Synthesis of substituted anilines via a gold-catalyzed three-component reaction

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Contents

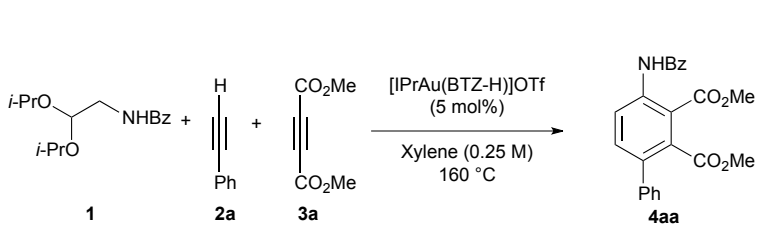
1. General Remarks.

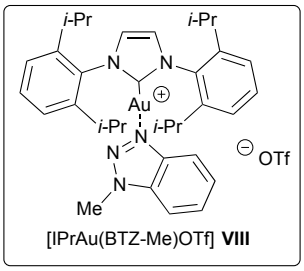
Materials were obtained from commercial suppliers and used without further purification unless otherwise mentioned. All reactions were carried out in oven-dried glassware under a slight positive pressure of argon unless otherwise noted. Anhydrous THF and CH_2Cl_2 were purchased from Kanto Chemical Co., Inc. Anhydrous xylene was purchased from FUJIFILM Wako Pure Chemical Corporation. Anhydrous MeOH, *i*-PrOH, and Et_3N were dried and distilled according to the standard protocols. Column chromatography was performed on Silica Gel 60N (Kanto Chemical Co., Inc., spherical neutral, 40–50 μm) using the indicated eluent. Preparative TLC and analytical TLC were performed on Merck 60 F_{254} glass plates precoated with a 0.25 mm thickness of silica gel. Microwave irradiation experiments were performed on a CEM Discover Microwave Reactor. IR spectra were measured on a SHIMADZU FT/IR-4100 spectrometer. NMR spectra were recorded on a JNM-AL400 spectrometer, and a JEOL ECA600 spectrometer with tetramethylsilane (0 ppm) or chloroform (7.26 ppm) or DMSO (2.49 ppm) as an internal standard. Chemical shifts were expressed in δ (ppm) values, and coupling constants were expressed in hertz (Hz). The following abbreviations are used for spin multiplicity: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, and br = broad. Mass spectra were recorded on a BRUKER micrOTOF II spectrometer.

2. Aniline Synthesis via a Gold-Catalyzed Three-Component Reaction

General Procedure for Aniline Synthesis

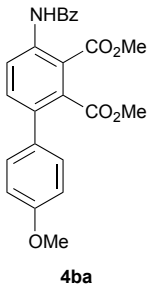
Dimethyl 4-benzamido-[1,1'-biphenyl]-2,3-dicarboxylate (4aa)





To a 10-mL screw cap test tube equipped with a Teflon-coated magnetic stirring bar containing [IPrAu(BTZ-H)]OTf (**VIII**) (4.3 mg, 0.10 mmol) in xylene (0.40 mL, 0.25 M) at room temperature were added phenylacetylene (**2a**) (54.9 µL, 0.500 mmol), dimethyl acetylenedicarboxylate (**3a**) (61.5 µL, 0.500 mmol), and acetal benzamide **1** (26.5 mg, 0.100 mmol) and the test tube was sealed with a Teflon liner screw cap. The resulting mixture was stirred at 160 °C. After stirring for 9 hours, the reaction mixture was cooled to room temperature and filtered through a pad of Celite. The filtrate and the washings was concentrated under reduced pressure and the residue was purified by silica gel column chromatography (hexane/AcOEt = 7:3, pentane/Et_2O/acetone = 9:1:1) to afford aniline **4aa** (30.6 mg, 0.0785 mmol, 79%) of as a pale yellow solid; R_f = 0.32 (Silica gel, hexanes/EtOAc = 7:3); IR (neat) 1731, 1683, 1592, 1521, 1232, 765, 702 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.28 (br s, 1H), 8.92 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 8.8 Hz, 2H), 7.65–7.50 (m, 4H), 7.45–7.30 (m, 5H), 3.91 (s, 3H), 3.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 168.1, 165.6, 139.4, 139.2, 135.4, 135.2, 134.8, 134.4, 132.2, 128.9, 128.4, 128.3, 127.7, 127.3, 122.2, 115.1, 53.1, 52.2; HRMS Calcd. for $C_{23}H_{19}NNaO_3$ [M^++23(Na)] 412.1155, found 412.1144.

Dimethyl 4-benzamido-4'-methoxy-[1,1'-biphenyl]-2,3-dicarboxylate (4ba)

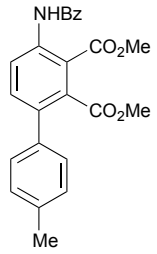


4ba

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 µmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-ethynylanisole (**2b**)[1)] (146 µL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 µL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 7:3) afforded aniline **4ba** (83.6 mg, 0.199 mmol, 88%) as a pale yellow solid; R_f = 0.21 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 1732, 1683, 1510, 1492, 1230 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.27 (br s, 1H), 8.89 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 7.6 Hz, 2H), 7.64–7.51 (m, 4H),

7.26 (d, J = 8.0 Hz, 2H), 6.93 (d, J = 8.0 Hz, 2H), 3.91 (s, 3H), 3.85 (s, 3H), 3.65 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 169.1, 168.1, 165.6, 159.2, 139.1, 135.4, 135.1, 134.7, 134.5, 132.2, 131.6, 129.6, 128.9, 127.3, 122.2, 115.1, 113.7, 55.3, 53.0, 52.2; HRMS Calcd. for $C_{24}H_{21}NNaO_6$ [M^++23(Na)] 442.1261, found 442.1257.

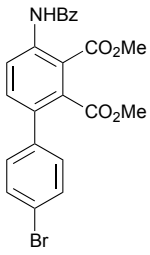
Dimethyl 4-benzamido-4'-methyl-[1,1'-biphenyl]-2,3-dicarboxylate (4ca)



4ca

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-ethynyltoluene (**2c**)[1)] (143 μL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 7:3) afforded aniline **4ca** (70.9 mg, 0.175 mmol, 78%) as a pale yellow solid; R_f = 0.43 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 1731, 1683, 1513, 1231, 703 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.25 (br, s, 1H), 8.89 (d, J = 8.8 Hz, 1H), 8.02 (d, J = 6.8 Hz, 2H), 7.61–7.50 (m, 4H), 7.21 (s, 4H), 3.91 (s, 3H), 3.62 (s, 3H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 168.1, 165.6, 139.2, 137.4, 136.3, 135.5, 135.3, 134.7, 134.5, 132.2, 129.0, 128.9, 128.3, 127.3, 122.2, 115.2, 53.0, 52.2, 21.1; HRMS Calcd. for $C_{24}H_{21}NNaO_5$ [M^++23(Na)] 426.1312, found 426.1313.

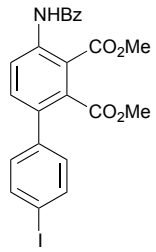
Dimethyl 4-benzamido-4'-bromo-[1,1'-biphenyl]-2,3-dicarboxylate (4da)



4da

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-bromophenylacetylene (**2d**)[1)] (205 μL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 7:3) afforded aniline **4da** (75.5 mg, 0.161 mmol, 71%) as a pale yellow solid; R_f = 0.57 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 1732, 1698, 1683, 1520, 1488, 1231, 825, 704 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 11.28 (br s, 1H), 8.92 (d, J = 8.8 Hz, 1H), 8.02 (d, J = 8.8 Hz, 2H), 7.62–7.50 (m, 6H), 7.20 (d, J = 8.4 Hz, 2H), 3.91 (s, 3H), 3.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.6, 167.9, 165.5, 139.7, 138.1, 134.9, 134.7, 134.3, 134.0, 132.2, 131.4, 130.1, 128.9, 127.3, 122.3, 122.1, 115.2, 53.1, 52.3; HRMS Calcd. for $C_{23}H_{18}BrNNaO_5$ [M^++23(Na)] 490.0261, found 490.0247.

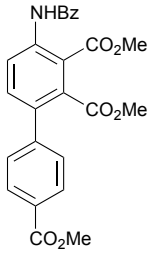
Dimethyl 4-benzamido-4'-iodo-[1,1'-biphenyl]-2,3-dicarboxylate (4ea)



4ea

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-iodophenylacetylene (**2e**)[1)] (258 mg, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 2:8, hexane/Et_2O/acetone = 7:1:1) afforded aniline **4ea** (79.5 mg, 0.154 mmol, 69%) as a pale yellow solid; R_f = 0.39 (Silica gel, hexane/AcOEt = 3:7); IR (neat) 1730, 1700, 1684, 1234, 1006, 770, 705 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.30 (br s, 1H), 8.92 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 7.2 Hz, 2H), 7.74 (d, *J* = 8.4 Hz, 2H), 7.64–7.48 (m, 4H), 7.07 (d, *J* = 8.4 Hz, 2H), 3.92 (s, 3H), 3.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 167.9, 165.6, 139.7, 138.7, 137.4, 135.0, 134.6, 134.3, 134.1, 132.3, 130.3, 128.9, 127.3, 122.3, 115.2, 93.8, 53.1, 52.4; HRMS Calcd. for $C_{23}H_{18}INO_5$ [M^++H] 516.0302, found 516.0284.

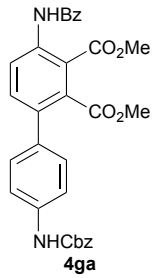
Trimethyl 4-benzamido-[1,1'-biphenyl]-2,3,4'-tricarboxylate (4fa)



4fa

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), methyl 4-ethynylbenzoate (**2f**)[1)] (177 mg, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7, hexane/Et_2O/acetone = 7:1:1) afforded aniline **4fa** (60.6 mg, 0.135 mmol, 40%) as a pale yellow solid; R_f = 0.38 (Silica gel, hexane/AcOEt = 3:7); IR (neat) 1718, 1698, 1677, 1523, 1279, 1232, 773 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.27 (br s, 1H), 8.95 (d, *J* = 8.8 Hz, 1H), 8.08 (d, *J* = 7.6 Hz, 2H), 8.02 (d, *J* = 7.6 Hz, 2H), 7.63–7.50 (m, 4H), 7.41 (d, *J* = 7.6 Hz, 2H), 3.95 (s, 3H), 3.92 (s, 3H), 3.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.6, 167.9, 166.8, 165.6, 143.9, 134.9, 134.8, 134.31, 134.30, 132.3, 129.6, 129.5, 128.9, 128.5, 127.3, 122.3, 115.3, 53.1, 52.3, 52.2; HRMS Calcd. for $C_{25}H_{21}NNaO_7$ [M^++23(Na)] 470.1210, found 470.1204.

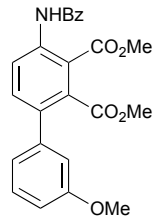
Dimethyl 4-benzamido-4'-(((benzyloxy)carbonyl)amino)-[1,1'-biphenyl]-2,3-dicarboxylate (4ga)



4ga

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (6.5 mg, 7.5 μmol), acetal benzamide **1** (40.0 mg, 0.151 mmol), benzyl 4-ethynylphenylcarbamate (**2g**)[1)] (189 mg, 0.754 mmol), and dimethyl acetylenedicarboxylate (**3a**) (93 μL, 0.75 mmol) in xylene (0.60 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7, hexane/Et_2O/acetone = 4:1:1) afforded aniline **4ga** (46.9 mg, 0.0870 mmol, 39%) as a pale yellow solid; R_f = 0.17 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 3324, 1732, 1717, 1703, 1519, 1580, 771 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.26 (br s, 1H), 8.89 (d, *J* = 8.4 Hz, 1H), 8.01 (dd, *J* = 8.0, 1.2 Hz, 2H), 7.63–7.50 (m, 4H), 7.48–7.32 (m, 7H), 7.30–7.24 (m, 2H), 6.75 (br s, 2H), 5.22 (s, 2H), 3.90 (s, 3H), 3.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 168.0, 165.6, 153.2, 139.3, 137.5, 135.9, 135.3, 134.8, 134.7, 134.4, 134.3, 132.2, 129.2, 128.9, 128.6, 128.4, 128.3, 127.3, 122.2, 118.3, 115.1, 67.1, 60.4, 53.1, 52.3, 21.0, 14.2; HRMS Calcd. for $C_{31}H_{26}N_2NaO_7$ [M^++23(Na)] 561.1632, found 561.1603.

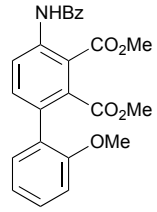
Dimethyl 4-benzamido-3'-methoxy-[1,1'-biphenyl]-2,3-dicarboxylate (4ia)



4ia

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 3-ethynylanisole (**2i**)[1)] (144 μL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7, hexane/Et_2O/acetone = 4:1:1) afforded aniline **4ia** (77.6 mg, 0.185 mmol, 82%) as a pale yellow solid; R_f = 0.30 (Silica gel, hexane/AcOEt = 3:7); IR (neat) 1732, 1698, 1683, 1520, 1438, 1234, 773, 708 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.27 (br s, 1H), 8.91 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 7.6 Hz, 2H), 7.64–7.50 (m, 4H), 7.30 (dd, *J* = 7.6, 7.6 Hz, 2H), 6.90 (d, *J* = 8.8 Hz, 1H), 6.89 (dd, *J* = 7.6, 7.6 Hz, 1H), 3.91 (s, 3H), 3.83 (s, 3H), 3.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 168.0, 165.5, 159.4, 140.5, 139.4, 135.3, 135.1, 134.7, 134.4, 132.2, 129.3, 128.9, 127.3, 122.2, 120.8, 115.1, 113.9, 113.5, 55.2, 53.0, 52.2; HRMS Calcd. for $C_{24}H_{21}NNaO_6$ [M^++23(Na)] 442.1261, found 261.1246.

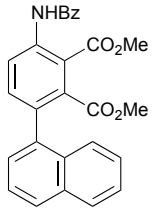
Dimethyl 4-benzamido-2'-methoxy-[1,1'-biphenyl]-2,3-dicarboxylate (4ja)



4ja

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 2-ethynylanisole (**2j**)[1)] (146 μL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7) afforded aniline **4ja** (72.1 mg, 0.171 mmol, 76%) as a pale yellow solid; R_f = 0.23 (Silica gel, hexane/AcOEt = 3:7); IR (neat) 1734, 1698, 1683, 1519, 1490, 1293, 1229, 754, 705 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.11 (br s, 1H), 8.87 (d, *J* = 8.8 Hz, 1H), 8.03–7.99 (2H, m), 7.61–7.51 (m, 4H), 7.34 (ddd, *J* = 8.4, 8.4, 1.2 Hz, 1H), 7.17 (dd, *J* = 8.4, 1.2 Hz, 1H), 6.99 (dd, *J* = 8.4, 8.4 Hz, 1H), 6.93 (d, *J* = 8.4 Hz, 1H), 3.89 (s, 3H), 3.74 (s, 3H), 3.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 168.4, 165.5, 156.5, 138.9, 136.1, 135.0, 134.5, 132.5, 132.2, 130.6, 129.4, 128.9, 127.9, 127.3, 122.1, 120.4, 115.9, 110.6, 55.4, 53.0, 52.0; HRMS Calcd. for $C_{24}H_{21}NNaO_6$ [M^++23(Na)] 442.1261, found 442.1259.

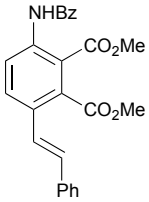
Dimethyl 3-benzamido-6-(naphthalen-1-yl)phthalate (4ka)



4ka

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.20 mg, 10.8 μmol), acetal benzamide **1** (57.3 mg, 0.216 mmol), 1-ethynylnaphthalene (**2k**)[1)] (155 μL, 1.08 mmol), and dimethyl acetylenedicarboxylate (**3a**) (133 μL, 1.08 mmol) in xylene (0.86 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7, hexane/Et_2O/acetone = 7:1:1) afforded aniline **4ka** (60.5 mg, 0.137 mmol, 64%) as a pale yellow solid; R_f = 0.41 (Silica gel, hexane/toluene = 1:3); IR (neat) 3331, 1732, 1698, 1683, 1521, 1490, 1232, 766, 702 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.26 (s, 1H), 8.91 (d, *J* = 8.8 Hz, 1H), 8.01 (d, *J* = 6.8 Hz, 2H), 7.62–7.50 (m, 4H), 7.43–7.30 (m, 5H), 7.26–7.24 (m, 2H), 3.91 (s, 3H), 3.59 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 168.9, 168.1, 165.6, 139.4, 139.3, 135.5, 135.3, 134.8, 134.5, 132.2, 128.9, 128.5, 128.3, 127.7, 127.4, 122.3, 115.2, 53.1, 52.2; HRMS Calcd. for $C_{20}H_{17}NNaO_4$ (M^+–Bz+Na) 358.1050, found 358.1064.

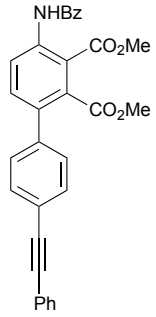
(*E*)-Dimethyl 3-benzamido-6-styrylphthalate (4la)



4la

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), (*E*)-1-phenyl-1-buten-3-yne (**2l**)[2] (145 mg, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 3:7, hexane/Et_2O/acetone = 8:1:1) afforded aniline **4la** (37.5 mg, 0.0903 mmol, 40%) as a pale yellow solid; R_f = 0.35 (Silica gel, AcOEt/hexane = 3:7); IR (neat) 1733, 1699, 1683, 1592, 1522, 1272, 1224, 771, 684 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.39 (br s, 1H), 8.93 (d, *J* = 8.8 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 2H), 7.94 (d, *J* = 8.8 Hz, 1H), 7.64–7.46 (m, 5 H), 7.37 (dd, *J* = 8.0, 8.0 Hz, 2H), 7.30 (d, *J* = 7.2 Hz, 1H), 7.12 (d, *J* = 16.0 Hz, 1H), 7.07 (d, *J* = 16.0 Hz, 1H), 3.95 (s, 3H), 3.94 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.8, 168.0, 165.5, 139.8, 136.8, 134.4, 134.0, 132.2, 131.9, 130.8, 130.4, 128.9, 128.7, 128.2, 127.3, 126.8, 123.8, 122.4, 114.8, 53.1, 52.6; HRMS Calcd. for $C_{25}H_{22}NO_5$ (M^++H) 416.1492, found 416.1420.

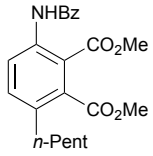
Dimethyl 3-benzamido-6-(phenylethynyl)phthalate (4ma)



4ma

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (6.4 mg, 7.4 μmol), acetal benzamide **1** (39.3 mg, 0.148 mmol), 1-ethynyl-2-(2-phenylethynyl)benzene (**2m**)[3] (150 mg, 0.742 mmol), and dimethyl acetylenedicarboxylate (**3a**) (91.0 μL, 0.742 mmol) in xylene (0.59 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 2:8, hexane/Et_2O/acetone = 7:1:1) afforded aniline **4ma** (36.1 mg, 0.0737 mmol, 40%) as a pale yellow solid; R_f = 0.36 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 1731, 1699, 1684, 1520, 1508, 1493, 1232, 757 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.27 (s, 1H), 8.93 (d, *J* = 8.8 Hz, 1H), 8.02 (d, *J* = 6.8 Hz, 2H), 7.63–7.51 (m, 8H), 7.41–7.30 (m, 5H), 3.92 (s, 3H), 3.63 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 168.0, 165.6, 139.6, 139.1, 135.0, 134.74, 134.67, 134.37, 132.2, 131.6, 131.5, 128.9, 128.6, 128.5, 128.4, 127.3, 123.1, 122.8, 122.3, 115.3, 90.3, 89.0, 53.1, 52.3; HRMS Calcd. for $C_{31}H_{24}NO_5$ (M^+) 490.1649, found 490.1618.

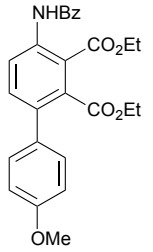
Dimethyl 3-benzamido-6-pentylphthalate (4na)



4na

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 1-heptyn (**2n**) (148 μL, 1.13 mmol), and dimethyl acetylenedicarboxylate (**3a**) (139 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 2:8, hexane/Et_2O/acetone = 8:1:1) afforded aniline **4na** (50.0 mg, 0.130 mmol, 58%) as a yellow oil; R_f = 0.41 (Silica gel, hexane/toluene = 1:3); IR (neat) 3335, 1732, 1698, 1683, 1592, 1521, 1319, 1294, 1280, 766, 702 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 11.27 (br, s, 1H), 8.79 (d, *J* = 8.8 Hz, 1H), 8.00 (d, *J* = 7.2 Hz, 2H), 7.39–7.63 (m, 4H), 3.91 (s, 3H), 3.90 (s, 3H), 2.58 (t, *J* = 8.0 Hz, 2H), 1.70–1.45 (m, 6H), 0.90 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 168.2, 165.5, 138.5, 135.4, 135.0, 134.6, 134.5, 132.1, 128.9, 127.3, 122.4, 114.8, 53.0, 52.0, 33.1, 31.5, 31.0, 22.4, 14.0; HRMS Calcd. for $C_{18}H_{15}NO$ [M^++(Na)] 406.1625, found 406.1617.

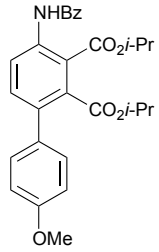
Diethyl 4-benzamido-4'-methoxy-[1,1'-biphenyl]-2,3-dicarboxylate (4bb)



4bb

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-ethynylanisole **2b** (146 μL, 1.13 mmol), and diethyl acetylenedicarboxylate (**3b**) (171 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 1:9, hexane/Et_2O/acetone = 5:1:1) afforded aniline **4bb** (82.8 mg, 0.185 mmol, 82%) as a pale yellow solid; R_f = 0.41 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 1724, 1696, 1683, 1511, 1247, 1229, 1030, 831, 773, 705 cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 11.33 (br s, 1 H), 8.88 (d, *J* = 8.4 Hz, 1H), 8.02 (d, *J* = 6.6 Hz, 2H), 7.60–7.50 (m, 4H), 7.26 (d, *J* = 8.4 Hz, 2H), 6.93 (d, *J* = 8.4 Hz, 2H), 4.38 (q, *J* = 7.2 Hz, 2H), 4.05 (q, *J* = 7.2 Hz, 2H), 3.83 (s, 3H), 1.34 (t, *J* = 7.2 Hz, 3H), 1.00 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 168.5, 167.8, 165.5, 159.2, 139.1, 135.2, 135.1, 135.0, 134.5, 132.1, 131.8, 129.8, 128.9, 127.3, 122.0, 115.2, 113.6, 62.4, 61.2, 55.3, 13.7; HRMS Calcd. for $C_{26}H_{26}NO_6$ (M^++H) 448.1755, found 448.1668.

Diisopropyl 4-benzamido-4'-methoxy-[1,1'-biphenyl]-2,3-dicarboxylate (4bc)

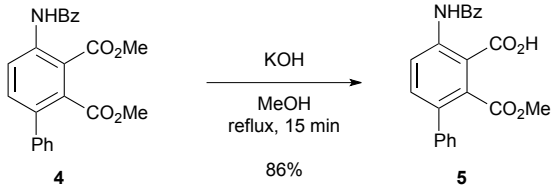


4bc

Reaction was conducted based on the general procedure using a solution of [IPrAu(BTZ-H)]OTf (**VIII**) (9.70 mg, 11.3 μmol), acetal benzamide **1** (60.0 mg, 0.226 mmol), 4-ethynylanisole **2b** (146 μL, 1.13 mmol), and diisopropyl acetylenedicarboxylate (**3b**) (218 μL, 1.13 mmol) in xylene (0.90 mL). Purification of the crude product by silica gel column chromatography (hexane/AcOEt = 1:9, hexane/Et_2O/acetone = 8:1:1) afforded aniline **4bc** (100 mg, 0.210 mmol, 93%) as a pale yellow solid; R_f = 0.41 (Silica gel, hexanes/toluene = 1:3); IR (neat) 1721, 1682, 1511, 1246, 1231, cm^{-1}; ^1H NMR (600 MHz, $CDCl_3$) δ 11.3 (br s, 1 H), 8.83 (d, *J* = 9.0 Hz, 1H), 8.01 (d, *J* = 8.4 Hz, 2H), 7.60–7.45 (m, 4H), 7.26 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 8.4 Hz, 2H), 5.33 (sep, *J* = 6.6 Hz, 1H), 4.92 (sep, *J* = 6.6 Hz, 1H), 3.83 (s, 3H), 1.35 (d, *J* = 6.6 Hz, 6H), 0.94 (d, *J* = 6.6 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.4, 165.5, 159.3, 138.9, 135.3, 135.1, 135.0, 134.7, 133.0, 132.0, 131.9, 130.2, 128.8, 127.3, 121.9, 115.8, 114.2, 113.5, 70.7, 69.2, 55.3, 21.4, 21.2; HRMS Calcd. for $C_{28}H_{30}NO_6$ (M^++H) 476.2068, found 476.2056.

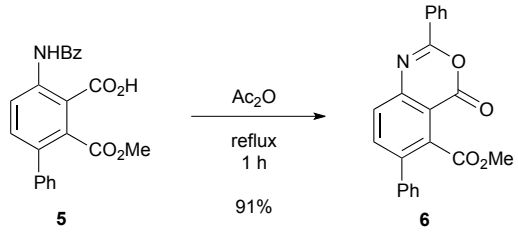
3. Transformation to Substituted Benzoxazine Derivatives

4-Benzamido-2-(methoxycarbonyl)-[1,1'-biphenyl]-3-carboxylic acid (5)



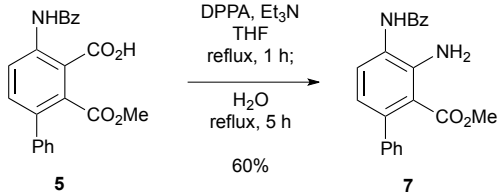
To a 1 M solution of potassium hydroxide in MeOH was added aniline **4** (90.0 mg, 0.231 mmol) at room temperature. After stirring for 15 minutes at 100 ºC, the reaction was quenched with 1 M HCl and a pale yellow precipitate was collected by filtration. The collected precipitate was washed with H_2O and dried under reduced pressure to afford **5** (74.2 mg, 0.199 mmol, 86%) as a yellow solid.; R_f = 0.17 (Silica gel, CH_2Cl_2/MeOH = 19:1); IR (neat) 3024, 2360, 1732, 1696, 1685, 1522, 1296, 1220, 770, 701 cm^{-1}; ^1H NMR (400 MHz, CD_3OD) δ 8.69 (d, *J* = 8.8 Hz, 1H), 7.99 (d, *J* = 7.6 Hz, 2H), 7.66–7.52 (m, 4H), 7.45–7.30 (m, 5H), 3.59 (s, 3H); ^{13}C NMR (100 MHz, CD_3OD) δ 170.8, 170.1, 167.7, 140.7, 139.9, 137.2, 136.5, 135.7, 135.52, 135.49, 130.0, 129.7, 129.4, 128.8, 128.4, 123.8, 119.0, 52.8; HRMS Calcd. for $C_{22}H_{17}NNaO_5$ [M^++23(Na)] 398.1004, found 398.0999.

