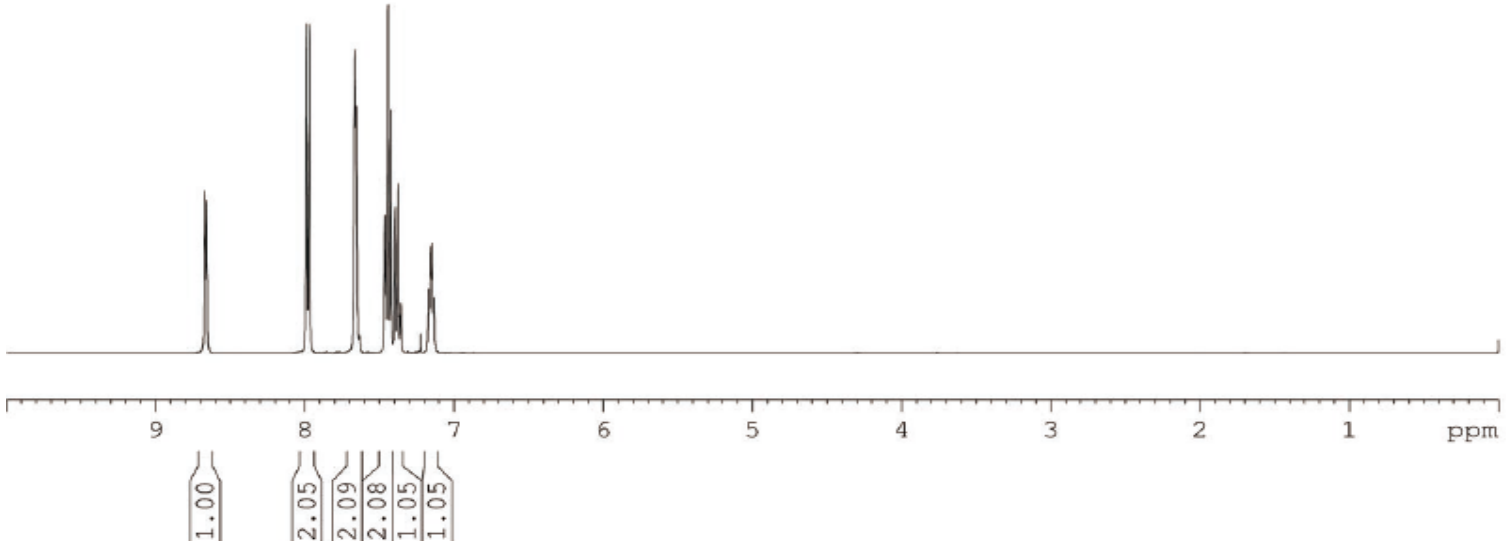
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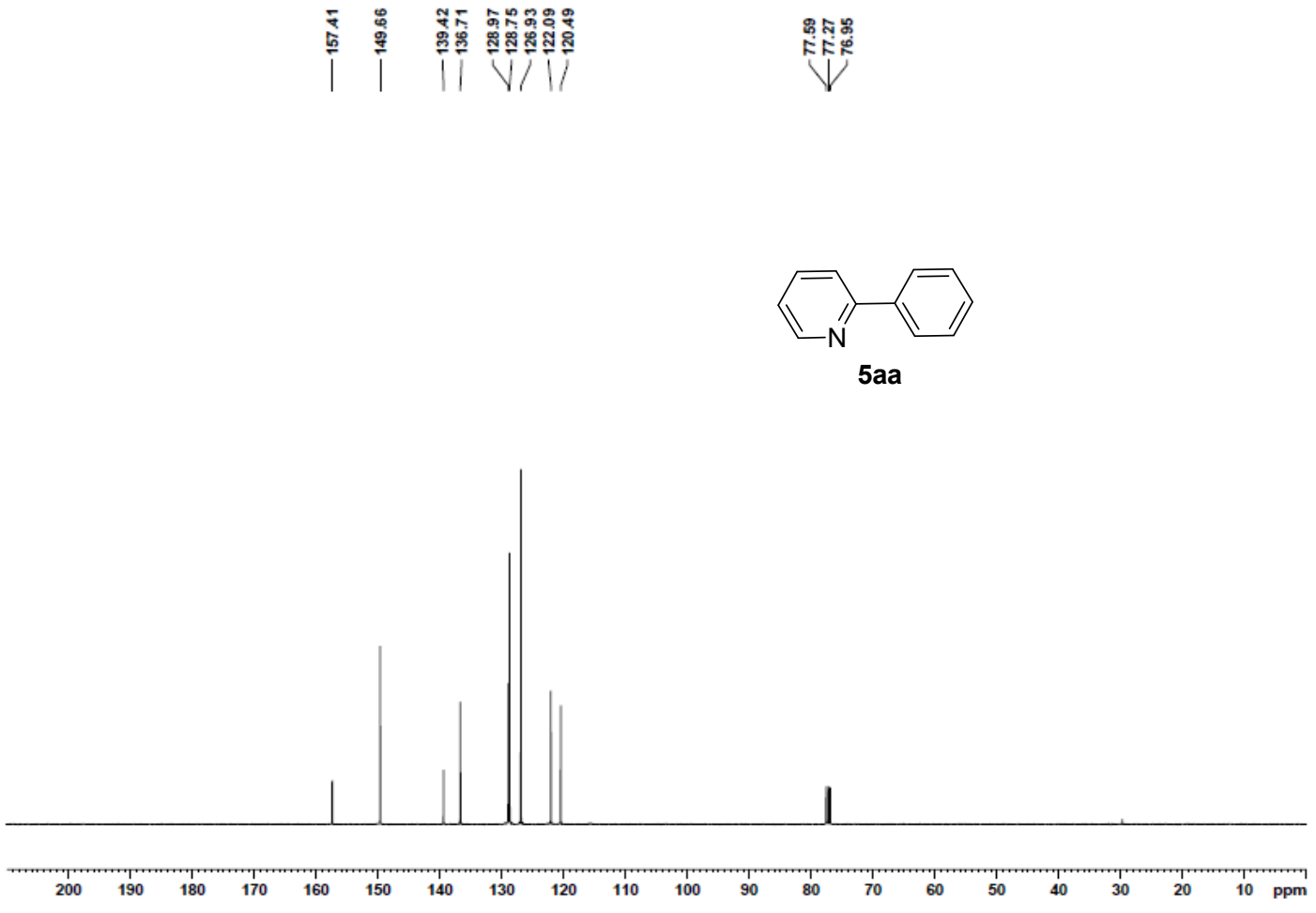
1.05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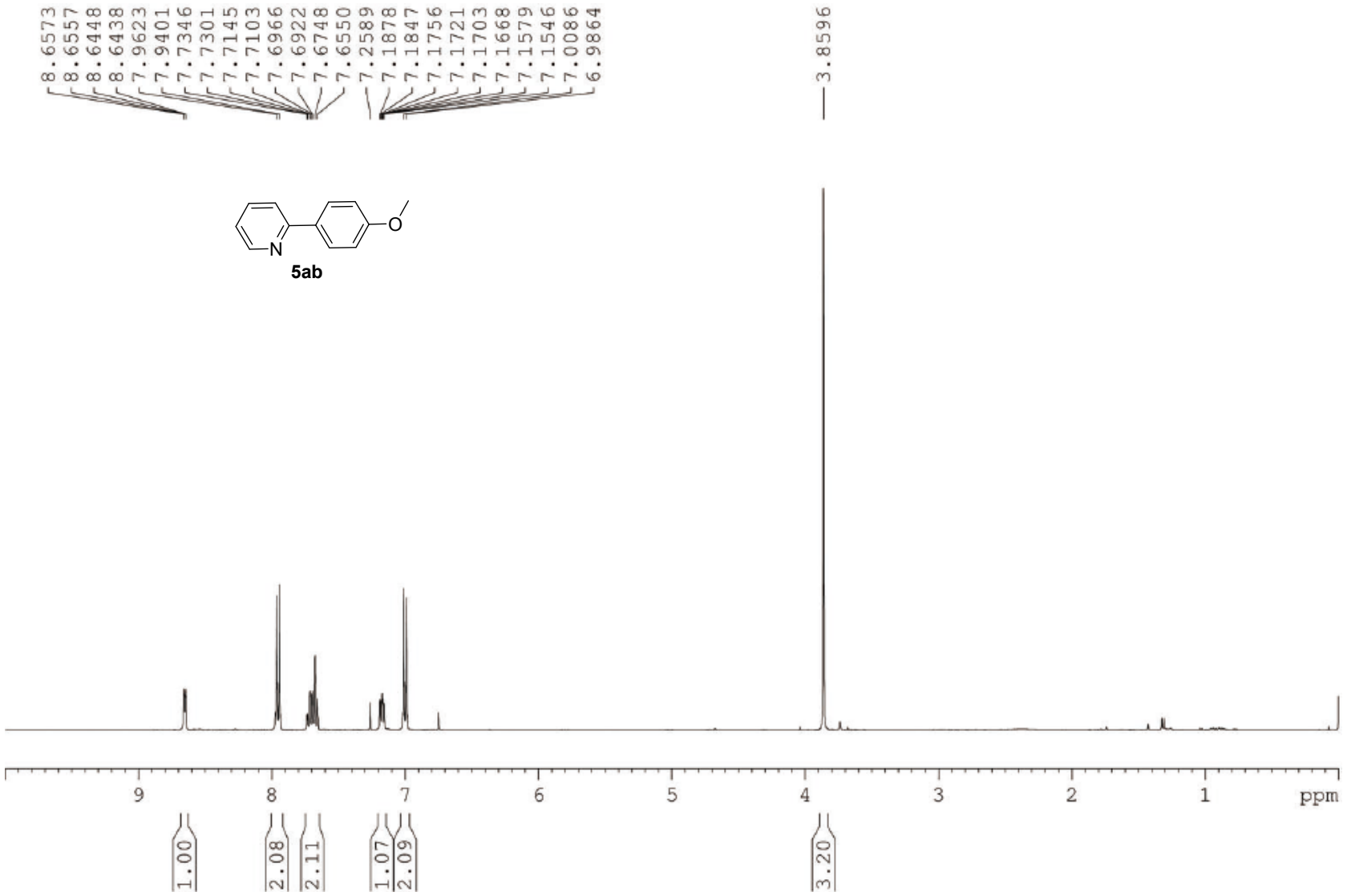
ppm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7.1546
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O
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8
7
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5
4
3
2
1
ppm
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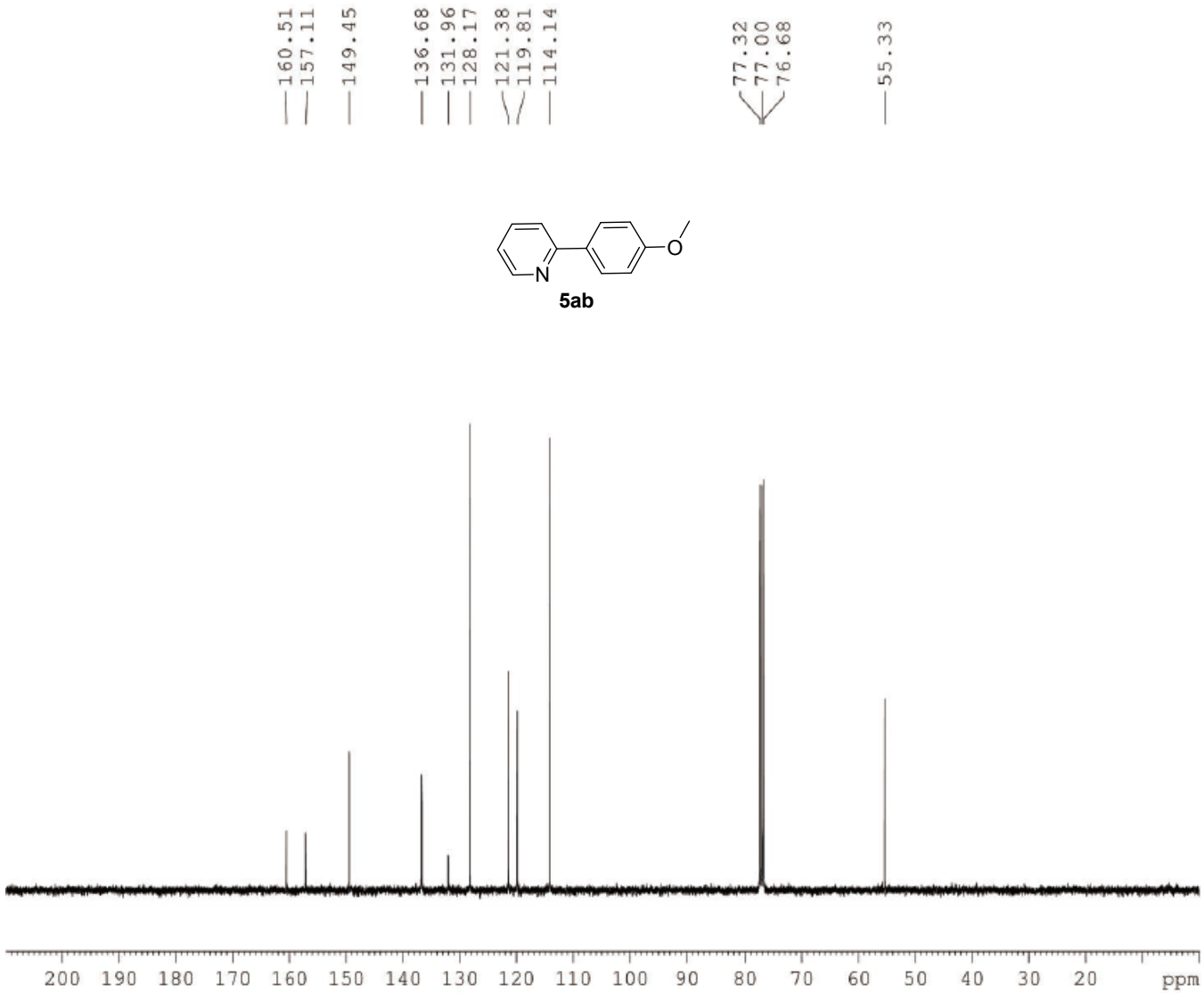
2.08
2.11
1.07
2.09
3.20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128.17
121.38
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77.00
76.68
55.33
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O
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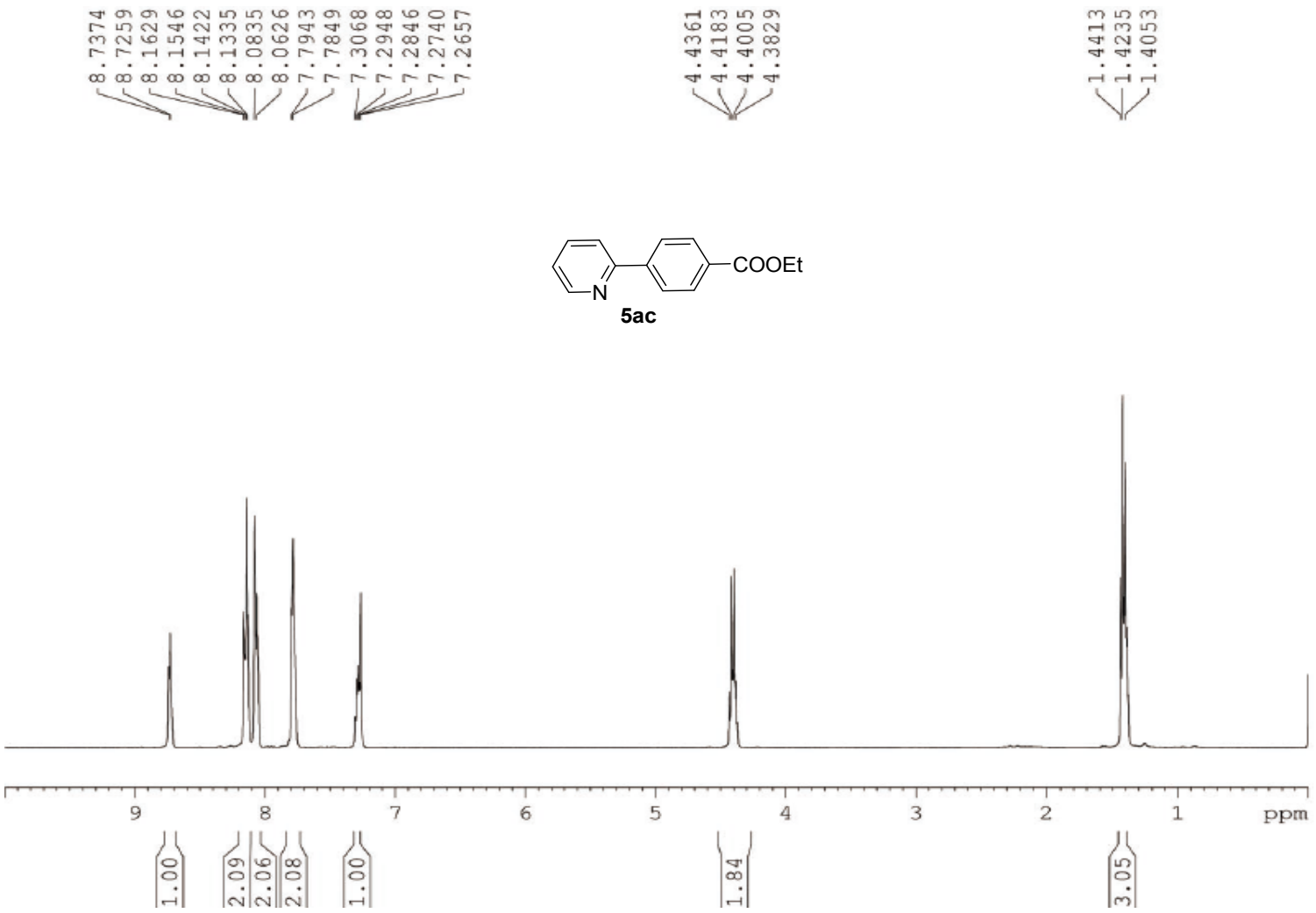
5ab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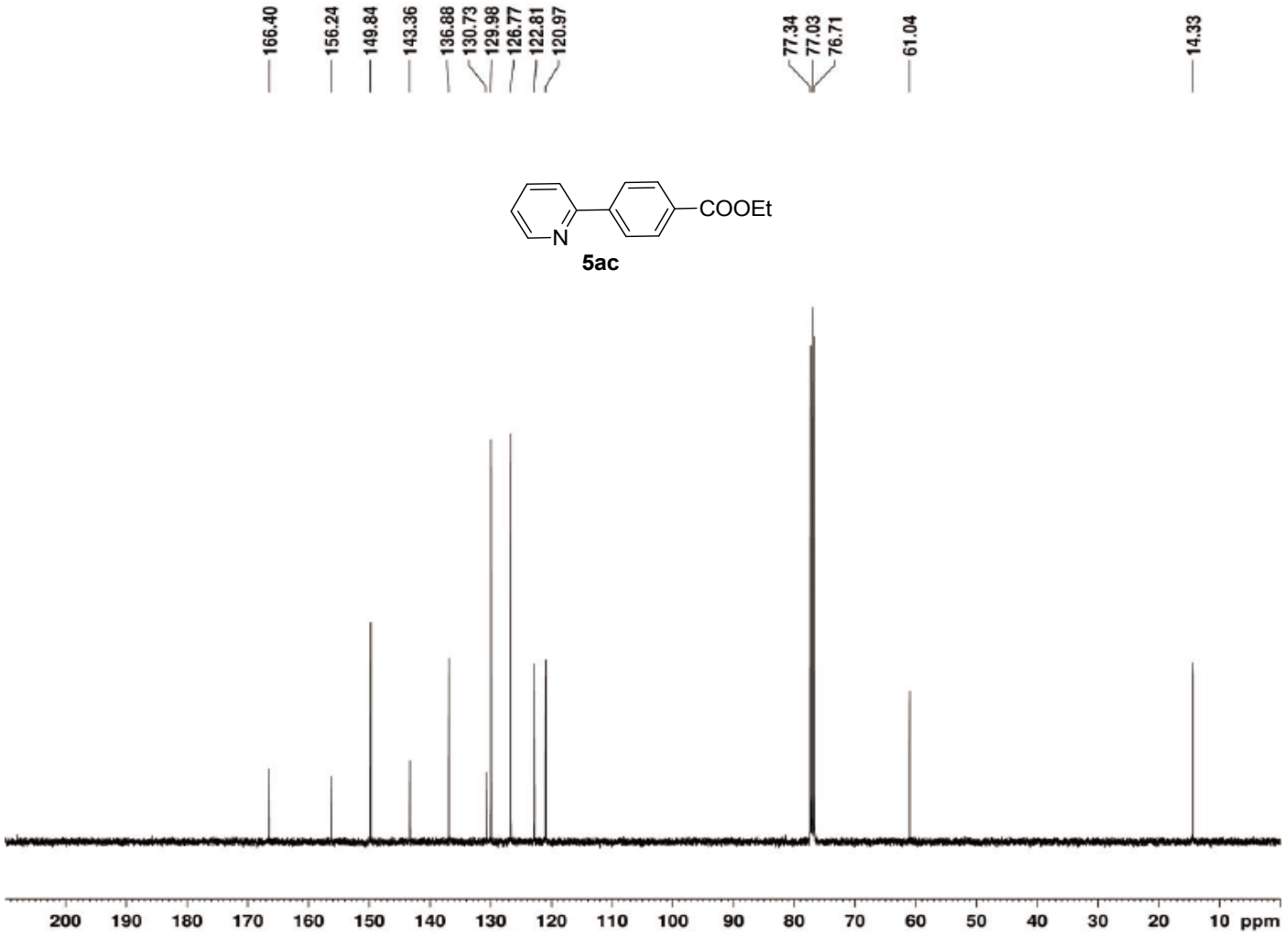
3.05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61.04
14.33
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5ac
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180
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70
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50
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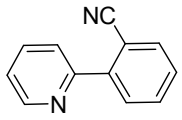
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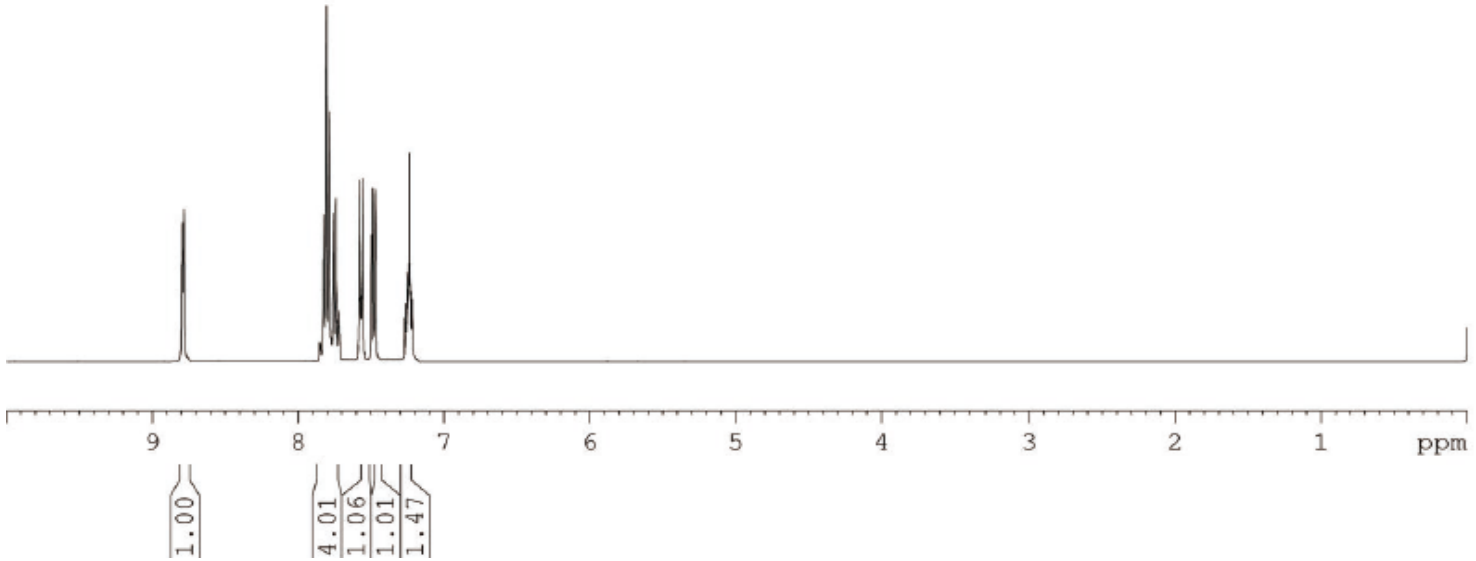
N

5ad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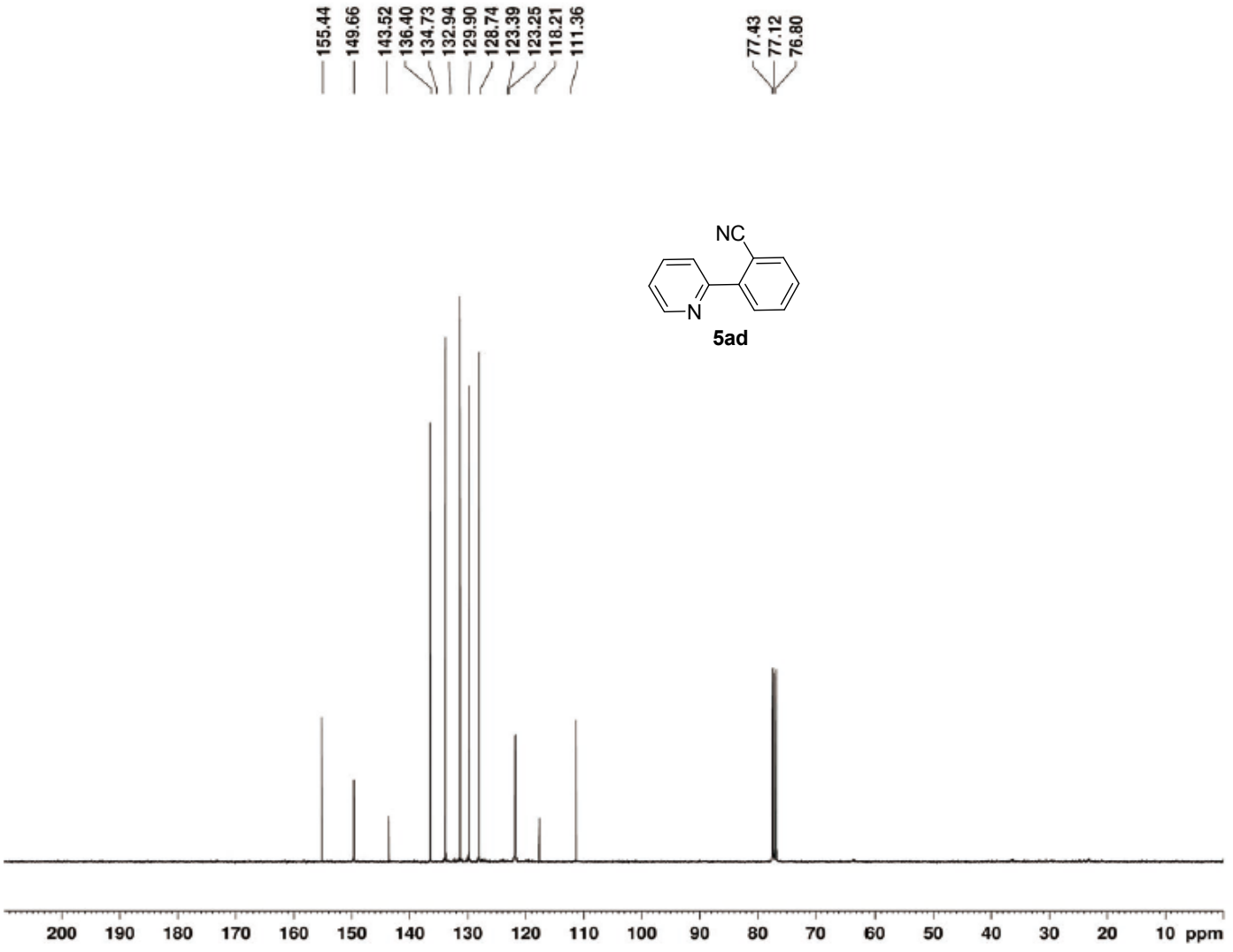
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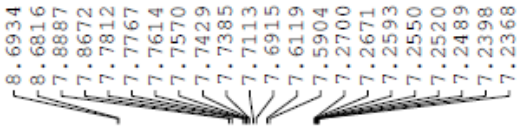
ppm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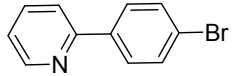
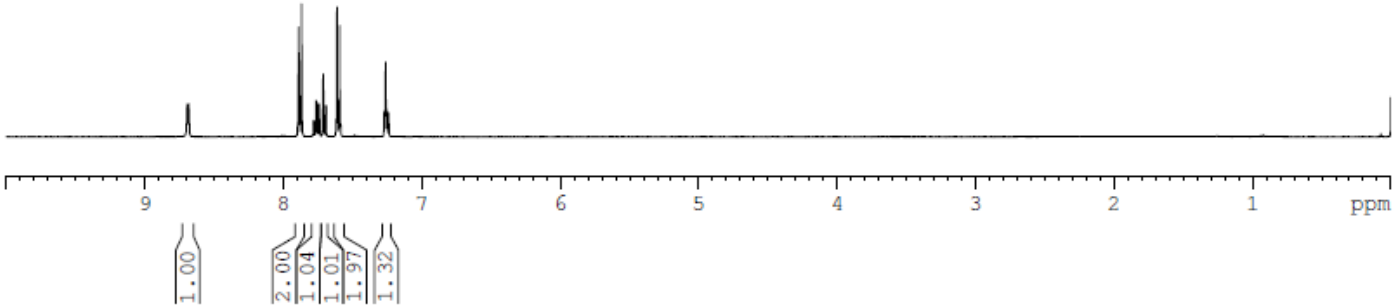

