Regio- and Stereoselective Ring-Opening Reaction of Spiro-Epoxyoxindoles with Ammonia under Catalyst-Free Conditions

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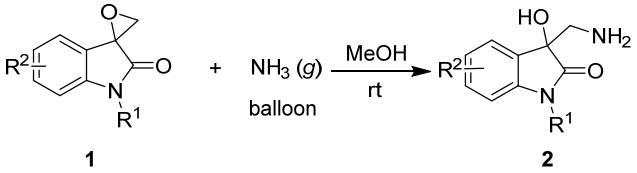
Contents

1. General information

Unless stated otherwise, all reactions were carried out in flame dried glassware. All solvents were purified and dried according to standard methods prior to use. Spiro-Epoxyoxindoles **1** were prepared according to literature.[1] ^{1}H and ^{13}C NMR spectra were recorded on a Varian instrument (300 MHz and 75 MHz, respectively) and internally referenced to tetramethylsilane signal or residual protio solvent signals. Data for 1H NMR are recorded as follows: chemical shift (δ, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, q = quartet or unresolved, coupling constant(s) in Hz, integration). Data for ^{13}C NMR are reported in terms of chemical shift (δ, ppm). IR spectra were recorded on a FT-IR spectrometer and only major peaks were reported in cm-1. Optical rotations were reported as follows: $[\alpha]_D^{rt}$ (c: g/100 mL, in solvent). High resolution mass spectra (HRMS) were obtained by the ESI ionization sources. The ee value determination was carried out using chiral HPLC with Daicel Chiracel column on Waters with a 996 UV-detector.

[1] S. Hajra, S. Maity ,R. Maity, *Org. Lett.* **2015**, 17, 3430−3433

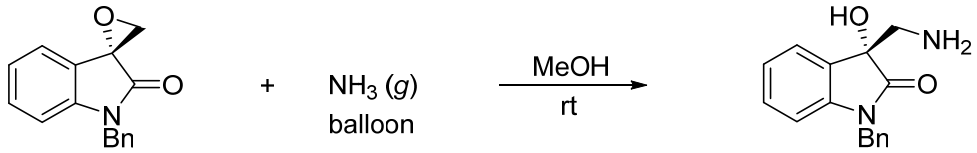
2. General procedure for preparation of 2



1 2

In an ordinary vial, spiro-epoxyoxindoles **1** (0.10 mmol) was added to MeOH (1.0 mL) in the ammonia atmosphere at room temperature. The mixture was stirred at this temperature for the requisite amount of time as monitored by TLC. The solvent was removed under vacuum and residue was chromatographed on silica gel (DCM:MeOH 20:1) and fractions were collected and concentrated in vacuo to provide the pure desired products **2**.

3. Scale-up Experiment

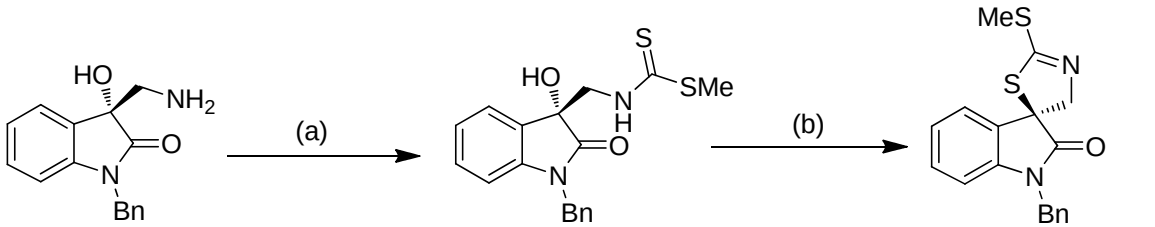


1'
10 mmol, 2.50 g

2a'
92% yield (2.46g)
99% ee

In an ordinary vial, spiro-epoxyoxindoles **1'** (10.0 mmol) was added to MeOH (60.0 mL) in the ammonia atmosphere at room temperature. The mixture was stirred at this temperature for the requisite amount of time as monitored by TLC. The solvent was removed under vacuum and residue was chromatographed on silica gel (DCM:MeOH 20:1) and fractions were collected and concentrated in vacuo to provide the pure desired products **2a'**.

4. Transformations of the Product of 2a'



99% ee

64% yield, 98% ee

3

51% yield, 96% ee

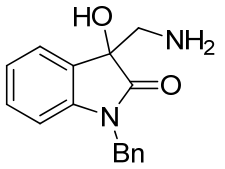
4

(**a**) To a solution of **2a'** (80 mg, 0.3 mmol) in CH_2Cl_2 (1 mL) was added dry pyridine (48 μL) and CS_2 (14 μL) at 0 ℃. After 4h, MeI (15 μL) was added and the mixture stirred at room temperature for 4h.Then the mixture was acidified with 1N HCl and extracted with EtOAc. The combined organic layers were washed with water, brine, dried over Na_2SO_4 and the solvent was removed under vacuum and residue was chromatographed on silica gel (petroleum ether/AcOEt 1:1) and fractions were collected and concentrated in vacuo to provide the pure desired products **3** (68.8 mg, 64% yield).

(**b**) To a solution of **3** (0.22 mmol) in CH_2Cl_2 (1 mL) was added dry pyridine (35 μL) and MsCl (58 μL) at room temperature for overnight. Then the mixture was neutralized with 1N HCl, and extracted with EtOAc. The combined organic layers were washed with water, brine, dried over Na_2SO_4 and the solvent was removed under vacuum and residue was chromatographed on silica gel and fractions were collected and concentrated in vacuo to provide the pure desired products **4** (38 mg, 51% yield).

5. Characterization of 2-4

3-(aminomethyl)-1-benzyl-3-hydroxyindolin-2-one (2a).



2a

90% yield;

White solid, m.p. 95 – 97 ℃;

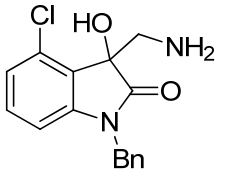
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46 – 7.14 (m, 7H), 7.05 (t, *J* = 7.3 Hz, 1H), 6.70 (d, *J* = 7.8 Hz, 1H), 4.96 (d, *J* = 15.7 Hz, 1H), 4.78 (d, *J* = 15.7 Hz, 1H), 3.08 (s, 2H), 2.87 (bs, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 178.1, 142.6, 135.4, 129.7, 129.2, 128.8, 127.7, 127.1, 123.8, 123.1, 109.5, 75.0, 48.6, 43.6;

IR: 3370, 1716, 1614, 1468, 1358, 1266, 1177, 1081, 737 cm^{-1};

HRMS (ESI): $C_{16}H_{16}N_2O_2$+H, Calc: 269.1285, Found: 269.1289.

3-(aminomethyl)-1-benzyl-4-chloro-3-hydroxyindolin-2-one (2b).



2b

86% yield;

White solid, m.p. 60 – 62 ℃;

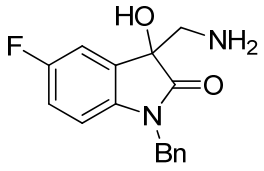
^{1}H NMR (300 MHz, DMSO) δ 7.43 – 7.28 (m, 4H), 7.23 (dd, *J* = 16.5, 7.8 Hz, 2H), 7.00 (d, *J* = 8.1 Hz, 1H), 6.74 (d, *J* = 7.8 Hz, 1H), 6.22 (bs, 1H), 4.88 (q, *J* = 16.1 Hz, 2H), 3.35 (bs, 1H), 3.34 (d, *J* = 12.4 Hz, 3H), 3.11 (d, *J* = 12.4 Hz, 1H);

^{13}C NMR (75 MHz, DMSO) δ 177.16, 145.28, 135.94, 130.67, 130.18, 128.54, 127.32, 127.15, 126.66, 123.18, 107.91, 77.90, 45.58, 42.63;

IR: 3435, 2252, 1657, 1027, 824, 761 cm^{-1};

HRMS (ESI): $C_{16}H_{15}ClN_2O_2$+H, Calc: 303.0895, Found: 303.0900.

3-(aminomethyl)-1-benzyl-5-fluoro-3-hydroxyindolin-2-one (2c).



2c

83% yield;

White solid, m.p. 154 – 156 ℃;

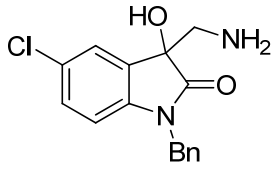
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.36 – 7.19 (m, 5H), 7.11 (dd, *J* = 7.5, 2.5 Hz, 1H), 6.88 (td, *J* = 8.9, 2.6 Hz, 1H), 6.60 (dd, *J* = 8.6, 4.0 Hz, 1H), 4.93 (d, *J* = 15.8 Hz, 1H), 4.75 (d, *J* = 15.8 Hz, 1H), 3.18 (bs, 3H), 3.05 (q, *J* = 13.3 Hz, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.91, 159.40 (d, *J* = 240.75 Hz), 138.31, 135.03, 130.96 (d, J = 7.5 Hz), 128.87, 127.78, 127.06, 115.88 (d, *J* = 23.25 Hz), 112.08 (d, *J* = 24.75 Hz), 110.19 (d, *J* = 7.5 Hz), 75.18, 48.40, 43.71;

IR: 3366, 1718, 1491, 1345, 1267, 1174, 1026, 736 cm^{-1};

HRMS (ESI): $C_{16}H_{15}FN_2O_2$+H, Calc: 287.1190, Found: 287.1194.

3-(aminomethyl)-1-benzyl-5-chloro-3-hydroxyindolin-2-one (2d).



2d

85% yield;

White solid, m.p. 110 – 112 ℃;

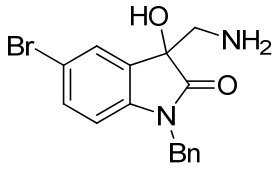
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.39 – 7.19 (m, 6H), 7.14 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.59 (d, *J* = 8.3 Hz, 1H), 4.91 (d, *J* = 15.8 Hz, 1H), 4.73 (d, *J* = 15.8 Hz, 1H), 3.12 (bs, 3H), 3.06 – 2.90 (m, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.73, 140.81, 134.87, 131.25, 129.36, 128.83, 128.47, 127.75, 126.99, 124.31, 110.45, 75.41, 48.50, 43.60;

IR: 3345, 1722, 1484, 1343, 1174, 813, 736 cm^{-1};

HRMS (ESI): $C_{16}H_{15}ClN_2O_2$+H, Calc: 303.0895, Found: 303.0896.

3-(aminomethyl)-1-benzyl-5-bromo-3-hydroxyindolin-2-one (2e).



2e

81% yield;

White solid, m.p. 115 – 117 ℃;

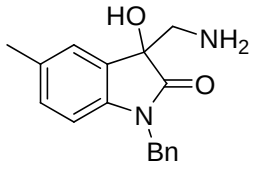
^{1}H NMR (300 MHz, DMSO) δ 7.54 (d, *J* = 2.0 Hz, 1H), 7.47 – 7.19 (m, 6H), 6.76 (d, *J* = 8.3 Hz, 1H), 4.87 (q, *J* = 16.0 Hz, 2H), 3.39 (bs, 3H), 3.00 (d, *J* = 12.7 Hz, 1H), 2.89 (d, *J* = 12.7 Hz, 1H);

^{13}C NMR (75 MHz, DMSO) δ 177.14, 142.05, 135.97, 133.36, 131.48, 128.60, 127.36, 127.13, 127.00, 114.25, 110.93, 76.49, 48.38, 42.48;

IR: 3436, 1716, 1614, 1468, 1358, 1266, 1177, 1054, 761 cm^{-1};

HRMS (ESI): $C_{16}H_{15}BrN_2O_2$+H, Calc: 347.0390, Found: 347.0394.

3-(aminomethyl)-1-benzyl-3-hydroxy-5-methylindolin-2-one (2f).



2f

73% yield;

White solid, m.p. 98 – 101 ℃;

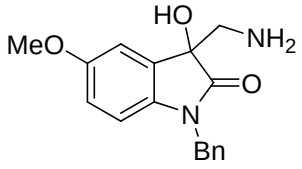
^{1}H NMR (300 MHz, DMSO) δ 7.45 – 7.19 (m, 6H), 7.00 (d, *J* = 7.9 Hz, 1H), 6.68 (d, *J* = 7.9 Hz, 1H), 4.84 (q, *J* = 15.9 Hz, 2H), 3.29 (bs, 3H), 2.91 (q, *J* = 12.9 Hz, 2H), 2.25 (s, 3H);

^{13}C NMR (75 MHz, DMSO) δ 177.40, 140.24, 136.39, 131.25, 130.65, 129.04, 128.54, 127.26, 127.14, 124.72, 108.75, 76.07, 48.53, 42.44, 20.70;

IR: 3438, 2250, 1656, 1468, 1358, 1266, 1177, 1055, 761 cm^{-1};

HRMS (ESI): $C_{17}H_{18}N_2O_2$+H, Calc: 283.1441, Found: 283.1443.

3-(aminomethyl)-1-benzyl-3-hydroxy-5-methoxyindolin-2-one (2g).



2g

76% yield;

White solid, m.p. 90 – 92 ℃;

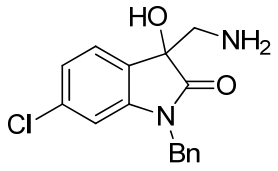
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 – 7.15 (m, 5H), 6.97 (d, *J* = 2.4 Hz, 1H), 6.69 (dd, *J* = 8.5, 2.4 Hz, 1H), 6.56 (d, *J* = 8.5 Hz, 1H), 4.91 (d, *J* = 15.7 Hz, 1H), 4.70 (d, *J* = 15.7 Hz, 1H), 3.71 (s, 3H), 3.15 (bs, 3H), 2.99 (s, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.80, 156.18, 135.52, 135.41, 130.70, 128.70, 127.53, 127.02, 113.95, 110.76, 109.94, 75.67, 55.64, 48.74, 43.54;

IR: 3368, 1710, 1604, 1494, 1346, 1275, 1179, 1018, 734 cm^{-1};

HRMS (ESI): $C_{17}H_{18}N_2O_3$+H, Calc: 299.1390, Found: 299.1394.

3-(aminomethyl)-1-benzyl-6-chloro-3-hydroxyindolin-2-one (2h).



2h

89% yield;

White solid, m.p. 79 – 81 ℃;

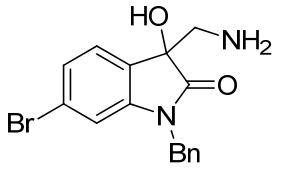
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38 – 7.17 (m, 6H), 7.01 (dd, *J* = 7.9, 1.6 Hz, 1H), 6.68 (d, *J* = 1.6 Hz, 1H), 4.92 (d, *J* = 15.8 Hz, 1H), 4.71 (d, *J* = 15.8 Hz, 1H), 3.02 (q, *J* = 13.1 Hz, 2H), 3.01 (bs, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 178.08, 143.76, 135.36, 134.83, 128.92, 127.85, 127.74, 127.01, 124.78, 122.99, 110.04, 74.84, 48.43, 43.63;

IR: 3340, 1726, 1611, 1490, 1374, 1265, 1178, 1075, 738 cm^{-1};

HRMS (ESI): $C_{16}H_{15}ClN_2O_2$+H, Calc: 303.0895, Found: 303.0894.

3-(aminomethyl)-1-benzyl-6-bromo-3-hydroxyindolin-2-one (2i).



2i

83% yield;

White solid, m.p. 99 – 101 ℃;

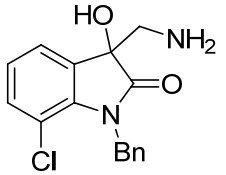
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 – 7.04 (m, 7H), 6.83 (s, 1H), 4.91 (d, *J* = 15.8 Hz, 1H), 4.70 (d, *J* = 15.8 Hz, 1H), 2.98 (d, *J* = 13.7 Hz, 2H), 2.88 (bs, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.96, 143.90, 134.83, 128.95, 128.26, 127.88, 127.02, 125.98, 125.15, 123.30, 112.78, 74.84, 48.36, 43.64;

IR: 3361, 1720, 1605, 1486, 1430, 1353, 1176, 1117, 1061, 734 cm^{-1};

HRMS (ESI): $C_{16}H_{15}BrN_2O_2$+H, Calc: 347.0390, Found: 347.0389.

3-(aminomethyl)-1-benzyl-7-chloro-3-hydroxyindolin-2-one (2j).



2j

78% yield;

White solid, m.p. 83 -85 ℃;

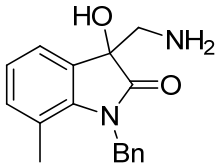
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 – 7.12 (m, 7H), 6.99 (t, *J* = 7.8 Hz, 1H), 5.28 (s, 2H), 3.05 (d, *J* = 13.2 Hz, 2H), 3.02 (bs, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 178.73, 138.60, 137.08, 132.32, 132.17, 128.57, 127.18, 126.29, 124.13, 122.43, 115.72, 74.39, 48.69, 44.59;

IR: 3332, 1721, 1608, 1452, 1353, 1267, 1134, 735 cm^{-1};

HRMS (ESI): $C_{16}H_{15}ClN_2O_2$+H, Calc: 303.0895, Found: 303.0894.

3-(aminomethyl)-1-benzyl-3-hydroxy-7-methylindolin-2-one (2k).



2k

75% yield;

White solid, m.p. 82 – 84 ℃;

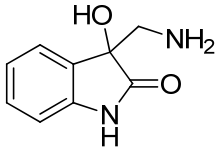
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 – 7.18 (m, 4H), 7.14 (d, *J* = 7.0 Hz, 2H), 6.96 (d, *J* = 4.6 Hz, 2H), 5.16 (d, *J* = 16.9 Hz, 1H), 5.06 (d, *J* = 16.9 Hz, 1H), 3.03 (s, 5H), 2.21 (s, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 179.14, 140.43, 137.17, 133.53, 130.14, 128.81, 127.15, 125.50, 123.22, 121.66, 120.17, 74.44, 48.94, 44.71, 18.62;

IR: 3365, 1714, 1452, 1354, 1163, 733 cm^{-1};

HRMS (ESI): $C_{17}H_{18}N_2O_2$+H, Calc: 283.1441, Found: 283.1443.

3-(aminomethyl)-3-hydroxyindolin-2-one (2l).



2l

80% yield;

White solid, m.p. 214 – 216 ℃;

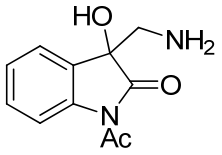
^{1}H NMR (300 MHz, DMSO) δ 10.37 (bs, 1H), 7.35 (d, *J* = 7.3 Hz, 1H), 7.23 (dd, *J* = 13.5, 5.8 Hz, 1H), 6.98 (t, *J* = 7.4 Hz, 1H), 6.81 (dd, *J* = 14.2, 7.6 Hz, 1H), 3.39 (bs, 3H), 2.92 (q, *J* = 13.2 Hz, 2H);

^{13}C NMR (75 MHz, DMSO) δ 178.24, 141.91, 130.29, 129.45, 124.37, 121.75, 109.82, 74.12, 46.61;

IR: 3432, 2251, 1656, 1027, 737 cm^{-1};

HRMS (ESI): $C_9H_{10}N_2O_2$+H, Calc: 179.0815, Found: 179.0815.

1-acetyl-3-(aminomethyl)-3-hydroxyindolin-2-one (2m).



2m

88% yield;

White solid, m.p. 136 – 138 ℃;

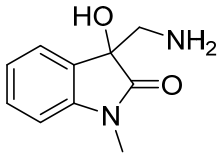
^{1}H NMR (300 MHz, $CDCl_3$) δ 9.80 (bs, 1H), 7.88 (d, *J* = 7.9 Hz, 1H), 7.37 (t, *J* = 7.4 Hz, 2H), 7.13 (t, *J* = 7.5 Hz, 1H), 6.59 (bs, 1H), 6.30 (d, *J* = 24.3 Hz, 1H), 3.22 (d, *J* = 5.8 Hz, 1H), 2.93 (d, *J* = 5.8 Hz, 1H), 2.19 (s, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 173.21, 168.85, 136.78, 129.51, 127.17, 126.72, 124.53, 124.25, 57.49, 54.15, 24.39;

IR: 3275, 1668, 1522, 1451, 1299, 927, 735 cm^{-1};

HRMS (ESI): $C_{11}H_{12}N_2O_3$+ Na, Calc: 243.0740, Found: 243.0745.

3-(aminomethyl)-3-hydroxy-1-methylindolin-2-one (2n).



2n

87% yield;

White solid, m.p. 68 – 71 ℃;

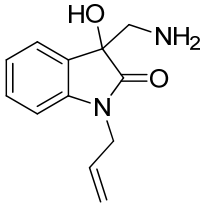
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 – 7.23 (m, 2H), 7.07 (t, *J* = 7.5 Hz, 1H), 6.82 (d, *J* = 7.7 Hz, 1H), 3.15 (s, 3H), 3.15 (bs, 3H), 3.04 – 2.86 (m, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.87, 143.28, 129.65, 129.36, 123.65, 123.05, 108.38, 75.12, 48.36, 26.06;

IR: 2929, 1722, 1614, 1470, 1375, 1249, 1121, 839 cm^{-1};

HRMS (ESI): $C_{11}H_{12}N_2O_3$+H, Calc: 193.0972, Found: 193.0973.

1-allyl-3-(aminomethyl)-3-hydroxyindolin-2-one (2o).



2o

85% yield;

White solid, m.p. 62– 64℃;

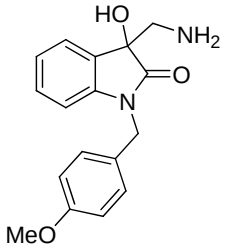
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35 (d, *J* = 7.2 Hz, 1H), 7.28 (t, *J* = 7.7 Hz, 1H), 7.07 (t, *J* = 7.4 Hz, 1H), 6.81 (d, *J* = 7.8 Hz, 1H), 5.80 (ddd, *J* = 22.1, 10.2, 5.1 Hz, 1H), 5.22 (d, *J* = 7.2 Hz, 1H), 5.18 (s, 1H), 4.34 (dd, *J* = 16.4, 4.9 Hz, 1H), 4.20 (dd, *J* = 16.4, 5.0 Hz, 1H), 3.24 (s, 3H), 2.96 (s, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 177.65, 142.41, 130.98, 129.51, 129.35, 123.71, 123.00, 117.58, 109.26, 75.12, 48.48, 42.07;

IR: 3360, 1715, 1613, 1468, 1364, 1184, 1106, 929, 755 cm^{-1};

HRMS (ESI): $C_{12}H_{14}N_2O_2$+H, Calc: 219.1128, Found: 219.1132.

3-(aminomethyl)-3-hydroxy-1-(4-methoxybenzyl)indolin-2-one (2p).



2p

89% yield;

White solid, m.p. 66 – 68℃;

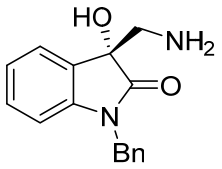
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.34 (d, *J* = 7.3 Hz, 1H), 7.18 (dd, *J* = 9.5, 4.7 Hz, 3H), 7.02 (t, *J* = 7.4 Hz, 1H), 6.81 (d, *J* = 8.4 Hz, 2H), 6.71 (d, *J* = 7.8 Hz, 1H), 4.86 (d, *J* = 15.4 Hz, 1H), 4.69 (d, *J* = 15.5 Hz, 1H), 3.74 (d, *J* = 4.6 Hz, 3H), 3.24 (bs, 3H), 3.01 (s, 2H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 178.00, 158.93, 142.39, 129.52, 129.37, 128.45, 127.36, 123.72, 123.02, 114.08, 109.44, 75.25, 55.14, 48.53, 42.97;

IR: 3357, 1716, 1613, 1513, 1356, 1248, 1178, 1109, 1032, 751 cm^{-1};

HRMS (ESI): $C_{17}H_{18}N_2O_3$+H, Calc: 299.1390, Found: 299.1394.

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxyindolin-2-one (2a').



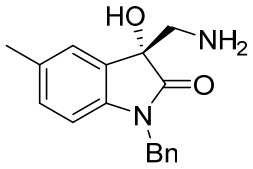
2a'

91% yield;

$[\alpha]_D^{rt}$ = - 46°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =8.9, t_{minor} = 6.1, 99% ee.

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxy-5-methylindolin-2-one (2f').



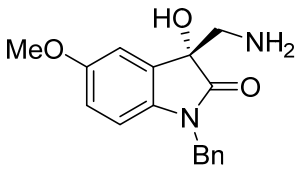
2f'

75% yield;

$[\alpha]_D^{rt}$ = - 37°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =9.7, t_{minor} = 5.7, 97% ee.

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxy-5-methoxyindolin-2-one (2g').



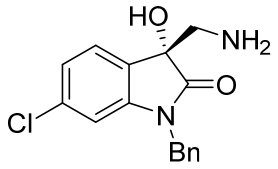
2g'

74% yield;

$[\alpha]_D^{rt}$ = - 106°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =12.1, t_{minor} = 7.1, 99% ee.

(*R*)-3-(aminomethyl)-1-benzyl-6-chloro-3-hydroxyindolin-2-one (2h').



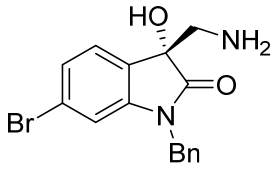
2h'

88% yield;

$[\alpha]_D^{rt}$ = - 22°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =8.6, t_{minor} = 6.5, 98% ee.

(*R*)-3-(aminomethyl)-1-benzyl-6-bromo-3-hydroxyindolin-2-one (2i').



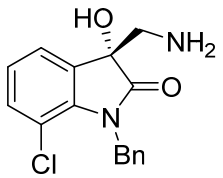
2i'

84% yield;

$[\alpha]_D^{rt}$ = - 32°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =8.9, t_{minor} = 6.7, 96% ee.

(*R*)-3-(aminomethyl)-1-benzyl-7-chloro-3-hydroxyindolin-2-one (2j').



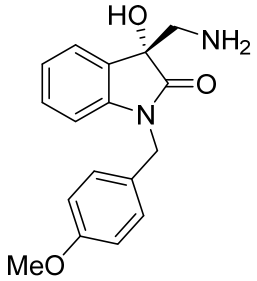
2j'

78% yield;

$[\alpha]_D^{rt}$ = - 49°(c = 1.00, $CHCl_3$).

