Electronic Supplementary Information

Pd-catalyzed decarboxylative arylation of silyl enol ester sp^3 β-C-H Bond under aerobic conditions

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General considerations: 1-methoxy-2-methyl-1-trimethylsilyloxy-propene **2a**, 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene **2b** and 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene **2c** were prepared following literature procedures,[1, 2] all other reagents were commercially available and were used as received unless otherwise noted. DMF and DMSO were distilled from CaH_2 under reduced pressure and stored under nitrogen. 4Å molecular sieves (MS) were activated by heating at 150 °C under vacuum overnight, and then stored in glove box. For convenience, stock solutions of silyl enolates of esters and triphenylamine in DMF were prepared and stored under nitrogen. Column chromatography was performed on silica gel 300-400 mesh. The yields reported are the isolated yields and the average of two runs. ^{1}H and ^{13}C NMR spectra were recorded at 400 and 100 MHz with $CDCl_3$ as solvent, respectively, all coupling constants (*J* values) were reported in Hertz (Hz). Elemental analyses were performed by the analysis center of this institute.

Detailed discussion of triphenylamine: Considering that *tert*-butyldimethylsilyl enolate of ester (*one coupling partner*) is somewhat sensitive to aromatic carboxylic acids (*the other coupling partner*), we hoped to find a weak base to temper acidity of reaction medium and improve the compatibility of silyl enolate of ester under acid condition. At the same time, this base must be a weak one because strong base as a ligand will reduce the electrophilicity of Pd catalyst toward decarboxylation step by coordinating to Pd. Gratifyingly, we finally found that triphenylamine (Ph_3N) significantly improved this reaction.

Although it is known that the oxidation of Ph_3N by Cu(II) salt led to formation of tetraphenylbenzidine and other products via radical cation step,[3-4] we speculated that if Ph_3N participated in the catalytic process via a radical cation under our aerobic oxidative conditions, there would be two possibilities for Ph_3N: 1) conversion of Ph_3N into tetraphenylbenzidine or other

compounds; 2) regeneration of Ph_3N from catalytic recycle. For the latter case, the radical cation formed from oxidation of Ph_3N could be trapped by adding nucleophile such as nBu$_4$NBr.[4]

However, we found that Ph_3N can be recovered unchanged from reaction system regardless of the presence or absence of silyl enolate of ester, and Ph_3N was isolated by column chromatography after reaction worked up. The isolated Ph_3N was characterized by ^{1}H NMR, ^{13}C NMR, mass spectrometry and measurement of its melting point. Therefore, the first possibility can be excluded.

According to literature, the radical cation formed from oxidation of dimethylaniline or triphenylamine could be trapped by adding nBu$_4$NBr.[4] Further experiments showed that the reaction of dimethylaniline with nBu$_4$NBr under our aerobic oxidative conditions (10 mol% $Pd(OAc)_2$, 1 atm O_2, 5% DMSO-DMF, 120 °C and 24 h) to form the brominated product via radical cation process with 35% of dimethylaniline recovered by GC/MS analysis. However, since triphenylamine (Eox = 0.92 v versus SCE) is more difficult to be oxidized than dimethylaniline (Eox = 0.81 v versus SCE),[3-4] the reaction of Ph_3N with nBu$_4$NBr under our aerobic oxidative conditions did not take place at all, indicating that Ph_3N did not undergo oxidation to generate radical cation under our aerobic oxidative conditions. Therefore, the second possibility can be excluded. Furthermore, in the reaction of 2,6-dimethoxybenzoic acid **1a** with *tert*-butyldimethylsilyl enolate of methyl isobutyrate **2b** under our aerobic oxidative conditions, significantly reduced yield (40%) was obtained when 0.2 equivalent of dimethylaniline as additive, whereas excellent yield (84%) was obtained when 0.2 equivalent of triphenylamine as additive.

Basing on above observations, we conclude that Ph_3N didn't participate in the catalytic process via a radical cation under our aerobic oxidative conditions. Since Ph_3N is a very weak base, we believe that there exist the interaction between Ph_3N and benzoic acids through hydrogen bond, which may well prevent silyl enolate of ester from decomposition caused by benzoic acids. In this sense, we refer to Ph_3N as a weak base. In Table 1 of this paper, we compared yields obtained when using Ph_3N with those using other bases such Et_3N and K_2CO_3 that are much stronger than Ph_3N, hopefully, to demonstrate correlation between the strength of bases and their effects on the reaction.

General procedure for the decarboxylative coupling reaction of aromatic carboxylic acid with silyl enolate of ester

(A) Procedure A: An oven-dried Schlenk tube equipped with a stir bar was charged with $Pd(OAc)_2$ (4.5 mg, 0.02 mmol, 10 mol%), aromatic carboxylic acid (0.2 mmol) and 4Å MS. The tube was fitted with a rubber septum, and then it was evacuated and refilled with dioxygen three times. Under dioxygen, DMSO (0.1 mL), solutions of triphenylamine and silyl enolate of ester in DMF (2 mL) were added successively via syringes. The rubber septum was replaced with a Teflon screwcap under dioxygen flow. With stirring, the reaction mixtures were heated at 120 °C for the indicated amount of time. After cooling to room temperature, the reaction mixtures were diluted with ether (10 mL) and filtered through a pad of silica gel that was then washed with ether (10 mL × 3). The combined organic phase was washed with brine (20 mL × 2), dried over Na_2SO_4, filtered and concentrated in vacuo. The resulting residue was purified by flash column chromatography over silica gel with ethyl acetate/hexane as eluent.

(B) Procedure B: An oven-dried Schlenk tube equipped with a stir bar was charged with $Pd(OAc)_2$ (4.5 mg, 0.02 mmol, 10 mol%), aromatic carboxylic acid (0.2 mmol), silver carbonate (165.5 mg, 0.6 mmol) and 4Å MS. The tube was fitted with a rubber septum, and then it was evacuated and refilled with dioxygen three times. Under dioxygen, DMSO (0.1 mL), solution of silyl enolate of ester in DMF (2 mL) was added successively via syringe. The rubber septum was replaced with a Teflon screwcap under dioxygen flow. With stirring, the reaction mixtures were heated at 120 °C for the indicated amount of time. After cooling to room temperature, the reaction mixtures were diluted with ether (10 mL) and filtered through a pad of silica gel that was then washed with ether (10 mL × 3). The combined organic phase was washed with brine (20 mL × 2), dried over Na_2SO_4, filtered and concentrated in vacuo. The resulting residue was purified by flash column chromatography over silica gel with ethyl acetate/hexane as eluent.

(C) Procedure C: An oven-dried Schlenk flask equipped with a stir bar was charged with $Pd(OAc)_2$ (22.5 mg, 0.1 mmol, 10 mol%), 2,6-dimethoxybenzoic acid (182.2 mg, 1 mmol), triphenylamine (49.1 mg, 0.2 mmol, 20 mol%) and 4Å MS. The flask was fitted with a rubber septum, and then it was evacuated and refilled with dioxygen three times, and then the flask connected to dioxygen ballon. Under dioxygen, DMSO (0.3 mL) and solution of 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene **2b** in DMF (6 mL) were added successively via syringes. The rubber septum was replaced with a glass stopper under dioxygen flow. With stirring, the reaction mixtures were heated at 120 °C for the indicated amount of time. After cooling to room temperature, the reaction mixtures were diluted with ether (30 mL) and filtered through a pad of silica gel that was then washed with ether (20 mL × 3). The combined organic phase was washed with brine (30 mL × 2), dried over Na_2SO_4, filtered and concentrated in vacuo. The resulting residue was purified by flash column chromatography over silica gel with ethyl acetate/hexane as eluent.

2-methyl-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (3ab, entry 1, Table 2) and **2-(2,6-dimethoxy-benzyl)-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (4ab, entry 1, Table 2)**

. Procedure C was followed using 2,6-dimethoxybenzoic acid (182.2 mg, 1 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (432.8 mg, 2 mmol, 2 equiv), palladium acetate (22.5 mg, 0.1 mmol), triphenylamine (49.1 mg, 0.2 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (2-6% ethyl acetate in hexanes) to afford 70.1 mg (32%) of the mono-substituted product as a colorless oil and 97.5 mg (52%) of the di-substituted product as a white solid.

3ab ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.53 (s, 1 H), 7.27 (t, J = 8.36 Hz, 1 H), 6.57 (d, J = 8.36 Hz, 2 H), 3.88-3.70 (sss, 6 H), 1.78 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.6, 157.6, 131.8, 130.7, 129.6, 113.3, 103.4, 55.5, 51.6, 15.1. Anal. Calcd. for $C_{13}H_{16}O_4$: C, 66.09; H, 6.83. Found: C, 66.07; H, 6.80.

4ab ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.36 (s, 1 H), 7.15 (t, J = 8.36 Hz, 1 H), 6.96 (t, J = 8.28 Hz, 1 H), 6.43 (d, J = 8.36 Hz, 2 H), 6.32 (d, J = 8.28 Hz, 2 H), 3.75 (s, 3 H), 3.67 (s, 6 H), 3.62 (s, 2 H), 3.60 (s,

6 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.7, 158.2, 157.3, 135.4, 131.2, 128.7, 126.3, 117.2, 114.1, 103.4, 103.1, 55.5, 55.3, 51.5, 22.8. Anal. Calcd. for $C_{21}H_{24}O_6$: C, 67.73; H, 6.50. Found: C, 67.74; H, 6.56.

3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (3ac, entry 2, Table 2) and **3,3-bis(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (4ac, entry 2, Table 2)**

Procedure A was followed using 2,6-dimethoxybenzoic acid (36.4 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy- propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (3-10% ethyl acetate in hexanes) to afford 12.3 mg (28%) of the mono-substituted product as a white solid and 13.1 mg (37%) of the di-substituted product as a white solid.

3ac ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.14 (d, J = 16.33 Hz, 1 H), 7.27 (t, J = 8.44 Hz, 1 H), 6.89 (d, J = 16.33 Hz, 1 H), 6.56 (d, J = 8.40 Hz, 2 H), 3.88 (s, 6 H), 3.80 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 160.0, 135.6, 131.1, 120.2, 112.2, 103.6, 55.7, 51.4. Anal. Calcd. for $C_{12}H_{14}O_4$: C, 64.85; H, 6.35. Found: C, 65.07; H, 6.42.

4ac ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.15 (tt, J = 7.68, 8.28 Hz, 2 H), 6.51 (d, J = 8.32 Hz, 4 H), 6.23 (s, 1 H), 3.64 (s, 12 H), 3.57 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 158.2, 157.6, 141.2, 128.7, 128.4, 125.2, 120.5, 118.9, 104.5, 104.2, 56.1, 56.0, 50.8. Anal. Calcd. for $C_{20}H_{22}O_6$: C, 67.03; H, 6.19. Found: C, 66.96; H, 6.20.

2-methyl-3-(2,4,6-trimethoxy-phenyl)-acrylic acid methyl ester (3bb, entry 3, Table 2) and **2-(2,4,6-trimethoxy-benzyl)-3-(2,4,6-trimethoxy-phenyl)-acrylic acid methyl ester (4bb, entry 3, Table 2)**

Procedure A was followed using 2,4,6-trimethoxybenzoic acid (42.4 mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column

chromatography on silica gel (10-20% ethyl acetate in hexanes) to afford 18.4 mg (35%) of the mono-substituted product as a white solid and 19.6 mg (45%) of the di-substituted product as a white solid.

3bb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (s, 1 H), 6.15 (s, 2 H), 3.84 (s, 3 H), 3.80 (s, 6 H), 3.78 (s, 3 H), 1.77 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.2, 160.0, 159.1, 139.2, 123.3, 107.4, 90.6, 55.8, 55.3, 51.7, 24.6. Anal. Calcd. for $C_{14}H_{18}O_5$: C, 63.15; H, 6.81. Found: C, 63.20; H, 6.78.

4bb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.32 (s, 1 H), 6.06 (s, 2 H), 5.96 (s, 2 H), 3.81 (s, 3 H), 3.73 (s, 3 H), 3.70 (s, 9 H), 3.61 (s, 6 H), 3.50 (s, 2 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.9, 161.0, 159.0, 158.9, 158.2, 134.7, 131.0, 109.9, 107.3, 90.4, 90.1, 55.5, 55.4, 55.3, 55.2, 51.4, 22.8. Anal. Calcd. for $C_{23}H_{28}O_8$: C, 63.88; H, 6.53. Found: C, 63.99; H, 6.46.

3-(2,4,6-trimethoxy-phenyl)-acrylic acid methyl ester (3bc, entry 4, Table 2) and **3,3-bis(2,4,6-trimethoxy-phenyl)-acrylic acid methyl ester (4bc, entry 4, Table 2)**

Procedure A was followed using 2,4,6-trimethoxybenzoic acid (42.4 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (4-20% ethyl acetate in hexanes) to afford 28 mg (55%) of the mono-substituted product as a white solid and 8.3 mg (20%) of the di-substituted product as a yellow solid.

3bc ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.08 (d, J = 16.25 Hz, 1 H), 6.75 (d, J = 16.25 Hz, 1 H), 6.10 (s, 2 H), 3.85 (s, 6 H), 3.83 (s, 3 H), 3.77 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.4, 162.7, 161.2, 135.6, 117.0, 105.7, 90.3, 55.6, 55.3, 51.3. Anal. Calcd. for $C_{13}H_{16}O_5$: C, 61.90; H, 6.39. Found: C, 61.90; H, 6.30.

4bc ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.14 (s, 1H), 6.08 (s, 2H), 6.07 (s, 2H), 3.79 (s, 6H), 3.63 (s, 6H), 3.62 (s, 6H), 3.57 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 160.5, 160.4, 158.9, 158.3, 141.4, 124.3, 113.9, 112.3, 91.1, 90.9, 56.1, 56.0, 55.2, 55.1, 50.7. Anal. Calcd. for $C_{22}H_{26}O_8$: C, 63.15; H, 6.26. Found: C, 62.95; H, 6.18.

2-methyl-3-(2,4,5-trimethoxy-phenyl)-acrylic acid methyl ester (3cb, entry 5, Table 2) and **2-(2,4,5-trimethoxy-benzyl)-3-(2,4,5-trimethoxy-phenyl)-acrylic acid methyl ester (4cb, entry 5, Table 2)**

Procedure A was followed using 2,4,5-trimethoxybenzoic acid (42.4 mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (10-25% ethyl acetate in hexanes) to afford 12.3 mg (23%) of the mono-substituted product as a white solid and 25.3 mg (58%) of the di-substituted product as a white solid.

3cb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (s, 1 H), 6.91 (s, 1 H), 6.54 (s, 1 H), 3.93 (s, 3 H), 3.85 (s, 6 H), 3.81 (s, 3 H), 2.09 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.3, 152.8, 150.4, 142.5, 134.4, 126.5, 116.3, 113.9, 96.9, 56.7, 56.4, 56.1, 51.9, 14.4. Anal. Calcd. for $C_{14}H_{18}O_5$: C, 63.15; H, 6.81. Found: C, 63.10; H, 6.86.

4cb ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15 (s, 1 H), 6.75 (s, 1 H), 6.63 (s, 1 H), 6.51 (s, 1 H), 6.48 (s, 1 H), 3.87 (s, 3 H), 3.85 (s, 3 H), 3.84 (s, 2 H), 3.82 (s, 2 H), 3.78 (s, 6 H), 3.72 (s, 3 H), 3.34 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2, 153.0, 151.5, 150.5, 147.9, 143.1, 142.5, 16.6, 127.6, 119.8, 115.8, 112.8, 112.6, 97.7, 96.6, 56.8, 56.4, 56.4, 56.2, 56.0, 55.5, 52.0, 27.7. Anal. Calcd. for $C_{23}H_{28}O_8$: C, 63.88; H, 6.53. Found: C, 63.80; H, 6.44.

3-(2,4,5-trimethoxy-phenyl)-acrylic acid methyl ester (3cc, entry 6, Table 2) and **3,3-bis(2,4,5-trimethoxy-phenyl)-acrylic acid methyl ester (4cc, entry 6, Table 2)**

Procedure A was followed using 2,4,5-trimethoxybenzoic acid (42.4 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (4-20% ethyl acetate in hexanes) to afford 9 mg (18%) of the mono-substituted product as a pale green solid and 28 mg (67%) of the di-substituted product as a yellow oil.

3cc ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.96 (d, J = 16.09 Hz, 1 H), 7.00 (s, 1 H), 6.49 (s, 1 H), 6.37 (d, J = 16.08 Hz, 1H), 3.92 (s, 3 H), 3.87 (s, 3 H), 3.86 (s, 3 H), 3.79 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.2, 153.9, 152.1, 143.2, 139.7, 115.4, 114.9, 110.9, 96.9, 56.4, 56.3, 56.1, 51.5. Anal. Calcd. for $C_{13}H_{16}O_5$: C, 61.90; H, 6.39. Found: C, 61.90; H, 6.51.

4cc ^{1}H NMR(400 MHz, $CDCl_3$): δ 6.60 (s, 1 H), 6.54 (s, 1 H), 6.53 (s, 1 H), 6.49 (s, 1 H), 6.45 (s, 1 H), 3.89 (s, 3 H), 3.88 (s, 3 H), 3.72 (s, 3 H), 3.69 (s, 6 H), 3.66 (s, 3 H), 3.59 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.0, 152.5, 151.1, 150.1, 149.3, 149.0, 142.7, 142.6, 122.1, 120.9, 120.1, 114.7, 113.6, 98.3, 97.6, 56.8, 56.7, 56.5, 56.4, 56.0, 55.9, 51.0. Anal. Calcd. for $C_{22}H_{26}O_8$: C, 63.15; H, 6.26. Found: C, 63.20; H, 6.31.

2-methyl-3-(2,4-dimethoxy-phenyl)-acrylic acid methyl ester (3db, entry 7, Table 2) and **2-(2,4-dimethoxy-benzyl)-3-(2,4-dimethoxy-phenyl)-acrylic acid methyl ester (4db, entry 7, Table 2)**

Procedure A was followed using 2,4-dimethoxybenzoic acid (36.4 mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (2-6% ethyl acetate in hexanes) to afford 14.8 mg (31%) of the mono-substituted product as a colorless oil and 20.3 mg (55%) of the di-substituted product as a white solid.

3db ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81(s, 1 H), 7.27 (d, J = 8.53 Hz, 1 H), 6.51 (d, J = 8.53 Hz, 1 H), 6.47 (s, 1 H), 3.84 (s, 6 H), 3.80 (s, 3 H), 2.06 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.4, 161.4, 159.1, 134.4, 131.0, 126.5, 117.7, 104.2, 98.3, 55.6, 55.5, 51.9, 14.4. Anal. Calcd. for $C_{13}H_{16}O_4$: C, 66.09; H, 6.83. Found: C, 66.18; H, 6.83.

4db ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (s, 1 H), 7.11 (d, J = 8.53 Hz, 1 H), 6.94 (d, J = 8.53 Hz, 1 H), 6.47 (s, 1 H), 6.45 (s, 1 H), 6.40 (d, J = 8.53 Hz, 1 H), 6.35 (d, J = 8.53 Hz, 1 H), 3.84 (s, 3 H), 3.80 (s, 3 H), 3.79 (s, 3 H), 3.78 (s, 3 H), 3.76 (s, 2 H), 3.74 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2,

161.9, 159.2, 159.1, 158.2, 136.3, 130.2, 128.2, 128.0, 120.6, 117.4, 104.3, 103.7, 98.5, 98.2, 55.5, 55.34, 55.29, 51.9, 27.3. Anal. Calcd. for $C_{21}H_{24}O_6$: C, 67.73; H, 6.50. Found: C, 67.69; H, 6.45.

3-(2,4-dimethoxy-phenyl)-acrylic acid methyl ester (3dc, entry 8, Table 2) and **3,3-bis(2,4-dimethoxy-phenyl)-acrylic acid methyl ester (4dc, entry 8, Table 2).**

Procedure A was followed using 2,4-dimethoxybenzoic acid (36.4 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (3-10% ethyl acetate in hexanes) to afford 14 mg (32%) of the mono-substituted product as a white solid and 16 mg (45%) of the di-substituted product as a colorless oil.

3dc ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 16.09 Hz, 1 H), 7.44 (d, J = 8.56 Hz, 1H), 6.50 (dd, J = 2.04, 8.52 Hz, 1 H), 6.46-6.40 (overlap m, 2 H), 3.86 (s, 3 H), 3.84 (s, 3 H), 3.78 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.3, 162.7, 159.8, 140.2, 130.4, 116.5, 115.6, 150.2, 98.4, 55.4, 51.4. Anal. Calcd. for $C_{12}H_{14}O_4$: C, 64.85; H, 6.35. Found: C, 65.06; H, 6.51.

4dc ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.97 (d, J = 8.52 Hz, 1 H), 6.91 (d, J = 8.28 Hz, 1 H), 6.50-6.43 (overlap m, 4 H), 6.39 (dd, J = 2.44, 8.56 Hz, 1 H), 3.81 (s, 3 H), 3.79 (s, 3 H), 3.72 (s, 3 H), 3.71 (s, 3 H), 3.59 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.1, 161.1, 160.5, 158.9, 157.7, 149.4, 132.1, 130.4, 123.3, 122.4, 119.6, 104.2, 104.0, 99.1, 98.6, 55.7, 55.6, 55.3, 55.2, 50.9. Anal. Calcd. for $C_{20}H_{22}O_6$: C, 67.03; H, 6.19. Found: C, 66.84; H, 6.21.

2-methyl-3-(2-methoxy-4-methyl-phenyl)-acrylic acid methyl ester (3eb, entry 9, Table 2) and **2-(2-methoxy-4-methyl-benzyl)-3-(2-methoxy-4-methyl-phenyl)-acrylic acid methyl ester (4eb, entry 9, Table 2)**

Procedure A was followed using 2-methoxy-4-methylbenzoic acid (33.2mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column

chromatography on silica gel (1-6% ether in hexanes) to afford 8.4 mg (19%) of the mono-substituted product as a colorless oil and 5.7 mg (17%) of the di-substituted product as a white solid.

3eb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (s, 1H), 7.20 (d, J = 7.72 Hz, 1 H), 6.78 (d, J = 7.76 Hz, 1 H), 6.72 (s, 1 H), 3.83 (s, 3 H), 3.80 (s, 3 H), 2.37 (s, 3 H), 2.05 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.2, 157.5, 140.3, 134.7, 129.9, 127.5, 121.9, 120.7, 111.4, 55.4, 51.9, 21.8, 14.2. Anal. Calcd. for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.77; H, 7.25.

4eb ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (s, 1H), 7.05 (d, J = 7.72 Hz, 1 H), 6.93 (d, J = 7.52 Hz, 1 H), 6.68 (m, 3 H), 6.61 (d, J = 7.72 Hz, 1 H), 3.83 (s, 3 H), 3.78 (m, 5 H), 3.72 (s, 3 H), 2.32 (s, 3 H), 2.31 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.0, 157.7, 157.1, 140.5, 136.7, 129.5, 129.1, 127.6, 125.2, 121.7, 121.0, 120.9, 111.3, 111.1, 55.4, 55.2, 51.9, 27.6, 21.7, 21.4. Anal. Calcd. for $C_{21}H_{24}O_4$: C, 74.09; H, 7.11. Found: C, 73.85; H, 7.04.

3-(2-methoxy-4-methyl-phenyl)-acrylic acid methyl ester (3ec, entry 10, Table 2)

Procedure A was followed using 2-methoxy-4-methylbenzoic acid (33.2mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (0.5-1% ether in hexanes) to afford 11.2 mg (27%) of the mono-substituted product as a pale green oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.96 (d, J = 16.17 Hz, 1 H), 7.39 (d, J = 7.80 Hz, 1 H), 6.77 (d, J = 7.84 Hz, 1 H), 6.72 (s, 1 H), 6.49 (d, J = 16.17 Hz, 1 H), 3.87 (s, 3 H), 3.79 (s, 3 H), 2.37 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.2, 158.3, 142.3, 140.4, 129.0, 121.4, 120.6, 117.1, 111.9, 55.4, 51.5, 21.9. Anal. Calcd. for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 70.11; H, 6.63.

3-(4-amino-5-chloro-2-methoxy-phenyl)-acrylic acid methyl ester (3fc, entry 11, Table 2) and **3,3-bis(4-amino-5-chloro-2-methoxy-phenyl)-acrylic acid methyl ester (4fc, entry 11, Table 2)**

Procedure A was followed using 4-amino-5-chloro-2-methoxybenzoic acid (40.3mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (10-35% ethyl acetate in hexanes) to afford 14.3 mg (30%) of the mono-substituted product as a yellow solid and 16.6 mg (42 %) of the di-substituted product as a yellow solid.

3fc ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, J = 16.09 Hz, 1 H), 7.39 (s, 1 H), 6.33 (d, J = 16.05 Hz, 2 H), 6.26 (s, 1 H), 4.34 (s, 2 H), 3.82 (s, 3 H), 3.77 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.3, 158.5, 145.7, 139.3, 129.7, 114.9, 114.8, 111.0, 98.0, 55.6, 51.5. Anal. Calcd. for $C_{11}H_{12}ClNO_3$: C, 54.67; H, 5.00; N, 5.80. Found: C, 54.53; H, 5.09, N, 5.73.

4fc ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.91 (s, 1 H), 6.83 (s, 1 H), 6.40 (s, 1 H), 6.31 (s, 1 H), 6.27 (s, 1 H) , 4.17 (s, 2 H) , 4.08 (s, 2 H) , 3.67 (s, 6 H) , 3.60 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.9, 157.6, 156.5, 147.3, 144.2, 143.4, 131.6, 130.1, 121.5, 120.7, 119.5, 110.5, 99.1, 99.0, 55.9, 55.8, 51.0. Anal. Calcd. for $C_{18}H_{18}Cl_2N_2O_4$: C, 54.42; H, 4.57; N, 7.05. Found: C, 54.48; H, 4.60, N, 7.12.

3-(4-methoxy-2-nitro-phenyl)-acrylic acid methyl ester (3gc, entry 12, Table 2)

Procedure B was followed using 4-methoxy-2-nitrobenzoic acid (39.4 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), silver carbonate (165.5 mg, 0.6 mmol) and palladium acetate (4.5 mg, 0.02 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (8% ethyl acetate in hexanes) to afford 16.4 mg (35%) of the mono-substituted product as a yellow solid.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.03 (d, J = 15.80 Hz, 1 H), 7.59 (d, J = 8.72 Hz, 1 H), 7.50 (d, J = 2.68 Hz, 1 H), 7.17 (dd, J = 2.64, 8.72 Hz, 1 H), 6.31 (d, J = 15.80 Hz, 1 H), 3.91 (s, 3 H), 3.82 (s, 3 H). ^{13}C NMR (100 MHz, CDCl3): δ 166.5, 160.9, 149.3, 139.5, 129.9, 122.4, 121.0, 120.0, 109.5, 56.1, 51.9. Anal. Calcd. for $C_{11}H_{11}NO_5$: C, 55.70; H, 4.67; N, 5.90. Found: C, 55.86; H, 4.60, N, 5.95.

3-(2-chloro-5-nitro-phenyl)-acrylic acid methyl ester (3hc, entry 13, Table 2)

Procedure B was followed using 2-chloro-5-nitrobenzoic acid (40.3 mg, 0.2 mmol), 1-*tert*-butyldimethylsilyloxy-1-methoxy-propene (81.0 mg, 0.4 mmol, 2 equiv), silver carbonate (165.5 mg, 0.6 mmol) and palladium acetate (4.5 mg, 0.02 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (4% ether in hexanes) to afford 15.6 mg (32%) of the mono-substituted product as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.49 (d, J = 2.60 Hz, 1 H), 8.17 (dd, J = 2.64, 8.80 Hz, 1 H), 8.05 (d, J = 16.04 Hz, 1 H), 7.62 (d, J = 8.80 Hz, 1 H), 6.59 (d, J = 16.00 Hz, 1 H), 3.86 (s, 3 H). ^{13}C NMR (100 MHz, CDCl3): δ 166.1, 146.8, 141.1, 138.4, 134.3, 131.2, 125.1, 123.4, 122.6, 52.2. Anal. Calcd. for $C_{10}H_8ClO_4$: C, 49.71; H, 3.34; N, 5.80. Found: C, 50.02; H, 3.34, N, 5.75.

