Copper-Catalyzed Diastereoselective O-Transfer Reaction of *N*-Vinyl-α,β-Unsaturated Nitrones with Ketenes into γ-Lactones through [5+2] Cycloaddition and N-O bond Cleavage

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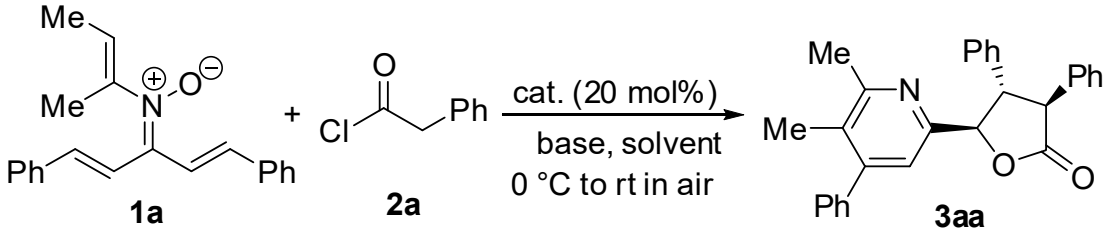
Contents

1. General Experimental Information:

^{1}H NMR and ^{13}C NMR spectra were recorded at ambient temperature using 400 or 500 MHz spectrometers. The data are reported as follows: chemical shift in ppm from internal tetramethylsilane on the δ scale, multiplicity (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), and integration. High resolution mass spectra were acquired on an LTQ FT spectrometer, and were obtained by peak matching. Melting points are reported uncorrected. Analytical thin layer chromatography was performed on 0.25 mm extra hard silica gel plates with UV254 fluorescent indicator. Chromatography was performed using with 300-400 mesh silica gel (SiO_2). Unless otherwise noted, all reactions were performed under air atmosphere. All reagents and solvents were obtained from commercial sources and, where appropriate, purified prior to use. Acetyl chlorides **2** were all purchased from Sigma-Aldrich. *N*-Substituted α,β-unsaturated nitrones **1a-1r**[1], epoxypyridine **5a**[2], and allenoate **6a**[3] was prepared according to literature method and their spectral data matched literature values.

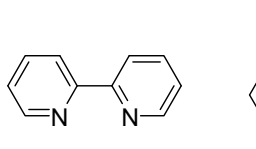
2. More detailed optimization conditions

Table S1. Optimization of the Reaction Conditions.



entry	cat.	solvent	base	**3aa**, yield %[b]
1	CuCl	THF	NEt_3	5
2	CuI	THF	NEt_3	8
3	CuOTf	THF	NEt_3	12
4	$Cu(OTf)_2$	THF	NEt_3	67
5	$Cu(NO_3)_2$	THF	NEt_3	64
6	$Cu(OAc)_2$	THF	NEt_3	82
7	$FeCl_3$	THF	NEt_3	49

8	$Fe(OTf)_3$	THF	NEt_3	51
9	$Cu(OAc)_2$	MeCN	NEt_3	<5
10	$Cu(OAc)_2$	toluene	NEt_3	23
11	$Cu(OAc)_2$	DCM	NEt_3	32
12	$Cu(OAc)_2$	Et_2O	NEt_3	50
13	$Cu(OAc)_2$	THF	NEt_3	56[c]
14	$Cu(OAc)_2$	THF	NEt_3	79[d]
15	$Cu(OAc)_2$	THF	pyridine	<5
16	$Cu(OAc)_2$	THF	TMEDA	41
17	$Cu(OAc)_2$	THF	NMMP	72
18	$Cu(OAc)_2$	THF	K_2CO_3	12
19	$Cu(OAc)_2$/**L1**	THF	NEt_3	62
20	$Cu(OAc)_2$/**L2**	THF	NEt_3	75
21	$Cu(OAc)_2$/**L3**	THF	NEt_3	68 (2)[e]
22	$Cu(OAc)_2$/**L4**	THF	NEt_3	78 (5)[e]
23	$Cu(OAc)_2$/**L5**	THF	NEt_3	45 (0)[e]
24	$Cu(OAc)_2$/**L6**	THF	NEt_3	34 (0)[e]
25	$Cu(OAc)_2$/**L7**	THF	NEt_3	<10
26	$Cu(OAc)_2$/**L8**	THF	NEt_3	23 (0)[e]



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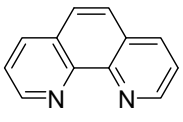

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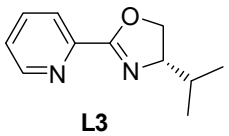

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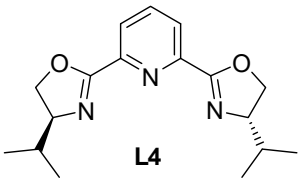

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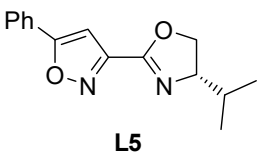

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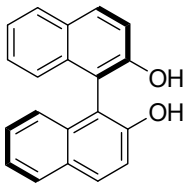

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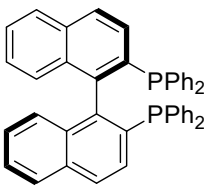

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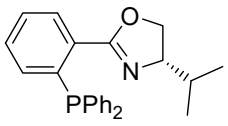
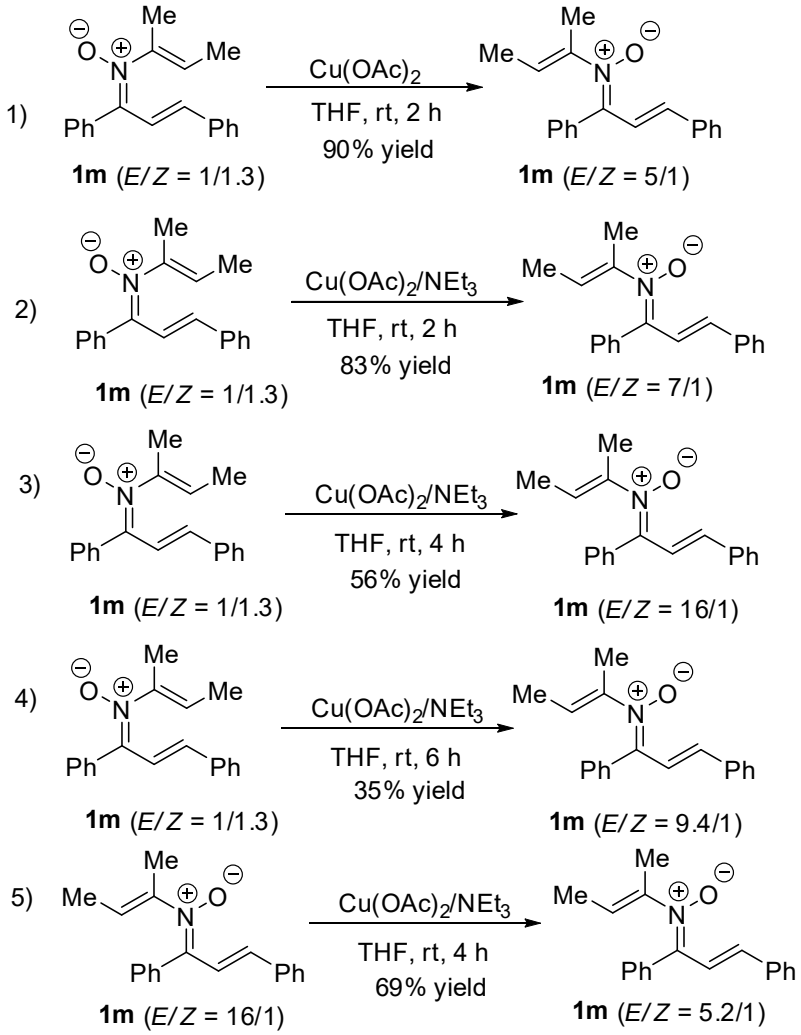


L8

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (0.4 mmol, 2.0 equiv.), $Cu(OAc)_2$ (20 mol%), base (2.0 equiv.), solvent (3.0 mL), 0 °C to 25 °C, 24−48 h; [b] isolated yield; [c] **2a** (1.5 equiv.); [d] **2a** (3.0 equiv.); [e] ee value.

3. Studies of *E/Z* isomerization of N-vinyl nitrone 1m



N-Vinyl nitrone **1m** (1:1.3 *E/Z*) was prepared as follows: In a 25 mL flask was charged with chalcone oxime (0.3 mmol), alkenyl boronic acids (0.6 mmol, 2.0 equiv), $Cu(OAc)_2$ (0.03 mmol, 10 mol%) and anhydrous Na_2SO_4 (6.0 equiv) in air atmosphere. Then, DCE (3.0 mL) and pyridine (3.0 mmol, 10.0 equiv) was added *via* syringe. The reaction flask was then capped with a septum pierced with a ventilation needle and stirred vigorously at 25 °C for 14 h until the oxime disappeared (monitored by TLC). At this time, the reaction was quenched by H_2O (10 mL) and extracted with DCM (3 × 10 mL). Then, dried over with Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the crude product was purified by a short column chromatography with 1/4, ethyl acetate/petroleum ether to provide *N*-vinyl nitrone **1m** (62 mg, 75% yield, 1:1.3 *E/Z*).

(1) In a 25 mL flask was charged with prepared nitrone **1m** (55 mg, 0.2 mmol) and THF (2.0 mL). Then, $Cu(OAc)_2$ (7.2 mg, 20 mol%) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 2 h. At this time, the solvent was removed under reduced pressure and the crude product was purified by a filtration with short pat of silica gel (1/4, ethyl acetate/petroleum ether) to provide nitrone **1m** (50 mg, 90% yield) with 5:1 *E/Z* ratio.

(2) In a 25 mL flask was charged with prepared nitrone **1m** (55 mg, 0.2 mmol, 1:1.3 E/Z) and THF (2.0 mL). Then, $Cu(OAc)_2$ (7.2 mg, 20 mol%) and NEt_3 (0.2 mmol, 1.0 equiv.) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 2 h. At this time, the solvent was removed under reduced pressure and the crude product was purified by a filtration with short pat of silica gel (1/4, ethyl acetate/petroleum ether) to provide nitrone **1m** (46 mg, 83% yield) with 7:1 *E/Z* ratio.

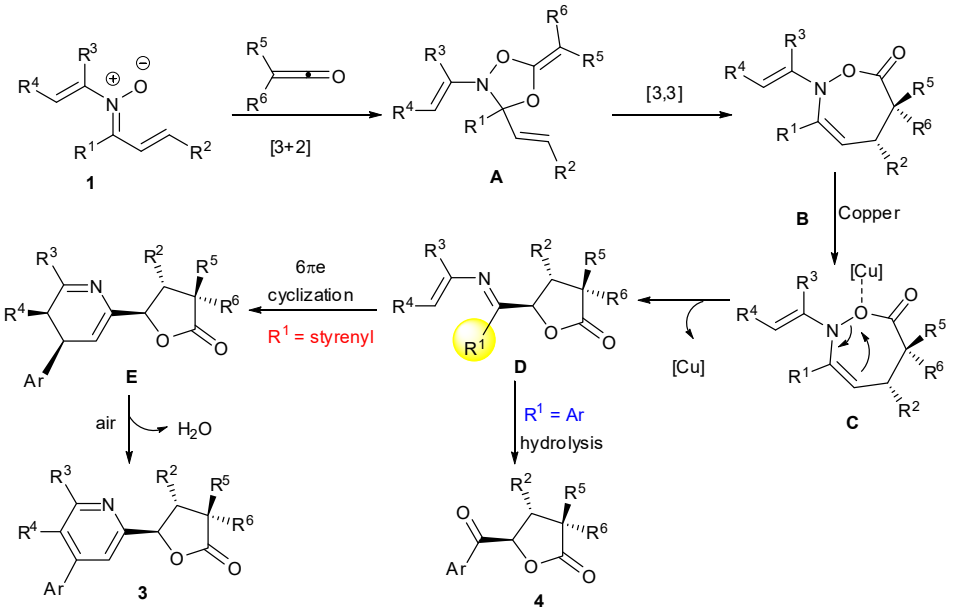
(3) In a 25 mL flask was charged with prepared nitrone **1m** (55 mg, 0.2 mmol, 1:1.3 E/Z) and THF (2.0 mL). Then, $Cu(OAc)_2$ (7.2 mg, 20 mol%) and NEt_3 (0.2 mmol, 1.0 equiv.) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 4 h. At this time, the solvent was removed under reduced pressure and the crude product was purified by a filtration with short pat of silica gel (1/4, ethyl acetate/petroleum ether) to provide nitrone **1m** (31 mg, 56% yield) with 16:1 *E/Z* ratio.

(4) In a 25 mL flask was charged with prepared nitrone **1m** (55 mg, 0.2 mmol, 1:1.3 E/Z) and THF (2.0 mL). Then, $Cu(OAc)_2$ (7.2 mg, 20 mol%) and NEt_3 (0.2 mmol, 1.0 equiv.) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 6 h. At this time, the solvent was removed under reduced pressure and the crude product was purified by a filtration with short pat of silica gel (1/4, ethyl acetate/petroleum ether) to provide nitrone **1m** (19 mg, 35% yield) with 9.4:1 *E/Z* ratio.

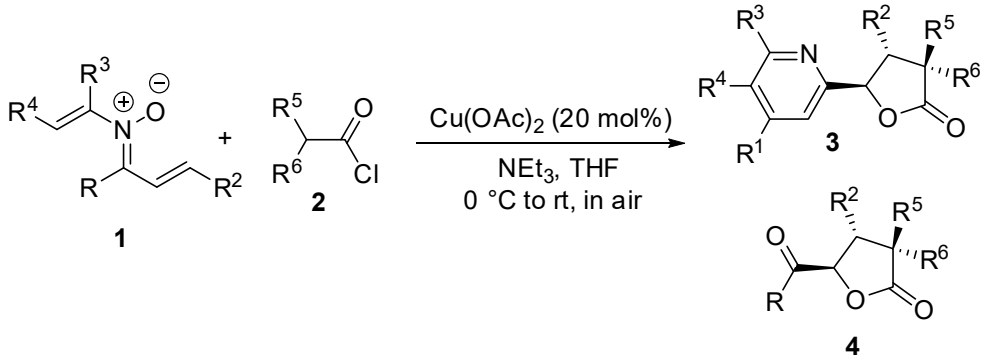
(5) In a 25 mL flask was charged with prepared nitrone **1m** (55 mg, 0.2 mmol, 16:1 E/Z) and THF (2.0 mL). Then, $Cu(OAc)_2$ (7.2 mg, 20 mol%) and NEt_3 (0.2 mmol, 1.0 equiv.) was added. The reaction vessel was stirred vigorously at room temperature

(about 25 °C) for 4 h. At this time, the solvent was removed under reduced pressure and the crude product was purified by a filtration with short pat of silica gel (1/4, ethyl acetate/petroleum ether) to provide nitrone **1m** (38 mg, 69% yield) with 5.2:1 *E/Z* ratio.

4. Possible [3+2]/[3,3]-rearrangement mechanism to form 3 and 4

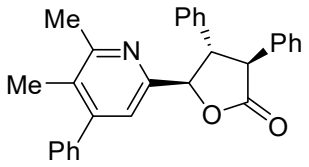


5. Synthesis of compounds 3 and 4



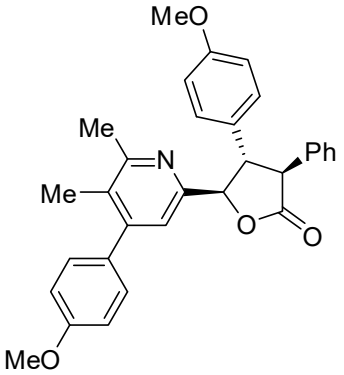
General procedure A: In a 25 mL flask was charged with acyl chloride **2** (0.4 mmol, 2.0 equiv.) and THF (3.0 mL). The flask was cooled to 0 °C and NEt_3 (55 μL, 0.2 mol, 2.0 equiv.) was added under air. The reaction was stirring at 0 °C for 0.5-2 h. Then, *N*-vinyl nitrones **1** (0.2 mmol) and $Cu(OAc)_2$ (7.2 mg, 20 mol%) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 24-48 h until the substrate **1** disappeared (monitored by TLC). At this time, the reaction was

quenched by H_2O (5 mL) and extracted with EtOAc (10 mL × 3). The combined organic layers were dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (the crude residue was dry loaded with silica gel, 1/50 to 1/10, ethyl acetate/petroleum ether) to provide γ-lactones **3** or **4**.



3aa

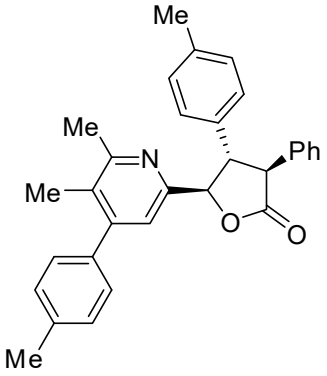
5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3,4-diphenyldihydrofuran-2(3H)-one (3aa), yellow solid, 0.069 g, 82% yield. Mp: 87−88 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41−7.37 (m, 3H), 7.27−7.21 (m, 10H), 7.19 (d, J = 7.2 Hz, 2H), 7.08 (s, 1H), 5.53 (d, J = 9.2 Hz, 1H), 4.39−4.34 (m, 1H), 4.20 (d, J = 12.0 Hz, 1H), 2.56 (s, 3H), 2.15 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.3, 158.1, 150.9, 149.9, 139.3, 136.7, 135.4, 129.4, 128.8, 128.7, 128.6, 128.5, 128.2, 127.8, 127.7, 127.6, 121.6, 85.0, 55.4, 54.4, 23.3, 16.0; IR (neat): 2925, 1783, 1710, 1603, 1454, 1385, 1148, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{26}NO_2$ $[M + H]^+$: 420.1958; found: 420.1953.



3ba

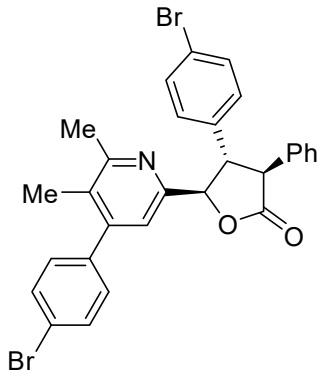
4-(4-Methoxyphenyl)-5-(4-(4-methoxyphenyl)-5,6-dimethylpyridin-2-yl)-3-phenyl dihydrofuran-2(3H)-one (3ba), white solid, 0.057 g, 59% yield. Mp: 83−84 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32−7.30 (m, 2H), 7.26 (brs, 3H), 7.20 (d, J = 10.5 Hz, 2H), 7.10 (d, J = 10.5 Hz, 2H), 7.06 (s, 1H), 6.97 (d, J = 10.5 Hz, 2H), 6.81 (d, J = 10.5 Hz, 2H), 5.47 (d, J = 12.0 Hz, 1H), 4.31−4.25 (m, 1H), 4.16 (d, J = 15.0 Hz, 1H), 3.86 (s, 3H), 3.75 (s, 3H), 2.55 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ

175.4, 159.4, 159.0, 158.1, 151.1, 149.7, 135.6, 131.8, 130.0, 129.4, 128.9, 128.8, 128.7, 127.7, 121.7, 114.2, 113.8, 85.4, 55.4, 55.2, 54.8, 54.7, 23.6, 16.2; IR (neat): 2963, 1712, 1611, 1291, 1178, 1031, 803 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{30}NO_4$ $[M + H]^+$: 480.2169; found: 480.2165.



3ca

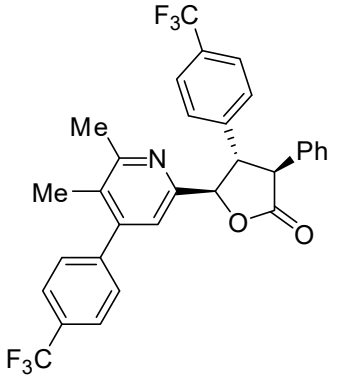
5-(5,6-Dimethyl-4-(p-tolyl)pyridin-2-yl)-3-phenyl-4-(p-tolyl)dihydrofuran-2(3H)-one (3ca), yellow oil, 0.060 g, 67% yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.33−7.24 (m, 7H), 7.15 (d, J = 8.0 Hz, 2H), 7.06 (s, 5H), 5.49 (d, J = 9.6 Hz, 1H), 4.34 (dd, J = 12.0 Hz, 9.6 Hz, 1H) , 4.18 (d, J = 12.0 Hz, 1H), 2.55 (s, 3H), 2.41 (s, 3H), 2.28 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.5, 158.1, 151.1, 149.9, 137.7, 137.3, 136.5, 135.6, 133.6, 129.5, 129.4, 129.0, 128.7, 128.6, 127.7, 127.6, 121.7, 85.3, 55.1, 54.6, 23.5, 21.2, 21.0, 16.2; IR (neat): 3022, 2958, 1710, 1515, 1325, 1129, 1023, 808 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{30}NO_2$ $[M + H]^+$: 448.2271; found: 448.2265.



3da

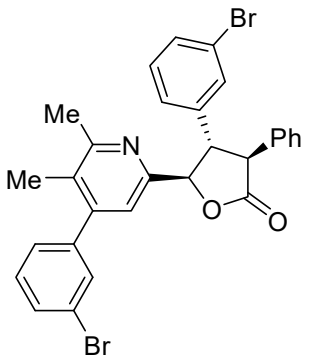
4-(4-Bromophenyl)-5-(4-(4-bromophenyl)-5,6-dimethylpyridin-2-yl)-3-phenyldihydrofuran-2(3H)-one (3da), yellow oil, 0.042 g, 57% yield. ^1H NMR (400 MHz, $CDCl_3$): δ 7.58 (d, J = 8.4 Hz, 2H), 7.41 (d, J = 8.0 Hz, 2H), 7.35−7.28 (m, 3H),

7.25–7.23 (m, 2H), 7.14 (d, J = 8.0 Hz, 2H), 7.08 (d, J = 9.6 Hz, 3H), 5.48 (d, J = 9.6 Hz, 1H), 4.34–4.29 (m, 1H), 4.16 (d, J = 12.4 Hz, 1H), 2.55 (s, 3H), 2.16 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 174.8, 158.4, 151.0, 148.9, 138.2, 135.8, 135.0, 131.9, 131.6, 130.3, 129.6, 129.3, 128.8, 128.5, 127.8, 122.2, 121.6, 121.2, 84.5, 54.9, 54.5, 23.5, 16.1; IR (neat): 3030, 2922, 2852, 1714, 1491, 1153, 1009, 828, 698 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{24}Br_2NO_2$ $[M + H]^+$: 576.0168; found: 576.0162.



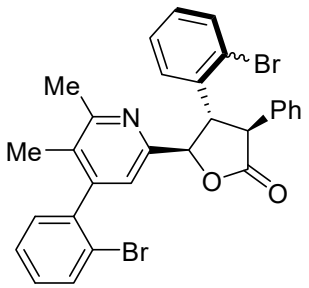
3ea

5-(5,6-Dimethyl-4-(4-(trifluoromethyl)phenyl)pyridin-2-yl)-3-phenyl-4-(4-(trifluoromethyl)phenyl)dihydrofuran-2(3H)-one (3ea), white solid, 0.086 g, 78% yield. Mp: 74–75 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, J = 7.6 Hz, 2H), 7.56 (d, J = 8.0 Hz, 2H), 7.39–7.29 (m, 7H), 7.26 (d, J = 6.8 Hz, 2H), 7.10 (s, 1H), 5.55 (d, J = 9.6 Hz, 1H), 4.48 (dd, J = 12.4 Hz, 9.6 Hz, 1H), 4.22 (d, J = 12.4 Hz, 1H), 2.56 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 174.7, 158.6, 151.0, 148.8, 142.9, 141.0, 134.9, 130.3 (q, J = 31.8 Hz), 129.5, 129.1, 128.9, 128.8, 128.6, 128.3, 128.0, 125.8 (q, J = 3.6 Hz), 125.4 (q, J = 3.6 Hz), 125.0 (q, J = 247 Hz), 121.2, 84.3, 55.1, 54.5, 23.5, 16.1; IR (neat): 2962, 1716, 1620, 1326, 1126, 847, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{24}F_6NO_2$ $[M + H]^+$: 556.1706; found: 556.1698.



3fa

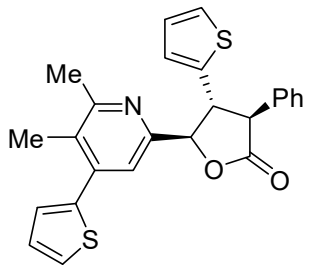
4-(3-Bromophenyl)-5-(4-(3-bromophenyl)-5,6-dimethylpyridin-2-yl)-3-phenyldihydrofuran-2(3H)-one (3fa), yellow solid, 0.057 g, 49% yield. Mp: 70–71 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (d, J = 7.6 Hz, 1H), 7.41 (s, 1H), 7.37–7.25 (m, 8H), 7.19 –7.15 (m, 3H), 7.06 (s, 1H), 5.48 (d, J = 8.0 Hz, 1H), 4.34–4.29 (m, 1H), 4.19 (d, J = 12.0 Hz, 1H), 2.56 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.8, 158.5, 151.1, 148.6, 141.4, 139.3, 135.1, 131.6, 131.2, 131.0, 130.9, 130.4, 129.9, 129.4, 128.9, 128.6, 127.9, 127.4, 126.5, 122.8, 122.5, 121.2, 84.5, 55.0, 54.4, 23.5, 16.1; IR (neat): 2923, 1775, 1598, 1491, 1154, 1010, 828, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{24}Br_2NO_2$ $[M + H]^+$: 576.0168; found: 576.0163.



3ga (*dr*= 1:1)

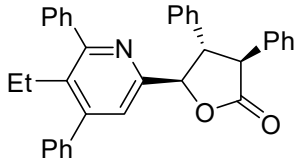
4-(2-Bromophenyl)-5-(4-(2-bromophenyl)-5,6-dimethylpyridin-2-yl)-3-phenyldihydrofuran-2(3H)-one (3ga), white solid, 0.046 g, 40% yield. Mp: 190–191 °C; *one isomer*: ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, J = 8.4 Hz, 1H), 7.54 (t, J = 8.4 Hz, 2H), 7.39–7.35 (m, 2H), 7.29–7.28 (m, 6H), 7.14–7.11 (m, 2H), 7.00 (s, 1H), 5.60 (d, J = 8.8 Hz, 1H), 4.84 (dd, J = 11.2 Hz, 8.8 Hz, 1H), 4.32 (d, J = 11.2 Hz, 1H), 2.52 (s, 3H), 2.02 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.1, 157.9, 151.9, 149.3, 140.4, 136.6, 135.1, 133.5, 132.7, 130.2, 129.9, 129.4, 129.1, 128.7, 128.5, 128.1, 127.8, 127.4, 125.5, 122.5, 122.6, 120.1, 85.0, 55.1, 54.6, 23.2, 15.8; *the other isomer:* ^{1}H

NMR (400 MHz, $CDCl_3$): δ 7.64 (d, J = 8.4 Hz, 1H), 7.48 (d, J = 8.4 Hz, 2H), 7.39–7.35 (m, 2H), 7.29–7.28 (m, 6H), 7.14–7.11 (m, 2H), 7.10 (s, 1H), 5.58 (d, J = 8.8 Hz, 1H), 4.76 (dd, J = 11.2 Hz, 8.8 Hz, 1H), 4.29 (d, J = 11.2 Hz, 1H), 2.47 (s, 3H), 2.03 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.1, 157.6, 151.4, 149.0, 140.3, 136.3, 134.9, 133.5, 132.7, 130.1, 129.8, 129.5, 129.0, 128.7, 128.5, 128.1, 127.7, 127.4, 125.3, 122.5, 119.5, 84.7, 54.6, 54.5, 23.1, 15.7; IR (neat): 2963, 1716, 1606, 1262, 1023, 802, 698 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{24}Br_2NO_2$ $[M + H]^+$: 576.0168; found: 576.0159.



3ha

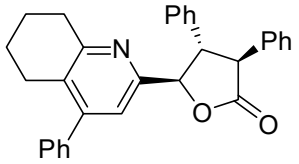
5-(5,6-Dimethyl-4-(thiophen-2-yl)pyridin-2-yl)-3-phenyl-4-(thiophen-2-yl)dihydrofuran-2(3H)-one (3ha), yellow oil, 0.065 g, 81% yield. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.43−7.42 (m, 1H), 7.39−7.31 (m, 5H), 7.27−7.26 (m, 1H), 7.17 (d, J = 6.5 Hz, 1H), 7.13−7.12 (m, 2H), 6.89−6.87 (m, 1H), 6.79−6.78 (m, 1H), 5.47 (d, J = 12.5 Hz, 1H), 4.74 (dd, J = 15.0 Hz, 12.5 Hz, 1H), 4.18 (d, J = 15.5 Hz, 1H), 2.61 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 174.7, 158.4, 150.5, 142.5, 140.1, 139.8, 135.0, 129.9, 128.8, 128.7, 128.0, 127.9, 127.4, 127.0, 126.7, 125.7, 124.5, 122.5, 84.9, 55.3, 50.3, 23.7, 16.4; IR (neat): 2976, 1712, 1663, 1600, 1507, 1244, 1188, 799 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{22}NO_2S_2$ $[M + H]^+$: 432.1086; found: 432.1088.



3ia

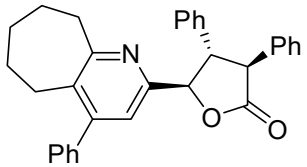
5-(5-Ethyl-4,6-diphenylpyridin-2-yl)-3,4-diphenyldihydrofuran-2(3H)-one (3ia), yellow oil, 0.063 g, 63% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (d, J = 8.0 Hz, 1H), 7.61 (t, J = 7.2 Hz, 1H), 7.43–7.42 (m, 10H), 7.35–7.28 (m, 6H), 7.24–7.22 (m,

5H), 5.66 (d, J = 12.0 Hz, 1H), 4.34–4.29 (m, 1H), 4.22 (d, J = 12.0 Hz, 1H), 2.69–2.65 (m, 2H), 0.74 (t, J = 7.6 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.4, 159.5, 151.7, 151.6, 140.8, 139.6, 136.8, 135.4, 135.3, 133.6, 130.1, 128.9, 128.8, 128.7, 128.6, 128.4, 128.3, 128.0, 127.9, 127.8, 127.7, 122.7, 85.0, 55.7, 54.6, 22.2, 14.6; IR (neat): 2935, 1714, 1602, 1497, 1152, 1009, 825, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{35}H_{30}NO_2$ $[M + H]^+$: 496.2271; found: 496.2267



3ja

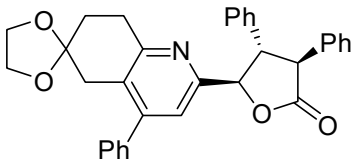
3,4-Diphenyl-5-(4-phenyl-5,6,7,8-tetrahydroquinolin-2-yl)dihydrofuran-2(3H)-one (3ja), white solid, 0.080 g, 90% yield. Mp: 112–113 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.38 (m, 3H), 7.33–7.30 (m, 2H), 7.28–7.21 (m, 8H), 7.20 (d, J = 5.6, 2H), 7.06 (s, 1H), 5.54 (d, J = 7.6 Hz, 1H), 4.34–4.30 (m, 1H), 4.21 (d, J = 9.2 Hz, 1H), 2.98 (t, J = 5.2 Hz, 2H), 2.62–2.61 (m, 2H), 1.90–1.86 (m, 2H), 1.72–1.70 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.4, 158.1, 151.8, 150.2, 139.0, 136.9, 135.5, 130.5, 128.8, 128.7, 128.6, 128.5, 128.4, 127.9, 127.7, 127.6, 121.0, 85.2, 55.5, 54.6, 33.0, 29.7, 27.3, 22.8; IR (neat): 3455, 2958, 1708, 1608, 1469, 1283, 1152, 1021, 803, 747 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{28}NO_2$ $[M + H]^+$: 446.2115; found: 446.2115.



3ka

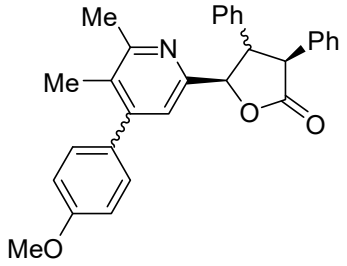
3,4-Diphenyl-5-(4-phenyl-6,7,8,9-tetrahydro-5H-cyclohepta[b]pyridin-2-yl)dihydrofuran-2(3H)-one (3ka), yellow oil, 0.064 g, 71% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.38 (m, 3H), 7.34–7.18 (m, 12H), 7.06 (s, 1H), 5.52 (d, J = 8.0 Hz, 1H), 4.42–4.36 (m, 1H), 4.22 (d, J = 12.0 Hz, 1H), 3.11–3.09 (m, 2H), 2.73–2.71 (m, 2H), 1.87–1.86 (m, 2H), 1.75–1.73 (m, 2H), 1.61–1.60 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.4, 164.5, 150.6, 149.4, 139.7, 137.0, 136.0, 135.5, 128.8, 128.7, 128.6,

128.3, 127.9, 127.8, 127.7, 127.6, 121.8, 85.2, 55.2, 54.5, 39.4, 32.3, 29.5, 27.7, 26.4; IR (neat): 2963, 1717, 1624, 1518, 1250, 1176, 1031, 803, 695 cm^{-1}; HRMS (ESI) m/z calcd for $C_{32}H_{30}NO_2$ $[M + H]^+$: 460.2271; found:460.2254.



3la

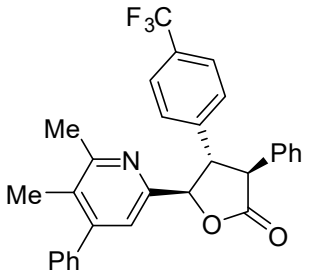
3,4-Diphenyl-5-(4'-phenyl-7',8'-dihydro-5'H-spiro[[1,3]dioxolane-2,6'-quinolin]-2'-yl)dihydrofuran-2(3H)-one (3la), yellow solid, 0.068 g, 68% yield. Mp: 123–124 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.38 (m, 3H), 7.32–7.23 (m, 10H), 7.19–7.18 (m, 2H), 7.09 (s, 1H), 5.56 (d, J = 7.6 Hz, 1H), 4.30–4.26 (m, 1H), 4.21 (d, J = 9.6 Hz, 1H), 3.98–3.89 (m, 4H), 3.18 (t, J = 5.6 Hz, 2H), 2.91–2.82 (m, 2H), 2.07 (t, J = 5.2 Hz, 2H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.3, 156.5, 152.6, 150.6, 138.4, 136.8, 135.5, 128.8, 128.7, 128.6, 128.5, 128.4, 128.1, 127.9, 127.7, 127.6, 127.5, 121.1, 107.7, 85.0, 64.5, 55.6, 54.7, 37.1, 31.3, 31.2; IR (neat): 2926, 1716, 1606, 1497, 1263, 1151, 1023, 804, 700 cm^{-1}; HRMS (ESI) m/z calcd for $C_{33}H_{30}NO_4$ $[M + H]^+$: 504.2169; found: 504.2164.



3qa (ratio = 1.5:1)

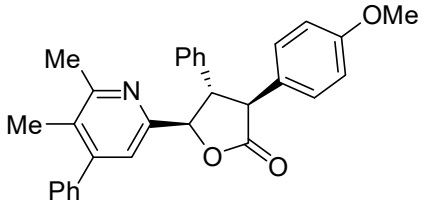
γ-Lactone 3qa, ratio = 1.5:1, yellow solid, 0.039 g, 43% yield. Mp: 145–146 °C; *major isomer.* ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41−7.40 (m, 2H), 7.33−7.23 (m, 6H), 7.19−7.17 (m, 3H), 7.08−7.06 (m, 2H), 6.96 (d, J = 8.4 Hz, 1H), 6.81 (d, J = 8.4 Hz, 1H), 5.52 (d, J = 9.6 Hz, 1H), 4.38−4.33 (m, 1H), 4.21 (d, J = 12.0 Hz, 1H), 3.85 (s, 3H), 2.55 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.4, 159.3, 158.2, 151.0, 149.6, 136.9, 135.5, 130.0, 129.4, 128.9, 128.7, 128.6, 128.3, 127.9, 127.7, 121.7, 121.6, 113.7, 85.1, 55.3, 55.1, 54.5, 23.5, 16.2; *minor isomer.* ^{1}H NMR (400

MHz, $CDCl_3$): δ 7.41−7.40 (m, 2H), 7.33−7.23 (m, 6H), 7.19−7.17 (m, 3H), 7.08−7.06 (m, 2H), 6.96 (d, J = 8.4 Hz, 1H), 6.81 (d, J = 8.4 Hz, 1H), 5.47 (d, J = 9.6 Hz, 1H), 4.31−4.26 (m, 1H), 4.18 (d, J = 12.0 Hz, 1H), 3.74 (s, 3H), 2.56 (s, 3H), 2.17 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.4, 158.9, 158.2, 151.1, 150.0, 139.5, 135.5, 131.7, 129.4, 128.9, 128.8, 128.6, 128.3, 127.8, 127.7, 121.7, 121.6, 114.2, 85.3, 55.4, 54.8, 54.6, 23.5, 16.1; IR (neat): 3432, 2927, 1714, 1608, 1457, 1254, 1028, 727 cm^{-1}; HRMS (ESI) m/z calcd for $C_{30}H_{28}NO_3$ $[M + H]^+$: 450.2064; found: 450.2057.



3ra

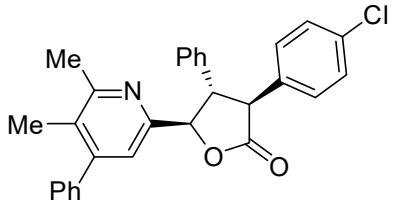
5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-phenyl-4-(4-(trifluoromethyl)phenyl)dihydrofuran-2(3H)-one (3ra), yellow solid, 0.073 g, 75% yield. Mp: 83–84 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.55 (d, J = 10.0 Hz, 2H), 7.46−7.40 (m, 3H), 7.34−7.32 (m, 5H), 7.26−7.24 (m, 4H), 7.12 (s, 1H), 5.54 (d, J = 11.5 Hz, 1H), 4.48 (dd, J = 15.0 Hz, 11.5 Hz, 1H), 4.22 (d, J = 15.5 Hz, 1H), 2.55 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 174.8, 158.3, 150.7, 150.3, 141.1, 139.4, 135.0, 130.1 (q, J = 26.2 Hz), 129.7, 129.0, 128.7, 128.6, 128.4, 128.3, 128.0, 127.9, 125.8 (q, J = 3.0 Hz), 124.9 (q, J = 247 Hz), 121.6, 84.6, 55.1, 54.6, 23.5, 16.2; IR (neat): 2960, 1713, 1621, 1327, 1123, 1018, 803, 702 cm^{-1}; HRMS (ESI) m/z calcd for $C_{30}H_{25}F_3NO_2$ $[M + H]^+$: 488.1832; found: 488.1827.



3ab

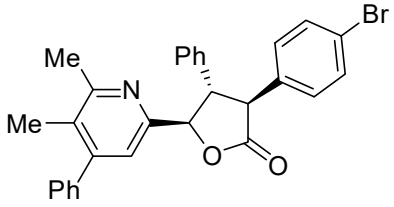
5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-(4-methoxyphenyl)-4-phenyldihydrofuran-2(3H)-one (3ab), yellow liquid, 0.055 g, 61% yield. ^{1}H NMR (500 MHz, $CDCl_3$):

δ 7.44−7.40 (m, 3H), 7.28−7.23 (m, 5H), 7.21−7.17 (m, 4H), 7.08 (s, 1H), 6.87 (d, J = 10.5 Hz, 2H), 5.51 (d, J = 12.0 Hz, 1H), 4.32 (dd, J = 15.0 Hz, 11.5 Hz, 1H), 4.16 (d, J = 15.5 Hz, 1H), 3.77 (s, 3H), 2.56 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.7, 159.1, 158.2, 151.2, 150.1, 139.5, 137.0, 129.7, 129.4, 128.8, 128.7, 128.4, 127.9, 127.6, 127.5, 121.6, 114.3, 85.1, 55.5, 55.2, 53.9, 23.5, 16.1; IR (neat): 2963, 1712, 1611, 1515, 1291, 1178, 1031, 695 cm^{-1}; HRMS (ESI) m/z calcd for $C_{30}H_{28}NO_3$ $[M + H]^+$: 450.2064; found: 450.2057.



3ac

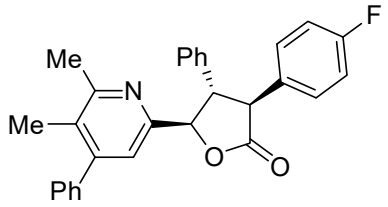
3-(4-Chlorophenyl)-5-(5,6-dimethyl-4-phenylpyridin-2-yl)-4-phenyldihydrofuran-2(3H)-one (3ac), white solid, 0.087 g, 97% yield. Mp: 120–121 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.38 (m, 3H), 7.30–7.21 (m, 9H), 7.18–7.16 (m, 2H), 7.06 (s, 1H), 5.52 (d, J = 8.0 Hz, 1H), 4.35 (dd, J = 9.6 Hz, 7.6 Hz, 1H), 4.19 (d, J = 10.0 Hz, 1H), 2.56 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 174.9, 158.3, 150.7, 150.0, 139.4, 136.6, 134.0, 133.7, 130.0, 129.6, 129.0, 128.9, 128.7, 128.4, 127.9, 127.8, 121.8, 85.2, 55.3, 54.0, 23.5, 16.1; IR (neat): 2962, 1715, 1607, 1407, 1282, 1020, 803, 750 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{25}ClNO_2$ $[M + H]^+$: 454.1568; found: 454.1566.



3ad

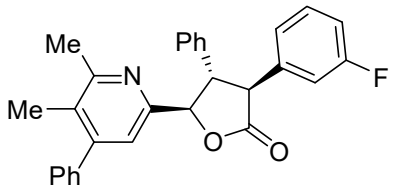
3-(4-Bromophenyl)-5-(5,6-dimethyl-4-phenylpyridin-2-yl)-4-phenyldihydrofuran-2(3H)-one (3ad), white solid, 0.096 g, 99% yield. Mp: 157–158 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46–7.36 (m, 5H), 7.29–7.22 (m, 5H), 7.18–7.15 (m, 4H), 7.06 (s, 1H), 5.52 (d, J = 9.6 Hz, 1H), 4.36–4.31 (m, 1H), 4.18 (d, J = 12.0 Hz, 1H), 2.56 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.3, 158.0, 151.8, 150.2, 139.0,

136.9, 135.5, 130.4, 128.8, 128.7, 128.6, 128.5, 128.3, 127.9, 127.7, 127.6, 120.9, 85.2, 55.5, 54.6, 27.4, 22.8; IR (neat): 2922, 1715, 1607, 1494, 1384, 1015, 804 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{25}BrNO_2$ $[M + H]^+$: 498.1063; found: 498.1061.



3ae

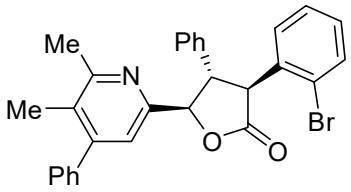
5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-(4-fluorophenyl)-4-phenyldihydrofuran-2(3H)-one (3ae), yellow oil, 0.072 g, 82% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.36 (m, 3H), 7.28–7.23 (m, 7H), 7.18–7.16 (m, 2H), 7.06 (s, 1H), 7.02 (t, J = 8.8 Hz, 2H), 5.52 (d, J = 9.6 Hz, 1H), 4.35–4.29 (m, 1H), 4.20 (d, J = 12.0 Hz, 1H), 2.56 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.2, 163.4 (d, J = 245 Hz), 158.3, 150.8, 150.0, 139.4, 136.6, 131.2 (d, J = 2.9 Hz), 130.3 (d, J = 8.0 Hz), 129.5, 128.9, 128.7, 128.3, 127.9, 127.8, 127.7, 121.7, 115.8 (d, J = 21.1 Hz), 85.1, 55.5, 53.9, 23.5, 16.1; IR (neat): 2967, 1715, 1608, 1467, 1282, 1019, 727 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{25}FNO_2$ $[M + H]^+$: 438.1864; found: 438.1862.



3af

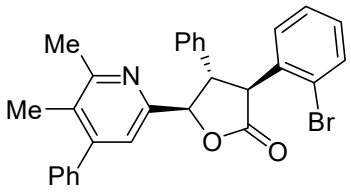
5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-(3-fluorophenyl)-4-phenyldihydrofuran-2(3H)-one (3af), yellow oil, 0.086 g, 99% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43–7.38 (m, 3H), 7.29–7.24 (m, 6H), 7.19–7.18 (m, 2H), 7.06 (s, 3H), 6.99 (t, J = 5.6 Hz, 1H), 5.52 (d, J = 7.2 Hz, 1H), 4.40–4.35 (m, 1H), 4.22 (d, J = 9.6 Hz, 1H), 2.57 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 174.7, 164.1 (d, J = 245 Hz), 158.4, 150.8, 150.1, 139.4, 137.9 (d, J = 7.3 Hz), 136.7, 130.3 (d, J = 8.8 Hz), 129.5, 128.9, 128.7, 128.4, 127.9, 127.8, 127.7, 124.5 (d, J = 2.9 H), 121.8, 115.8 (d, J = 21.8 Hz), 114.9 (d, J = 21.2 Hz), 85.2, 55.1, 54.2, 23.5, 16.1; IR (neat): 3062,

2962, 1717, 1608, 1454, 1260, 1023, 804, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{25}FNO_2$ $[M + H]^+$: 438.1864; found: 438.1860.



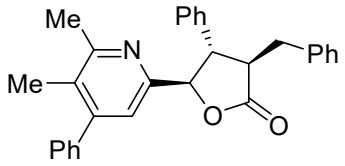
3ag

3-(2-Bromophenyl)-5-(5,6-dimethyl-4-phenylpyridin-2-yl)-4-phenyldihydrofuran-2(3H)-one (3ag), yellow solid, 0.082 g, 82% yield. Mp: 199–200 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.45−7.43 (m, 3H), 7.41− 7.38 (m, 1H), 7.30−7.29 (m, 2H), 7.15 (s, 1H), 7.13−7.10 (m, 3H), 7.05−7.04 (m, 2H), 6.94−6.92 (m, 2H), 6.76−6.74 (m, 1H), 5.82 (s, 1H), 5.49 (d, J = 9.0 Hz, 1H), 4.60 (d, J = 8.5 Hz, 1H), 2.64 (s, 3H), 2.23 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 176.3, 158.6, 153.1, 150.2, 139.5, 138.7, 133.9, 132.0, 131.4, 129.2, 128.7, 128.5, 128.4, 128.3, 127.9, 127.6, 127.2, 126.9, 125.5, 120.2, 84.4, 51.4, 50.4, 23.7, 16.1; IR (neat): 2924, 1712, 1607, 1459, 1130, 1022, 728 cm^{-1}; HRMS (ESI) m/z calcd for $C_{29}H_{25}BrNO_2$ $[M + H]^+$: 498.1063; found: 498.1070.



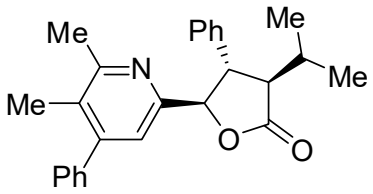
3ah

5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-4-phenyl-3-(thiophen-2-yl)dihydrofuran-2(3H)-one (3ah), yellow solid, 0.035 g, 41% yield. Mp: 147–148 °C; ^1H NMR (400 MHz, $CDCl_3$): δ 7.44−7.37 (m, 3H), 7.31−7.22 (m, 8H), 7.06 (s, 1H), 7.01−7.00 (m, 1H), 6.96–6.94 (m, 1H), 5.50 (d, J = 9.2 Hz, 1H), 4.53 (d, J = 12.4 Hz, 1H), 4.44 (dd, J = 12.0 Hz, 9.6 Hz, 1H), 2.55 (s, 3H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.9, 158.2, 150.6, 150.0, 139.4, 136.8, 136.4, 129.5, 128.9, 128.7, 128.3, 127.9, 127.8, 126.8, 126.4, 125.1, 121.7, 85.4, 55.2, 49.1, 23.5, 16.1; IR (neat): 3446, 2978, 1710, 1508, 1469, 1283, 1021, 728 cm^{-1}; HRMS (ESI) m/z calcd for $C_{27}H_{24}NO_2S$ $[M + H]^+$: 426.1522; found: 426.1522.



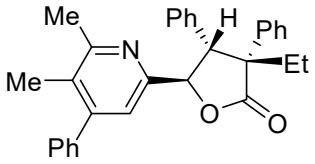
3ai

3-Benzyl-5-(5,6-dimethyl-4-phenylpyridin-2-yl)-4-phenyldihydrofuran-2(3H)-one (3ai), white solid, 0.060 g, 69% yield. Mp: 154–155 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38−7.31 (m, 3H), 7.29−7.24 (m, 3H), 7.20−7.18 (m, 3H), 7.16−7.06 (m, 5H), 6.99 (s, 1H), 6.84 (d, J = 7.2 Hz, 2H), 5.48 (s, 1H), 3.90 (d, J = 8.4 Hz, 1H), 3.65–3.60 (m, 1H), 3.09 (dd, J = 14.8 Hz, 3.6 Hz, 1H), 2.49 (s, 3H), 2.29 (dd, J = 14.4 Hz, 10.4 Hz, 1H), 2.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.7, 158.4, 153.5, 150.1, 139.5, 139.3, 138.8, 128.9, 128.8, 128.7, 128.6, 128.4, 128.2, 127.9, 127.6, 126.2, 119.2, 85.6, 49.9, 44.3, 31.6, 23.6, 16.1; IR (neat): 2963, 1718, 1607, 1456, 1023, 728 cm^{-1}; HRMS (ESI) m/z calcd for $C_{30}H_{28}NO_2$ $[M + H]^+$: 434.2115; found: 434.2111.



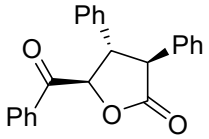
3aj

5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-isopropyl-4-phenyldihydrofuran-2(3H)-one (3aj), yellow solid, 0.056 g, 72% yield. Mp: 145–146 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46–7.38 (m, 3H), 7.36–7.35 (m, 4H), 7.31–7.28 (m, 3H), 7.11 (s, 1H), 5.47 (s, 1H), 4.10 (d, J = 5.2 Hz, 1H), 2.82 (t, J = 6.8 Hz, 1H), 2.59 (s, 3H), 2.21 (s, 3H), 1.75–1.71 (m, 1H), 1.13 (d, J = 5.6 Hz, 3H), 0.78 (d, J = 5.6 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 177.9, 158.2, 153.7, 150.2, 139.6, 139.5, 128.8, 128.7, 128.6, 128.4, 128.1, 127.9, 127.4, 119.1, 84.7, 50.5, 48.8, 25.8, 23.6, 21.8, 20.1, 16.1; IR (neat): 2959, 1710, 1607, 1384, 1022, 803 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{28}NO_2$ $[M + H]^+$: 386.2115; found: 386.2112.



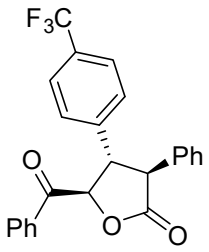
3ak

5-(5,6-Dimethyl-4-phenylpyridin-2-yl)-3-ethyl-3,4-diphenyldihydrofuran-2(3H)-one (3ak), yellow oil, 0.044 g, 49% yield. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.43−7.37 (m, 3H), 7.21−7.20 (m, 3H), 7.17−7.14 (m, 3H), 7.10−7.09 (m, 3H), 6.77–6.73 (m, 4H), 5.57 (d, J = 10.0 Hz, 1H), 4.27 (d, J = 10.0 Hz, 1H), 2.47 (s, 3H), 2.19 (q, J = 7.0 Hz, 2H), 2.11 (s, 3H), 1.21 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 178.1, 157.9, 151.3, 149.9, 139.6, 136.4, 134.0, 129.5, 129.3, 128.7, 128.3, 128.0, 127.9, 127.8, 127.4, 127.3, 121.2, 81.6, 59.3, 56.3, 27.9, 23.4, 16.1, 9.1; IR (neat): 2975, 1714, 1634, 1528, 1279, 1 1166, 1027, 812, 689 cm^{-1}; HRMS (ESI) m/z calcd for $C_{31}H_{30}NO_2$ $[M + H]^+$: 448.2271; found: 448.2252.



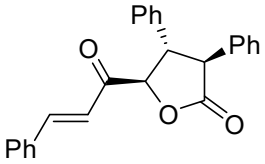
4ma

5-Benzoyl-3,4-diphenyldihydrofuran-2(3H)-one (4ma), yellow solid, 0.077 g, 91% yield. Mp: 153–154 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87 (d, J = 6.0 Hz, 2H), 7.58–7.55 (m, 1H), 7.42–7.39 (m, 2H), 7.32–7.25 (m, 8H), 7.19 (d, J = 5.6 Hz, 2H), 5.75 (d, J = 7.2 Hz, 1H), 4.21 (d, J = 8.8 Hz, 1H), 4.14–4.10 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.8, 174.6, 137.2, 135.0, 134.5, 134.2, 129.3, 129.2, 129.0, 128.8, 128.4, 128.2, 128.0, 127.7, 82.0, 54.1, 52.3; IR (neat): 2924, 1687, 1607, 1412, 1284, 1017, 803, 727 cm^{-1}; HRMS (ESI) m/z calcd for $C_{23}H_{18}O_3Na$ $[M + Na]^+$: 365.1148; found: 365.1148.



4na

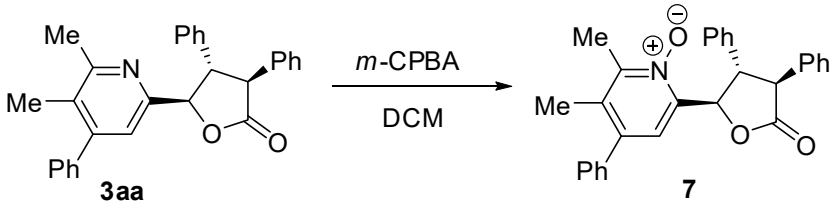
5-Benzoyl-3-phenyl-4-(4-(trifluoromethyl)phenyl)dihydrofuran-2(3H)-one (4na), yellow oil, 0.074 g, 90% yield. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.99 (d, J = 8.4 Hz, 2H), 7.68 (d, J = 8.0 Hz, 2H), 7.34−7.25 (m, 8H), 7.18 (d, J = 6.4 Hz, 2H), 5.72 (d, J = 8.8 Hz, 1H), 4.24 (d, J = 11.2 Hz, 1H) , 4.13–4.08 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 192.1, 174.3, 137.0, 136.6, 135.7 (q, J = 32 Hz), 134.6, 129.5, 129.4, 129.0, 128.4, 128.3, 128.1, 127.7, 125.8 (q, J = 3.6 Hz), 124.3 (q, J = 267 Hz), 82.1, 53.9, 52.3; IR (neat): 3444, 2962,1706, 1620, 1326, 1068, 698 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{18}F_3O_3$ $[M + H]^+$: 411.1203; found: 411.1199.



4oa

5-Cinnamoyl-3,4-diphenyldihydrofuran-2(3H)-one (4oa), yellow solid, 0.092 g, 95% yield. Mp: 155–156 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, J = 15.6 Hz, 1H), 7.50 (d, J = 6.4 Hz, 2H), 7.42 – 7.25 (m, 11H), 7.16 (d, J = 6.4 Hz, 2H), 6.95 (d, J = 16.0 Hz, 1H), 5.22 (d, J = 9.6 Hz, 1H), 4.16 (d, J = 11.6 Hz, 1H), 3.86–3.81 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 193.1, 174.6, 146.4, 136.7, 134.7, 133.9, 131.4, 129.3, 129.0, 128.9, 128.8, 128.3, 128.2, 128.0, 127.8, 120.7, 84.5, 54.3, 53.5; IR (neat): 2924, 1714, 1608, 1468, 1283, 1151, 1023, 803, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{20}O_3Na$ $[M + Na]^+$: 391.1305; found: 391.1305.

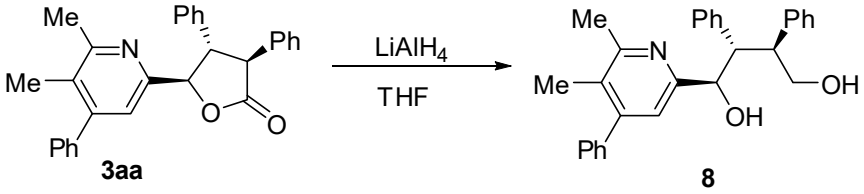
6. Synthesis of compound 7 and 8



In a 25 mL flask was charged with γ-latone **3aa** (0.084 g, 0.2 mmol), m-CPBA (0.4 mmol, 2.0 equiv.) and DCM (5.0 mL). The mixture was stirred vigorously at room temperature (about 25 °C) for 4 h until the substrate **3aa** disappeared (monitored by TLC). At this time, the reaction was quenched by H_2O (50 mL) and extracted with

DCM (10 mL × 3). The combined organic layers were dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash chromatography (the crude residue was dry loaded on silica gel, 1/30 to 1/4, ethyl acetate/petroleum ether) to provide compound **7**.

2,3-Dimethyl-6-(-5-oxo-3,4-diphenyltetrahydrofuran-2-yl)-4-phenylpyridine 1-oxide (7), white solid, 0.087 g, 100% yield. Mp: 249−250 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46–7.39 (m, 3H), 7.36−7.22 (m, 8H), 7.18−7.16 (m, 5H), 6.17 (d, J = 6.0 Hz, 1H), 4.16−4.11 (m, 2H) , 2.56 (s, 3H), 2.22 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 175.8, 149.4, 144.1, 140.3, 139.6, 138.2, 135.5, 132.2, 129.3, 129.0, 128.8, 128.7, 128.5, 128.2, 128.1, 127.7, 127.6, 127.1, 122.1, 80.4, 54.7, 53.5, 17.3, 14.5; IR (neat): 3037, 1714, 1608, 1468, 1144, 1021, 803, 727 cm^{-1}; HRMS (ESI) *m/z* calcd for $C_{29}H_{26}NO_3$ $[M + H]^+$: 436.1907; found: 436.1902.

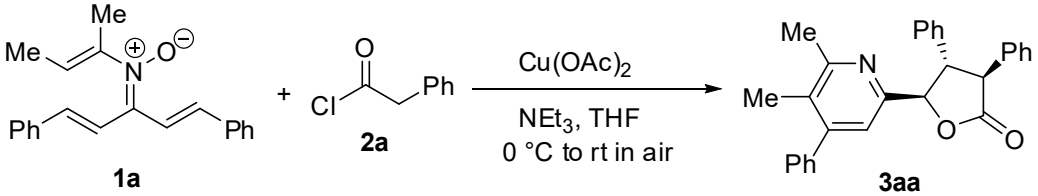


In a 25 mL round-bottom flask was charged with γ-latone **3aa** (0.084 g, 0.2 mmol) and THF (5.0 mL), after stirring for 2 min, $LiAlH_4$ (8 mmol, 4.0 equiv) was added. The mixture was stirred vigorously at room temperature (about 25 °C) for 12 h until the substrate **3aa** disappeared (monitored by TLC). At this time, the reaction was quenched by H_2O (50 mL) and extracted with EtOAc (20 mL × 3). The combined organic layers were dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash chromatography (the crude residue was dry loaded on silica gel, 1/30 to 1/1, ethyl acetate/petroleum ether) to provide 1,4-diol **8**.

1-(5,6-Dimethyl-4-phenylpyridin-2-yl)-2,3-diphenylbutane-1,4-diol (8), white solid, 0.048 g, 57% yield. Mp: 77−78 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31−7.30 (m, 3H), 7.15−7.02 (m, 9H), 6.90–6.89 (m, 2H), 6.73–6.72 (m, 2H), 6.20 (s, 1H), 5.04 (d, J = 8.0 Hz, 1H), 4.84 (brs, 1H), 4.19 (brs, 1H), 4.07 (dd, J = 11.2 Hz, 8.0 Hz, 1H),

3.91 (dd, J = 11.2 Hz, 4.8 Hz, 1H), 3.73– 3.68 (m, 1H), 3.33 (t, J = 8.0 Hz, 1H), 2.58 (s, 3H), 2.09 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.1, 155.9, 149.5, 141.2, 139.9, 139.5, 129.7, 128.8, 128.5, 128.0, 127.9, 127.6, 127.5, 126.2, 126.1,121.2, 74.7, 66.1, 56.9, 50.8, 22.9, 15.8; IR (neat): 3427, 2956, 1608, 1384, 1020, 804, 703 cm^{-1}; HRMS (ESI) *m/z* calcd for $C_{29}H_{29}NO_2K$ $[M + K]^+$: 462.1830; found: 462.1828.

7. Gram scale preparation of 3aa



In a 100 mL round-bottom flask was charged with 2-phenylacetyl chloride **2a** (1.0 mL, 8 mmol, 2.0 equiv.) and THF (60.0 mL). The flask was cooled to 0 °C and NEt_3 (1.1 mL, 8 mol, 2.0 equiv.) was added under air. The reaction was stirring for 2 h at 0 °C. Then, *N*-vinyl nitrones **1a** (1.2 g, 4.0 mmol) and $Cu(OAc)_2$ (140 mg, 20 mol%) was added. The reaction vessel was stirred vigorously at room temperature (about 25 °C) for 72 h until the substrate **1a** disappeared (monitored by TLC). At this time, the reaction was quenched by H_2O (50 mL) and extracted with EtOAc (30 mL × 3). The combined organic layers were dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (the crude residue was dry loaded with silica gel, 1/50 to 1/10, ethyl acetate/petroleum ether) to provide γ-lactones **3aa** (1.2 g, 72% yield).

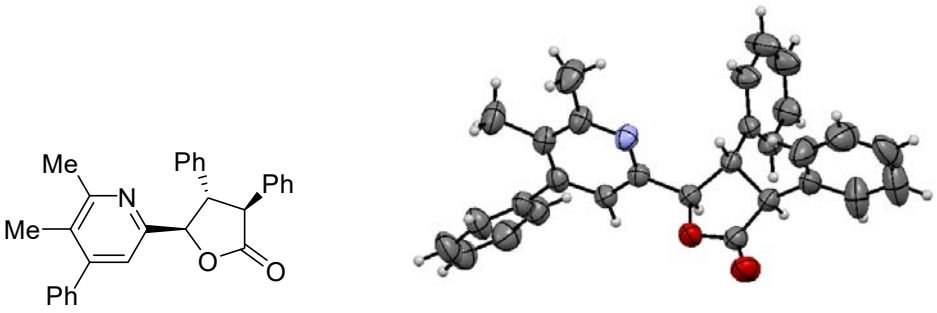
8. References

[1] (a) Zou, N.; Jiao, J.-W.; Feng, Y.; Pan, C.-X.; Liang, C.; Su, G.-F.; Mo, D.-L. *Org. Lett.* **2019**, *21*, 481. (b) Ma, X.-P.; Li, L.-G.; Zhao, H.-P.; Du, M.; Liang, C.; Mo, D.-L. *Org. Lett.* **2018**, *20*, 4571.

[2] Chen, C.-H.; Wu, Q.-Y.; Wei, C.; Liang, C.; Su, G.-F.; Mo, D.-L. *Green Chem.* **2018**, *20*, 2722

[3] Lang, R. W.; Hansen, H.-J. *Helvetica Chimica Acta* **1980**, *63*, 438.

9. X-ray structure for compounds 3aa



3aa

Figure S1: ORTEP diagram of **3aa** at 50% ellipsoid probability

10. NMR spectra for 3, 4, 7, 8, and isomerization of 1m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7.383
7.372
7.355
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7.276
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7.212
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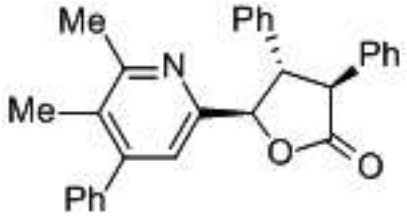
0.002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Ph
Ph
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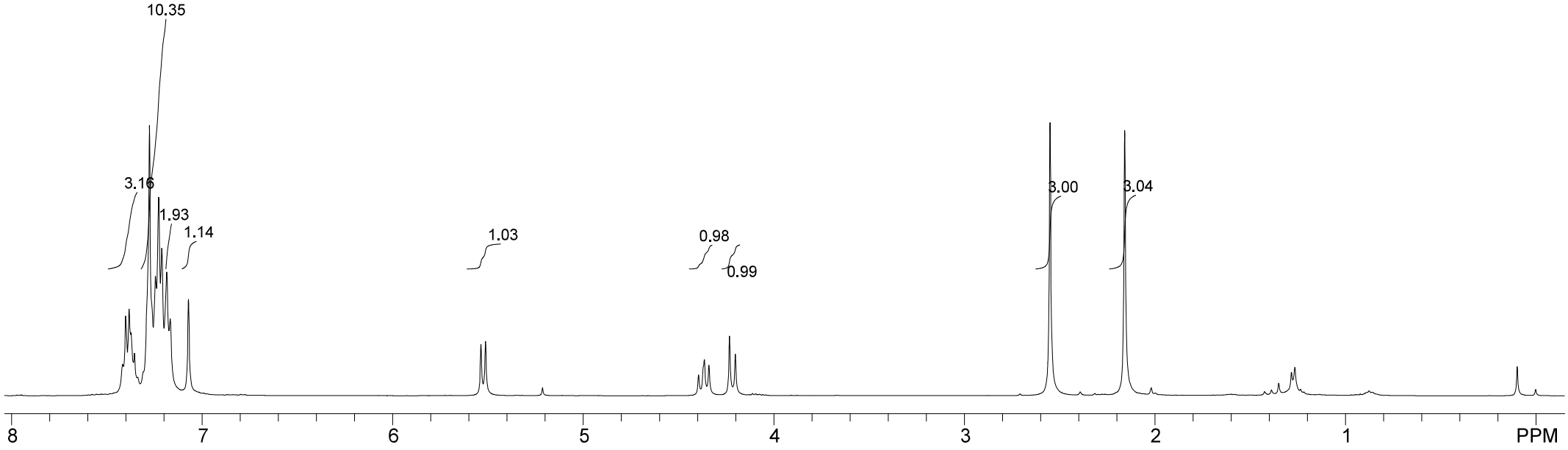
Me
O
O
Ph

3aa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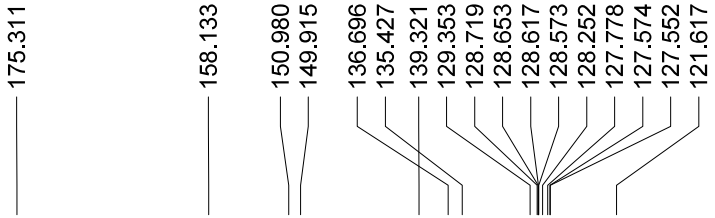
2
1
PPM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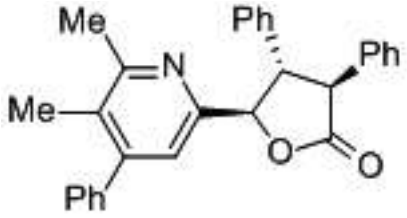
Me
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Ph
N
Me
O
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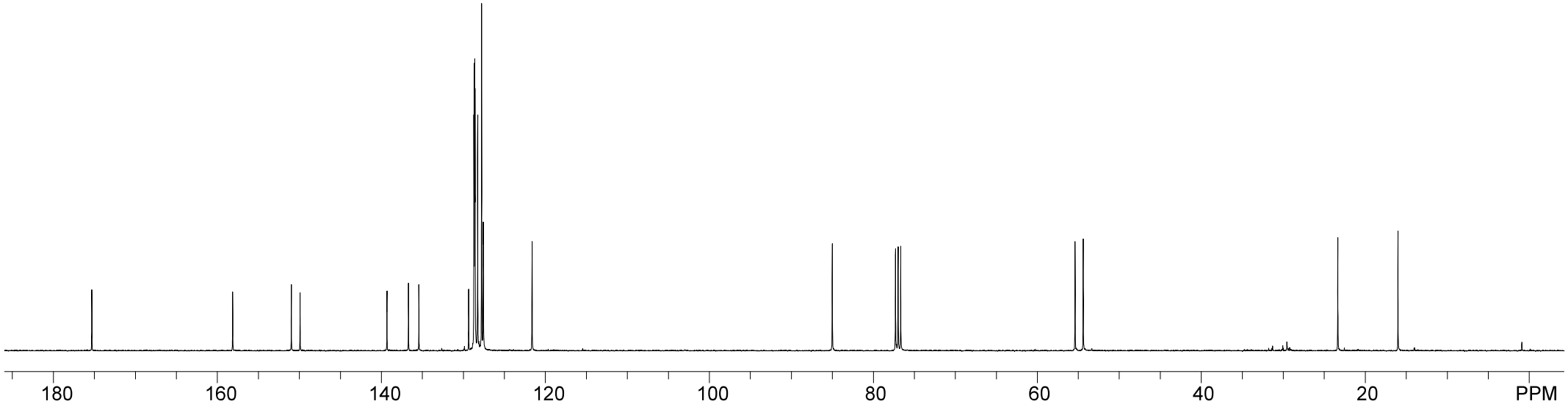
Ph

3aa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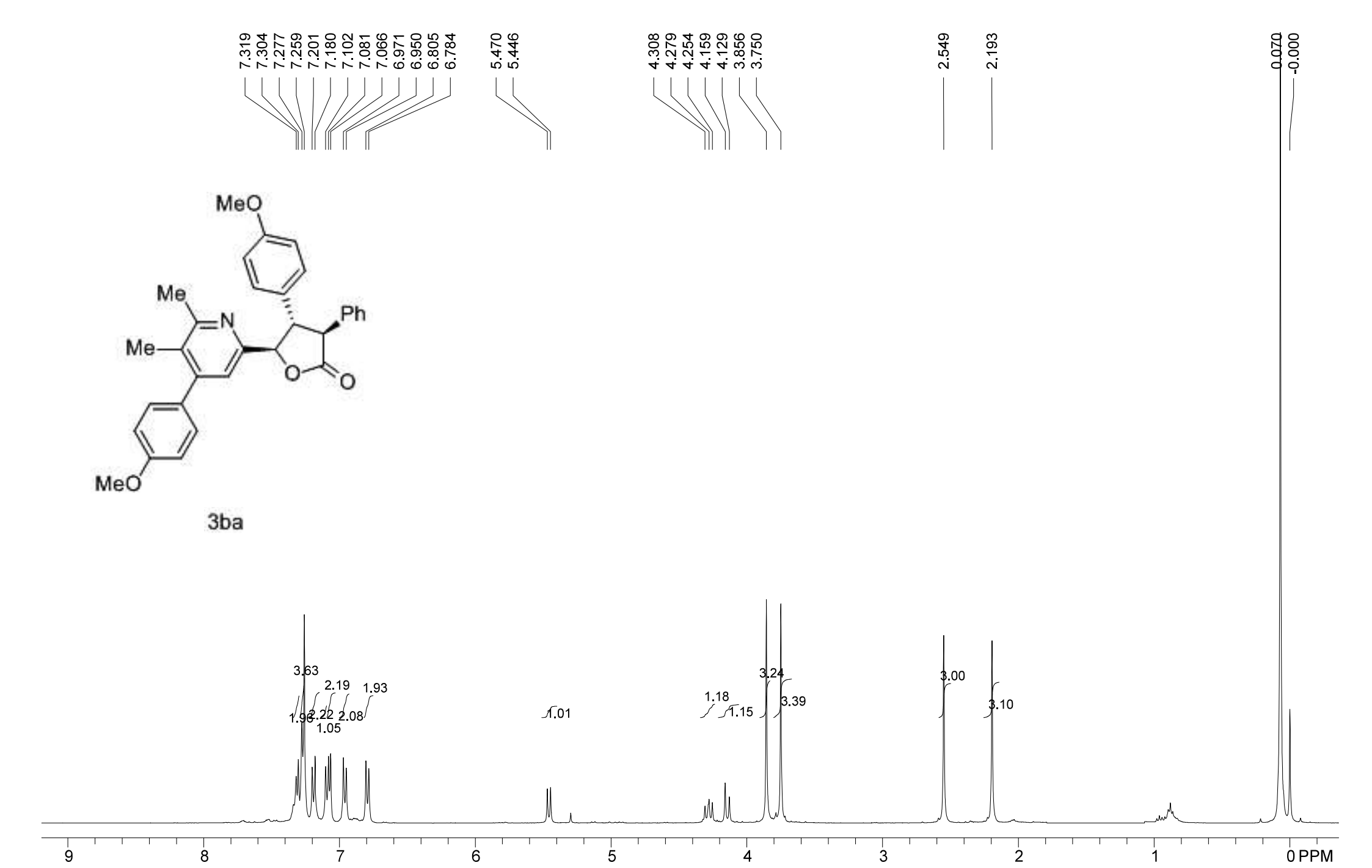
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1.96
2.22
2.08
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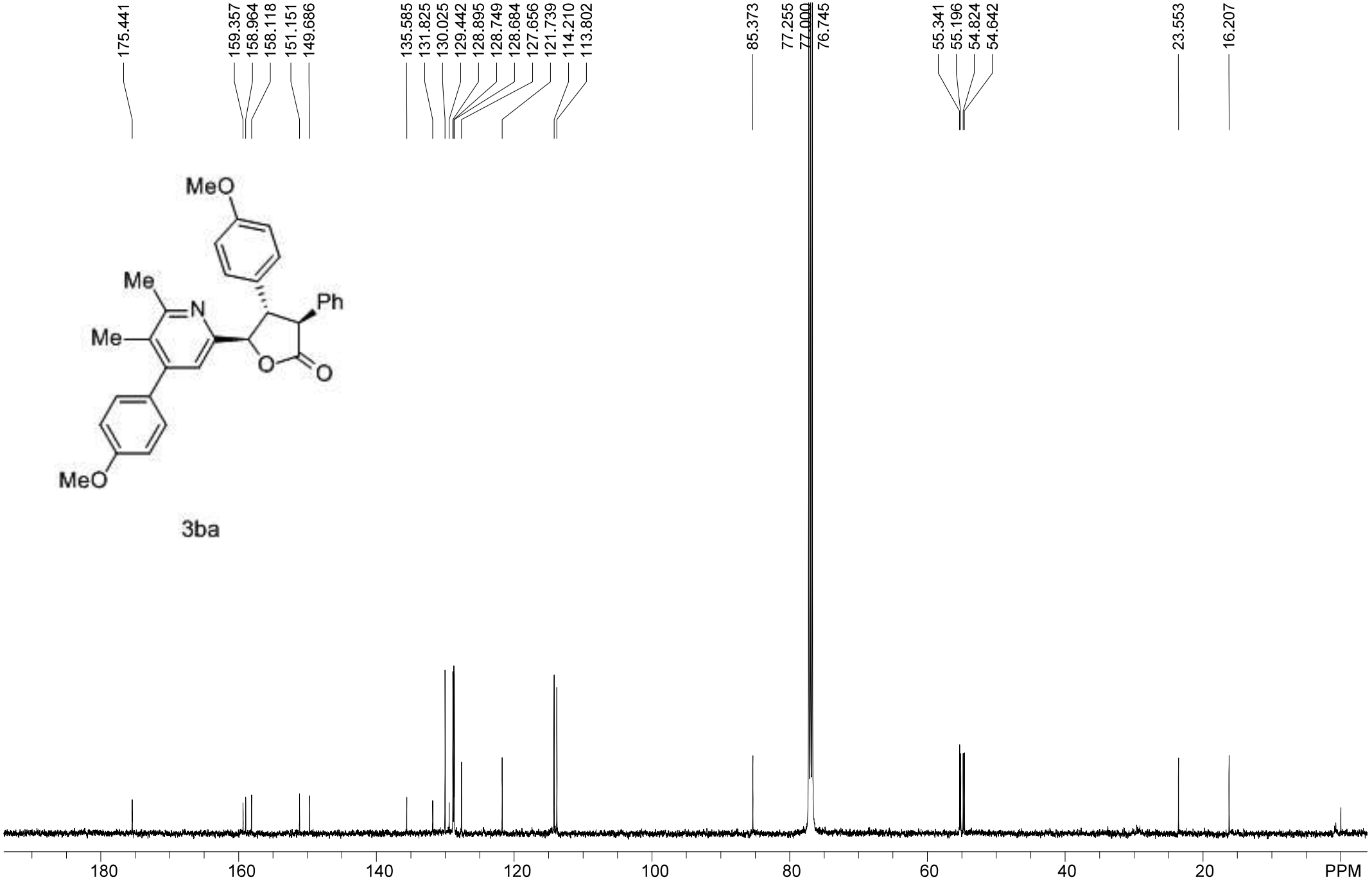
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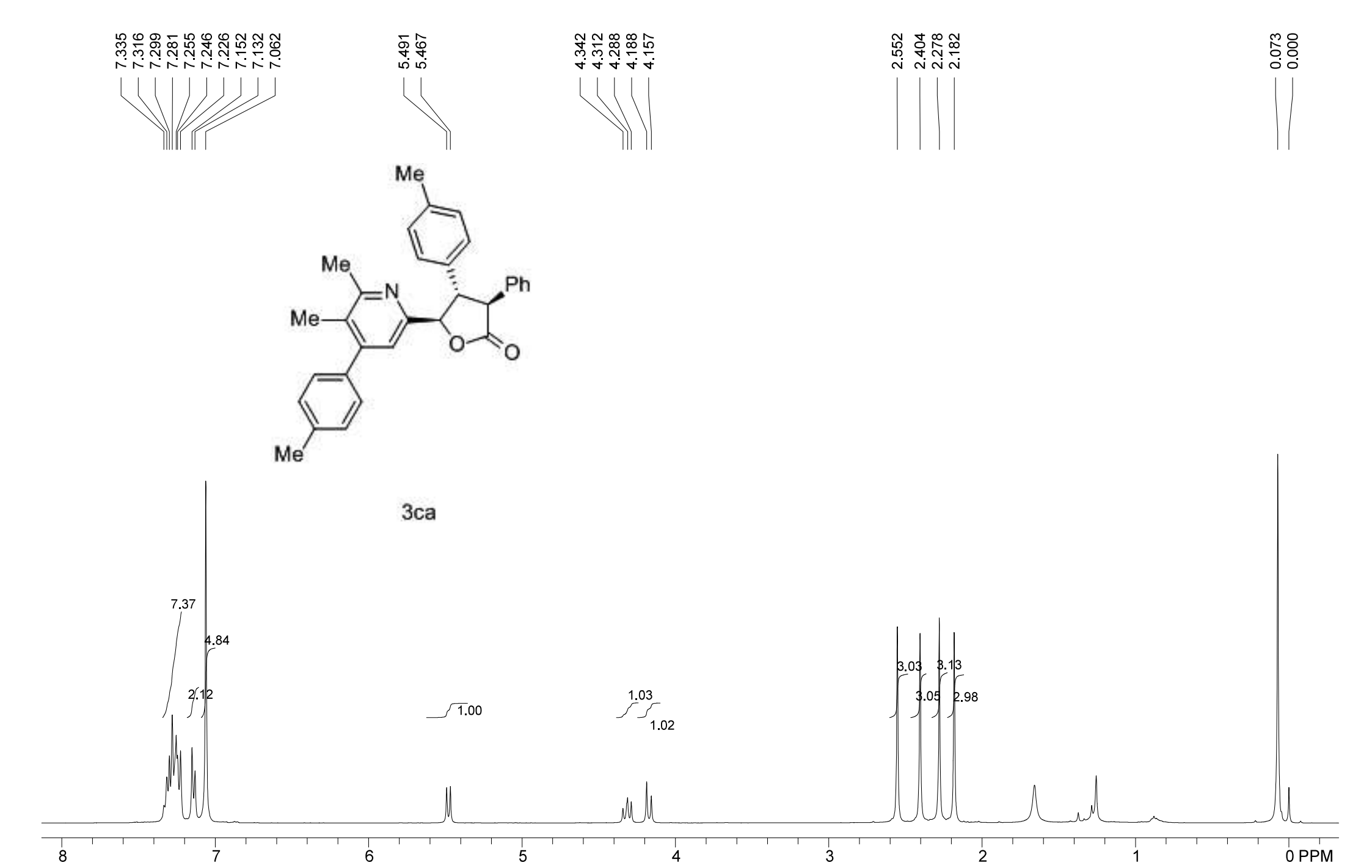
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Ph
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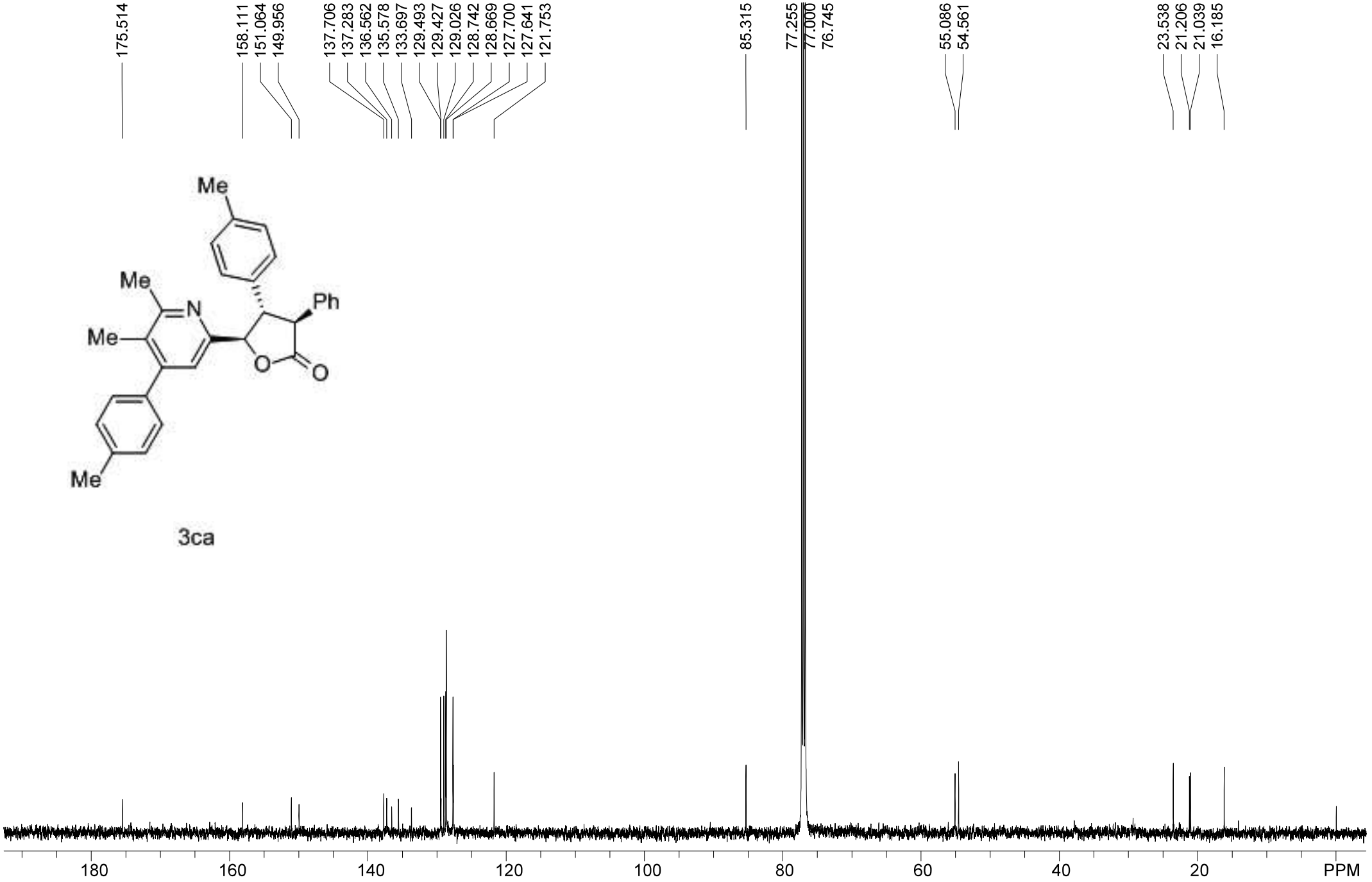
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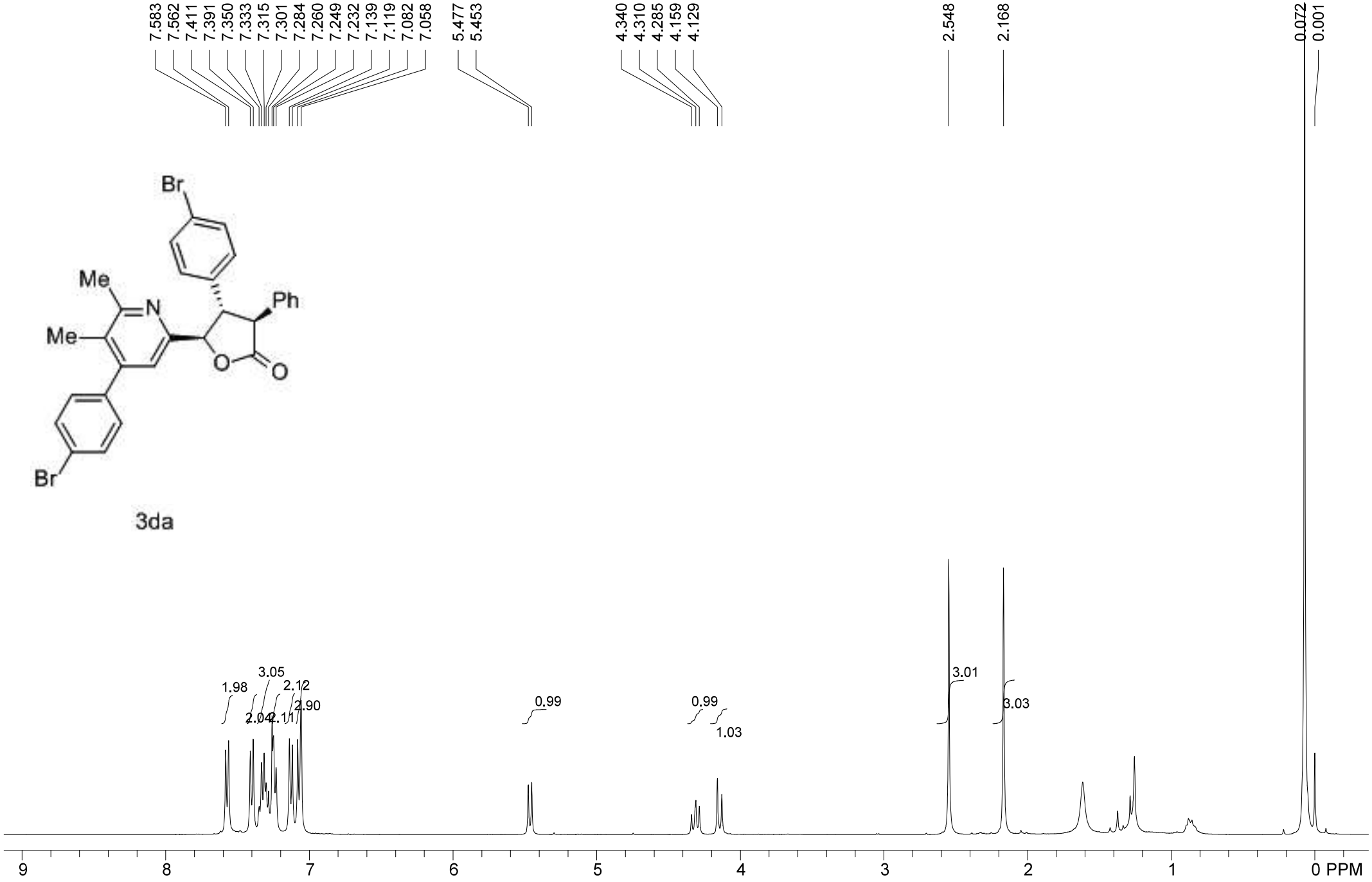
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Ph
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O
O
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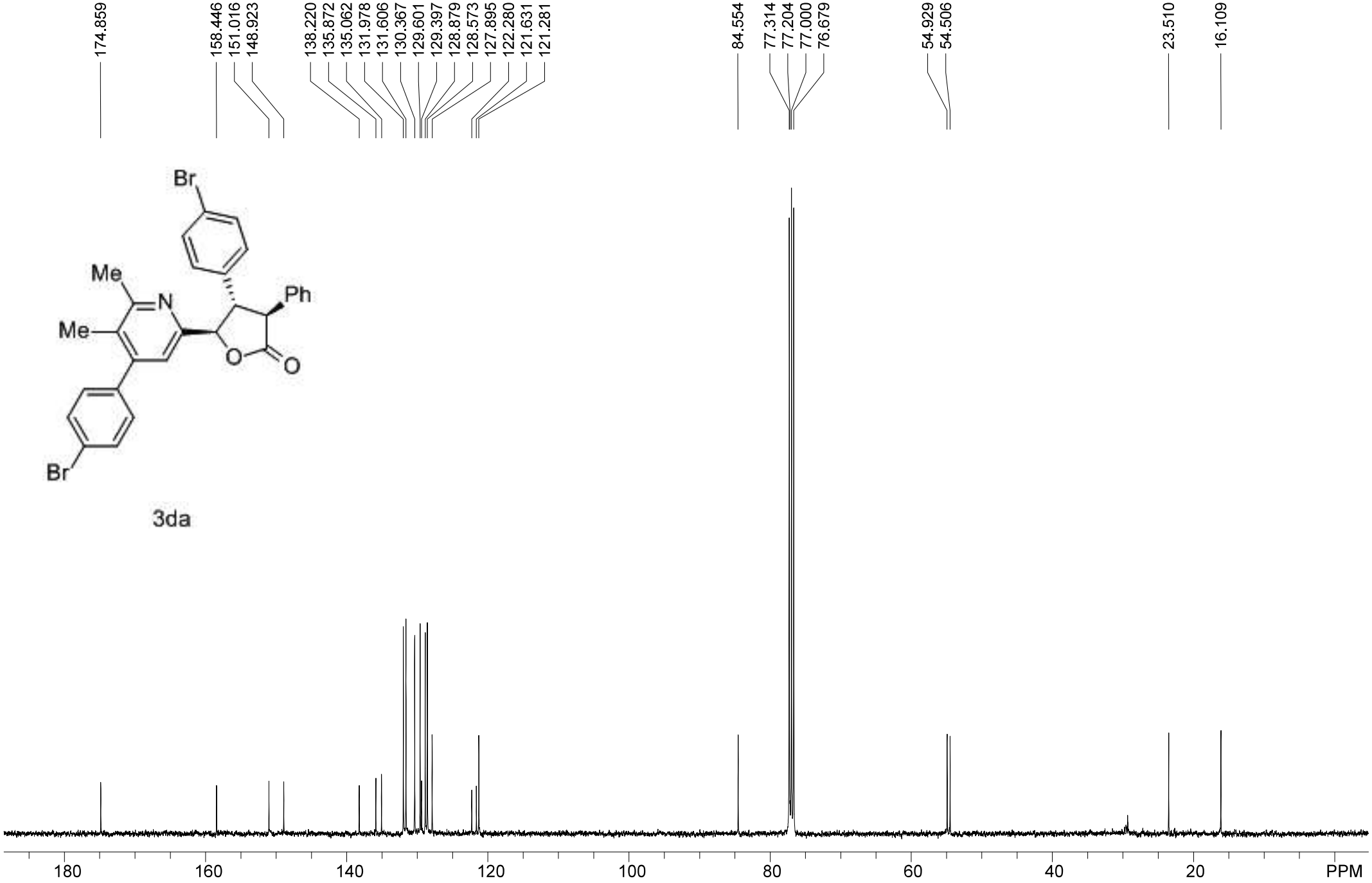
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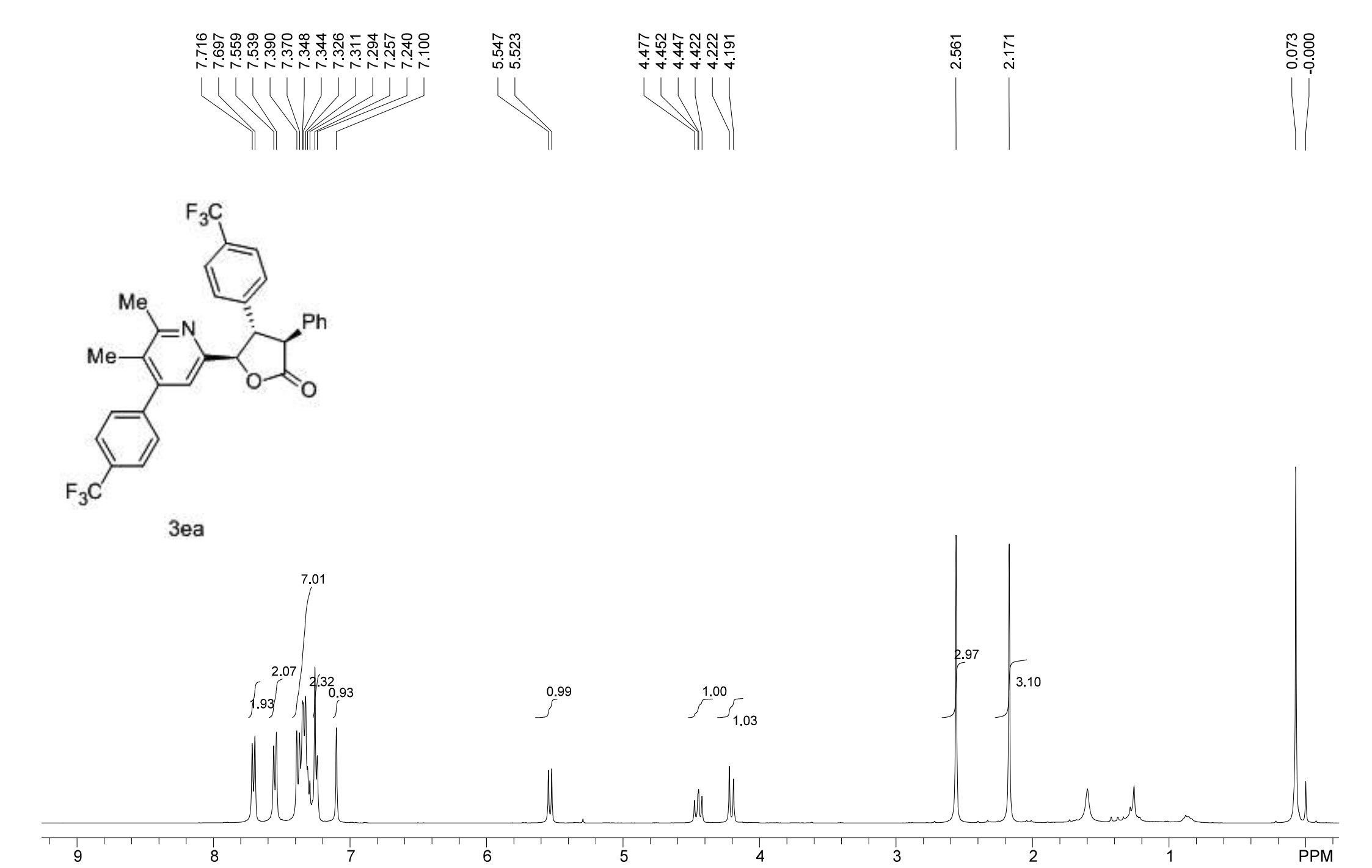
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N
Ph
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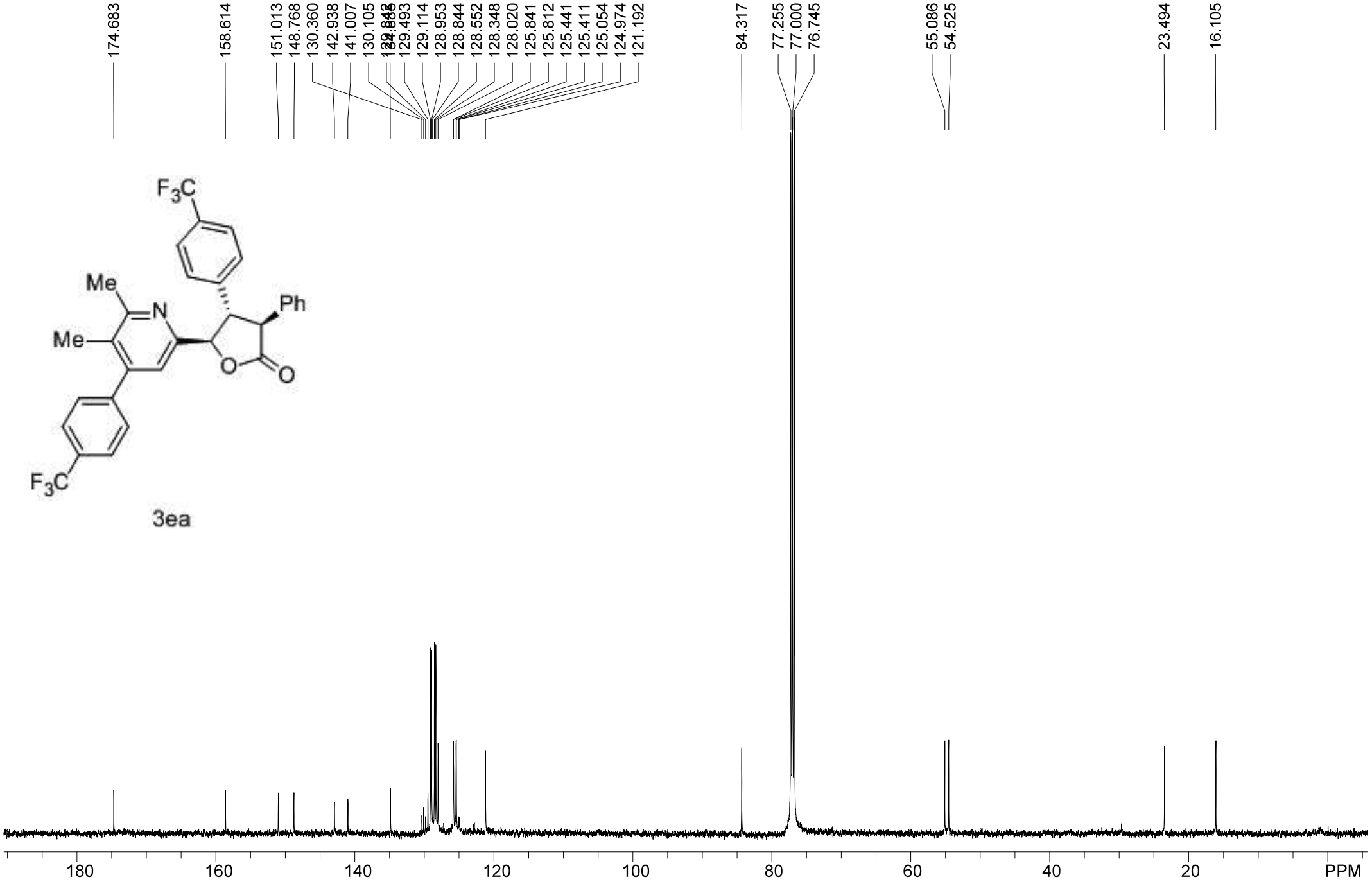
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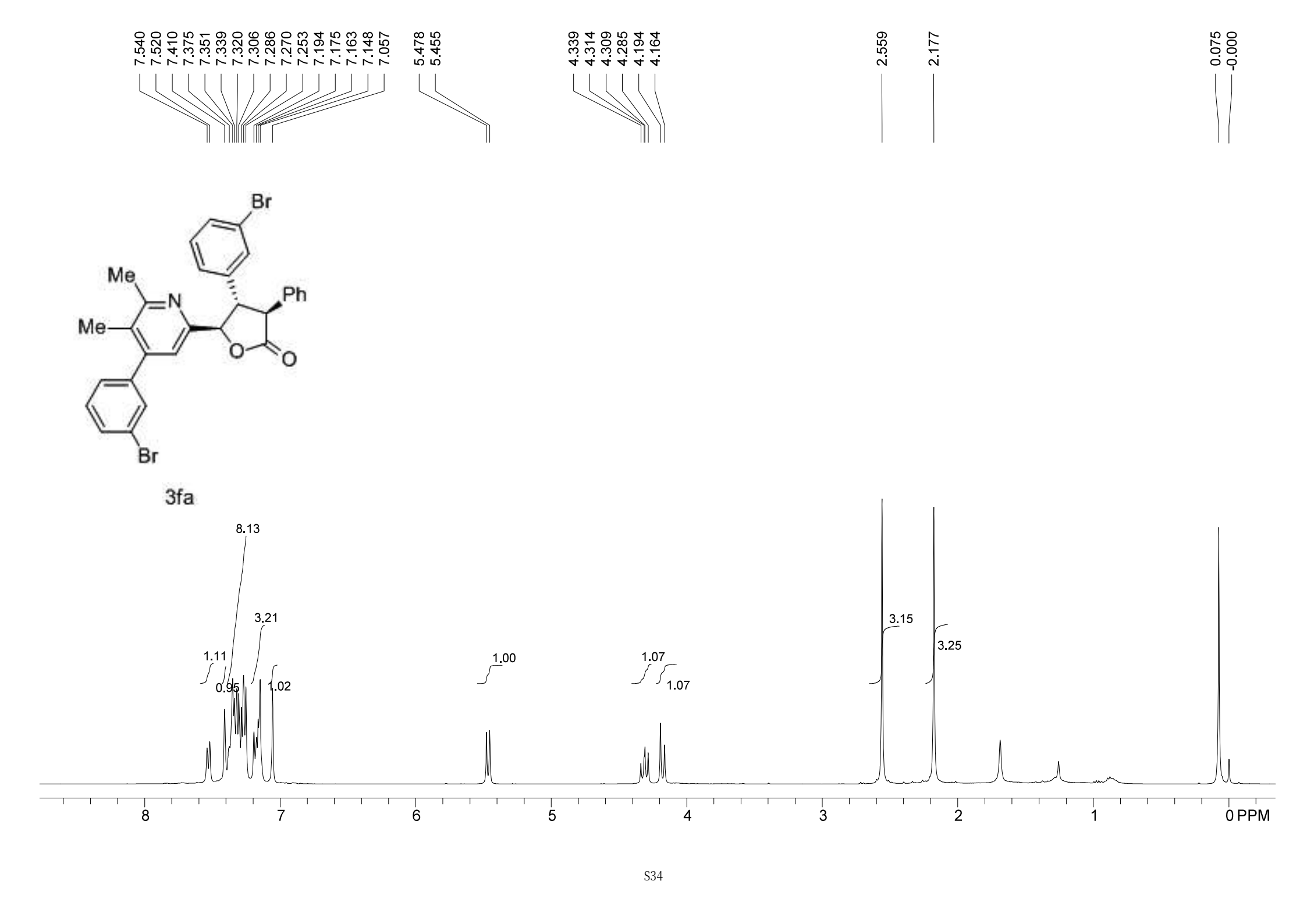
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Ph
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O
O
Br
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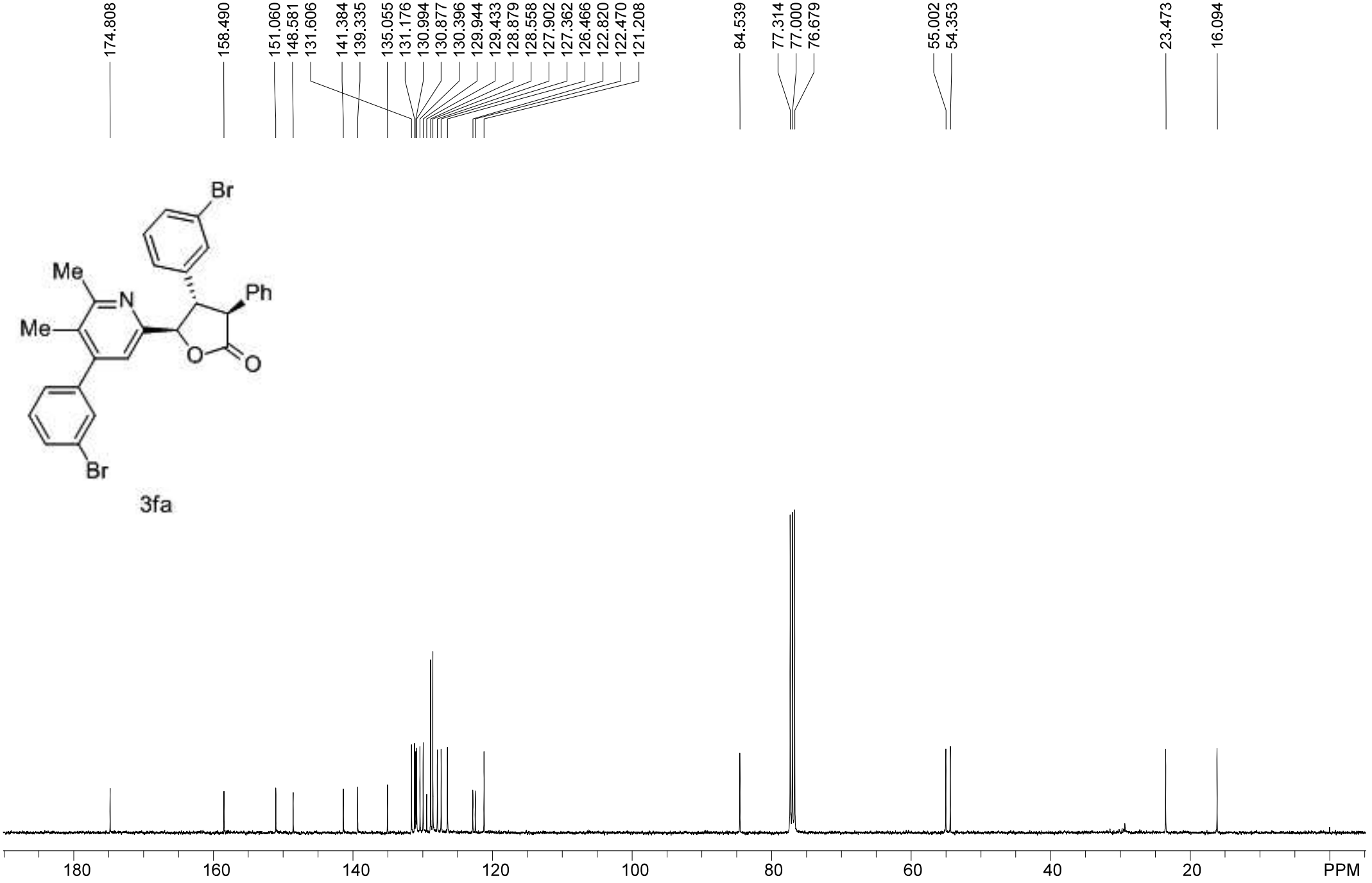
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77.000
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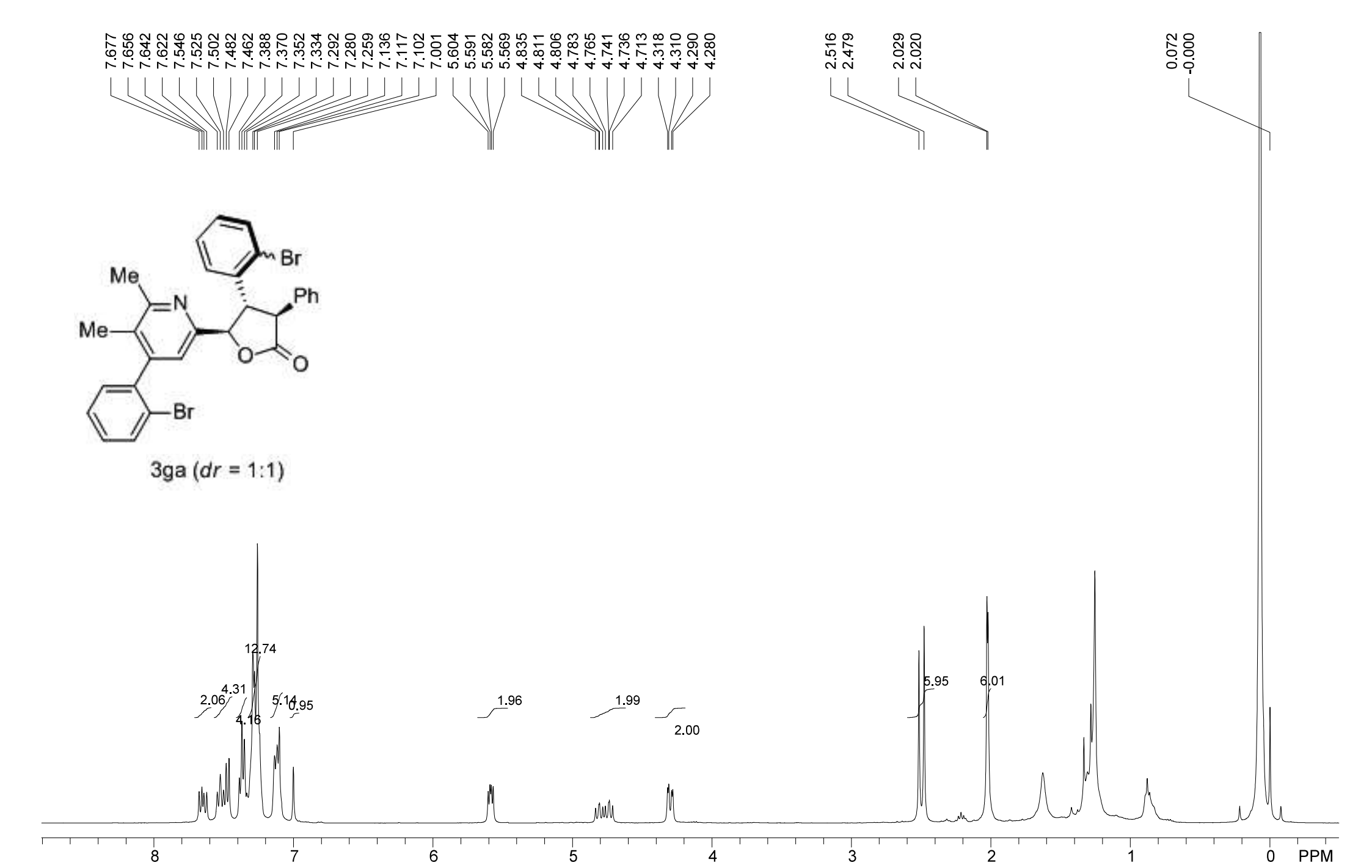
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2.479
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Br
Me
N
Ph
Me
O
O
Br
3ga (dr = 1:1)
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4.16
5.14
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6.01
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5
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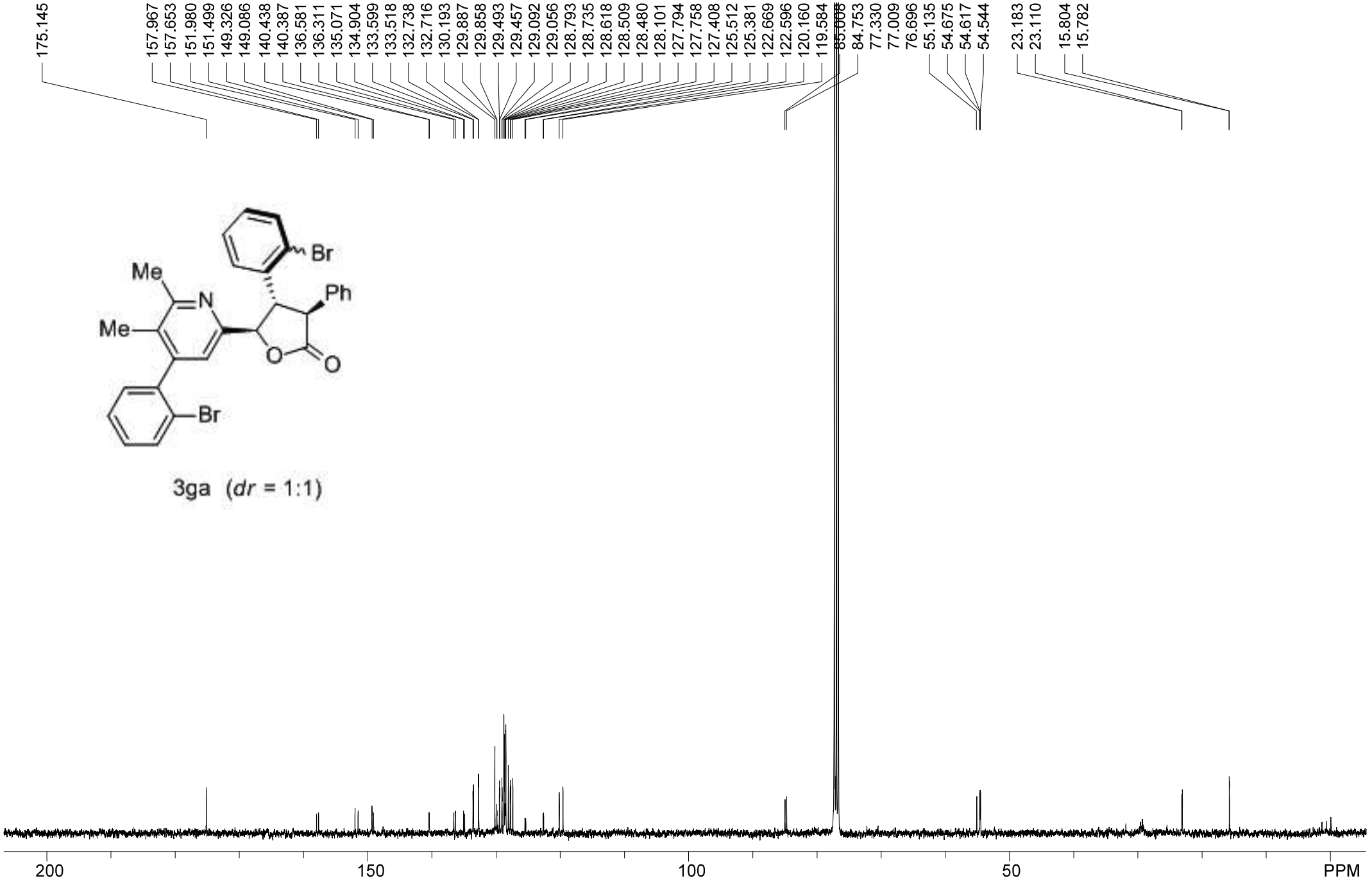
0
PPM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132.738
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129.056
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50
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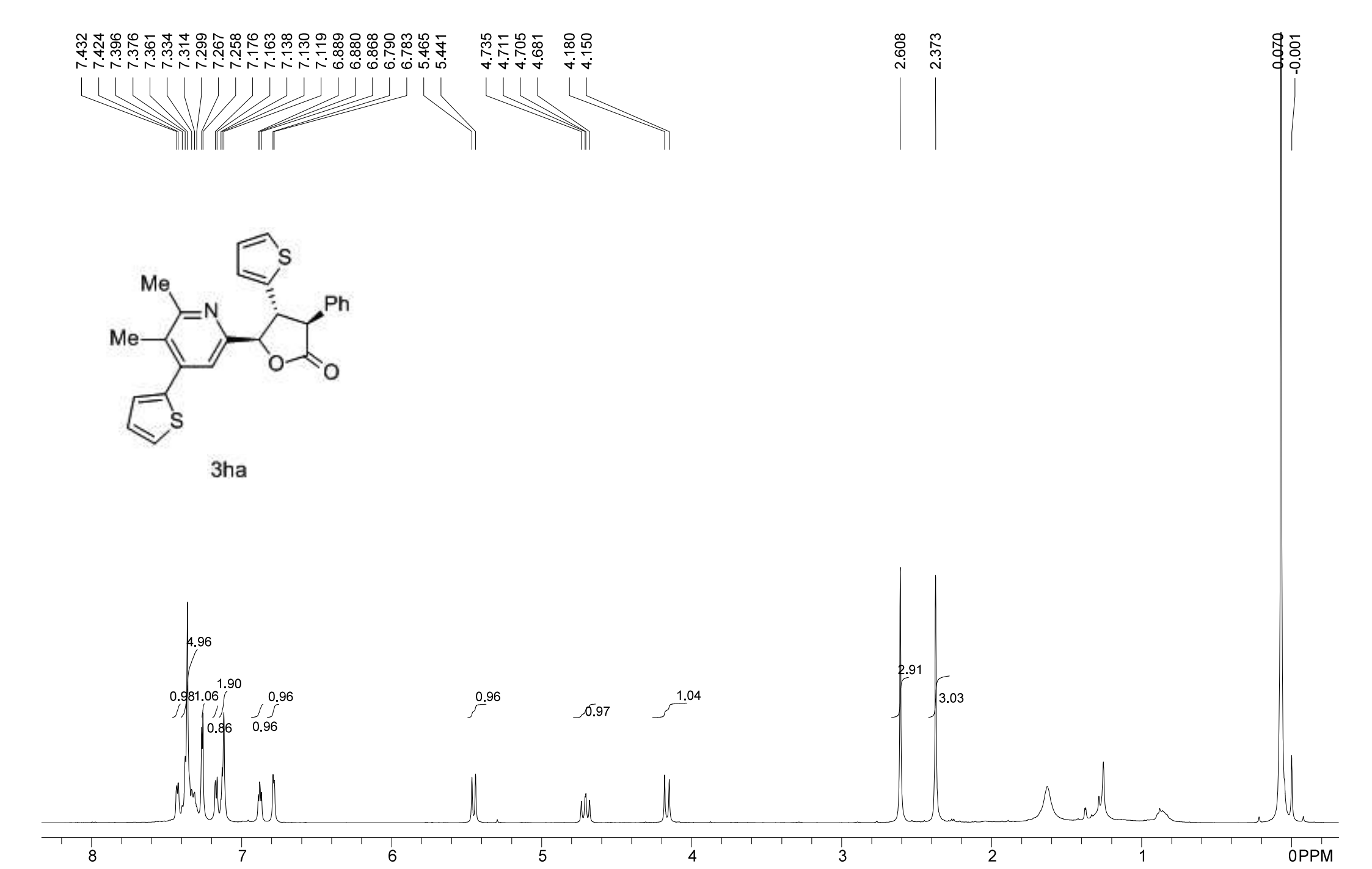
3ga (*dr* = 1:1)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Ph
O
O
S
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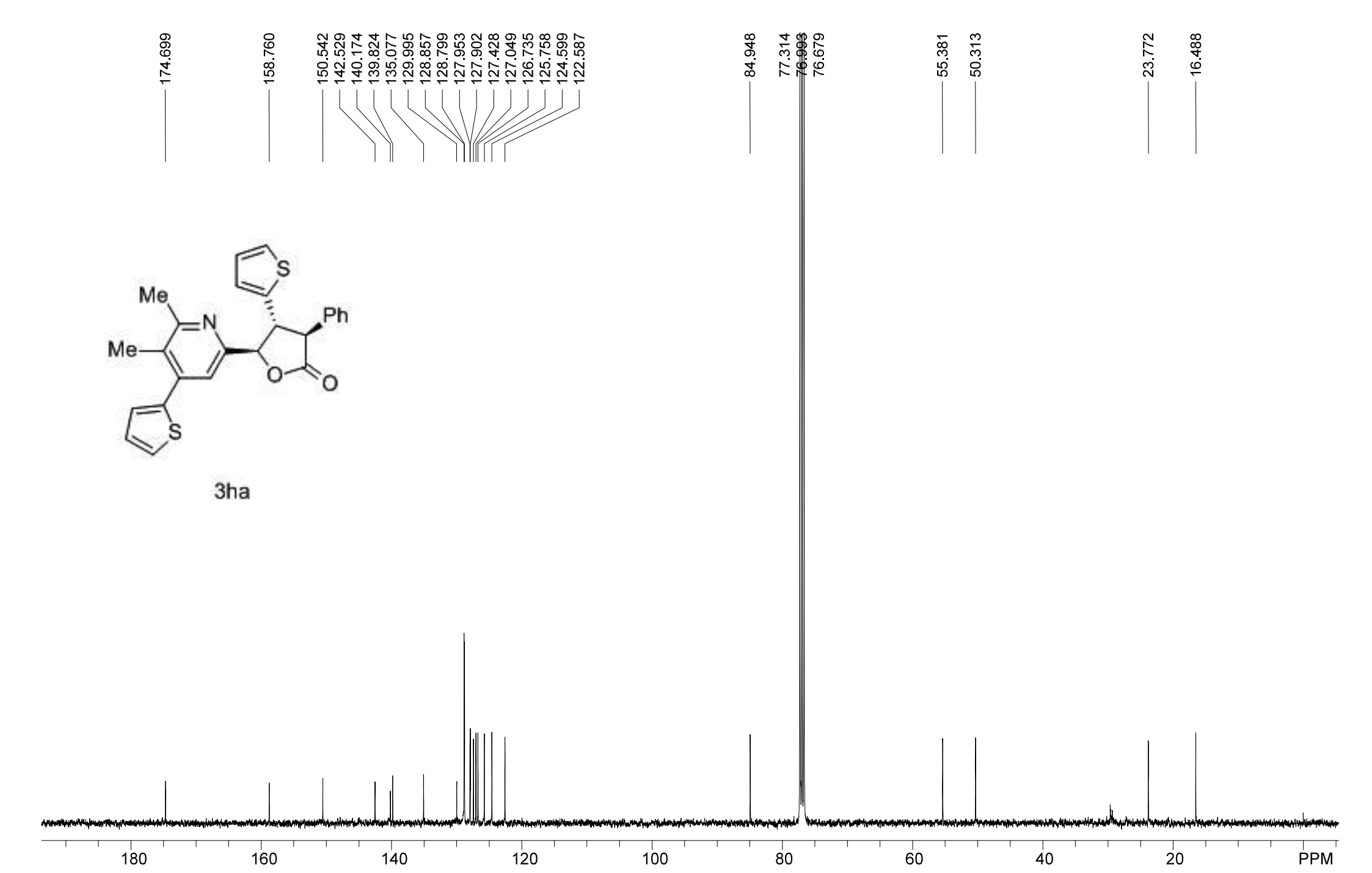
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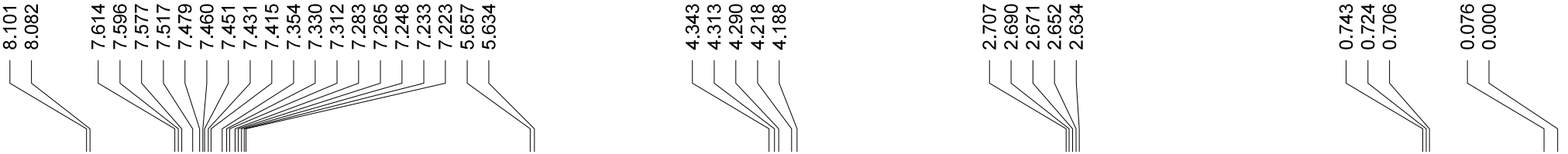
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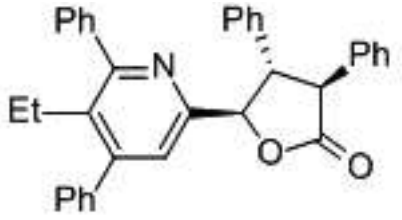
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Ph
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Et
O
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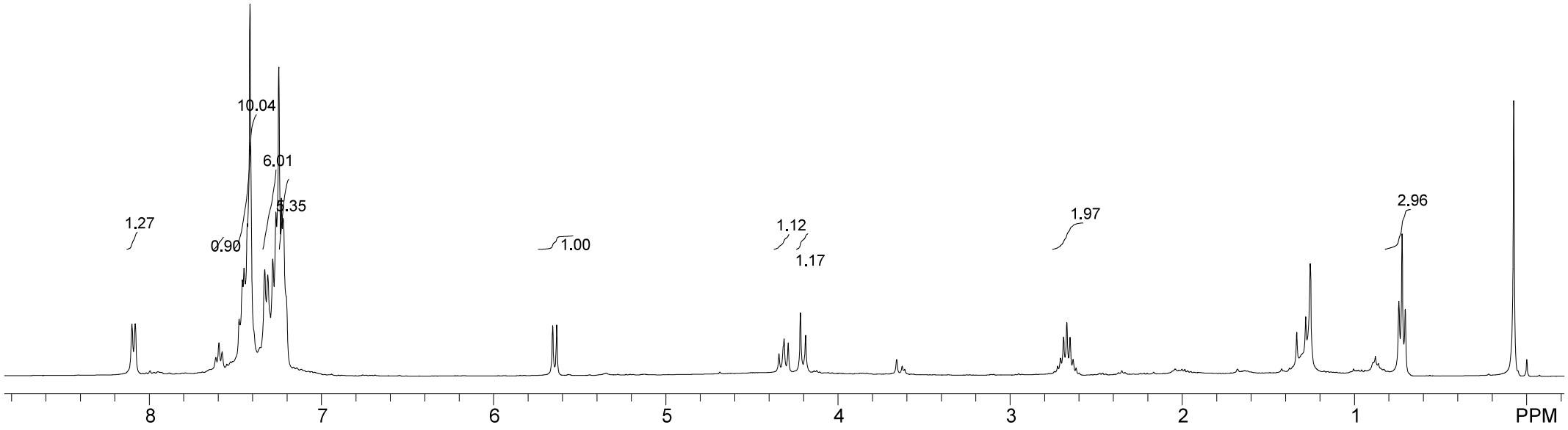
3ia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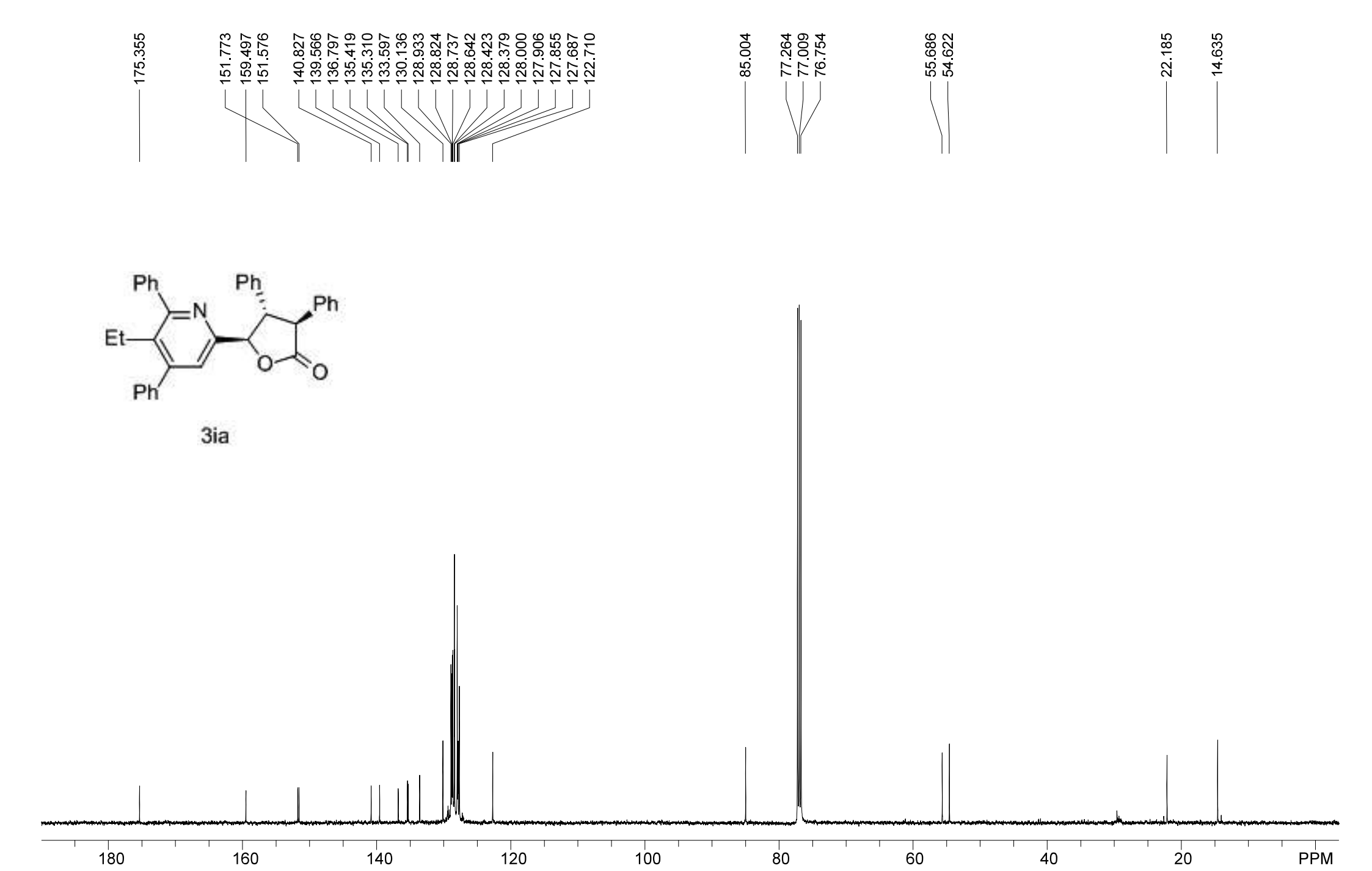
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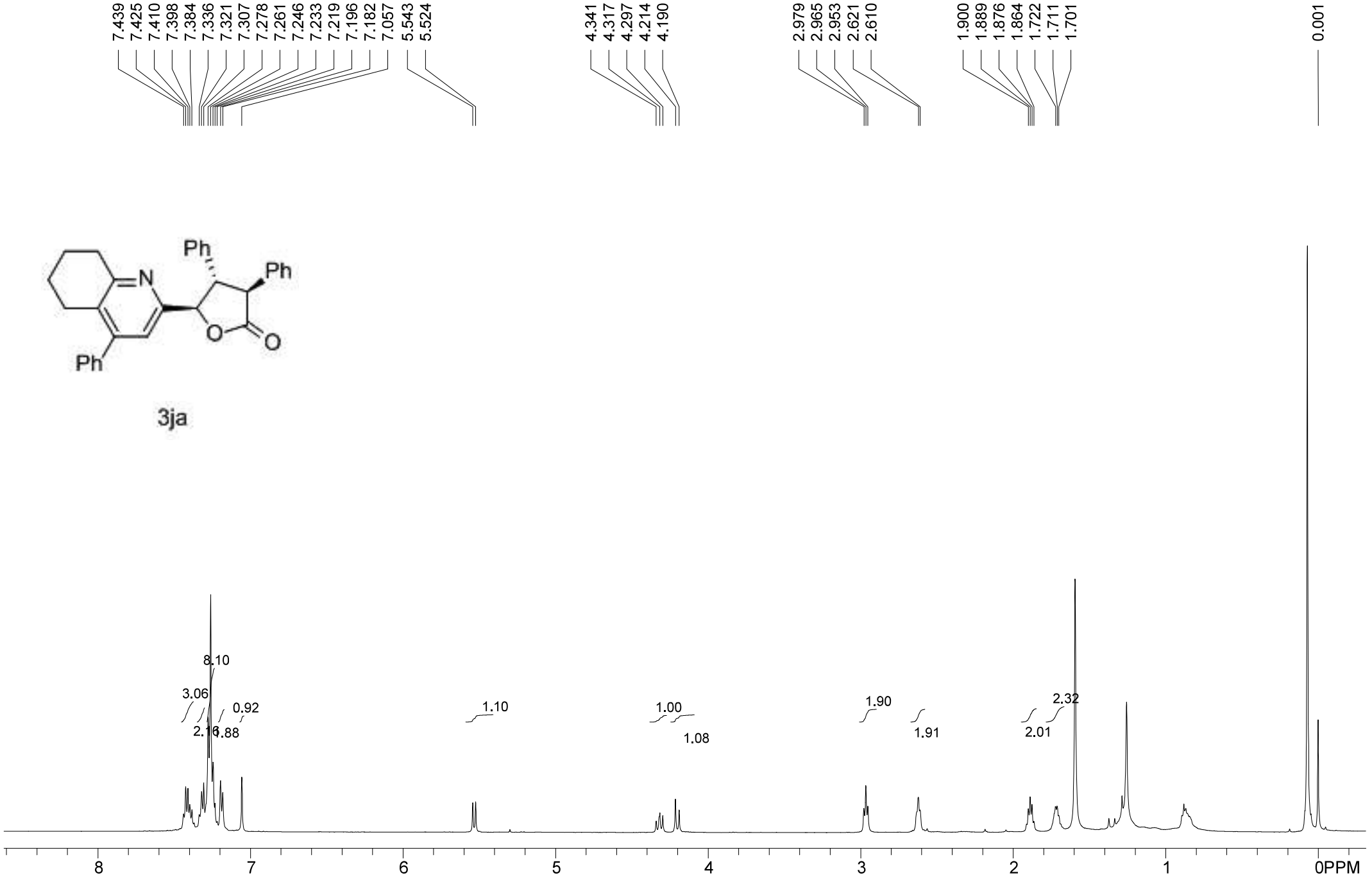
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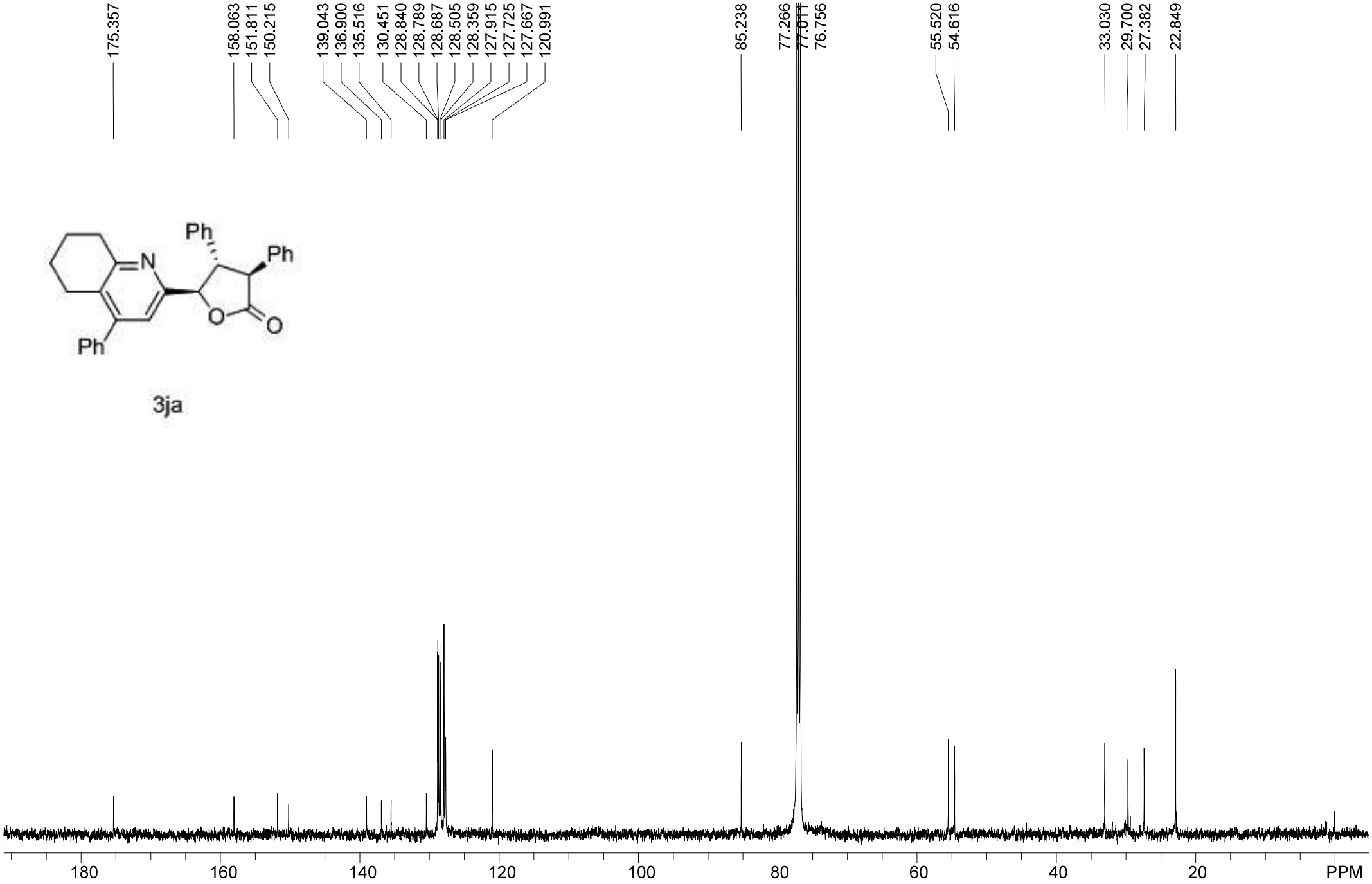
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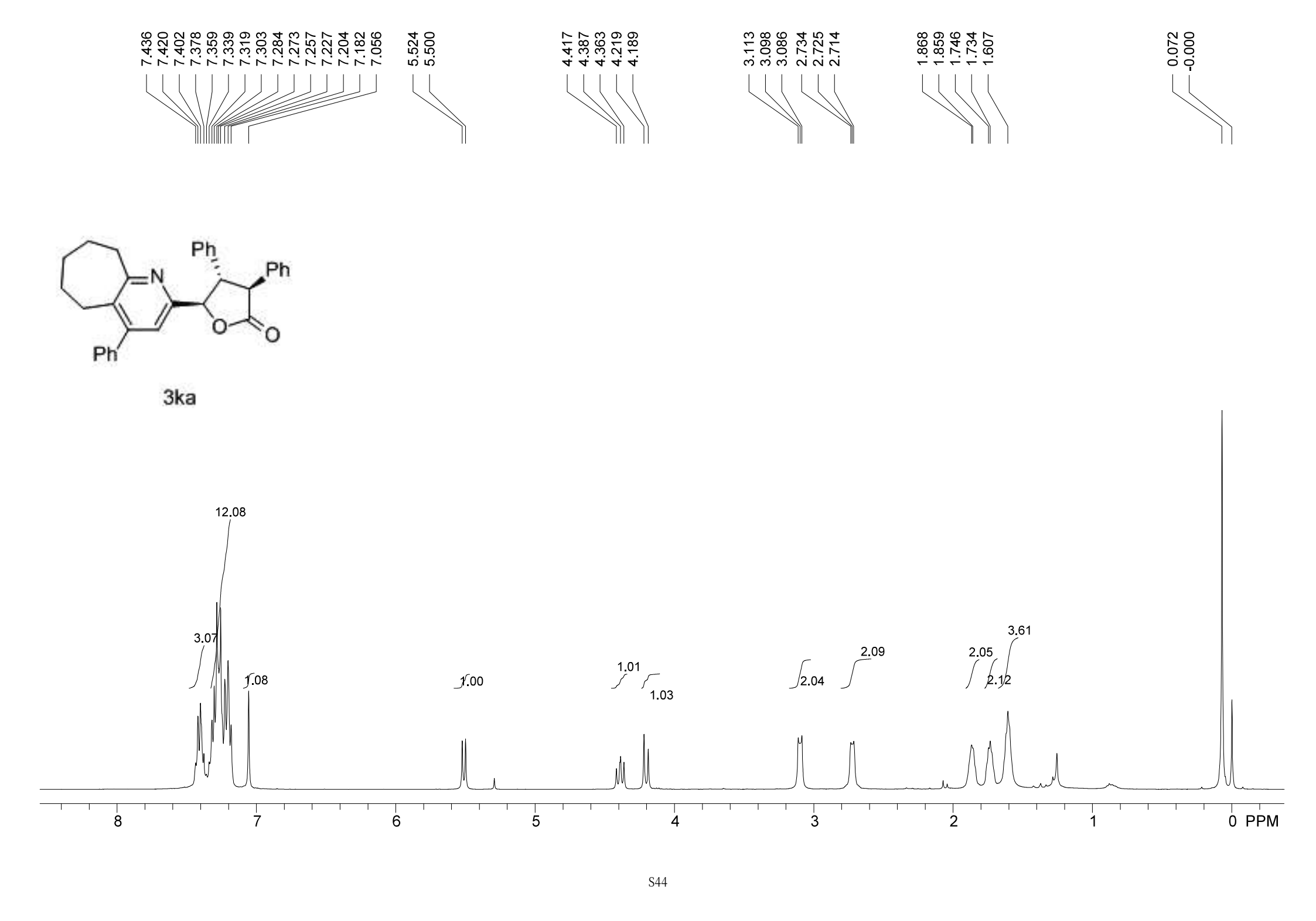
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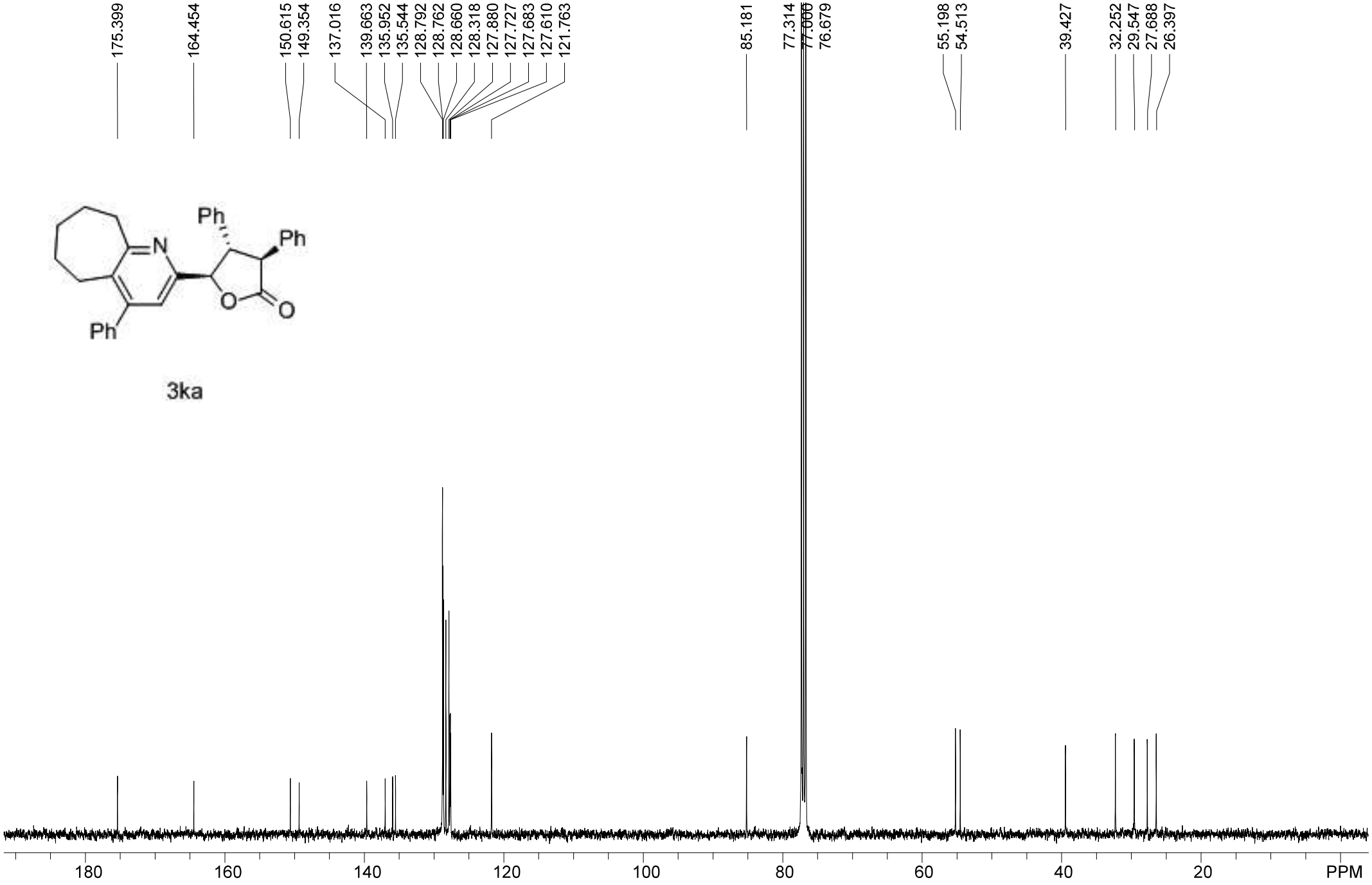
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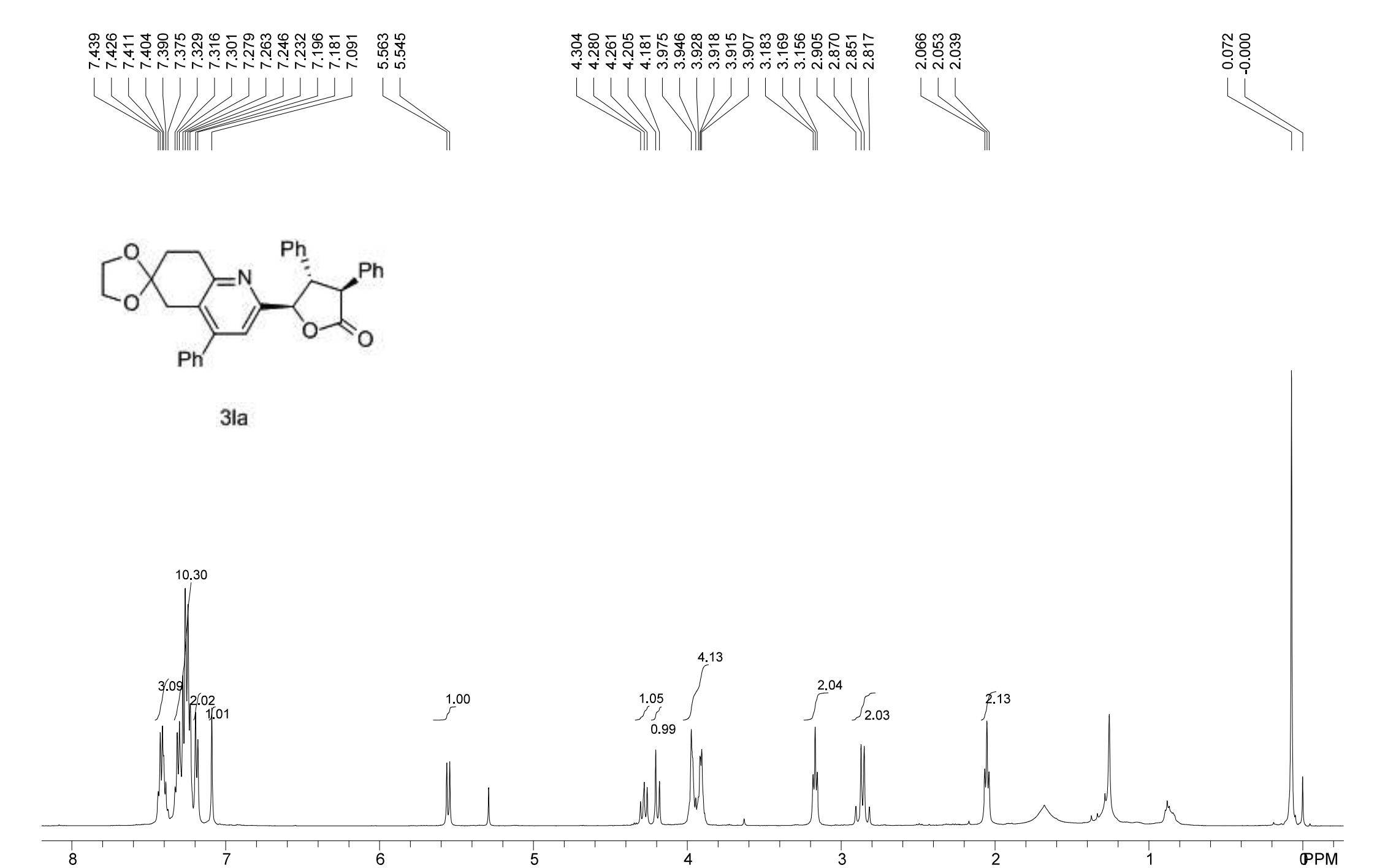
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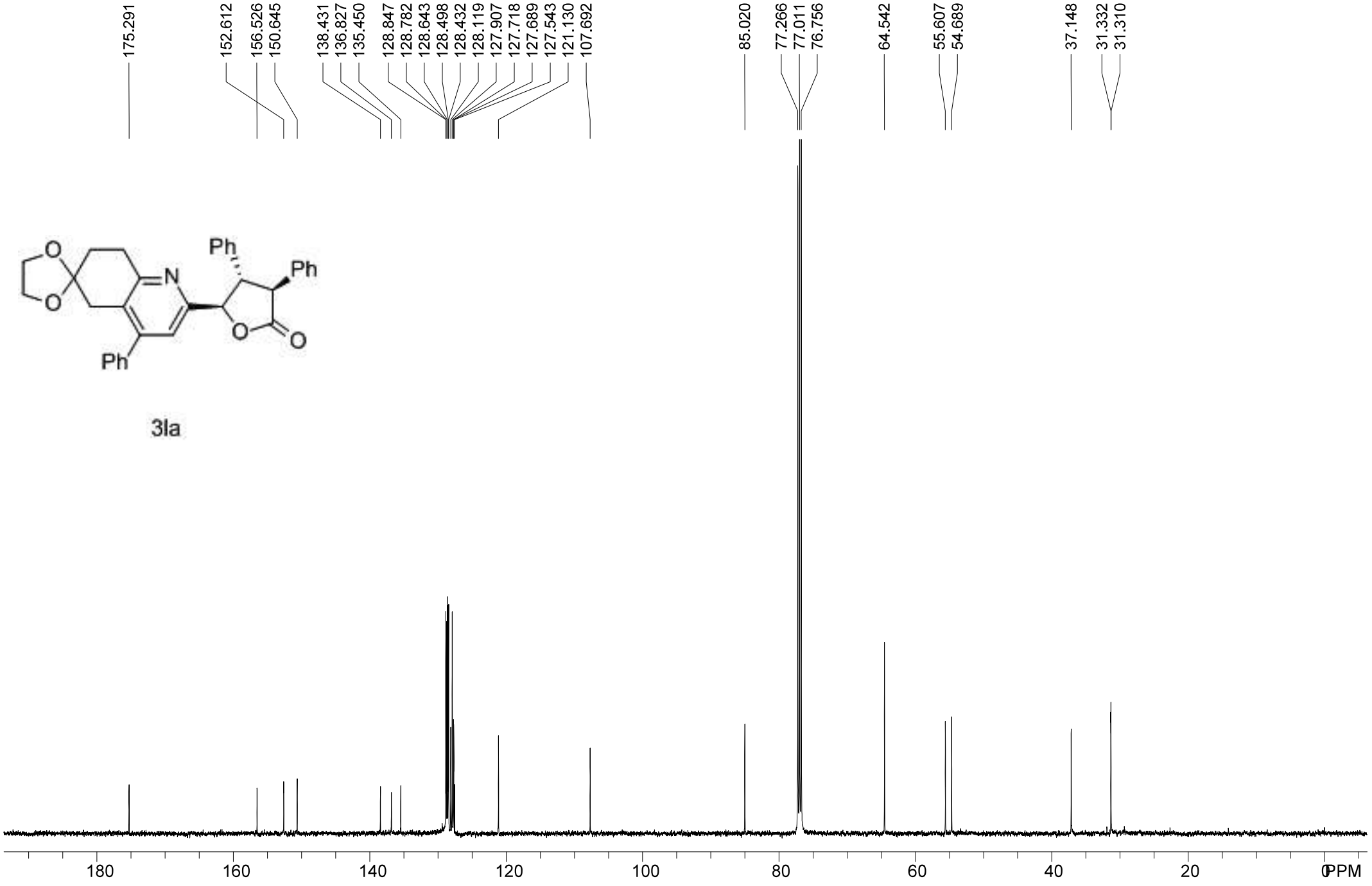
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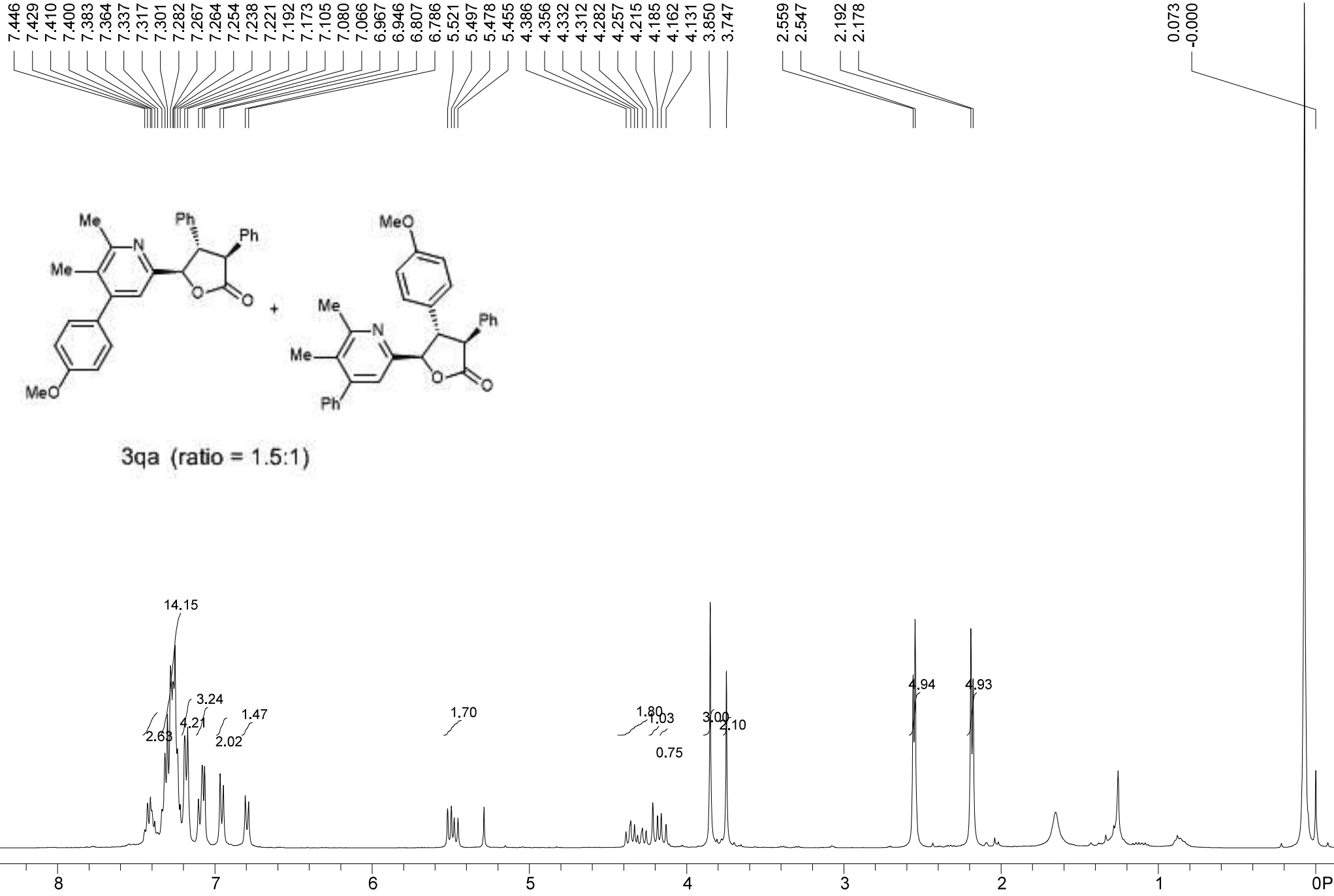
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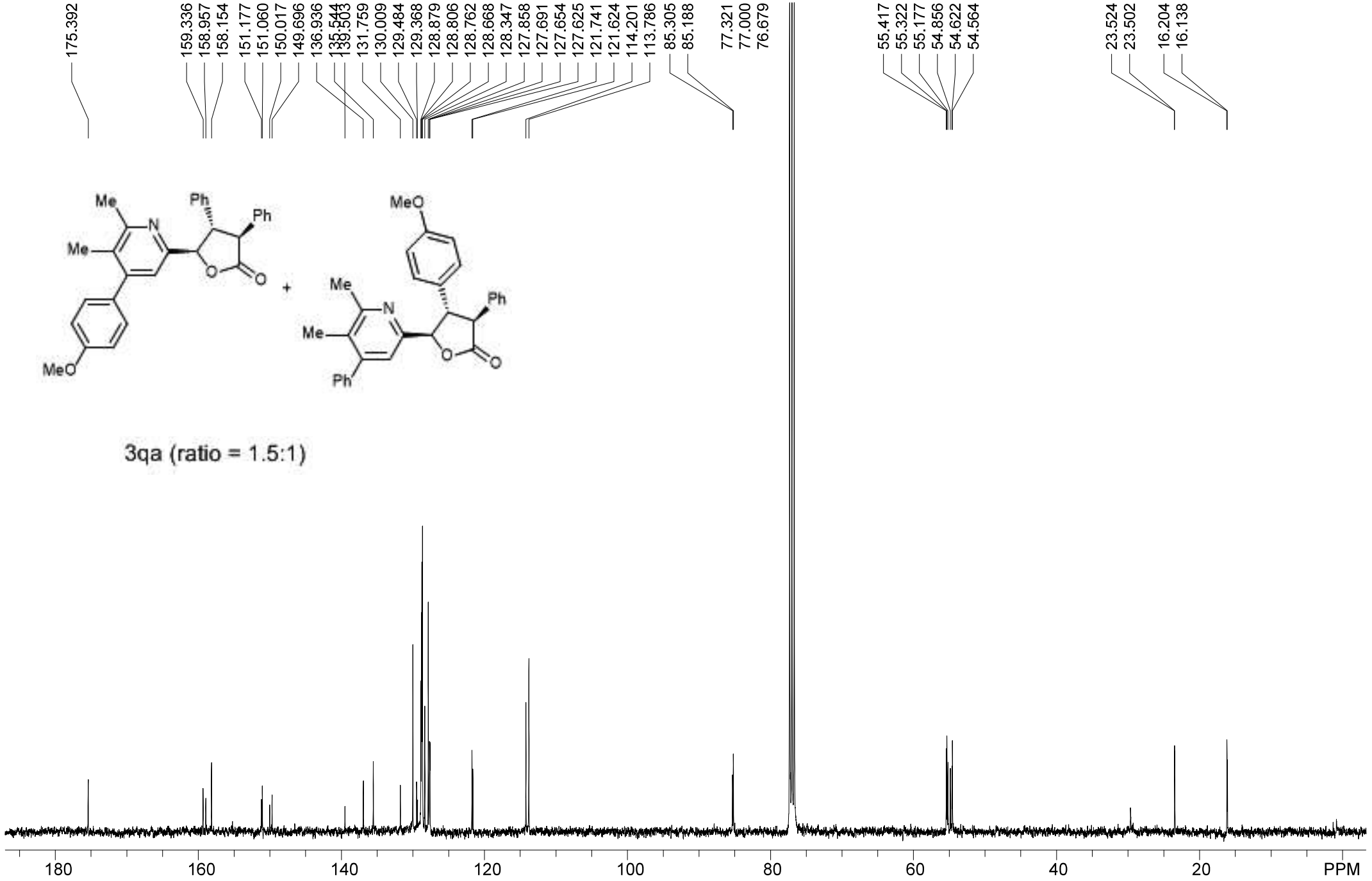
7.105
7.080
7.066
6.967
6.946
6.807
6.786
5.521
5.497
5.478
5.455
4.386
4.356
4.332
4.312
4.282
4.257
4.215
4.185
4.162
4.131
3.850
3.747
2.559
2.547
2.192
2.178
0.073
-0.000
Me
Ph
Ph
N
Me
O
O
MeO
+
MeO
Me
N
Ph
Me
O
O
Ph
3qa (ratio = 1.5:1)
14.15
3.24
4.21
2.63
2.02
1.47
1.70
1.80
1.03
0.75
3.00
2.10
4.94
4.93
8
7
6
5
4
3
2
1
0PPM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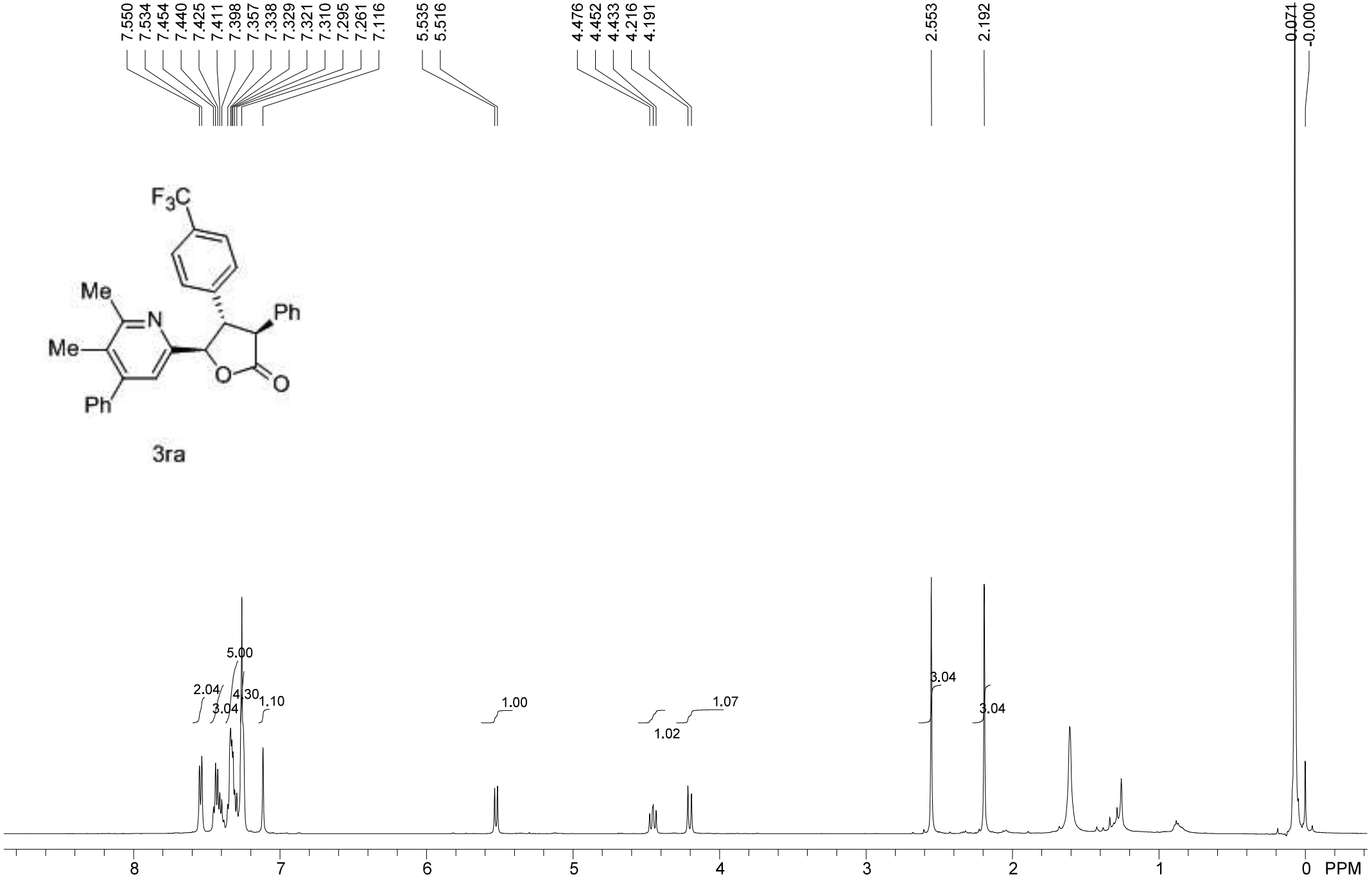
158.957
158.154
151.177
151.060
150.017
149.696
136.936
135.544
135.503
131.759
130.009
129.484
129.368
128.879
128.806
128.762
128.668
128.347
127.858
127.691
127.654
127.625
121.741
121.624
114.201
113.786
85.305
85.188
77.321
77.000
76.679
55.417
55.322
55.177
54.856
54.622
54.564
23.524
23.502
16.204
16.138
Me
Ph
Ph
Me
N
O
O
MeO
+
MeO
Me
N
Ph
Me
O
O
Ph
3qa (ratio = 1.5:1)
180
160
140
120
100
80
60
40
20
PPM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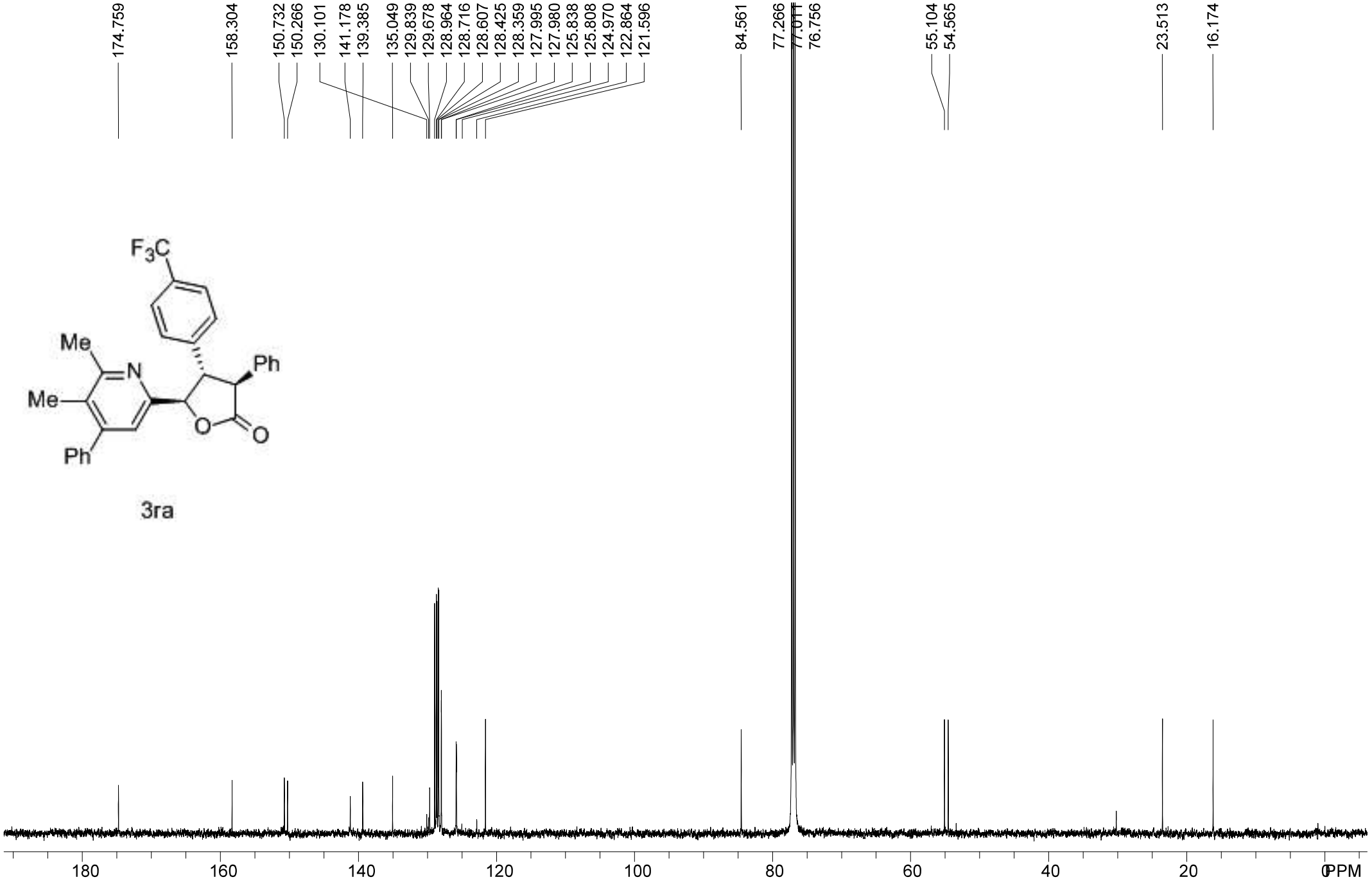
7.534
7.454
7.440
7.425
7.411
7.398
7.357
7.338
7.329
7.321
7.310
7.295
7.261
7.116
5.535
5.516
4.476
4.452
4.433
4.216
4.191
2.553
2.192
0.071
-0.000
F3C
Me
N
Ph
Me
O
O
Ph
3ra
5.00
2.04
3.04
4.30
1.10
1.00
1.02
1.07
3.04
3.04
8
7
6
5
4
3
2
1
0
PPM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158.304
150.732
150.266
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141.178
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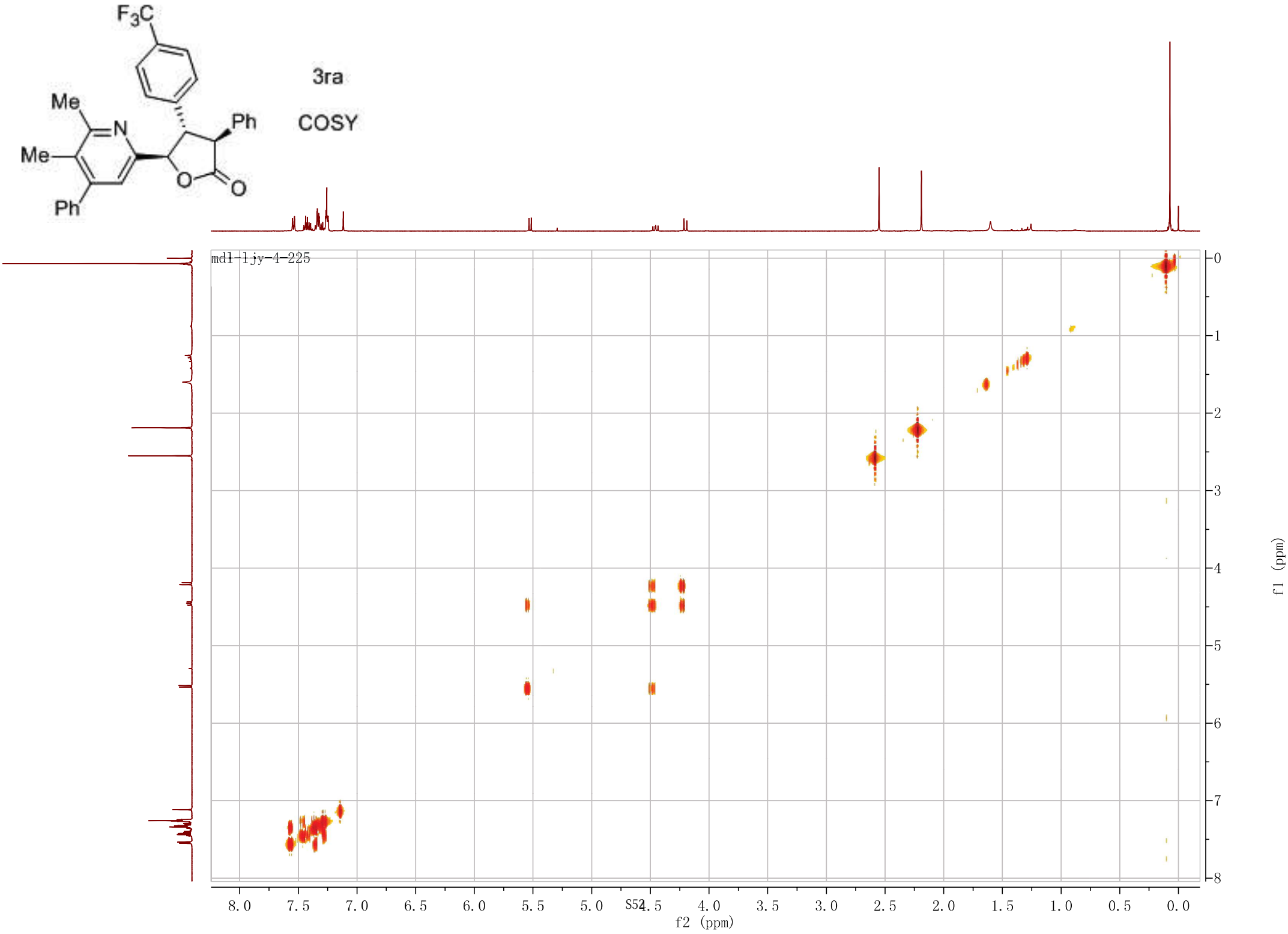
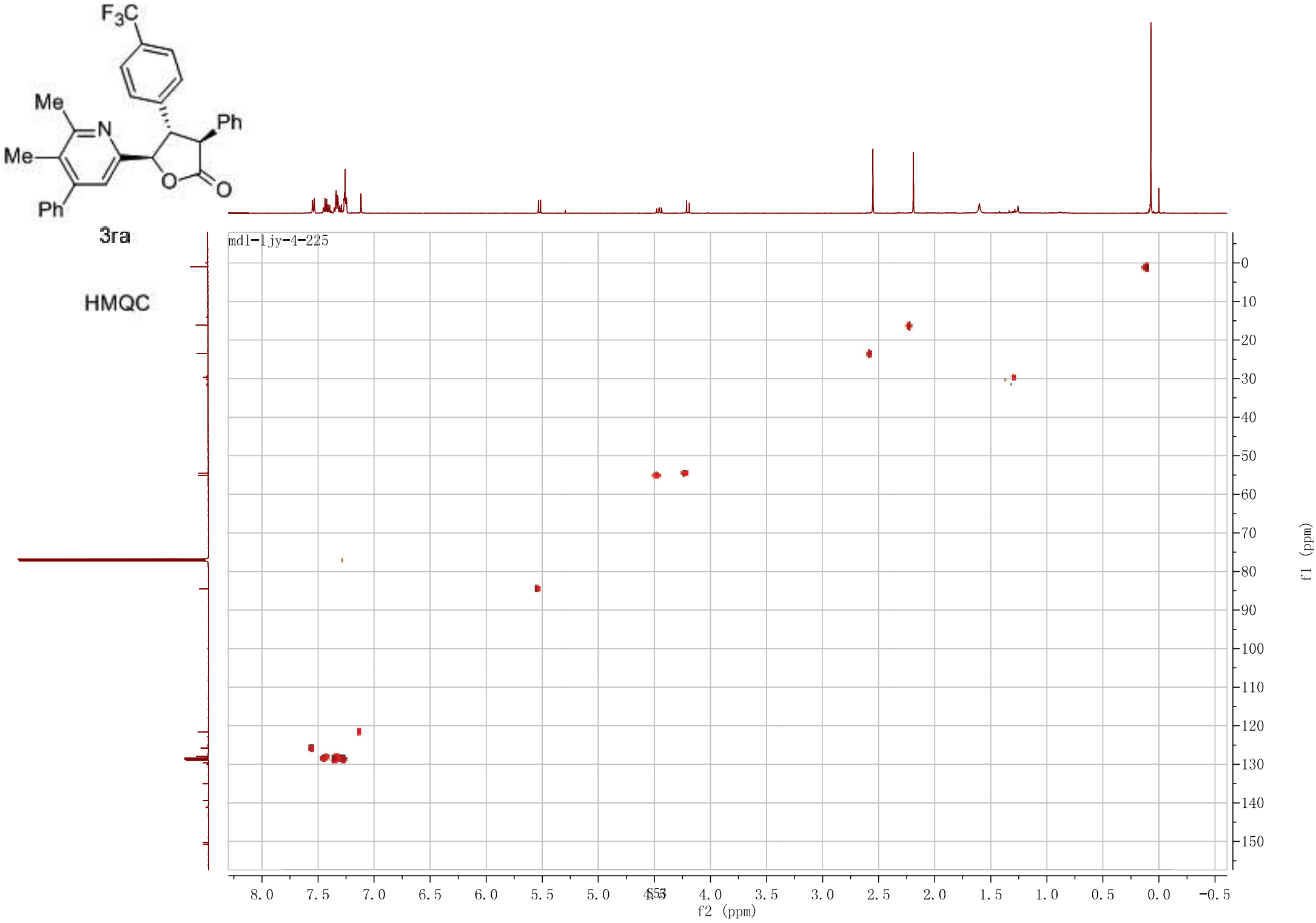
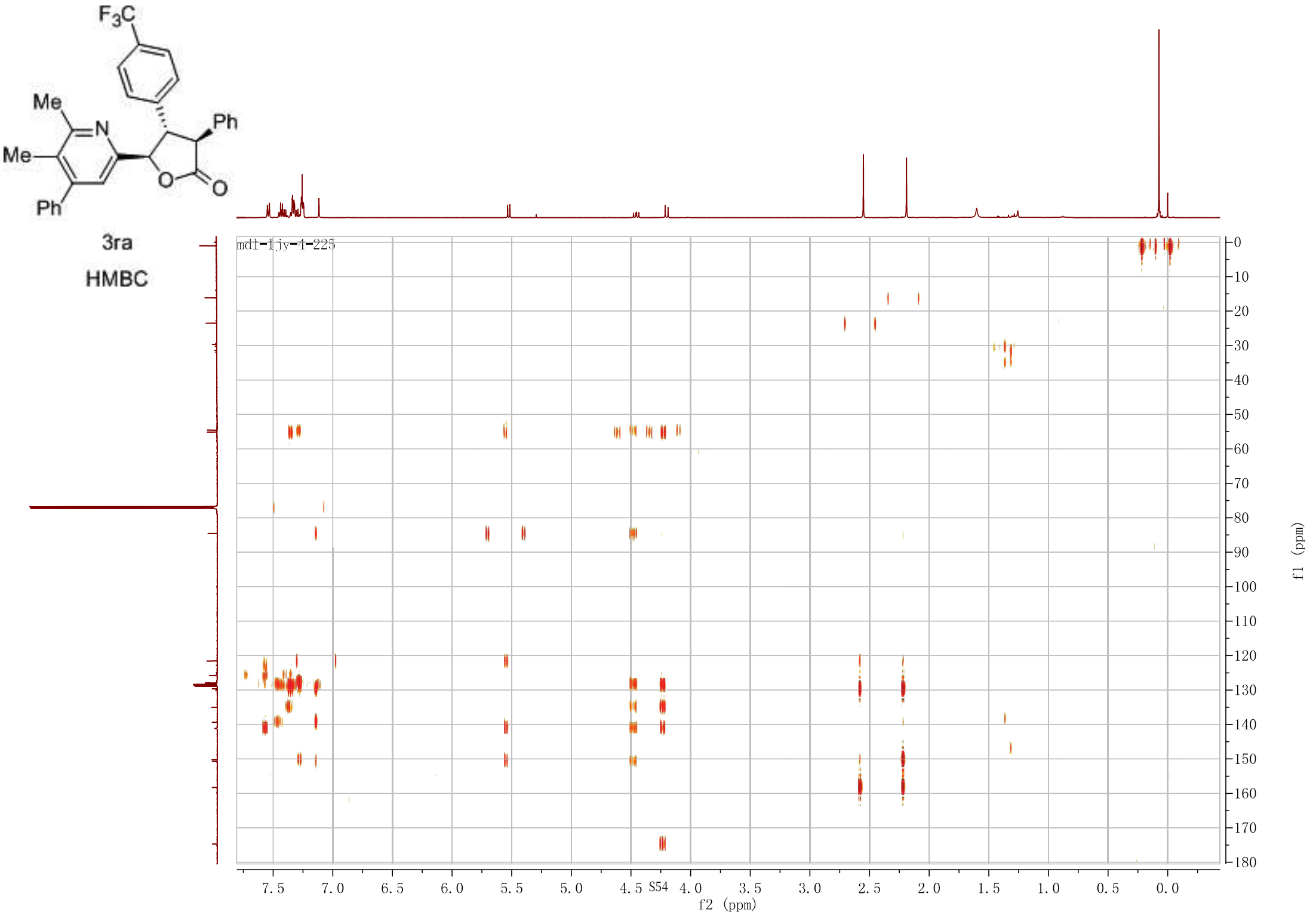
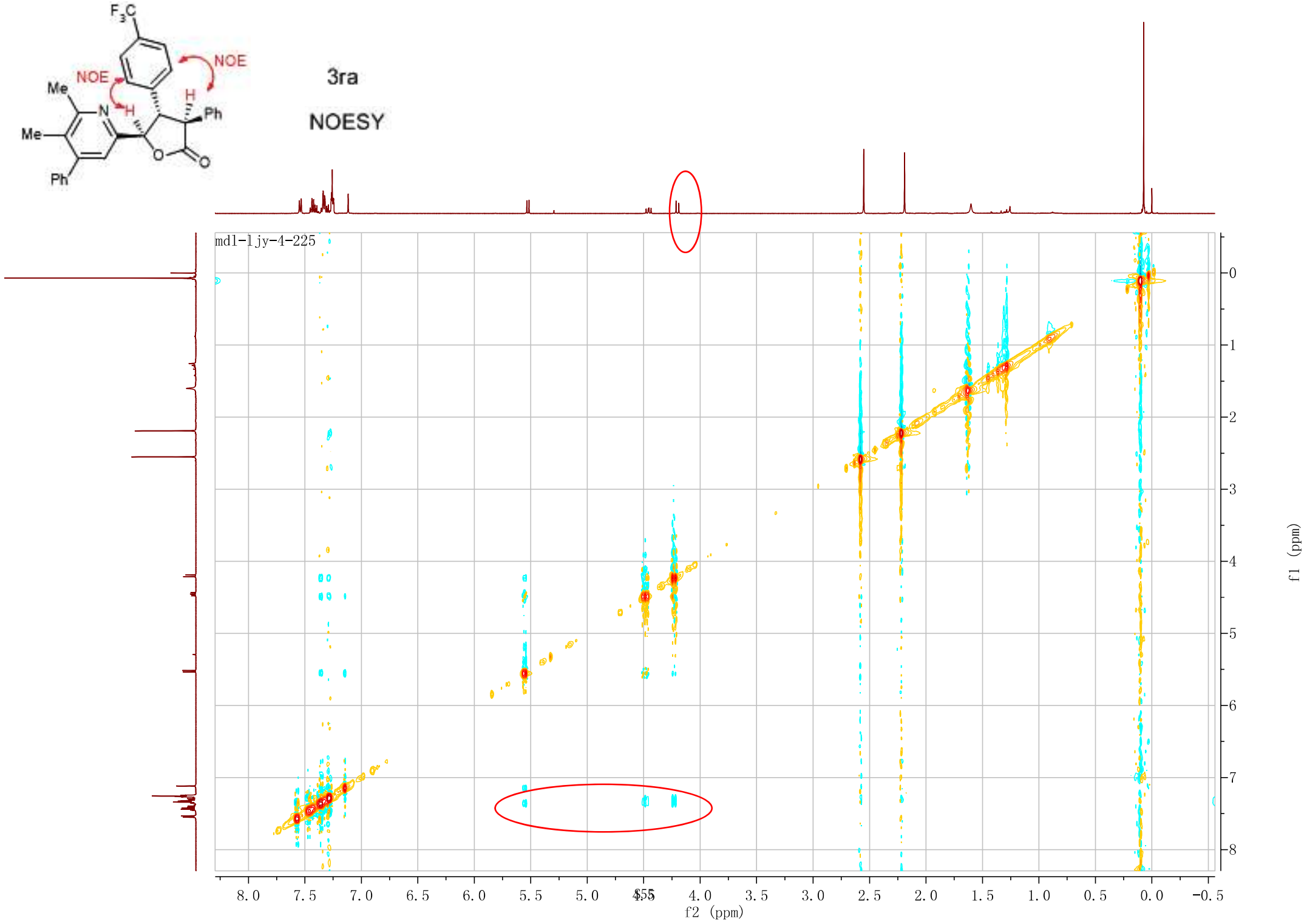
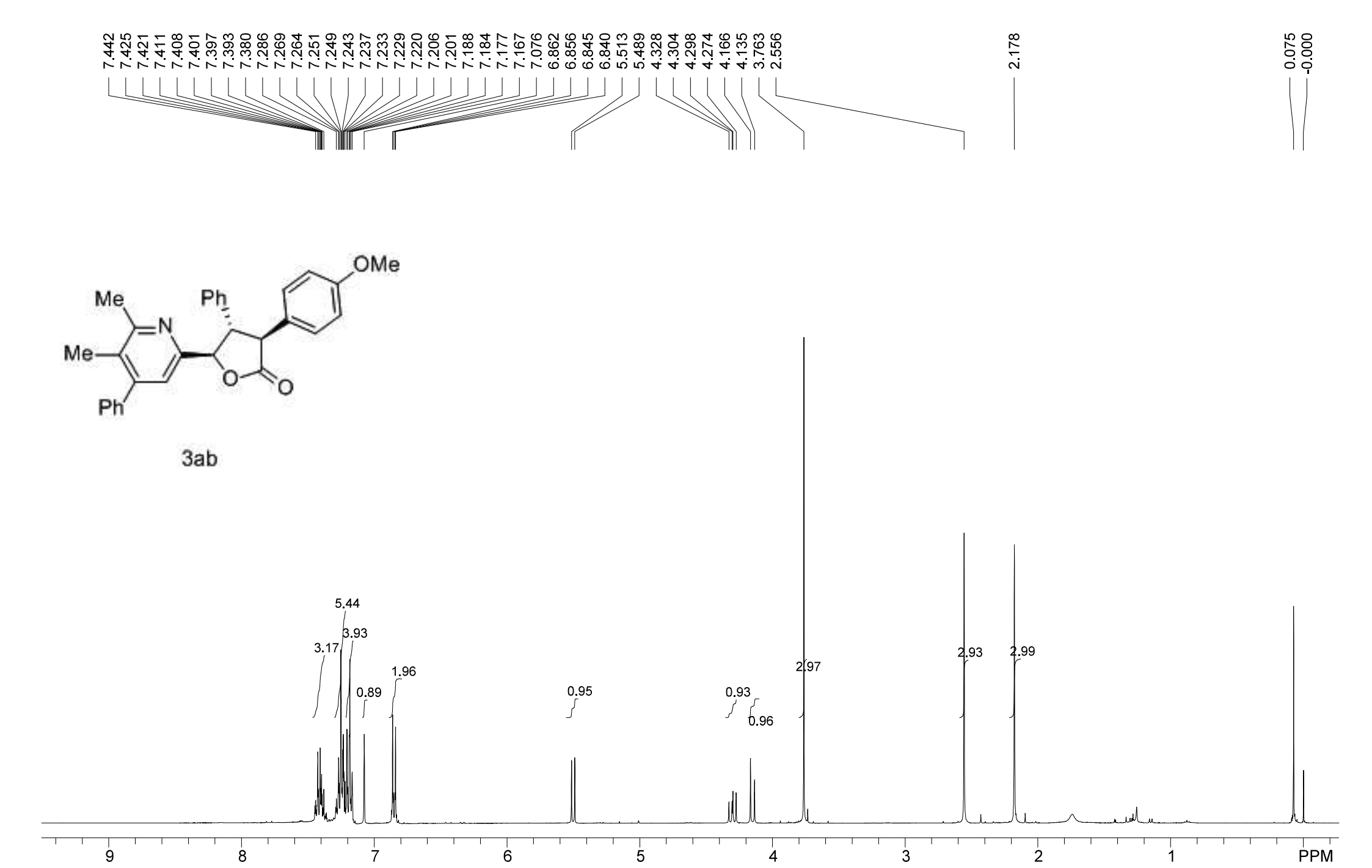
135.049
129.839
129.678
128.964
128.716
128.607
128.425
128.359
127.995
127.980
125.838
125.808
124.970
122.864
121.596
84.561
77.266
77.011
76.756
55.104
54.565
23.513
16.174
F3C
Me
N
Me
Ph
Ph
O
O
3ra
180
160
140
120
100
80
60
40
20
0
PPM

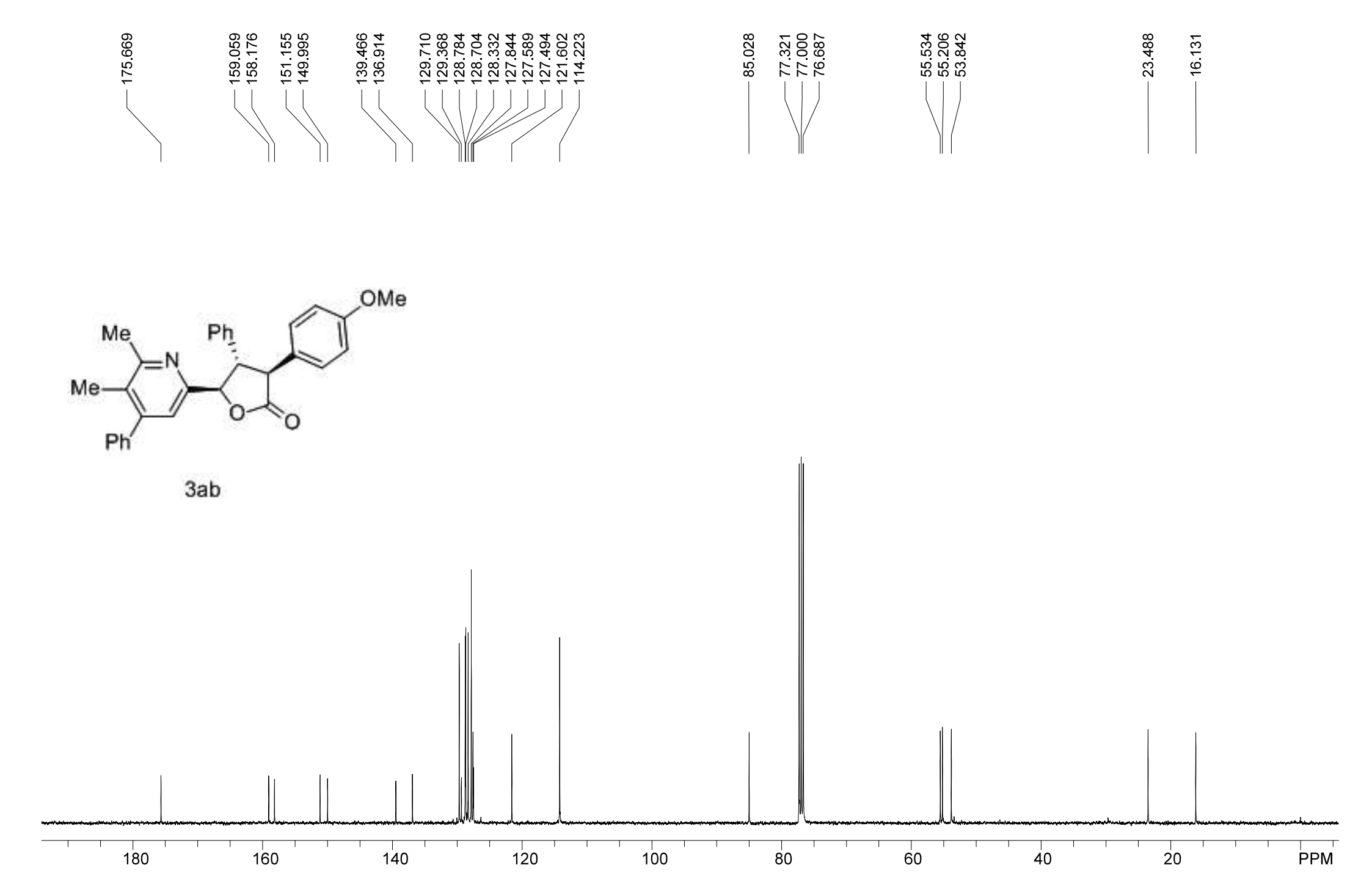

F3C
Me
N
Ph
Me
O
O
Ph
3ra
COSY
md1-ljy-4-225
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)


F3C
Me
N
Ph
Me
O
O
Ph
3ra
HMQC
mdl-ljy-4-225
f2 (ppm)
f1 (ppm)


F3C
Me
N
Ph
Me
O
O
Ph
3ra
HMBC
md1-ljy-1-225
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f2 (ppm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
f1 (ppm)


F3C
NOE
NOE
Me
N
H
H
Ph
Me
O
O
Ph
3ra
NOESY
mdl-ljy-4-225
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
f2 (ppm)
0
1
2
3
4
5
6
7
8
f1 (ppm)


7.442
7.425
7.421
7.411
7.408
7.401
7.397
7.393
7.380
7.286
7.269
7.264
7.251
7.249
7.243
7.237
7.233
7.229
7.220
7.206
7.201
7.188
7.184
7.177
7.167
7.076
6.862
6.856
6.845
6.840
5.513
5.489
4.328
4.304
4.298
4.274
4.166
4.135
3.763
2.556
2.178
0.075
-0.000
OMe
Me
Ph
N
Me
O
O
Ph
3ab
5.44
3.93
3.17
1.96
0.89
0.95
0.93
0.96
2.97
2.93
2.99
9
8
7
6
5
4
3
2
1
PPM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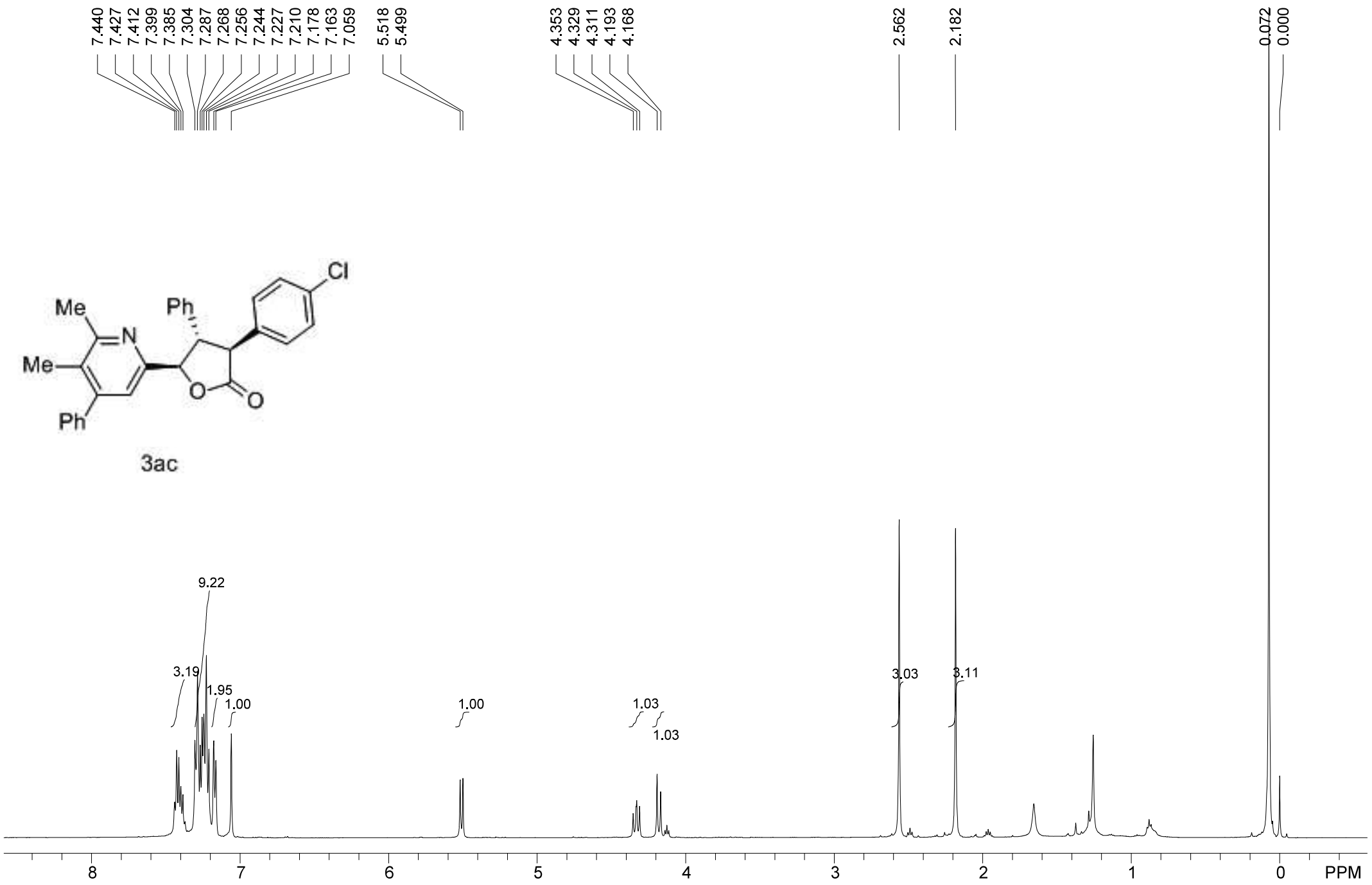
158.176
151.155
149.995
139.466
136.914
129.710
129.368
128.784
128.704
128.332
127.844
127.589
127.494
121.602
114.223
85.028
77.321
77.000
76.687
55.534
55.206
53.842
23.488
16.131
OMe
Me
Ph
N
Me
O
O
Ph
3ab
180
160
140
120
100
80
60
40
20
PPM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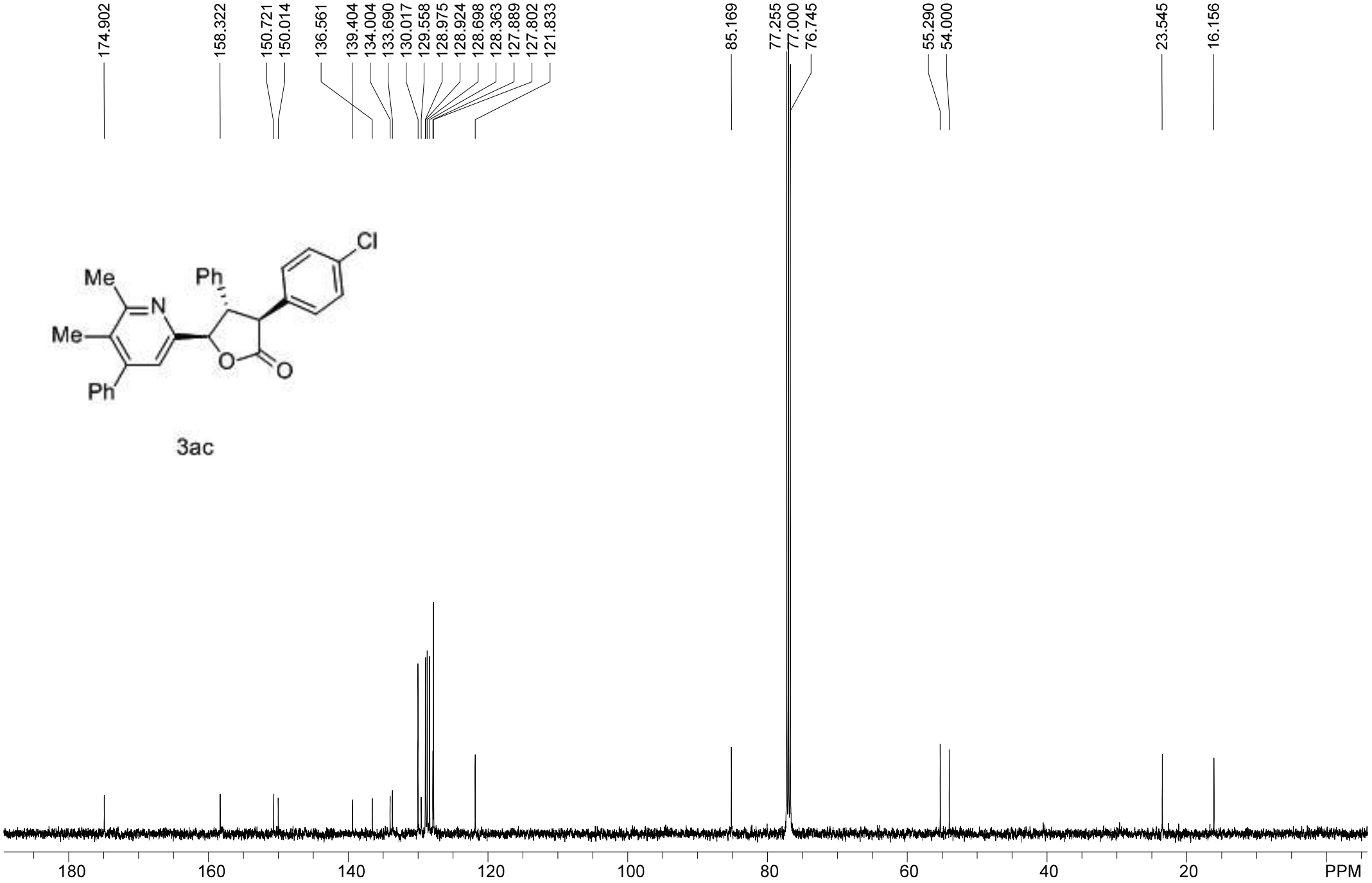
7.427
7.412
7.399
7.385
7.304
7.287
7.268
7.256
7.244
7.227
7.210
7.178
7.163
7.059
5.518
5.499
4.353
4.329
4.311
4.193
4.168
2.562
2.182
0.072
0.000
Me
Ph
N
Cl
Me
O
O
Ph
3ac
9.22
3.19
1.95
1.00
1.00
1.03
1.03
3.03
3.11
8
7
6
5
4
3
2
1
0
PPM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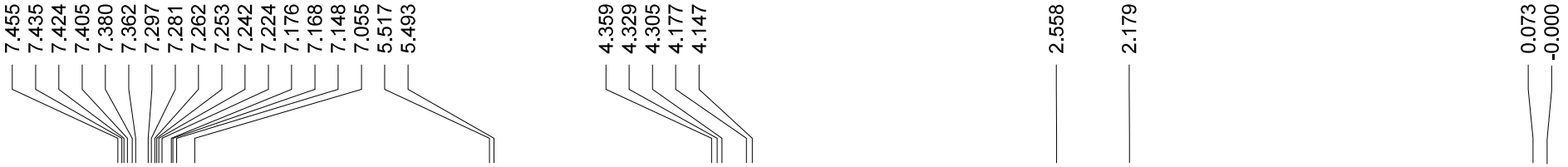
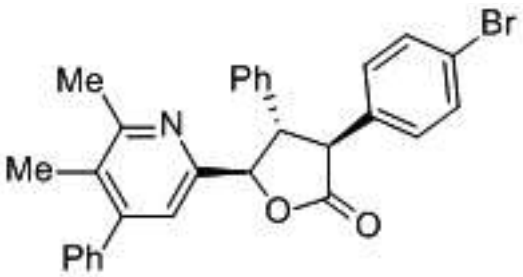
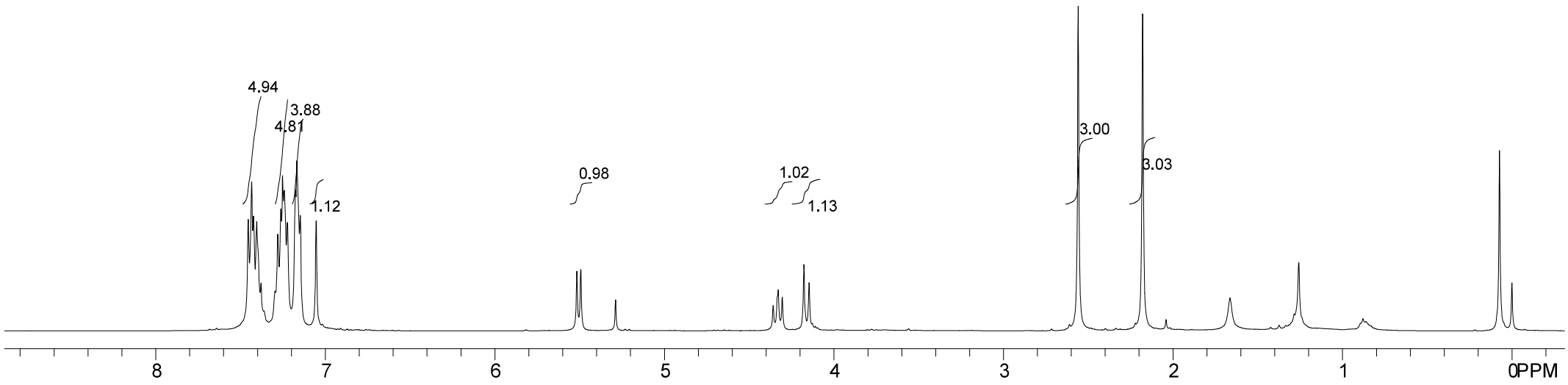
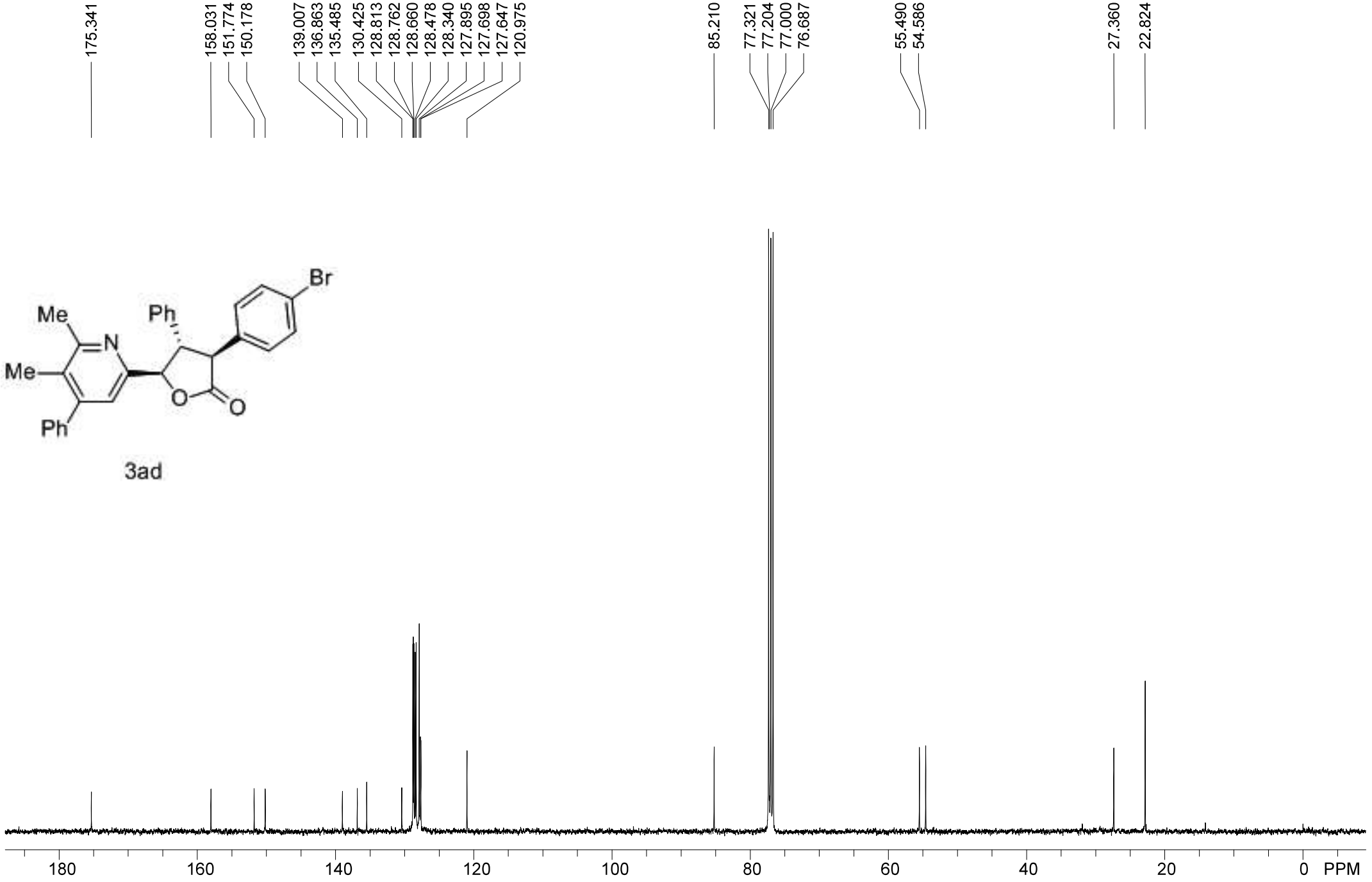
158.322
150.721
150.014
136.561
139.404
134.004
133.690
130.017
129.558
128.975
128.924
128.698
128.363
127.889
127.802
121.833
85.169
77.255
77.000
76.745
55.290
54.000
23.545
16.156
Cl
Me
Ph
N
Me
O
O
Ph
3ac
180
160
140
120
100
80
60
40
20
PPM


7.455
7.435
7.424
7.405
7.380
7.362
7.297
7.281
7.262
7.253
7.242
7.224
7.176
7.168
7.148
7.055
5.517
5.493
4.359
4.329
4.305
4.177
4.147
2.558
2.179
0.073
-0.000


Br
Me
Ph
N
Me
O
O
Ph

3ad


4.94
3.88
4.81
1.12
0.98
1.02
1.13
3.00
3.03
8
7
6
5
4
3
2
1
0PPM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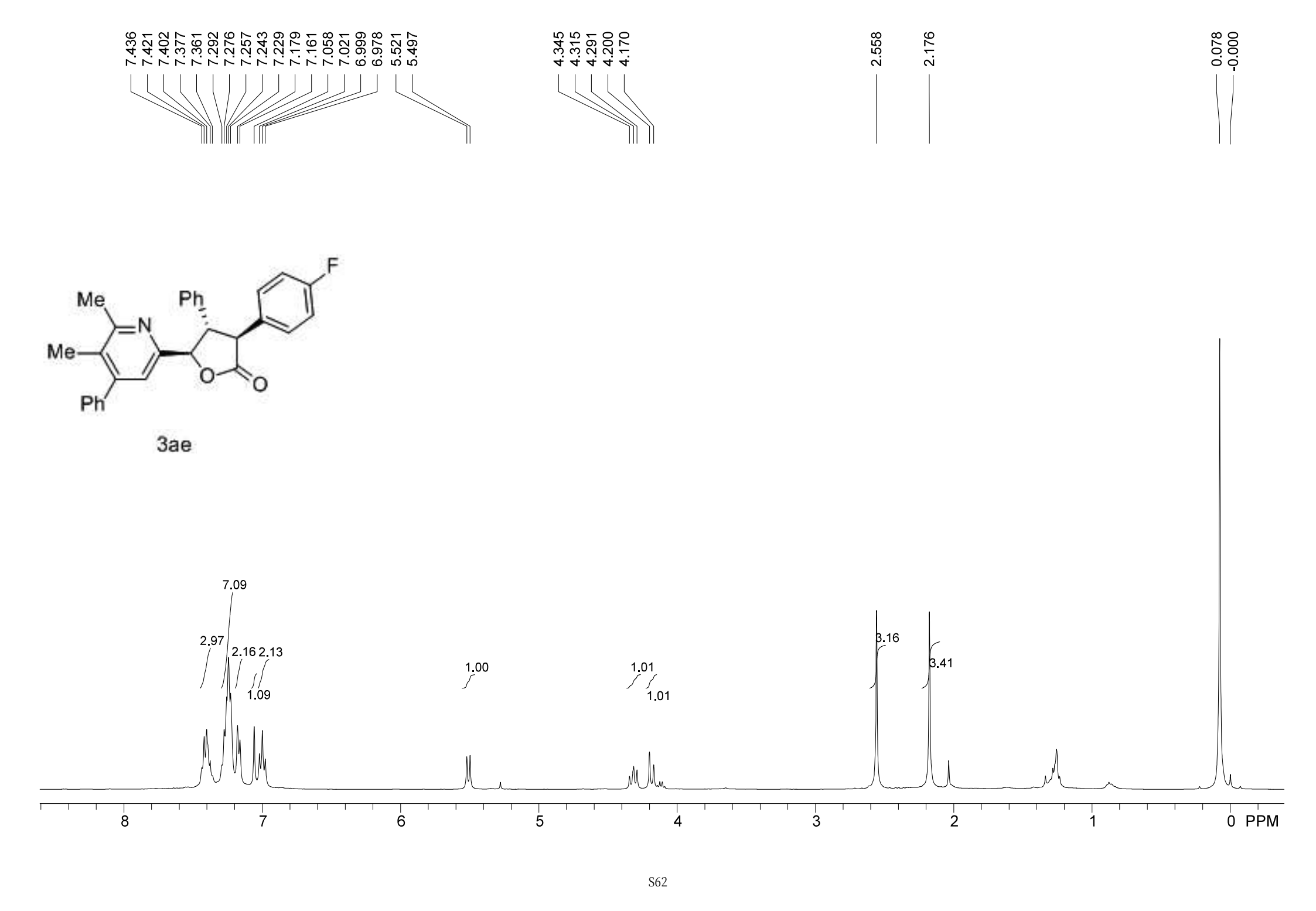
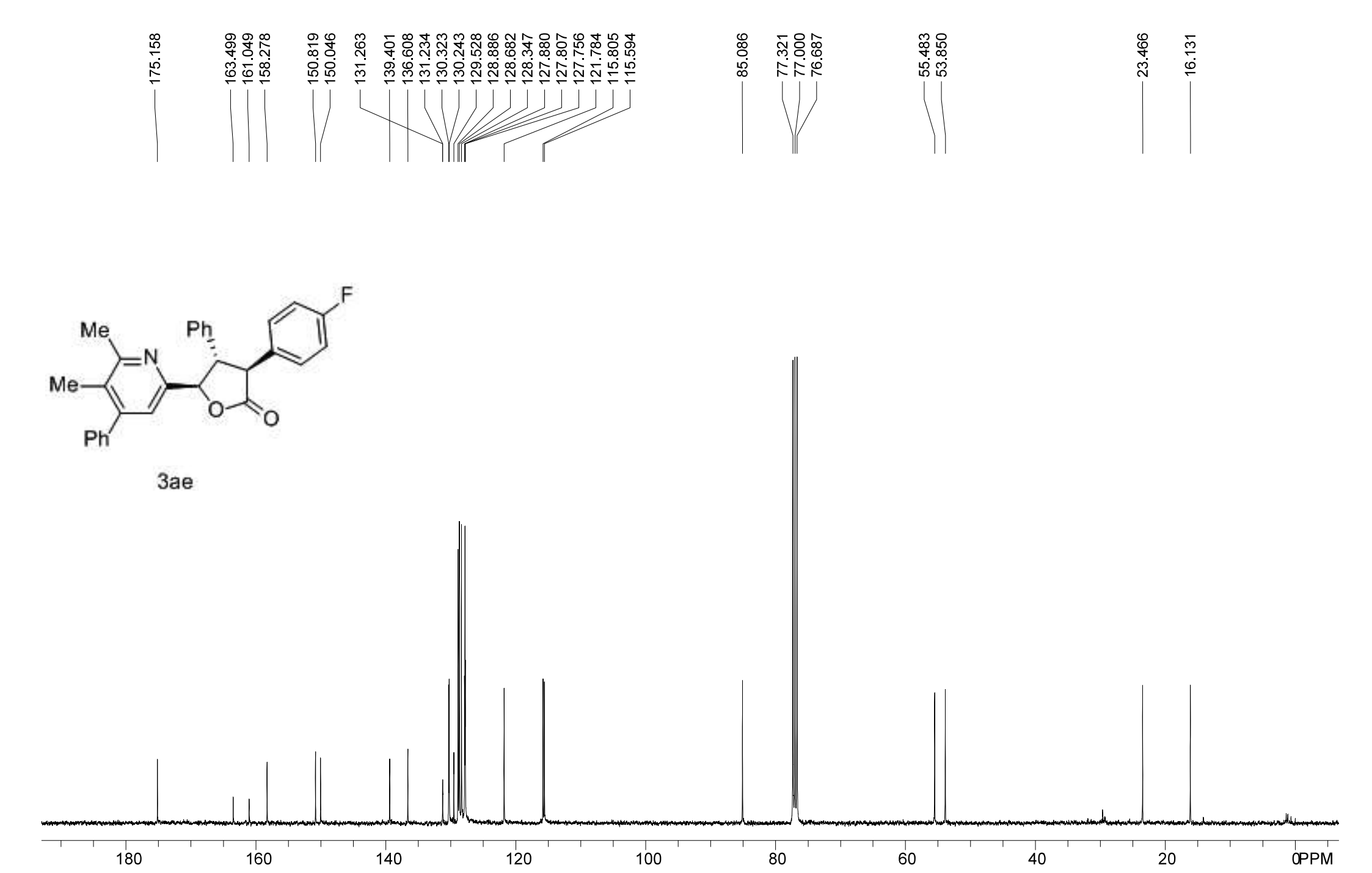
150.178
139.007
136.863
135.485
130.425
128.813
128.762
128.660
128.478
128.340
127.895
127.698
127.647
120.975
85.210
77.321
77.204
77.000
76.687
55.490
54.586
27.360
22.824
Br
Me
Ph
N
Me
O
O
Ph
3ad
180
160
140
120
100
80
60
40
20
0
PPM


7.436
7.421
7.402
7.377
7.361
7.292
7.276
7.257
7.243
7.229
7.179
7.161
7.058
7.021
6.999
6.978
5.521
5.497
4.345
4.315
4.291
4.200
4.170
2.558
2.176
0.078
-0.000
Me
Ph
N
Me
O
O
F
Ph
3ae
7.09
2.97
2.16
2.13
1.09
1.00
1.01
1.01
3.16
3.41
8
7
6
5
4
3
2
1
0 PPM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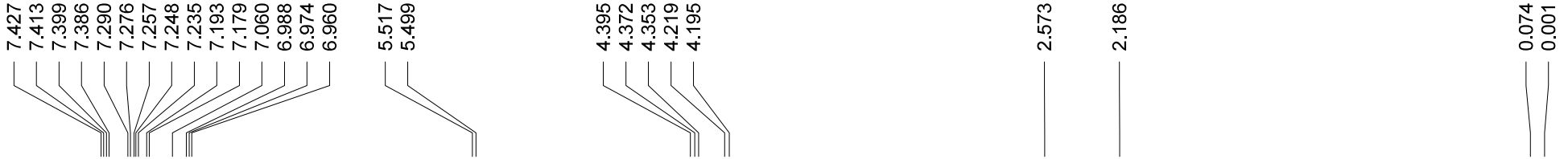
161.049
158.278
150.819
150.046
131.263
139.401
136.608
131.234
130.323
130.243
129.528
128.886
128.682
128.347
127.880
127.807
127.756
121.784
115.805
115.594
85.086
77.321
77.000
76.687
55.483
53.850
23.466
16.131
Me
Ph
N
Me
O
O
Ph
F
3ae
180
160
140
120
100
80
60
40
20
0
PPM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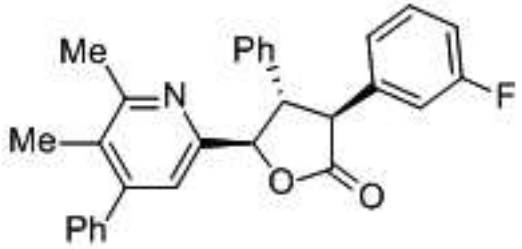
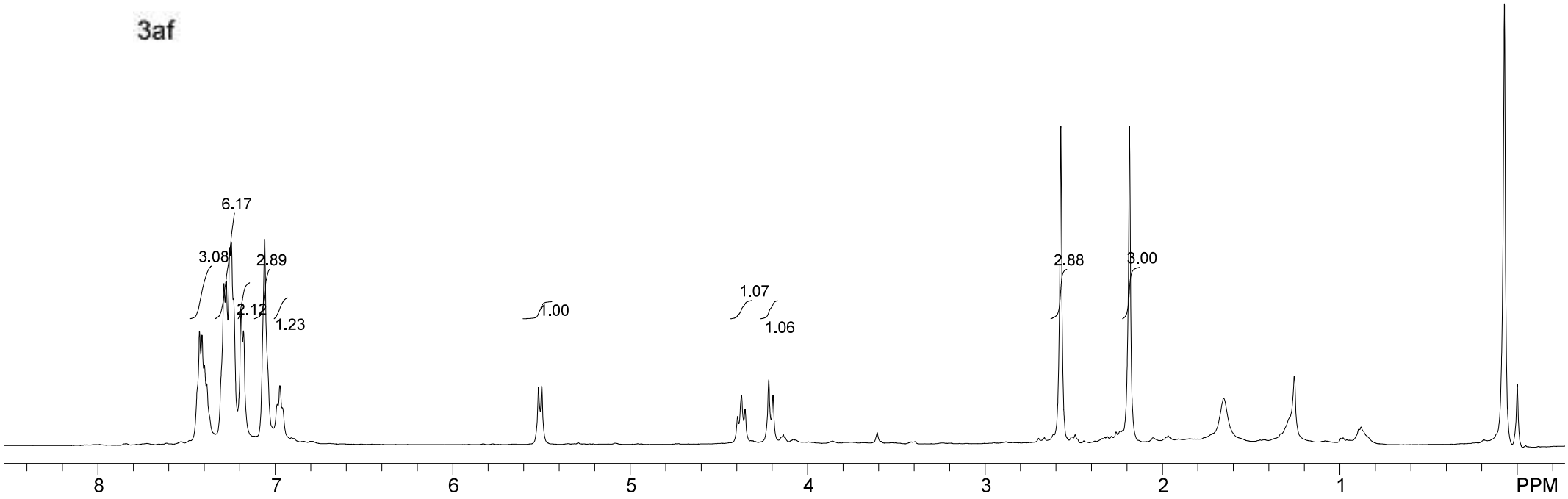
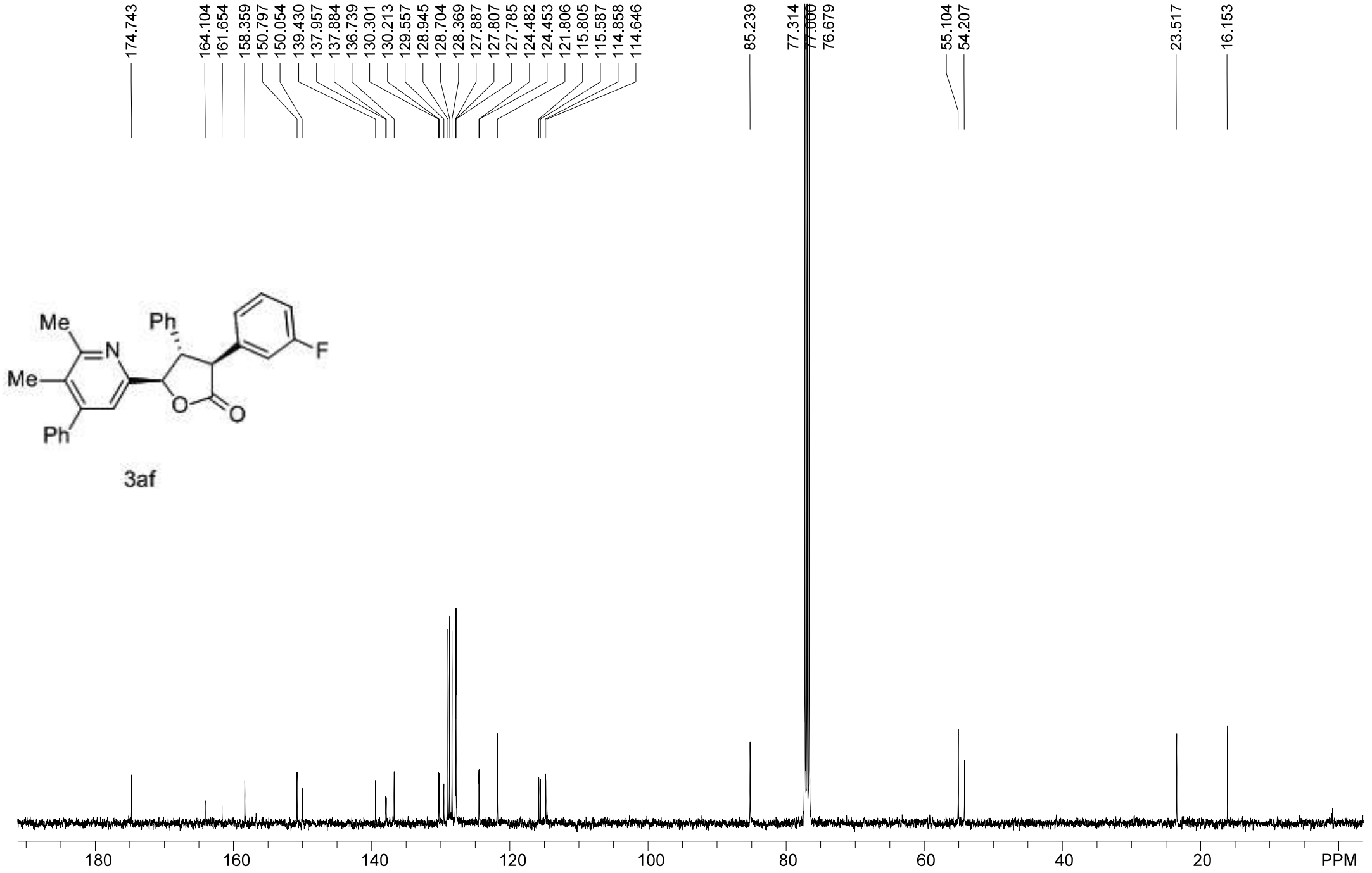
7.413
7.399
7.386
7.290
7.276
7.257
7.248
7.235
7.193
7.179
7.060
6.988
6.974
6.960
5.517
5.499
4.395
4.372
4.353
4.219
4.195
2.573
2.186
0.074
0.001


Me
Ph
N
F
Me
O
O
Ph

3af


6.17
3.08
2.89
2.12
1.23
1.00
1.07
1.06
2.88
3.00
8
7
6
5
4
3
2
1
PPM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161.654
158.359
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150.054
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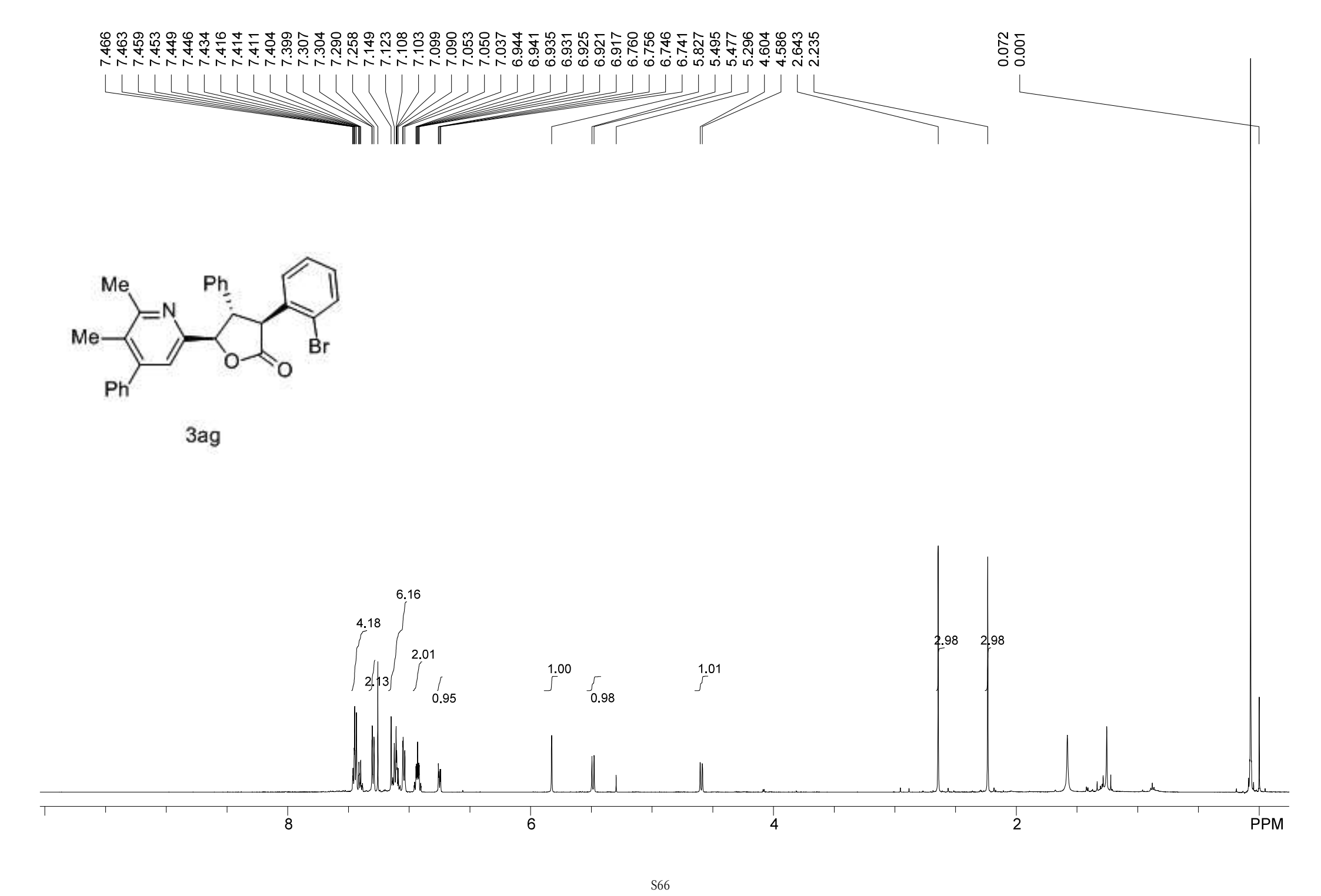
137.957
137.884
136.739
130.301
130.213
129.557
128.945
128.704
128.369
127.887
127.807
127.785
124.482
124.453
121.806
115.805
115.587
114.858
114.646
85.239
77.314
77.000
76.679
55.104
54.207
23.517
16.153
Me
Ph
N
F
Me
O
O
Ph
3af
180
160
140
120
100
80
60
40
20
PPM


7.466
7.463
7.459
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7.449
7.446
7.434
7.416
7.414
7.411
7.404
7.399
7.307
7.304
7.290
7.258
7.149
7.123
7.108
7.103
7.099
7.090
7.053
7.050
7.037
6.944
6.941
6.935
6.931
6.925
6.921
6.917
6.760
6.756
6.746
6.741
5.827
5.495
5.477
5.296
4.604
4.586
2.643
2.235
0.072
0.001
Me
Ph
N
Me
Br
O
O
Ph
3ag
6.16
4.18
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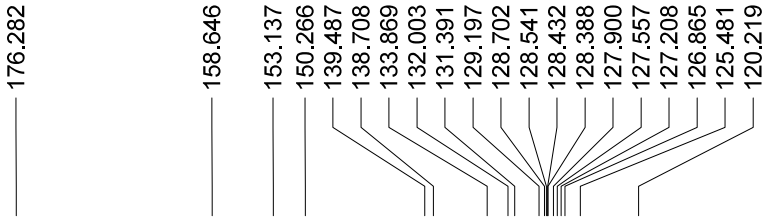
2.13
0.95
1.00
0.98
1.01
2.98
2.98
8
6
4
2
PPM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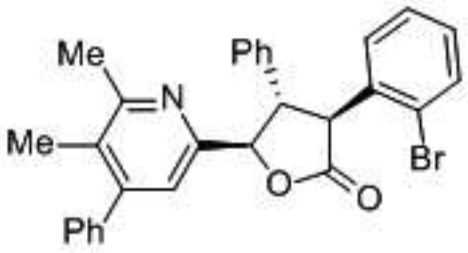
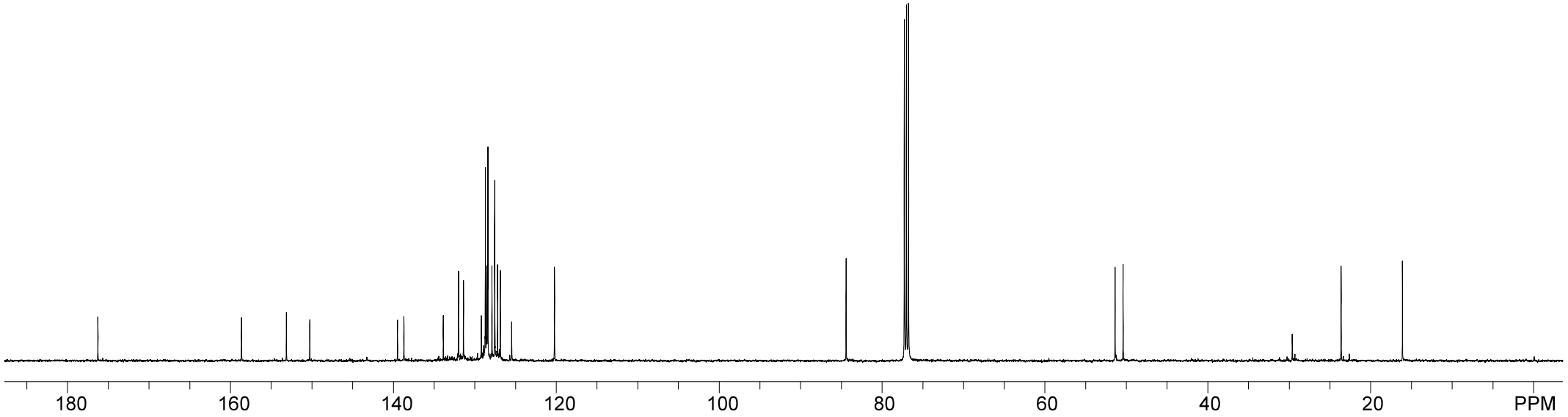
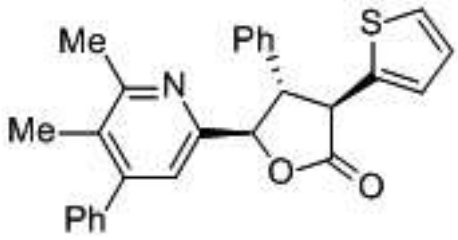
158.646
153.137
150.266
139.487
138.708
133.869
132.003
131.391
129.197
128.702
128.541
128.432
128.388
127.900
127.557
127.208
126.865
125.481
120.219
84.415
77.259
77.011
76.756
51.395
50.404
23.658
16.137


Me
Ph
N
Me
Br
O
O
Ph

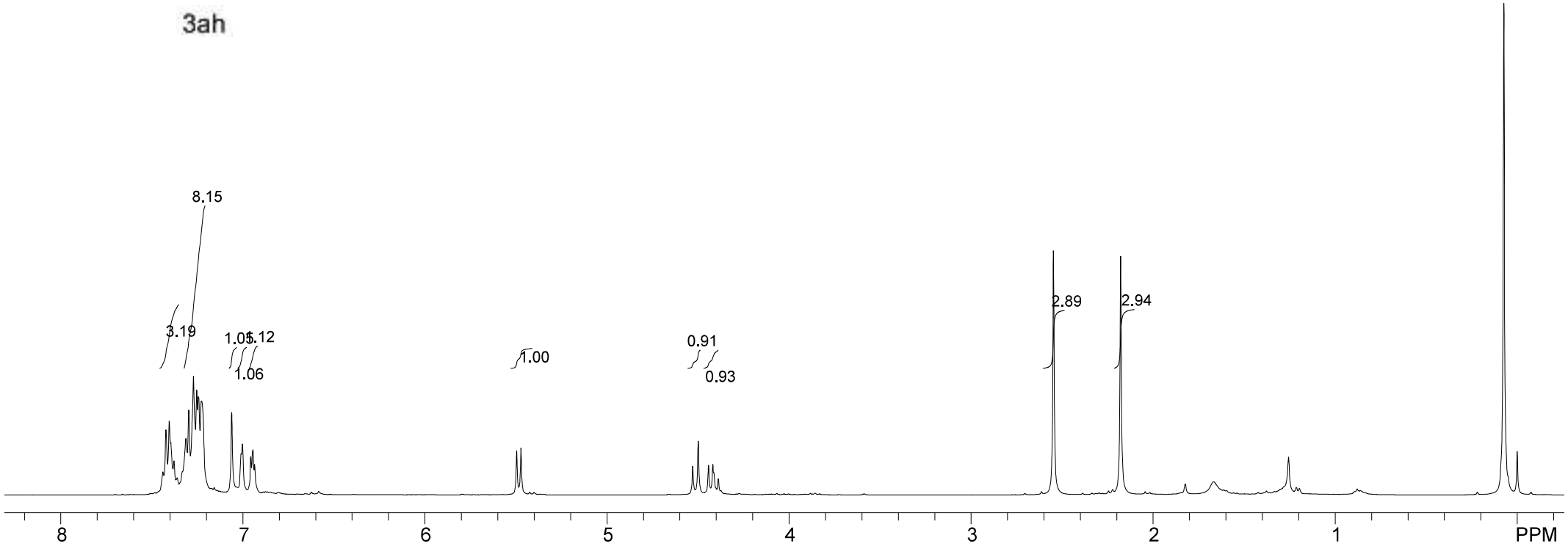
3ag


180
160
140
120
100
80
60
40
20
PPM


7.440
7.422
7.404
7.396
7.378
7.361
7.332
7.313
7.298
7.271
7.254
7.245
7.229
7.226
7.061
7.010
7.003
6.957
6.945
6.935
5.496
5.473
4.530
4.499
4.443
4.419
4.413
2.548
2.179
0.073
0.000


Me
Ph
S
N
Me
O
O
Ph

3ah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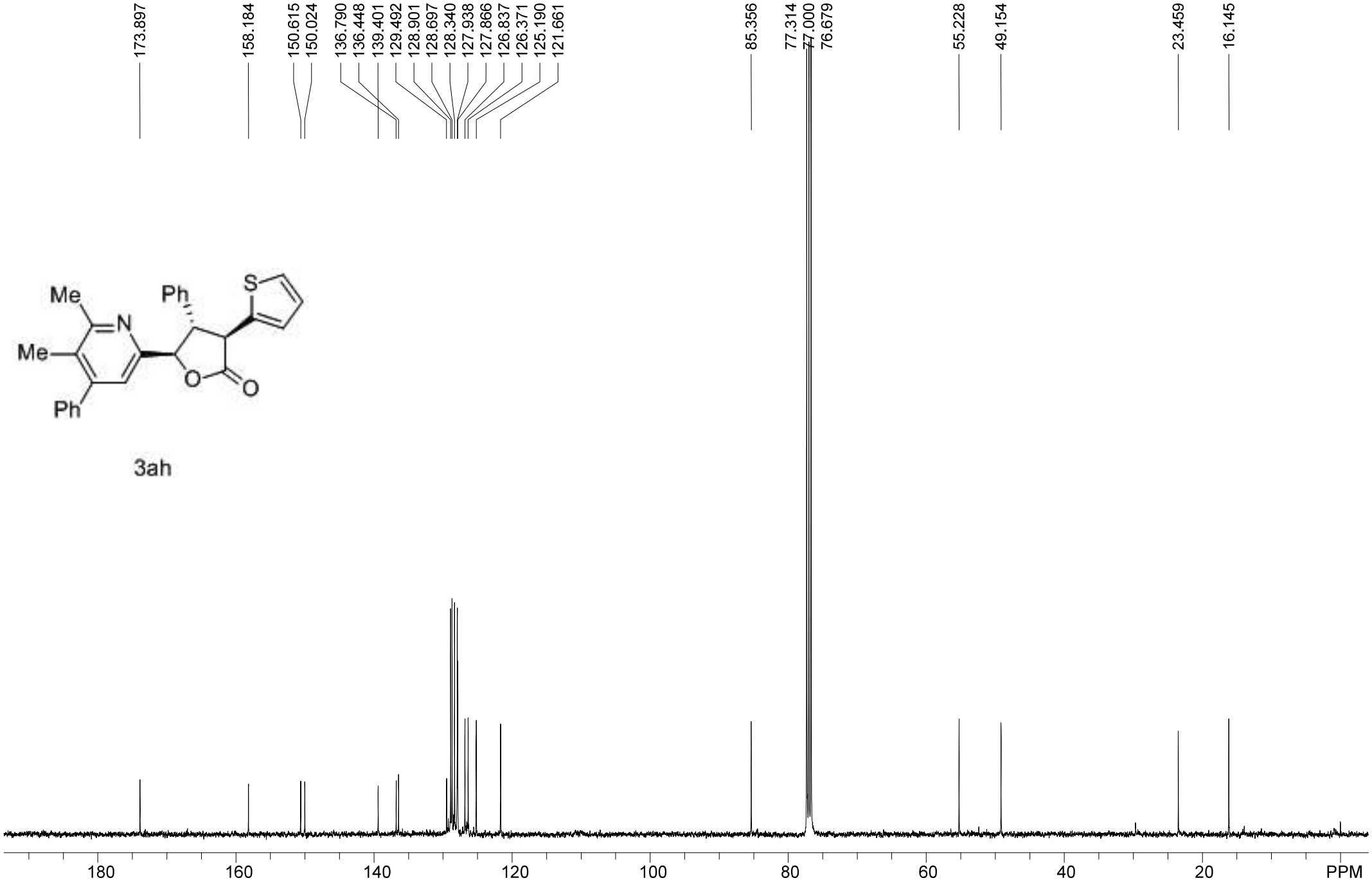
3.19
1.05
1.12
1.06
1.00
0.91
0.93
2.89
2.94
8
7
6
5
4
3
2
1
PPM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150.024
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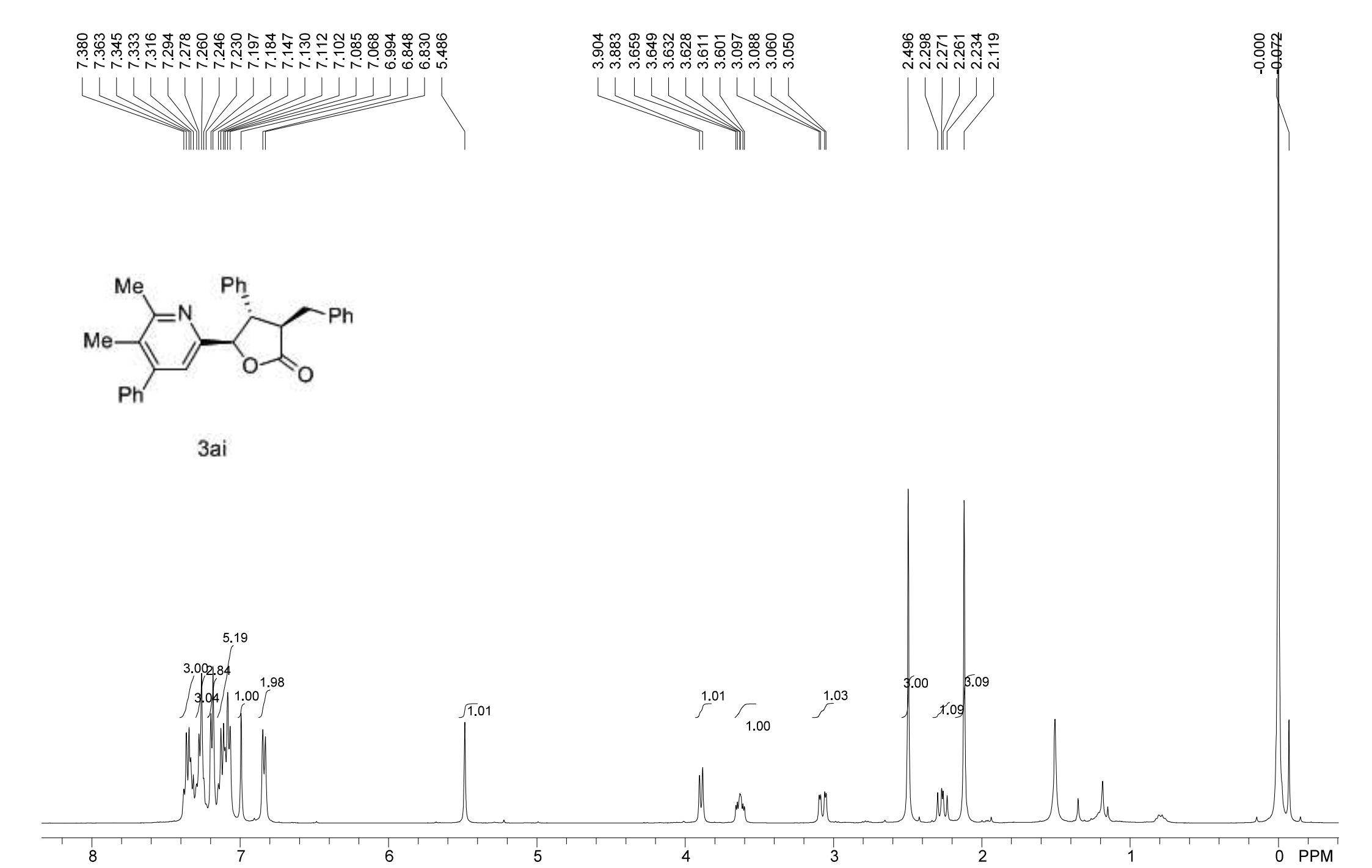
139.401
129.492
128.901
128.697
128.340
127.938
127.866
126.837
126.371
125.190
121.661
85.356
77.314
77.000
76.679
55.228
49.154
23.459
16.145
Me
Ph
S
N
Me
O
O
Ph
3ah
180
160
140
120
100
80
60
40
20
PPM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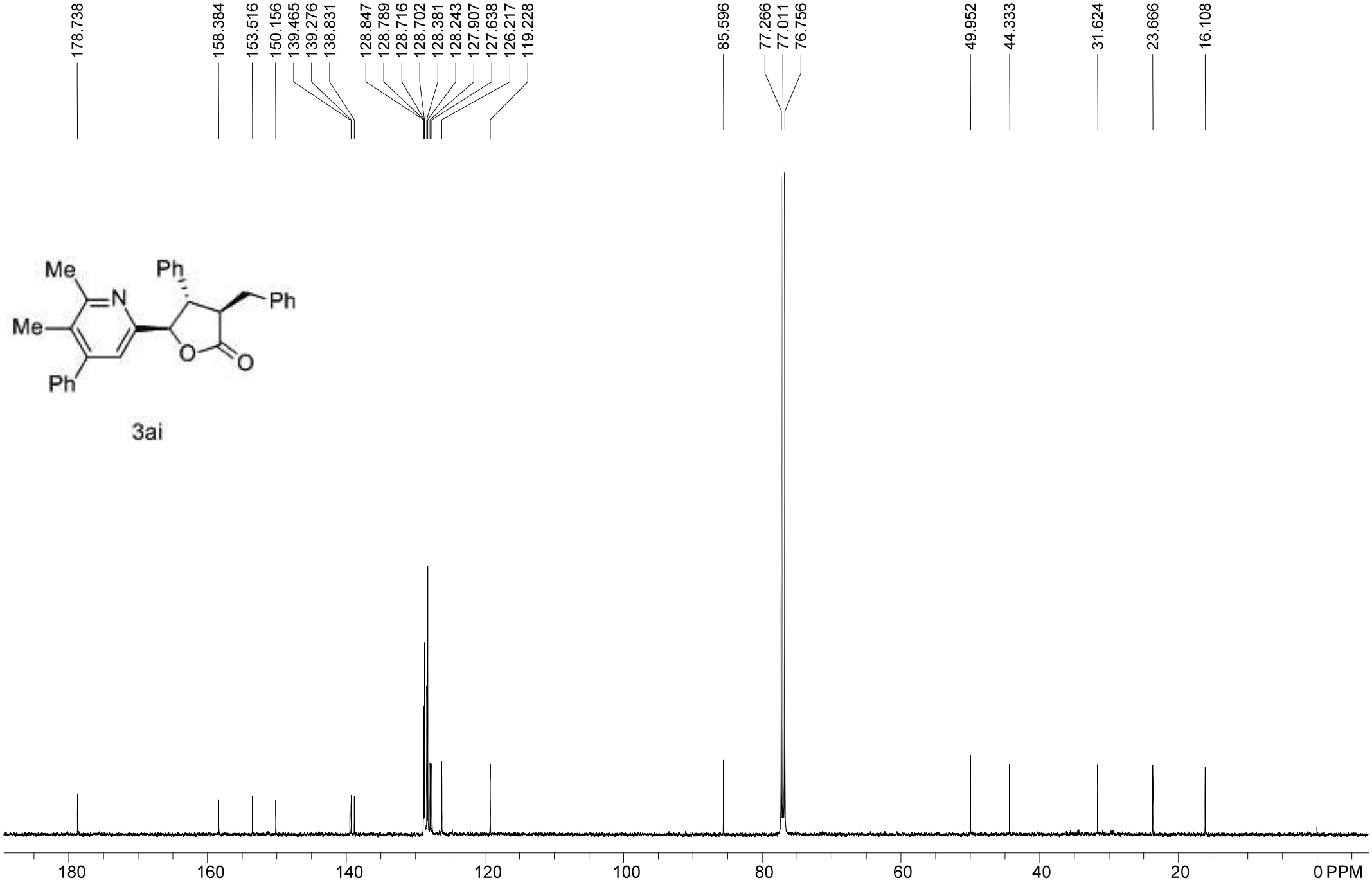
7.363
7.345
7.333
7.316
7.294
7.278
7.260
7.246
7.230
7.197
7.184
7.147
7.130
7.112
7.102
7.085
7.068
6.994
6.848
6.830
5.486
3.904
3.883
3.659
3.649
3.632
3.628
3.611
3.601
3.097
3.088
3.060
3.050
2.496
2.298
2.271
2.261
2.234
2.119
-0.000
-0.072
Me
Ph
N
Ph
Me
O
O
Ph
3ai
5.19
3.00
2.84
3.04
1.00
1.98
1.01
1.01
1.00
1.03
3.00
1.09
3.09
8
7
6
5
4
3
2
1
0
PPM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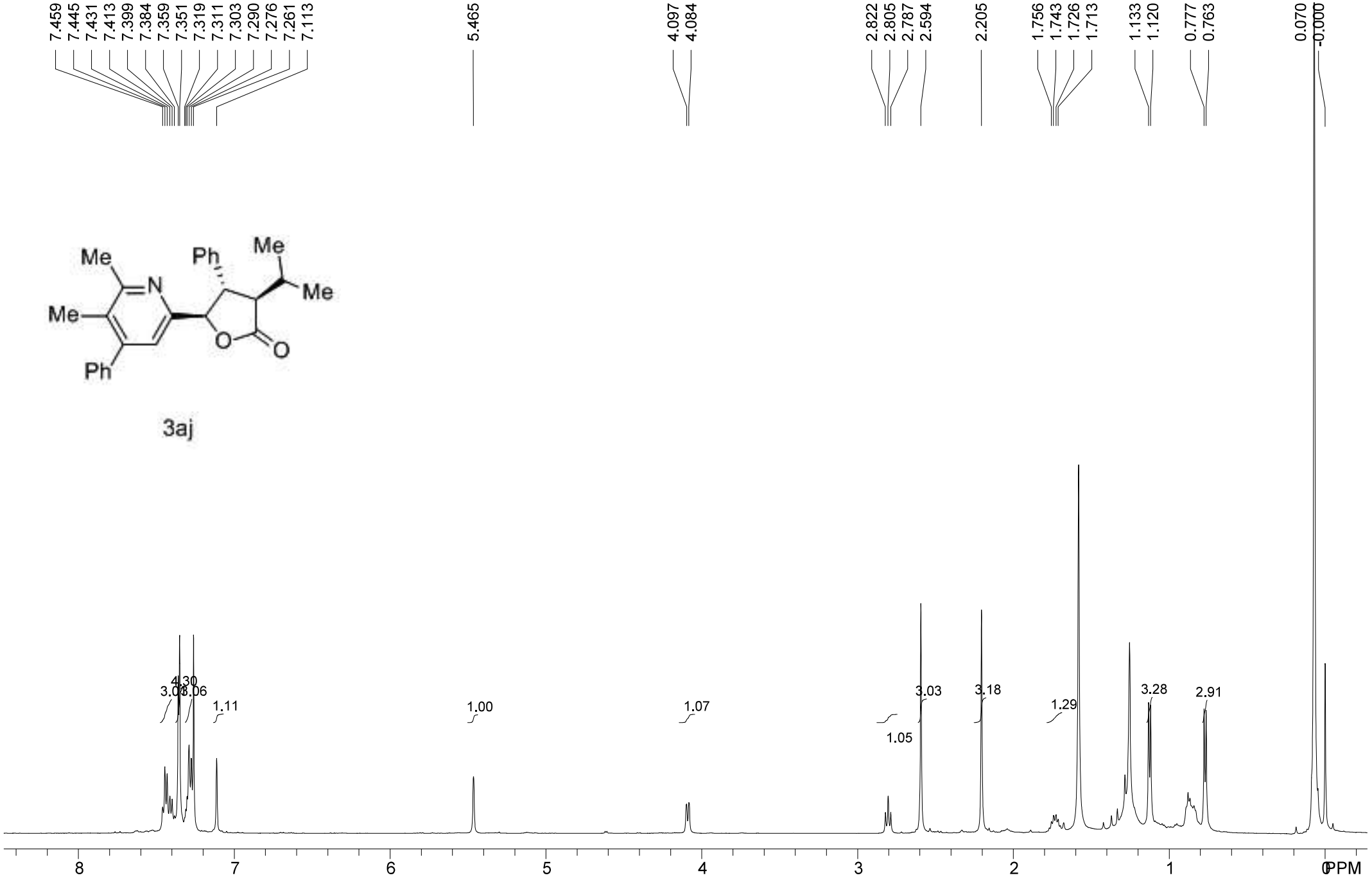
158.384
153.516
150.156
139.465
139.276
138.831
128.847
128.789
128.716
128.702
128.381
128.243
127.907
127.638
126.217
119.228
85.596
77.266
77.011
76.756
49.952
44.333
31.624
23.666
16.108
Me
Ph
N
Ph
Me
O
O
Ph
3ai
180
160
140
120
100
80
60
40
20
0 PPM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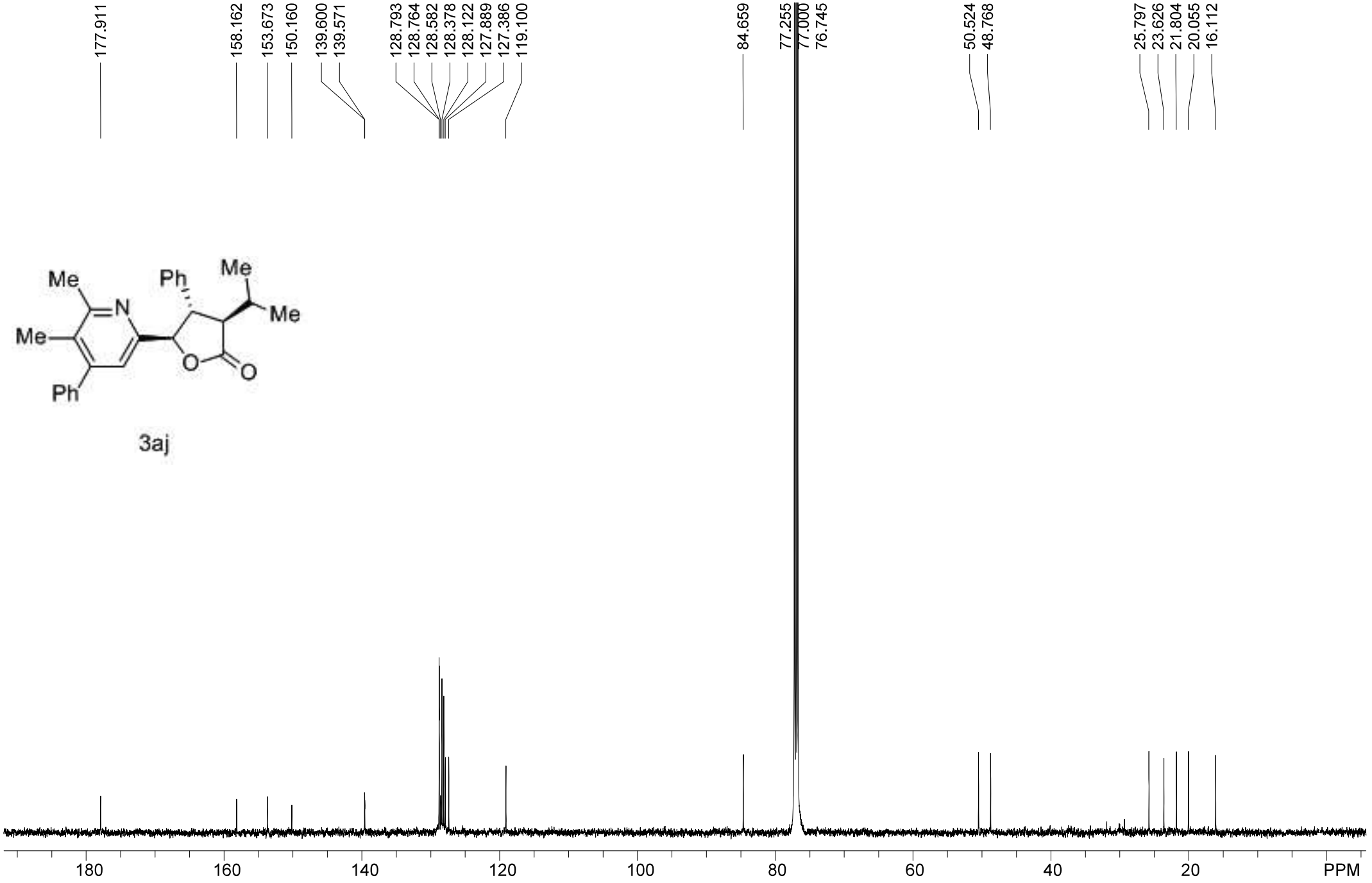
7.445
7.431
7.413
7.399
7.384
7.359
7.351
7.319
7.311
7.303
7.290
7.276
7.261
7.113
5.465
4.097
4.084
2.822
2.805
2.787
2.594
2.205
1.756
1.743
1.726
1.713
1.133
1.120
0.777
0.763
0.070
-0.000
Me
Ph
Me
Me
N
Me
O
O
Ph
3aj
3.00
4.30
3.06
1.11
1.00
1.07
1.05
3.03
3.18
1.29
3.28
2.91
8
7
6
5
4
3
2
1
0
PPM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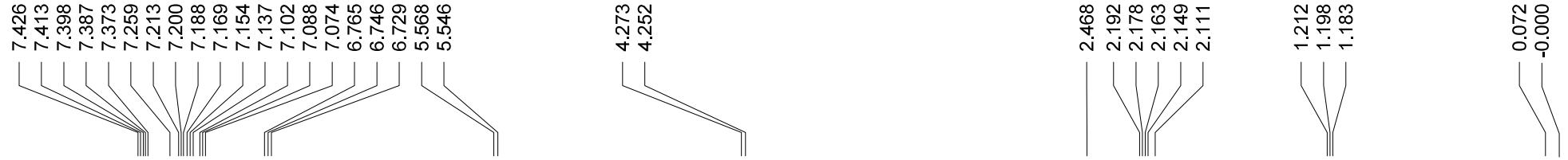
158.162
153.673
150.160
139.600
139.571
128.793
128.764
128.582
128.378
128.122
127.889
127.386
119.100
84.659
77.255
77.000
76.745
50.524
48.768
25.797
23.626
21.804
20.055
16.112
Me
Ph
Me
N
Me
Me
O
O
Ph
180
160
140
120
100
80
60
40
20
PPM

3aj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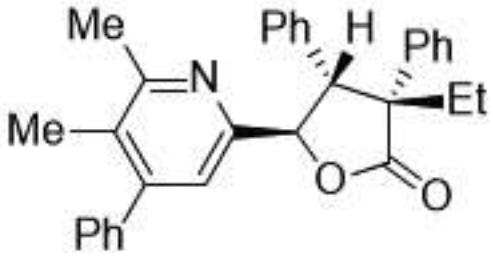
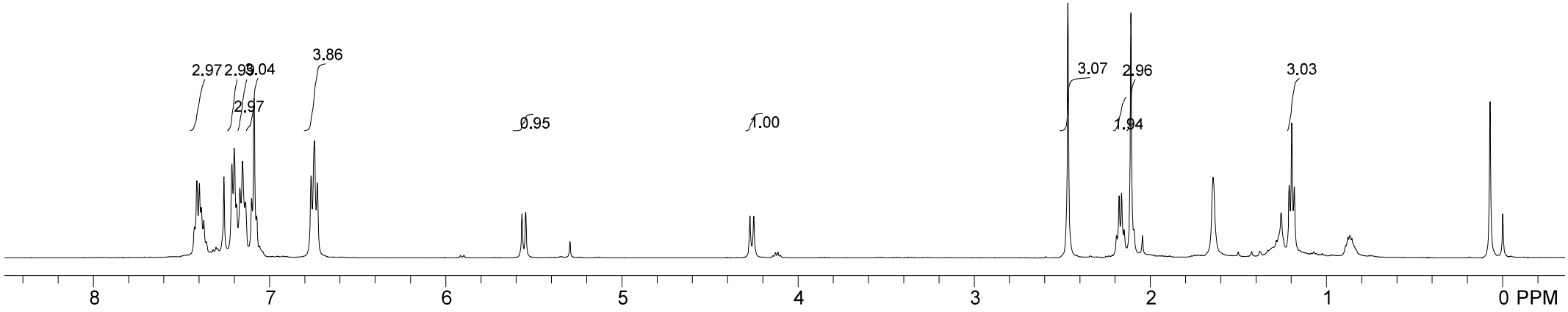
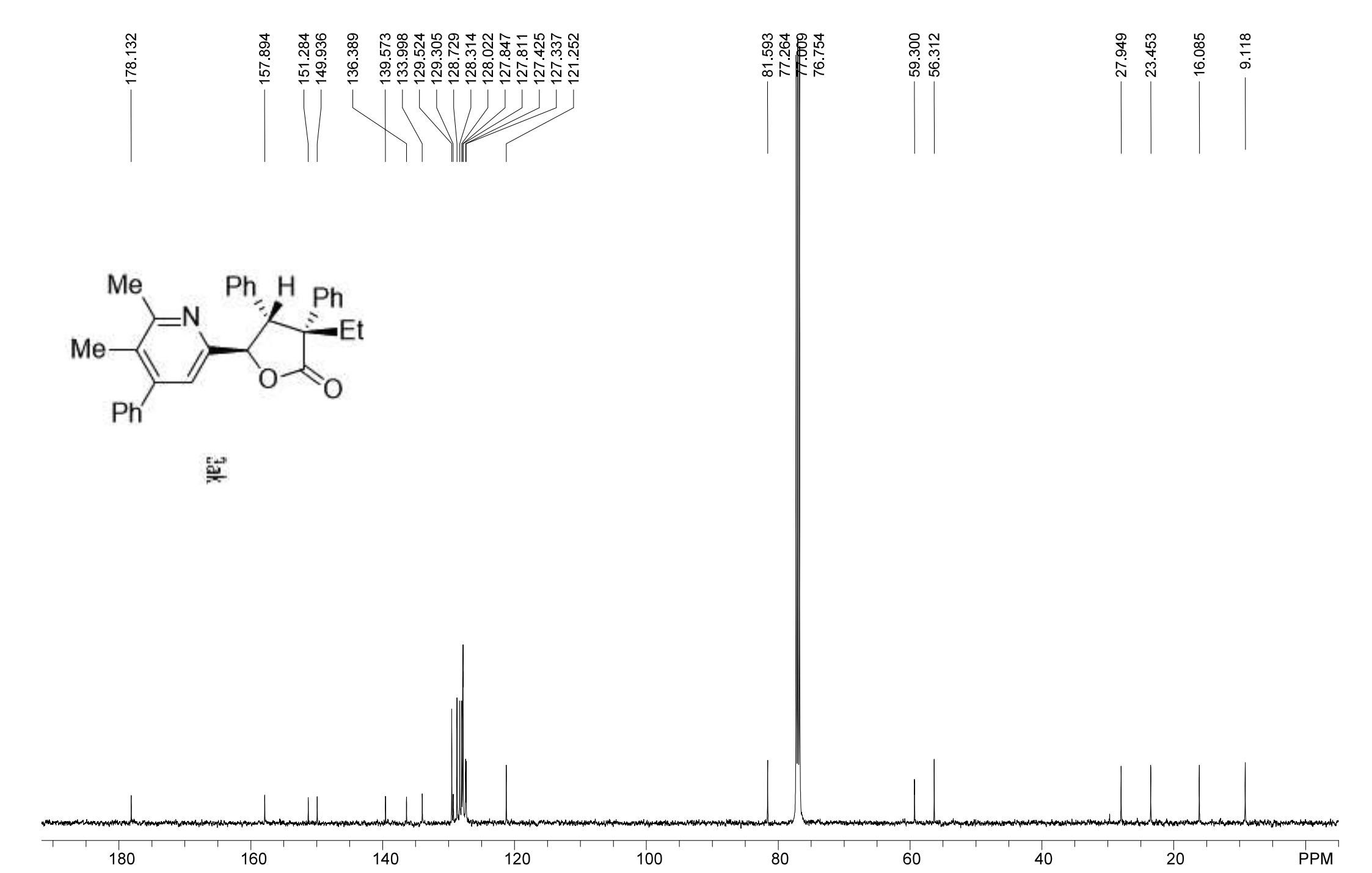
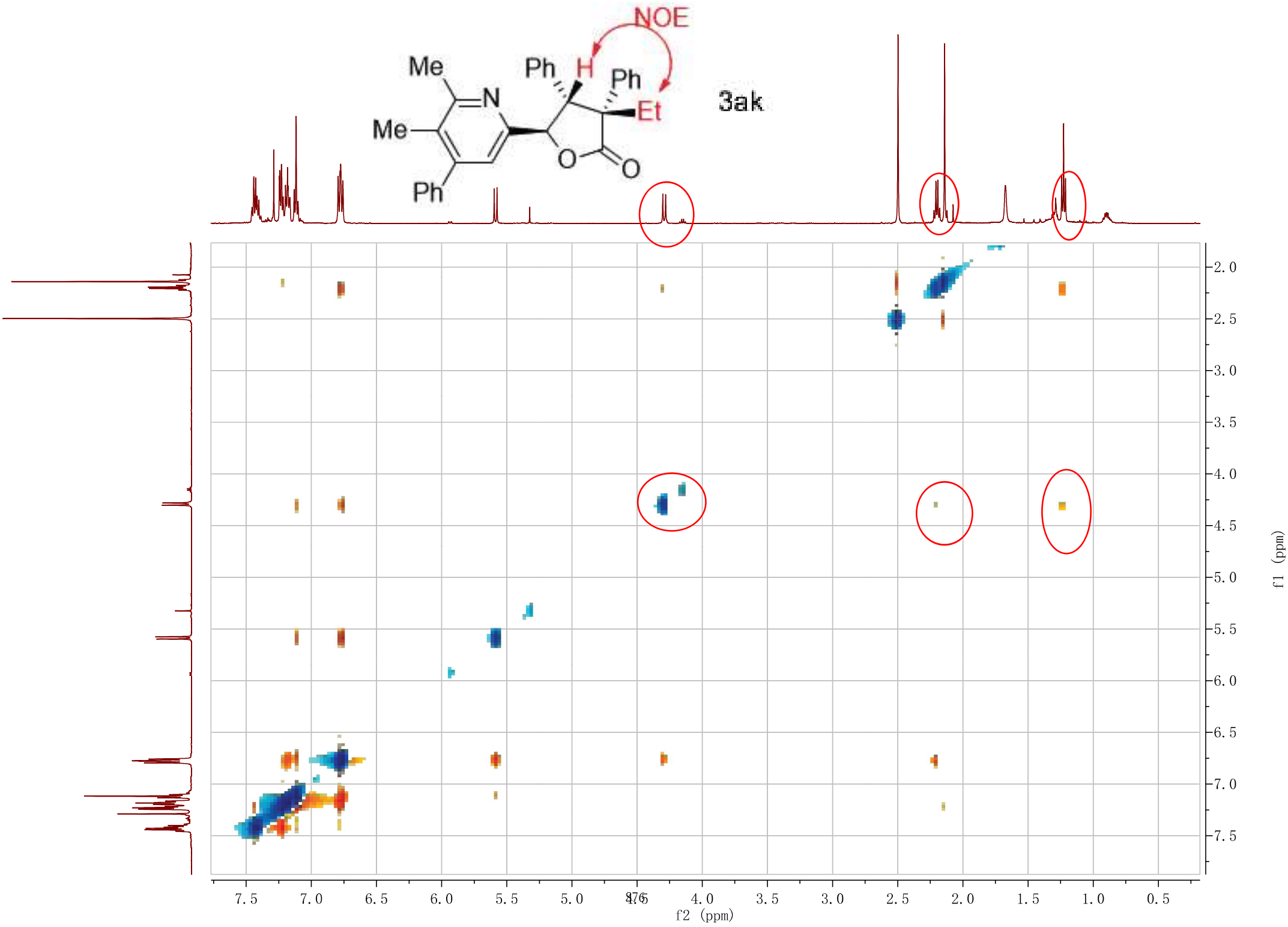
7.413
7.398
7.387
7.373
7.259
7.213
7.200
7.188
7.169
7.154
7.137
7.102
7.088
7.074
6.765
6.746
6.729
5.568
5.546
4.273
4.252
2.468
2.192
2.178
2.163
2.149
2.111
1.212
1.198
1.183
0.072
-0.000

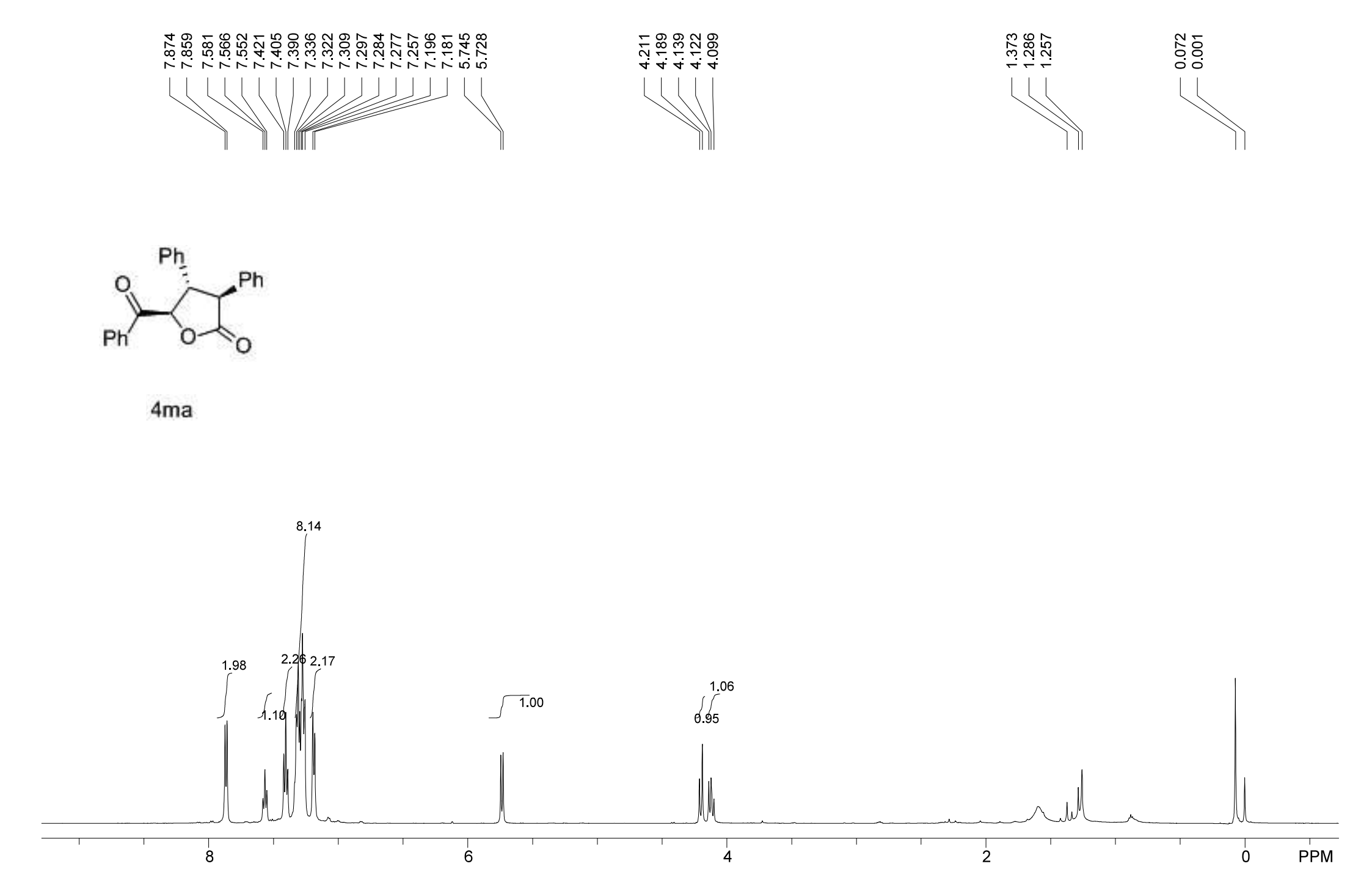

Me
Ph
H
Ph
N
Et
Me
O
O
Ph

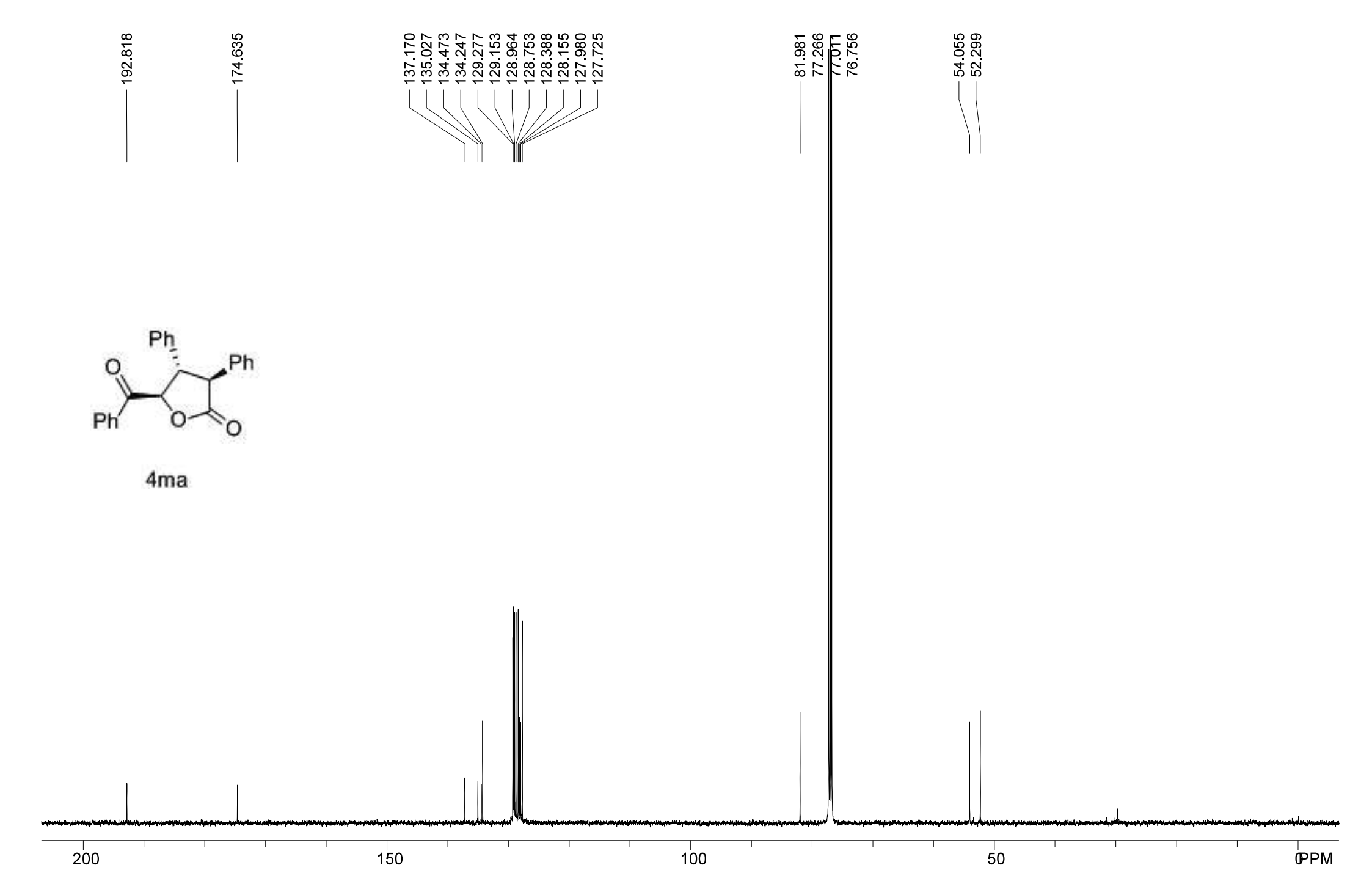
3ak

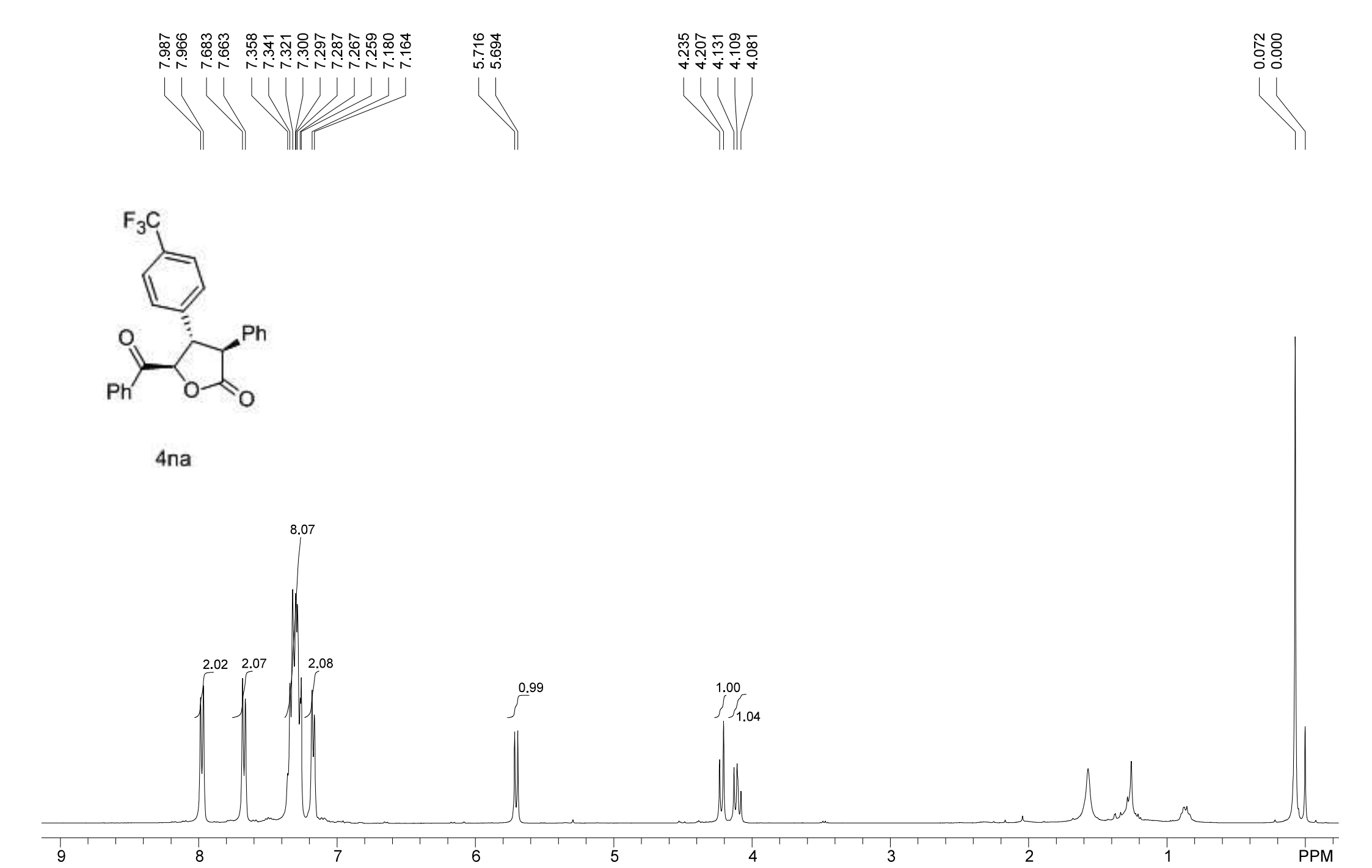

2.97
2.93
3.04
2.97
3.86
0.95
1.00
3.07
2.96
1.94
3.03
8
7
6
5
4
3
2
1
0 PPM

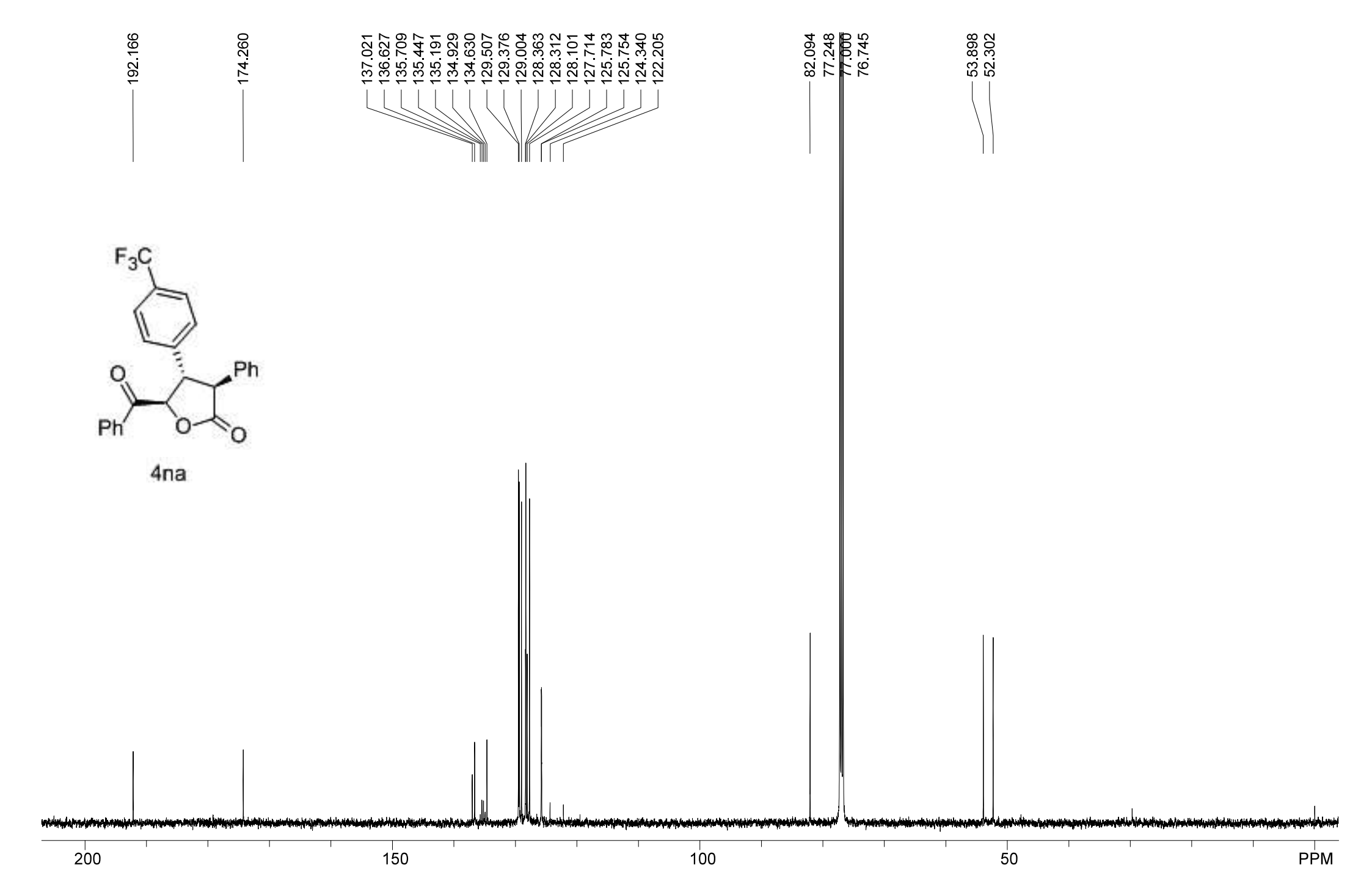

178.132
157.894
151.284
149.936
136.389
139.573
133.998
129.524
129.305
128.729
128.314
128.022
127.847
127.811
127.425
127.337
121.252
81.593
77.264
77.009
76.754
59.300
56.312
27.949
23.453
16.085
9.118
Me
Ph
H
Ph
Et
N
Me
O
O
Ph
180
160
140
120
100
80
60
40
20
PPM

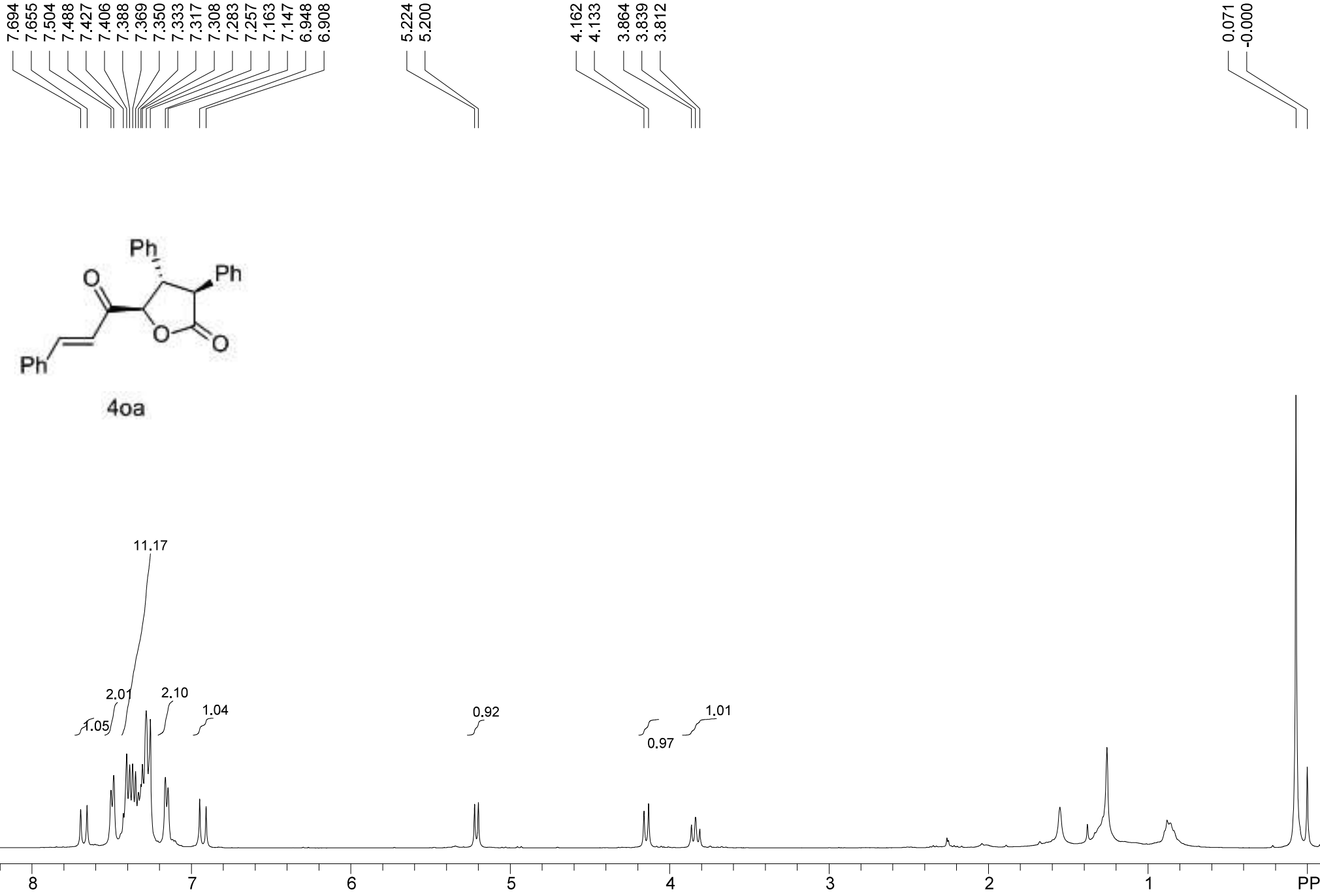

NOE
Me
N
Me
Ph
H
Ph
Et
O
O
Ph
3ak
f2 (ppm)
f1 (ppm)

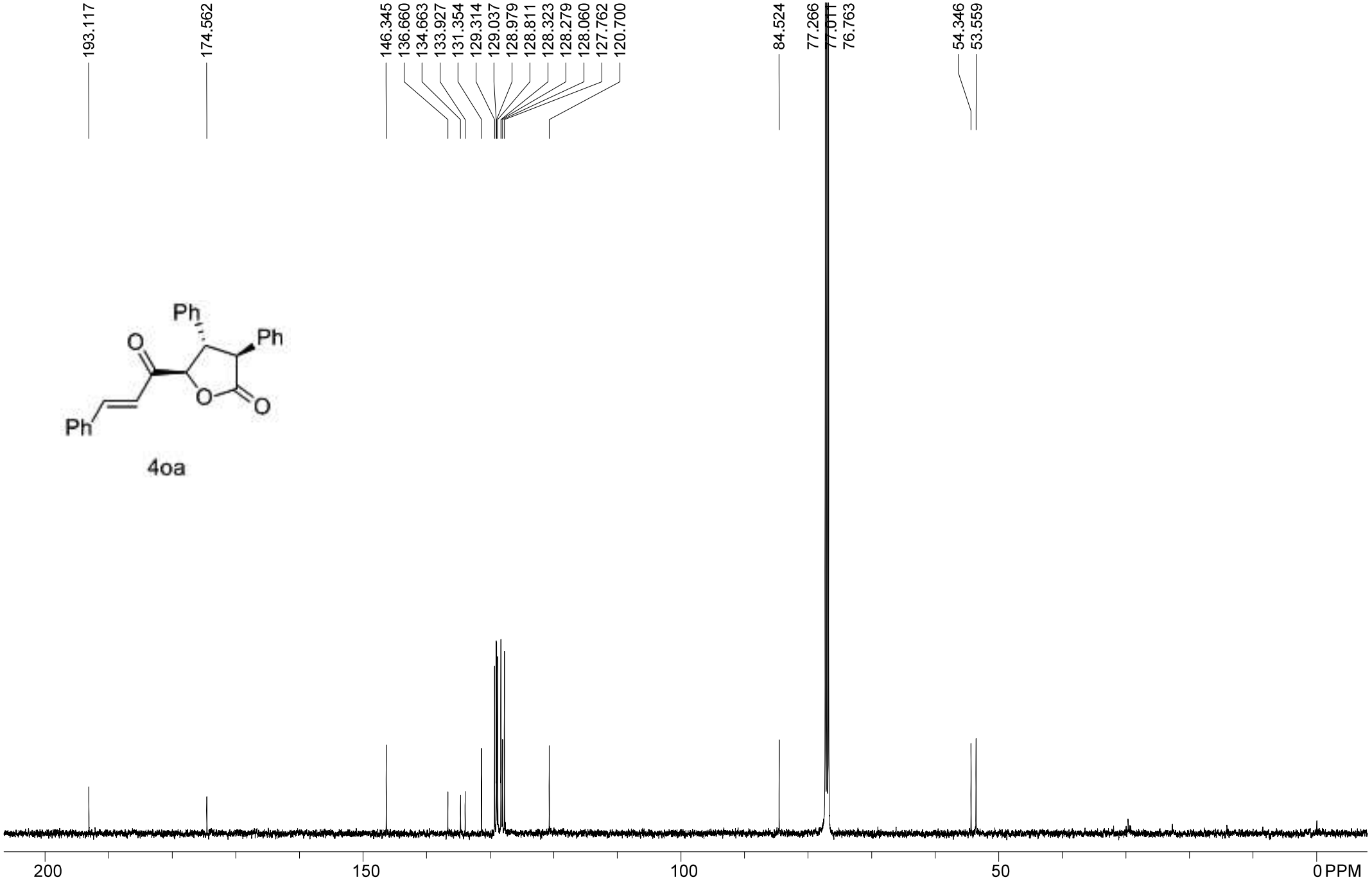

7.874
7.859
7.581
7.566
7.552
7.421
7.405
7.390
7.336
7.322
7.309
7.297
7.284
7.277
7.257
7.196
7.181
5.745
5.728
4.211
4.189
4.139
4.122
4.099
1.373
1.286
1.257
0.072
0.001
Ph
Ph
O
Ph
O
O
4ma
8.14
1.98
2.26
2.17
1.10
1.00
1.06
0.95
8
6
4
2
0
PPM

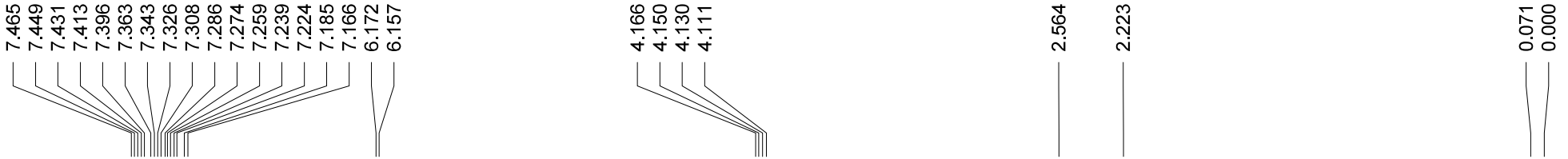

192.818
174.635
137.170
135.027
134.473
134.247
129.277
129.153
128.964
128.753
128.388
128.155
127.980
127.725
81.981
77.266
77.011
76.756
54.055
52.299
Ph
Ph
O
Ph
O
O
4ma
200
150
100
50
0
PPM

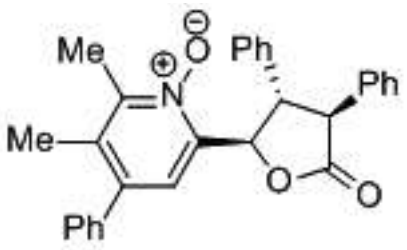

7.987
7.966
7.683
7.663
7.358
7.341
7.321
7.300
7.297
7.287
7.267
7.259
7.180
7.164
5.716
5.694
4.235
4.207
4.131
4.109
4.081
0.072
0.000
F3C
Ph
O
Ph
O
O
4na
8.07
2.02
2.07
2.08
0.99
1.00
1.04
9
8
7
6
5
4
3
2
1
PPM


192.166
174.260
137.021
136.627
135.709
135.447
135.191
134.929
134.630
129.507
129.376
129.004
128.363
128.312
128.101
127.714
125.783
125.754
124.340
122.205
82.094
77.248
77.000
76.745
53.898
52.302
F3C
Ph
O
Ph
O
O
4na
200
150
100
50
PPM

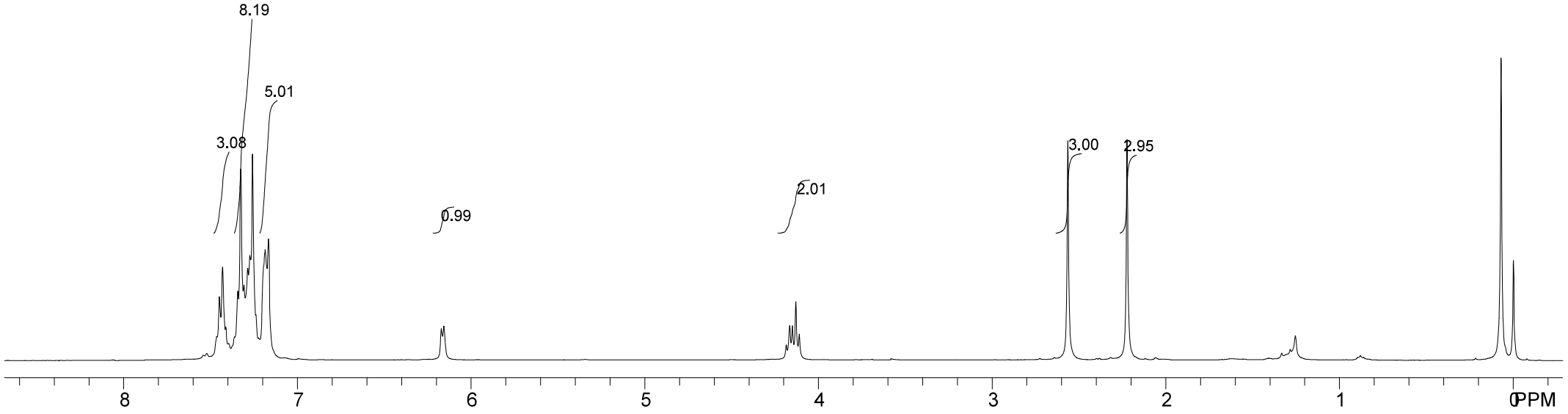

7.694
7.655
7.504
7.488
7.427
7.406
7.388
7.369
7.350
7.333
7.317
7.308
7.283
7.257
7.163
7.147
6.948
6.908
5.224
5.200
4.162
4.133
3.864
3.839
3.812
0.071
-0.000
Ph
Ph
O
O
O
Ph
4oa
11.17
2.01
2.10
1.04
1.05
0.92
0.97
1.01
8
7
6
5
4
3
2
1
PPM

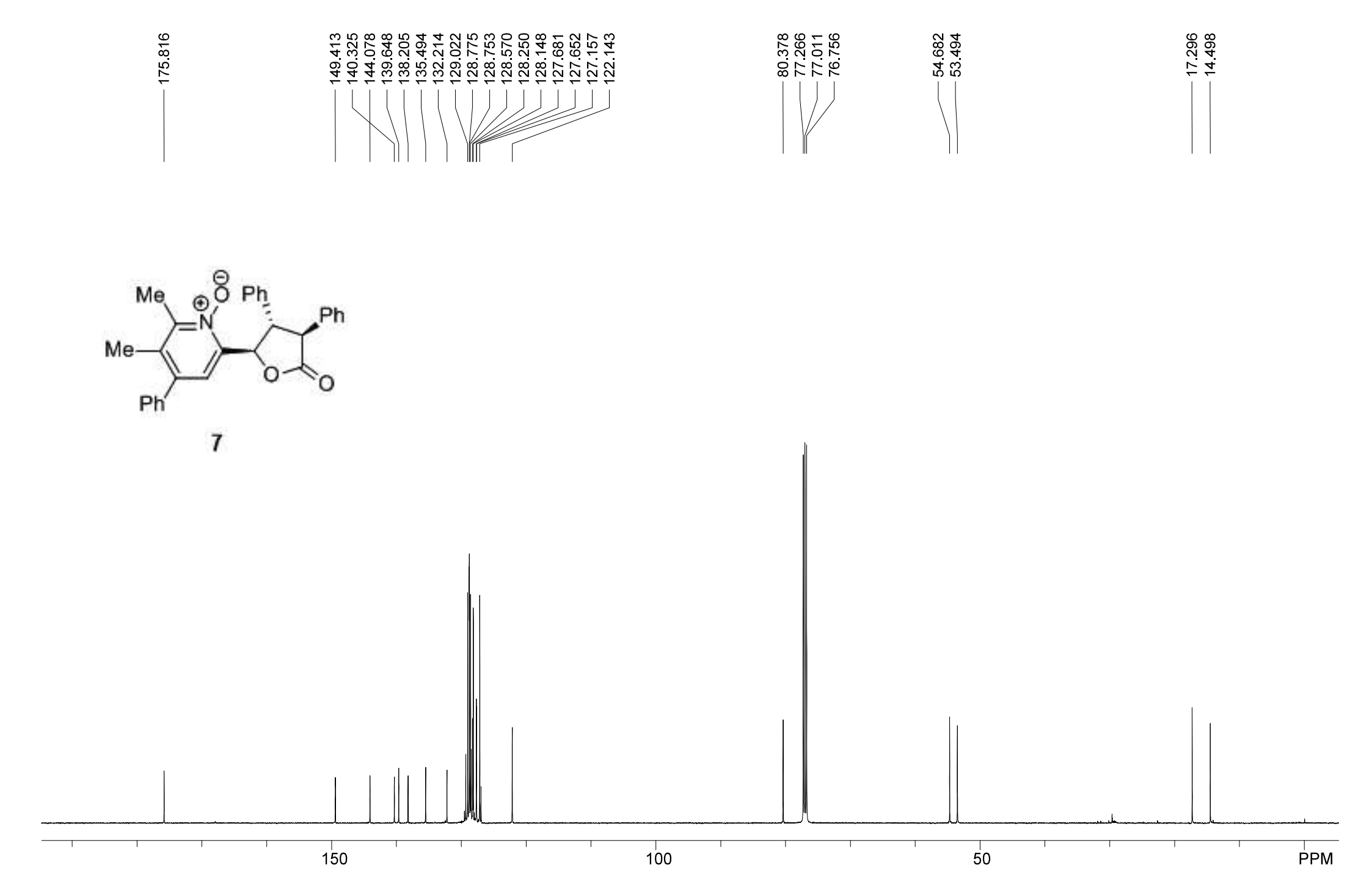

193.117
174.562
146.345
136.660
134.663
133.927
131.354
129.314
129.037
128.979
128.811
128.323
128.279
128.060
127.762
120.700
84.524
77.266
77.011
76.763
54.346
53.559
Ph
Ph
O
O
O
Ph
4oa
200
150
100
50
0 PPM

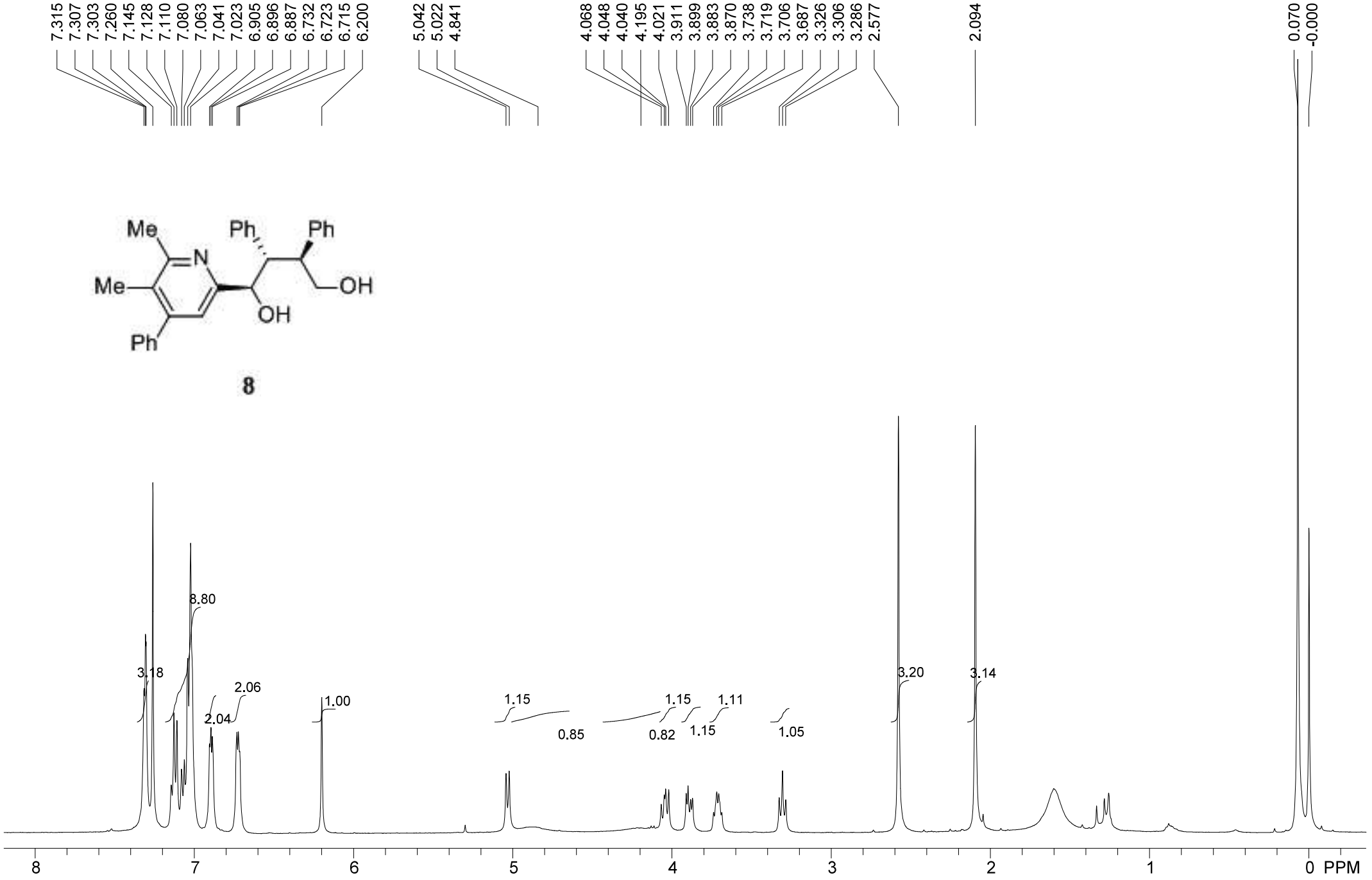

7.465
7.449
7.431
7.413
7.396
7.363
7.343
7.326
7.308
7.286
7.274
7.259
7.239
7.224
7.185
7.166
6.172
6.157
4.166
4.150
4.130
4.111
2.564
2.223
0.071
0.000


Me
Ph
Ph
Me
Ph
O
O

7


8.19
5.01
3.08
0.99
2.01
3.00
2.95
8
7
6
5
4
3
2
1
0
PPM


175.816
149.413
140.325
144.078
139.648
138.205
135.494
132.214
129.022
128.775
128.753
128.570
128.250
128.148
127.681
127.652
127.157
122.143
80.378
77.266
77.011
76.756
54.682
53.494
17.296
14.498
Me
Me
Ph
Ph
Ph
O
O
O
N
7
150
100
50
PPM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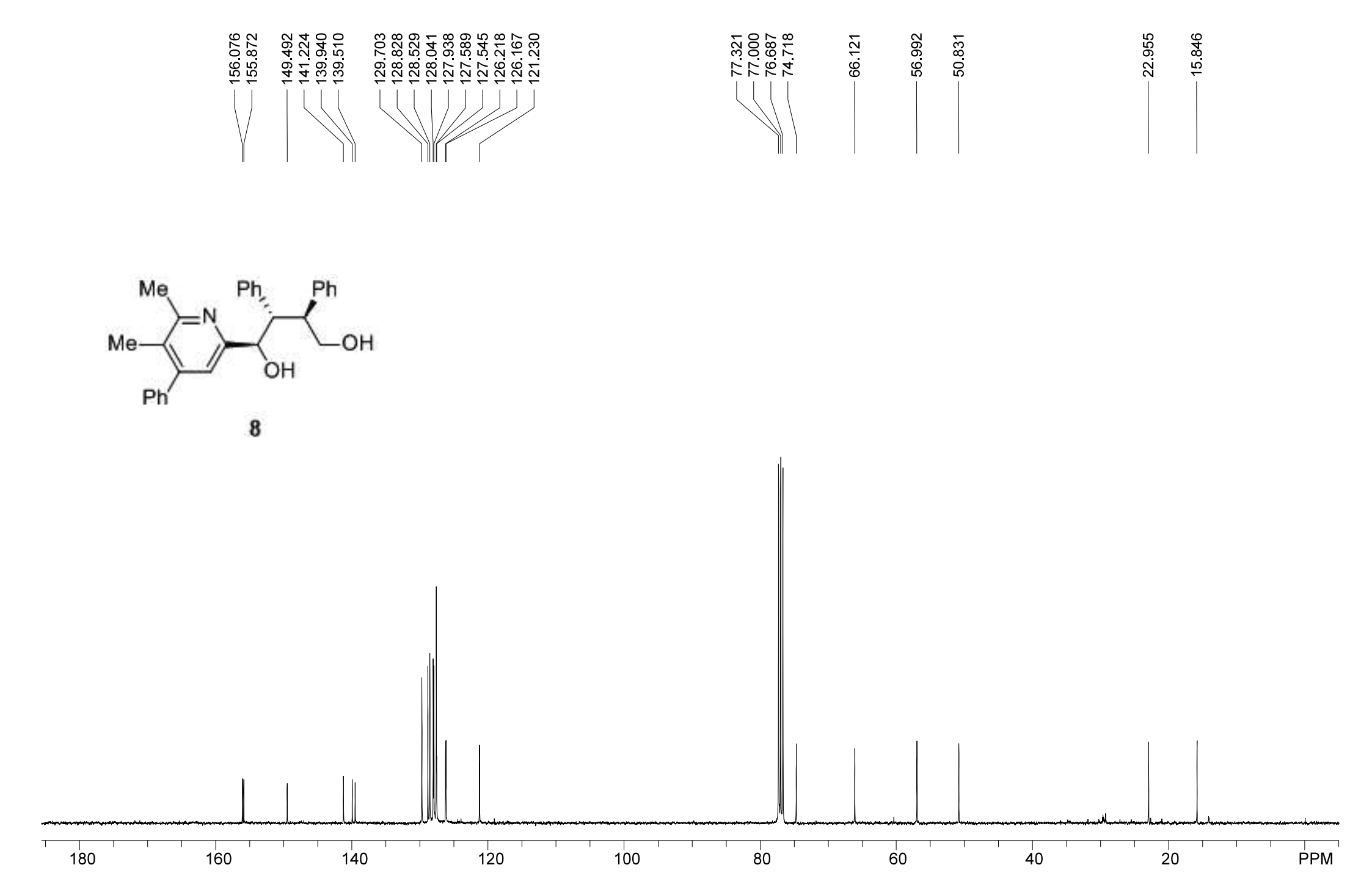
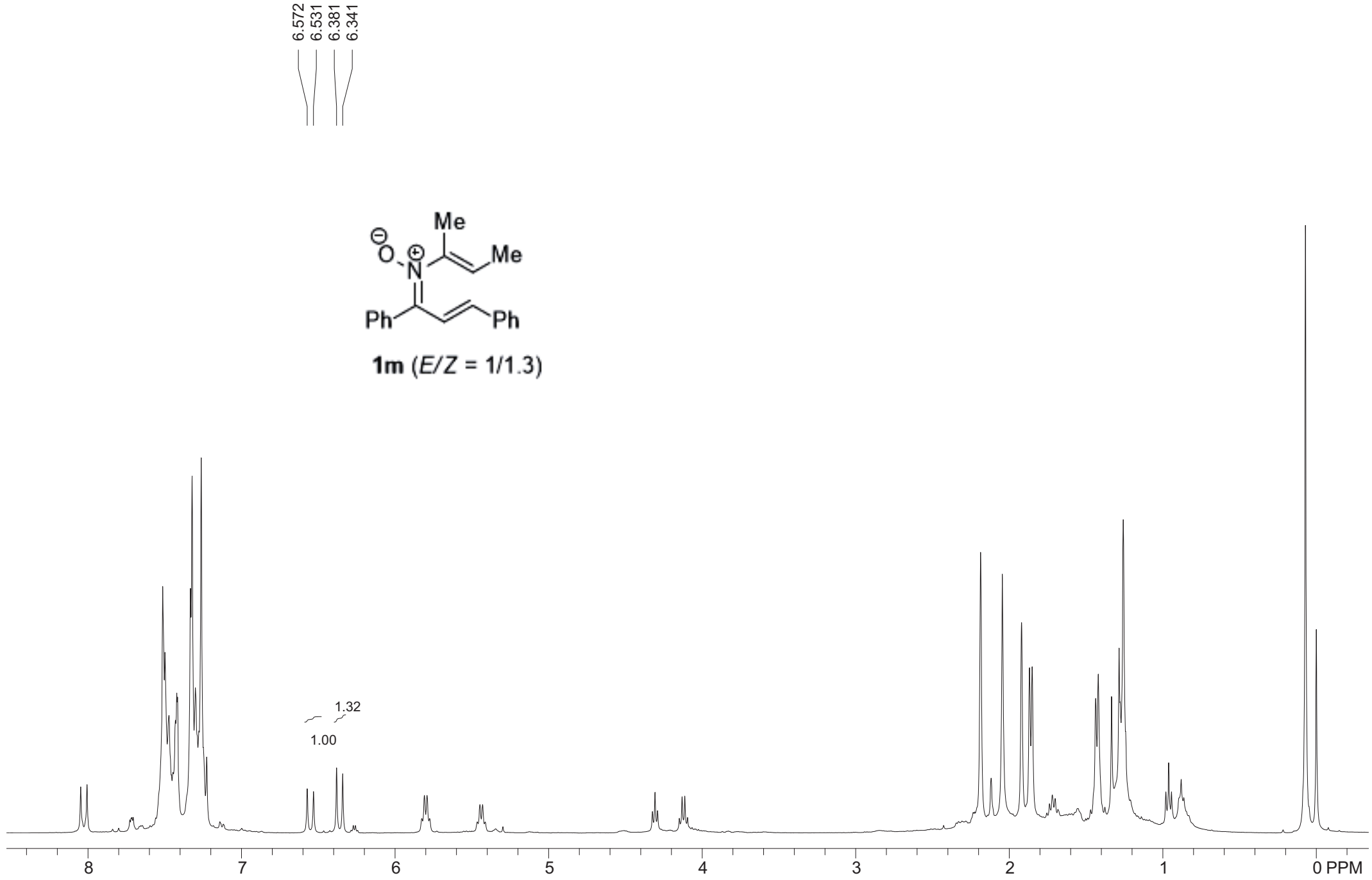
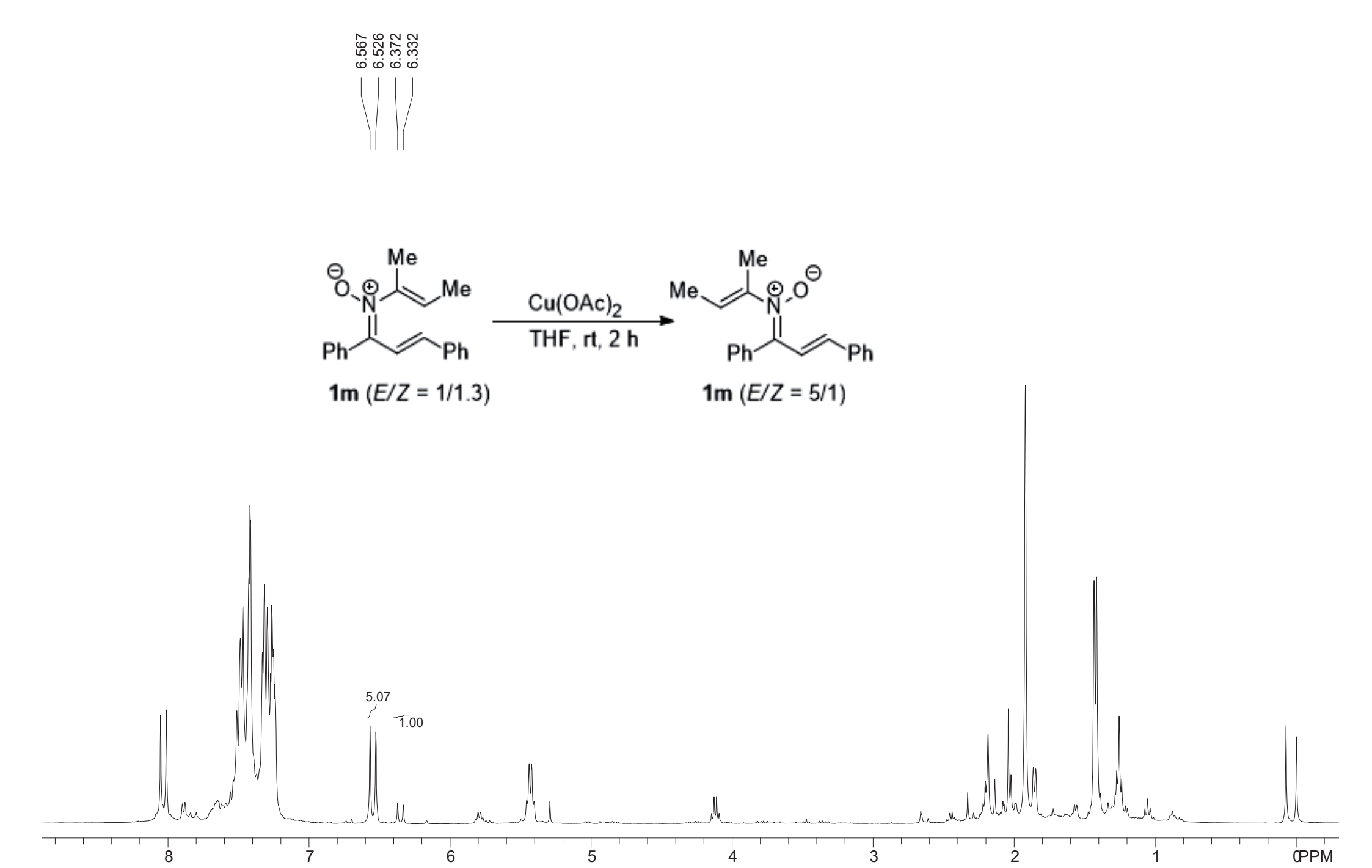
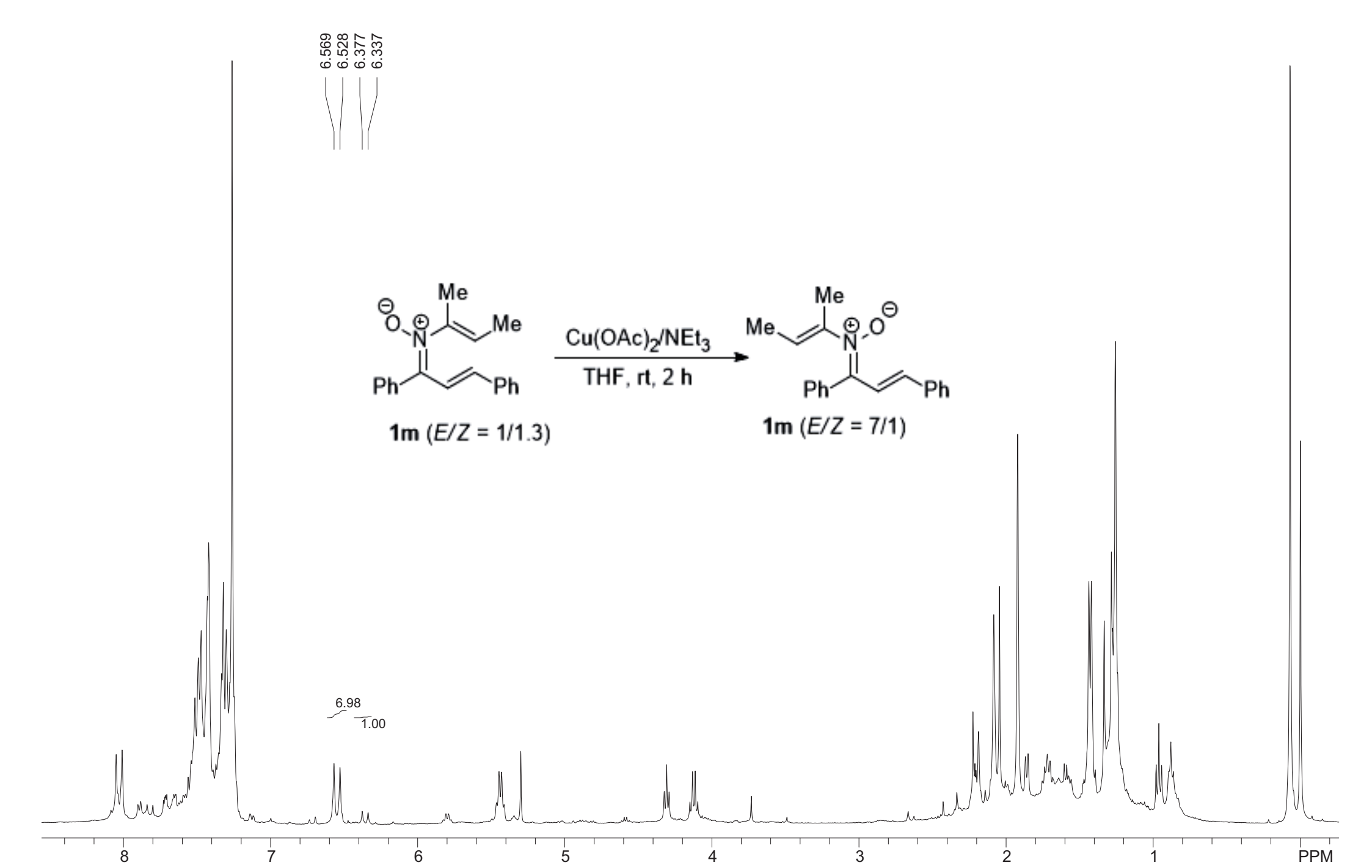
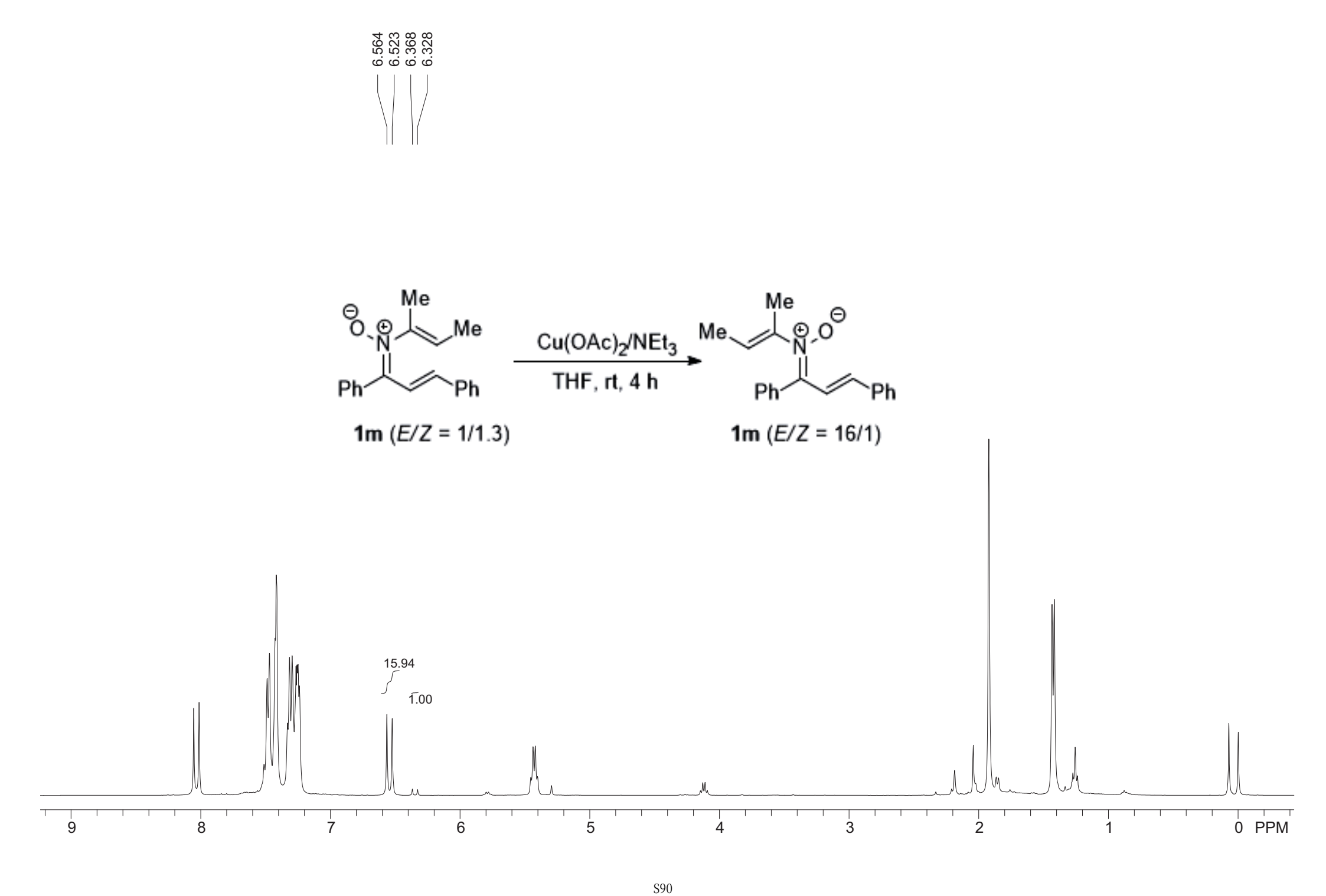
7.145
7.128
7.110
7.080
7.063
7.041
7.023
6.905
6.896
6.887
6.732
6.723
6.715
6.200
5.042
5.022
4.841
4.068
4.048
4.040
4.195
4.021
3.911
3.899
3.883
3.870
3.738
3.719
3.706
3.687
3.326
3.306
3.286
2.577
2.094
0.070
-0.000
Me
Ph
Ph
N
Me
OH
OH
Ph
8
3.18
8.80
2.04
2.06
1.00
1.15
0.85
1.15
0.82
1.11
1.15
1.05
3.20
3.14
8
7
6
5
4
3
2
1
0 PPM

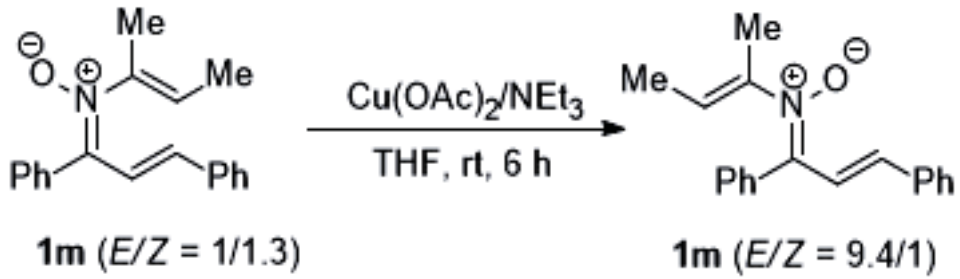

156.076
155.872
149.492
141.224
139.940
139.510
129.703
128.828
128.529
128.041
127.938
127.589
127.545
126.218
126.167
121.230
77.321
77.000
76.687
74.718
66.121
56.992
50.831
22.955
15.846
Me
Ph
Ph
N
Me
OH
OH
Ph
8
180
160
140
120
100
80
60
40
20
PPM


6.572
6.531
6.381
6.341
Me
Me
Ph
Ph
1m (E/Z = 1/1.3)
1.32
1.00
8
7
6
5
4
3
2
1
0 PPM


6.567
6.526
6.372
6.332
Me
Me
Ph
Ph
Cu(OAc)2
THF, rt, 2 h
Me
Me
Ph
Ph
1m (E/Z = 1/1.3)
1m (E/Z = 5/1)
5.07
1.00
8
7
6
5
4
3
2
1
0
PPM

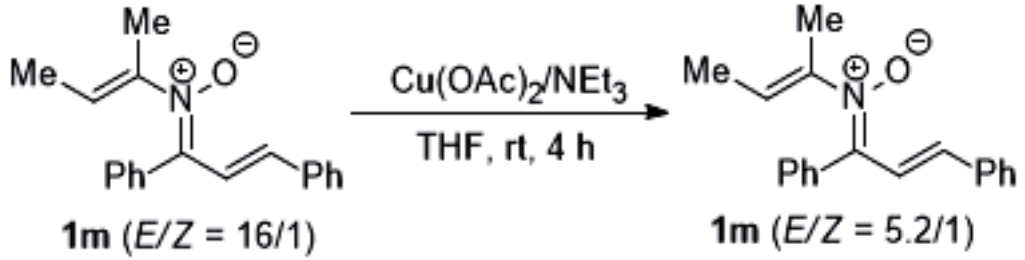

6.569
6.528
6.377
6.337
Me
Me
Ph
Ph
Cu(OAc)2/NEt3
THF, rt, 2 h
Me
Me
Ph
Ph
1m (E/Z = 1/1.3)
1m (E/Z = 7/1)
6.98
1.00
8
7
6
5
4
3
2
1
PPM


6.564
6.523
6.368
6.328
Me
Me
Ph
Ph
Cu(OAc)2/NEt3
THF, rt, 4 h
Me
Me
Ph
Ph
1m (E/Z = 1/1.3)
1m (E/Z = 16/1)
15.94
1.00
9
8
7
6
5
4
3
2
1
0
PPM



1m (*E*/*Z* = 1/1.3)

1m (*E*/*Z* = 9.4/1)



1m (*E*/*Z* = 16/1)

1m (*E*/*Z* = 5.2/1)