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =10.4, t_{minor} = 6.3, 96% ee.

(*R*)-3-(aminomethyl)-3-hydroxy-1-(4-methoxybenzyl)indolin-2-one (2p').



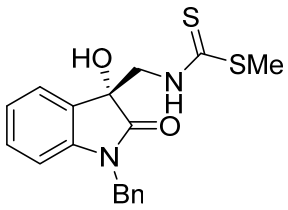
2p'

86% yield;

[α]$_D^{rt}$ = - 51°(c = 1.00, $CHCl_3$).

HPLC: DAICEL CHIRALCEL OD, Hexane/EtOH = 7/3, flow rate = 1.0 ml/min, retention time: t_{major} =9.9, t_{minor} = 7.1, 98% ee.

methyl (R)-((1-benzyl-3-hydroxy-2-oxoindolin-3-yl)methyl)carbamodithioate (3).



3

64% yield;

White solid, m.p. 67 – 68 ℃;

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.30 (bs, 1H), 7.42 (d, *J* = 7.3 Hz, 1H), 7.36 – 7.16 (m, 6H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.70 (d, *J* = 7.8 Hz, 1H), 4.87 (d, *J* = 15.8 Hz, 1H), 4.82 (bs, 1H), 4.71 (d, *J* = 15.7 Hz, 1H), 4.54 (dd, *J* = 14.3, 6.2 Hz, 1H), 3.96 (dd, *J* = 14.3, 4.0 Hz, 1H), 2.59 (s, 3H);

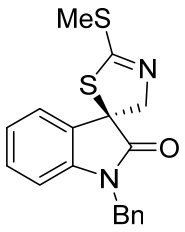
^{13}C NMR (75 MHz, $CDCl_3$) δ 200.96, 176.72, 141.70, 134.72, 130.20, 128.84, 128.15, 127.77, 127.08, 124.20, 123.68, 109.91, 74.68, 52.45, 43.84, 18.22;

IR: 3454, 1716, 1614, 1358, 1260, 1177, 1005, 730 cm^{-1};

HRMS (ESI): $C_{18}H_{18}N_2O_2S_2$+H, Calc: 359.0882, Found: 359.0889.

HPLC: DAICEL CHIRALCEL AS, Hexane/EtOH =8/2, flow rate = 1.0 ml/min, retention time: t_{major} =17.9, t_{minor} = 13.6, 98% ee.

(R)-1-benzyl-2'-(methylthio)-4'H-spiro[indoline-3,5'-thiazol]-2-one (4).



4

51% yield;

White solid, m.p. 43 – 45 ℃;

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46 – 7.24 (m, 6H), 7.20 (td, *J* = 7.8, 1.2 Hz, 1H), 7.06 (td, *J* = 7.6, 0.8 Hz, 1H), 6.73 (d, *J* = 7.8 Hz, 1H), 4.92 (d, *J* = 1.7 Hz, 2H), 4.71 (d, *J* = 15.1 Hz, 1H), 4.52 (d, *J* = 15.1 Hz, 1H), 2.63 (s, 3H);

^{13}C NMR (75 MHz, $CDCl_3$) δ 176.02, 164.03, 141.35, 135.15, 130.66, 129.54, 128.85, 127.82, 127.28, 124.11, 123.60, 109.46, 74.97, 64.23, 44.32, 15.66;

IR: 3378, 1745, 1614, 1490, 1358, 1249, 1177, 1081, 737 cm^{-1};

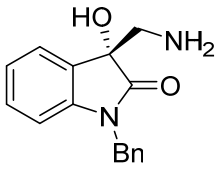
HRMS (ESI): $C_{18}H_{16}N_2OS_2$+H, Calc: 341.0777, Found: 341.0785;

$[\alpha]_D^{rt}$ = - 72°(c = 1.00, $CHCl_3$);

HPLC: DAICEL CHIRALCEL AD, Hexane/EtOH = 8/2, flow rate = 1.0 ml/min, retention time: t_{major} =17.8, t_{minor} = 21.2, 96% ee.

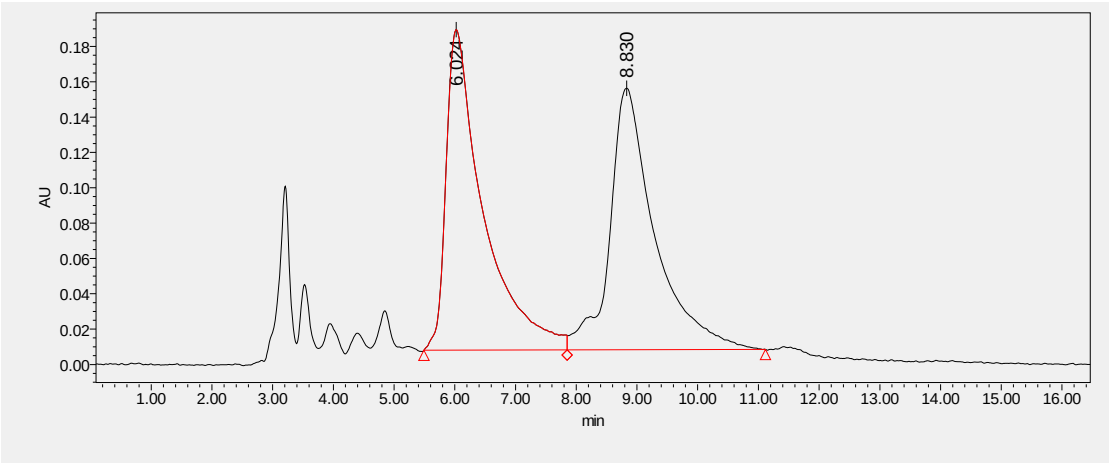
6. Copies of HPLC spectra for 2-4

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxyindolin-2-one (Table 3, entry 1)

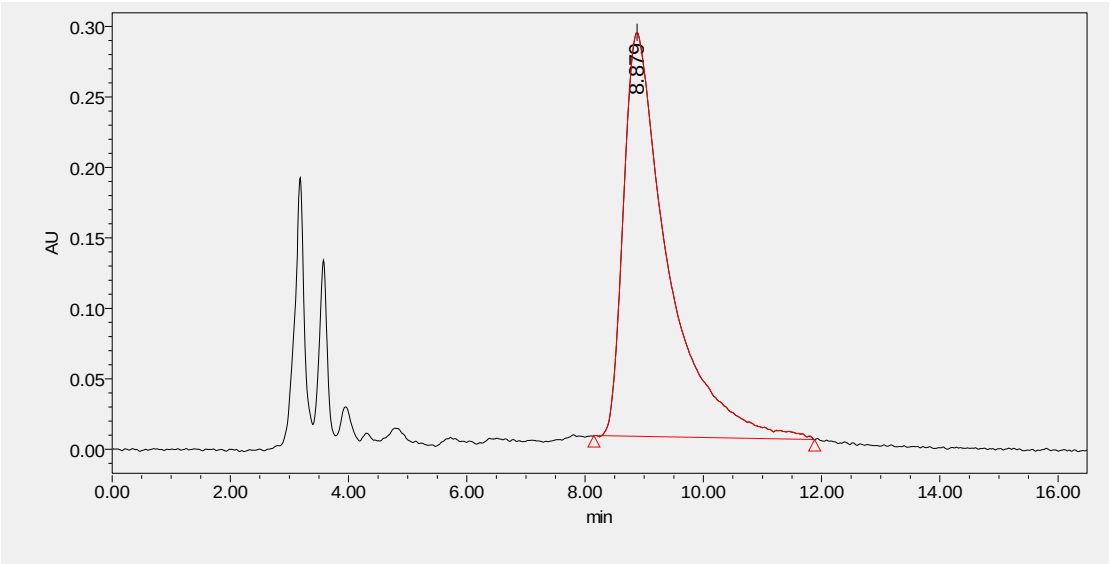


2a'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

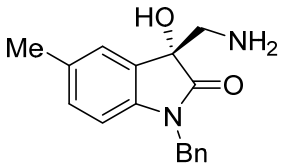


	Retention time	Area	% Area	Height	Integral type
1	6.024	7715904	50.48	181448	bv
2	8.830	7569897	49.52	148061	vb



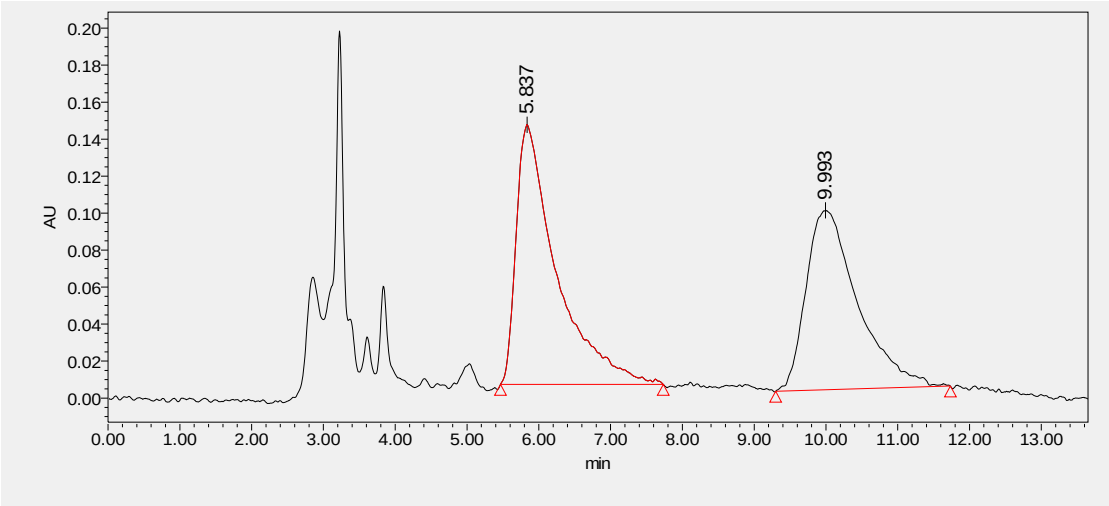
	Retention time	Area	% Area	Height	Integral type
1	8.879	14943171	100.00	286775	bb

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxy-5-methylindolin-2-one (Table 3, entry 2)

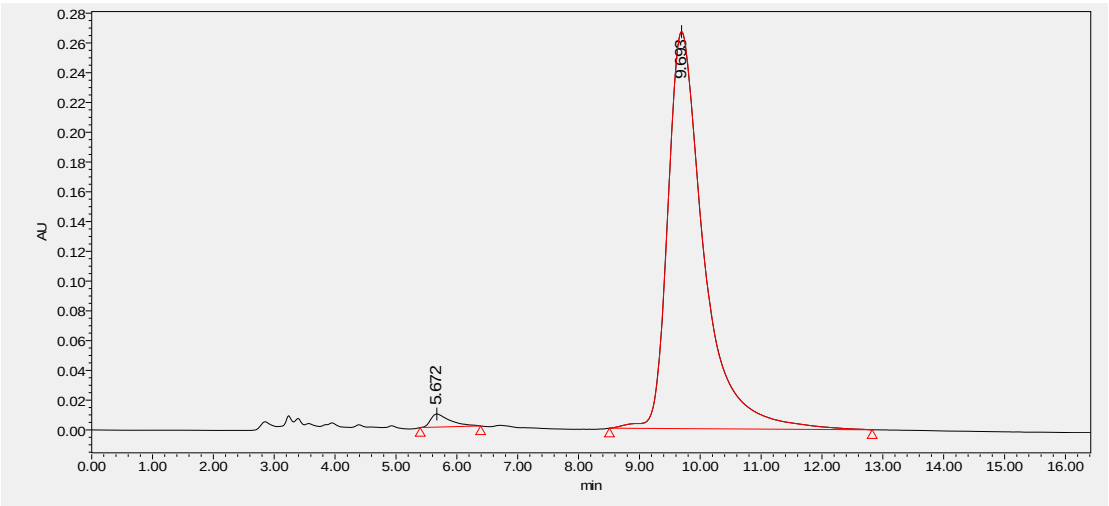


2f'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

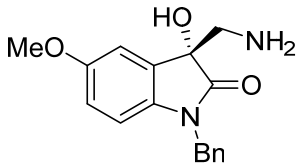


	Retention time	Area	% Area	Height	Integral type
1	5.837	5436947	52.86	140415	bb
2	9.993	4848747	47.14	96976	bb



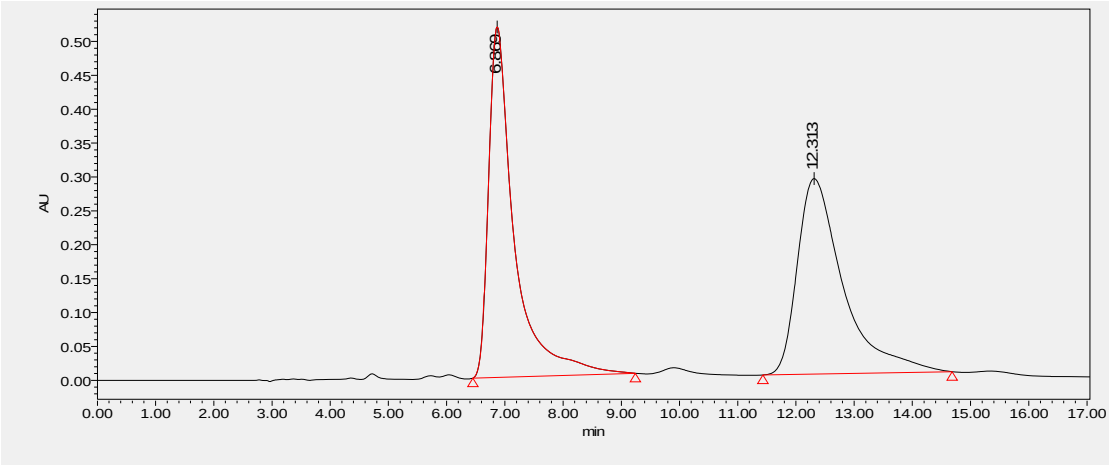
	Retention time	Area	% Area	Height	Integral type
1	5.672	196249	1.75	8806	bb
2	9.693	10989674	98.25	266698	bb

(*R*)-3-(aminomethyl)-1-benzyl-3-hydroxy-5-methoxyindolin-2-one (Table 3, entry 3)

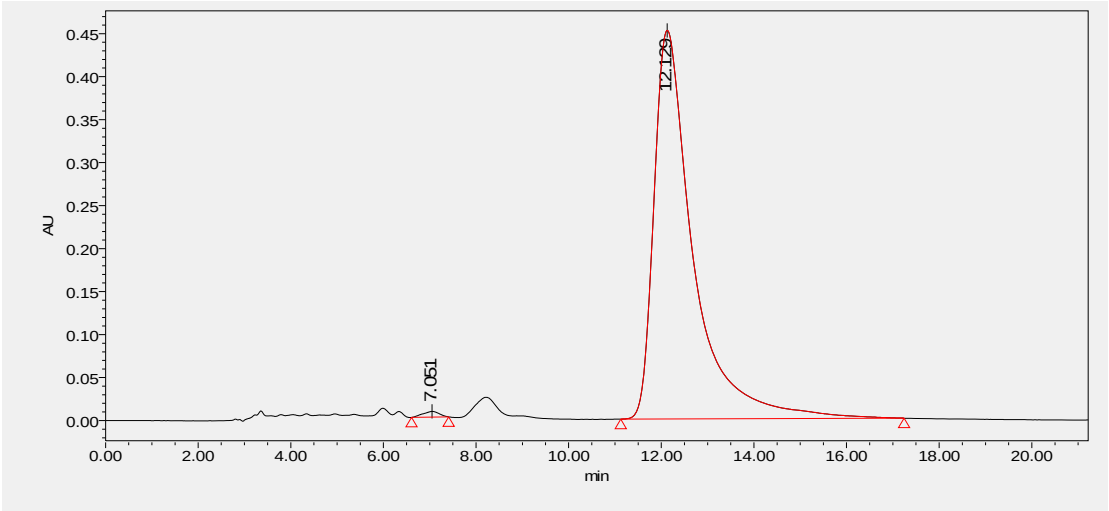


2g'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

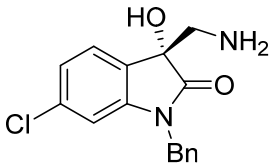


	Retention time	Area	% Area	Height	Integral type
1	6.869	15830031	50.11	517196	bb
2	12.313	15762766	49.89	288453	bb



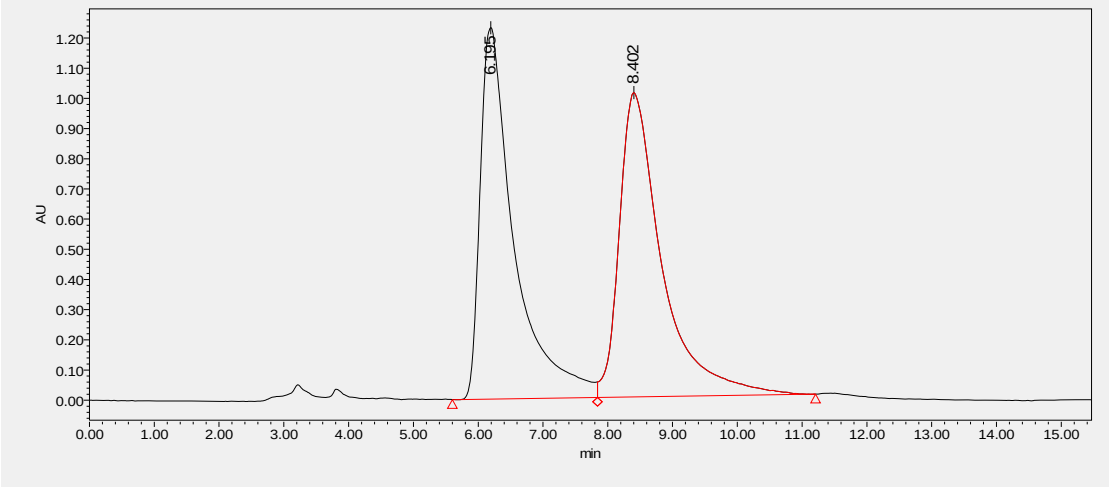
	Retention time	Area	% Area	Height	Integral type
1	7.051	161632	0.60	6631	bb
2	12.129	26612364	99.40	451971	bb

(*R*)-3-(aminomethyl)-1-benzyl-6-chloro-3-hydroxyindolin-2-one (Table 3, entry 4)

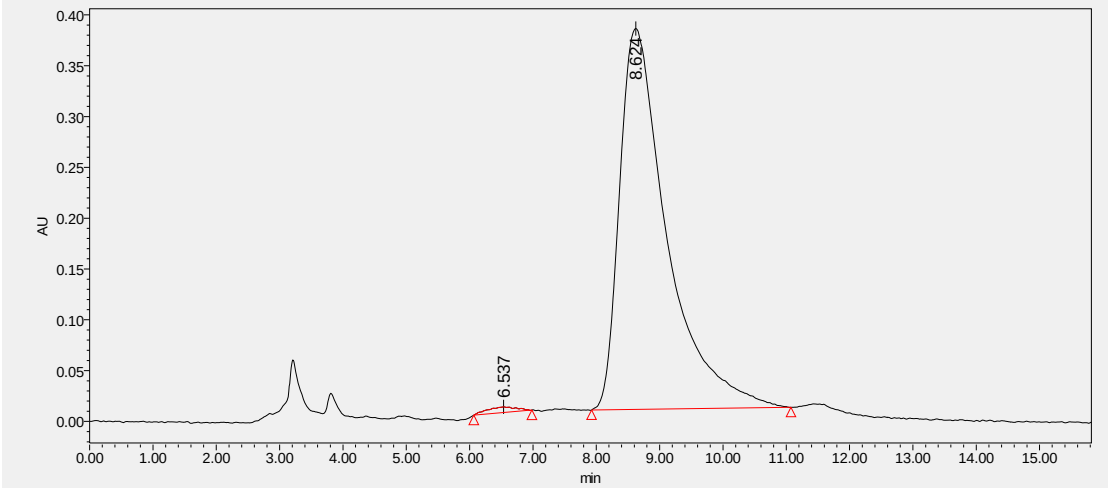


2h'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

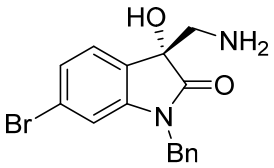


	Retention time	Area	% Area	Height	Integral type
1	6.195	44617719	49.29	1230356	bv
2	8.402	45906199	50.71	1007696	vb



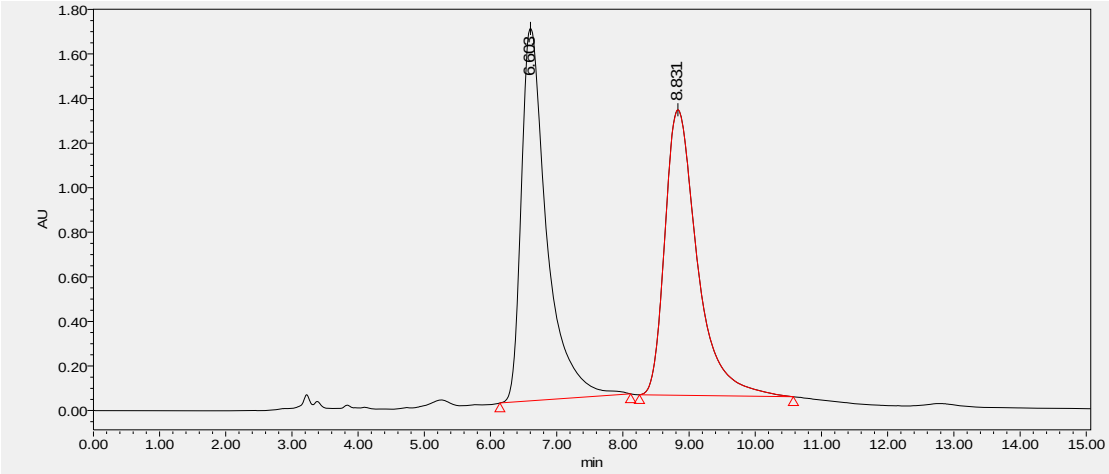
	Retention time	Area	% Area	Height	Integral type
1	6.537	183726	0.94	5635	bb
2	8.624	19461183	99.06	374773	bb

(*R*)-3-(aminomethyl)-1-benzyl-6-bromo-3-hydroxyindolin-2-one (Table 3, entry 5)

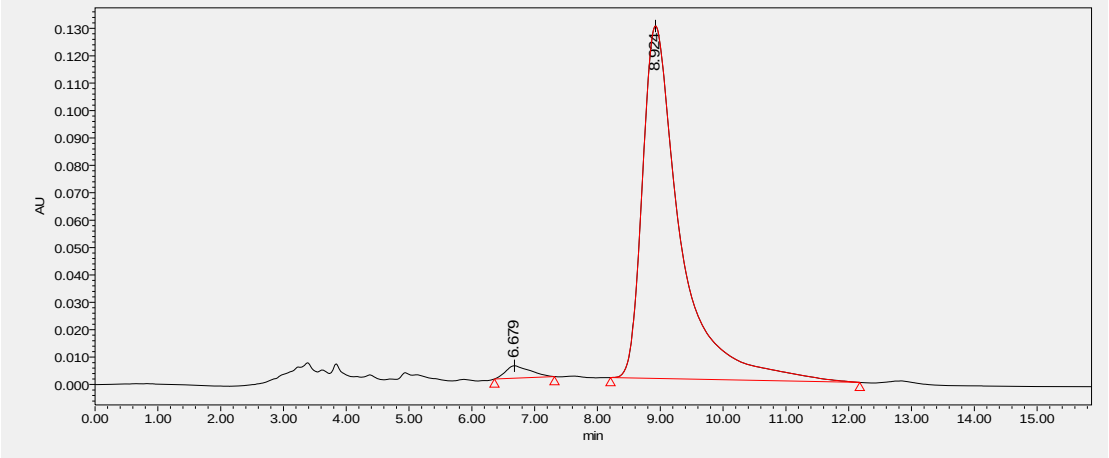


2i'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

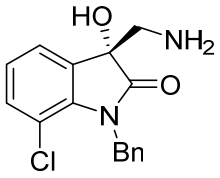


	Retention time	Area	% Area	Height	Integral type
1	6.603	44677878	50.56	1670989	bb
2	8.831	43680220	49.44	1281028	bb



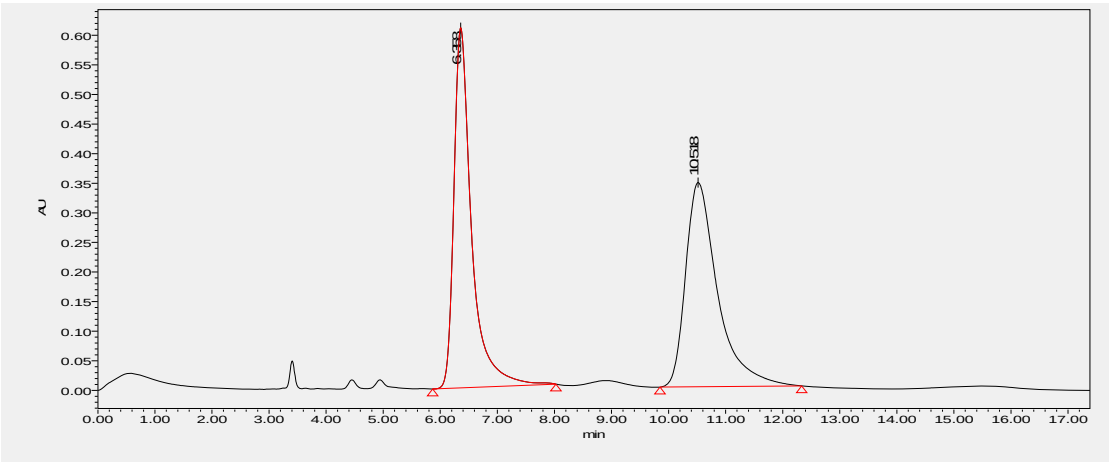
	Retention time	Area	% Area	Height	Integral type
1	6.679	121785	2.20	4540	bb
2	8.924	5416442	97.80	128652	bb