2-methyl-3-(3-methylbenzofuran-2-yl)-acrylic acid methyl ester (3ib, entry 14, Table 2) and **2-((3-methylbenzofuran-2-yl)methyl)-3-(3-methylbenzofuran-2-yl)-acrylic acid methyl ester (4ib, entry 14, Table 2)**

Procedure A was followed using 3-methylbenzofuran-2-carboxylic acid (35.2mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction mixtures were purified by flash column chromatography on silica gel (0.2-3% ether in hexanes) to afford 3.0 mg (7%) of the mono-substituted product as a colorless solid and 20.3 mg (56 %) of the di-substituted product as a yellow solid.

3ib ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56 (s, 1 H), 7.53 (d, J = 7.76 Hz, 1 H), 7.46 (d, J = 8.16 Hz, 1 H), 7.35 (t, J = 7.58 Hz, 1 H), 7.25 (t, J = 7.44 Hz, 1 H), 3.83 (s, 3 H), 2.43 (s, 3 H), 2.36 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 169.3, 154.7, 149.4, 129.2, 126.4, 125.9, 123.2, 122.7, 120.2, 119.8, 111.2, 52.1, 14.3, 8.6. Anal. Calcd. for $C_{14}H_{14}O_3$: C, 73.03; H, 6.13. Found: C, 73.10; H, 6.16.

4ib ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (s, 1 H), 7.53 (d, J = 7.68 Hz, 1 H), 7.43 (d, J = 8.20 Hz, 1 H), 7.40-7.38 (m, 1 H), 7.34 (t, J = 7.52 Hz, 1 H), 7.28-7.25 (m, 1 H), 7.23 (d, J = 8.08 Hz, 1 H), 7.16-7.12 (m, 2 H), 4.49 (s, 2 H), 3.80 (s, 3 H), 2.38 (s, 3 H), 2.29 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ

168.4, 154.8, 153.9, 151.2, 148.7, 130.4, 129.1, 126.4, 125.3, 124.6, 123.0, 122.8, 121.9, 121.7, 120.0, 118.6, 111.3, 110.7, 110.3, 52.2, 25.4, 8.7, 8.0. Anal. Calcd. for $C_{23}H_{20}O_4$: C, 76.65; H, 5.59. Found: C, 76.69; H, 5.68.

2-methyl-3-(3-bromo-2,6-dimethoxy-phenyl)-acrylic acid methyl ester (3jb, entry 15, Table 2) and **2-(3-bromo-2,6-dimethoxy-benzyl)-3-(3-bromo-2,6-dimethoxy-phenyl)-acrylic acid methyl ester (4jb, entry 15, Table 2)**

Procedure A was followed using 3-bromo-2,6-dimethoxybenzoic acid (52.2mg, 0.2 mmol), 1-methoxy-2-methyl-1-*tert*-butyldimethylsilyloxy-propene (86.6 mg, 0.4 mmol, 2 equiv), palladium acetate (4.5 mg, 0.02 mmol), triphenylamine (9.8 mg, 0.04 mmol). The reaction was conducted at 90°C for 24h. The reaction mixtures were purified by flash column chromatography on silica gel (2-5% ethyl acetate in hexanes) to afford 7.1 mg (11%) of the mono-substituted product as a colorless oil and 13.6 mg (26%) of the di-substituted product as a colorless oil.

3jb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 (s, 1 H), 7.47 (d, J = 8.9 Hz, 1 H), 6.60 (d, J = 8.93 Hz, 1 H), 3.82 (s, 3 H), 3.80 (s, 3 H), 3.67 (s, 3 H), 1.80 (d, J = 1.36 Hz, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.4, 157.3, 155.2, 132.8, 132.3, 131.0, 120.5, 108.3, 107.9, 60.9, 56.0, 52.0, 15.1. Anal. Calcd. for $C_{13}H_{15}BrO_4$: C, 49.54; H, 4.80. Found: C, 49.48; H, 4.75.

4jb ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (s, 1 H), 7.34 (dd, J = 0.44, 8.84 Hz, 1 H), 7.16 (d, J = 8.80 Hz, 1 H), 6.38 (d, J = 8.88 Hz, 1 H), 6.26 (d, J = 8.88 Hz, 1 H), 3.79 (s, 3 H), 3.73 (s, 2 H), 3.64 (s, 3 H), 3.62 (s, 3 H), 3.61 (s, 3 H), 3.55 (s, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.0, 157.6, 157.0, 155.8, 154.7, 136.0, 132.2, 130.7, 130.3, 124.3, 120.5, 107.9, 107.6, 107.2, 107.1, 60.6, 60.5, 55.6, 55.5, 52.0, 23.4. Anal. Calcd. for $C_{21}H_{22}Br_2O_6$: C, 47.57; H, 4.18. Found: C, 47.76; H, 4.23.

Pd-catalyzed protodecarboxylation of 2,6-dimethoxybenzoic acid under aerobic oxidative conditions (Scheme 1): An oven-dried Schlenk tube equipped with a stir bar was charged with $Pd(OAc)_2$ (4.5 mg, 0.02 mmol, 10 mol%) and 2,6-dimethoxybenzoic acid (36.4 mg, 0.2 mmol). The tube was fitted, and then it was evacuated and refilled with dioxygen three times. Under dioxygen, DMSO (0.1 mL) and DMF (2 mL) were added successively via syringes. The rubber septum was replaced with a Teflon screwcap under dioxygen flow. With stirring, the reaction mixtures were heated at 120 °C for 10 hours. After cooling to room temperature, the reaction mixture was diluted with ether (10 mL) and filtered through a pad of silica gel that was then washed with ether (10 mL × 3). The combined organic phase was washed with brine (20 mL × 2), dried over Na_2SO_4, filtered and concentrated in vacuo. The reaction mixtures were purified by flash column chromatography on silica gel (2% ethyl acetate in hexanes) to afford 14.7 mg (37%) of the 1,3-dimethoxybenzene as a pale yellow oil.

1,3-dimethoxybenzene ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20 (t, J = 8.20 Hz, 1H), 6.52 (dd, J = 2.32, 8.20 Hz, 1H), 6.56 (d, J = 2.32 Hz, 1H), 6.48 (t, J = 2.28 Hz, 1H), 3.80 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.9, 129.9, 106.2, 100.5, 55.3.

The product was identified by comparison of the NMR spectral data with literature values.[5]

Aerobic oxdative decarboxylative with methyl methacrylate (Scheme 2): An oven-dried Schlenk tube equipped with a stir bar was charged with $Pd(OAc)_2$ (4.5 mg, 0.02 mmol, 10 mol%) and 2,6-dimethoxybenzoic acid (36.4 mg, 0.2 mmol). The tube was fitted with a rubber septum, and it was evacuated and refilled with dioxygen three times. Under dioxygen, DMSO (0.1 mL) and solution of methyl methacrylate (41 mg, 0.4 mmol, 2 equiv) in DMF (2 mL) were added successively via syringes. The rubber septum was replaced with a Teflon screwcap under dioxygen flow. With stirring, the reaction mixtures were heated at 120 °C for the indicated amount of time. After cooling to room temperature, the reaction mixture was diluted with ether (10 mL) and filtered through a pad of silica gel that was then washed with ether (10 mL × 3). The combined organic phase was washed with brine (20

mL × 2), dried over Na_2SO_4, filtered and concentrated in vacuo. The reaction mixtures were purified by flash column chromatography on silica gel (1-6% ethyl acetate in hexanes) to afford 28.4 mg (60%) of the 2-(2,6-dimethoxybenzyl)-acrylic acid methyl ester as a colorless oil, 12.8 mg (27%) of the 2-methyl-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester as mono-substituted product as a colorless oil and 3.6 mg (10%) of 2-(2,6-dimethoxy-benzyl)-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester as di-substituted product as a white solid.

2-(2,6-dimethoxy-benzyl)-acrylic acid methyl ester (6, Scheme 2) ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.20 (t, J = 8.32 Hz, 1 H), 6.58 (s, 1 H), 6.56 (s, 1 H), 6.05 (s, 1 H), 5.01 (s, 1 H) , 3.80 (s, 3 H) , 3.77 (s, 6 H) , 3.65 (s, 2 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 168.1, 158.5, 138.9, 127.7, 123.4, 115.0, 103.8, 55.8, 51.8, 24.9. Anal. Calcd. for $C_{13}H_{16}O_4$: C, 66.09; H, 6.83. Found: C, 65.99; H, 6.76.

2-methyl-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (3ab): the data of NMR and elemental analysis are in entry 1, Table 2.

2-(2,6-dimethoxy-benzyl)-3-(2,6-dimethoxy-phenyl)-acrylic acid methyl ester (4ab): the data of NMR and elemental analysis are in entry 1, Table 2.

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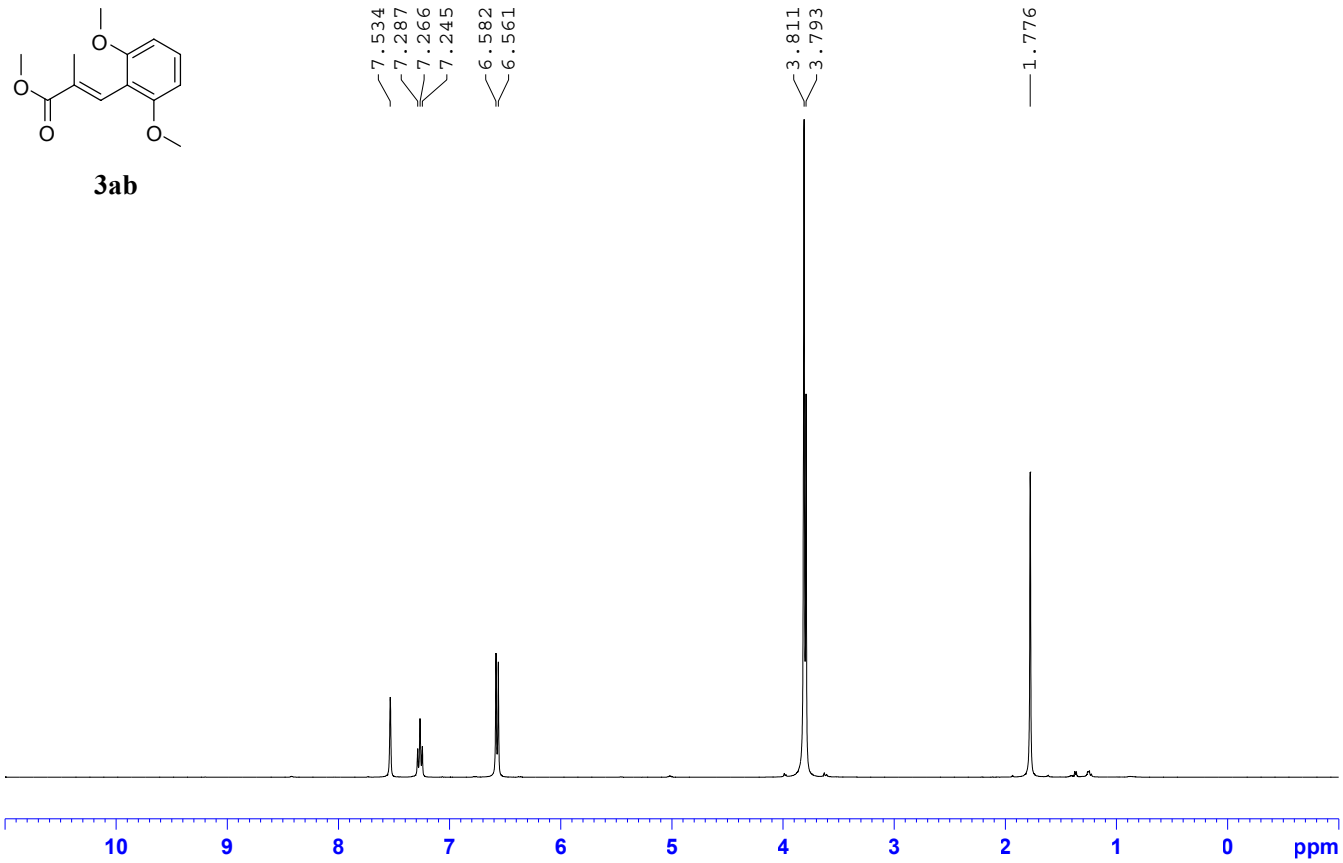

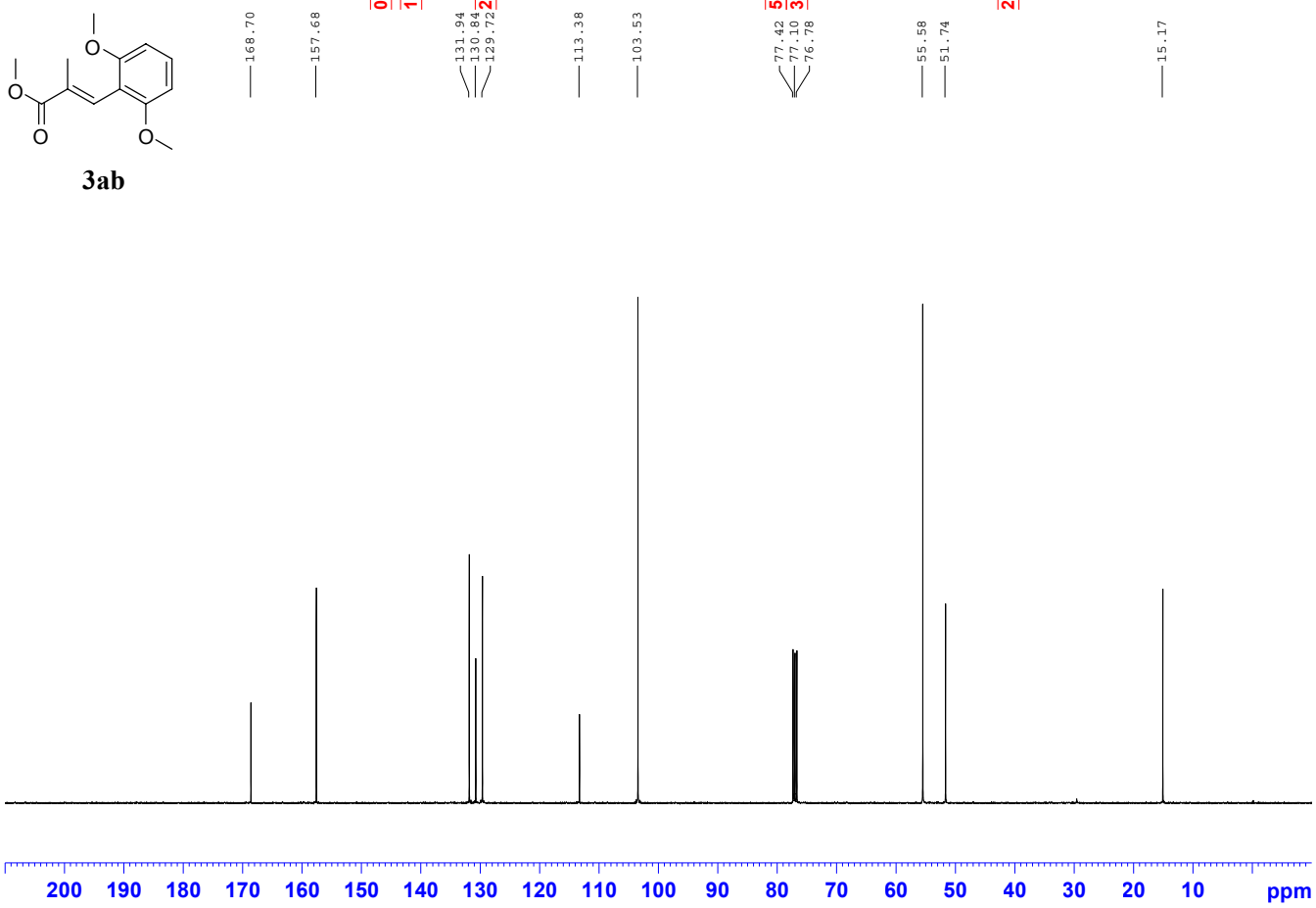

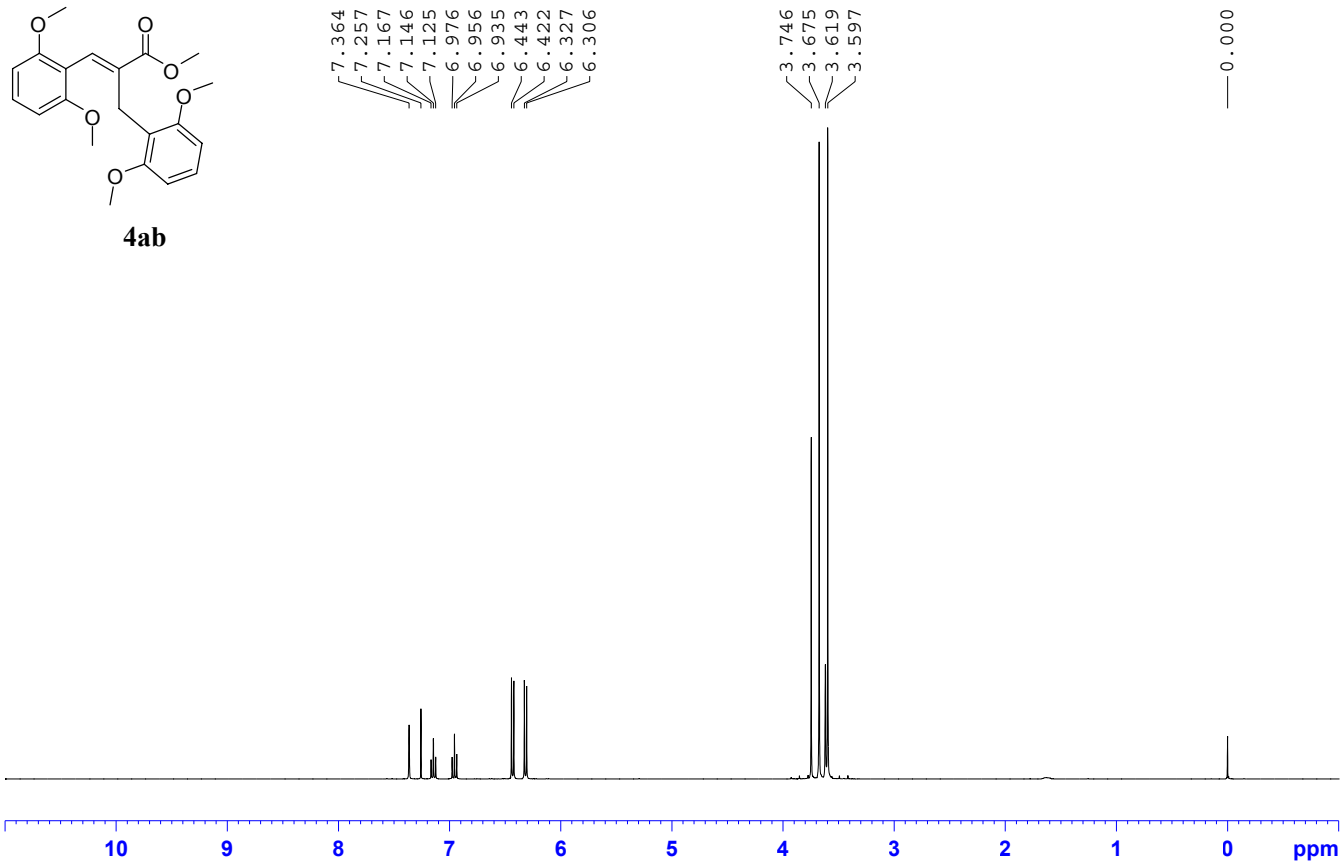

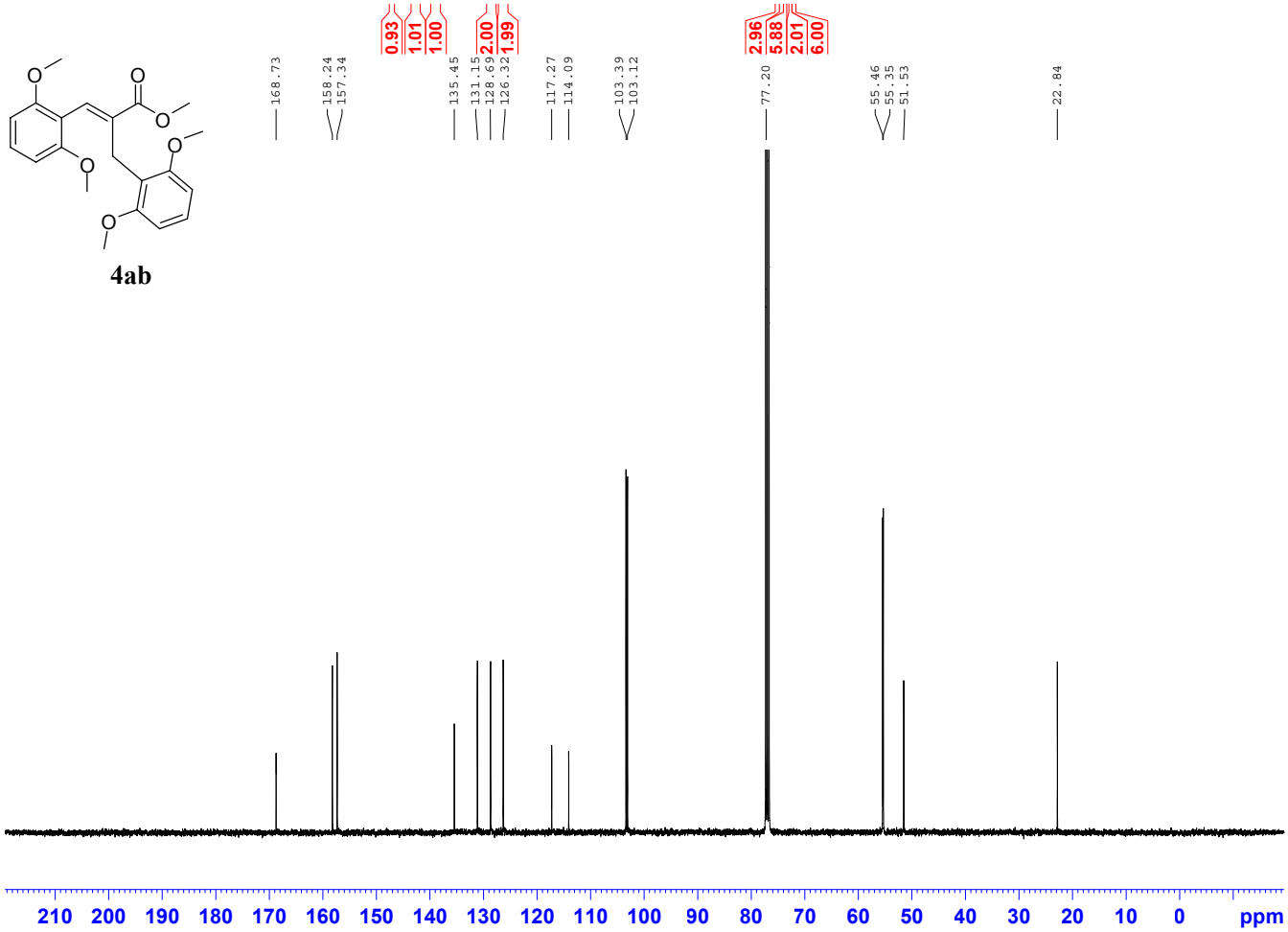

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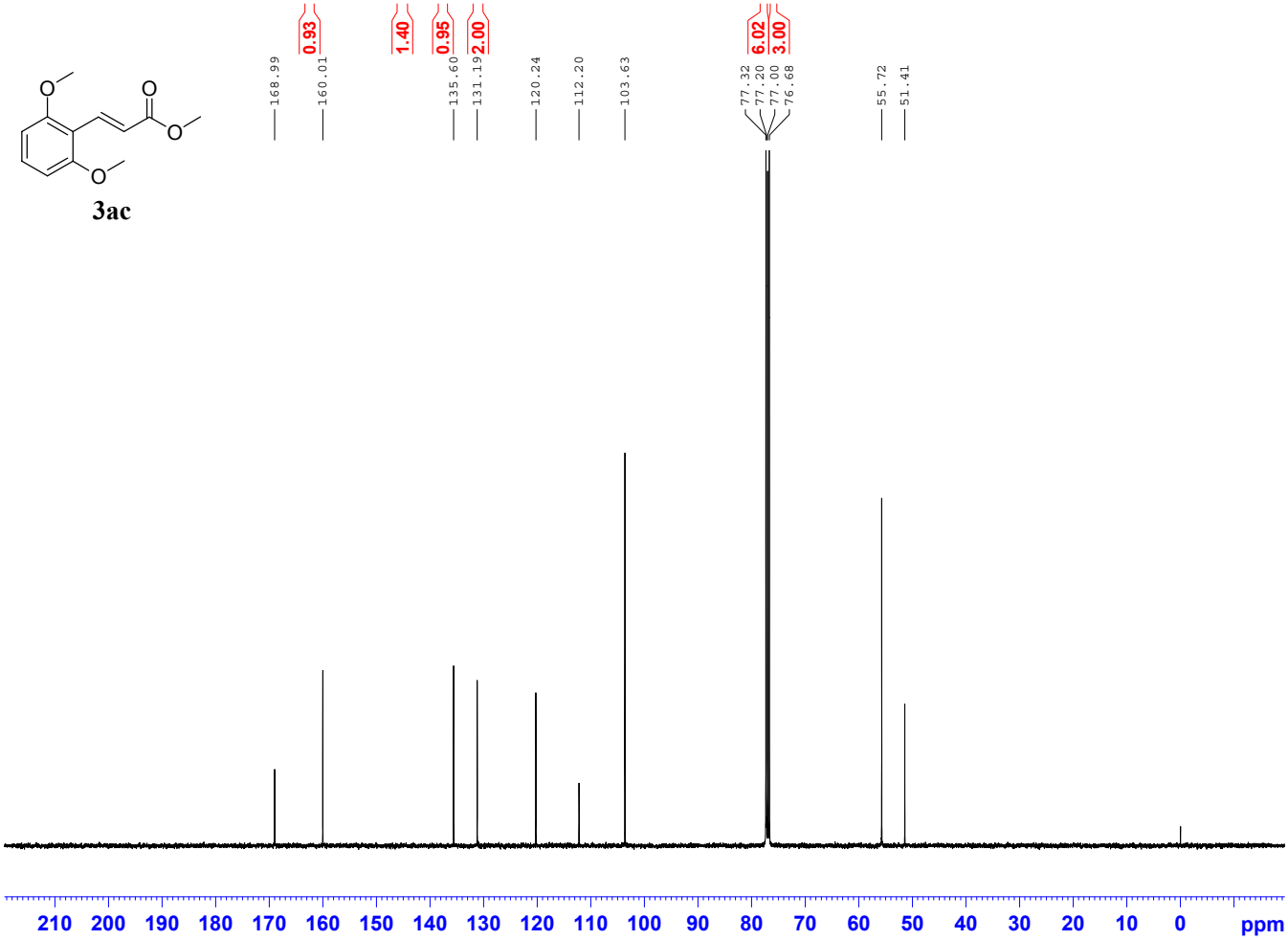