N
Br

5ae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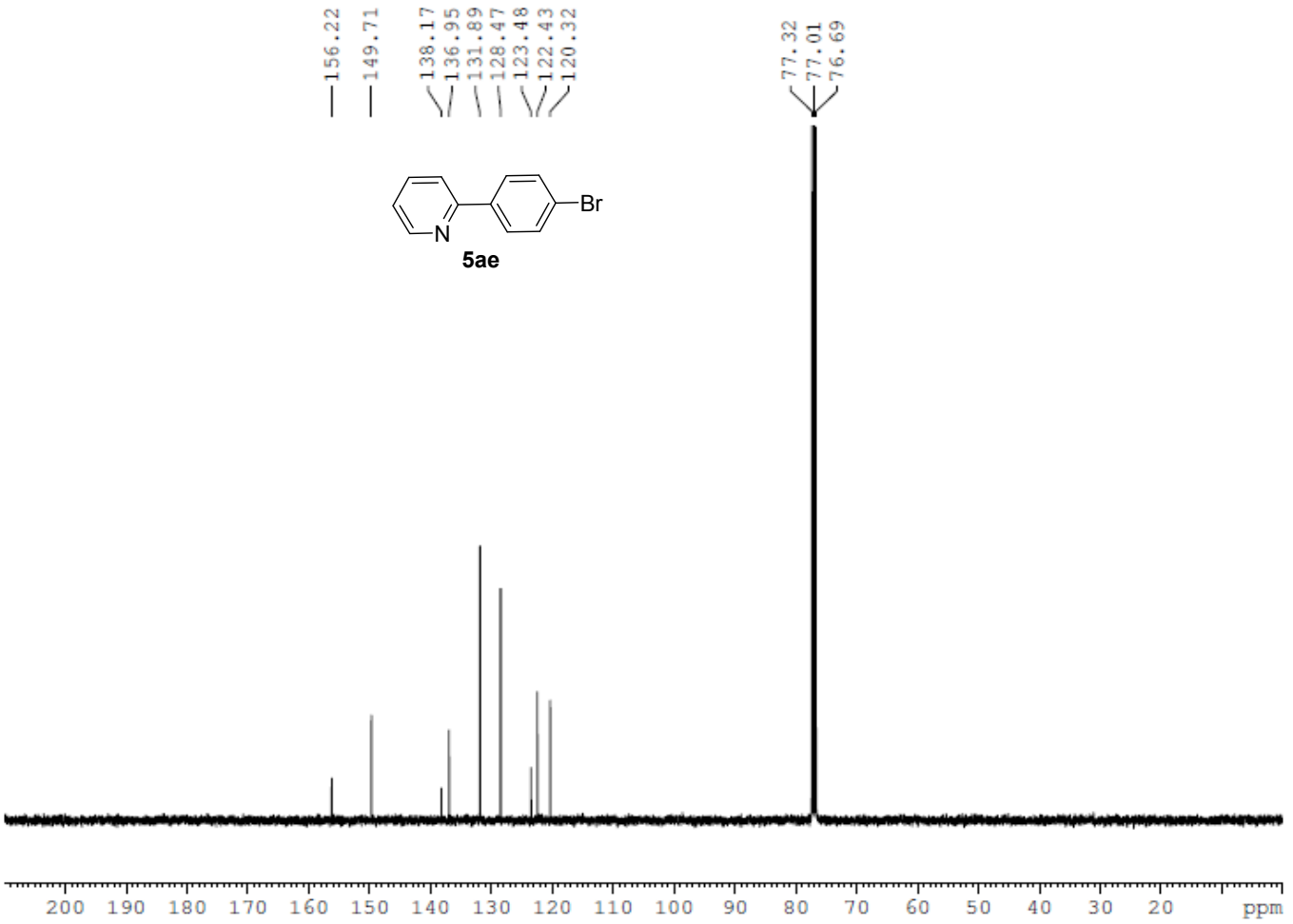
1.32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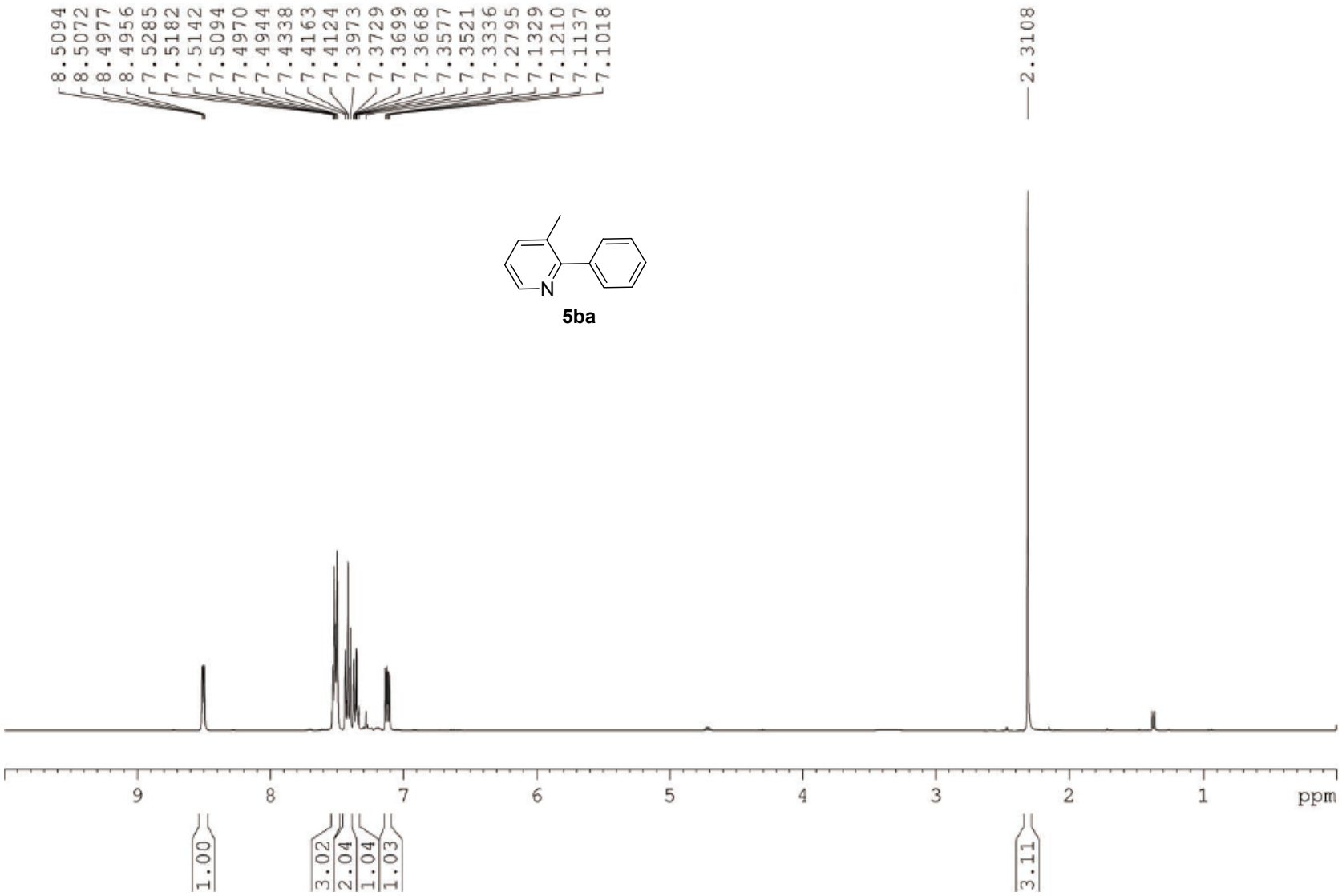
77.32
77.01
76.69
Br
N
5ae
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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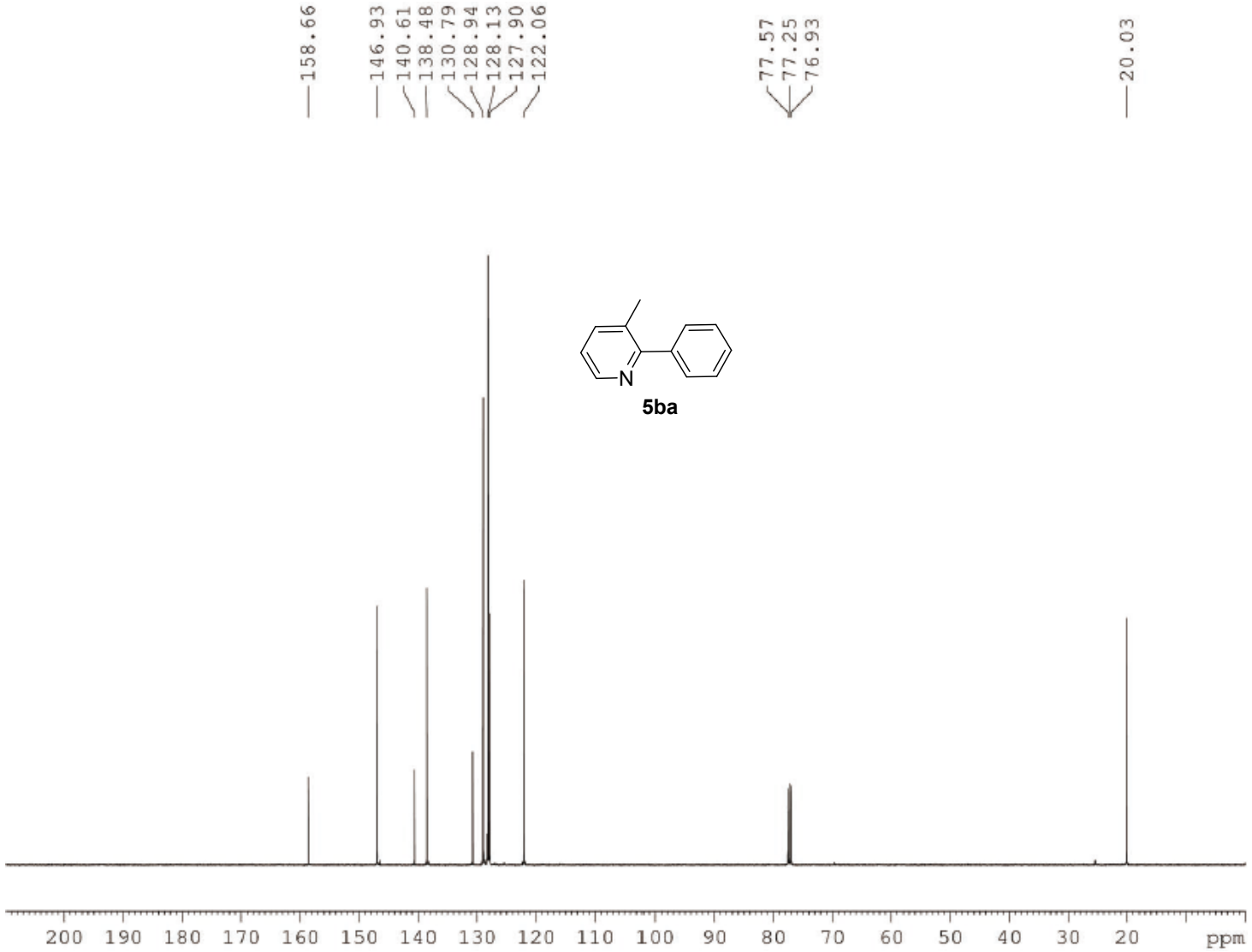
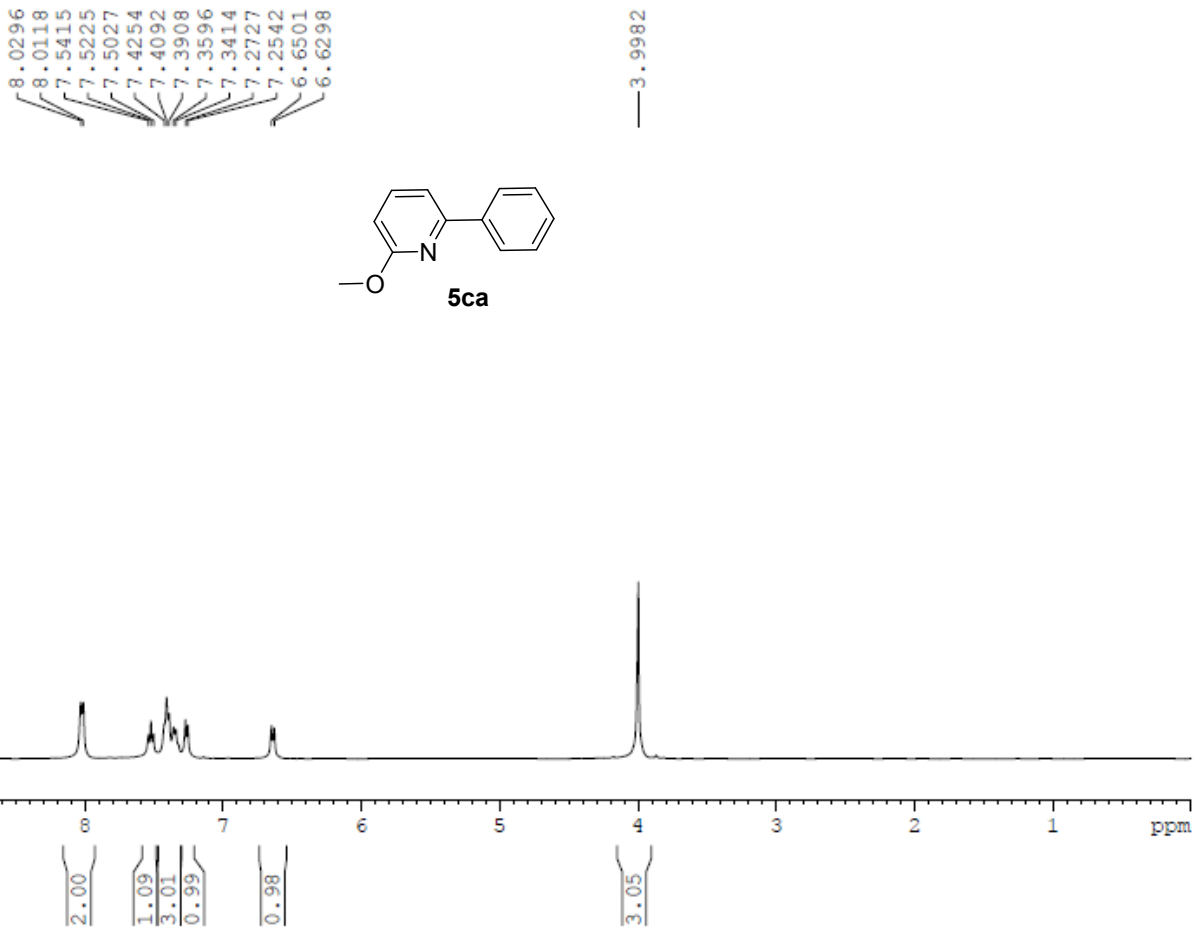
8.5072
8.4977
8.4956
7.5285
7.5182
7.5142
7.5094
7.4970
7.4944
7.4338
7.4163
7.4124
7.3973
7.3729
7.3699
7.3668
7.3577
7.3521
7.3336
7.2795
7.1329
7.1210
7.1137
7.1018
2.3108
N
9
8
7
6
5
4
3
2
1
ppm
1.00
3.02
2.04
1.04
1.03
3.11

5ba


158.66
146.93
140.61
138.48
130.79
128.94
128.13
127.90
122.06
77.57
77.25
76.93
20.03
N
5ba
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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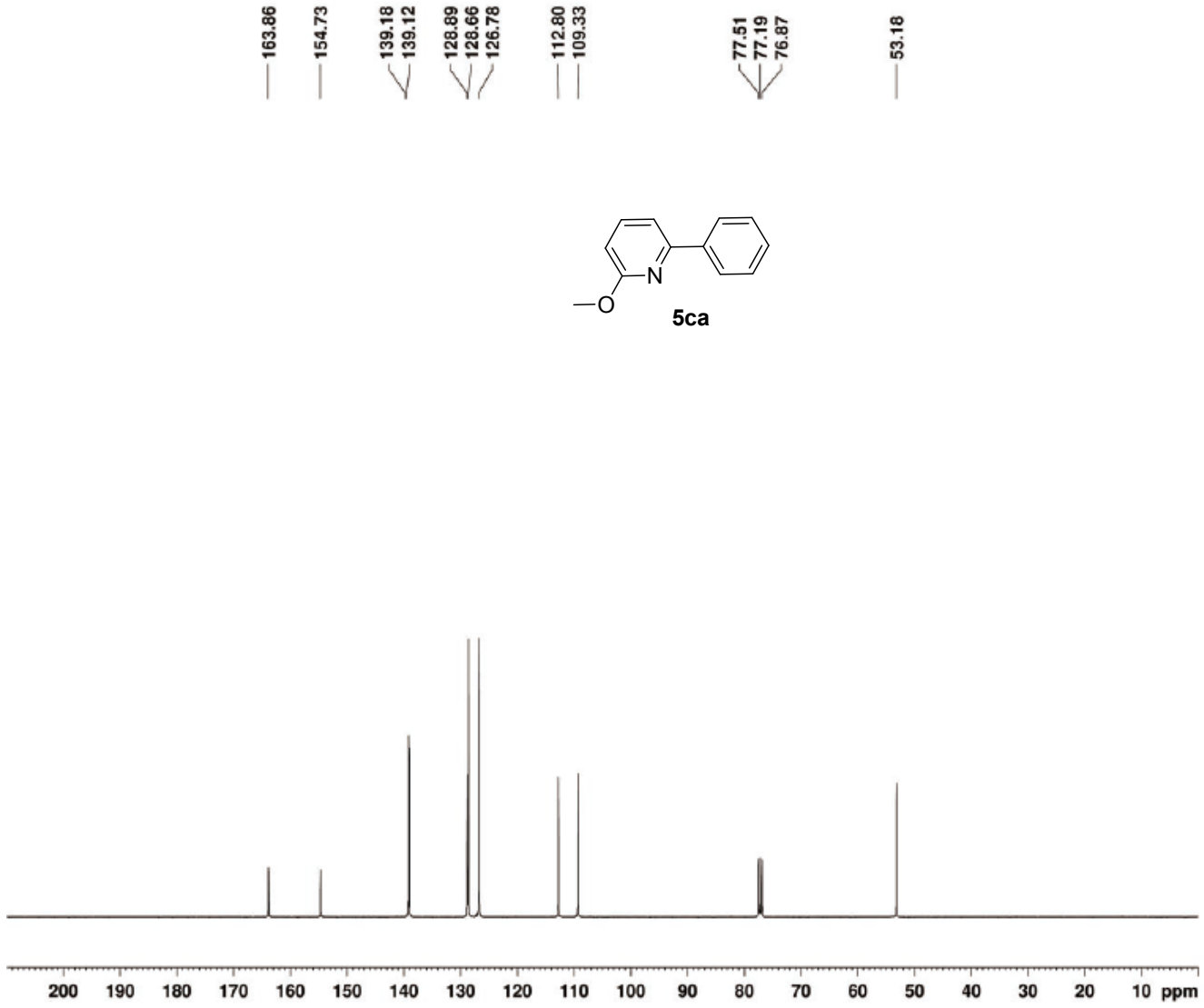
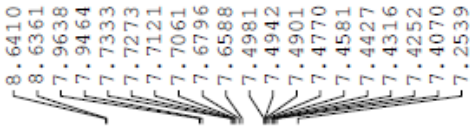
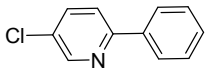
8.0118
7.5415
7.5225
7.5027
7.4254
7.4092
7.3908
7.3596
7.3414
7.2727
7.2542
6.6501
6.6298
3.9982
N
O
9
8
7
6
5
4
3
2
1
ppm
2.00
1.09
3.01
0.99
0.98
3.05

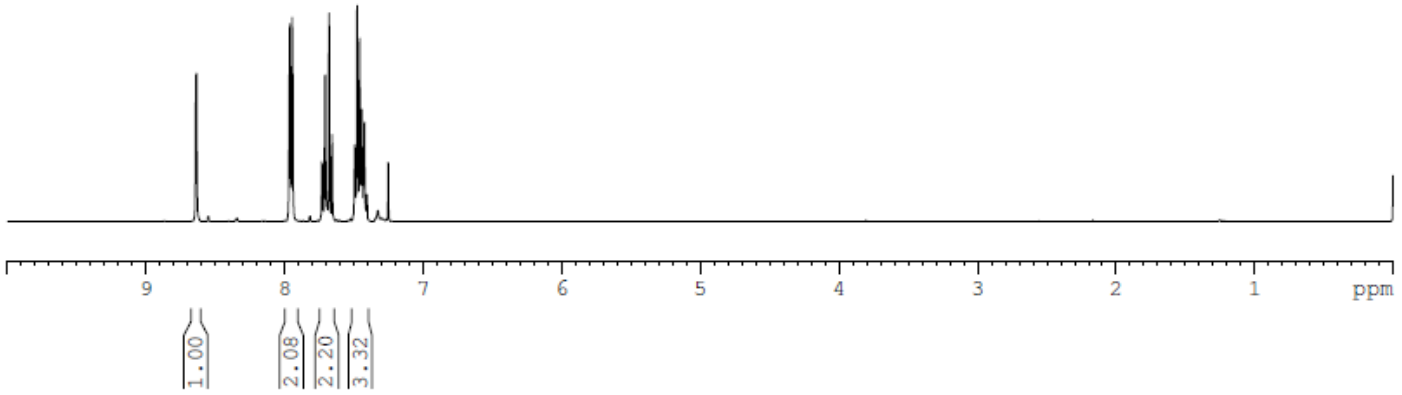
5ca

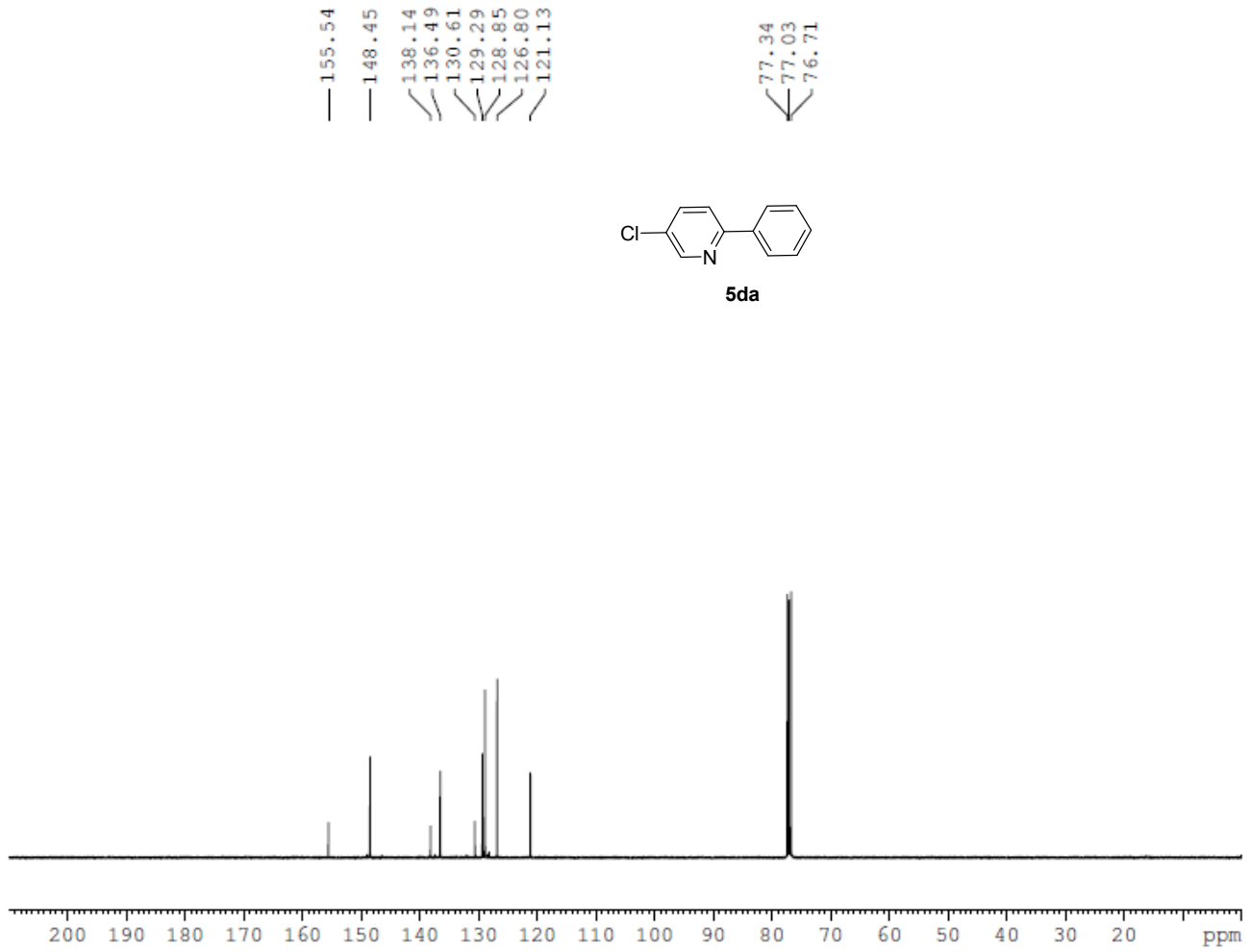

163.86
154.73
139.18
139.12
128.89
128.66
126.78
112.80
109.33
77.51
77.19
76.87
53.18
N
O
5ca
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


8.6410
8.6361
7.9638
7.9464
7.7333
7.7273
7.7121
7.7061
7.6796
7.6588
7.4981
7.4942
7.4901
7.4770
7.4581
7.4427
7.4316
7.4252
7.4070
7.2539

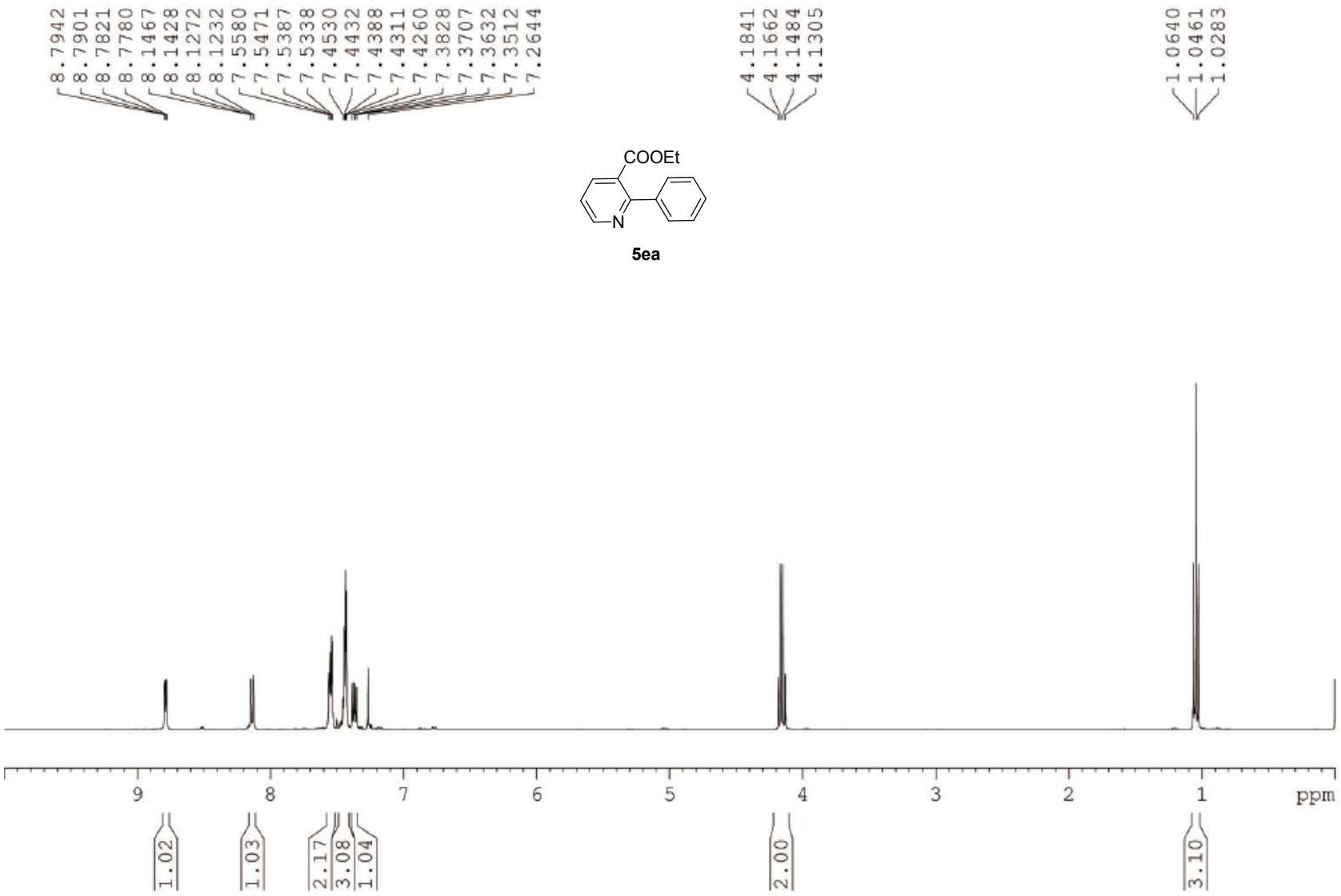

Cl
N

5da


9
8
7
6
5
4
3
2
1
ppm
1.00
2.08
2.20
3.32


155.54
148.45
138.14
136.49
130.61
129.29
128.85
126.80
121.13
77.34
77.03
76.71
Cl
N
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

5da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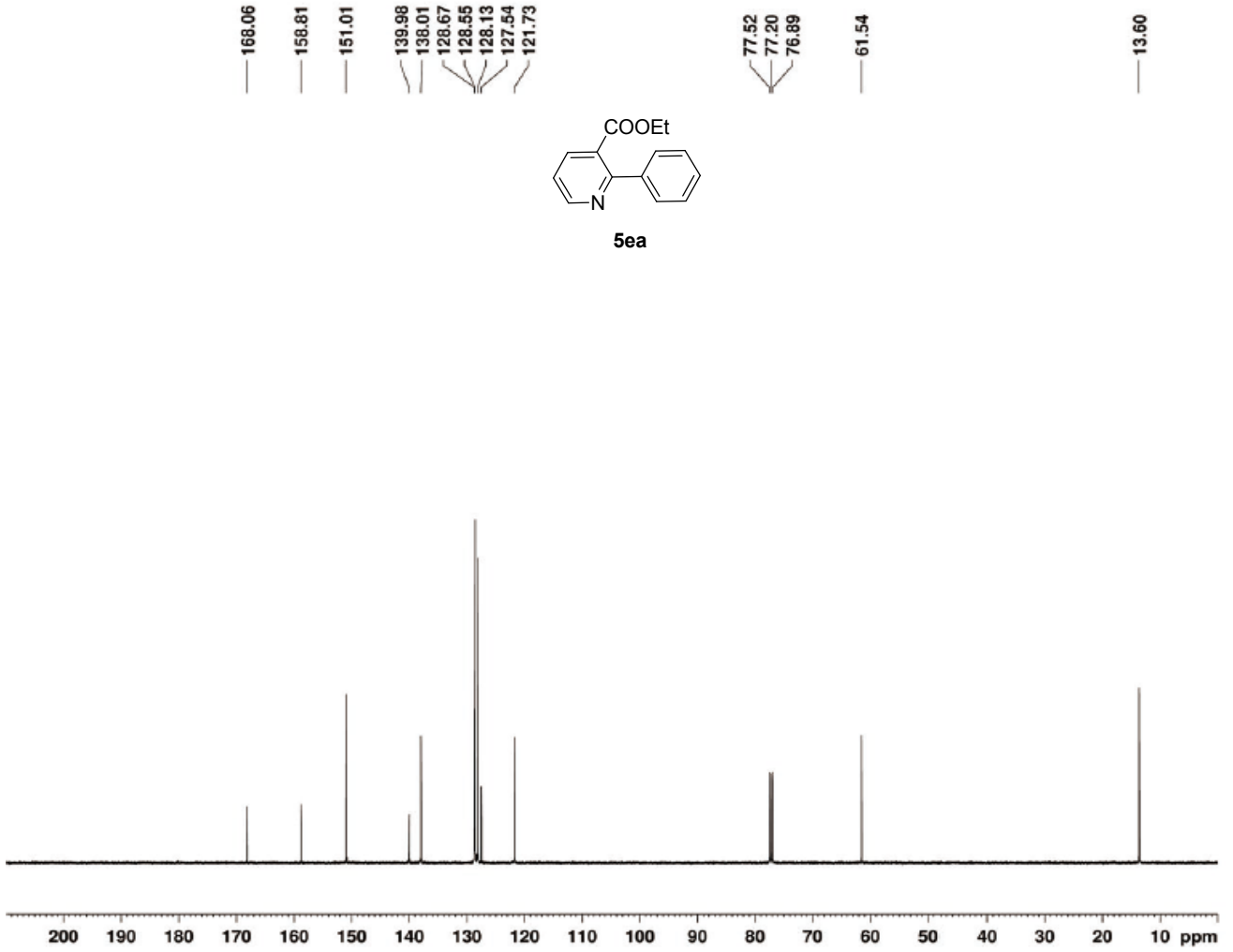
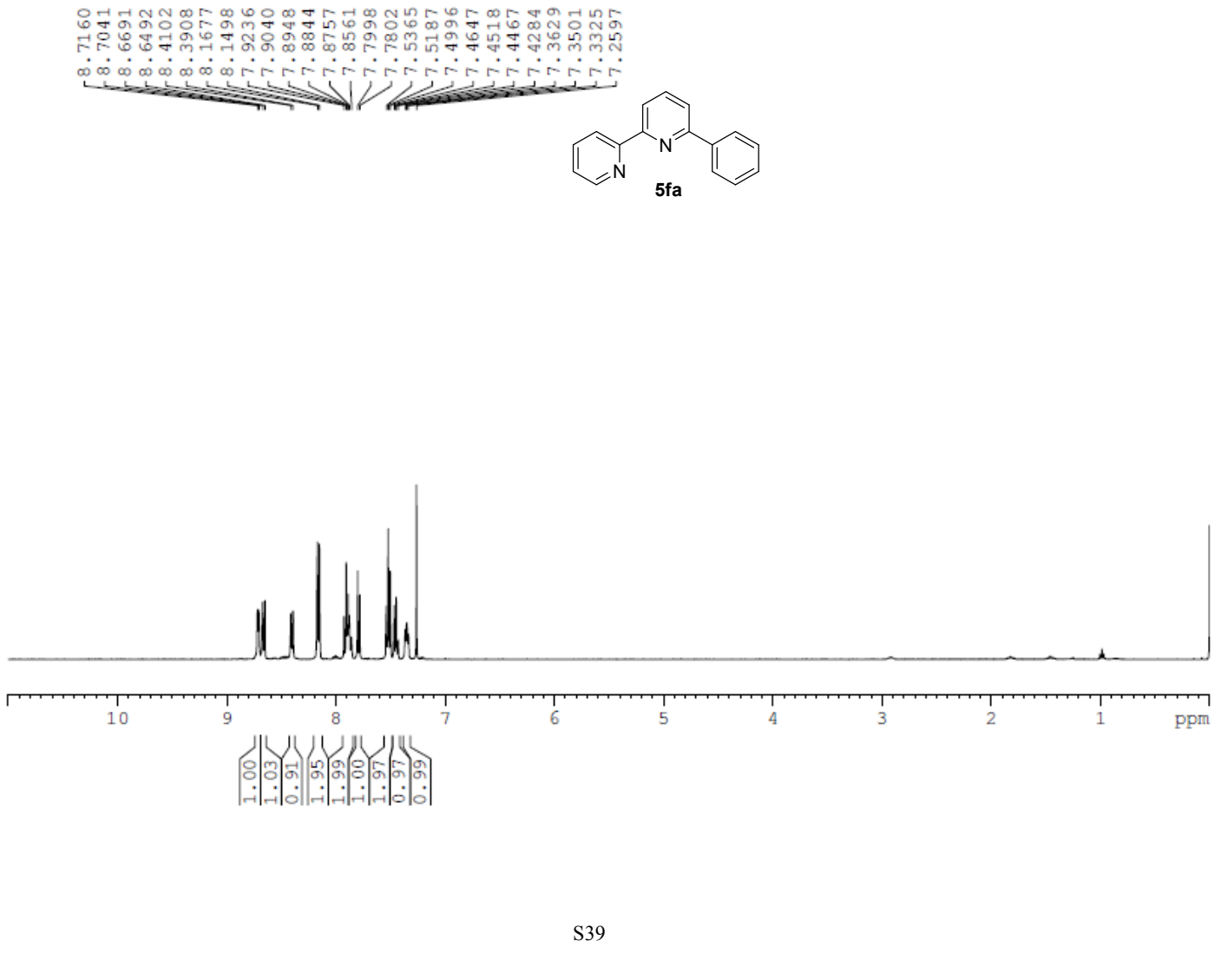
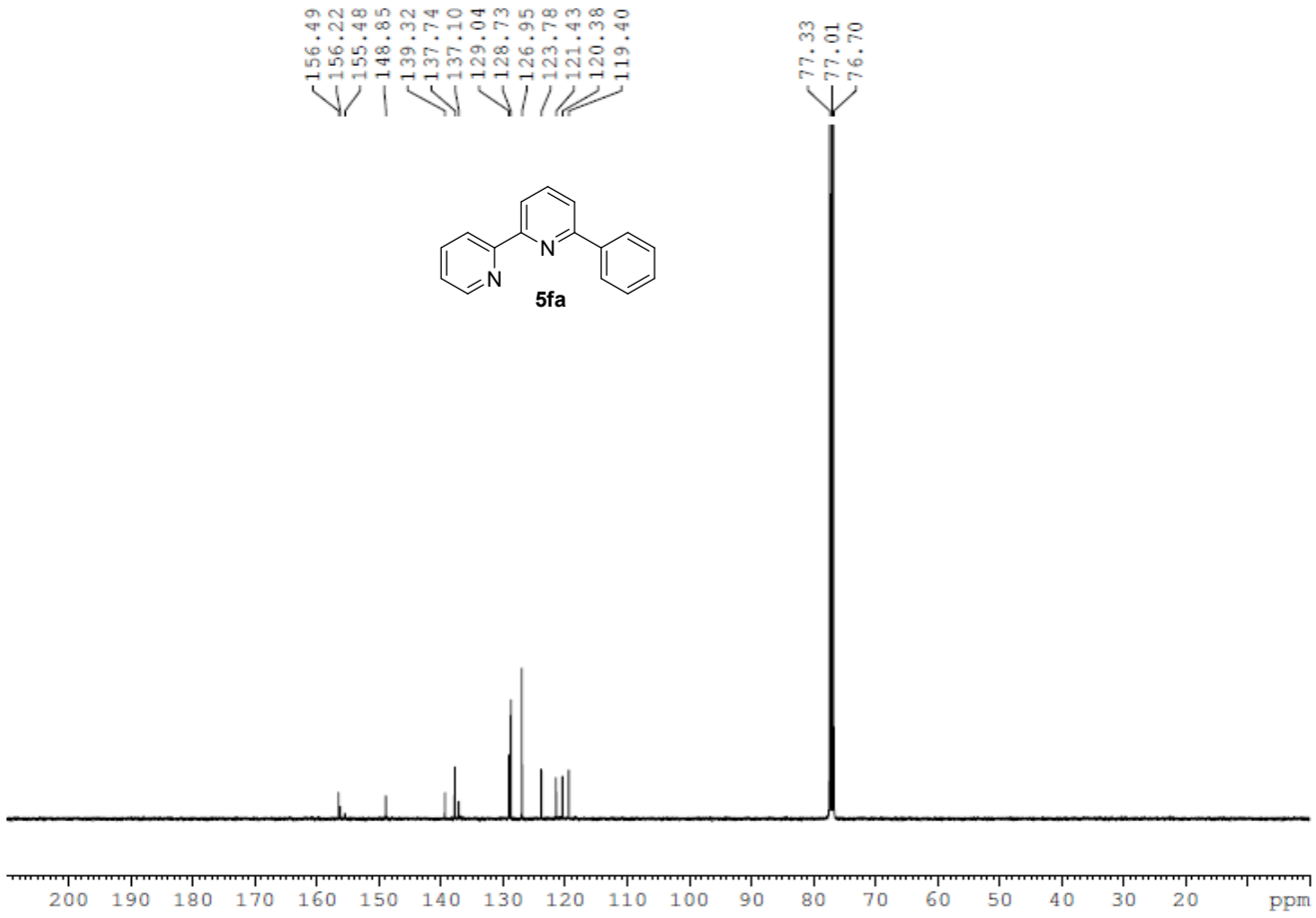
8.7901
8.7821
8.7780
8.1467
8.1428
8.1272
8.1232
7.5580
7.5471
7.5387
7.5338
7.4530
7.4432
7.4388
7.4311
7.4260
7.3828
7.3707
7.3632
7.3512
7.2644
4.1841
4.1662
4.1484
4.1305
1.0640
1.0461
1.0283
COOEt
N
9
8
7
6
5
4
3
2
1
ppm
1.02
1.03
2.17
3.08
1.04
2.00
3.10

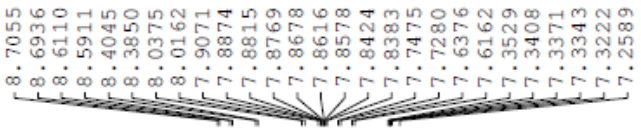
5ea

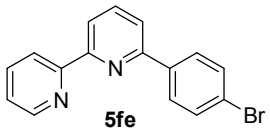

168.06
158.81
151.01
139.98
138.01
128.67
128.55
128.13
127.54
121.73
77.52
77.20
76.89
61.54
13.60
COOEt
N
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

5ea

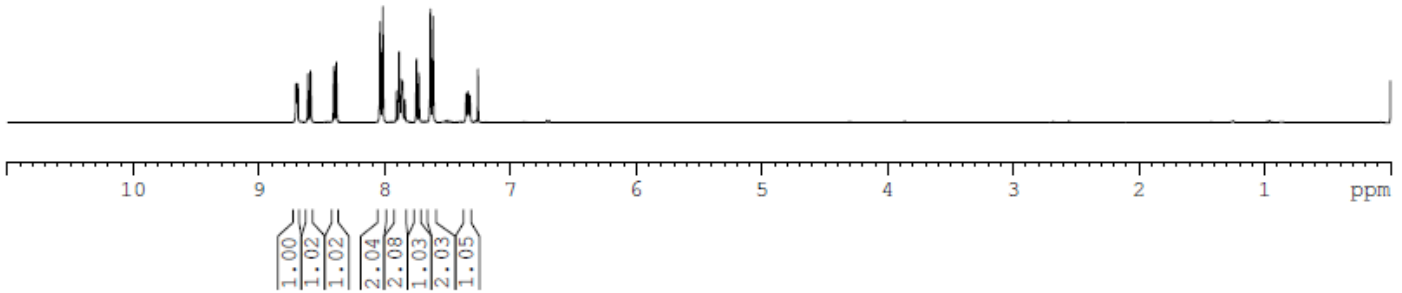

8.7160
8.7041
8.6691
8.6492
8.4102
8.3908
8.1677
8.1498
7.9236
7.9040
7.8948
7.8844
7.8757
7.8561
7.7998
7.7802
7.5365
7.5187
7.4996
7.4647
7.4518
7.4467
7.4284
7.3629
7.3501
7.3325
7.2597
N
N
5fa
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
0.91
1.95
1.99
1.00
1.97
0.97
0.99