(*R*)-3-(aminomethyl)-1-benzyl-7-chloro-3-hydroxyindolin-2-one (Table 3, entry 6)

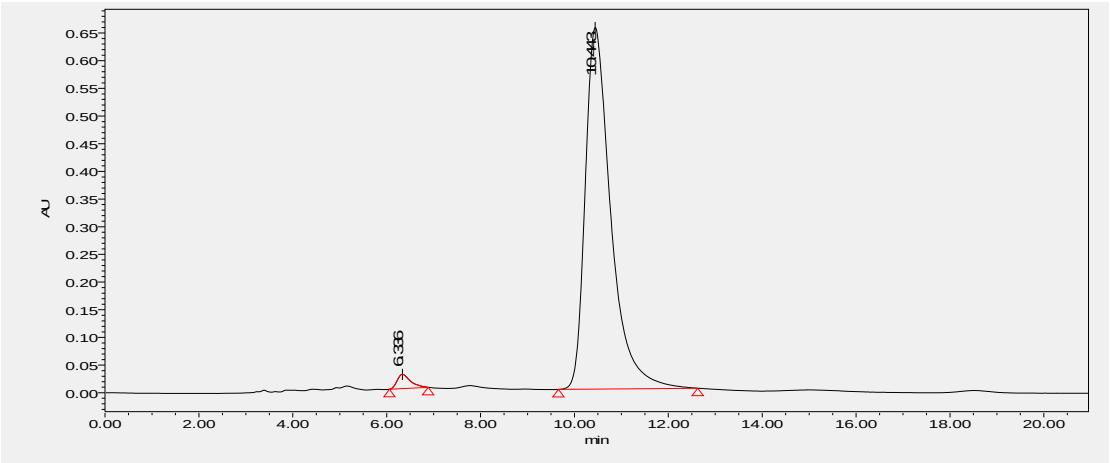


2j'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

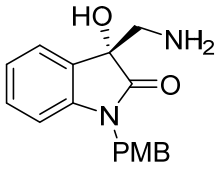


	Retention time	Area	% Area	Height	Integral type
1	6.358	13111383	49.38	608499	bb
2	10.518	13441431	50.62	345053	bb



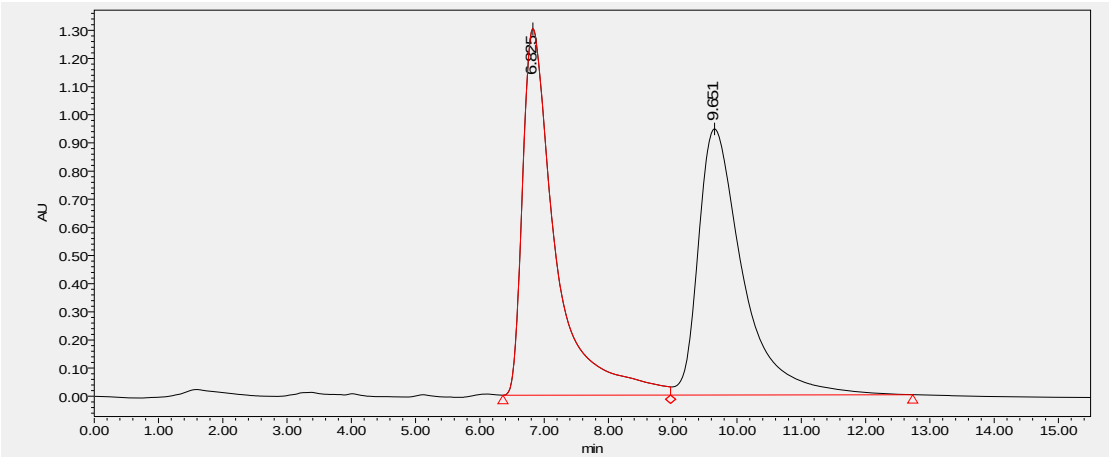
	Retention time	Area	% Area	Height	Integral type
1	6.336	513935	2.03	25822	bb
2	10.443	24788016	97.97	653245	bb

(*R*)-3-(aminomethyl)-3-hydroxy-1-(4-methoxybenzyl)indolin-2-one (Table 3, entry 7)

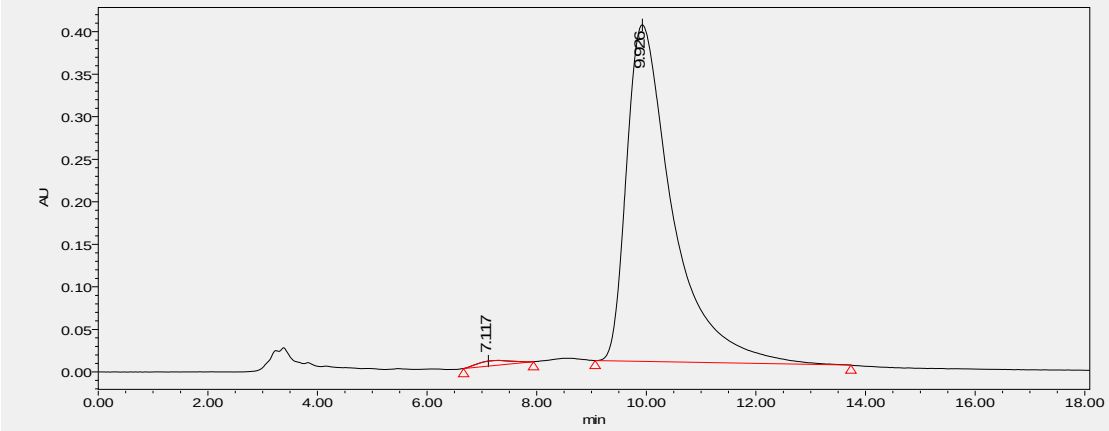


2p'

Chiralpak OD-H column, hexane/EtOH (7:3), flow rate 1.0 mL/min

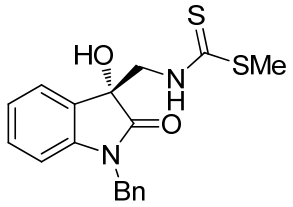


	Retention time	Area	% Area	Height	Integral type
1	6.825	46648109	50.59	1301998	bv
2	9.651	45556671	49.41	945292	vb



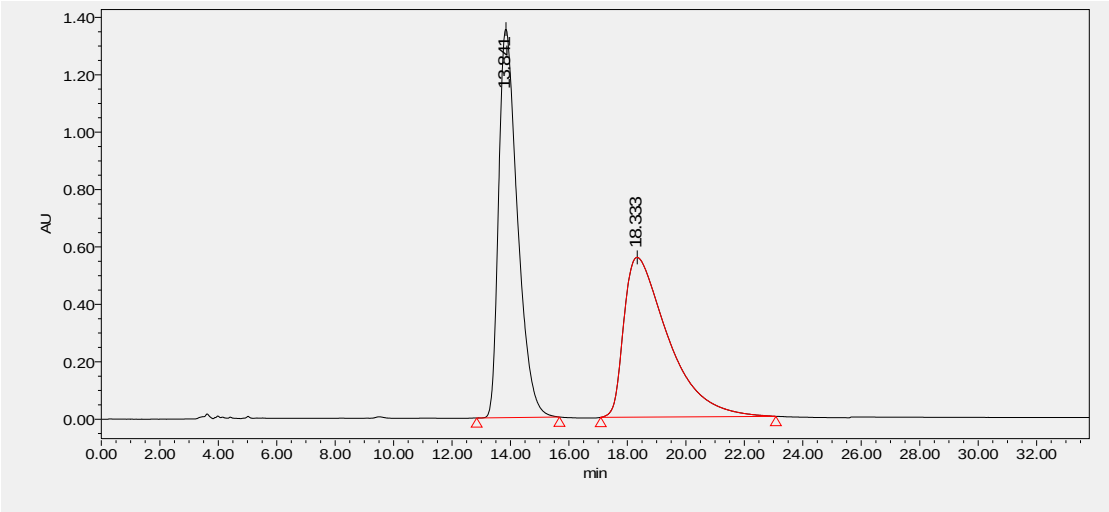
	Retention time	Area	% Area	Height	Integral type
1	7.117	250256	1.07	6021	bb
2	9.926	23116760	98.93	395584	bb

(*R*)-methyl ((1-benzyl-3-hydroxy-2-oxoindolin-3-yl)methyl)carbamodithioate (Scheme 2, **3**)

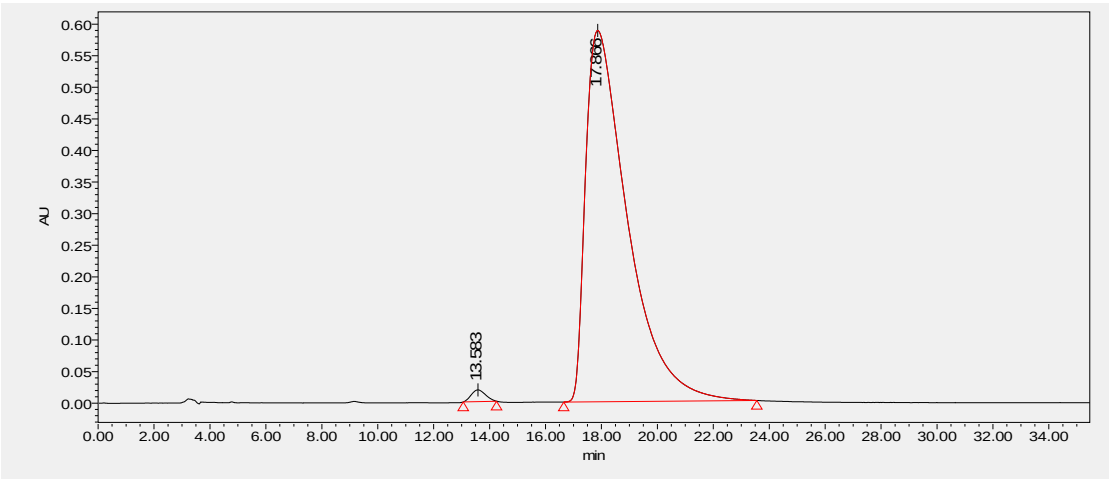


3

Chiralpak AS column, hexane/EtOH (8:2), flow rate 1.0 mL/min

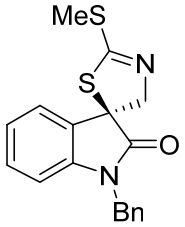


	Retention time	Area	% Area	Height	Integral type
1	13.841	60668556	50.80	1353628	bb
2	18.333	58752826	49.20	556557	bb



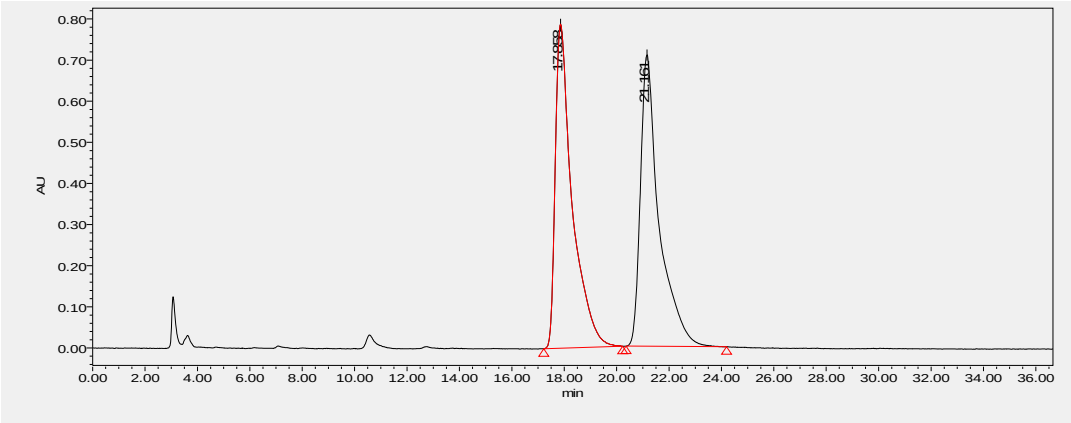
	Retention time	Area	% Area	Height	Integral type
1	13.583	657222	1.06	18508	bb
2	17.866	61222987	98.94	587755	bb

(*R*)-1-benzyl-2'-(methylthio)-4'H-spiro[indoline-3,5'-thiazol]-2-one (Scheme 2, **4**)

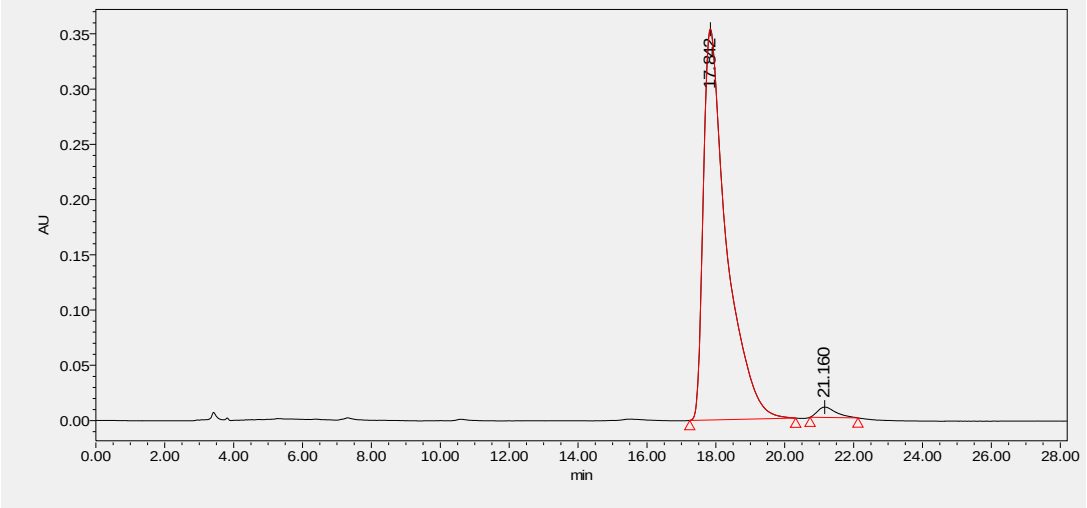


4

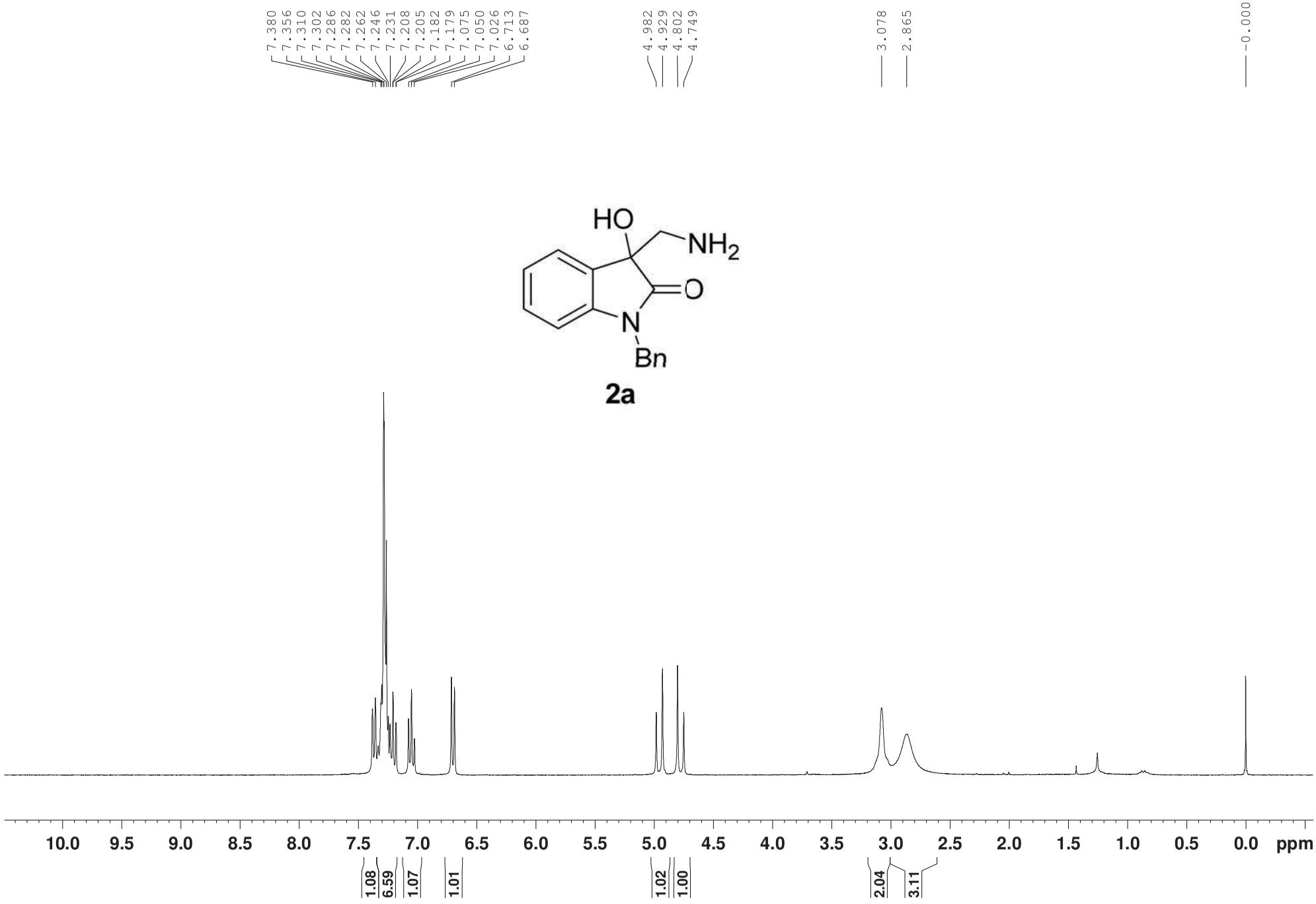
Chiralpak AD column, hexane/EtOH (8:2), flow rate 1.0 mL/min

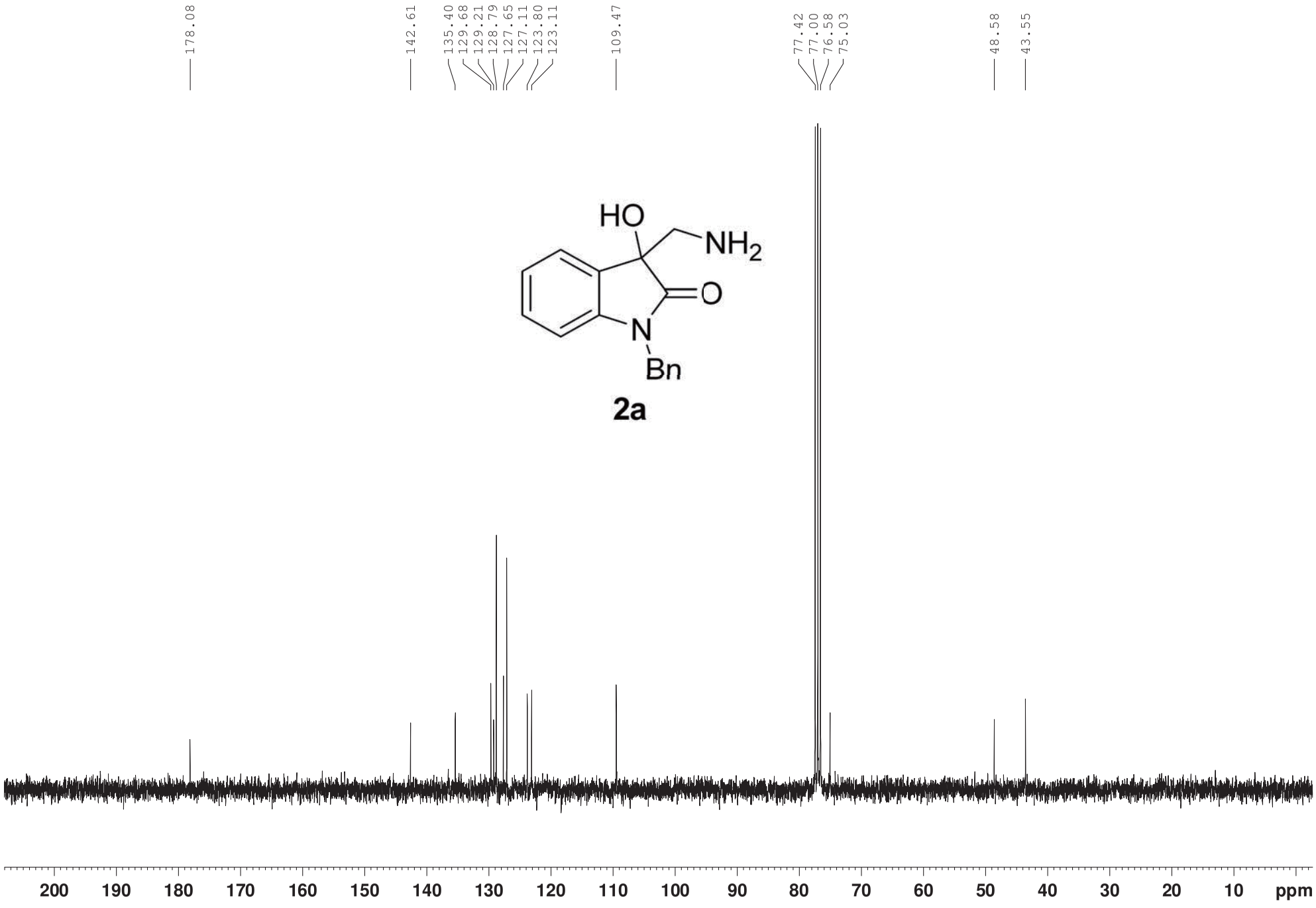


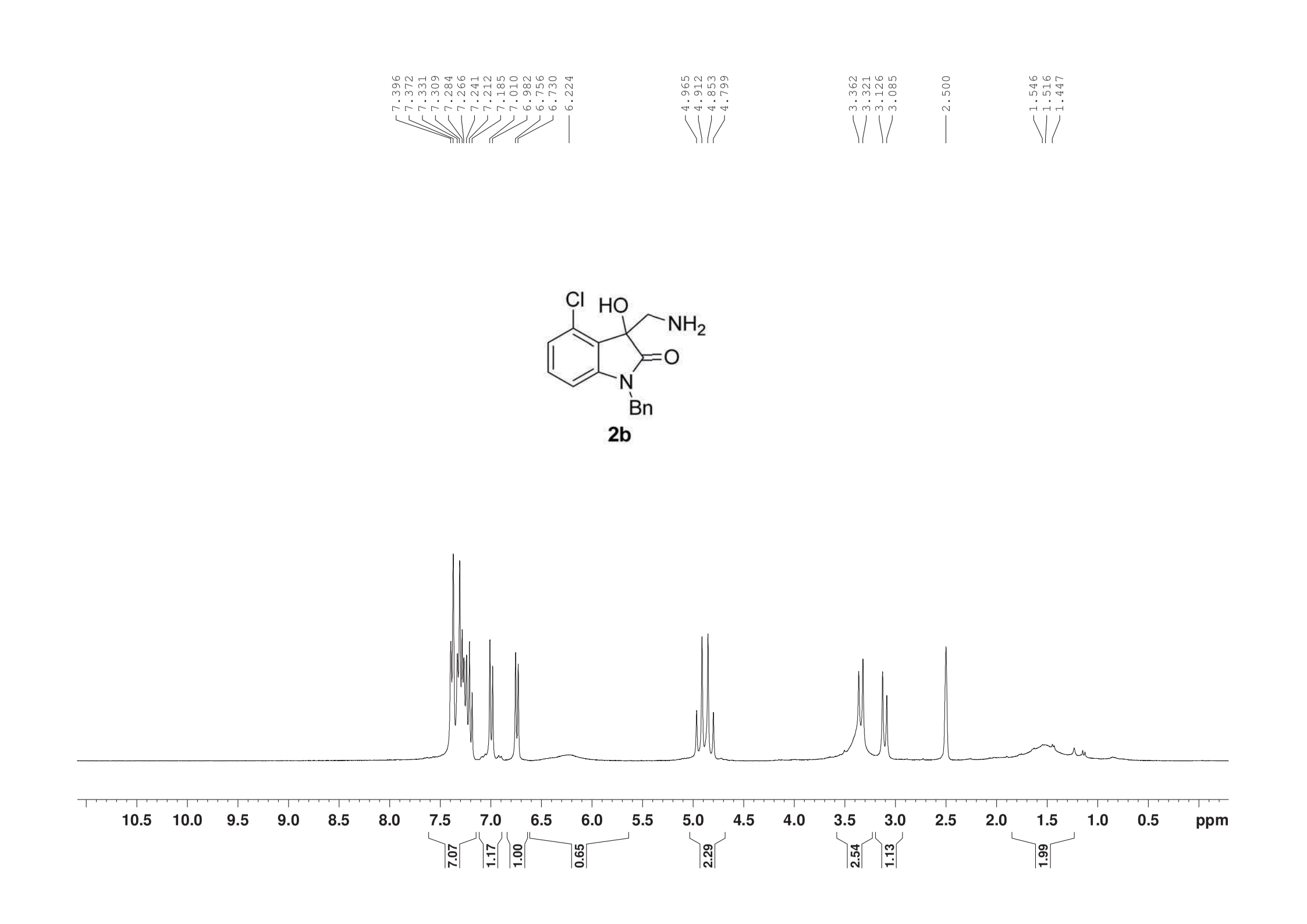
	Retention time	Area	% Area	Height	Integral type
1	17.858	35387474	50.32	787462	bb
2	21.161	34941844	49.68	708519	bb