Methyl 4-*oxo*-2,6-diphenyl-4H-benzo[*d*][1,3]oxazine-5-carboxylate (6)



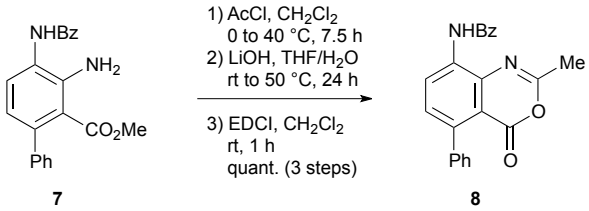
A solution of aniline **5** (30.0 mg, 0.0800 mmol) in Ac_2O (0.40 mL) was stirred at reflux. After stirring for an hour, the reaction was quenched with H_2O and white precipitate was formed. The precipitate was collected by filtration and washed with H_2O to afford **6** (26.0 mg, 0.0726 mmol, 91%) as a white solid. R_f = 0.17 (Silica gel, hexane/AcOEt = 7:3); IR (KBr) 3468, 3372, 1703, 1618, 1277, 1265, 768, 700 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.32 (d, *J* = 7.2 Hz, 2H), 7.83 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.63–7.40 (m, 8H), 3.82 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 157.8, 157.7, 148.8, 146.3, 139.9, 138.1, 133.9, 132.9, 129.8, 128.8, 128.7, 128.6, 128.43, 128.39, 128.2, 113.8, 52.9; HRMS Calcd. for $C_{22}H_{16}NNaO_4$ (M^++H) 358.1079, found 358.1074.

Methyl 3-amino-4-benzamido-[1,1'-biphenyl]-2-carboxylate (7)



To a mixture of benzoic acid **5** (75.0 mg, 0.200 mmol), Et_3N (279 µL, 2.00 mmol) in THF (400 µL) was added DPPA (215 µL, 0.999 mmol). After stirring at reflux for an hour, H_2O (80.0 µL) was added to the reaction mixture. After stirring at reflux for additional 5 hours, the reaction was quenched with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc three times, dried over Na_2SO_4, filtered, and concentrated under reduced pressure to afford a yellow solid. The solid was purified by preparative TLC (hexane/AcOEt = 7:3) to afford aniline **7** (41.6 mg, 0.120 mmol, 60%) as a colorless oil; IR (neat) 1539, 1373, 1188, 1150, 1065, 762, 606 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 6.8 Hz, 2H), 7.52 (dd, *J* = 6.8, 6.8 Hz, 1H), 7.47–7.36 (m, 5H), 7.33 (d, *J* = 7.2 Hz, 2H), 7.07 (dd, *J* = 8.0 Hz, 1H), 6.76 (d, *J* = 7.6 Hz, 1H), 5.20 (br s, 2H), 3.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$); δ 168.9, 154.6, 146.8, 143.7, 141.3, 131.6, 129.8, 129.2, 128.6, 128.3, 127.73, 127.70, 123.0, 119.9, 119.5, 116.6, 51.8, HRMS Calcd. for $C_{21}H_{18}N_2NaO_3$ $[M^+$+23(Na)] 369.1215, found 369.1210.

***N*-(2-Methyl-4-*oxo*-5-phenyl-4*H*-benzo[*d*][1,3]oxazin-8-yl)benzamide (8)**



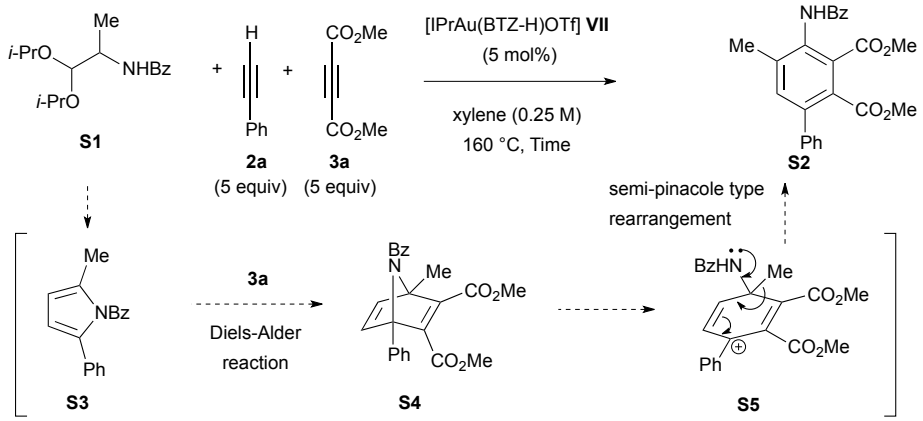
To a mixture of aniline **7** (25.0 mg, 72.2 µmol) in CH_2Cl_2 (722 µL) was added AcCl (7.6 µL, 79 µmol) at 0 ºC. After stirring for 7.5 hours at 40 °C, the reaction was quenched with sat. $NaHCO_3$ and the separated aqueous layer was extracted with EtOAc three times. The combined organic extracts were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To a stirred solution of the above crude amide in THF (216 µL) and H_2O (72 µL) was added $LiOH{\cdot}H_2O$ (3.9 mg, 94 µmol) at room temperature. After stirring for 24 hours, the reaction mixture was acidified with 1 M HCl and extracted with EtOAc three times, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To a solution of the above crude benzoic acid derivative in CH_2Cl_2 (361 μL) was added EDCI (50.0 mg, 0.261 mmol) at room temperature. After stirring for an hour, the reaction mixture was washed with H_2O three times, dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by preparative TLC on silica gel (hexane/AcOEt = 7:3) to afford an benzoxadinone **8** (26.2 mg, 73.5 μmol, quant.) as a colorless foam; R_f = 0.26 (Silica gel, hexane/AcOEt = 7:3); IR (neat) 2972, 2928, 2359, 2341, 1456, 1381, 1128, 1030, 698 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.4 Hz, 1H), 7.60–7.52 (m, 3H), 7.52–7.45 (m, 4H), 7.43–7.38 (m, 4H), 2.14 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6, 156.3, 155.5, 148.3, 142.9, 138.7, 133.2, 131.1, 131.0, 129.7, 129.2, 128.9, 128.6, 128.4, 128.1, 124.4, 115.3, 21.0; HRMS Calcd. for $C_{15}H_{26}NO_2$ ($[M–Bz]^+$) 251.0815, found 251.0185.

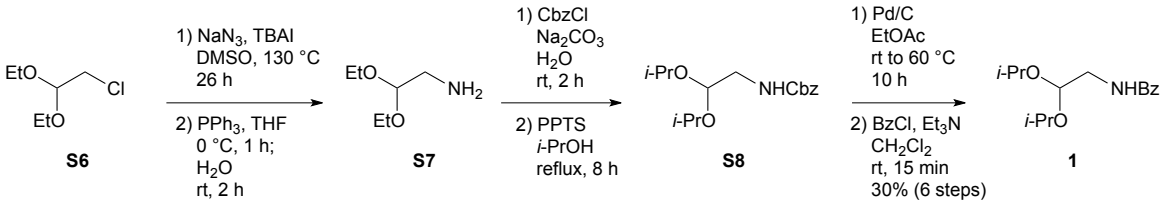
4. Application to the Substituted Acetal Amide

We envisioned the application of the established method to the substituted acetal amide **S1** would provide penta-substituted aniline **S2** via Au-catalyzed pyrrole synthesis, Diels-Alder reaction, cleavage of C-N bond, following semi-pinacol type rearrangement. Disappointingly, formation of the corresponding pyrrole **S3** was observed, but aniline product was not detected at all.



5. Preparation of Acetal Substrate

N-(2,2-Diisopropoxyethyl)benzamide (1)



To a solution of 2-chloro-1,1'-diethoxyethane (**S6**) (20.0 mL, 133 mmol), tetra-*n*-butylammonium iodide (TBAI) (4.91 g, 90.0 mmol) and DMSO (133 mL) was added NaN_3 (9.65 g, 148 mmol). After stirring at 130 ºC for 26 hours, the reaction mixture was diluted with AcOEt and the reaction was quenched with H_2O. The mixture was washed with H_2O three times and the separated organic layer was dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To a stirred solution of the above crude azide derivative in THF (100 mL) was added PPh_3 (34.9 g, 133 mmol) at 0 ºC. After stirring for an hour, H_2O (3.10 mL, 172 mmol) was added to the reaction mixture and the reaction mixture stirred for 3 hours at room temperature. The reaction mixture was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To a stirred solution of the above crude amine **S7** and Na_2CO_3 (15.5 g, 146 mmol) in H_2O (440 mL) was added CbzCl (20.8 mL, 146 mmol) at 0 ºC. After stirring for 2 hours, the reaction mixture was poured into Et_2O and the resultant precipitate was removed by filtration. The filtrate was extracted with Et_2O three times, washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To a solution of the above crude carbamate in *i*-PrOH (300 mL) was added PPTS (3.34 g, 13.3 mmol) and the reaction mixture was stirred for 8 hours at the reflux. Then, the reaction was quenched with saturated aqueous $NaHCO_3$. The separated aqueous layer was extracted with AcOEt three times. The combined organic extracts were dried over $MgSO_4$, filtered and concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

To the mixture of the above crude carbamate **S8** and 10% Pd/C (7.05 g, 6.65 mmol) was added AcOEt (200 mL). After the reaction mixture was stirred under a hydrogen atmosphere at room temperature for 4 hours, the reaction mixture was heated at 45 ºC and stirred for an hour. After stirring for additional 5 hours at 60 ºC, the reaction mixture was filtered through a pad of Celite. The filtrate and washings were concentrated under reduced pressure. The residue was subjected to the next reaction without further purification.

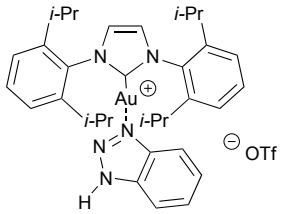
To a solution of the above crude amine and Et_3N (55.6 mL, 399 mmol) in CH_2Cl_2 (266 mL) was added BzCl (17.0 mL, 146 mmol) at 0 ºC and stirred for 15 minutes. Then, the reaction was quenched with saturated aqueous NH_4Cl, and the resulting mixture was extracted with AcOEt three times. The combined organic extracts were dried over $MgSO_4$ filtered and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel (hexane/AcOEt = 8:2, toluene/AcOEt = 7:3) and recrystallized (Et_2O/hexanes) to afford benzamide **1** (10.5 g, 39.6 mmol, 30% over 6 steps) as a white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, *J* = 6.8 Hz, 2H), 7.55–7.40 (m, 3H), 6.43 (br s, 1H), 4.72 (t, *J* = 5.2 Hz, 1H), 3.90 (sep, *J* = 6.0 Hz, 1H), 3.90 (sep, *J* = 6.0 Hz, 1H), 3.54 (dd, *J* = 5.2, 5.2 Hz, 2H), 1.24 (d, *J* = 6.0 Hz, 6H), 1.18 (d, *J* = 6.0 Hz, 6H). Its ^{1}H NMR spectra was identical with that reported in the literature.[1)]

6. Preparation of Gold Catalysts

General Procedure for Gold Benzotriazole Complexes[4)]

To a suspension of AgOTf (1 eq) and benzotriazole (1 eq) in MeOH (0.05 M) was added gold chloride (III) (1 eq) at room temperature with shading. After stirring for 6 hours, the solvent was removed under reduced pressure. The residue was filtered through a pad of Celite, and washed with CH_2Cl_2. The filtrate was concentrated under reduced pressure, and the residue was purified by recrystallization from hexane and CH_2Cl_2.

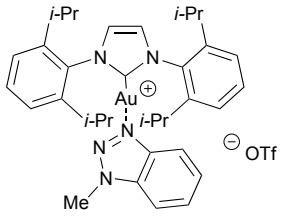
[IPrAu(BTZ-H)]OTf (VII)[4)]



VII

According to the general procedure, gold benzotriazole complex **VII** was prepared with IPrAuCl **III**, AgOTf and 1,2,3-benzotriazole in 0.0618 mmol scale (47.5 mg, 0.0556 mmol, 90%); The white solid was purified by recrystallization (hexane/CH_2Cl_2); (hexane/CH_2Cl_2) ; ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.04 (d, *J* = 9.0 Hz, 1H), 7.61 (dd, *J* = 7.8, 7.8 Hz, 2H), 7.46 (dd, *J* = 7.8, 7.8 Hz, 1H), 7.41–7.37 (m, 6H), 7.32 (dd, *J* = 7.8, 7.8 Hz, 1H), 6.92 (d, *J* = 7.8 Hz, 1H), 2.63–2.57 (m, 4H), 1.35 (d, *J* = 7.2 Hz, 12H), 1.29 (d, *J* = 6.6 Hz, 12H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.4, 145.7, 142.1, 133.7, 133.4, 131.3, 128.8, 127.1, 124.6, 124.3, 114.6, 114.0, 29.0, 24.7, 24.0; HRMS Calcd. for $C_{33}H_{41}AuN_5$ [M^+–(OTf)] 704.3100, found 704.3022.

[IPrAu(BTZ-Me)]OTf (VIII)



VIII

According to the general procedure, gold benzotriazole complex **VIII** was prepared with IPrAuCl **III**, AgOTf and 1-methyl-1,2,3-benzotriazole in 0.495 mmol scale (419 mg, 0.483 mmol, 97%). The white solid was purified by recrystallization (hexane/CH_2Cl_2); mp 222–223 °C (hexane/CH_2Cl_2); IR (neat) 3163, 3076, 3011, 2964, 2926, 2869, 1471, 1462, 1267, 1225, 1152, 1031, 754, 637 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.8 Hz, 1H), 7.95–7.59 (m, 3H),

7.51 (s, 2H), 7.44–7.37 (m, 5H), 6.92 (d, J = 8.8 Hz, 1H), 4.39 (s, 3H), 2.60 (sep, J = 6.8 Hz, 4H), 1.34 (d, J = 6.8 Hz, 12H), 1.30 (d, J = 6.8 Hz, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 145.8, 143.2, 133.9, 133.4, 131.2, 129.8, 128.0, 124.8, 124.5, 115.3, 112.4, 36.5, 29.0, 24.7, 24.0; ESI-MS *m/z* Calcd for $C_{34}H_{43}AuN_5$ 718.3178 (M^+), Found 718.3151

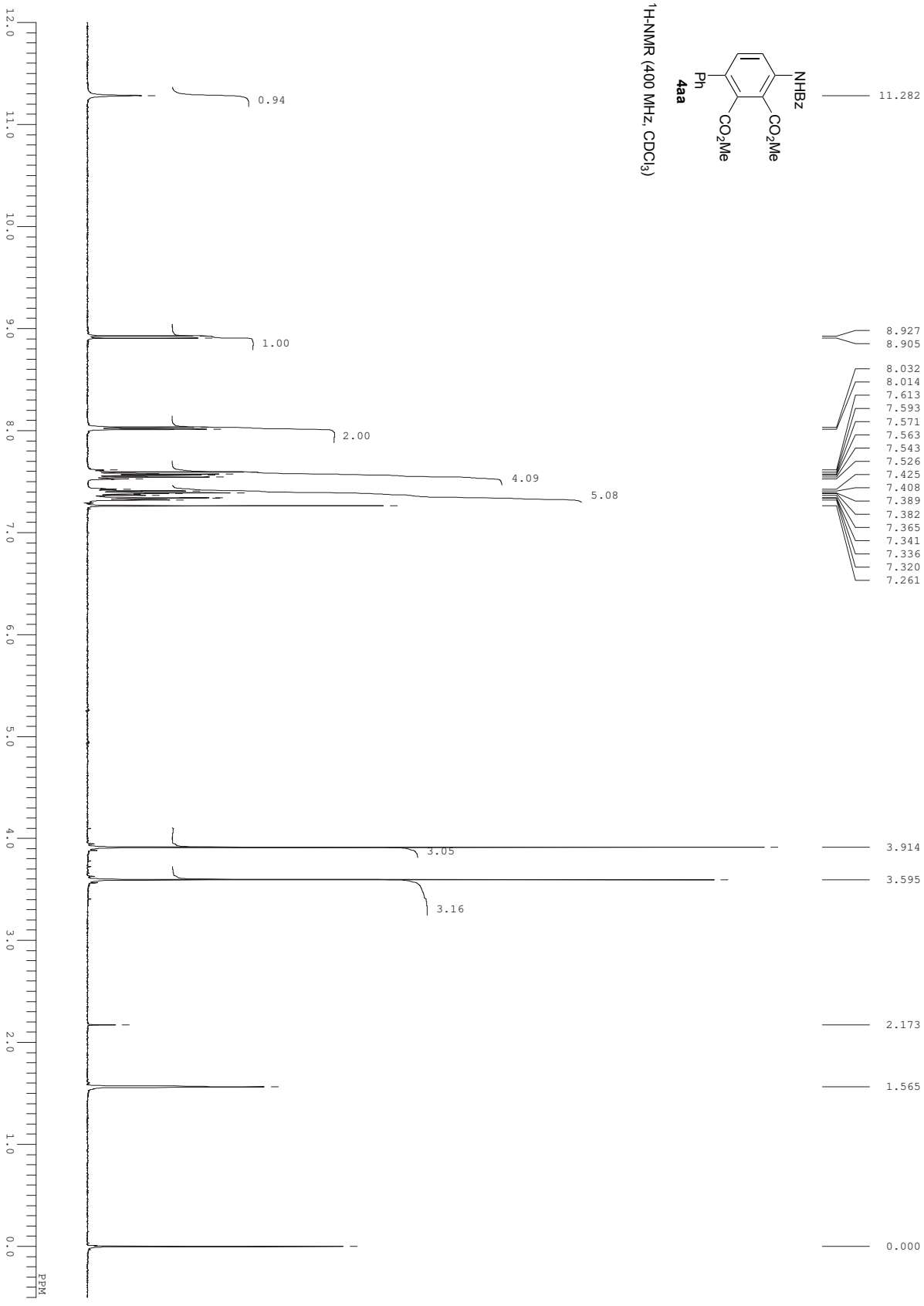
7. References

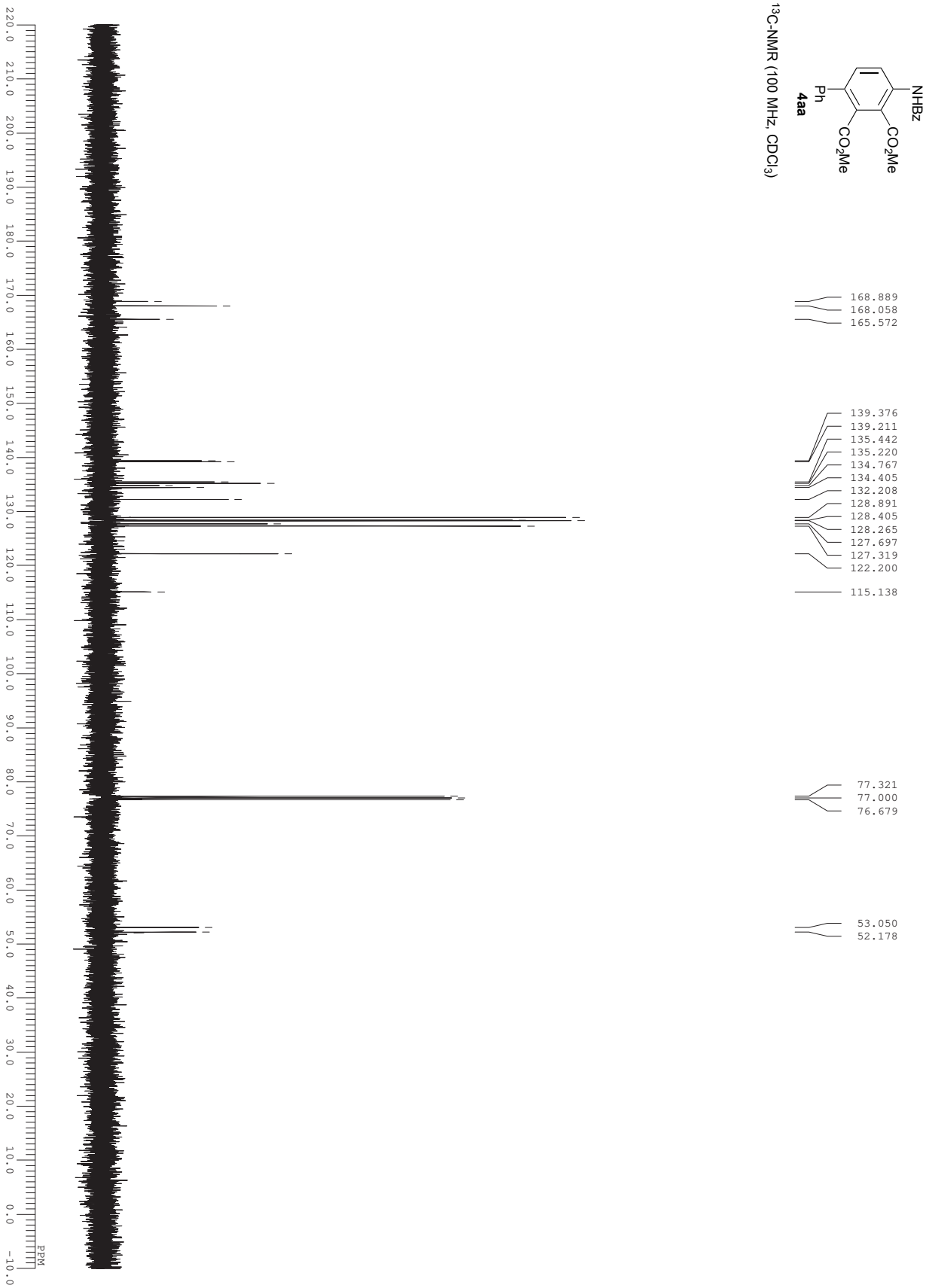
1) H. Ueda, M. Yamaguchi, H. Kameya, K. Sugimoto and H. Tokuyama, *Org. Lett.,* 2014, **16**, 4948.

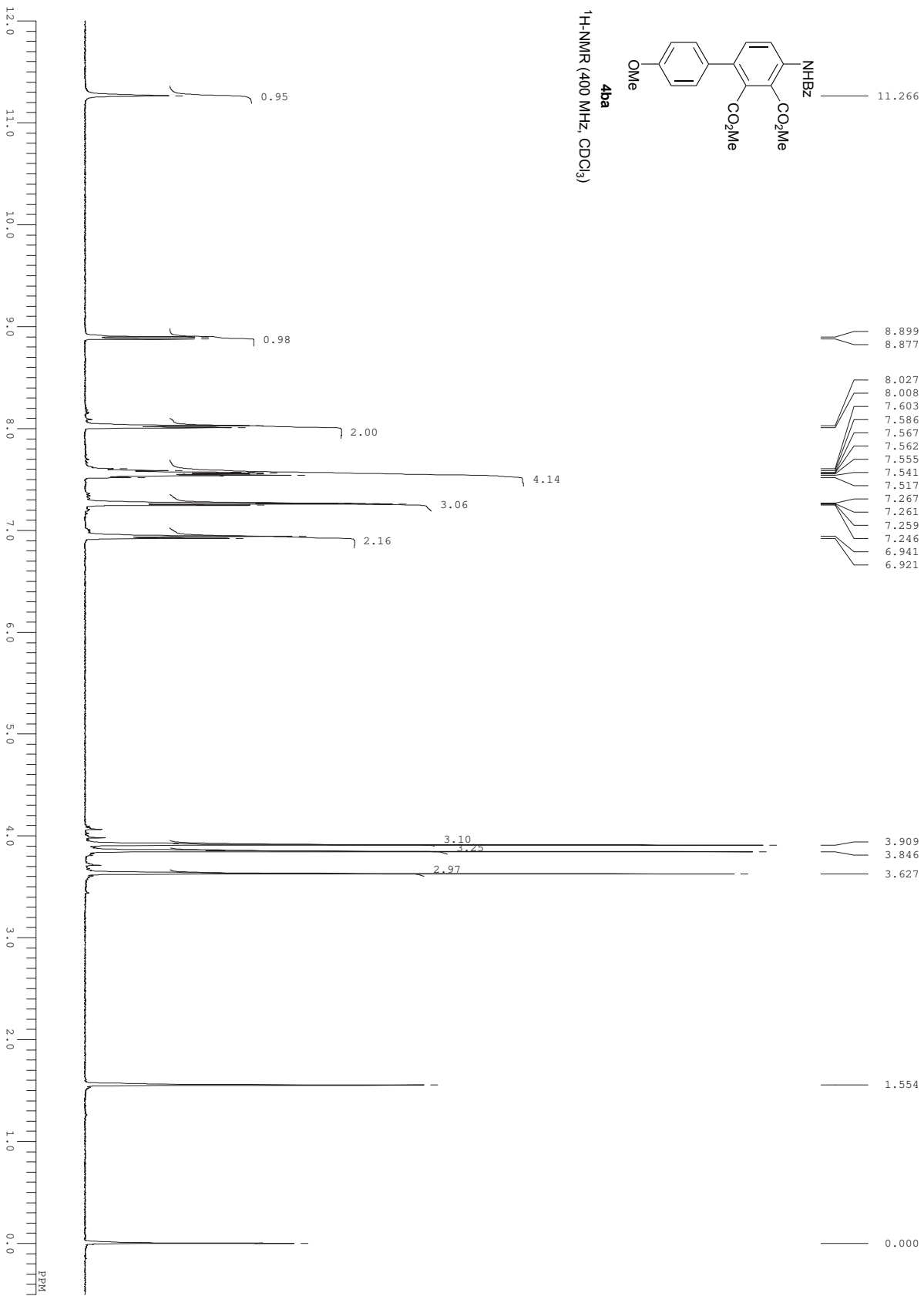
2) R. A. Fernandes, S. P. Gholap, V. P. Chavan, A. S. Saiyed and S. Bhattacharyya, *Org. Lett.,* 2020, **22**, 3438.

3) X. Zhang, X. Xie and Y. Liu, *J. Am. Chem. Soc.,* 2018, **140**, 24.

4) D. Wang, R. Cai, S. Sharma, J. Jirak, S. Thummanapelli, N. Akhmedov, H. Zhang, X. Liu, J. Petersen and X. Shi, *J. Am. Chem. Soc.,* 2012, **134**, 9012–9019.