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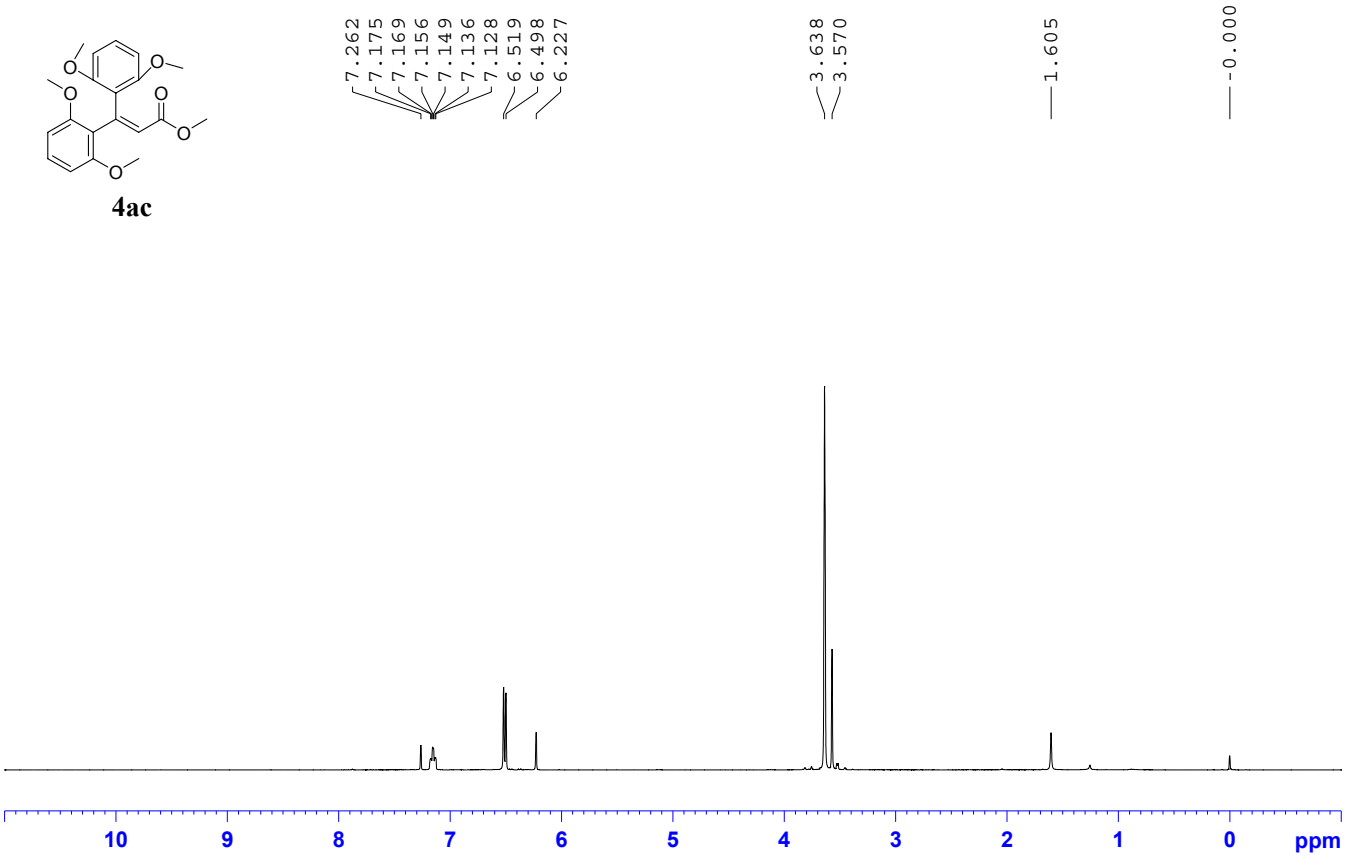

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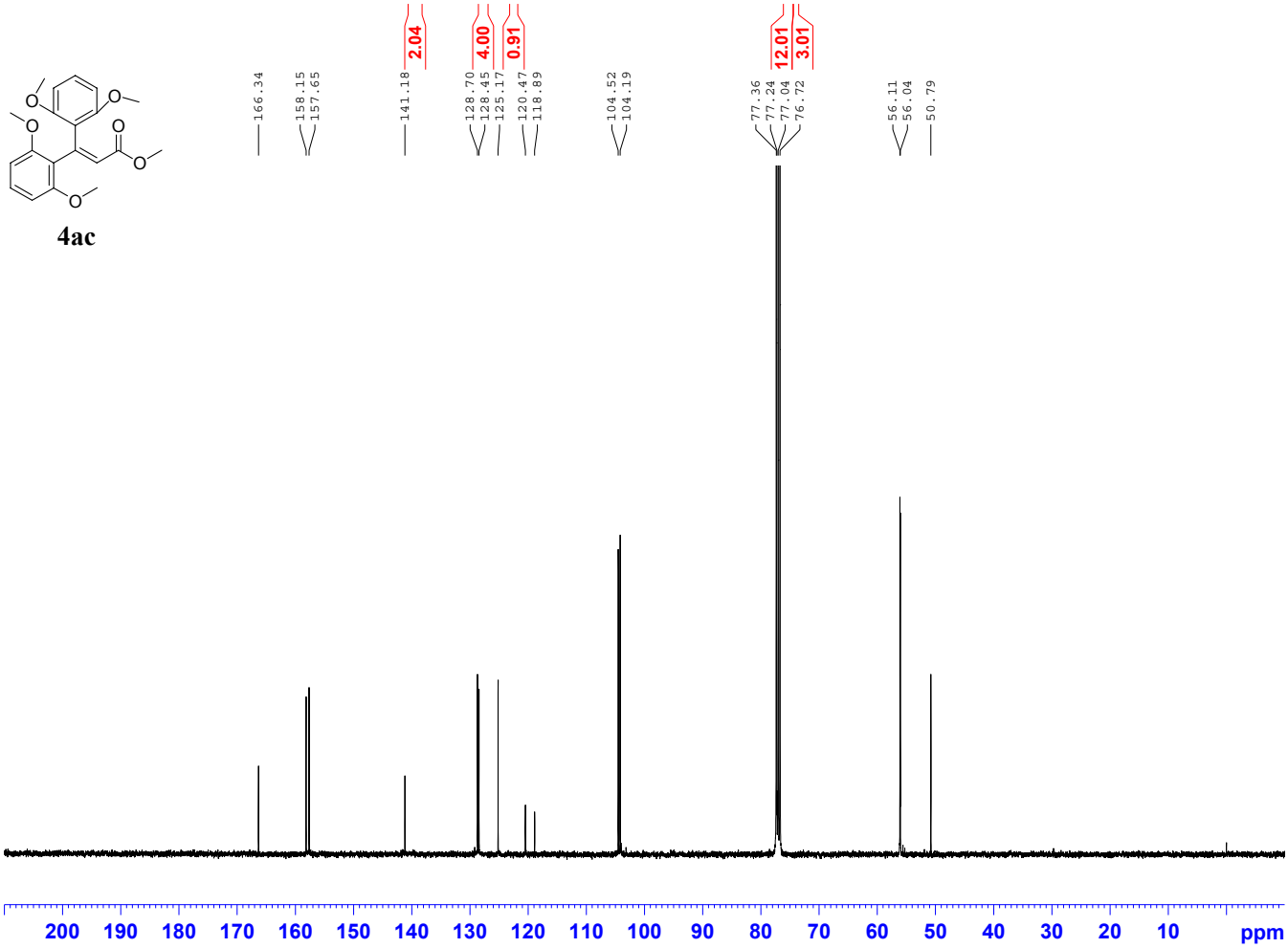

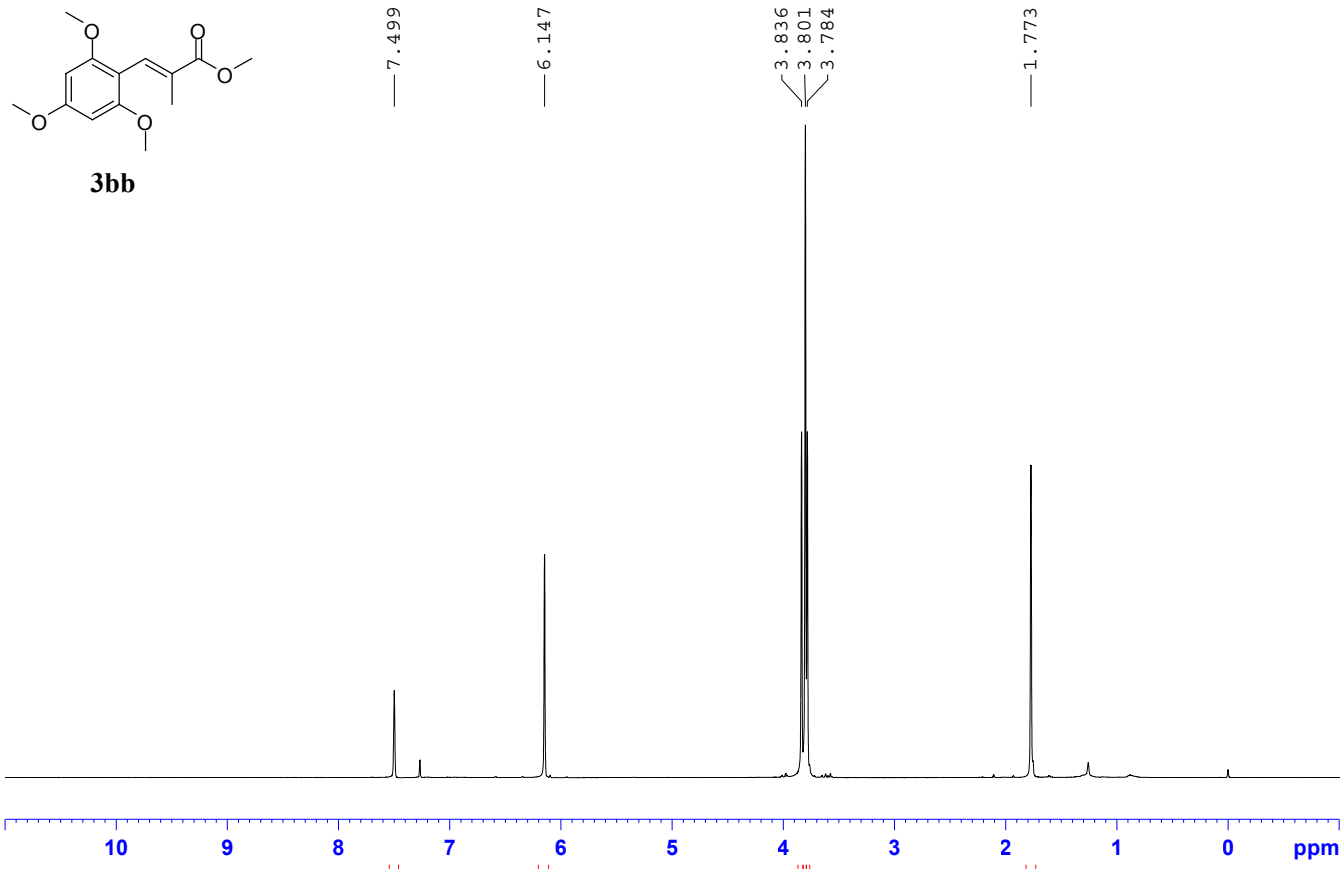

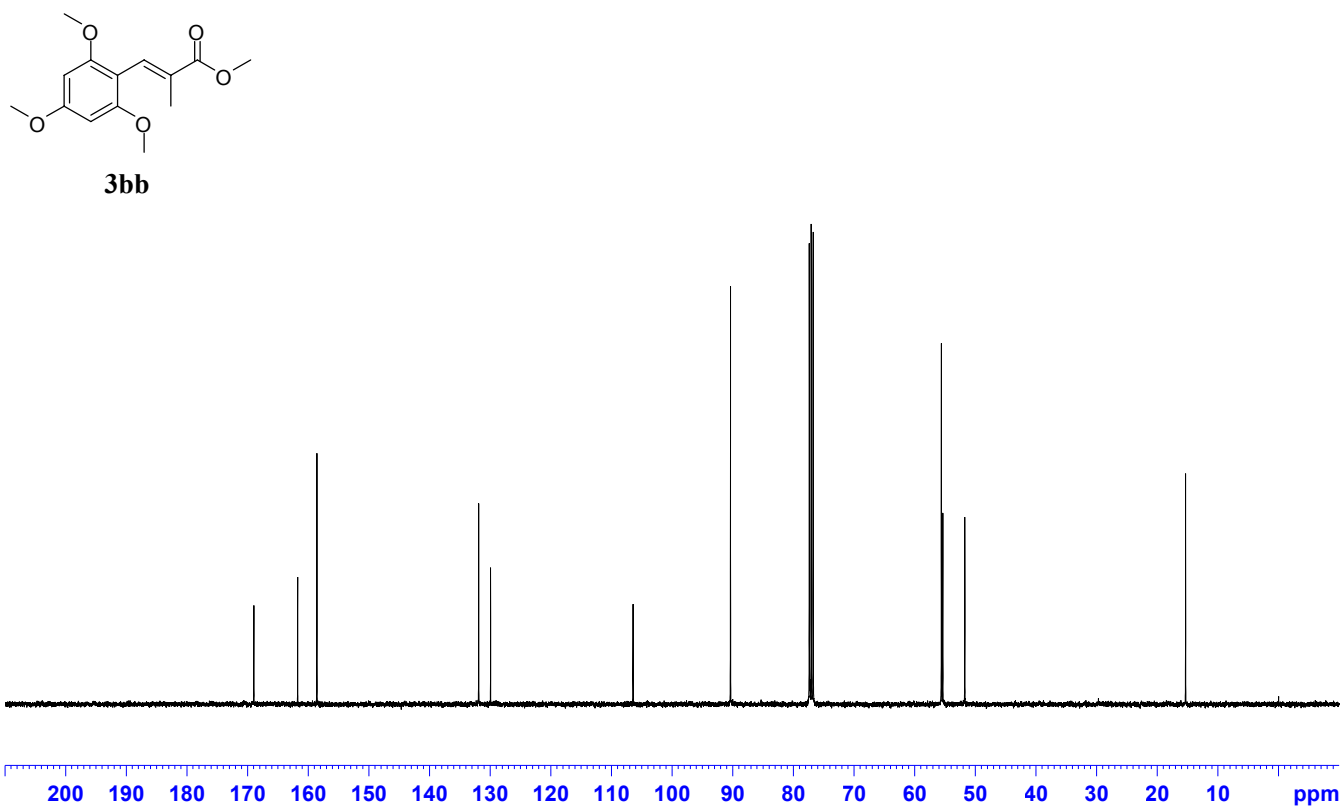

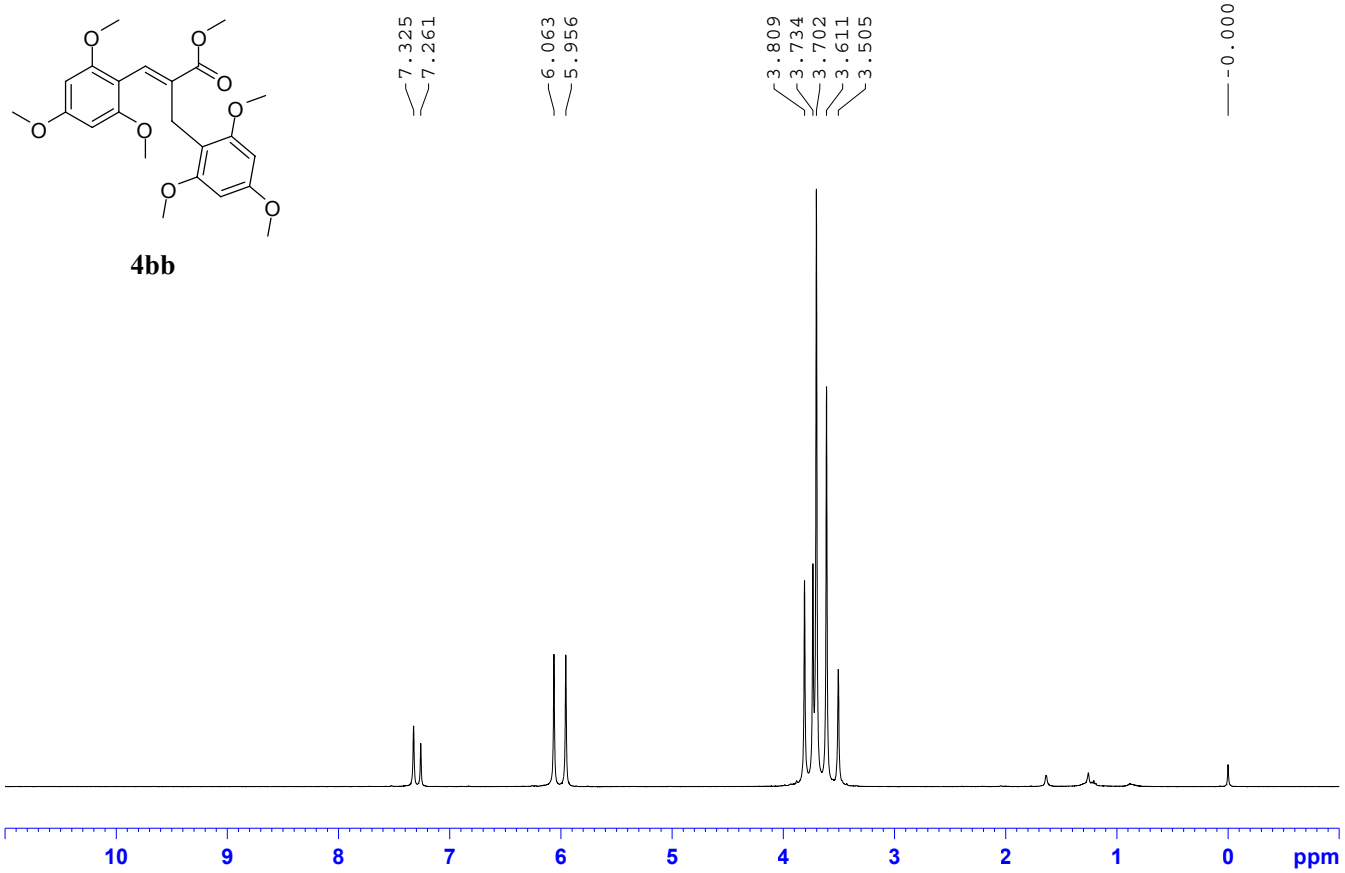

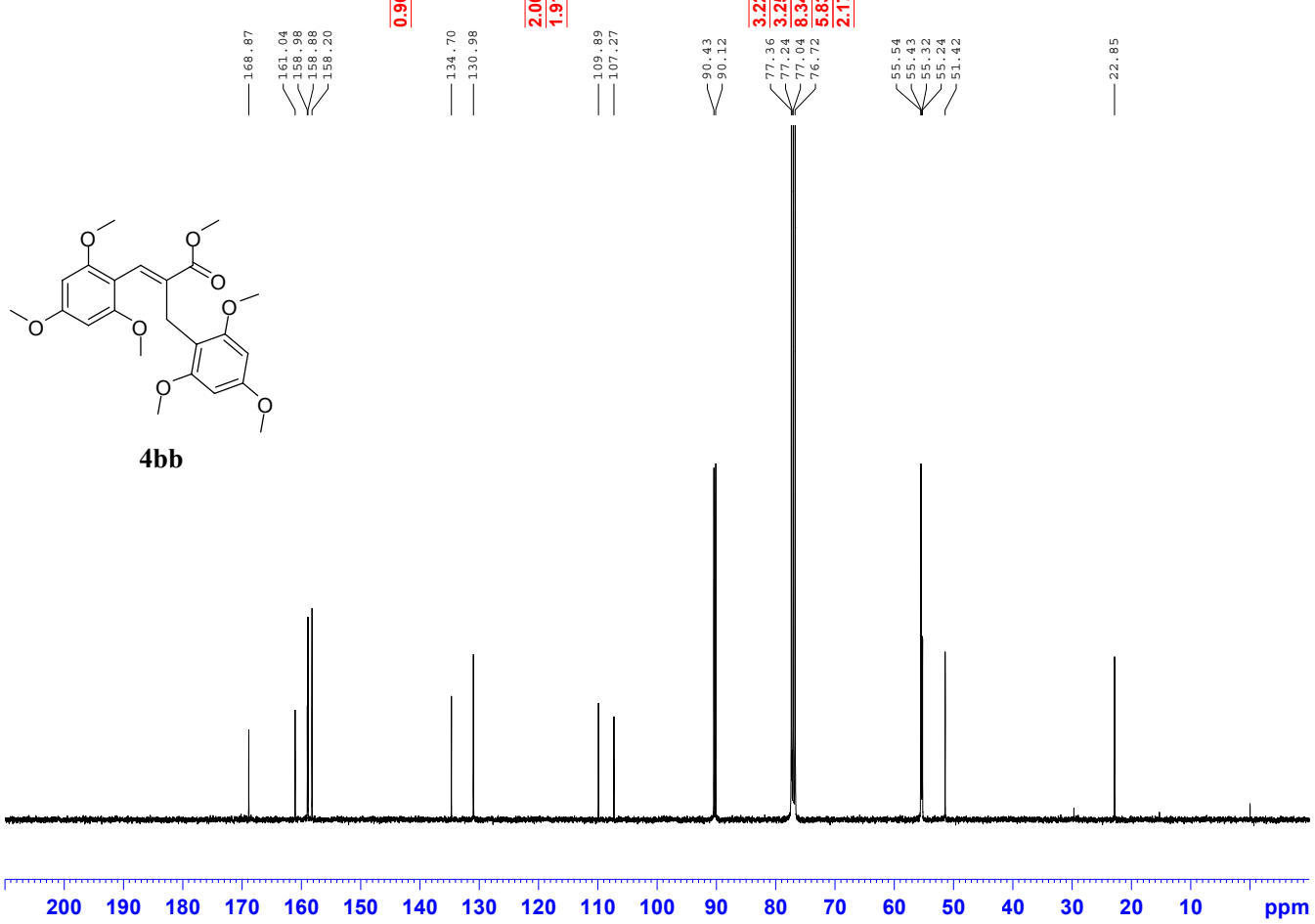

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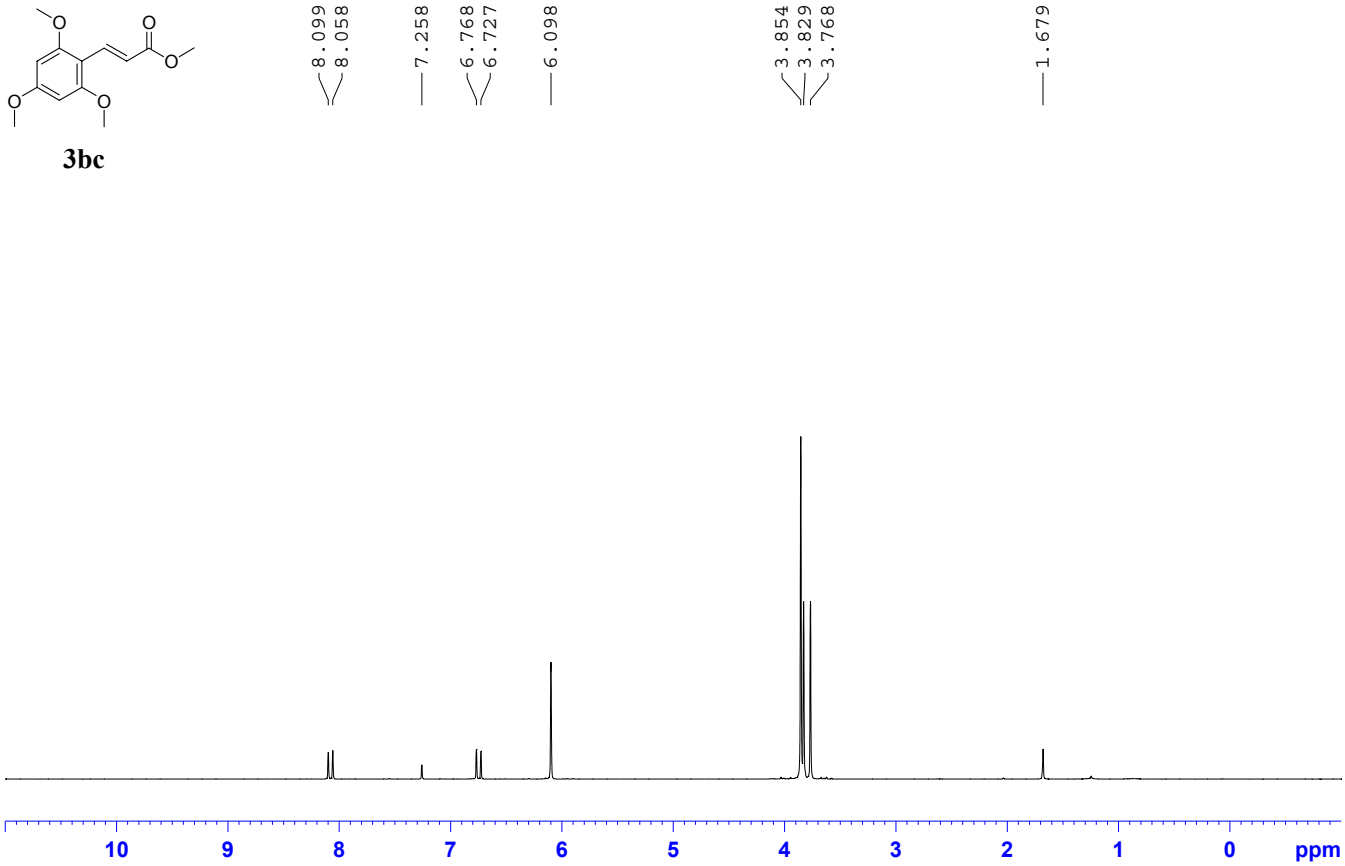

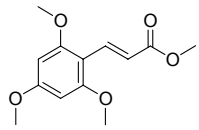

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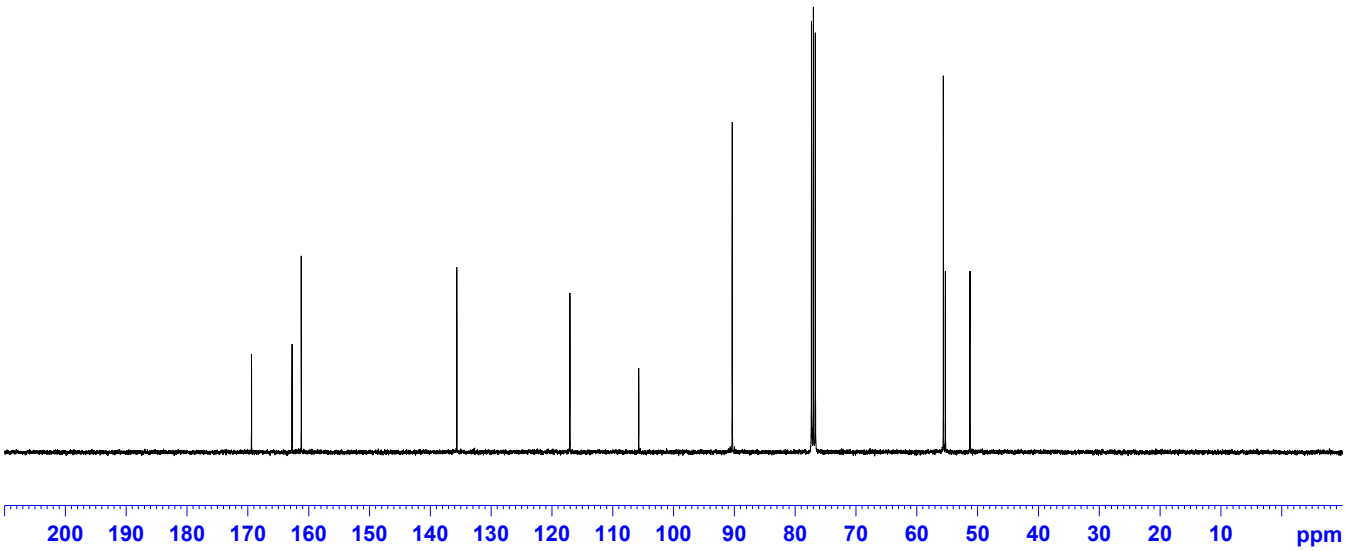

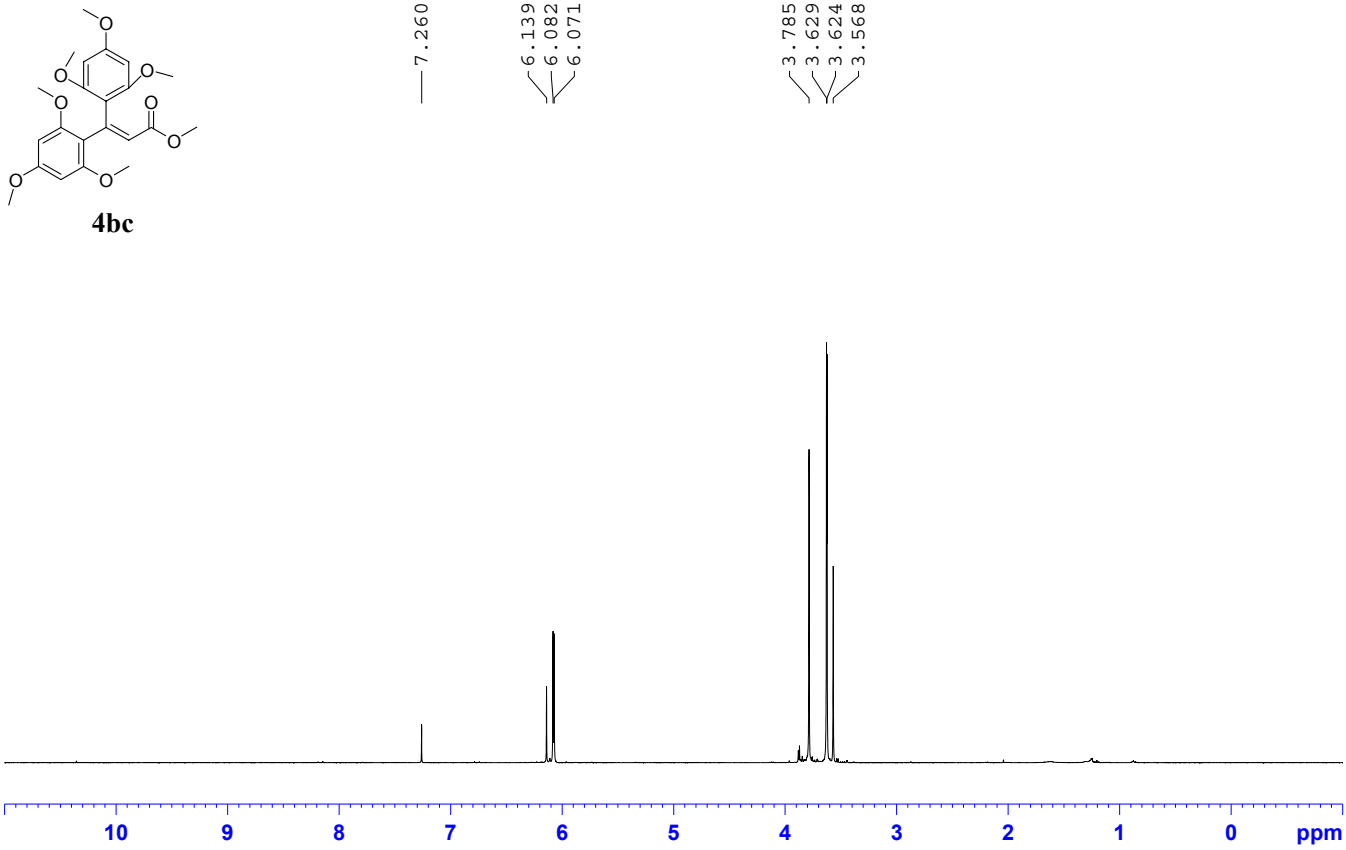

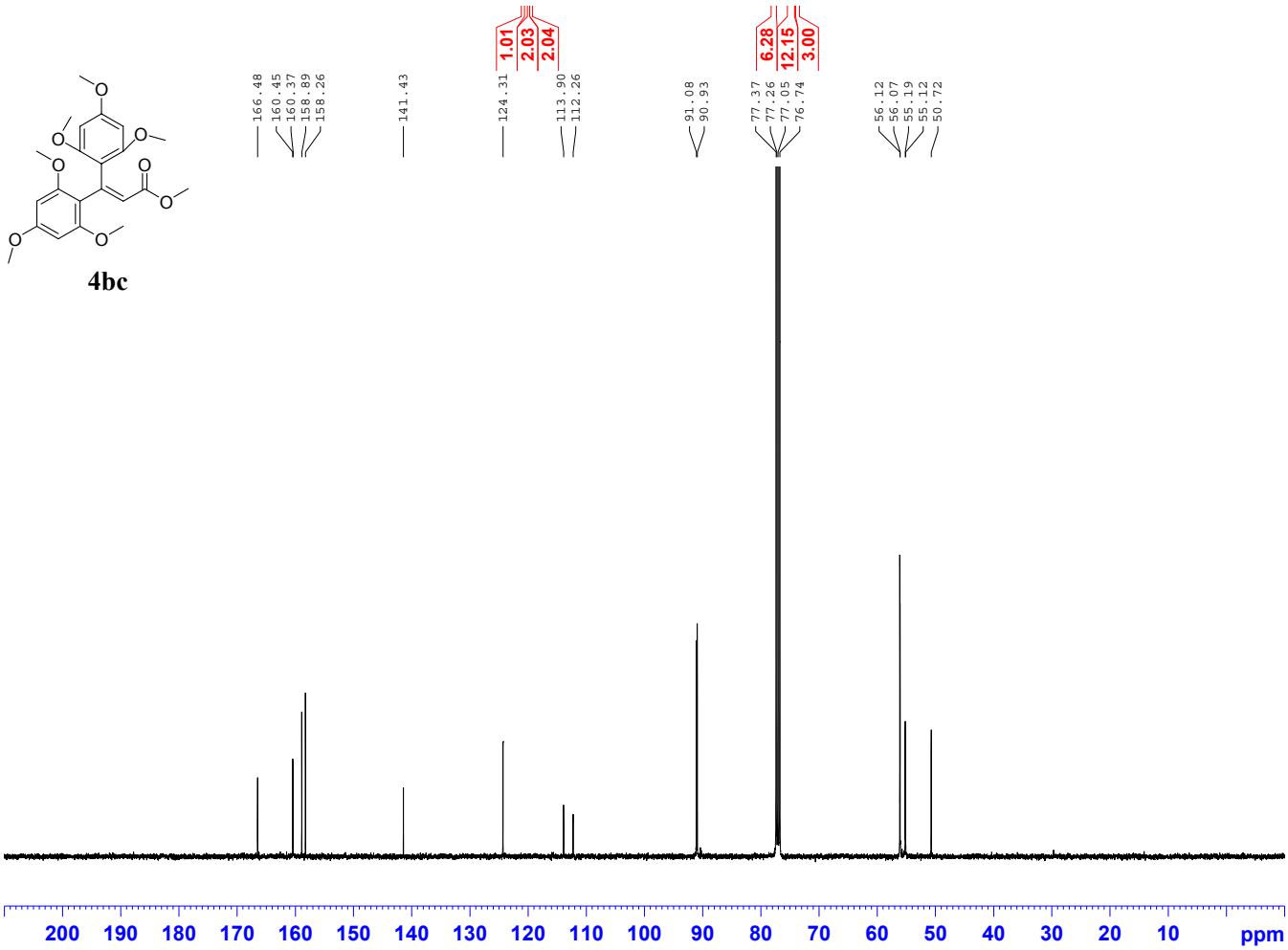

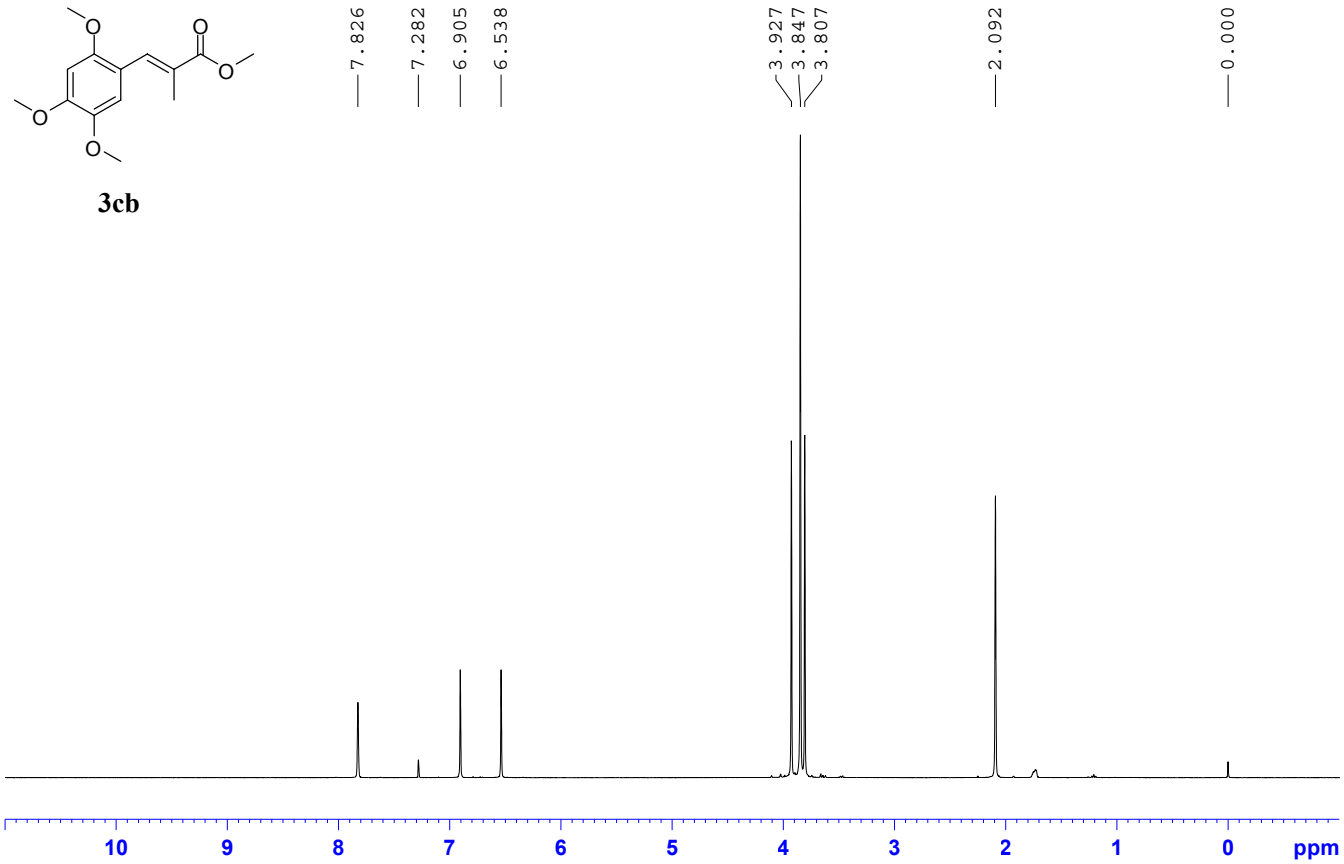

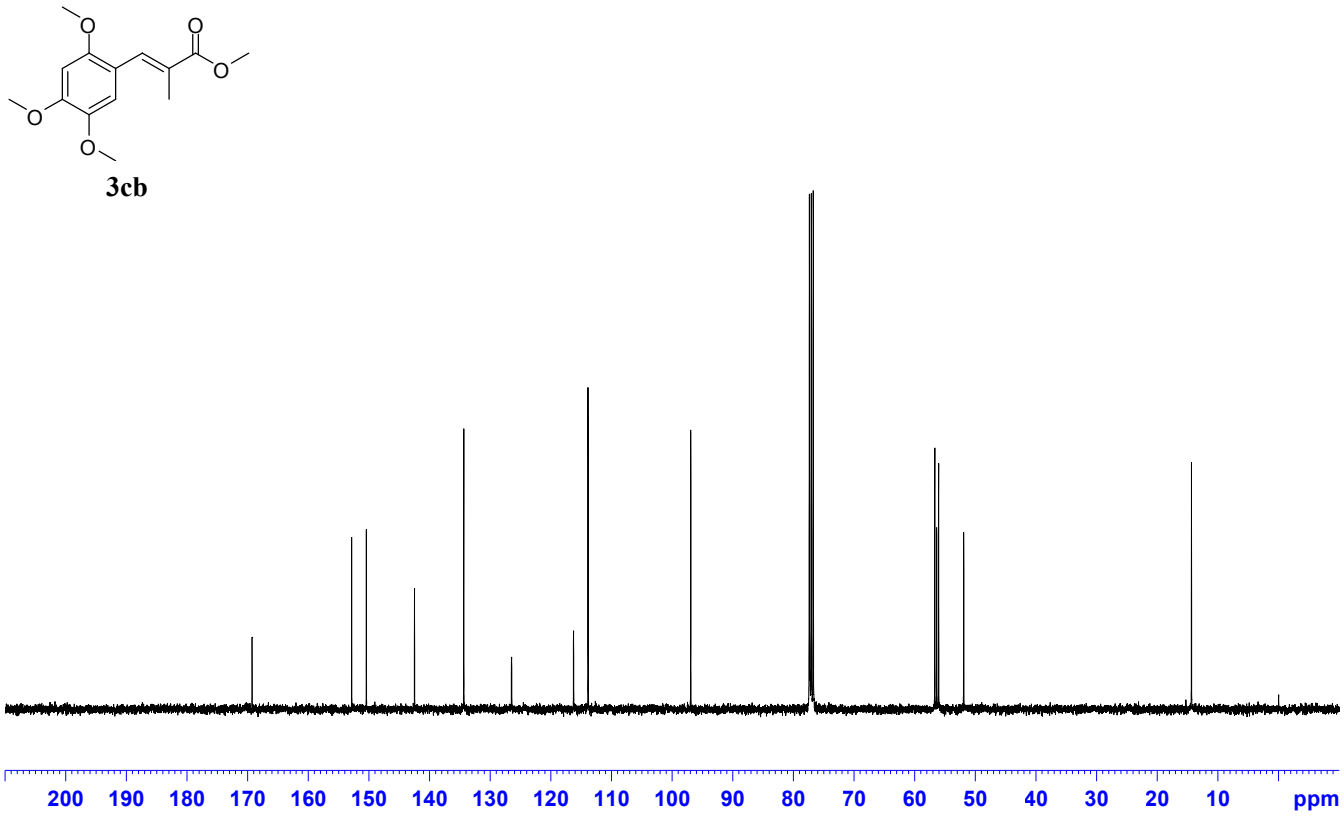

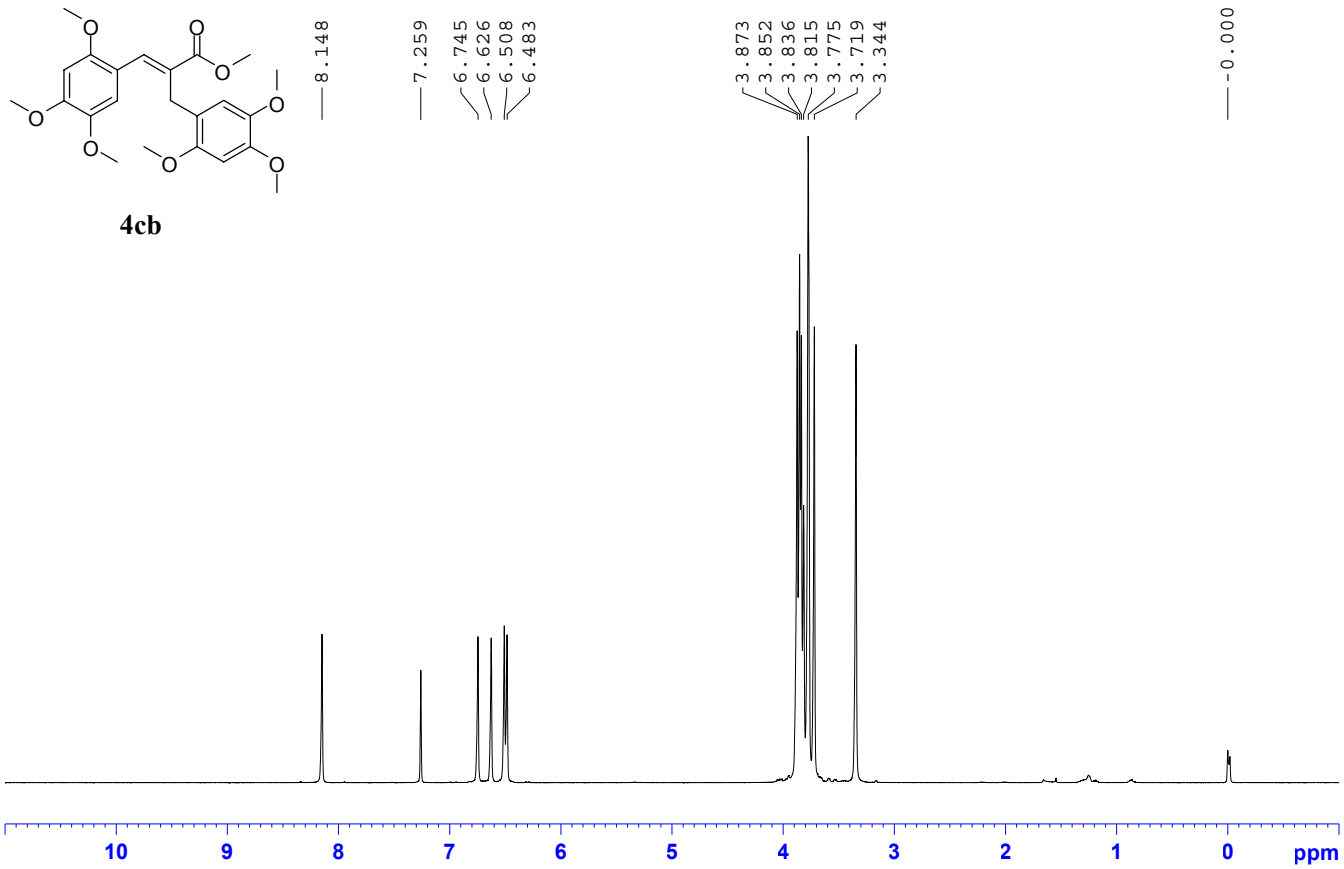

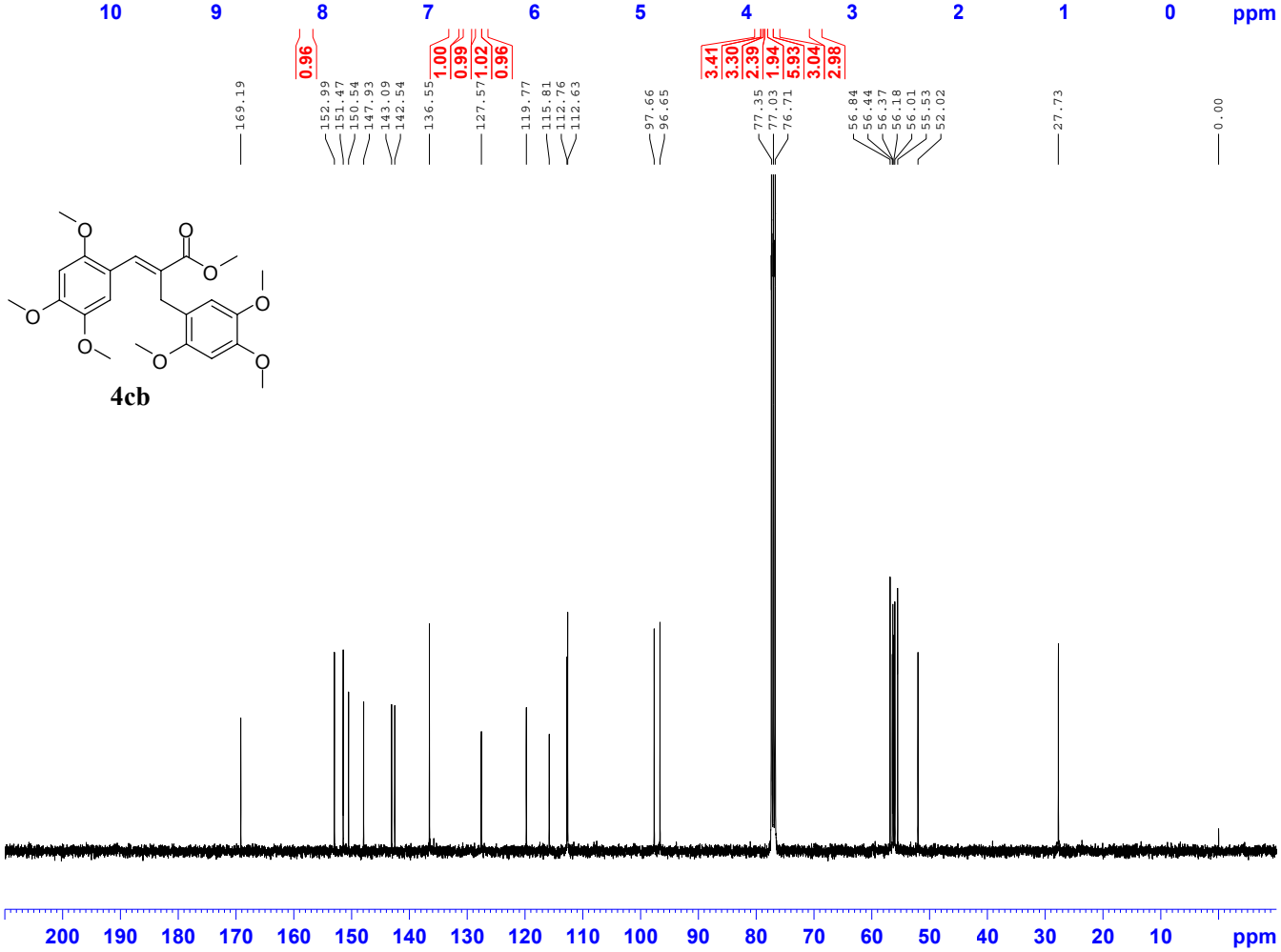

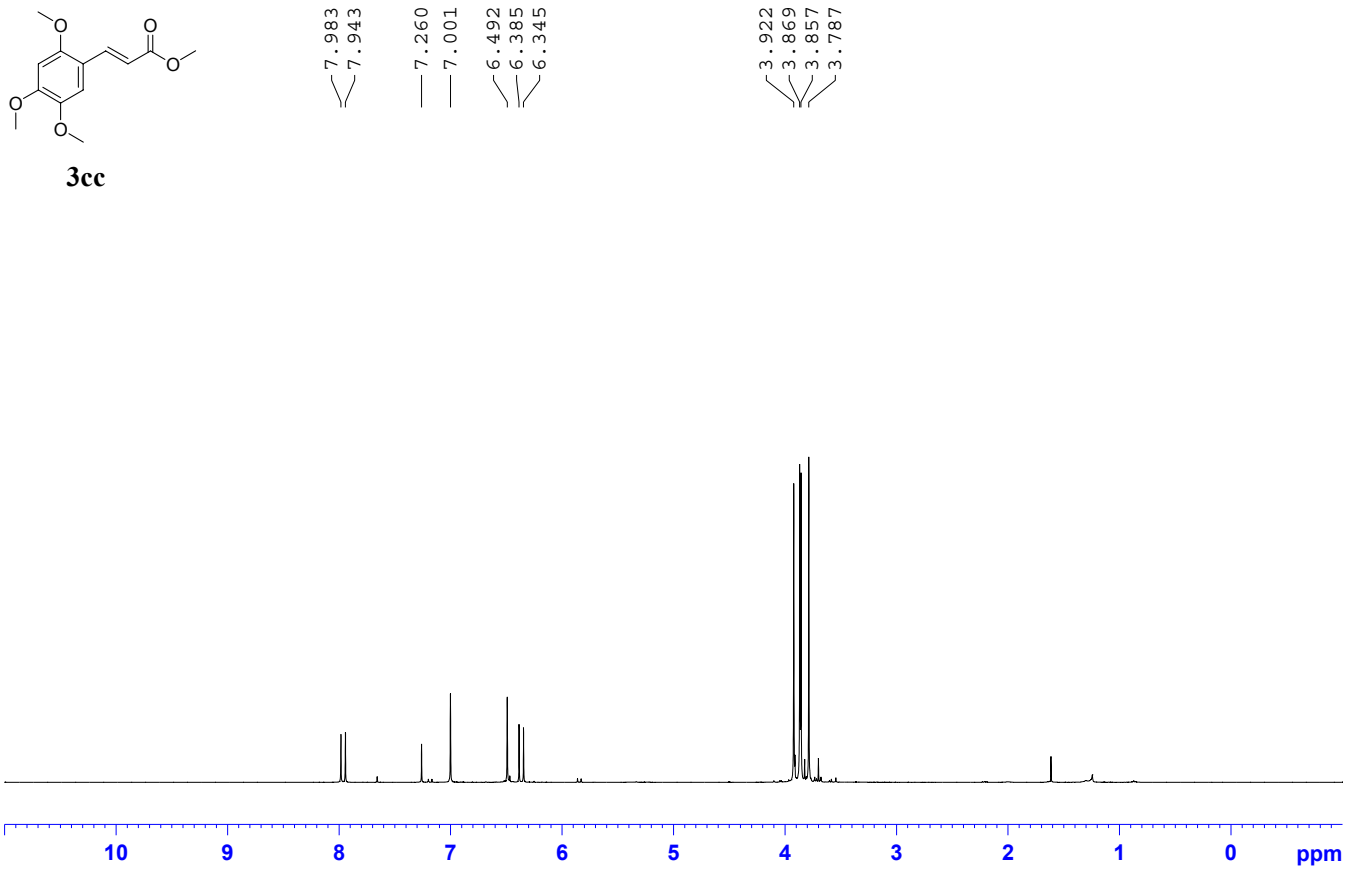

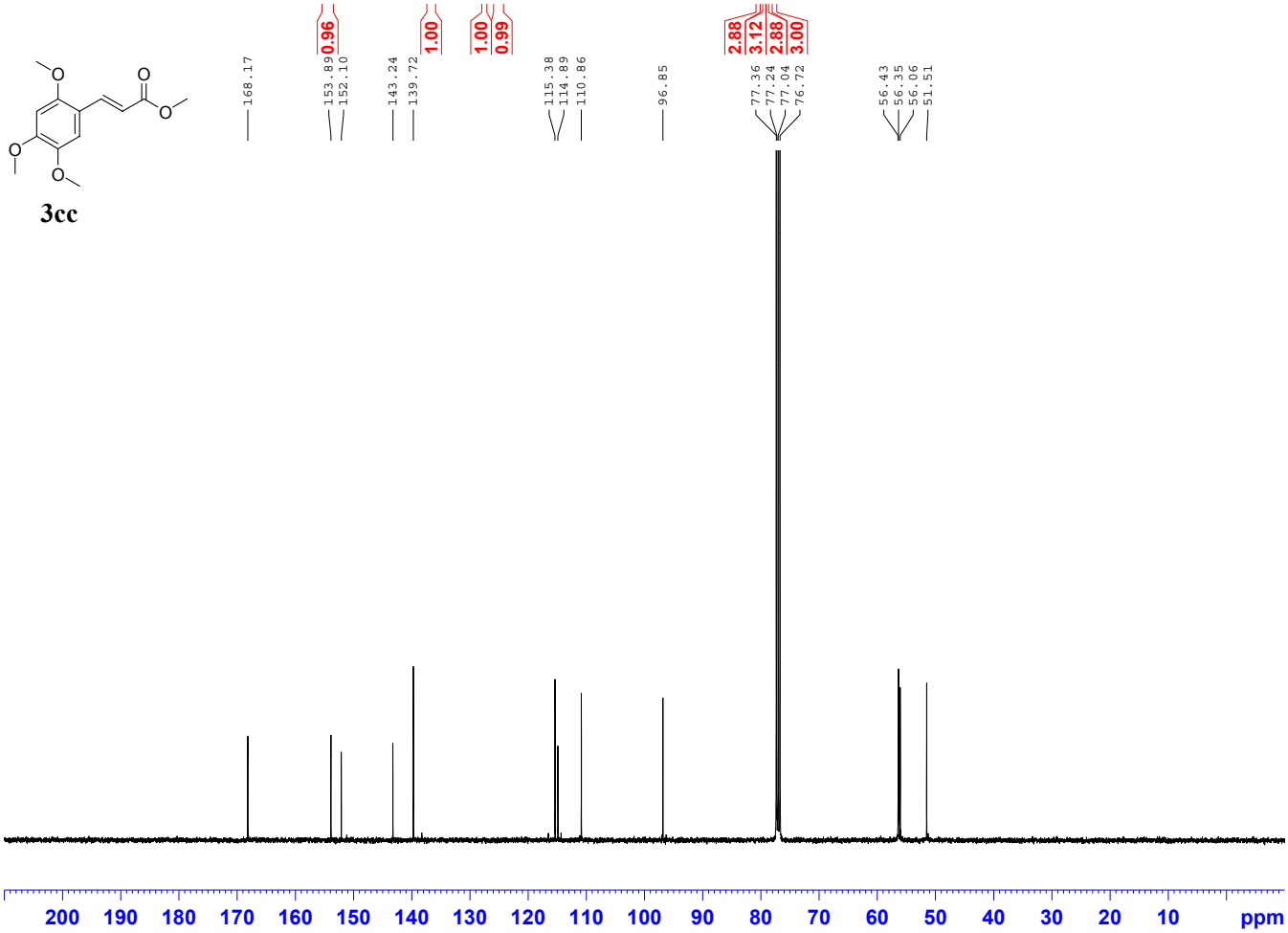

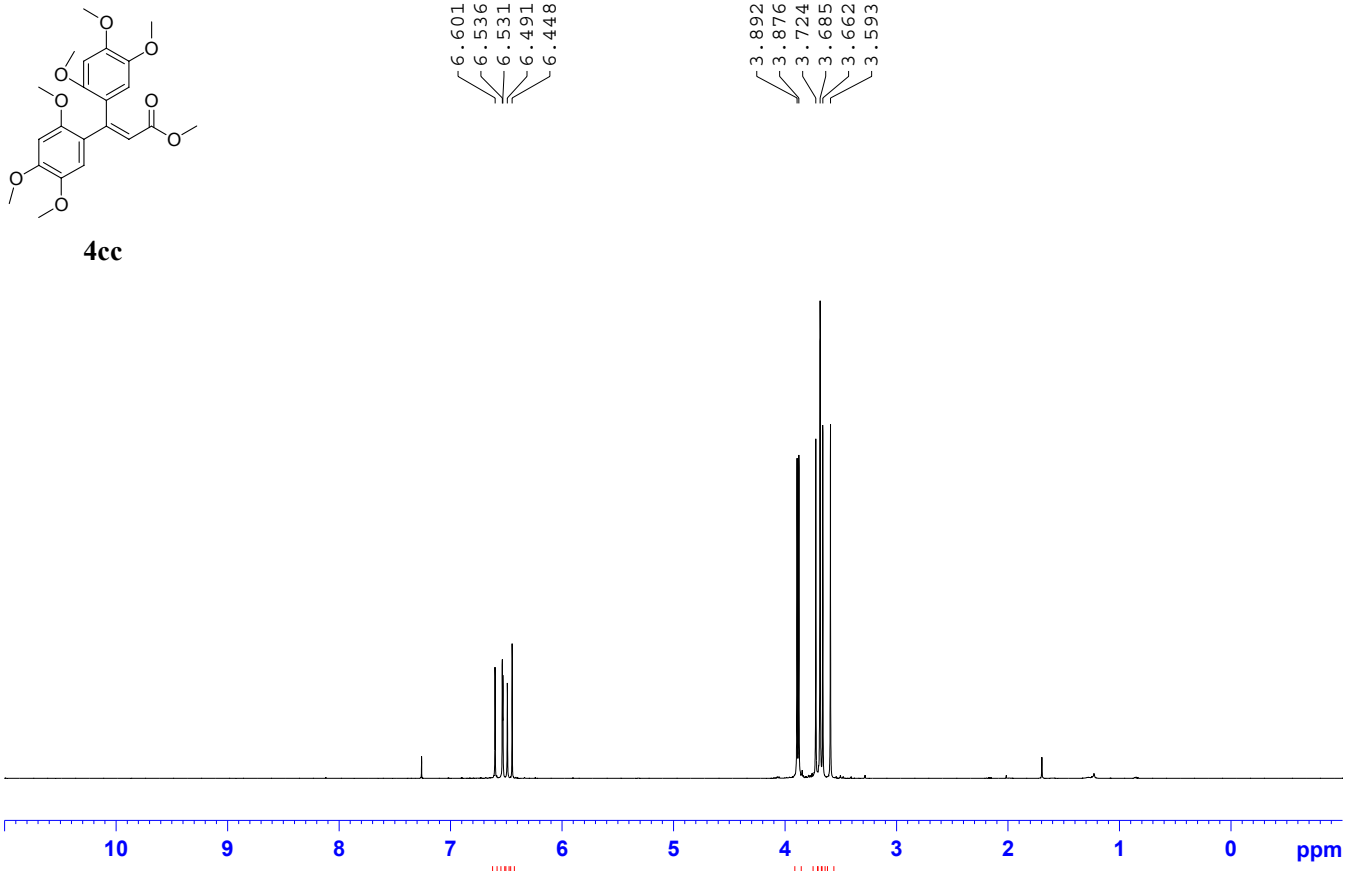

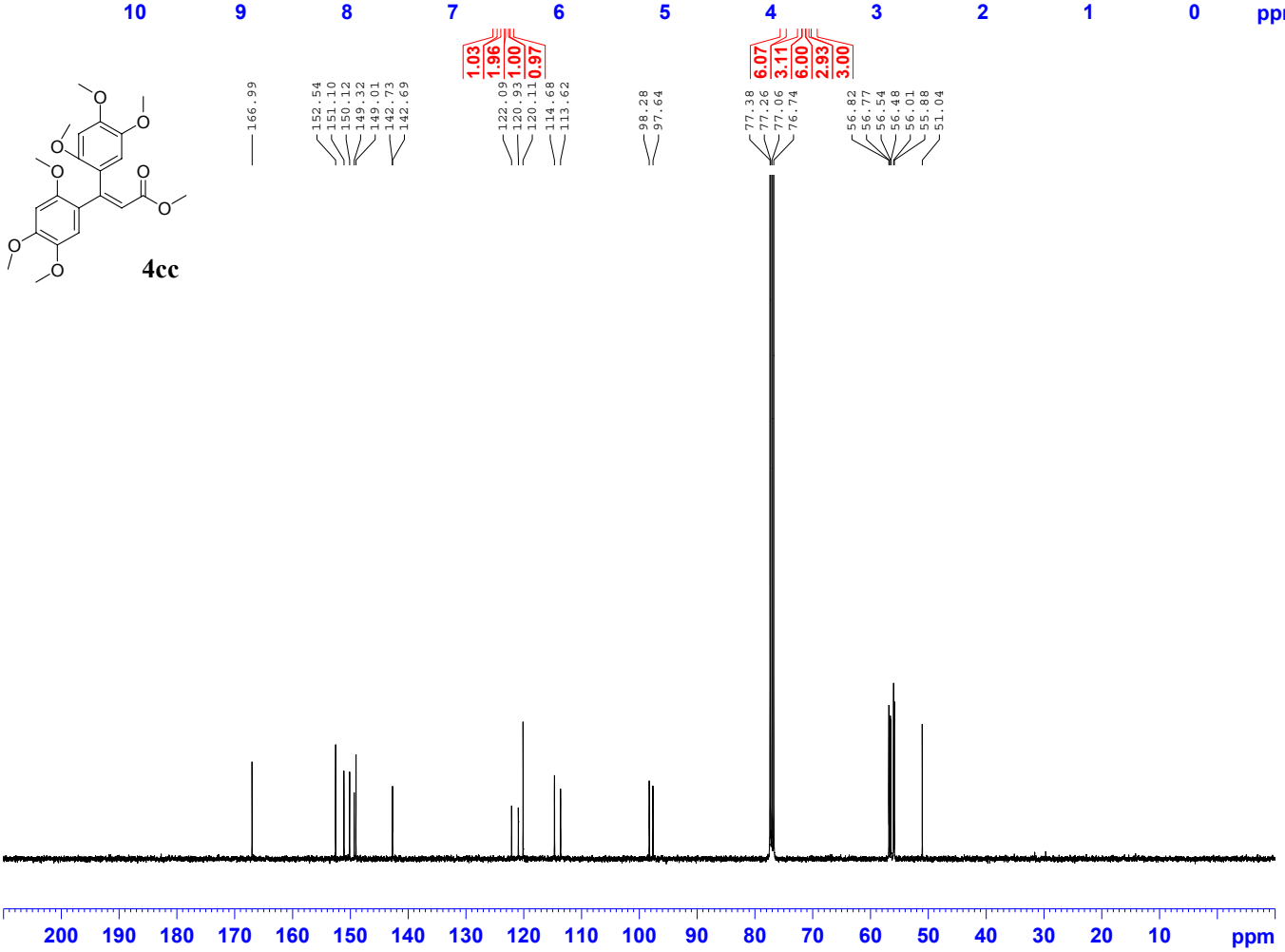

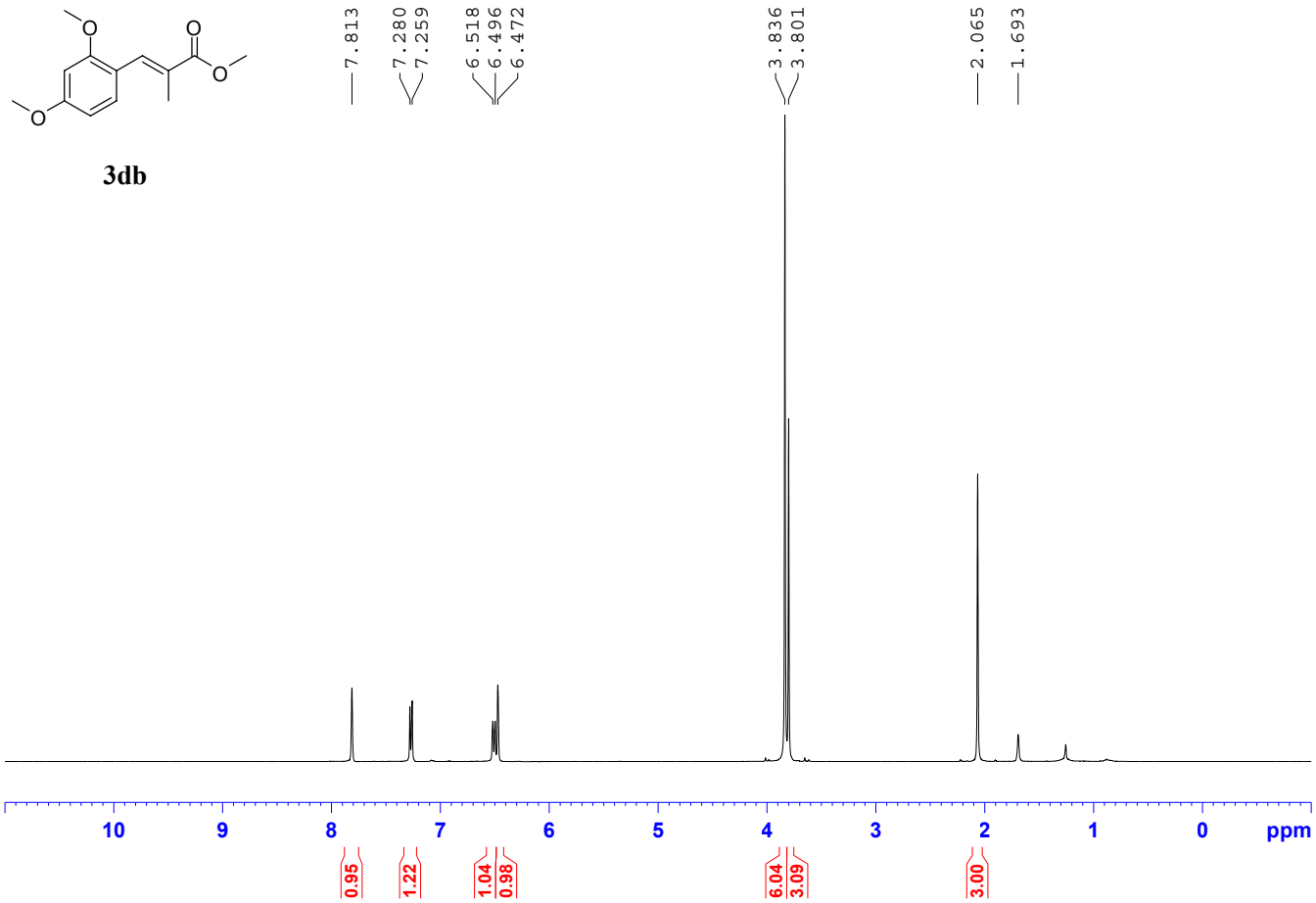

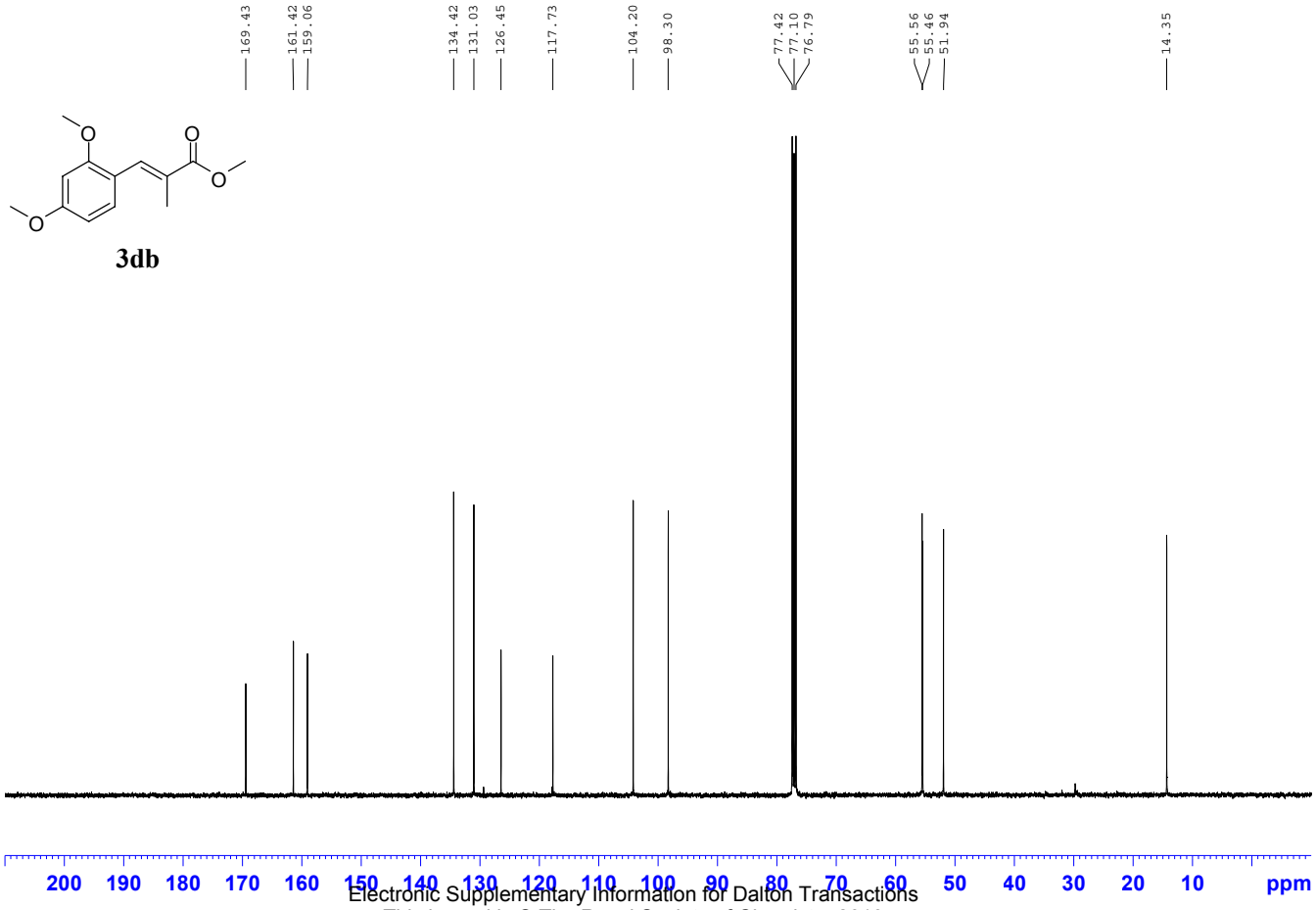

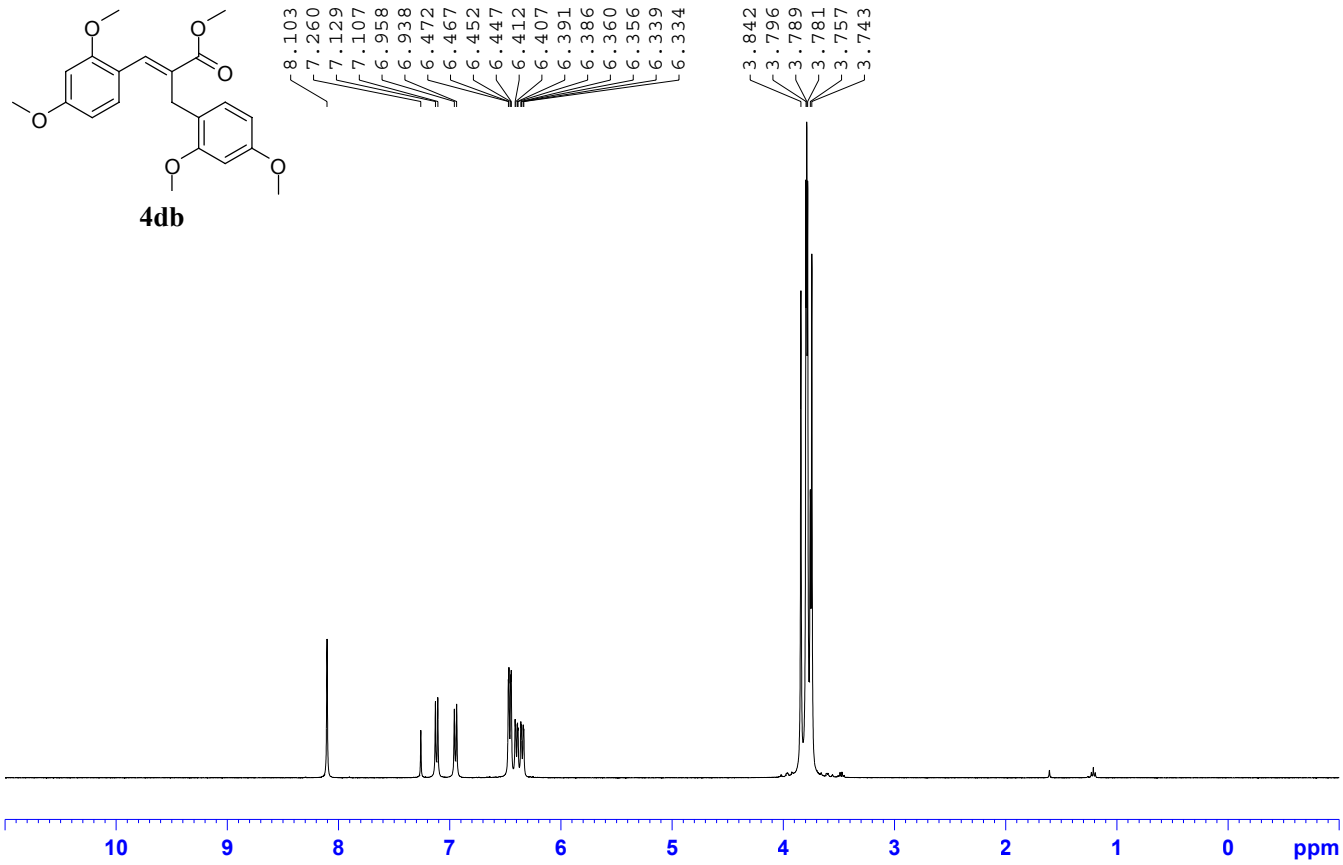

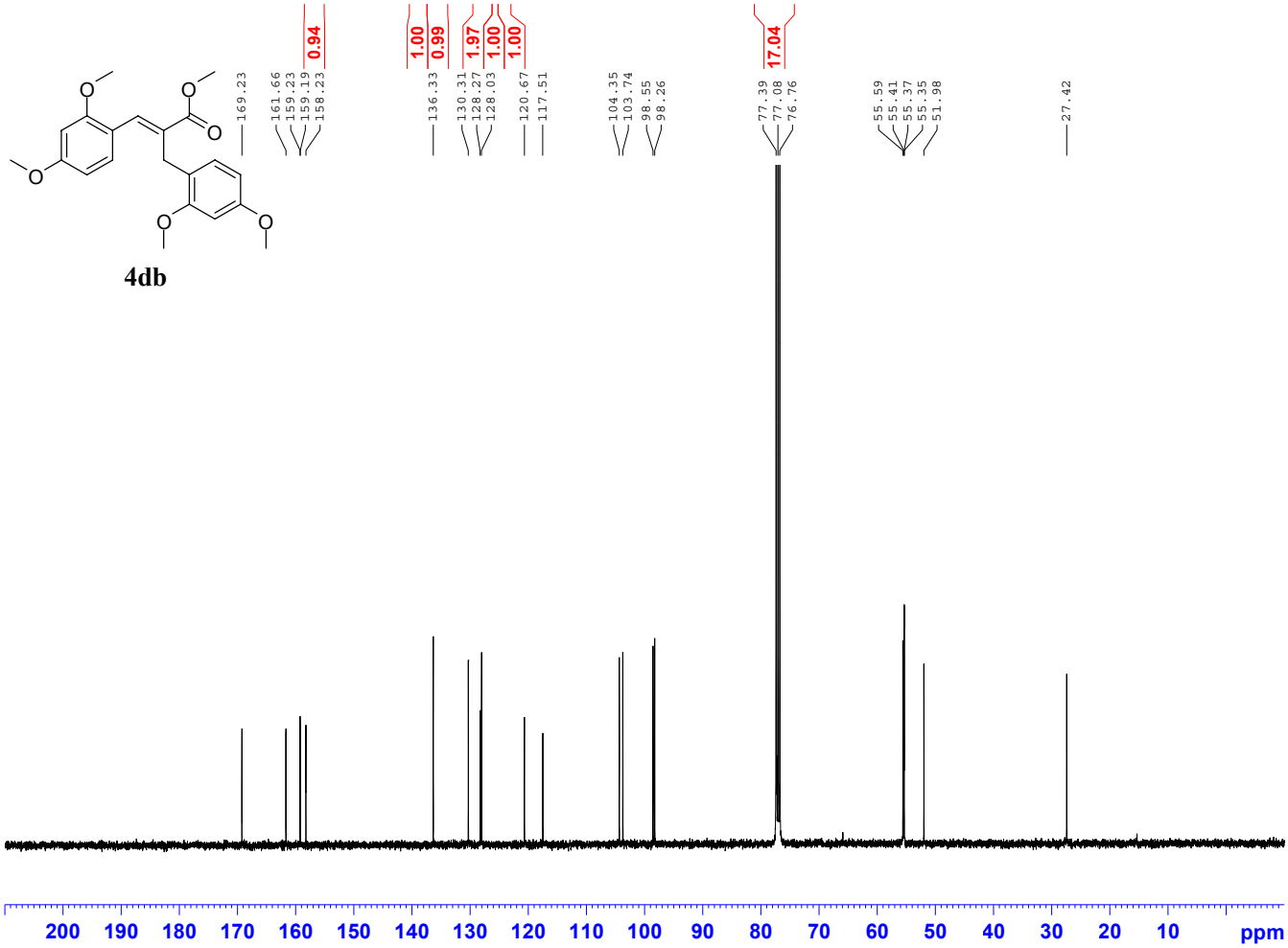

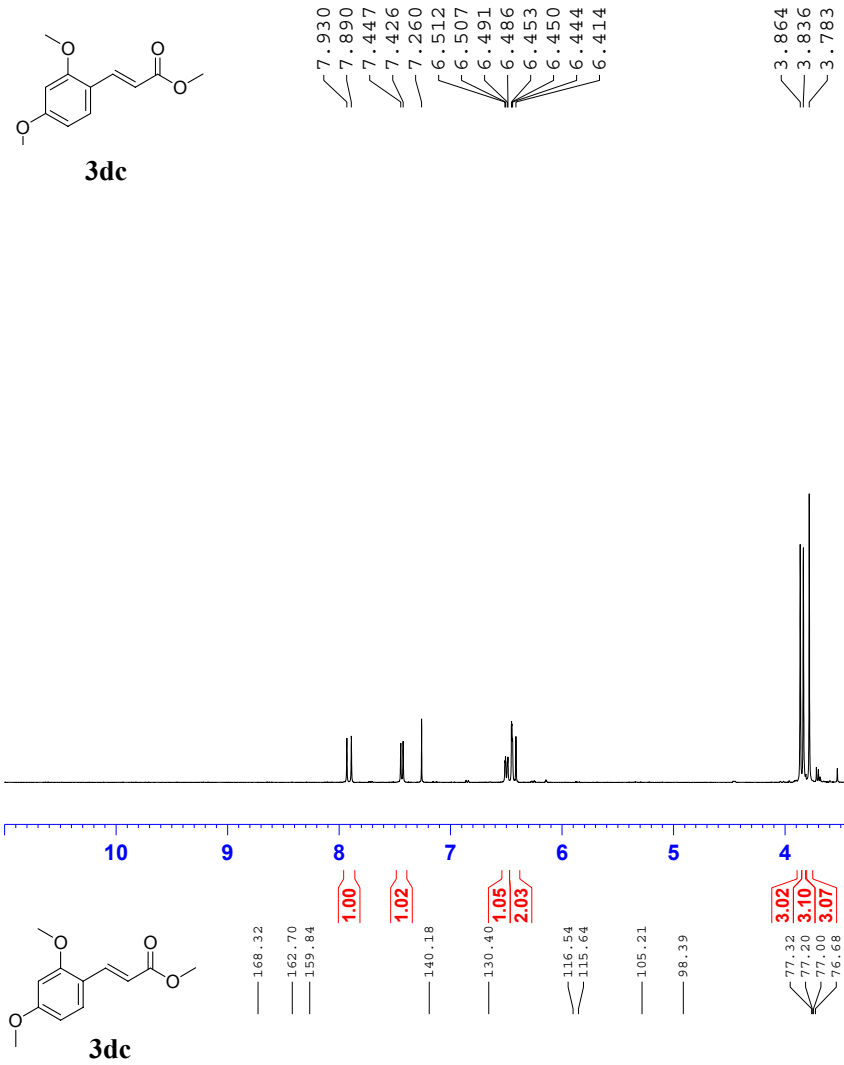

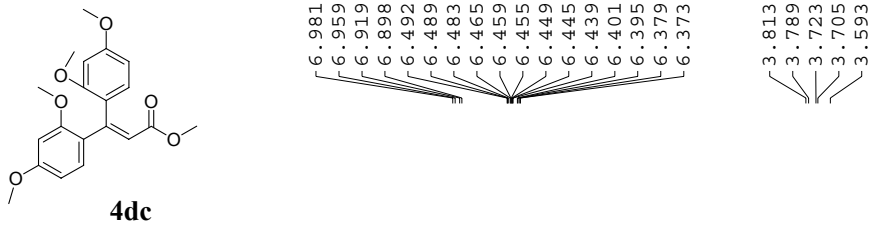

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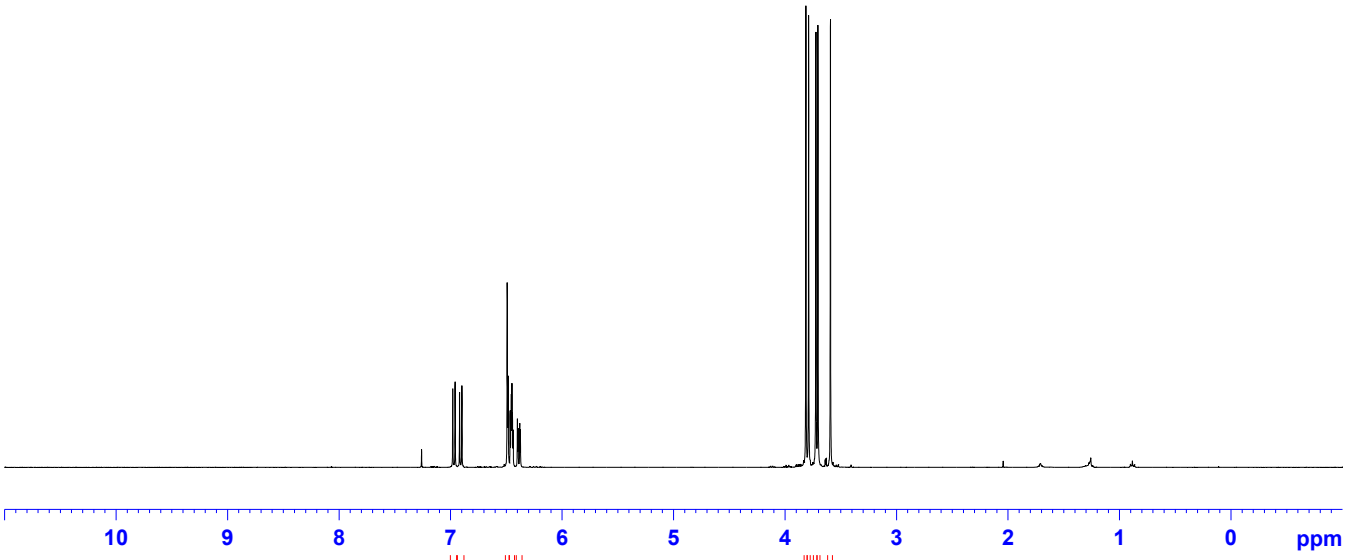

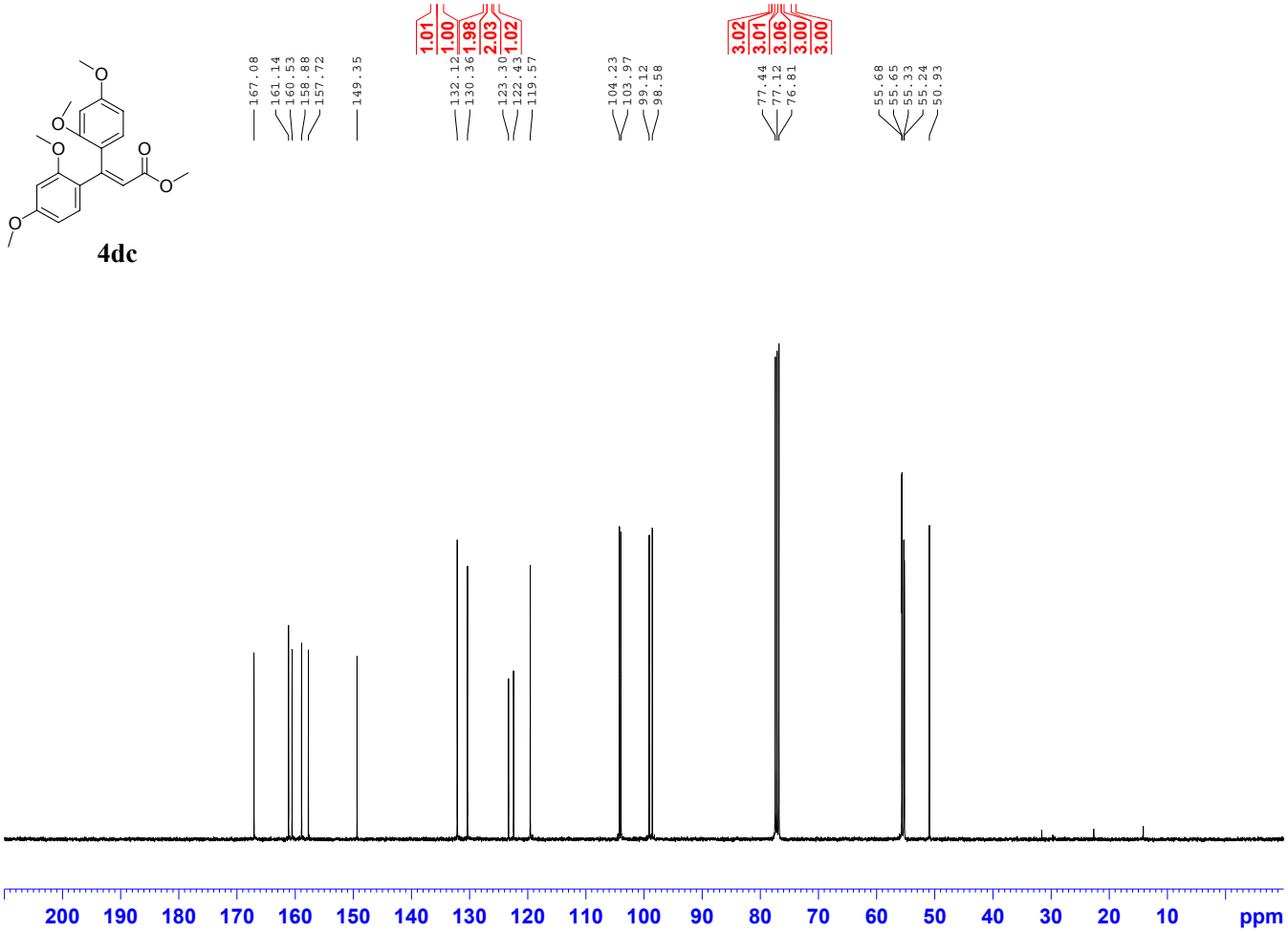

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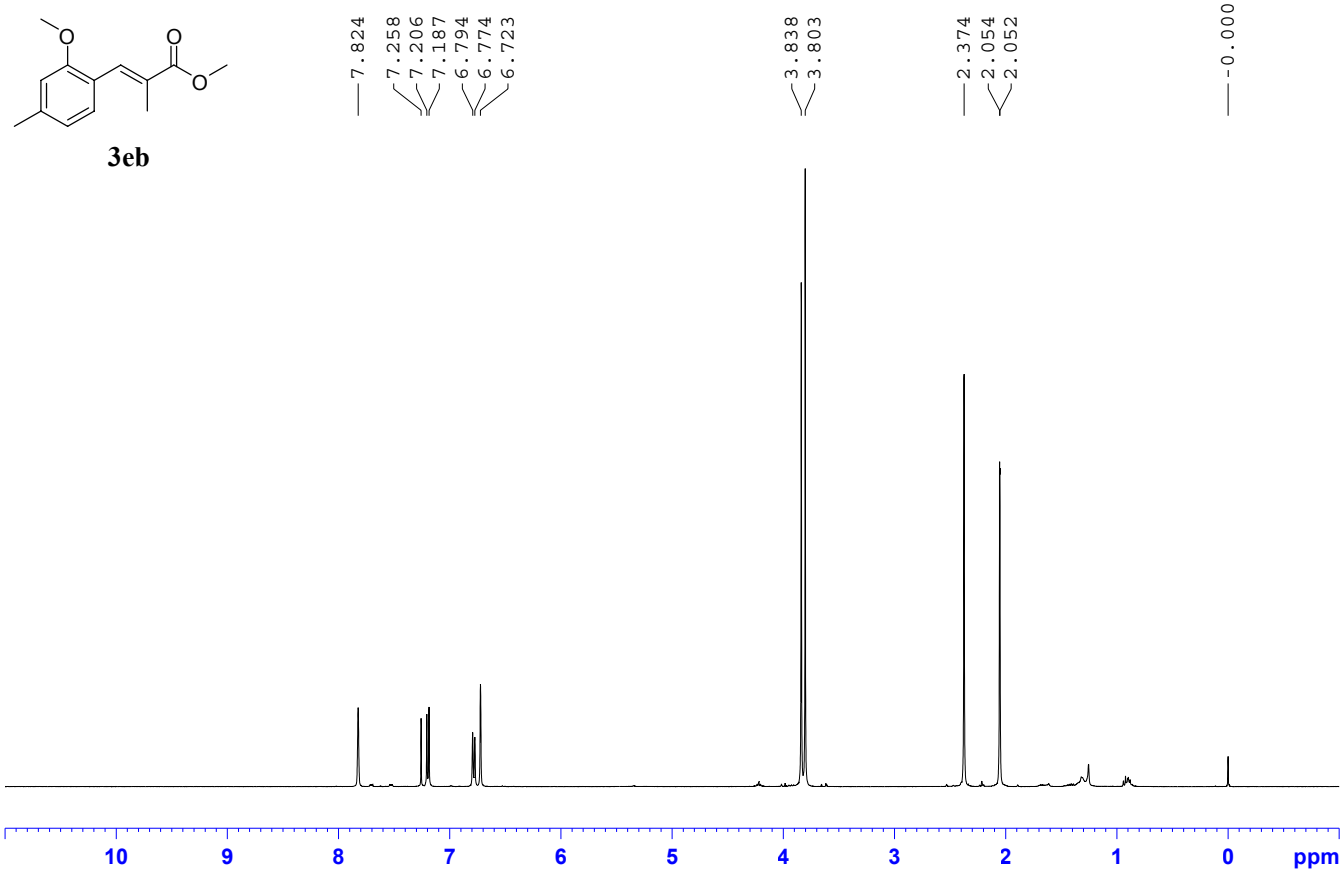

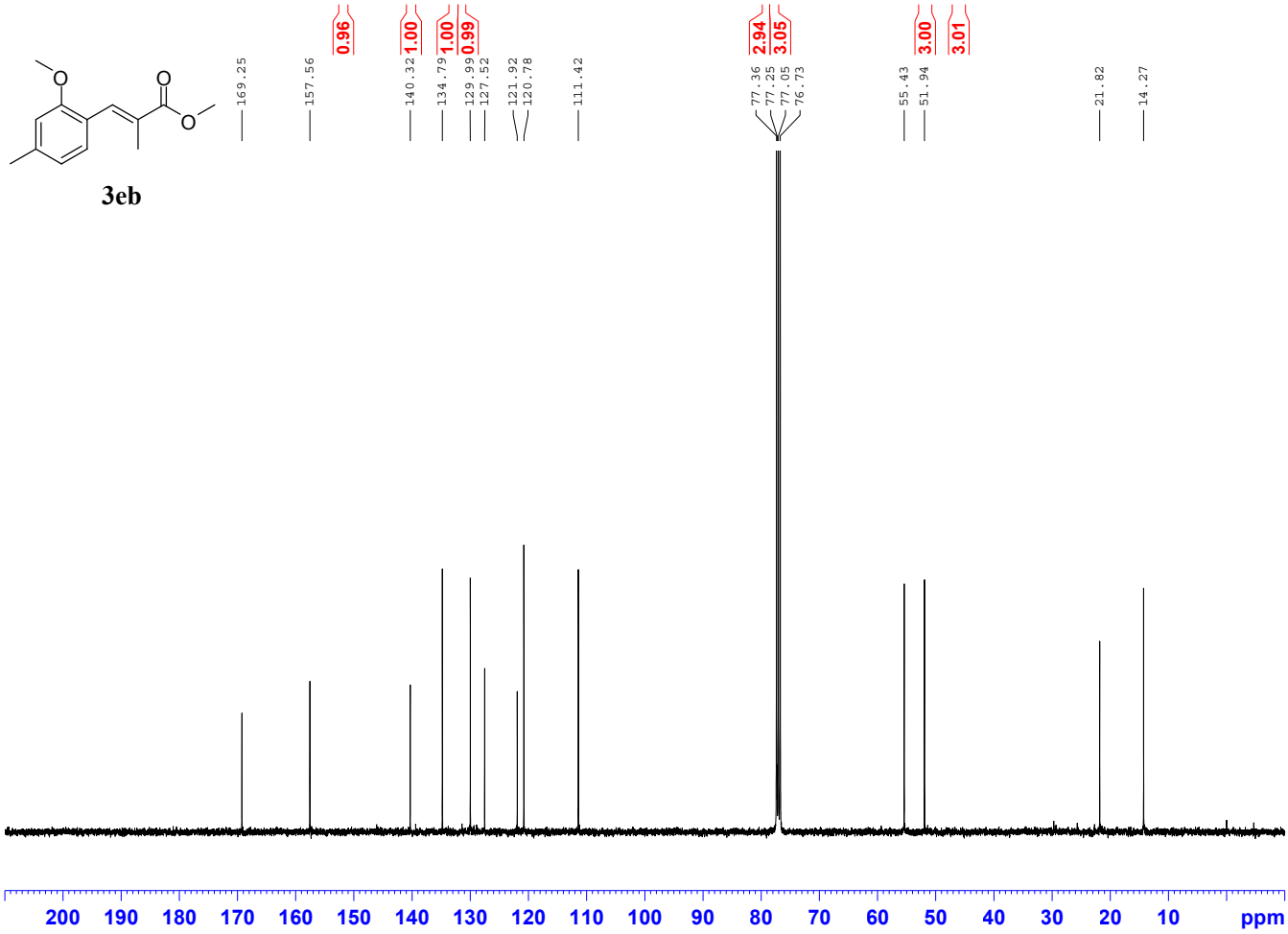

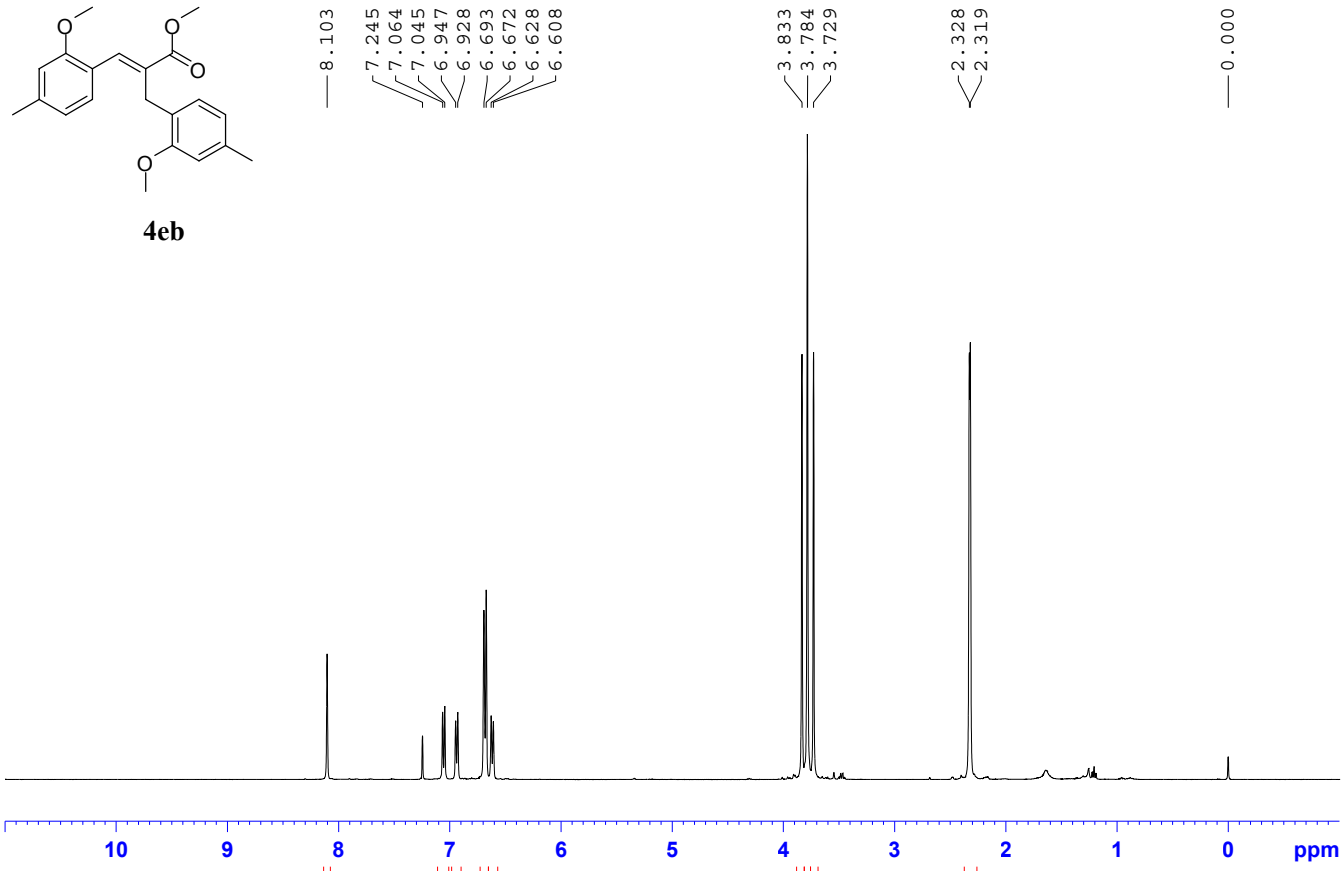

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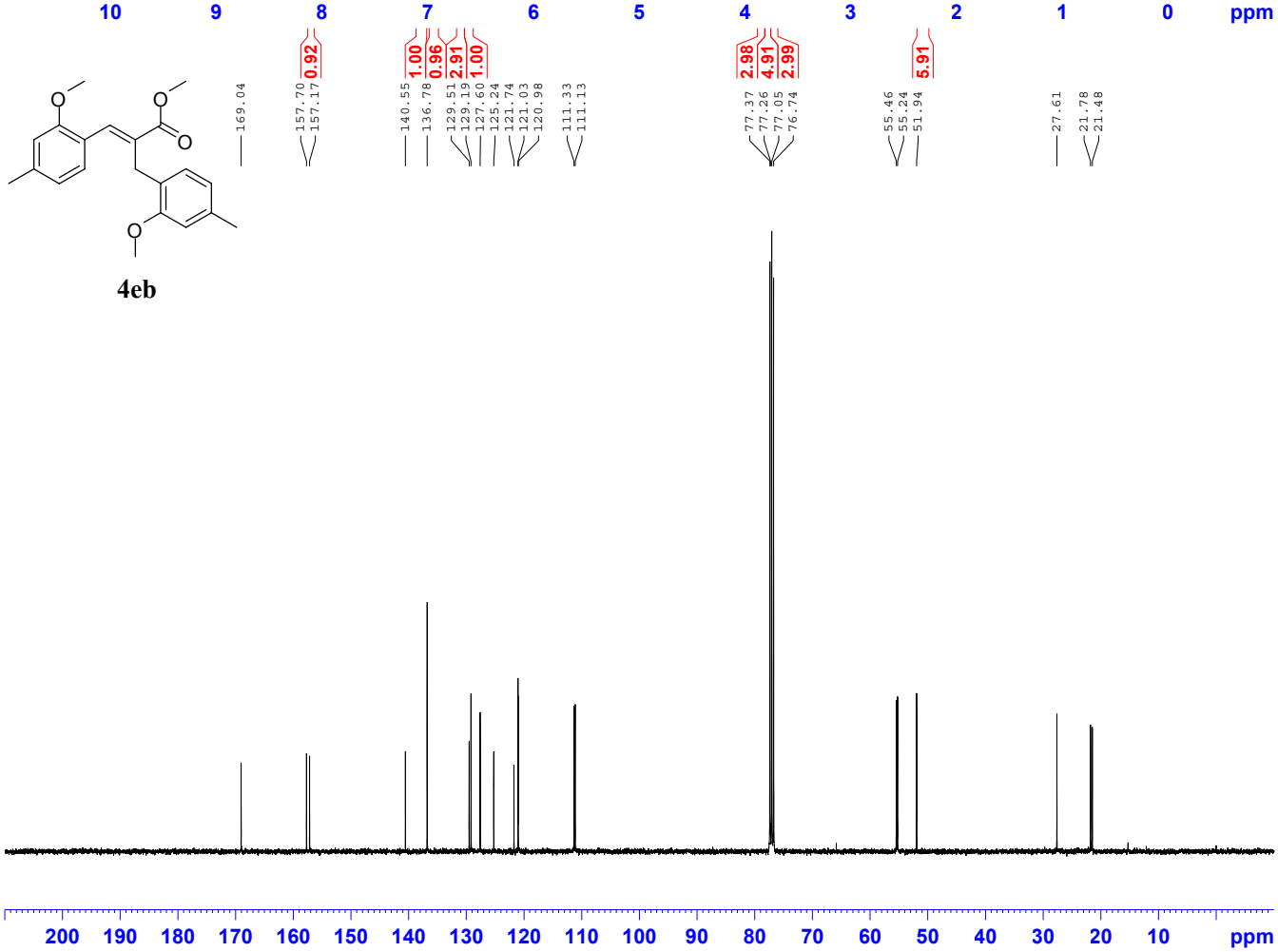

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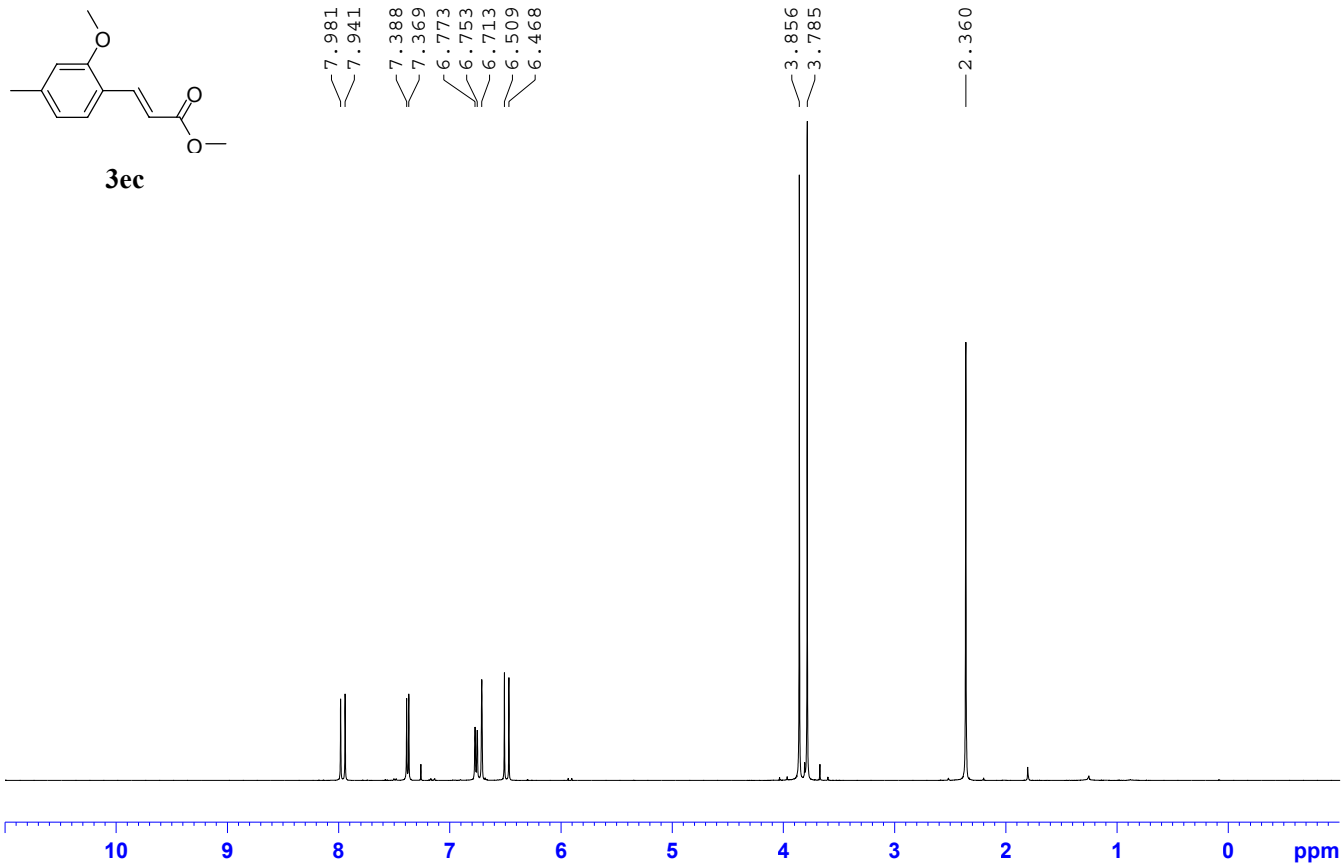