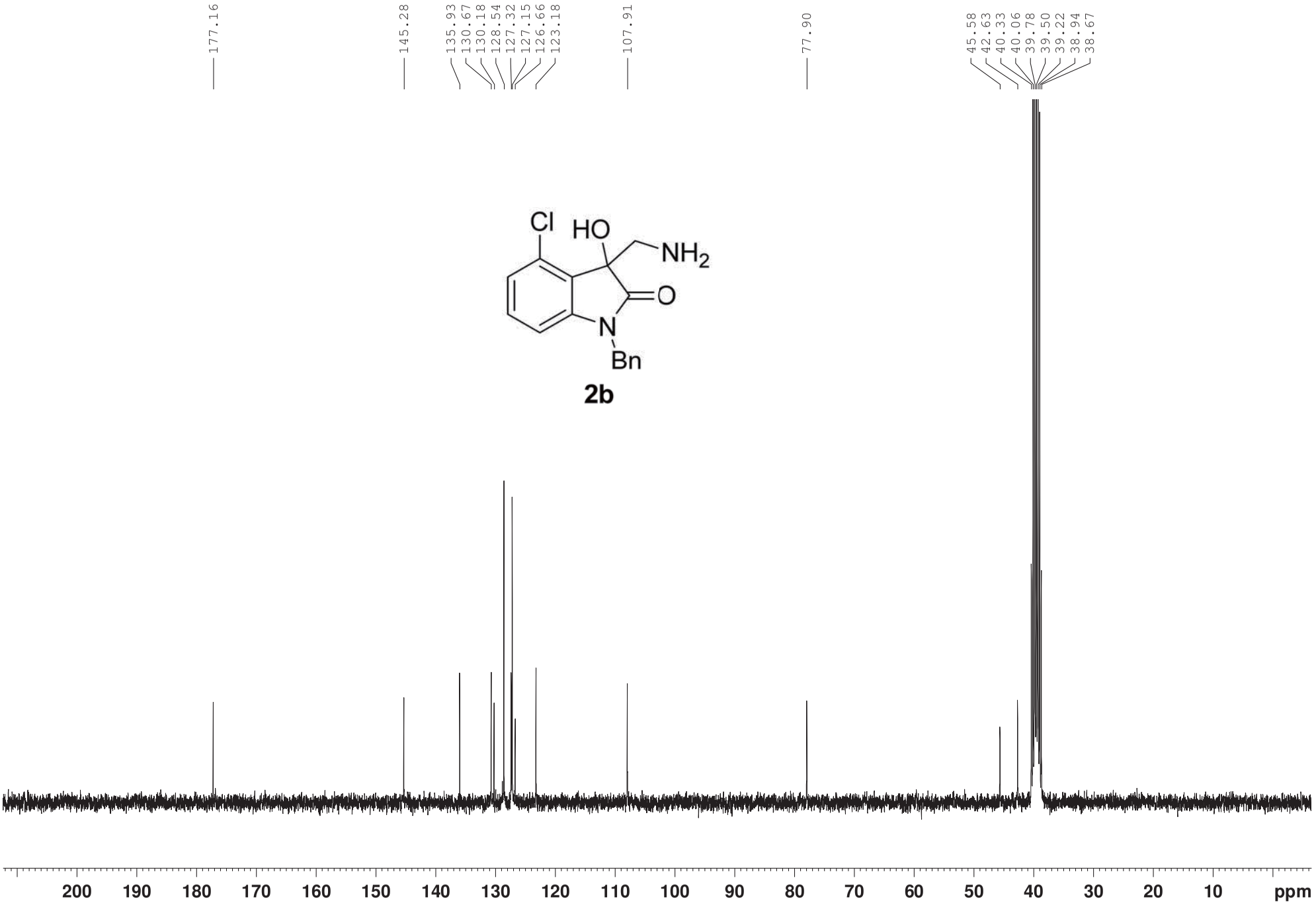


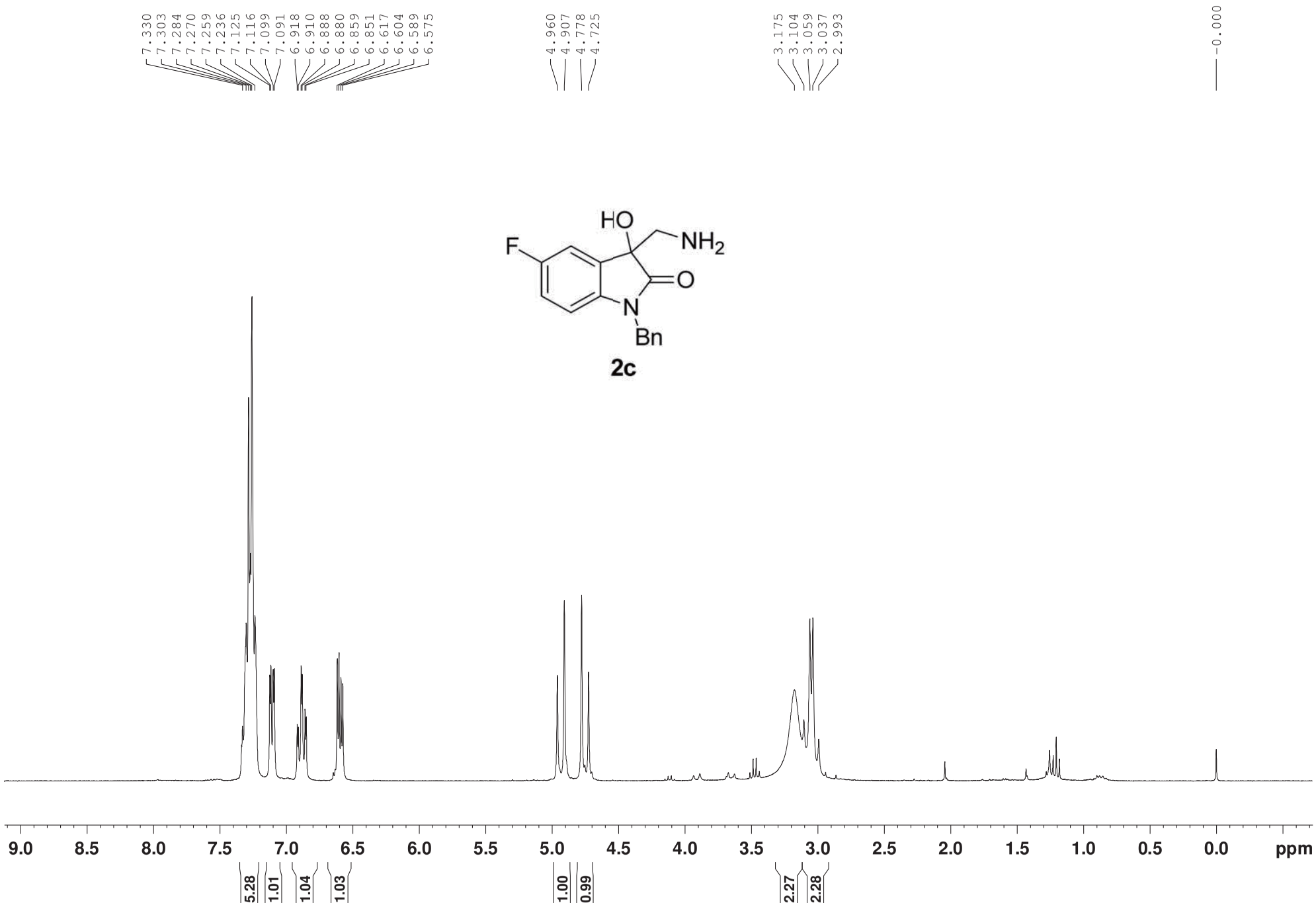
	Retention time	Area	% Area	Height	Integral type
1	17.842	16509374	97.94	353649	bb
2	21.160	347475	2.06	9335	bb

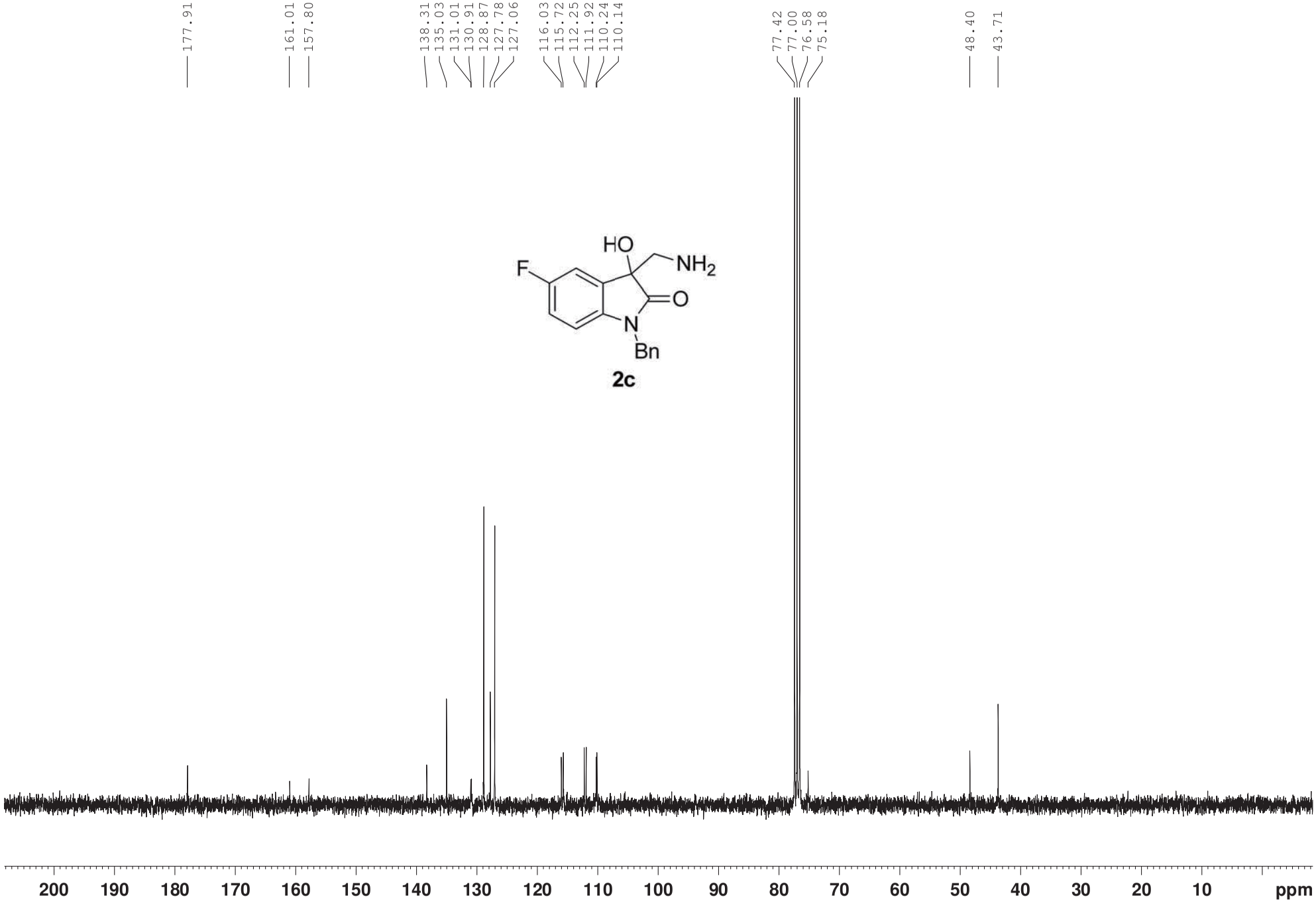

7.380
7.356
7.310
7.302
7.286
7.282
7.262
7.246
7.231
7.208
7.205
7.182
7.179
7.075
7.050
7.026
6.713
6.687
4.982
4.929
4.802
4.749
3.078
2.865
-0.000
HO
NH2
O
N
Bn
2a
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
1.08
6.59
1.07
1.01
1.02
1.00
2.04
3.11

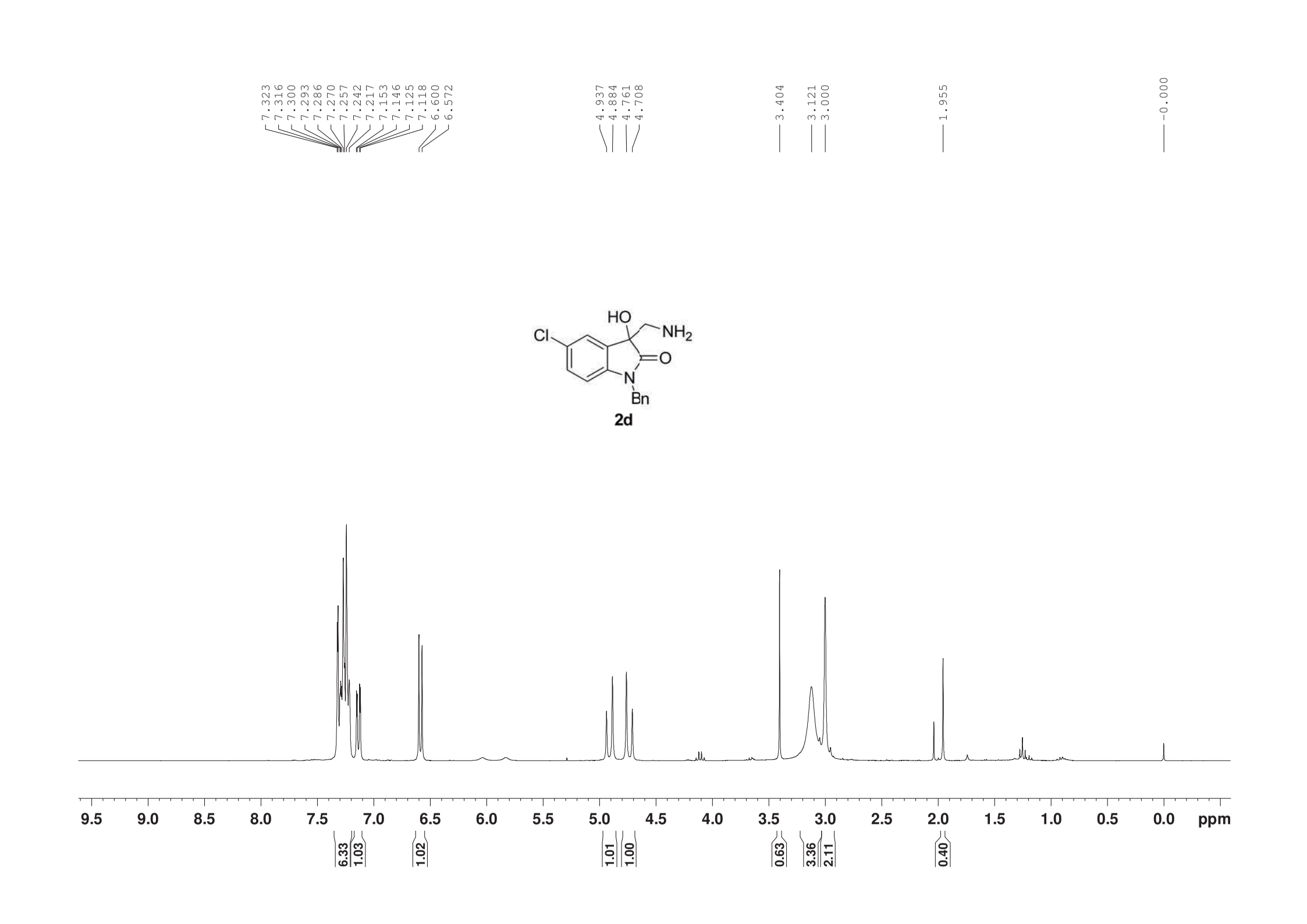

178.08
142.61
135.40
129.68
129.21
128.79
127.65
127.11
123.80
123.11
109.47
77.42
77.00
76.58
75.03
48.58
43.55
HO
NH2
O
N
Bn
2a
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.396
7.372
7.331
7.309
7.284
7.266
7.241
7.212
7.185
7.010
6.982
6.756
6.730
6.224
4.965
4.912
4.853
4.799
3.362
3.321
3.126
3.085
2.500
1.546
1.516
1.447
Cl
HO
NH2
O
N
Bn
2b
10.5
10.0
9.5
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
7.07
1.17
1.00
0.65
2.29
2.54
1.13
1.99


177.16
145.28
135.93
130.67
130.18
128.54
127.32
127.15
126.66
123.18
107.91
77.90
45.58
42.63
40.33
40.06
39.78
39.50
39.22
38.94
38.67
Cl
HO
NH2
O
N
Bn
2b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

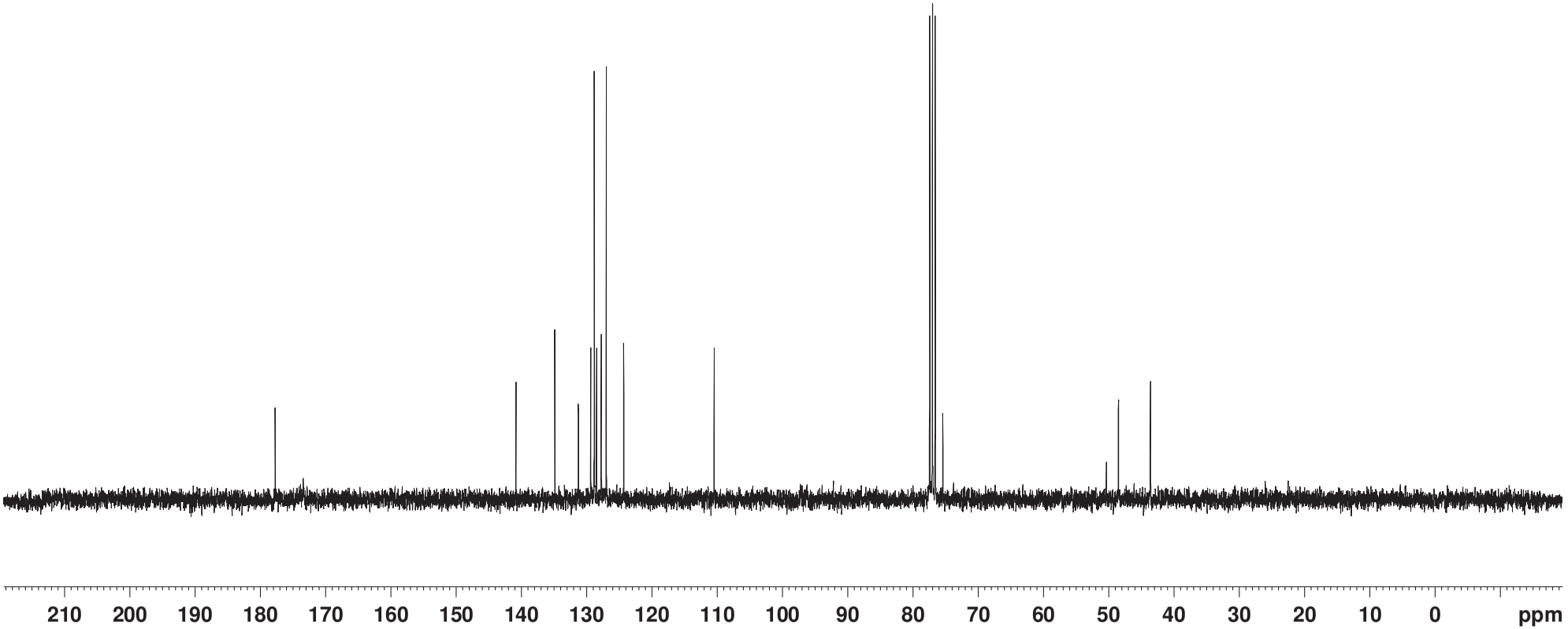

7.330
7.303
7.284
7.270
7.259
7.236
7.125
7.116
7.099
7.091
6.918
6.910
6.888
6.880
6.859
6.851
6.617
6.604
6.589
6.575
4.960
4.907
4.778
4.725
3.175
3.104
3.059
3.037
2.993
0.000
HO
NH2
F
O
N
Bn
2c
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
5.28
1.01
1.04
1.03
1.00
0.99
2.27
2.28

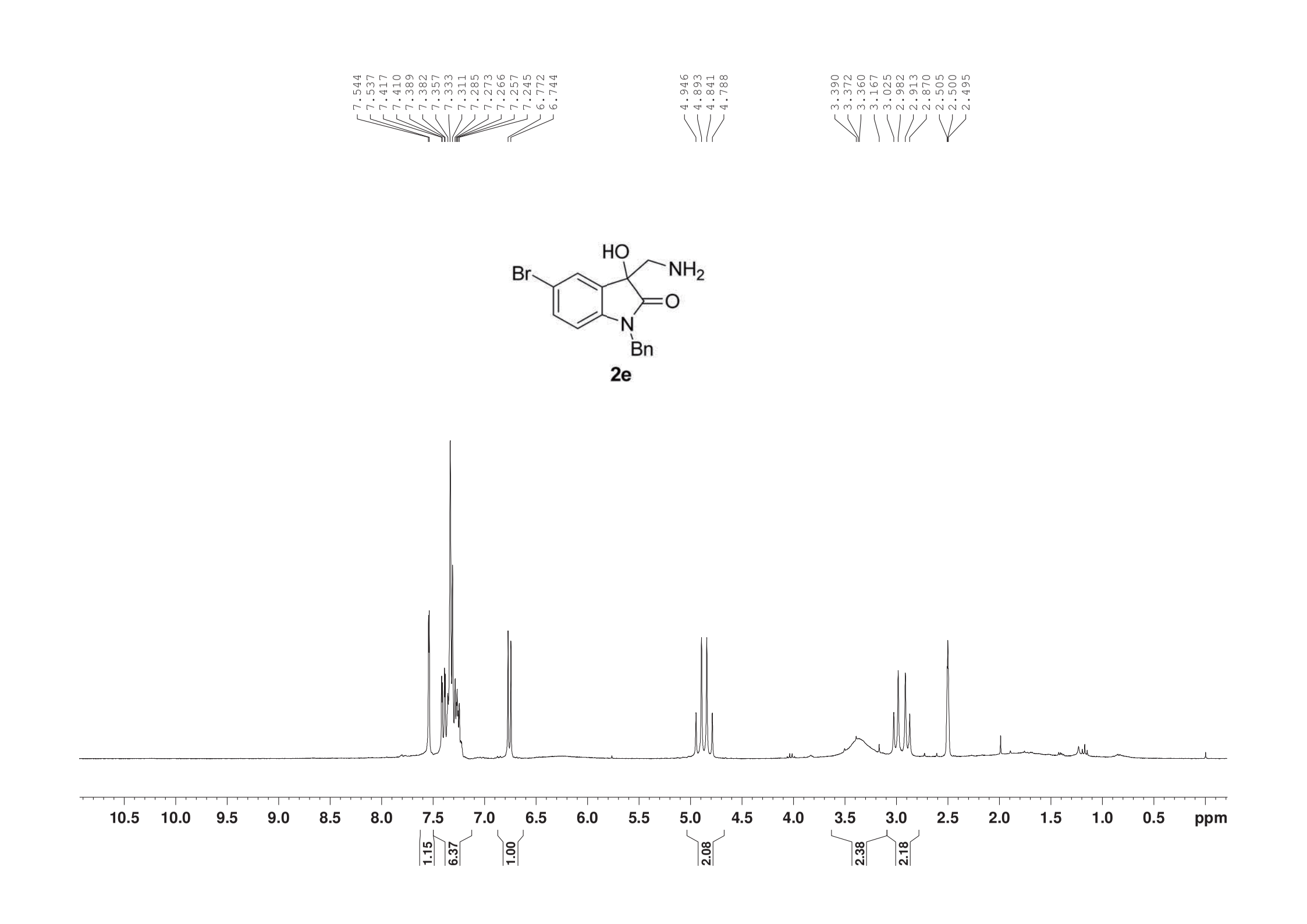

177.91
161.01
157.80
138.31
135.03
131.01
130.91
128.87
127.78
127.06
116.03
115.72
112.25
111.92
110.24
110.14
77.42
77.00
76.58
75.18
48.40
43.71
HO
NH2
F
O
N
Bn
2c
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.323
7.316
7.300
7.293
7.286
7.270
7.257
7.242
7.217
7.153
7.146
7.125
7.118
6.600
6.572
4.937
4.884
4.761
4.708
3.404
3.121
3.000
1.955
-0.000
HO
NH2
Cl
O
N
Bn
2d
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
6.33
1.03
1.02
1.01
1.00
0.63
3.36
2.11
0.40

177.73
140.81
134.87
131.25
129.35
128.83
128.47
127.75
126.98
124.31
110.45
77.42
77.00
76.58
75.40
48.50
43.59