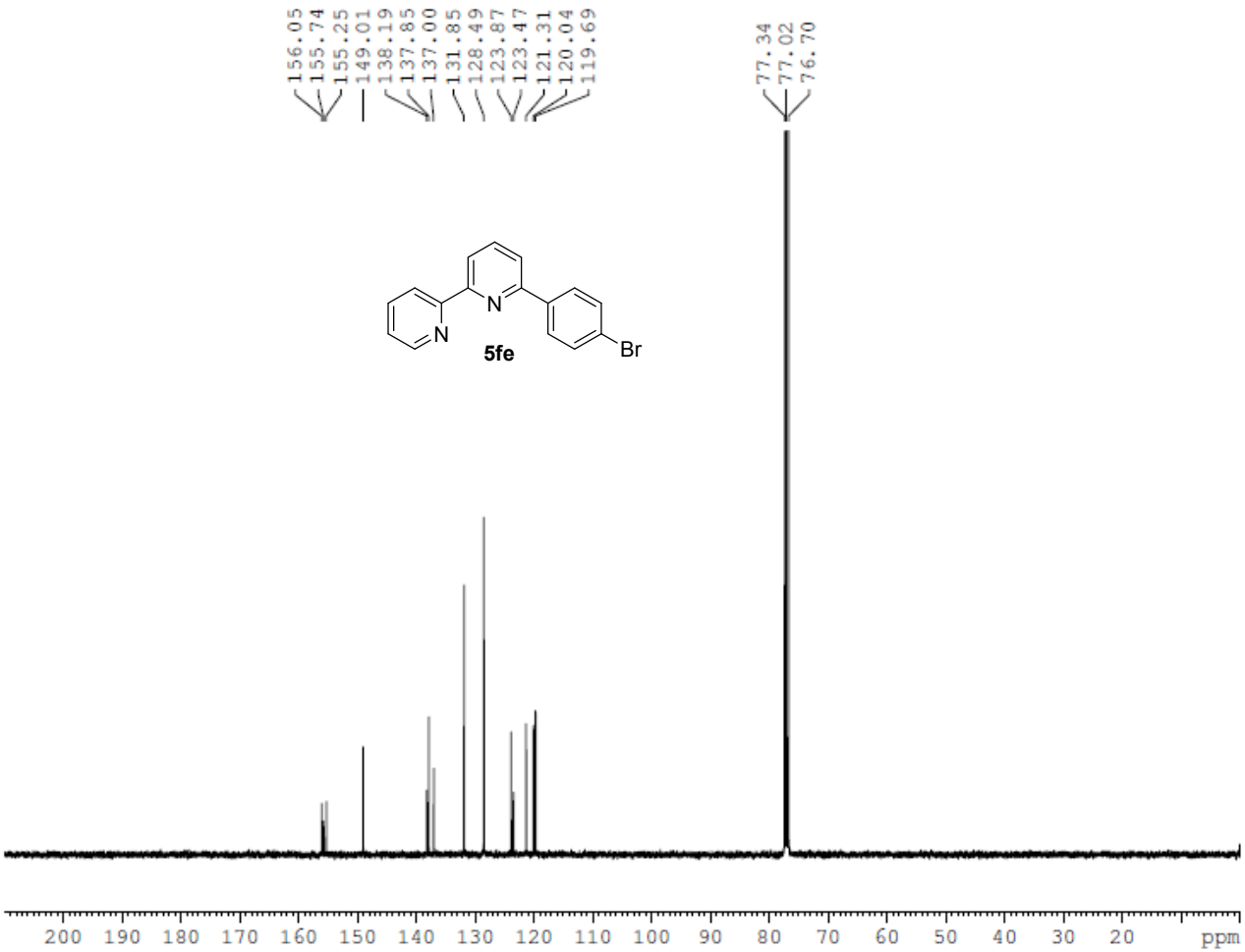

156.49
156.22
155.48
148.85
139.32
137.74
137.10
129.04
128.73
126.95
123.78
121.43
120.38
119.40
77.33
77.01
76.70
N
N
5fa
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

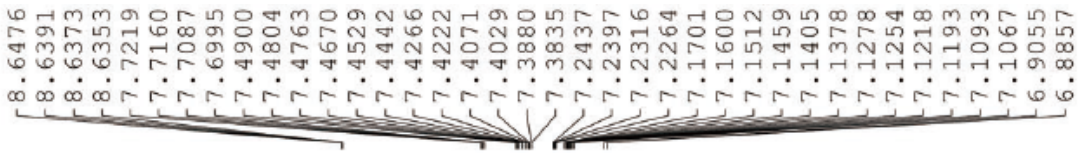

8.7055
8.6936
8.6110
8.5911
8.4045
8.3850
8.0375
8.0162
7.9071
7.8874
7.8815
7.8769
7.8678
7.8616
7.8578
7.8424
7.8383
7.7475
7.7280
7.6376
7.6162
7.3529
7.3408
7.3371
7.3343
7.3222
7.2589


N
N
Br

5fe


10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.02
1.02
2.04
2.08
1.03
2.03
1.05


156.05
155.74
155.25
149.01
138.19
137.85
137.00
131.85
128.49
123.87
123.47
121.31
120.04
119.69
77.34
77.02
76.70
N
N
Br
5fe
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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8.6391
8.6373
8.6353
7.7219
7.7160
7.7087
7.6995
7.4900
7.4804
7.4763
7.4670
7.4529
7.4442
7.4266
7.4222
7.4071
7.4029
7.3880
7.3835
7.2437
7.2397
7.2316
7.2264
7.1701
7.1600
7.1512
7.1459
7.1405
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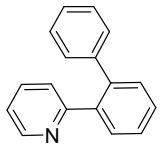
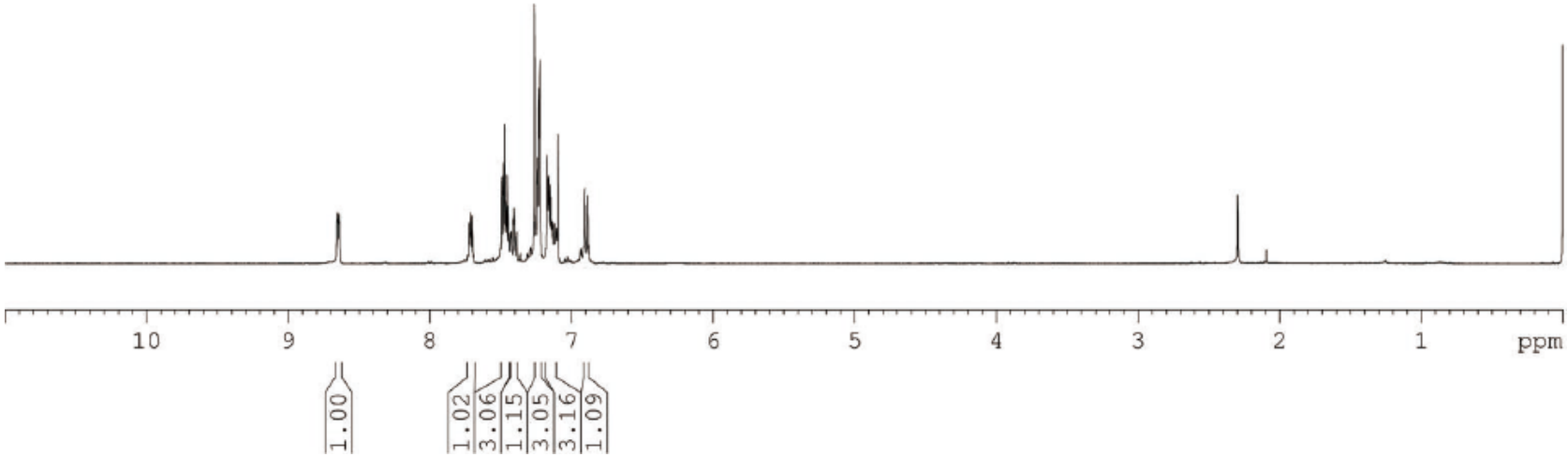
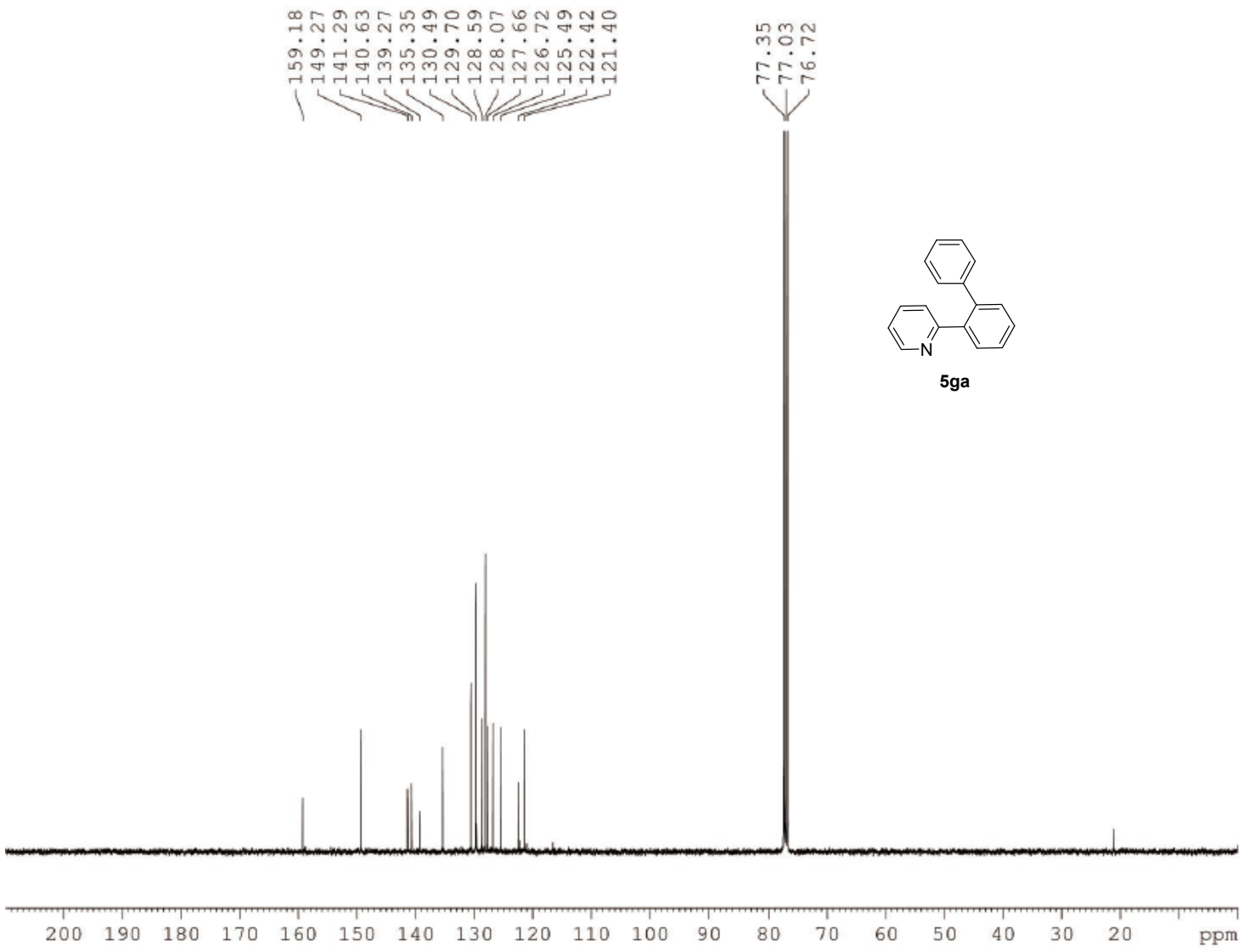
7.1278
7.1254
7.1218
7.1193
7.1093
7.1067
6.9055
6.8857

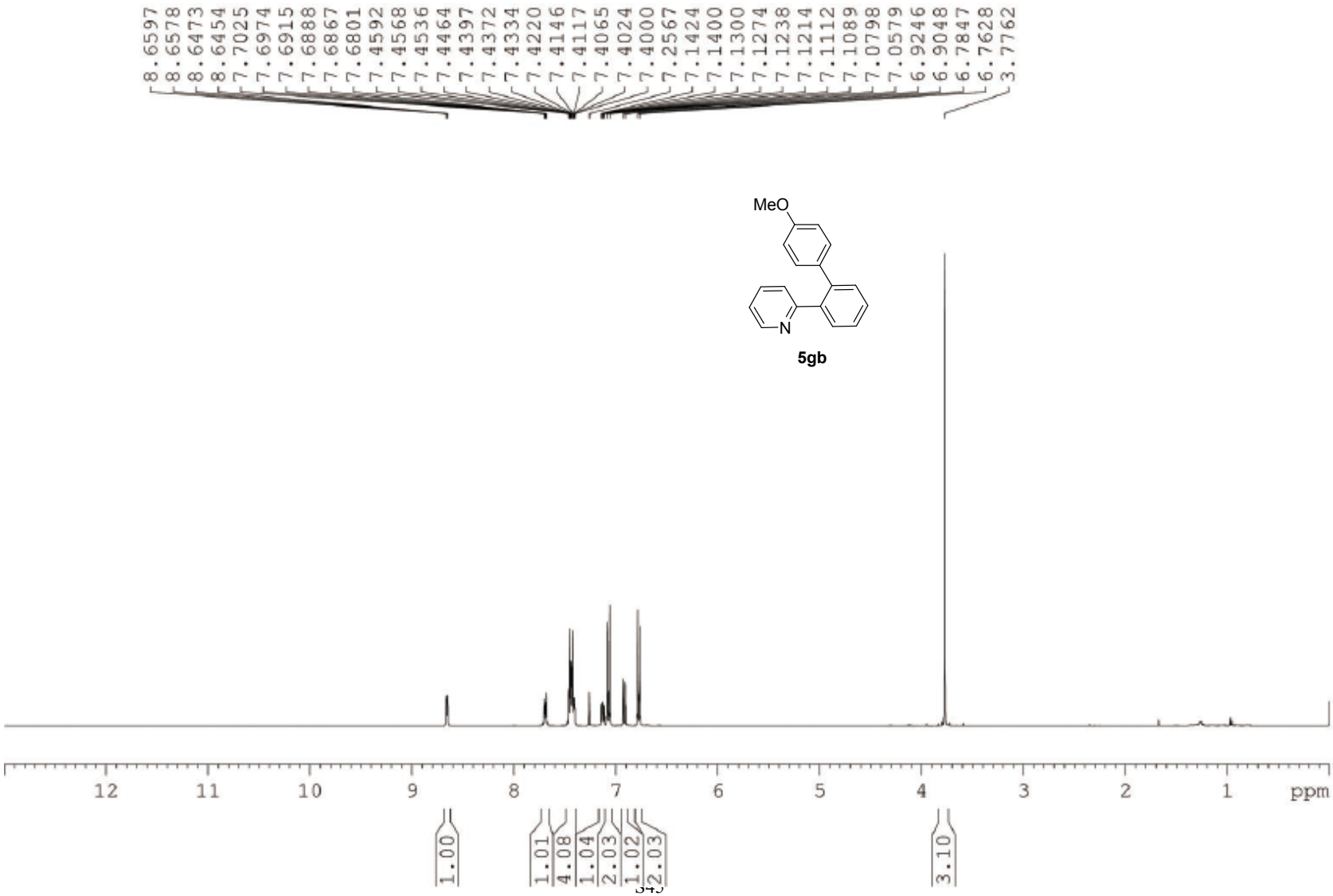

N

5ga


10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.02
3.06
1.15
3.05
3.16
1.09


159.18
149.27
141.29
140.63
139.27
135.35
130.49
129.70
128.59
128.07
127.66
126.72
125.49
122.42
121.40
77.35
77.03
76.72
N
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

5ga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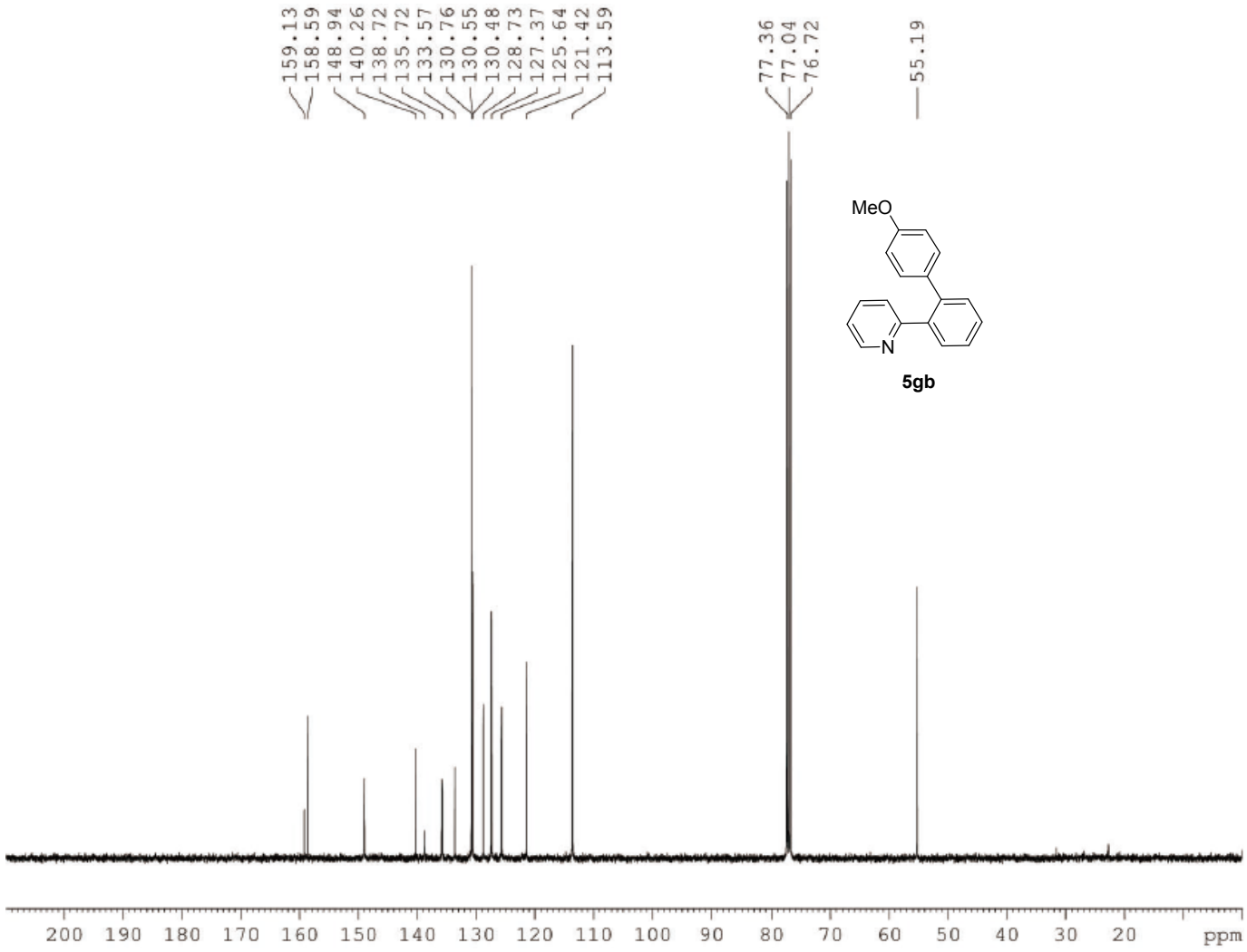
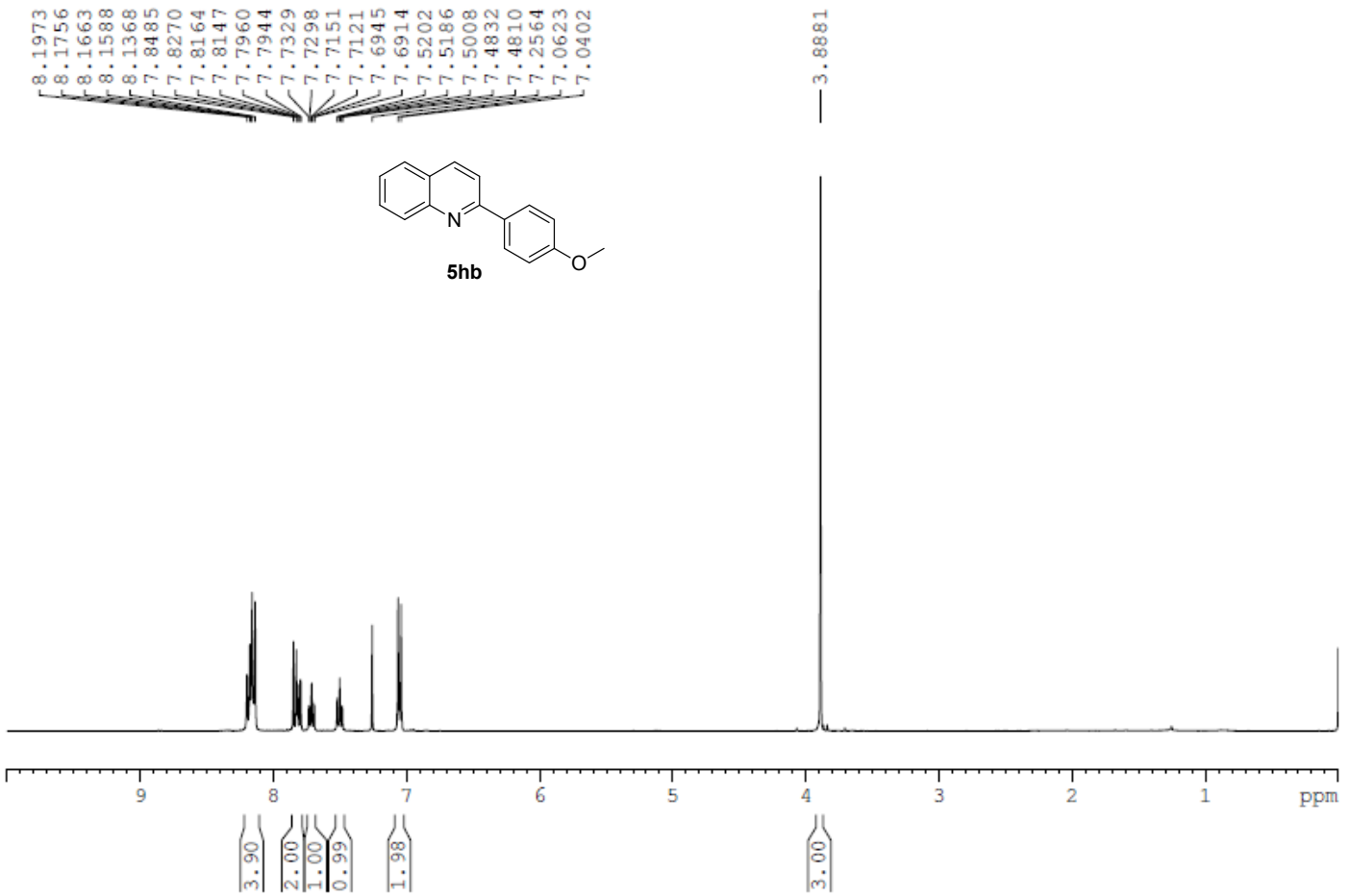
8.6578
8.6473
8.6454
7.7025
7.6974
7.6915
7.6888
7.6867
7.6801
7.4592
7.4568
7.4536
7.4464
7.4397
7.4372
7.4334
7.4220
7.4146
7.4117
7.4065
7.4024
7.4000
7.2567
7.1424
7.1400
7.1300
7.1274
7.1238
7.1214
7.1112
7.1089
7.0798
7.0579
6.9246
6.9048
6.7847
6.7628
3.7762
MeO
N
5gb
12
11
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.01
4.08
1.04
2.03
1.02
2.03
3.10


159.13
158.59
148.94
140.26
138.72
135.72
133.57
130.76
130.55
130.48
128.73
127.37
125.64
121.42
113.59
77.36
77.04
76.72
55.19
MeO
N
5gb
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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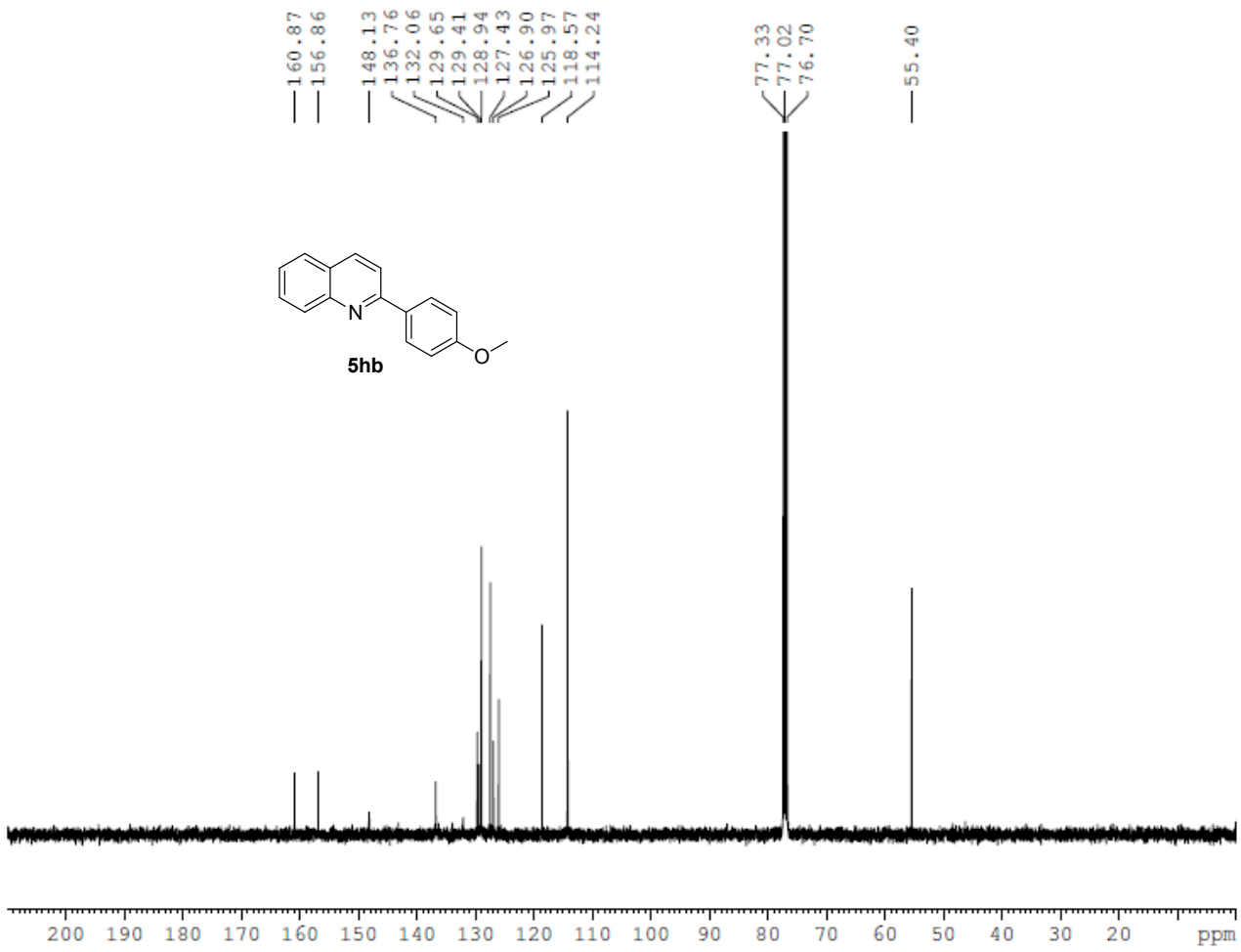
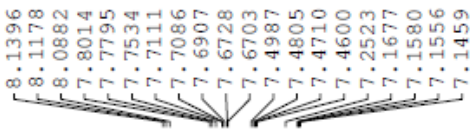
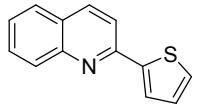
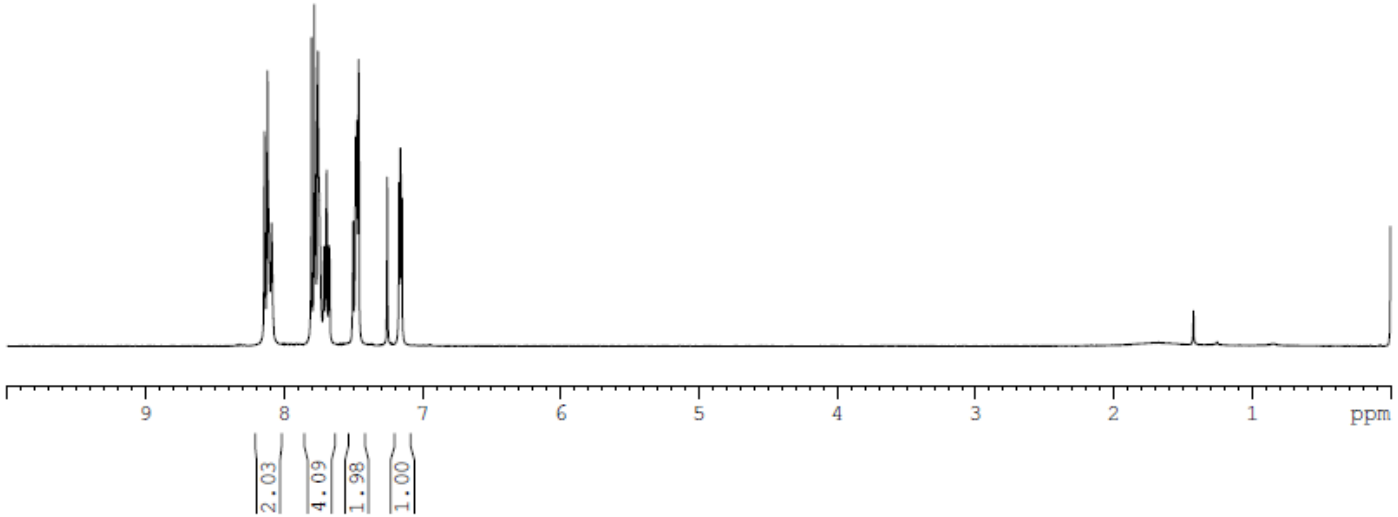
8.1756
8.1663
8.1588
8.1368
7.8485
7.8270
7.8164
7.8147
7.7960
7.7944
7.7329
7.7298
7.7151
7.7121
7.6945
7.6914
7.5202
7.5186
7.5008
7.4832
7.4810
7.2564
7.0623
7.0402
3.8881
N
O
5hb
9
8
7
6
5
4
3
2
1
ppm
3.90
2.00
1.00
0.99
1.98
3.00

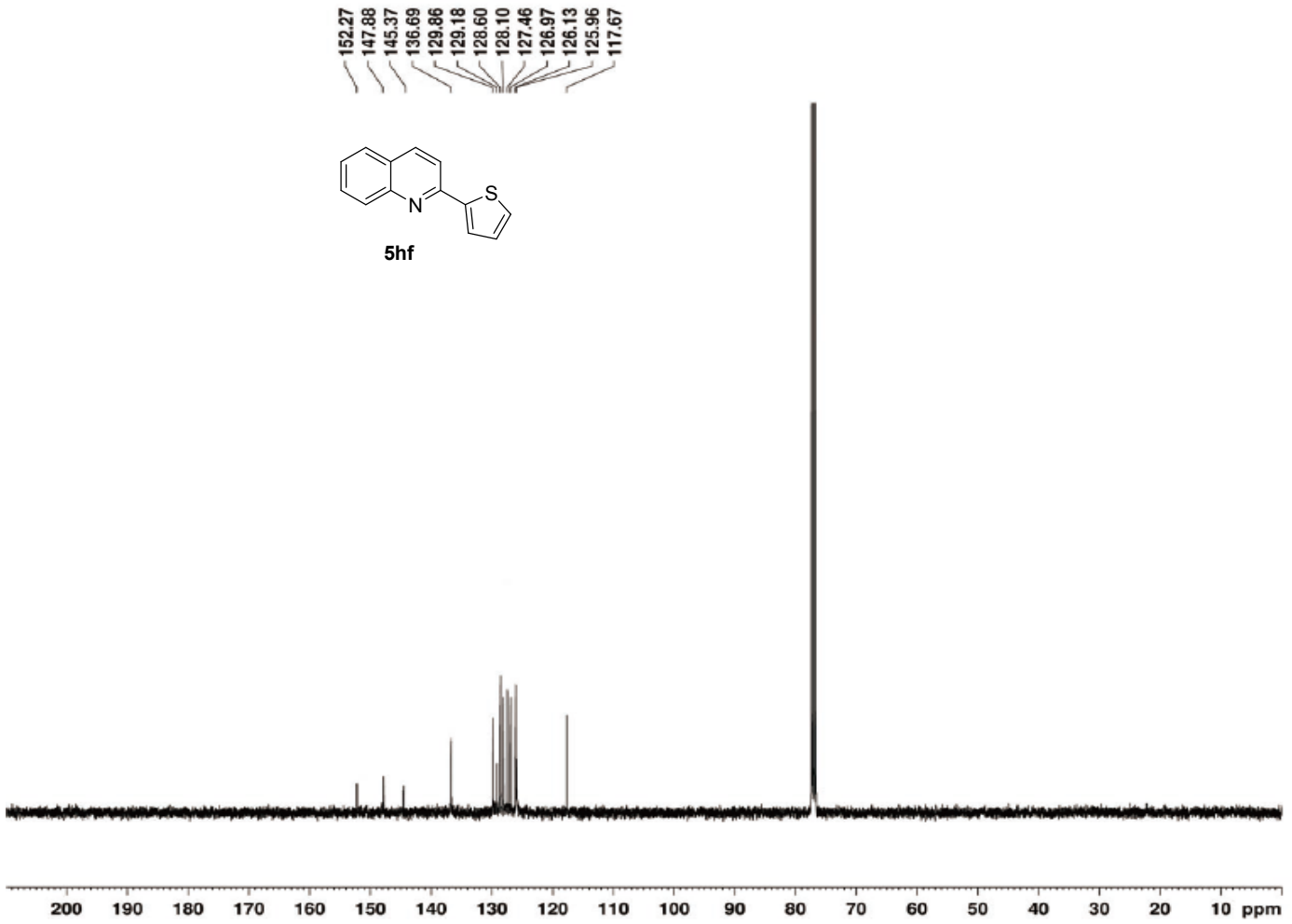

160.87
156.86
148.13
136.76
132.06
129.65
129.41
128.94
127.43
126.90
125.97
118.57
114.24
77.33
77.02
76.70
55.40
N
O
5hb
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

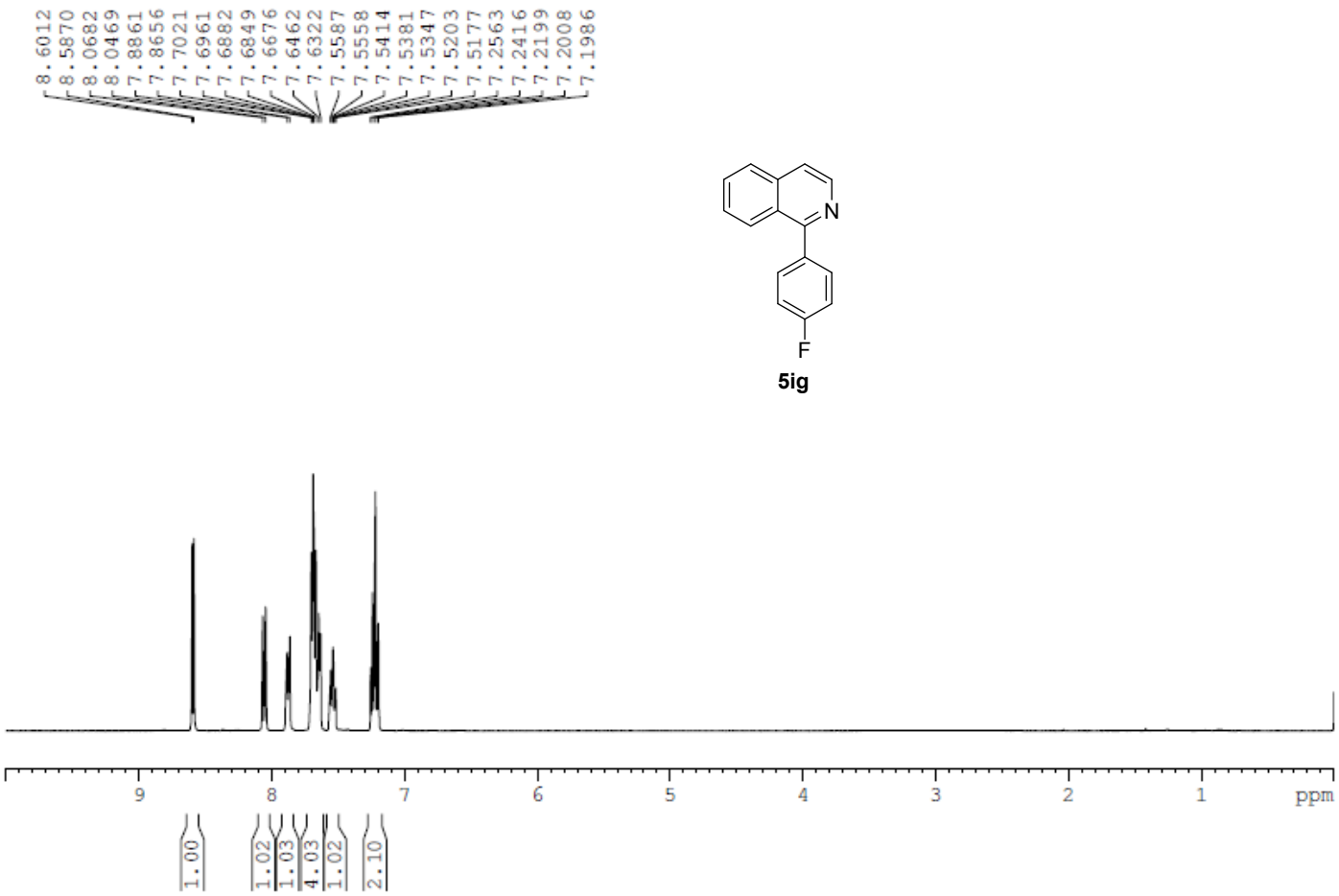

8.1396
8.1178
8.0882
7.8014
7.7795
7.7534
7.7111
7.7086
7.6907
7.6728
7.6703
7.4987
7.4805
7.4710
7.4600
7.2523
7.1677
7.1580
7.1556
7.1459


N
S

5hf


9
8
7
6
5
4
3
2
1
ppm
2.03
4.09
1.98
1.00


152.27
147.88
145.37
136.69
129.86
129.18
128.60
128.10
127.46
126.97
126.13
125.96
117.67
N
S
5hf
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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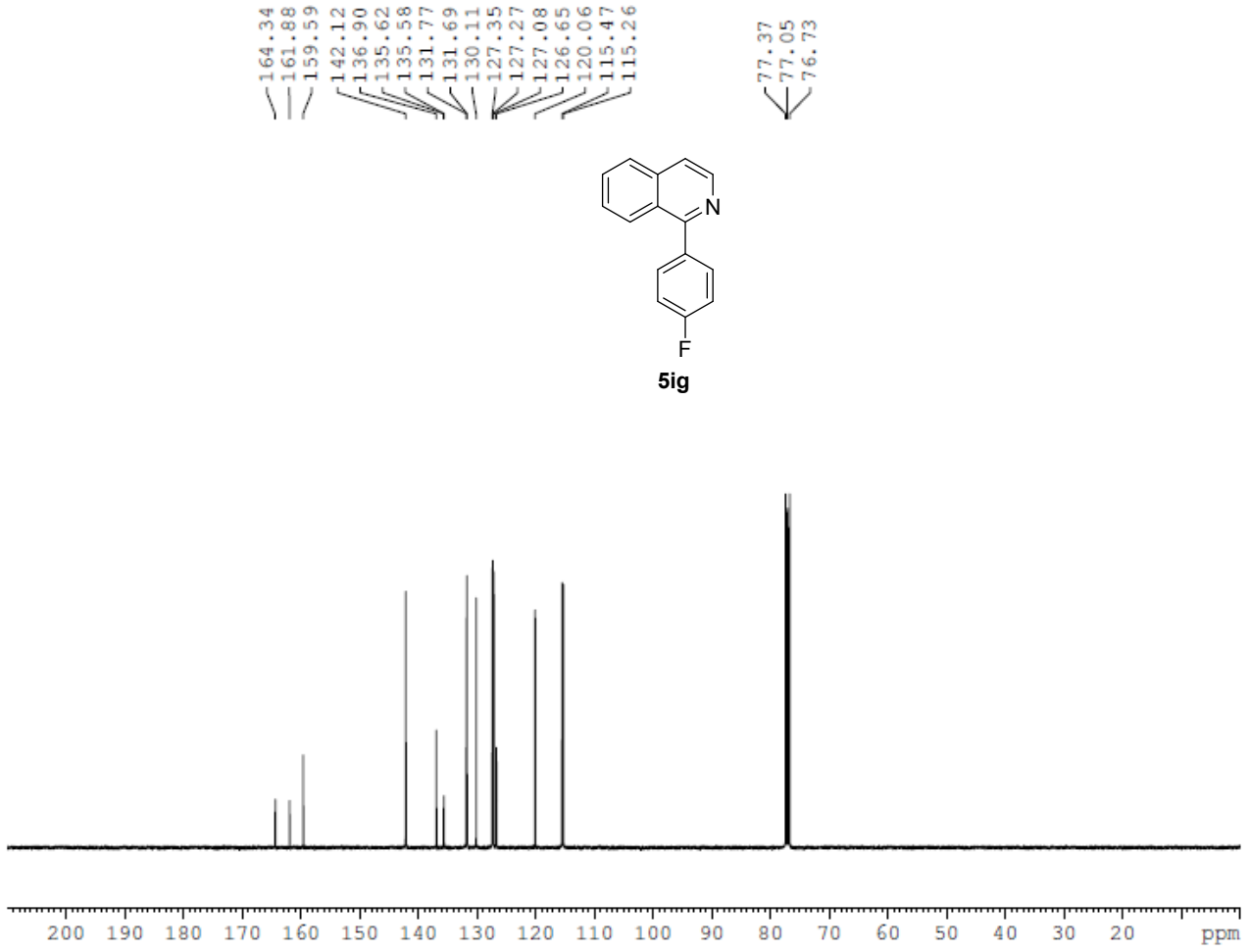
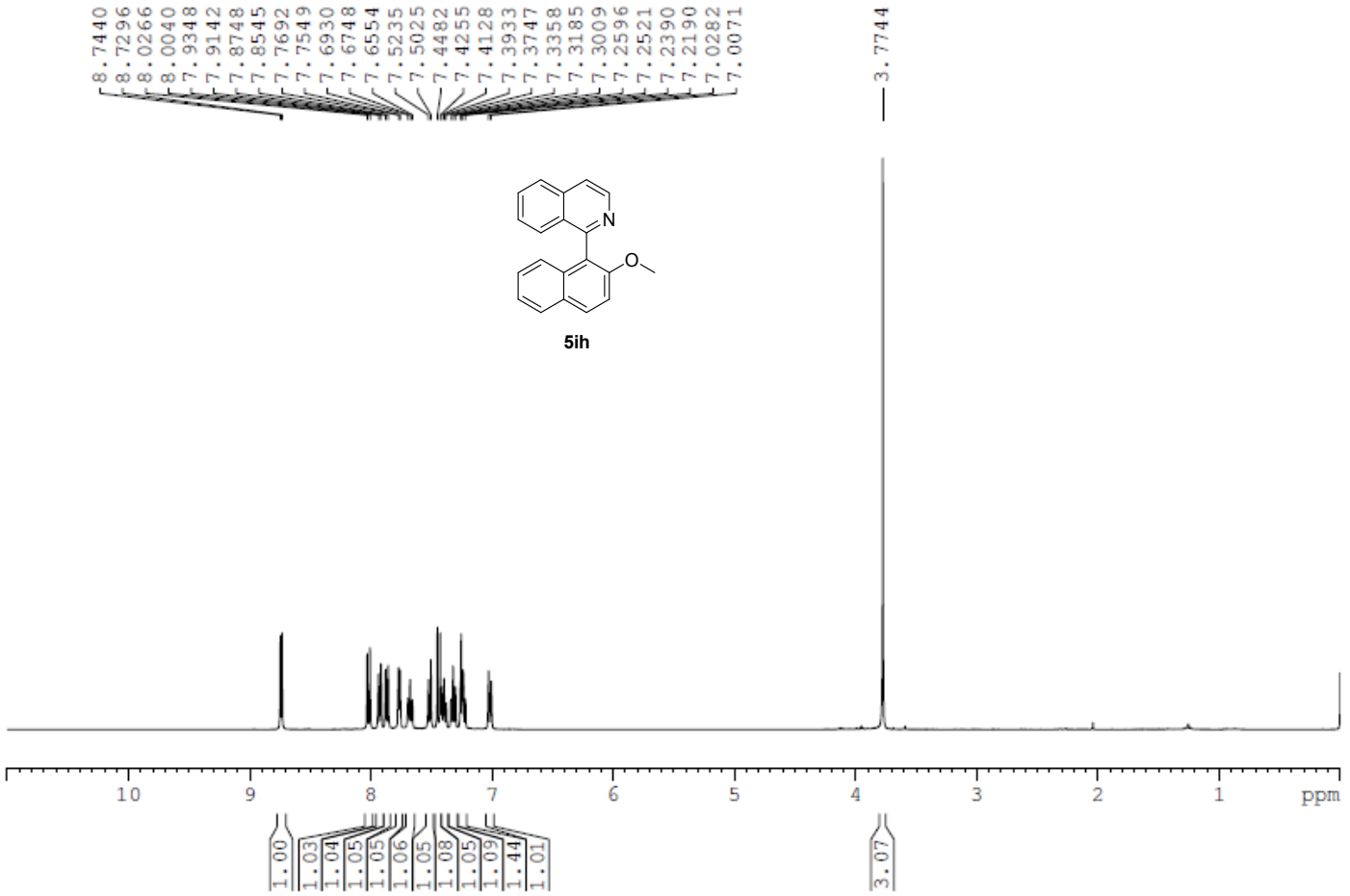
8.0682
8.0469
7.8861
7.8656
7.7021
7.6961
7.6882
7.6849
7.6676
7.6462
7.6322
7.5587
7.5558
7.5414
7.5381
7.5347
7.5203
7.5177
7.2563
7.2416
7.2199
7.2008
7.1986
N
F
9
8
7
6
5
4
3
2
1
ppm
1.00
1.02
1.03
4.03
1.02
2.10

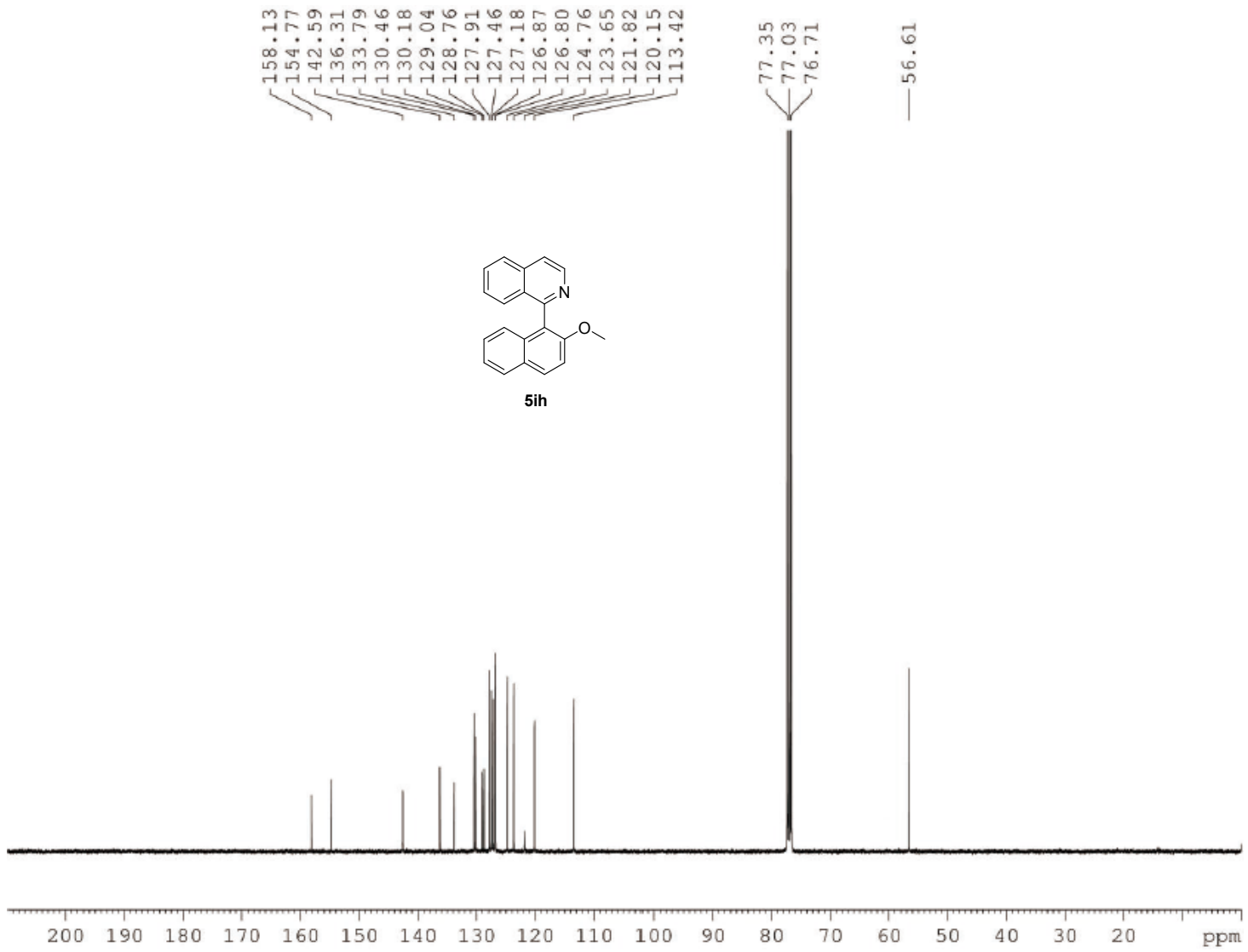
5ig


164.34
161.88
159.59
142.12
136.90
135.62
135.58
131.77
131.69
130.11
127.35
127.27
127.08
126.65
120.06
115.47
115.26
77.37
77.05
76.73
N
F
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

5ig


8.7440
8.7296
8.0266
8.0040
7.9348
7.9142
7.8748
7.8545
7.7692
7.7549
7.6930
7.6748
7.6554
7.5235
7.5025
7.4482
7.4255
7.4128
7.3933
7.3747
7.3358
7.3185
7.3009
7.2596
7.2521
7.2390
7.2190
7.0282
7.0071
3.7744
N
O
10
9
8
7
6
5
4
3
2
1
ppm
1.00
1.03
1.04
1.05
1.05
1.06
1.05
1.08
1.05
1.09
1.44
1.01
3.07

5ih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142.59
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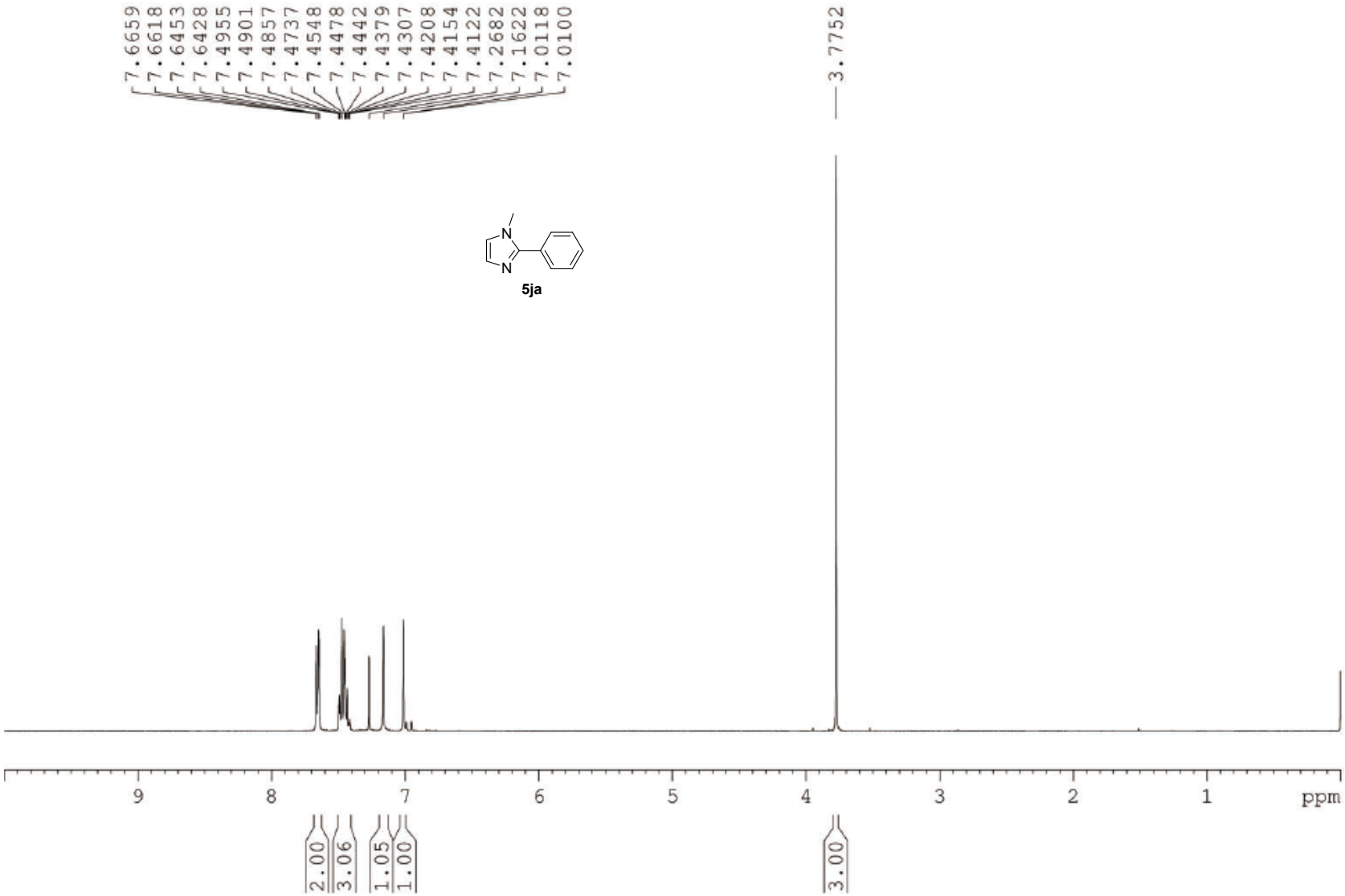
130.46
130.18
129.04
128.76
127.91
127.46
127.18
126.87
126.80
124.76
123.65
121.82
120.15
113.42
77.35
77.03
76.71
56.61
N
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

5ih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7.6428
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7.4857
7.4737
7.4548
7.4478
7.4442
7.4379
7.4307
7.4208
7.4154
7.4122
7.2682
7.1622
7.0118
7.0100
3.7752
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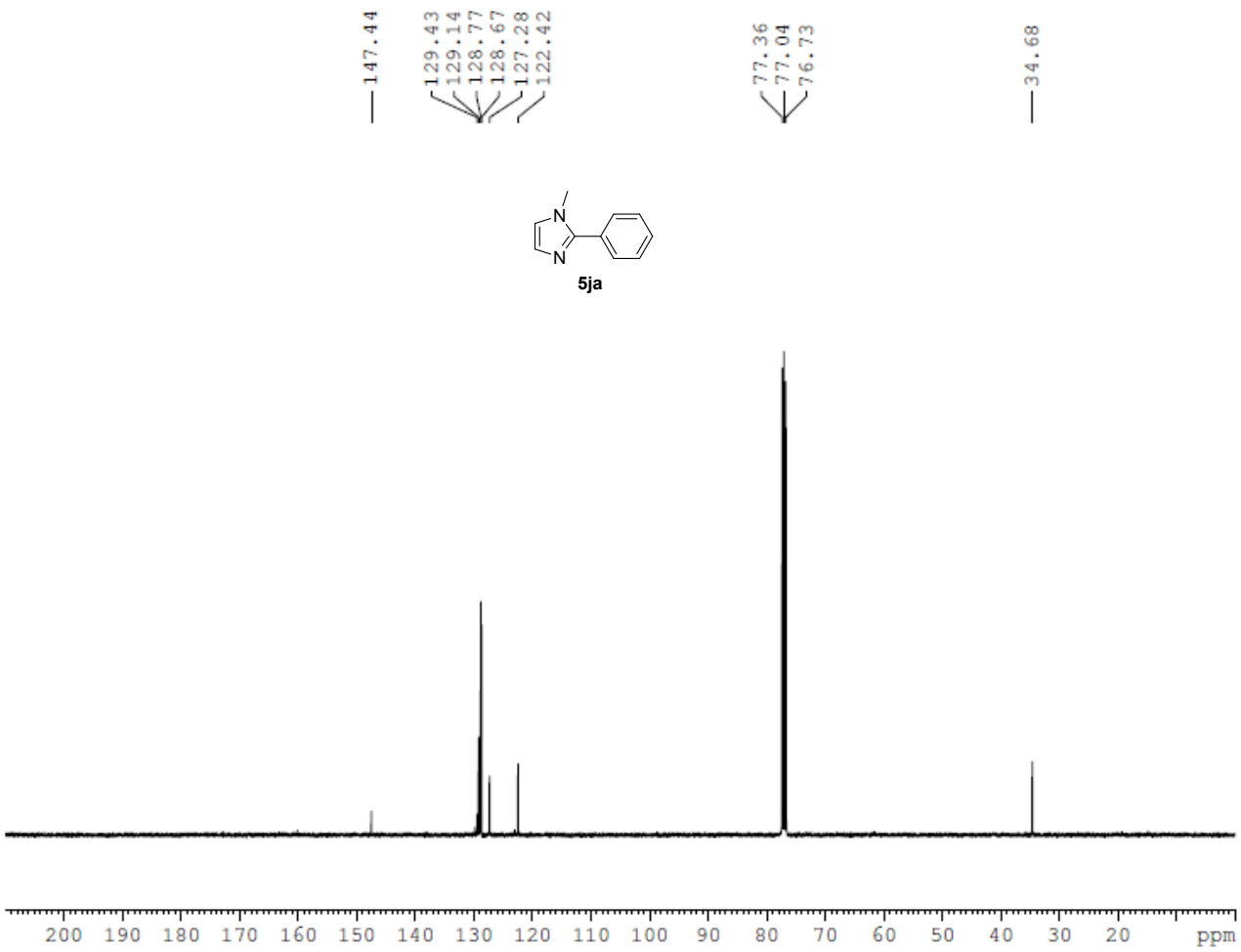
ppm
2.00
3.06
1.05
1.00
3.00


147.44
129.43
129.14
128.77
128.67
127.28
122.42
77.36
77.04
76.73
34.68
N
N
5ja
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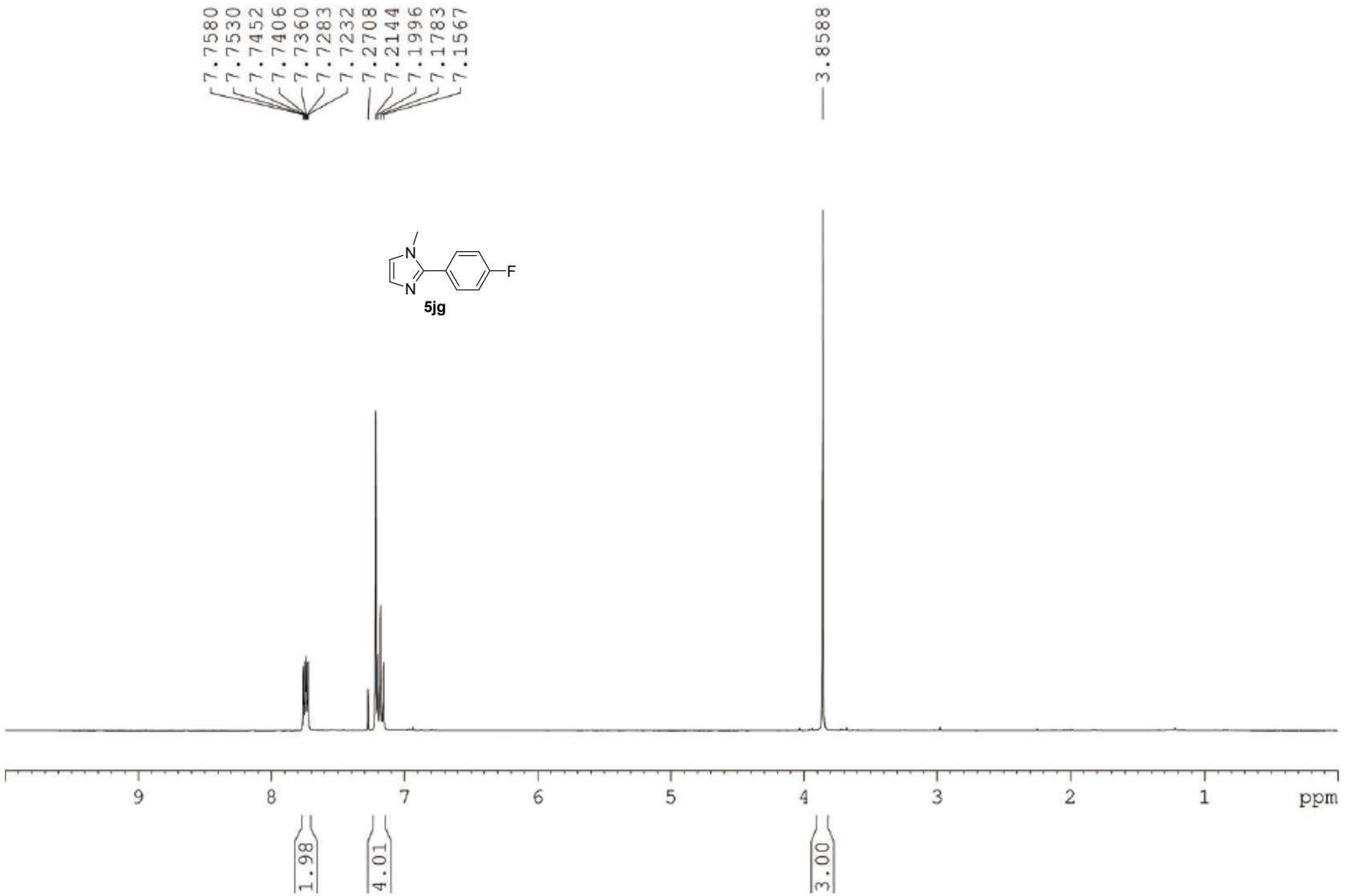
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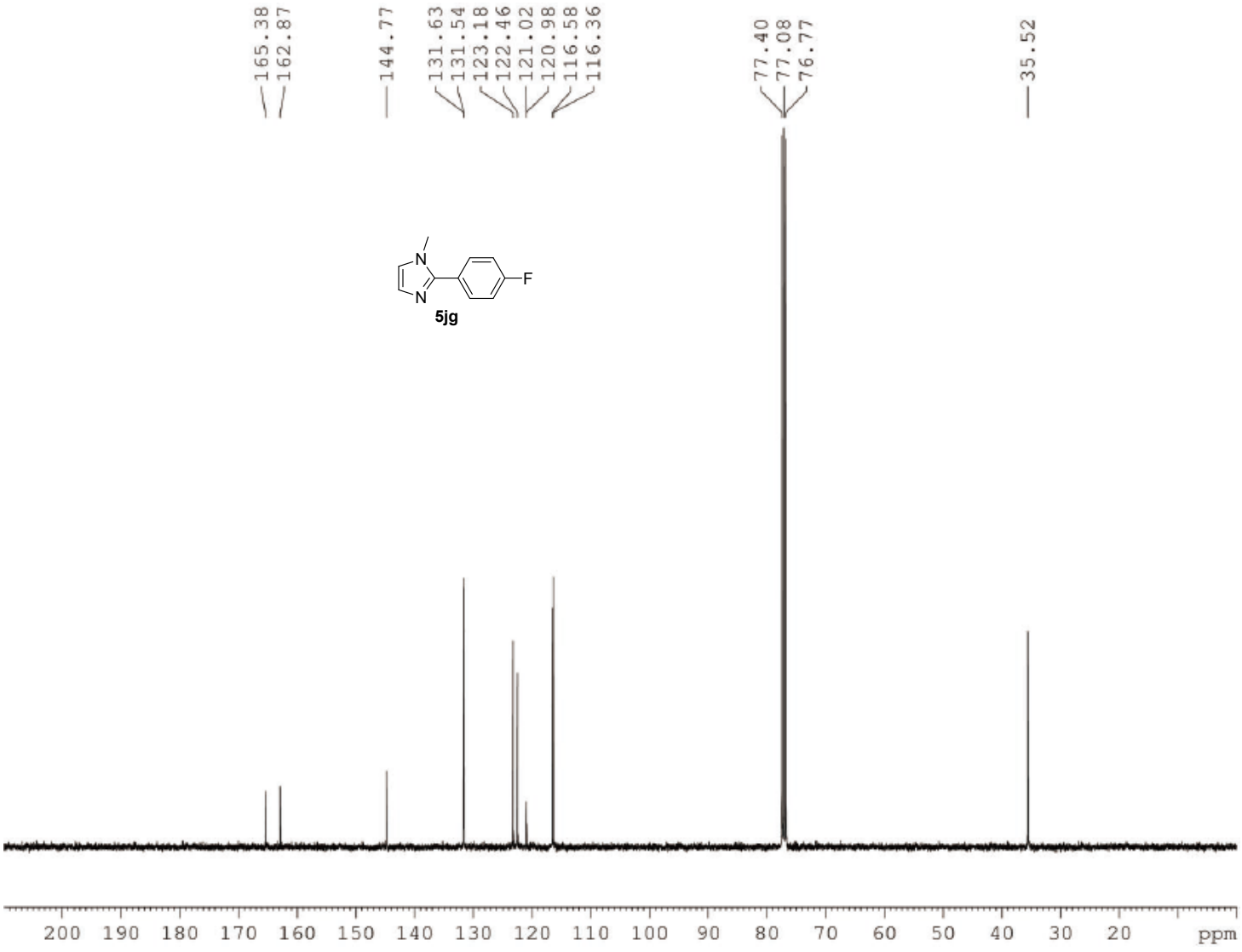
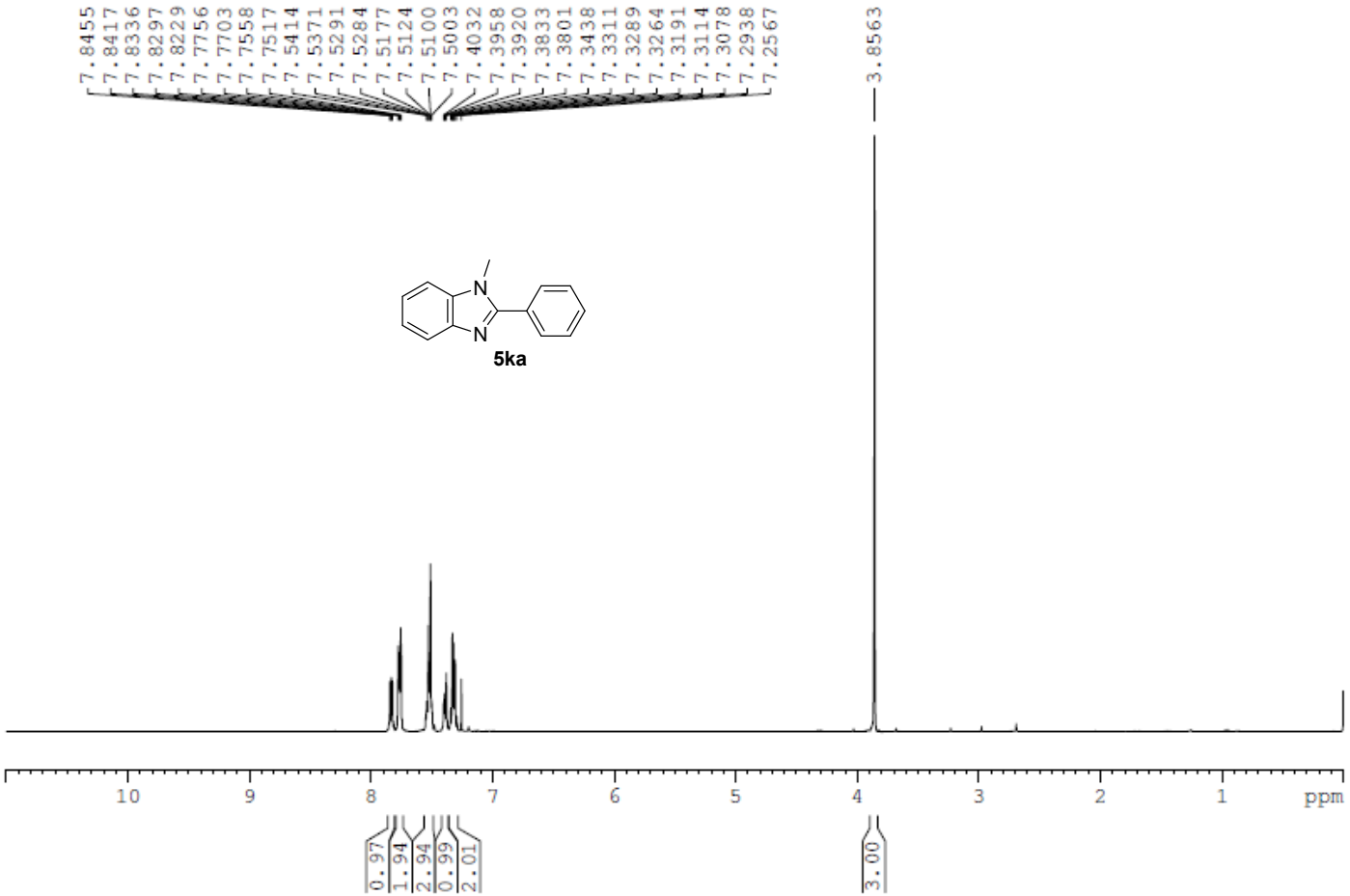
7.7530
7.7452
7.7406
7.7360
7.7283
7.7232
7.2708
7.2144
7.1996
7.1783
7.1567
3.8588
N
N
F
5jg
9
8
7
6
5
4
3
2
1
ppm
1.98
4.01
3.00


165.38
162.87
144.77
131.63
131.54
123.18
122.46
121.02
120.98
116.58
116.36
77.40
77.08
76.77
35.52
N
N
F
5jg
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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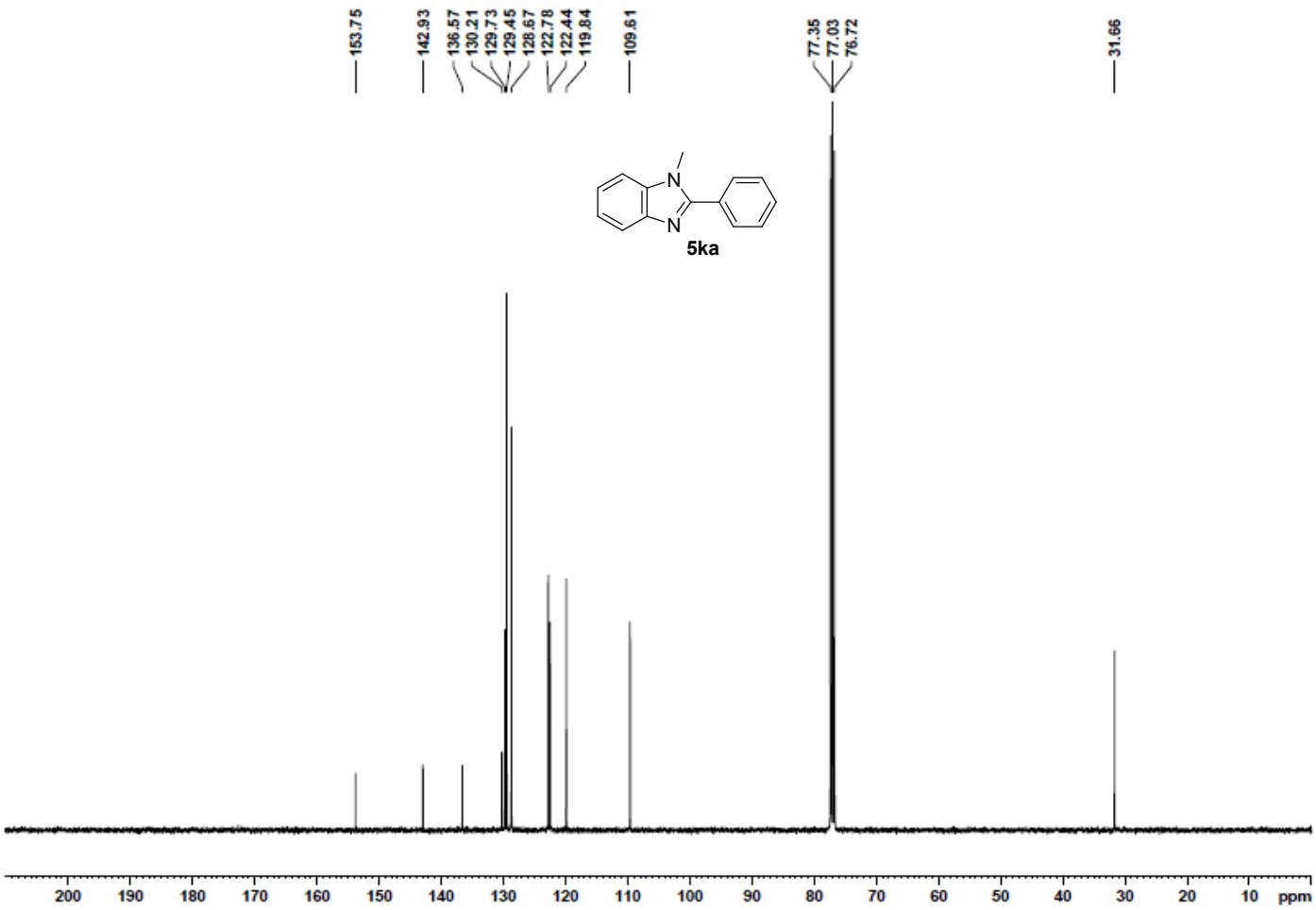
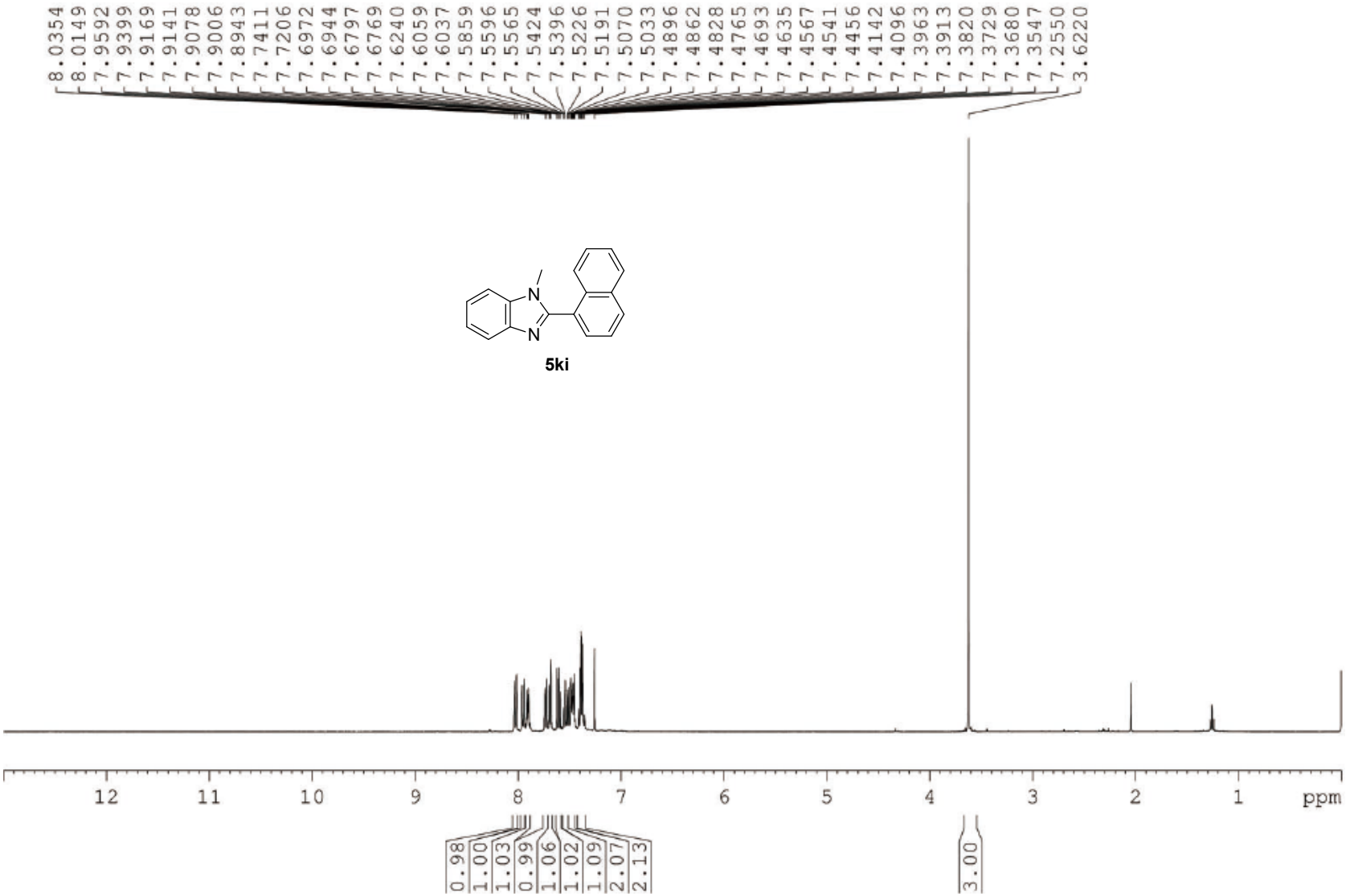
7.8417
7.8336
7.8297
7.8229
7.7756
7.7703
7.7558
7.7517
7.5414
7.5371
7.5291
7.5284
7.5177
7.5124
7.5100
7.5003
7.4032
7.3958
7.3920
7.3833
7.3801
7.3438
7.3311
7.3289
7.3264
7.3191
7.3114
7.3078
7.2938
7.2567
3.8563
N
N
5ka
10
9
8
7
6
5
4
3
2
1
ppm
0.97
1.94
2.94
0.99
2.01
3.00


153.75
142.93
136.57
130.21
129.73
129.45
128.67
122.78
122.44
119.84
109.61
77.35
77.03
76.72
31.66
N
N
5ka
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.9592
7.9399
7.9169
7.9141
7.9078
7.9006
7.8943
7.7411
7.7206
7.6972
7.6944
7.6797
7.6769
7.6240
7.6059
7.6037
7.5859
7.5596
7.5565
7.5424
7.5396
7.5226
7.5191
7.5070
7.5033
7.4896
7.4862
7.4828
7.4765
7.4693
7.4635
7.4567
7.4541
7.4456
7.4142
7.4096
7.3963
7.3913
7.3820
7.3729
7.3680
7.3547
7.2550
3.6220
N
N
12
11
10
9
8
7
6
5
4
3
2
1
ppm
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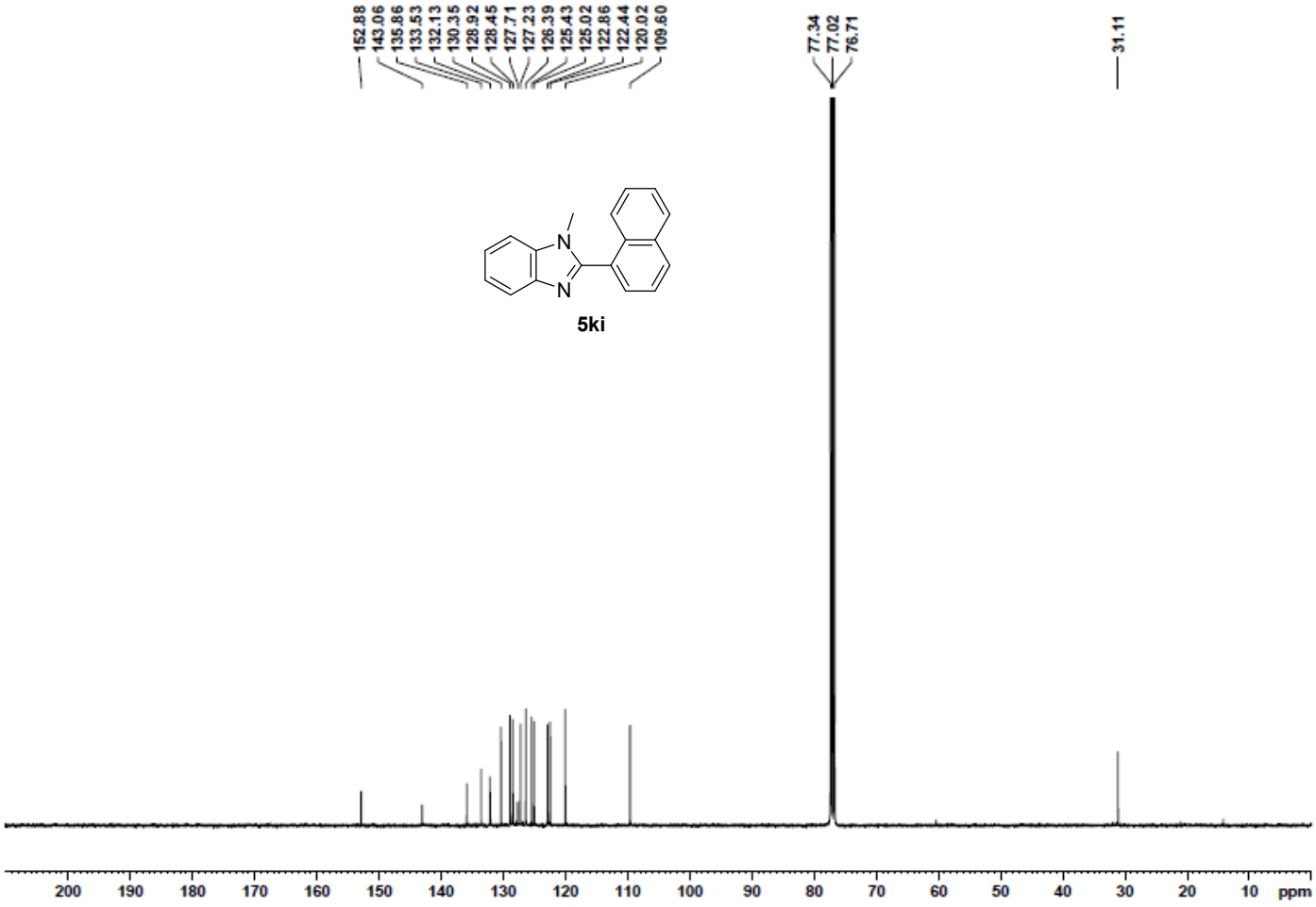
1.00
1.03
0.99
1.06
1.02
1.09
2.07
2.13
3.00

5ki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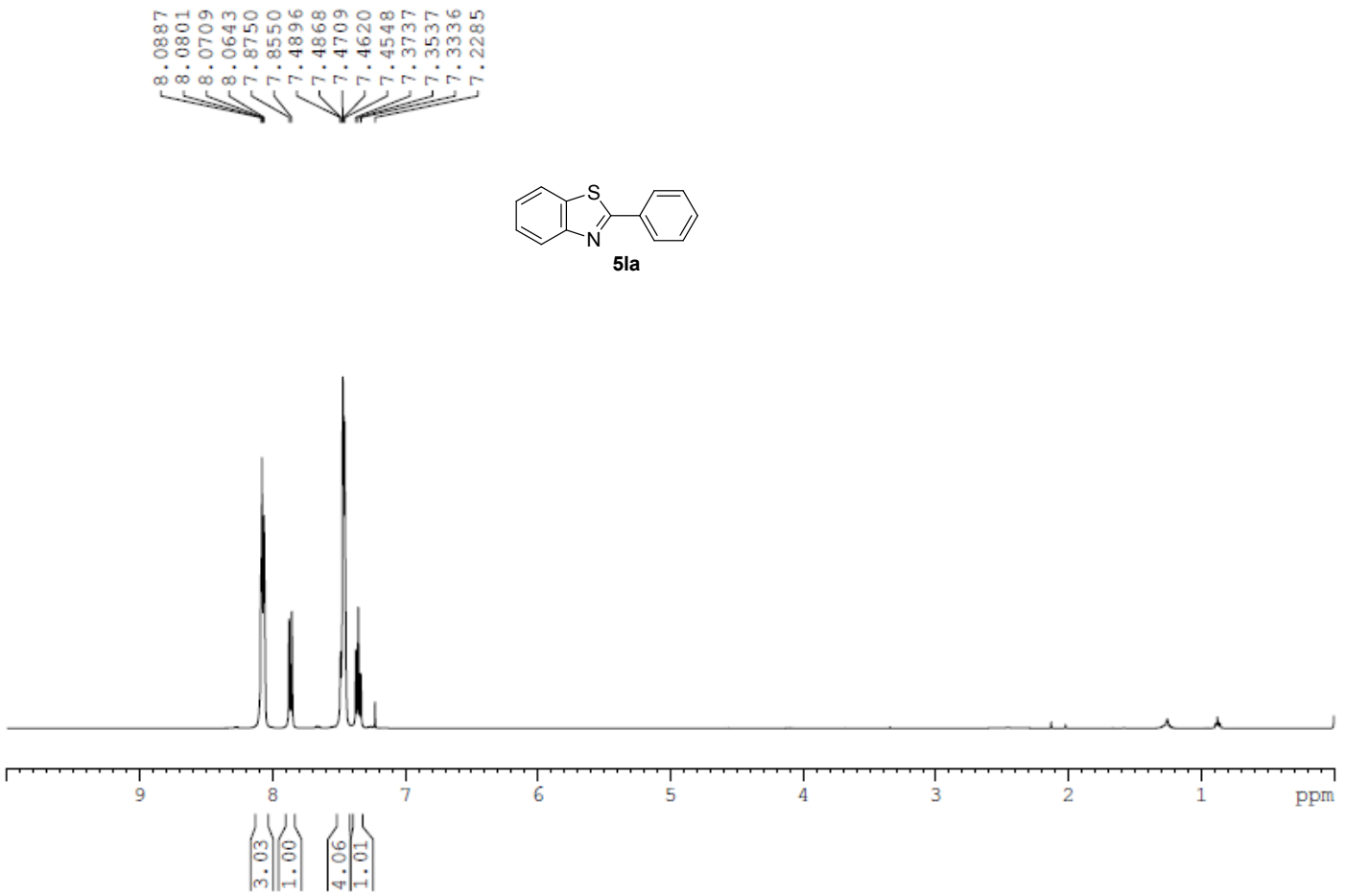
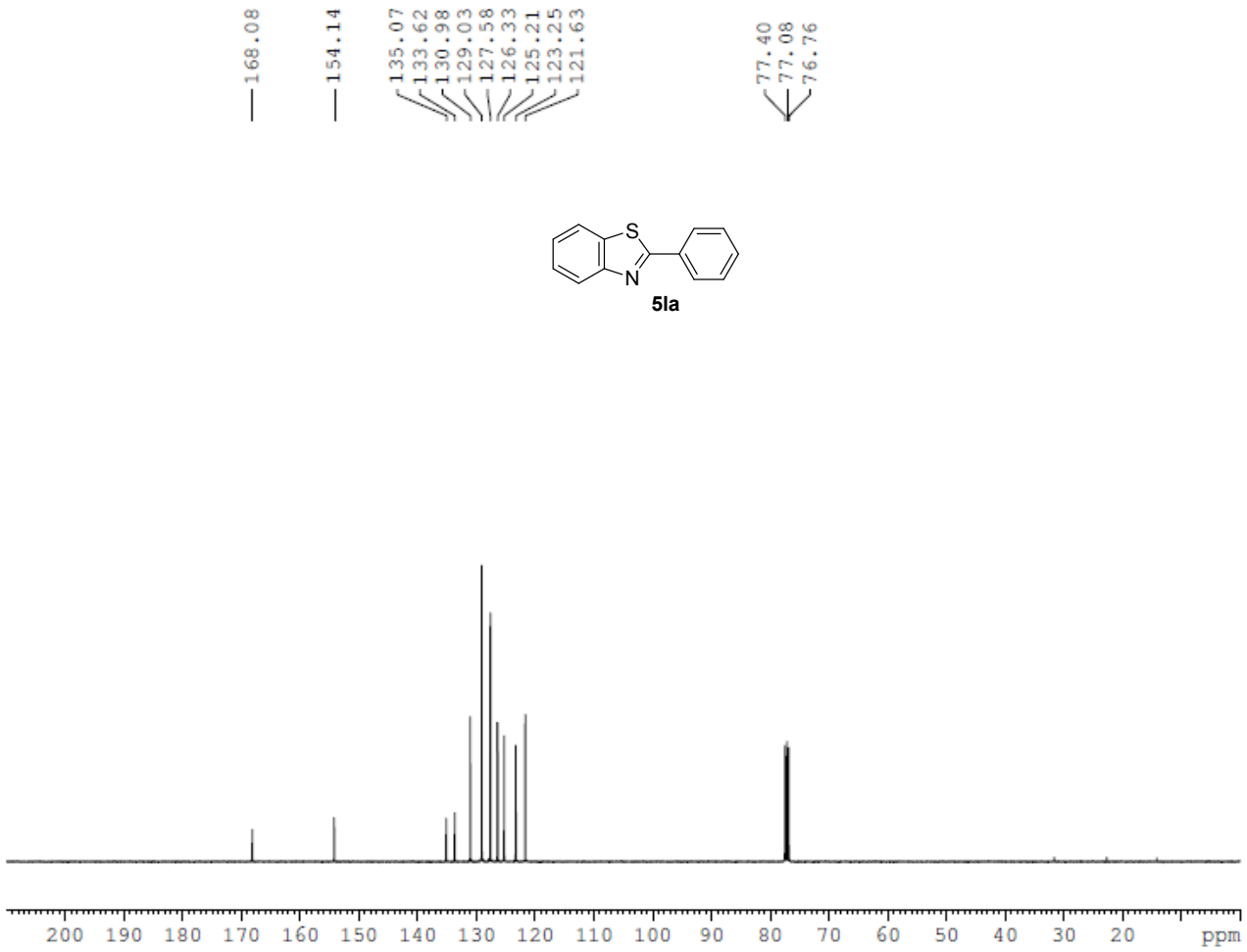
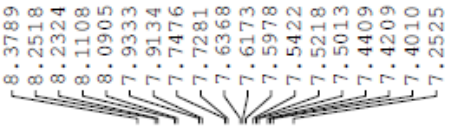
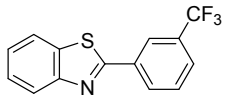
143.06
135.86
133.53
132.13
130.35
128.92
128.45
127.71
127.23
126.39
125.43
125.02
122.86
122.44
120.02
109.60
77.34
77.02
76.71
31.11
N
N
5ki
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


8.0887
8.0801
8.0709
8.0643
7.8750
7.8550
7.4896
7.4868
7.4709
7.4620
7.4548
7.3737
7.3537
7.3336
7.2285
S
N
5Ia
9
8
7
6
5
4
3
2
1
ppm
3.03
1.00
4.06
1.01

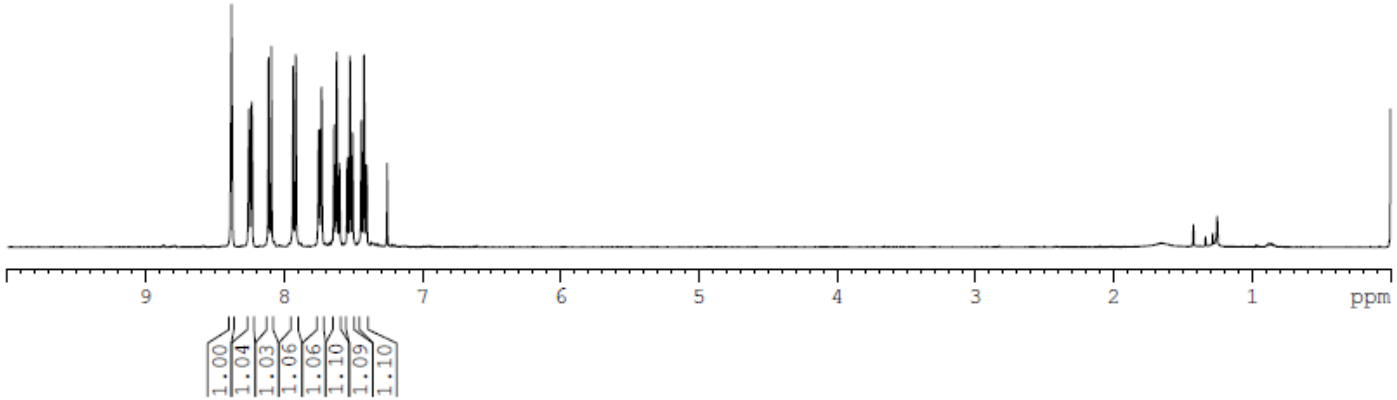

168.08
154.14
135.07
133.62
130.98
129.03
127.58
126.33
125.21
123.25
121.63
77.40
77.08
76.76
S
N
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

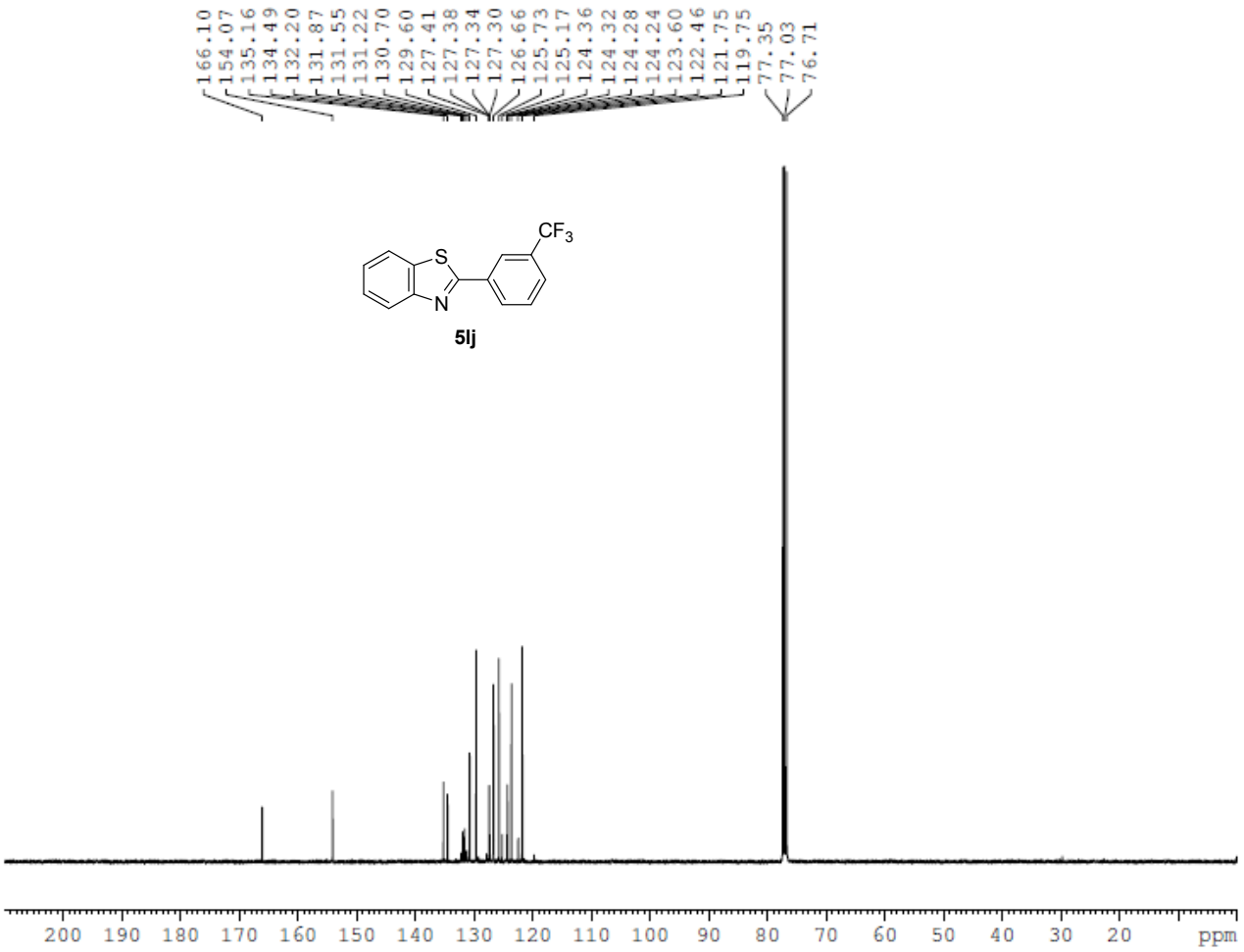
5la

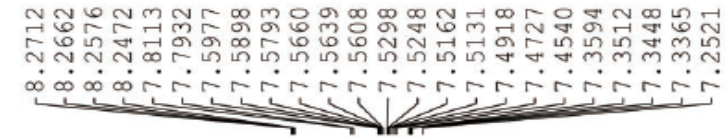

8.3789
8.2518
8.2324
8.1108
8.0905
7.9333
7.9134
7.7476
7.7281
7.6368
7.6173
7.5978
7.5422
7.5218
7.5013
7.4409
7.4209
7.4010
7.2525

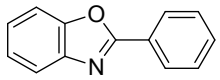

CF3
S
N

5lj

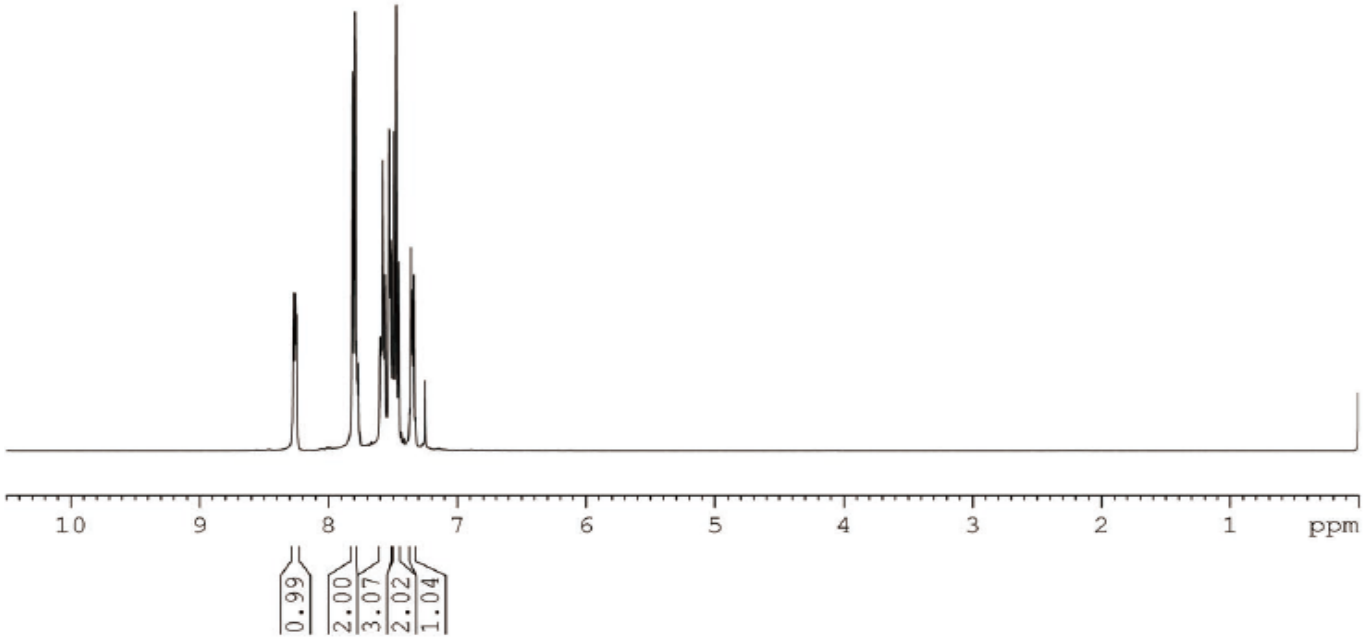

9
8
7
6
5
4
3
2
1
ppm
1.00
1.04
1.03
1.06
1.06
1.10
1.09
1.10

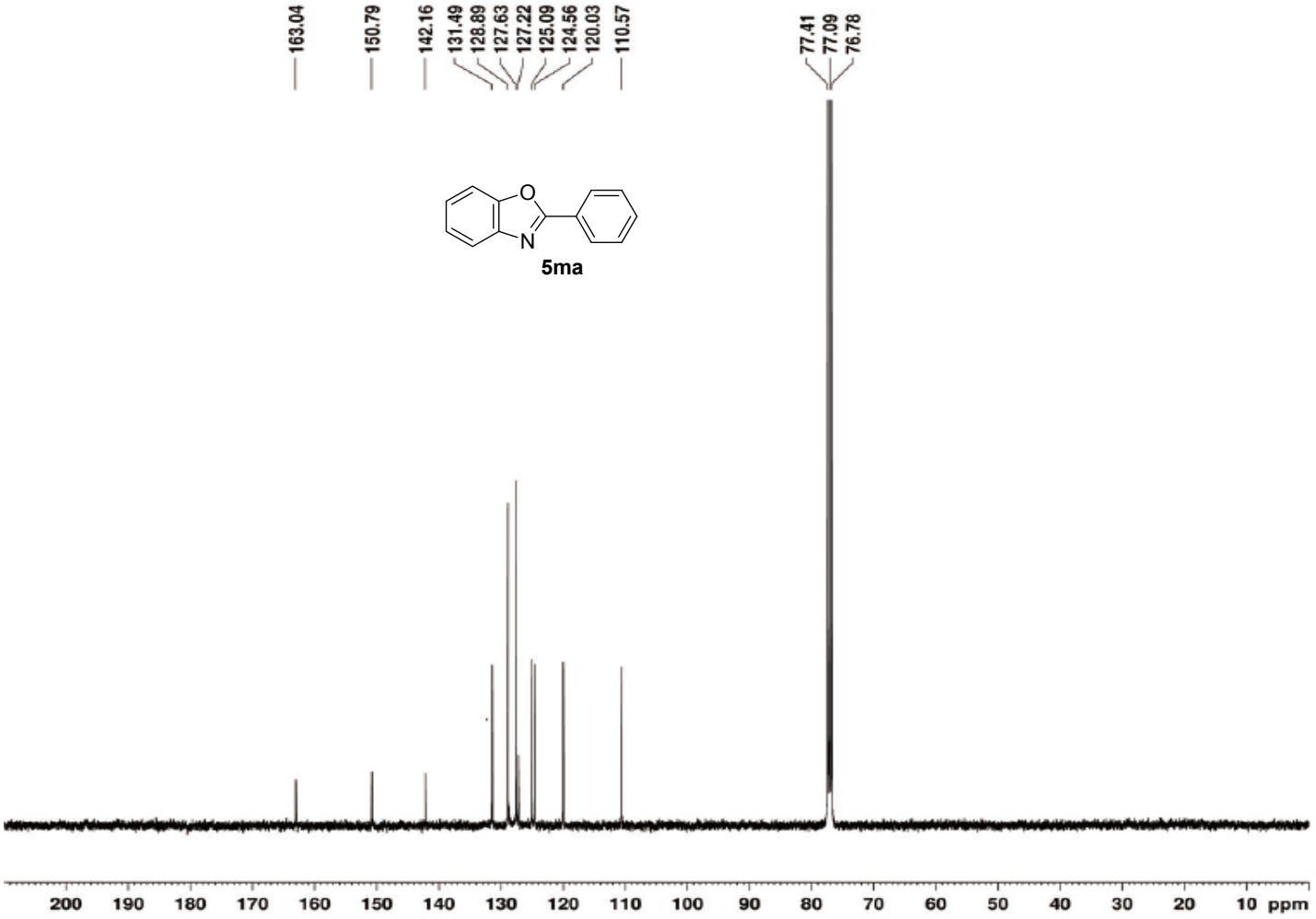

166.10
154.07
135.16
134.49
132.20
131.87
131.55
131.22
130.70
129.60
127.41
127.38
127.34
127.30
126.66
125.73
125.17
124.36
124.32
124.28
124.24
123.60
122.46
121.75
119.75
77.35
77.03
76.71
CF3
S
N
5lj
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

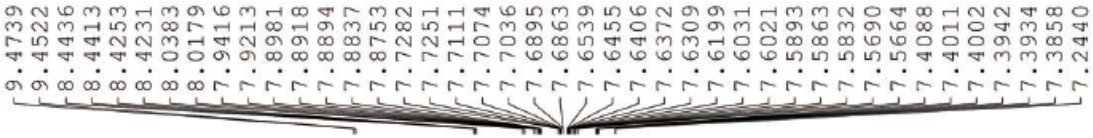

8.2712
8.2662
8.2576
8.2472
7.8113
7.7932
7.5977
7.5898
7.5793
7.5660
7.5639
7.5608
7.5298
7.5248
7.5162
7.5131
7.4918
7.4727
7.4540
7.3594
7.3512
7.3448
7.3365
7.2521

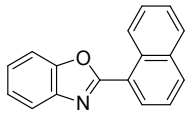


5ma

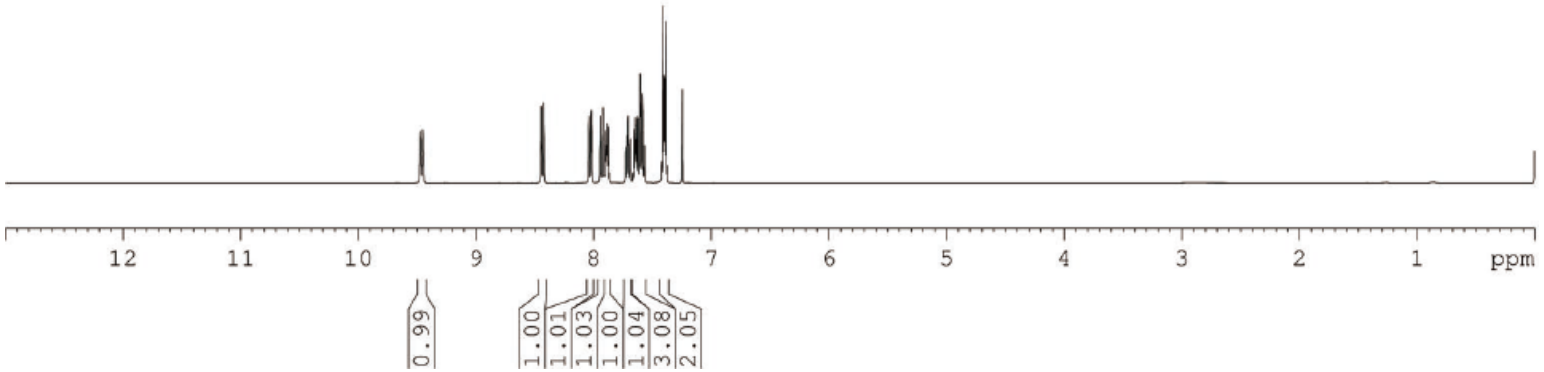

10
9
8
7
6
5
4
3
2
1
ppm
0.99
2.00
3.07
2.02
1.04

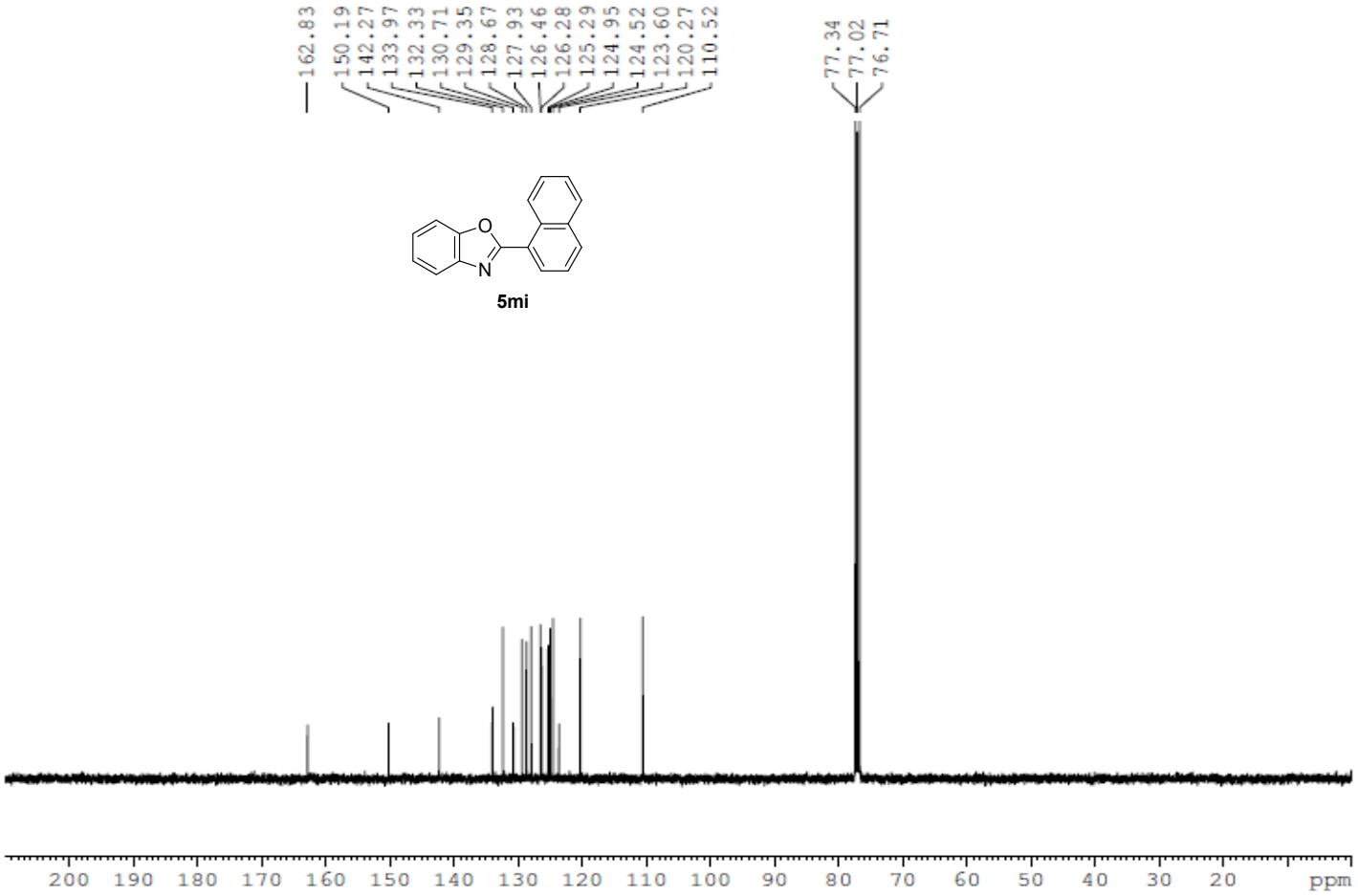

163.04
150.79
142.16
131.49
128.89
127.63
127.22
125.09
124.56
120.03
110.57
77.41
77.09
76.78
O
N
5ma
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


9.4739
9.4522
8.4436
8.4413
8.4253
8.4231
8.0383
8.0179
7.9416
7.9213
7.8981
7.8918
7.8894
7.8837
7.8753
7.7282
7.7251
7.7111
7.7074
7.7036
7.6895
7.6863
7.6539
7.6455
7.6406
7.6372
7.6309
7.6199
7.6031
7.6021
7.5893
7.5863
7.5832
7.5690
7.5664
7.4088
7.4011
7.4002
7.3942
7.3934
7.3858
7.2440


O
N

5mi


12
11
10
9
8
7
6
5
4
3
2
1
ppm
0.99
1.00
1.01
1.03
1.00
1.04
3.08
2.05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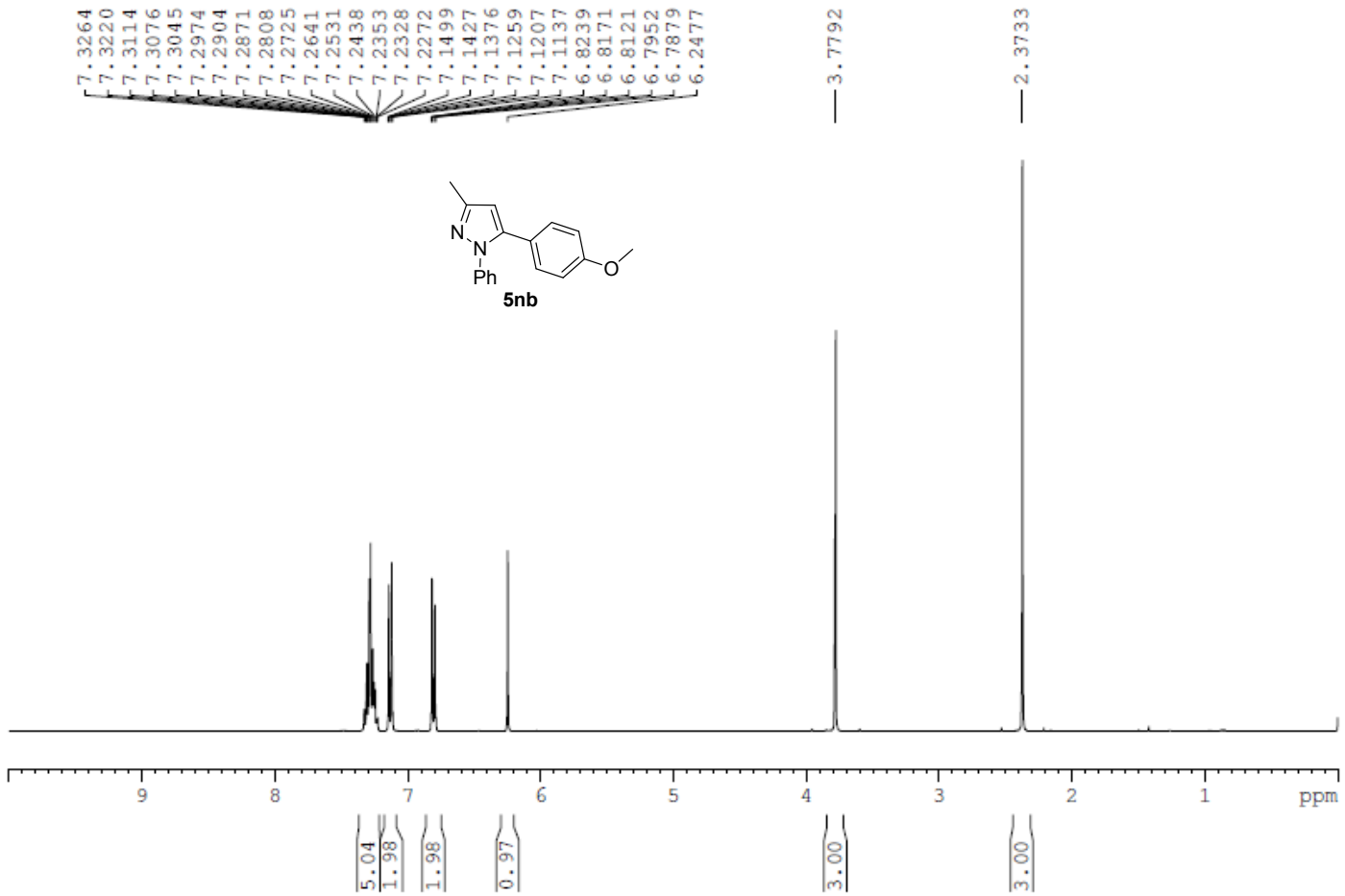
150.19
142.27
133.97
132.33
130.71
129.35
128.67
127.93
126.46
126.28
125.29
124.95
124.52
123.60
120.27
110.52
77.34
77.02
76.71
O
N
5mi
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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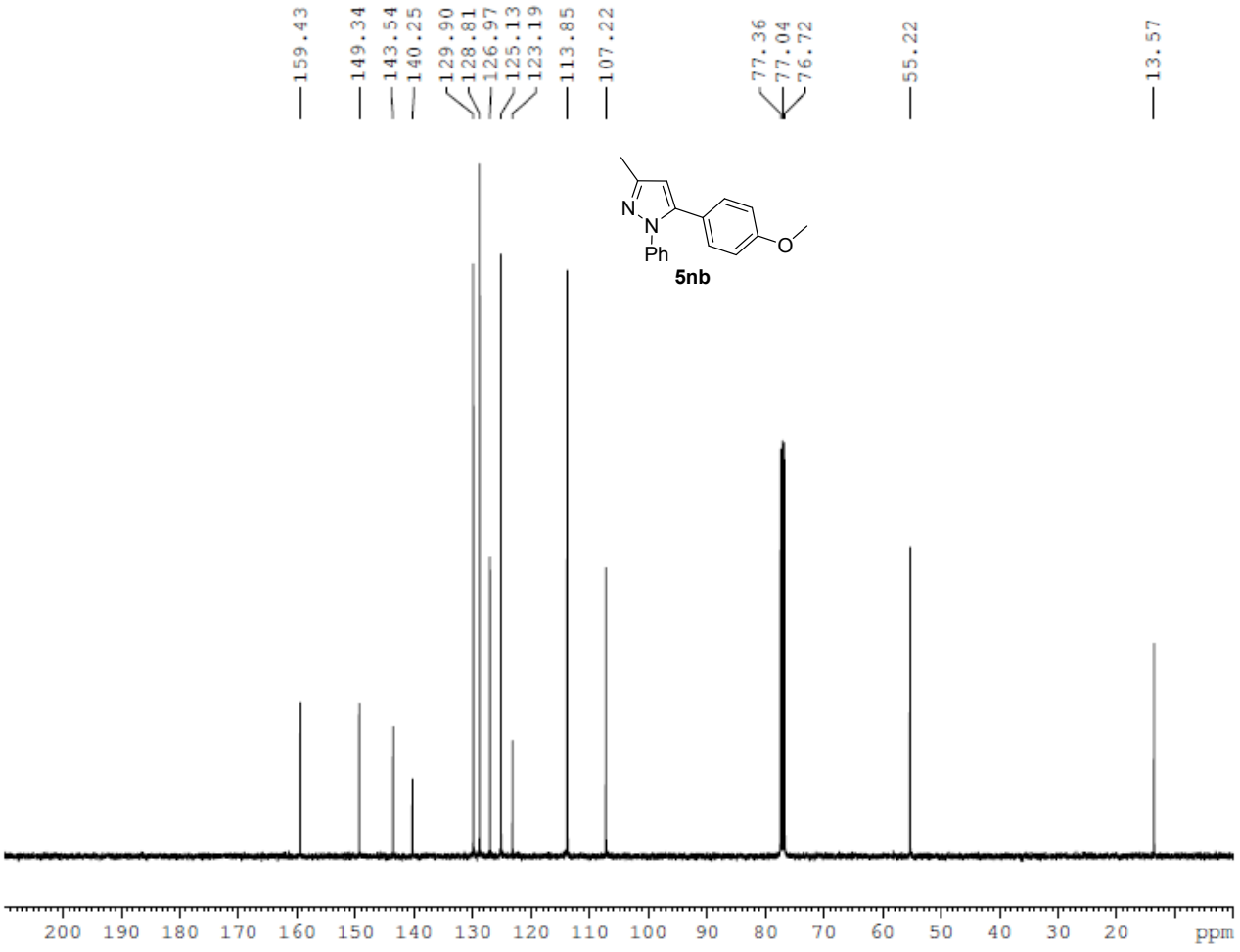
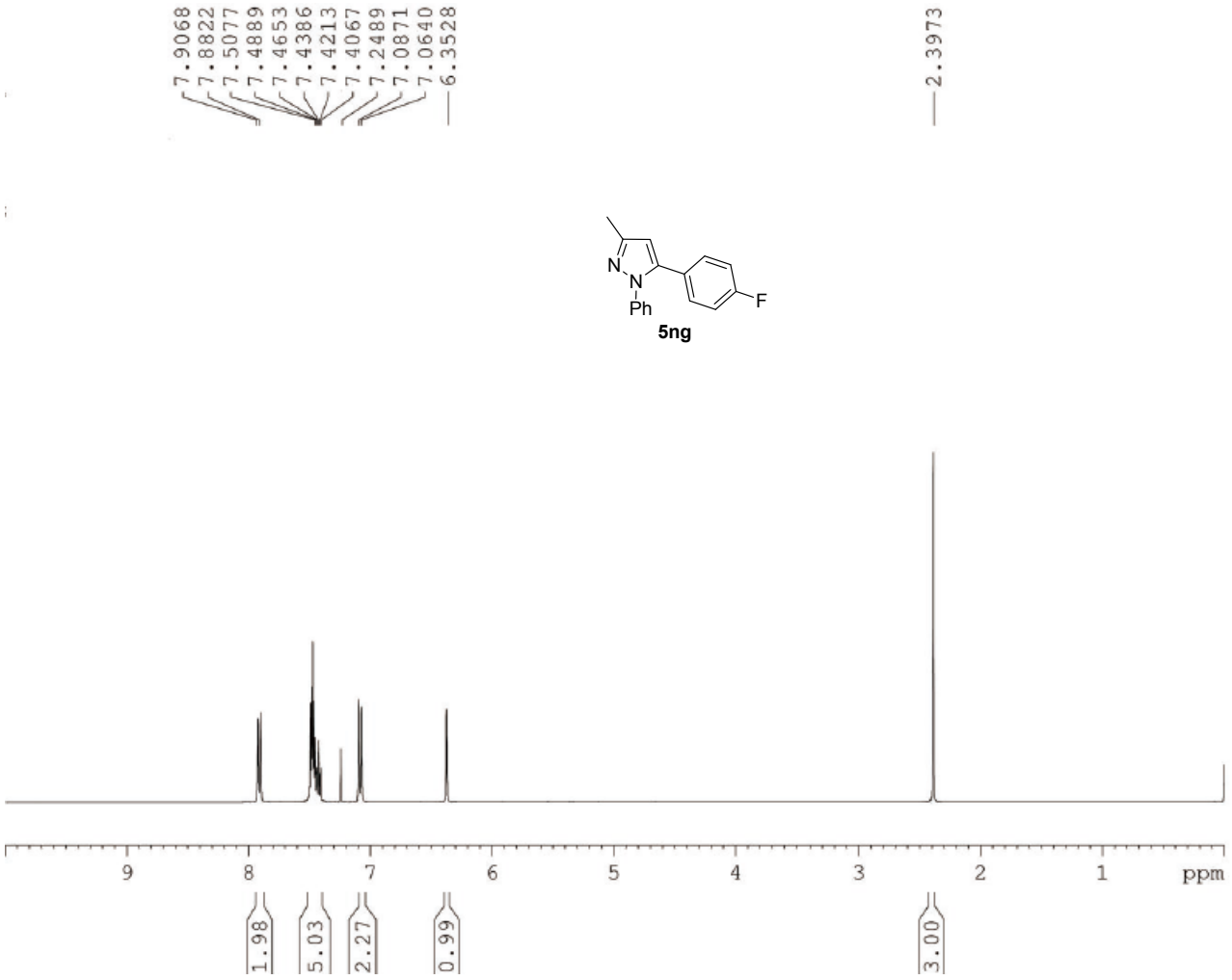
7.3220
7.3114
7.3076
7.3045
7.2974
7.2904
7.2871
7.2808
7.2725
7.2641
7.2531
7.2438
7.2353
7.2328
7.2272
7.1499
7.1427
7.1376
7.1259
7.1207
7.1137
6.8239
6.8171
6.8121
6.7952
6.7879
6.2477
3.7792
2.3733
N
N
Ph
O
5nb
9
8
7
6
5
4
3
2
1
ppm
5.04
1.98
1.98
0.97
3.00
3.00


159.43
149.34
143.54
140.25
129.90
128.81
126.97
125.13
123.19
113.85
107.22
77.36
77.04
76.72
55.22
13.57
N
N
Ph
O
5nb
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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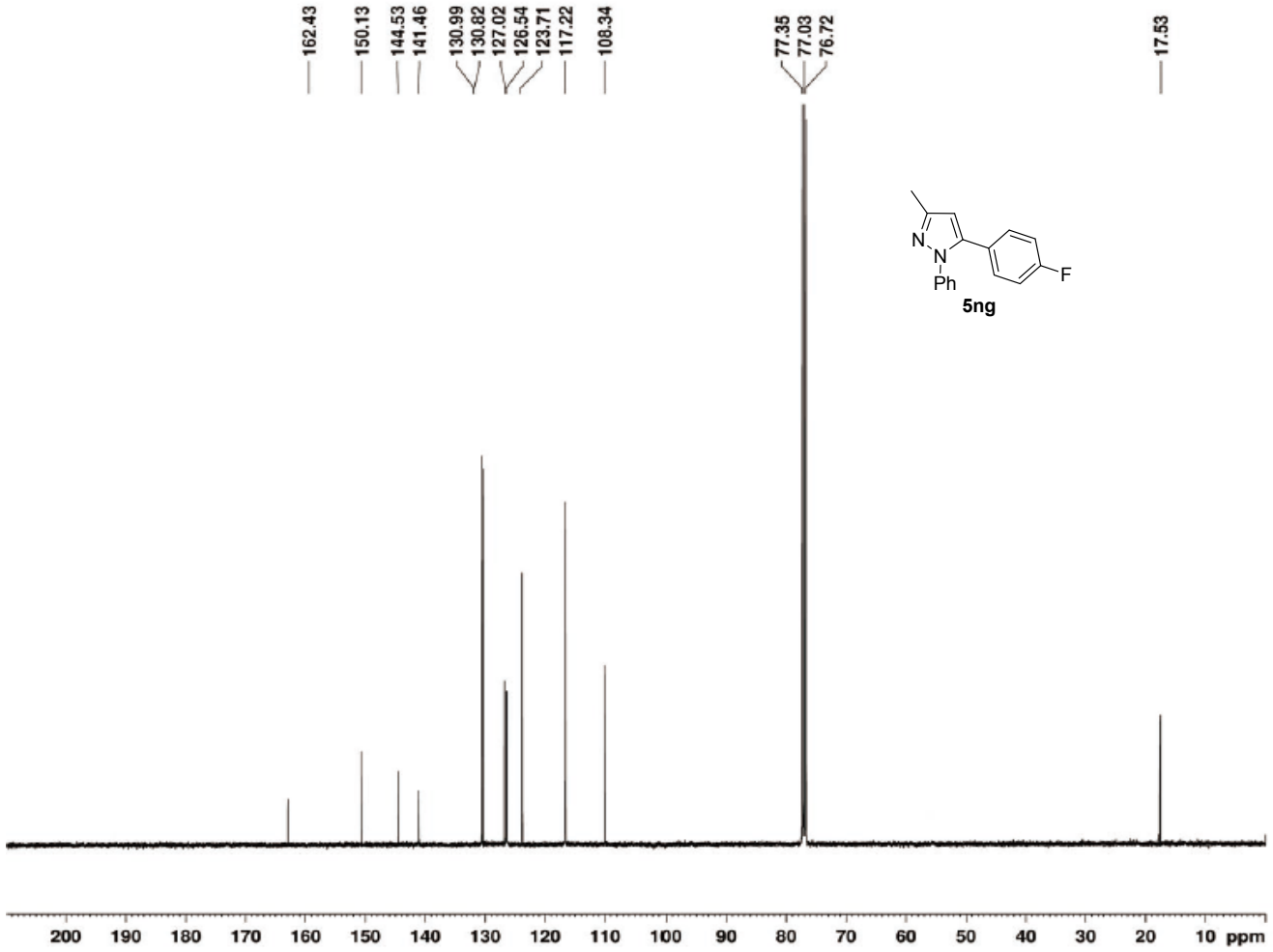
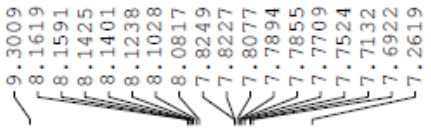
7.8822
7.5077
7.4889
7.4653
7.4386
7.4213
7.4067
7.2489
7.0871
7.0640
6.3528
2.3973
N
N
Ph
F
5ng
9
8
7
6
5
4
3
2
1
ppm
1.98
5.03
2.27
0.99
3.00


162.43
150.13
144.53
141.46
130.99
130.82
127.02
126.54
123.71
117.22
108.34
77.35
77.03
76.72
17.53
N
N
Ph
F
5ng
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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8.1619
8.1591
8.1425
8.1401
8.1238
8.1028
8.0817
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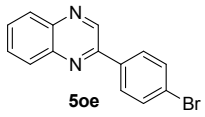
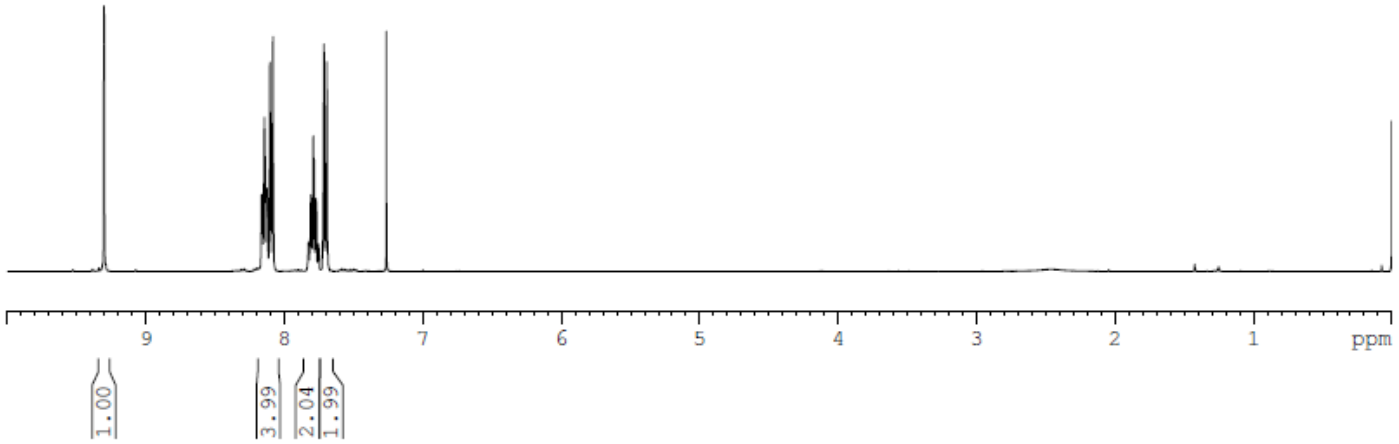
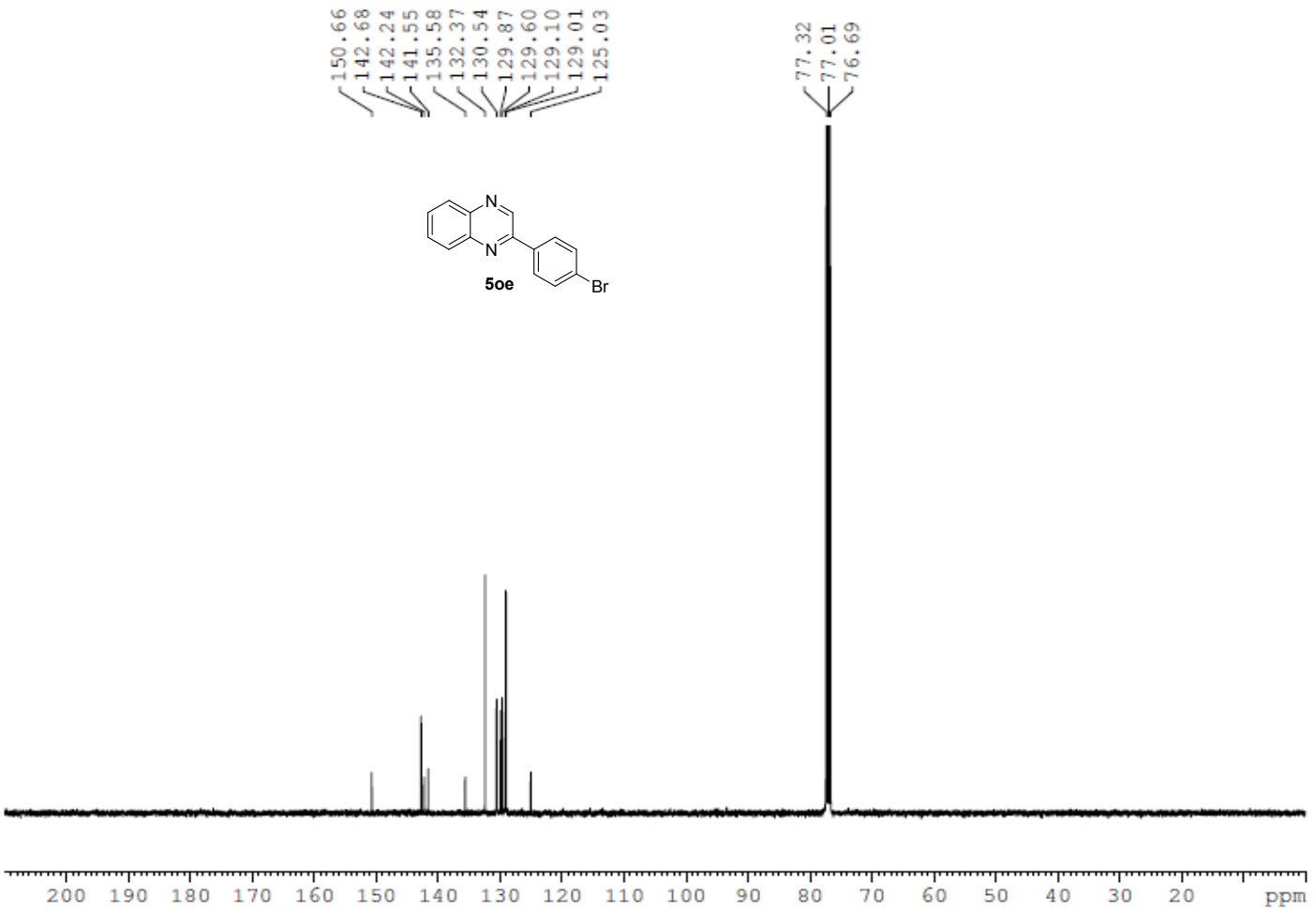
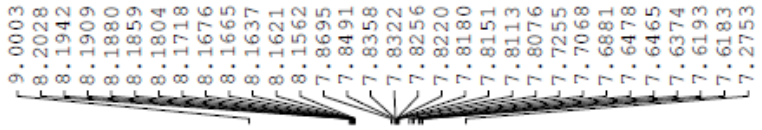
7.7709
7.7524
7.7132
7.6922
7.2619


N
N
Br

5oe


9
8
7
6
5
4
3
2
1
ppm
1.00
3.99
2.04
1.99


150.66
142.68
142.24
141.55
135.58
132.37
130.54
129.87
129.60
129.10
129.01
125.03
77.32
77.01
76.69
N
N
Br
5oe
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm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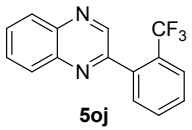
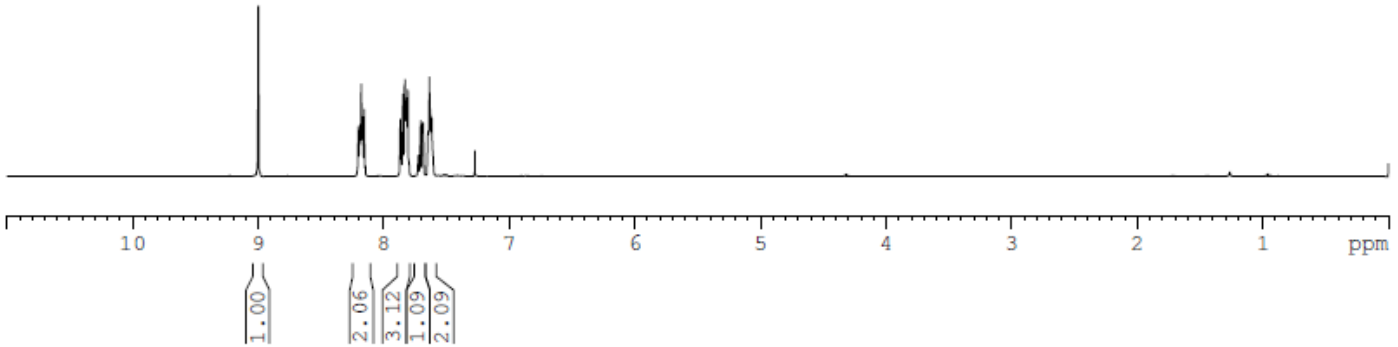
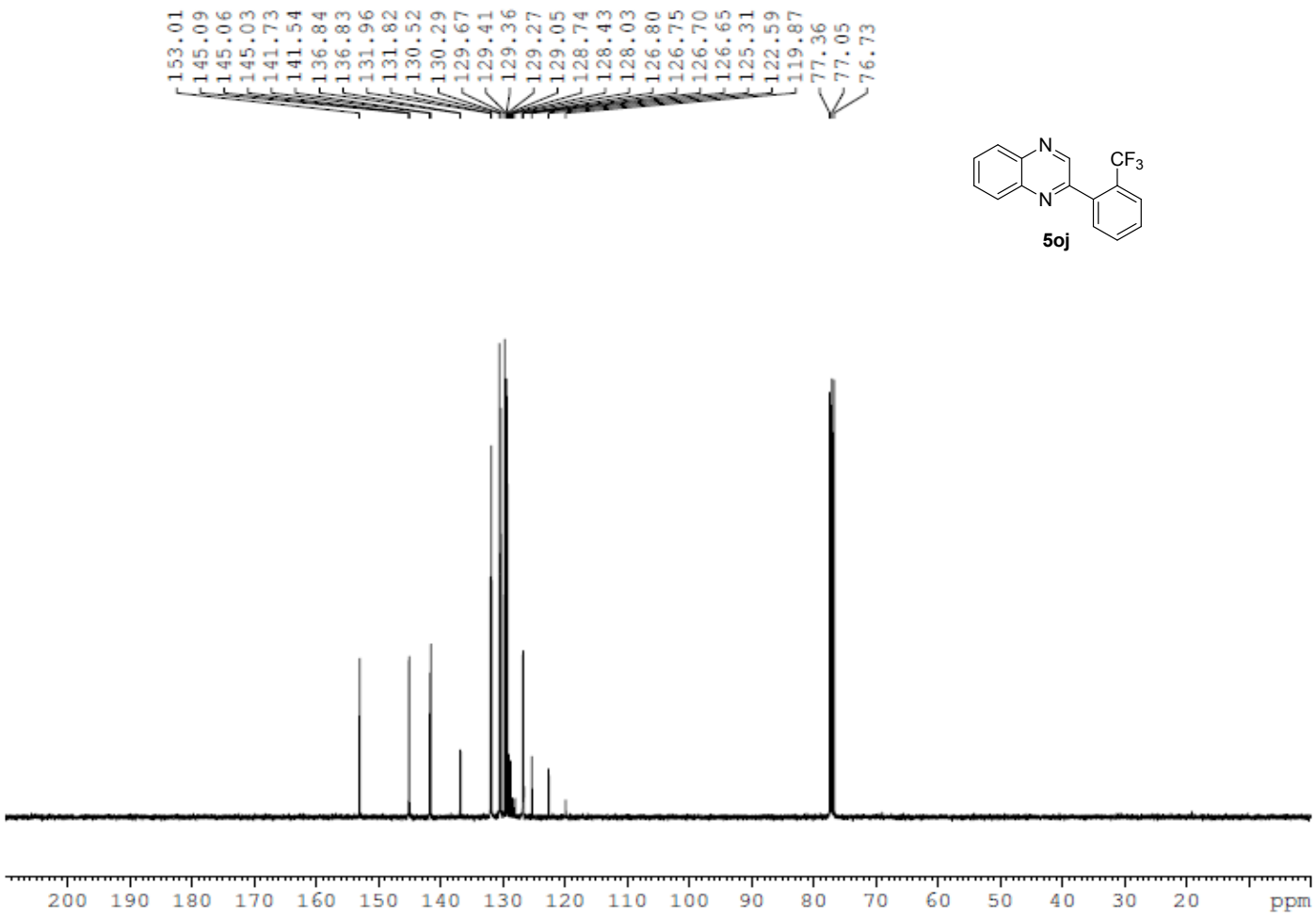
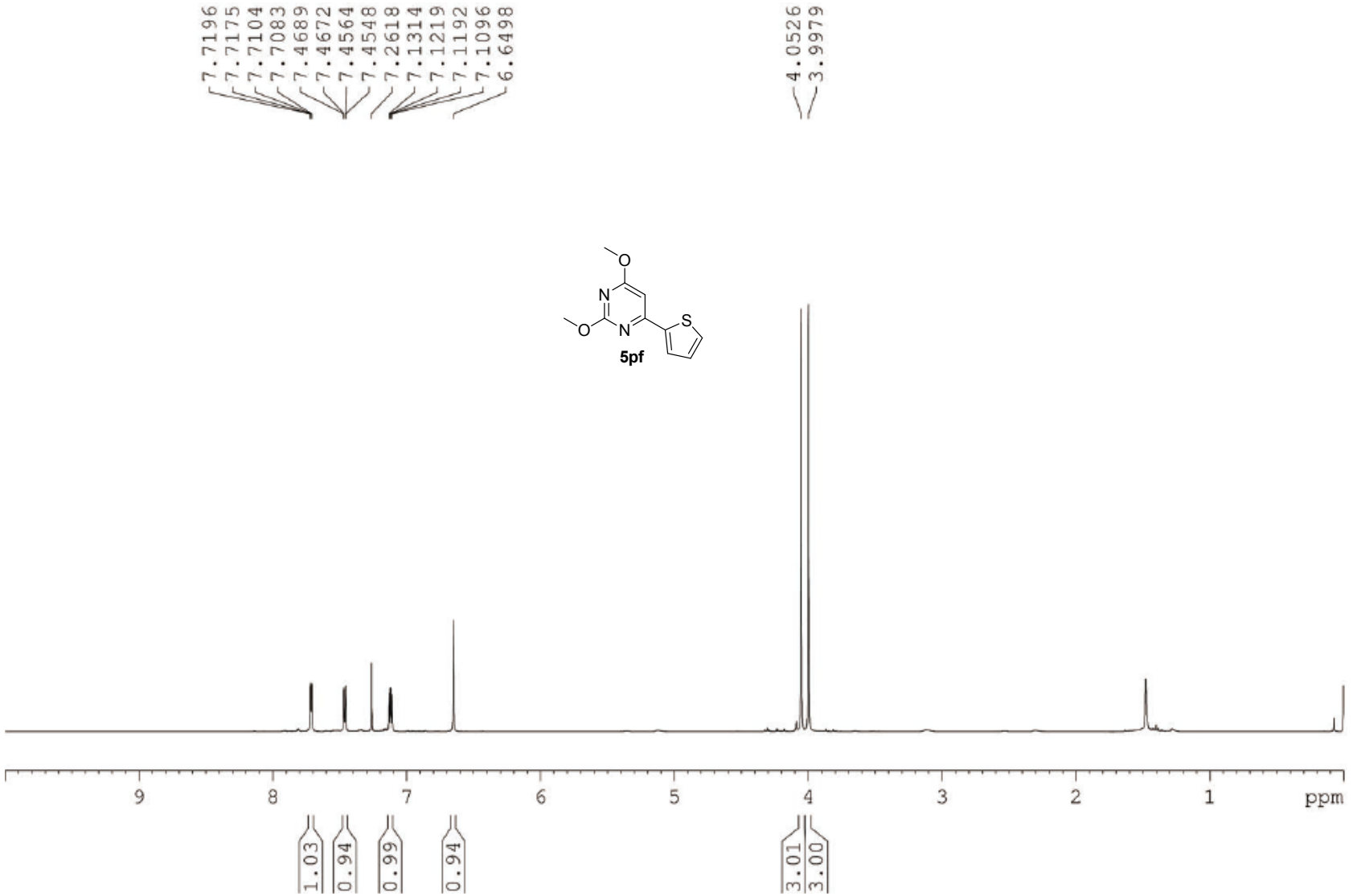
8.2028
8.1942
8.1909
8.1880
8.1859
8.1804
8.1718
8.1676
8.1665
8.1637
8.1621
8.1562
7.8695
7.8491
7.8358
7.8322
7.8256
7.8220
7.8180
7.8151
7.8113
7.8076
7.7255
7.7068
7.6881
7.6478
7.6465
7.6374
7.6193
7.6183
7.2753


N
N
CF3

5oj


10
9
8
7
6
5
4
3
2
1
ppm
1.00
2.06
3.12
1.09
2.09


153.01
145.09
145.06
145.03
141.73
141.54
136.84
136.83
131.96
131.82
130.52
130.29
129.67
129.41
129.36
129.27
129.05
128.74
128.43
128.03
126.80
126.75
126.70
126.65
125.31
122.59
119.87
77.36
77.05
76.73
N
N
CF3
5oj
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm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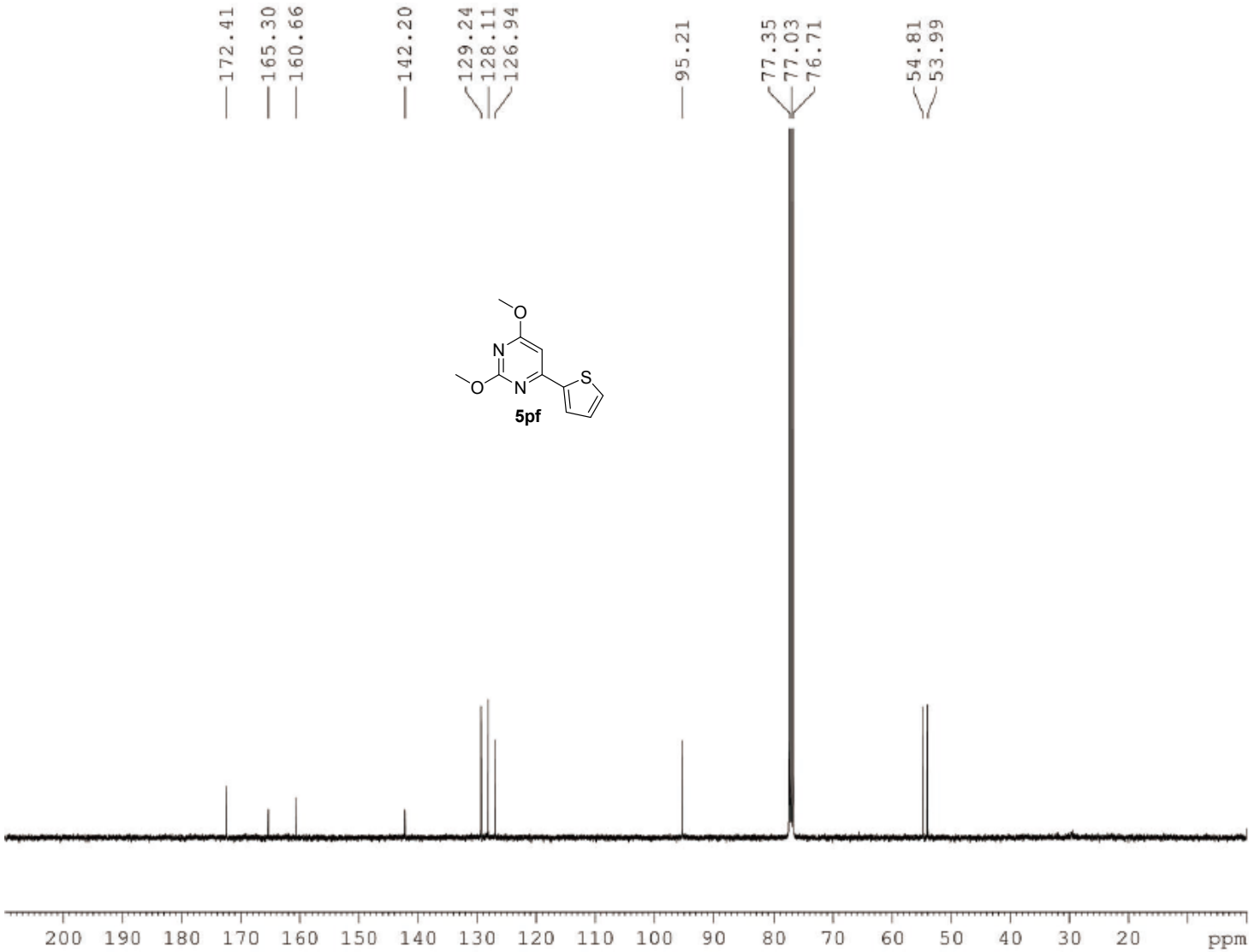
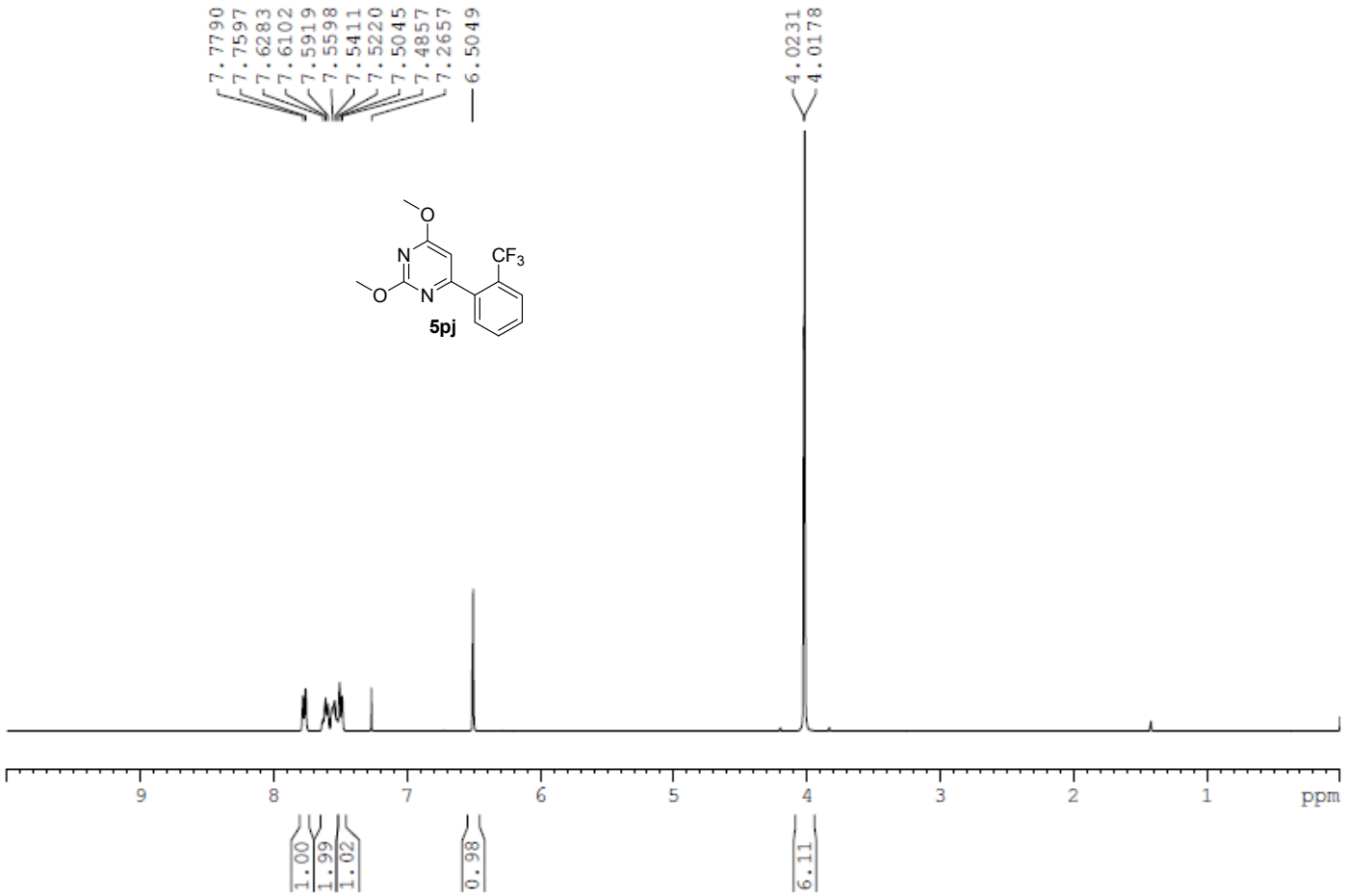
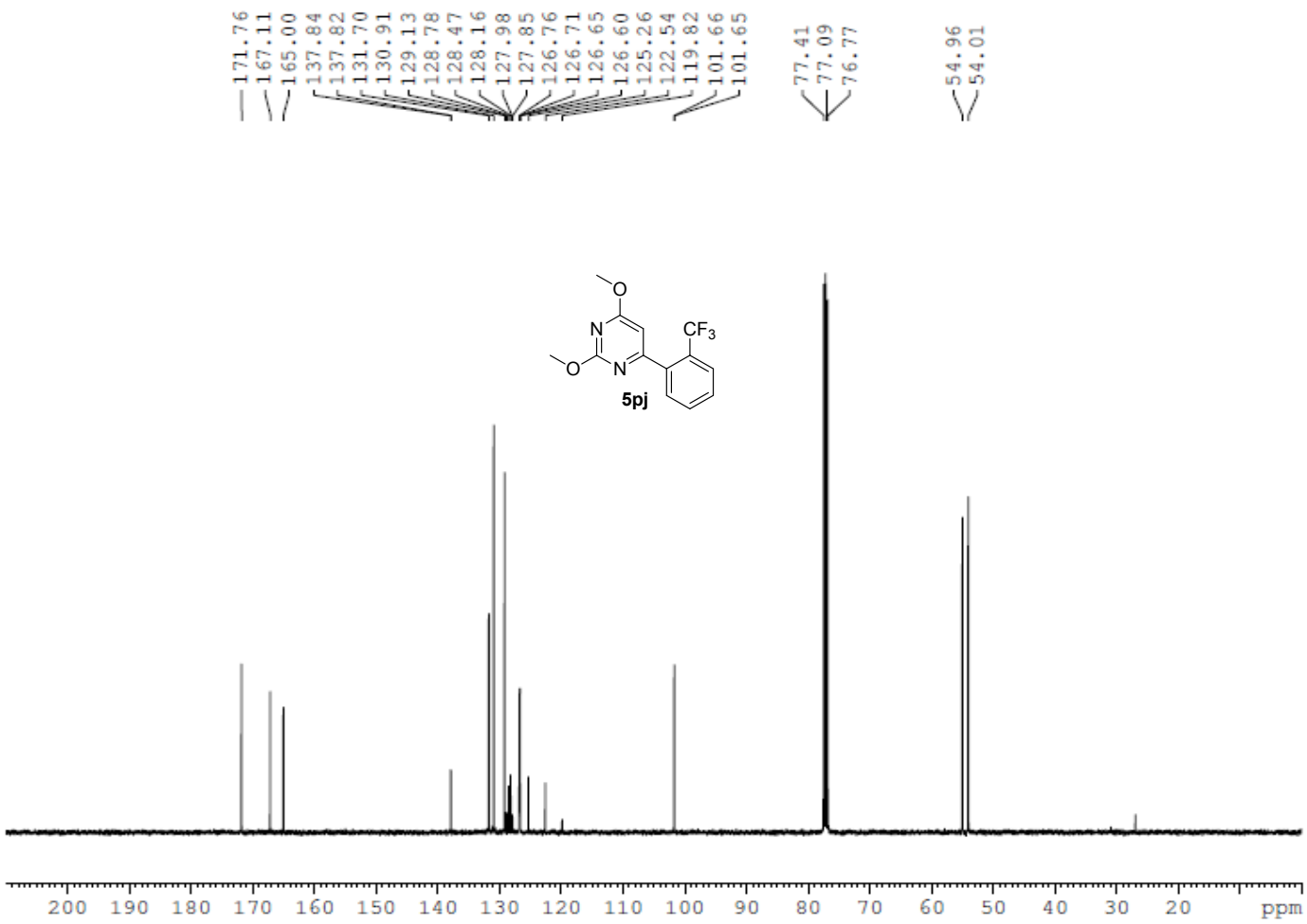
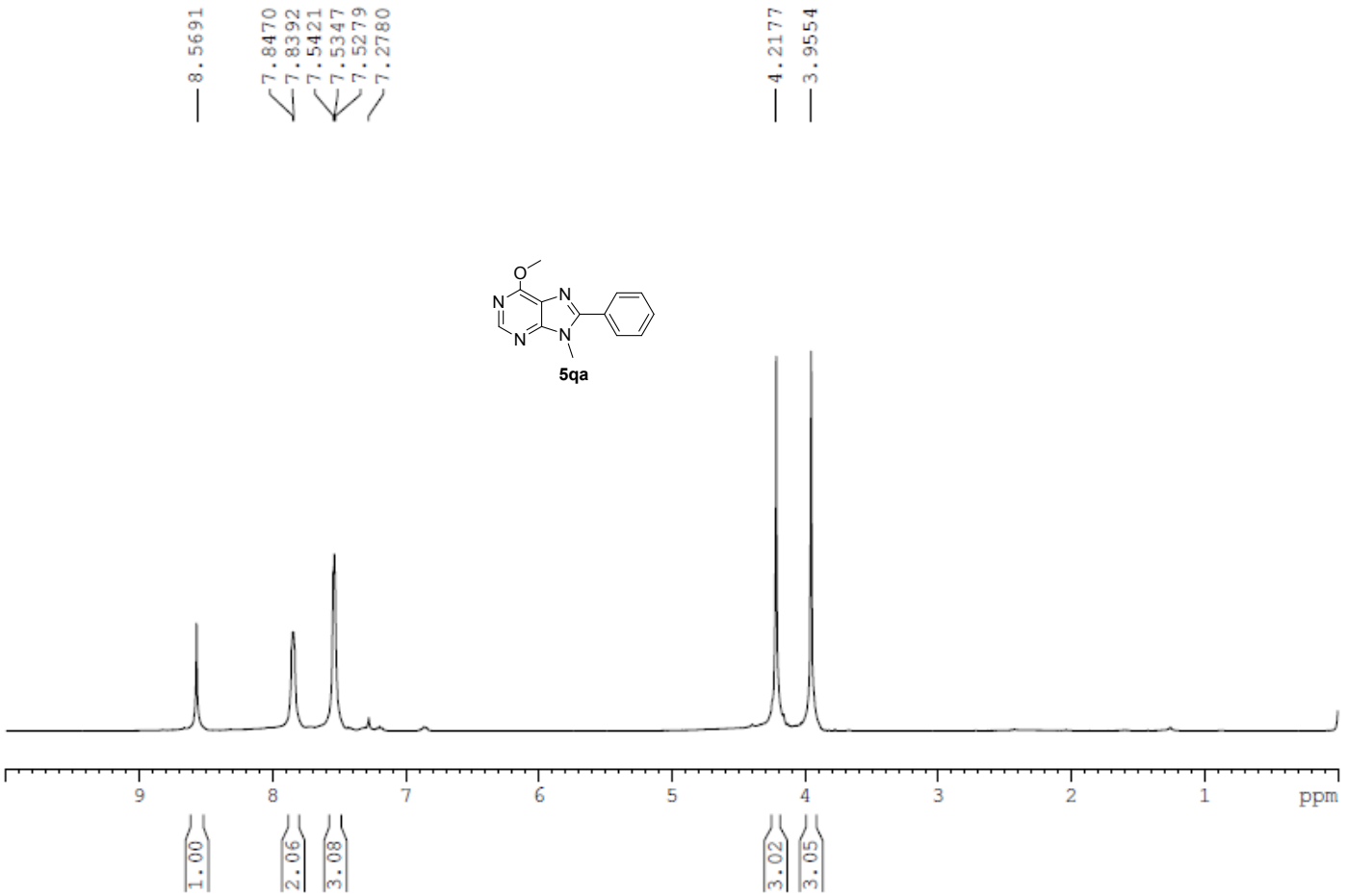
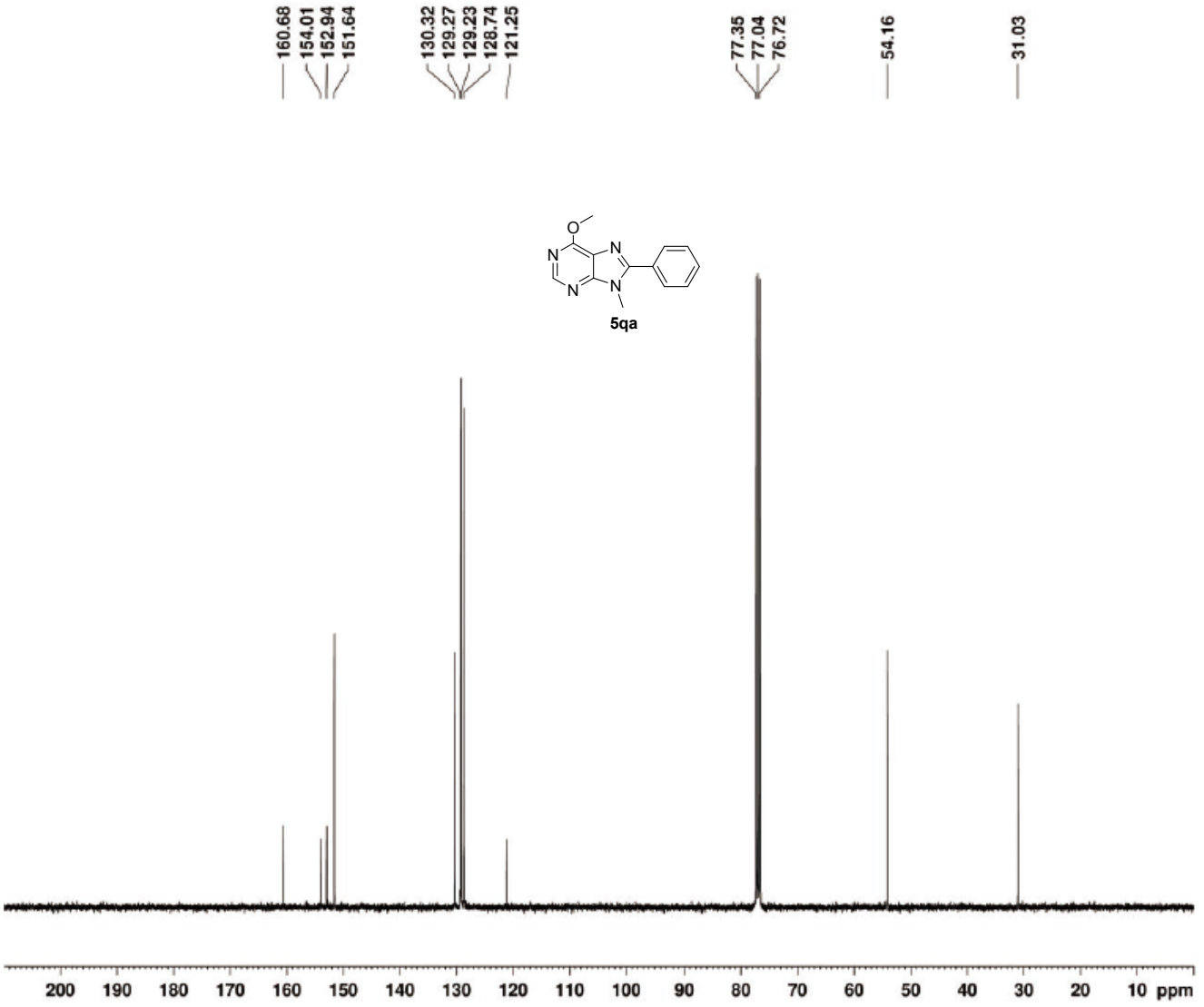
7.7175
7.7104
7.7083
7.4689
7.4672
7.4564
7.4548
7.2618
7.1314
7.1219
7.1192
7.1096
6.6498
4.0526
3.9979
O
N
O
N
S
5pf
9
8
7
6
5
4
3
2
1
ppm
1.03
0.94
0.99
0.94
3.01
3.00

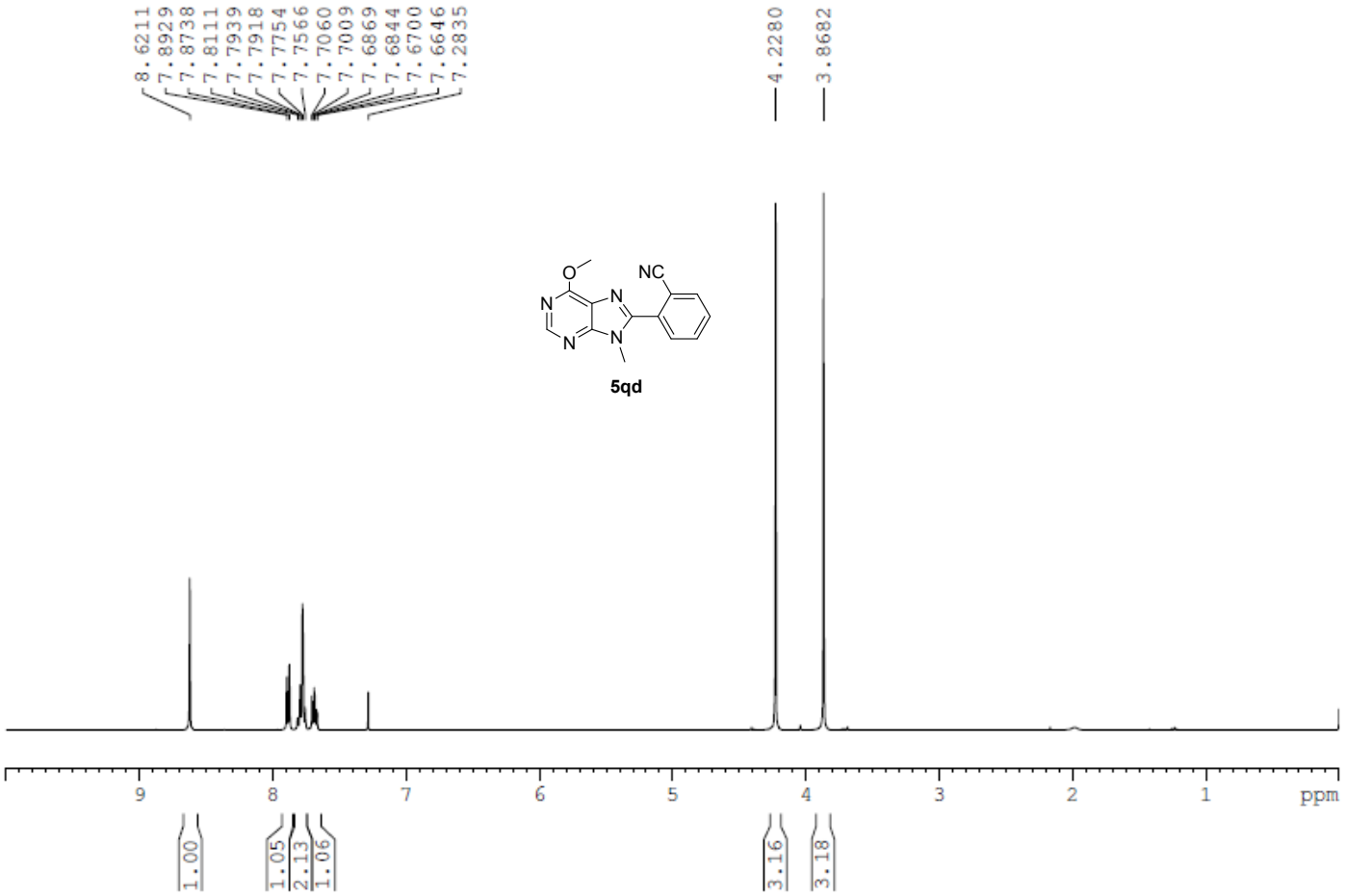

172.41
165.30
160.66
142.20
129.24
128.11
126.94
95.21
77.35
77.03
76.71
54.81
53.99
O
N
O
N
S
5pf
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

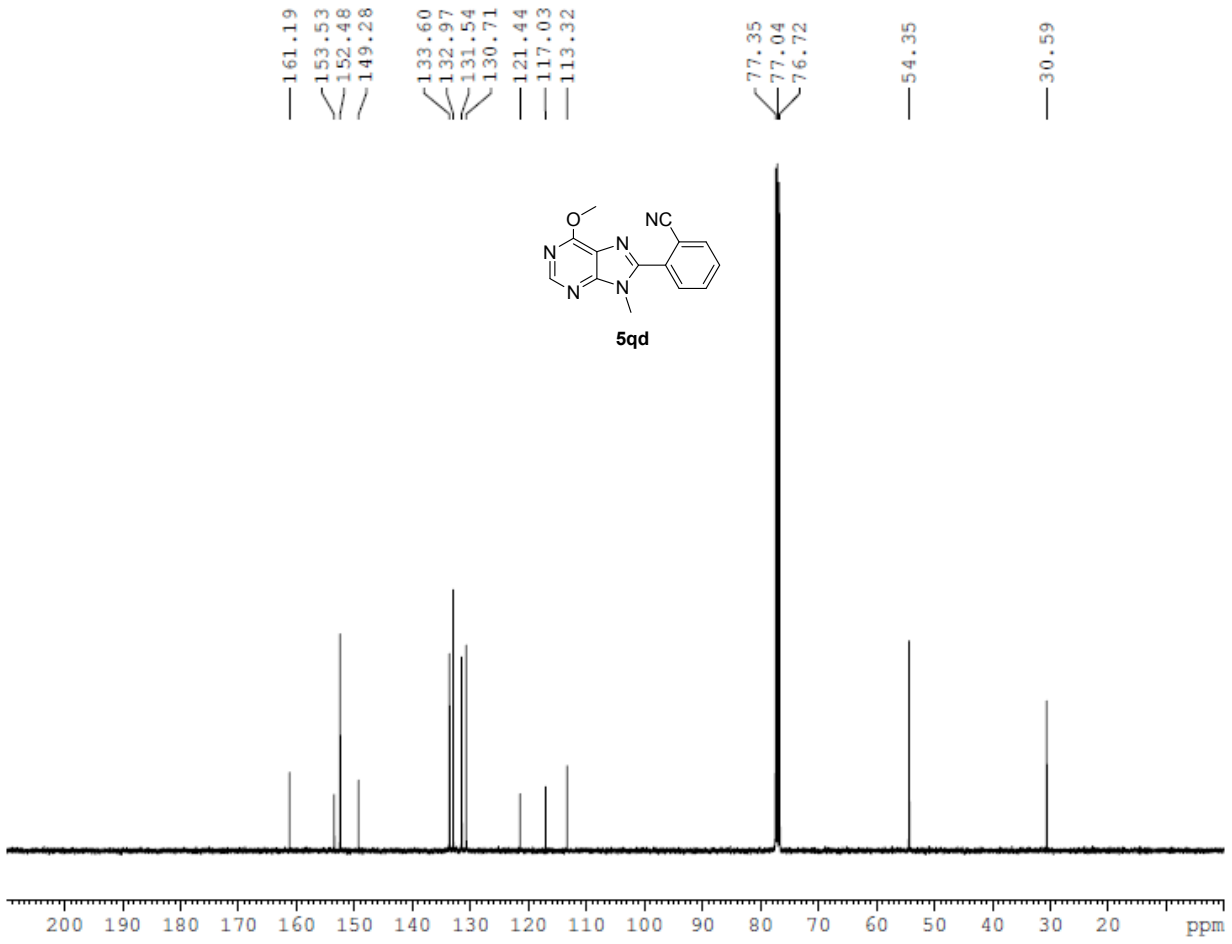

7.7790
7.7597
7.6283
7.6102
7.5919
7.5598
7.5411
7.5220
7.5045
7.4857
7.2657
6.5049
4.0231
4.0178
O
N
O
N
CF3
5pj
9
8
7
6
5
4
3
2
1
ppm
1.00
1.99
1.02
0.98
6.11

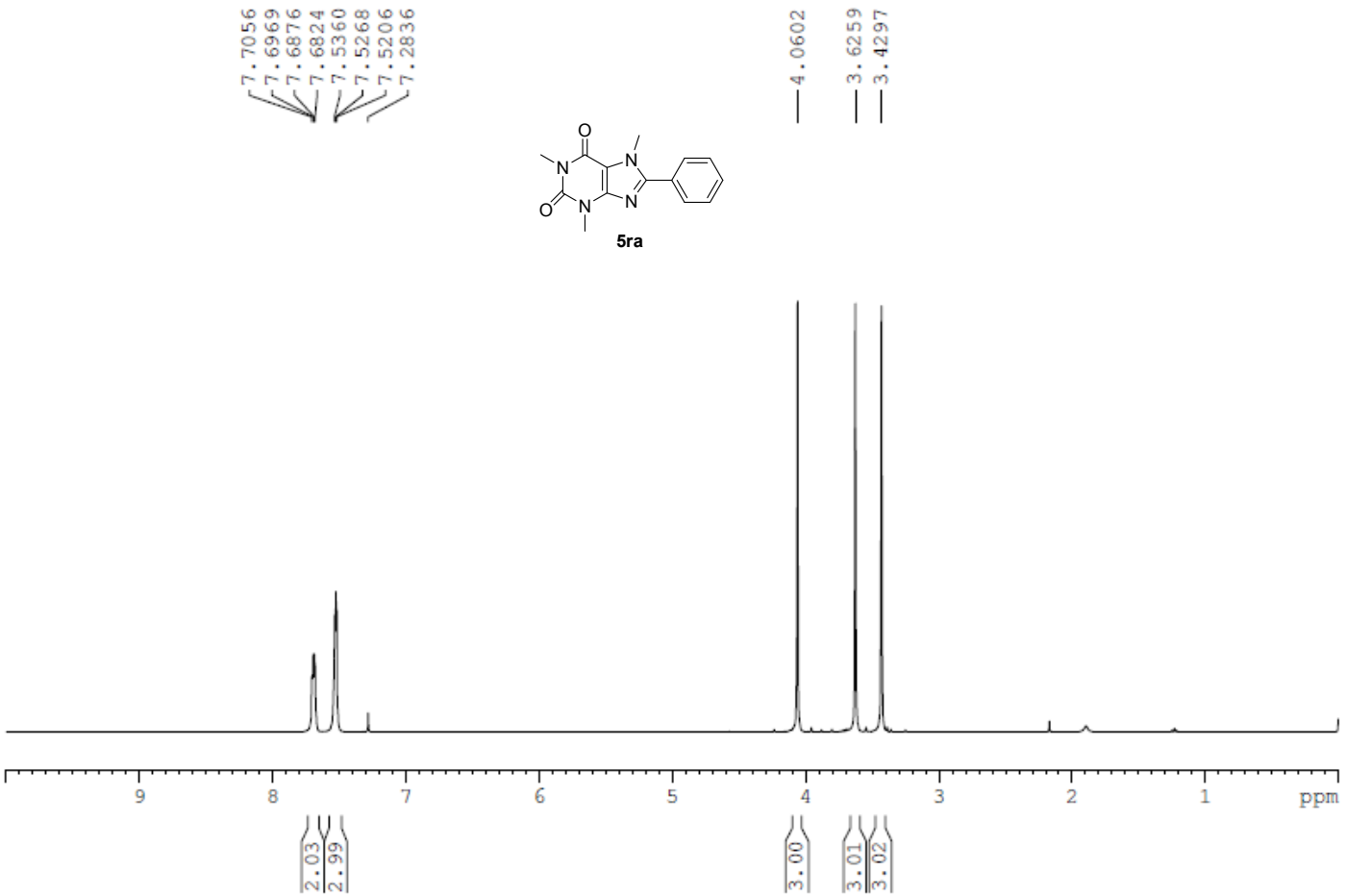

171.76
167.11
165.00
137.84
137.82
131.70
130.91
129.13
128.78
128.47
128.16
127.98
127.85
126.76
126.71
126.65
126.60
125.26
122.54
119.82
101.66
101.65
77.41
77.09
76.77
54.96
54.01
O
N
CF3
O
N
5pj
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

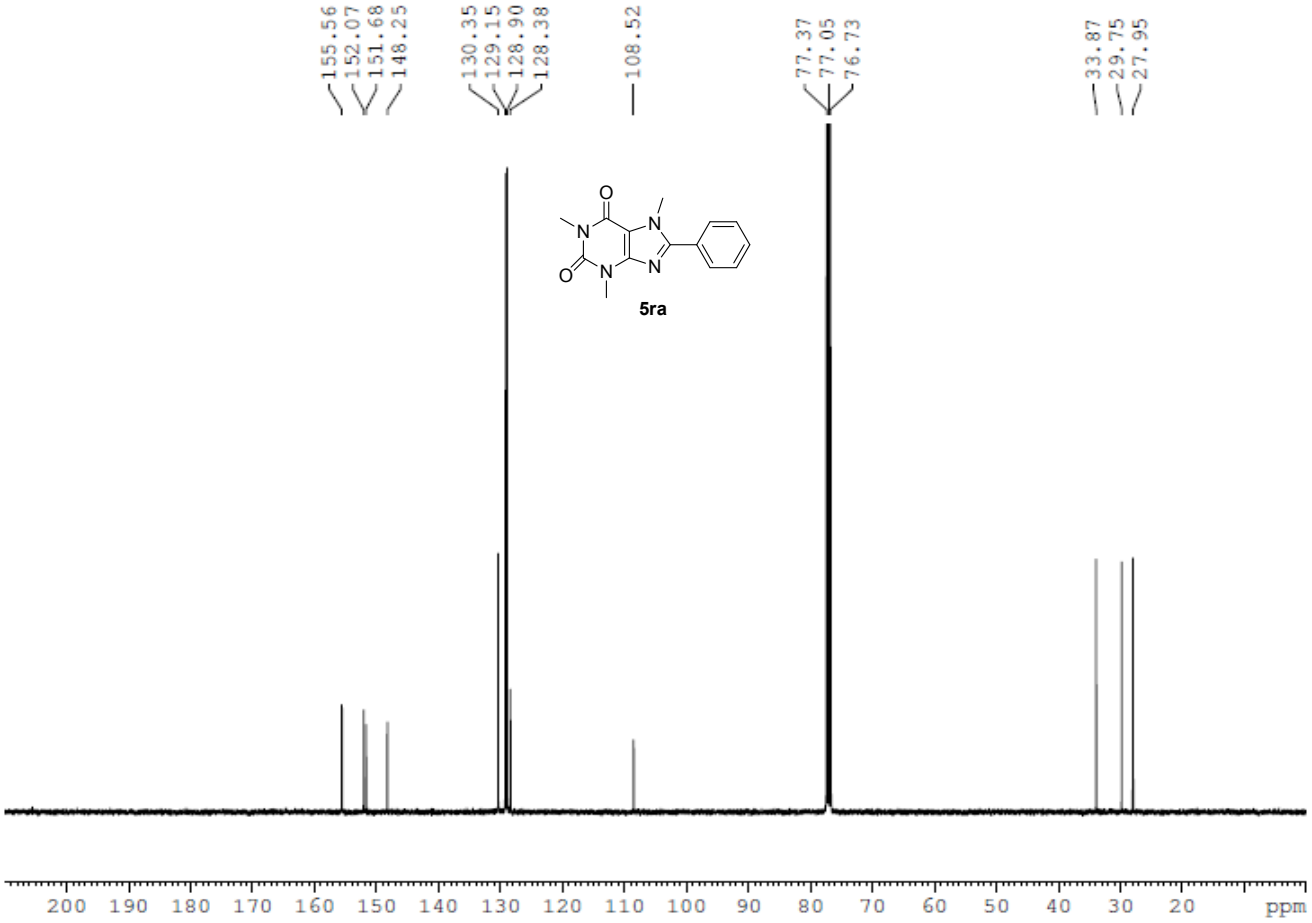

8.5691
7.8470
7.8392
7.5421
7.5347
7.5279
7.2780
4.2177
3.9554
5qa
9
8
7
6
5
4
3
2
1
ppm
1.00
2.06
3.08
3.02
3.05

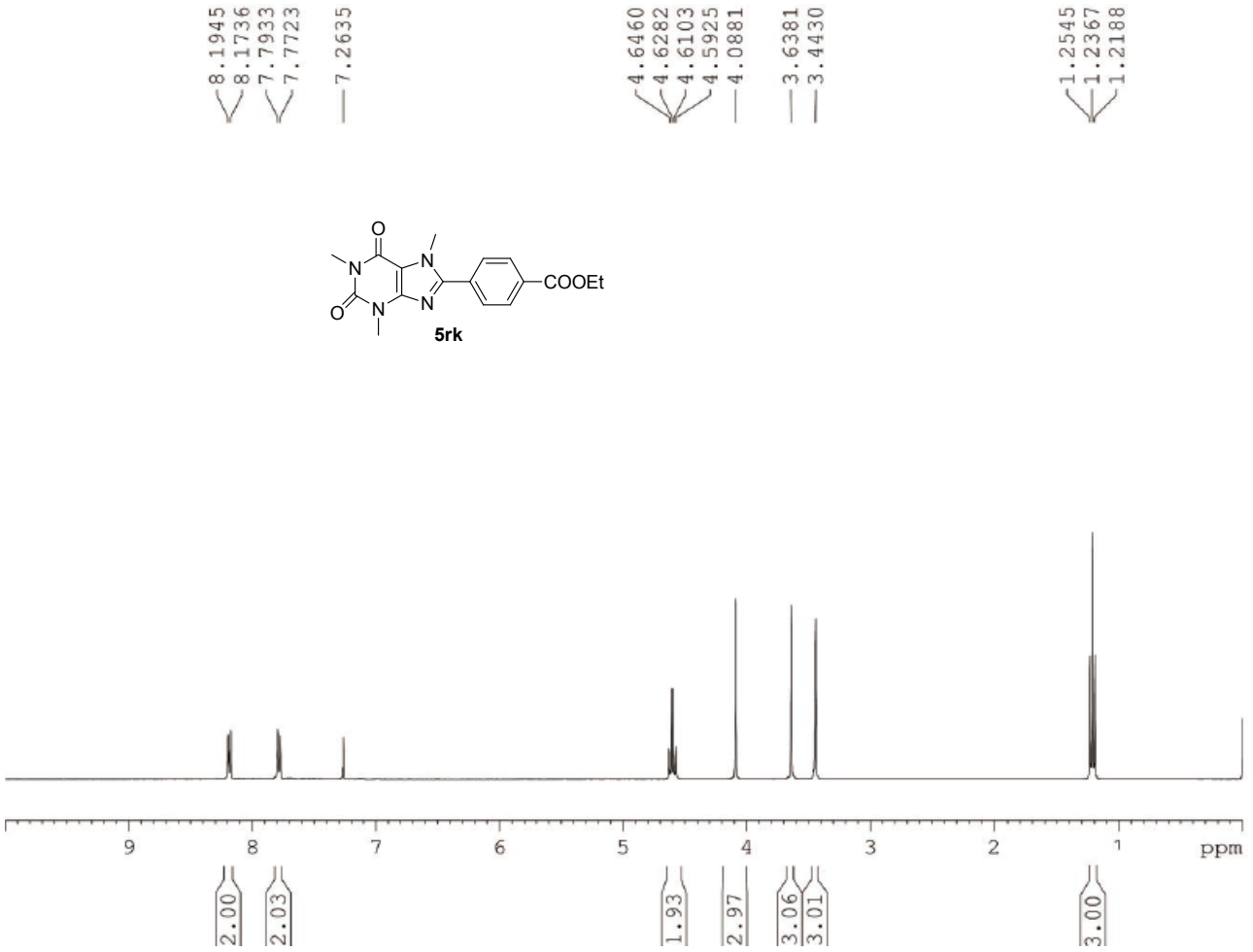

160.68
154.01
152.94
151.64
130.32
129.27
129.23
128.74
121.25
77.35
77.04
76.72
54.16
31.03
O
N
N
N
N
5qa
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10 ppm

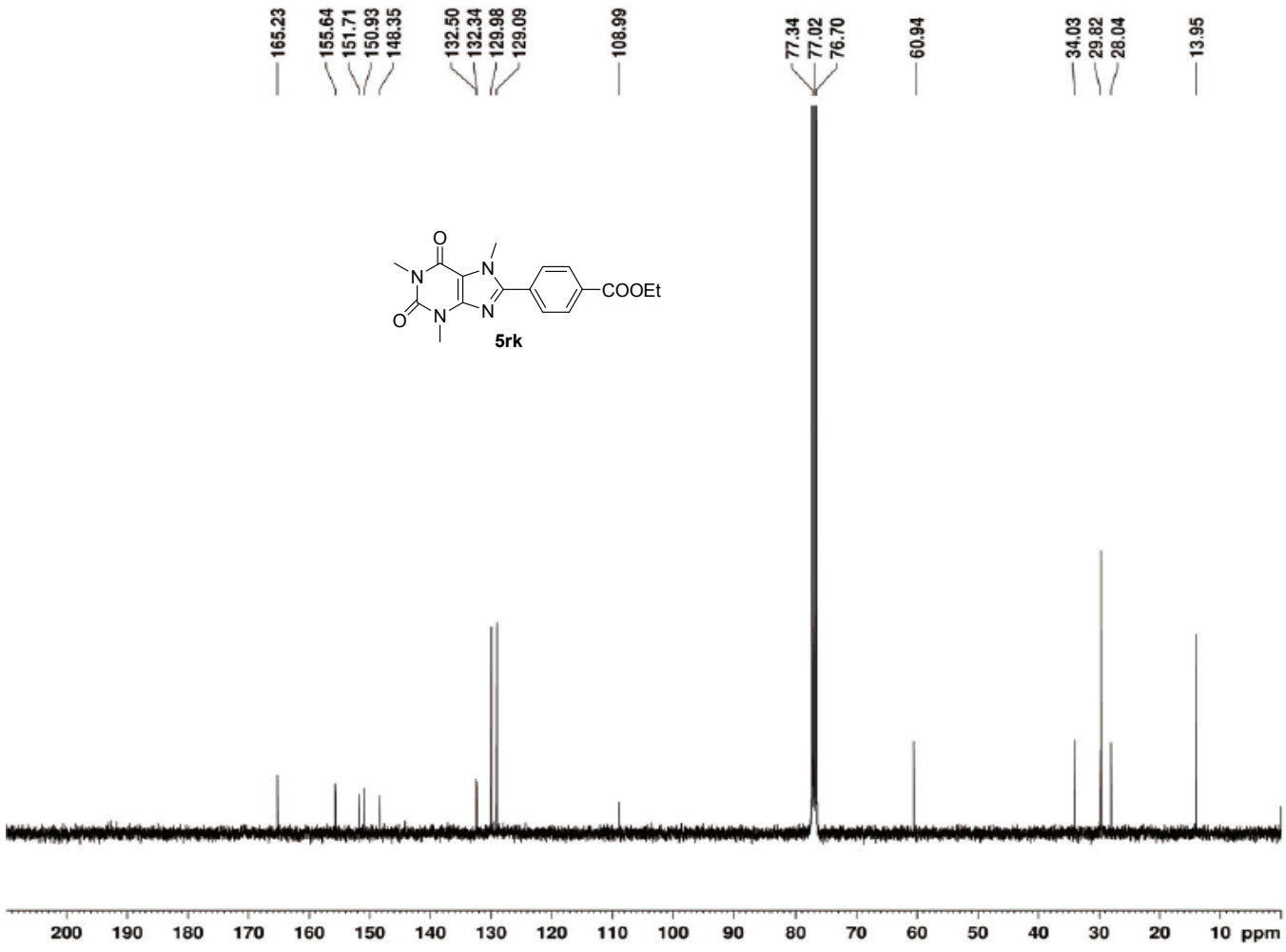

8.6211
7.8929
7.8738
7.8111
7.7939
7.7918
7.7754
7.7566
7.7060
7.7009
7.6869
7.6844
7.6700
7.6646
7.2835
4.2280
3.8682
O
NC
N
N
N
N
5qd
9
8
7
6
5
4
3
2
1
ppm
1.00
1.05
2.13
1.06
3.16
3.18

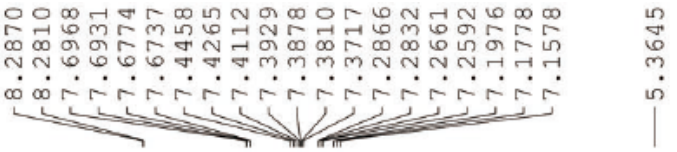

161.19
153.53
152.48
149.28
133.60
132.97
131.54
130.71
121.44
117.03
113.32
77.35
77.04
76.72
54.35
30.59
O
NC
N
N
N
N
5qd
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm


7.7056
7.6969
7.6876
7.6824
7.5360
7.5268
7.5206
7.2836
4.0602
3.6259
3.4297
5ra
9
8
7
6
5
4
3
2
1
ppm
2.03
2.99
3.00
3.01
3.02


155.56
152.07
151.68
148.25
130.35
129.15
128.90
128.38
108.52
77.37
77.05
76.73
33.87
29.75
27.95
5ra
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm


8.1945
8.1736
7.7933
7.7723
7.2635
4.6460
4.6282
4.6103
4.5925
4.0881
3.6381
3.4430
1.2545
1.2367
1.2188
COOEt
5rk
9
8
7
6
5
4
3
2
1
ppm
2.00
2.03
1.93
2.97
3.06
3.01
3.00


165.23
155.64
151.71
150.93
148.35
132.50
132.34
129.98
129.09
108.99
77.34
77.02
76.70
60.94
34.03
29.82
28.04
13.95
O
N
N
O
N
N
COOEt
5rk
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm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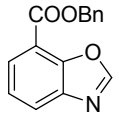
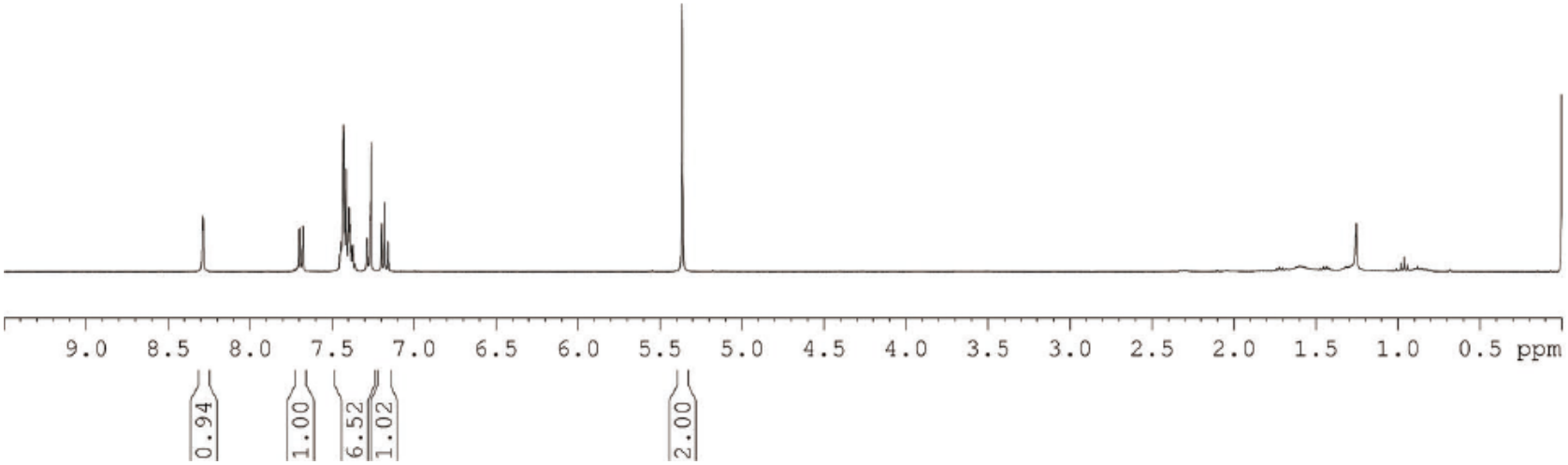
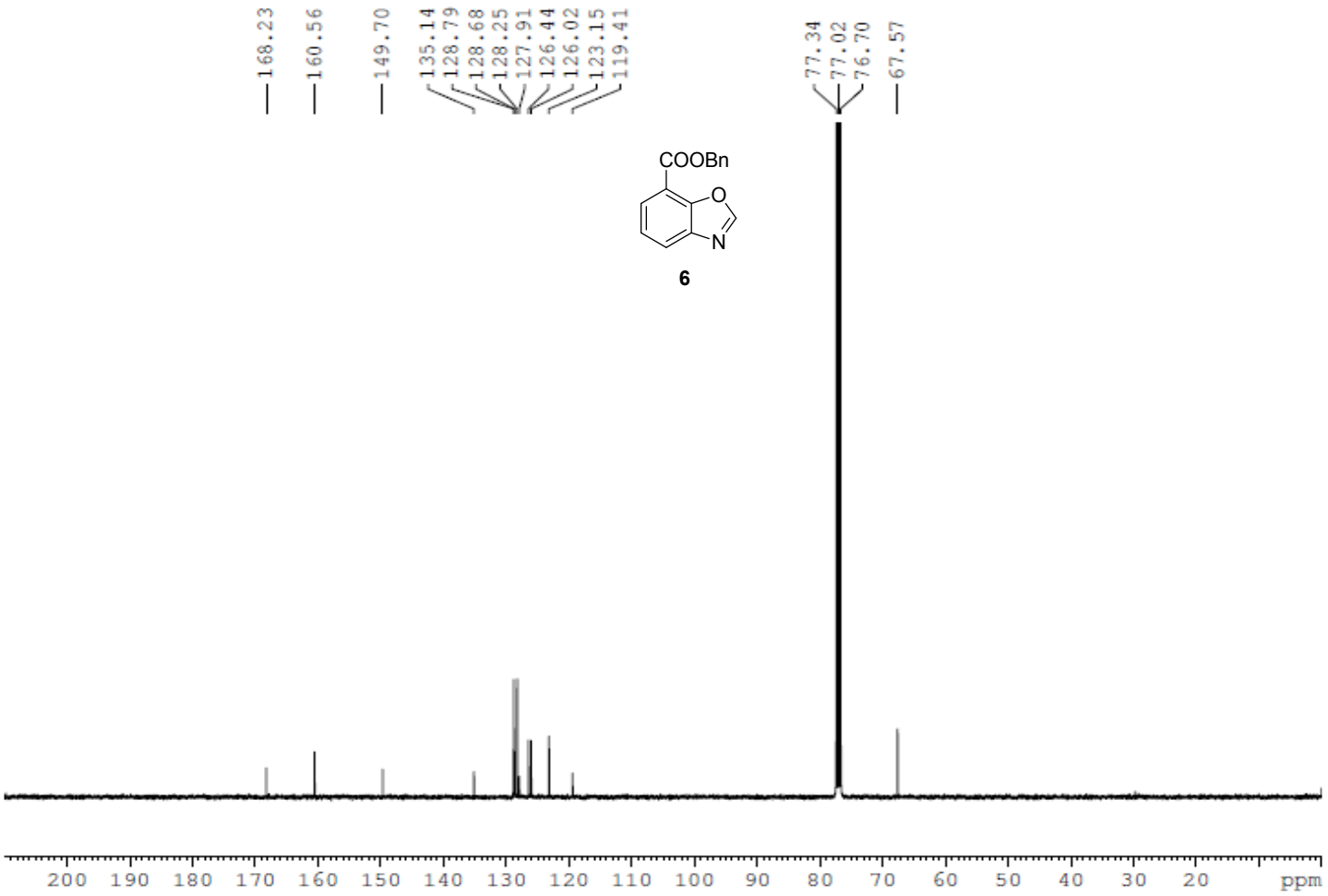
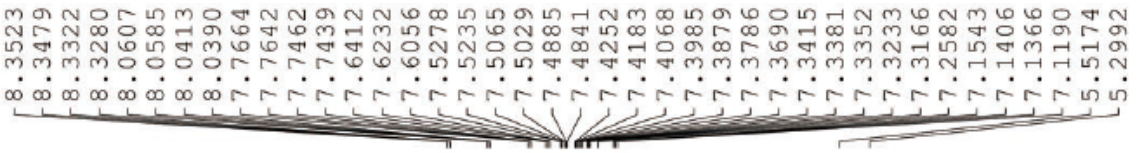
8.2810
7.6968
7.6931
7.6774
7.6737
7.4458
7.4265
7.4112
7.3929
7.3878
7.3810
7.3717
7.2866
7.2832
7.2661
7.2592
7.1976
7.1778
7.1578
5.3645

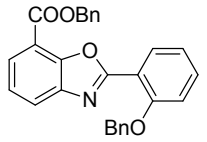

COOBn
O
N

6

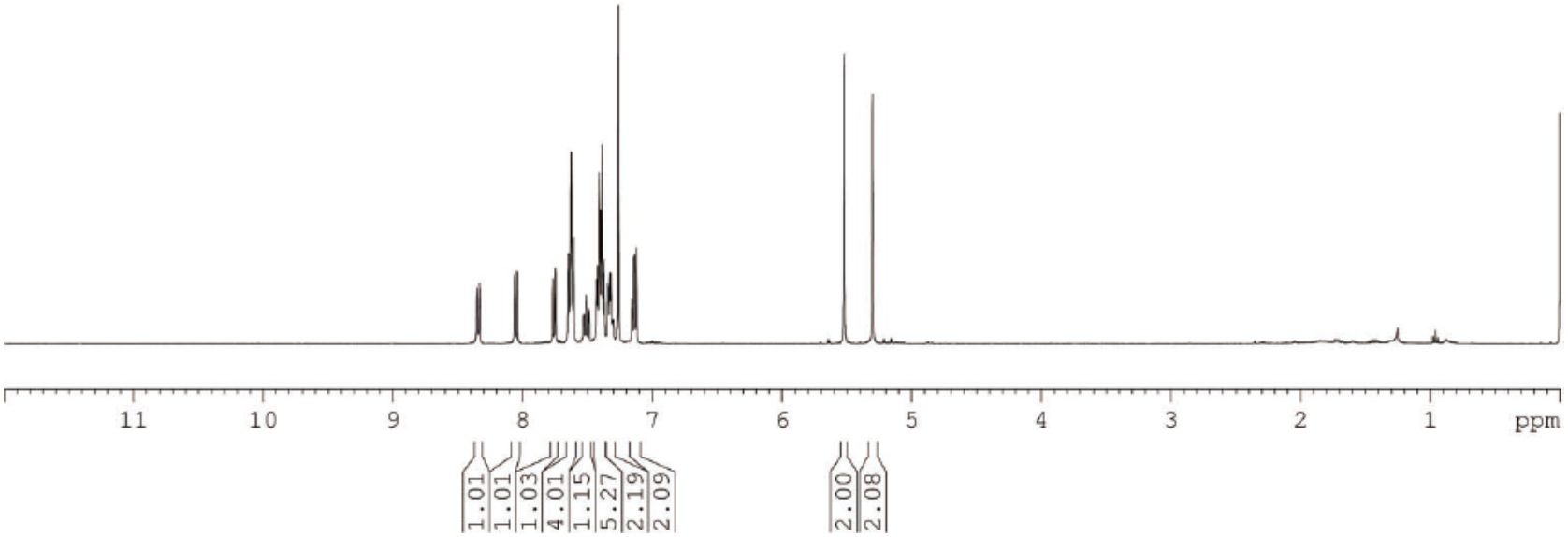

9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5 ppm
0.94
1.00
6.52
1.02
2.00

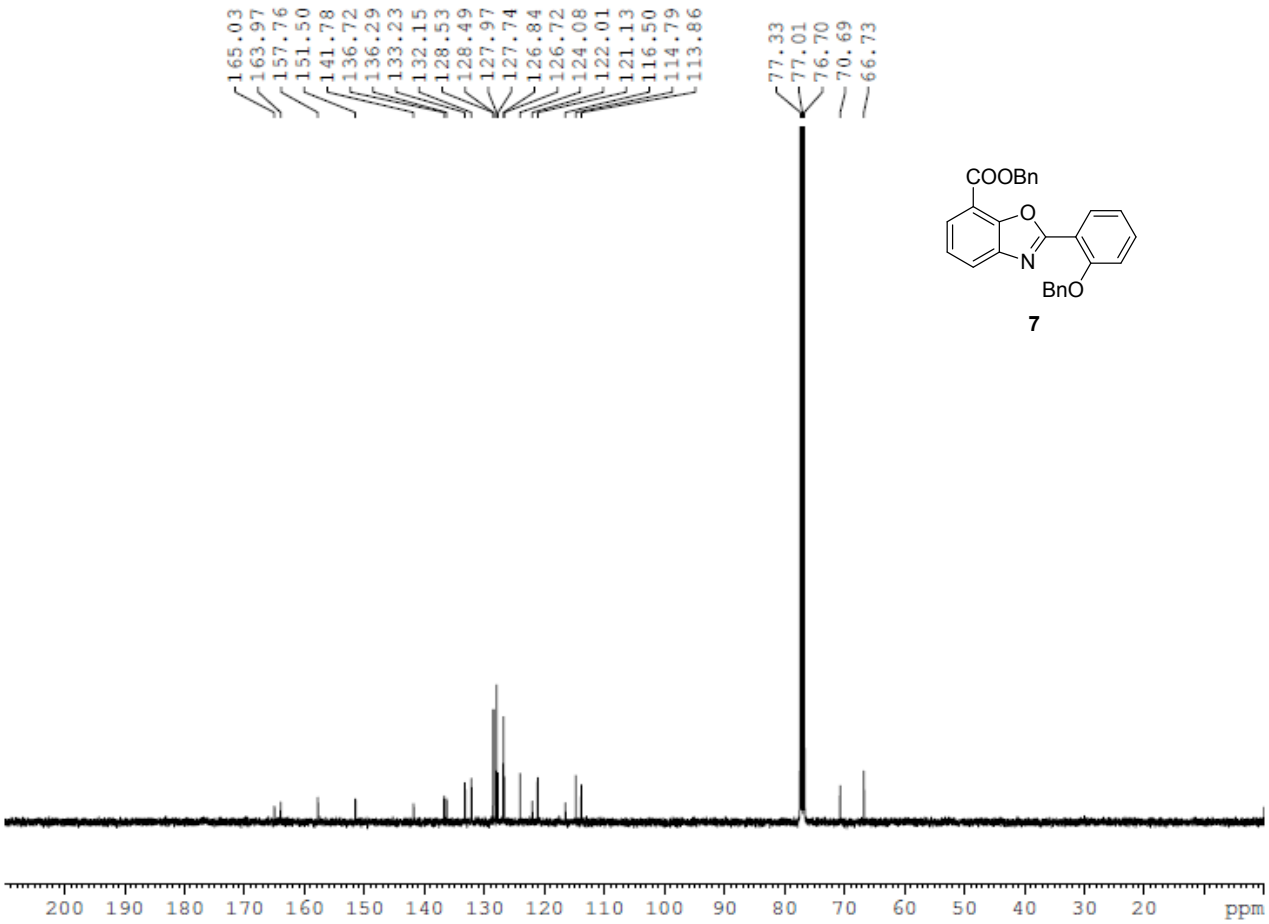

168.23
160.56
149.70
135.14
128.79
128.68
128.25
127.91
126.44
126.02
123.15
119.41
77.34
77.02
76.70
67.57
COOBn
O
N
6
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

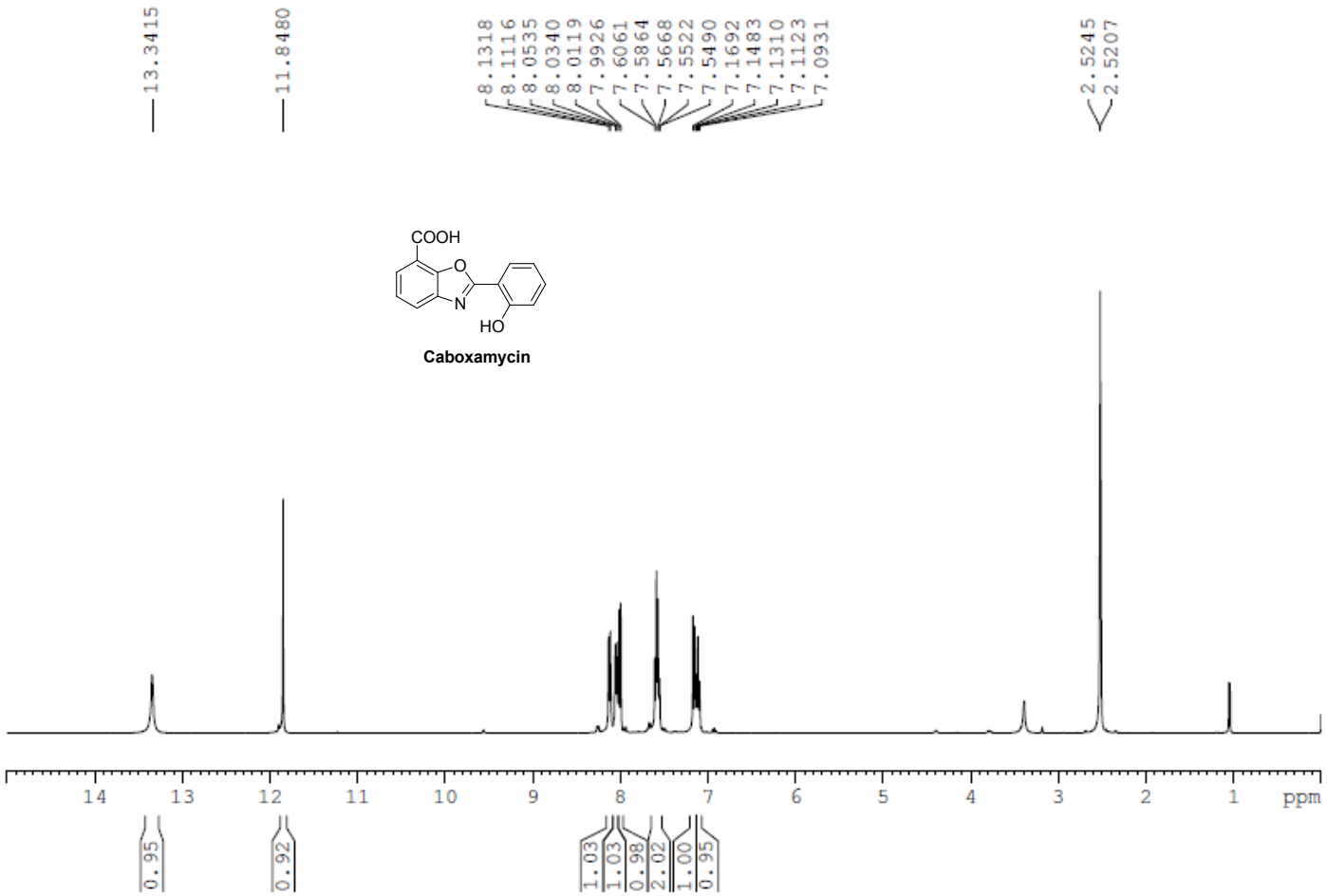

8.3523
8.3479
8.3322
8.3280
8.0607
8.0585
8.0413
8.0390
7.7664
7.7642
7.7462
7.7439
7.6412
7.6232
7.6056
7.5278
7.5235
7.5065
7.5029
7.4885
7.4841
7.4252
7.4183
7.4068
7.3985
7.3879
7.3786
7.3690
7.3415
7.3381
7.3352
7.3233
7.3166
7.2582
7.1543
7.1406
7.1366
7.1190
5.5174
5.2992


COOBn
O
N
BnO

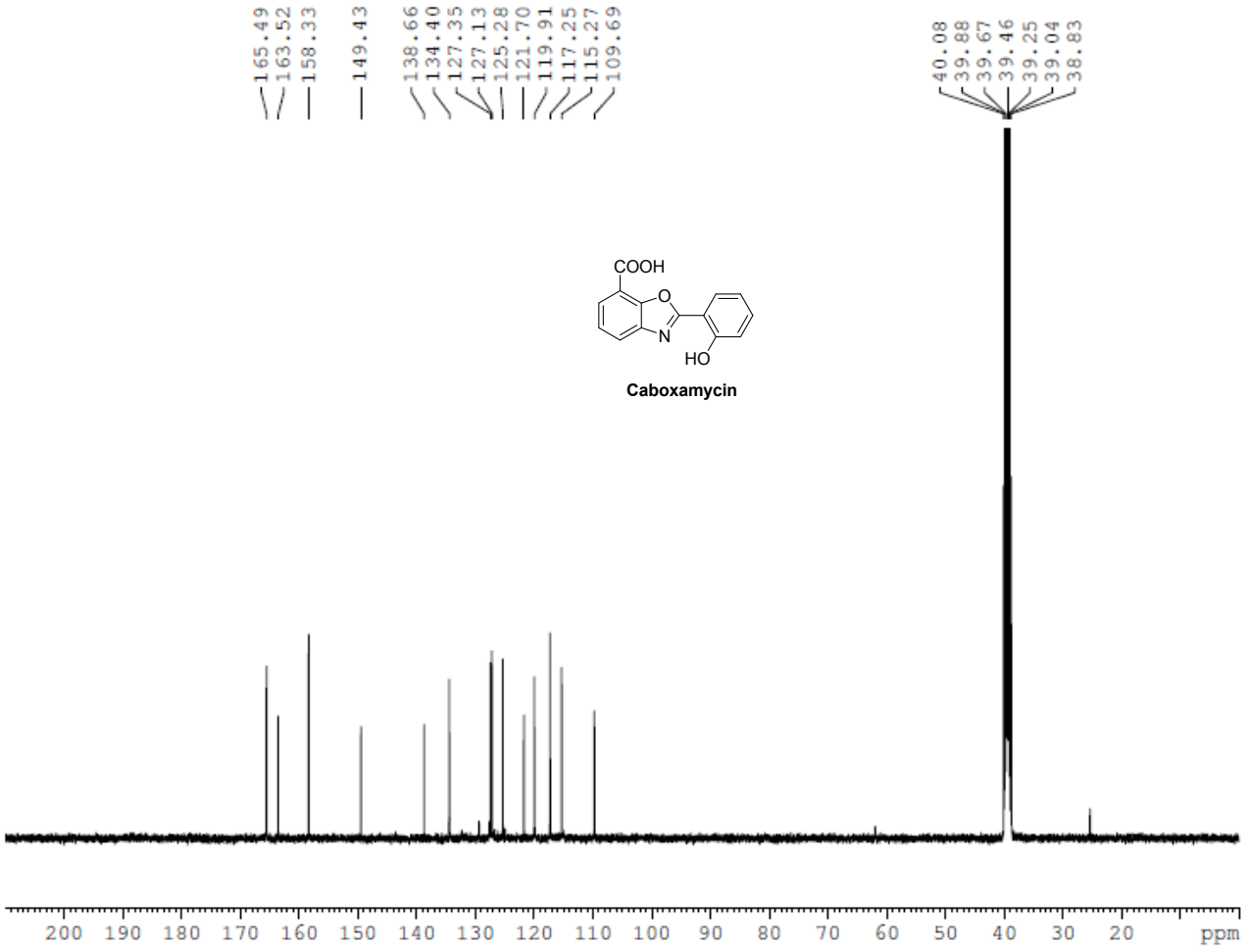
7


11
10
9
8
7
6
5
4
3
2
1
ppm
1.01
1.01
1.03
4.01
1.15
5.27
2.19
2.09
2.00
2.08

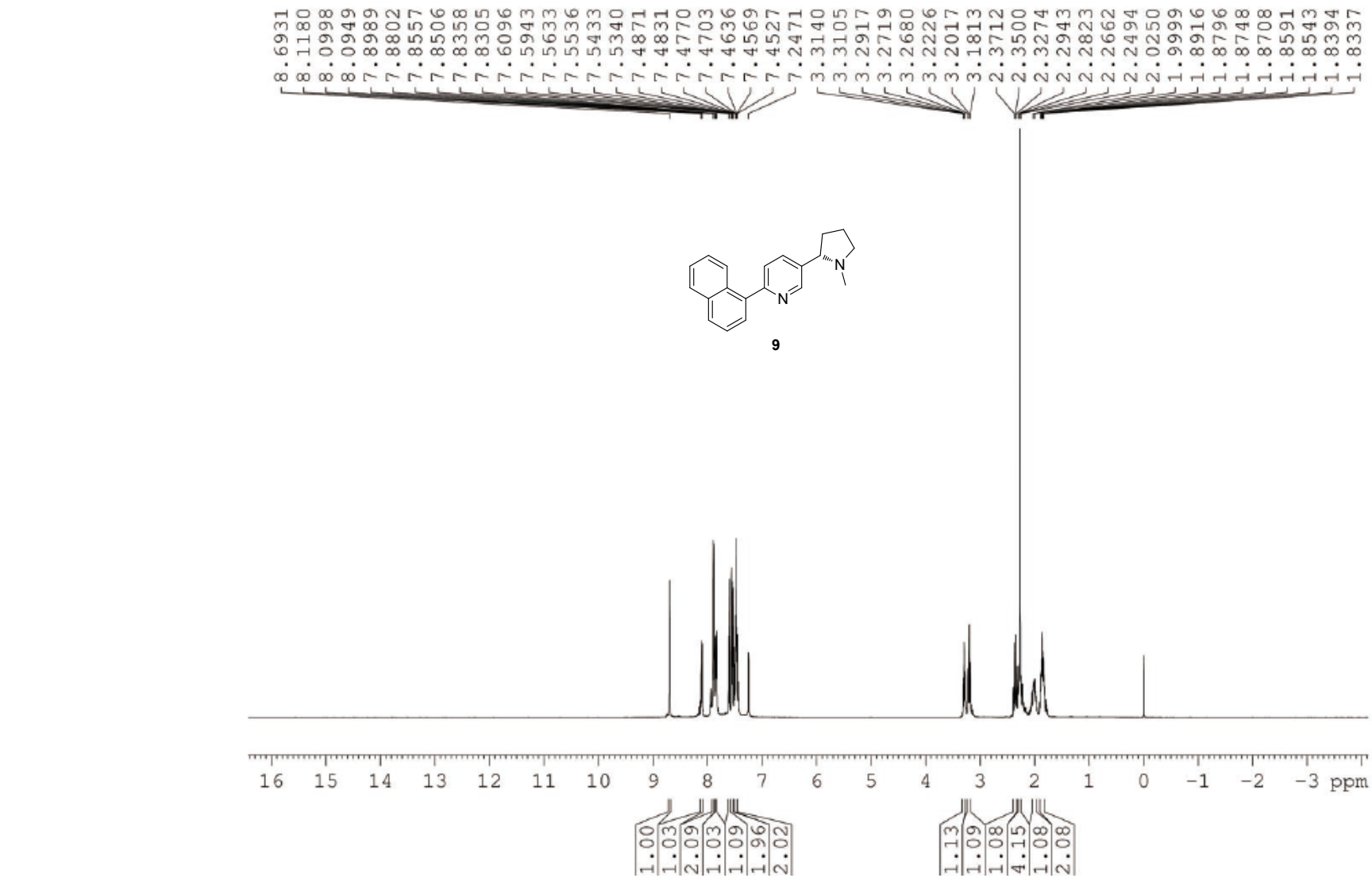

165.03
163.97
157.76
151.50
141.78
136.72
136.29
133.23
132.15
128.53
128.49
127.97
127.74
126.84
126.72
124.08
122.01
121.13
116.50
114.79
113.86
77.33
77.01
76.70
70.69
66.73
COOBn
O
N
BnO
7
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm

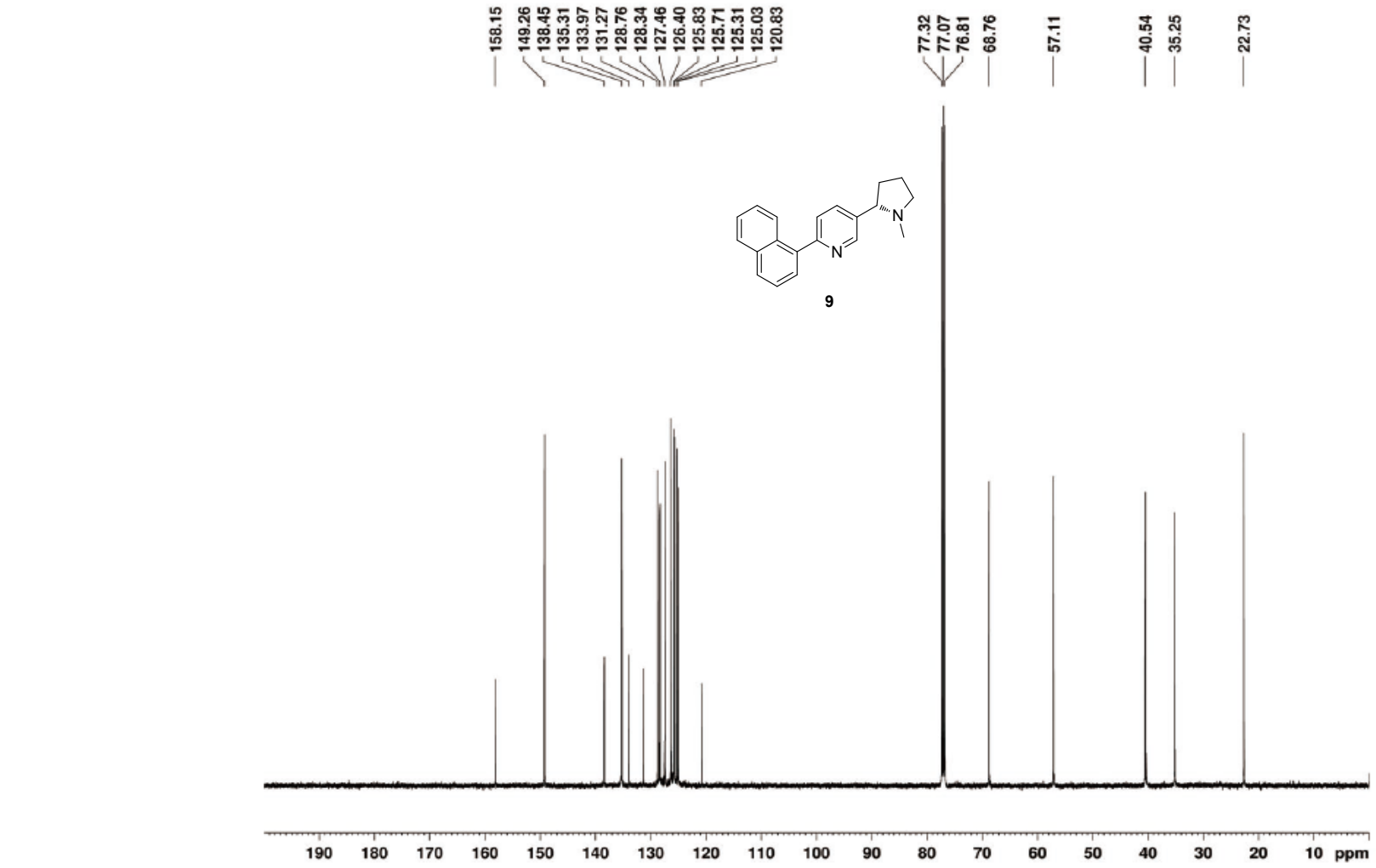


Caboxamycin



Caboxamycin


8.6931
8.1180
8.0998
8.0949
7.8989
7.8802
7.8557
7.8506
7.8358
7.8305
7.6096
7.5943
7.5633
7.5536
7.5433
7.5340
7.4871
7.4831
7.4770
7.4703
7.4636
7.4569
7.4527
7.2471
3.3140
3.3105
3.2917
3.2719
3.2680
3.2226
3.2017
3.1813
2.3712
2.3500
2.3274
2.2943
2.2823
2.2662
2.2494
2.0250
1.9999
1.8916
1.8796
1.8748
1.8708
1.8591
1.8543
1.8394
1.8337
N
N
9
16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 ppm
1.00 1.03 2.09 1.03 1.09 1.96 2.02
1.13 1.09 1.08 4.15 1.08 2.08


158.15
149.26
138.45
135.31
133.97
131.27
128.76
128.34
127.46
126.40
125.83
125.71
125.31
125.03
120.83
77.32
77.07
76.81
68.76
57.11
40.54
35.25
22.73
N
N
9
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

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