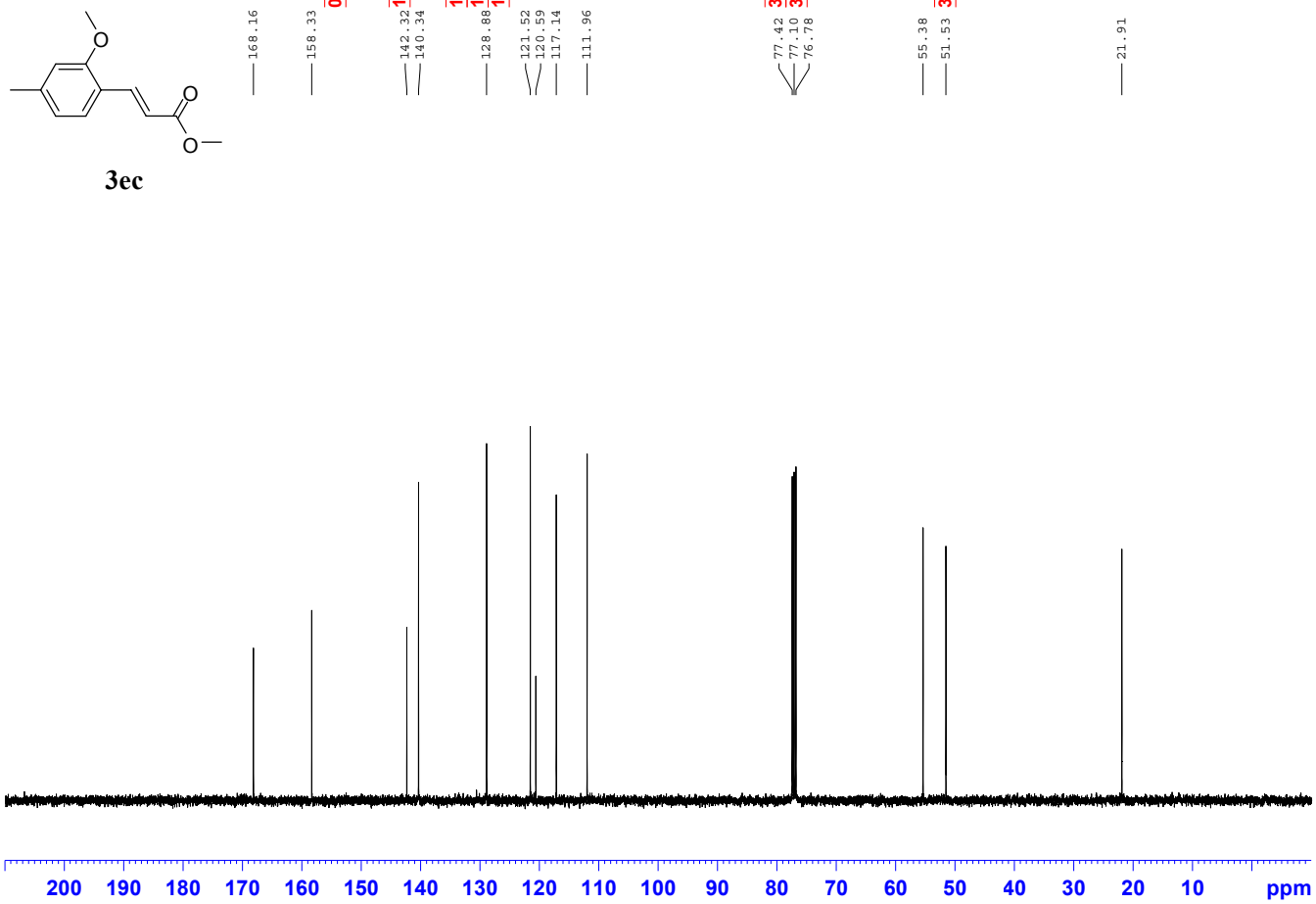

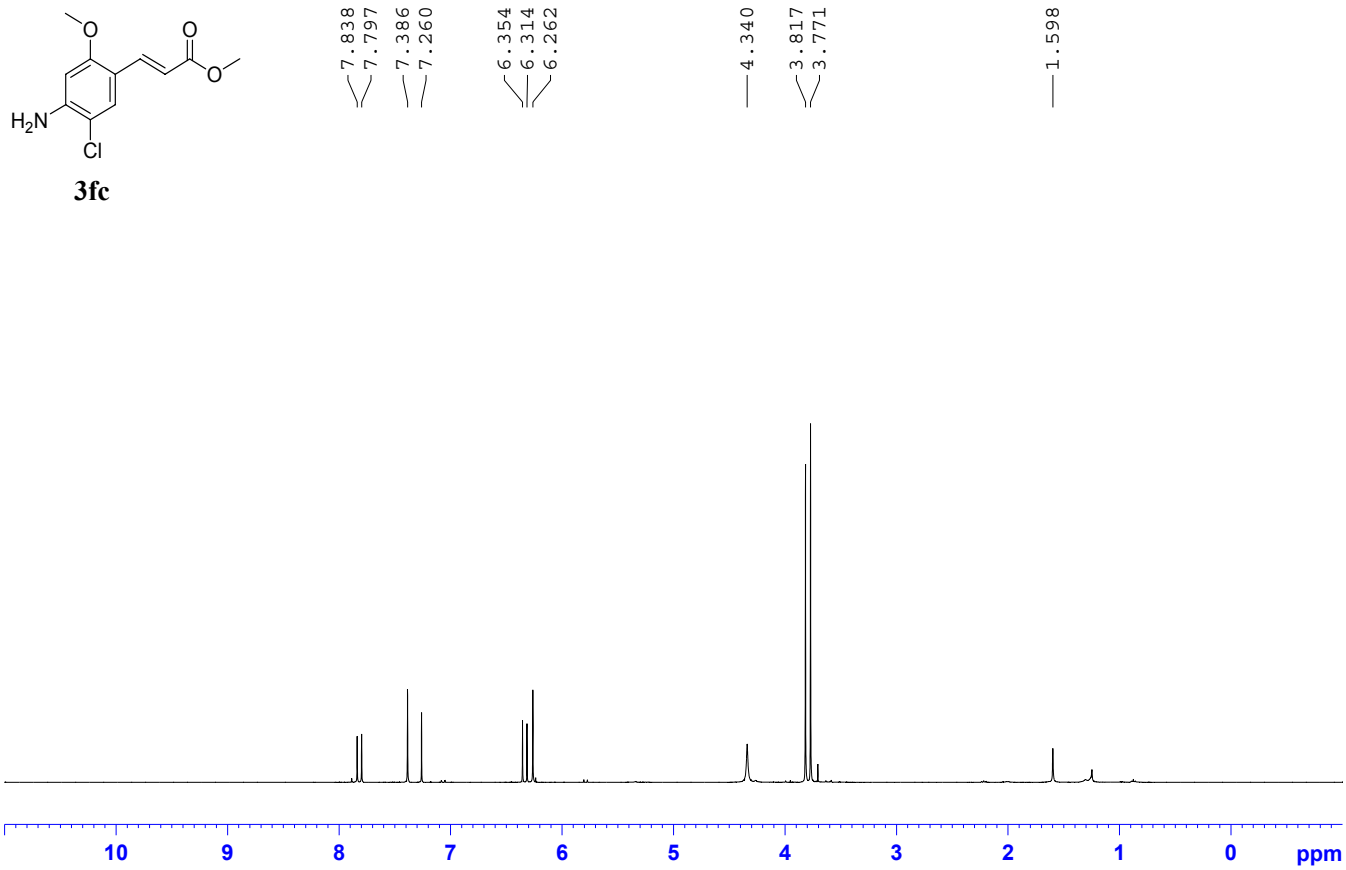

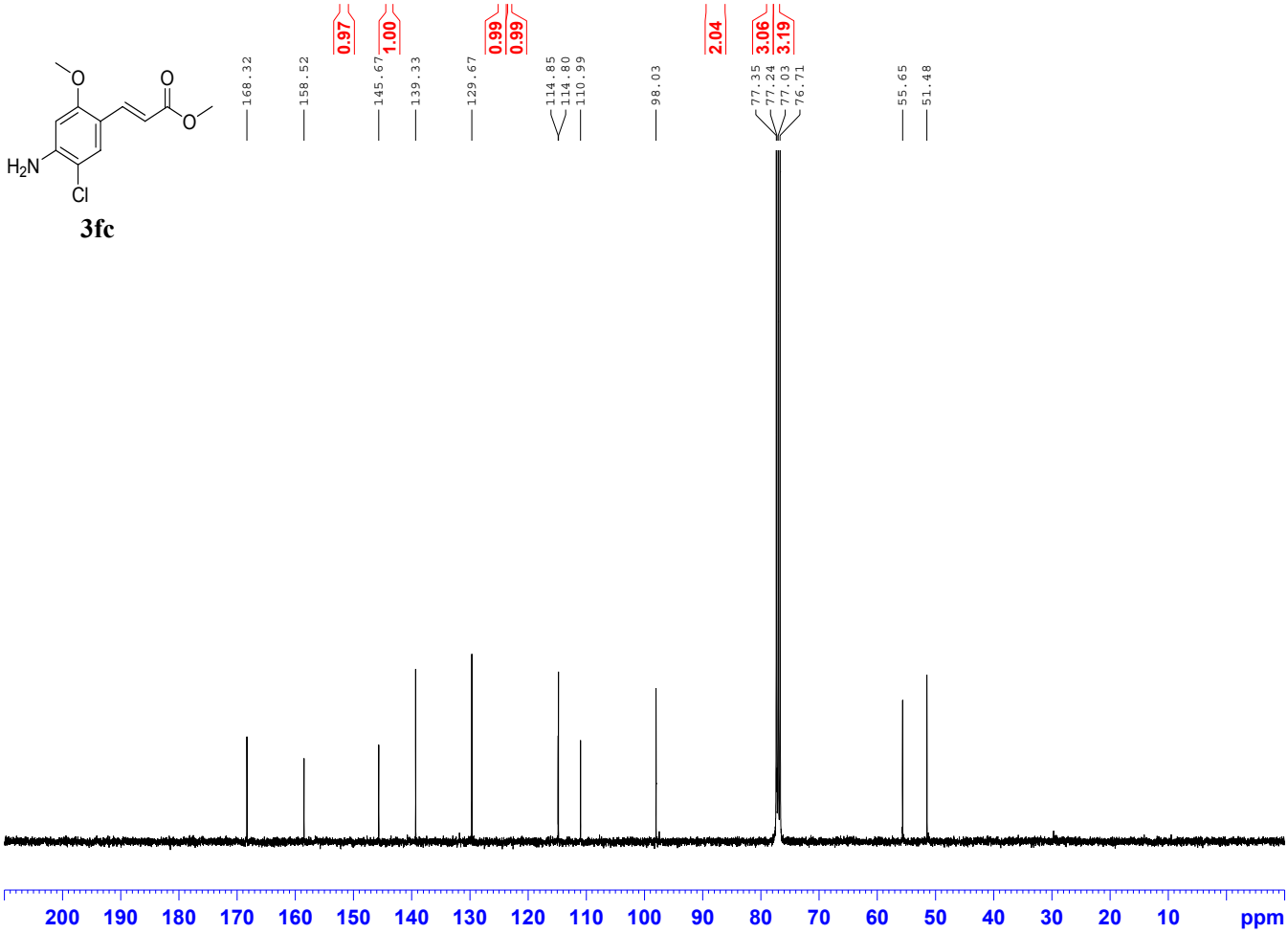

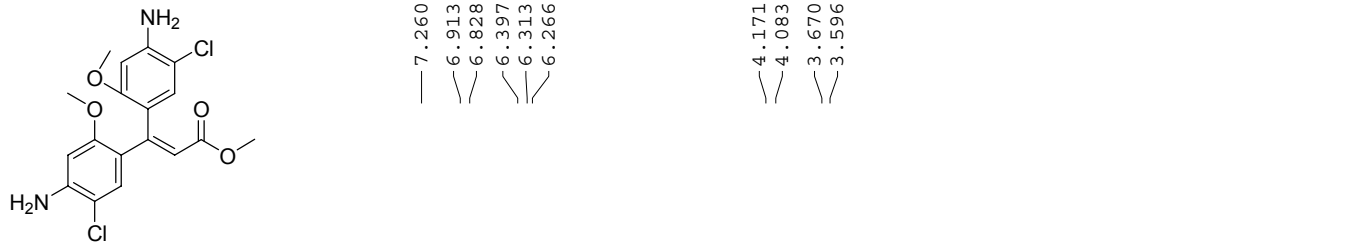

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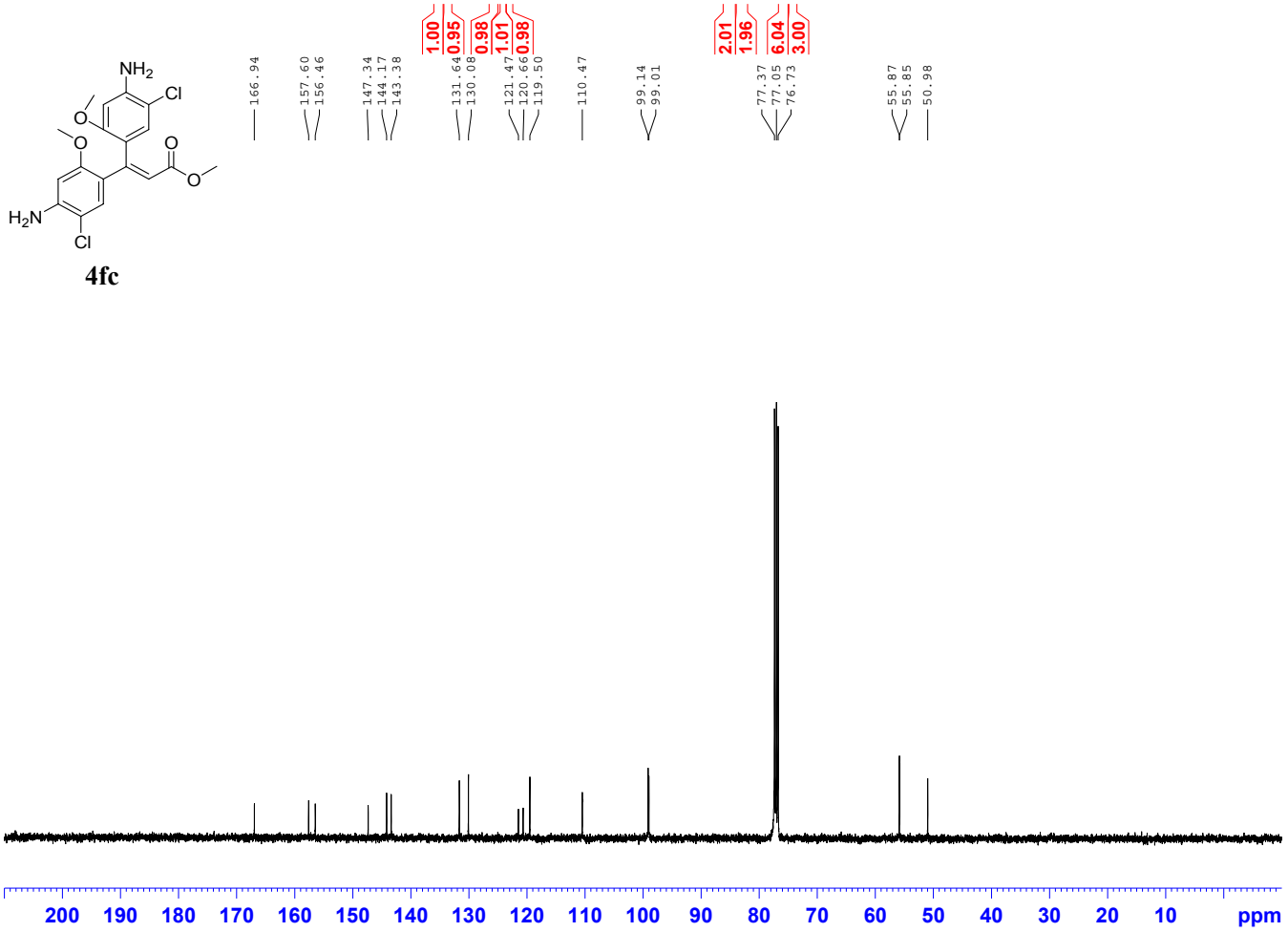

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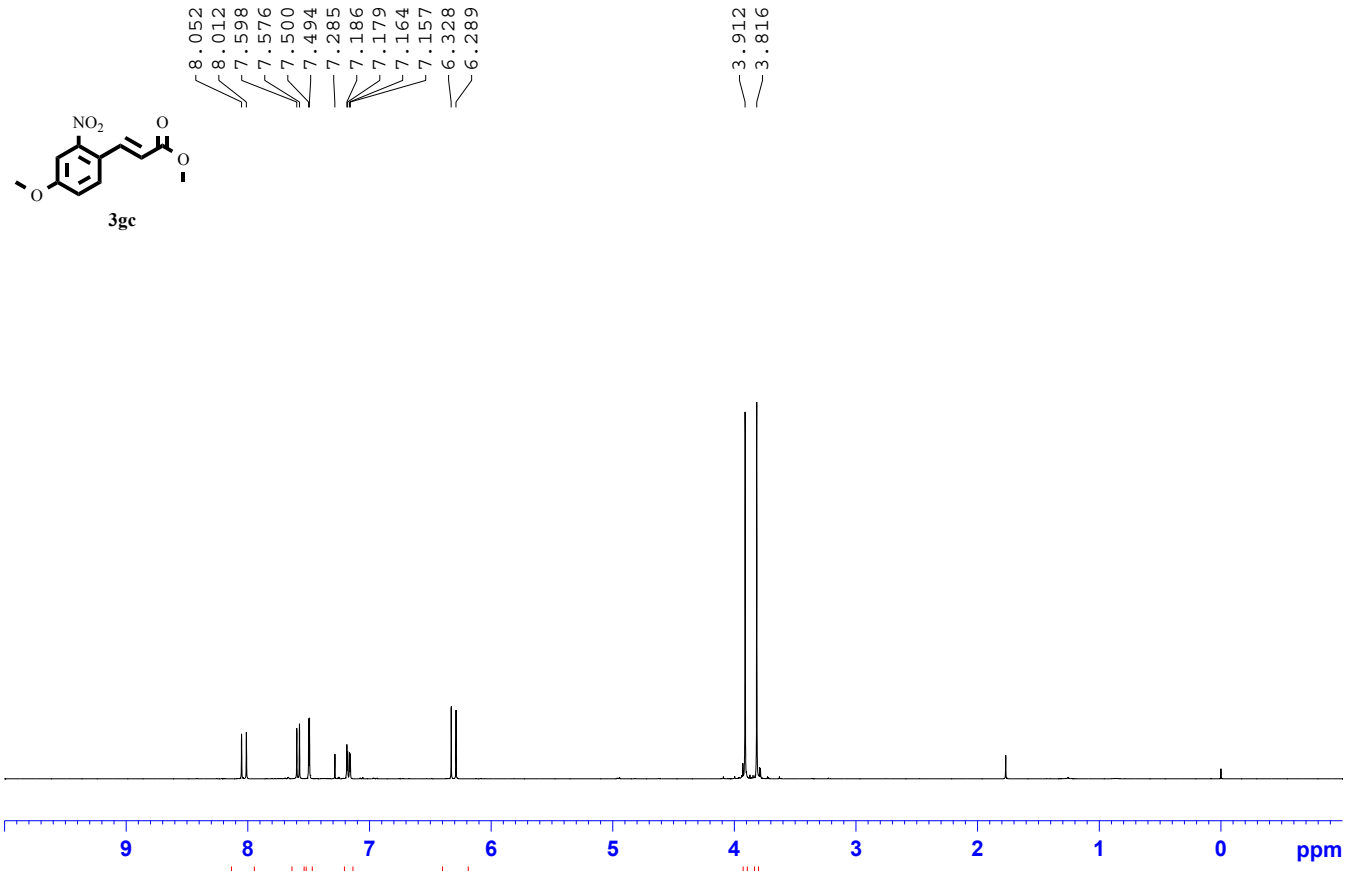

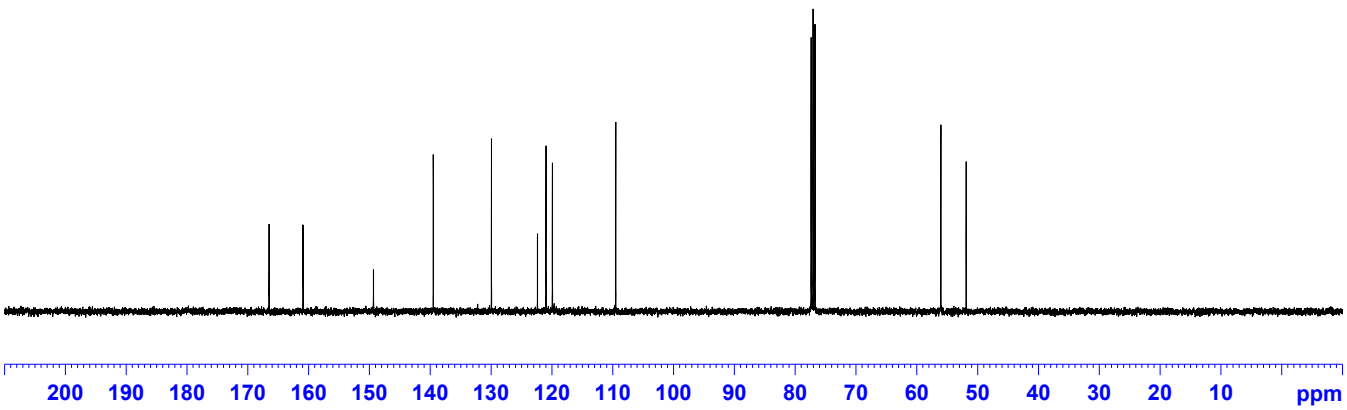

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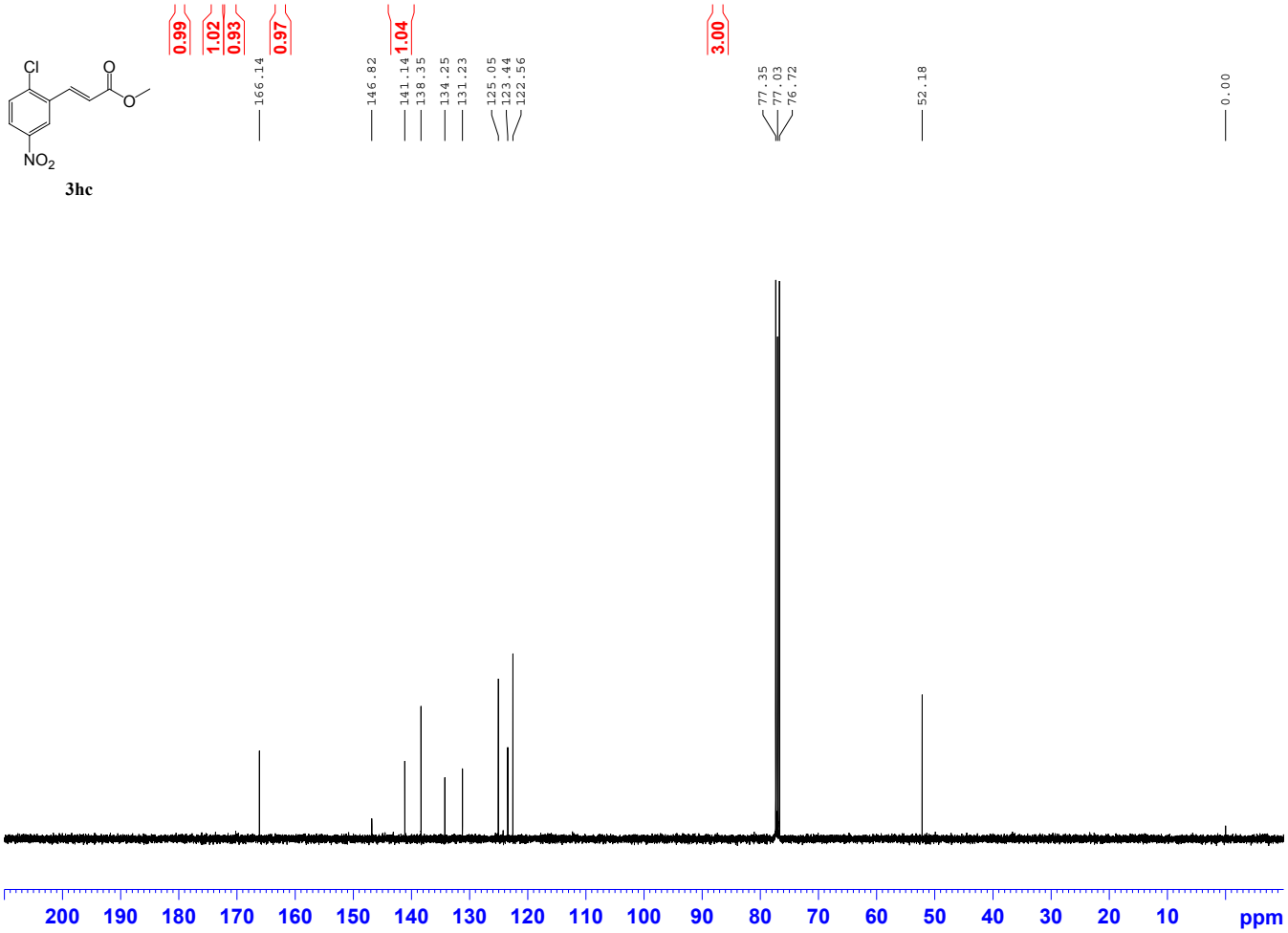

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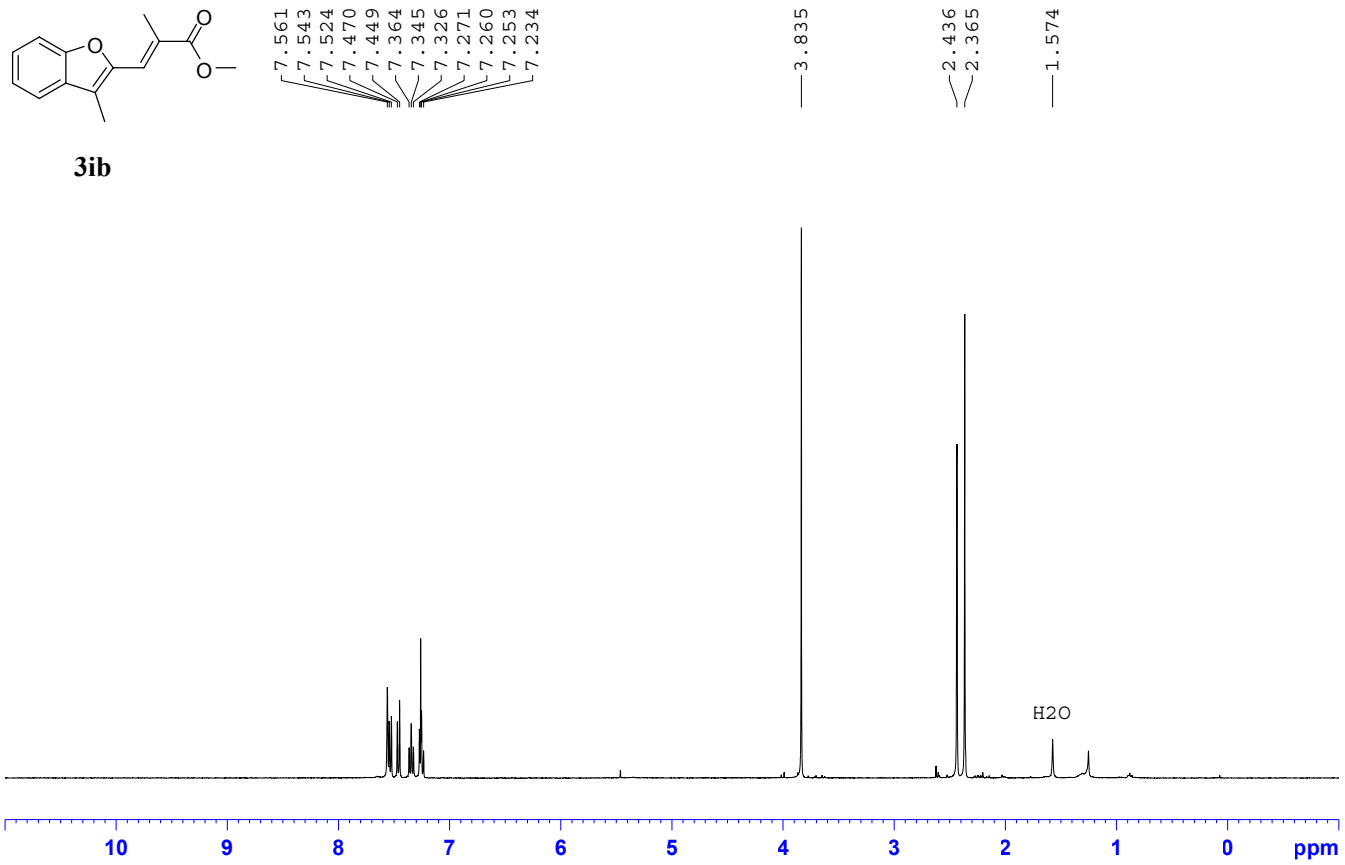

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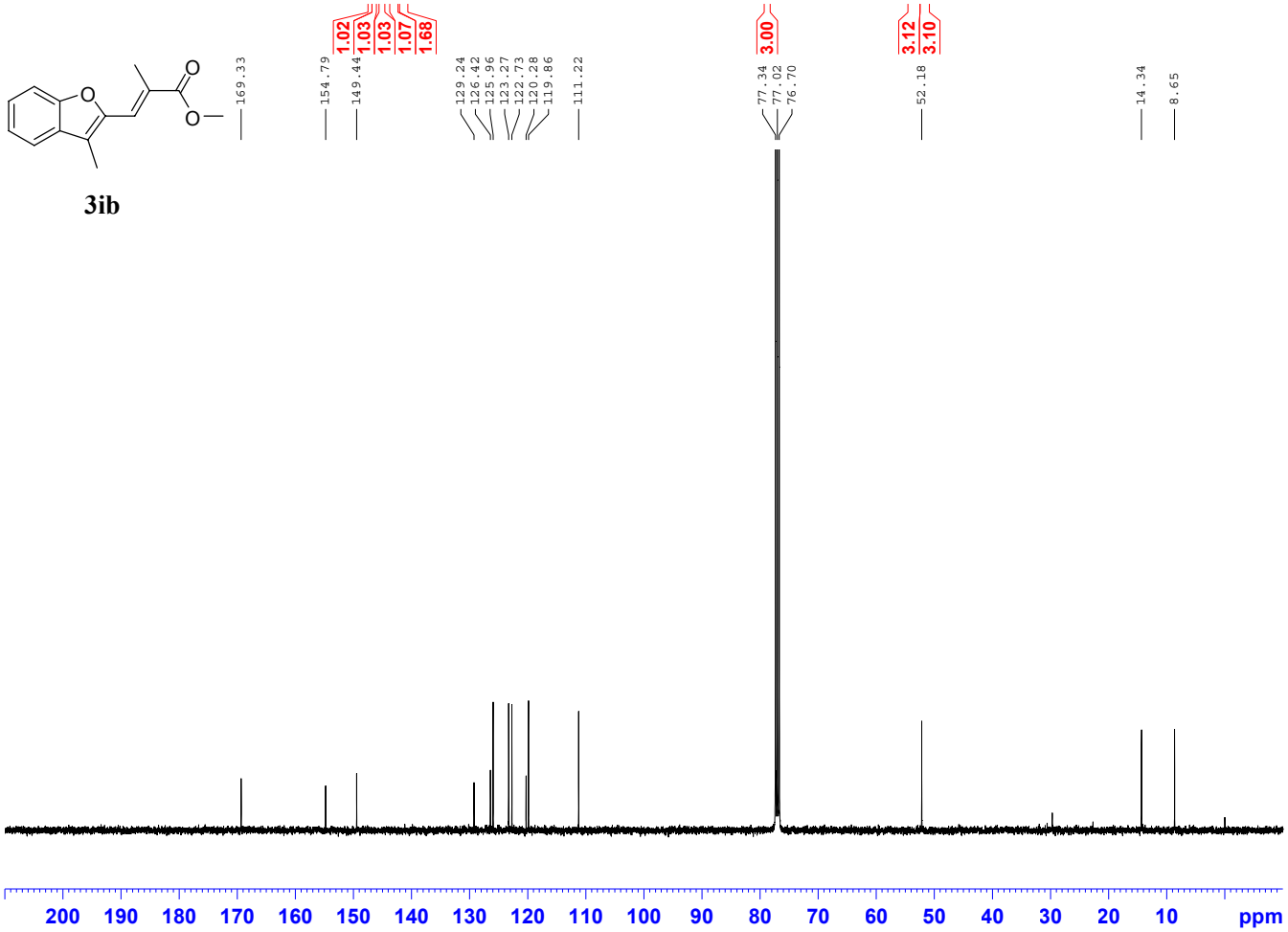

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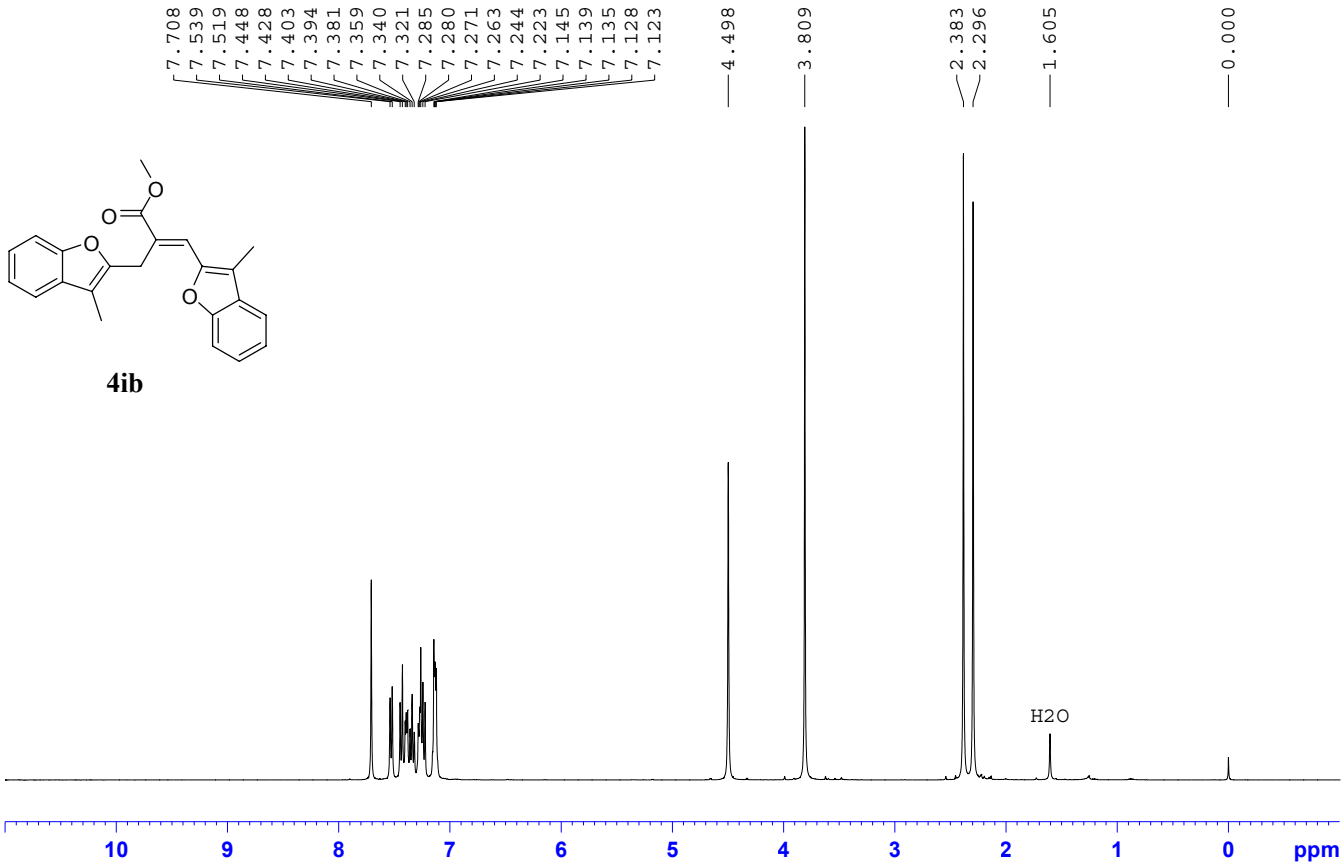

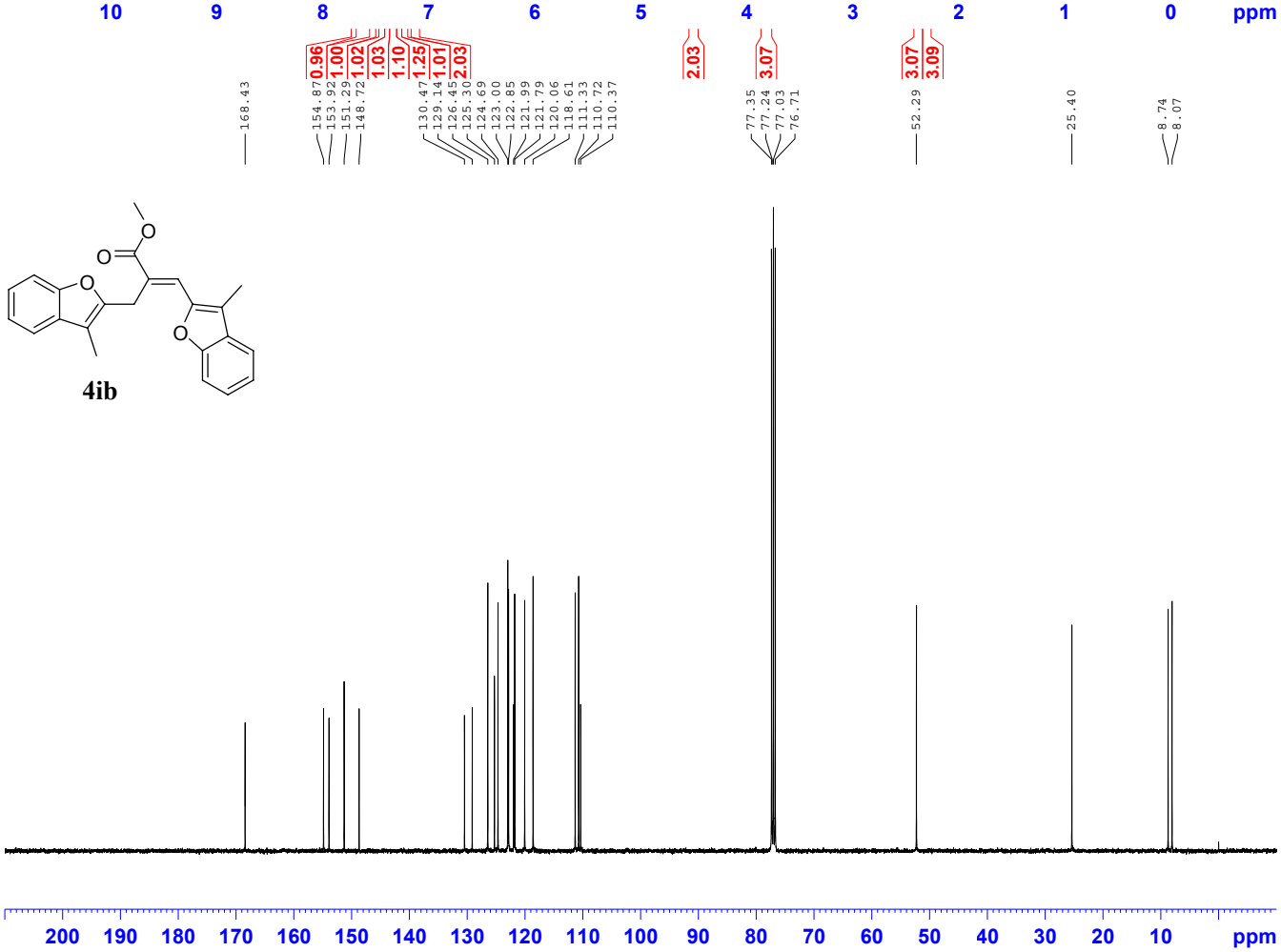

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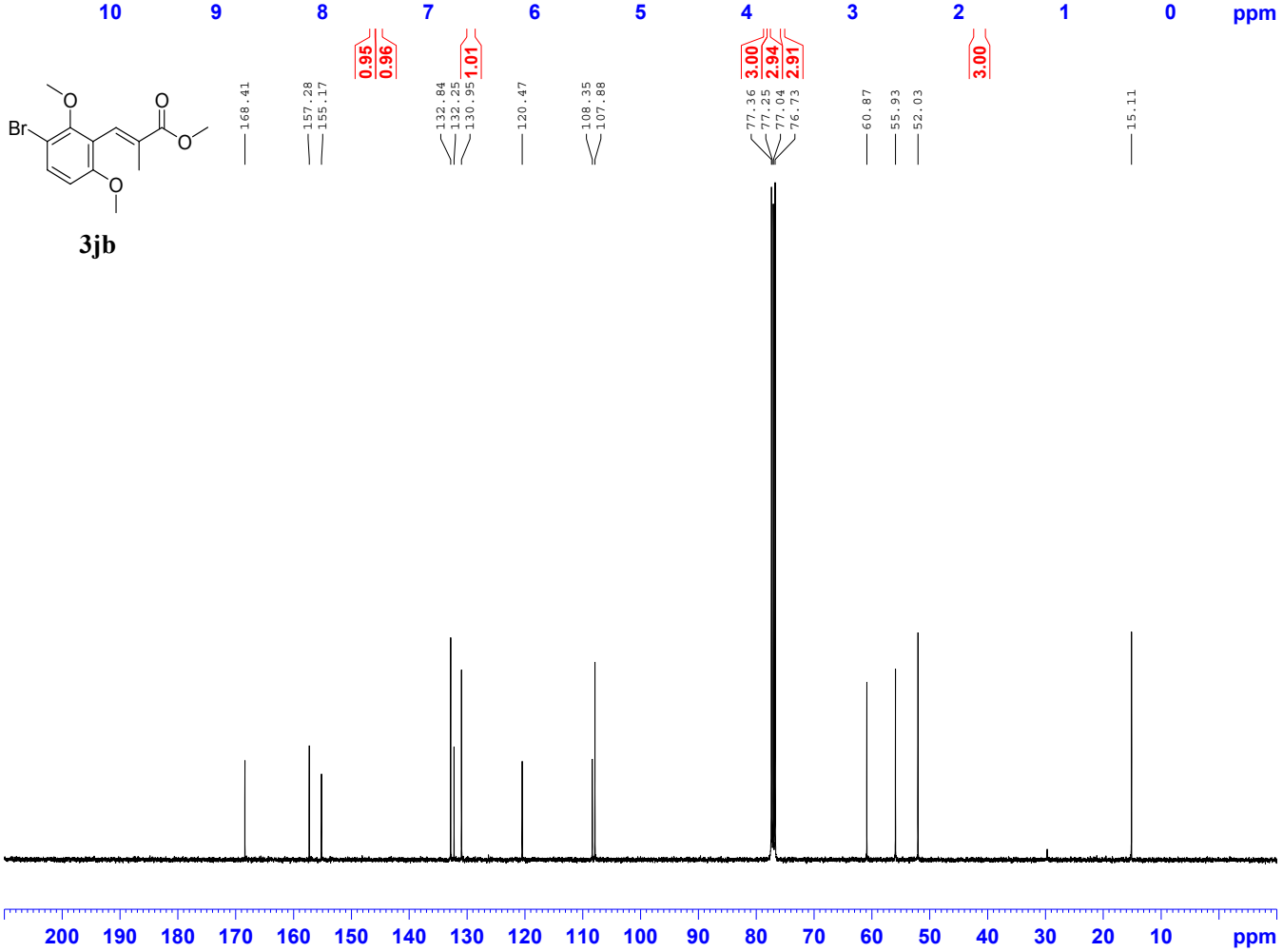

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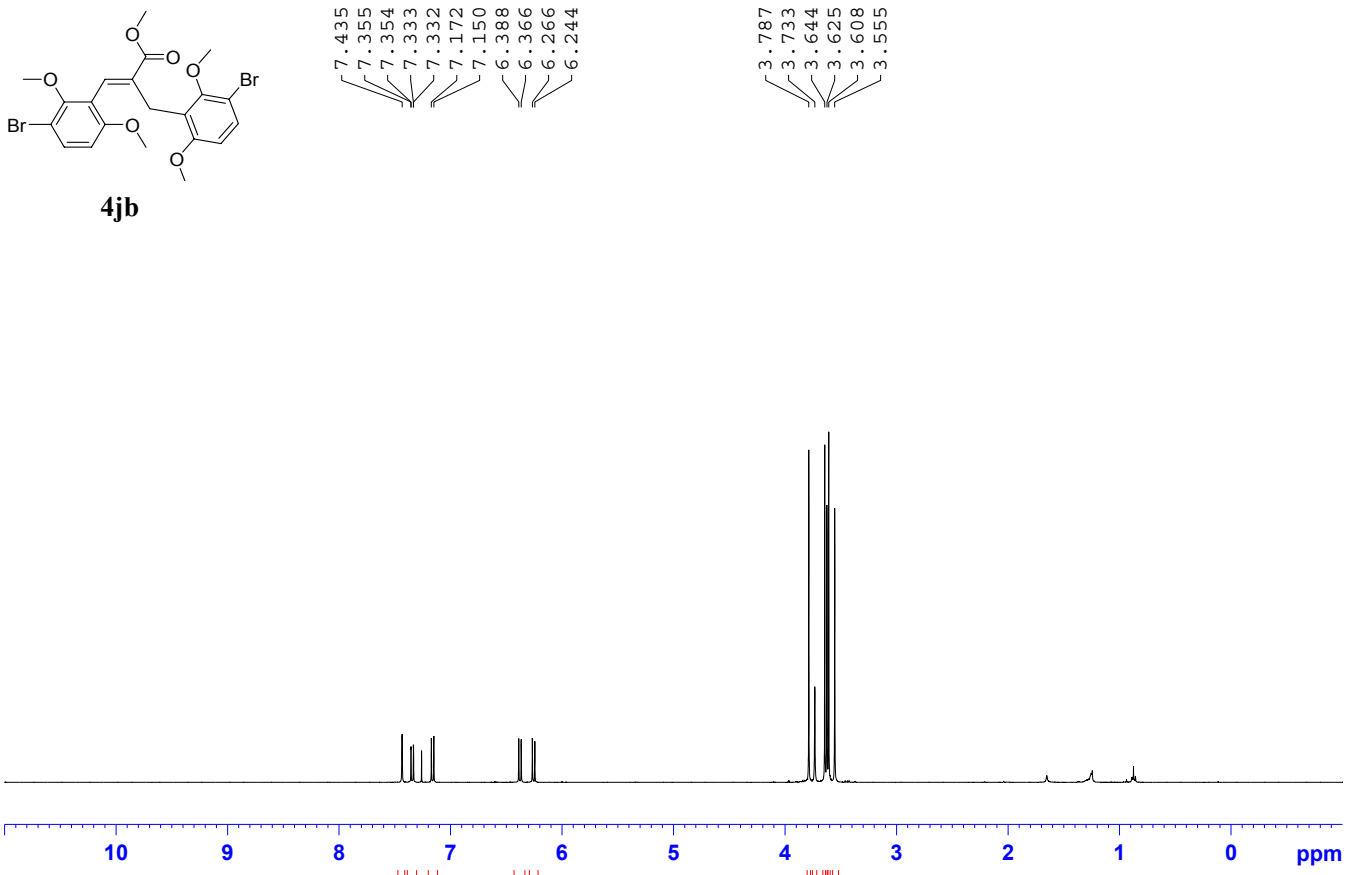

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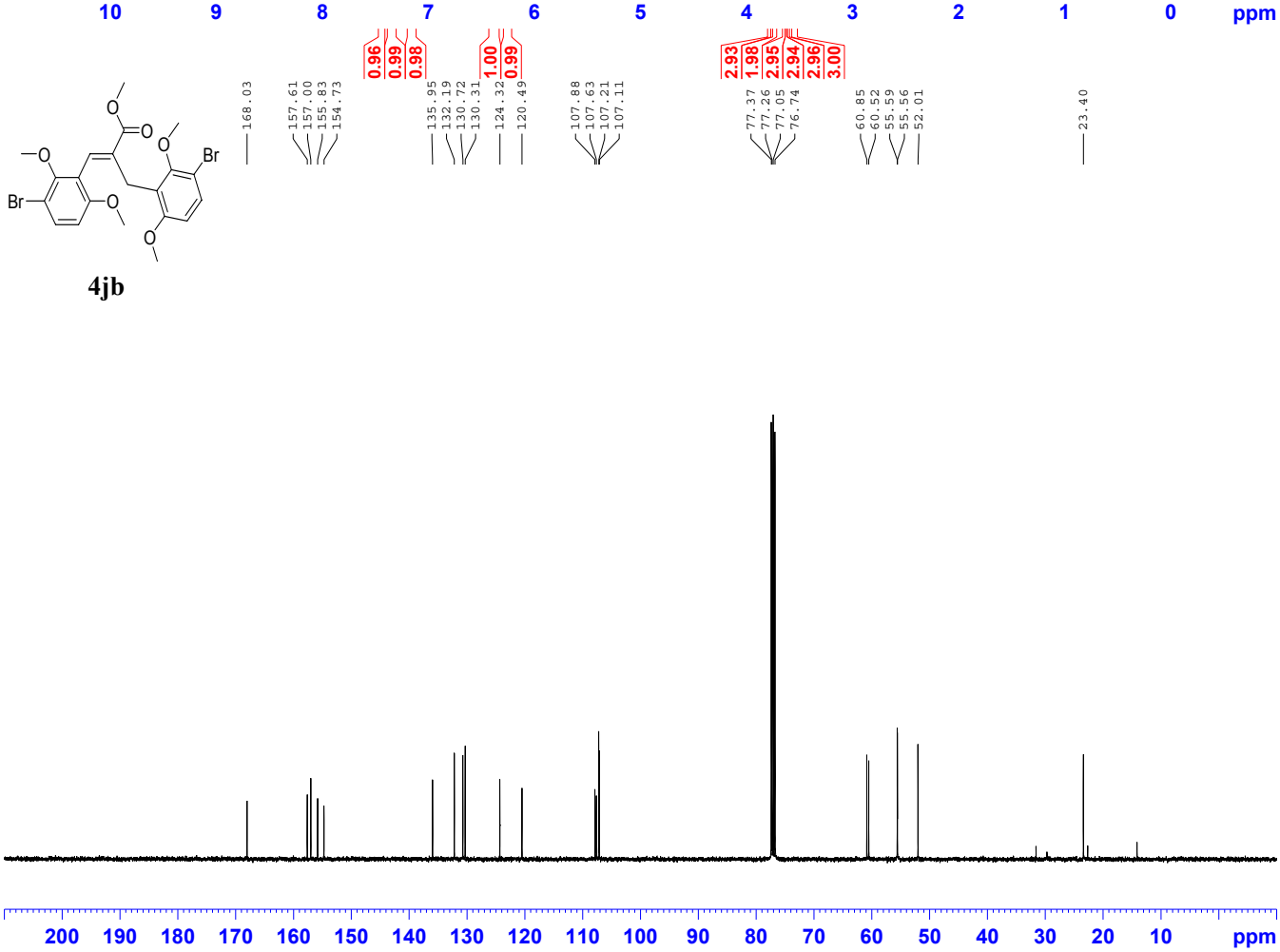

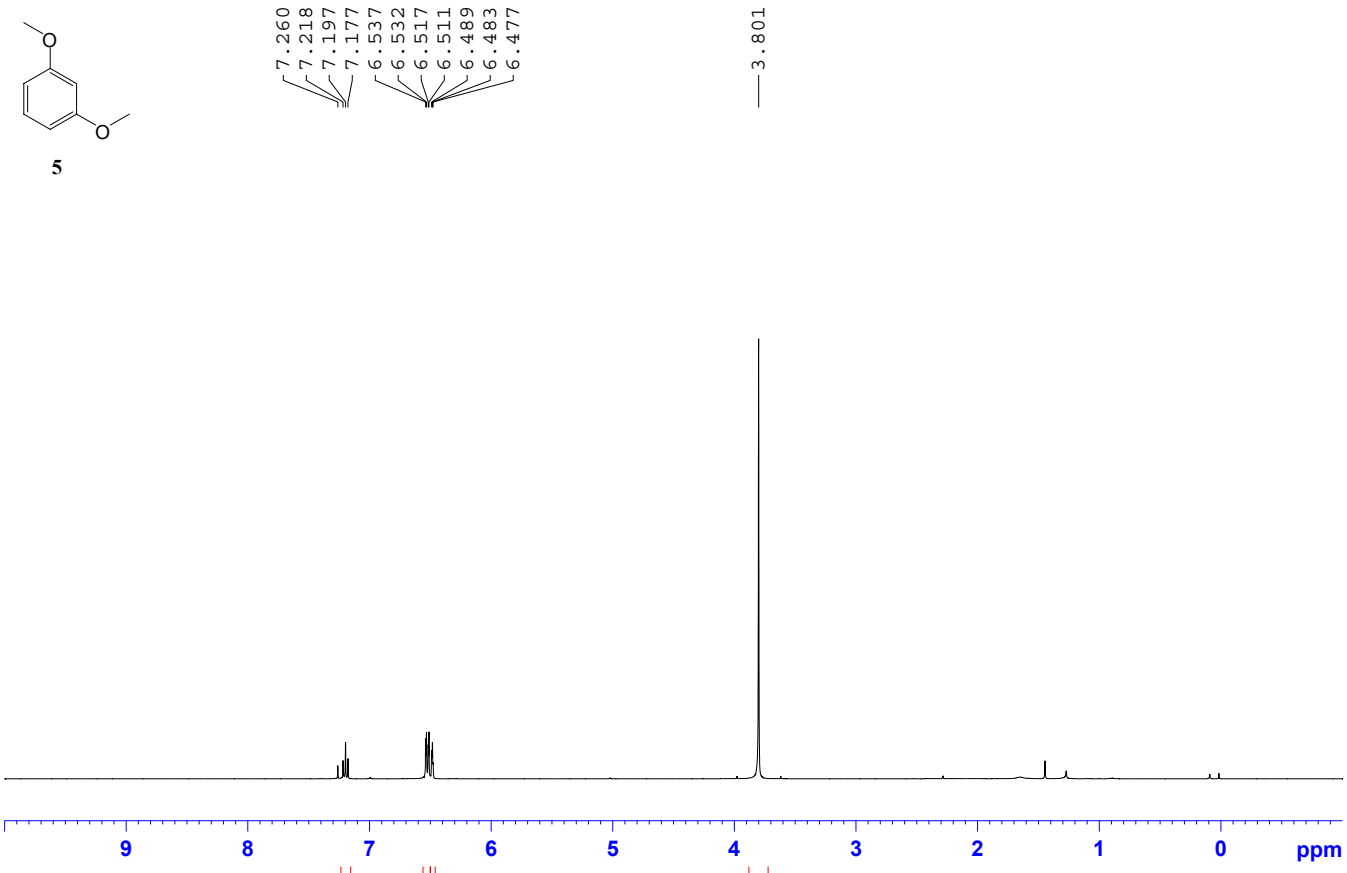

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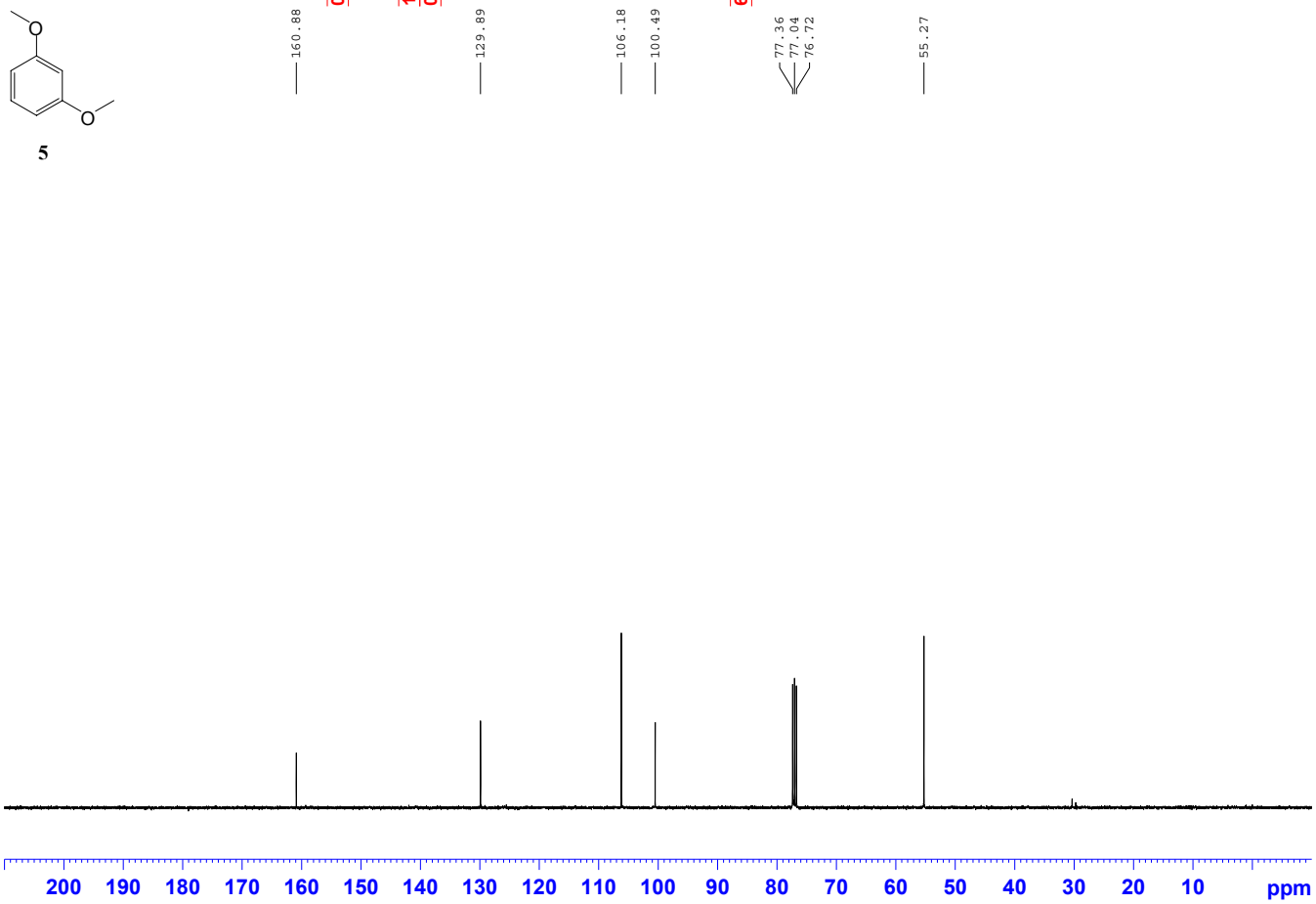

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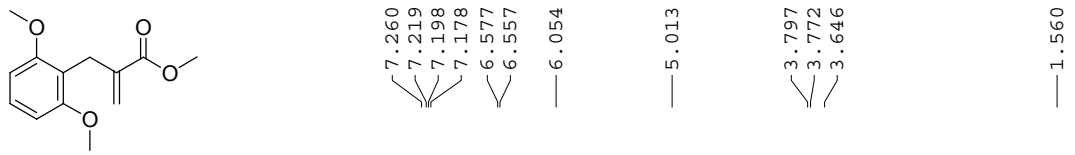
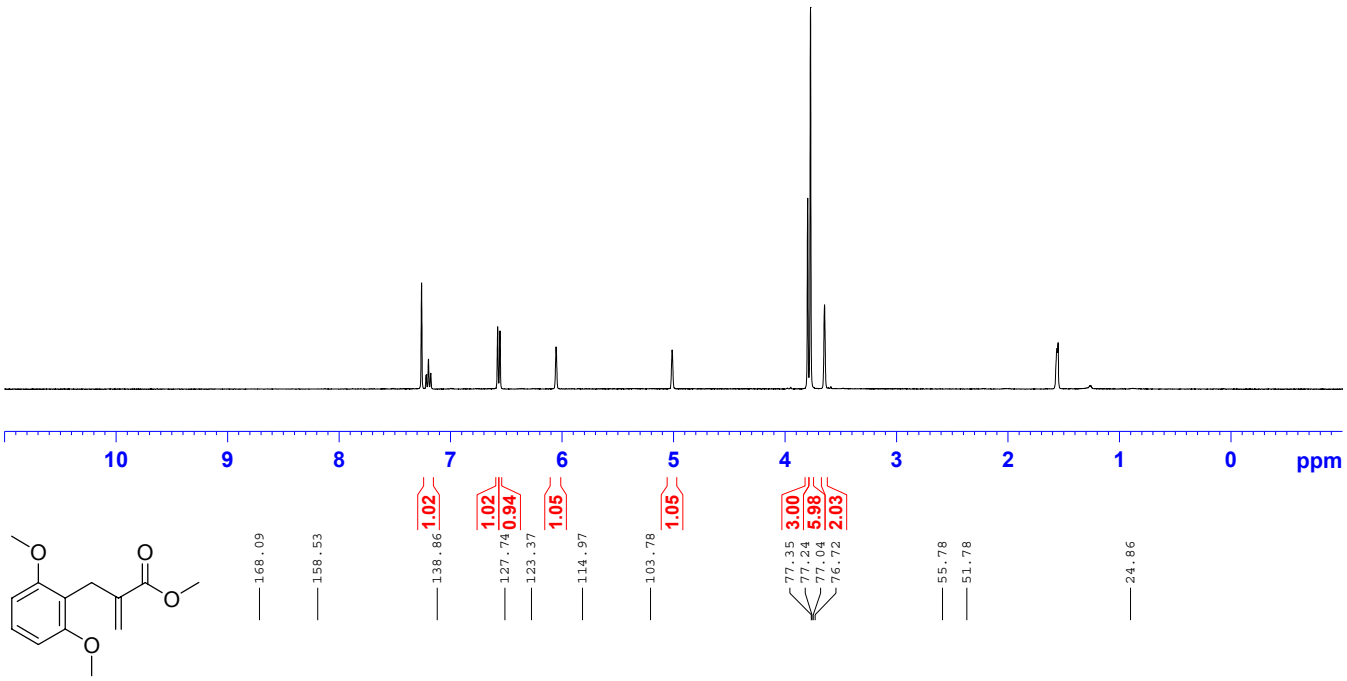


Scheme 2, Product 6



Scheme 2, Product 6