2d

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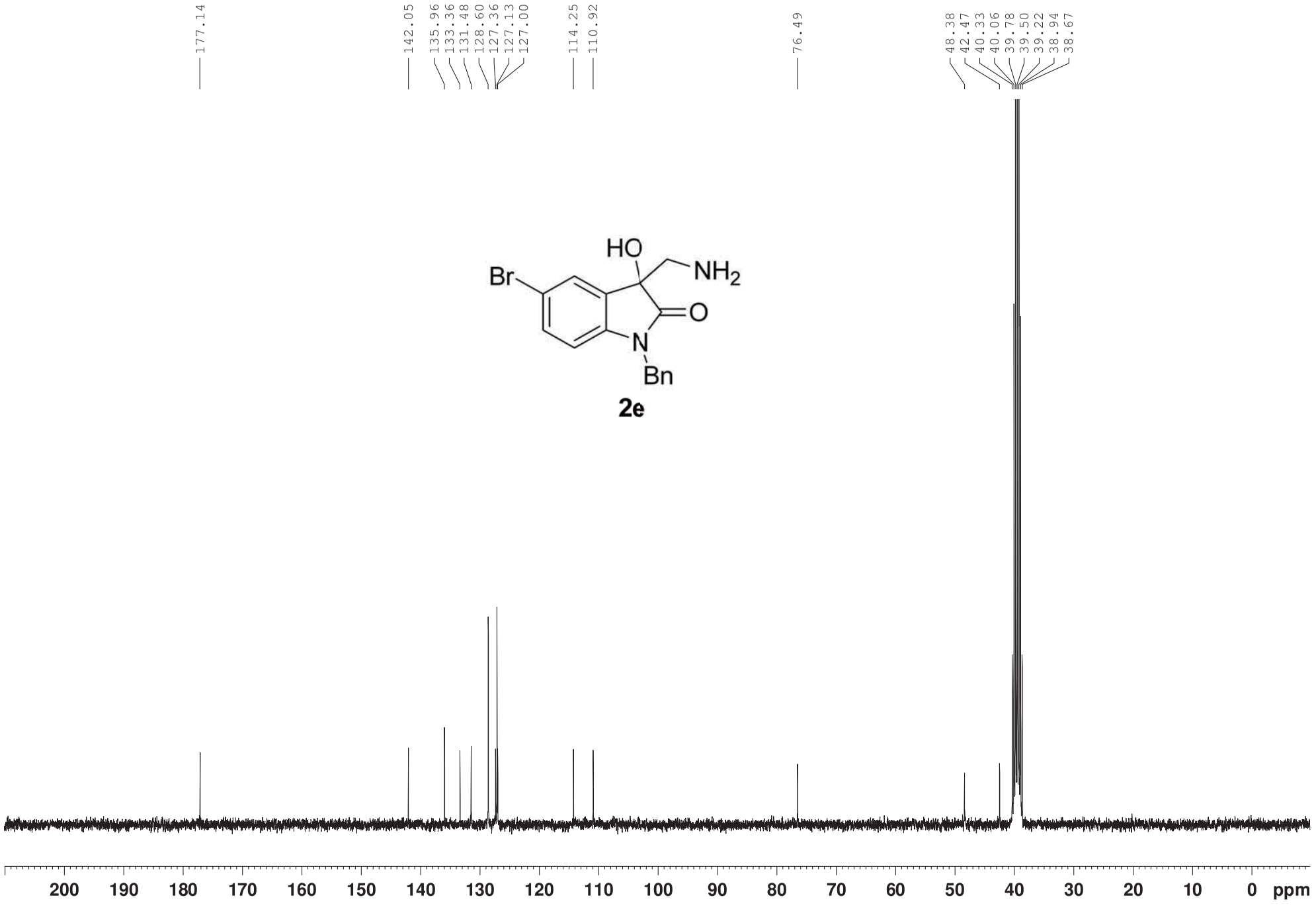
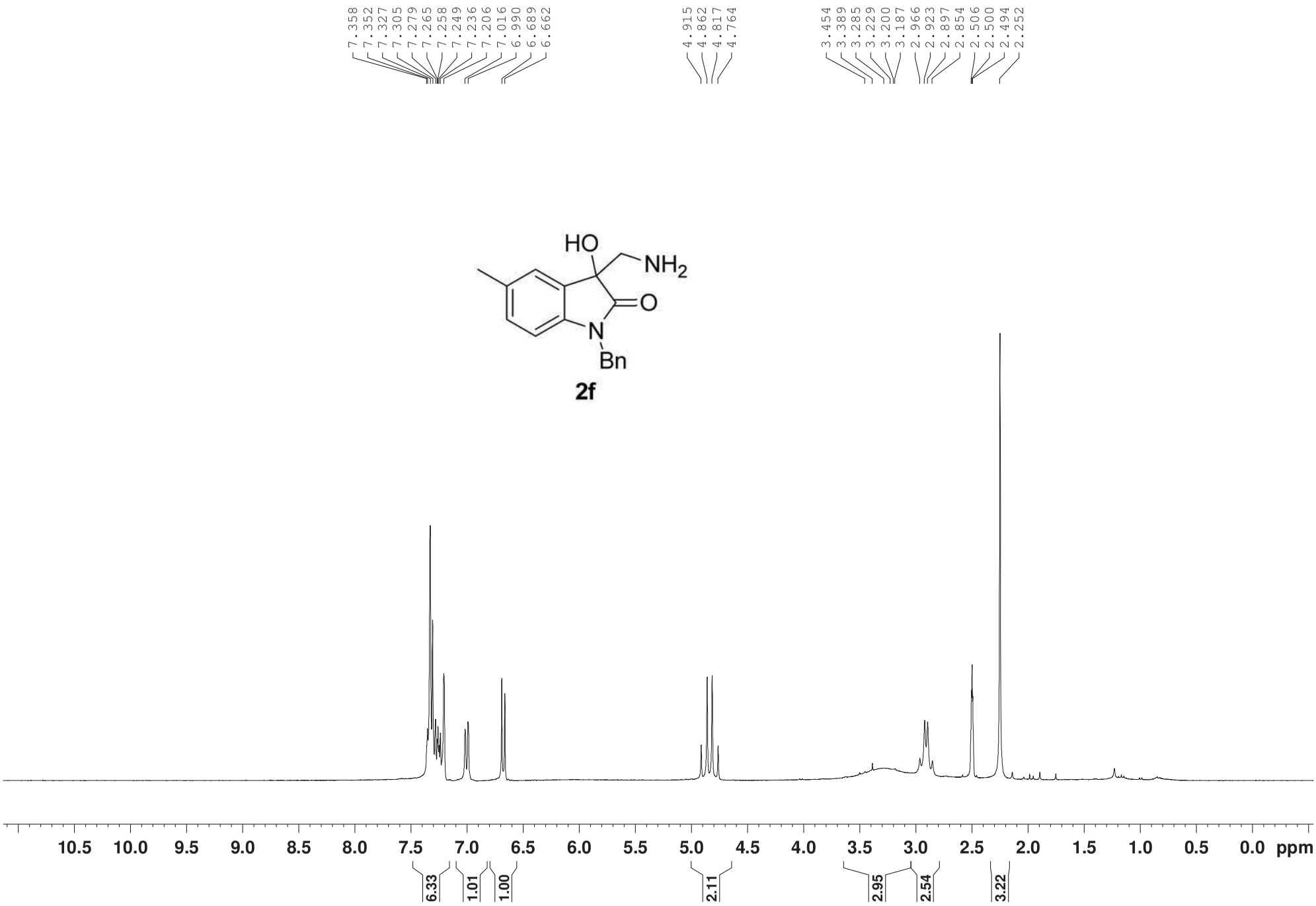
7.537
7.417
7.410
7.389
7.382
7.357
7.333
7.311
7.285
7.273
7.266
7.257
7.245
6.772
6.744
4.946
4.893
4.841
4.788
3.390
3.372
3.360
3.167
3.025
2.982
2.913
2.870
2.505
2.500
2.495
HO
NH2
Br
O
N
Bn
2e
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
1.15
6.37
1.00
2.08
2.38
2.18


177.14
142.05
135.96
133.36
131.48
128.60
127.36
127.13
127.00
114.25
110.92
76.49
48.38
42.47
40.33
40.06
39.78
39.50
39.22
38.94
38.67
HO
NH2
Br
O
N
Bn
2e
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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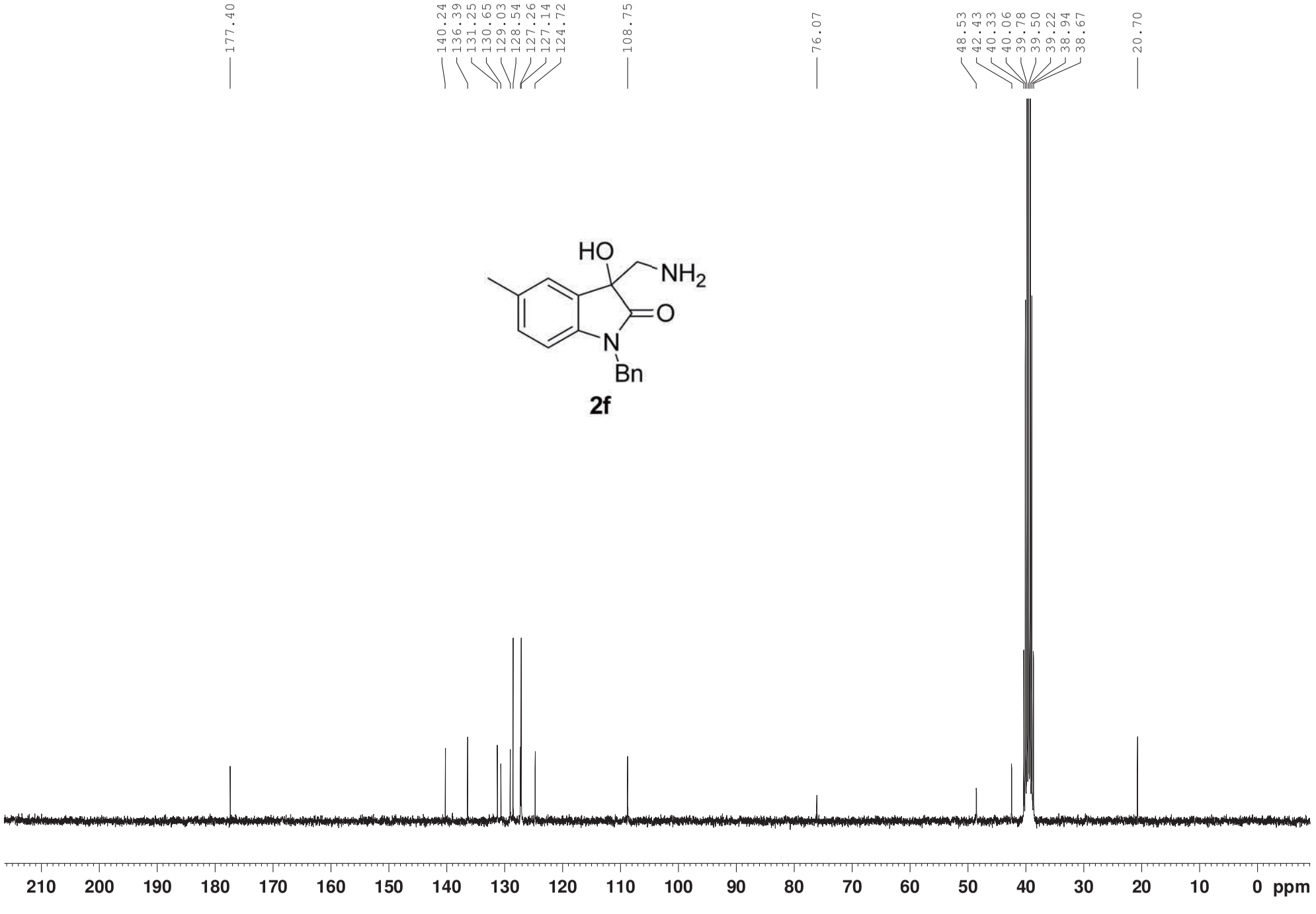
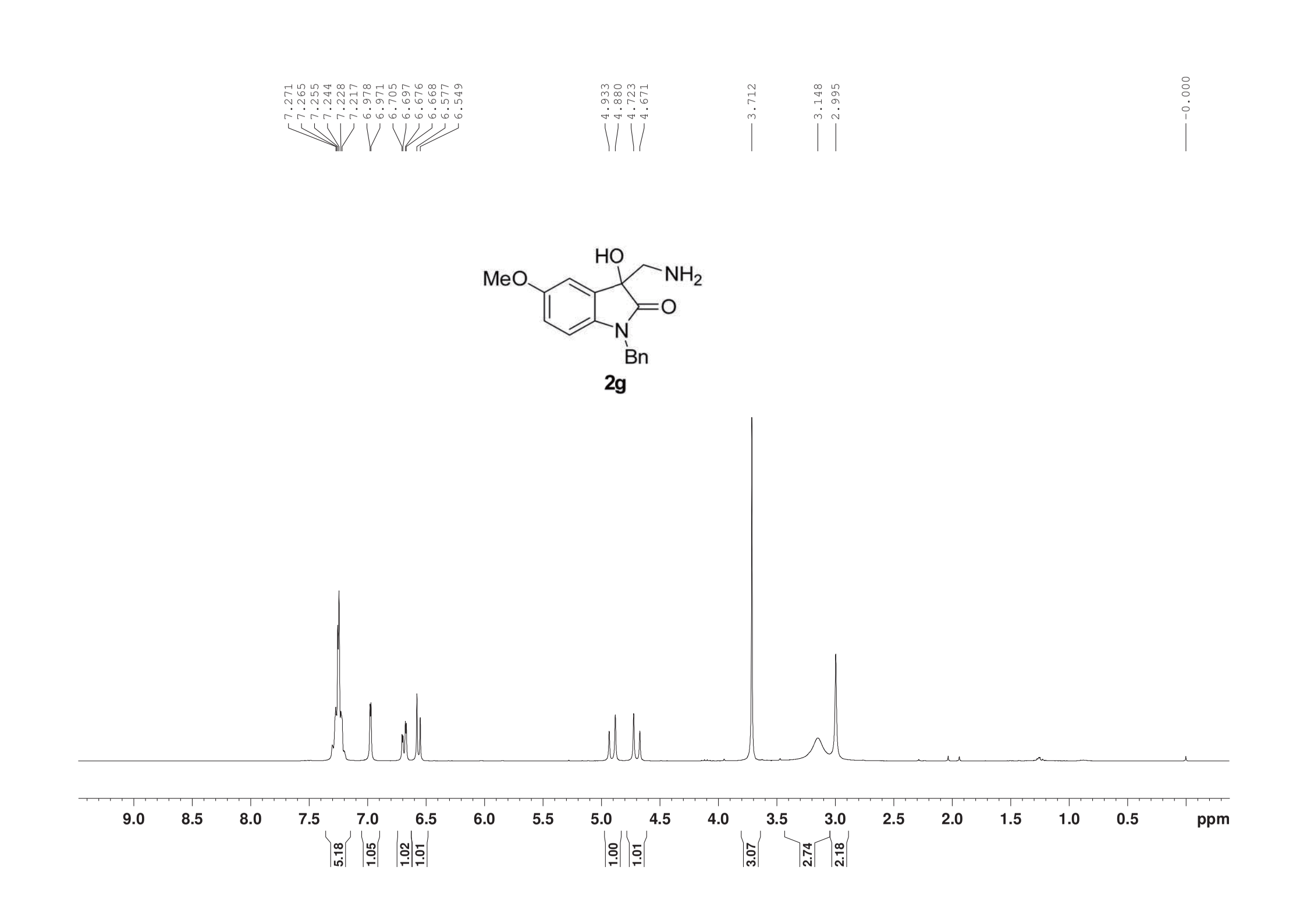
7.352
7.327
7.305
7.279
7.265
7.258
7.249
7.236
7.206
7.016
6.990
6.689
6.662
4.915
4.862
4.817
4.764
3.454
3.389
3.285
3.229
3.200
3.187
2.966
2.923
2.897
2.854
2.506
2.500
2.494
2.252
HO
NH2
O
N
Bn
2f
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm
6.33
1.01
1.00
2.11
2.95
2.54
3.22


177.40
140.24
136.39
131.25
130.65
129.03
128.54
127.26
127.14
124.72
108.75
76.07
48.53
42.43
40.33
40.06
39.78
39.50
39.22
38.94
38.67
20.70
HO
NH2
O
N
Bn
2f
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0 ppm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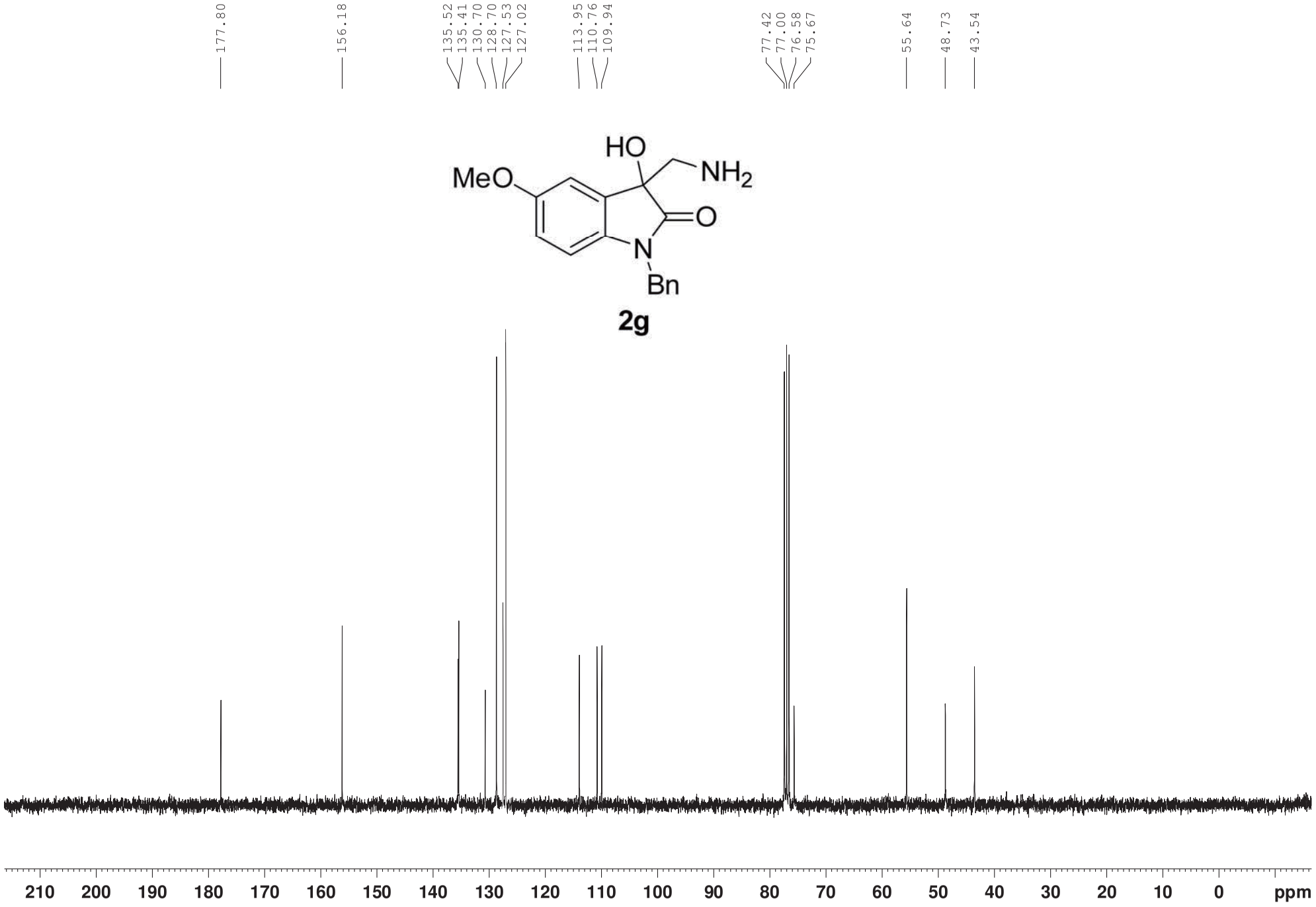
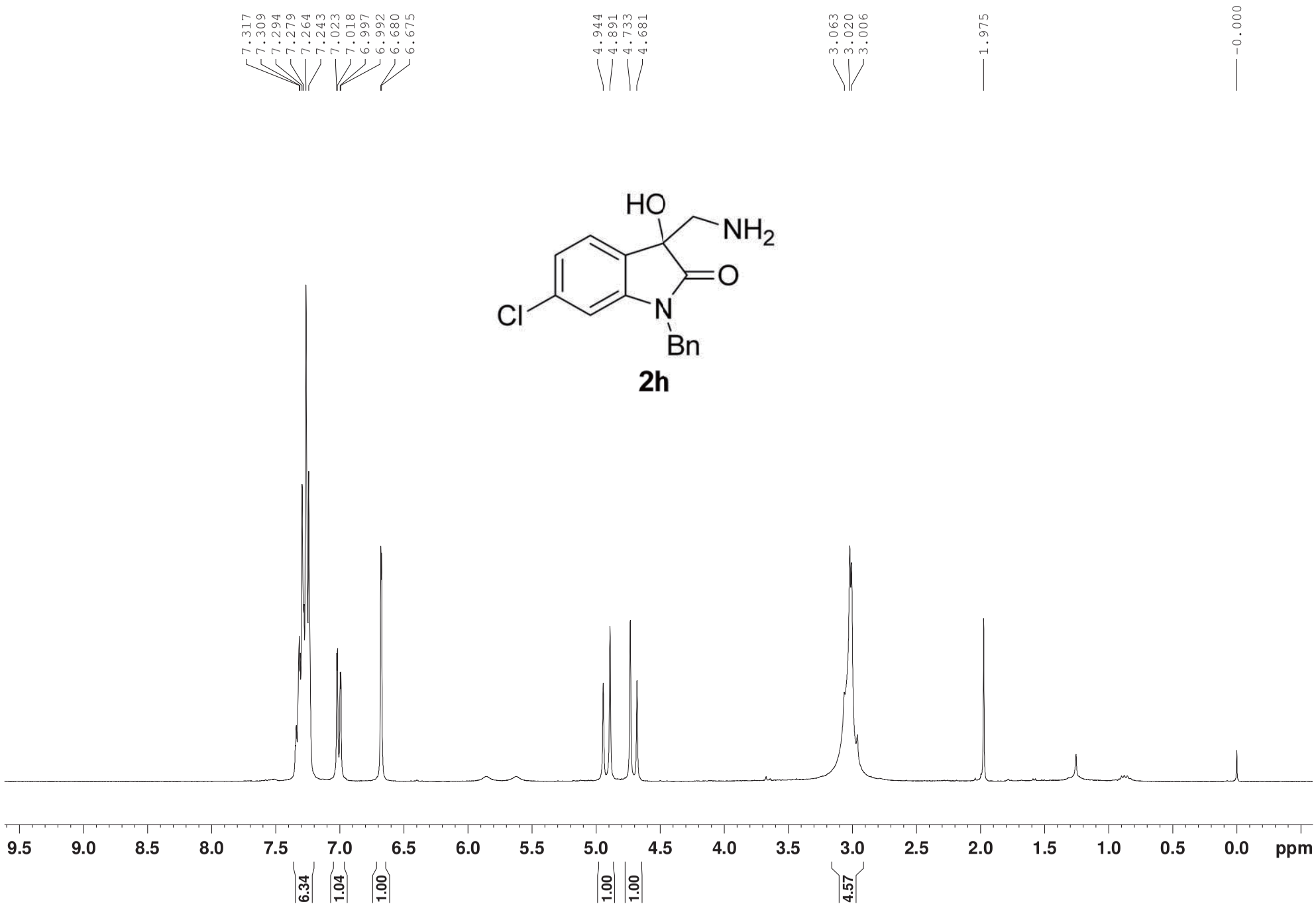
7.265
7.255
7.244
7.228
7.217
6.978
6.971
6.705
6.697
6.676
6.668
6.577
6.549
4.933
4.880
4.723
4.671
3.712
3.148
2.995
-0.000
HO
NH2
MeO
O
N
Bn
2g
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
5.18
1.05
1.02
1.01
1.00
1.01
3.07
2.74
2.18