^{1}H-NMR (400 MHz, $CDCl_3$)
4aa
Ph
CO_2Me
CO_2Me
NHBz
11.282
8.927
8.905
8.032
8.014
7.613
7.593
7.571
7.563
7.543
7.526
7.425
7.408
7.389
7.382
7.365
7.341
7.336
7.320
7.261
3.914
3.595
2.173
1.565
0.000
0.94
1.00
2.00
4.09
5.08
3.05
3.16
PPM


^{13}C-NMR (100 MHz, CDCl$_3$)
4aa
Ph
CO$_2$Me
CO$_2$Me
NHBz
168.889
168.058
165.572
139.376
139.211
135.442
135.220
134.767
134.405
132.208
128.891
128.405
128.265
127.697
127.319
122.200
115.138
77.321
77.000
76.679
53.050
52.178
PPM


4ba
^{1}H-NMR (400 MHz, CDCl$_3$)
OMe
NHBz
CO$_2$Me
CO$_2$Me
11.266
8.899
8.877
8.027
8.008
7.603
7.586
7.567
7.562
7.555
7.541
7.517
7.267
7.261
7.259
7.246
6.941
6.921
3.909
3.846
3.627
1.554
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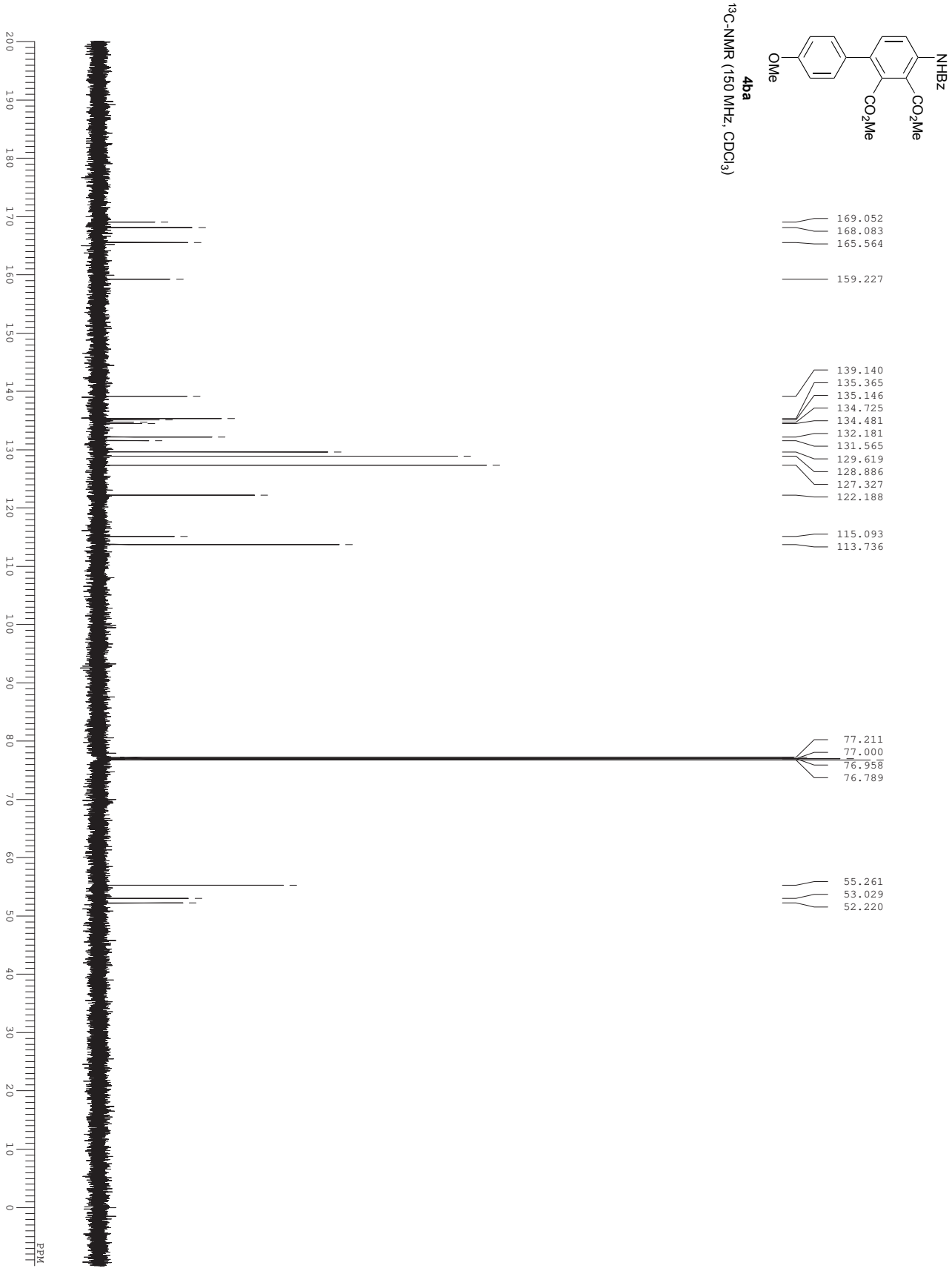
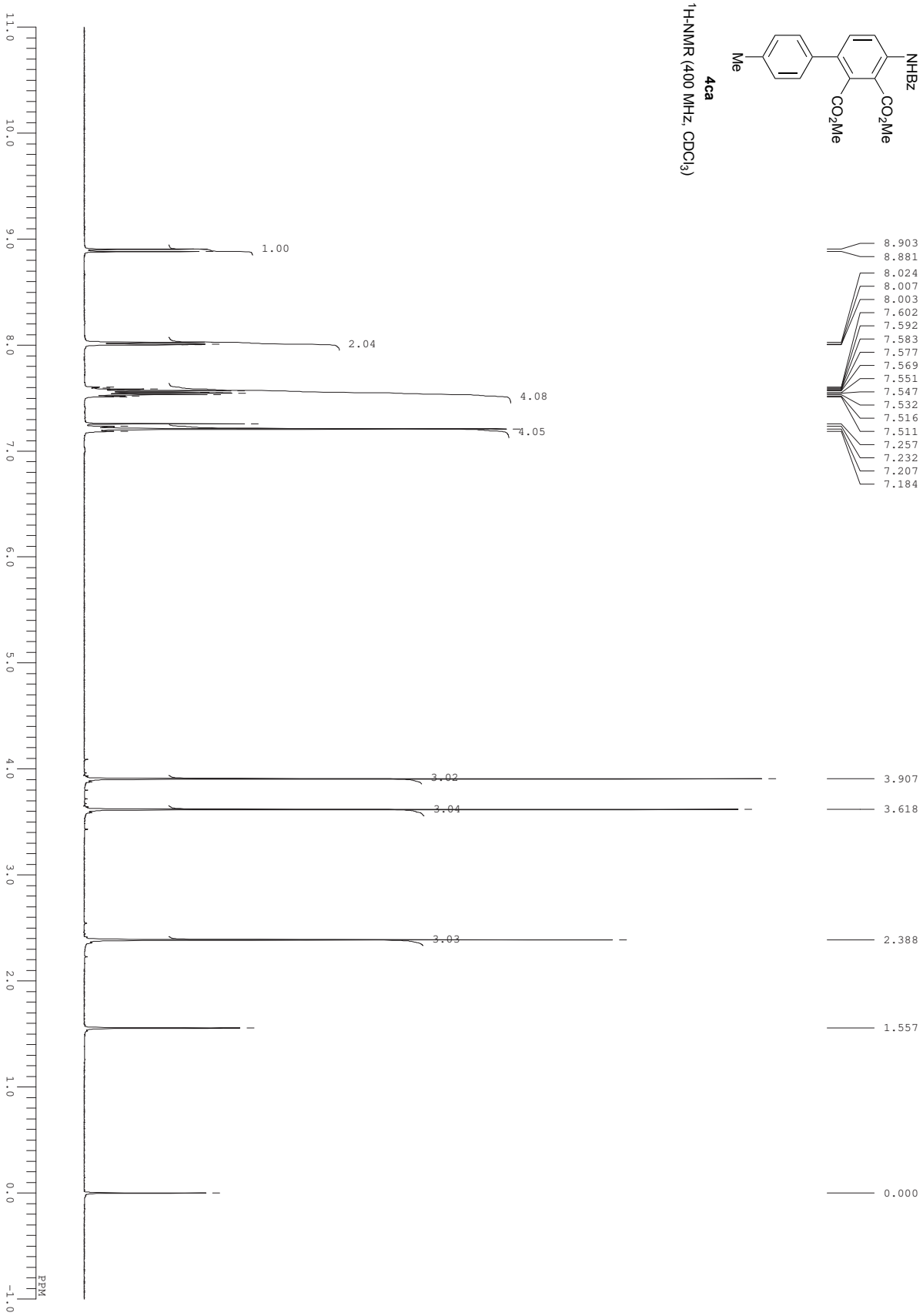
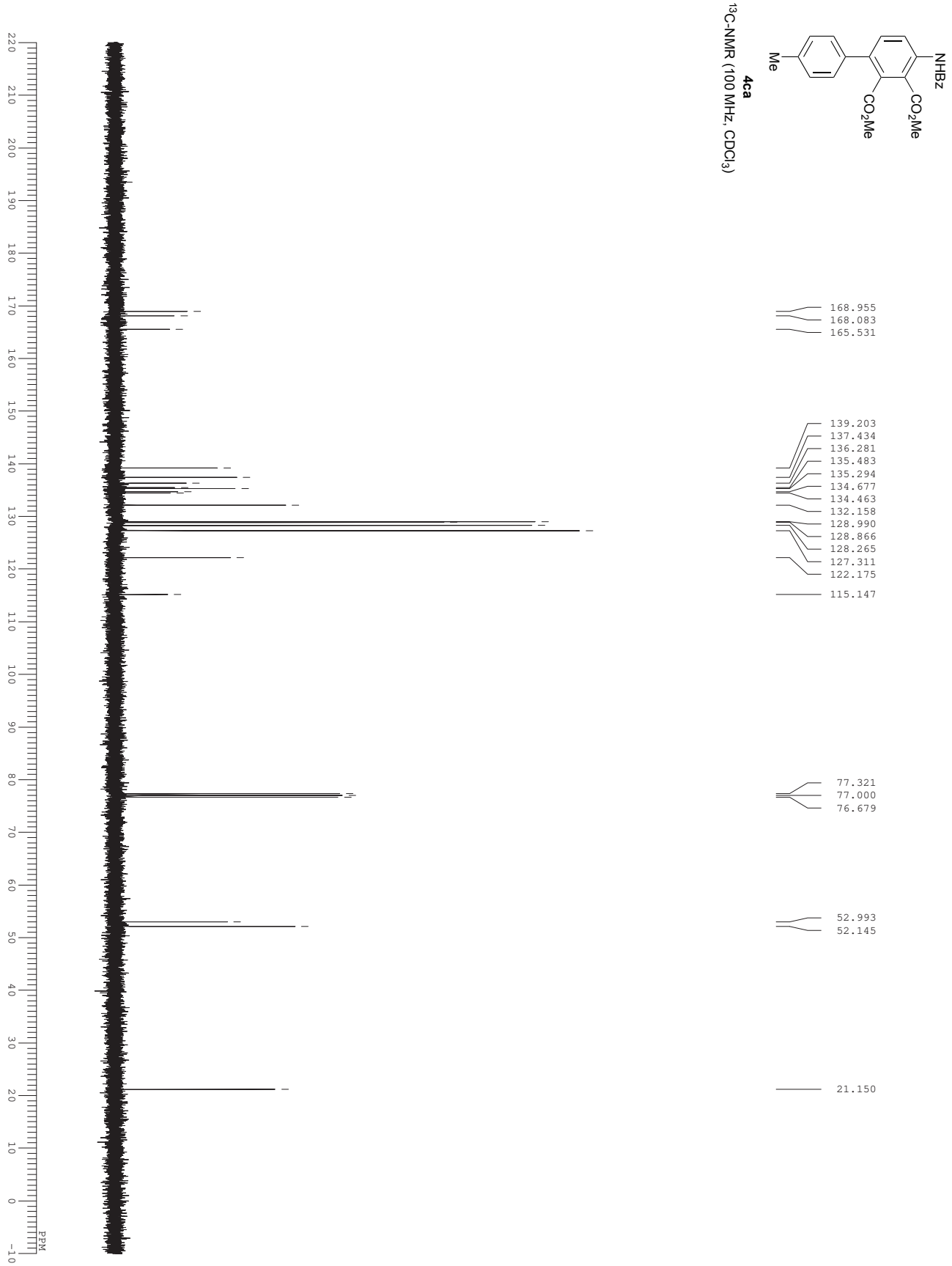
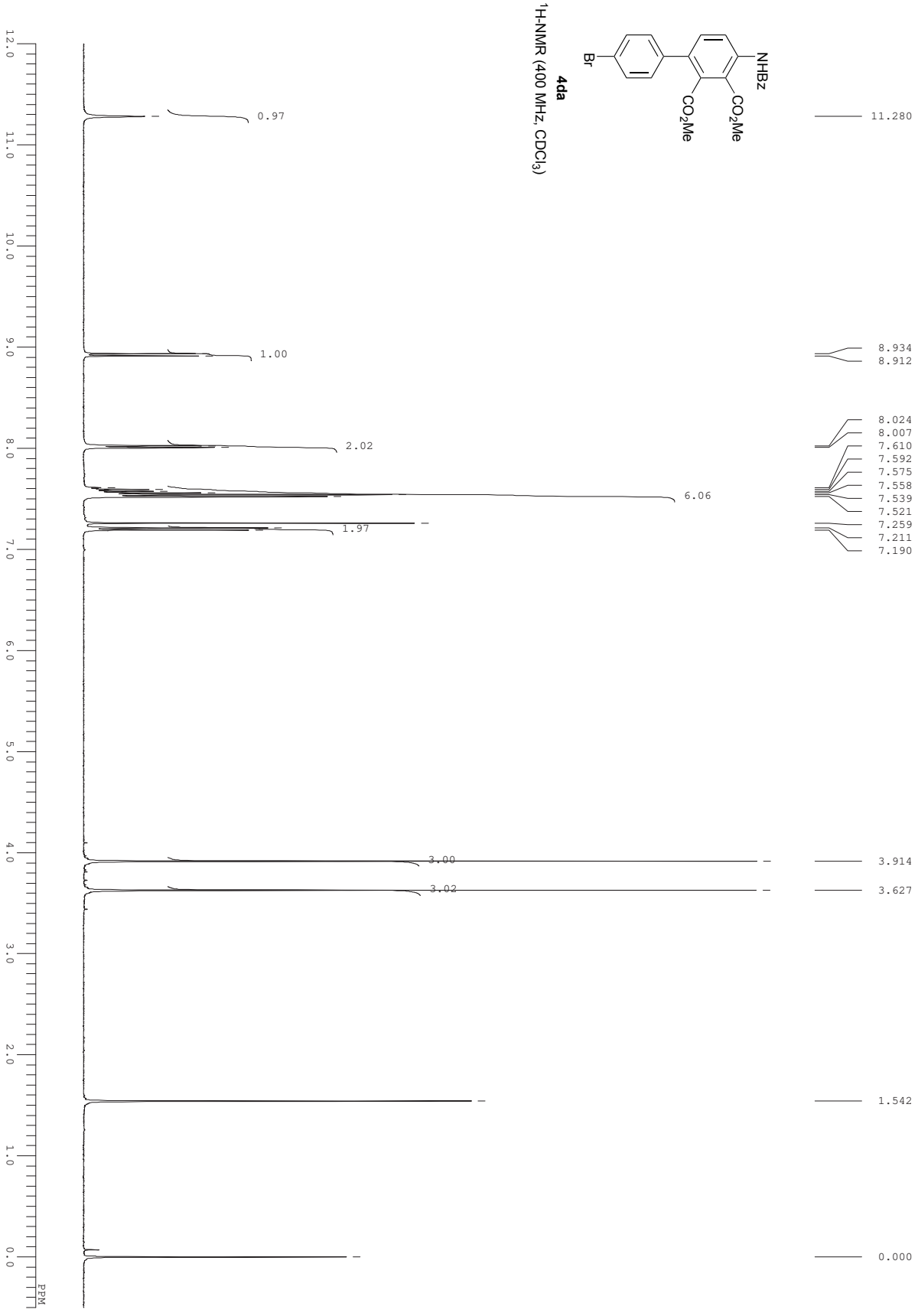
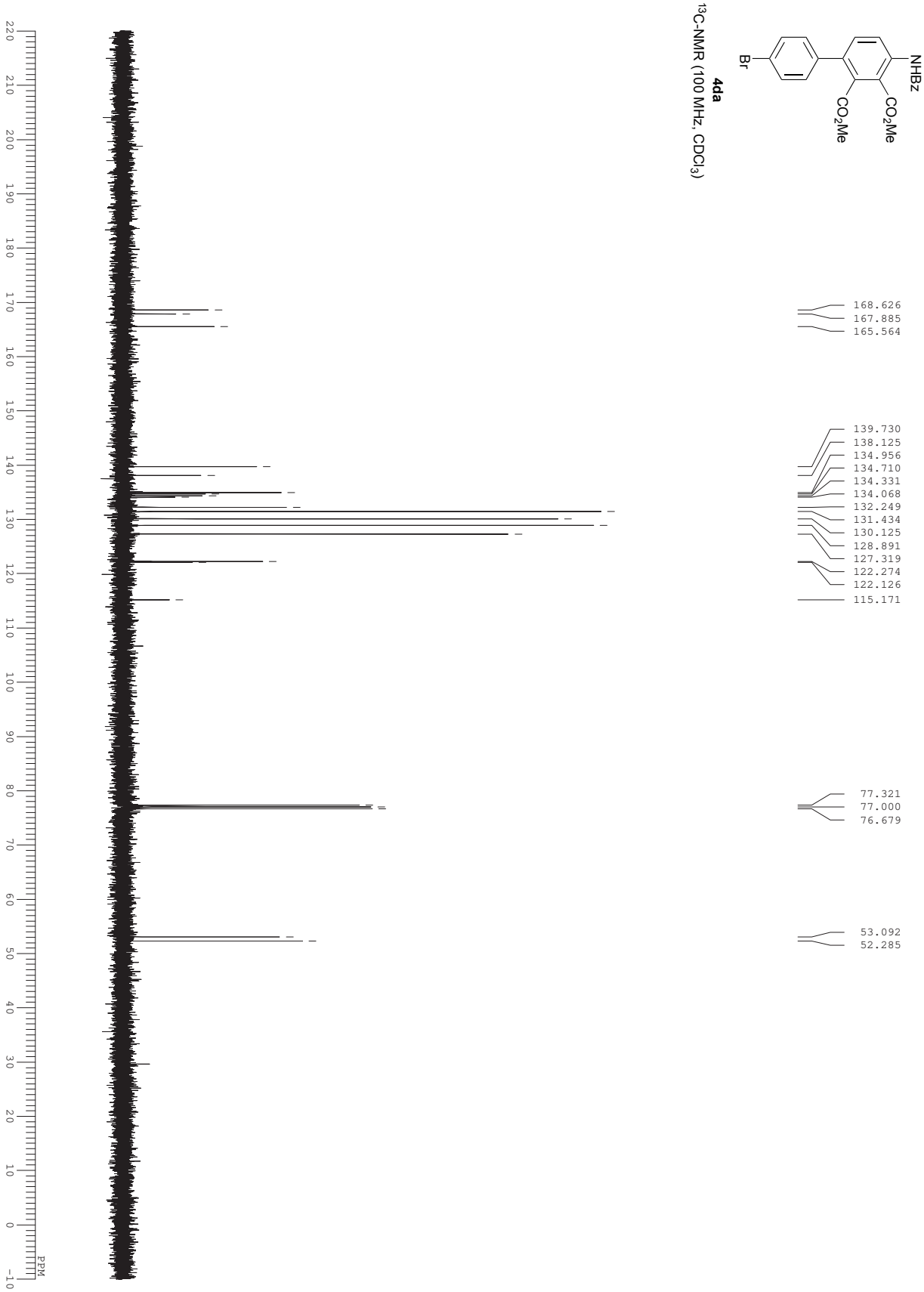
0.95
0.98
2.00
4.14
3.06
2.16
3.10
3.25
2.97
PPM

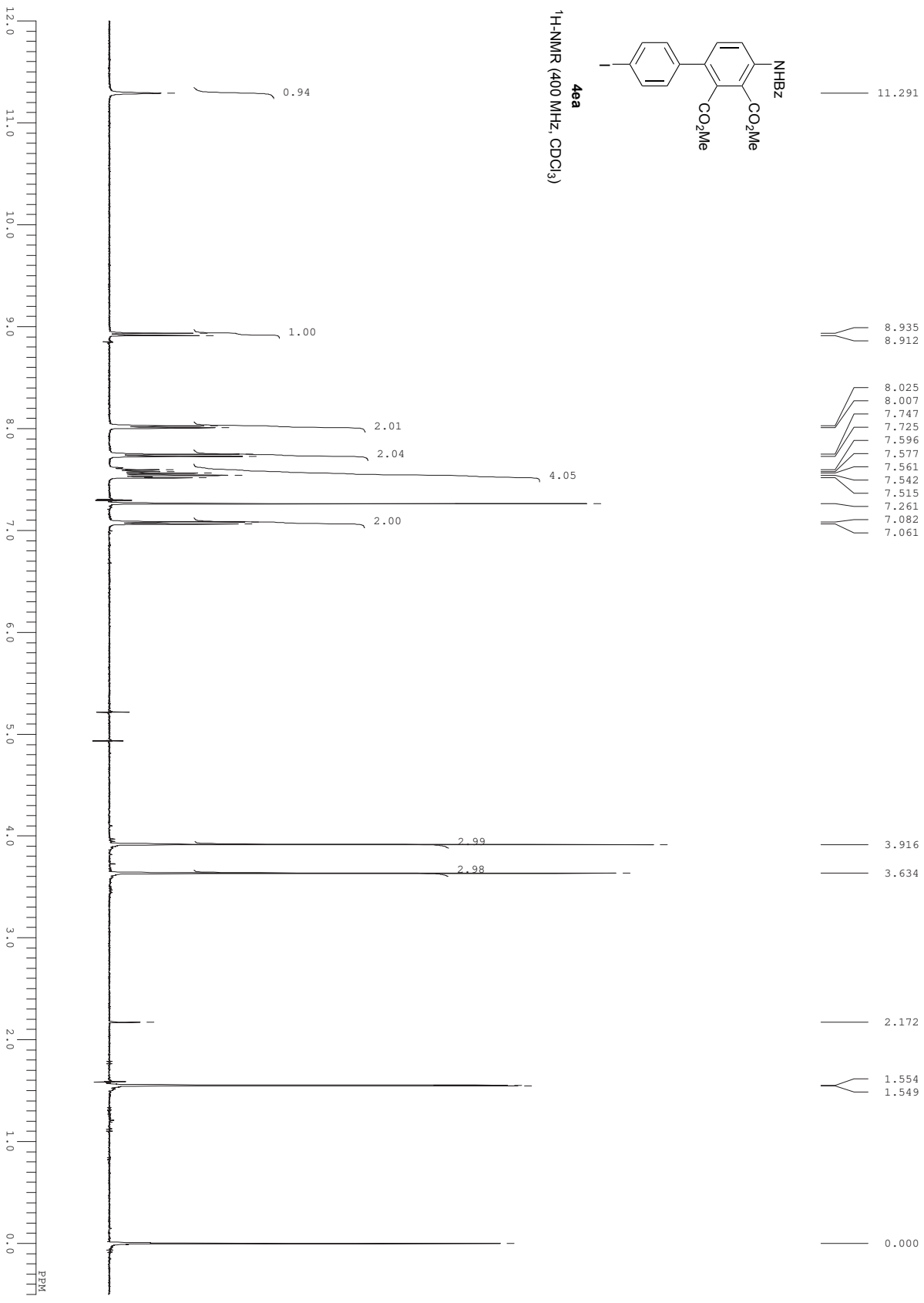

4ba
^{13}C-NMR (150 MHz, CDCl$_3$)
OMe
NHBz
CO$_2$Me
CO$_2$Me
169.052
168.083
165.564
159.227
139.140
135.365
135.146
134.725
134.481
132.181
131.565
129.619
128.886
127.327
122.188
115.093
113.736
77.211
77.000
76.958
76.789
55.261
53.029
52.220
PPM

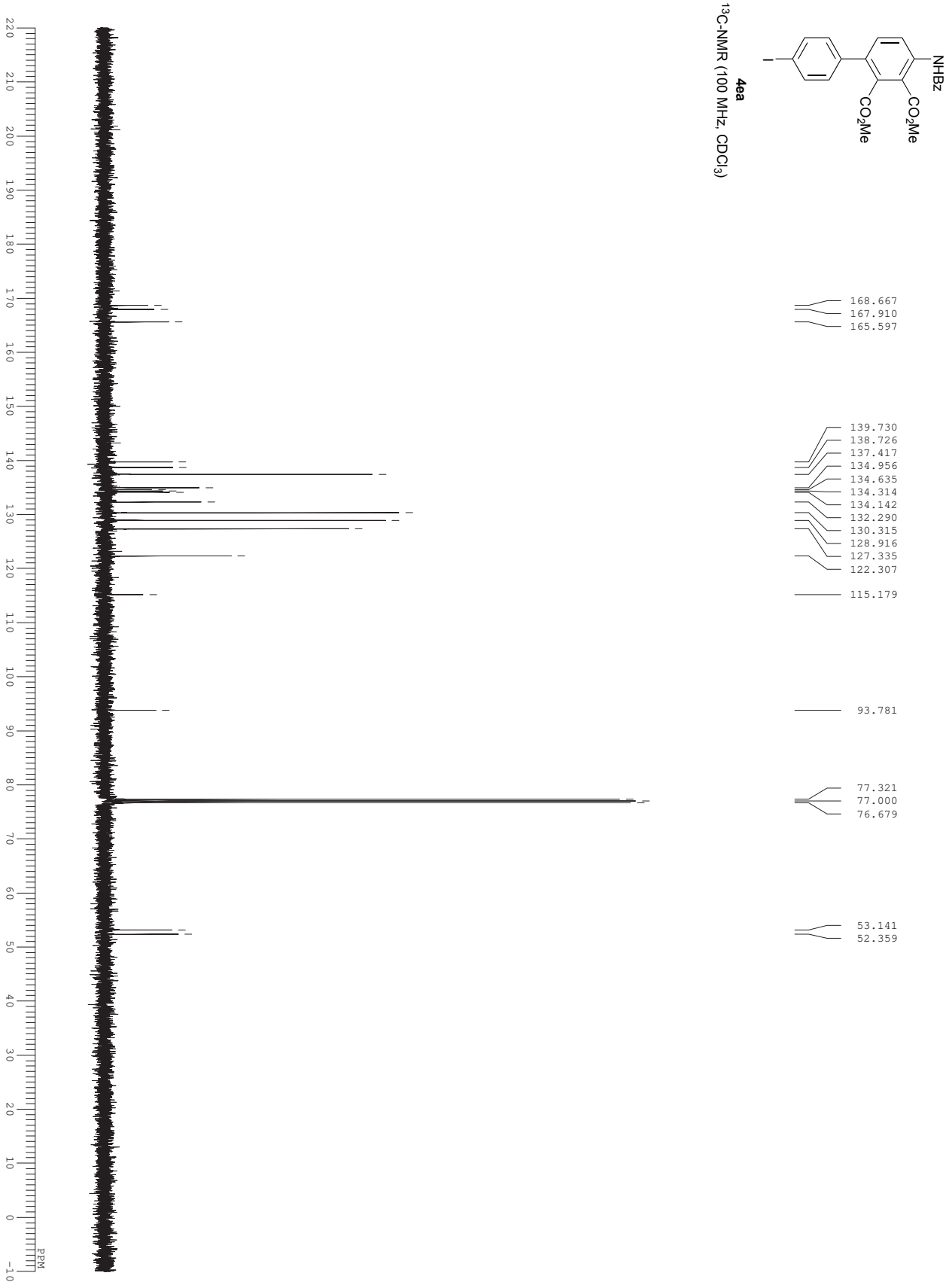

4ca
1H-NMR (400 MHz, CDCl3)
Me
NHBz
CO2Me
CO2Me
8.903
8.881
8.024
8.007
8.003
7.602
7.592
7.583
7.577
7.569
7.551
7.547
7.532
7.516
7.511
7.257
7.232
7.207
7.184
1.00
2.04
4.08
4.05
3.02
3.04
3.03
3.907
3.618
2.388
1.557
0.000
PPM

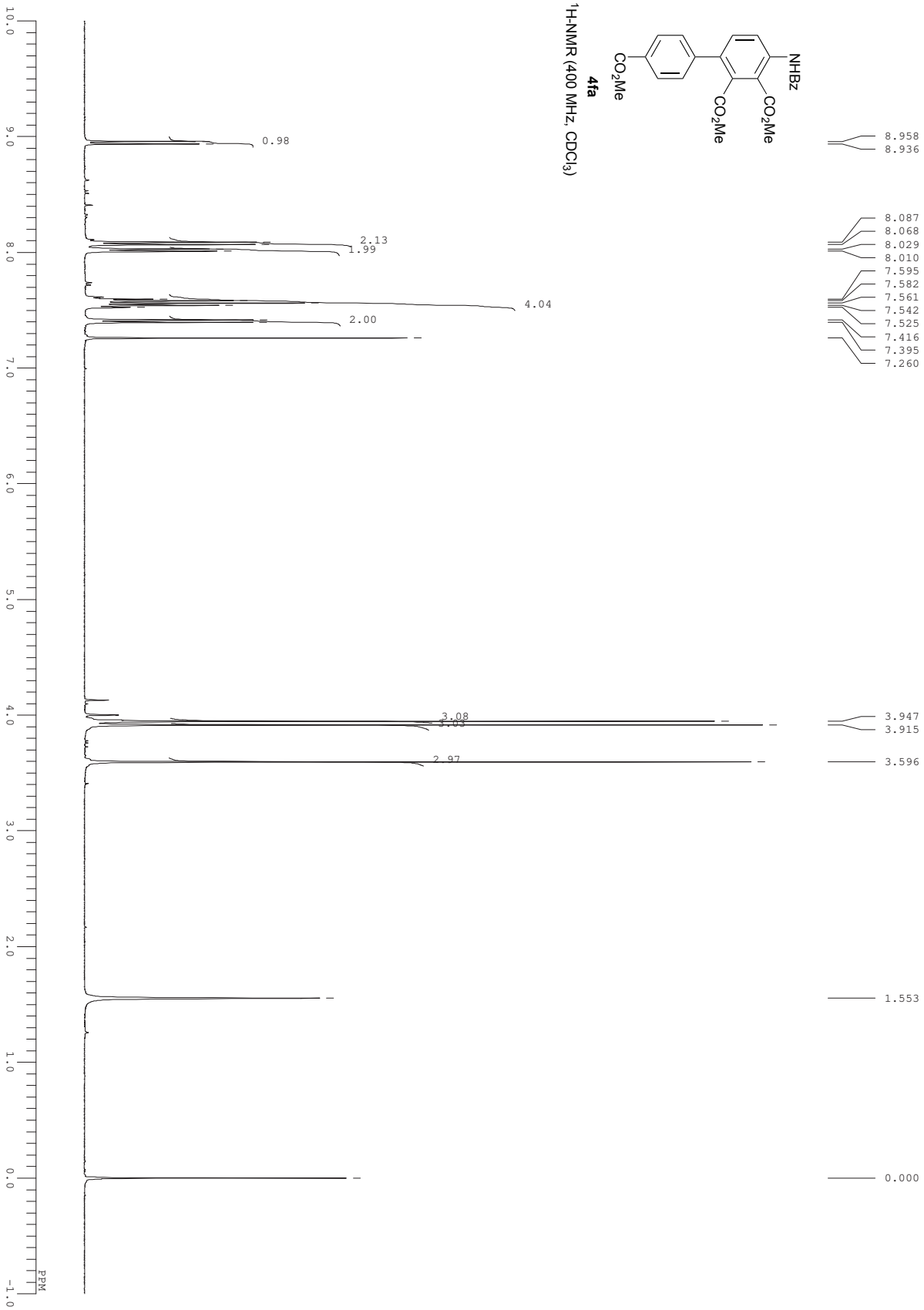

4ca
^{13}C-NMR (100 MHz, $CDCl_3$)
Me
CO_2Me
CO_2Me
NHBz
168.955
168.083
165.531
139.203
137.434
136.281
135.483
135.294
134.677
134.463
132.158
128.990
128.866
128.265
127.311
122.175
115.147
77.321
77.000
76.679
52.993
52.145
21.150
PPM

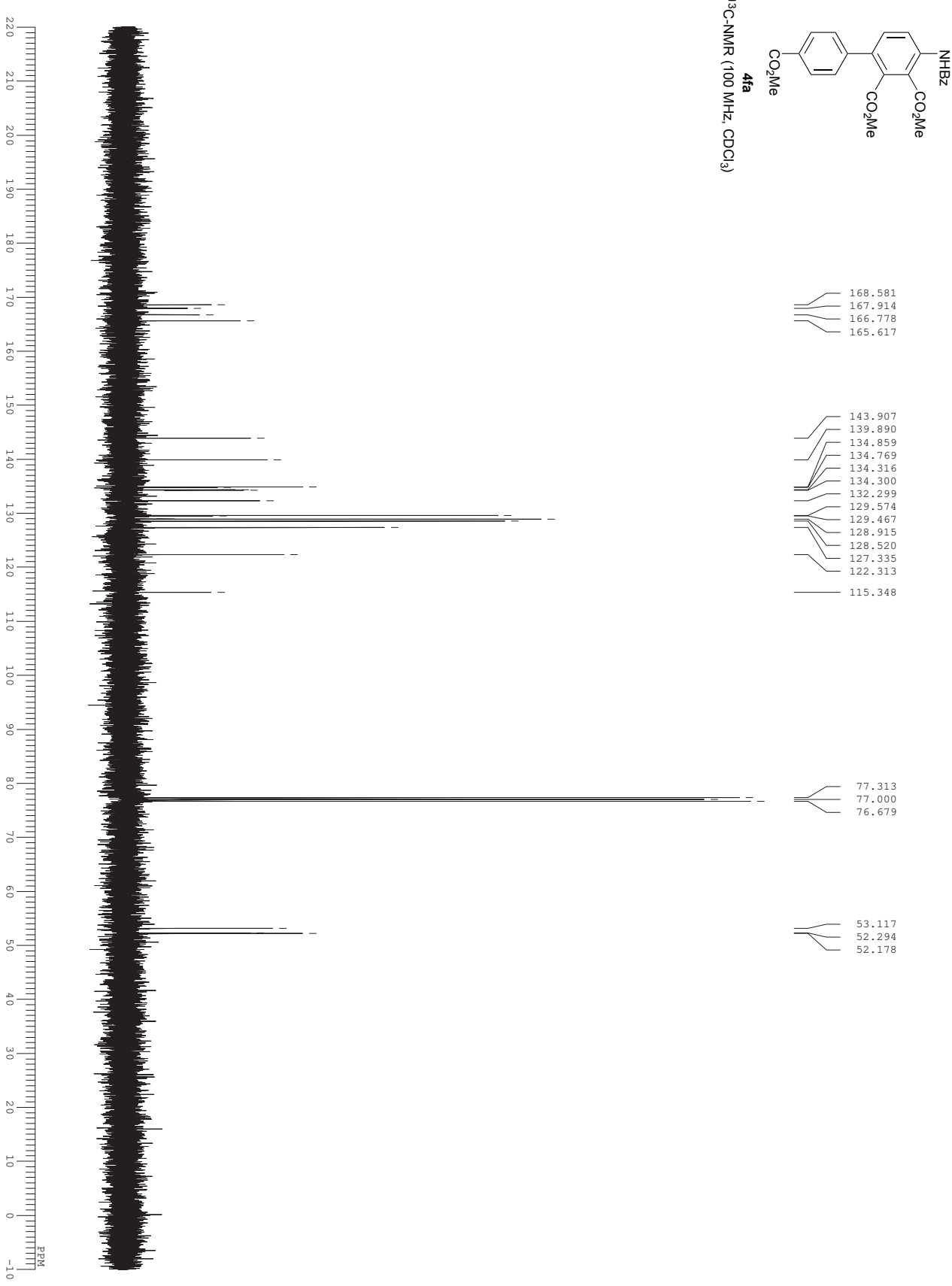

4da
^{1}H-NMR (400 MHz, CDCl$_3$)
Br
NHBz
CO$_2$Me
CO$_2$Me
0.97
1.00
2.02
6.06
1.97
3.00
3.02
11.280
8.934
8.912
8.024
8.007
7.610
7.592
7.575
7.558
7.539
7.521
7.259
7.211
7.190
3.914
3.627
1.542
0.000
PPM

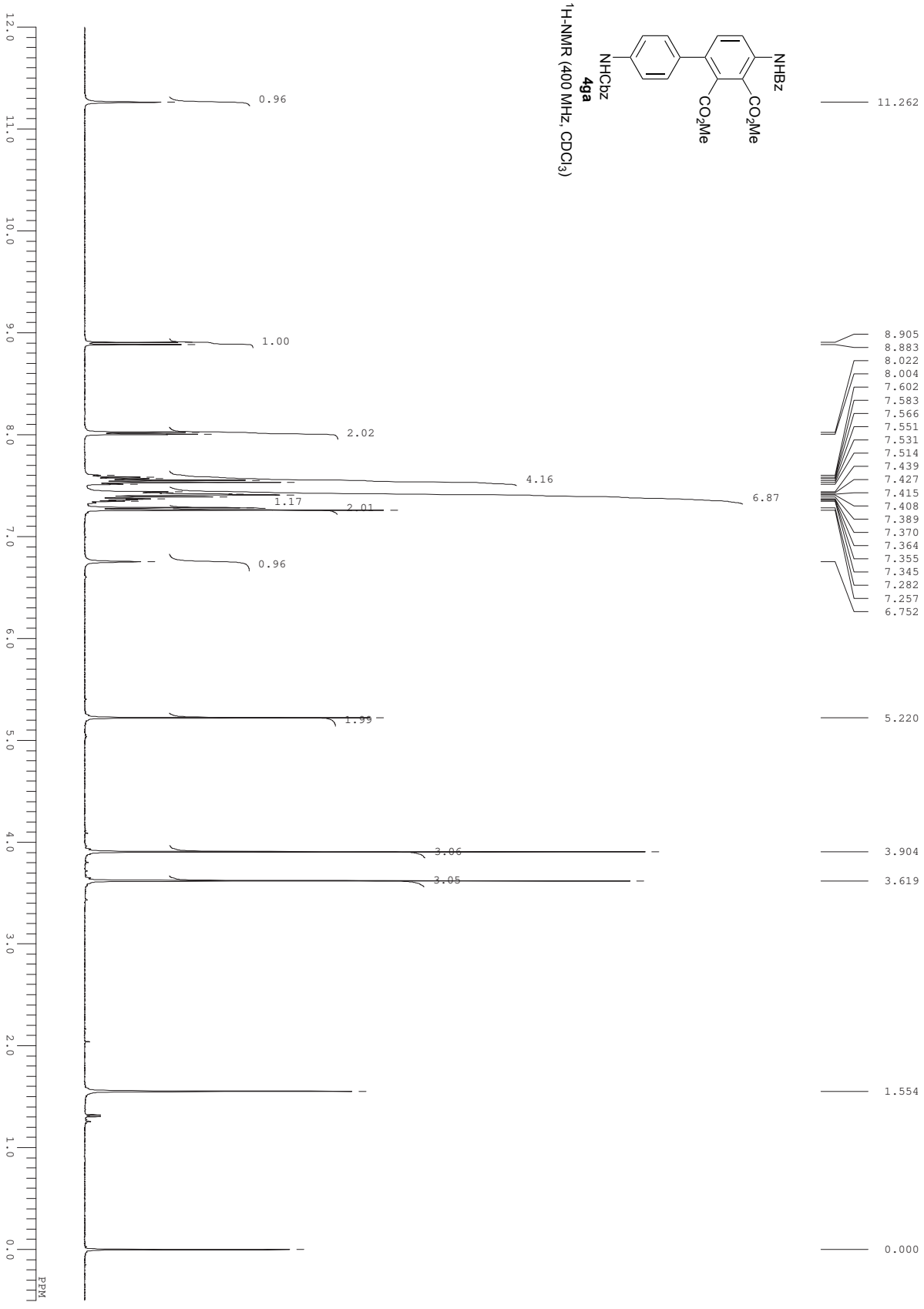

4da
13C-NMR (100 MHz, CDCl3)
Br
NHBz
CO2Me
CO2Me
168.626
167.885
165.564
139.730
138.125
134.956
134.710
134.331
134.068
132.249
131.434
130.125
128.891
127.319
122.274
122.126
115.171
77.321
77.000
76.679
53.092
52.285
PPM


4ea
^{1}H-NMR (400 MHz, CDCl$_3$)
NHBz
CO$_2$Me
CO$_2$Me
0.94
1.00
2.01
2.04
4.05
2.00
2.99
2.98
11.291
8.935
8.912
8.025
8.007
7.747
7.725
7.596
7.577
7.561
7.542
7.515
7.261
7.082
7.061
3.916
3.634
2.172
1.554
1.549
0.000
PPM


4ea
^{13}C-NMR (100 MHz, $CDCl_3$)
I
NHBz
CO_2Me
CO_2Me
168.667
167.910
165.597
139.730
138.726
137.417
134.956
134.635
134.314
134.142
132.290
130.315
128.916
127.335
122.307
115.179
93.781
77.321
77.000
76.679
53.141
52.359
PPM


4fa
^{1}H-NMR (400 MHz, $CDCl_3$)
CO_2Me
CO_2Me
CO_2Me
NHBz
0.98
2.13
1.99
4.04
2.00
3.08
3.03
2.97
8.958
8.936
8.087
8.068
8.029
8.010
7.595
7.582
7.561
7.542
7.525
7.416
7.395
7.260
3.947
3.915
3.596
1.553
0.000
PPM


4fa
^{13}C-NMR (100 MHz, CDCl$_3$)
NHBz
CO$_2$Me
CO$_2$Me
CO$_2$Me
168.581
167.914
166.778
165.617
143.907
139.890
134.859
134.769
134.316
134.300
132.299
129.574
129.467
128.915
128.520
127.335
122.313
115.348
77.313
77.000
76.679
53.117
52.294
52.178
PPM


1H-NMR (400 MHz, CDCl3)
4ga
NHCbz
NHBz
CO2Me
CO2Me
0.96
1.00
2.02
4.16
1.17
2.01
6.87
0.96
1.99
3.06
3.05
11.262
8.905
8.883
8.022
8.004
7.602
7.583
7.566
7.551
7.531
7.514
7.439
7.427
7.415
7.408
7.389
7.370
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7.257
6.752
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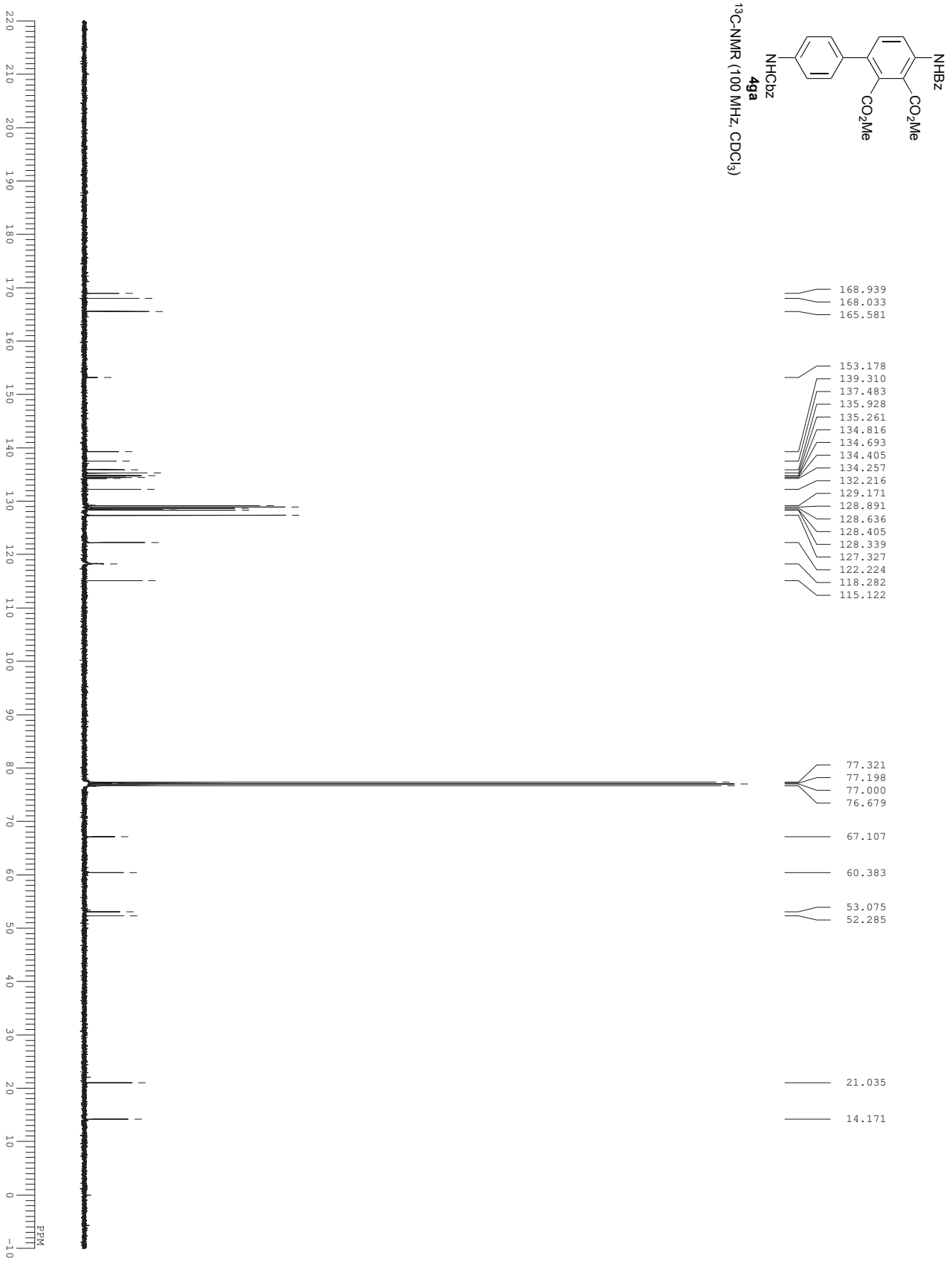
13C-NMR (100 MHz, CDCl3)
4ga
NHCbz
NHBz
CO2Me
CO2Me
168.939
168.033
165.581
153.178
139.310
137.483
135.928
135.261
134.816
134.693
134.405
134.257
132.216
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128.405
128.339
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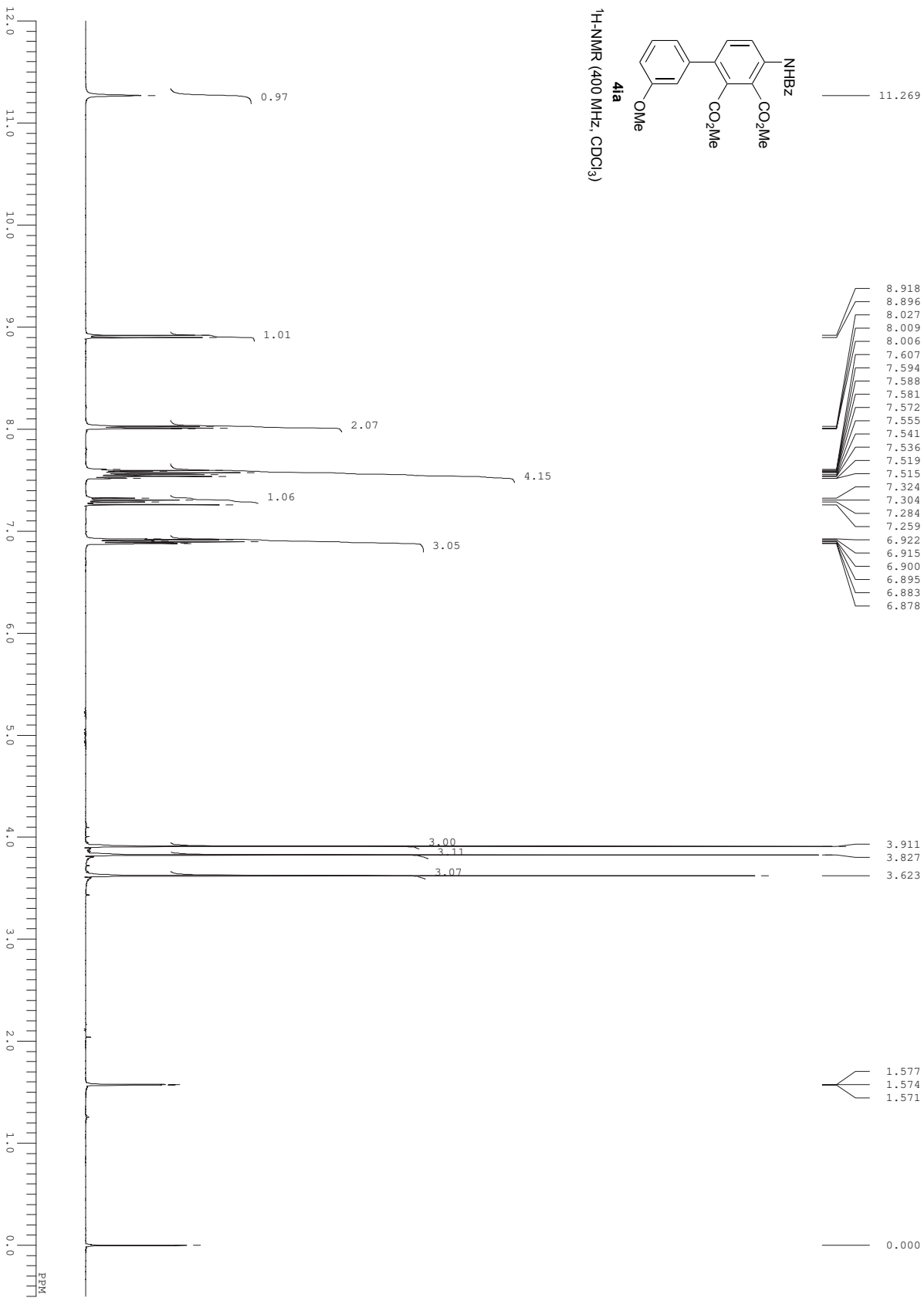
4ia
1H-NMR (400 MHz, CDCl3)
NHBz
CO2Me
CO2Me
OMe
11.269
8.918
8.896
8.027
8.009
8.006
7.607
7.594
7.588
7.581
7.572
7.555
7.541
7.536
7.519
7.515
7.324
7.304
7.284
7.259
6.922
6.915
6.900
6.895
6.883
6.878
0.97
1.01
2.07
4.15
1.06
3.05
3.00
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3.07
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3.827
3.623
1.577
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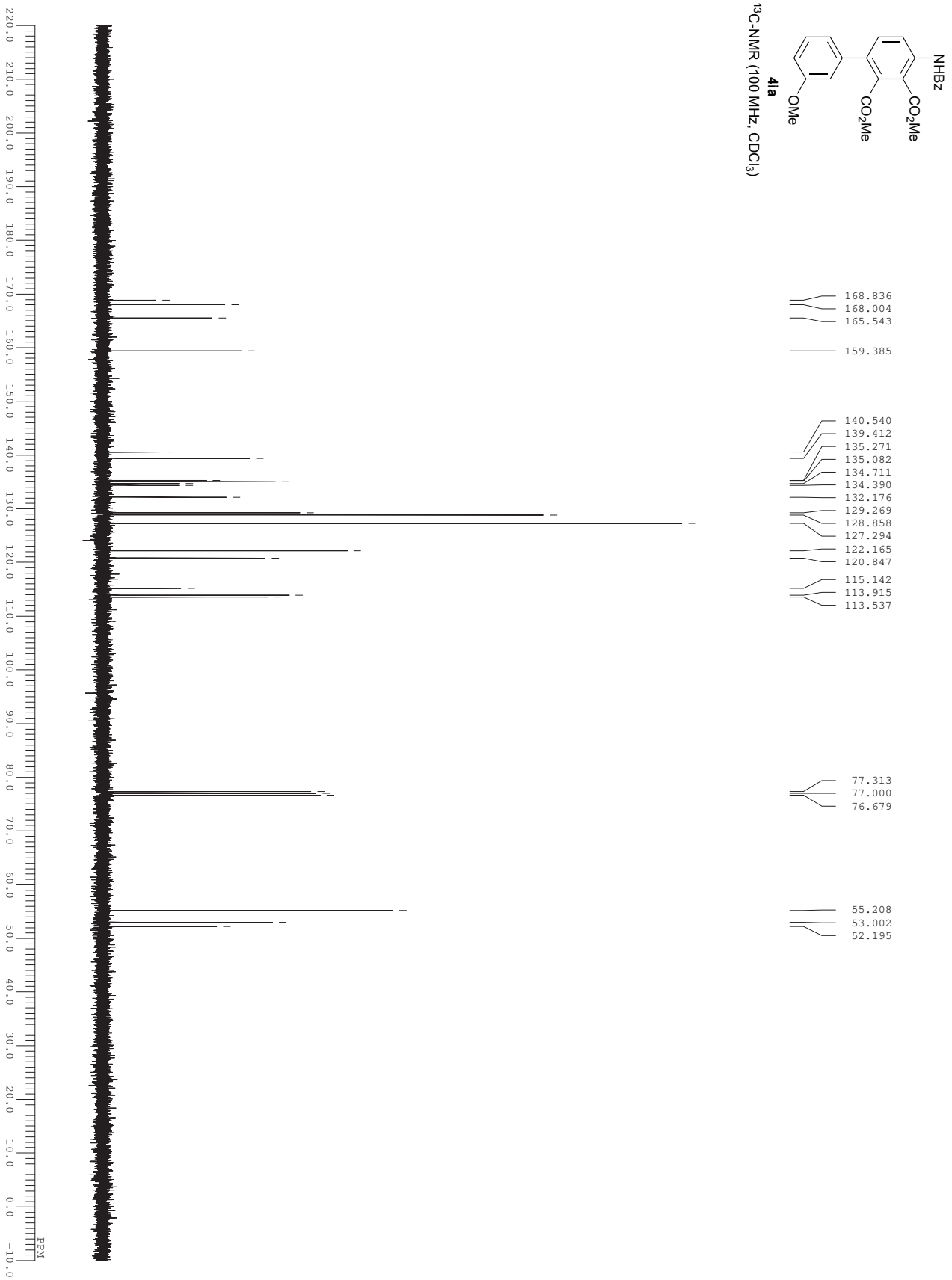
0.000
PPM


4ia
13C-NMR (100 MHz, CDCl3)
NHBz
CO2Me
CO2Me
OMe
168.836
168.004
165.543
159.385
140.540
139.412
135.271
135.082
134.711
134.390
132.176
129.269
128.858
127.294
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115.142
113.915
113.537
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76.679
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53.002
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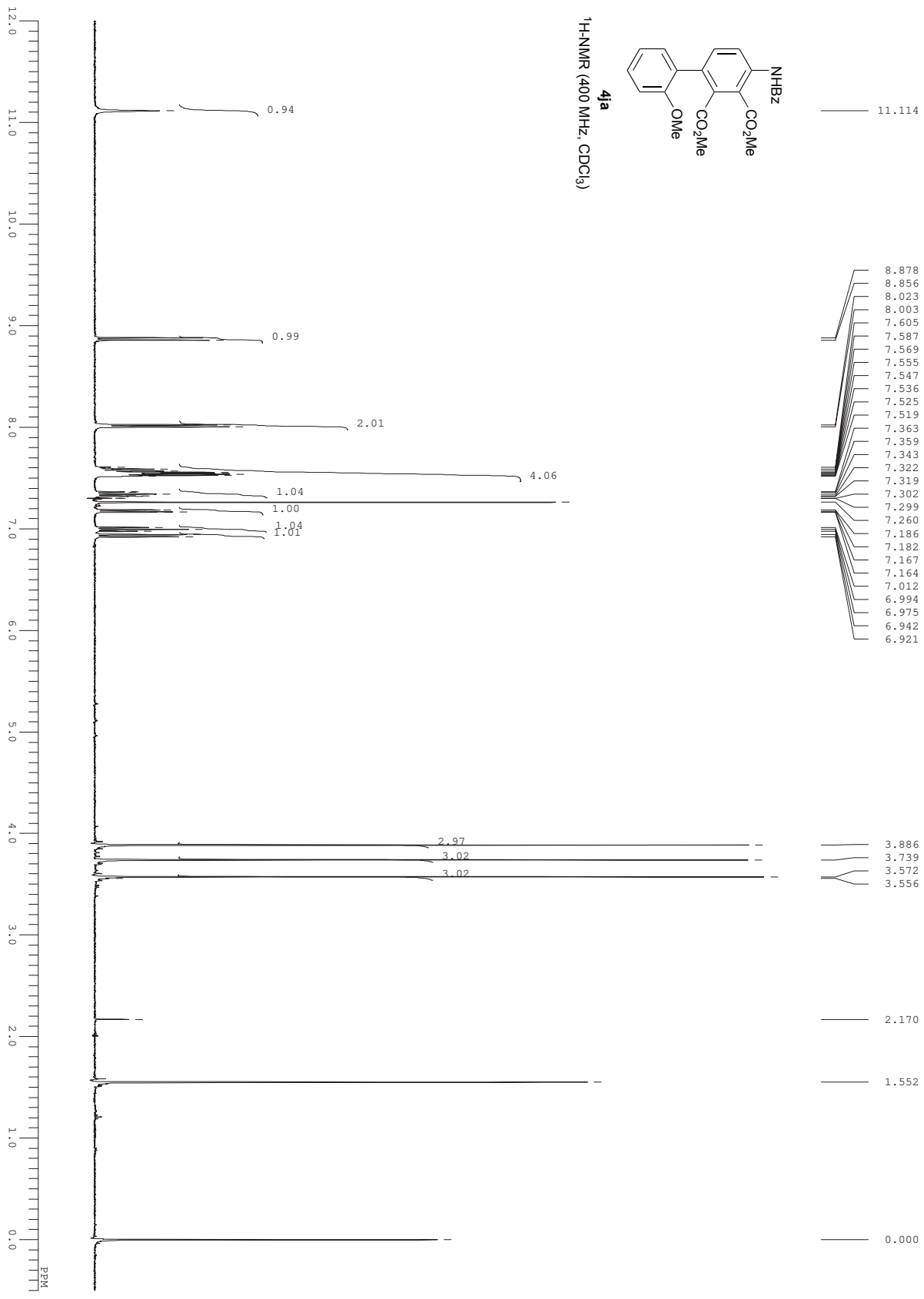
PPM


4ja
1H-NMR (400 MHz, CDCl3)
NHBz
CO2Me
CO2Me
OMe
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8.003
7.605
7.587
7.569
7.555
7.547
7.536
7.525
7.519
7.363
7.359
7.343
7.322
7.319
7.302
7.299
7.260
7.186
7.182
7.167
7.164
7.012
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6.975
6.942
6.921
3.886
3.739
3.572
3.556
2.170
1.552
0.000
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1.01
2.97
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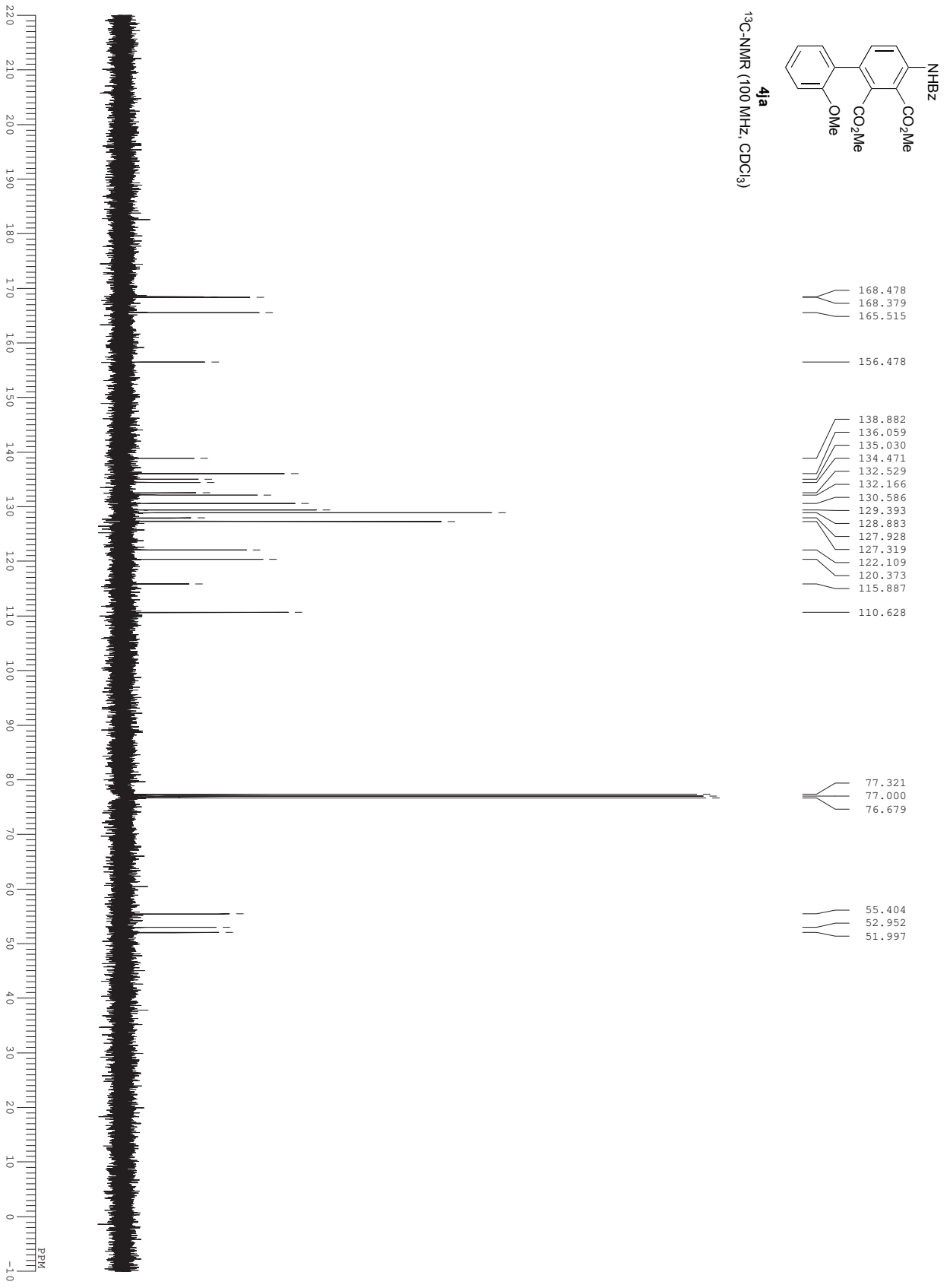
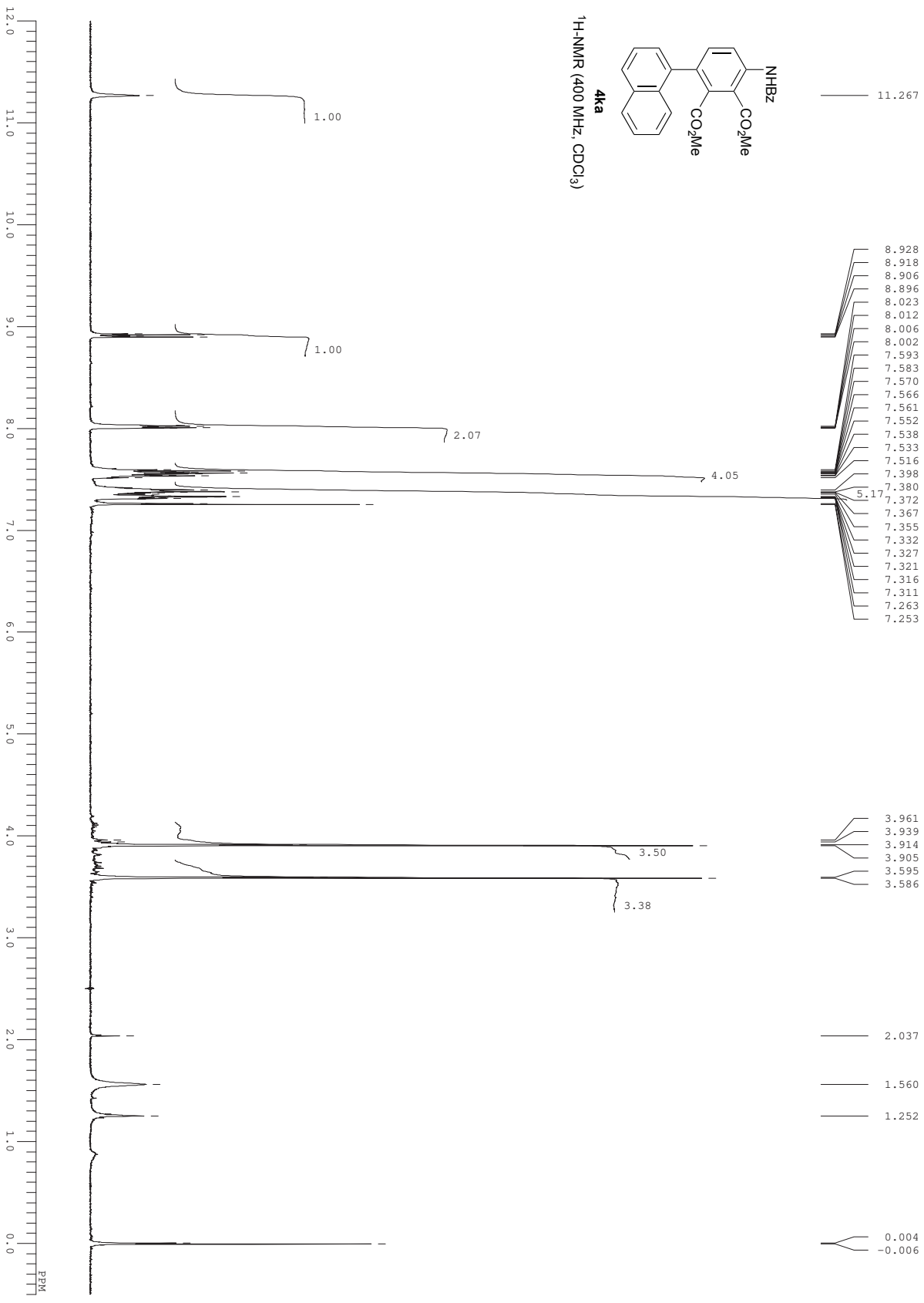

4ja
^{13}C-NMR (100 MHz, $CDCl_3$)
NHBz
CO_2Me
CO_2Me
OMe
168.478
168.379
165.515
156.478
138.882
136.059
135.030
134.471
132.529
132.166
130.586
129.393
128.883
127.928
127.319
122.109
120.373
115.887
110.628
77.321
77.000
76.679
55.404
52.952
51.997
PPM


4ka
1H-NMR (400 MHz, CDCl3)
NHBz
CO2Me
CO2Me
1.00
1.00
2.07
4.05
5.17
3.50
3.38
11.267
8.928
8.918
8.906
8.896
8.023
8.012
8.006
8.002
7.593
7.583
7.570
7.566
7.561
7.552
7.538
7.533
7.516
7.398
7.380
7.372
7.367
7.355
7.332
7.327
7.321
7.316
7.311
7.263
7.253
3.961
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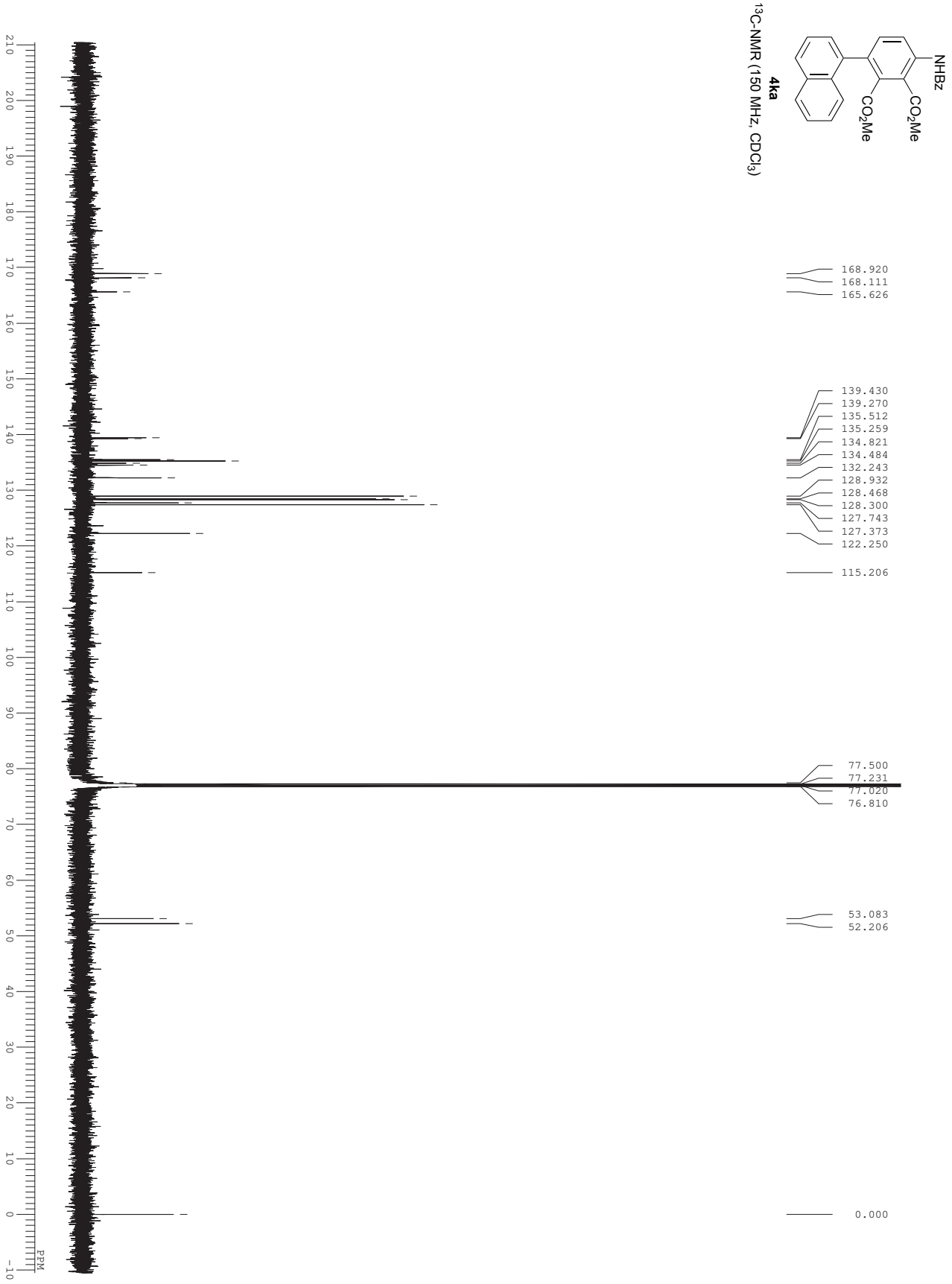
3.586
2.037
1.560
1.252
0.004
-0.006
PPM


4ka
^{13}C-NMR (150 MHz, $CDCl_3$)
NHBz
CO_2Me
CO_2Me
168.920
168.111
165.626
139.430
139.270
135.512
135.259
134.821
134.484
132.243
128.932
128.468
128.300
127.743
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122.250
115.206
77.500
77.231
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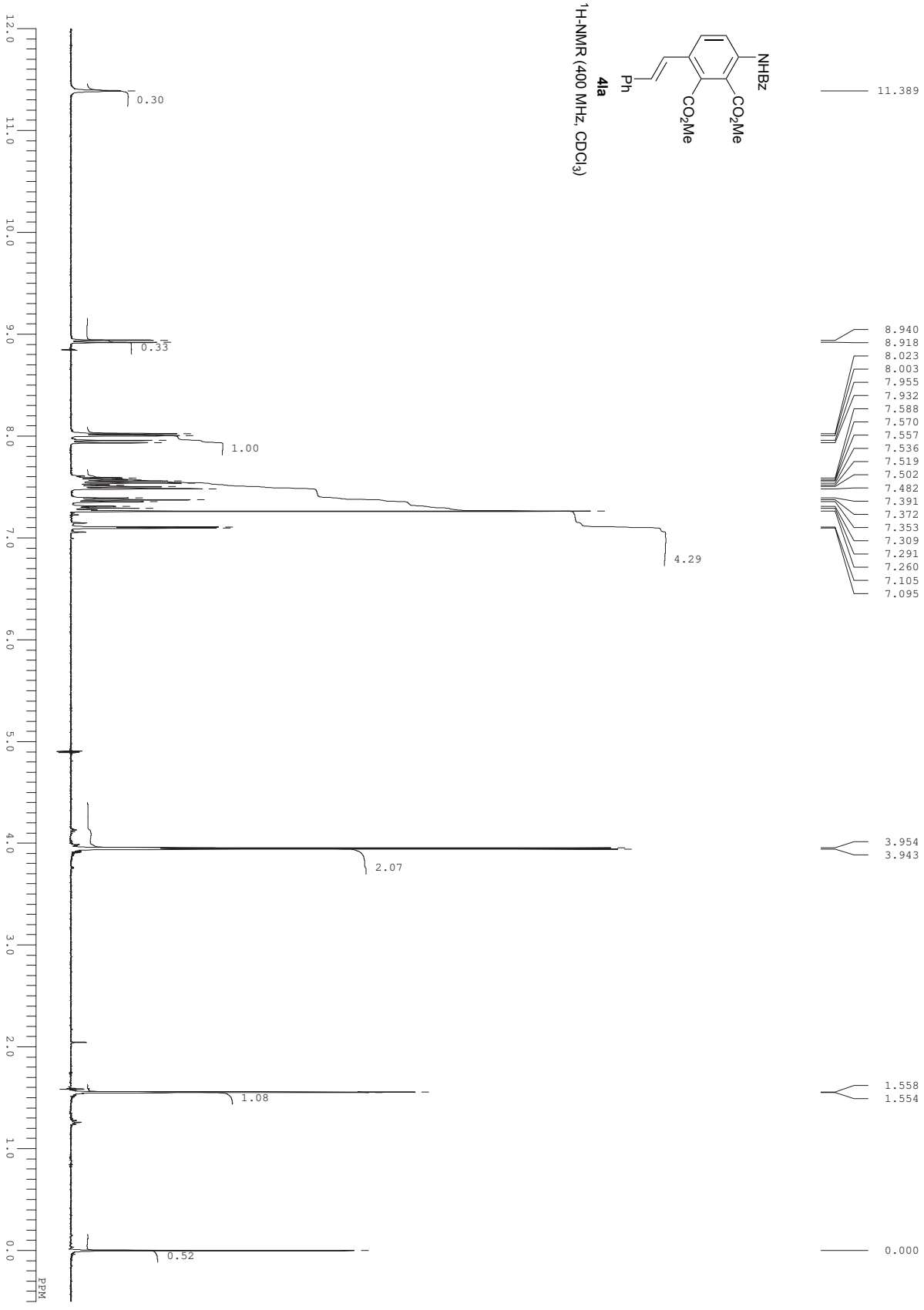
PPM


4la
^{1}H-NMR (400 MHz, CDCl$_3$)
Ph
NHBz
CO$_2$Me
CO$_2$Me
11.389
8.940
8.918
8.023
8.003
7.955
7.932
7.588
7.570
7.557
7.536
7.519
7.502
7.482
7.391
7.372
7.353
7.309
7.291
7.260
7.105
7.095
3.954
3.943
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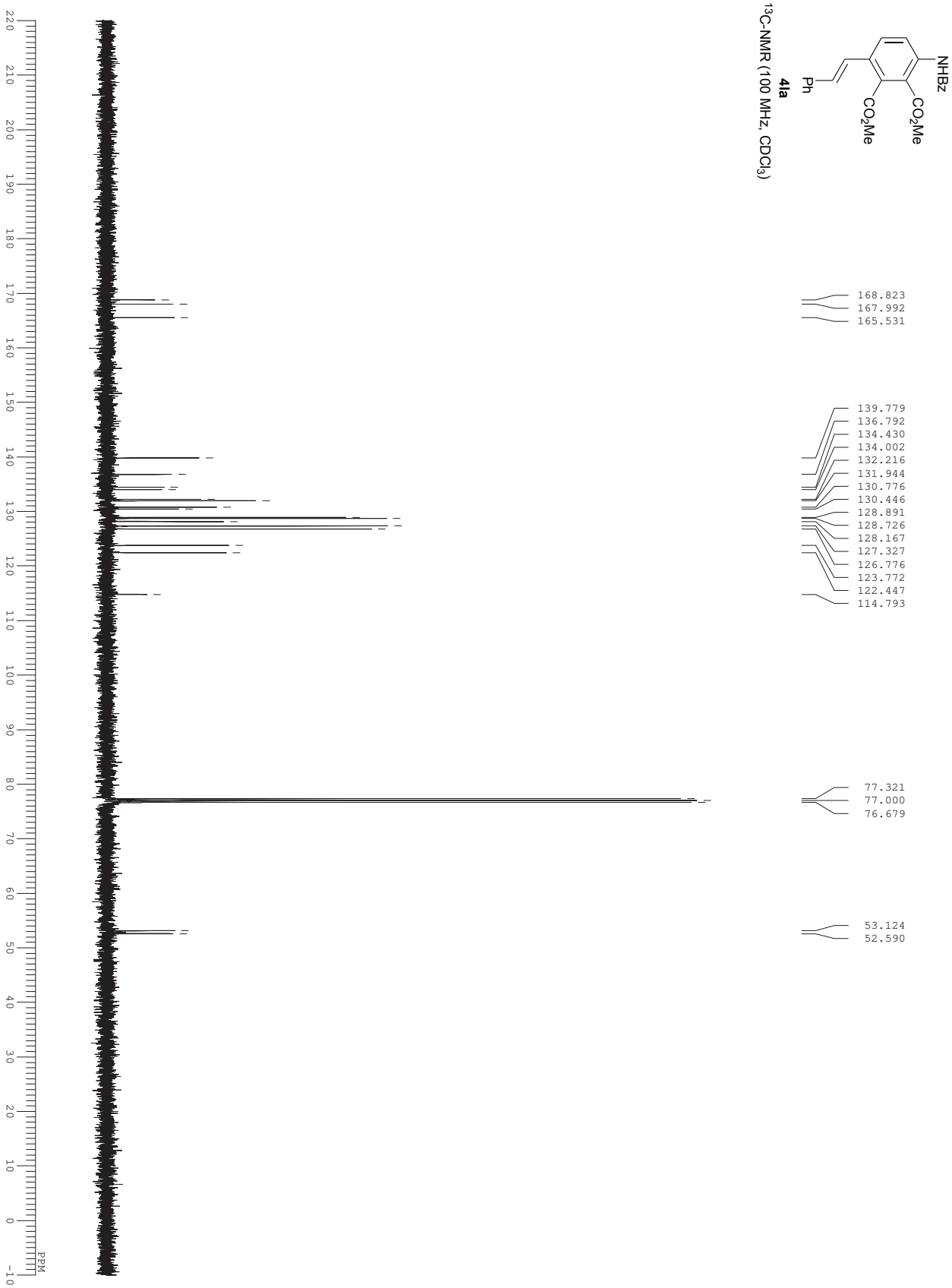
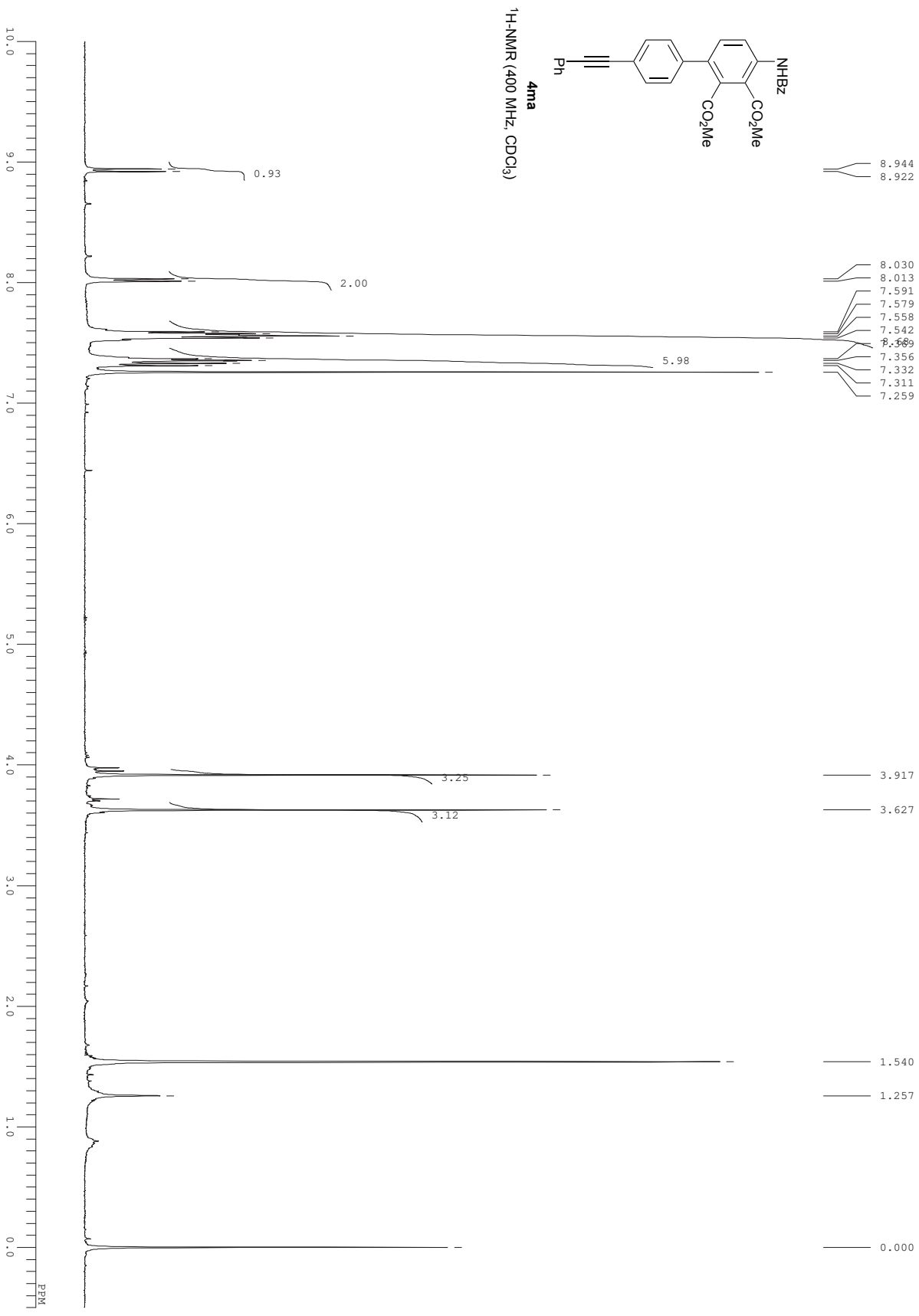
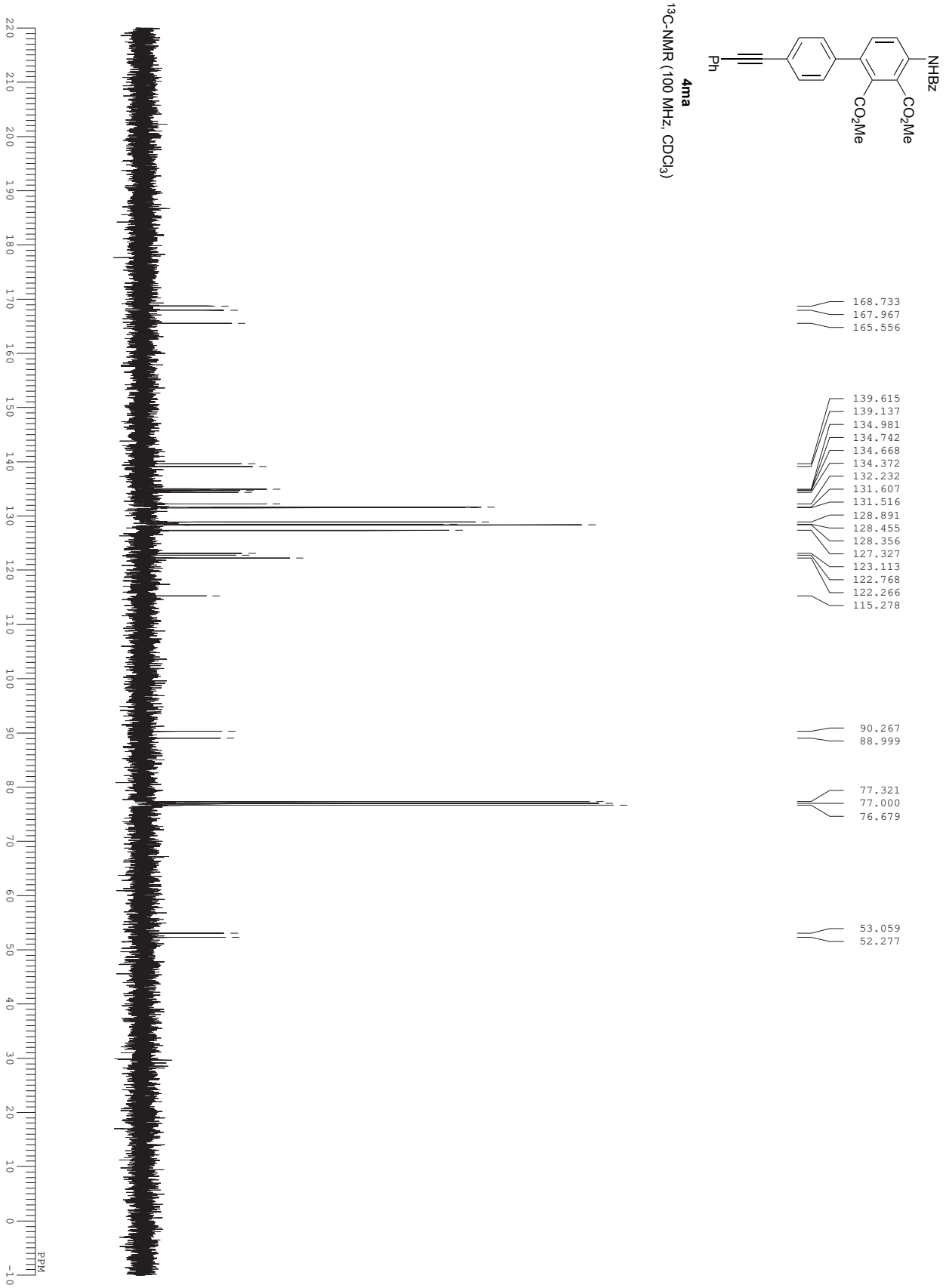
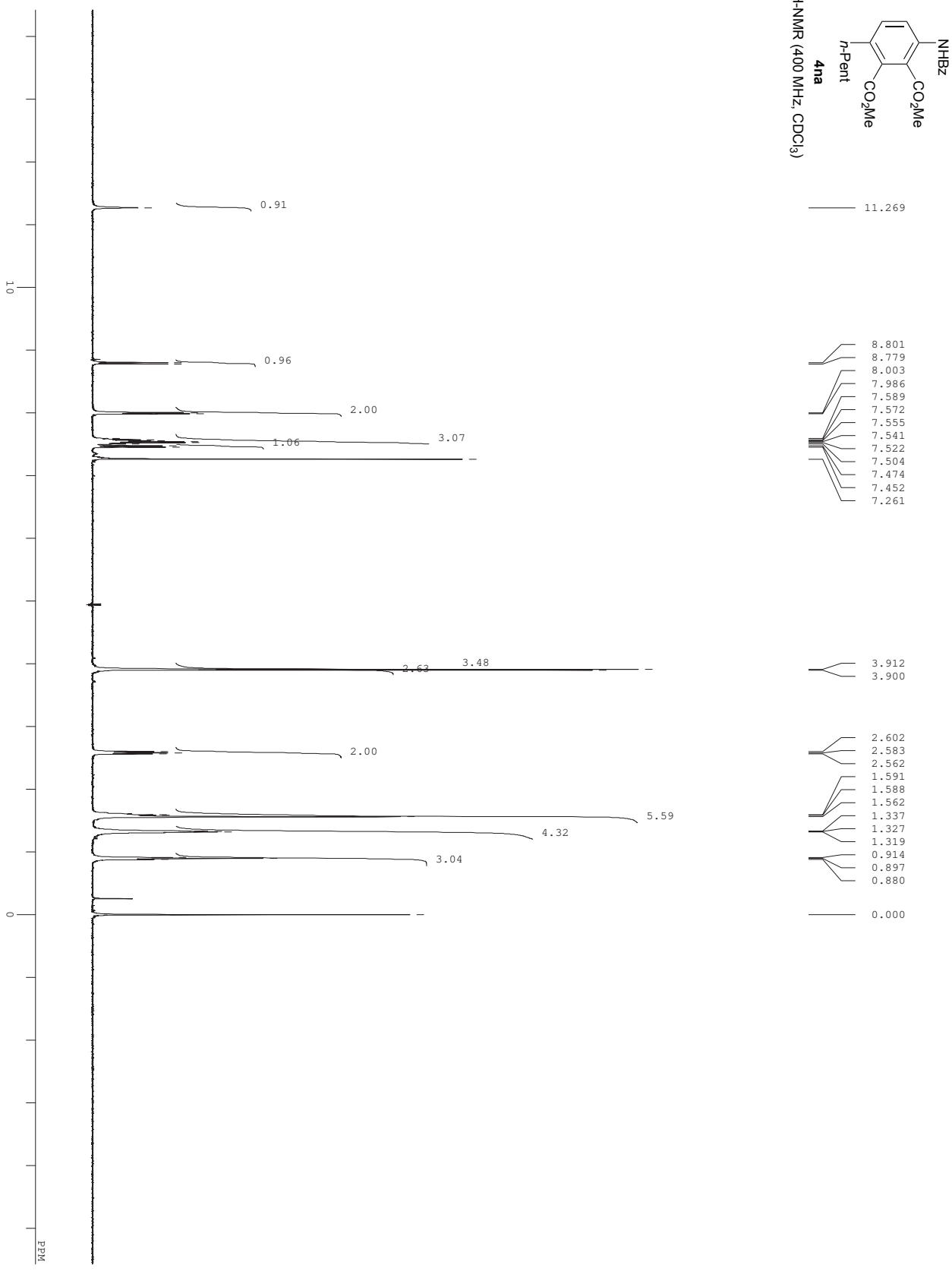
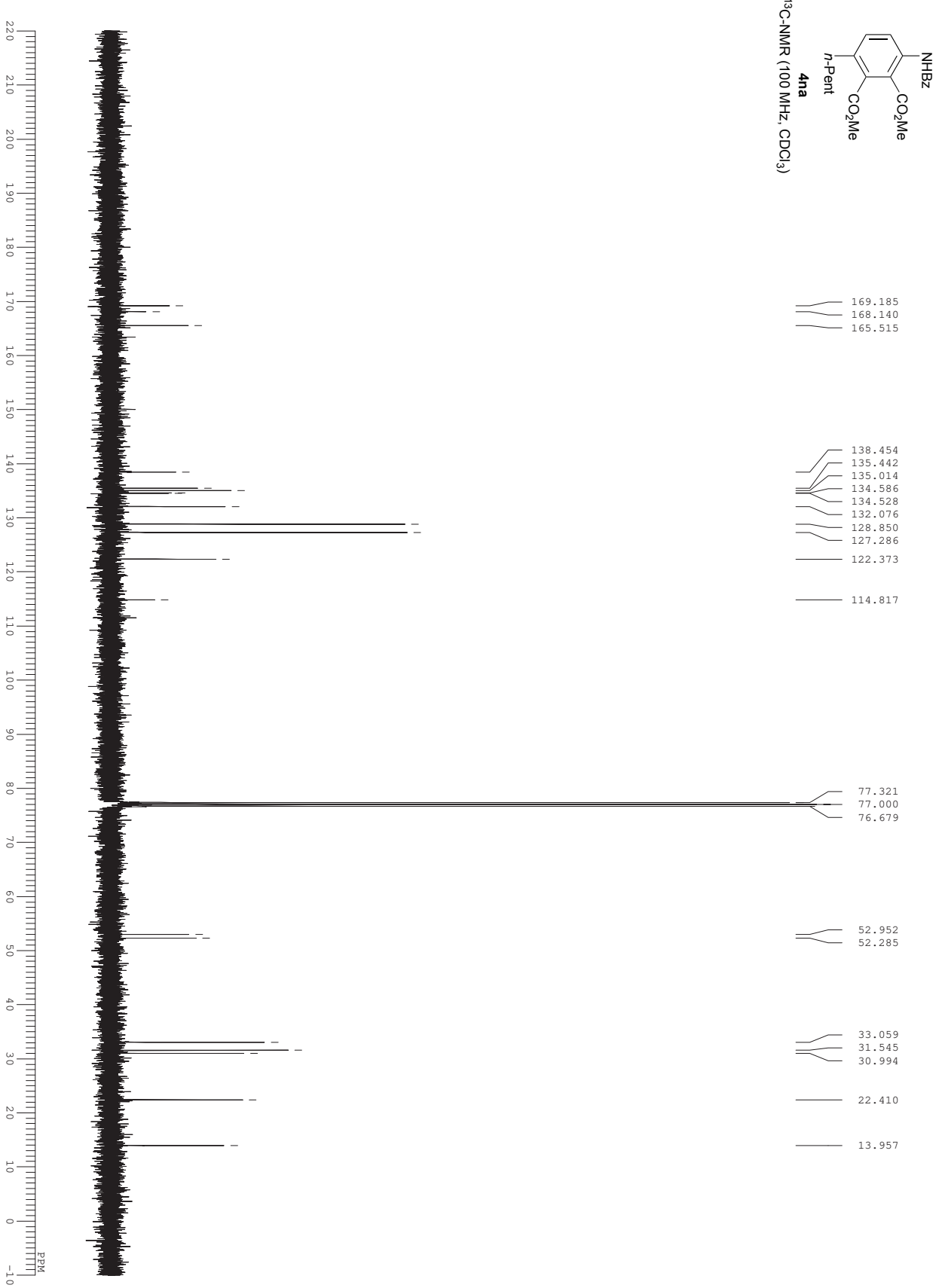
1.554
0.000
0.30
0.33
1.00
4.29
2.07
1.08
0.52
PPM

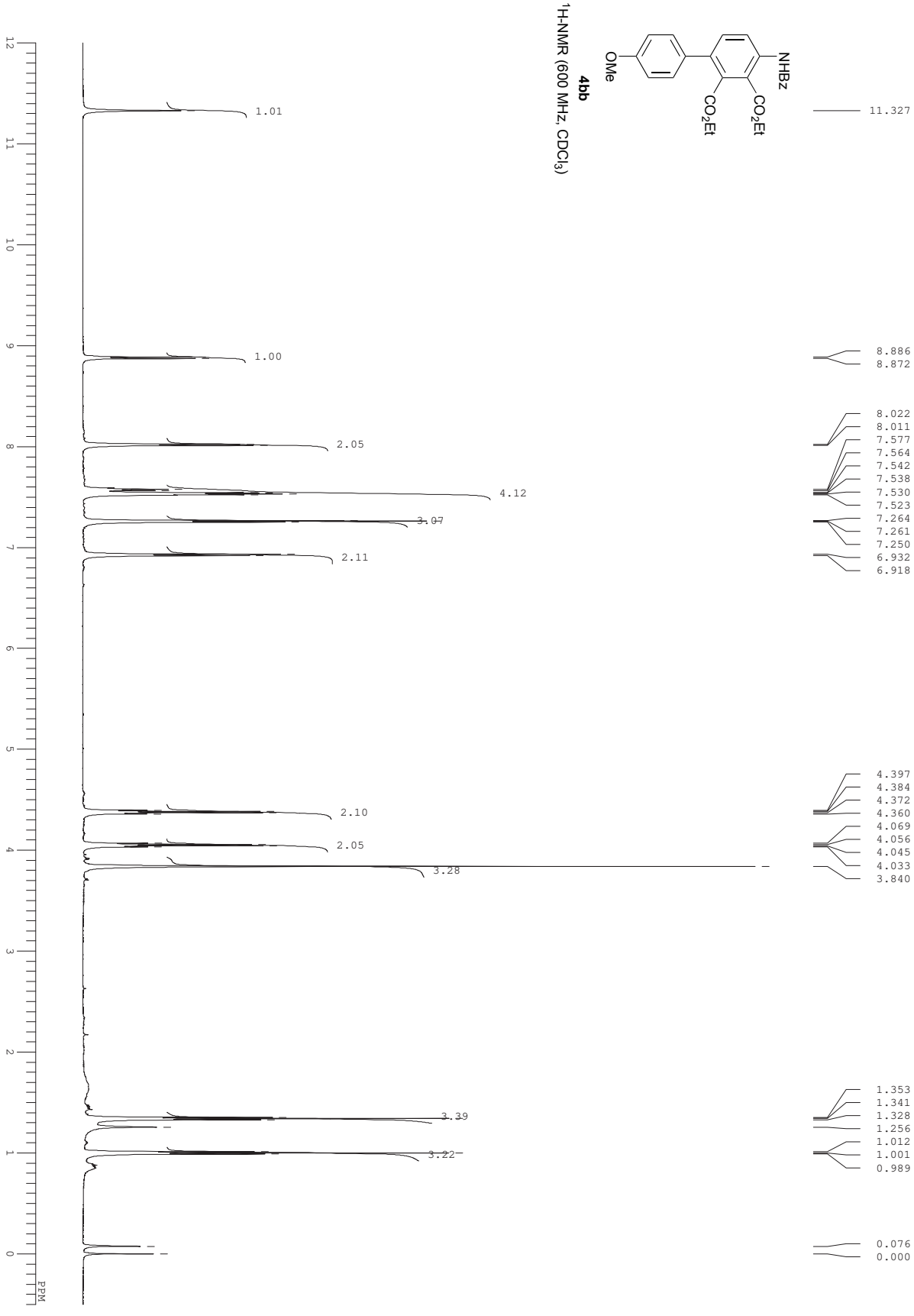

4la
13C-NMR (100 MHz, CDCl3)
NHBz
Ph
CO2Me
CO2Me
168.823
167.992
165.531
139.779
136.792
134.430
134.002
132.216
131.944
130.776
130.446
128.891
128.726
128.167
127.327
126.776
123.772
122.447
114.793
77.321
77.000
76.679
53.124
52.590
PPM

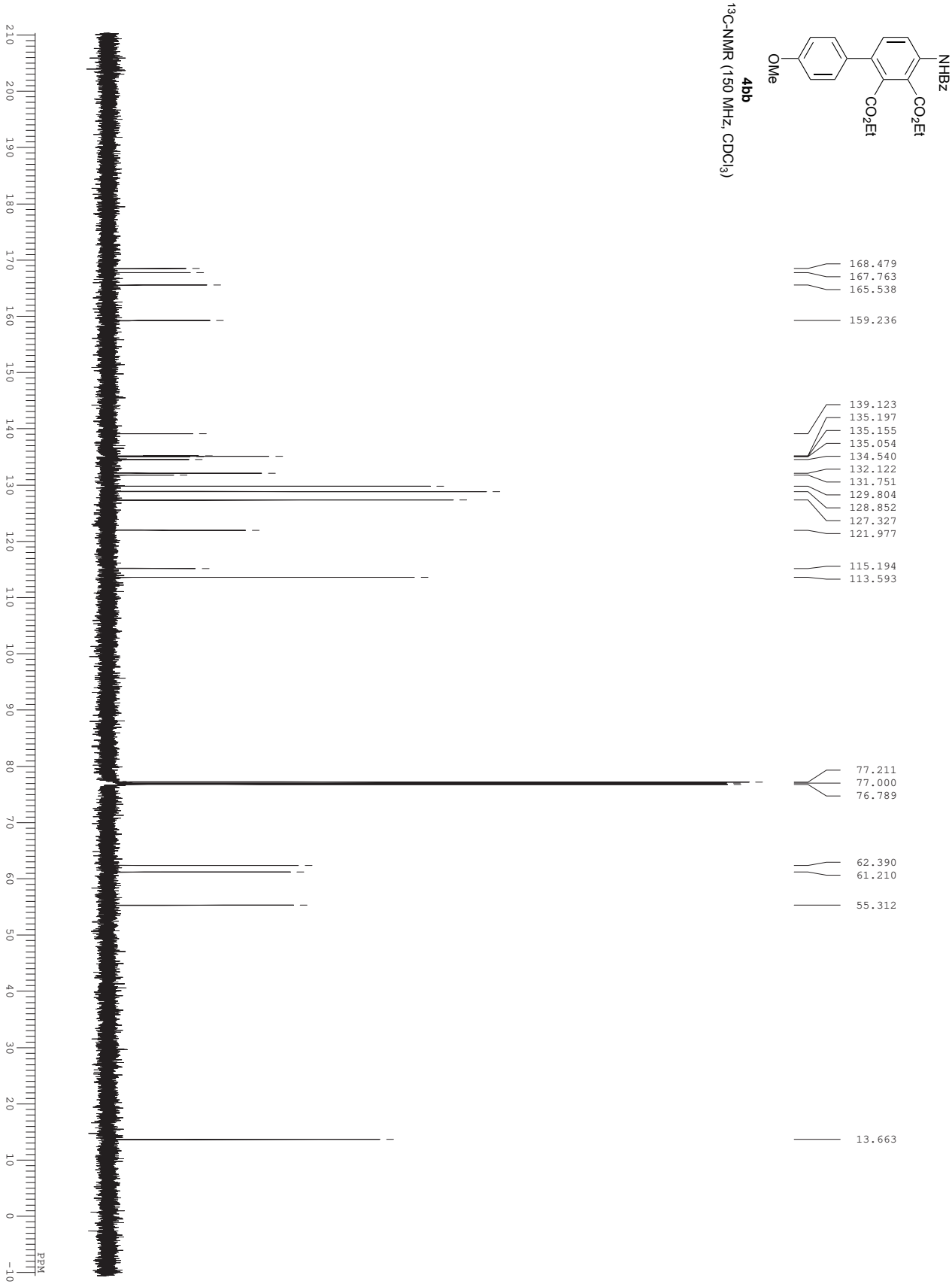

4ma
1H-NMR (400 MHz, CDCl3)
Ph
NHBz
CO2Me
CO2Me
0.93
2.00
5.98
3.25
3.12
8.944
8.922
8.030
8.013
7.591
7.579
7.558
7.542
7.356
7.332
7.311
7.259
3.917
3.627
1.540
1.257
0.000
PPM

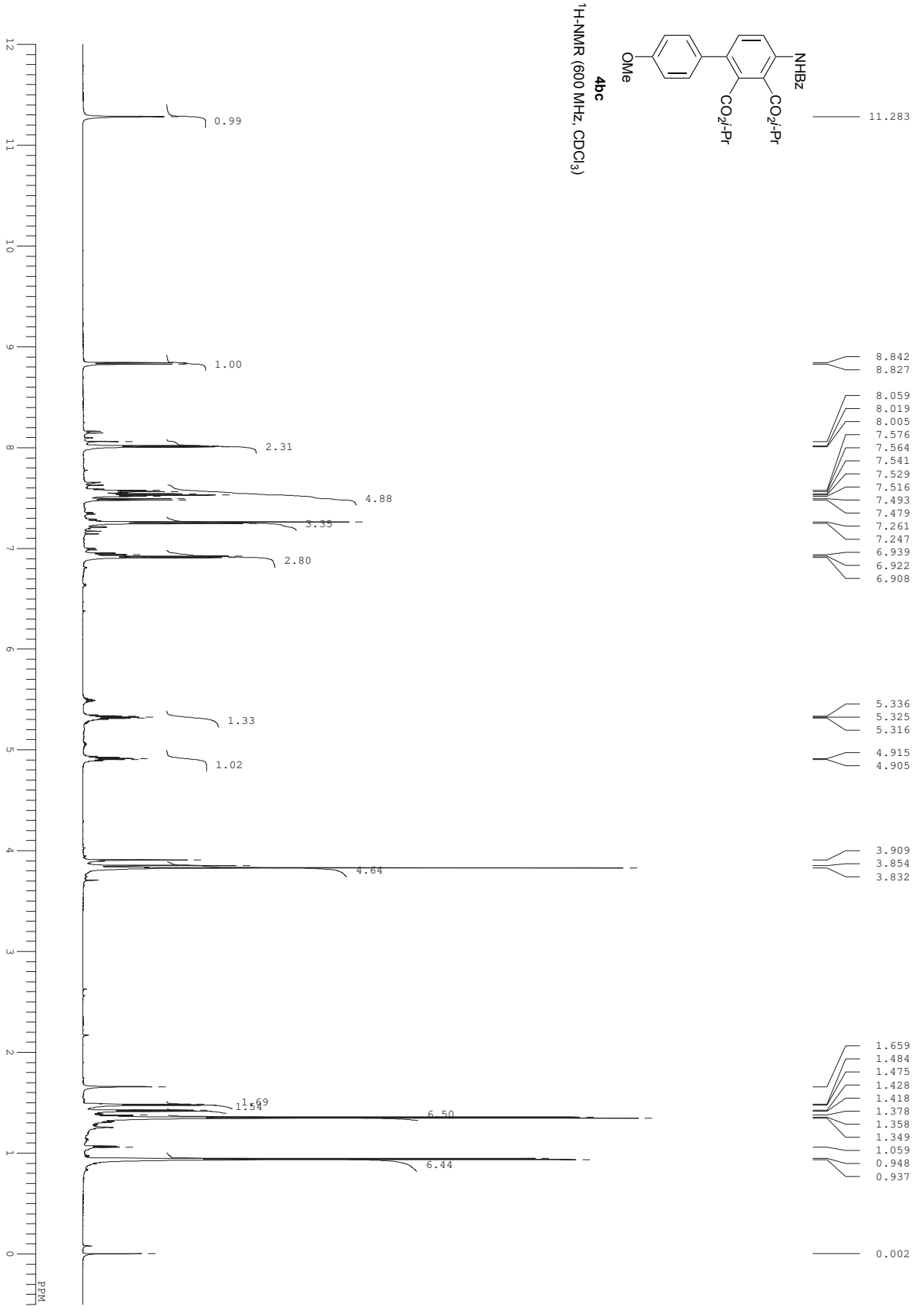

4ma
^{13}C-NMR (100 MHz, CDCl$_3$)
Ph
NHBz
CO$_2$Me
CO$_2$Me
168.733
167.967
165.556
139.615
139.137
134.981
134.742
134.668
134.372
132.232
131.607
131.516
128.891
128.455
128.356
127.327
123.113
122.768
122.266
115.278
90.267
88.999
77.321
77.000
76.679
53.059
52.277
PPM

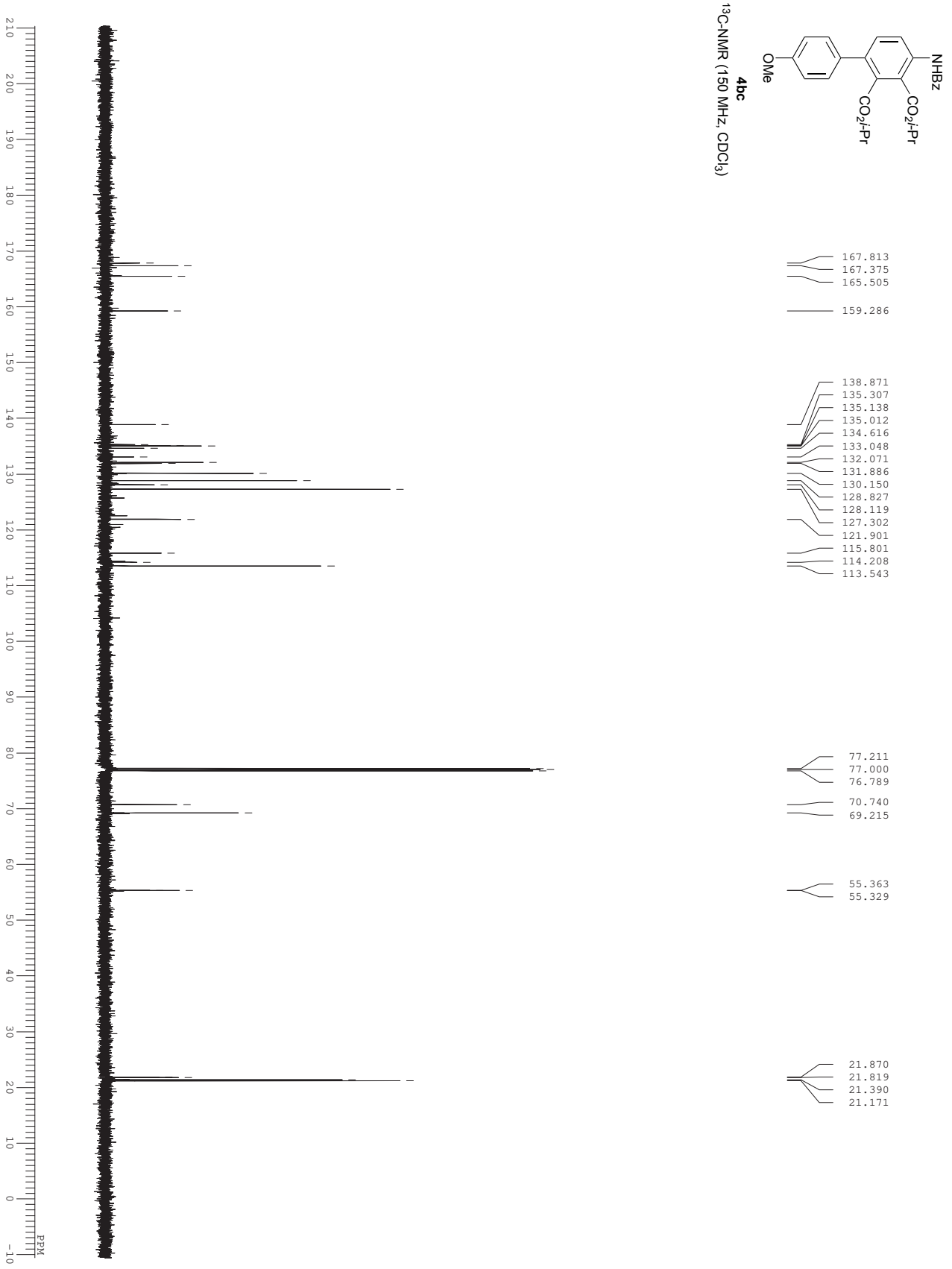

4na
^{1}H-NMR (400 MHz, CDCl$_3$)
NHBz
n-Pent
CO$_2$Me
CO$_2$Me
11.269
8.801
8.779
8.003
7.986
7.589
7.572
7.555
7.541
7.522
7.504
7.474
7.452
7.261
3.912
3.900
2.602
2.583
2.562
1.591
1.588
1.562
1.337
1.327
1.319
0.914
0.897
0.880
0.000
0.91
0.96
2.00
1.06
3.07
2.63
3.48
2.00
5.59
4.32
3.04
10
0
PPM

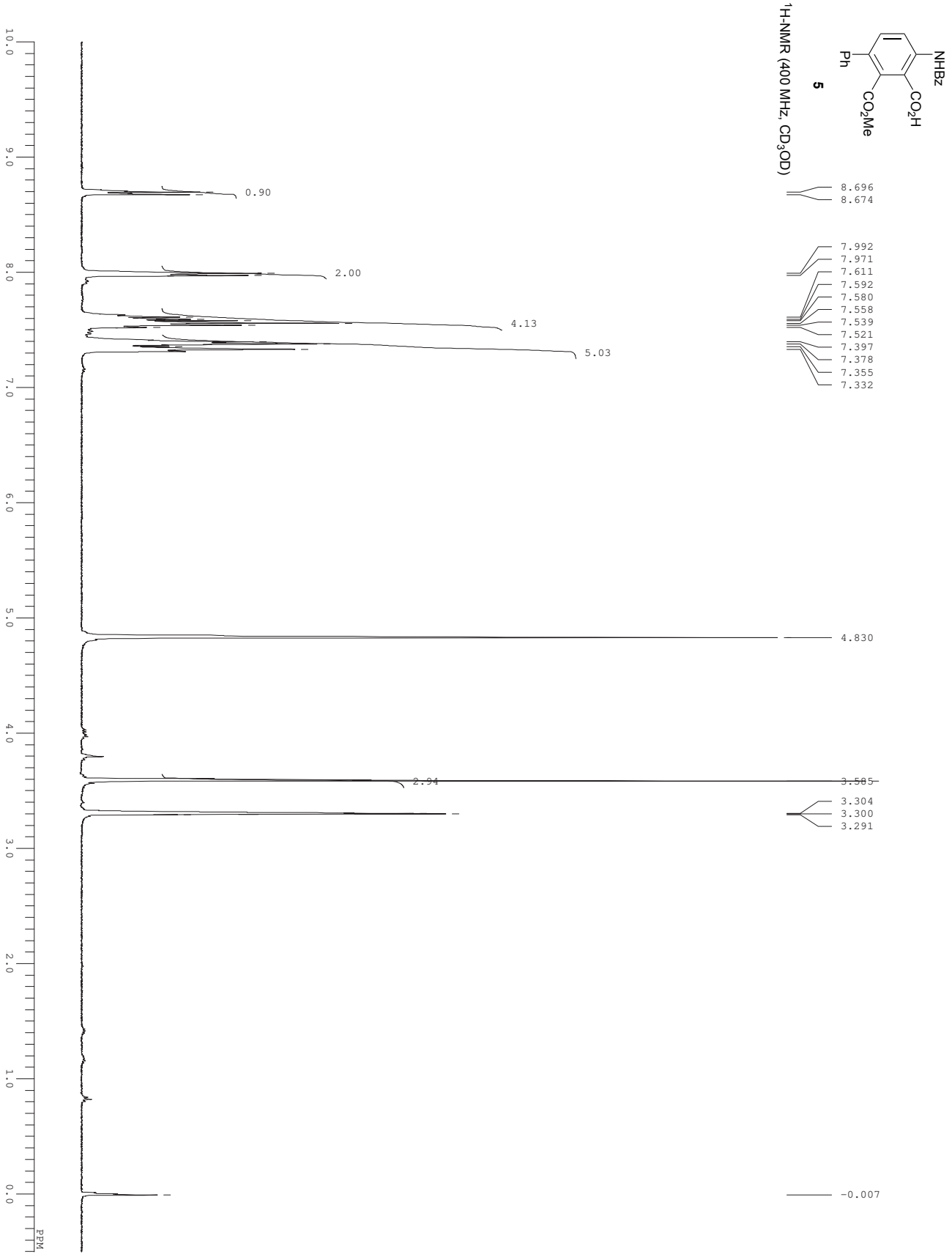

NHBz
CO2Me
CO2Me
n-Pent
4na
13C-NMR (100 MHz, CDCl3)
169.185
168.140
165.515
138.454
135.442
135.014
134.586
134.528
132.076
128.850
127.286
122.373
114.817
77.321
77.000
76.679
52.952
52.285
33.059
31.545
30.994
22.410
13.957
PPM

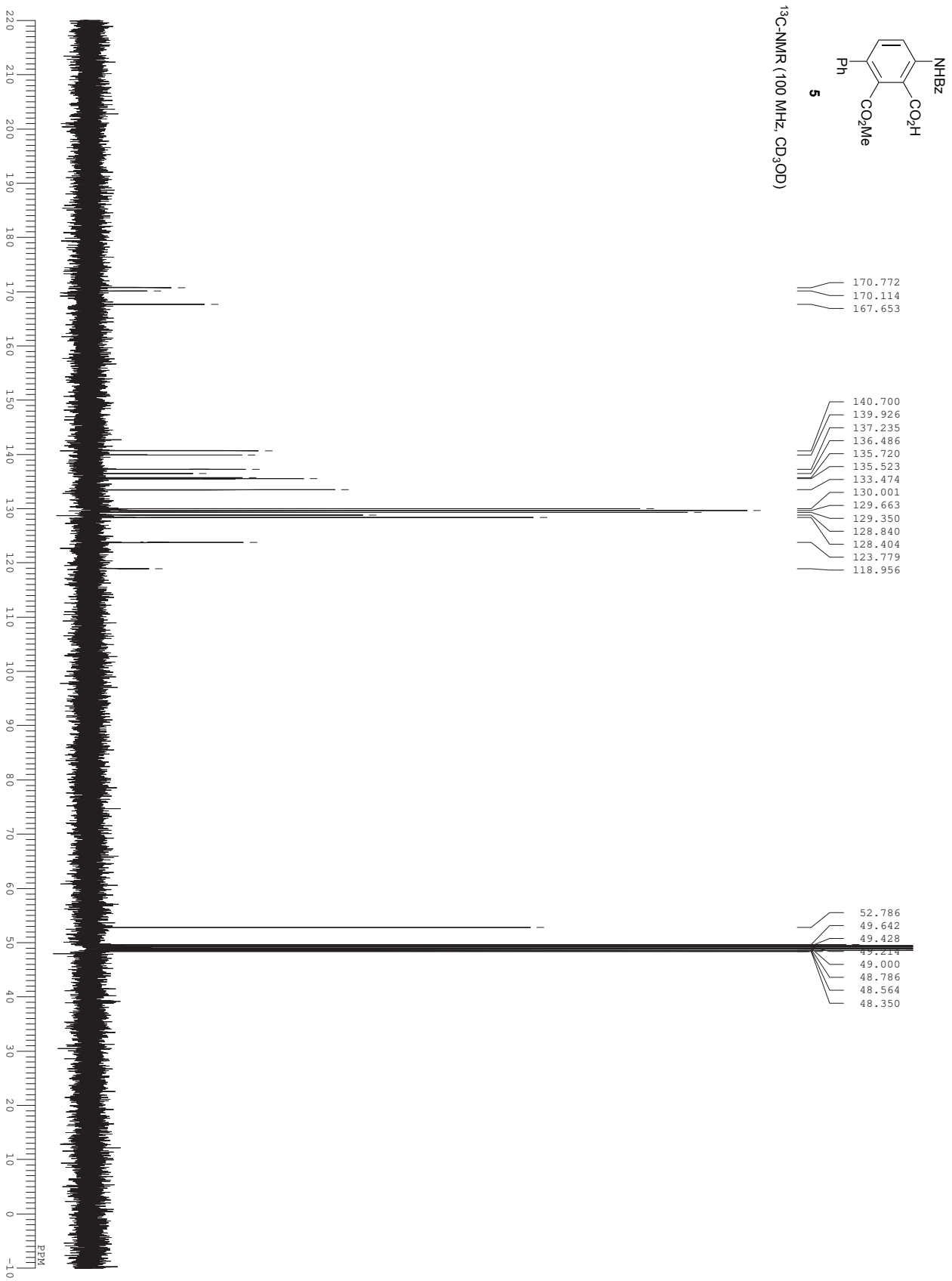

4bb
^{1}H-NMR (600 MHz, $CDCl_3$)
OMe
NHBz
CO_2Et
CO_2Et
11.327
8.886
8.872
8.022
8.011
7.577
7.564
7.542
7.538
7.530
7.523
7.264
7.261
7.250
6.932
6.918
4.397
4.384
4.372
4.360
4.069
4.056
4.045
4.033
3.840
1.353
1.341
1.328
1.256
1.012
1.001
0.989
0.076
0.000
1.01
1.00
2.05
4.12
3.07
2.11
2.10
2.05
3.28
3.39
3.22
PPM

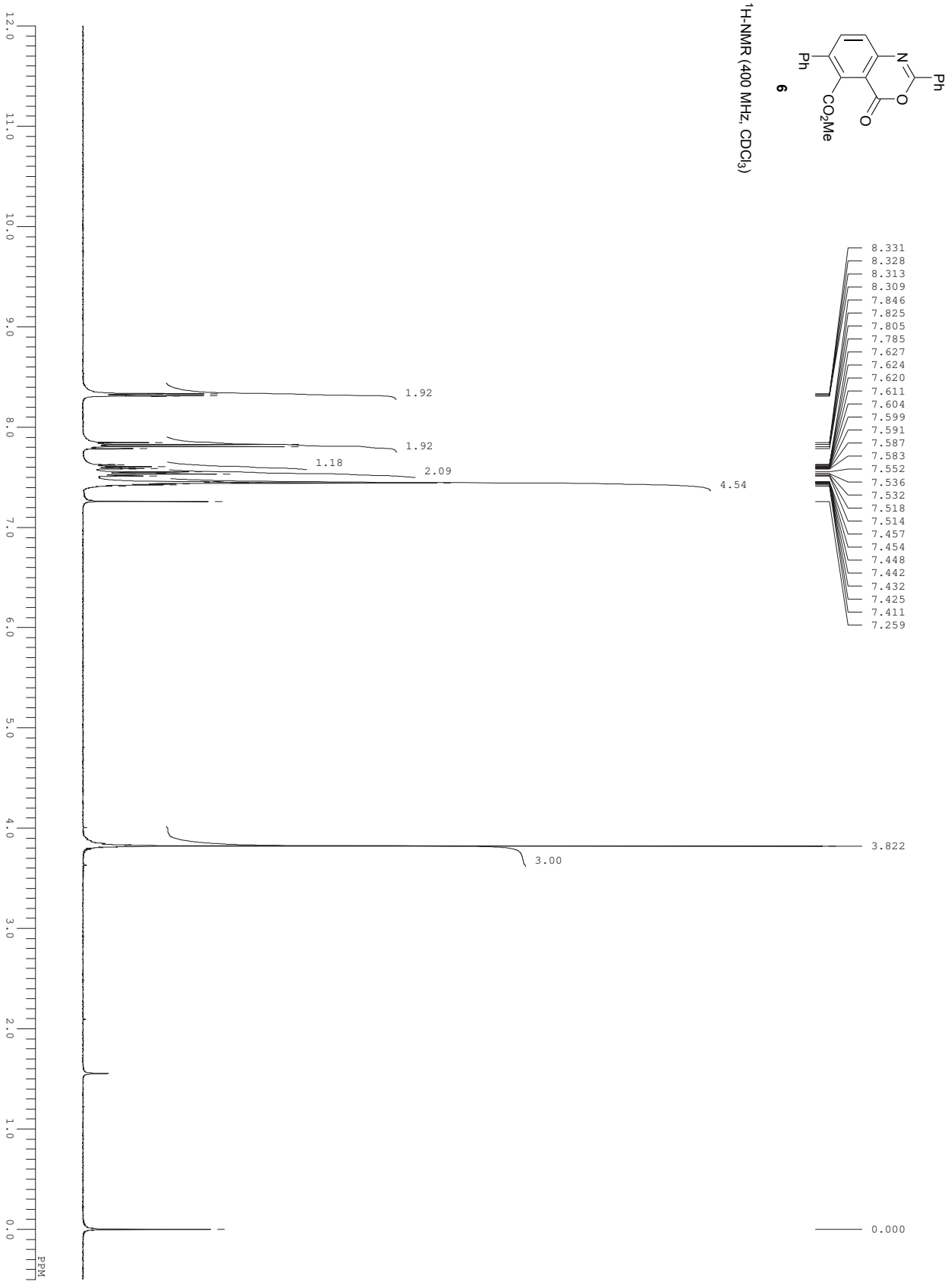

4bb
^{13}C-NMR (150 MHz, CDCl$_3$)
OMe
NHBz
CO$_2$Et
CO$_2$Et
168.479
167.763
165.538
159.236
139.123
135.197
135.155
135.054
134.540
132.122
131.751
129.804
128.852
127.327
121.977
115.194
113.593
77.211
77.000
76.789
62.390
61.210
55.312
13.663
PPM

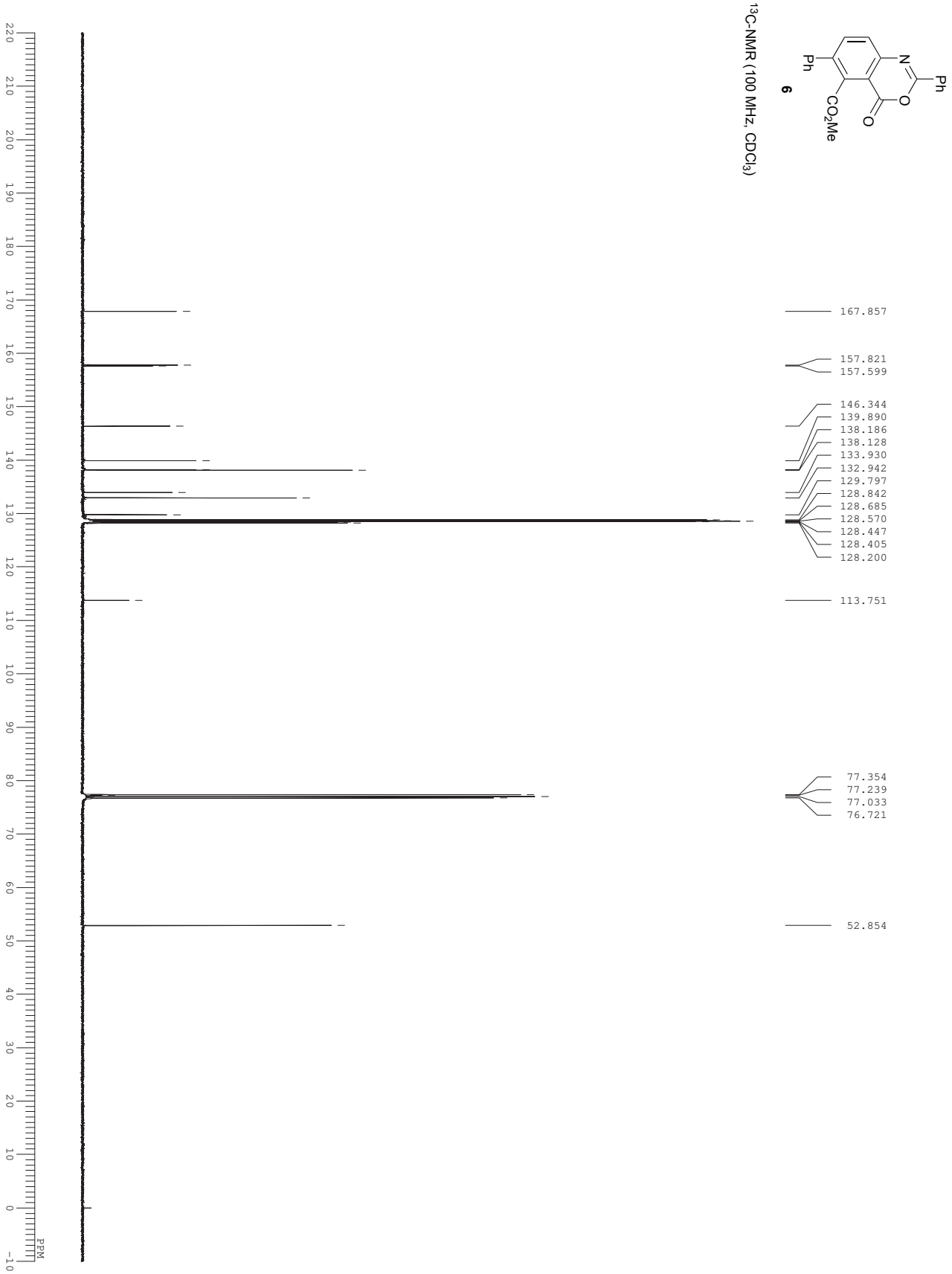

4bc
^{1}H-NMR (600 MHz, CDCl$_3$)
OMe
NHBz
CO$_2$i-Pr
CO$_2$i-Pr
11.283
8.842
8.827
8.059
8.019
8.005
7.576
7.564
7.541
7.529
7.516
7.493
7.479
7.261
7.247
6.939
6.922
6.908
5.336
5.325
5.316
4.915
4.905
3.909
3.854
3.832
1.659
1.484
1.475
1.428
1.418
1.378
1.358
1.349
1.059
0.948
0.937
0.002
0.99
1.00
2.31
4.88
3.35
2.80
1.33
1.02
4.64
1.69
1.54
6.50
6.44
PPM

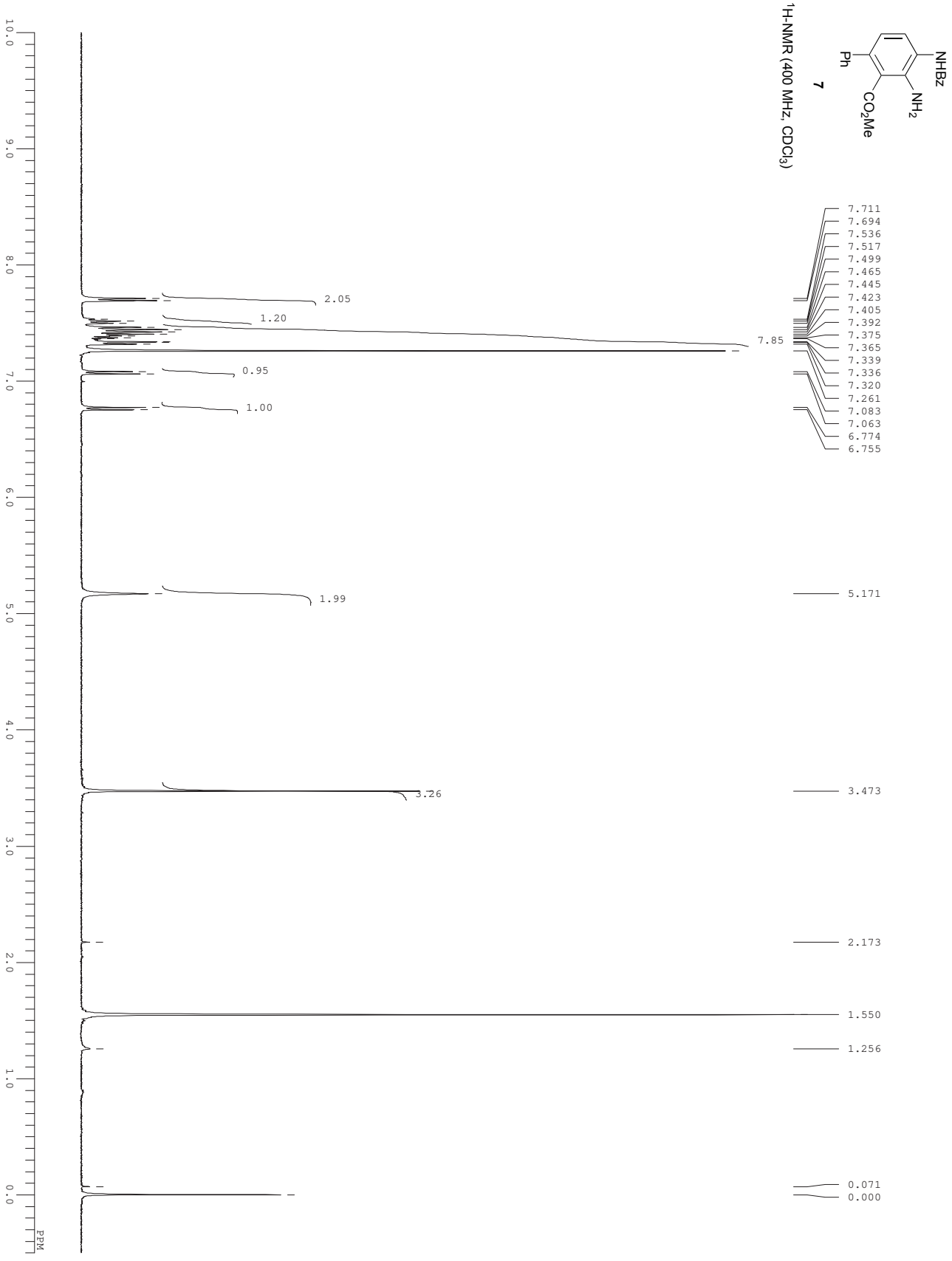

4bc
^{13}C-NMR (150 MHz, CDCl$_3$)
OMe
NHBz
CO$_2$i-Pr
CO$_2$i-Pr
167.813
167.375
165.505
159.286
138.871
135.307
135.138
135.012
134.616
133.048
132.071
131.886
130.150
128.827
128.119
127.302
121.901
115.801
114.208
113.543
77.211
77.000
76.789
70.740
69.215
55.363
55.329
21.870
21.819
21.390
21.171
PPM

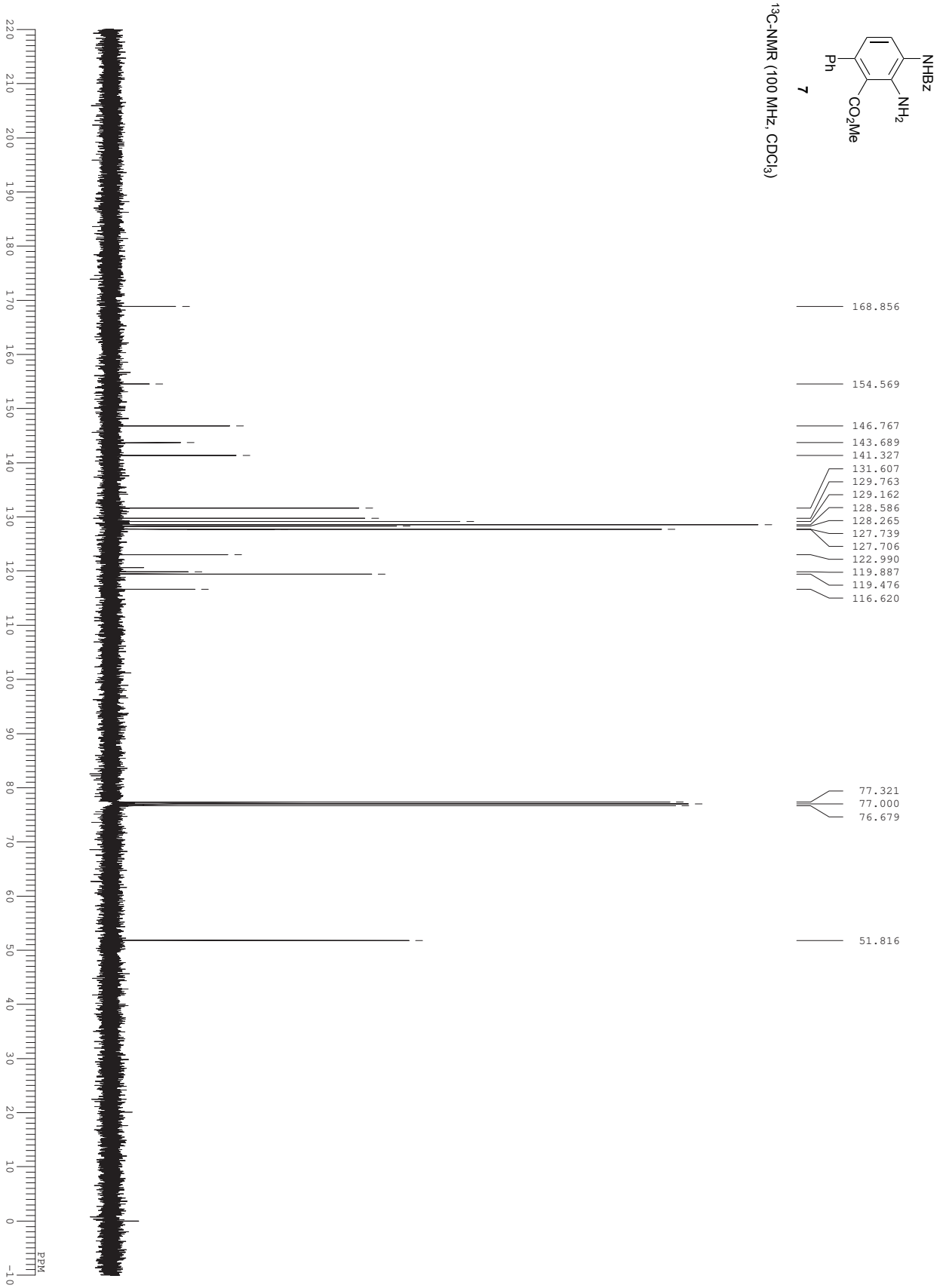

5
^{1}H-NMR (400 MHz, CD_3OD)
Ph
NHBz
CO_2Me
CO_2H
8.696
8.674
7.992
7.971
7.611
7.592
7.580
7.558
7.539
7.521
7.397
7.378
7.355
7.332
4.830
3.585
3.304
3.300
3.291
-0.007
0.90
2.00
4.13
5.03
2.94
PPM

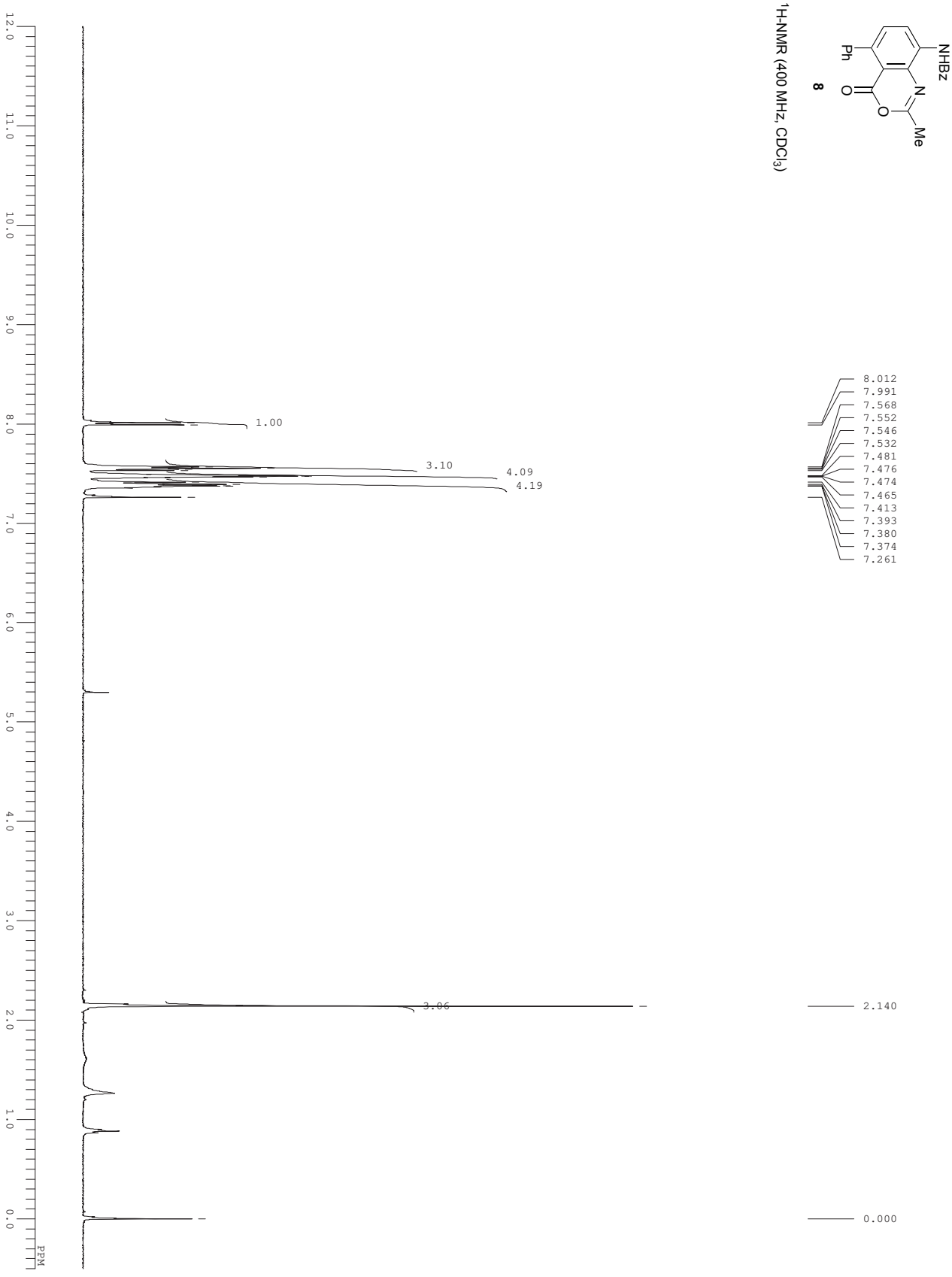

13C-NMR (100 MHz, CD3OD)
5
NHBz
CO2H
CO2Me
Ph
170.772
170.114
167.653
140.700
139.926
137.235
136.486
135.720
135.523
133.474
130.001
129.663
129.350
128.840
128.404
123.779
118.956
52.786
49.642
49.428
49.214
49.000
48.786
48.564
48.350
PPM

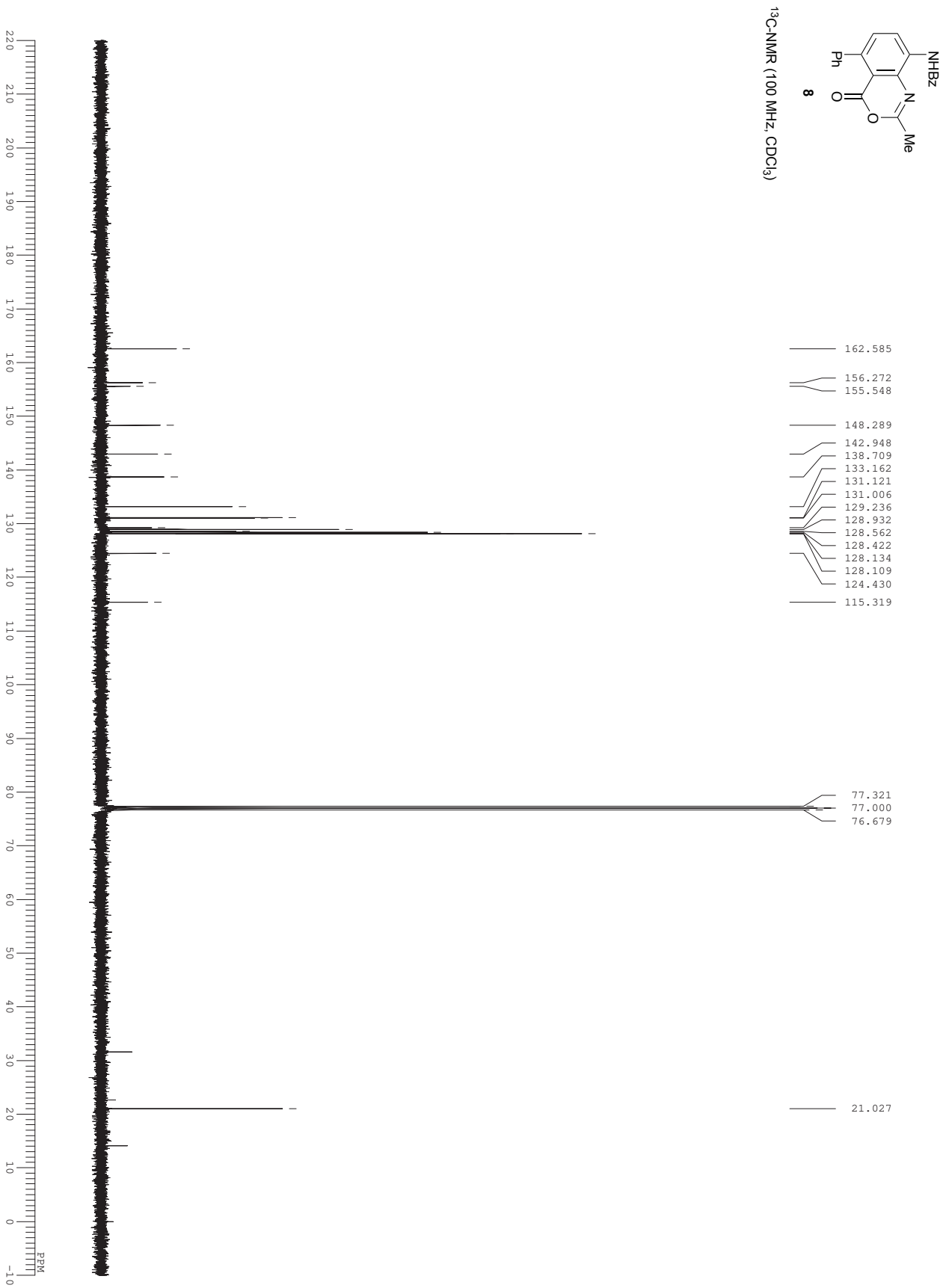

^{1}H-NMR (400 MHz, CDCl$_3$)
6
Ph
Ph
N
O
O
O
CO$_2$Me
8.331
8.328
8.313
8.309
7.846
7.825
7.805
7.785
7.627
7.624
7.620
7.611
7.604
7.599
7.591
7.587
7.583
7.552
7.536
7.532
7.518
7.514
7.457
7.454
7.448
7.442
7.432
7.425
7.411
7.259
1.92
1.92
1.18
2.09
4.54
3.822
3.00
0.000
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PPM

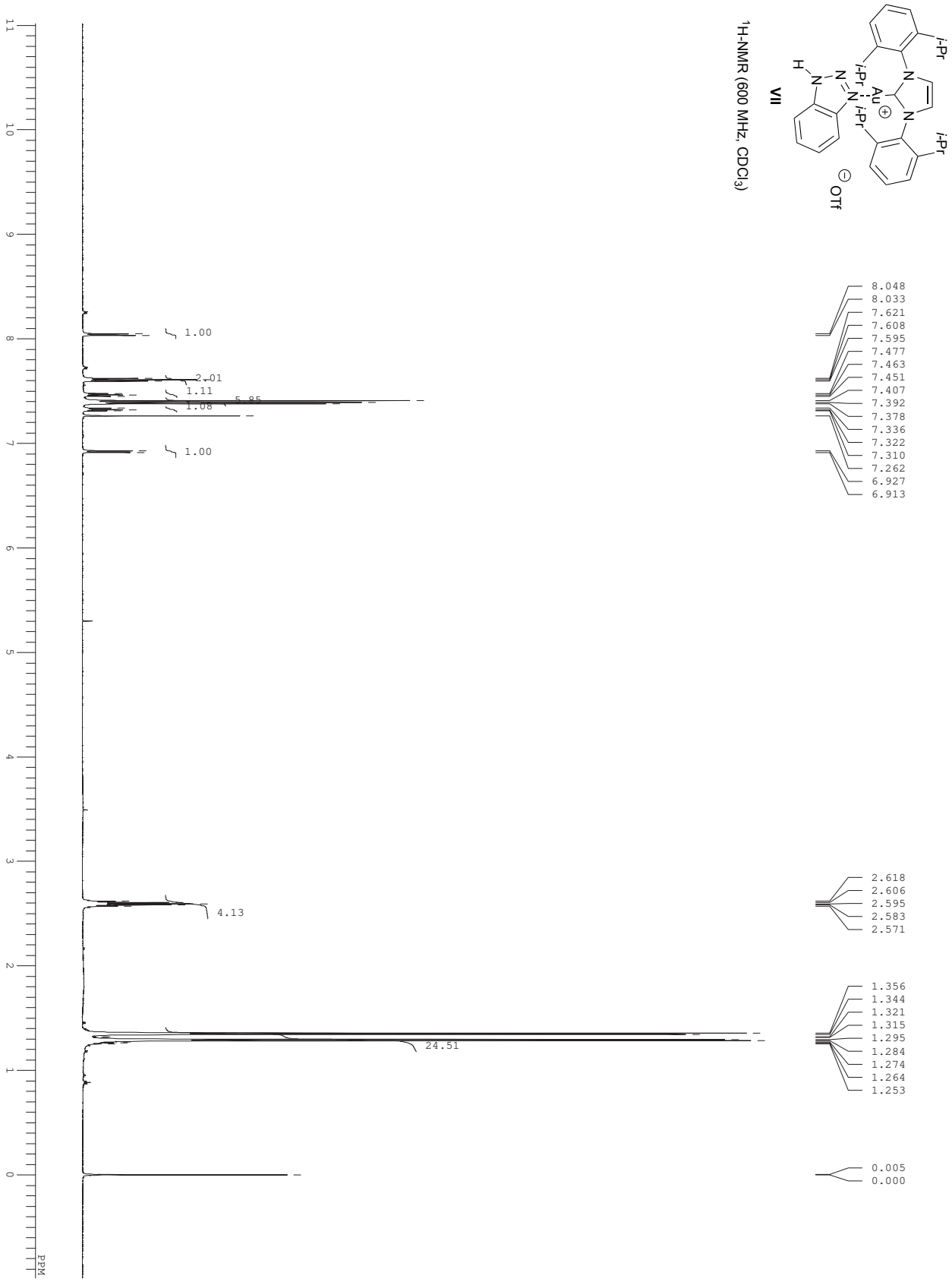

13C-NMR (100 MHz, CDCl3)
6
Ph
N
Ph
O
O
CO2Me
167.857
157.821
157.599
146.344
139.890
138.186
138.128
133.930
132.942
129.797
128.842
128.685
128.570
128.447
128.405
128.200
113.751
77.354
77.239
77.033
76.721
52.854
PPM

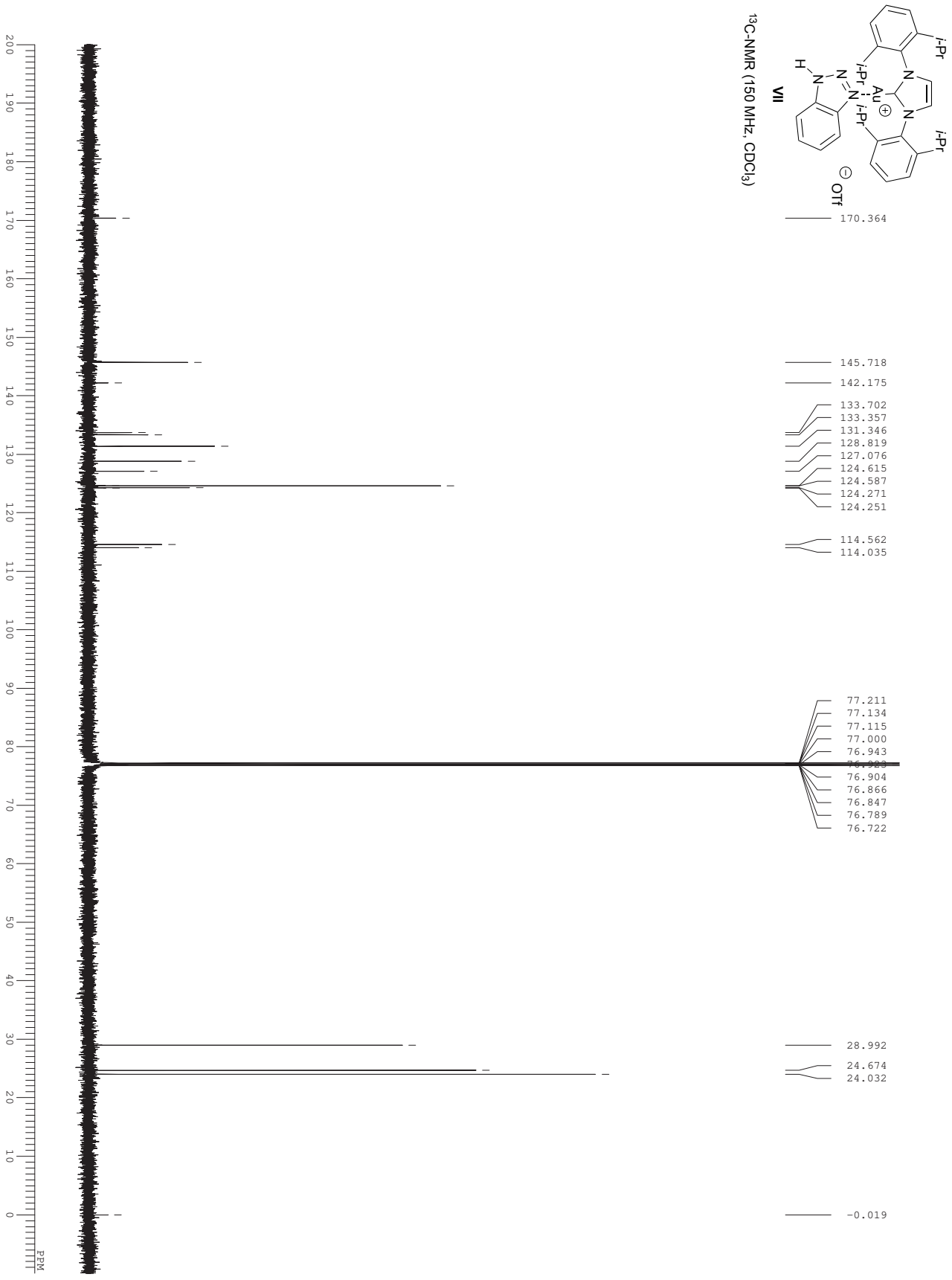

1H-NMR (400 MHz, CDCl3)
7
Ph
CO2Me
NH2
NHBz
7.711
7.694
7.536
7.517
7.499
7.465
7.445
7.423
7.405
7.392
7.375
7.365
7.339
7.336
7.320
7.261
7.083
7.063
6.774
6.755
5.171
3.473
2.173
1.550
1.256
0.071
0.000
2.05
1.20
7.85
0.95
1.00
1.99
3.26
PPM

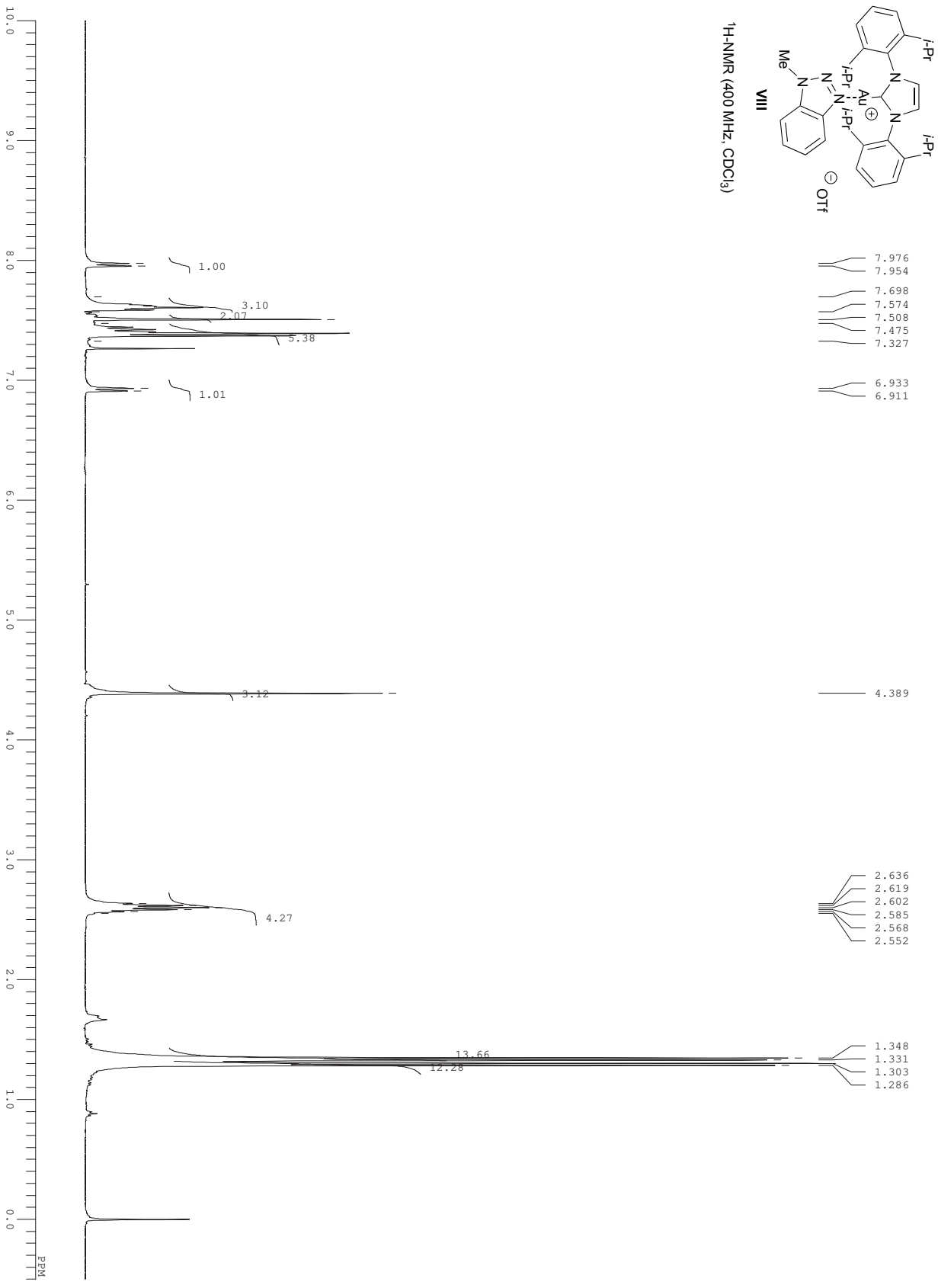

7
^{13}C-NMR (100 MHz, CDCl$_3$)
NHBz
Ph
NH$_2$
CO$_2$Me
168.856
154.569
146.767
143.689
141.327
131.607
129.763
129.162
128.586
128.265
127.739
127.706
122.990
119.887
119.476
116.620
77.321
77.000
76.679
51.816
PPM

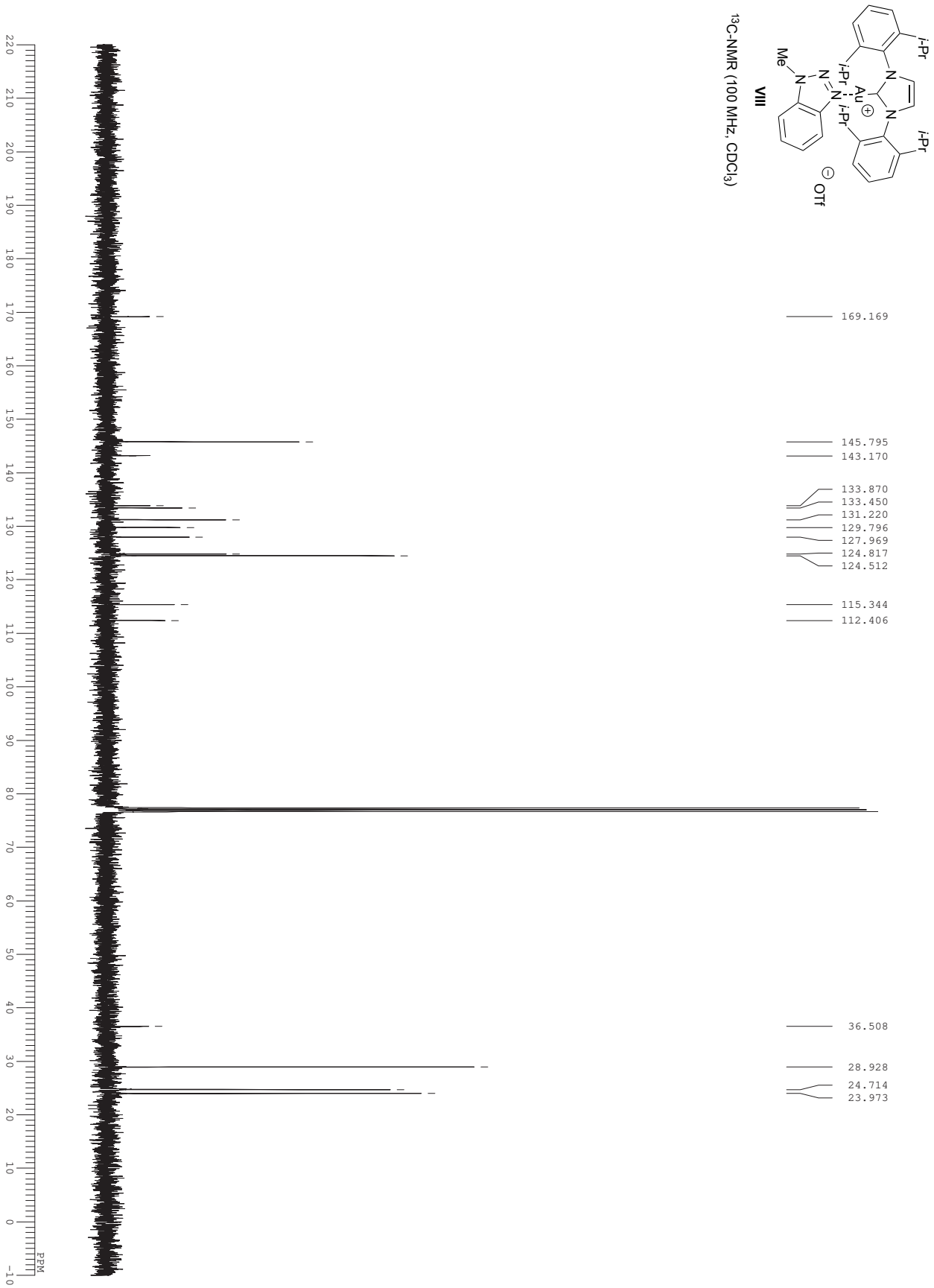

1H-NMR (400 MHz, CDCl3)
8
NHBz
Ph
O
O
N
Me
8.012
7.991
7.568
7.552
7.546
7.532
7.481
7.476
7.474
7.465
7.413
7.393
7.380
7.374
7.261
2.140
0.000
1.00
3.10
4.09
4.19
3.06
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PPM


13C-NMR (100 MHz, CDCl3)
8
NHBz
Ph
O
N
O
Me
162.585
156.272
155.548
148.289
142.948
138.709
133.162
131.121
131.006
129.236
128.932
128.562
128.422
128.134
128.109
124.430
115.319
77.321
77.000
76.679
21.027
PPM


VII
1H-NMR (600 MHz, CDCl3)
i-Pr
i-Pr
i-Pr
i-Pr
Au
H
N
OTf
8.048
8.033
7.621
7.608
7.595
7.477
7.463
7.451
7.407
7.392
7.378
7.336
7.322
7.310
7.262
6.927
6.913
2.618
2.606
2.595
2.583
2.571
1.356
1.344
1.321
1.315
1.295
1.284
1.274
1.264
1.253
0.005
0.000
1.00
2.01
1.11
5.85
1.08
1.00
4.13
24.51
ppm


^{13}C-NMR (150 MHz, CDCl$_3$)
VII
i-Pr
i-Pr
i-Pr
i-Pr
H
N
N
N
Au
N
N
OTf
170.364
145.718
142.175
133.702
133.357
131.346
128.819
127.076
124.615
124.587
124.271
124.251
114.562
114.035
77.211
77.134
77.115
77.000
76.943
76.904
76.866
76.847
76.789
76.722
28.992
24.674
24.032
-0.019
PPM


VIII
^{1}H-NMR (400 MHz, CDCl$_3$)
i-Pr
i-Pr
i-Pr
i-Pr
Me
N
N
N
Au
N
OTf
7.976
7.954
7.698
7.574
7.508
7.475
7.327
6.933
6.911
4.389
2.636
2.619
2.602
2.585
2.568
2.552
1.348
1.331
1.303
1.286
1.00
3.10
2.07
5.38
1.01
3.12
4.27
13.66
12.28
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PPM


VIII
^{13}C-NMR (100 MHz, $CDCl_3$)
169.169
145.795
143.170
133.870
133.450
131.220
129.796
127.969
124.817
124.512
115.344
112.406
36.508
28.928
24.714
23.973
PPM