177.80
156.18
135.52
135.41
130.70
128.70
127.53
127.02
113.95
110.76
109.94
77.42
77.00
76.58
75.67
55.64
48.73
43.54
HO
NH2
MeO
O
N
Bn
2g
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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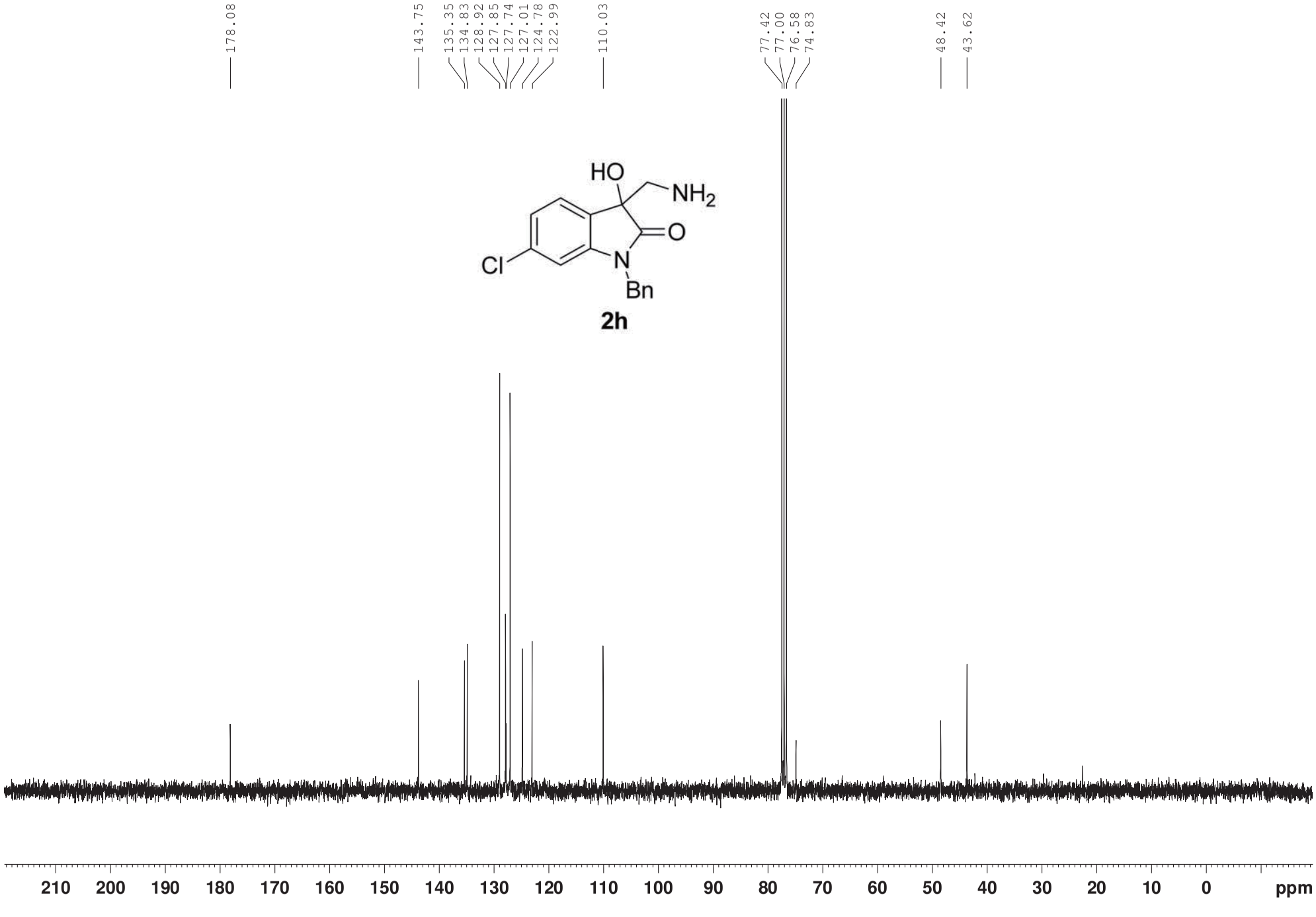
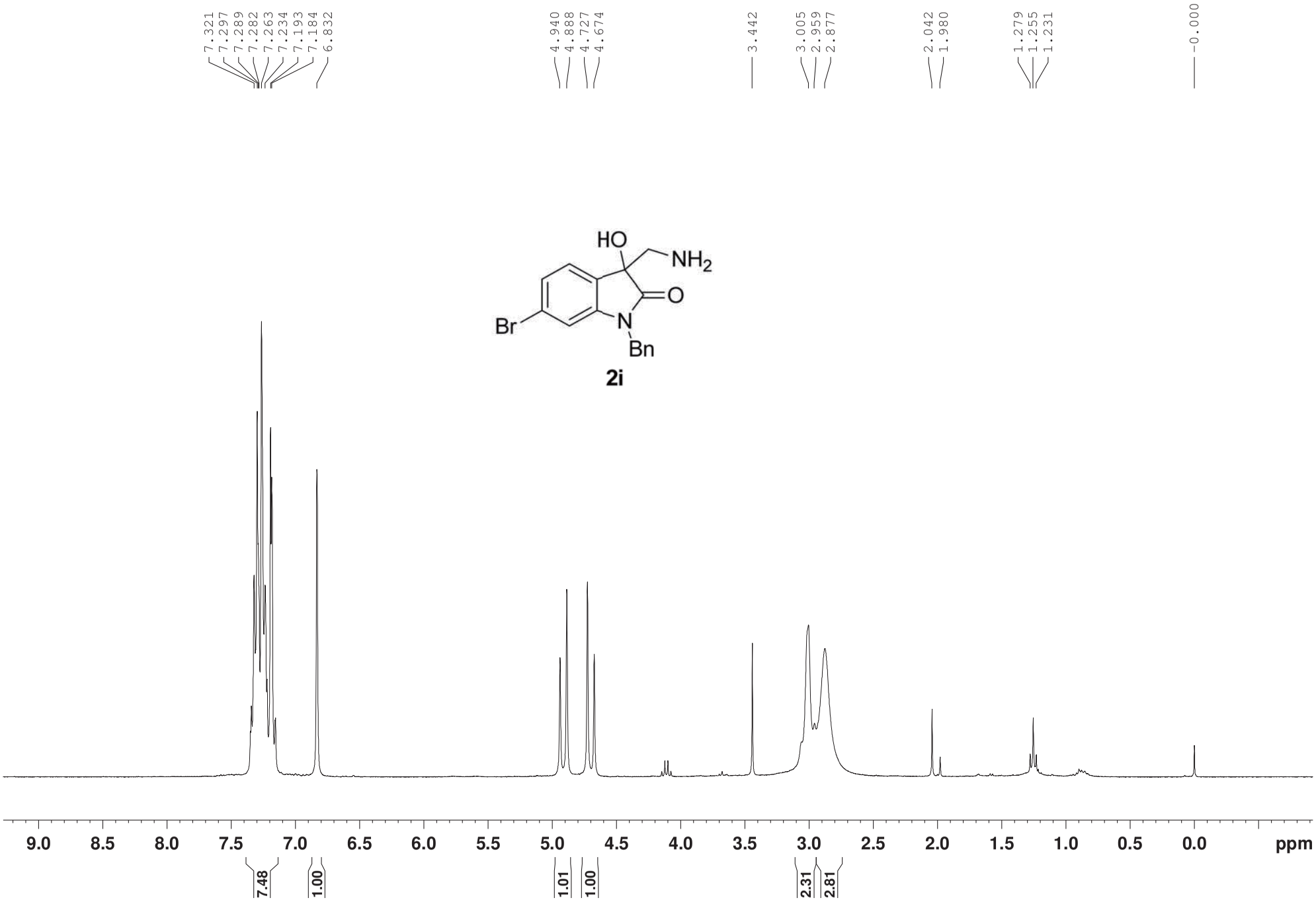
7.294
7.279
7.264
7.243
7.023
7.018
6.997
6.992
6.680
6.675
4.944
4.891
4.733
4.681
3.063
3.020
3.006
1.975
-0.000
HO
NH2
O
Cl
N
Bn
2h
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
6.34
1.04
1.00
1.00
1.00
4.57


178.08
143.75
135.35
134.83
128.92
127.85
127.74
127.01
124.78
122.99
110.03
77.42
77.00
76.58
74.83
48.42
43.62
HO
NH2
O
Cl
N
Bn
2h
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.297
7.289
7.282
7.263
7.234
7.193
7.184
6.832
4.940
4.888
4.727
4.674
3.442
3.005
2.959
2.877
2.042
1.980
1.279
1.255
1.231
-0.000
HO
NH2
O
Br
N
Bn
2i
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm
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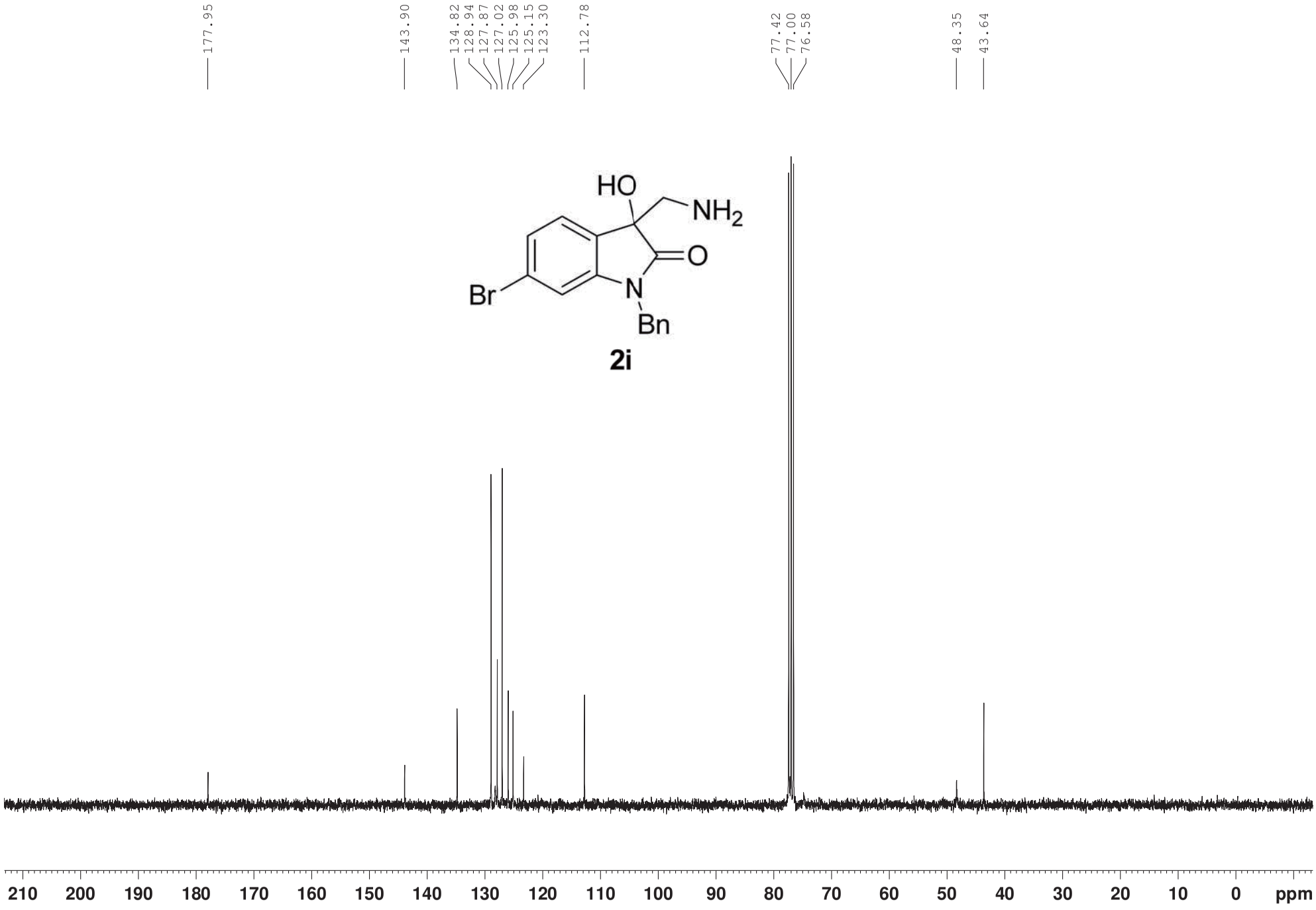
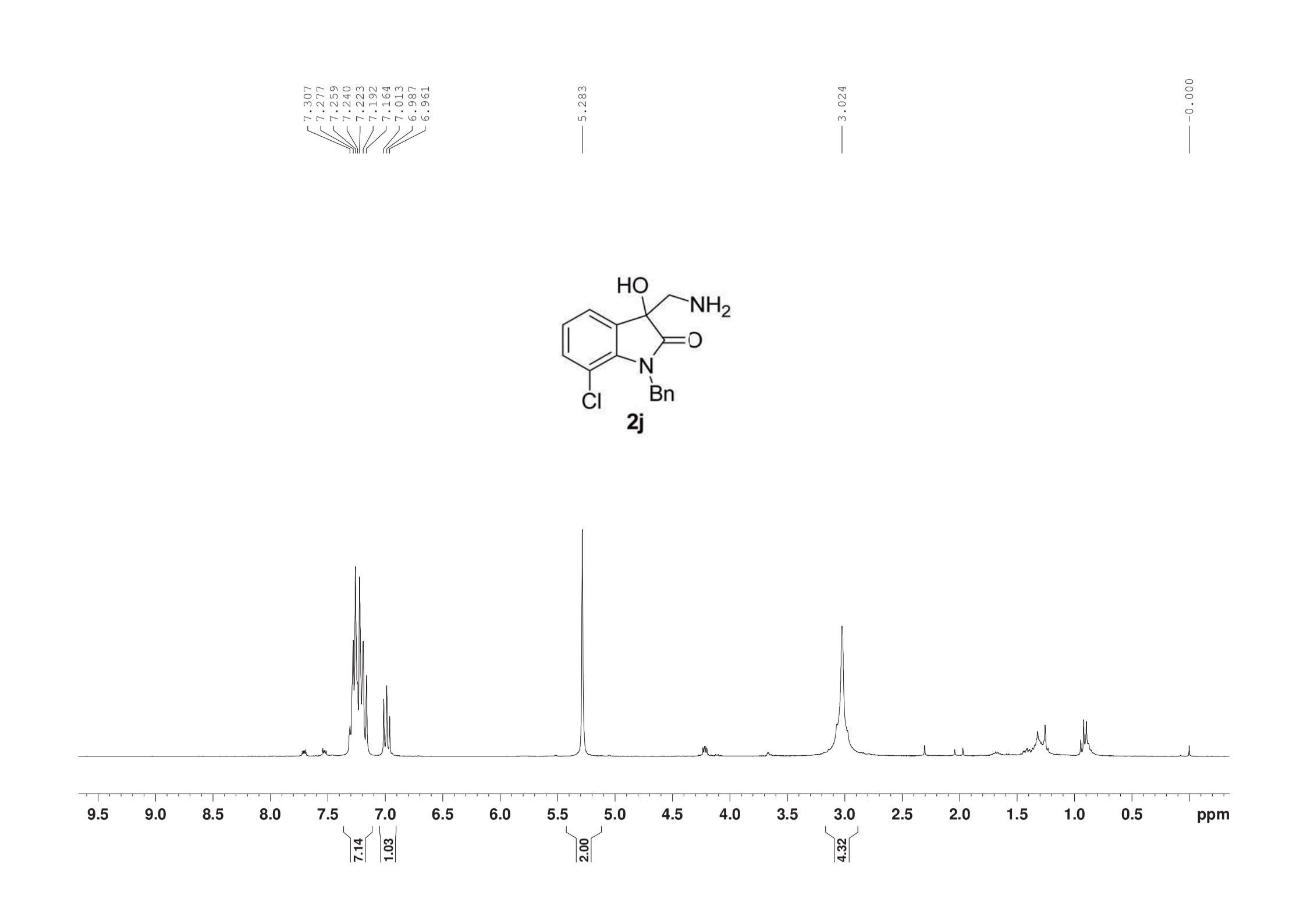
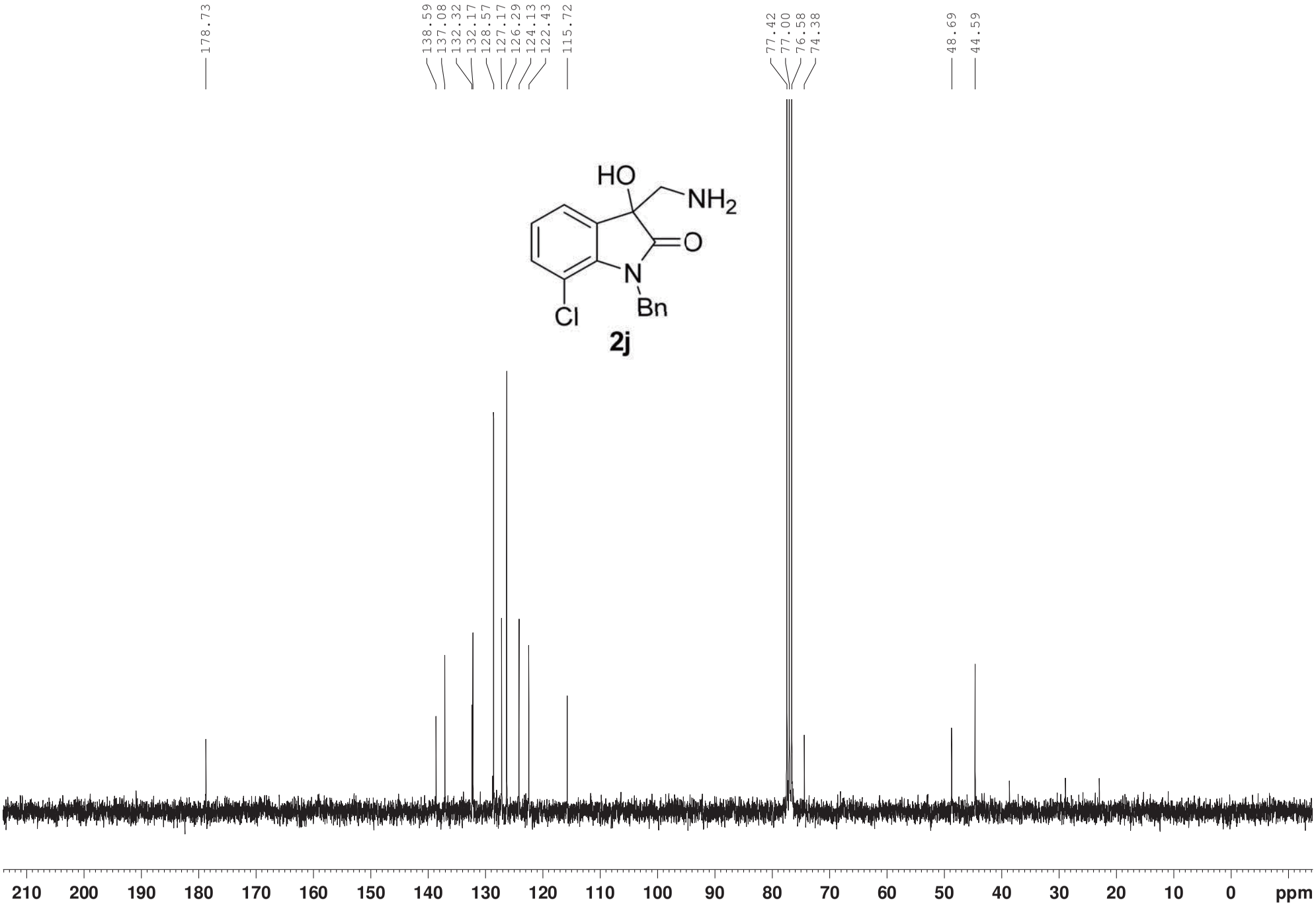
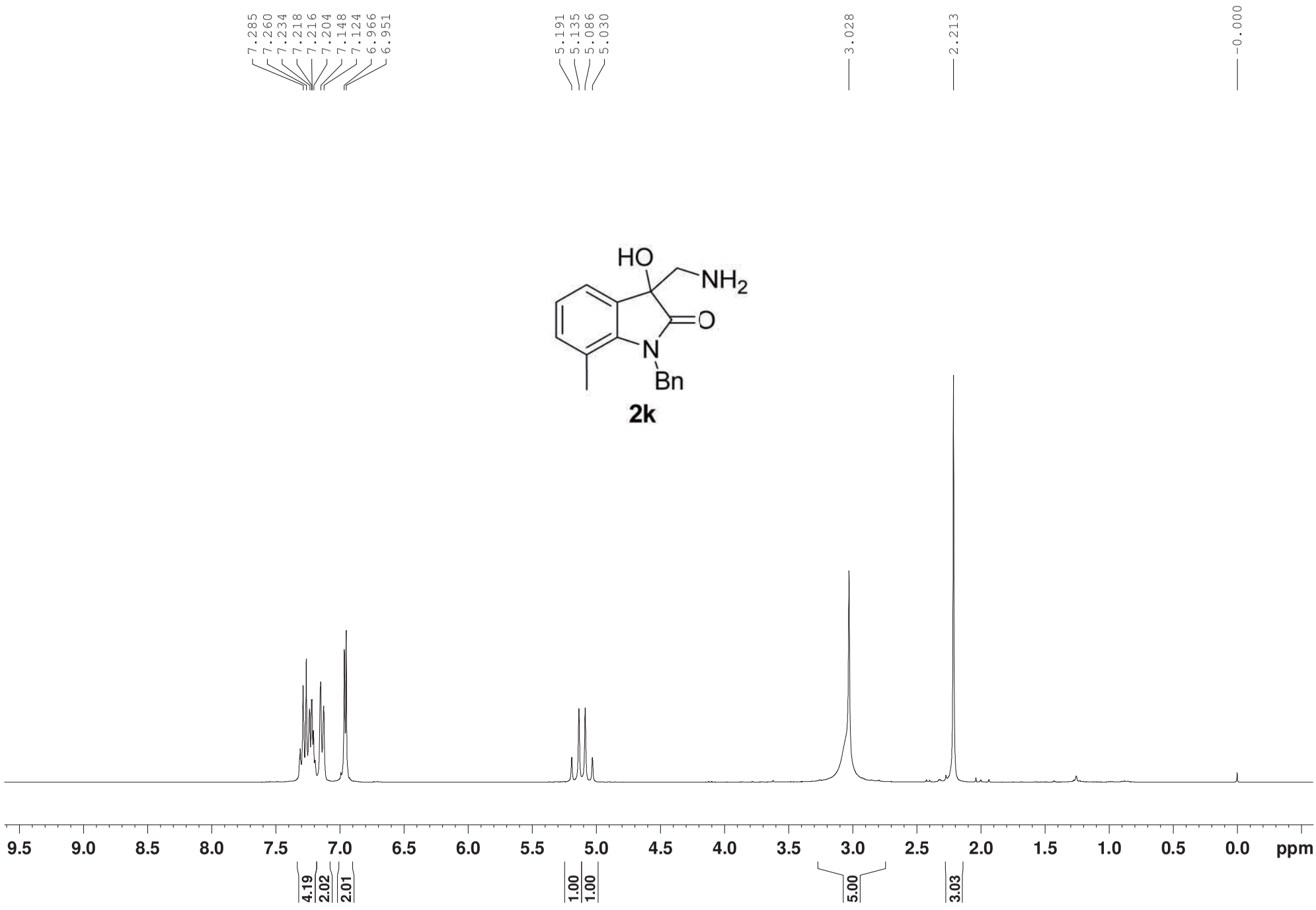
1.00
1.01
1.00
2.31
2.81


177.95
143.90
134.82
128.94
127.87
127.02
125.98
125.15
123.30
112.78
77.42
77.00
76.58
48.35
43.64
HO
NH2
O
Br
N
Bn
2i
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.307
7.277
7.259
7.240
7.223
7.192
7.164
7.013
6.987
6.961
5.283
3.024
0.000
HO
NH2
O
N
Bn
Cl
2j
9.5
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
7.14
1.03
2.00
4.32


178.73
138.59
137.08
132.32
132.17
128.57
127.17
126.29
124.13
122.43
115.72
77.42
77.00
76.58
74.38
48.69
44.59
HO
NH2
O
N
Bn
Cl
2j
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.124
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6.951
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5.135
5.086
5.030
3.028
2.213
-0.000
HO
NH2
O
N
Bn
2k
9.5
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
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ppm
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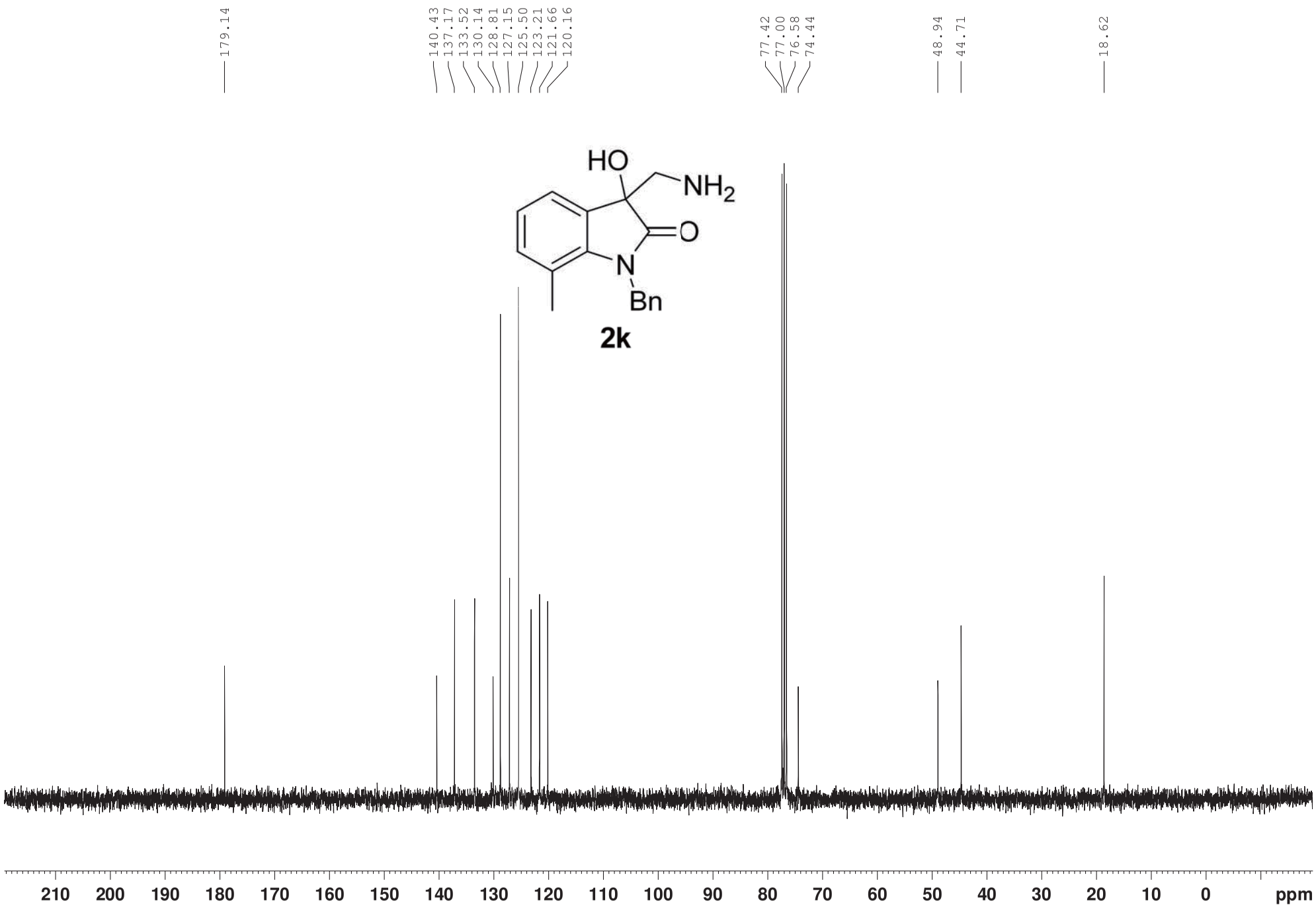
5.00
3.03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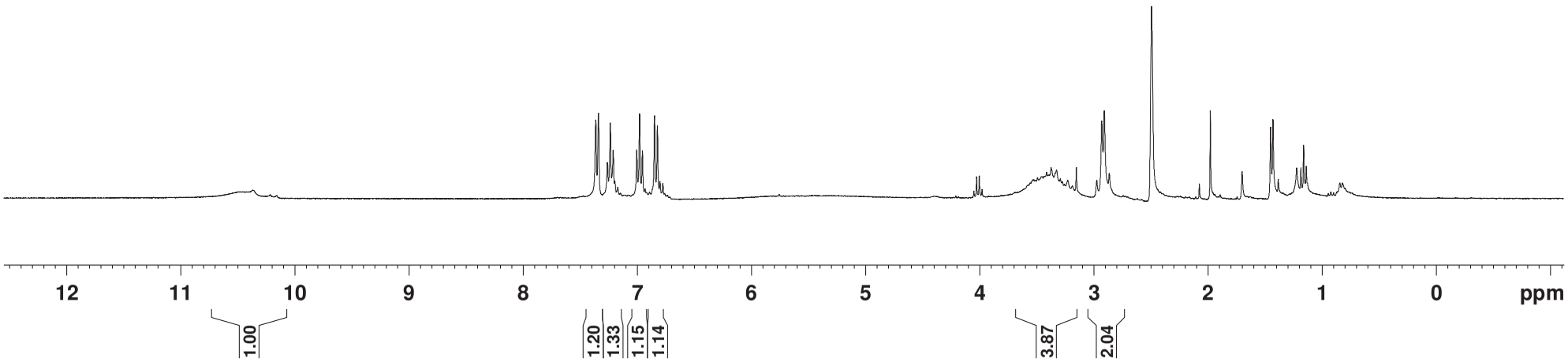
140.43
137.17
133.52
130.14
128.81
127.15
125.50
123.21
121.66
120.16
77.42
77.00
76.58
74.44
48.94
44.71
18.62
HO
NH2
O
N
Bn
2k
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.363
7.339
7.261
7.236
7.211
7.196
7.003
6.979
6.954
6.848
6.822
6.800
3.533
3.523
3.509
3.492
3.451
3.429
3.411
3.373
3.325
3.291
3.273
3.256
3.227
2.973
2.929
2.906
2.862
2.492


HO
NH2
O
N
H

2l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10
9
8
7
6
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2
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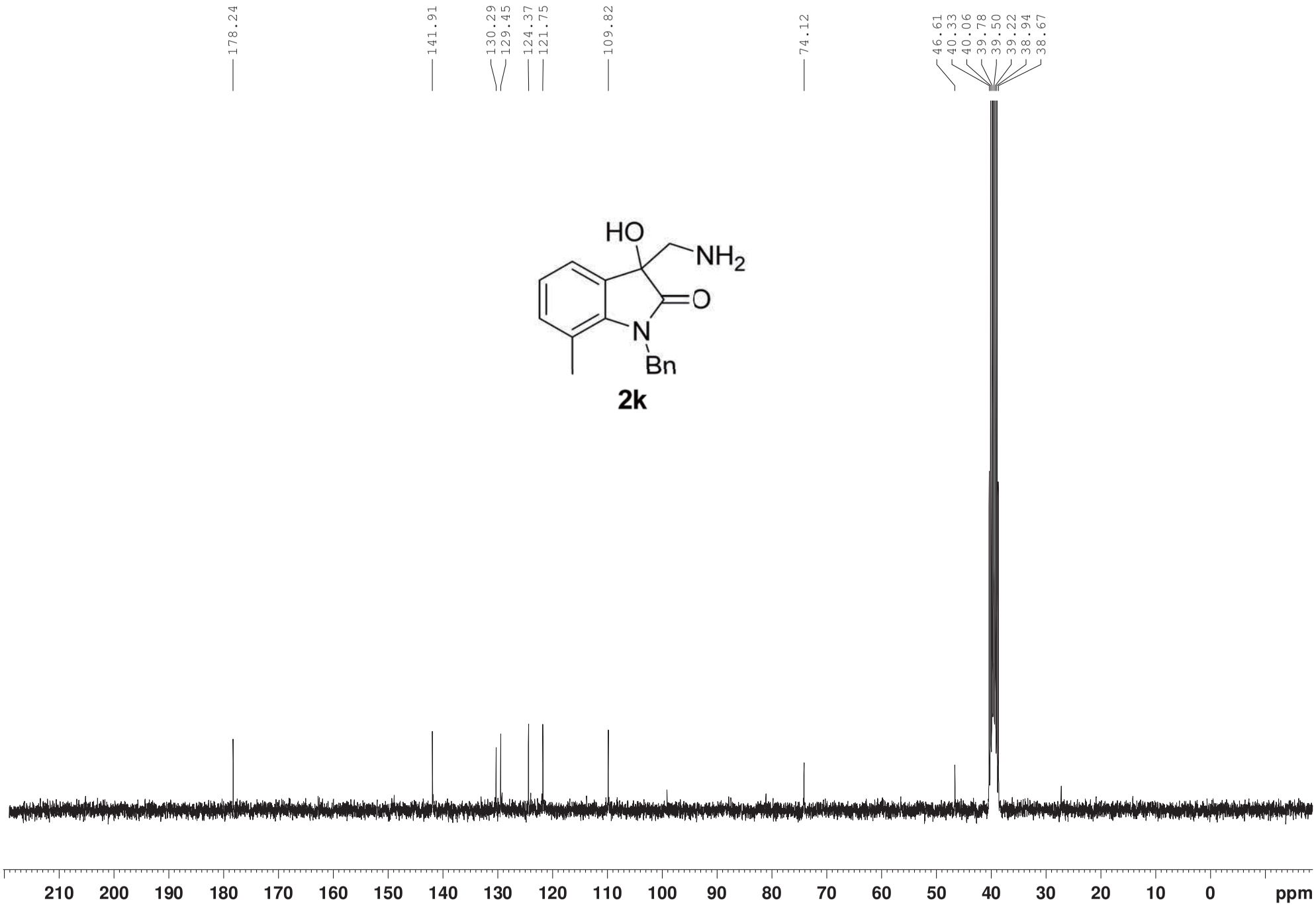
1.15
1.14
3.87
2.04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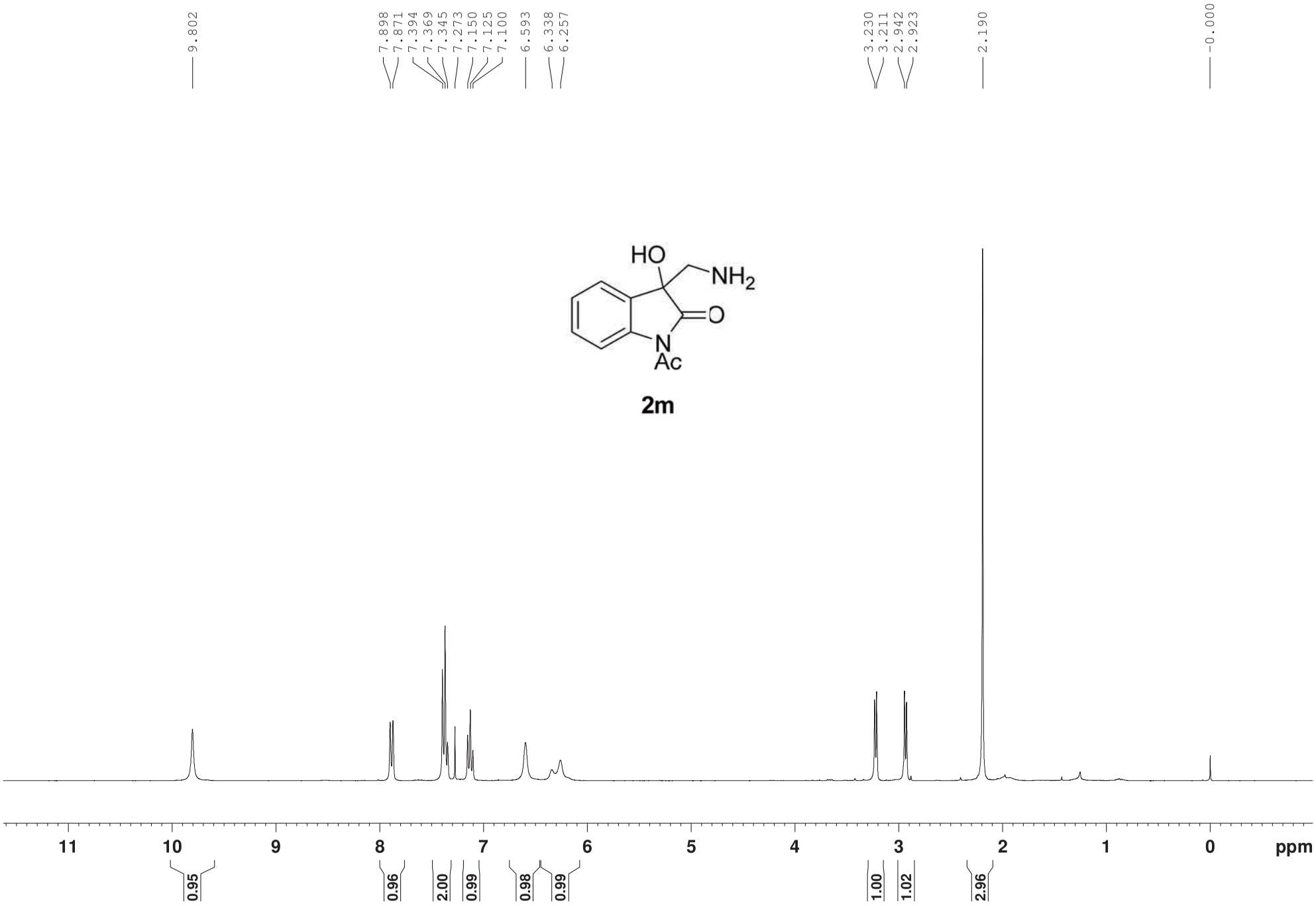
141.91
130.29
129.45
124.37
121.75
109.82
74.12
46.61
40.33
40.06
39.78
39.50
39.22
38.94
38.67
HO
NH2
O
N
Bn
2k
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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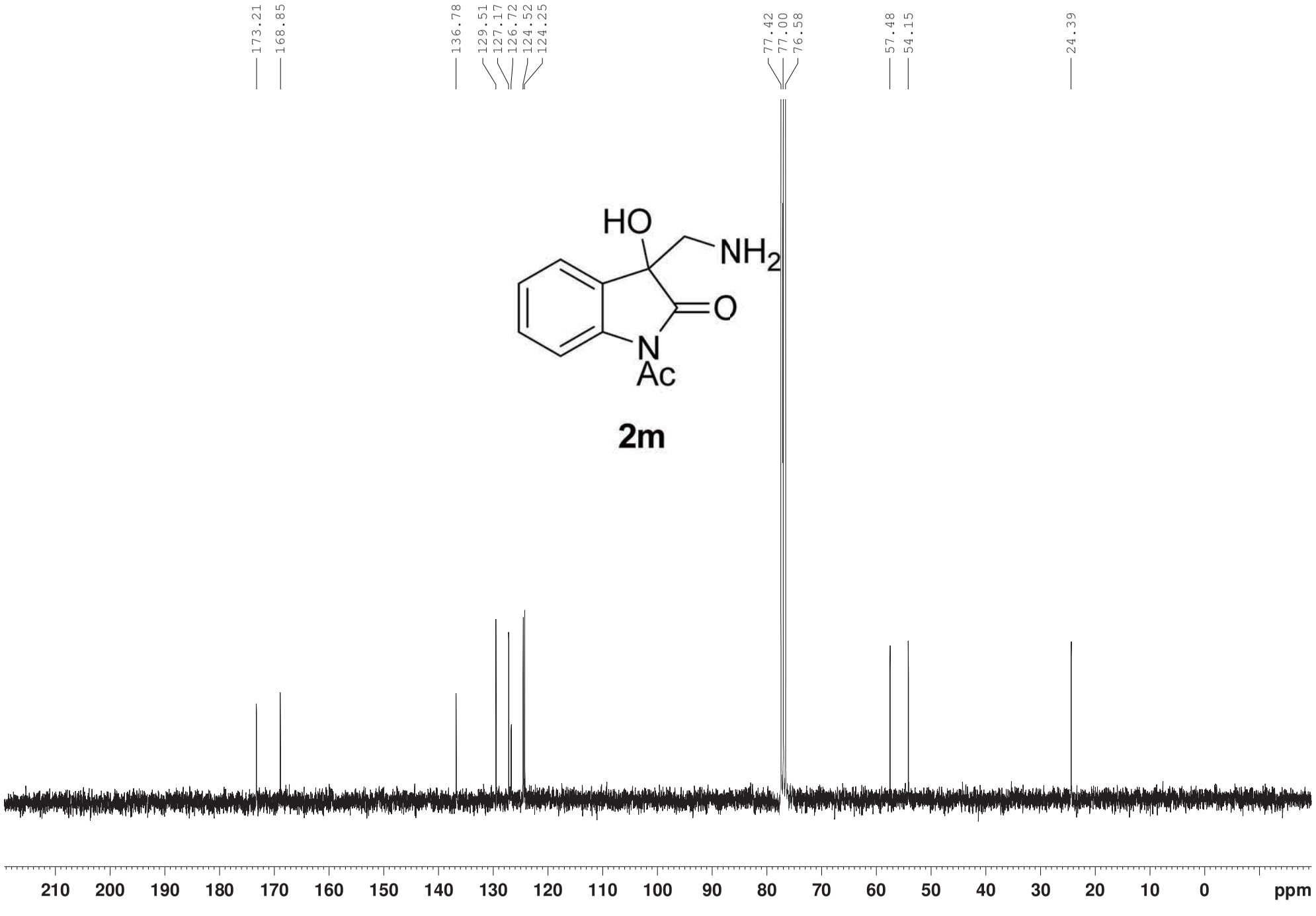
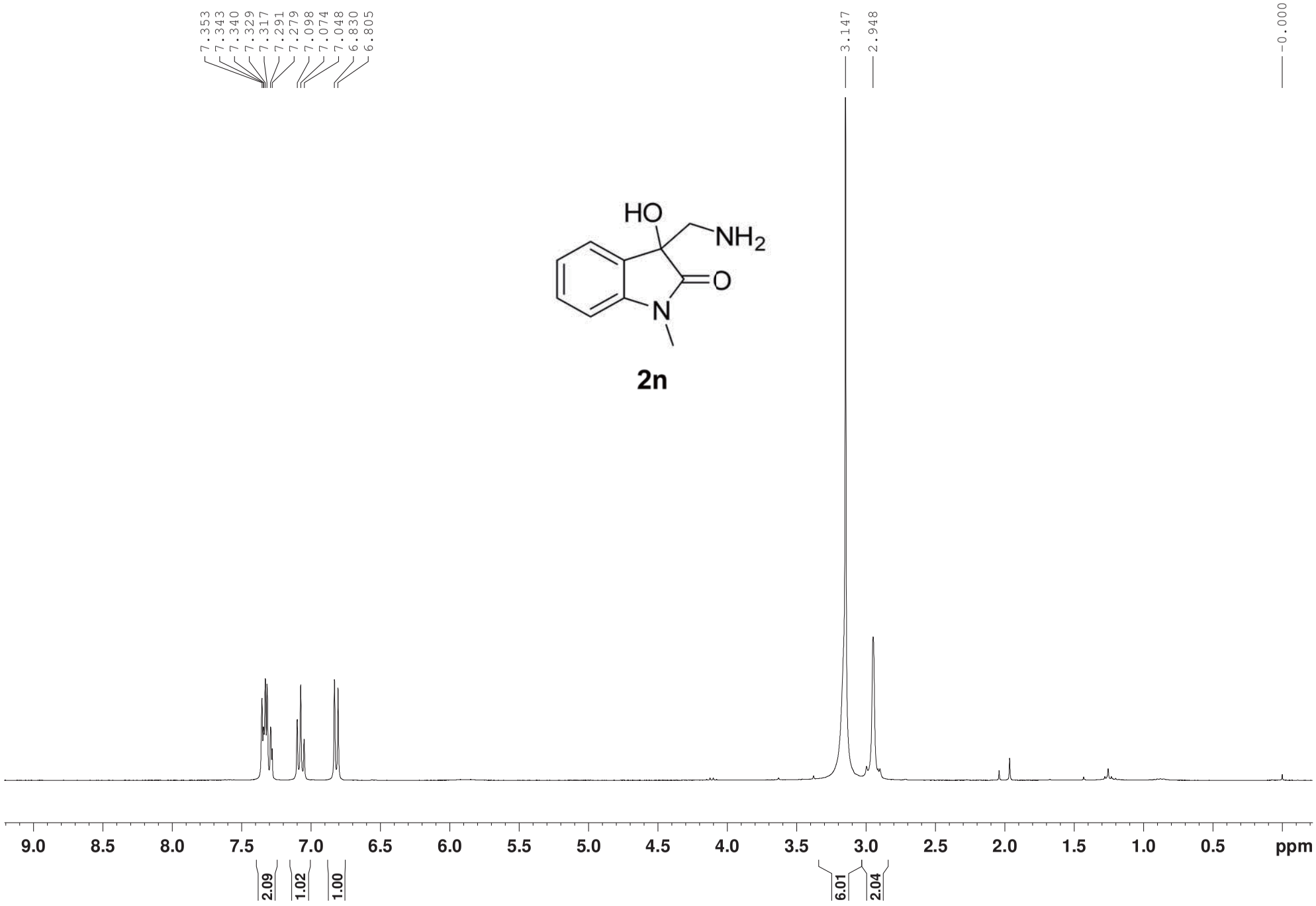
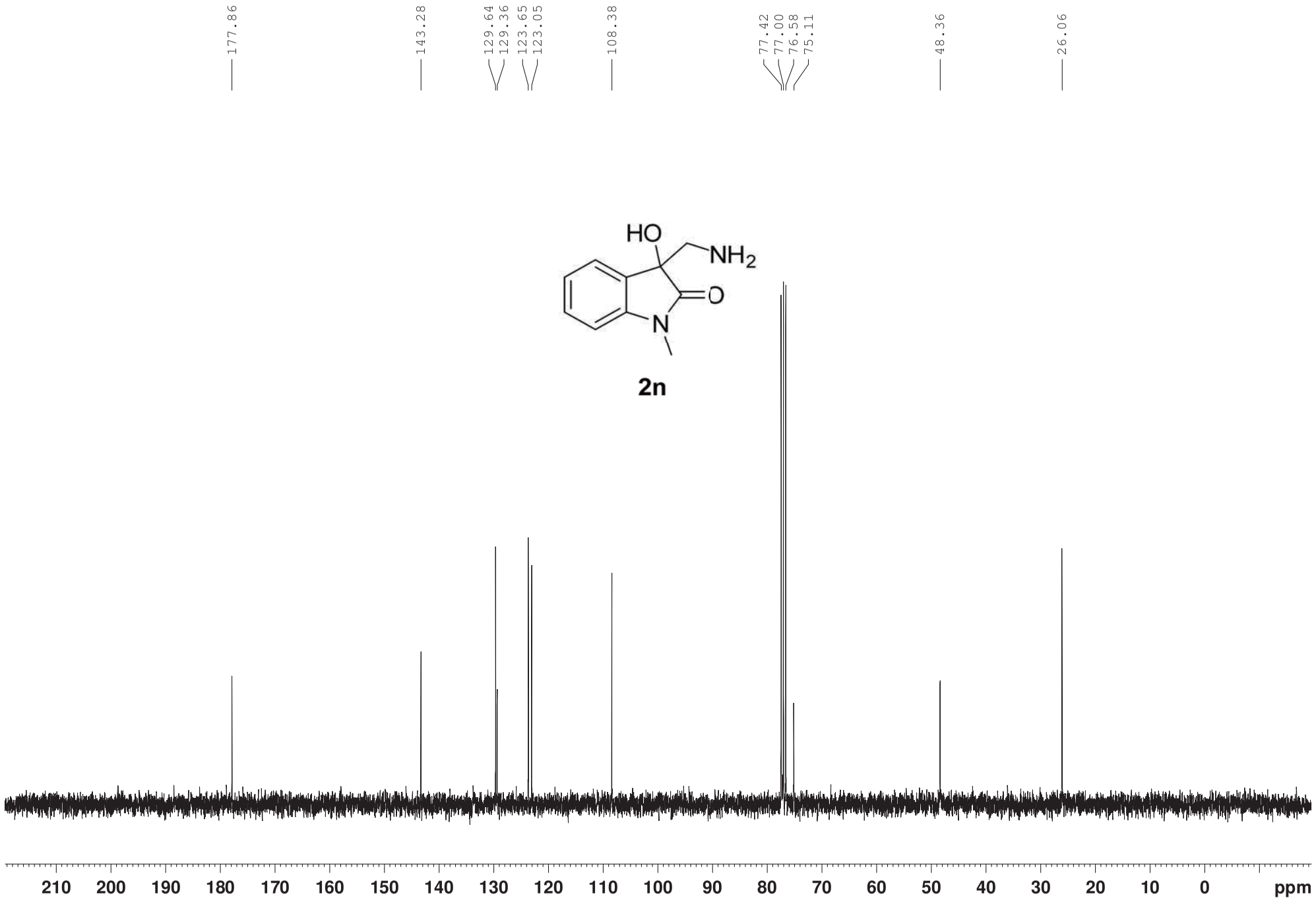
7.898
7.871
7.394
7.369
7.345
7.273
7.150
7.125
7.100
6.593
6.338
6.257
3.230
3.211
2.942
2.923
2.190
-0.000
HO
NH2
O
N
Ac
2m
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.95
0.96
2.00
0.99
0.98
0.99
1.00
1.02
2.96


173.21
168.85
136.78
129.51
127.17
126.72
124.52
124.25
77.42
77.00
76.58
57.48
54.15
24.39
HO
NH2
O
N
Ac
2m
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


7.353
7.343
7.340
7.329
7.317
7.291
7.279
7.098
7.074
7.048
6.830
6.805
3.147
2.948
-0.000
HO
NH2
O
N
2n
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
2.09
1.02
1.00
6.01
2.04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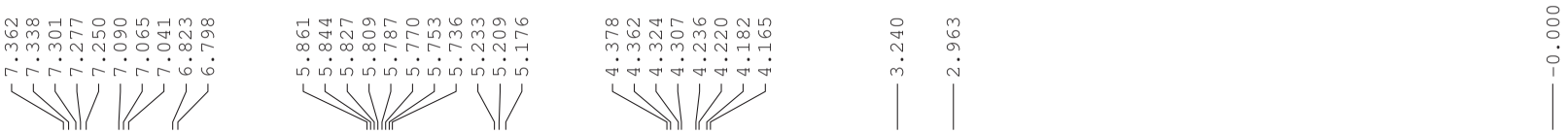
143.28
129.64
129.36
123.65
123.05
108.38
77.42
77.00
76.58
75.11
48.36
26.06
HO
NH2
O
N
2n
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.301
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7.250
7.090
7.065
7.041
6.823
6.798
5.861
5.844
5.827
5.809
5.787
5.770
5.753
5.736
5.233
5.209
5.176
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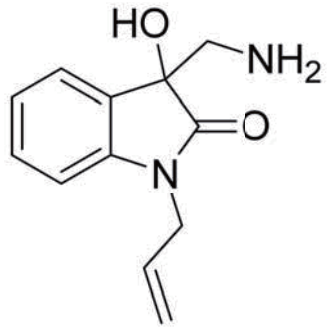
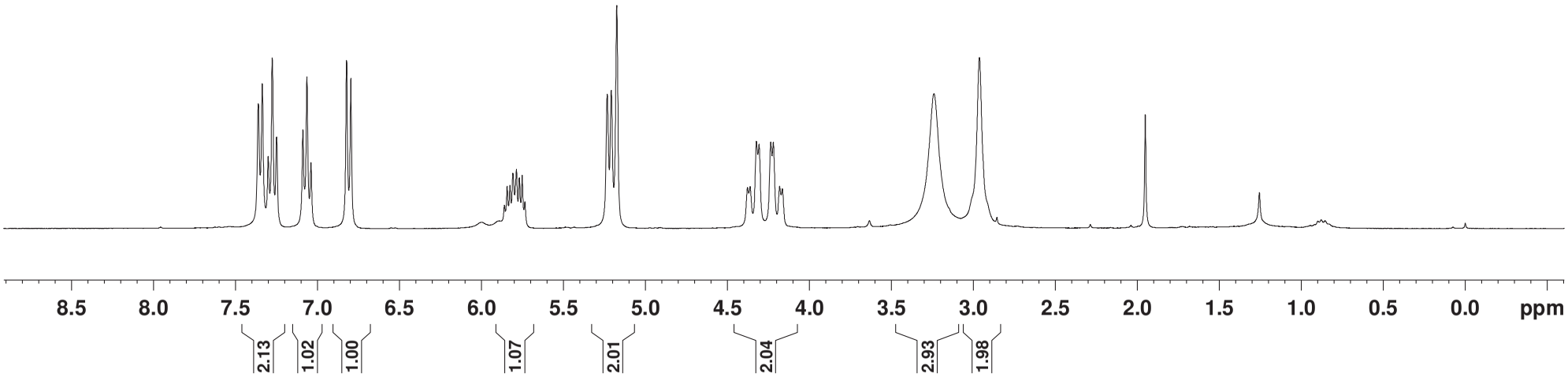
4.362
4.324
4.307
4.236
4.220
4.182
4.165
3.240
2.963
0.000


HO
NH2
O
N

2o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7.5
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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
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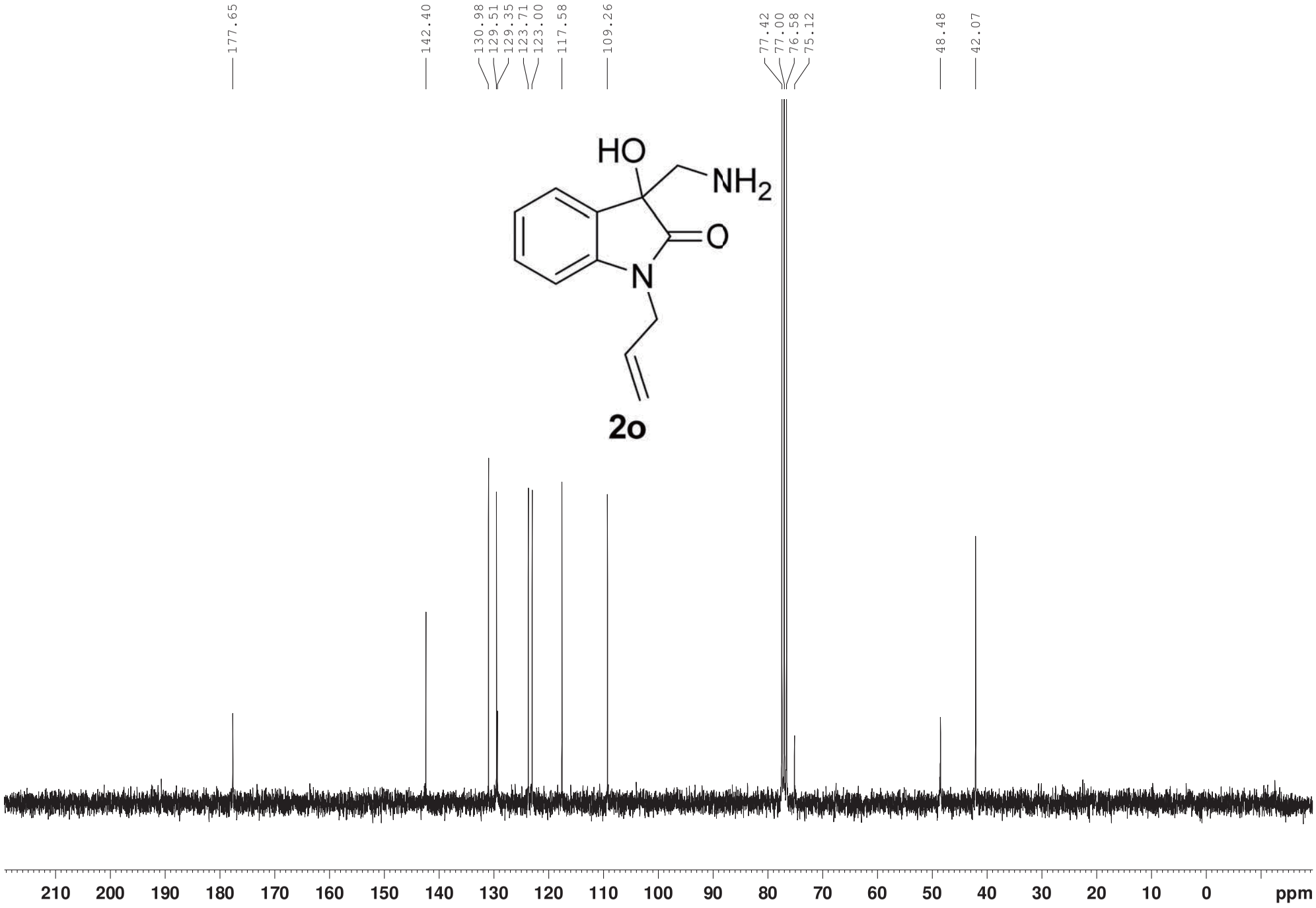
0.0
ppm
2.13
1.02
1.00
1.07
2.01
2.04
2.93
1.98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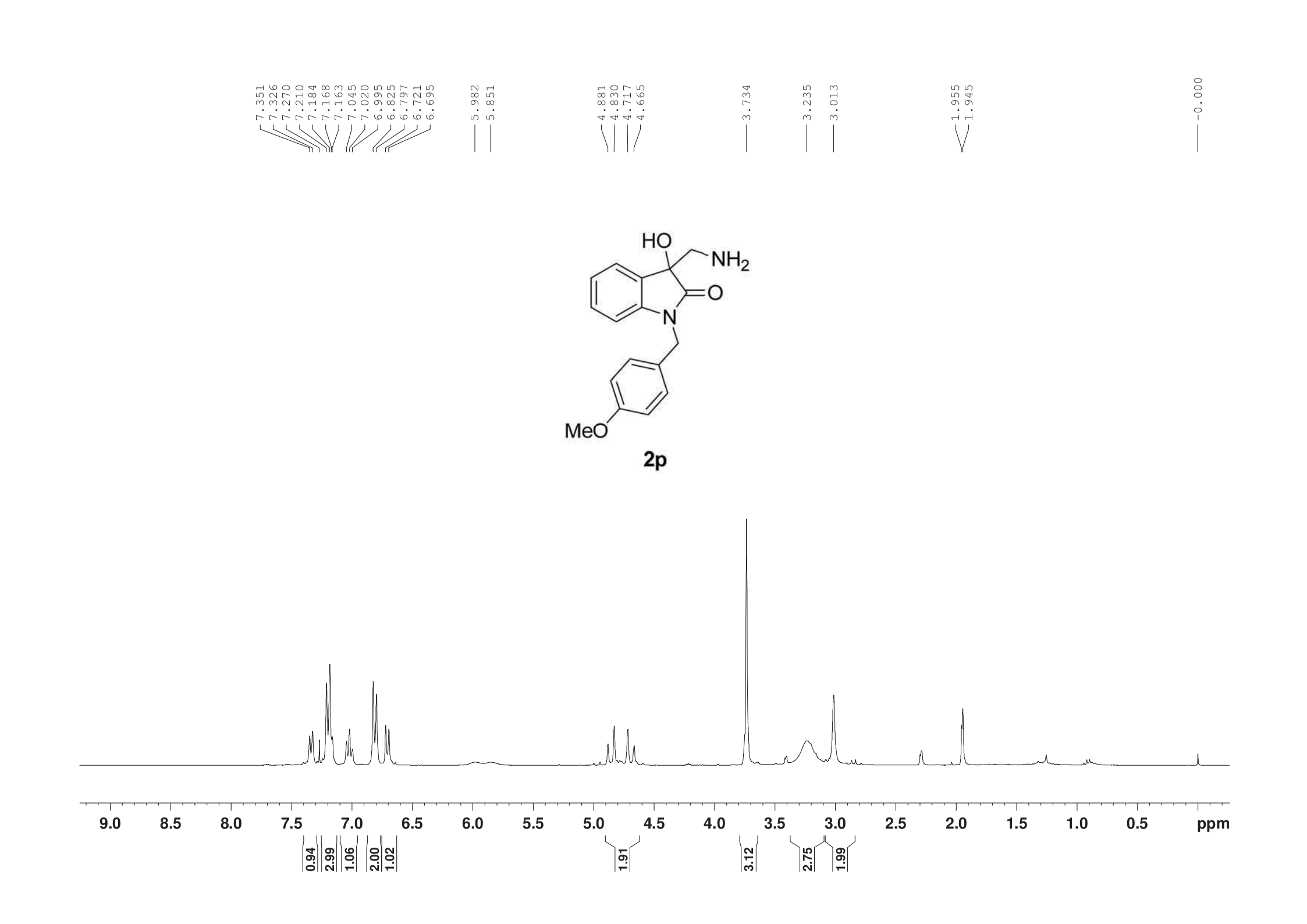
123.00
117.58
109.26
77.42
77.00
76.58
75.12
48.48
42.07
HO
NH2
O
N
2o
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.163
7.045
7.020
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6.825
6.797
6.721
6.695
5.982
5.851
4.881
4.830
4.717
4.665
3.734
3.235
3.013
1.955
1.945
-0.000
HO
NH2
O
N
MeO
2p
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
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ppm
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1.06
2.00
1.02
1.91
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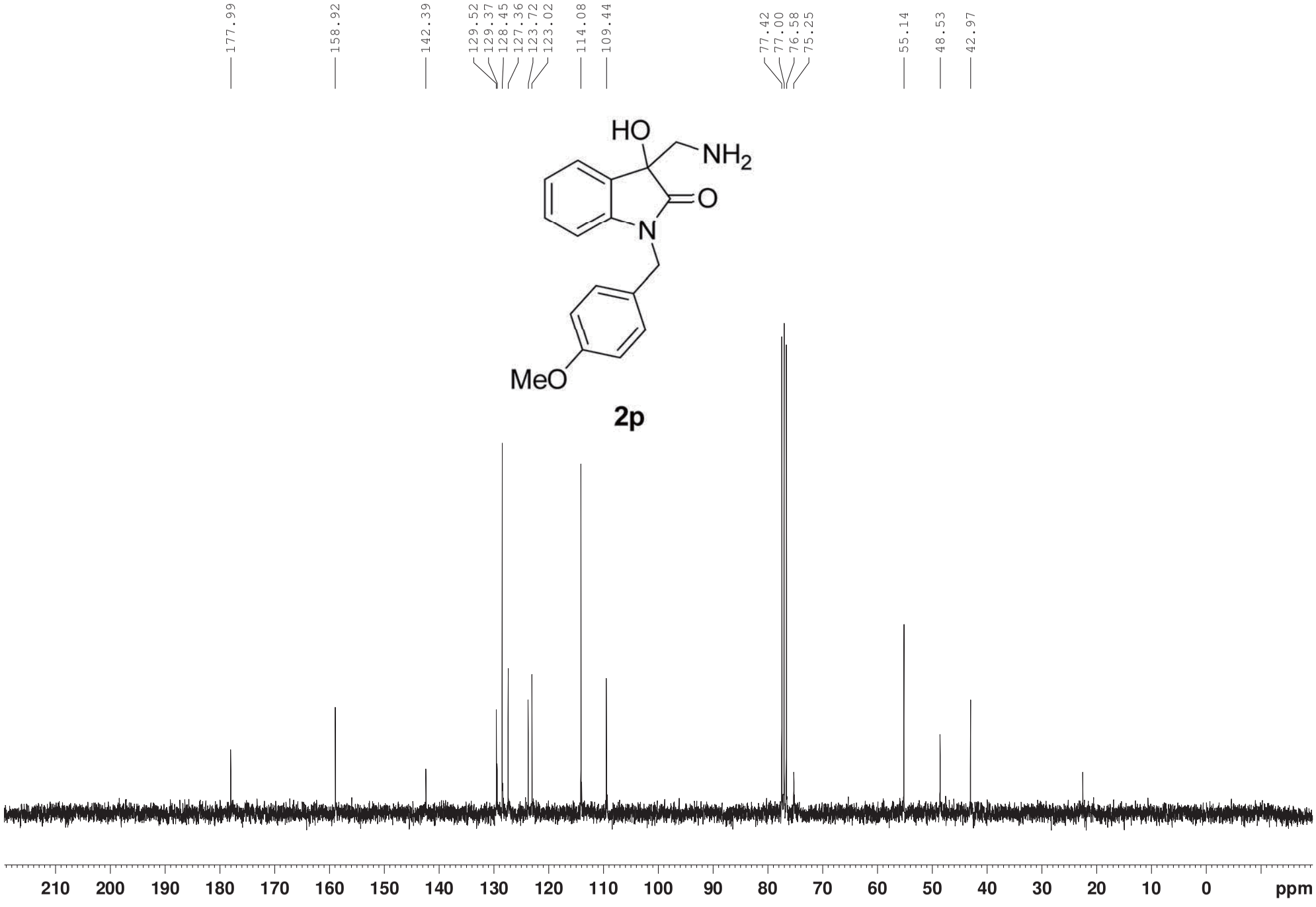
2.75
1.99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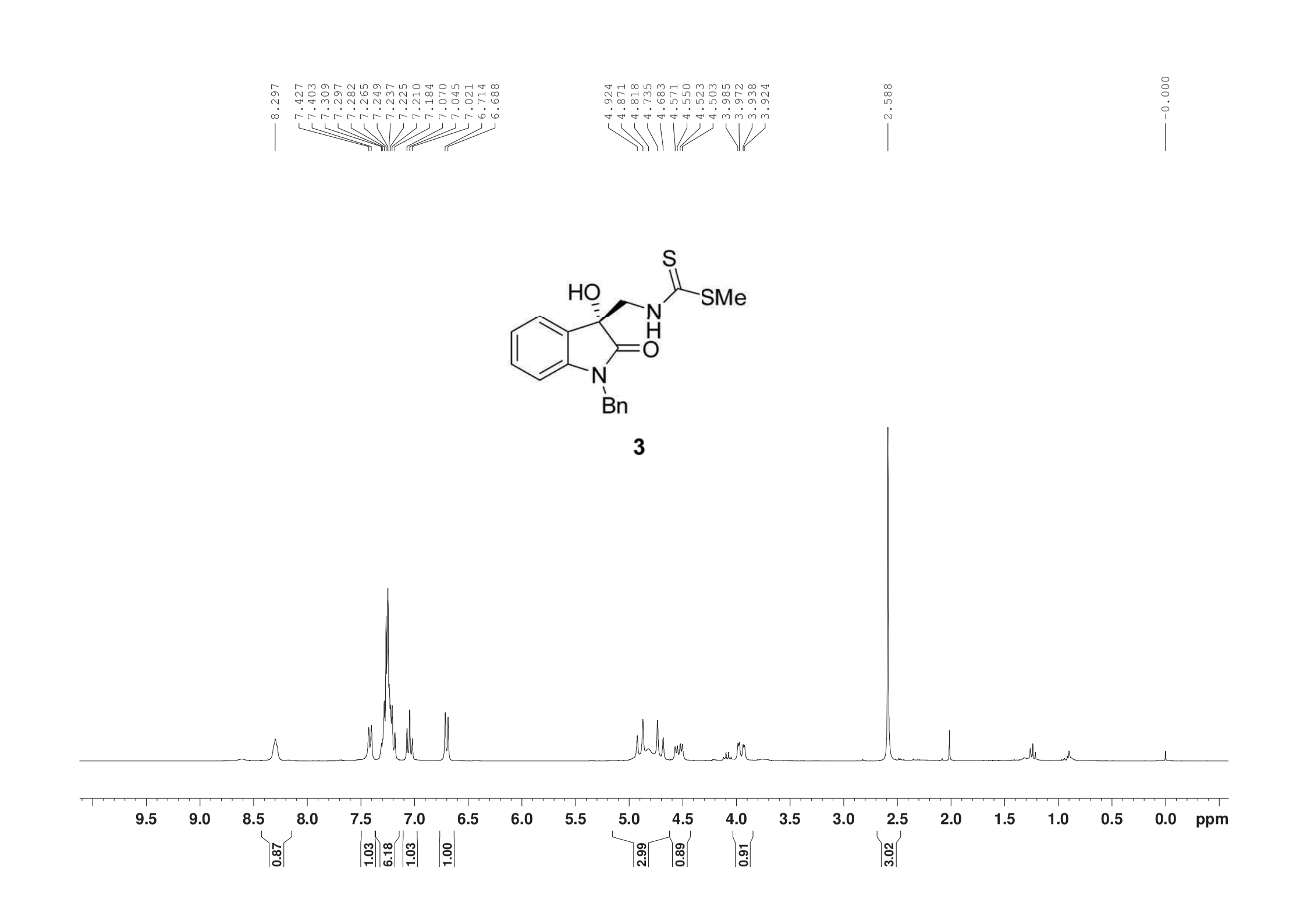
128.45
127.36
123.72
123.02
114.08
109.44
77.42
77.00
76.58
75.25
55.14
48.53
42.97
HO
NH2
O
N
MeO
2p
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.282
7.265
7.249
7.237
7.225
7.210
7.184
7.070
7.045
7.021
6.714
6.688
4.924
4.871
4.818
4.735
4.683
4.571
4.550
4.523
4.503
3.985
3.972
3.938
3.924
2.588
-0.000
HO
S
SMe
N
H
O
N
Bn
3
9.5
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
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ppm
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1.00
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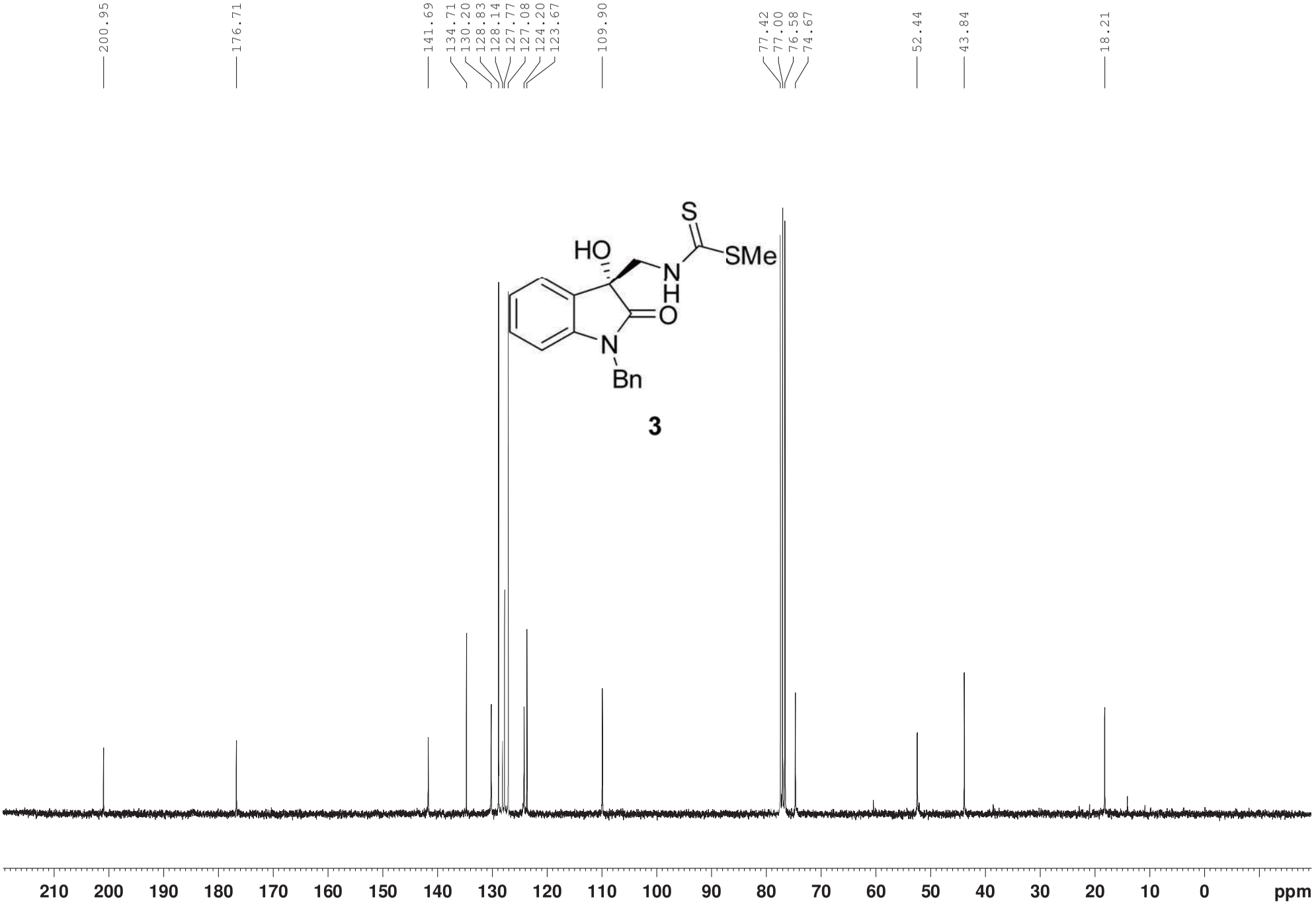
3.02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127.77
127.08
124.20
123.67
109.90
77.42
77.00
76.58
74.67
52.44
43.84
18.21
HO
S
SMe
N
H
O
N
Bn
3
210
200
190
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140
130
120
110
100
90
80
70
60
50
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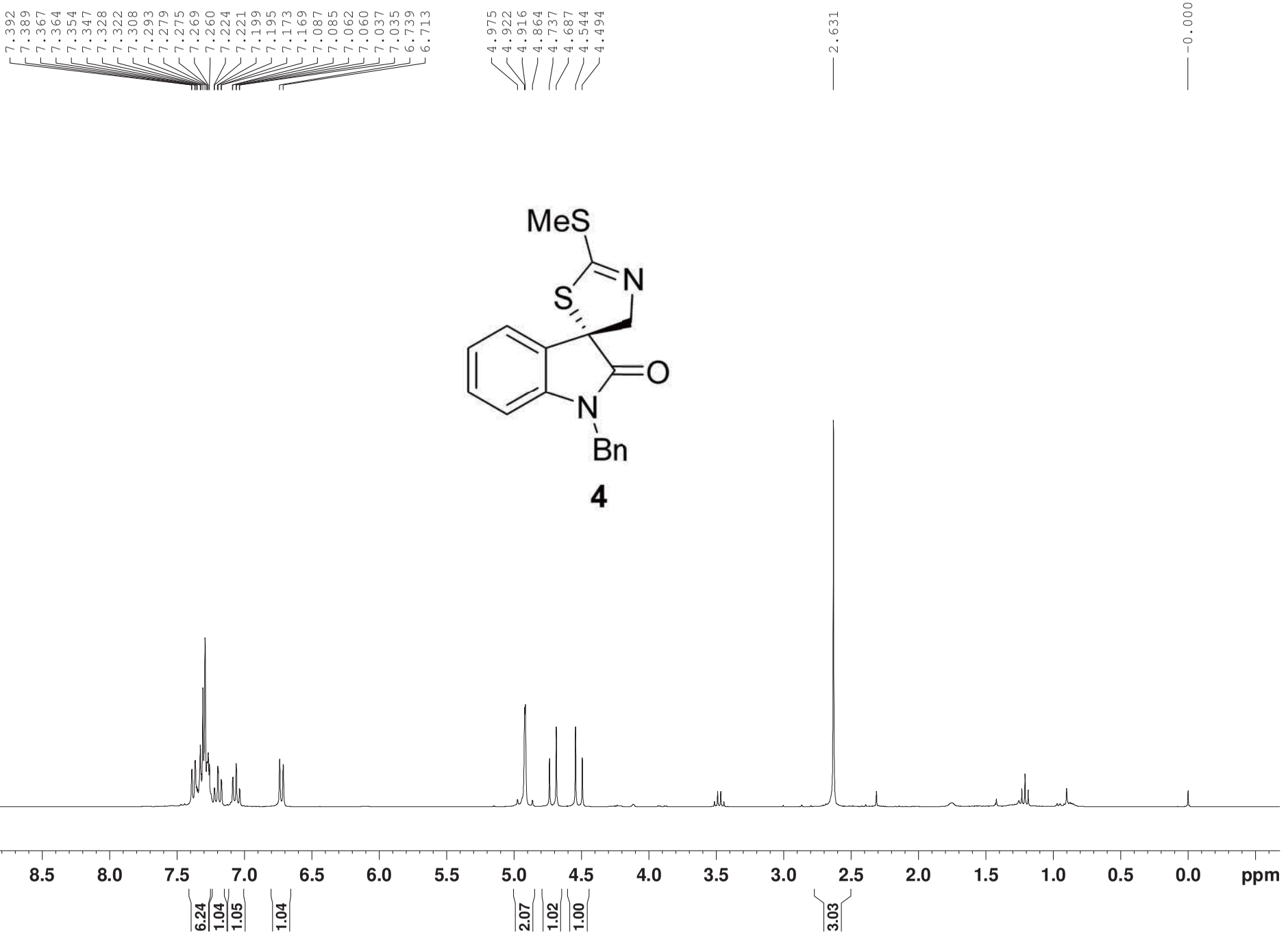
20
10
0
ppm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7.279
7.275
7.269
7.260
7.224
7.221
7.199
7.195
7.173
7.169
7.087
7.085
7.062
7.060
7.037
7.035
6.739
6.713
4.975
4.922
4.916
4.864
4.737
4.687
4.544
4.494
2.631
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S
O
N
Bn
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8.0
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7.0
6.5
6.0
5.5
5.0
4.5
4.0
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3.0
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2.0
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1.04
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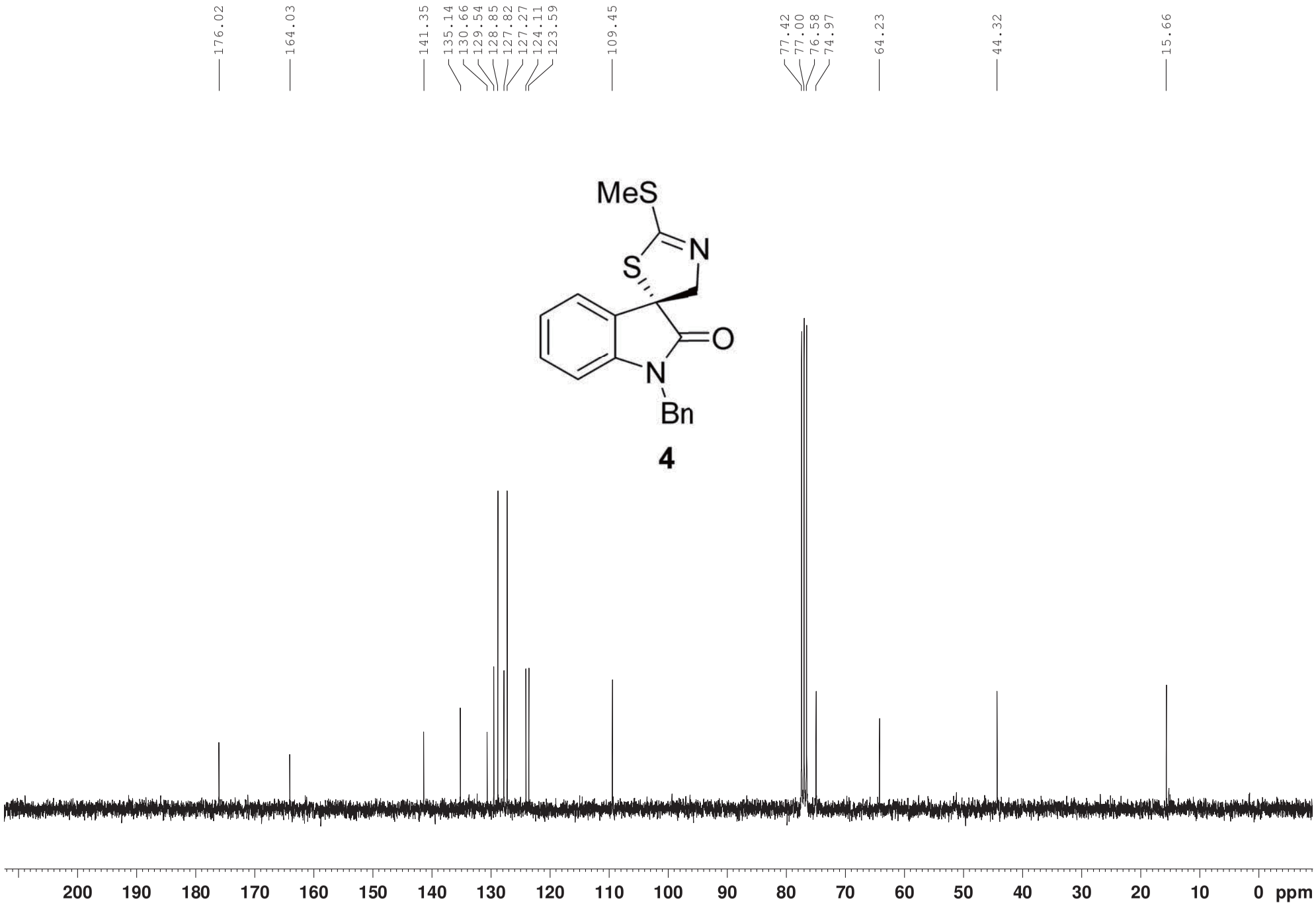
3.03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129.54
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127.27
124.11
123.59
109.45
77.42
77.00
76.58
74.97
64.23
44.32
15.66
MeS
S
N
O
N
Bn
4
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm