Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Directed C-C Bond Cleavage of Cyclopropane Intermediate Generated from *N*-Tosylhydrazones and Stable Enaminones: Expedient Synthesis of Functionalized 1, 4–Ketoaldehydes

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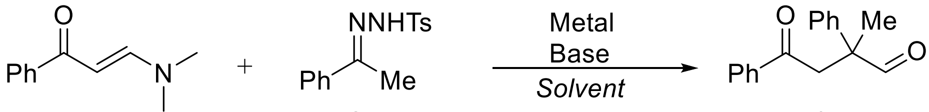
General methods:

All reactions were carried out in flame or oven-dried glassware under argon atmosphere with freshly distilled dry solvents under anhydrous conditions unless otherwise indicated. Flash column chromatography was performed with silica gel 60 (230 – 400 mesh). Chromatograms were visualized by fluorescence quenching with UV light at 254 nm or by staining with base solution of potassium permanganate and molybdate. NMR spectra were recorded at RT on 300 or 400 MHz Bruker spectrometers. The residual solvent signals were taken as the reference (0.00 ppm for ^{1}H NMR spectra and 77.0 ppm for ^{13}C NMR spectra in $CDCl_3$). Chemical shift (δ) is reported in ppm, coupling constants (J) are given in Hz. The following abbreviations classify the multiplicity: s = singlet, d = doublet, t = triplet, m = multiplet, dd = doublet of doublet, q = quartet and br = broad signal. HRMS (ESI) spectra were recorded on a Waters Q-Tof premier TM mass spectrometer.

Screening reaction condition[a]:



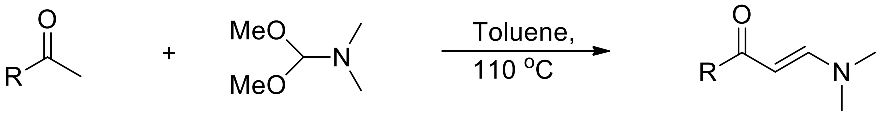
1a **2a** **3aa**

entry	metal	base	solvent	yield (%)[b]
1	CuI	$\mathrm{LiO}^t\mathrm{Bu}$	ACN	14
2	CuI	$\mathrm{LiO}^t\mathrm{Bu}$	DCE	11
3	CuI	$\mathrm{LiO}^t\mathrm{Bu}$	Dioxane	18
4	CuI	$\mathrm{LiO}^t\mathrm{Bu}$	$PhCH_3$	38
5	CuI	Cs_2CO_3	$PhCH_3$	15
6	CuI	LiOH	$PhCH_3$	8
7	CuI	NaOH	$PhCH_3$	3
8	CuI	KOH	$PhCH_3$	trace
9	CuI	Na_2CO_3	$PhCH_3$	7
10	CuI	K_2CO_3	$PhCH_3$	47
11	CuCl	K_2CO_3	$PhCH_3$	39
12	CuBr	K_2CO_3	$PhCH_3$	63
13	Cu(OTf)	K_2CO_3	$PhCH_3$	58
14	CuF_2	K_2CO_3	$PhCH_3$	27

15	$CuBr_2$	K_2CO_3	$PhCH_3$	40
16	$Cu(acac)_2$	K_2CO_3	$PhCH_3$	26
17	CuSCN	K_2CO_3	$PhCH_3$	23
18	$CuBF_4$ $(CH_3CN)_4$	K_2CO_3	$PhCH_3$	43
19	$CuPF_6$ $(CH_3CN)_4$	K_2CO_3	$PhCH_3$	41

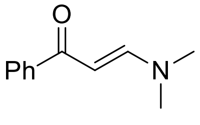
[a]Conditions: A mixture of **1a** (0.1 mmol, 1 equiv), **2a** (0.2 mmol, 2 equiv), base (0.20 mmol, 2.0 equiv), catalyst (20 mol %) and solvent (1 mL) were sealed in Schlenk tube under Ar atmosphere at 80 ^{o}C and the mixture was stirred for 24h or until the **1a** was consumed completely. [b]Yields were determined by 1H NMR *vs* an internal standard.

General procedure for the synthesis of enaminones[1]:



To a stirred solution of ketone (5.0 mmol, 1.0 eq.) in toluene (5.0 mL), 1,1-dimethoxy-N,N-dimethylmethanamine (7.0 mmol, 1.4 eq.) was added and stirred at 110 ^{o}C. After completion of the reaction (monitored by TLC), it was quenched with water, extracted with ethyl acetate and dried with anhydrous Na_2SO_4. Then the reaction mixture was concentrated under reduced pressure and purified by column chromatography (hexane : ethyl acetate = 1 : 1) to give the desired product **1**.

(*E*)-3-(dimethylamino)-1-phenylprop-2-en-1-one (1a):



The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 91 - 92 ºC. Yield 67%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 - 7.89 (m, 2H), 7.81 - 7.78 (d, J = 12.3 Hz, 1H), 7.47 - 7.38 (m, 3H), 5.73 - 5.70 (d, J = 12.3 Hz, 1H), 3.12 (s, 1H), 2.91 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.6, 154.1, 140.4, 130.8,

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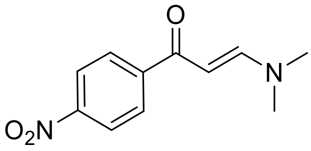
[1] Y. Jiang, V. Y. K. Zhong, L. Emmanuvel and C.-M. Park, *Chem. Commun.*, 2012. **48**, 3133-3135.

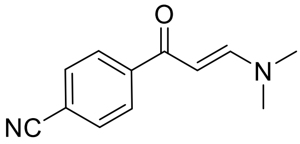
128.0, 127.4, 92.1, 45.0, 37.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{11}H_{14}NO$: 177.2429. Found: 177.2425.

(*E*)-3-(Dimethylamino)-1-(4-nitrophenyl)prop-2-en-1-one (1b):



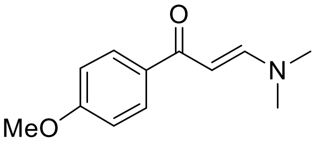
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 148 - 149 ºC. Yield 67%; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.25 - 8.23 (m, 2H), 8.01 (d, *J* = 8.8 Hz, 2H), 7.86 (d, *J* = 12.4 Hz, 1H), 5.68 (d, *J* = 12.0 Hz, 1H), 3.21 (s, 3H), 2.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 186.0, 155.2, 149.0, 146.0, 128.3, 123.3, 91.9, 45.3, 37.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{11}H_{13}N_2O_3$: 221.0926. Found: 221.0932.

(*E*)-4-(3-(Dimethylamino)acryloyl)benzonitrile (1c):



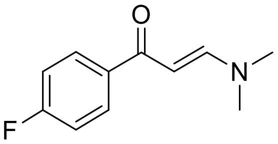
The title compound was prepared according to the general procedure. The product was obtained as yellow solid. Mp. 117 - 118 ºC. Yield 75%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.7 Hz, 2H), 7.85 (d, *J* = 12.2 Hz, 1H), 7.70 (d, *J* = 8.7 Hz, 2H), 5.66 (d, *J* = 12.2 Hz, 1H), 3.19 (s, 3H), 2.96 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 187.3, 156.0, 145.2, 132.9, 128.9, 119.6, 114.9, 92.6, 46.2, 38.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{12}H_{13}N_2O$: 202.2524. Found: 202.2521.

(*E*)-3-(Dimethylamino)-1-(4-methoxyphenyl)prop-2-en-1-one (1d):



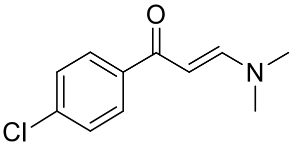
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 90 - 91 ºC. Yield 82%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.90 - 7.87 (m, 2H), 7.77 (d, *J* = 12.4 Hz, 1H), 6.90 - 6.87 (m, 1H), 5.69 (d, *J* = 12.4 Hz, 1H), 3.82 (s, 3H), 3.06 - 2.92 (m, 6H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 187.3, 161.9, 153.7, 133.0, 129.4, 113.2, 91.6, 55.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{12}H_{16}NO_2$: 206.1181. Found: 206.1182.

(*E*)-3-(Dimethylamino)-1-(4-fluorophenyl)prop-2-en-1-one (1e):



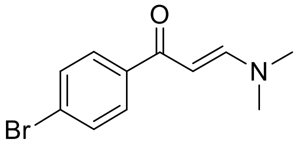
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 83 - 84 ºC. Yield 88%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.93 - 7.90 (m, 2H), 7.81 (d, *J* = 12.4 Hz, 1H), 7.10 - 7.05 (m, 2H), 5.67 (d, *J* = 12.4 Hz, 1H), 3.15 (s, 3H), 2.93 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 187.0, 165.7, 163.2, 154.3, 136.6 (*J* = 3.0 Hz), 129.7 (*J* = 9.0 Hz), 114.9 (*J* = 21 Hz), 91.6, 45.0, 37.2; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{11}H_{13}FNO$: 194.0981. Found: 194.0984.

(*E*)-1-(4-Chlorophenyl)-3-(dimethylamino)prop-2-en-1-one (1f):



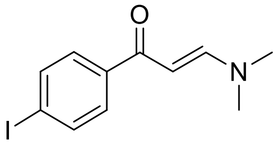
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 88 - 89 ºC. Yield 83%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.86 - 7.83 (m, 2H), 7.80 (d, *J* = 12.4 Hz, 1H), 7.39 - 7.35 (m, 2H), 5.66 (d, *J* = 12.4 Hz, 1H), 3.15 (s, 3H), 2.92 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 187.1, 154.5, 138.8, 136.9, 128.9, 128.2, 91.6, 45.0; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{11}H_{13}ClNO$: 210.0686. Found: 210.0690.

(*E*)-1-(4-Bromophenyl)-3-(dimethylamino)prop-2-en-1-one (1g):



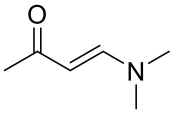
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 82 - 83 ºC. Yield 84%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.80 (d, J = 12.4 Hz, 1H), 7.78 - 7.76 (m, 2H), 7.54 - 7.52 (m, 2H), 5.65 (d, J = 12.0 Hz, 1H), 3.14 (s, 3H), 2.92 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 187.1, 154.5, 139.2, 131.2, 129.1, 125.4, 91.6, 45.0, 37.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{11}H_{13}BrNO$: 254.0181. Found: 254.0184.

(*E*)-3-(Dimethylamino)-1-(4-iodophenyl)prop-2-en-1-one (1h):



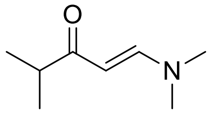
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 121 - 122 ºC. Yield 65%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.78 (d, J = 12.4 Hz, 1H), 7.75 - 7.73 (m, 2H), 7.63 - 7.61 (m, 2H), 5.64 (d, J = 12.4 Hz, 1H), 3.12 (s, 3H), 2.90 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 187.1, 154.4, 139.7, 129.0, 97.7, 91.4, 45.0, 37.2; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{11}H_{13}INO$: 302.0042. Found: 302.0039.

(*E*)-4-(Dimethylamino)but-3-en-2-one (1j):



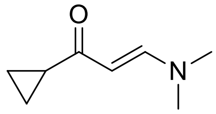
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 57 %; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.48 (d, J = 12.8 Hz, 1H), 5.05 (d, J = 12.8 Hz, 1H), 2.96 - 2.90 (m, 6H), 2.10 (s, 3H); HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_6H_{12}NO$: 114.0919, Found: 114.0924.

(*E*)-1-(Dimethylamino)-4-methylpent-1-en-3-one (1k):



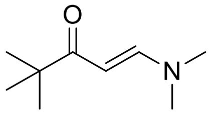
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 62 %; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.57 (d, J = 12.6 Hz, 1H), 5.05 (d, J = 12.6 Hz, 1H), 2.96 - 2.80 (m, 6H), 2.60 - 2.51 (m, 1H), 1.10 (d, J = 3.3 Hz, 6H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 202.3, 152.6, 93.6, 39.5, 19.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for Calcd for $C_8H_{16}NO$: 142.1232, Found: 142.1224

(*E*)-1-Cyclopropyl-3-(dimethylamino)prop-2-en-1-one (1l):



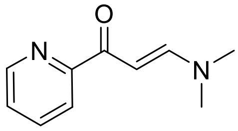
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 58 %; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.56 (d, J = 12.6 Hz, 1H), 5.20 (d, J = 12.6 Hz, 1H), 2.95 (d, 6H), 1.83 - 1.75 (m, 1H), 1.03 - 0.98 (m, 2H), 0.77 - 0.71 (m, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 197.2, 151.7, 95.8, 44.7, 37.1, 19.8, 9.1; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_8H_{14}NO$: 141.2108. Found: 141.2112.

(*E*)-1-(Dimethylamino)-4,4-dimethylpent-1-en-3-one (1m):



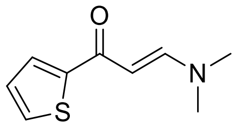
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 47 %; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.60 (d, J = 12.4 Hz, 1H), 5.24 (d, J = 12.4 Hz, 1H), 2.94 (s, 6H), 1.15 (s, 9H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 203.6, 153.2, 90.5, 41.9, 27.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_9H_{18}NO$: 156.1388, found: 156.1389.

(*E*)-3-(Dimethylamino)-1-(pyridin-2-yl)prop-2-en-1-one (1n):



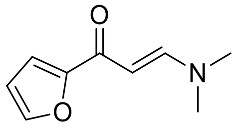
The title compound was prepared according to the general procedure. The product was obtained as yellow solid. Mp. 124 - 125 ºC. Yield 71%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 8.64 - 8.62 (m, 1H), 8.15 (d, 1H), 7.92 (d, *J* = 12.7 Hz, 1H), 7.83 - 7.77 (m, 1H), 7.38 - 7.34 (m, 1H), 6.45 (d, *J* = 12.7 Hz, 1H), 3.18 (s, 3H), 3.00 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 186.7, 156.0, 154.6, 148.1, 136.6, 125.3, 121.9, 90.9, 45.0, 37.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{10}H_{13}N_2O$: 178.2310. Found: 178.2314.

(*E*)-3-(Dimethylamino)-1-(thiophen-2-yl)prop-2-en-1-one (1o):



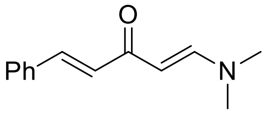
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 117 - 118 ºC. Yield 79%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.76 (d, *J* = 12.4 Hz, 1H), 7.62 - 7.61 (m, 1H), 7.47 - 7.45 (m, 1H), 7.08 - 7.06 (m, 1H), 5.62 (d, *J* = 12.0 Hz, 1H), 3.10 (s, 3H), 2.90 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 180.6, 153.4, 147.3, 130.0, 128.2, 127.4, 91.5, 44.8, 37.1; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_9H_{12}NOS$: 182.0640. Found: 182.0640.

(*E*)-3-(Dimethylamino)-1-(furan-2-yl)prop-2-en-1-one (1p):



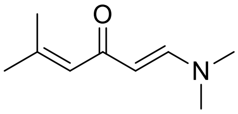
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 80 - 81 ºC. Yield 81%; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.80 (d, *J* = 12.4 Hz, 1H), 7.49 (s, 1H), 7.06 (d, *J* = 2.8 Hz, 1H), 6.48 (s, 1H), 5.68 (d, *J* = 12.8 Hz, 1H), 3.14 (s, 3H), 2.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 177.4, 154.7, 153.5, 144.1, 113.3, 111.7, 91.4, 44.9, 37.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_9H_{12}NO_2$: 166.0868. Found: 166.0869.

(1*E*, 4*E*)-1-(Dimethylamino)-5-phenylpenta-1, 4-dien-3-one (1q):



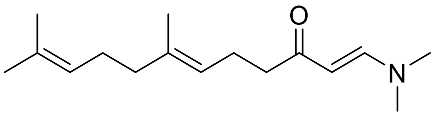
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 99 - 100 ºC. Yield 78%; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.75 (d, *J* = 12.4 Hz, 1H), 7.59 - 7.54 (m, 3H), 7.38 - 7.32 (m, 3H), 6.79 (d, *J* = 12.8 Hz, 1H), 5.28 (d, *J* = 12.8 Hz, 1H), 3.12 (s, 3H), 2.88 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 186.2, 153.3, 138.3, 135.7, 129.1, 128.6, 128.2, 127.8, 96.3, 44.9, 37.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{13}H_{16}NO$: 202.1232. Found: 202.1229.

(*E*)-1-(Dimethylamino)-5-methylhexa-1, 4-dien-3-one (1r):



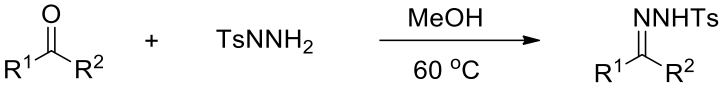
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 43 %; ^{1}H NMR (300 MHz, $CDCl_3$) *δ* 7.54 (d, *J* = 12.6 Hz, 1H), 5.97 - 5.96 (t, *J* = 0.9 Hz, 1H), 5.06 (d, *J* = 12.6 Hz, 1H), 2.96 - 2.94 (m, 6H), 2.14 (d, *J* = 0.9 Hz, 3H), 1.85 (d, *J* = 0.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 189.1, 152.7, 149.0, 125.9, 98.2, 58.3, 27.4, 20.3, 18.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_9H_{16}NO$: 155.2374. Found: 155.2370.

(1*E*, 6*E*)-1-(Dimethylamino)-6, 11-dimethyldodeca-1, 6, 10-trien-3-one (1s):



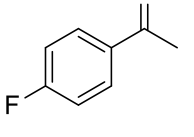
The title compound was prepared according to the general procedure. The product was obtained as yellow oil. Yield 72%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, J = 12.8 Hz, 1H), 5.17 - 5.03 (m, 2H), 5.03 (d, J = 12.4 Hz, 1H), 3.00 - 2.84 (m, 6H), 2.36 - 2.29 (m, 4H), 2.06 - 2.03 (m, 3H), 1.99 - 1.97 (m, 1H), 1.62 - 1.59 (m, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.6, 197.5, 152.1, 135.5, 135.3, 131.3, 131.1, 124.4, 124.2, 123.6, 95.7, 41.5, 39.6, 31.8, 26.6, 26.5, 25.6, 24.2, 24.1, 23.3, 17.5, 17.5; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{16}H_{28}NO$: 250.2171. Found: 250.2177.

General procedure for the synthesis of hydrazone:



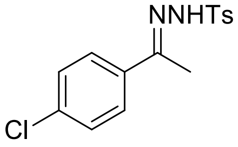
A solution of pure $TsNHNH_2$ (5 mmol) in methanol (5 mL) was stirred at 60 °C until the $TsNHNH_2$ was completely dissolved. The mixture was cooled to room temperature. Then carbonyl compounds were dropped to the mixture slowly. After approximately 5 minutes the crude products could be obtained as solid precipitations. The precipitations were washed by petroleum ether then kept in vacuo to give the pure products.

N'-(1-(4-Fluorophenyl)ethylidene)-4-methylbenzenesulfonohydrazide (2b):



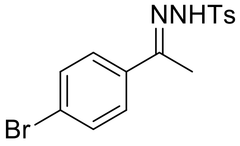
The title compound was prepared according to the general procedure. The product was obtained as white solid in a *cis* : *trans* of 7 : 93. Mp. 150 - 151 °C. Yield: 90%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 - 7.97 & 7.92 - 7.90 (m, 2H), 7.81 - 7.79 & 7.65 - 7.62 (m, 2H), 7.61 - 7.59 (m, 1H), 7.38 - 7.32 (m, 2H), 7.17 - 7.11 & 7.05 - 7.00 (m, 2H), 2.60 & 2.42 (s, 3H), 2.46 & 2.13 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.8, 162.3, 151.8, 144.2, 135.2, 133.4, 129.6, 128.2 (d, J = 8.4 Hz), 128.0, 115.2 (d, J = 21.56Hz), 21.5, 13.5; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{15}H_{16}FN_2O_2S$: 308.3711. Found: 308.3715.

N'-(1-(4-Chlorophenyl)ethylidene)-4-methylbenzenesulfonohydrazide (2c):



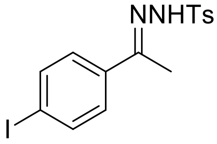
The title compound was prepared according to the general procedure. The product was obtained as white solid in a *cis* : *trans* of 7 : 93. Mp. 166 - 167 ºC. Yield: 85%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 - 7.89 & 7.81 - 7.79 (m, 2H), 7.75 & 7.60 - 7.59 (m, 1H), 7.58 - 7.57 & 7.45 - 7.42 (m, 2H), 7.38 - 7.36 & 7.34 - 7.30 (m, 4H), 2.60 & 2.42 (s, 3H), 2.46 & 2.12 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.4, 144.3, 135.7, 135.5, 135.2, 129.6, 128.4, 128.0, 127.5, 21.6, 13.4; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{15}H_{16}ClN_2O_2S$: 324.8257. Found: 324.8253.

N'-(1-(4-Bromophenyl)ethylidene)-4-methylbenzenesulfonohydrazide (2d):



The title compound was prepared according to the general procedure. The product was obtained as yellow solid in a *cis* : *trans* of 13 : 87. Mp. 185 - 186 ºC. Yield: 86%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 - 7.89 & 7.83 - 7.79 (m, 2H), 7.62 - 7.60 & 7.57 (m, 1H), 7.53 - 7.51 (m, 2H), 7.48 - 7.46 (m, 2H), 7.38 - 7.36 & 7.34 - 7.32 (m, 2H), 2.59 & 2.42 (s, 3H), 2.46 & 2.12 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.4, 144.3, 136.1, 135.2, 131.4, 129.6, 128.1, 127.8, 123.9, 21.6, 13.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{15}H_{16}BrN_2O_2S$: 369.2767. Found: 369.2769.

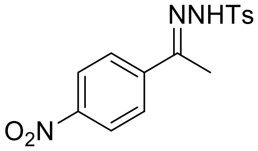
N'-(1-(4-Iodophenyl)ethylidene)-4-methylbenzenesulfonohydrazide (2e):



The title compound was prepared according to the general procedure. The product was obtained as white solid in a *cis* : *trans* of 4 : 96. Mp. 199 - 200 ºC. Yield: 84%. ^{1}H NMR (400

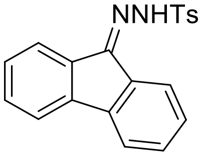
MHz, $CDCl_3$) δ 7.90 - 7.88 & 7.81 - 7.80 (m, 2H), 7.79 - 7.78 & 7.69 - 7.67 (m, 2H), 7.53 - 7.51 (m, 2H), 7.49 (s, 1H), 7.39 - 7.36 (m, 2H), 7.33 - 7.31 (m, 2H), 2.46 & 2.42 (s, 3H), 2.17 & 2.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 151.3, 144.3, 137.5, 136.7, 135.2, 129.6, 128.1, 127.9, 96.0, 21.6, 13.1; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{15}H_{16}IN_2O_2S$: 416.2772. Found: 416.2774.

4-Methyl-N'-(1-(4-nitrophenyl)ethylidene)benzenesulfonohydrazide (2j):



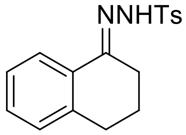
The title compound was prepared according to the general procedure. The product was obtained as white solid in a *cis* : *trans* of 5 : 95. Mp. 196 - 197 ºC. Yield: 91%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.32 - 8.31 & 8.22 - 8.19 (m, 2H), 8.12 - 8.10 & 7.92 - 7.90 (m, 2H), 7.82 - 7.80 (m, 3H), 7.36 - 7.34 (m, 2H), 2.69 & 2.43 (s, 3H), 2.19 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.3, 148.2, 144.7, 143.0, 135.0, 129.8, 128.1, 127.0, 123.6, 21.6, 13.3; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{15}H_{16}N_3O_4S$: 335.3782. Found: 335.3781.

N'-(9H-fluoren-9-ylidene)-4-methylbenzenesulfonohydrazide (2o):



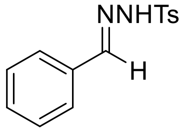
The title compound was prepared according to the general procedure. The product was obtained as yellow solid. Mp. 181 - 182 ºC. Yield: 95%. ^1H NMR (400 MHz, $CDCl_3$) δ 8.42 (s, 1H), 7.99 - 7.97 (m, 2H), 7.87 - 7.85 (m, 1H), 7.70 - 7.68 (m, 1H), 7.63 - 7.61 (m, 1H), 7.52 - 7.51 (m, 1H), 7.45 - 7.41 (m, 1H), 7.36 - 7.29 (m, 4H), 7.26 – 7.23 (m, 1H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.6, 144.6, 142.5, 139.7, 136.3, 134.6, 131.7, 130.4, 129.6, 129.5, 128.4, 128.2, 128.1, 126.3, 122.2, 120.8, 119.7, 21.6; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{20}H_{17}N_2O_2S$: 350.4341. Found: 350.4244.

N'-(3,4-Dihydronaphthalen-1(2*H*)-ylidene)-4-methylbenzenesulfonohydrazide (2p):



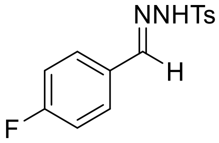
The title compound was prepared according to the general procedure. The product was obtained as white solid. Mp. 183 - 184 ºC. Yield: 82%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.99 - 7.97 (m, 1H), 7.94 - 7.92 (m, 2H), 7.70 (s, 1H), 7.33 - 7.31 (m, 2H), 7.24 - 7.17 (m, 2H), 7.09 - 7.08 (m, 1H), 2.72 - 2.69 (m, 2H), 2.48 - 2.44 (m, 2H), 2.41 (s, 3H), 1.91 - 1.85 (m, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 152.7, 144.1, 139.8, 135.4, 131.5, 129.6, 128.3, 128.1, 126.4, 125.0, 29.2, 25.4, 21.6, 21.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{17}H_{19}N_2O_2S$: 316.4179. Found: 316.4177.

(*E*)-N'-benzylidene-4-methylbenzenesulfonohydrazide (2q):



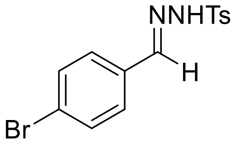
The title compound was prepared according to the general procedure. The product was obtained as white solid. Mp. 127 - 128 ºC. Yield: 95%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.67 (s, 1H), 7.90 - 7.87 (d, 2H), 7.80 (s, 1H), 7.60 - 7.50 (t, 2H), 7.40 - 7.20 (m, 5H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 148.1, 144.3, 135.2, 133.3, 130.4, 129.8, 128.6, 128.0, 127.4, 21.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{14}H_{15}N_2O_2S$: 276.3540. Found: 276.3543.

(*E*)-N'-(4-Fluorobenzylidene)-4-methylbenzenesulfonohydrazide (2r):



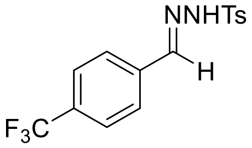
The title compound was prepared according to the general procedure. The product was obtained as white solid. Mp. 123 - 124 ºC. Yield: 80%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.09 (s, 1H), 7.89 - 7.86 (m, 2H), 7.75 - 7.73 (m, 1H), 7.59 - 7.54 (m, 2H), 7.34 - 7.31 (m, 2H), 7.07 - 7.01 (m, 2H), 2.41 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 165.2, 162.7, 147.0, 144.4, 135.1, 129.8, 129.5 (d, J = 12.1 Hz), 129.2 (d, J = 34.2 Hz), 127.9, 115.8 (d, J = 87.8 Hz), 21.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{14}H_{14}FN_2O_2S$: 294.3445. Found: 294.3447.

(*E*)-N'-(4-Bromobenzylidene)-4-methylbenzenesulfonohydrazide (2s):



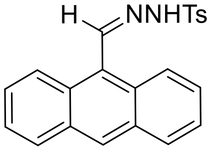
The title compound was prepared according to the general procedure. The product was obtained as white solid. Mp. 178 - 179 ºC. Yield: 80%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.03 (s, 1H), 7.88 - 7.85 (m, 2H), 7.70 (s, 1H), 7.50 - 7.42 (m, 4H), 7.33 - 7.30 (m, 2H), 2.41 (s, 3H) ; ^{13}C NMR (100 MHz, CDCl$_3$) δ 146.3, 144.5, 135.1, 132.1, 131.9, 129.8, 128.7, 127.9, 124.8, 21.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{14}H_{14}BrN_2O_2S$: 355.2501. Found: 355.2505.

(*E*)-4-Methyl-N'-(4-(trifluoromethyl)benzylidene)benzenesulfonohydrazide (2t):



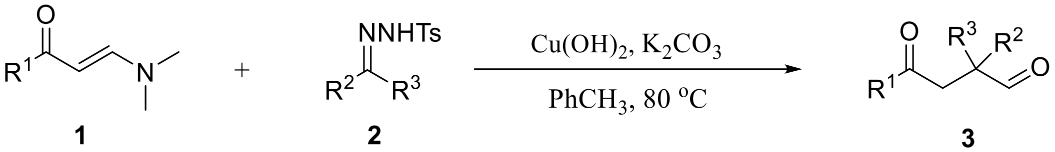
The title compound was prepared according to the general procedure. The product was obtained as white solid. Mp. 164 - 165 ºC. Yield: 87%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.97 (s, 1H), 7.89 - 7.86 (d, 2H), 7.77 (s, 1H), 7.71 - 7.60 (m, 4H), 7.35 - 7.32 (m, 2H), 2.42 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 145.7, 144.6, 136.5, 135.0, 131.9 (d, J = 128.6 Hz), 129.8, 127.9, 127.5, 125.6 (d, J = 14.5 Hz), 125.1, 122.4; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{15}H_{14}F_3N_2O_2S$: 344.3520. Found: 344.3521.

N'-(Anthracen-9-ylmethylene)-4-methylbenzenesulfonohydrazide (2u):



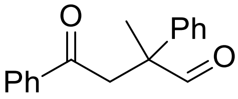
The title compound was prepared according to the general procedure. The product was obtained as yellow solid. Mp. 163 - 164 ºC. Yield%: 87%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.90 (s, 1H), 8.47(s, 1H), 8.23 - 8.19 (m, 3H), 8.00 - 7.97(m, 4H), 7.50 - 7.40 (m, 4H), 7.39 - 7.36 (m, 2H), 2.46 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 146.8, 144.5, 135.4, 131.1, 130.1, 130.0, 129.9, 128.9, 128.4, 127.0, 125.3, 124.6, 124.2, 21.7; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{22}H_{19}N_2O_2S$: 376.4714. Found: 376.4711.

General procedure for synthesis of 1, 4-ketoaldehydes:



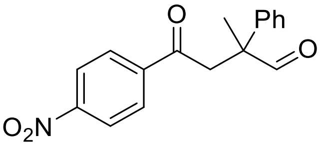
A mixture of **1a** (0.2 mmol, 1.0 equiv.), **2a** (0.6 mmol, 2.0 equiv.), K_2CO_3 (0.4 mmol, 2.0 equiv.), $Cu(OH)_2$ (0.02 mmol, 10 mol %) and solvent (4 mL) was sealed in a Schlenk tube under Ar protection at 80 °C and the mixture was stirred for 24h or until the **1a** was consumed completely. Then the reaction mixture was concentrated under reduced pressure and purified by column chromatography (hexane : ethyl acetate = 1 : 5) to give the desired product.

2-Methyl-4-oxo-2, 4-diphenylbutanal (3aa):



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 96%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.74 (s, 1H), 7.93 (d, J = 7.6 Hz, 2H), 7.58 - 7.54 (m, 1H), 7.46 - 7.43 (m, 2H), 7.39 - 7.28 (m, 5H), 3.78 - 3,68 (m, 2H), 1.68 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 197.2, 139.8, 136.8, 133.4, 128.9, 128.6, 128.1, 127.4, 126.9, 51.8, 46.1, 20.7; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{17}O_2$: 253.1229, Found: 253.1228.

2-Methyl-4-(4-nitrophenyl)-4-oxo-2-phenylbutanal (3ba):



The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 125 - 126 ºC. Yield 81%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.66 (s, 1H), 8.27 (d, *J* = 8.7 Hz, 2H), 8.04 (d, *J* = 8.8 Hz, 2H), 7.41 - 7.36 (m, 2H), 7.32 - 7.28 (m, 3H), 3.68 (s, 2H), 1.74, (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 195.9, 150.4, 141.2, 138.9, 129.1, 127.7, 126.9, 123.8, 52.1, 46.2, 20.0; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}NO_4$: 298.1079, Found: 298.1078.

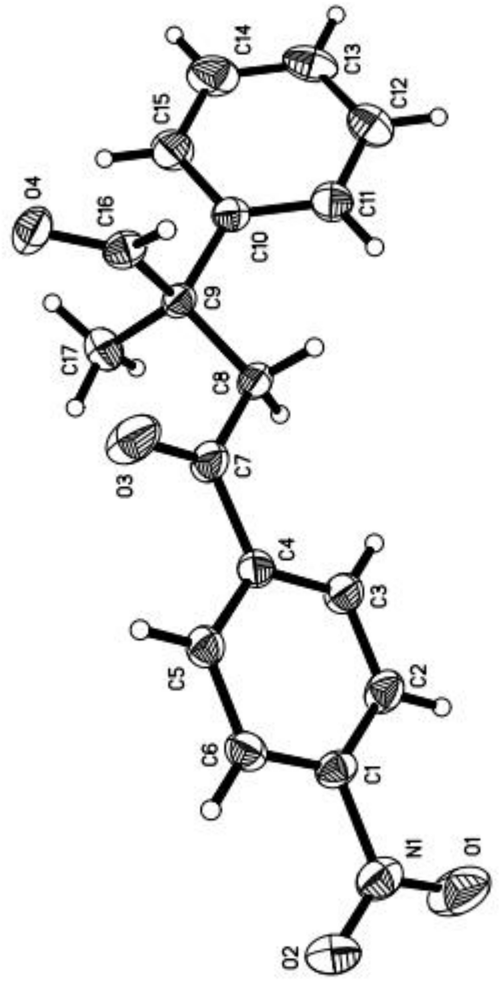
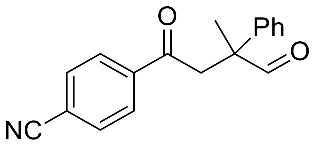


Table 1. Sample and crystal data for 3ba

Identification code	**3ba**
Chemical formula	$C_{17}H_{15}NO_4$

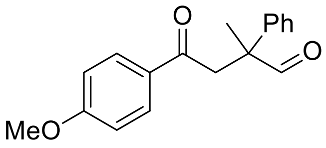
Formula weight	297.30 g/mol	
Temperature	173(2) K	
Wavelength	0.71073 Å	
Crystal size	0.150 x 0.170 x 0.370 mm	
Crystal system	monoclinic	
Space group	P 1 21/n 1	
Unit cell dimensions	a = 6.3645(5) Å	α = 90°
	b = 14.4689(12) Å	β = 99.228(3)°
	c = 15.7267(12) Å	γ = 90°
Volume	1429.5(2) $Å^3$	
Z	4	
Density (calculated)	1.381 g/cm^3	
Absorption coefficient	0.099 mm^{-1}	
F(000)	624	

4-(3-Methyl-4-oxo-3-phenylbutanoyl)benzonitrile (3ca):



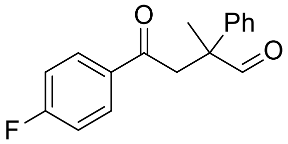
The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 127 - 128 ºC. Yield: 78%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (s, 1H), 7.98 (d, J = 8.3 Hz, 2H), 7.73 (d, J = 8.3, Hz, 2H), 7.40 - 7.36 (m, 2H), 7.31 - 7.27 (m, 3H), 3.69 - 3.64 (m, 2H), 1.72 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.9, 196.1, 139.8, 139.0, 132.8, 129.1, 128.5, 127.7, 126.9, 117.8, 116.5, 52.1, 46.0, 20.0; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{18}H_{16}NO_2$: 278.1181, Found: 278.1180.

4-(4-Methoxyphenyl)-2-methyl-4-oxo-2-phenylbutanal (3da):



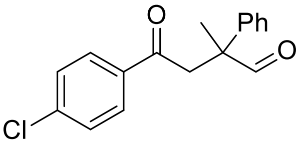
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 104 - 105 ºC. Yield: 97%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.75 (s, 1H), 7.93 - 7.91 (d, J = 8.8 Hz, 2H), 7.39 - 7.35 (m, 2H), 7.34 - 7.32 (m, 2H), 7.30 - 7.28 (m, 1H), 6.93 - 6.90 (m, 2H), 3.86 (s, 3H), 3.73 – 3.64 (m, 2H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.6, 195.7, 163.7, 139.9, 130.4, 129.8, 128.9, 127.3, 126.9, 113.7, 55.5, 51.8, 45.7, 20.9; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{18}H_{19}O_3$: 283.1334, Found: 278.1331.

4-(4-Fluorophenyl)-2-methyl-4-oxo-2-phenylbutanal (3ea):



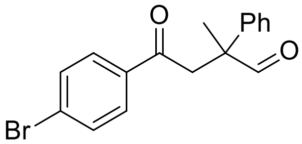
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 90%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.71 (s, 1H), 7.97 - 7.94 (m, 2H), 7.40 - 7.36 (m, 2H), 7.33 - 7.27 (m, 3H), 7.14 - 7.08 (m, 2H), 3.73 - 3.63 (m, 2H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.4, 195.7, 165.9 (d, J = 253.8 Hz), 139.6, 133.3 (d, J = 3.3 Hz), 130.8 (d, J = 9.3 HZ), 129.0, 127.5, 126.9, 115.7 (d, J = 21.8 Hz), 51.9, 45.9, 20.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{17}H_{16}O_2F$: 271.1134, Found: 271.1140.

4-(4-Chlorophenyl)-2-methyl-4-oxo-2-phenylbutanal (3fa):



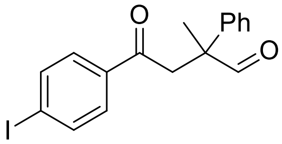
The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 70 - 71 ºC. Yield: 91%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.70 (s, 1H), 7.87 - 7.84 (m, 2H), 7.43 - 7.39 (m, 2H), 7.37 - 7.36 (m, 2H), 7.32 - 7.27 (m, 3H), 3.71 - 3.62 (m, 2H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.3, 196.0, 139.8, 139.5, 135.2, 129.5, 129.0, 128.9, 127.5, 126.9, 51.9, 45.9, 20.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2Cl$: 287.0839. Found: 287.0837.

4-(4-Bromophenyl)-2-methyl-4-oxo-2-phenylbutanal (3ga):



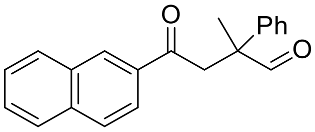
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 70 - 71 ºC. Yield: 97%. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 9.70 (s, 1H), 7.79 - 7.76 (m, 2H), 7.59 - 7.56 (m, 2H), 7.39 - 7.36 (m, 2H), 7.32 - 7.26 (m, 3H), 3.70 - 3.61 (m, 2H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 201.2, 196.2, 139.8, 139.4, 135.6, 131.9, 129.6, 129.0, 128.5, 127.5, 126.8, 51.9, 45.8, 20.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2Br$: 331.0334. Found: 331.0329.

4-(4-Iodophenyl)-2-methyl-4-oxo-2-phenylbutanal (3ha):



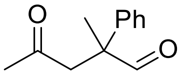
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 69 - 70 ºC, Yield: 82%. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 9.69 (s, 1H), 7.8 (d, *J* = 8 Hz, 2H), 7.62 (d, *J* = 8.3 Hz, 2H), 7.39 - 7.35 (m, 2H), 7.31 - 7.28 (m, 3H), 3.69 - 3.60 (m, 2H), 1.68 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 201.2, 196.5, 139.4, 137.9, 136.1, 129.4, 129.0, 127.5, 126.8, 101.3, 51.9, 45.8, 20.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_9H_{12}NO_2$: 379.0195. Found: 379.0199.

2-Methyl-4-(naphthalen-2-yl)-4-oxo-2-phenylbutanal (3ia):



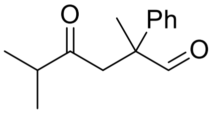
The title compound was prepared according to the general procedure. The product was obtained as canary yellow solid, Mp. 102 - 103 ºC, Yield: 94 %. ^{1}H NMR (400 MHz, CDCl$_3$) *δ* 9.80 (s, 1H), 8.46 (s, 1H), 8.00 - 7.93 (m, 2H), 7.87 (d, *J* = 8 Hz, 2H), 7.63 - 7.54 (m, 2H), 7.39 - 7.38 (m, 4H), 7.32 - 7.28 (m, 1H), 3.87 (s, 2H), 1.73 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) *δ* 201.6, 197.2, 139.8, 135.7, 134.2, 132.4, 130.0, 129.6, 129.0, 128.7, 128.5, 127.8, 127.5, 127.0, 126.9, 123.7, 52.0, 46.1, 20.7; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{21}H_{19}O_2$: 303.1385, Found: 303.1383.

2-Methyl-4-oxo-2-phenylpentanal (3ja):



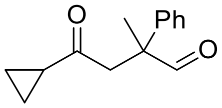
The title compound was prepared according to the general procedure. The product was obtained as pale oil, Yield 70%; ^{1}H NMR (300 MHz, CDCl$_3$) ^{1}H NMR (400 MHz, CDCl$_3$) *δ* 9.56 (s, 1H), 7.30 - 7.35 (m, 2H), 7.35 - 7.31 (m, 1H), 7.28 - 7.26 (m, 3H), 3.20 - 3.0 (m, 2H), 2.08 (s, 3H), 1.62 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) *δ* 206.0, 201.0, 139.2, 129.0, 127.5, 126.8, 51.9, 50.4, 31.0, 19.8; HRMS (ESI) m/z [M+H]$^+$: Calcd for: $C_{12}H_{15}O_2$: 191.1072 Found: 191.1078.

2, 5-Dimethyl-4-oxo-2-phenylhexanal (3ka):



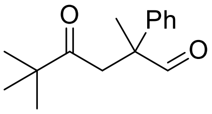
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield 54%; ^{1}H NMR (300 MHz, CDCl$_3$) *δ* 9.62 (s, 1H), 7.41 - 7.36 (m, 2H), 7.31 - 7.27 (m, 3H), 3.25 - 3.11 (m, 2H), 2.60 - 2.51 (m, 1H), 1.61 (s, 3H), 1.09 (d, *J* = 6.9 Hz, 3H), 1.04 (d, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 211.9, 201.2, 139.6, 128.9, 127.4, 126.8, 51.7, 47.7, 41.3, 20.2, 18.0, 17.9; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{14}H_{19}O_2$: 219.1385, Found: 219.1378.

4-Cyclopropyl-2-methyl-4-oxo-2-phenylbutanal (3la):



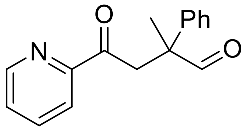
The title compound was prepared according to the general procedure. The product was obtained as colorless oil, Yield 58%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.60 (s, 1H), 7.39 - 7.35 (m, 2H), 7.30 - 7.25 (m, 3H), 3.32 - 3.23 (m, 2H), 1.88 - 1.79 (m, 1H), 1.58 (s, 3H), 1.03 - 0.89 (m, 2H), 0.87- 0.74 (m, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 208.1, 201.0, 139.5, 128.9, 127.4, 126.9, 51.8, 50.5, 21.3, 20.2, 11.1, 11.08; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{14}H_{17}O_2$: 217.1229, Found: 217.1232.

2, 5, 5-Trimethyl-4-oxo-2-phenylhexanal (3ma):



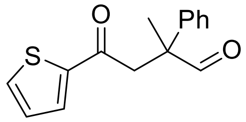
The title compound was prepared according to the general procedure. The product was obtained as colorless oil, Yield 29%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.64 (s, 1H), 7.39 - 7.34 (m, 2H), 7.29 - 7.24 (m, 3H), 3.27 - 3.20 (m, 2H), 1.56 (s, 3H), 1.12 (s, 9H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 213.2, 201.4, 139.9, 128.8, 127.3, 126.8, 51.5, 44.7, 44.2, 26.2, 20.4; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{15}H_{21}O_2$: 233.1542, Found: 233.1546.

2-Methyl-4-oxo-2-phenyl-4-(pyridin-2-yl)butanal (3na):



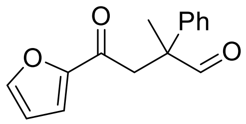
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield 61%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.78 (s, 1H), 8.68 - 8.66 (m, 1H), 7.99 - 7.96 (m, 1H), 7.84 - 7.79 (m, 1H), 7.49 - 7.45 (m, 1H), 7.37 (d, J = 4.2 Hz, 4H), 7.29 - 7.25 (m, 2H), 4.07 - 3.98 (m, 2H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.7, 199.2, 153.2, 148.9, 140.0, 137.0, 128.8, 127.4, 127.3, 127.0, 121.8, 52.0, 44.6, 21.0; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{16}H_{16}NO_2$: 254.1181, Found: 254.1185.

2-Methyl-4-oxo-2-phenyl-4-(thiophen-2-yl)butanal (3oa):



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield 88%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.68 (s, 1H), 7.68 - 7.67 (m, 1H), 7.63 - 7.61 (m,1H), 7.42 - 7.25 (m, 5H), 7.11 - 7.08 (m, 1H), 3.65 - 3.59 (m 2H), 1.68 (s, 1H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 200.9, 190.2, 144.2, 139.3, 134.1, 132.3, 129.0, 128.2, 127.5, 126.9, 52.1, 46.3, 20.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{15}H_{15}O_2S$: 259.0793, Found: 259.0794.

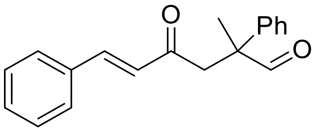
4-(Furan-2-yl)-2-methyl-4-oxo-2-phenylbutanal (3pa):



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield 93%; ^{1}H NMR (300 MHz, CDCl$_3$) δ 9.67 (s, 1H), 7.54 - 7.53 (m, 1H), 7.39 - 7.27 (m, 5H), 7.14 - 7.13 (m, 1H), 6.51 - 6.49 (m, 1H), 3.54 - 3.53 (m, 2H), 1.66

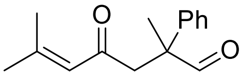
(s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.9, 186.5, 152.7, 146.5, 139.3, 128.9, 127.5, 126.9, 117.4, 112.4, 52.1, 45.1, 20.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{15}H_{14}O_3$: 243.1021, Found: 243.1018.

(*E*)-2-Methyl-4-oxo-2, 6-diphenylhex-5-enal (3qa):



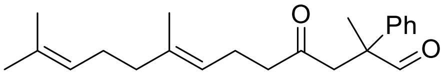
The title compound was prepared according to the general procedure. The product was obtained as colorless oil, Yield: 64 %. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.66 (s, 1H), 7.50 (d, J = 16.2 Hz, 1H), 7.49 - 7.47 (m, 2H), 7.40 - 7.37 (m, 5H), 7.33 - 7.27 (m, 3H), 6.63 (d, J = 16.2 Hz, 1H), 3.39 – 3.35 (m, 2H), 1.64 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.1, 197.3, 143.2, 139.5, 134.3, 130.7, 128.9, 128.4, 127.5, 127.0, 126.1, 52.1, 48.2, 20.2. HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{19}H_{19}O_2$: 279.1385, Found: 279.1381.

2, 6-Dimethyl-4-oxo-2-phenylhept-5-enal (3ra):



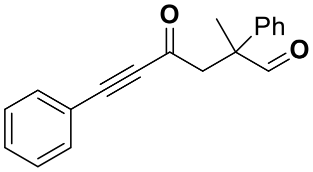
The title compound was prepared according to the general procedure. The product was obtained as pale oil, Yield 52%; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.66 (S, 1H), 7.39 - 7.34 (m, 2H), 7.29 - 7.24 (m, 3H), 6.02 – 6.01 (m, 1H), 3.23 - 3.08 (m, 2H), 2.09 (d, J = 0.6 Hz, 3H), 1.85 (d, J = 0.9 Hz, 3H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.4, 197.7, 156.8, 139.8, 128.8, 127.3, 126.9, 123.7, 52.0, 51.2, 27.7, 20.8, 20.6; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{14}H_{16}O_2$: 231.1385, Found: 231.1392.

(*E*)-2, 7, 12-Trimethyl-4-oxo-2-phenyltrideca-7, 11-dienal (3sa):



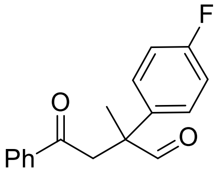
The title compound was prepared according to the general procedure. The product was obtained as colorless oil, Yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.57 (s, 1H), 7.39 - 7.45 (t, 2H), 7.30 - 7.24 (m, 3H), 5.08 - 5.05 (m, 1H), 5.02 - 4.98 (t, 1H), 3.15 - 3.03 (m, 2H), 2.45 - 2.37 (m, 1H), 2.34 - 2.27 (m, 1H), 2.22 - 2.17 (m, 2H), 2.06 - 2.01 (m, 2H), 1.96 - 1.93 (m, 2H), 1.67 (s, 3H), 1.60 - 1.59 (d, 6H), 1.57 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 208.1, 201.1, 139.4, 136.5, 131.4, 128.9, 127.5, 126.8, 124.2, 122.3, 51.9, 49.7, 43.7, 39.6, 26.6, 25.7, 22.3, 20.0, 17.7, 16.0. HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{22}H_{31}O_2$: 327.2324, Found; 327.2322.

2-Methyl-4-oxo-2,6-diphenylhex-5-ynal (3ta):



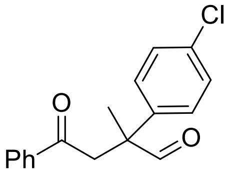
The title compound was prepared according to the general procedure. The product was obtained as pale brown oil, Yield: 41%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (s, 1H), 7.49 - 7.47(d, 2H), 7.45 - 7.43 (m, 1H), 7.41 - 7.38 (m, 2H), 7.38 - 7.34 (m, 2H), 7.33 (s, 1H), 7.31 - 7.28 (m, 2H), 3.40 - 3.46 (m, 2H), 1.68 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.20, 184.5, 139.4, 138.5, 133.1, 129.0, 128.6, 127.7, 127.1, 119.7, 91.5, 88.2, 52.3, 52.0, 19.6. HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{19}H_{17}O_2$: 277.1229, Found: 277.1225.

2-(4-Fluorophenyl)-2-methyl-4-oxo-4-phenylbutanal (3ab):



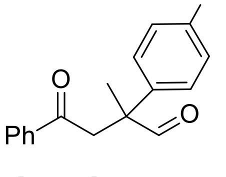
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 71%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.70 (s, 1H), 7.94 - 7.92(m, 2H), 7.59 - 7.56 (m, 1H), 7.47 - 7.43 (m, 2H), 7.32 - 7.29 (m, 2H), 7.08 - 7.04 (m, 2H), 3.70(s, 2H), 1.67 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.1, 197.0, 161.9 (d, J = 245.6 Hz), 136.6, 135.3 (d, J = 3.1 Hz), 133.4, 128.6 (d, J = 7.8 Hz), 128.6, 128.0, 115.7 (d, J = 21.3 Hz), 51.3, 46.1, 20.8; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2$ F: 271.1134. Found: 271.1139.

2-(4-Chlorophenyl)-2-methyl-4-oxo-4-phenylbutanal (3ac):



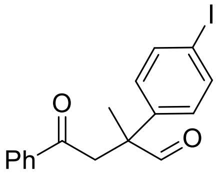
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 92%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.71 (s, 1H), 7.94 - 7.92 (m, 2H), 7.59 - 7.55 (m, 1H), 7.47 - 7.44 (m, 2H), 7.35 - 7.32 (m, 2H), 7.28 - 7.27 (m, 1H), 7.26 - 7.25 (m, 1H), 3.70 (s, 2H), 1.66 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 196.9, 138.3, 136.6, 133.5, 133.4, 129.0, 128.7, 128.3, 128.1, 51.4, 46.1, 20.9; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2Cl$: 287.0839. Found: 287.0838.

2-(4-Bromophenyl)-2-methyl-4-oxo-4-phenylbutanal (3ad):



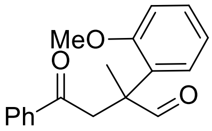
The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 54 - 55 ºC. Yield: 89%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.71 (s, 1H), 7.94 - 7.92(m, 2H), 7.60 - 7.56 (m, 1H), 7.50 - 7.44 (m, 4H), 7.22 - 7.20 (m, 2H), 3.71(s, 2H), 1.66 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 196.8, 138.9, 136.6, 133.5, 132.0, 128.7, 128.1, 121.6, 51.5, 46.0, 20.8; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2Br$: 331.0334. Found: 331.0336.

2-(4-Iodophenyl)-2-methyl-4-oxo-4-phenylbutanal (3ae):



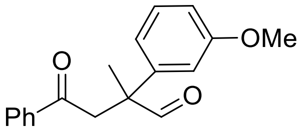
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 78 - 79 ºC. Yield: 70%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.70 (s, 1H), 7.93 - 7.91(m, 2H), 7.70 - 7.68 (m, 2H), 7.60 - 7.56 (m, 1H), 7.47 - 7.44 (m, 2H), 7.10 - 7.07 (m, 2H), 3.70(s, 2H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.0, 196.8, 139.6, 136.6, 133.5, 128.9, 128.7, 128.1, 93.2, 51.5, 46.0, 20.8; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2I$: 379.0195. Found: 379.0200.

2-(2-Methoxyphenyl)-2-methyl-4-oxo-4-phenylbutanal (3af):



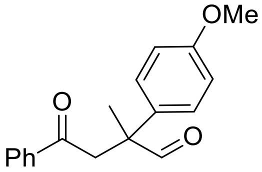
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 98 - 99 ºC. Yield: 95%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.74 (s, 1H), 7.88 - 7.86(m, 2H), 7.53 - 7.50 (m, 1H), 7.41 - 7.38 (m, 2H), 7.47 - 7.44 (m, 2H), 7.30 - 7.23 (m, 2H), 3.79 (s, 3H), 3.74 - 3.69 (m, 2H); 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 203.5, 198.4, 156.2, 137.2, 133.0, 128.9, 128.4, 128.1, 128.0, 121.1, 111.1, 55.3, 50.2, 43.9, 20.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{18}H_{19}O_3$: 283.1334. Found: 283.1336.

2-(3-Methoxyphenyl)-2-methyl-4-oxo-4-phenylbutanal (3ag):



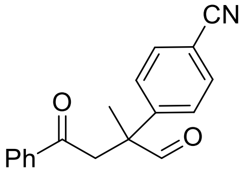
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 84%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.72 (s, 1H), 7.95 - 7.92(m, 2H), 7.59 - 7.54 (m, 1H), 7.47 - 7.43 (m, 2H), 7.31 - 7.27 (m, 1H), 6.92 - 6.90 (m, 1H), 6.88 - 6.86 (m, 2H), 6.82 - 6.80 (m, 1H) 3.78 (s, 3H), 3.72 - 3.71 (m, 2H), 1.66 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.3, 197.2, 159.9, 141.4, 136.7, 133.3, 129.9, 128.6, 128.1, 119.1, 113.3, 112.1, 55.2, 51.8, 46.0, 20.7; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{18}H_{19}O_3$: 283.1334. Found: 283.1335.

2-(4-Methoxyphenyl)-2-methyl-4-oxo-4-phenylbutanal (3ah):



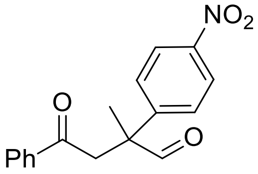
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 66 - 67 °C. Yield: 76%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.66 (s, 1H), 7.95 – 7.92(m, 2H), 7.59 - 7.55 (m, 1H), 7.47 - 7.43 (m, 2H), 7.25 - 7.23 (m, 2H), 6.92 – 6.88 (m, 2H), 3.80 (s, 3H), 3.69 (s, 2H), 1.66 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.3, 197.4, 158.8, 136.8, 133.3, 131.3, 128.6, 128.1, 114.3, 55.3, 51.1, 45.9, 20.5; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{18}H_{19}O_3$: 283.1334. Found: 283.1336.

4-(2-Methyl-1,4-dioxo-4-phenylbutan-2-yl)benzonitrile (3ai):



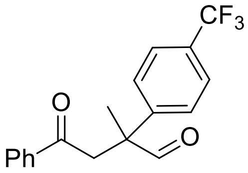
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp. 90 - 91 ºC. Yield: 43%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.76 (s, 1H), 7.94 - 7.92 (m, 2H), 7.68 - 7.66 (m, 2H), 7.49 - 7.46 (m, 4H), 3.77 (s, 2H), 1.69 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 200.6, 196.4, 145.5, 136.2, 133.7, 132.5, 128.8, 128.1, 127.8, 118.4, 111.3, 52.0, 46.2, 21.2; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{18}H_{16}NO_2$: 278.1181. Found: 278.1182.

2-Methyl-2-(4-nitrophenyl)-4-oxo-4-phenylbutanal (3aj):



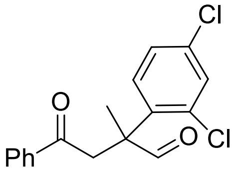
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp.136 - 137 ºC. Yield: 68%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.80 (s, 1H), 8.24 – 8.21 (m, 2H), 7.94 - 7.92 (m, 2H), 7.62 - 7.58 (m, 2H), 7.54 - 7.51 (m, 2H), 7.49 – 7.45 (m, 2H), 3.80 (s, 2H), 1.72 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 200.4, 196.3, 147.5, 147.0, 136.2, 133.8, 128.8, 128.1, 128.0, 123.9, 52.0, 46.4, 21.5; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{17}H_{16}NO_4$: 298.1079. Found: 298.1089.

2-Methyl-4-oxo-4-phenyl-2-(4-(trifluoromethyl)phenyl)butanal (3ak):



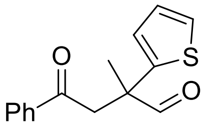
The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 60 - 61 ºC. Yield: 73%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.78 (s, 1H), 7.95 - 7.92 (m, 2H), 7.64 - 7.61 (m, 2H), 7.59 - 7.57 (m, 1H), 7.48 - 7.45 (m, 4H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.0, 196.7, 144.1, 136.4, 133.6, 129.6 (q, J = 32.4), 128.1, 127.4, 125.8 (q, *J* = 7.4 Hz), 125.3, 122.6, 51.8, 46.3, 21.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{18}H_{16}O_2F_3$: 321.1102. Found: 321.1108.

2-(2, 4-Dichlorophenyl)-2-methyl-4-oxo-4-phenylbutanal (3al):



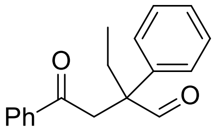
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 92%. ^1H NMR (400 MHz, $CDCl_3$) δ 9.89 (s, 1H), 7.91 – 7.89(m, 2H), 7.59 - 7.55 (m, 2H), 7.48 - 7.42 (m, 2H), 7.40 - 7.34 (m, 2H), 7.28 – 7.27 (m, 1H), 7.26 – 7.25 (m, 1H) 3.93 – 3.84 (m, 2H), 1.67 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.0, 197.4, 137.2, 136.6, 134.3, 133.5, 130.7, 130.6, 129.5, 128.7, 128.0, 127.5, 52.1, 44.5, 21.3; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{15}O_2Cl_2$: 321.0449. Found: 321.0447.

2-Methyl-4-oxo-4-phenyl-2-(thiophen-2-yl)butanal (3am):



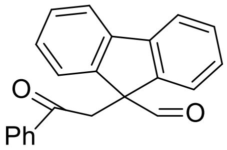
The title compound was prepared according to the general procedure. The product was obtained as brown oil, Yield: 22%. ^1H NMR (400 MHz, $CDCl_3$) δ 9.73 (s, 1H), 7.97 - 7.95(m, 2H), 7.61 - 7.57 (m, 1H), 7.49 - 7.45 (m, 2H), 7.29 - 7.29 (m, 1H), 7.03 - 7.01 (m, 1H), 6.98 - 6.97 (m, 1H) 3.85 - 3.72 (m, 2H), 1.74 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.1, 196.7, 144.3, 136.5, 133.5, 128.7, 128.2, 127.4, 125.3, 125.0, 50.0, 47.6, 21.8; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{15}H_{15}O_2S$: 259.0793. Found: 259.0789.

2-Ethyl-4-oxo-2, 4-diphenylbutanal (3an):



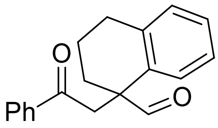
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 88%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.84 (s, 1H), 7.96 - 7.94 (m, 2H), 7.59 - 7.55 (m, 1H), 7.48 - 7.44 (m, 2H), 7.38 - 7.34 (m, 2H), 7.31 - 7.28 (m, 2H), 3.83 - 3.74 (m, 2H), 2.36 - 2.26 (m, 1H), 2.11 - 2.02 (m, 2H), 0.78 (t, J = 7.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.7, 197.4, 138.7, 136.7, 133.4, 128.8, 128.7, 128.1, 127.4, 127.2, 55.8, 42.3, 27.3, 8.6; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{18}H_{19}O_2$: 267.1385. Found: 267.1386.

9-(2-Oxo-2-phenylethyl)-9*H*-fluorene-9-carbaldehyde (3ao):



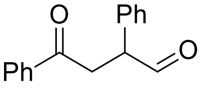
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp.160 - 161 ºC. Yield: 57%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.34 (s, 1H), 7.92 - 7.90 (m, 2H), 7.83 - 7.82 (m, 2H), 7.66 - 7.64 (m, 2H), 7.56 - 7.52 (m, 1H), 7.49 - 7.46 (m, 2H), 7.44 - 7.40 (m, 2H); 7.38 - 7.34 (m, 2H), 4.01 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.8, 196.3, 142.7, 141.9, 136.4, 133.4, 128.9, 128.6, 128.1, 128.0, 125.7, 120.3, 63.6, 45.0; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{22}H_{17}O_2$: 313.1229. Found: 313.1233.

1-(2-Oxo-2-phenylethyl)-1, 2, 3, 4-tetrahydronaphthalene-1-carbaldehyde (3ap):



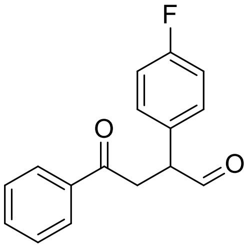
The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp.126 - 127 ºC. Yield: 40%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.76 (s, 1H), 7.93 - 7.92(m, 2H), 7.58 - 7.54 (m, 1H), 7.46 - 7.42 (m, 2H), 7.25 - 7.24 (m, 1H), 7.21 - 7.15 (m, 3H), 3.80 - 3.57 (m, 2H), 2.90 - 2.80 (m, 2H), 2.44 - 2.38 (m, 1H), 2.22 - 2.16 (m, 1H), 1.99 - 1.82 (m, 2H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 201.5, 197.1, 138.7, 136.9, 133.6, 133.2, 130.0, 128.6, 128.2, 128.1, 127.2, 126.5, 51.2, 47.1, 29.9, 28.8, 19.3; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{19}H_{19}O_2$: 279.1385. Found: 279.1378.

4-Oxo-2, 4-diphenylbutanal (3aq):



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 79%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.81 (s, 1H), 7.99 - 7.96(t, 2H), 7.59 - 7.55 (m, 1H), 7.48 - 7.37 (m, 4H), 7.34 - 7.25 (m, 3H), 4.48 - 4.45 (m, 1H), 3.96 (dd, J_1 = 8.4 Hz, J_2 = 18 Hz, 1H), 3.23 (dd, J_1 = 4.9 Hz, J_2 = 18 Hz, 1H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 199.0, 197.3, 136.5, 135.5, 133.3, 129.3, 129.1, 128.6, 128.1, 127.9, 53.7, 39.5; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{16}H_{15}O_2$: 239.1072. Found: 239.1061.

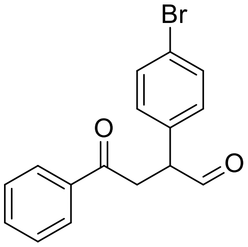
2-(4-Fluorophenyl)-4-oxo-4-phenylbutanal (3ar):



The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp.49 - 50 ºC. Yield: 73%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.79 (s, 1H), 7.98 – 7.95 (m, 2H), 7.58 - 7.55 (m, 2H), 7.49 - 7.44 (m, 2H), 7.25 - 7.05 (m, 4H), 4.46 -

4.42 (m, 1H), 3.93 (dd, J_1 = 8.1 Hz, J_2 = 18 Hz, 1H), 3.22 (dd, J_1 = 5.2 Hz, J_2 = 18 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.8, 197.1, 136.4, 133.5, 131.2, 130.8, 128.7, 128.1, 116.4, 116.2, 52.8, 39.6; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{16}H_{14}O_2F$: 257.0978. Found: 257.0987.

2-(4-Bromophenyl)-4-oxo-4-phenylbutanal (3as):



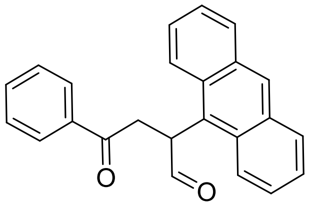
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 79%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.78 (s, 1H), 7.97 - 7.94(m, 2H), 7.60 - 7.54 (m, 1H), 7.53 - 7.43 (m, 4H), 7.17 - 7.13 (m, 2H), 4.43 - 4.39 (m, 1H), 3.92 (dd, J_1 = 8.1 Hz, J_2 = 18 Hz, 1H), 3.22 (dd, J_1 = 5.2 Hz, J_2 = 18 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.5, 196.9, 162.4 (d, 245.7), 136.3, 133.4, 131.1 (d, J = 3.3 Hz), 130.7 (d, J = 8.2 Hz), 128.6, 128.1, 116.2 (d, J = 21.5 Hz), 52.8, 39.5; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{16}H_{14}O_2Br$: 317.0177, Found: 317.0181.

4-Oxo-4-phenyl-2-(4-(trifluoromethyl)phenyl)butanal (3at):

The title compound was prepared according to the general procedure. The product was obtained as yellow solid, Mp.102 - 103 ºC. Yield: 74%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.83 (s, 1H), 7.99 - 7.96(m, 2H), 7.67 - 7.64 (m, 2H), 7.61 - 7.57 (m, 1H), 7.50 - 7.40 (m, 4H), 4.56 - 4.51 (m, 1H), 3.98 (dd, J_1 = 8.0 Hz, J_2 = 18 Hz, 1H), 3.28 (dd, J_1 = 5.2 Hz, J_2 = 18 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 196.7, 139.6, 136.1, 133.5, 129.5,130.2 (q, J =

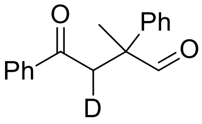
64.1 Hz), 129.5, 128.7, 128.1, 126.1 (q, J = 7.4 Hz), 125.2, 122.5, 53.3, 39.4; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{14}O_2F_3$: 307.0946. Found: 307.0933.

2-(Anthracen-9-yl)-4-oxo-4-phenylbutanal (3au):



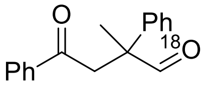
The title compound was prepared according to the general procedure. The product was obtained as red solid, Mp. 102 - 103 ºC. Yield: 42%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.87 (s, 1H), 8.60 - 8.49(m, 2H), 8.07 - 7.97 (m, 4H), 7.90 - 7.48 (m, 6H), 7.44 - 7.39 (m, 2H), 5.98 - 5.95 (m, 1H), 4.58 (dd, J_1 = 6.7 Hz, J_2 = 18 Hz, 1H), 3.31 (dd, J_1 = 3.8 Hz, J_2 = 18 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 197.4, 136.4, 133.4, 131.8, 129.7, 128.9, 128.7, 128.6, 128.3, 127.0, 126.7, 125.2, 124.0, 48.1, 38.8; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{24}H_{19}O_2$: 339.1385, Found: 339.1396.

2-Methyl-4-oxo-2, 4-diphenylbutanal-3-*d* (3ax)



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 58%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.74 (s, 1H), 7.95 - 7.93 (m, 2H), 7.59 - 7.55 (m, 1H), 7.47 - 7.43 (m, 2H), 7.40 - 7.27 (m, 5H), 3.78 - 3.69 (m, 1.5 H), 1.68 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 197.3, 197.2, 139.7, 136.8, 133.3, 128.9, 128.6, 128.1, 127.4, 126.9, 51.8, 46.0, 20.7; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{16}O_2D$: 254.1291, Found: 254.1291.

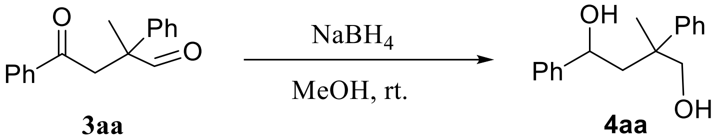
2-Methyl-4-oxo-2,4-diphenylbutanal-^{18}O (3ay)



The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 50%. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.74 (s, 1H), 7.95 - 7.93 (m, 2H), 7.59 - 7.55 (m, 1H), 7.47 - 7.43 (m, 2H), 7.40 - 7.33 (m, 4H), 7.30 - 7.27 (m, 1H), 3.78 - 3.69(m, 2H), 1.68(s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 197.2, 139.7, 136.7, 133.4, 128.9, 128.6, 128.1, 127.4, 126.9, 51.8, 46.0, 20.7; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{17}{}^{16}O^{18}O$: 255.1271, Found: 255.1271.

Application of 1, 4-ketoaldehydes

3-Methyl-1,3-diphenylbutane-1,4-diol (4aa)[2]:



To a solution of 2-methyl-4-oxo-2,4-diphenylbutanal **3aa** (0.20 mmol, 50.2 mg) in MeOH (2.00 mL) was added $NaBH_4$ (0.4 mmol, 83.2 mg) at room temperature and the reaction mixture was stirred at the same temperature for 30 min under nitrogen atmosphere. The mixture was poured into H_2O (5 mL) and extracted with EtOAc (10 mL). The organic layer was washed with brine (10 mL) and dried with Na_2SO_4. After removal of the solvent, the residue was subjected to column chromatography to give **4aa** (97% yield) as colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 - 7.36 (m, 4H), 7.33 - 7.30 (m, 2H), 7.27 - 7.23 (m, 4H), 4.59 (d, J = 8.68 Hz, 1H), 4.09 (d, J = 11.4 Hz, 1H), 3.77 (d, J = 11.4 Hz, 1H), 3.44 (s, 1H), 2.76 (s, 1H), 2.24 - 2.11 (m, 2H), 1.25 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.5, 145.2,

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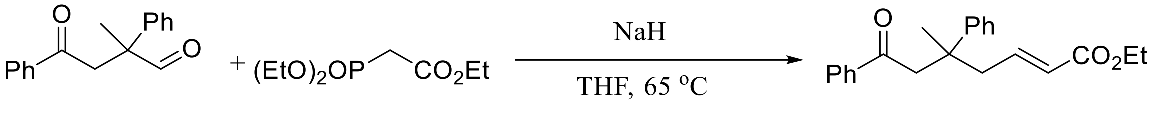
[2] H. Suzuki, S. Yoshioka, A. Igesaka, H. Nishioka and Y. Takeuchi, *Tetrahedron.*, 2013, **69**, 6399 - 6403.

128.6, 128.6, 127.5, 126.6, 126.2, 125.4, 71.7, 69.7, 48.8, 43.2, 27.6; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{17}H_{21}O_2$: 257.1542, Found: 257.1539.

(*E*)-Ethyl 5-methyl-7-oxo-5, 7-diphenylhept-2-enoate (5aa)[3]:



3aa **5aa**

A flame-dried round-bottomed flask (RBF) was charged with sodium hydride (0.3 mmol, 12 mg, 60% suspension in mineral oil) and THF (1 ml), then cooled to 0 °C. Triethylphosponoacetate (0.26 mmol, 51.5 ul) was added dropwise. The reaction was stirred at 0 °C for 10 min., then 2-methyl-4-oxo-2,4-diphenylbutanal **3aa** (0.2 mmol, 50.4 mg) was added dropwise and the mixture was heated to reflux for 16 h. The reaction was cooled to room temperature and H_2O : EtOAc = 1:1 (10 ml) was added. The layers were separated and the aqueous layer was extracted with EtOAc (2 × 5 ml). The combined organic layers were washed with 1 M NaOH (5 ml), H_2O (20 ml) and brine (10 ml), then dried (Na_2SO_4). After removal of the solvent, the residue was subjected to column chromatography to give **5aa** (89% yield) as yellow oil. ^1H NMR (400 MHz, $CDCl_3$) δ 7.86 - 7.84 (m, 1H), 7.55 - 7.50 (m, 1H), 7.43 - 7.36 (m, 2H), 7.34 (d, J = 16.0 Hz, 1H), 7.31 - 7.28 (m, 4H), 7.22 - 7.18 (m, 1H), 5.82 (d, J = 16.0 Hz, 1H), 4.21 - 4.16 (m, 2H), 3.61 - 3.50 (m, 2H), 1.67 (s, 3H), 1.28 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.1,166.8, 155.3, 144.8, 137.5, 133.0, 128.5, 127.9, 126.6, 126.2, 119.2, 60.4, 48.0, 43.3, 25.3, 14.2; HRMS (ESI) m/z $[M+H]^+$: Calcd for $C_{22}H_{25}O_3$: 337.1804, Found: 337.1814.

(3-Methylcyclobut-1-ene-1, 3-diyl)dibenzene (6aa)[4]:

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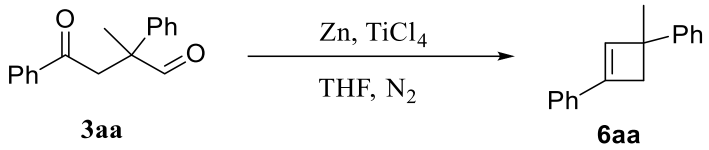
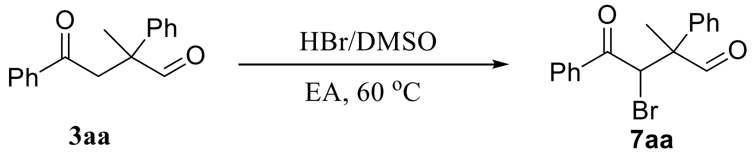
[3] E. C. A. De Silva, P. J. Silk, P. Mayo, N. K. Hillier and G. C. Cutler, *J. Chem. Eool.,* 2013, **39**, 1169 - 1181.



In a flame-dried flask, dry THF (2 mL) was added to zinc dust (1.6 mmol, 0.1046 g). The flask was cooled in an ice bath, and titanium tetrachloride (0.8 mmol, 88 uL) was added dropwise. A yellow cloud formed and the solution became dark blue. The resulting (dark blue) solution was refluxed for 1.0 h then cooled to 0 °C and a solution of **3aa** (0.2 mmol, 50.4 mg) in THF (2 mL) was added to the reaction mixture. The reaction mixture was then heated to reflux for 3 h. After cooling the reaction to ambient temperature, 10 mL water was added and gas evolution was seen. After the bubbling subsided, the mixture was extracted with ethyl acetate (3 x 10 mL). The organic layers were combined, dried over Na_2SO_4, filtered and the solvent was removed *in vacuo*. The resulting colorless liquid was purified by column chromatography (SiO_2, 9:1 petroleum ether:ethyl acetate) to give **6aa** (69 % yield) as a colorless oil. ^{1}H NMR (300 MHz, CDCl3) δ 7.40 - 7.38 (m, 4H), 7.35 - 7.27 (m, 5H), 7.21 - 7.17 (m, 1H), 2.99 - 2.89 (m, 2H), 1.63 (s, 3H).

3-Bromo-2-methyl-4-oxo-2,4-diphenylbutanal (7aa)[5]:



Aldehyde **3aa** (0.2 mmol, 50.4 mg) and DMSO (0.24 mmol, 17 μL) were dissolved in EA (2 mL). Aqueous hydrobromic acid (1.2 mmol, 48%, 19.4 mg) was added to the solution at 60 °C and the mixture were stirred for 0.5 h under air at that temperature. After cooling down to

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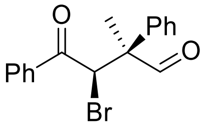
[4] (a) M. D. Connors and N. S. Goroff, *Org. Lett.*, 2016, **18**, 4262-4265. (b) V. L. Carrillo, A. M. Echavarren, *J. Am. Chem. Soc.*, 2010, **132**, 9292-9294.

[5] S. Song, X. W. Li, X. Sun, Y. Z. Yuan and N. Jiao, *Green Chem.*, 2015, **17**, 3285-3289.

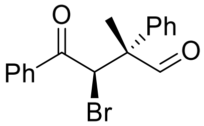
room temperature and concentrating in vacuum, the residue was purified by chromatography on silica gel (petroleum ether/ethyl acetate) to afford the brominated product.

3-Bromo-2-methyl-4-oxo-2, 4-diphenylbutanal (7aa, isomer-1):



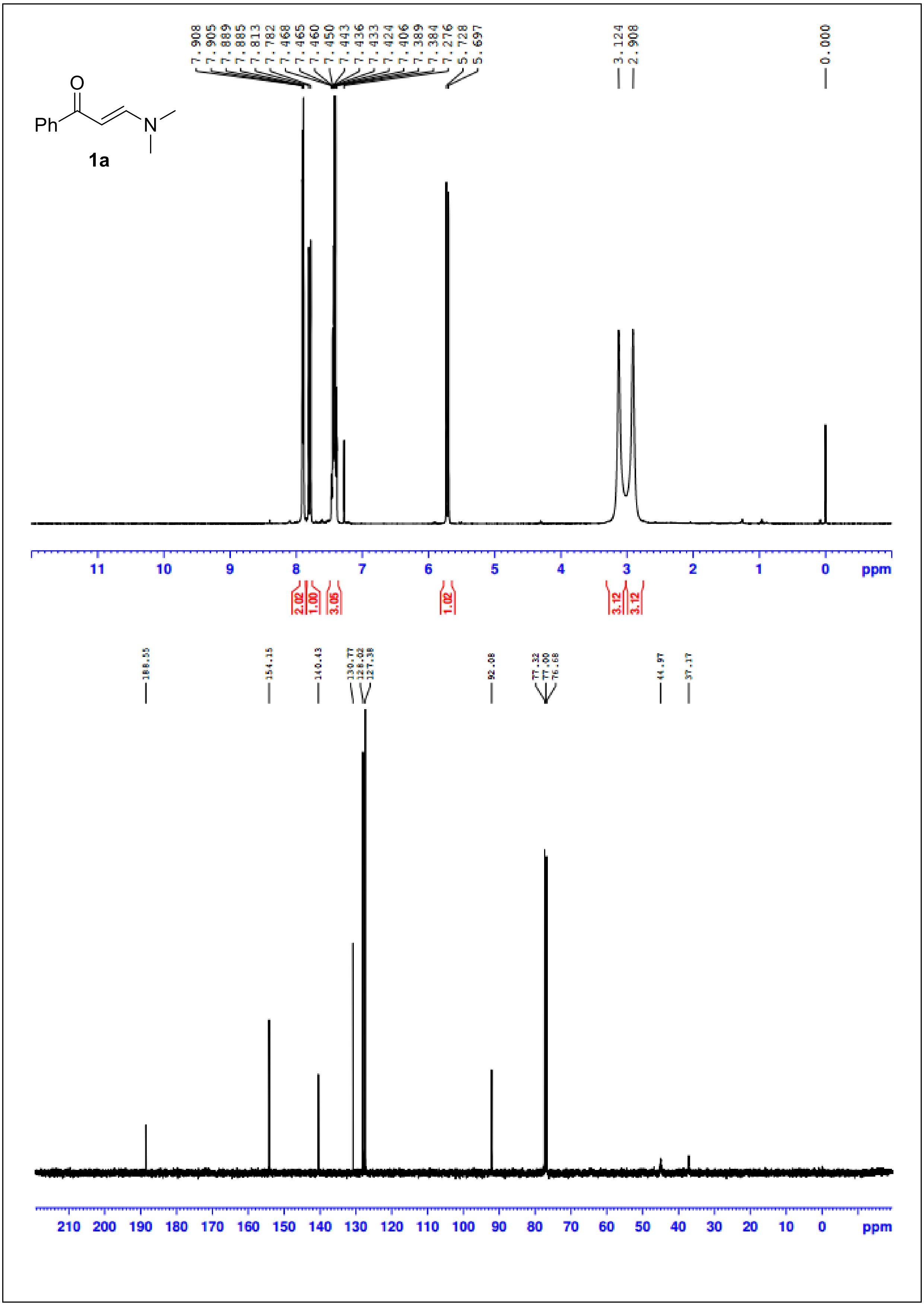
The title compound was prepared according to the general procedure. The product was obtained as yellow oil, Yield: 24%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.67 (s, 1H), 7.98 - 7.96 (m, 2H), 7.61 - 7.57 (m, 1H), 7.50 - 7.46 (m, 2H), 7.44 - 7.33 (m, 5H), 5.62 (s, 1H), 2.06 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 199.0,193.4, 137.1, 135.0, 133.6, 129.0, 128.7, 128.7, 128.7, 128.3, 127.6, 57.5, 53.0, 17.1; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{17}H_{16}O_2Br$: 331.0334, Found: 331.0330.

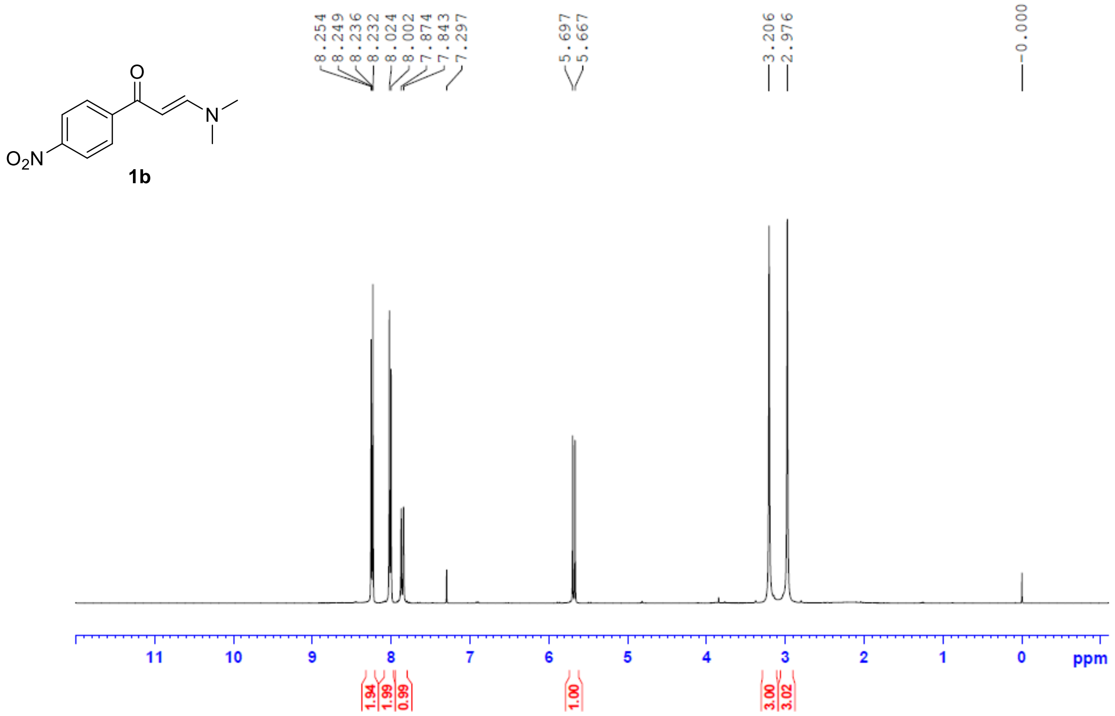
3-Bromo-2-methyl-4-oxo-2, 4-diphenylbutanal (7aa, isomer-2):



The title compound was prepared according to the general procedure. The product was obtained as white solid, Mp. 85 - 86 °C. Yield: 71%. ^{1}H NMR (400 MHz, CDCl$_3$) δ 9.64 (s, 1H), 7.87 - 7.85 (m, 2H), 7.57 - 7.53 (m, 1H), 7.32 - 7.29 (m, 4H), 7.25 - 7.23 (m, 1H), 6.02 (s, 1H), 1.95 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$) δ 199.0, 192.5,135.9, 134.8, 133.8, 129.0, 128.7, 128.5, 128.2, 127.5, 55.4, 48.6, 18.0; HRMS (ESI) m/z [M+H]$^+$: Calcd for $C_{17}H_{16}O_2Br$: 331.0334, Found: 331.0330.

NMR Spetra for enaminones:





1b

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9
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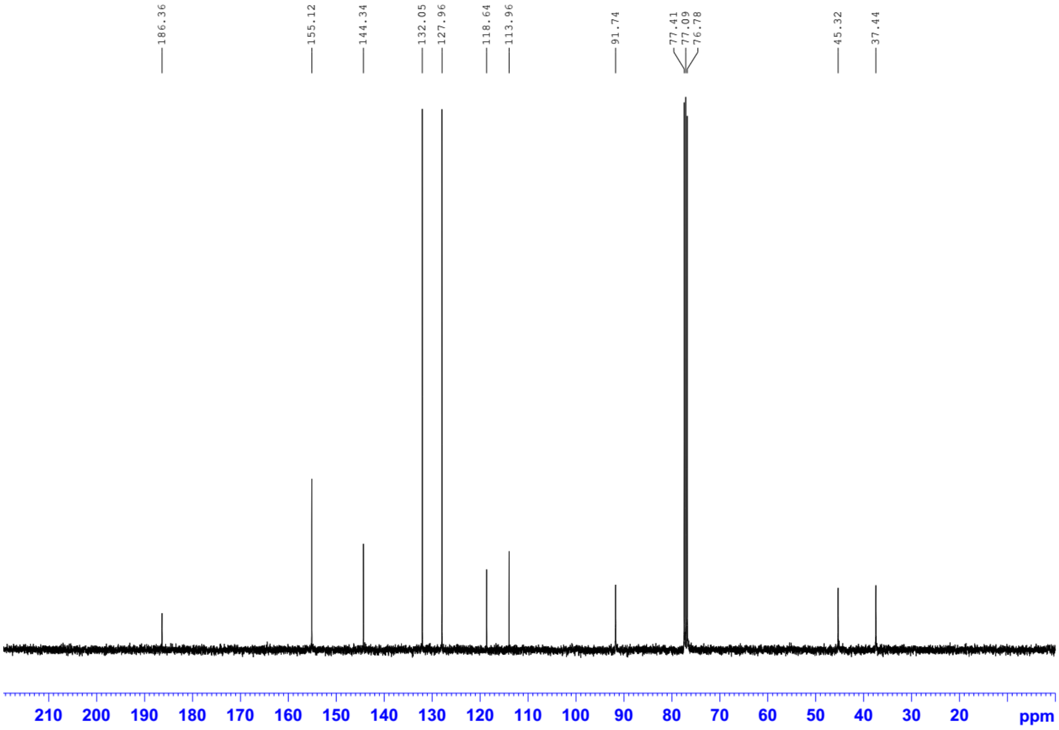
3.02



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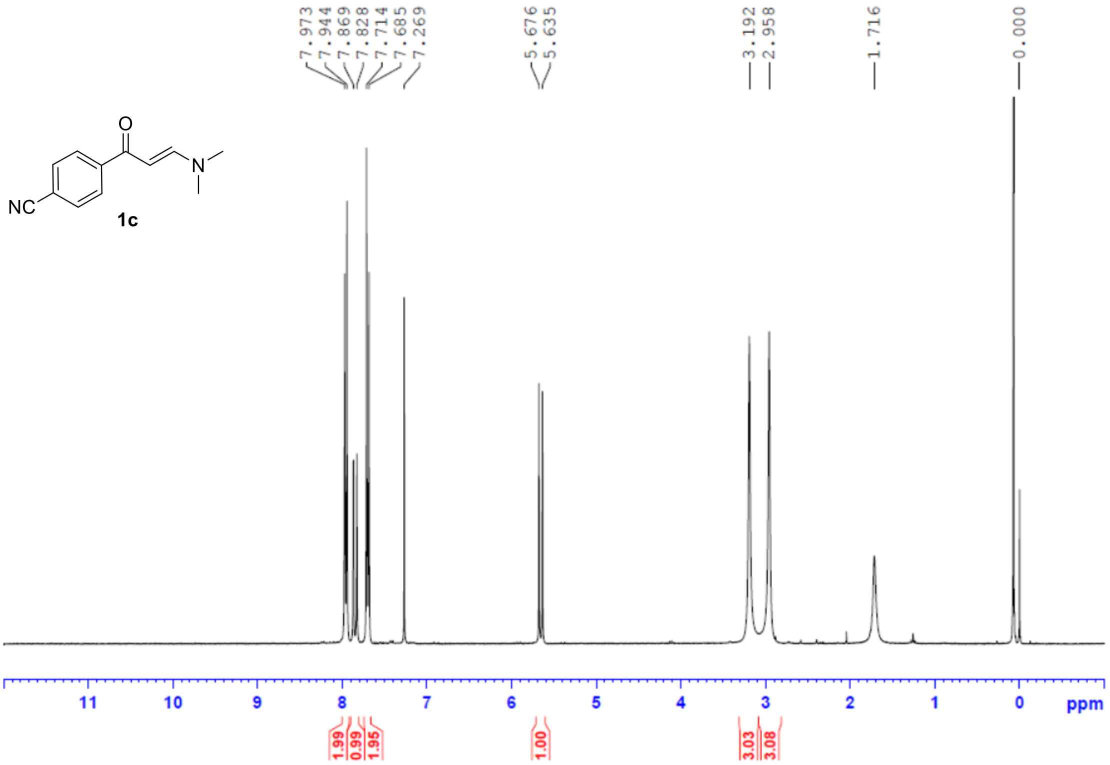
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11
10
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4
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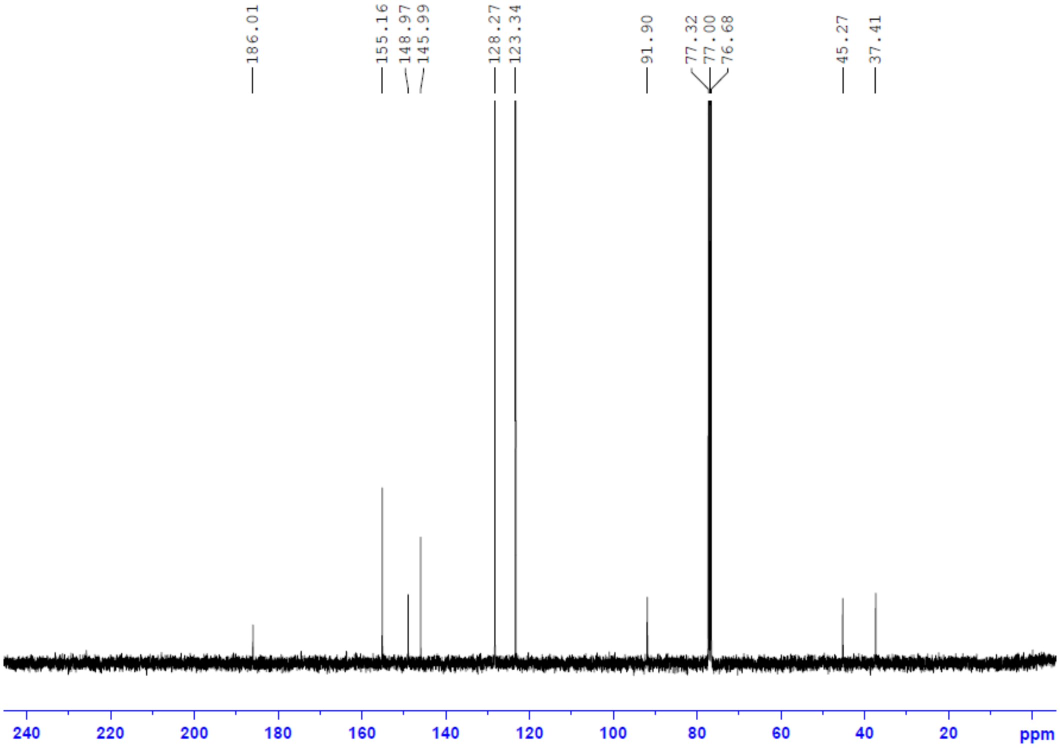
3.08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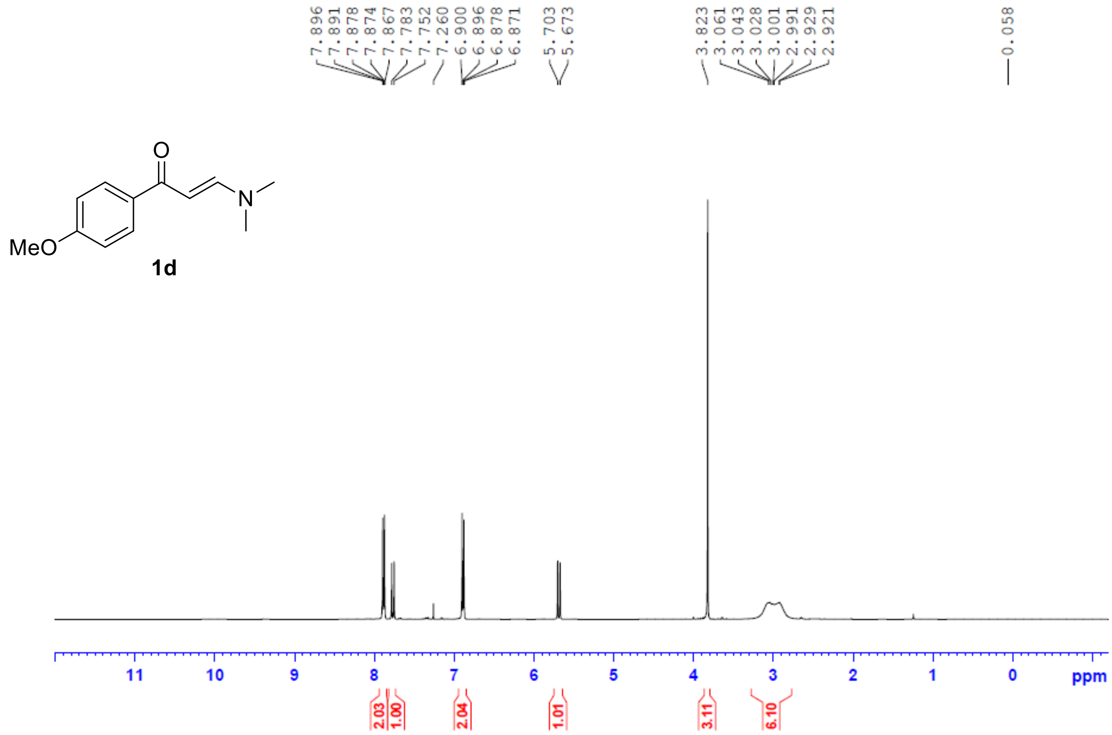
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5.673
3.823
3.061
3.043
3.028
3.001
2.991
2.929
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N
MeO
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8
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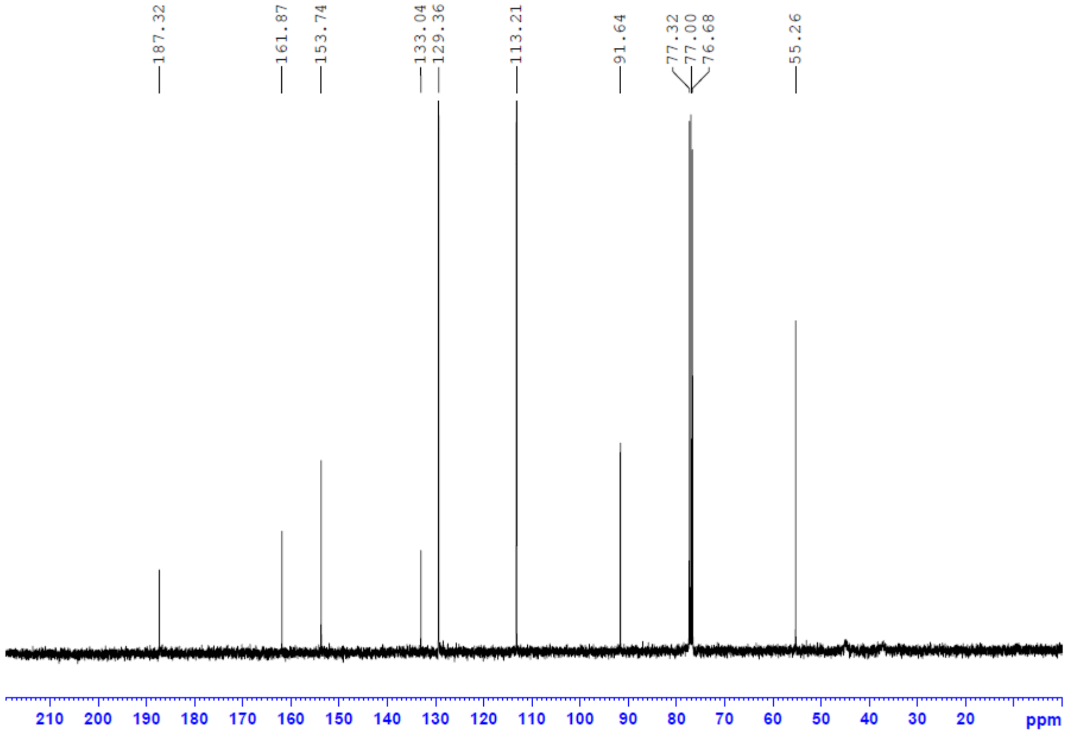
1d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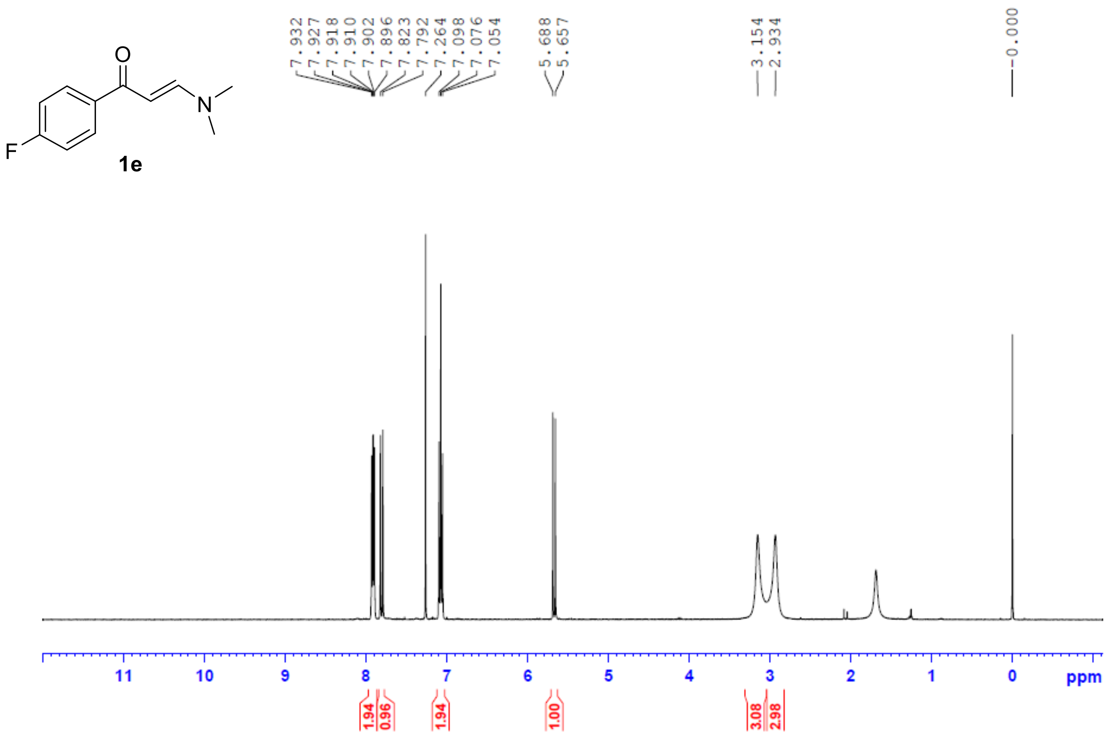
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9
8
7
6
5
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O
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F

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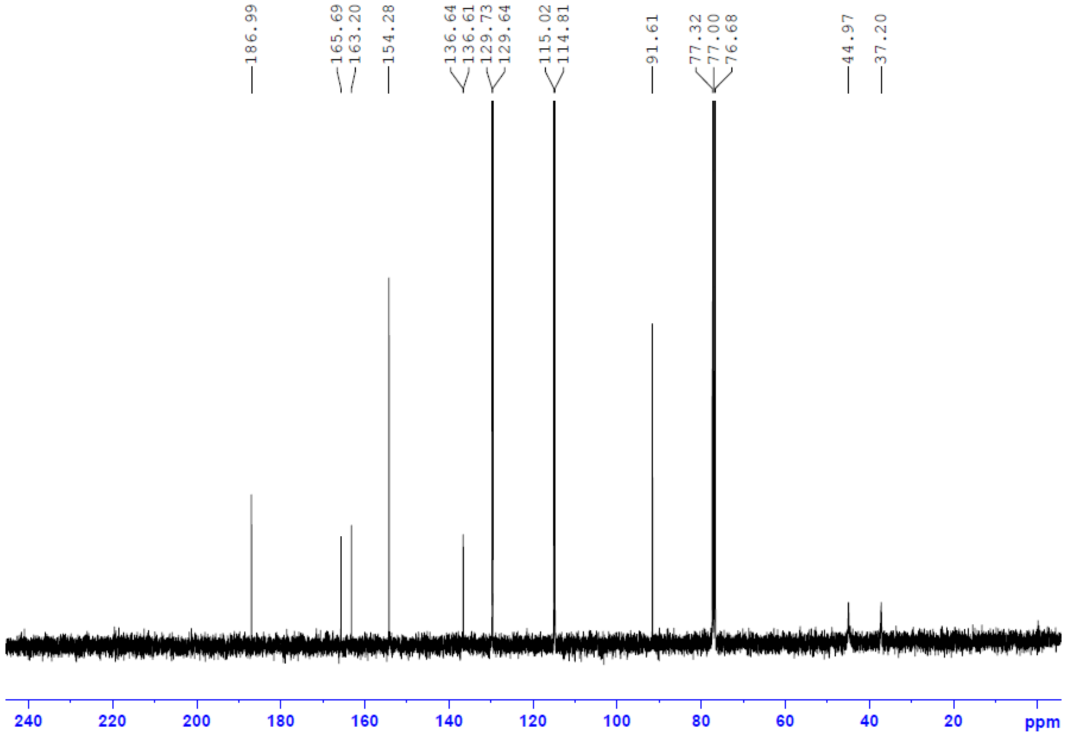
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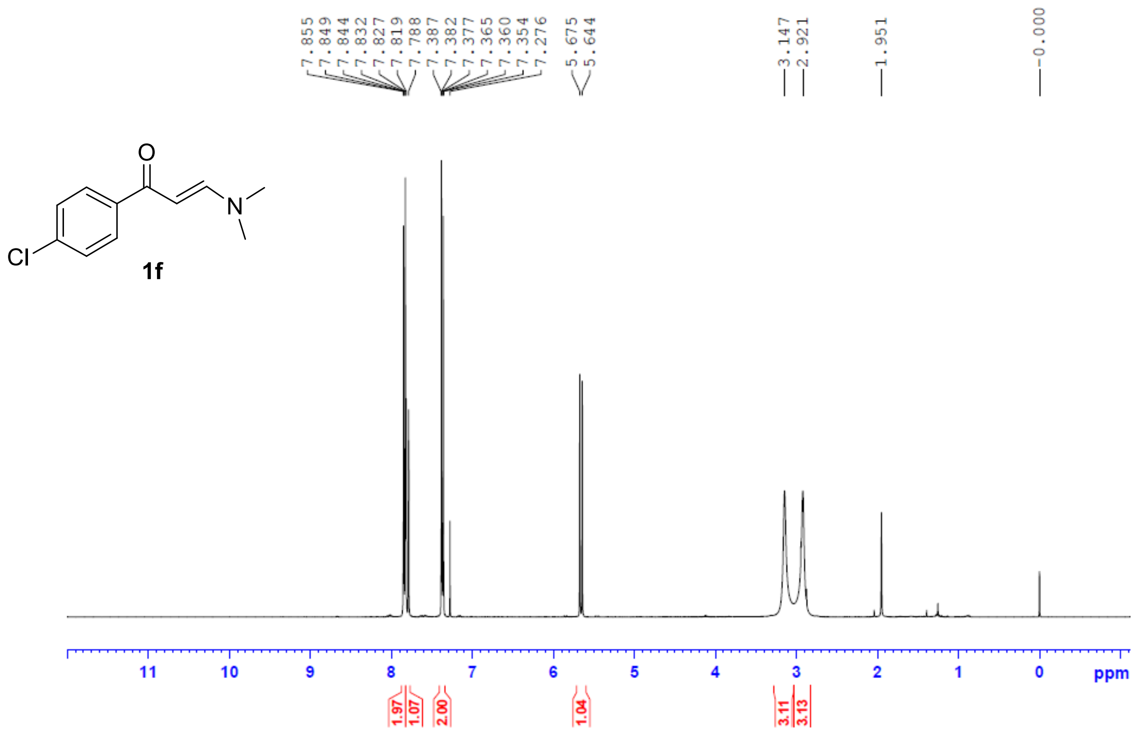
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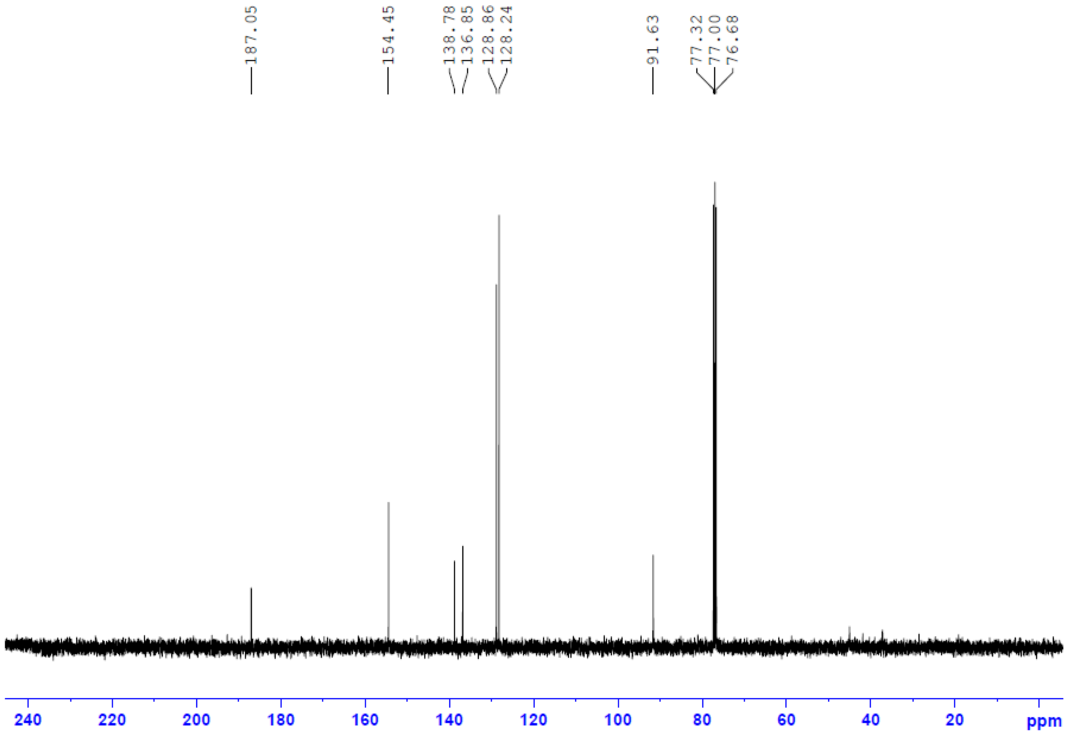
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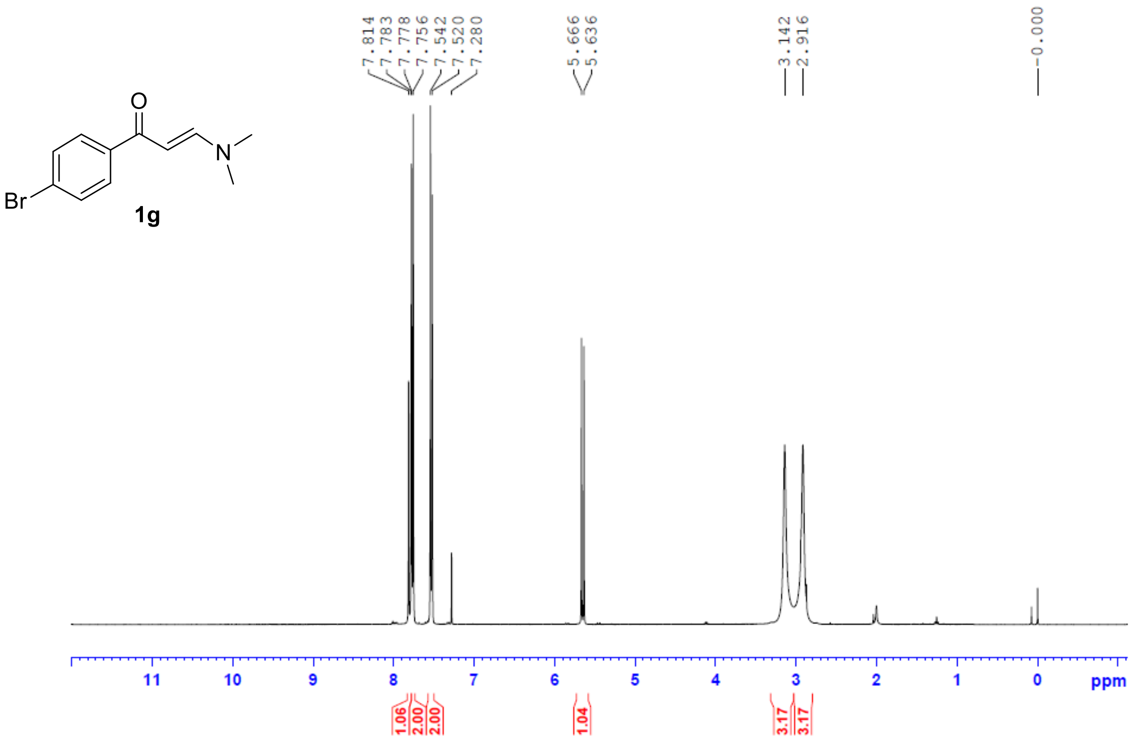

1g

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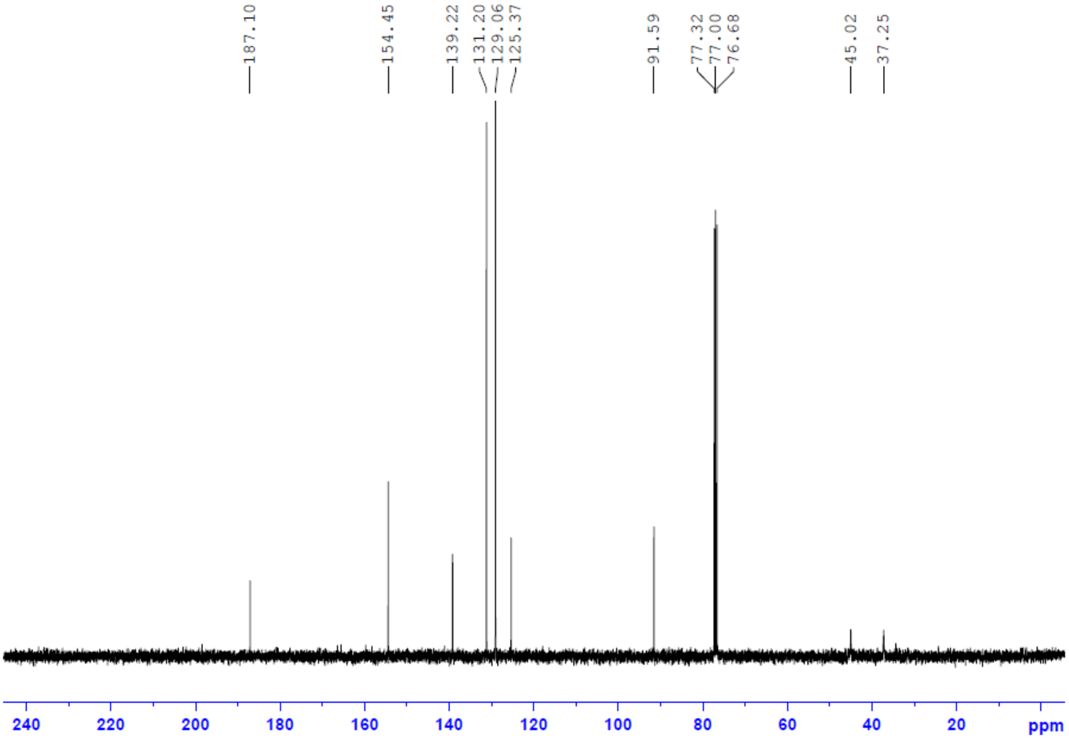

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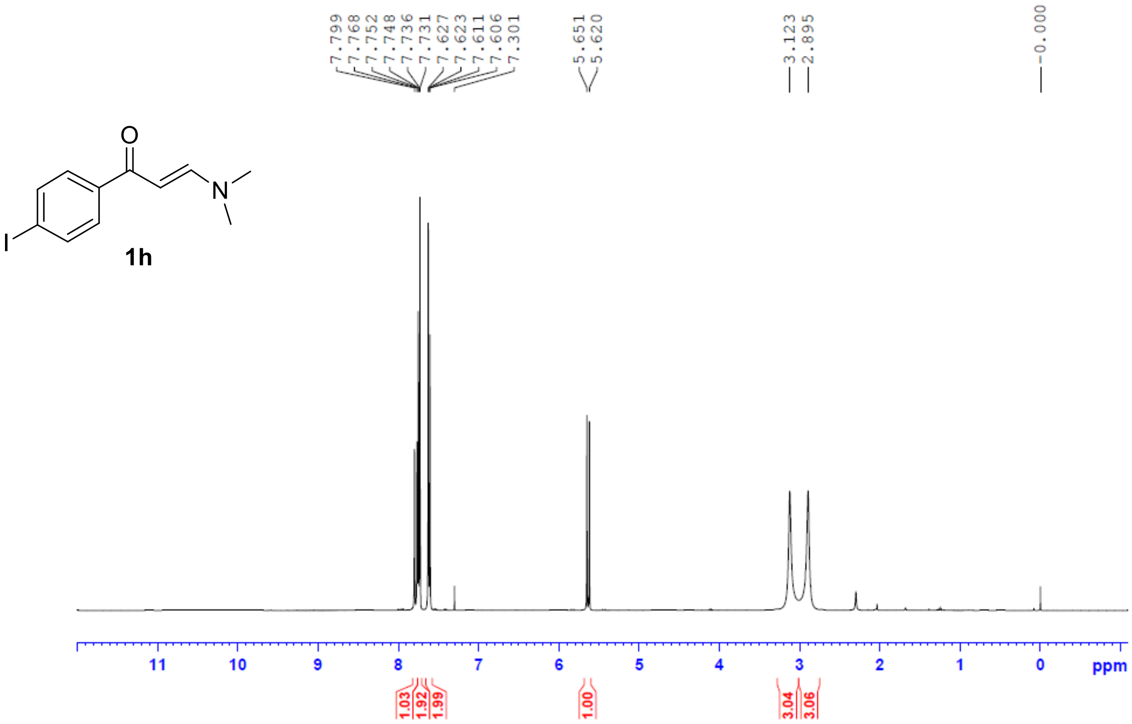
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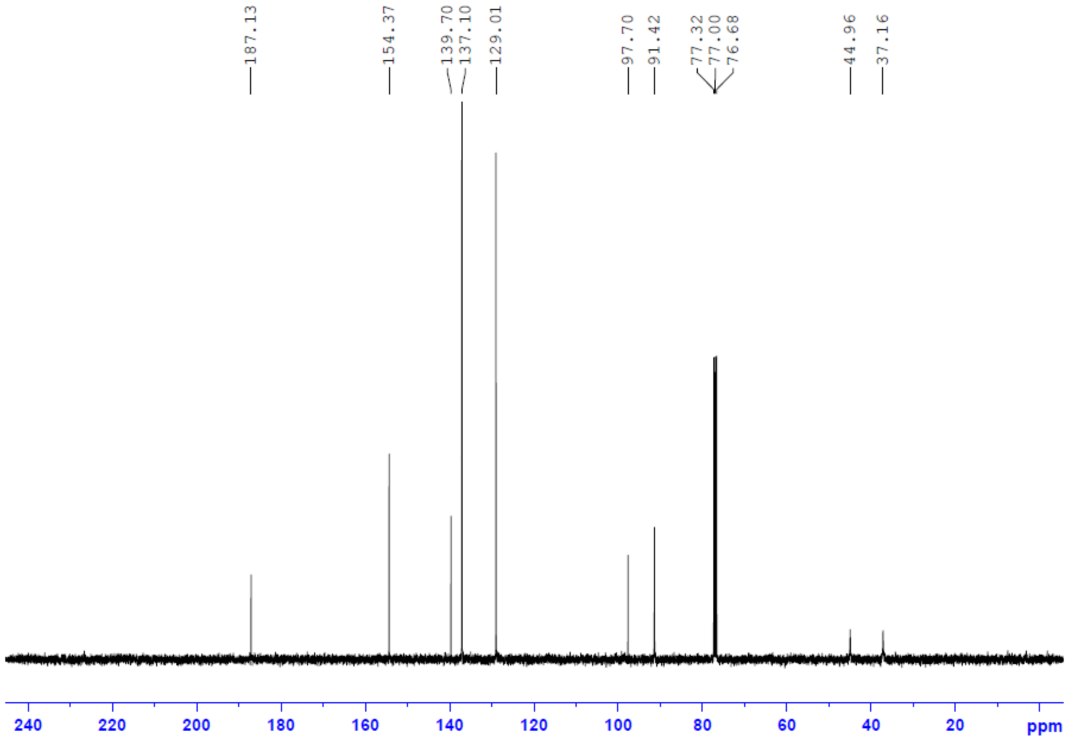
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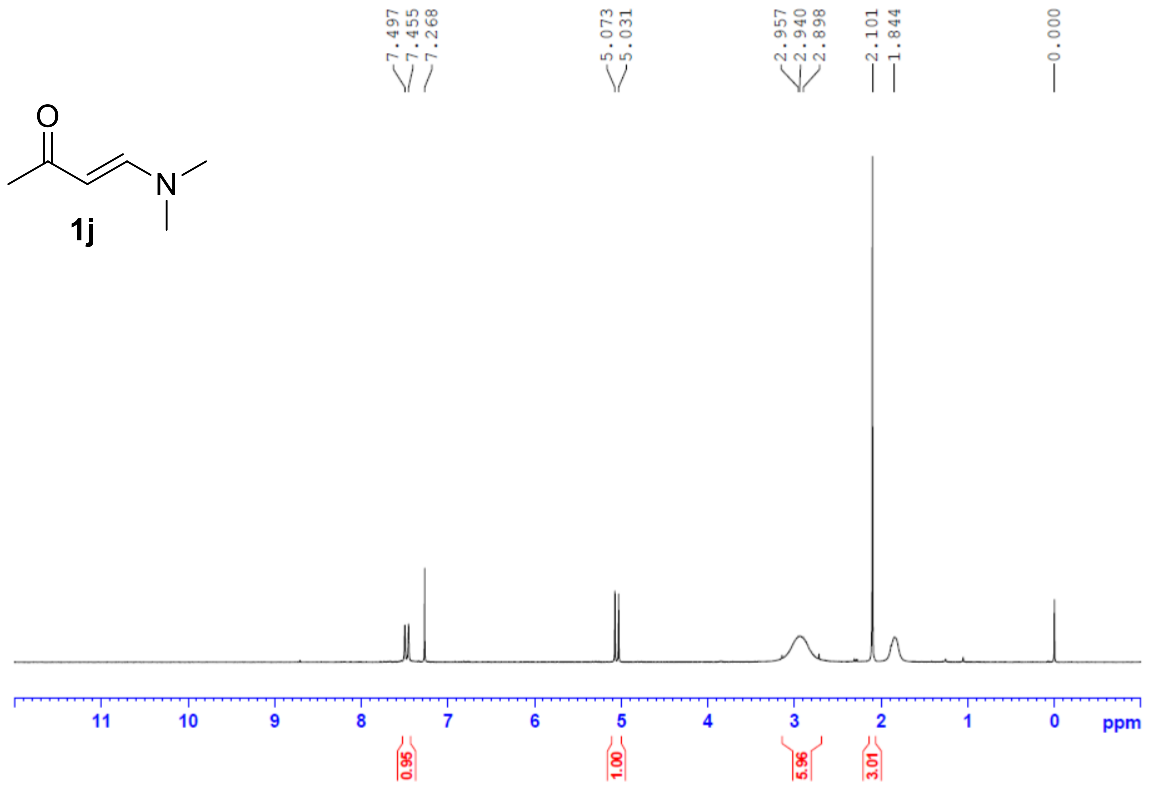
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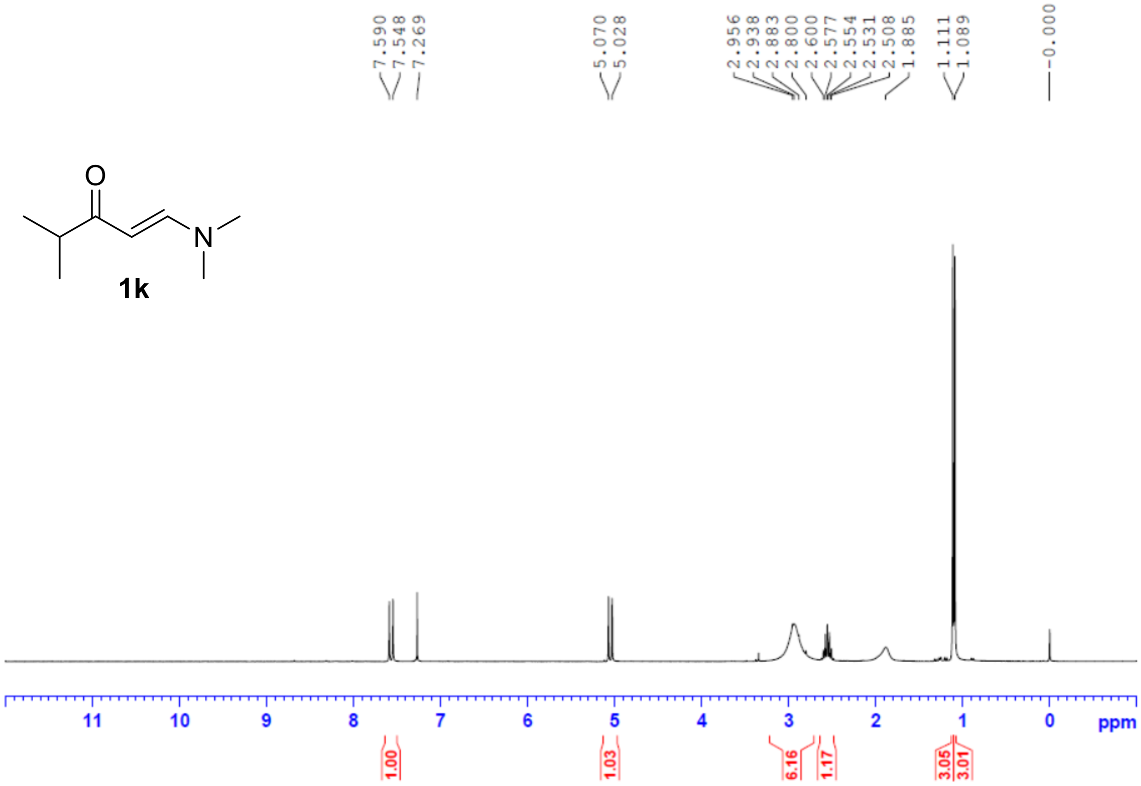
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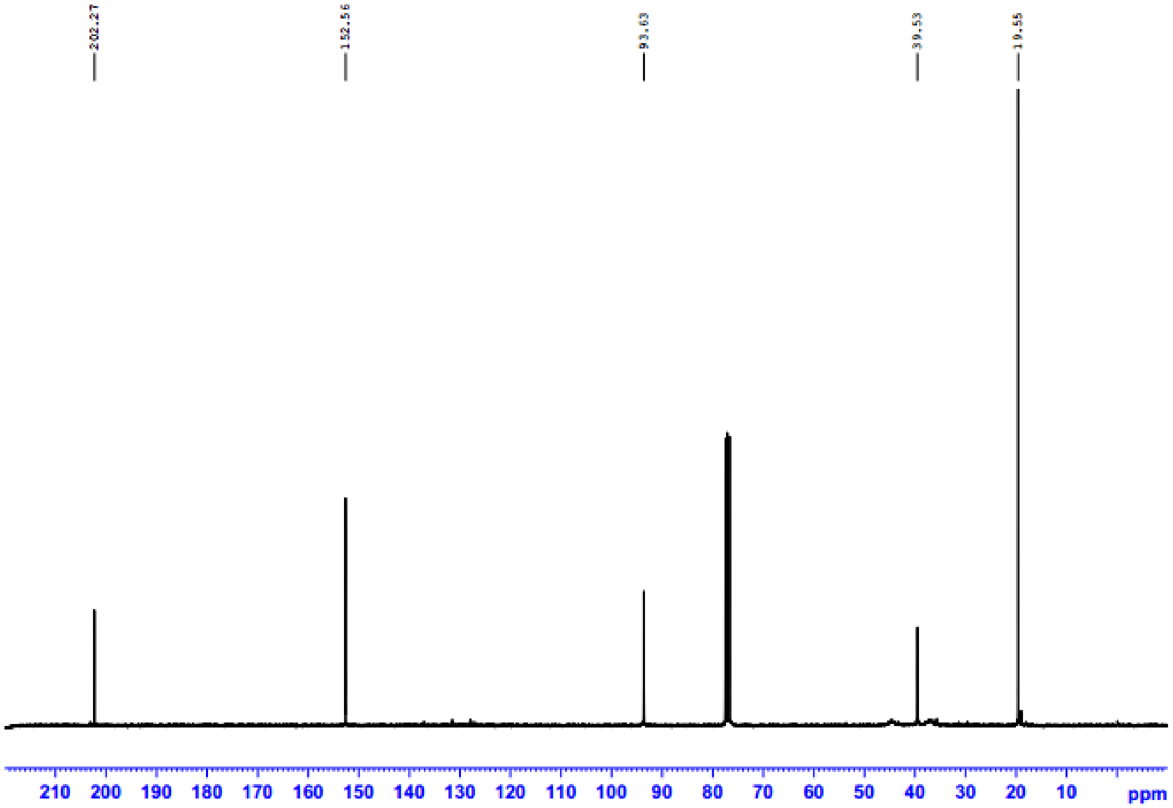
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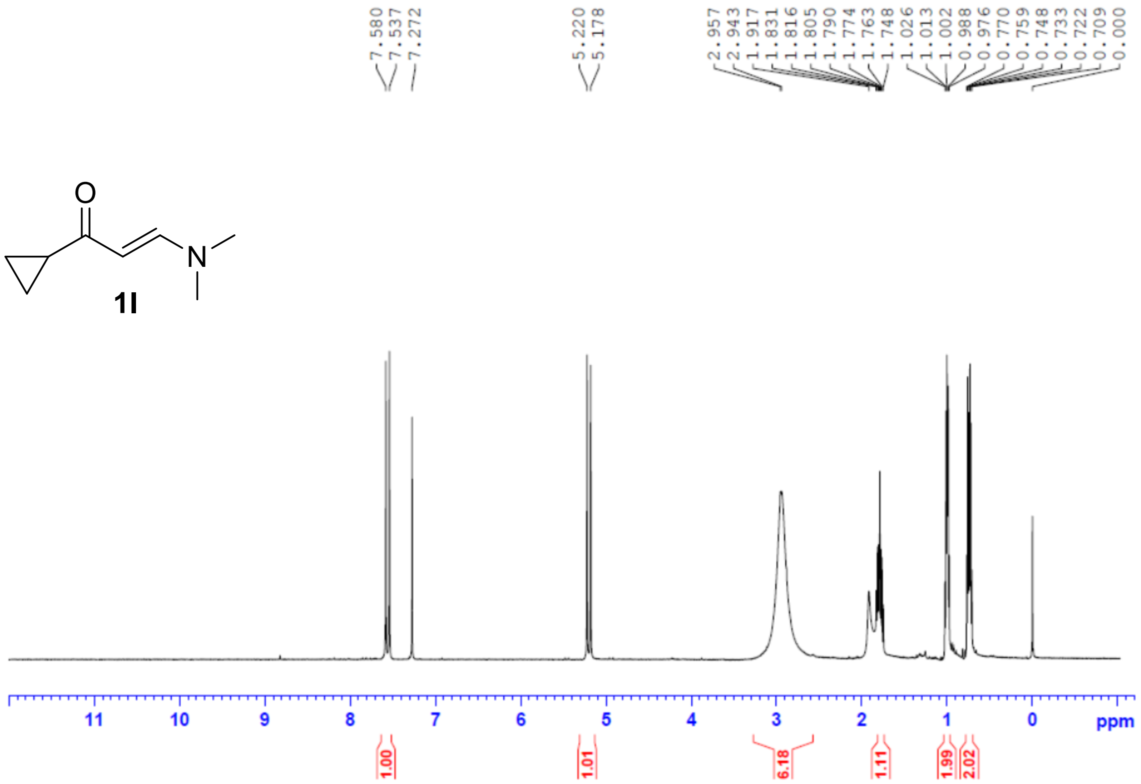
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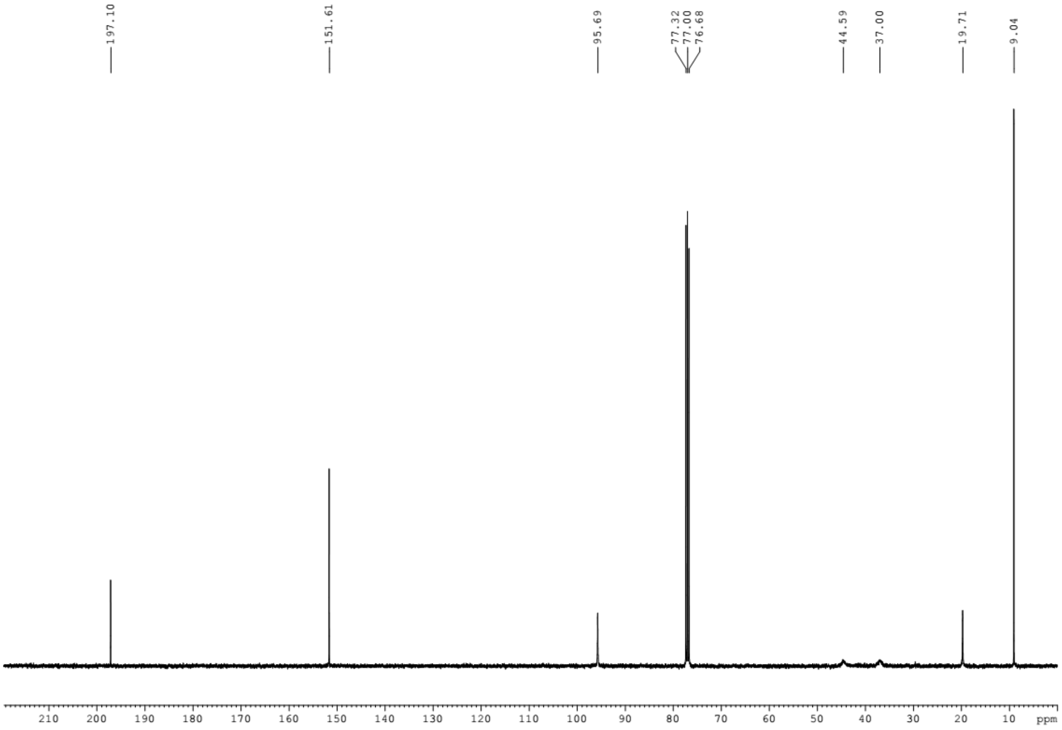
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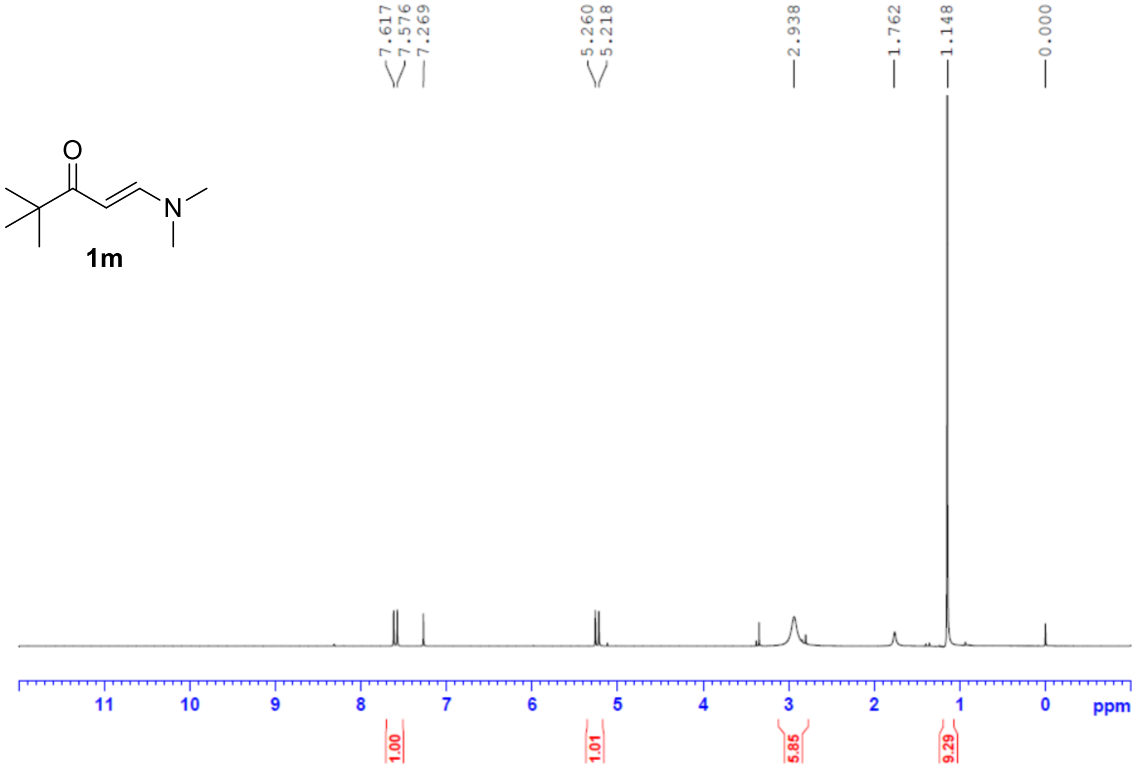
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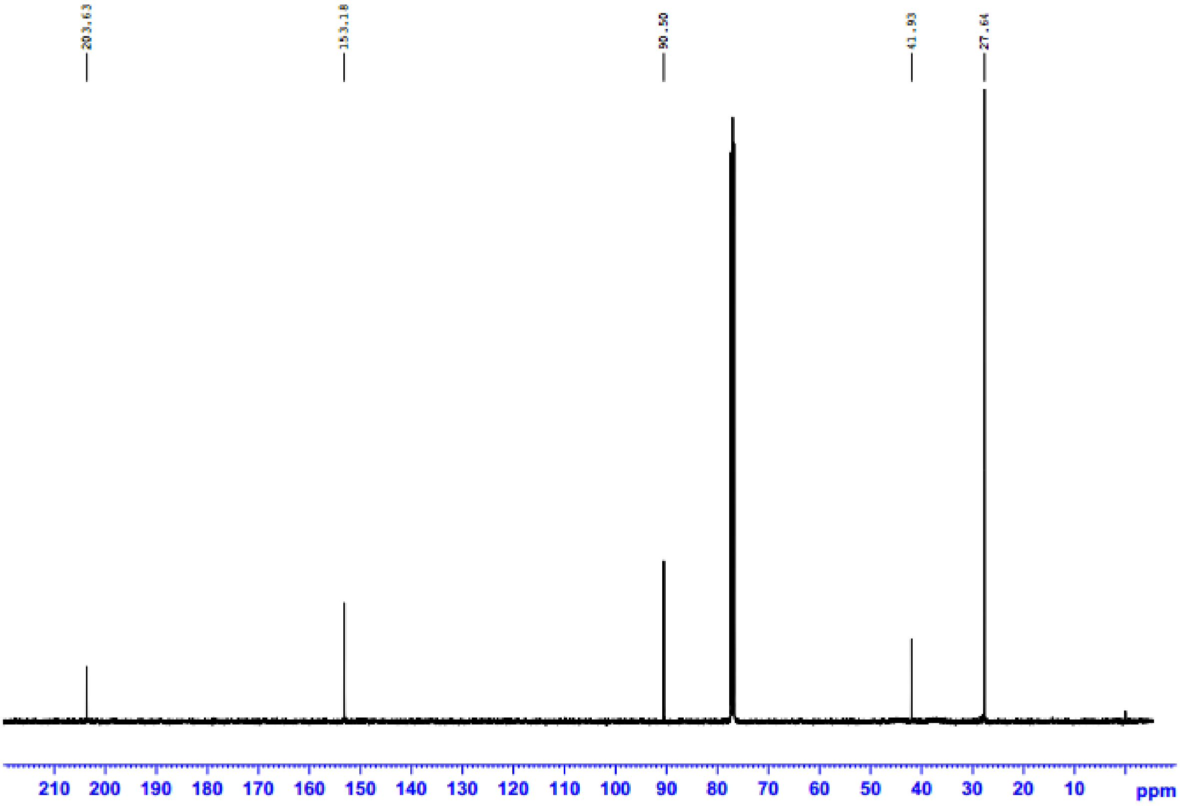
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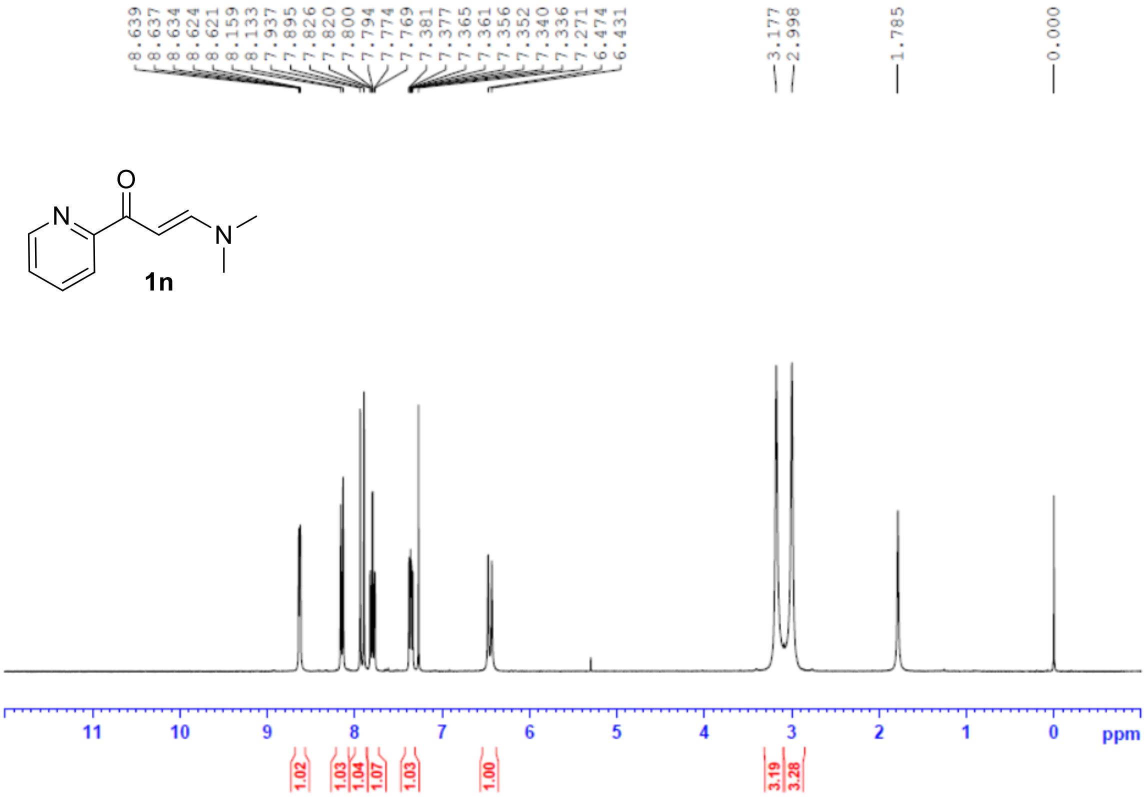
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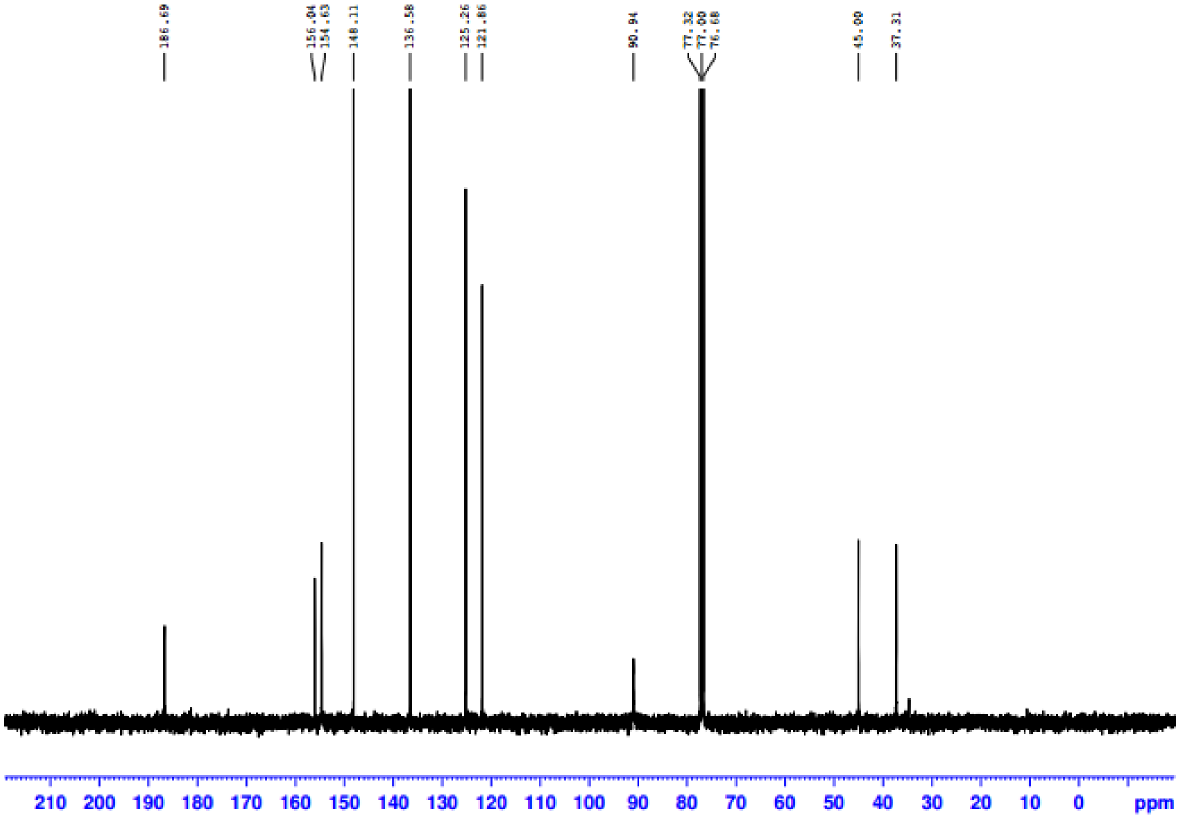
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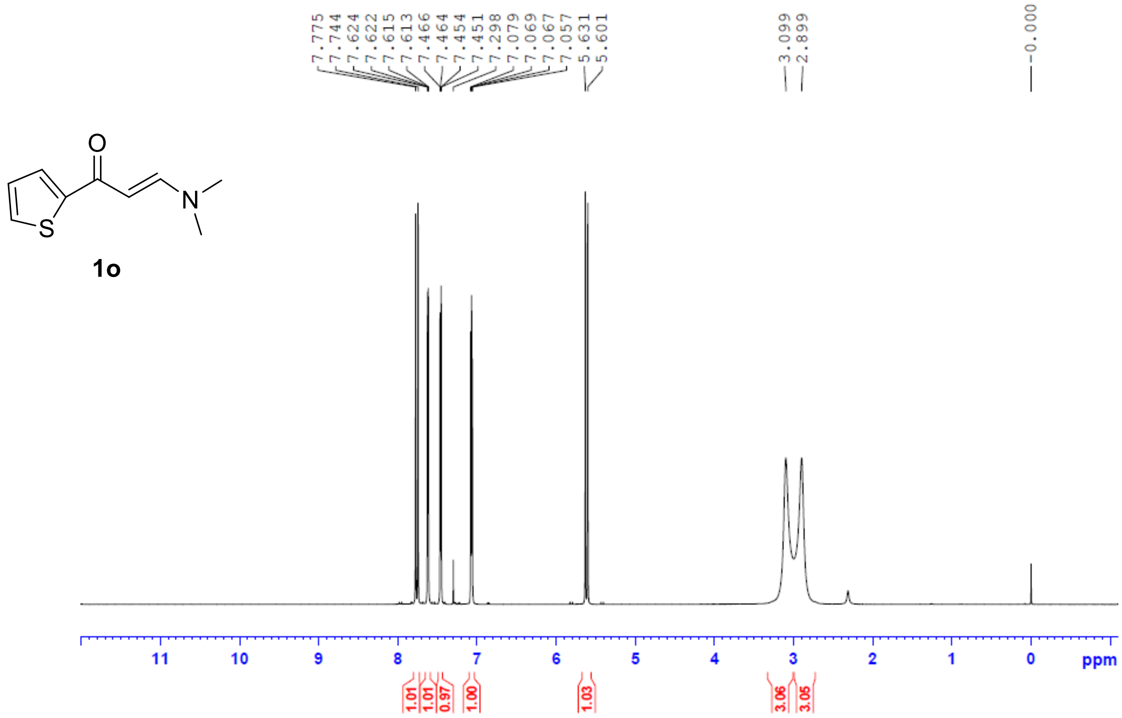
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O
N
S
11
10
9
8
7
6
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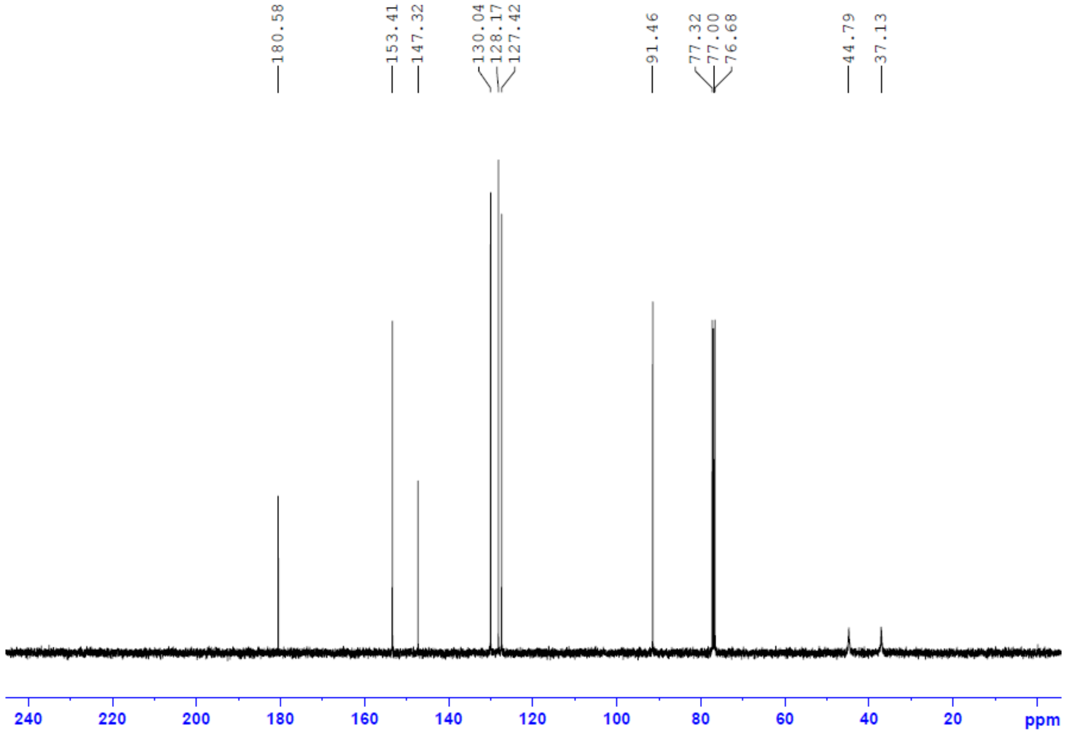
1
0
ppm
1.01
1.01
0.97
1.00
1.03
3.06
3.05

1o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153.41
147.32
130.04
128.17
127.42
91.46
77.32
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37.13
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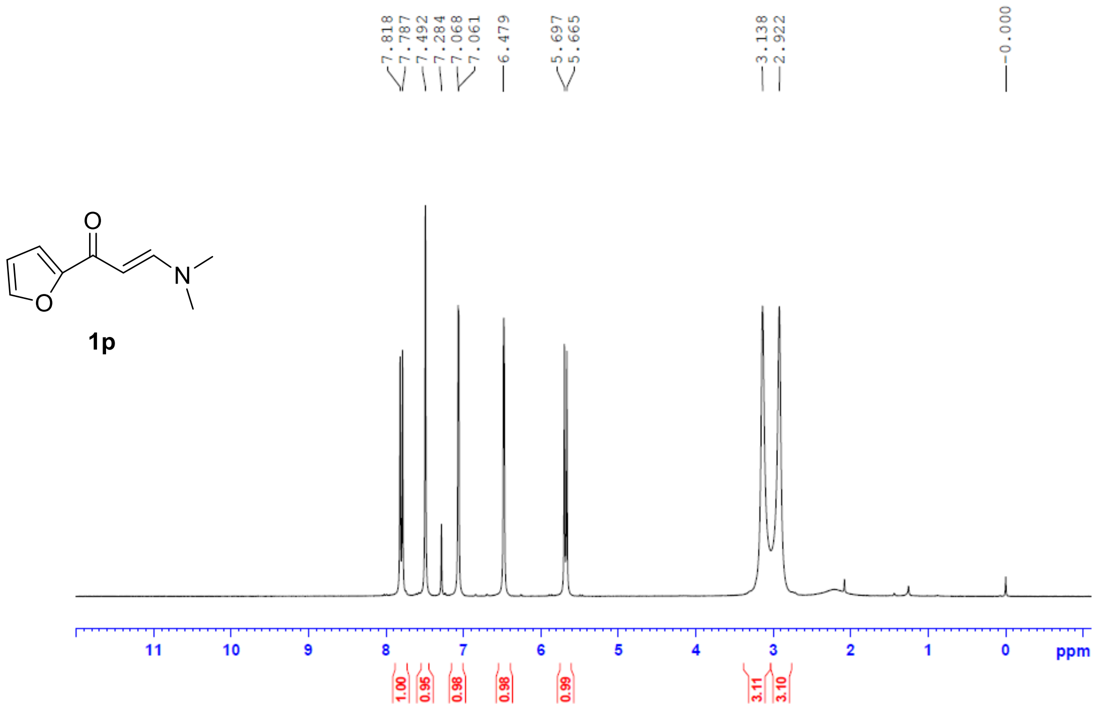
ppm



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7.068
7.061
6.479
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5.665
3.138
2.922
-0.000
11
10
9
8
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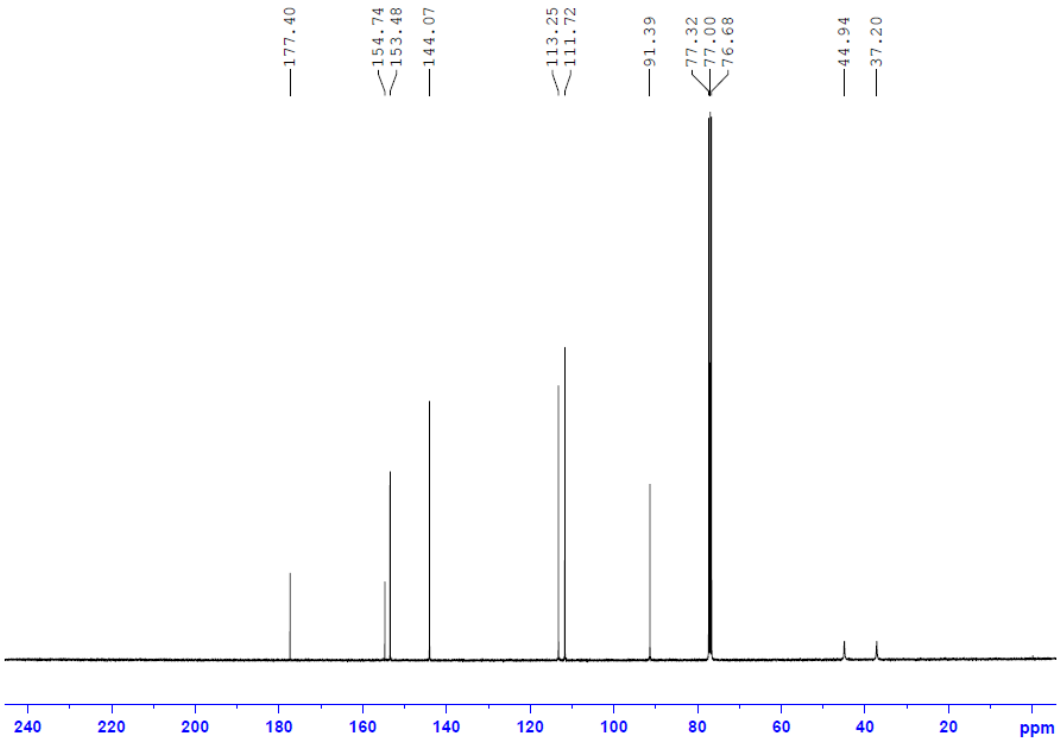
3.10


177.40
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113.25
111.72
91.39
77.32
77.00
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37.20
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220
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140
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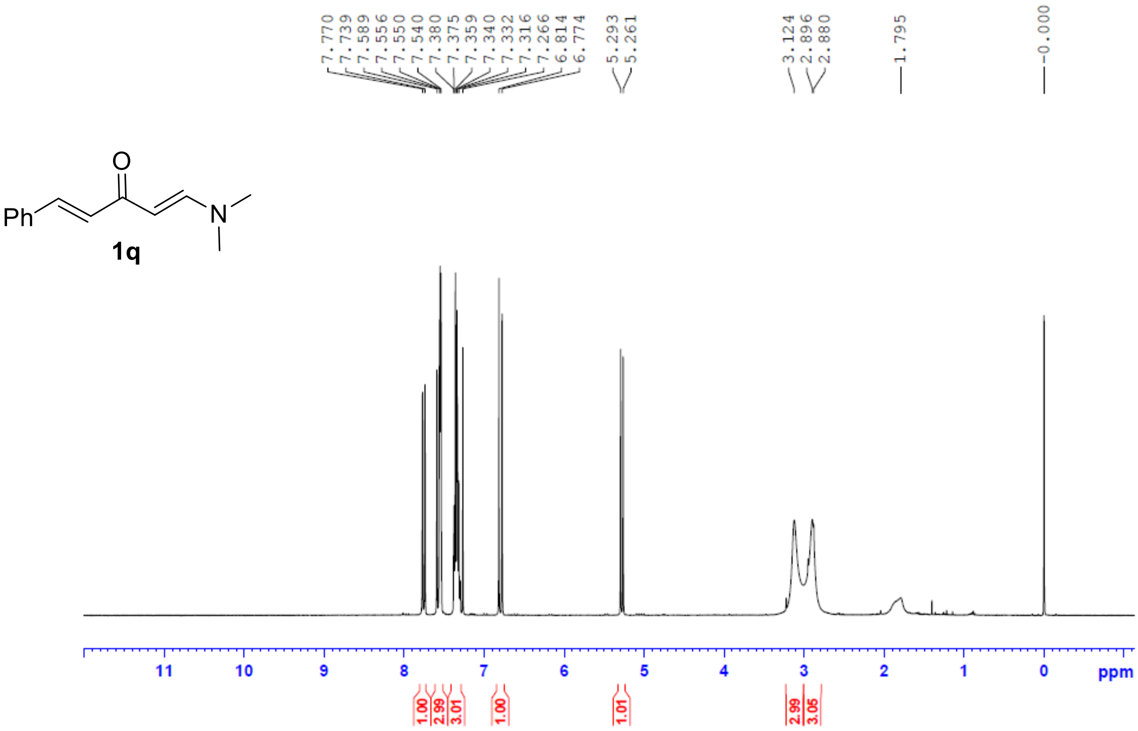

1q

7.770
7.739
7.589
7.556
7.550
7.540
7.380
7.375
7.359
7.340
7.332
7.316
7.266
6.814
6.774
5.293
5.261
3.124
2.896
2.880
1.795
0.000
O
Ph
N
11
10
9
8
7
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2
1
0
ppm
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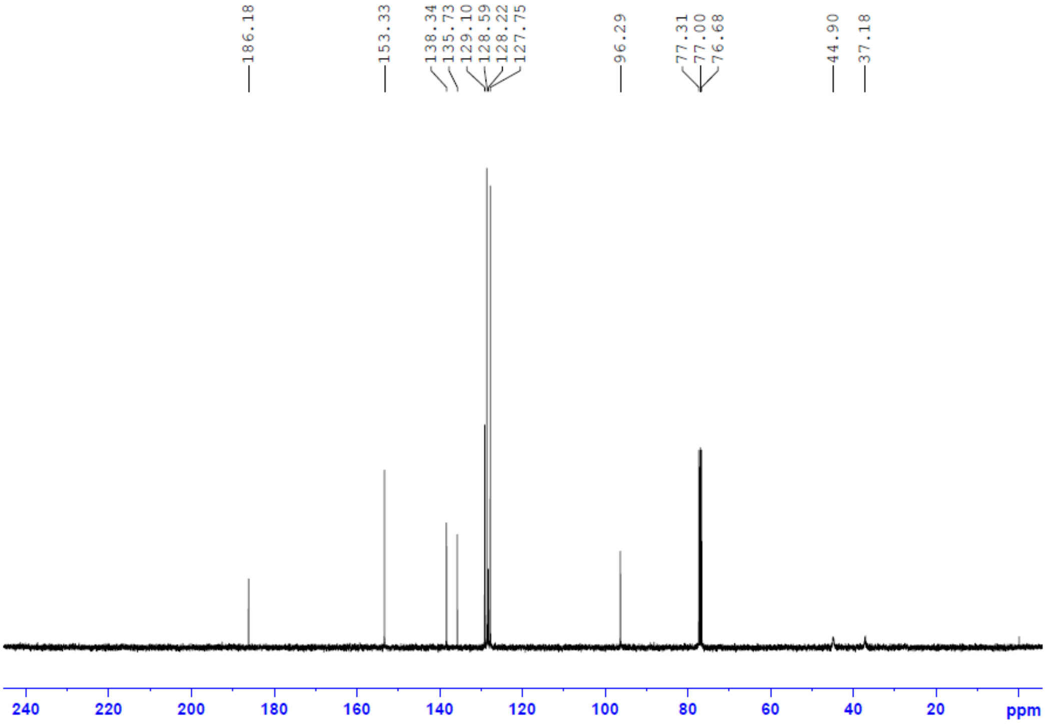
3.01
1.00
1.01
2.99
3.05



186.18
153.33
138.34
135.73
129.10
128.59
128.22
127.75
96.29
77.31
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37.18
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200
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160
140
120
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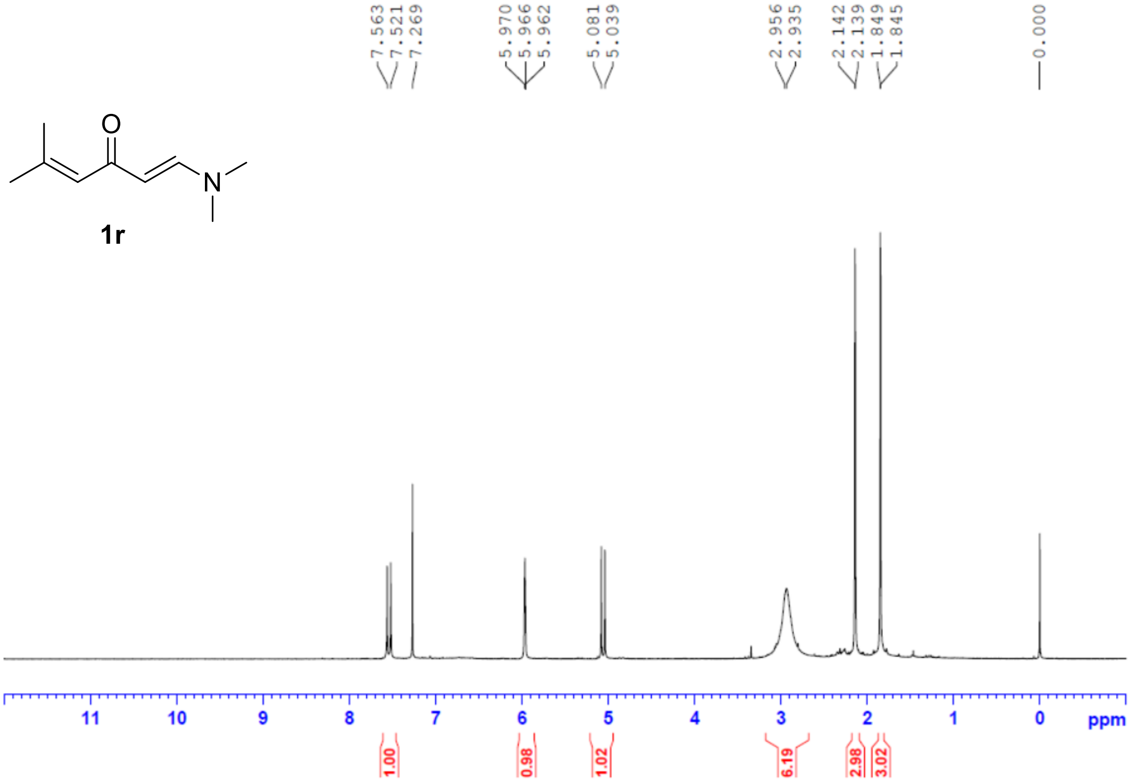
80
60
40
20
ppm

1r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7.521
7.269
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5.966
5.962
5.081
5.039
2.956
2.935
2.142
2.139
1.849
1.845
0.000
11
10
9
8
7
6
5
4
3
2
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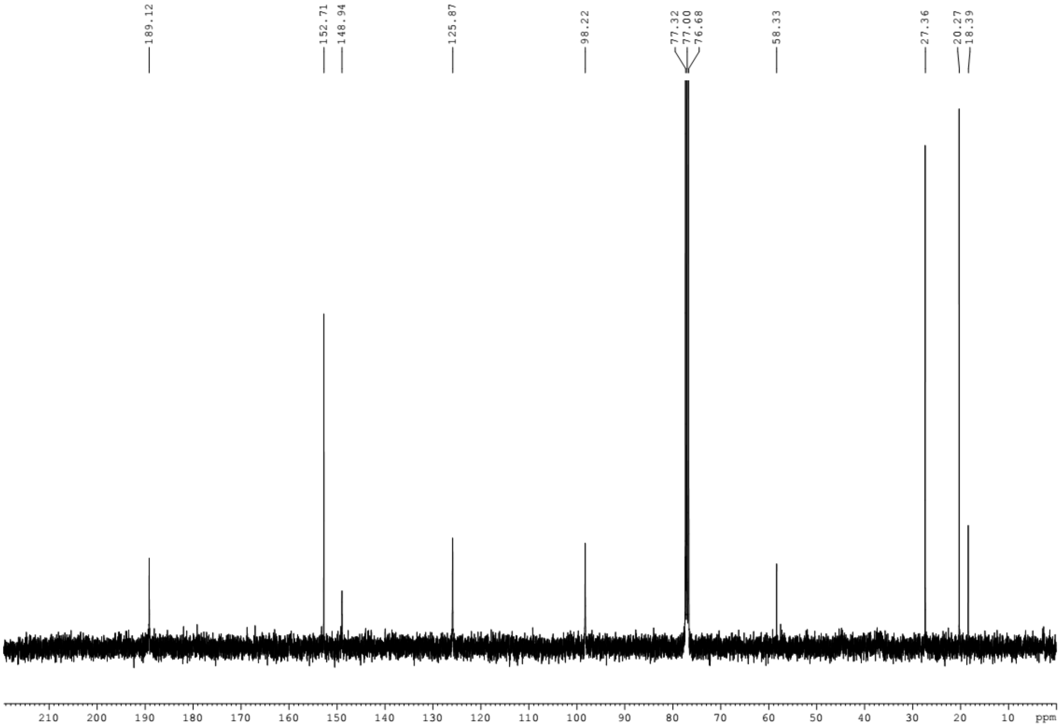
0.98
1.02
6.19
2.98
3.02


189.12
152.71
148.94
125.87
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77.32
77.00
76.68
58.33
27.36
20.27
18.39
210
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140
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120
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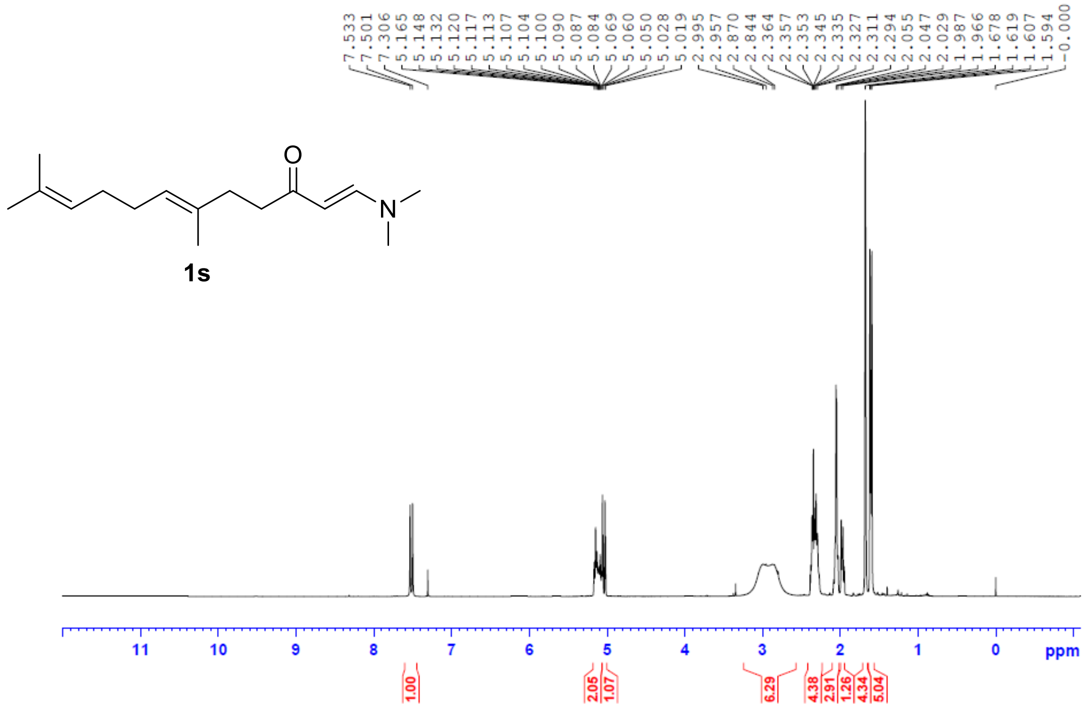
10
ppm



1s
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7.501
7.306
5.165
5.148
5.132
5.120
5.117
5.113
5.107
5.104
5.100
5.090
5.087
5.084
5.069
5.060
5.050
5.028
5.019
2.995
2.957
2.870
2.844
2.364
2.357
2.353
2.345
2.335
2.327
2.311
2.294
2.055
2.047
2.029
1.987
1.966
1.678
1.619
1.607
1.594
-0.000
11
10
9
8
7
6
5
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ppm
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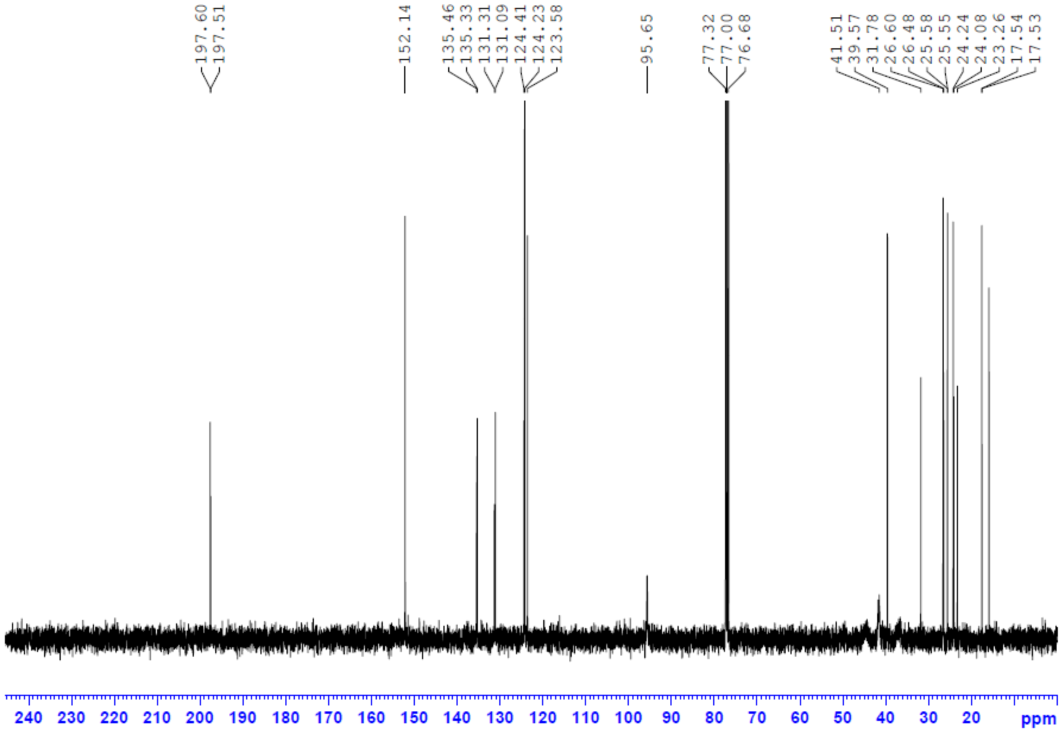
5.04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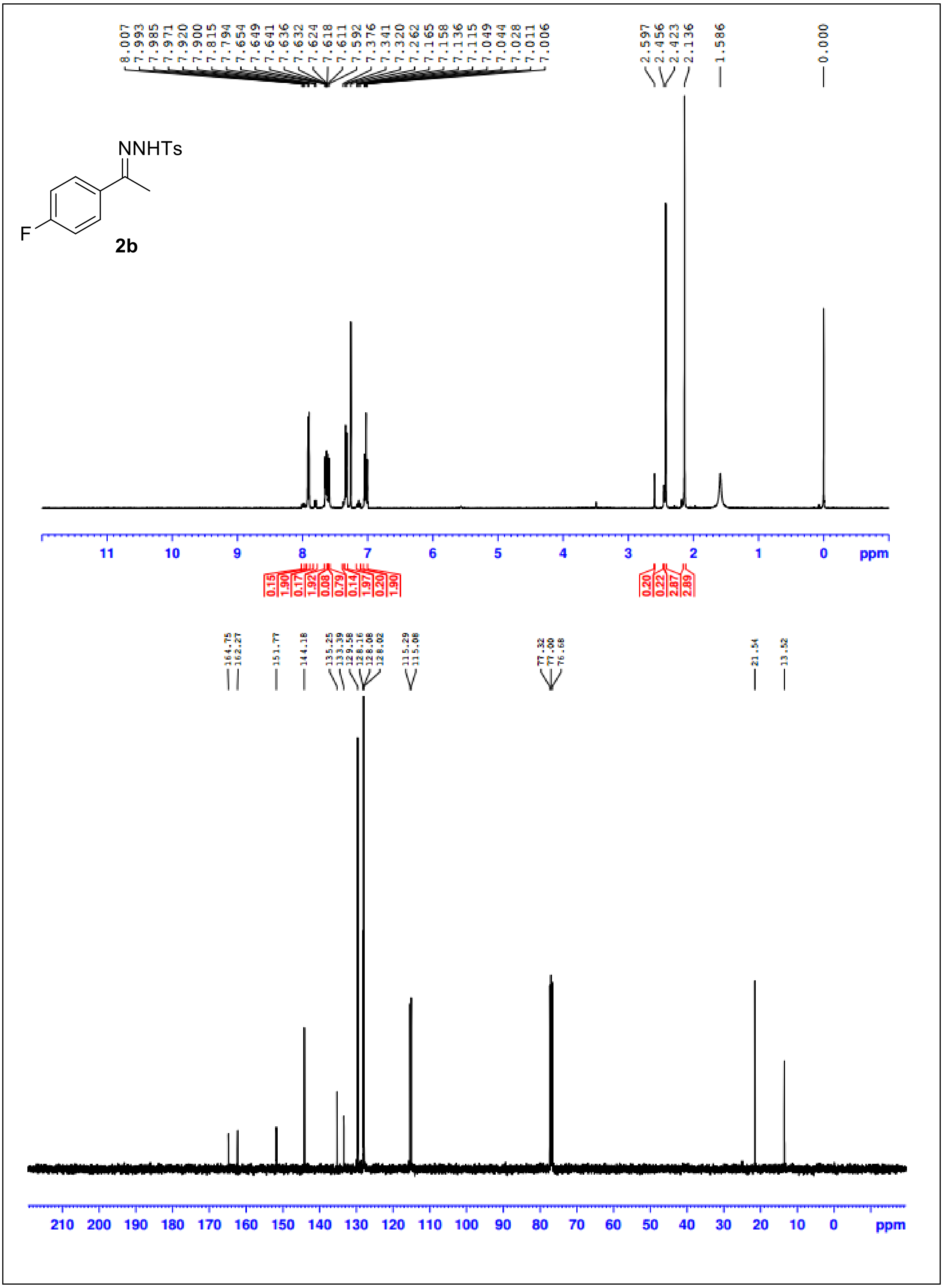
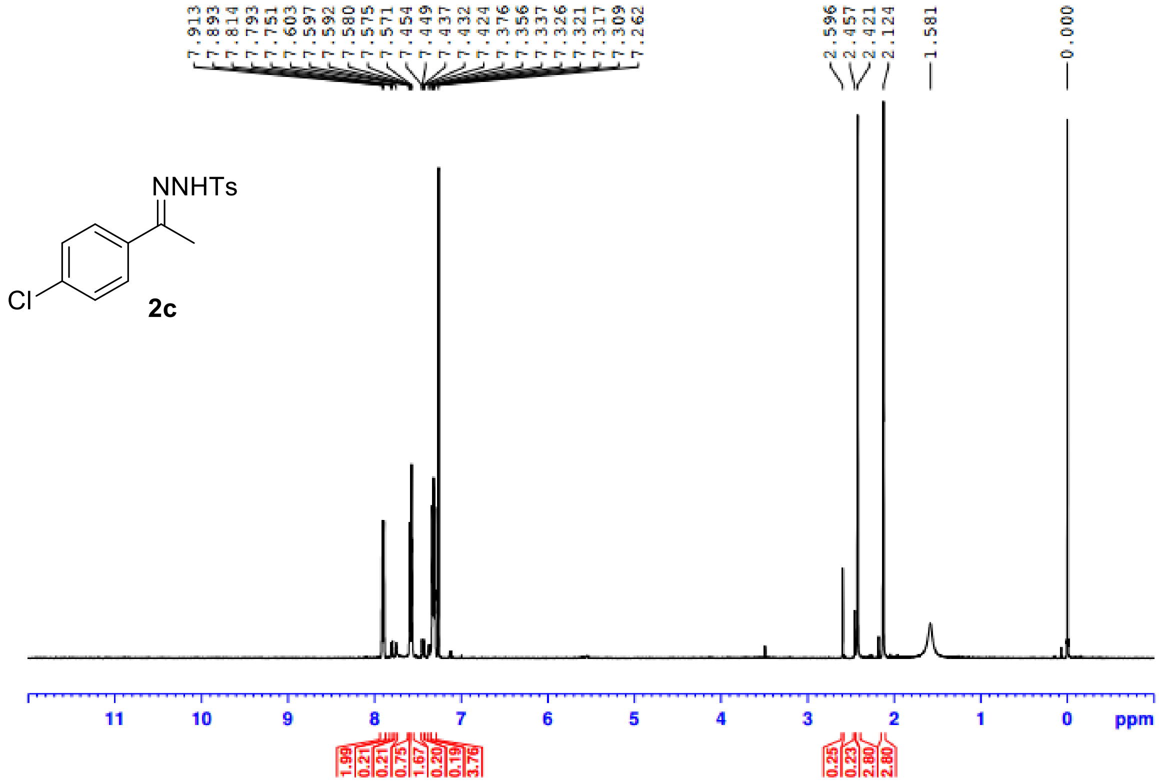
197.51
152.14
135.46
135.33
131.31
131.09
124.41
124.23
123.58
95.65
77.32
77.00
76.68
41.51
39.57
31.78
26.60
26.48
25.58
25.55
24.24
24.08
23.26
17.54
17.53
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
ppm

NMR Spetra for hydrazones:

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7.814
7.793
7.751
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7.597
7.592
7.580
7.575
7.571
7.454
7.449
7.437
7.432
7.424
7.376
7.356
7.337
7.326
7.321
7.317
7.309
7.262
2.596
2.457
2.421
2.124
1.581
0.000
NNHTs
Cl
2c
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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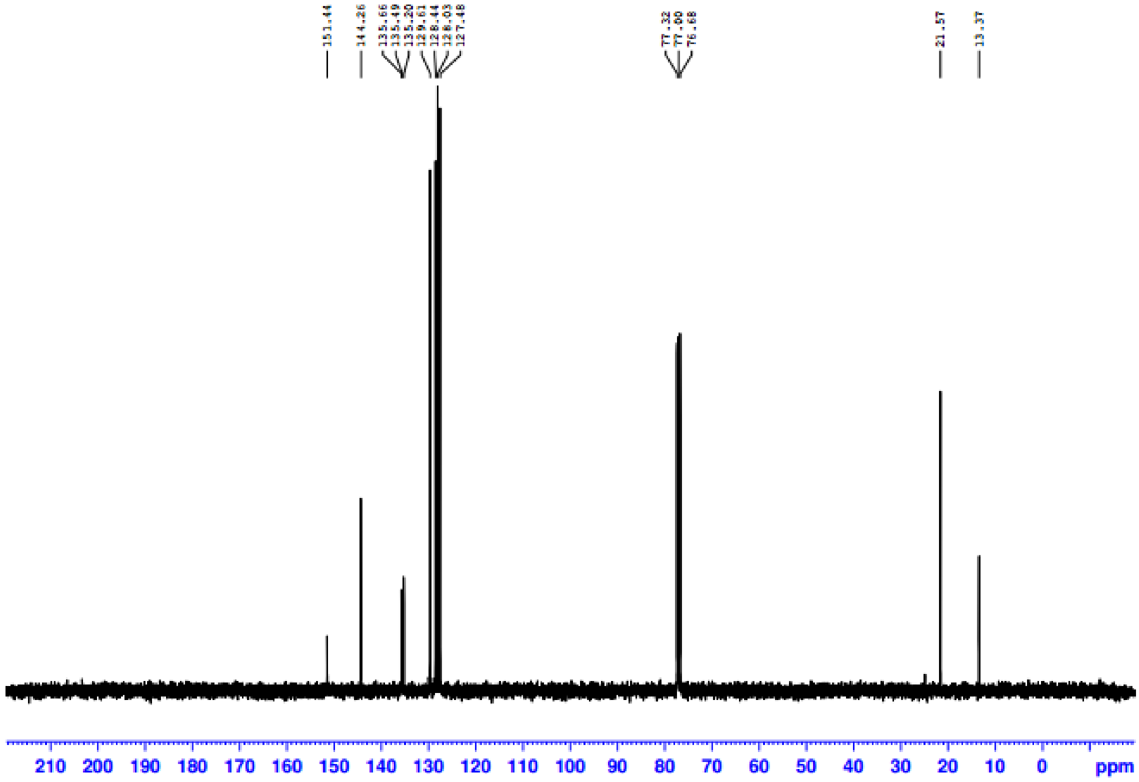
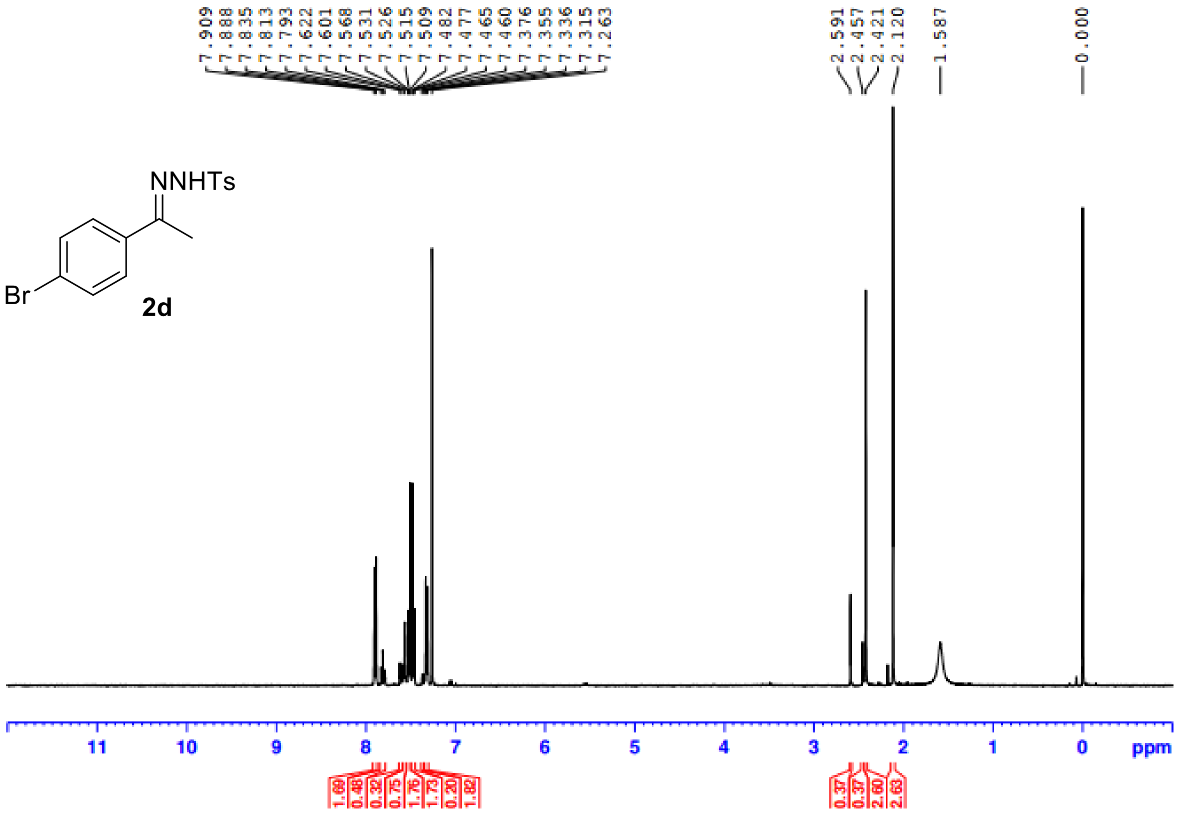
0.21
0.75
1.67
0.20
0.19
3.76
0.25
0.23
2.80
2.80


151.44
144.26
135.66
135.49
135.20
129.61
128.44
128.03
127.48
77.32
77.00
76.68
21.57
13.37
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.835
7.813
7.793
7.622
7.601
7.568
7.531
7.526
7.515
7.509
7.482
7.477
7.465
7.460
7.376
7.355
7.336
7.315
7.263
2.591
2.457
2.421
2.120
1.587
0.000
NNHTs
Br
2d
11
10
9
8
7
6
5
4
3
2
1
0
ppm
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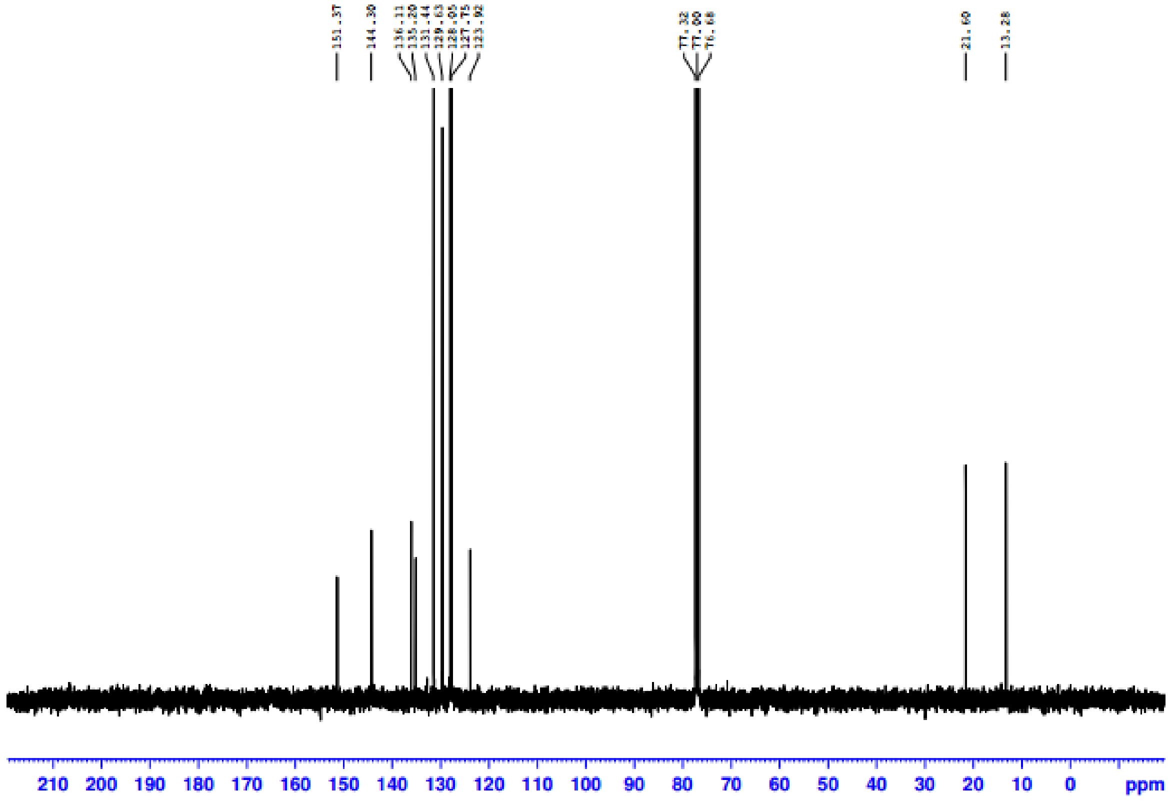
0.48
0.32
0.75
1.76
1.73
0.20
1.82
0.37
0.37
2.60
2.63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144.30
136.11
135.20
131.44
129.63
128.05
127.75
123.92
77.32
77.00
76.68
21.60
13.28
210
200
190
180
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150
140
130
120
110
100
90
80
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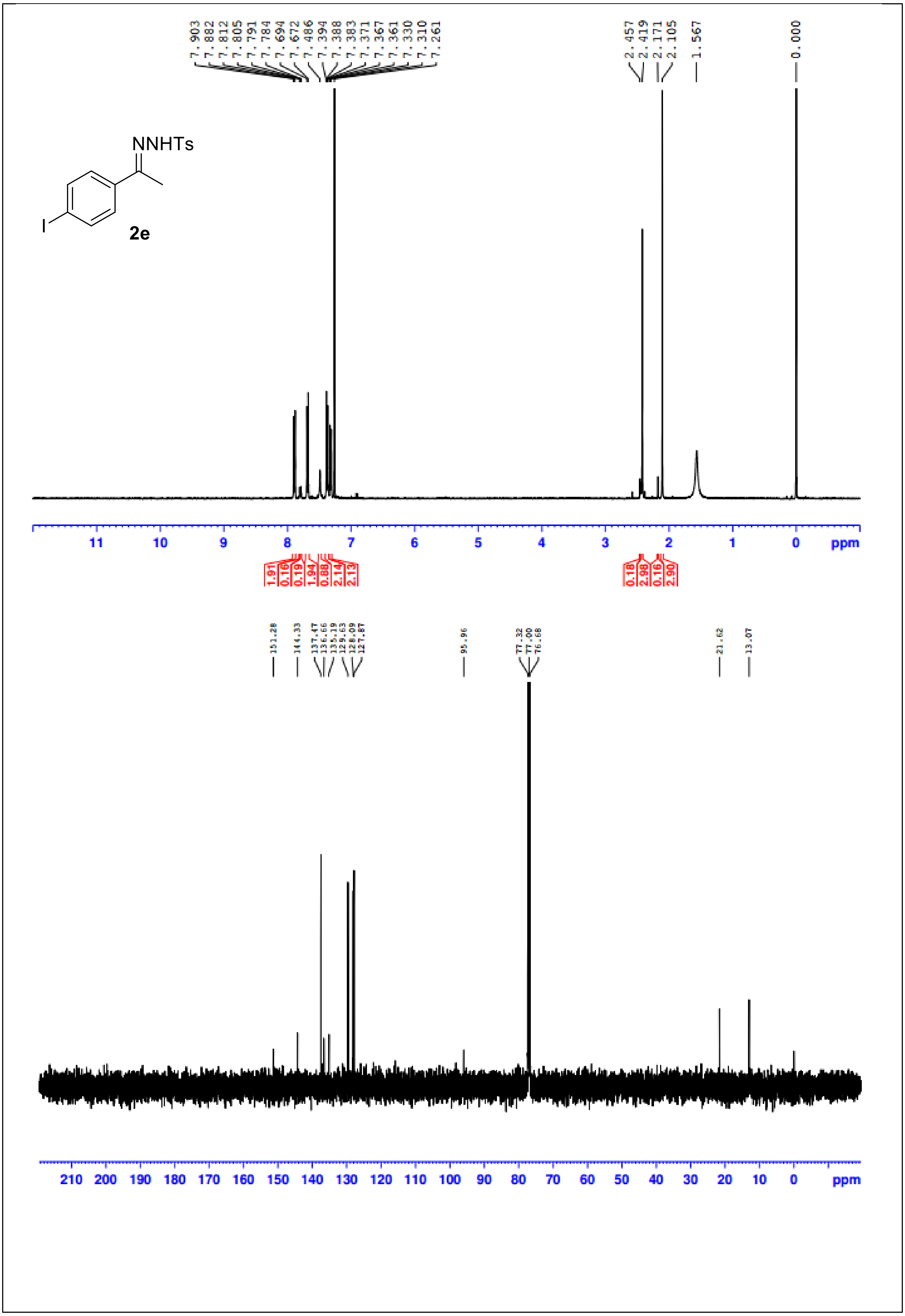
60
50
40
30
20
10
0
ppm



NNHTs
I
2e
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7.882
7.812
7.805
7.791
7.784
7.694
7.672
7.486
7.394
7.388
7.383
7.371
7.367
7.361
7.330
7.310
7.261
2.457
2.419
2.171
2.105
1.567
0.000
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.91
0.16
0.19
1.94
0.88
2.14
2.13
0.18
2.98
0.16
2.90
151.28
144.33
137.47
136.66
135.19
129.63
128.09
127.87
95.96
77.32
77.00
76.68
21.62
13.07
210
200
190
180
170
160
150
140
130
120
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100
90
80
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20
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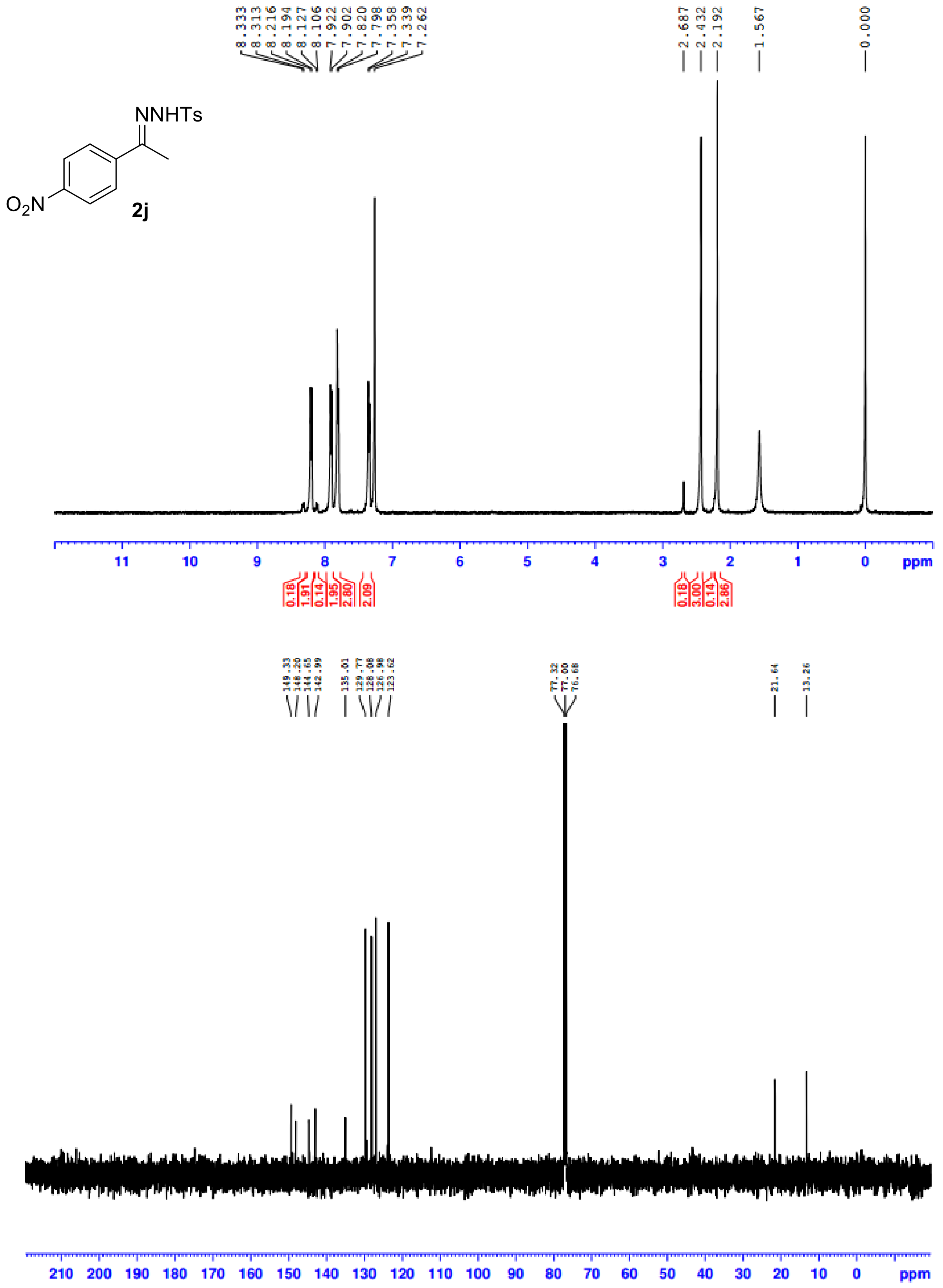
0
ppm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7.902
7.820
7.798
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7.339
7.262
2.687
2.432
2.192
1.567
0.000
NNHTs
O_2N
2j
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.18
1.91
0.14
1.95
2.80
2.09
0.18
3.00
0.14
2.86
149.33
148.20
144.65
142.99
135.01
129.77
128.08
126.98
123.62
77.32
77.00
76.68
21.64
13.26
210
200
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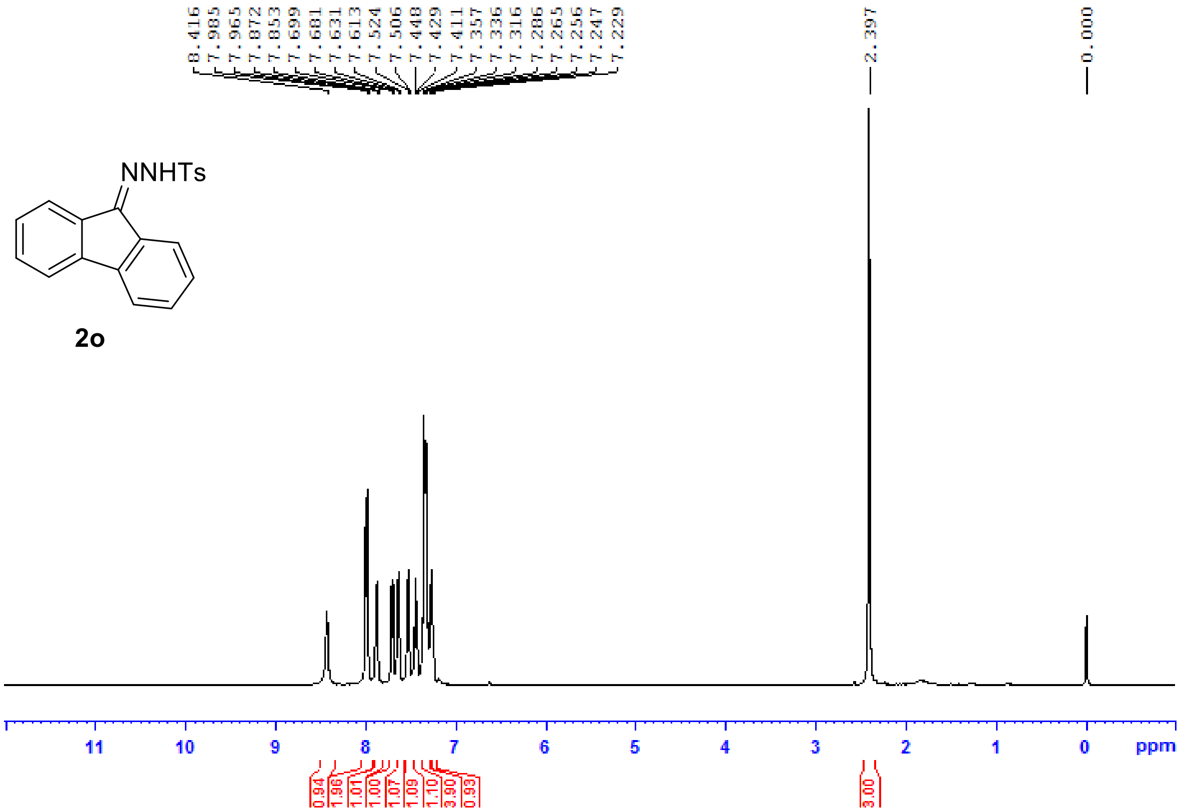
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7.631
7.613
7.524
7.506
7.448
7.429
7.411
7.357
7.336
7.316
7.286
7.265
7.256
7.247
7.229
2.397
0.000
NNHTs
2o
11
10
9
8
7
6
5
4
3
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ppm
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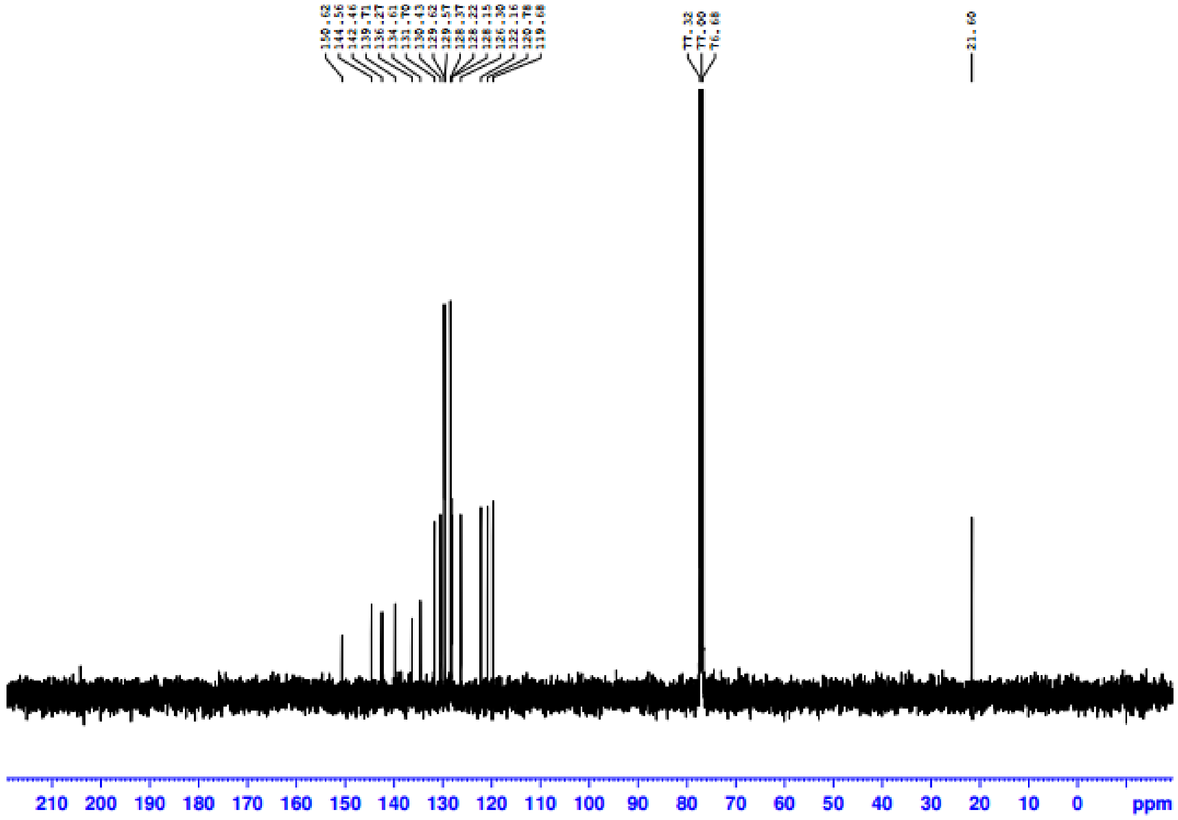
1.96
1.01
1.00
1.07
1.09
1.10
3.90
0.93
3.00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129.57
128.37
128.22
128.15
126.30
122.16
120.78
119.68
77.32
77.00
76.68
21.60
210
200
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130
120
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100
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80
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60
50
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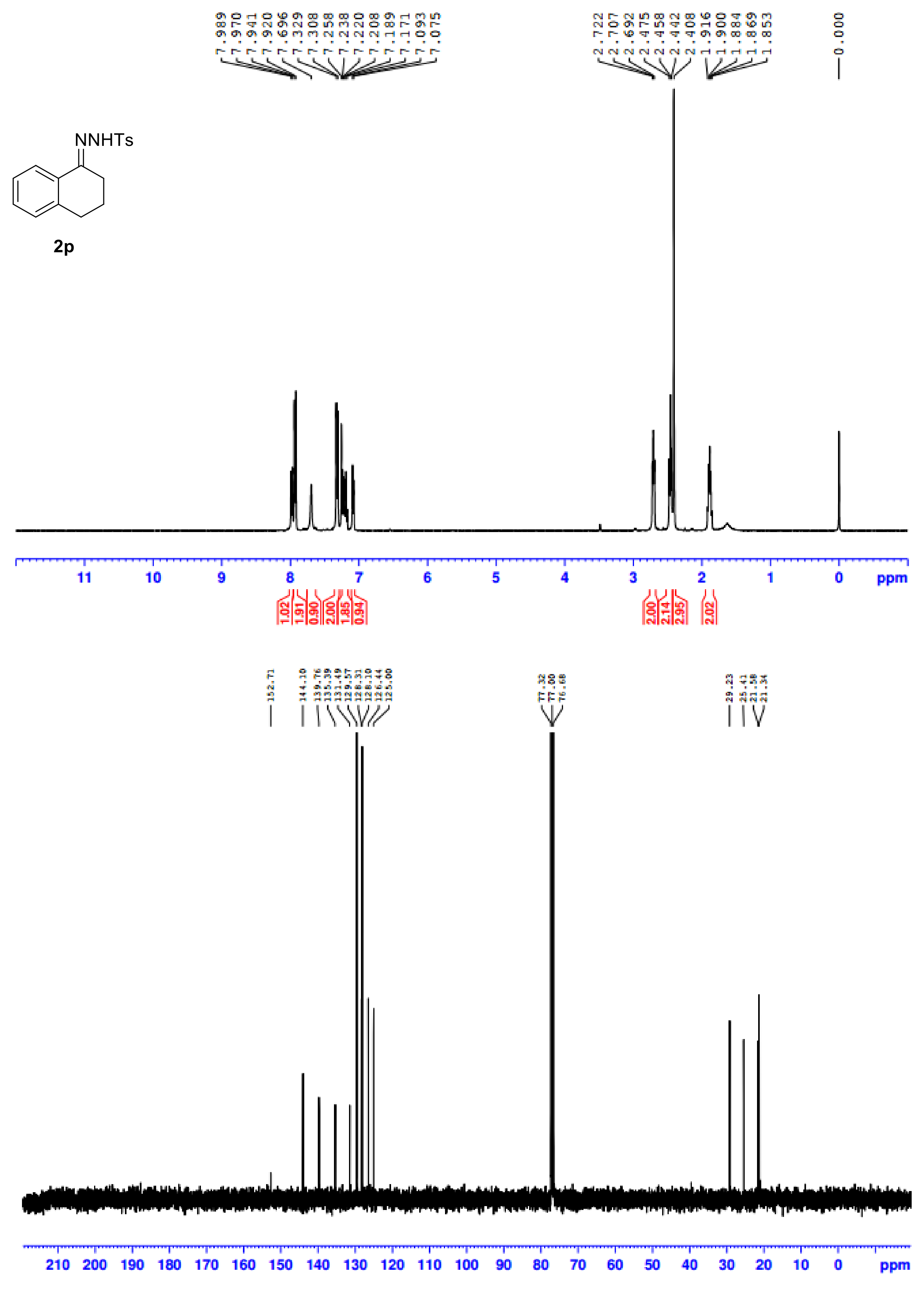
30
20
10
0
ppm

NNHTs
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7.238
7.220
7.208
7.189
7.171
7.093
7.075
2.722
2.707
2.692
2.475
2.458
2.442
2.408
1.916
1.900
1.884
1.869
1.853
0.000
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.02
1.91
0.90
2.00
1.85
0.94
2.00
2.14
2.95
2.02
152.71
144.10
139.76
135.39
131.49
129.57
128.31
128.10
126.44
125.00
77.32
77.00
76.68
29.23
25.41
21.58
21.34
210
200
190
180
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120
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100
90
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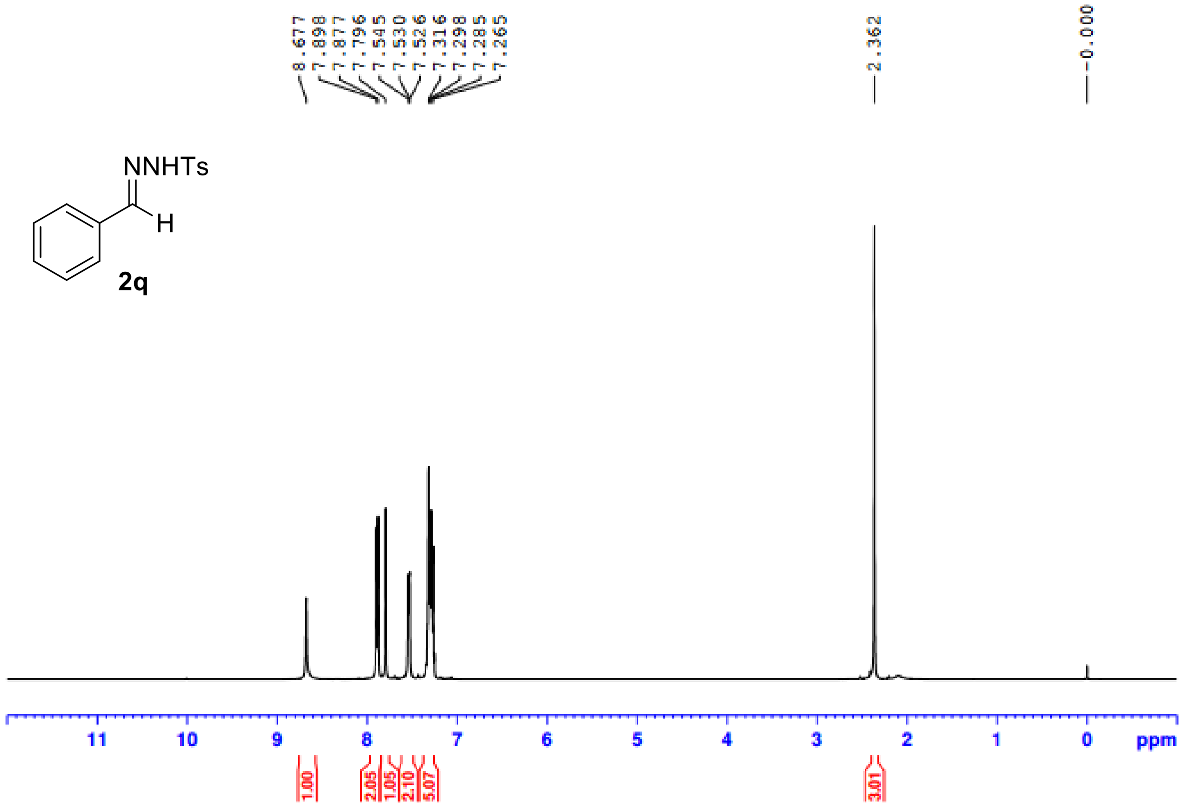
30
20
10
0
ppm

2p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7.526
7.316
7.298
7.285
7.265
2.362
-0.000
NNHTs
H
2q
11
10
9
8
7
6
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4
3
2
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0
ppm
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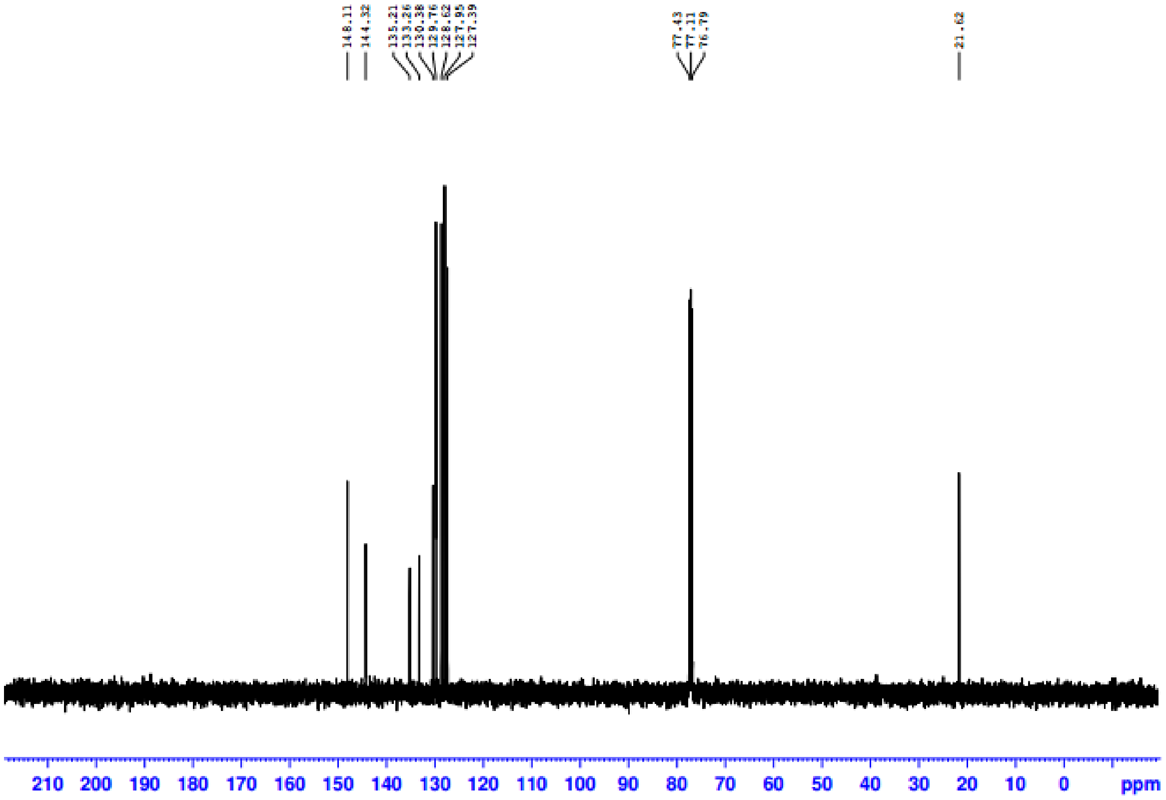
2.05
1.05
2.10
5.07
3.01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130.38
129.76
128.62
127.95
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77.43
77.11
76.79
21.62
210
200
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180
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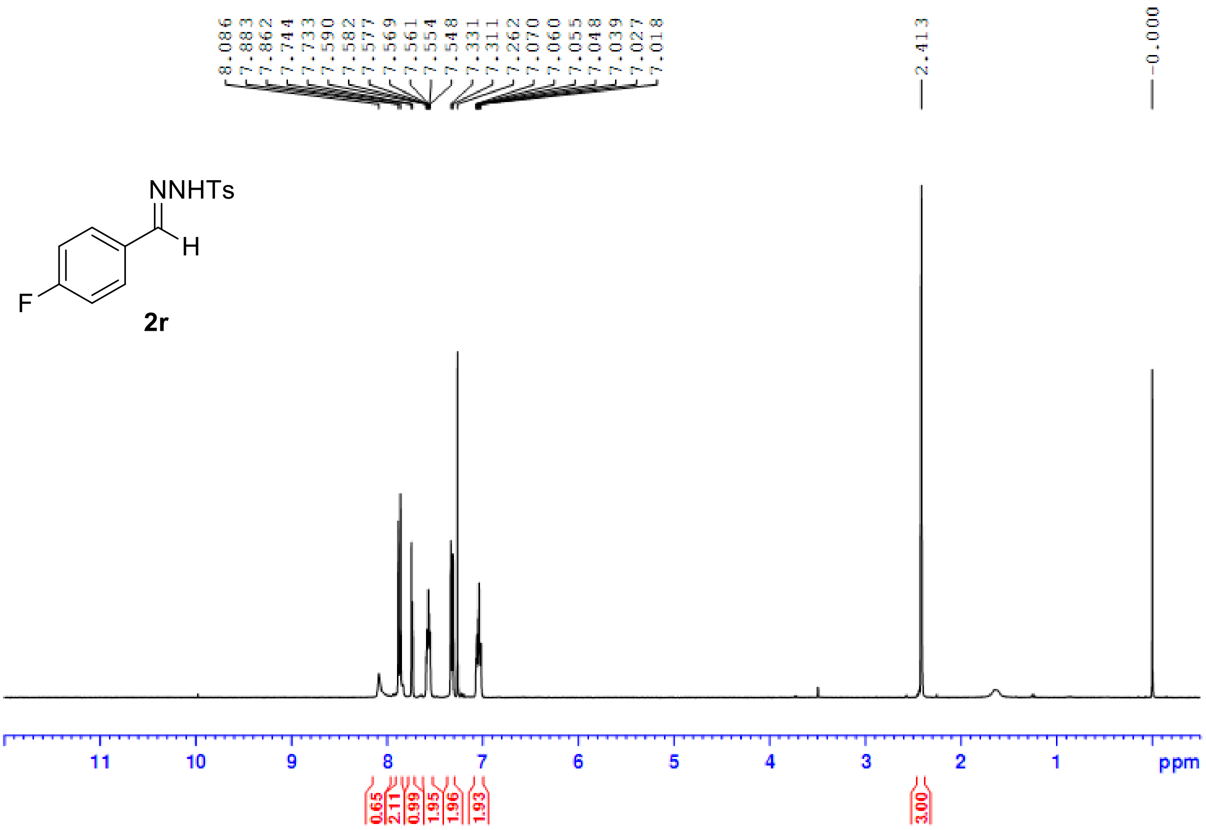
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm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7.577
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7.561
7.554
7.548
7.331
7.311
7.262
7.070
7.060
7.055
7.048
7.039
7.027
7.018
2.413
0.000
NNHTs
H
F
2r
11
10
9
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6
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4
3
2
1
ppm
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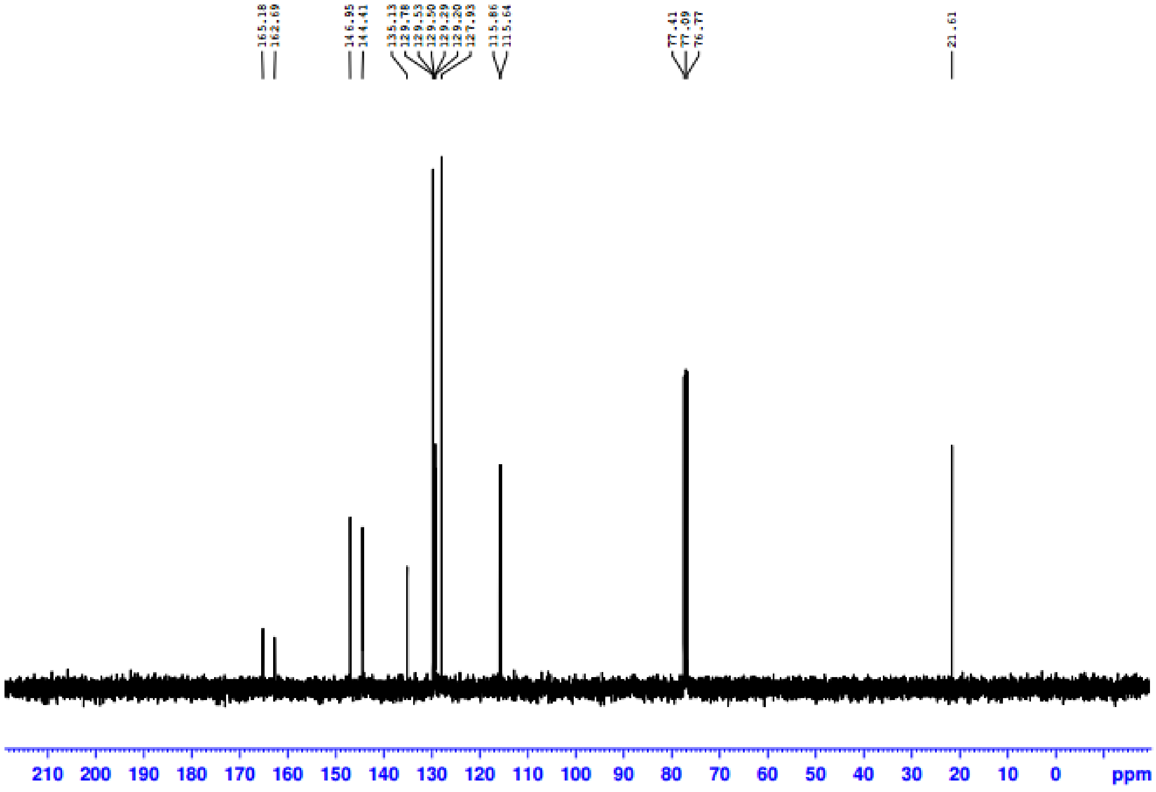
1.96
1.93
3.00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129.20
127.93
115.86
115.64
77.41
77.09
76.77
21.61
210
200
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180
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140
130
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100
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60
50
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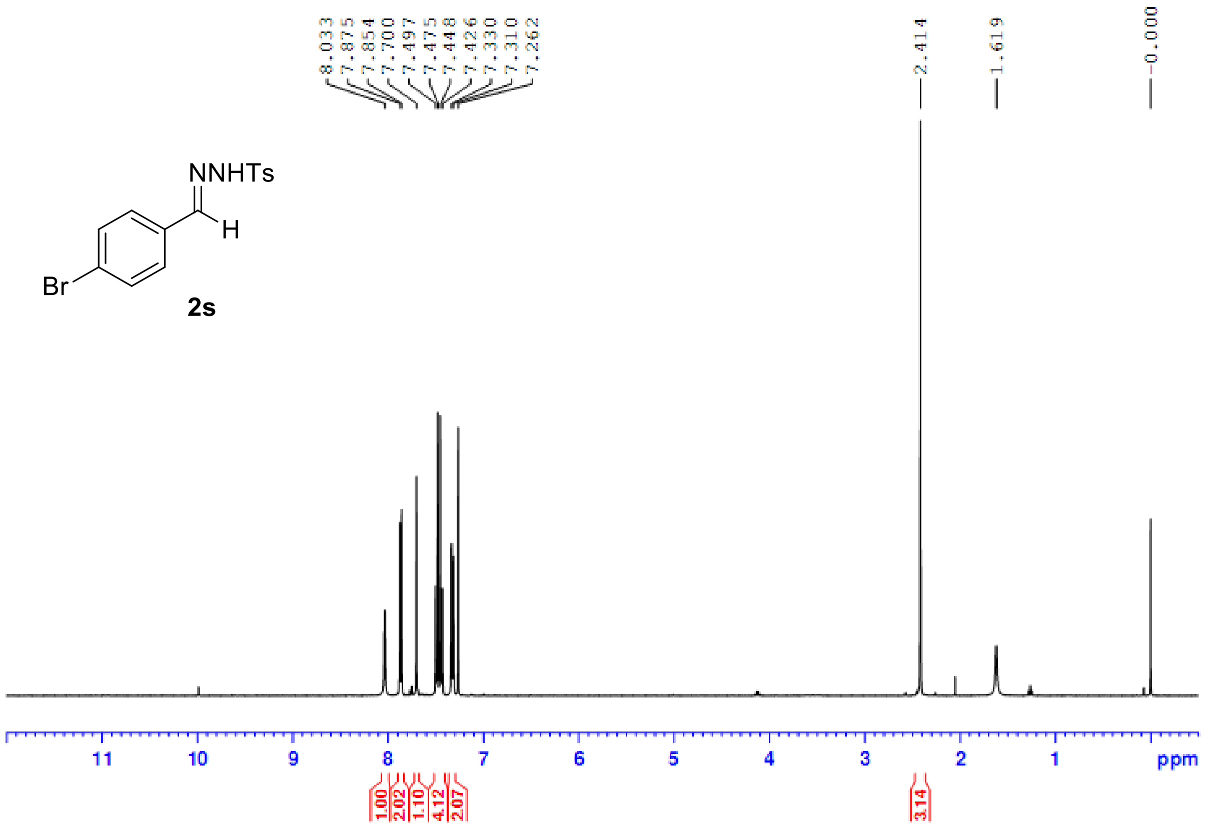
20
10
0
ppm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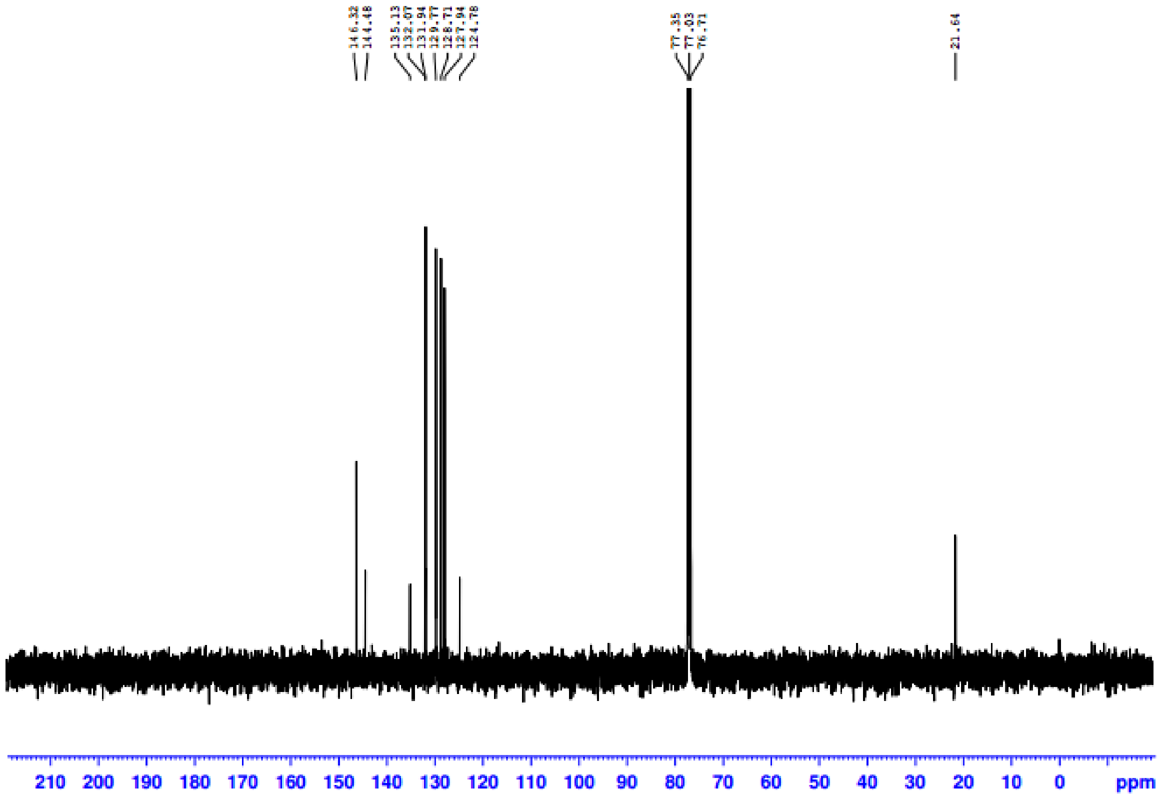
7.426
7.330
7.310
7.262
2.414
1.619
-0.000
NNHTs
H
Br
2s
11
10
9
8
7
6
5
4
3
2
1
ppm
1.00
2.02
1.10
4.12
2.07
3.14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127.94
124.78
77.35
77.03
76.71
21.64
210
200
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60
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30
20
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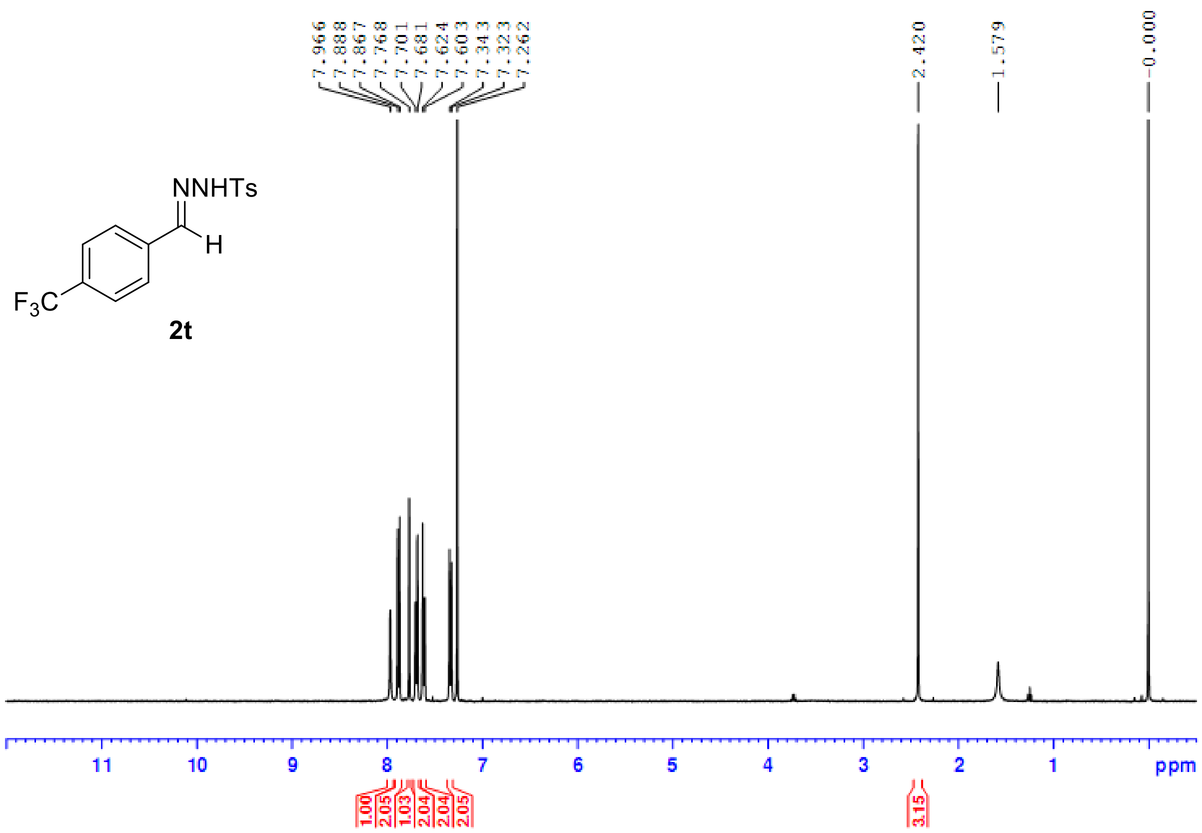
0
ppm


2t
NNHTs
H
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7.681
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7.343
7.323
7.262
2.420
1.579
0.000
11
10
9
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7
6
5
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3
2
1
ppm
1.00
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1.03
2.04
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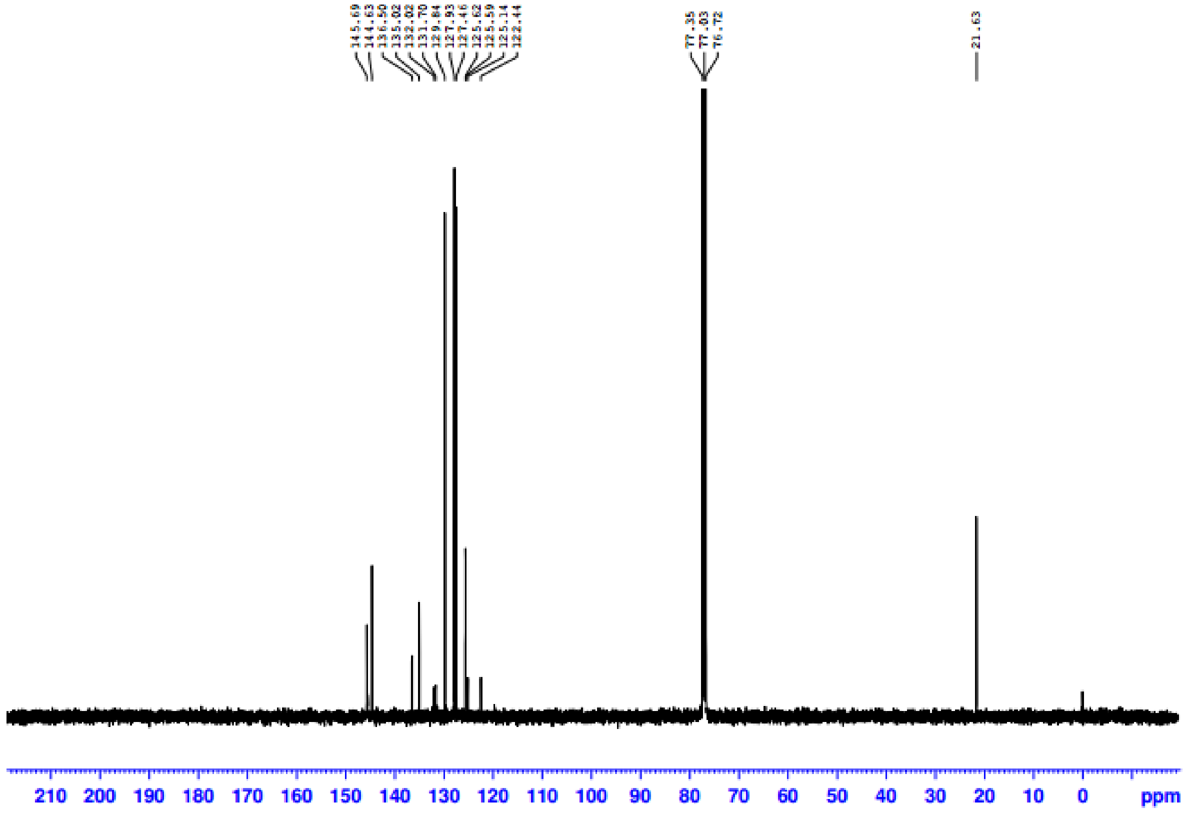
2.05
3.15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125.14
122.44
77.35
77.03
76.72
21.63
210
200
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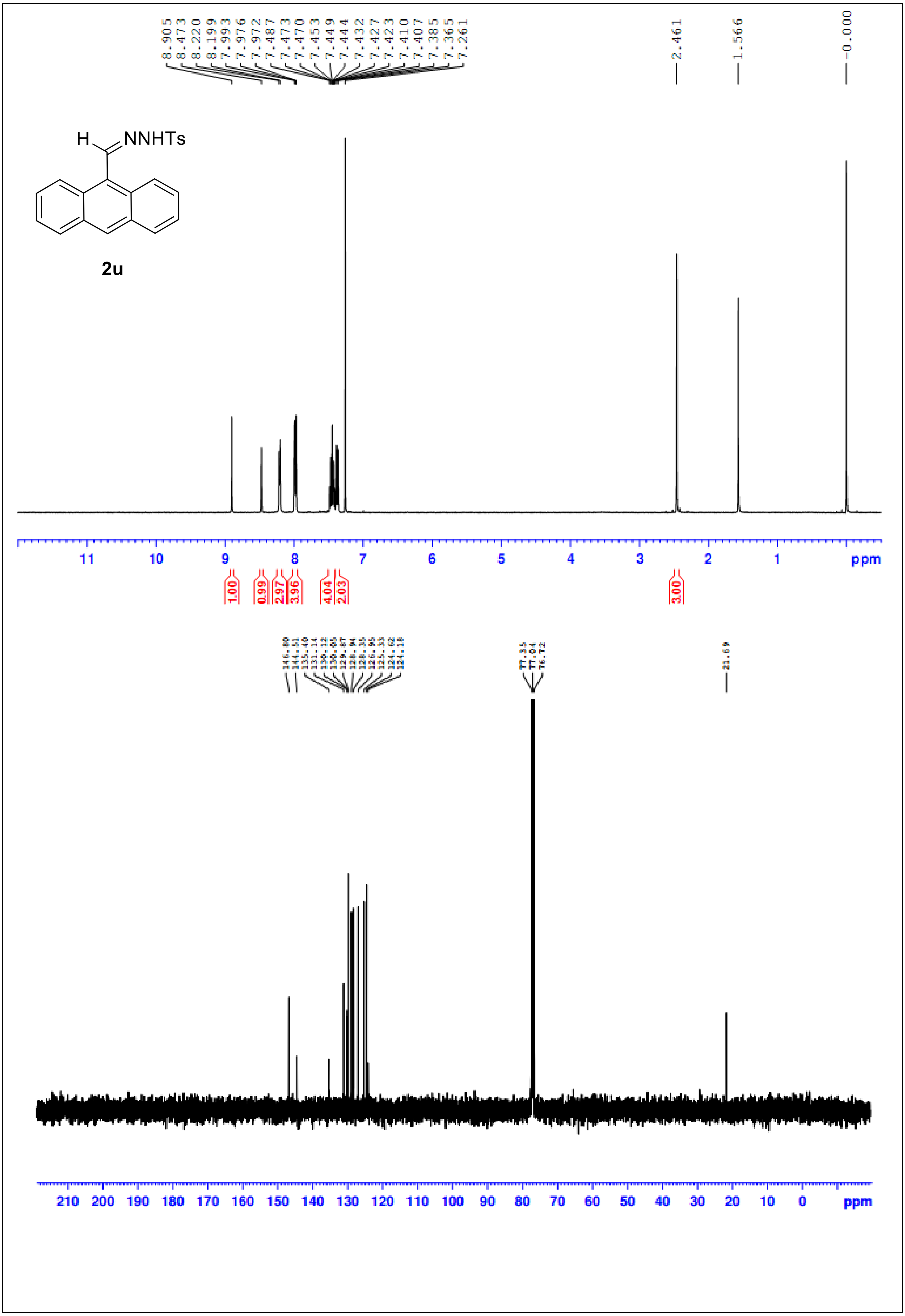
ppm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7.449
7.444
7.432
7.427
7.423
7.410
7.407
7.385
7.365
7.261
2.461
1.566
-0.000
H
NNHTs
11
10
9
8
7
6
5
4
3
2
1
ppm
1.00
0.99
2.97
3.96
4.04
2.03
3.00
146.80
144.51
135.40
131.14
130.12
130.05
129.87
128.94
128.35
126.95
125.53
124.62
124.18
77.35
77.04
76.72
21.69
210
200
190
180
170
160
150
140
130
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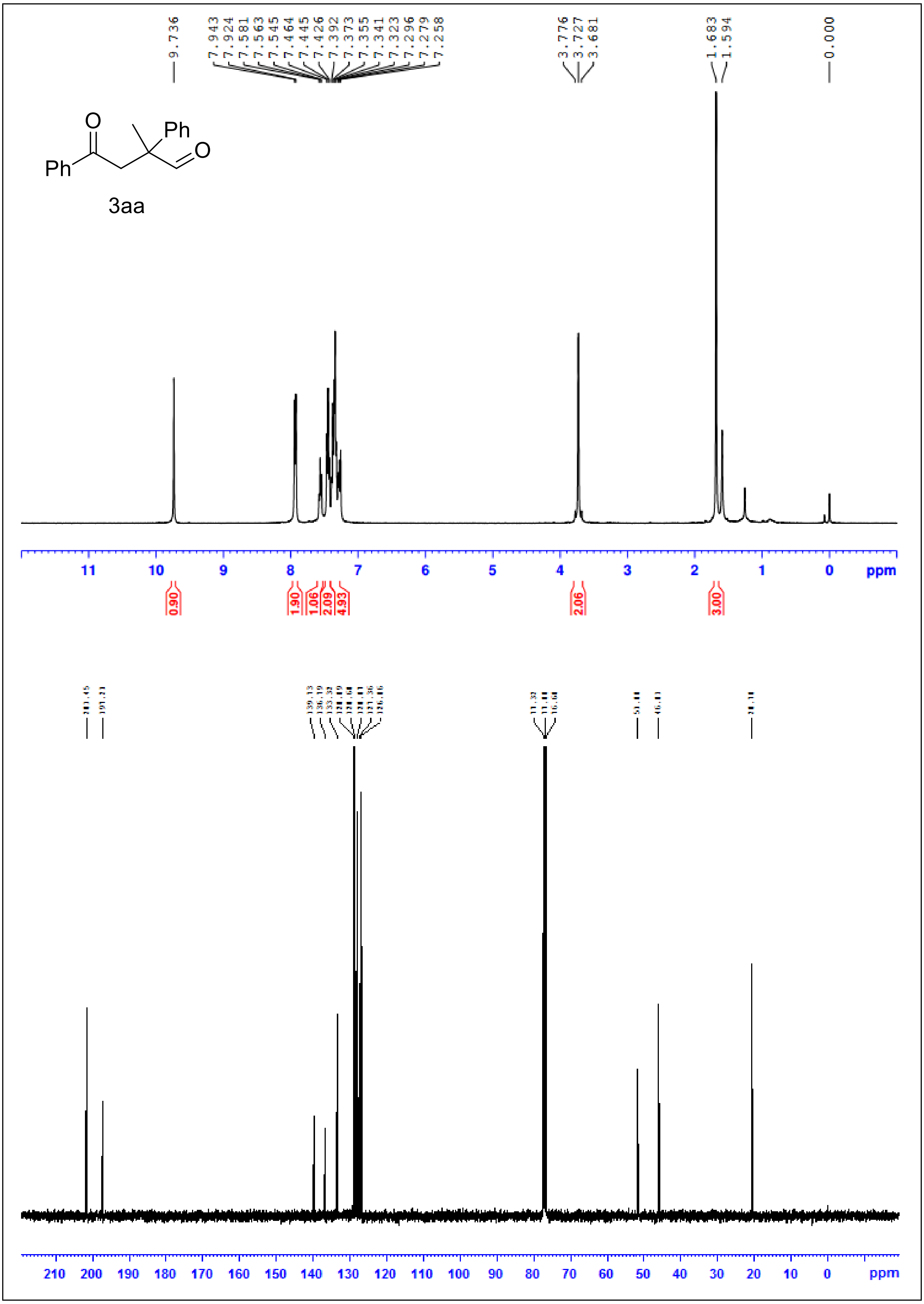
ppm

2u

NMR Spetra for 1, 4-ketoaldehydes: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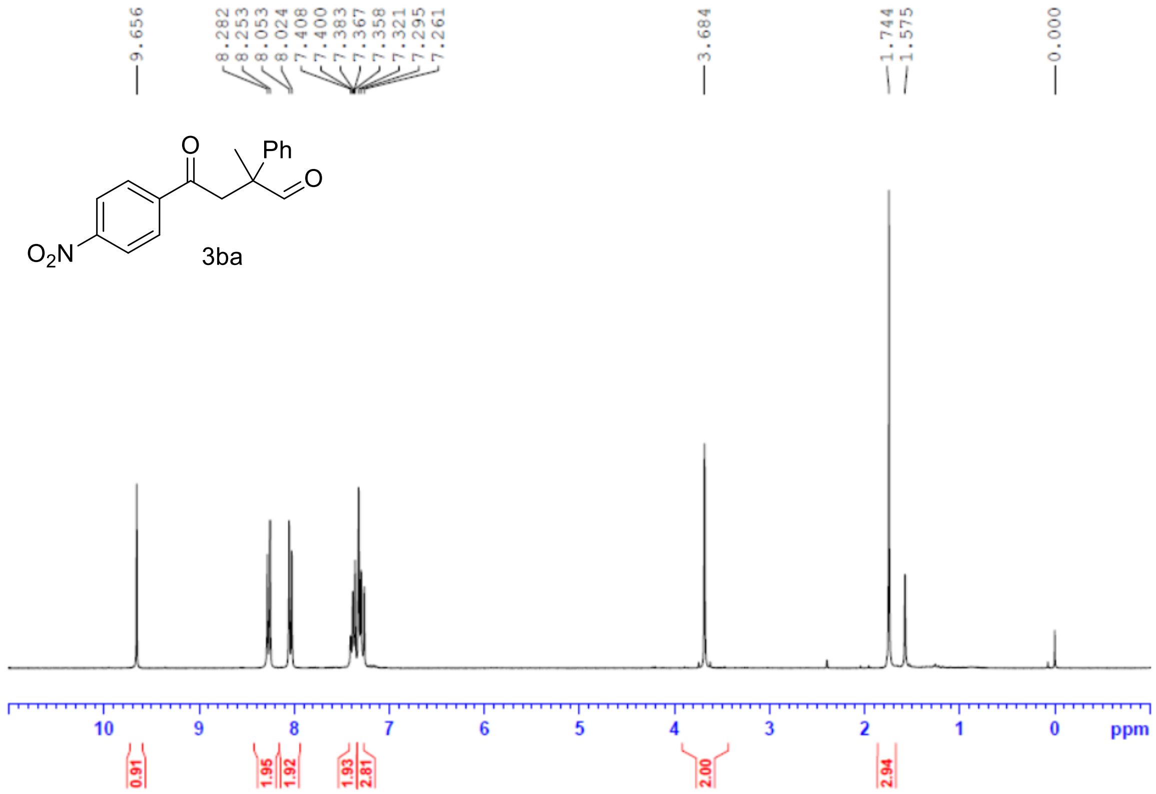
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7.295
7.261
3.684
1.744
1.575
0.000
O
Ph
O
O_2N
3ba
10
9
8
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1.92
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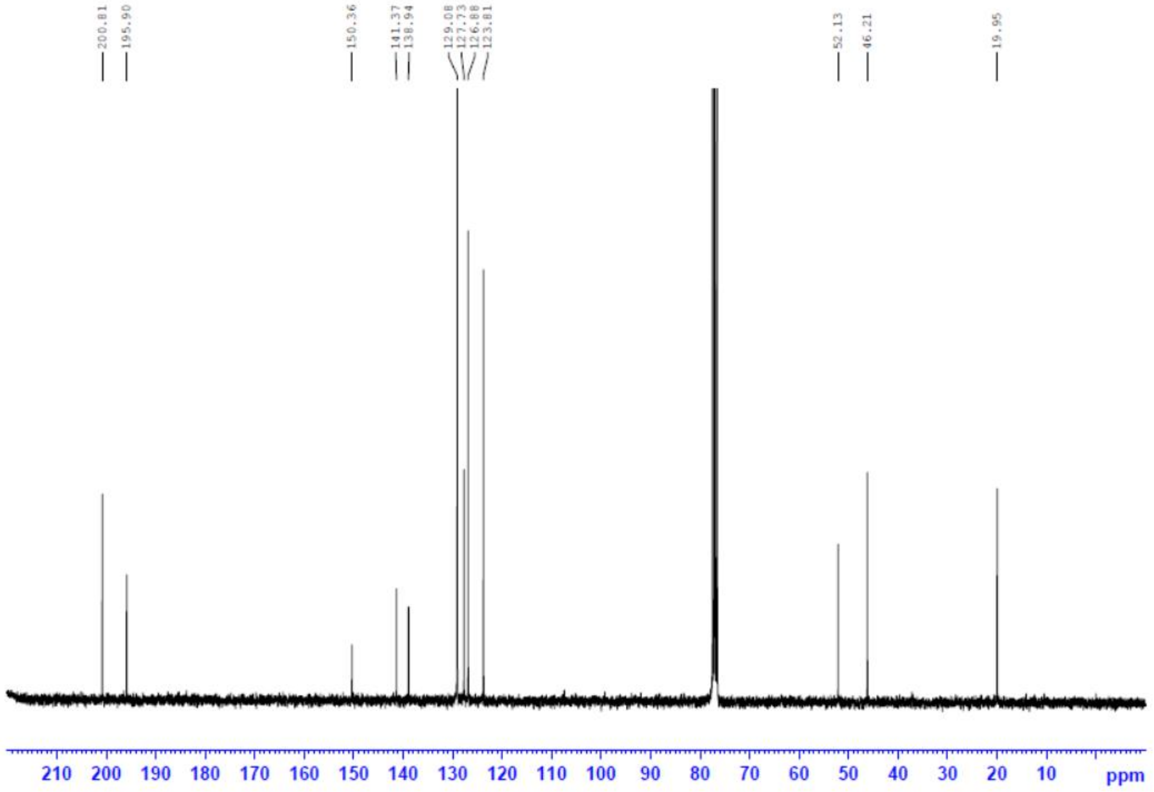
2.94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126.88
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46.21
19.95
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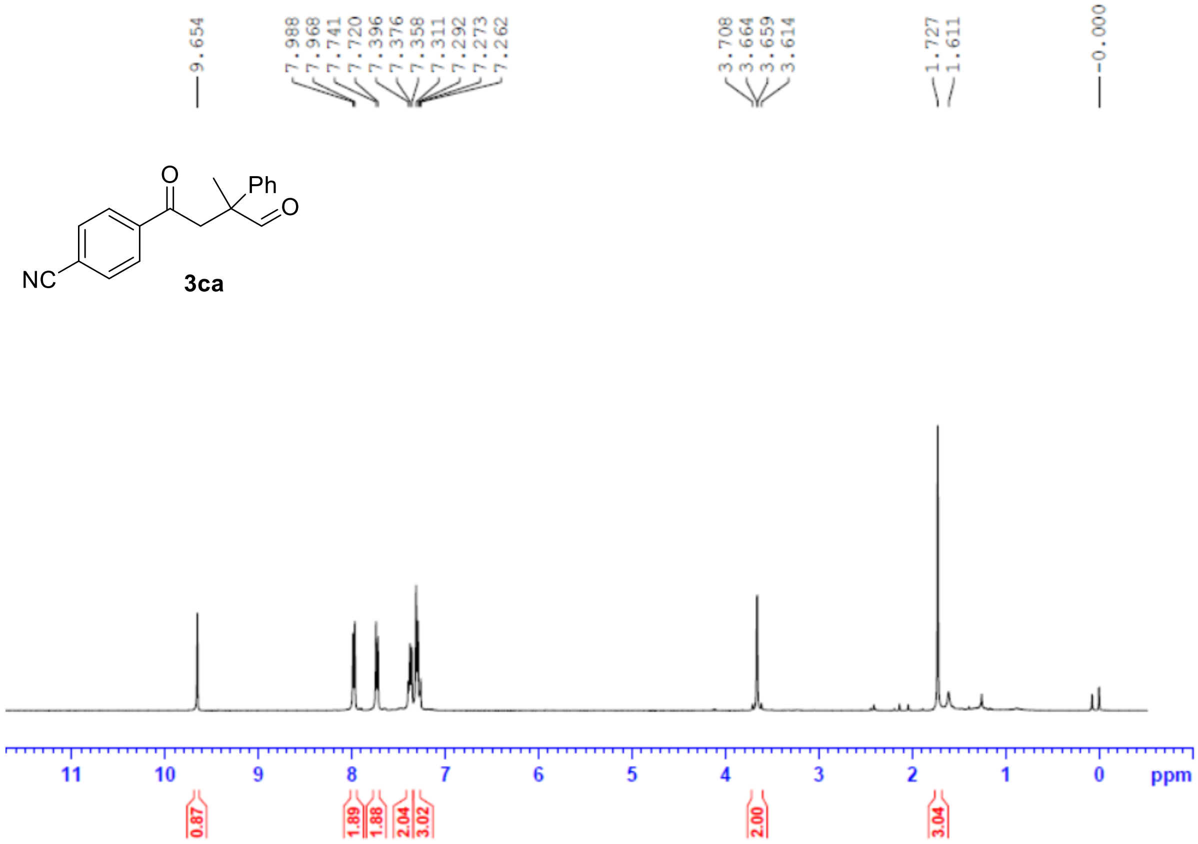
ppm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Ph
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7.311
7.292
7.273
7.262
3.708
3.664
3.659
3.614
1.727
1.611
-0.000
11
10
9
8
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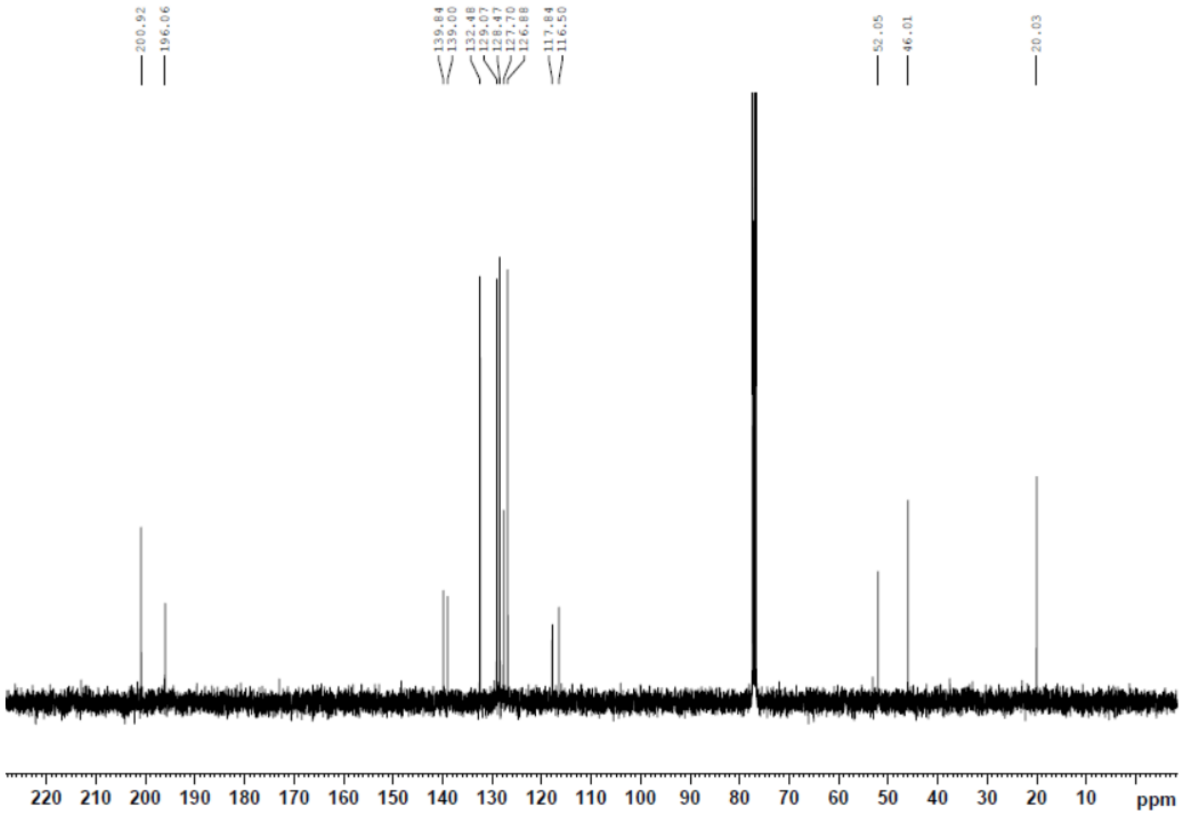
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20.03
220
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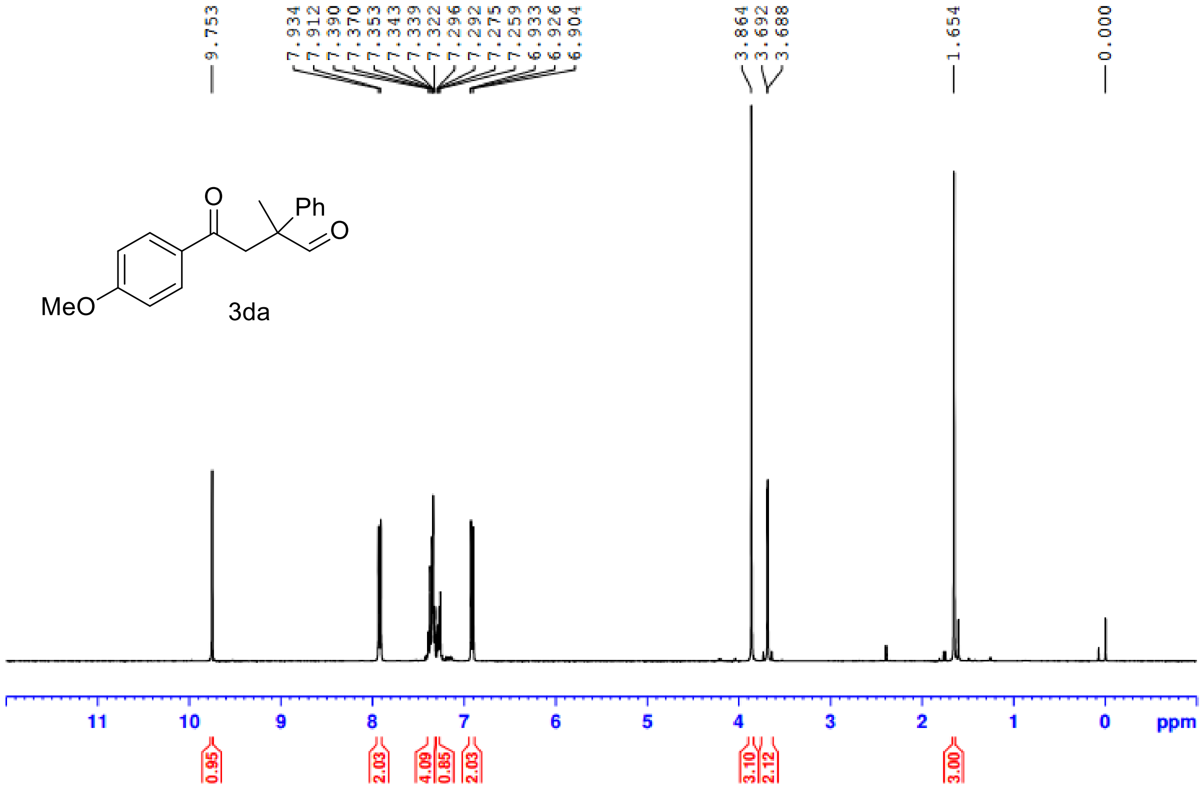
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7.339
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7.292
7.275
7.259
6.933
6.926
6.904
3.864
3.692
3.688
1.654
0.000
O
Ph
O
MeO
3da
11
10
9
8
7
6
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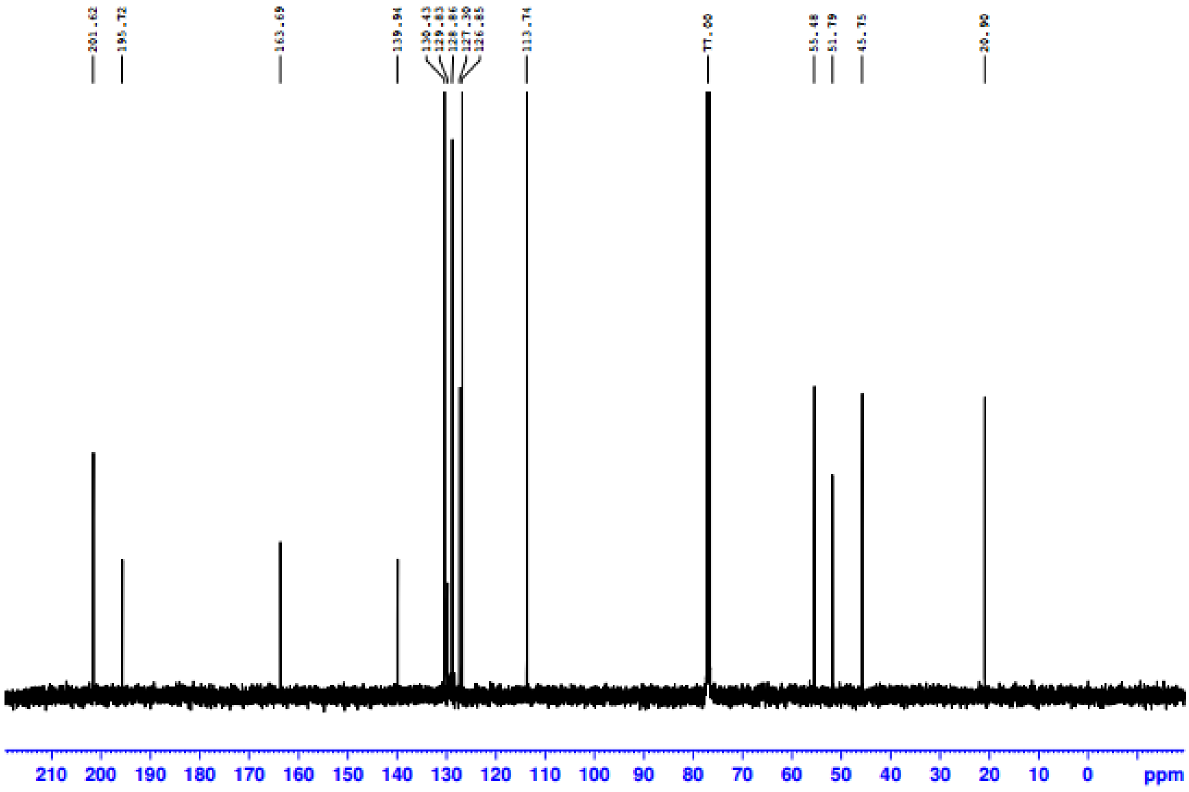
3.00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45.75
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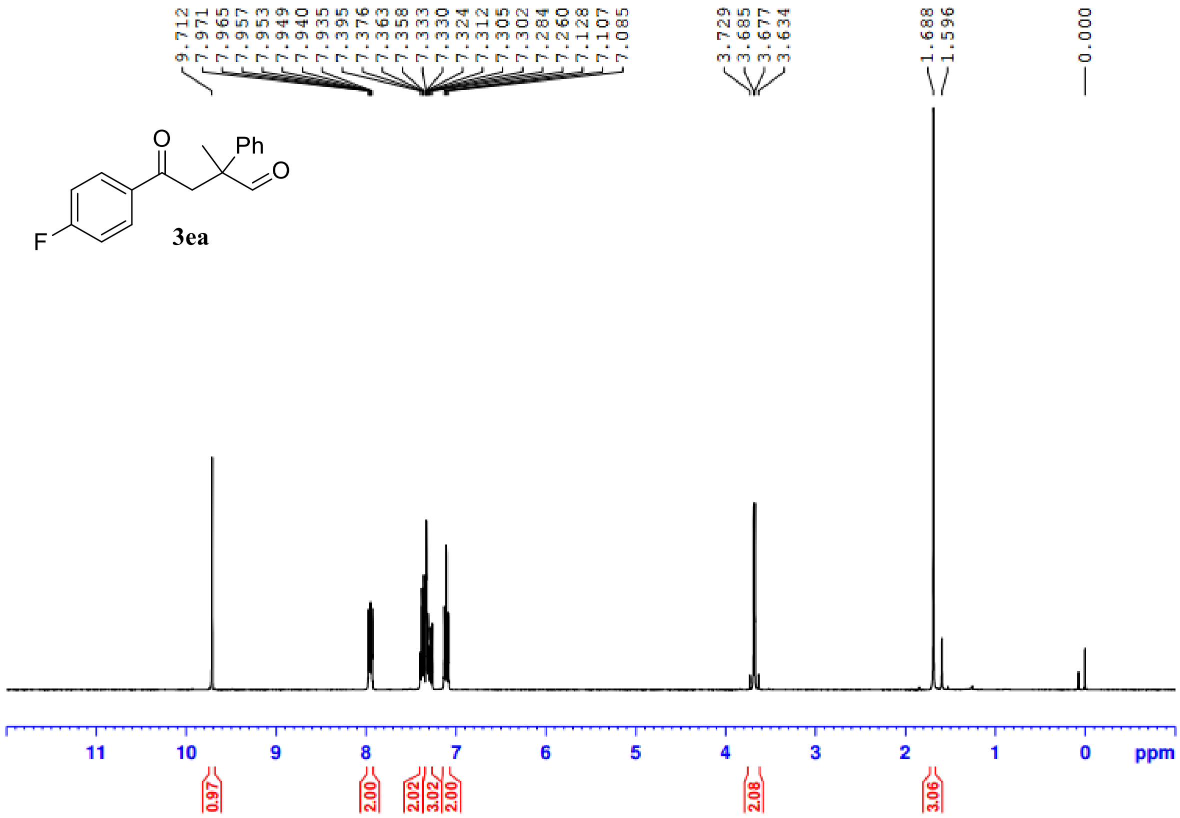
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7.324
7.312
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7.302
7.284
7.260
7.128
7.107
7.085
3.729
3.685
3.677
3.634
1.688
1.596
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O
Ph
O
F
11
10
9
8
7
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3.02
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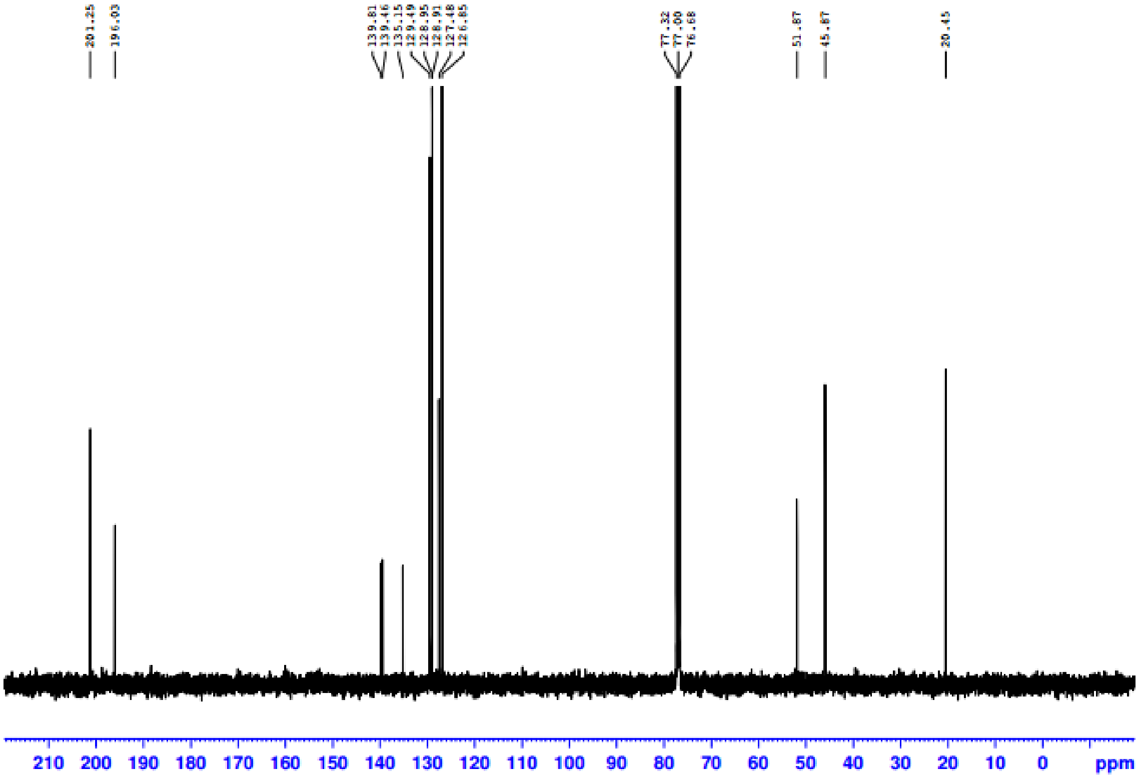
3ea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128.91
127.48
126.85
77.32
77.00
76.68
51.87
45.87
20.45
210
200
190
180
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140
130
120
110
100
90
80
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60
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20
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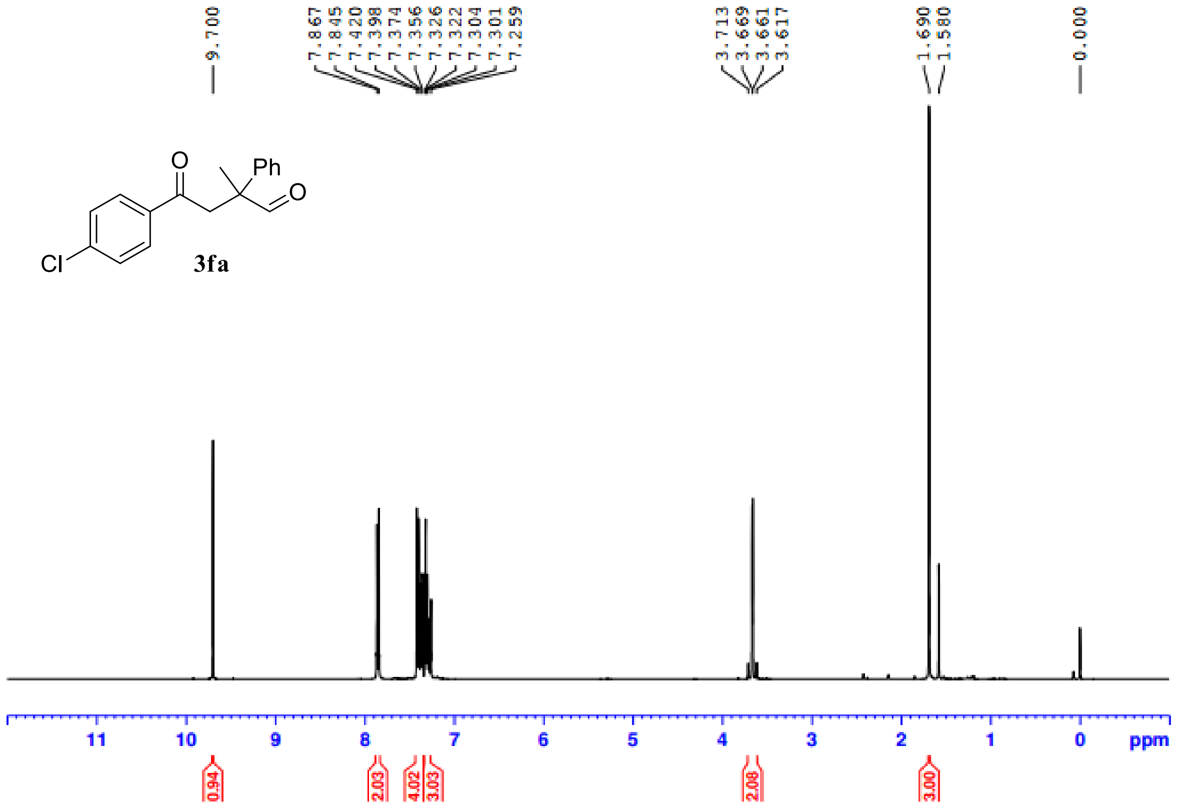

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7.398
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7.326
7.322
7.304
7.301
7.259
3.713
3.669
3.661
3.617
1.690
1.580
0.000
O
Ph
O
Cl
3fa
11
10
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8
7
6
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4
3
2
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0
ppm
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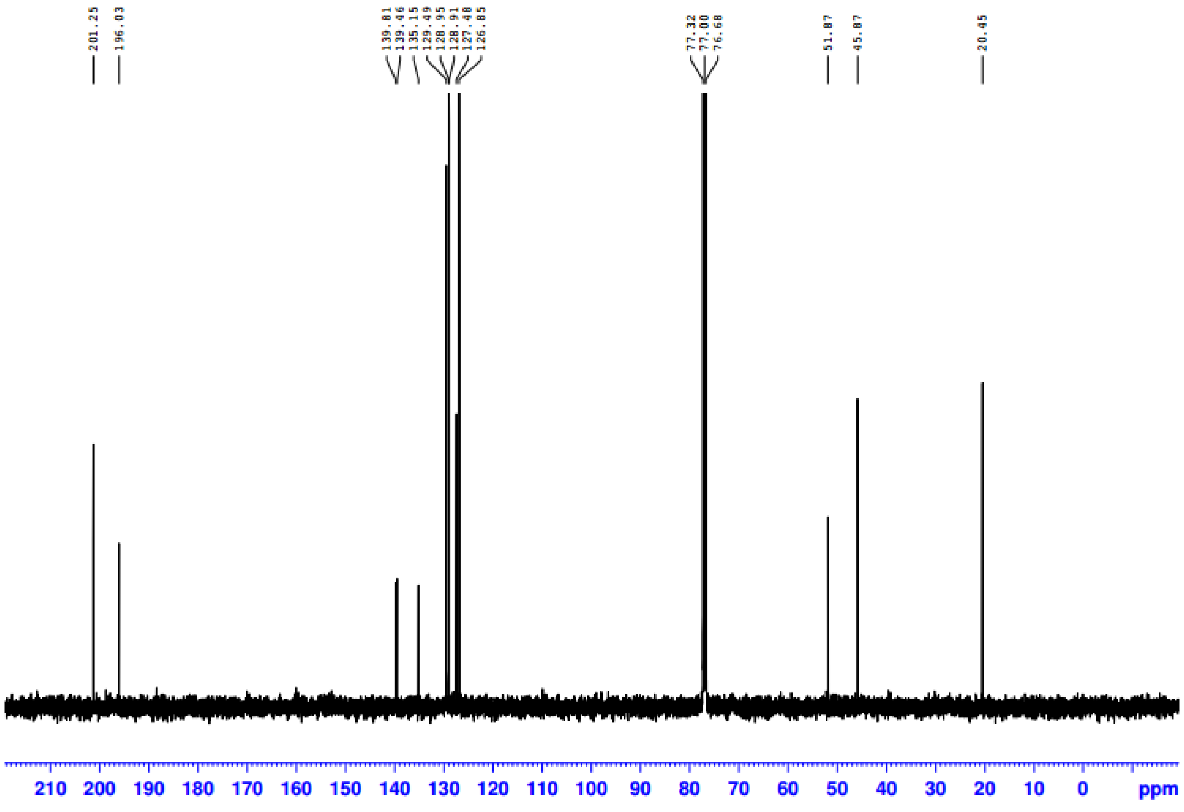
4.02
3.03
2.08
3.00



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139.81
139.46
135.15
129.49
128.95
128.91
127.48
126.85
77.32
77.00
76.68
51.87
45.87
20.45
210
200
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140
130
120
110
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60
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20
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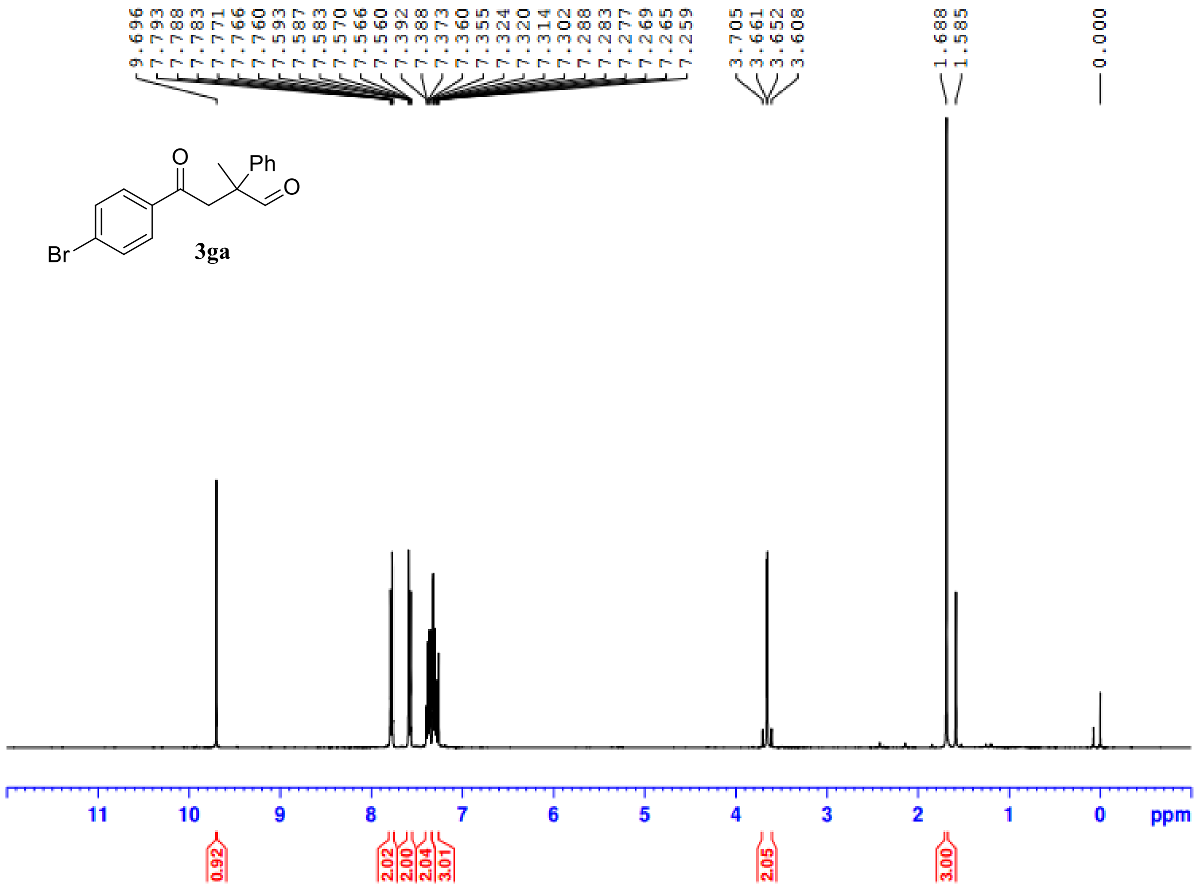
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7.583
7.570
7.566
7.560
7.392
7.388
7.373
7.360
7.355
7.324
7.320
7.314
7.302
7.288
7.283
7.277
7.269
7.265
7.259
3.705
3.661
3.652
3.608
1.688
1.585
0.000
O
Ph
O
Br
3ga
11
10
9
8
7
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5
4
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2
1
0
ppm
0.92
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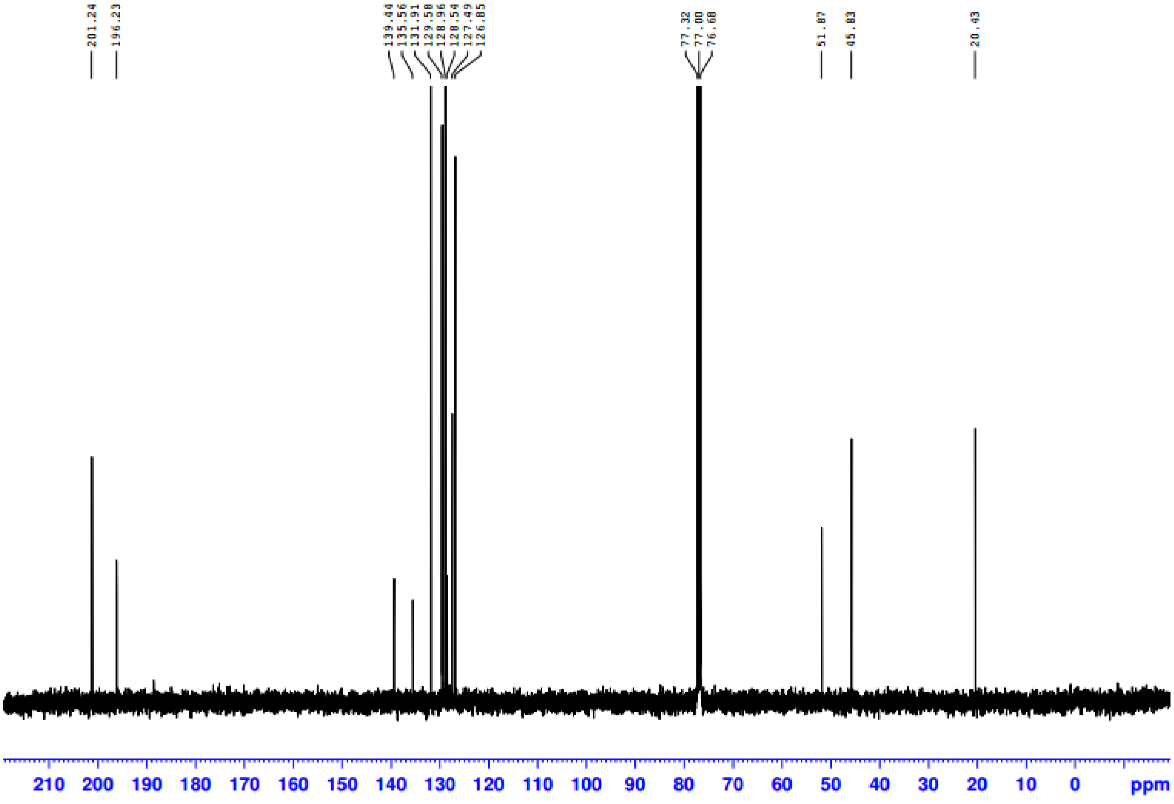
2.00
2.04
3.01
2.05
3.00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128.54
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126.85
77.32
77.00
76.68
51.87
45.83
20.43
210
200
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180
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140
130
120
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100
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80
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60
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40
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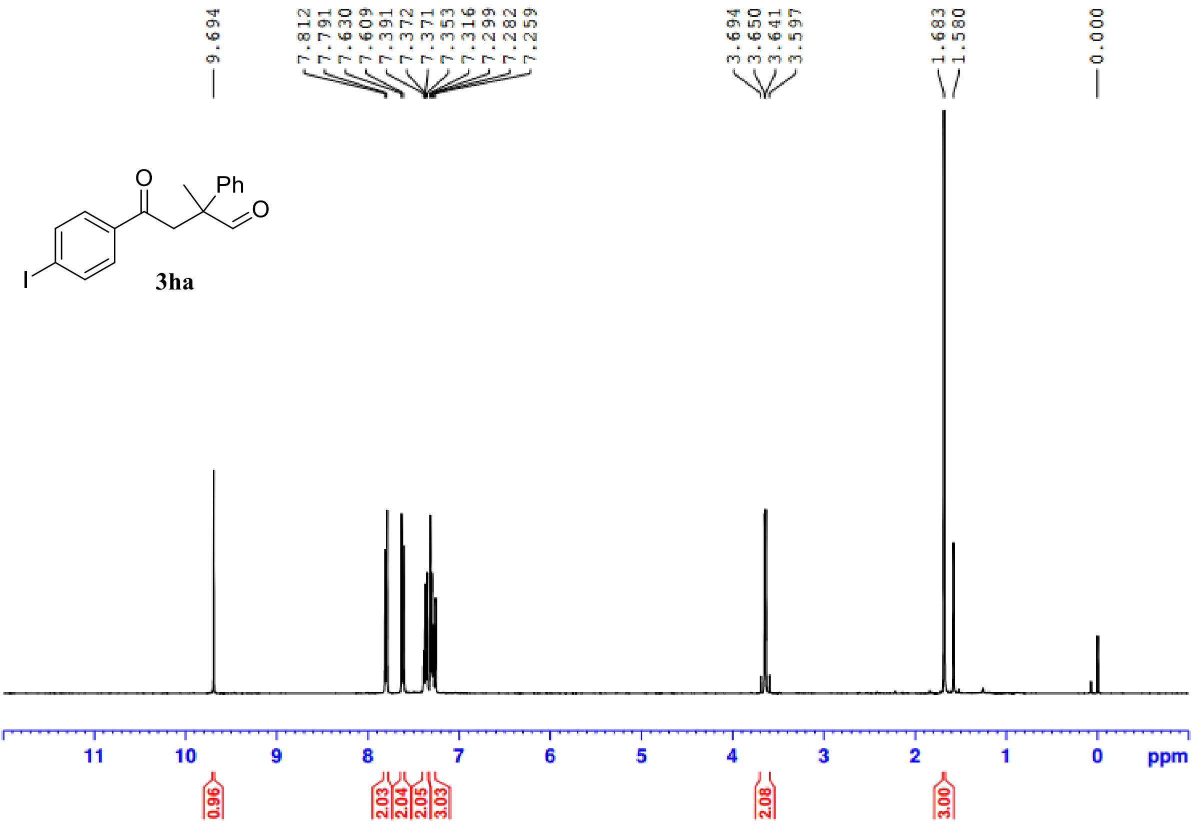
20
10
0
ppm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7.316
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7.282
7.259
3.694
3.650
3.641
3.597
1.683
1.580
0.000
O
Ph
O
I
11
10
9
8
7
6
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1
0
ppm
0.96
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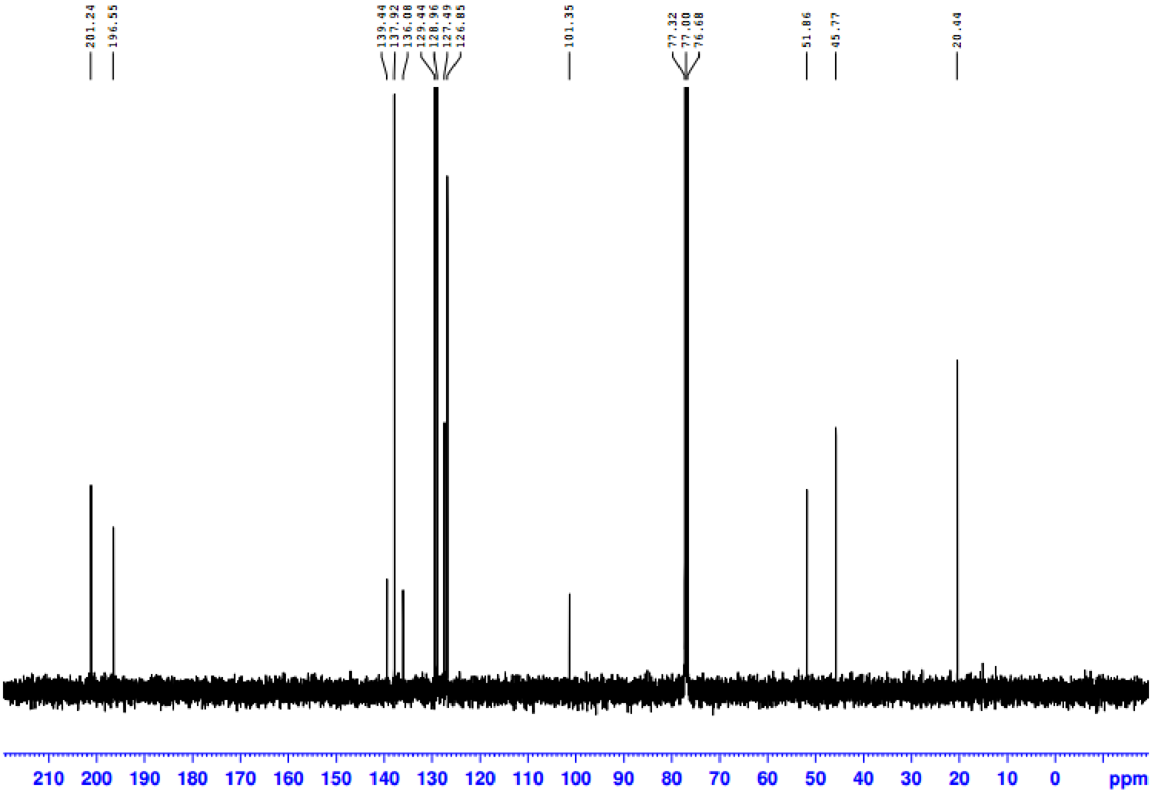
2.04
2.05
3.03
2.08
3.00

3ha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127.49
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101.35
77.32
77.00
76.68
51.86
45.77
20.44
210
200
190
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140
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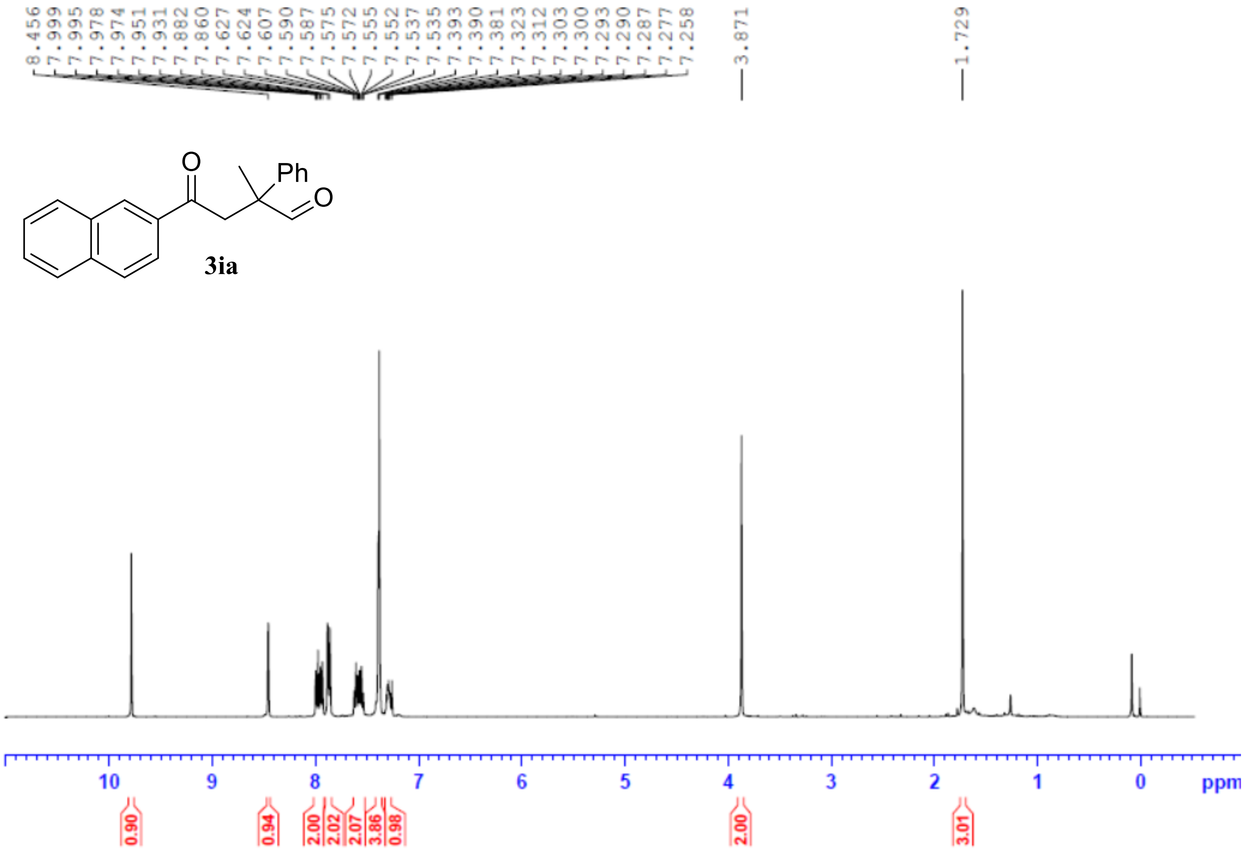
30
20
10
0
ppm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7.590
7.587
7.575
7.572
7.555
7.552
7.537
7.535
7.393
7.390
7.381
7.323
7.312
7.303
7.300
7.293
7.290
7.287
7.277
7.258
3.871
1.729
O
Ph
O
3ia
10
9
8
7
6
5
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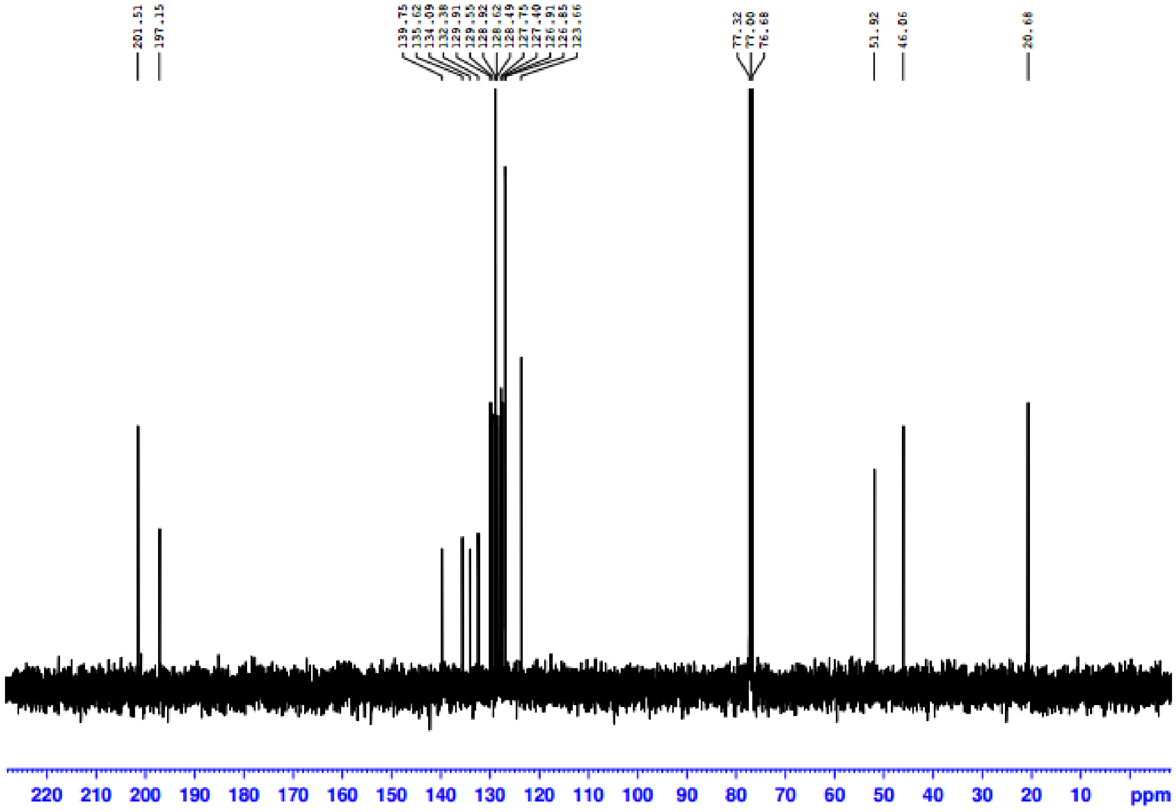
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127.40
126.91
126.85
123.66
77.32
77.00
76.68
51.92
46.06
20.68
220
210
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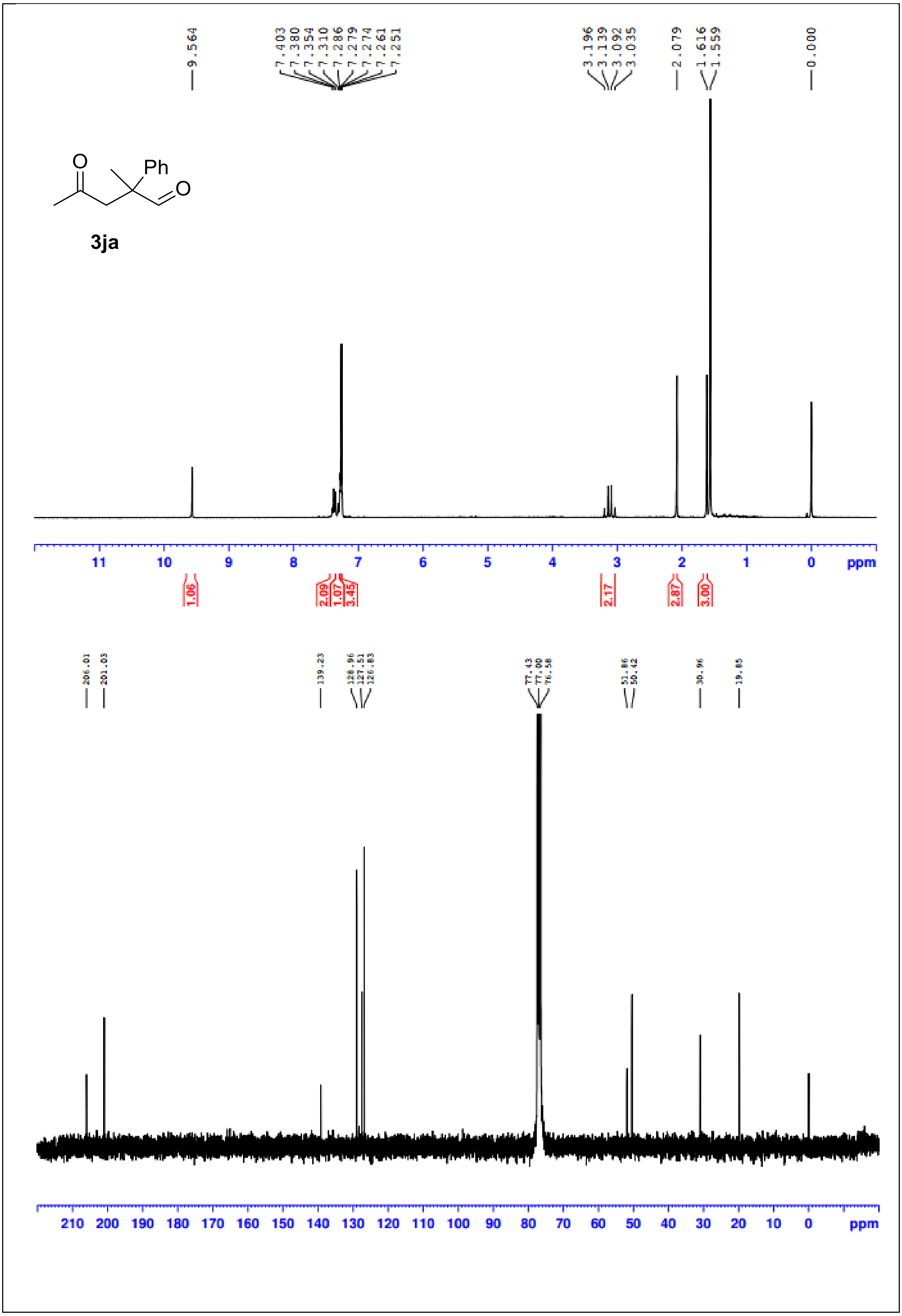
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1.559
0.000
11 10 9 8 7 6 5 4 3 2 1 0 ppm
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2.09
1.07
3.45
2.17
2.87
3.00
206.01
201.03
139.23
128.96
127.51
126.83
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51.86
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19.85
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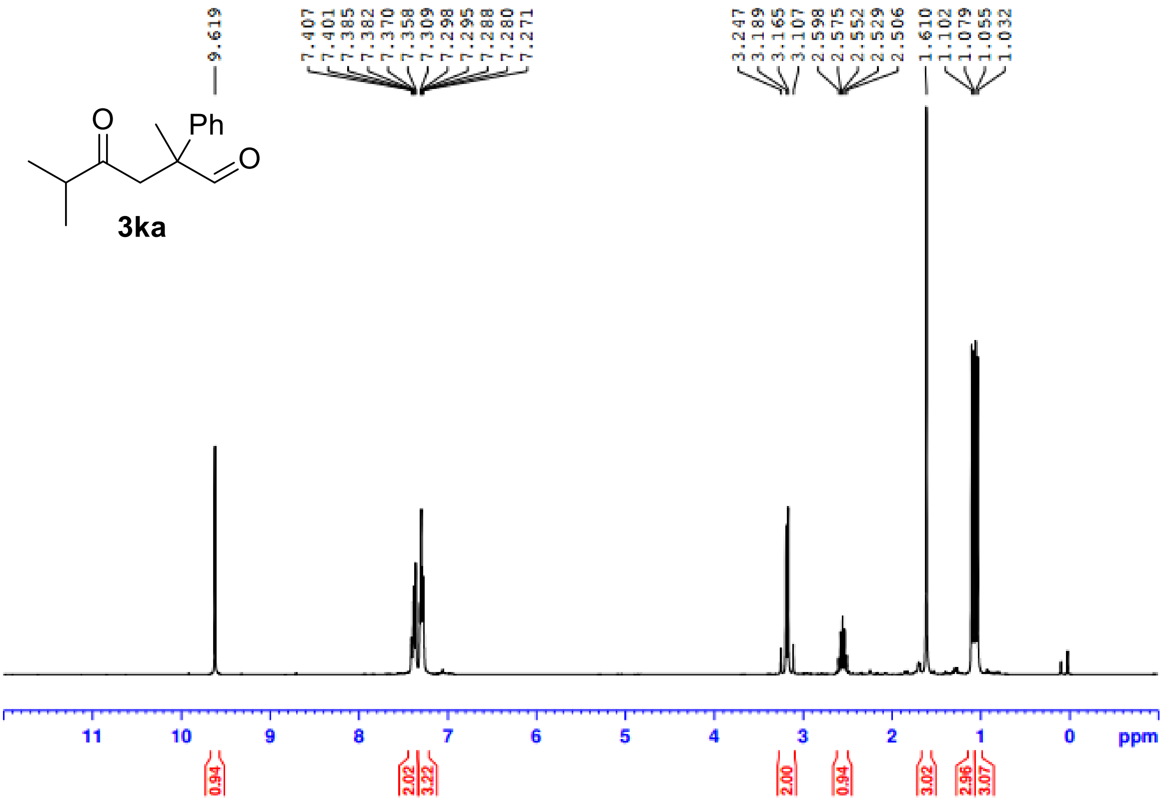
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7.280
7.271
3.247
3.189
3.165
3.107
2.598
2.575
2.552
2.529
2.506
1.610
1.102
1.079
1.055
1.032
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10
9
8
7
6
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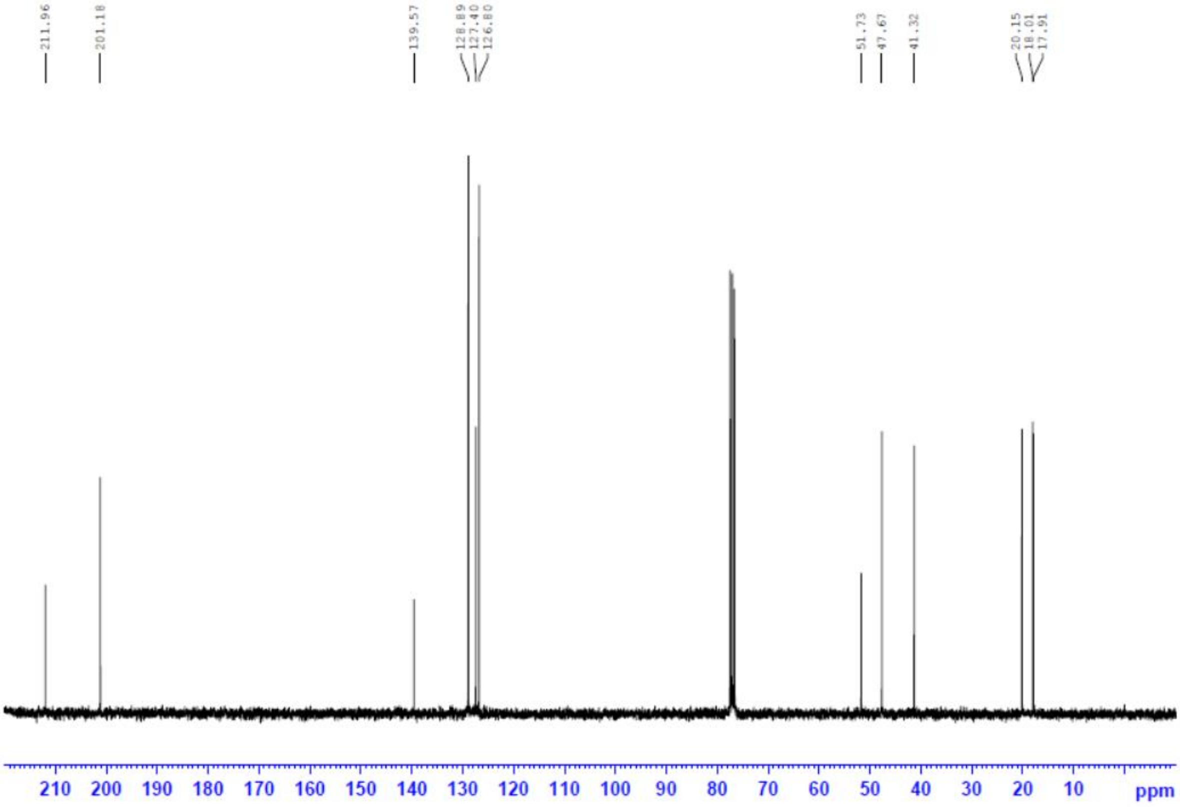
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210
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70
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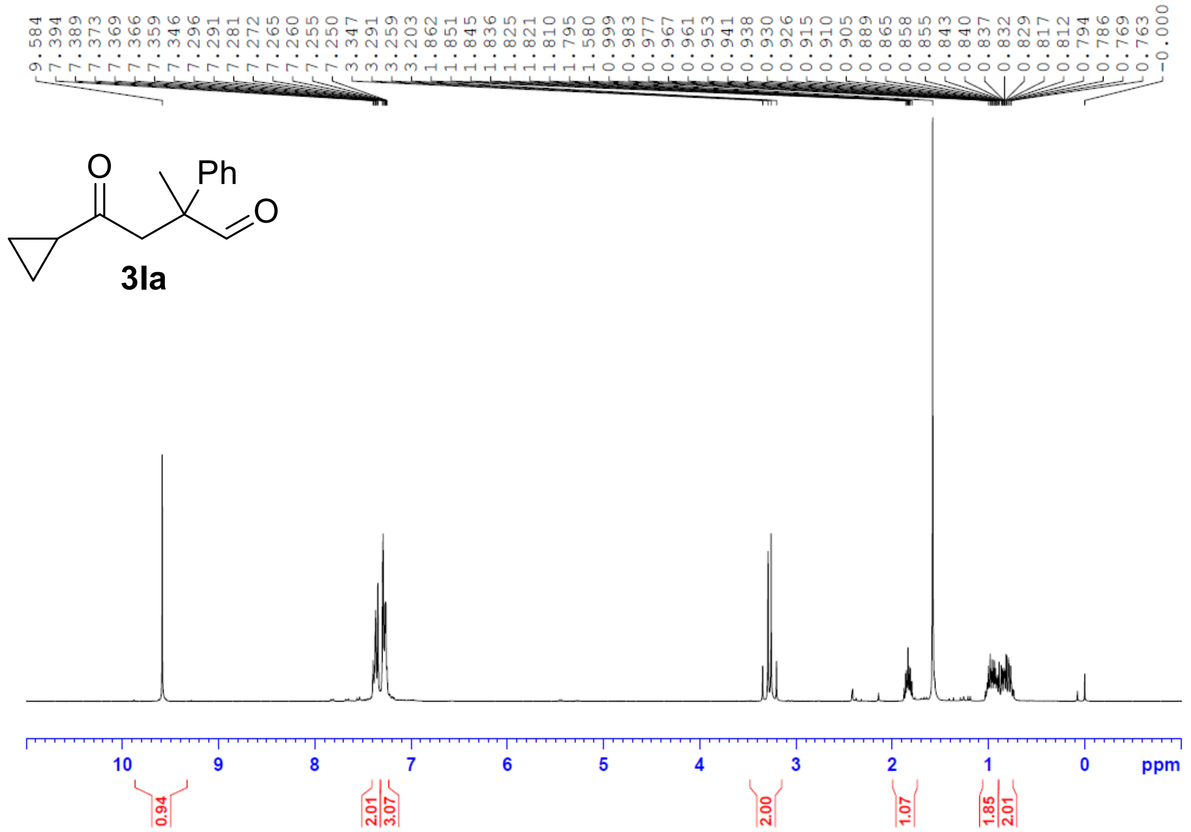
10
ppm



3la

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7.272
7.265
7.260
7.255
7.250
3.347
3.291
3.259
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1.851
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1.836
1.825
1.821
1.810
1.795
1.580
0.999
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0.977
0.967
0.961
0.953
0.941
0.938
0.930
0.926
0.915
0.910
0.905
0.889
0.865
0.858
0.855
0.843
0.840
0.837
0.832
0.829
0.817
0.812
0.794
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0.769
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-0.000
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Ph
O
10
9
8
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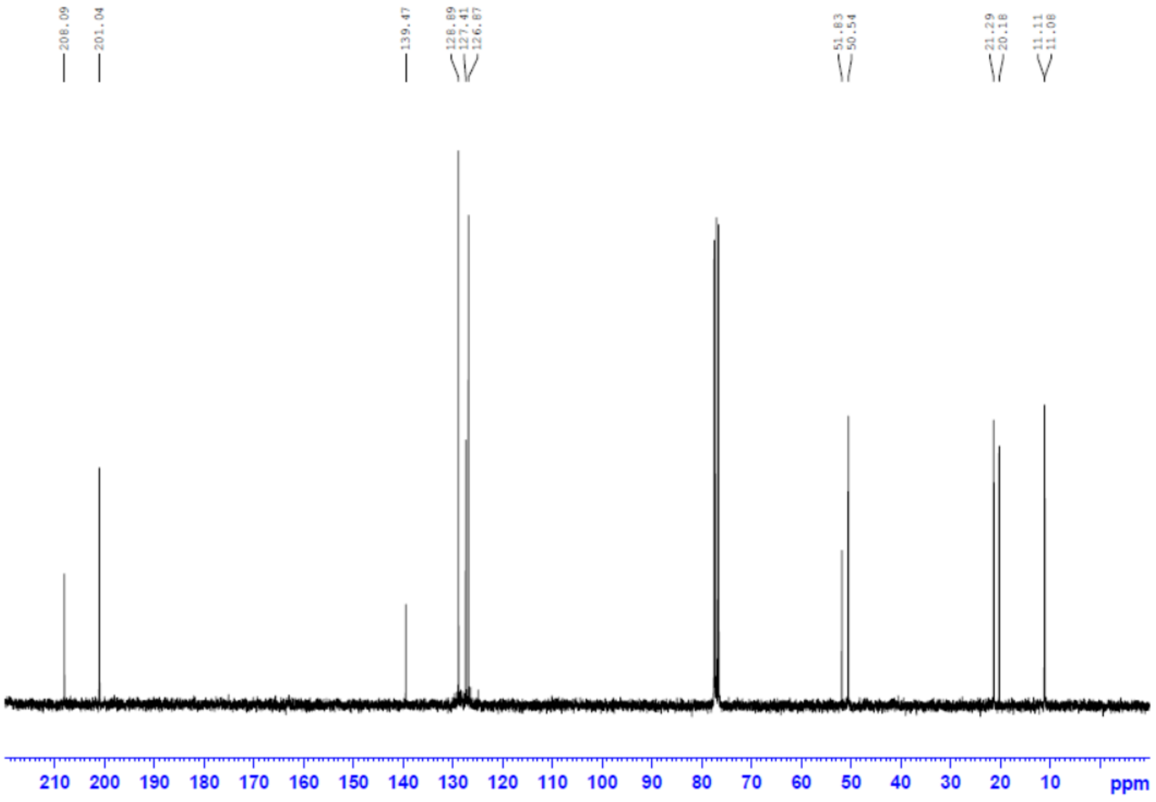

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210
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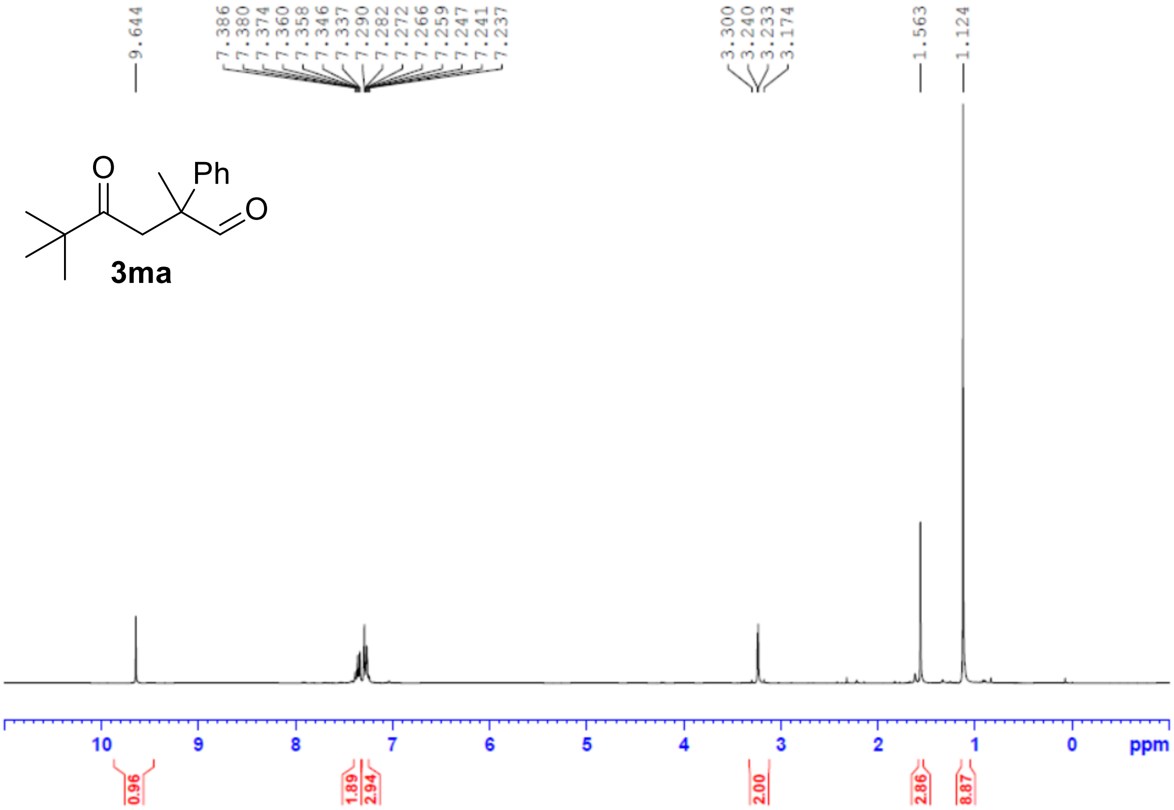

3ma

O
Ph
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7.282
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7.266
7.259
7.247
7.241
7.237
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3.240
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3.174
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1.124
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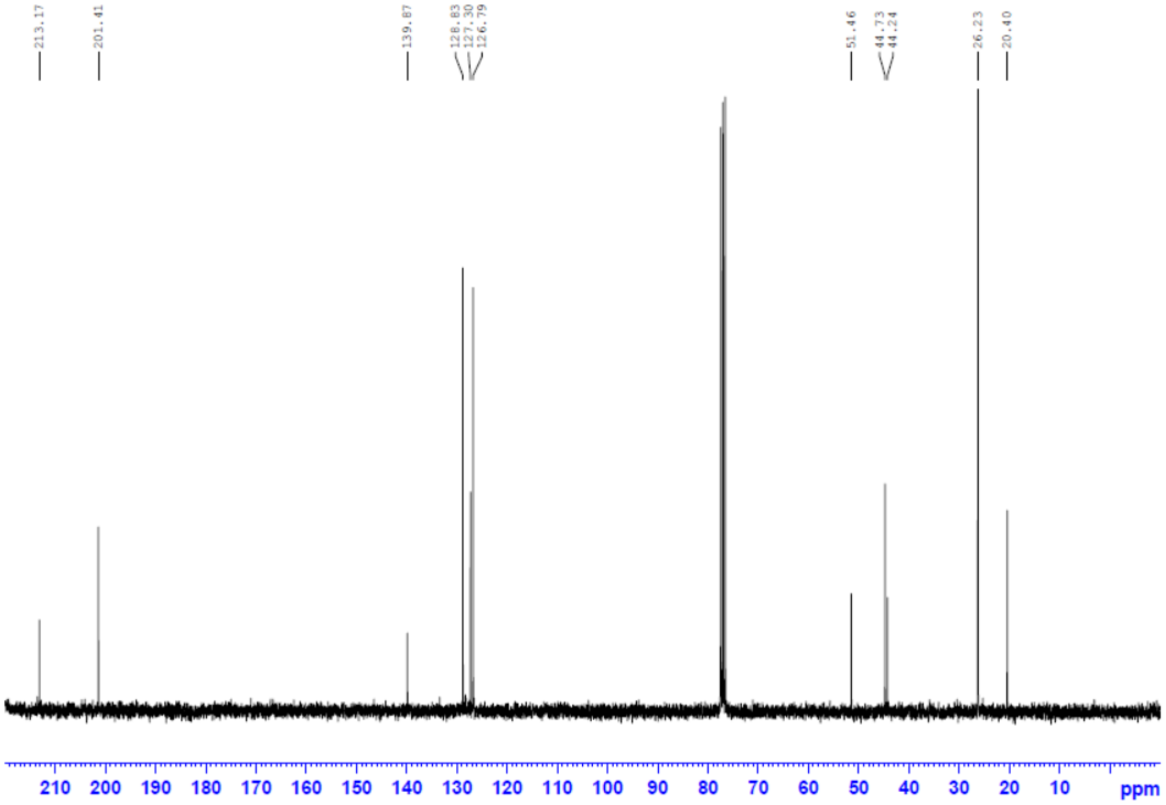

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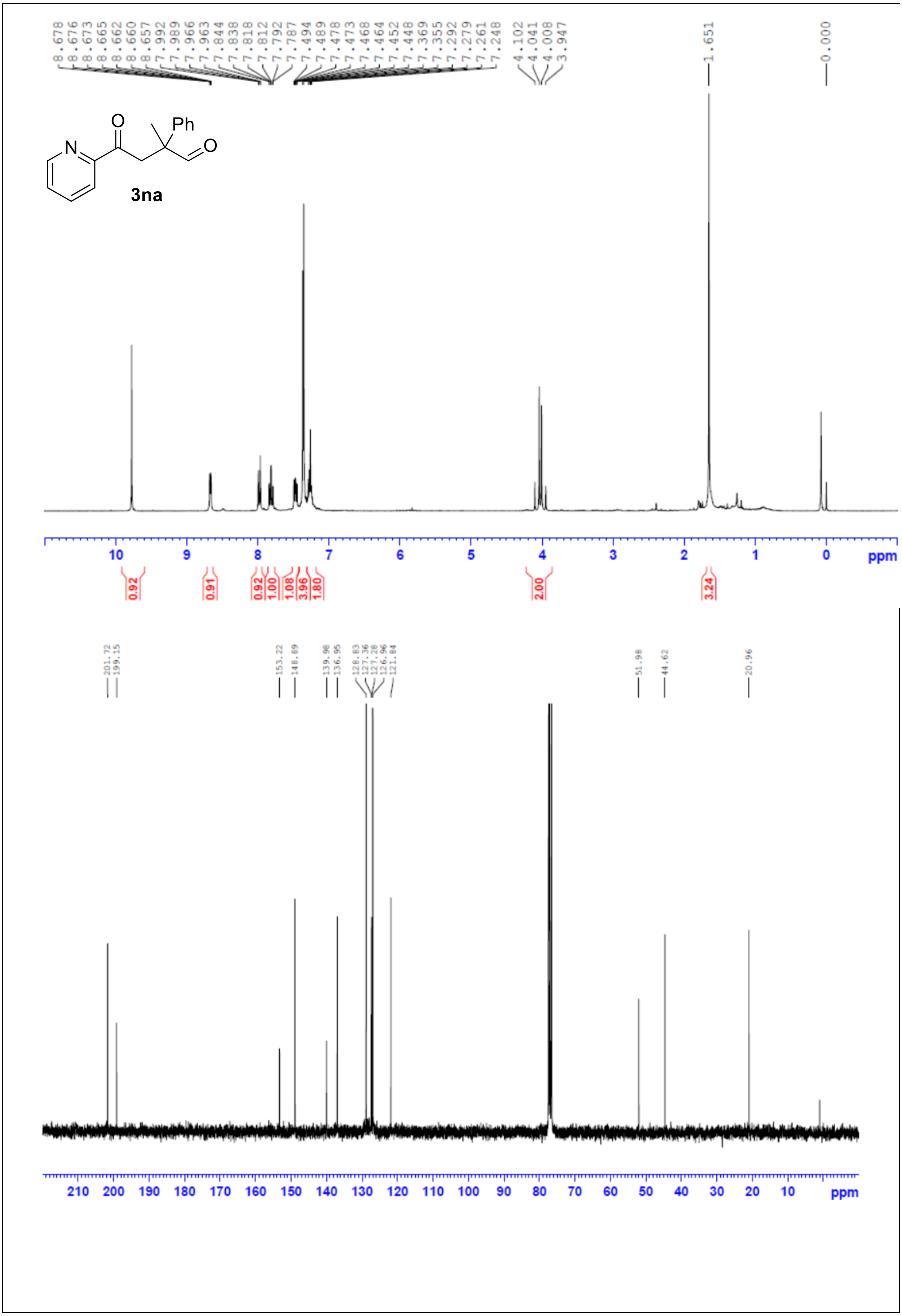
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7.448
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O
Ph
N
O
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ppm
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0.91
0.92
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1.08
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2.00
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128.83
127.36
127.28
126.96
121.84
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44.62
20.96
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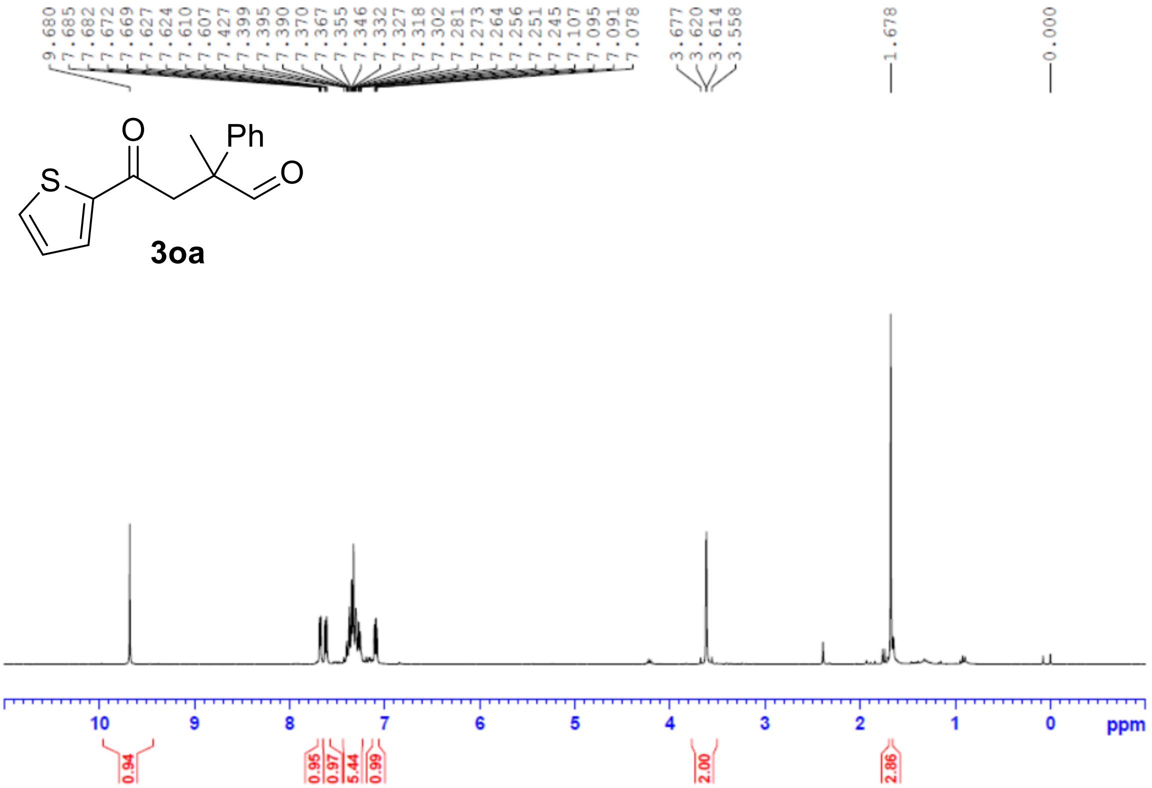
ppm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7.367
7.355
7.346
7.332
7.327
7.318
7.302
7.281
7.273
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7.256
7.251
7.245
7.107
7.095
7.091
7.078
3.677
3.620
3.614
3.558
1.678
0.000
S
O
Ph
O
3oa
10
9
8
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2
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0.97
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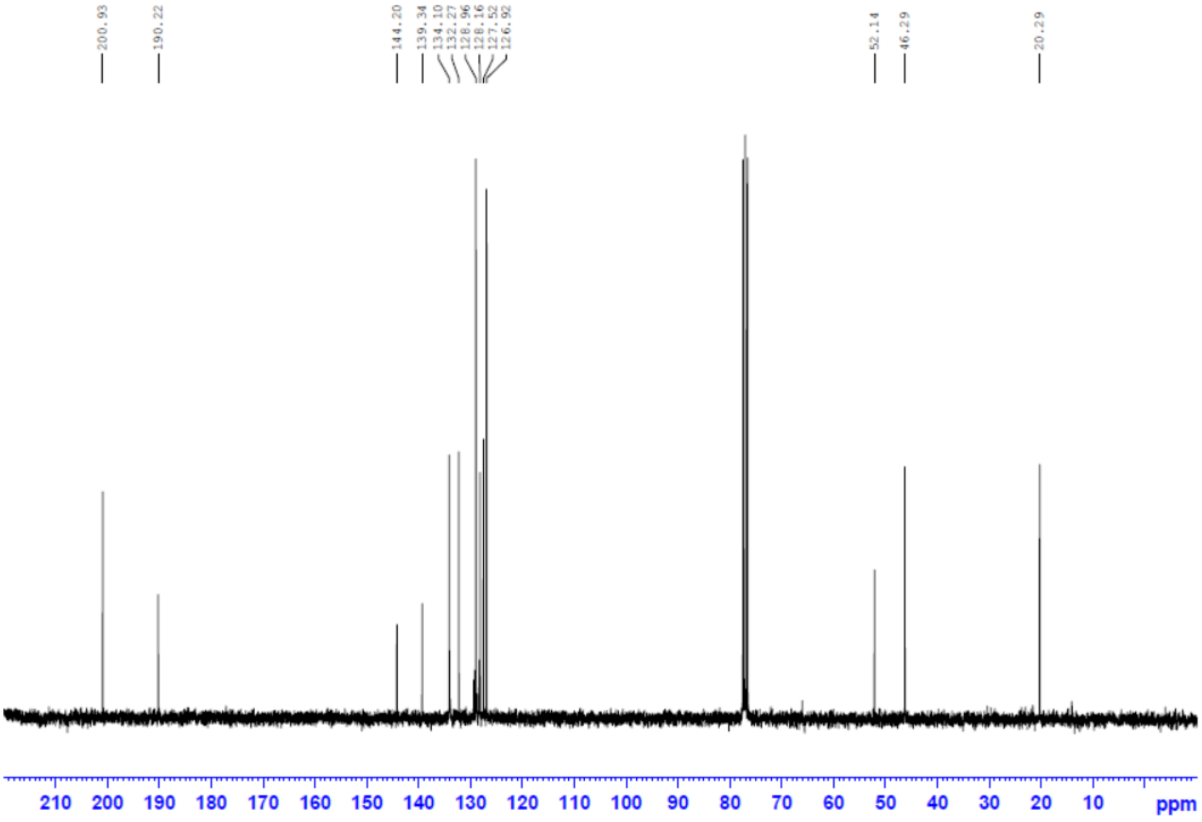
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20.29
210
200
190
180
170
160
150
140
130
120
110
100
90
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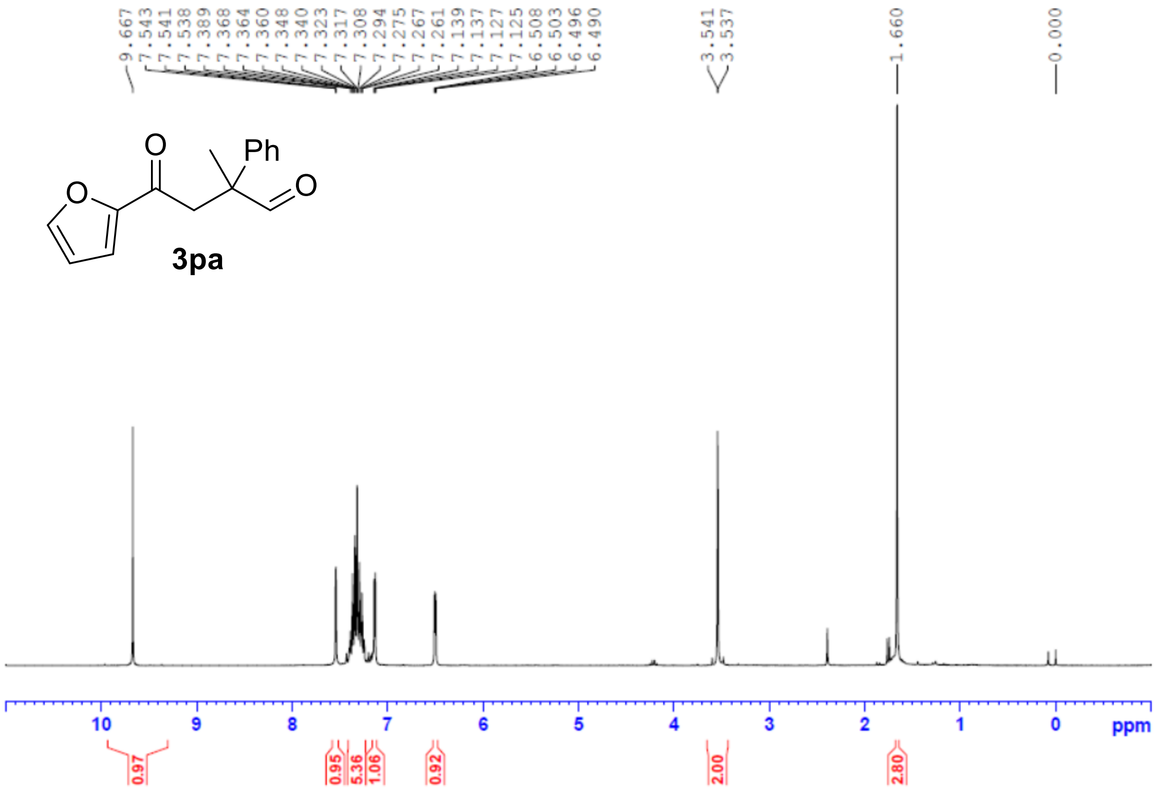
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Ph
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O
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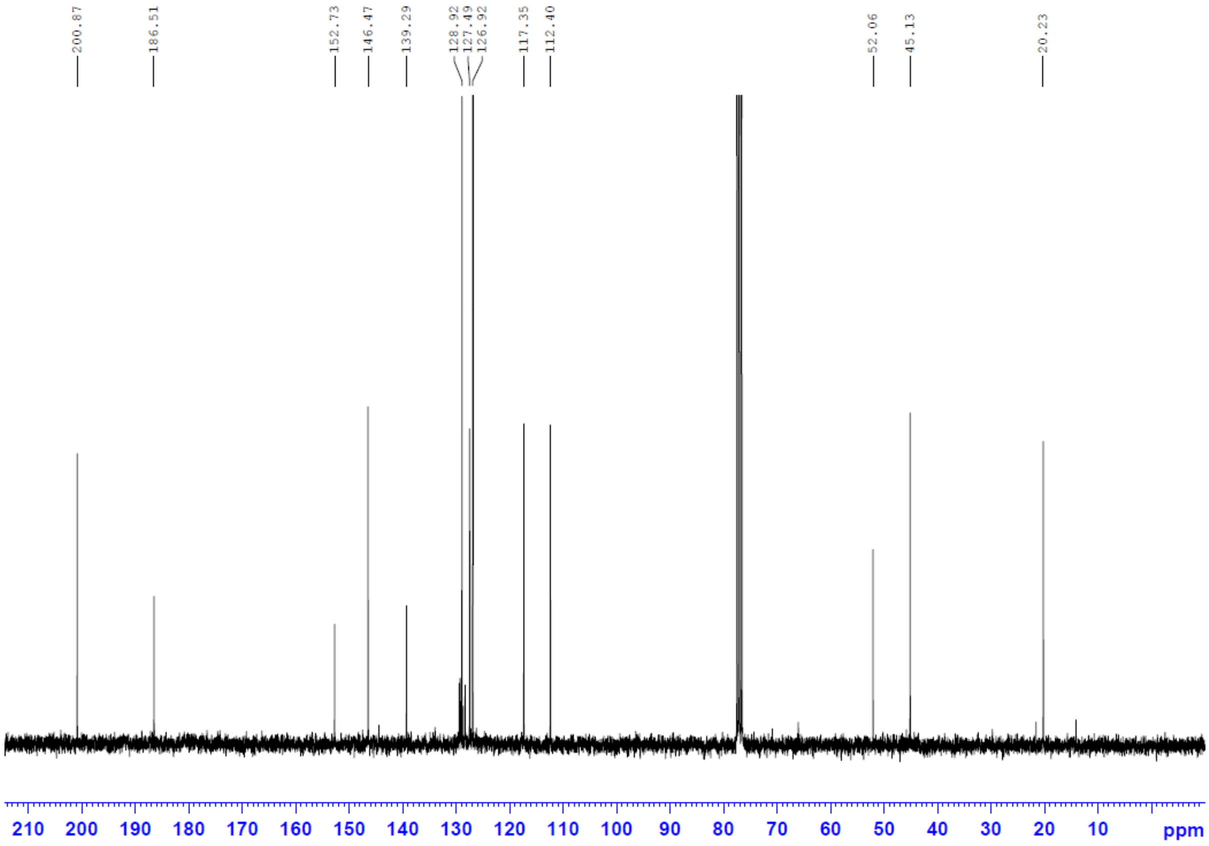
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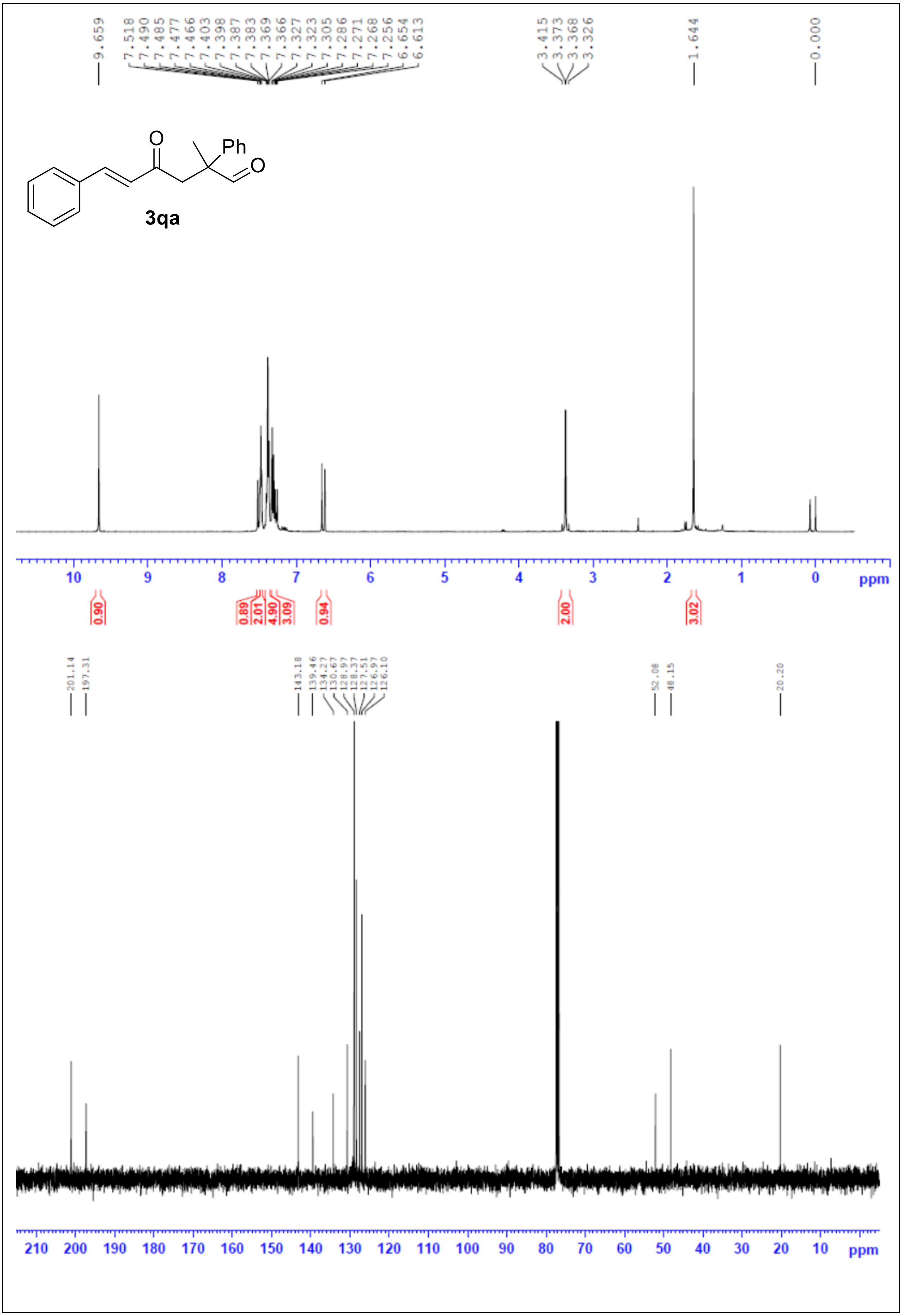
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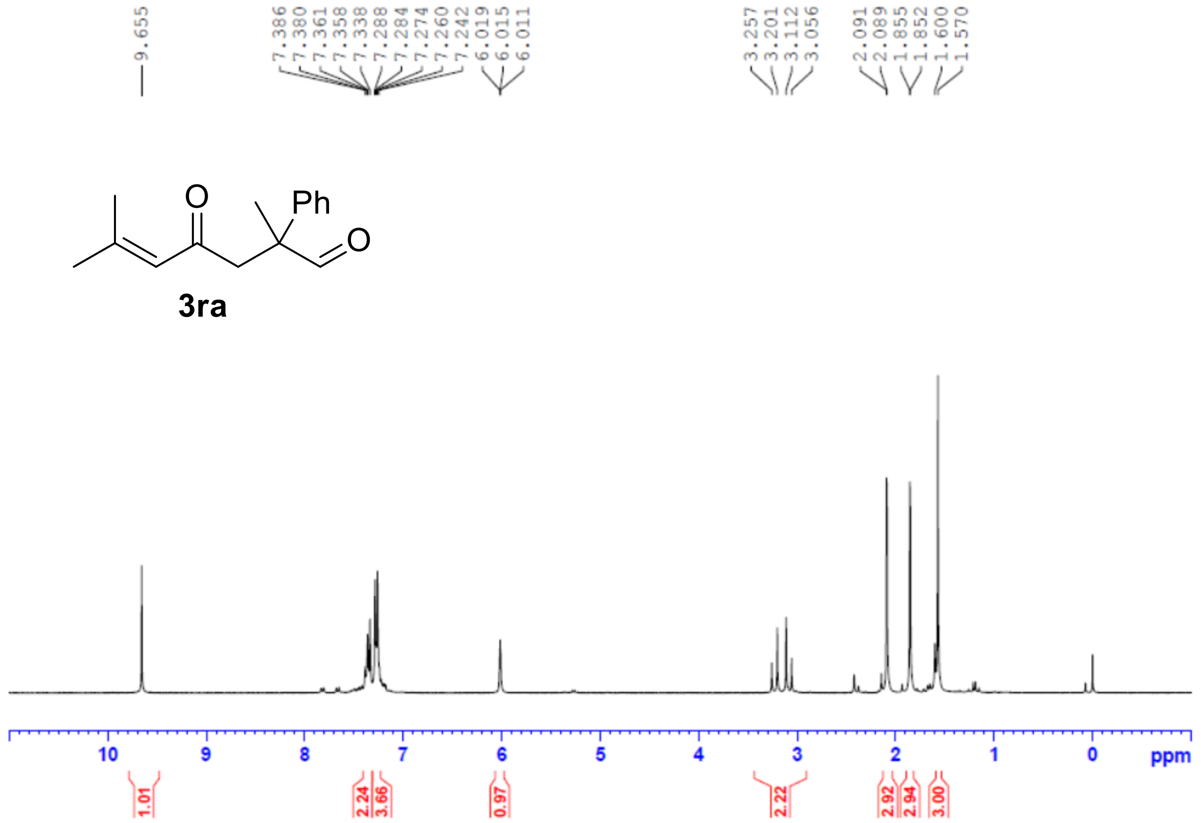
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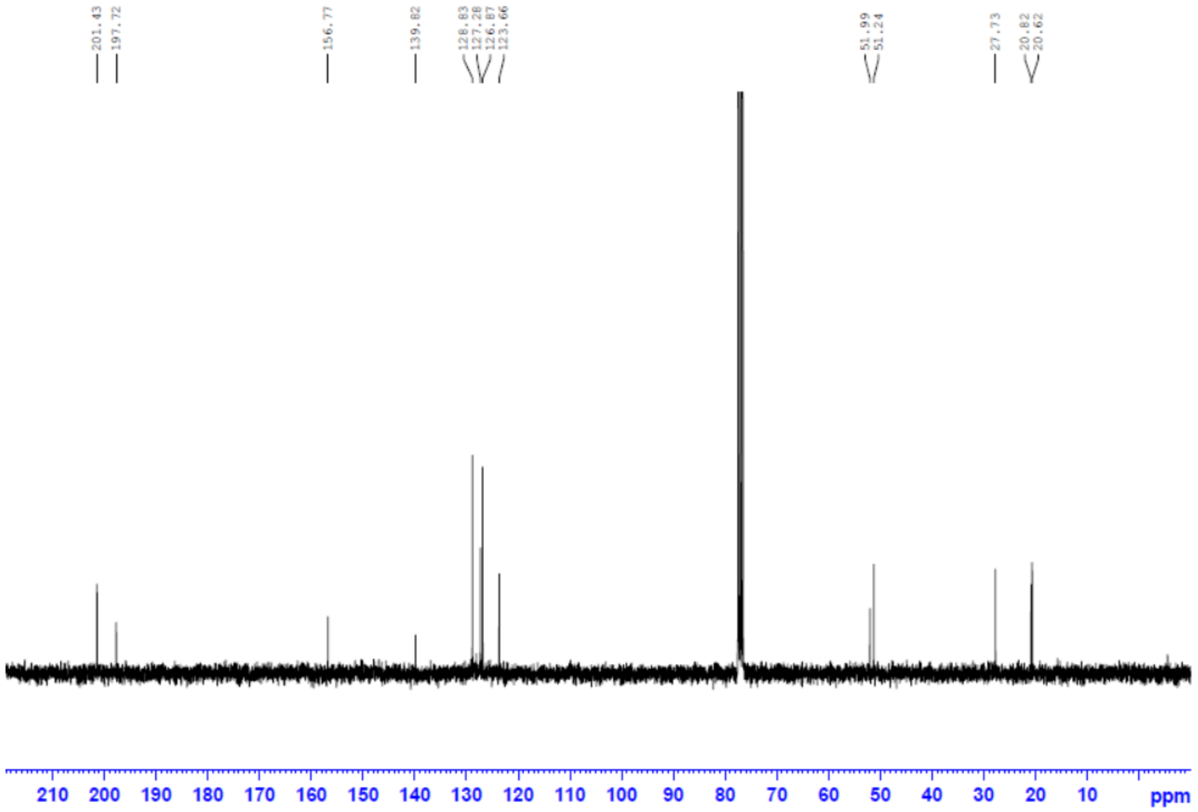

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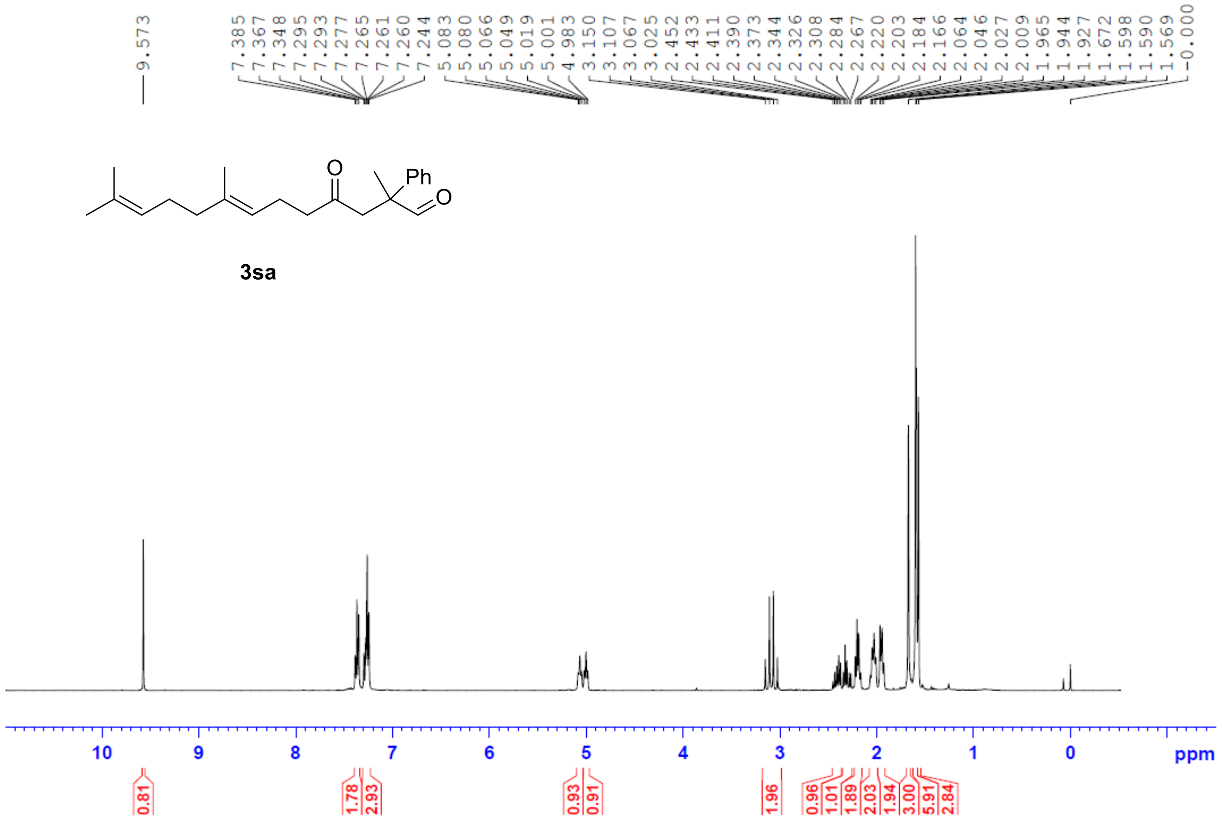
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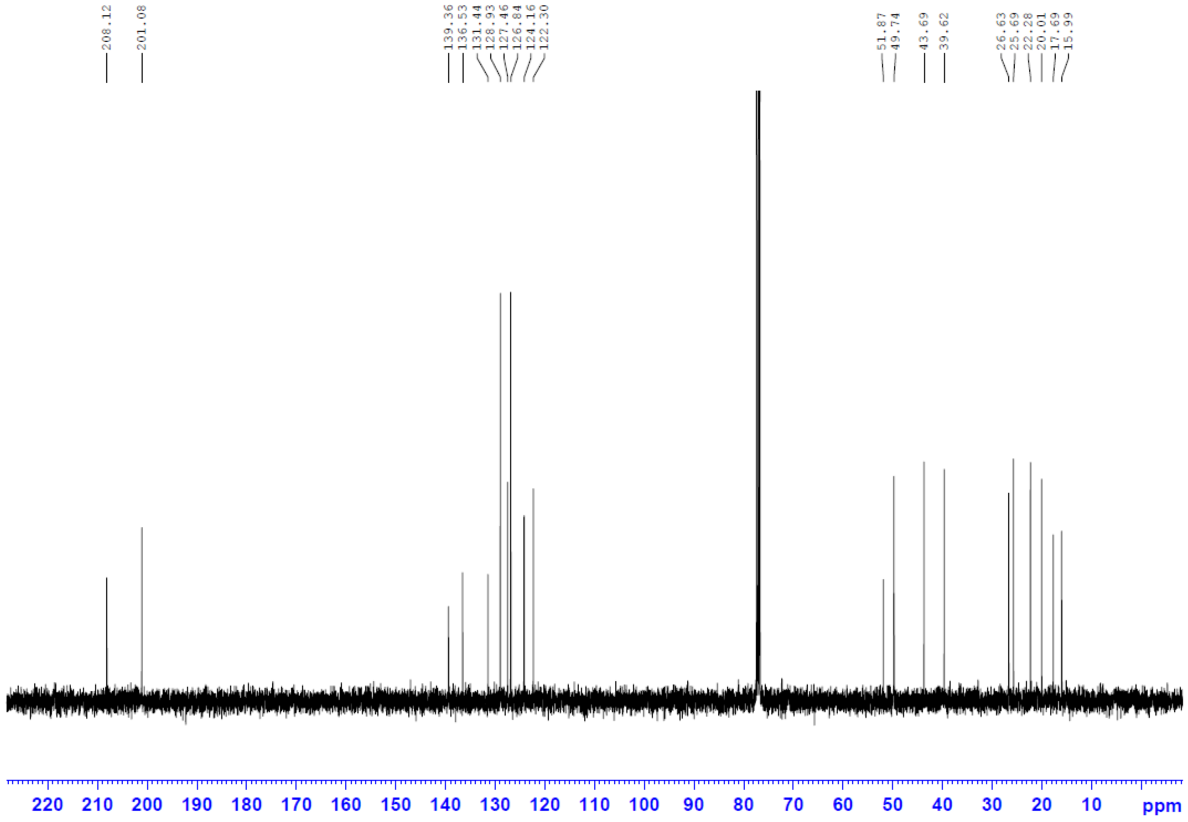
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26.63
25.69
22.28
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15.99
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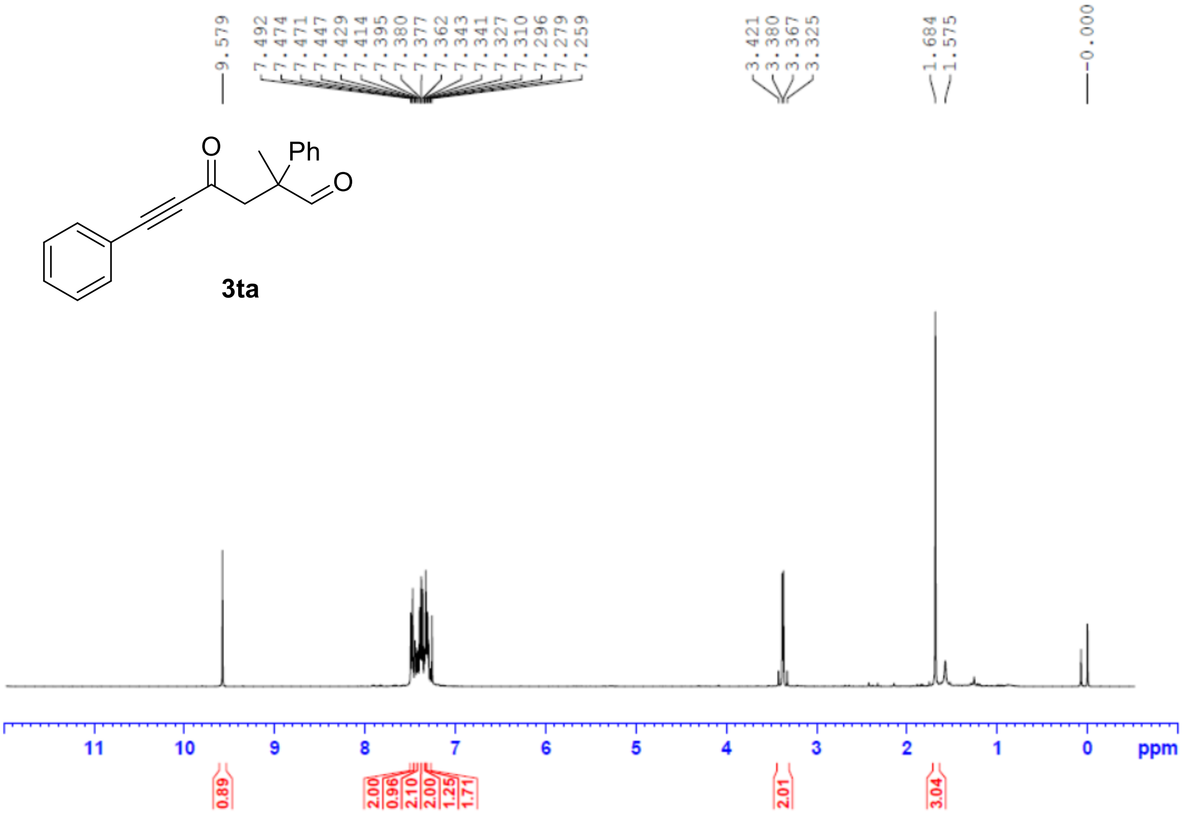
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Ph
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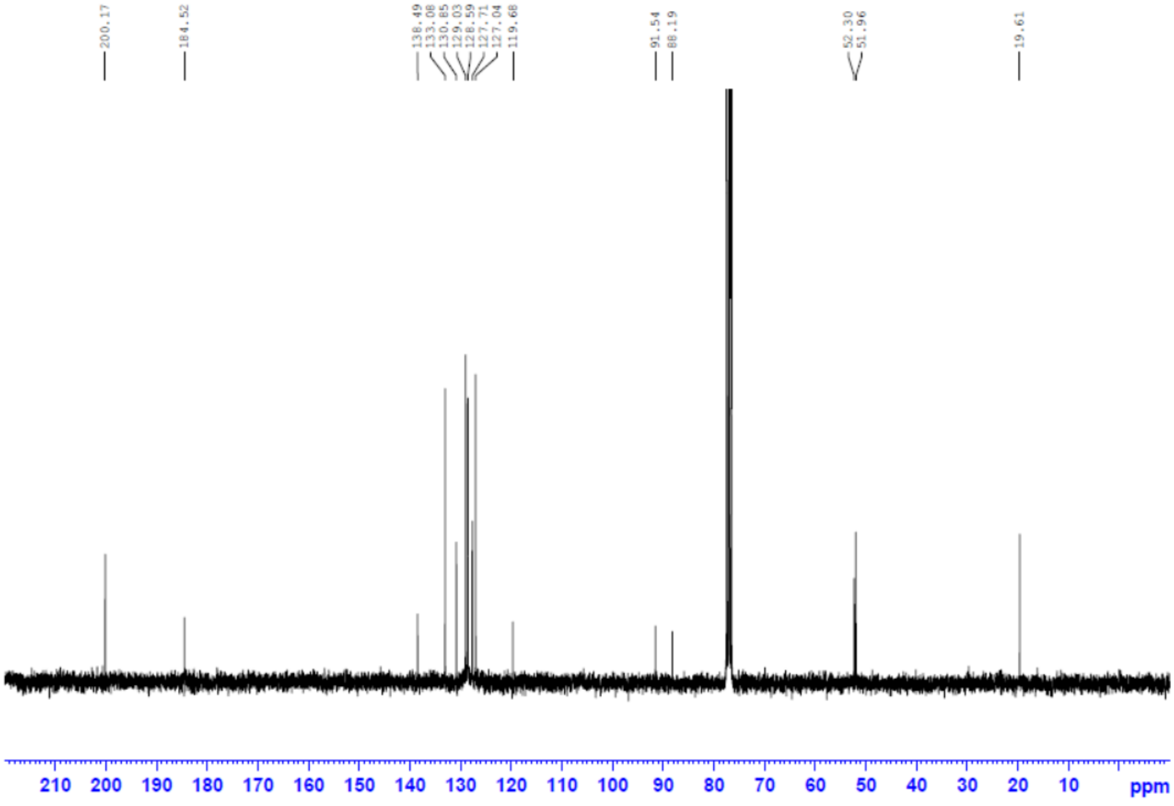
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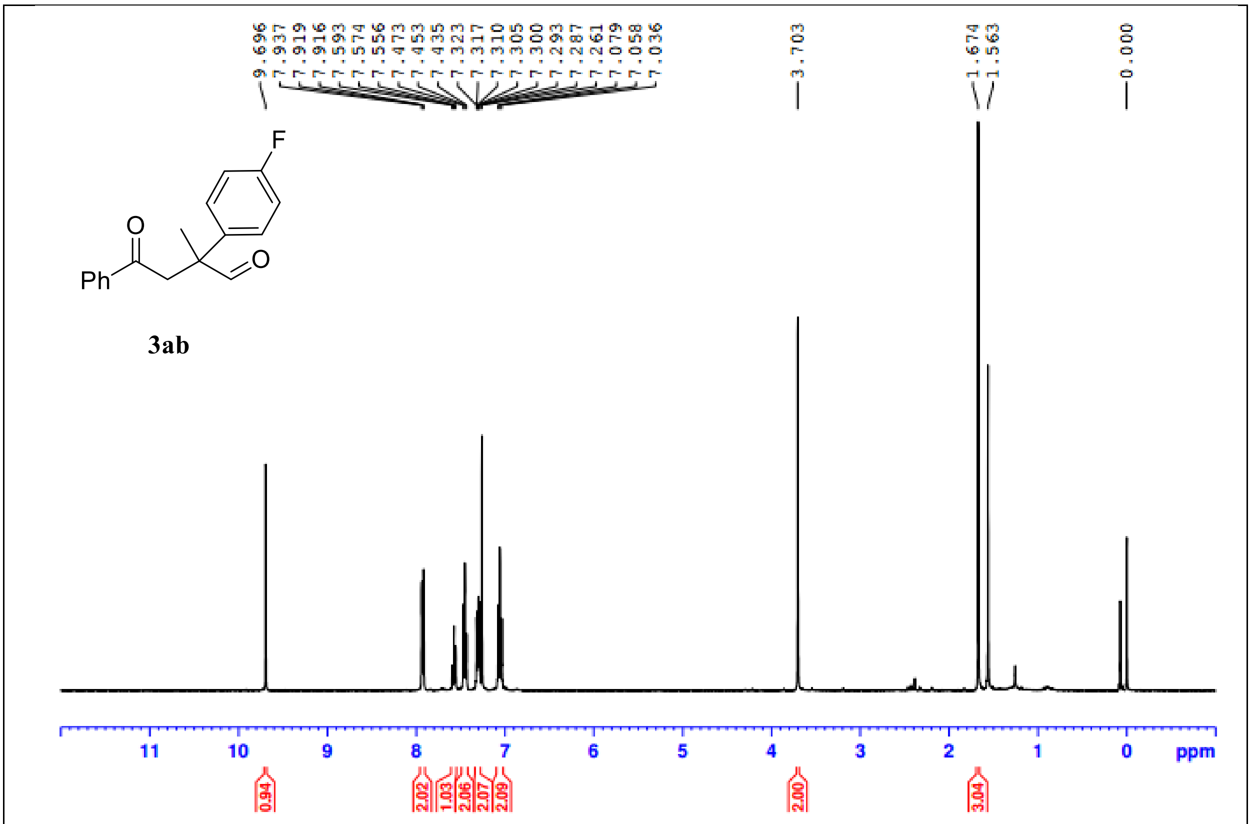
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8
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6
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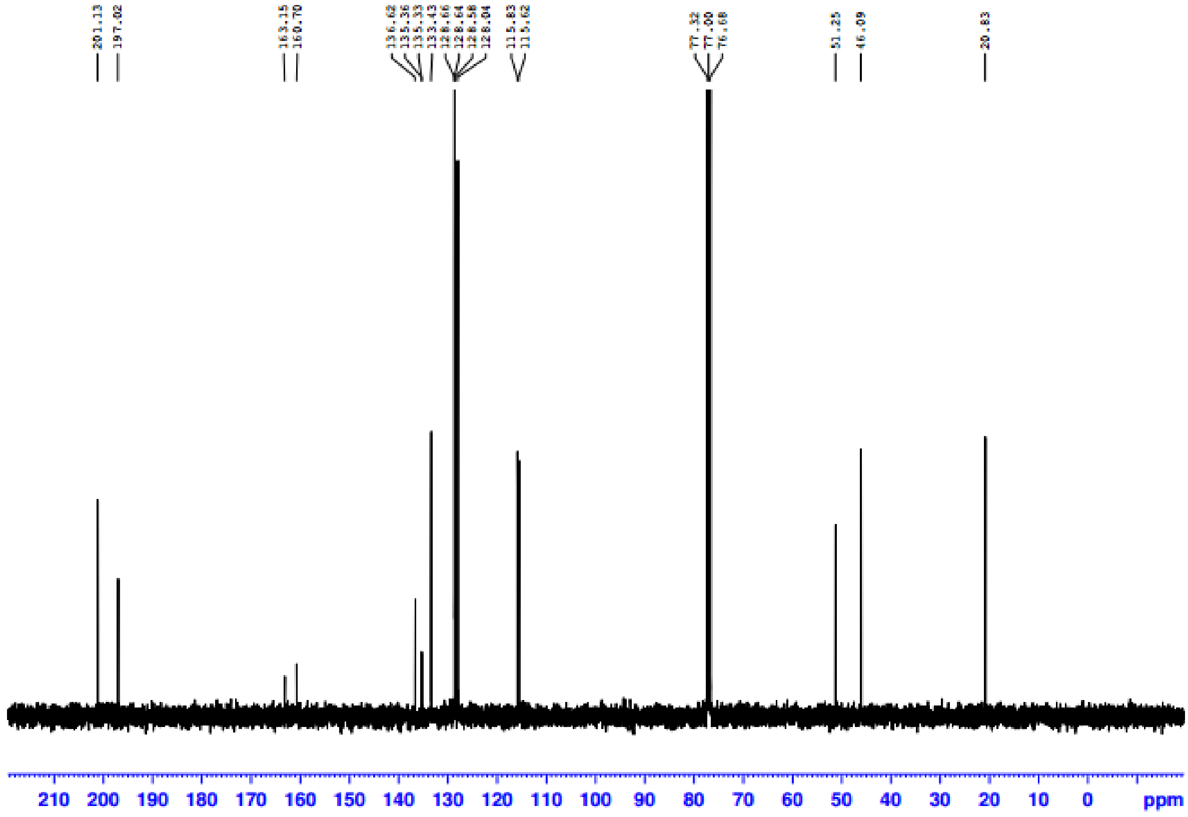
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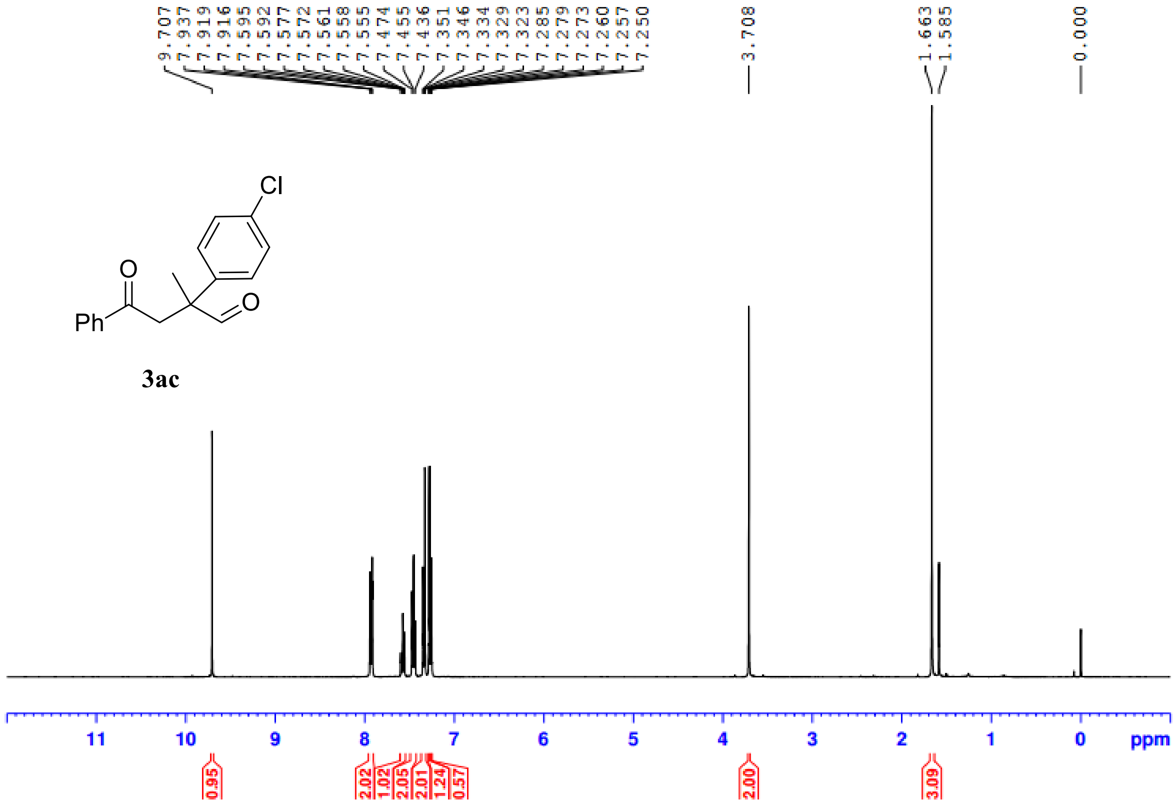
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7.250
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O
Ph
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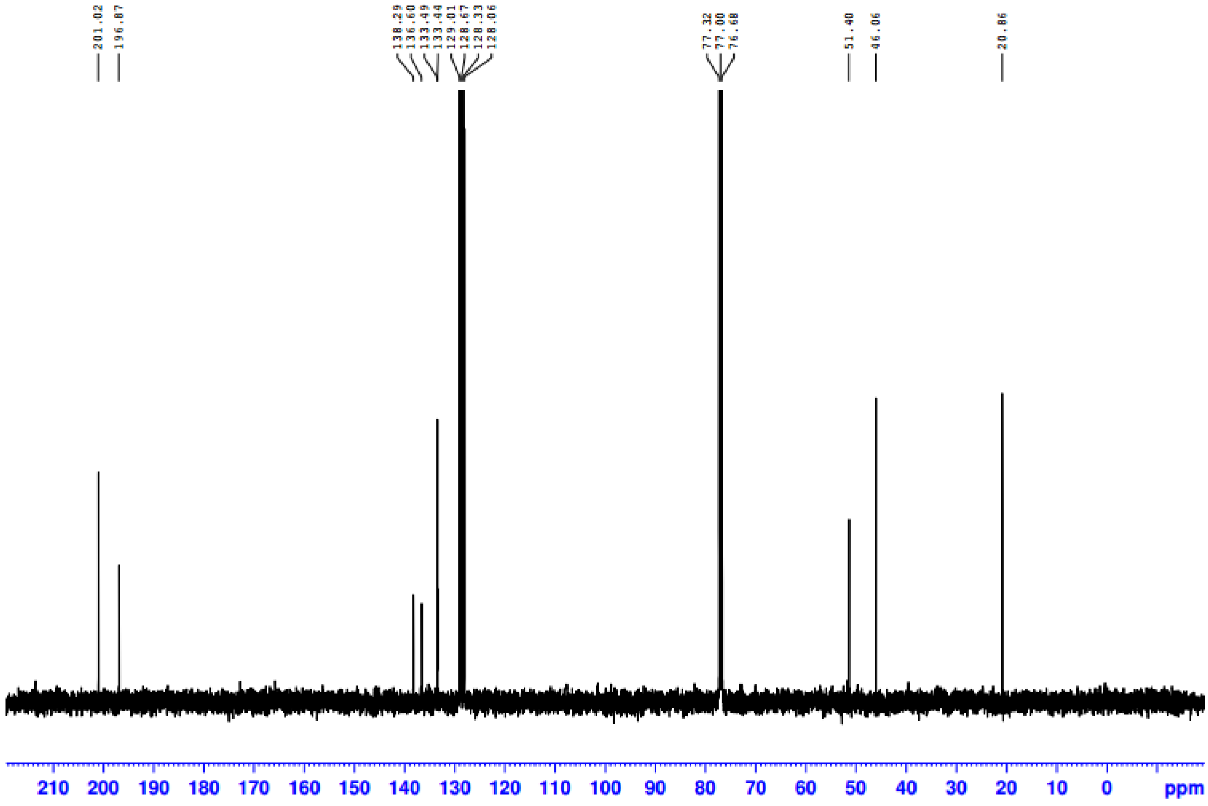
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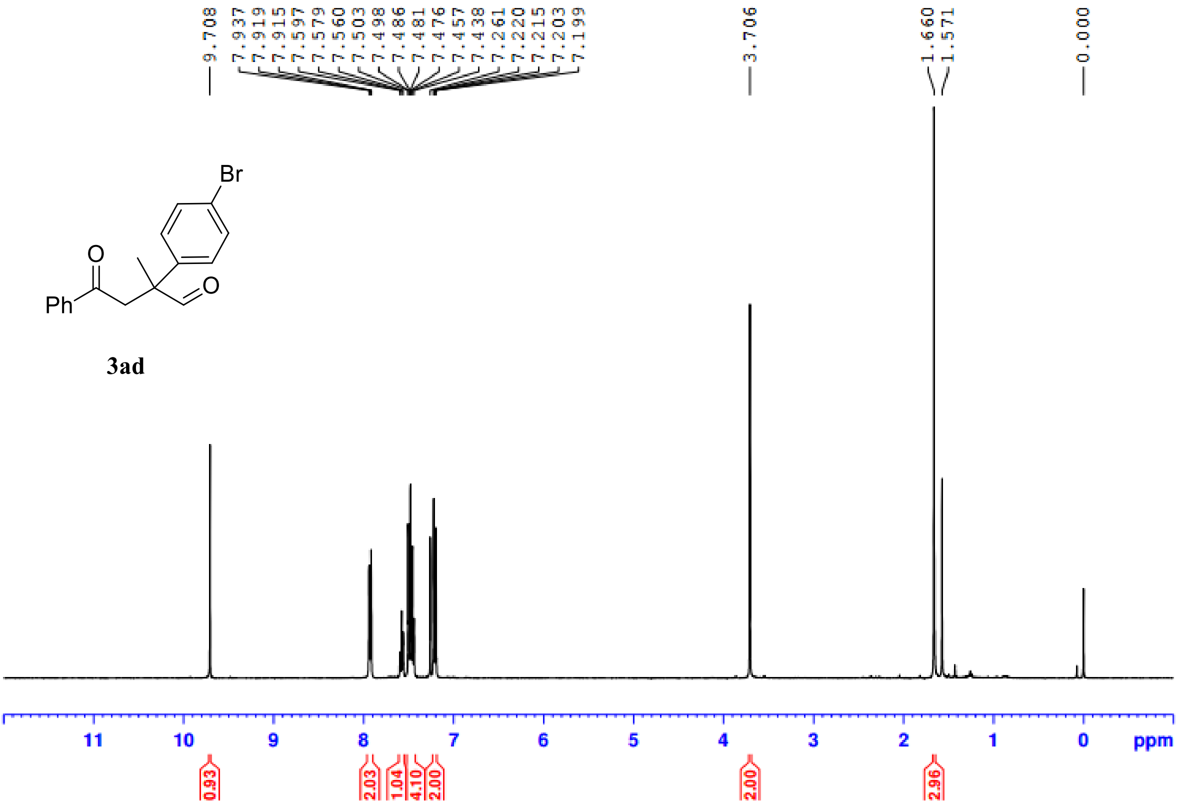
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Ph
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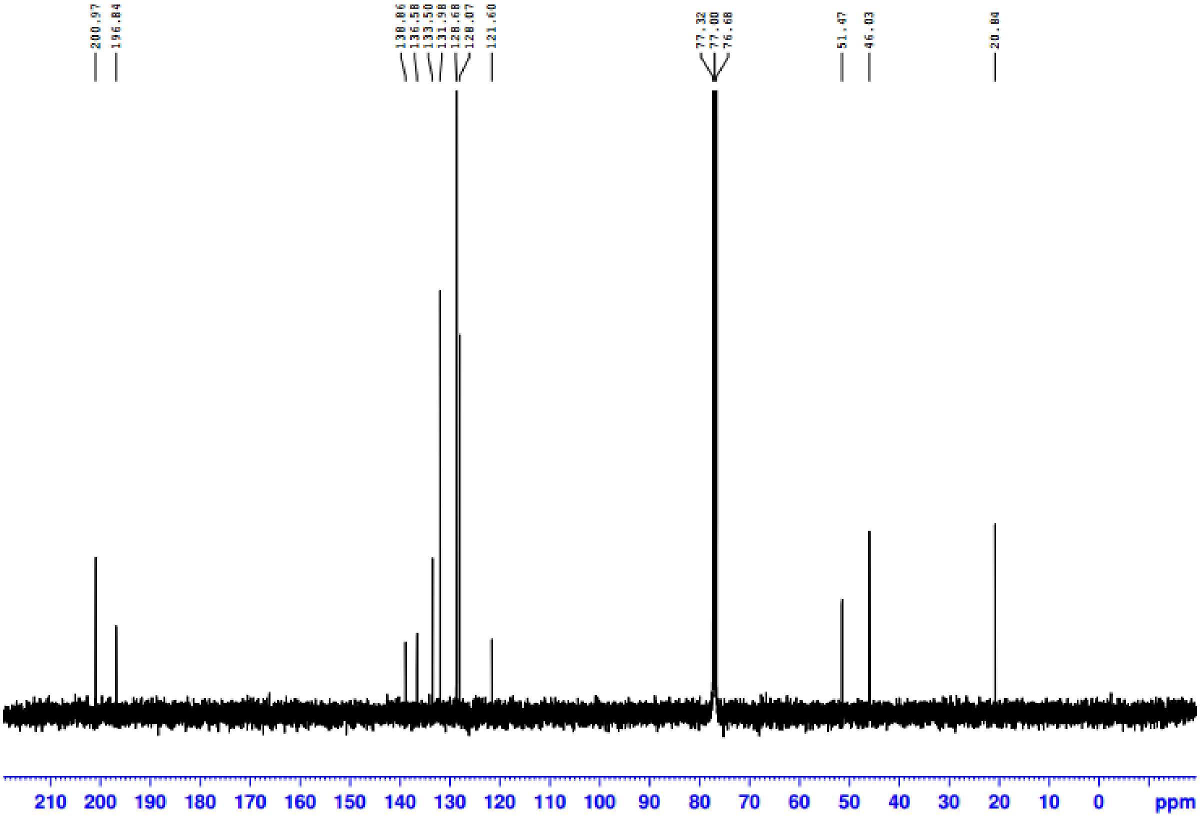
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200
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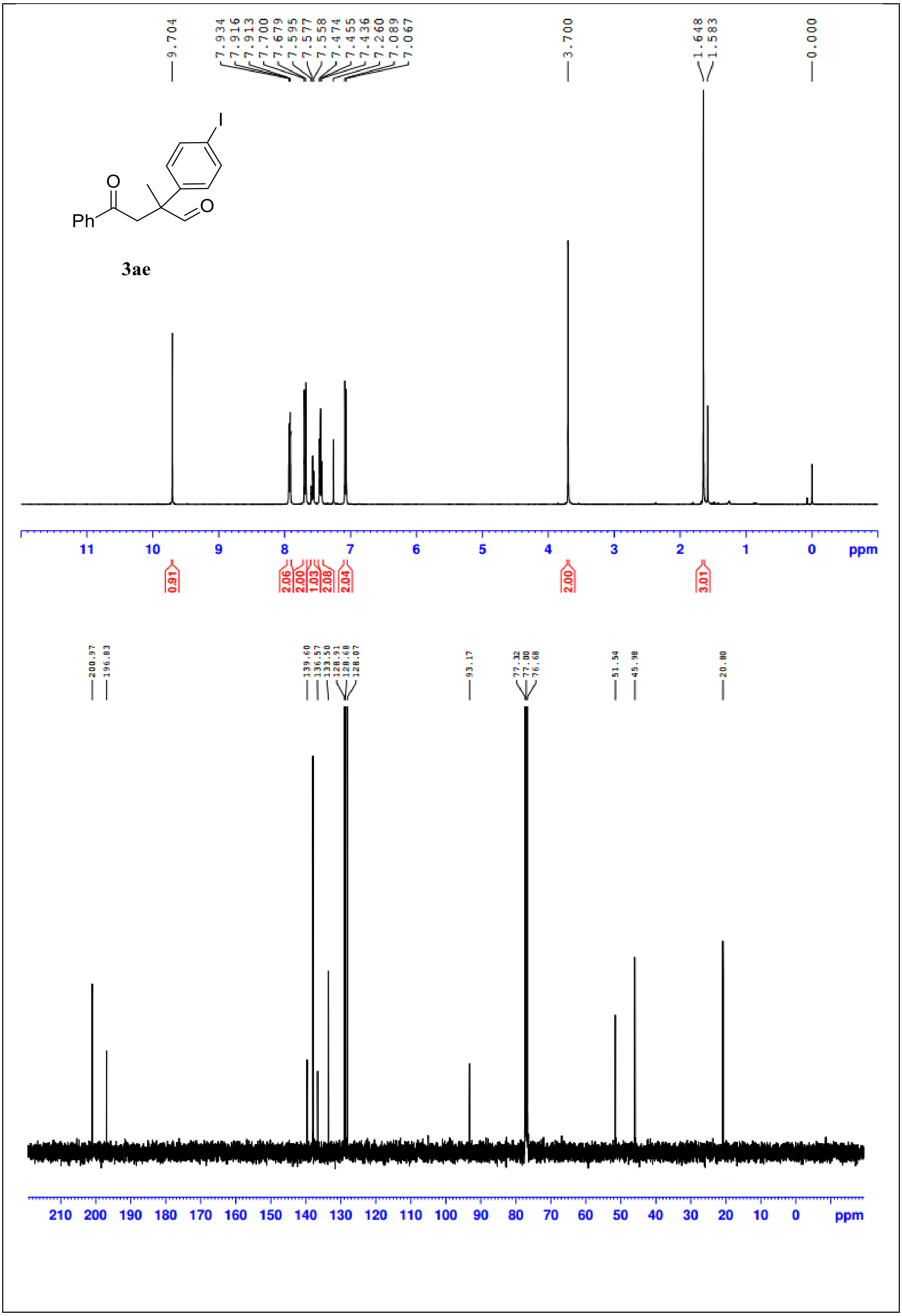

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Ph
O

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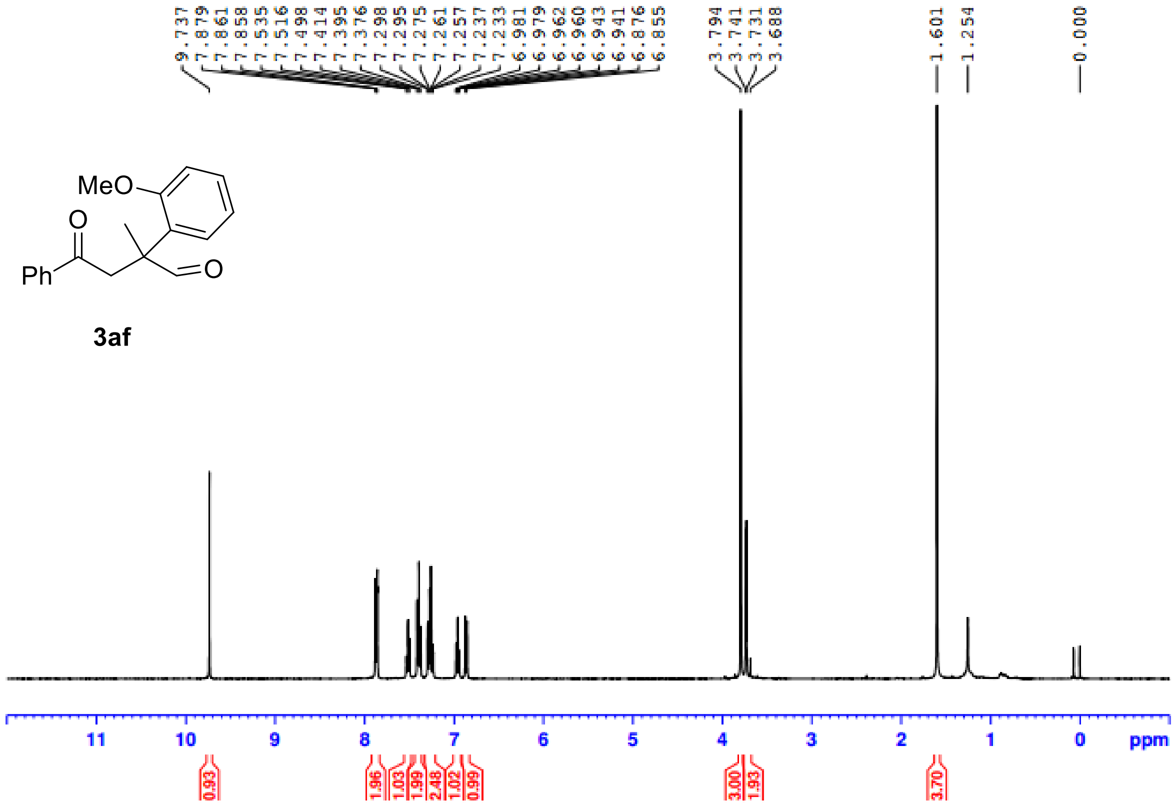
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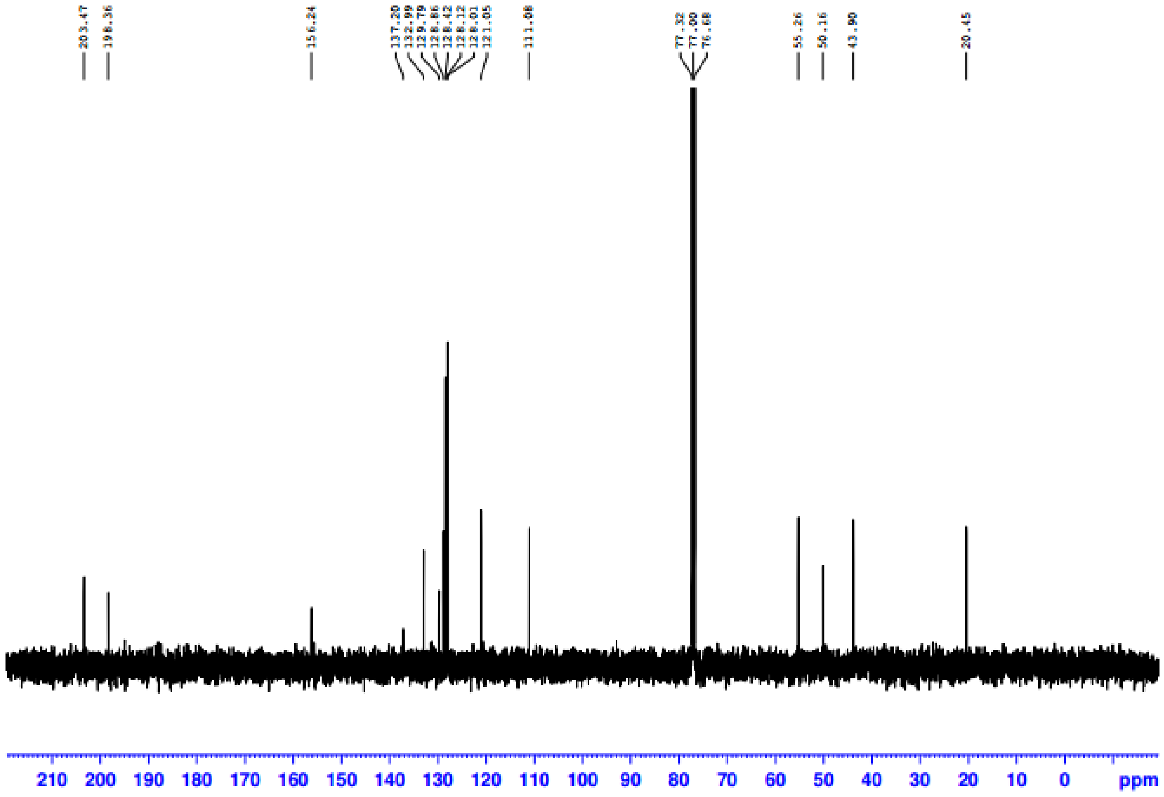
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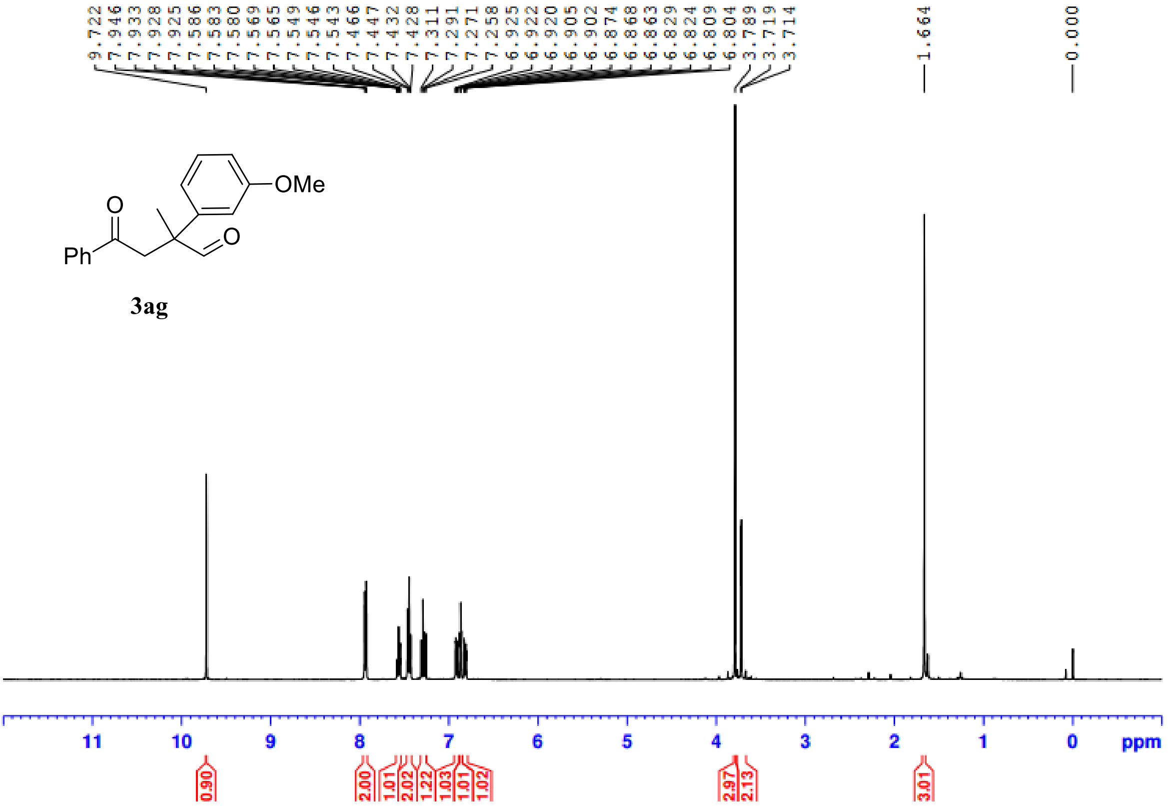
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OMe
Ph
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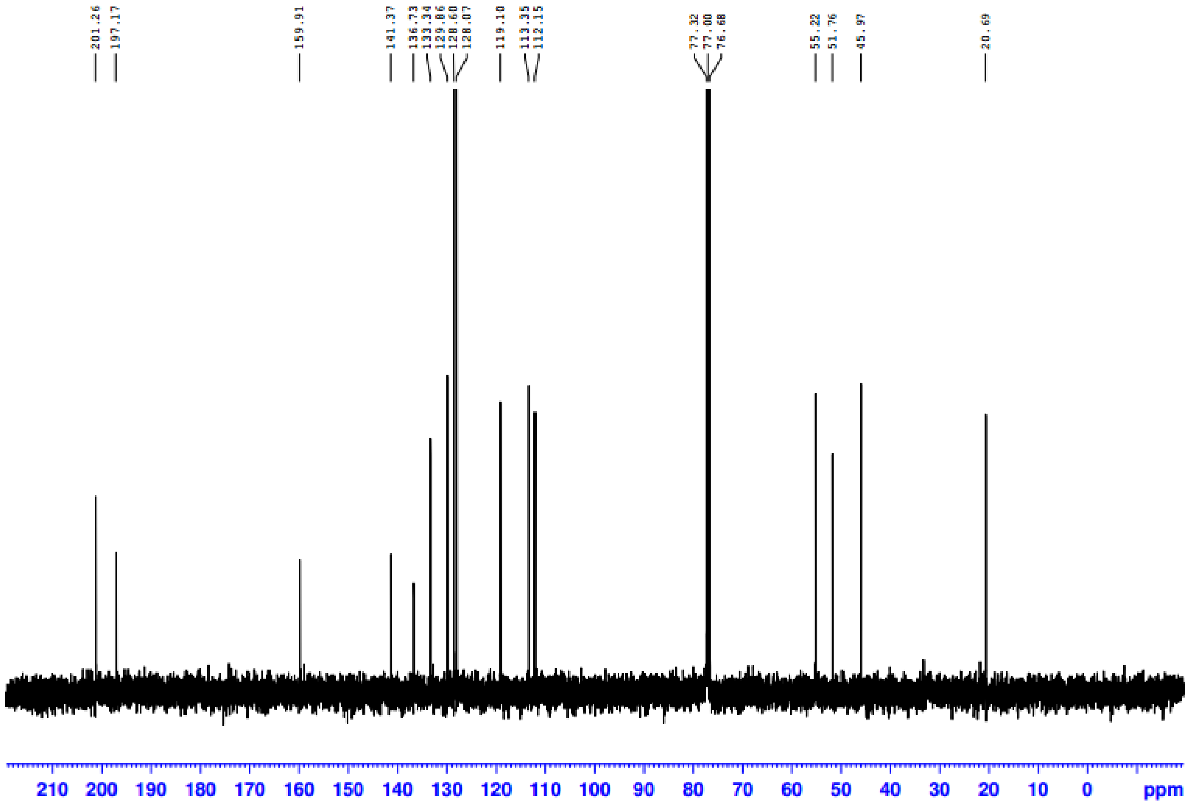
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200
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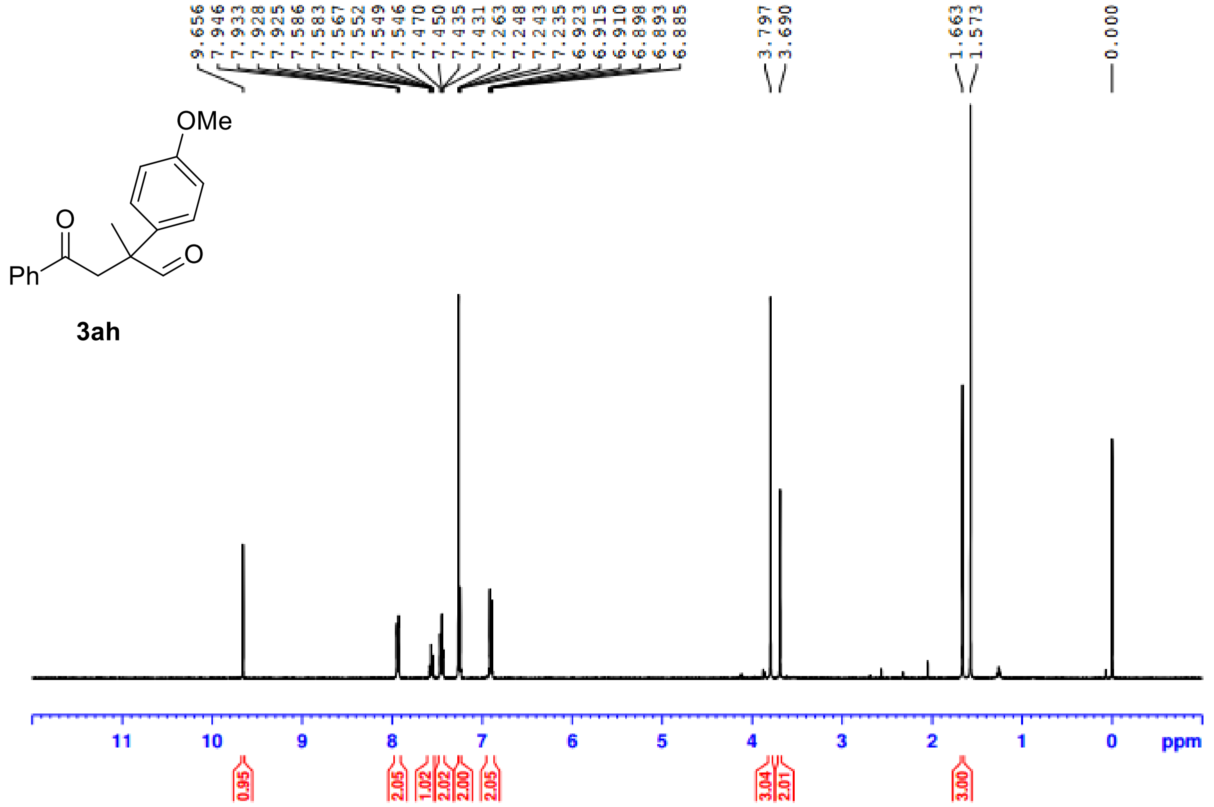
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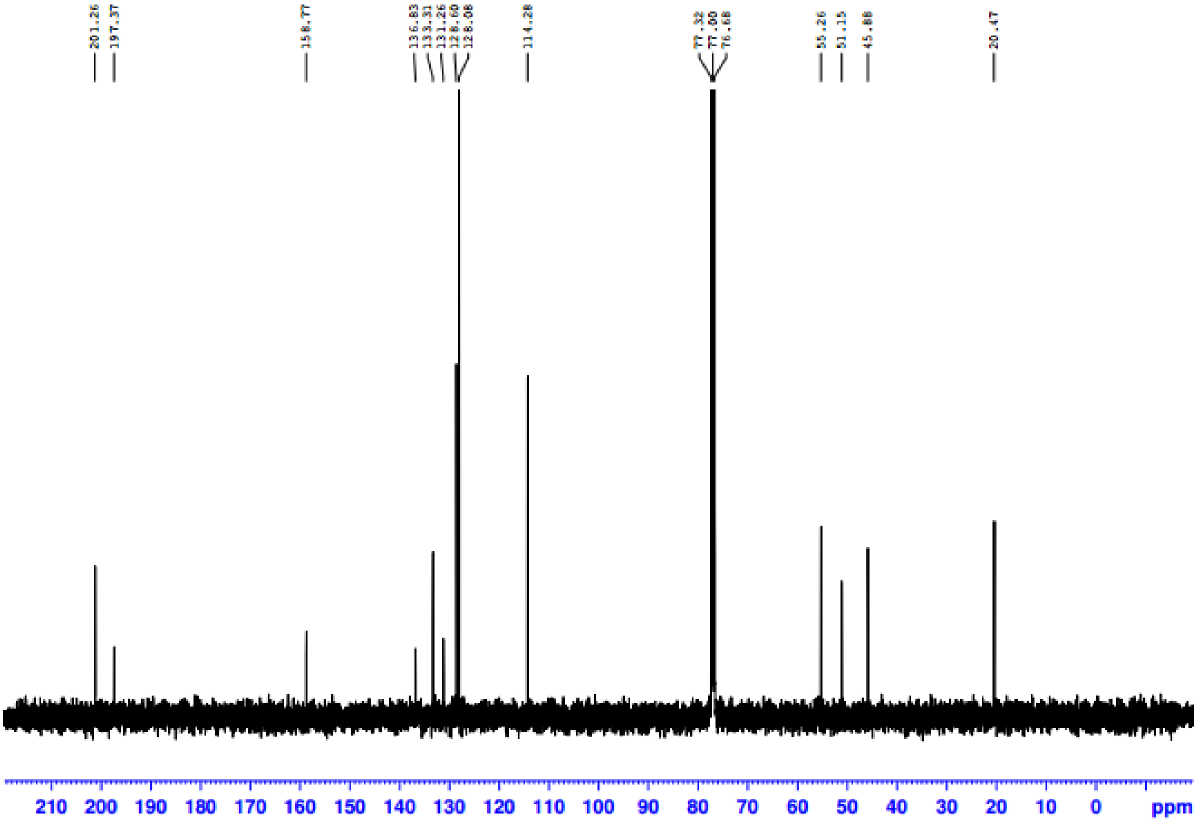
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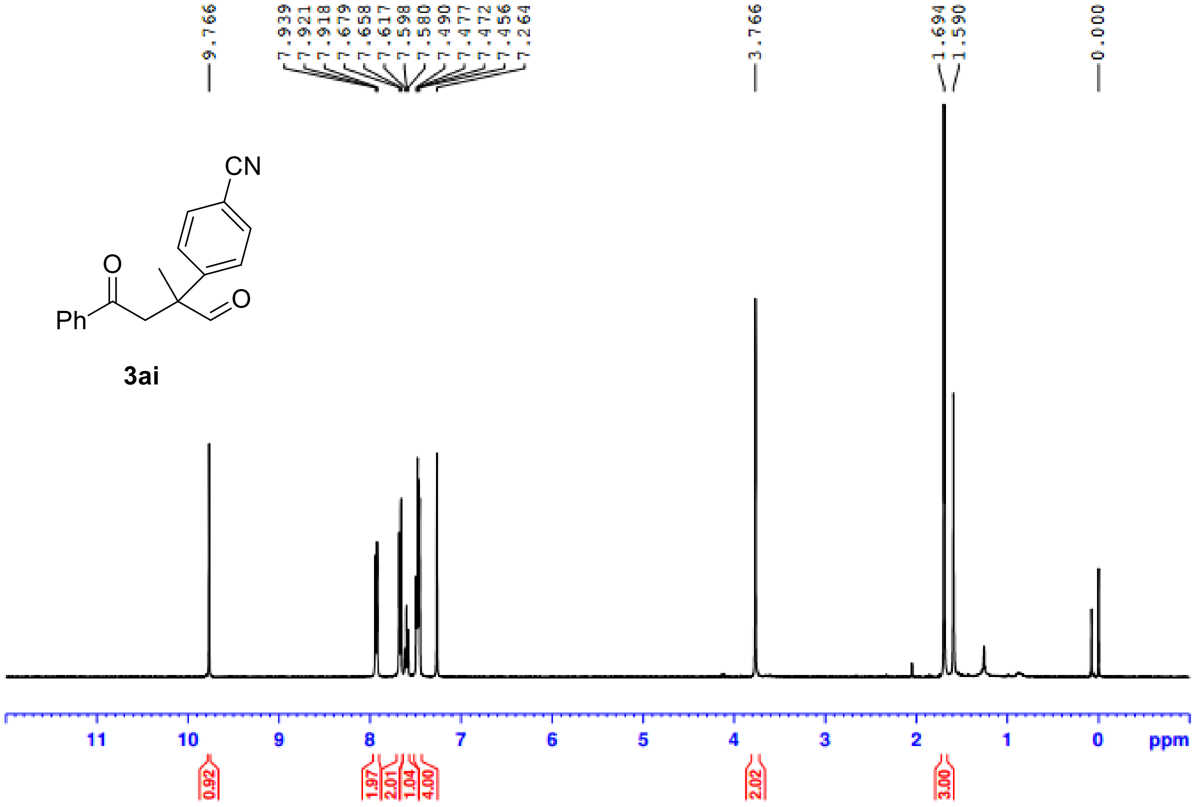
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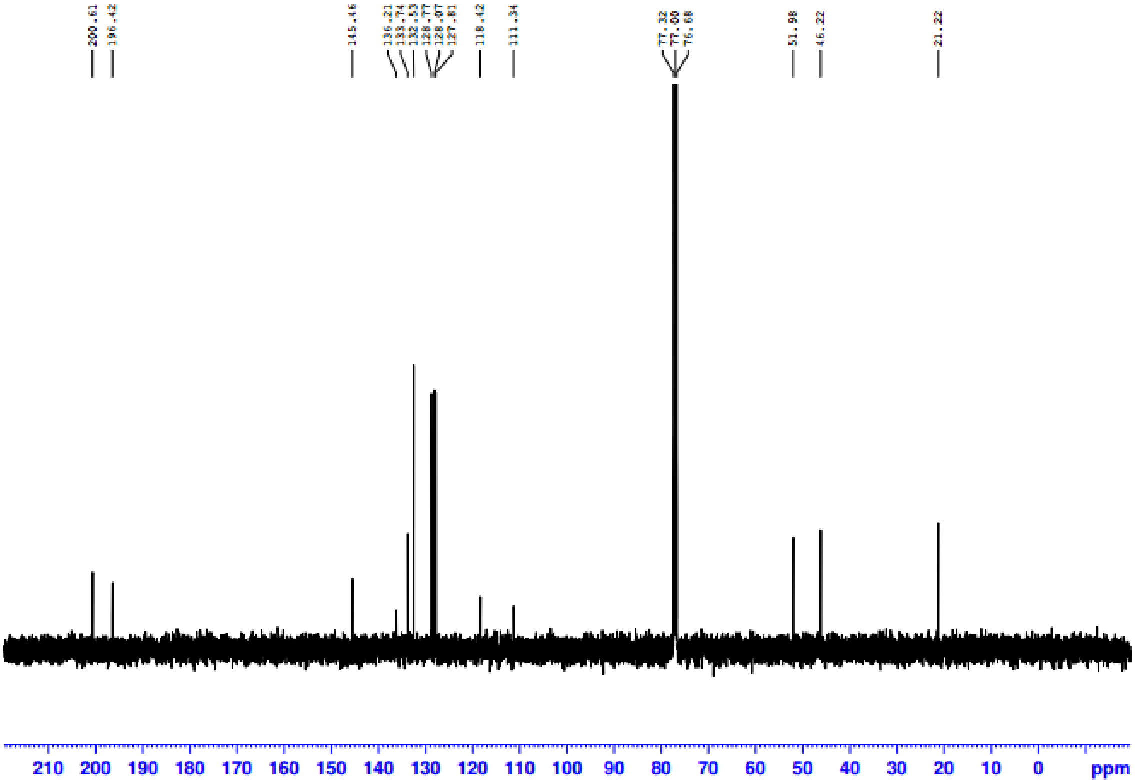
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21.22
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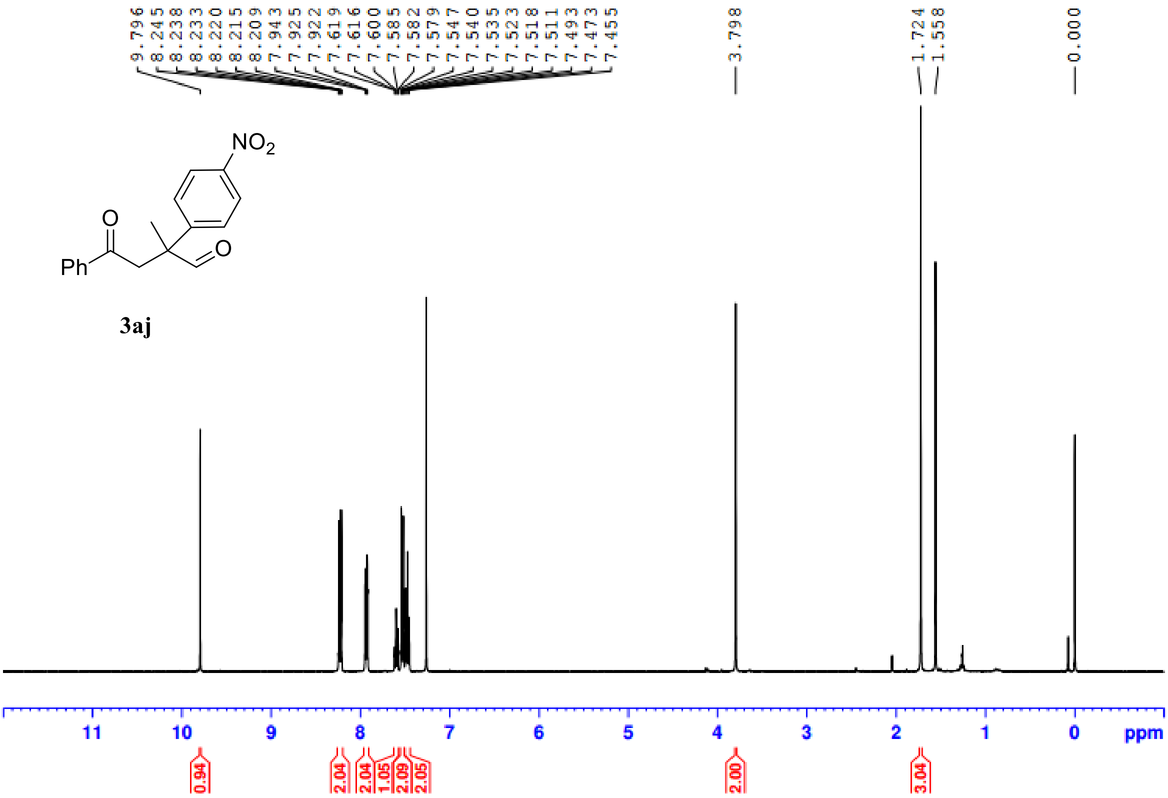
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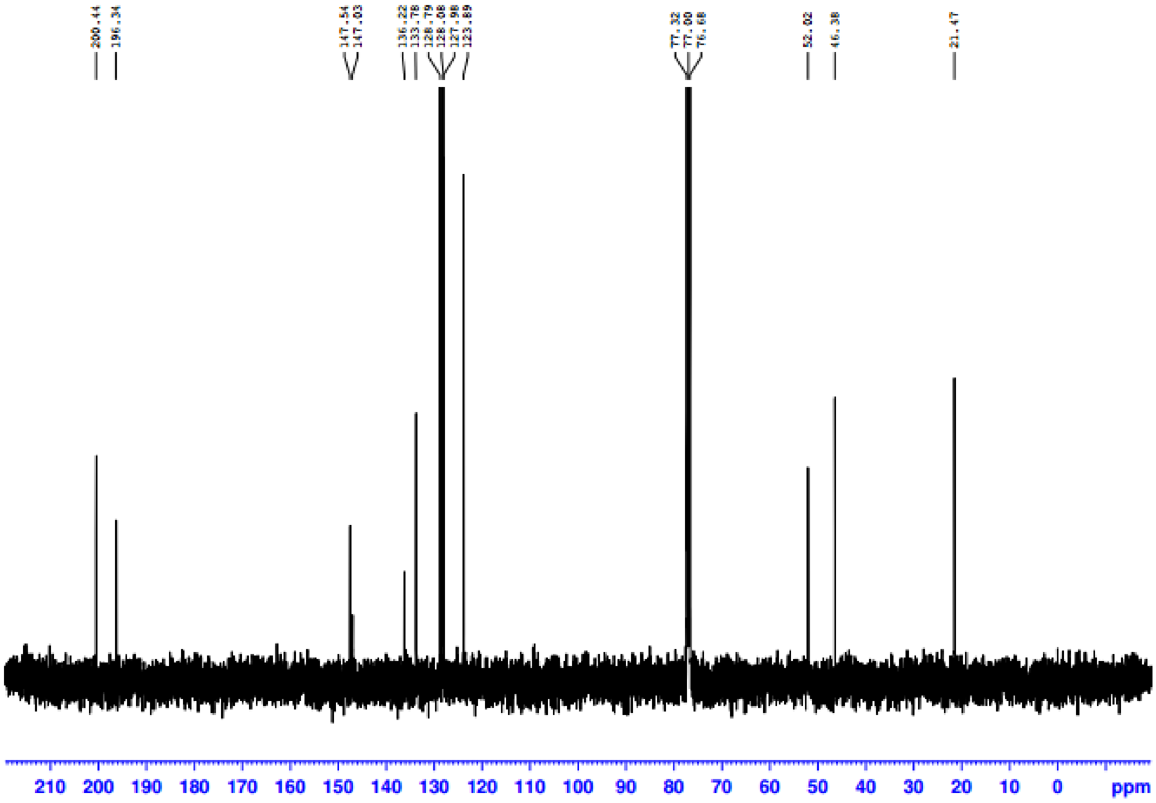
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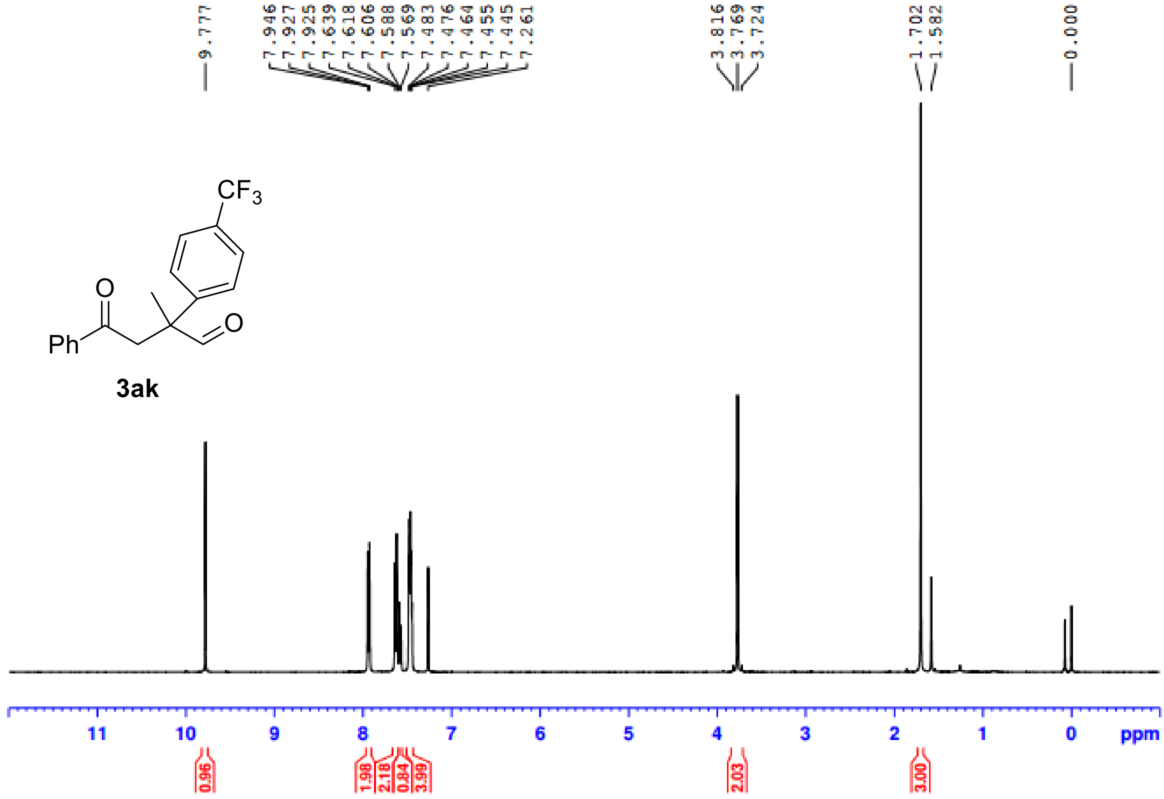
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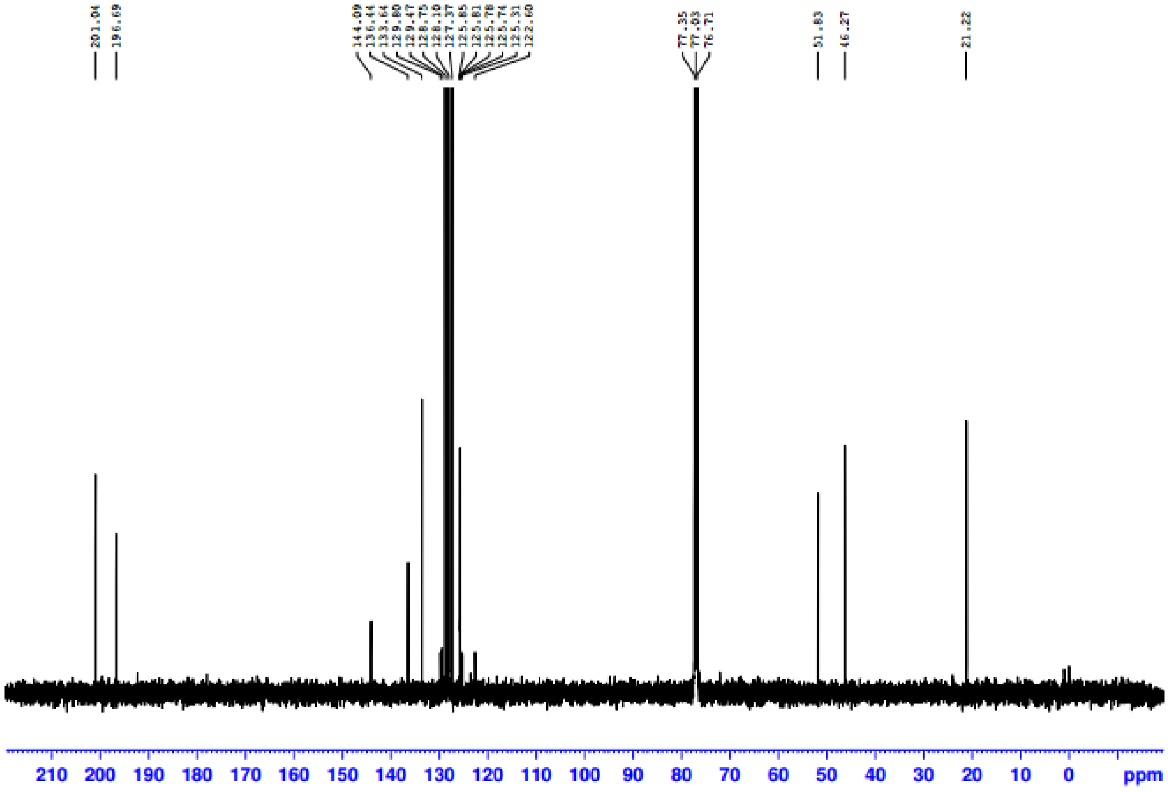
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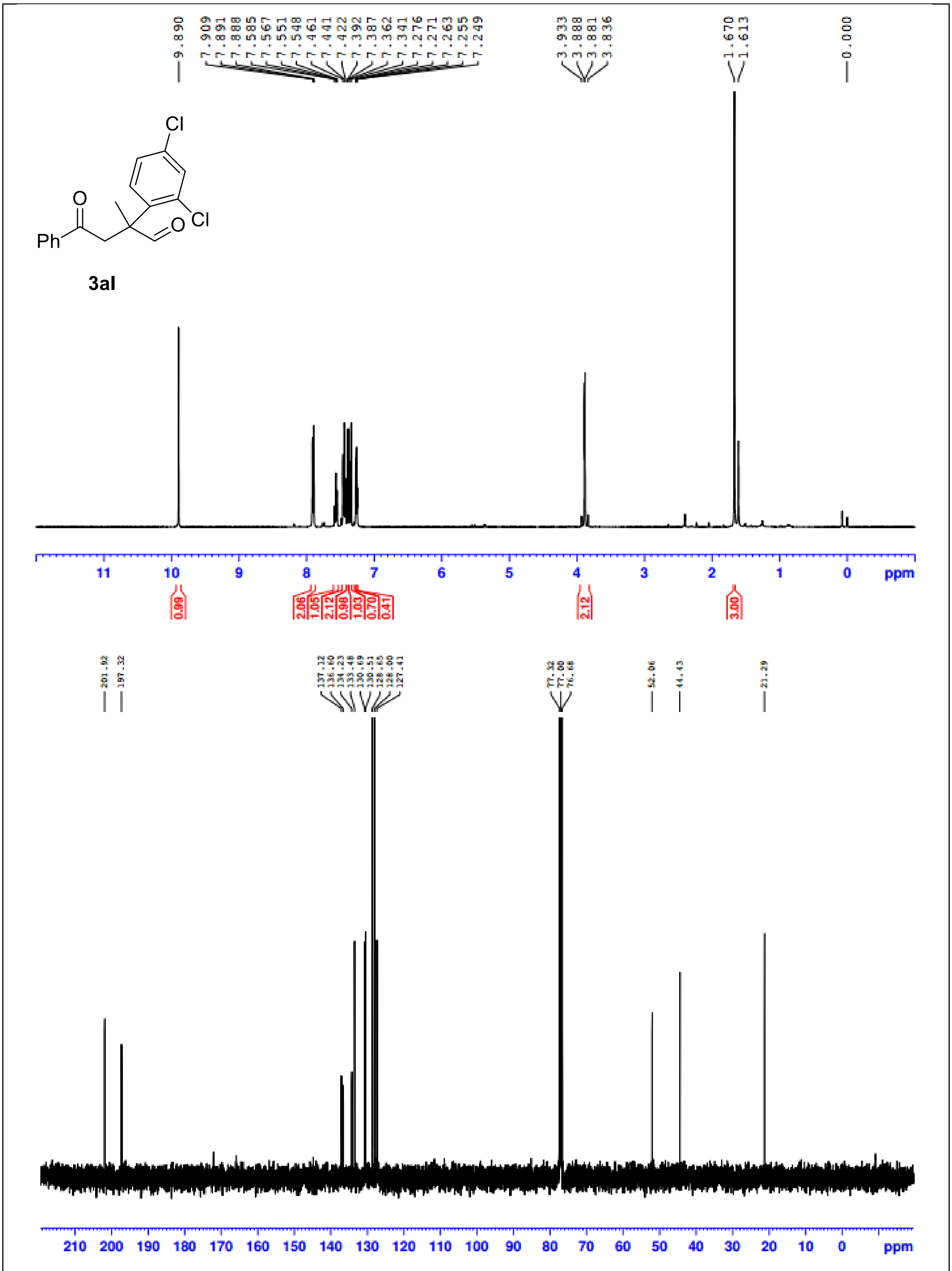
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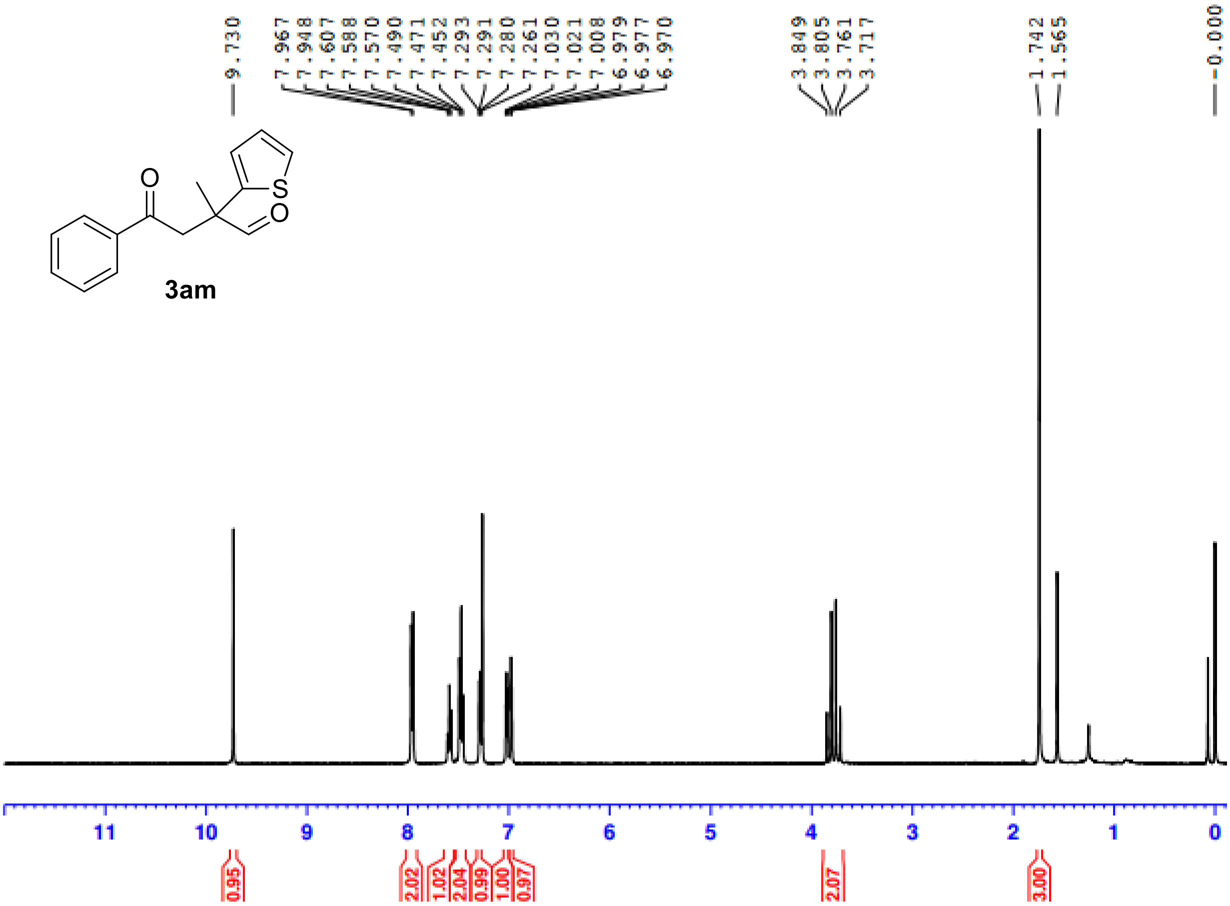
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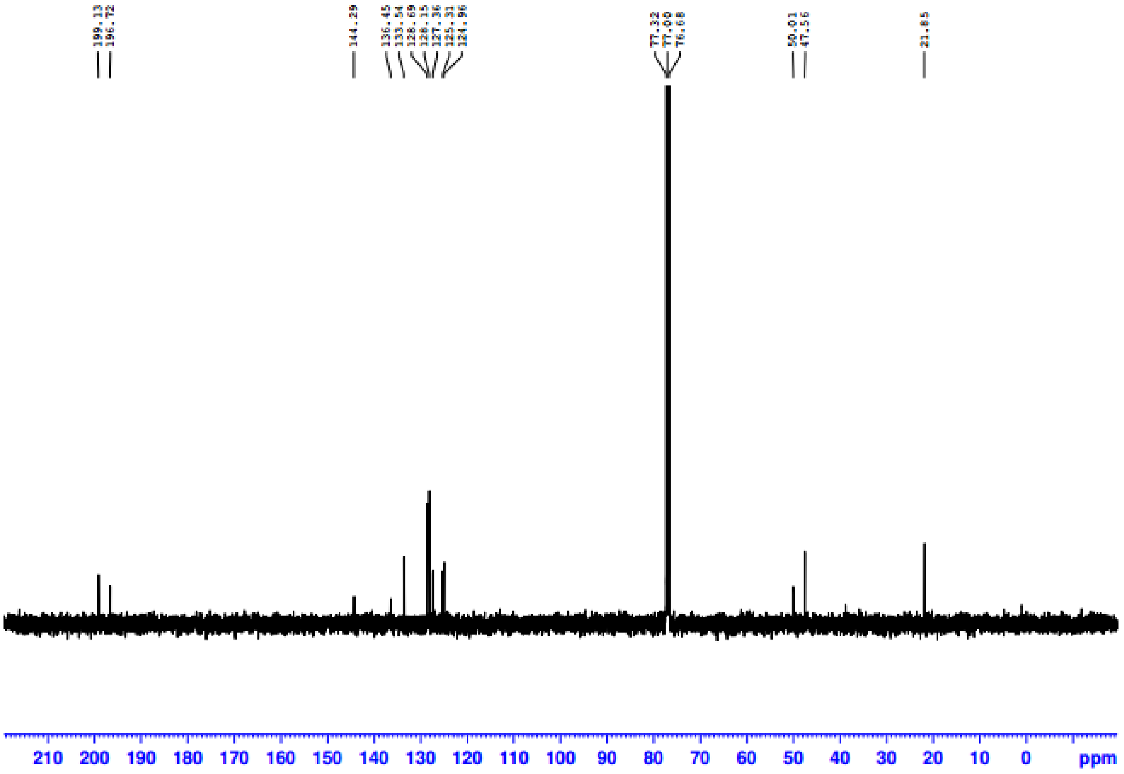
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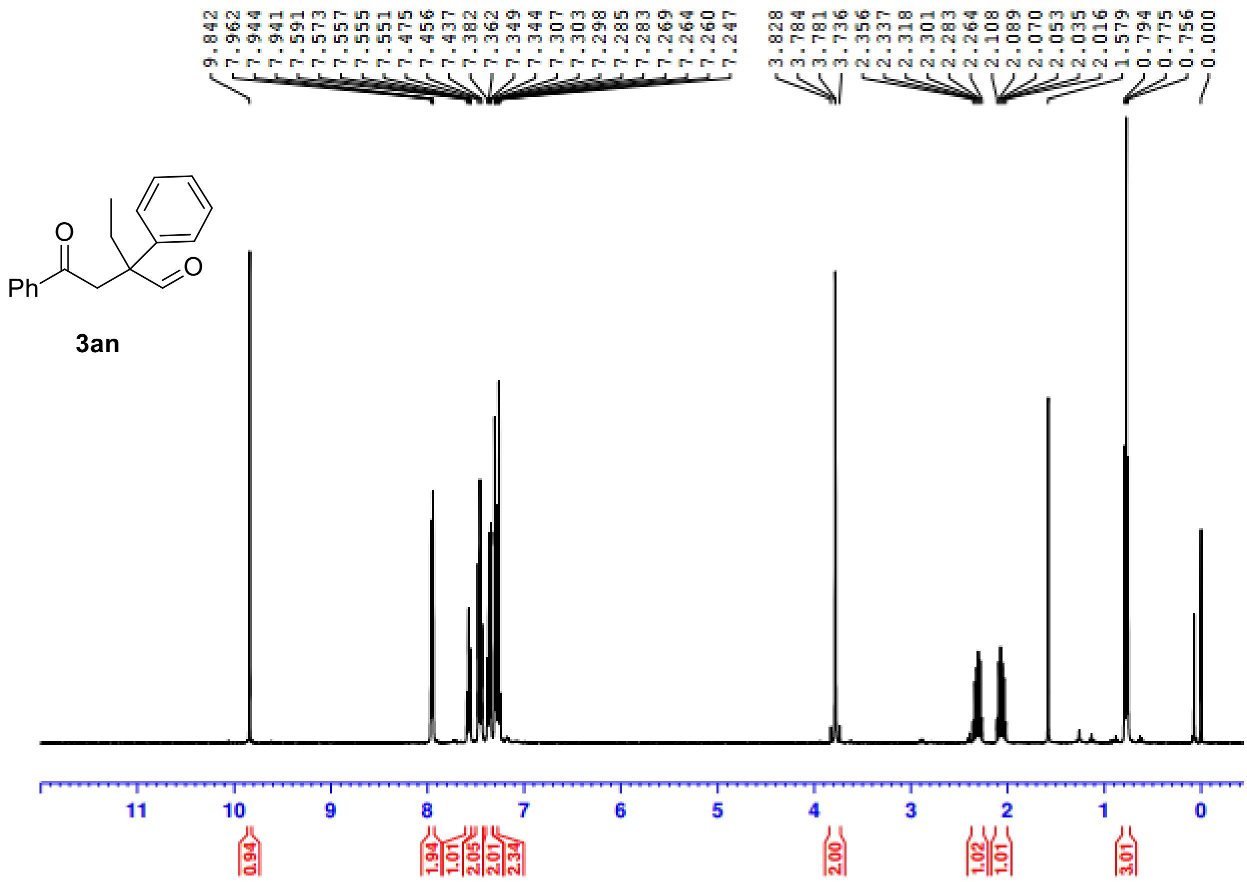
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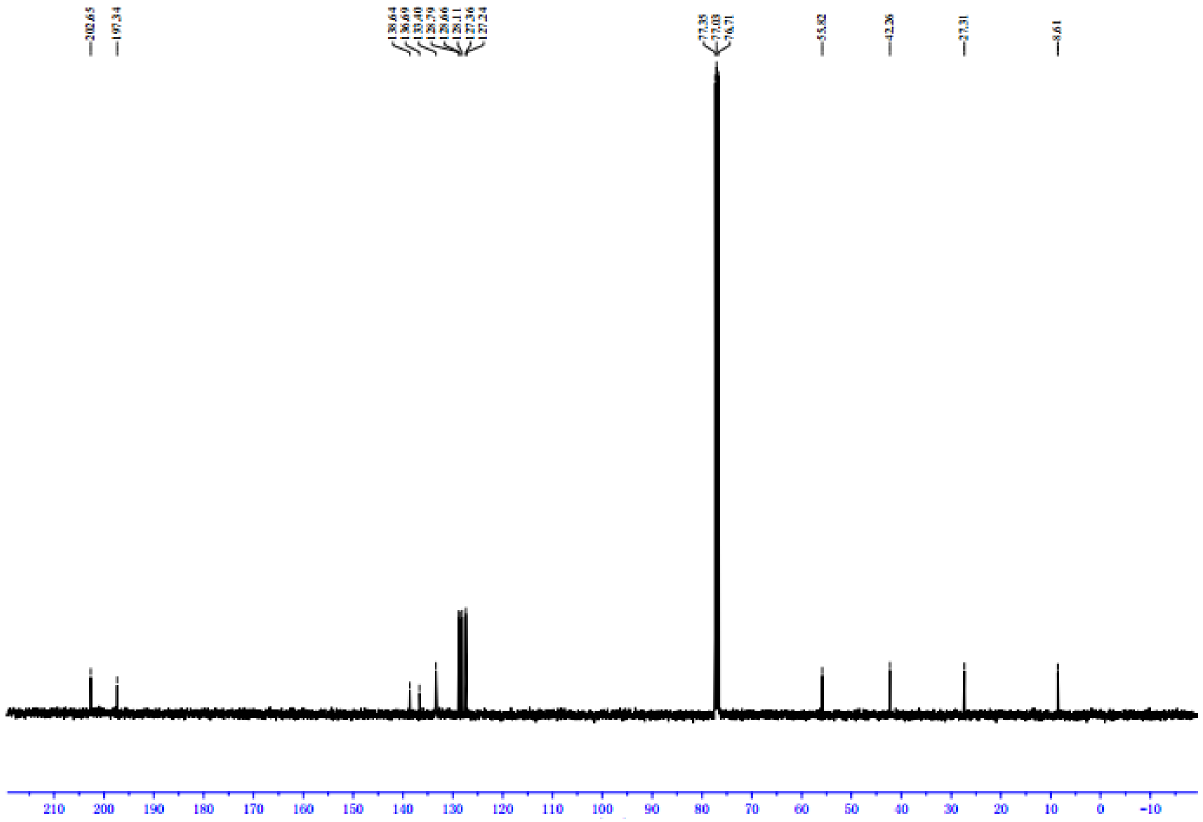
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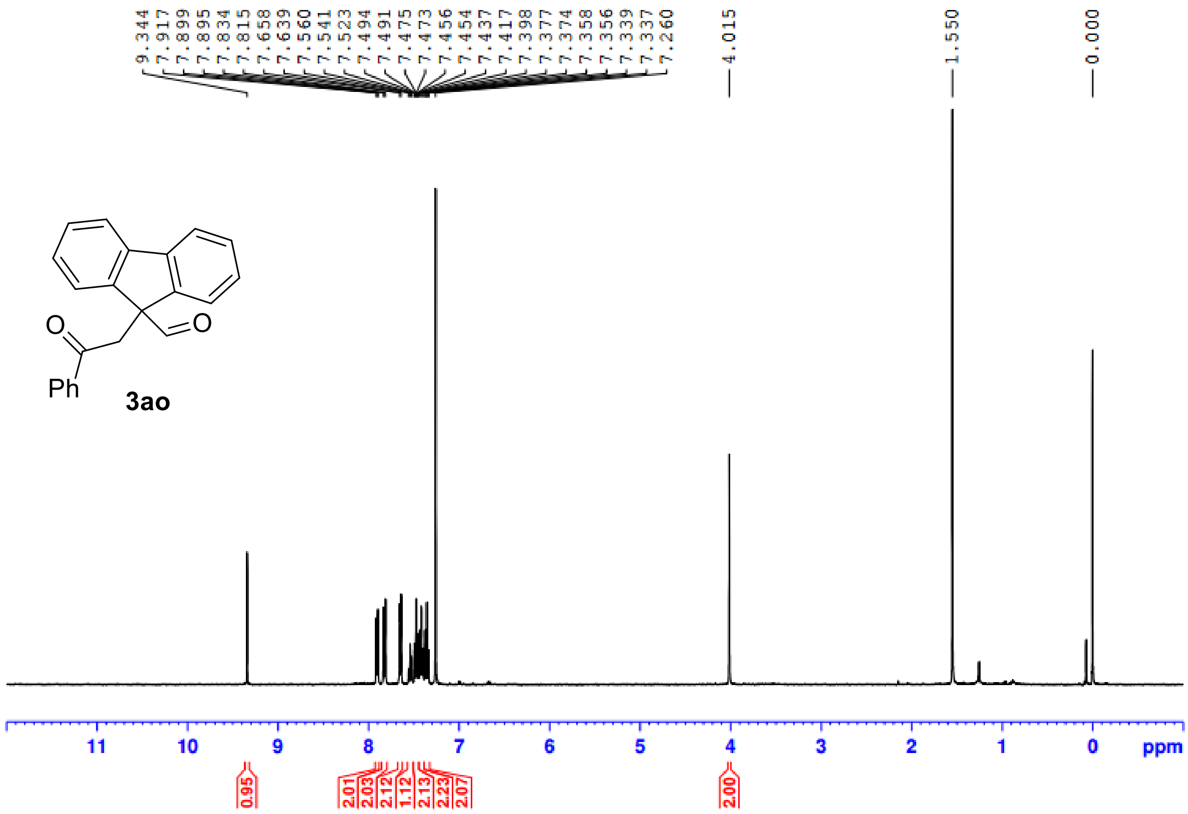
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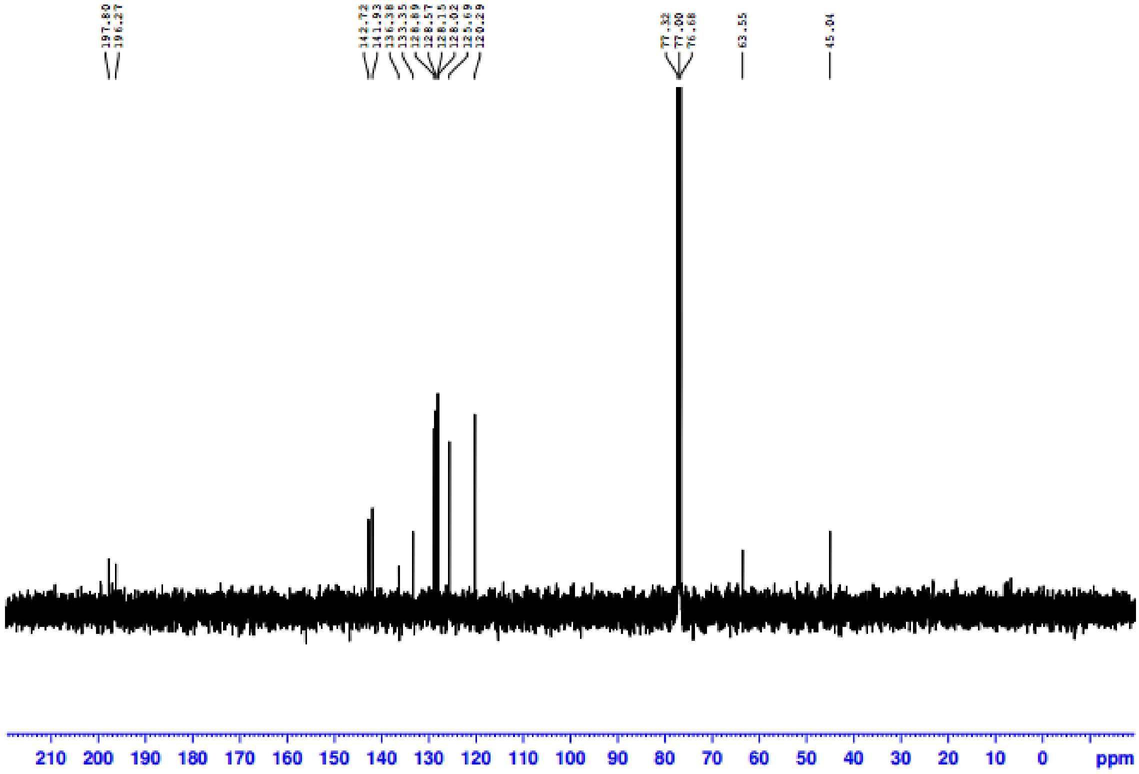
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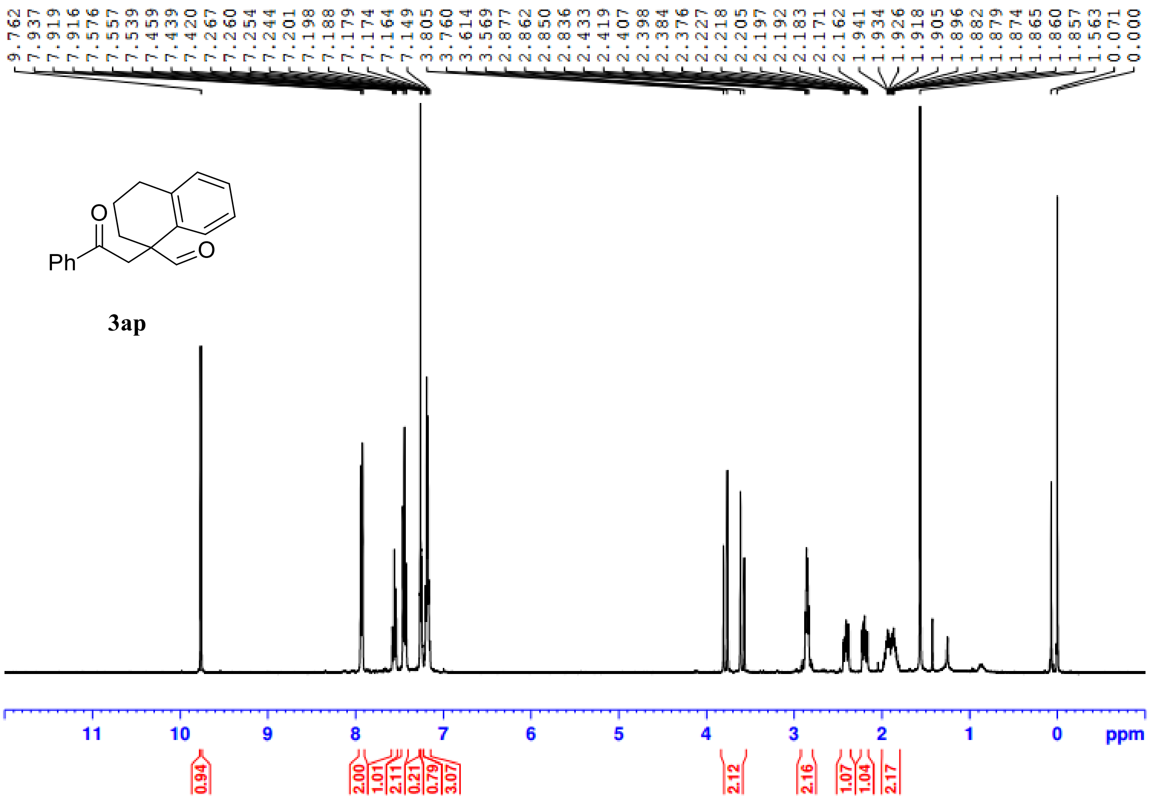
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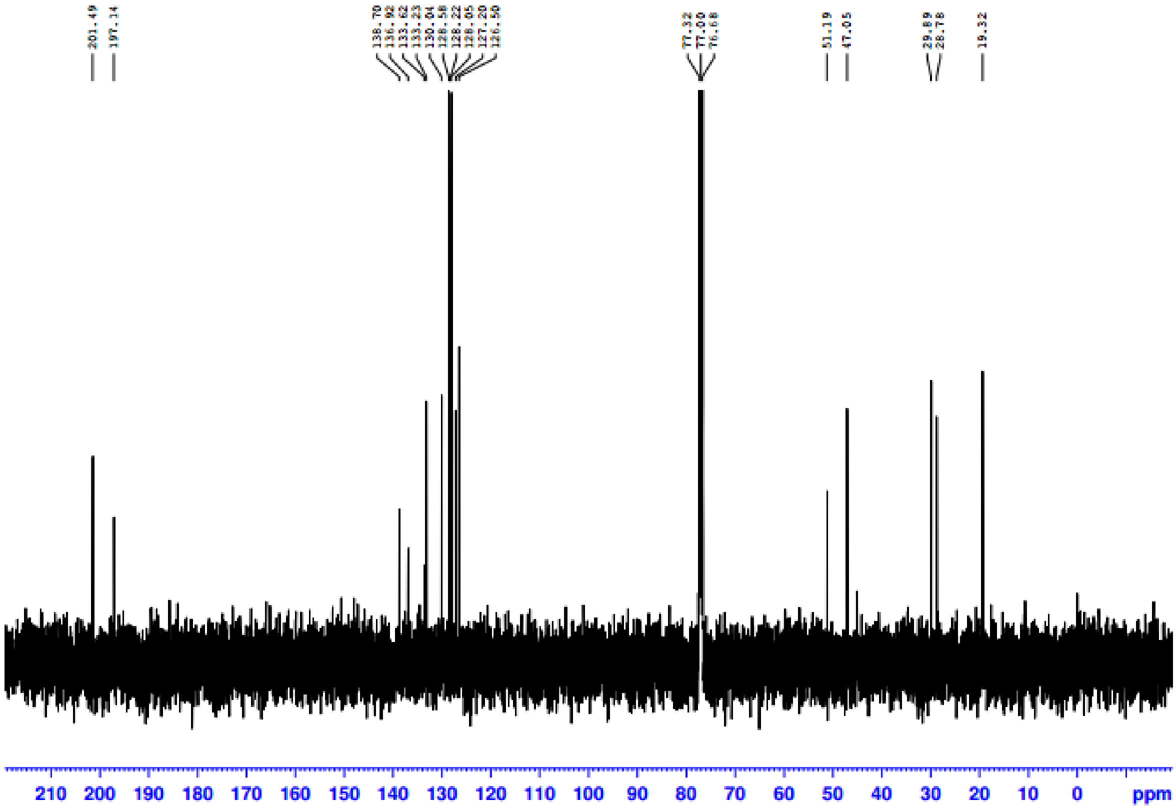
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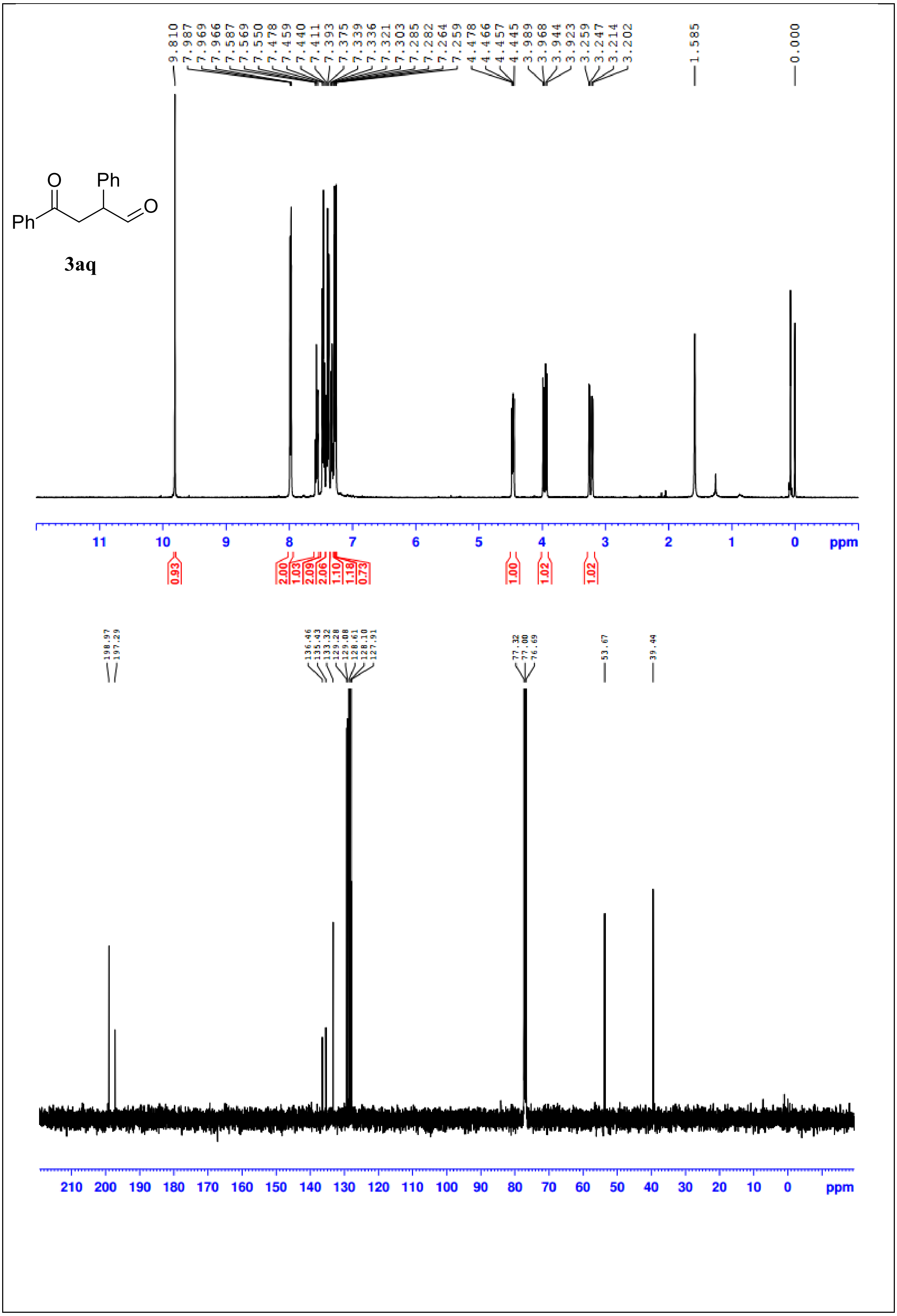
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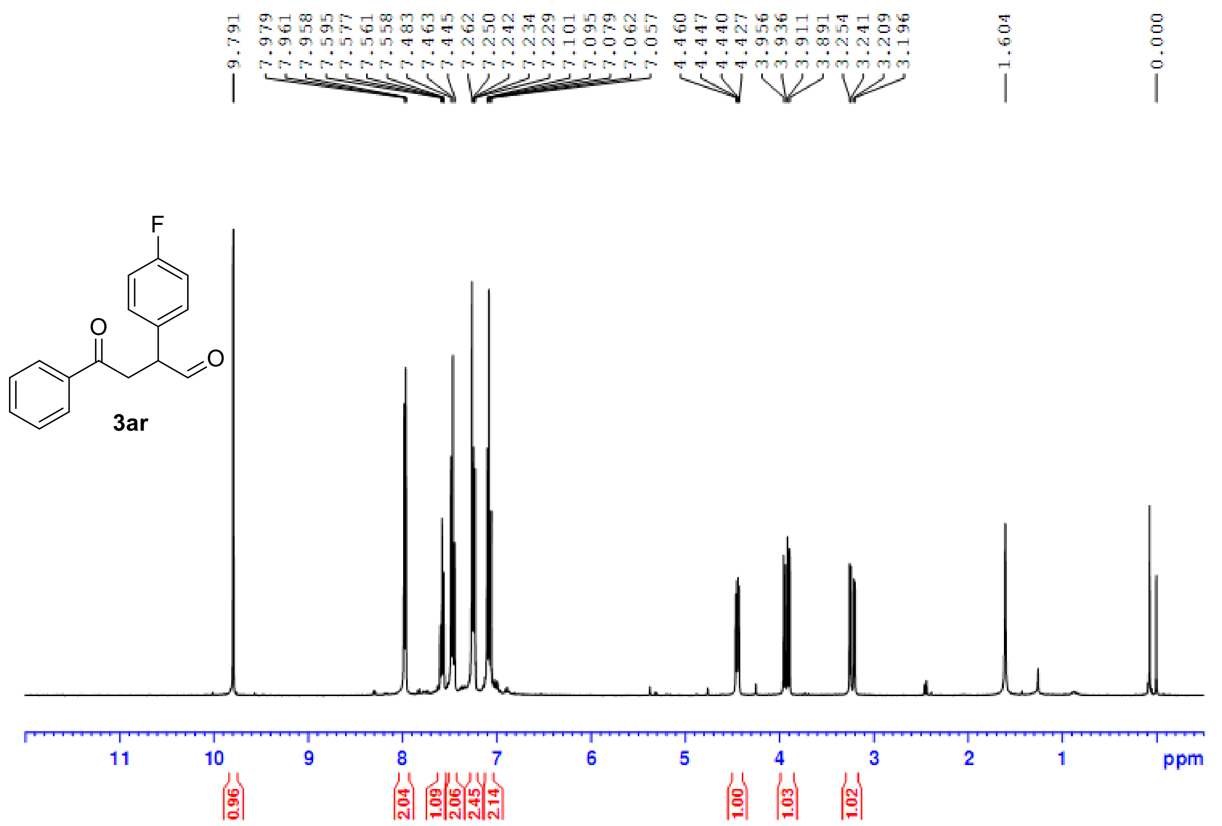
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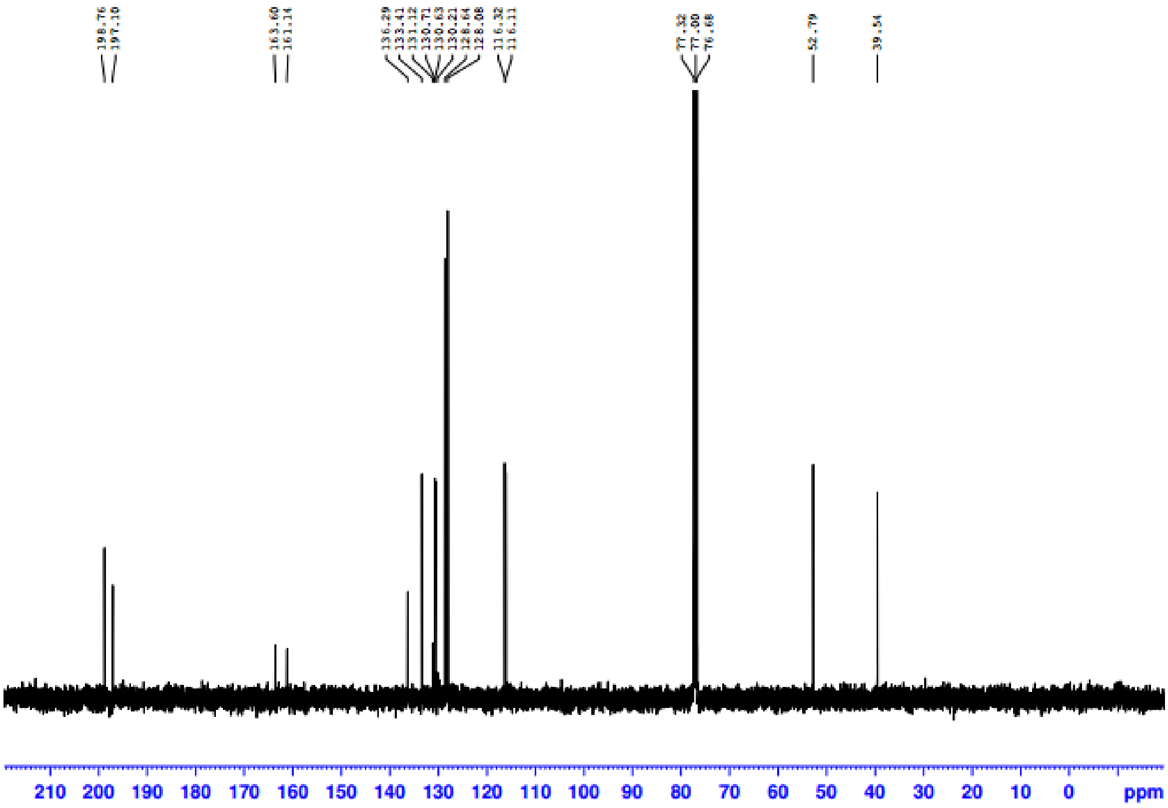
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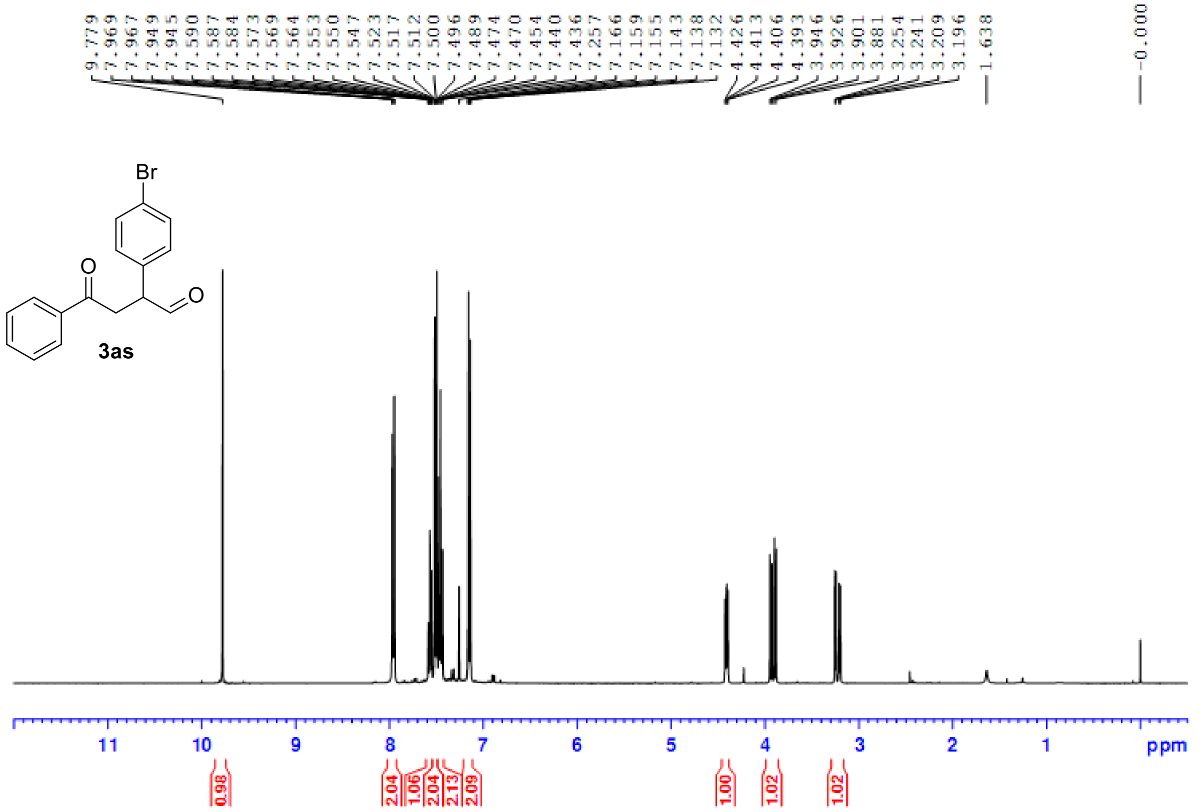

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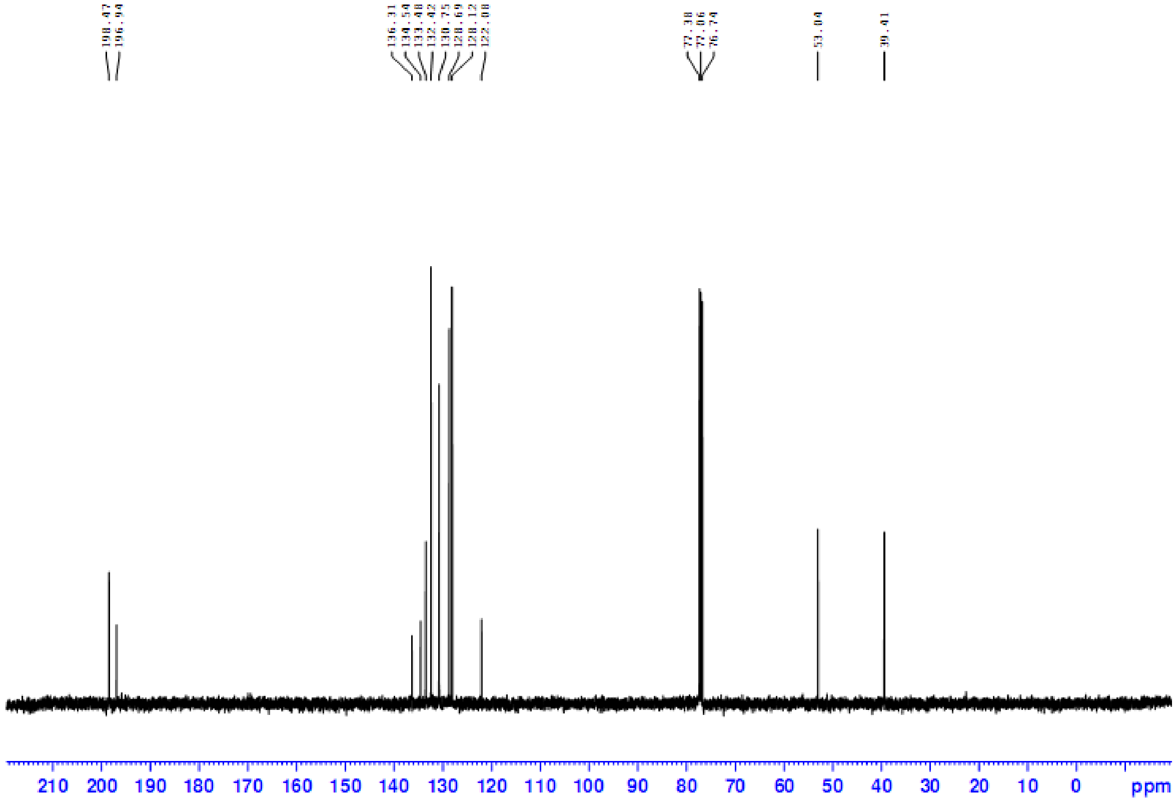

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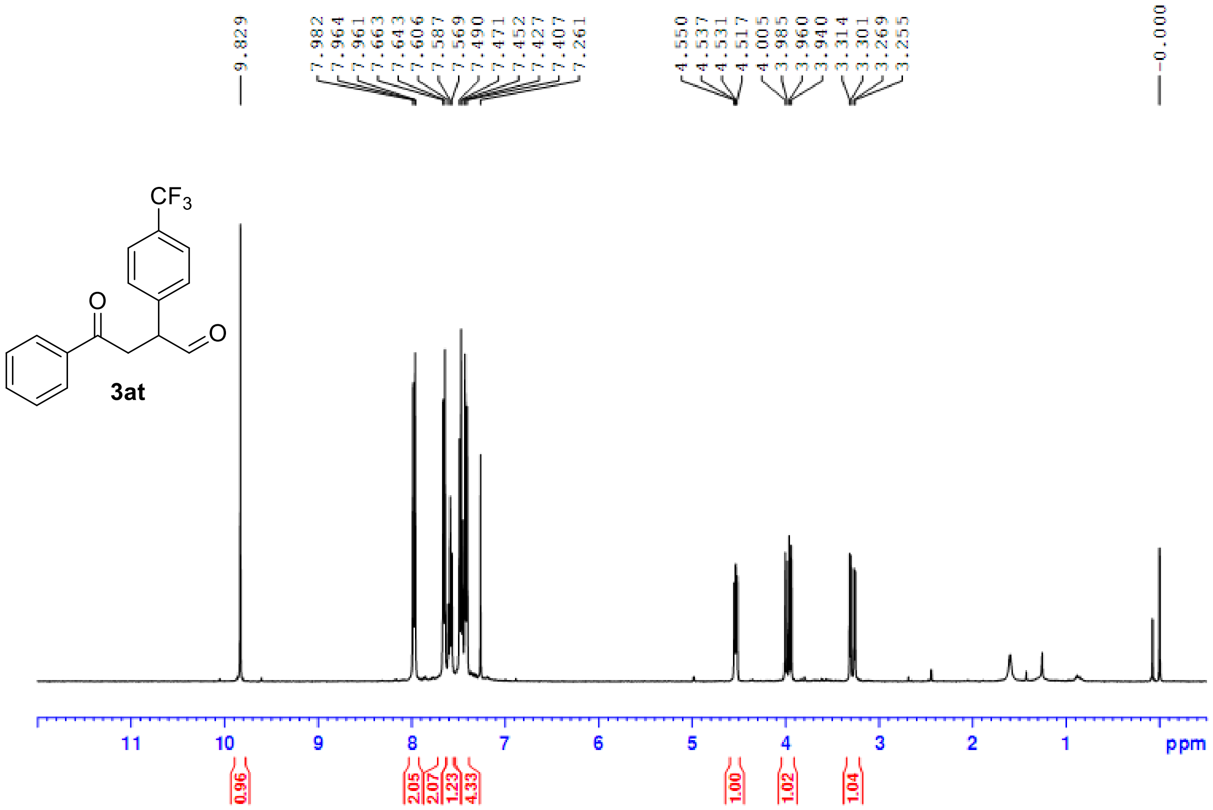
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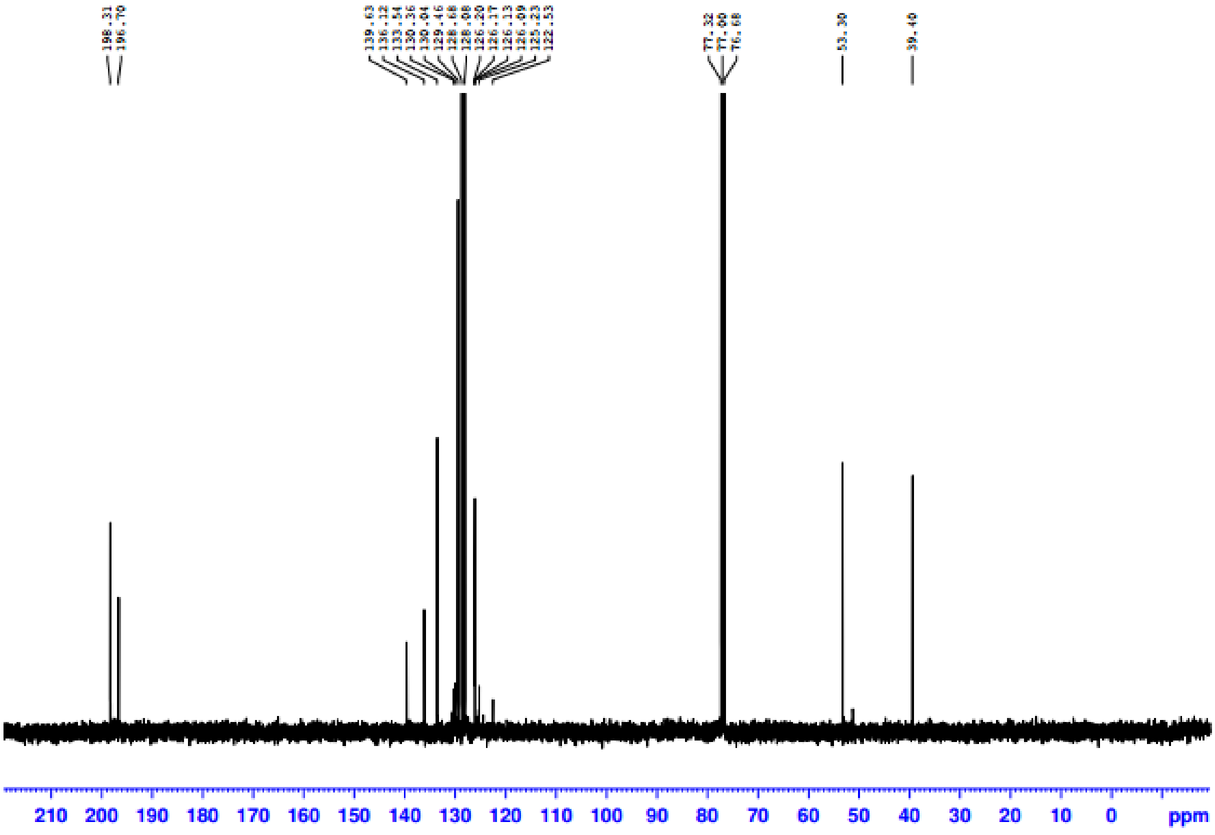
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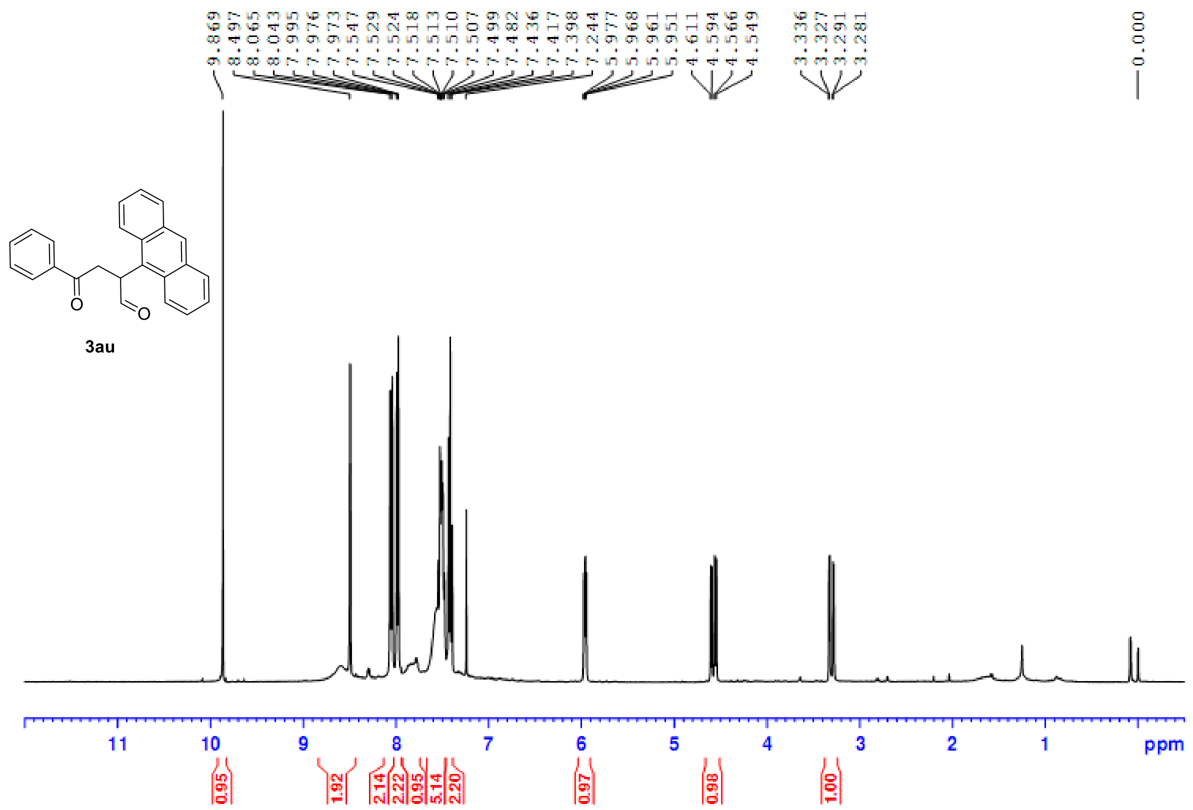
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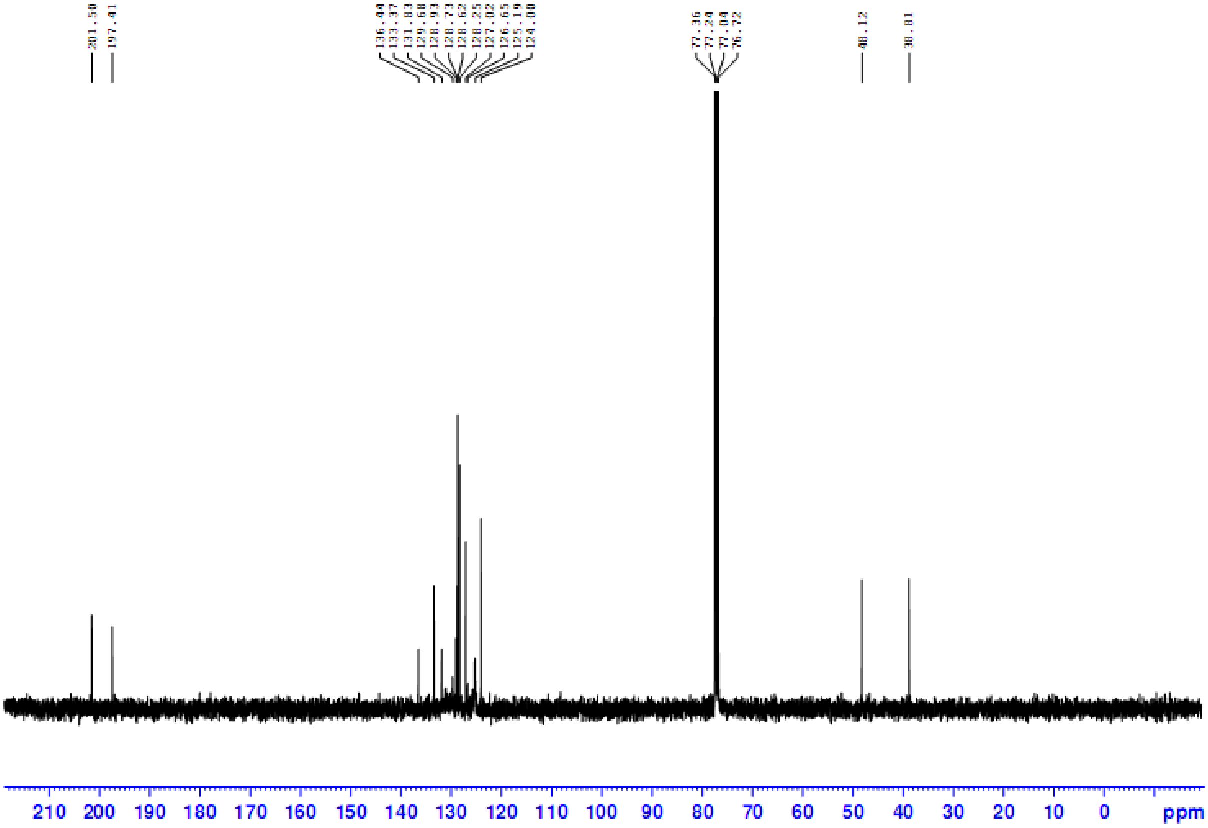
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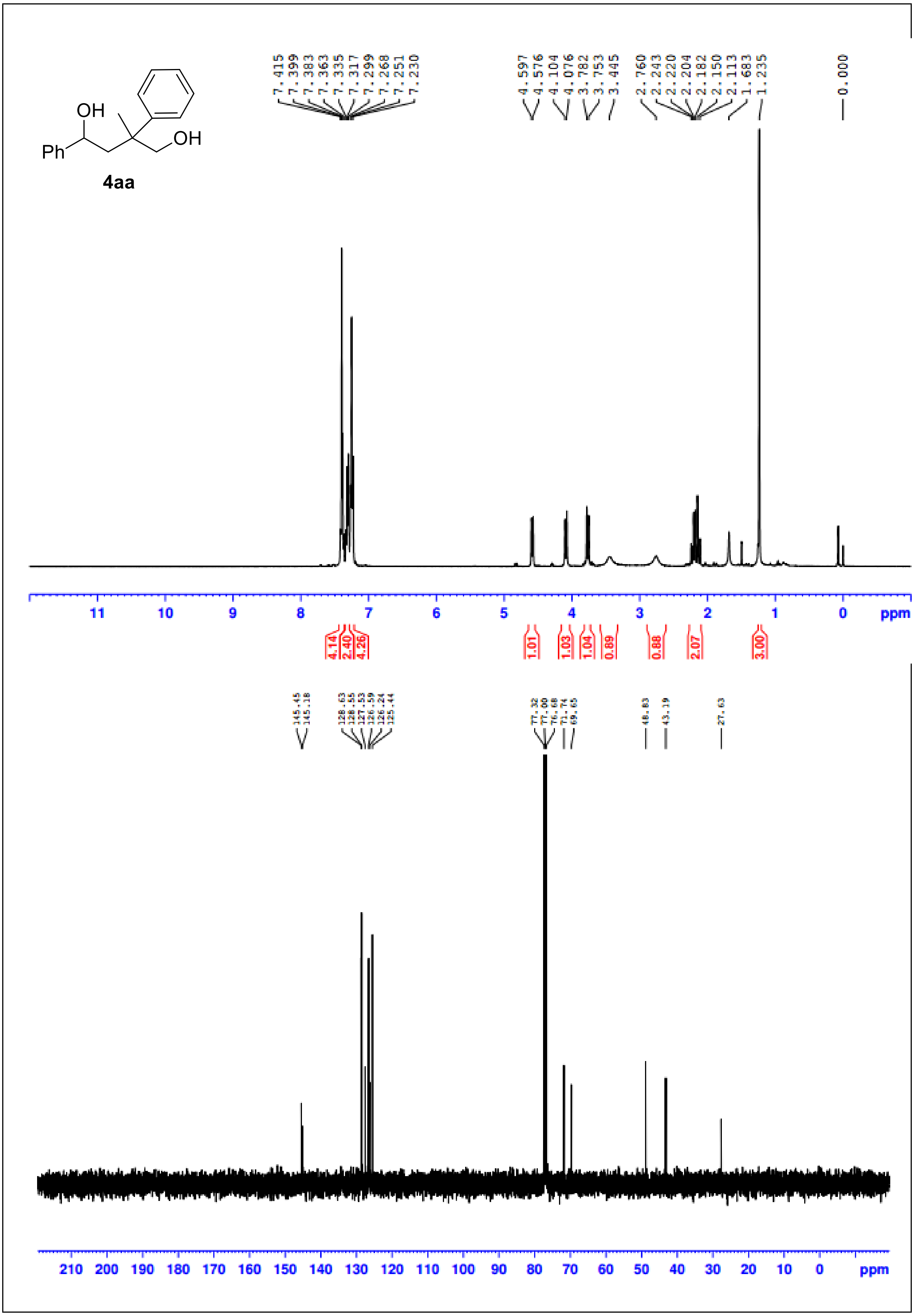
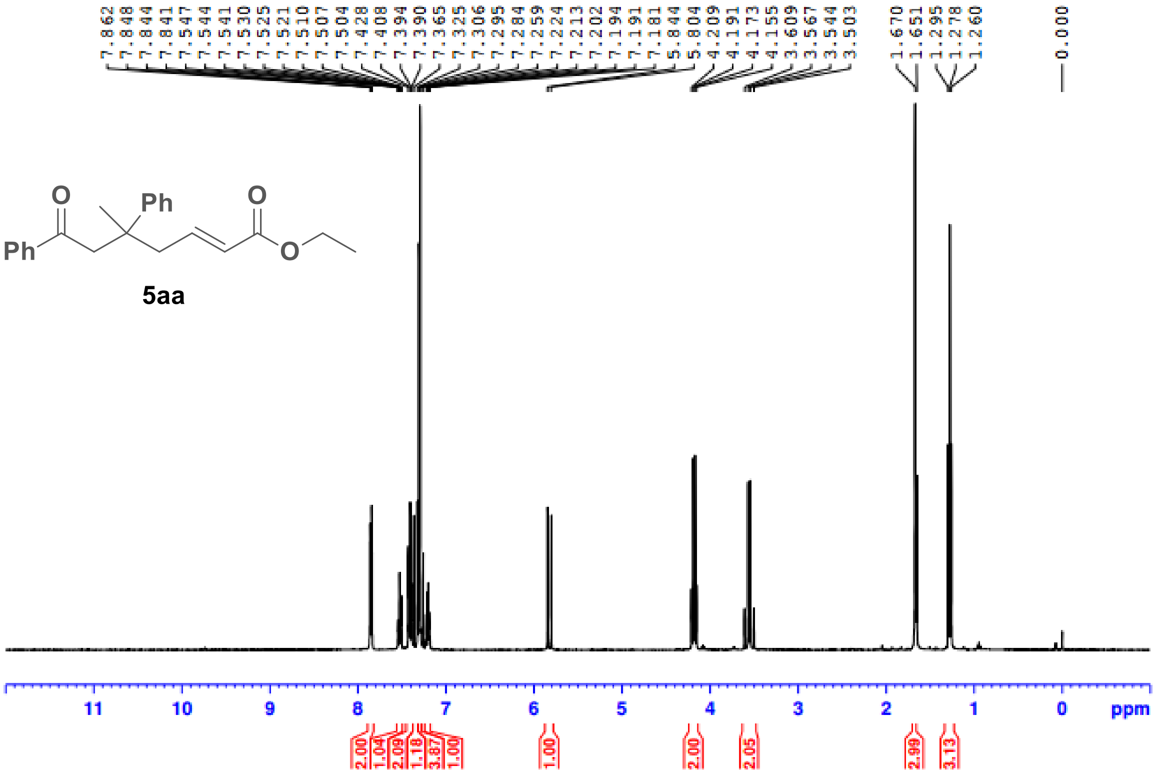
NMR Spetra for applications of 1, 4-ketoaldehydes

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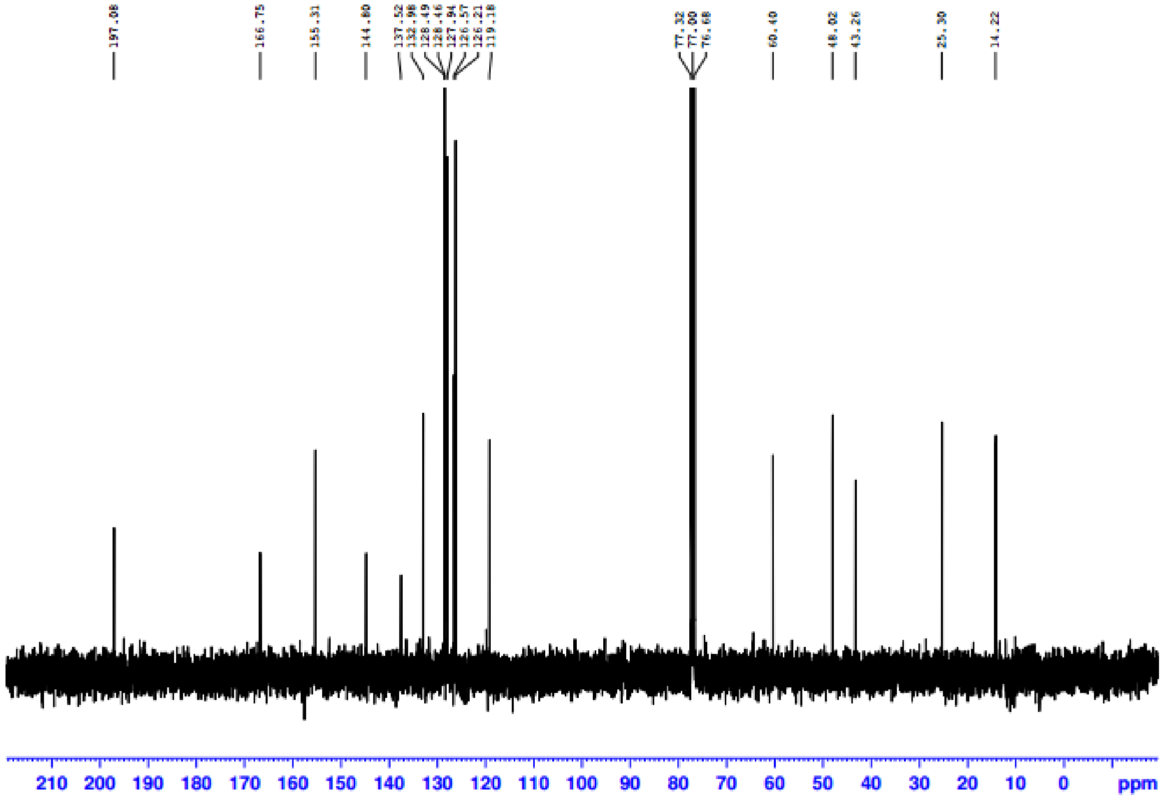
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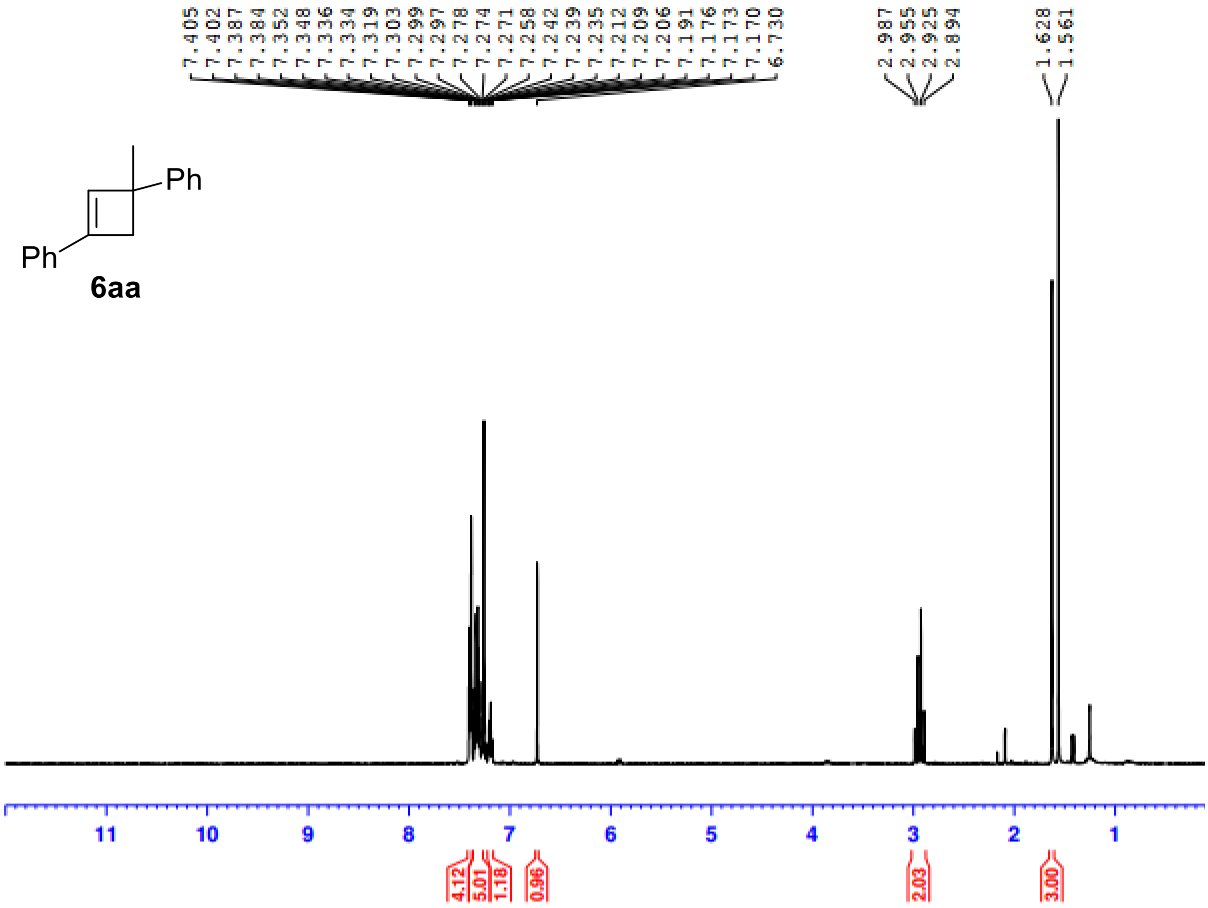
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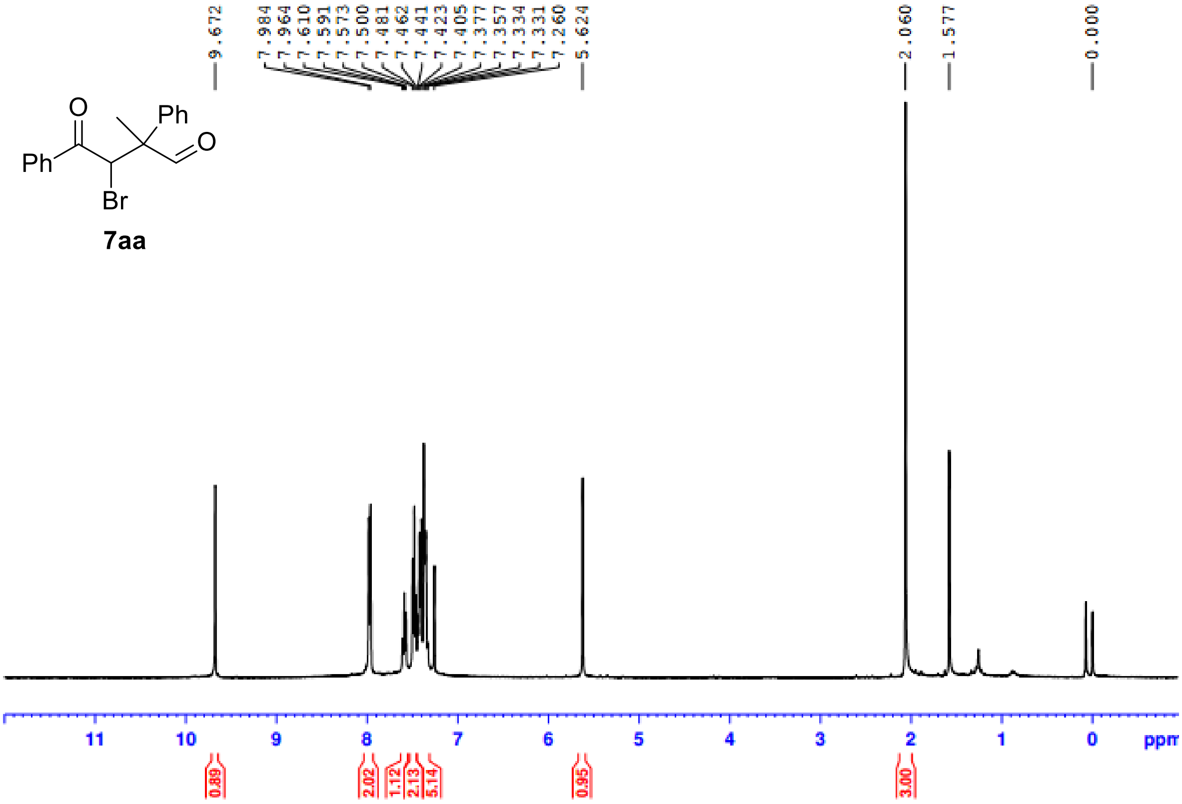
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0.000
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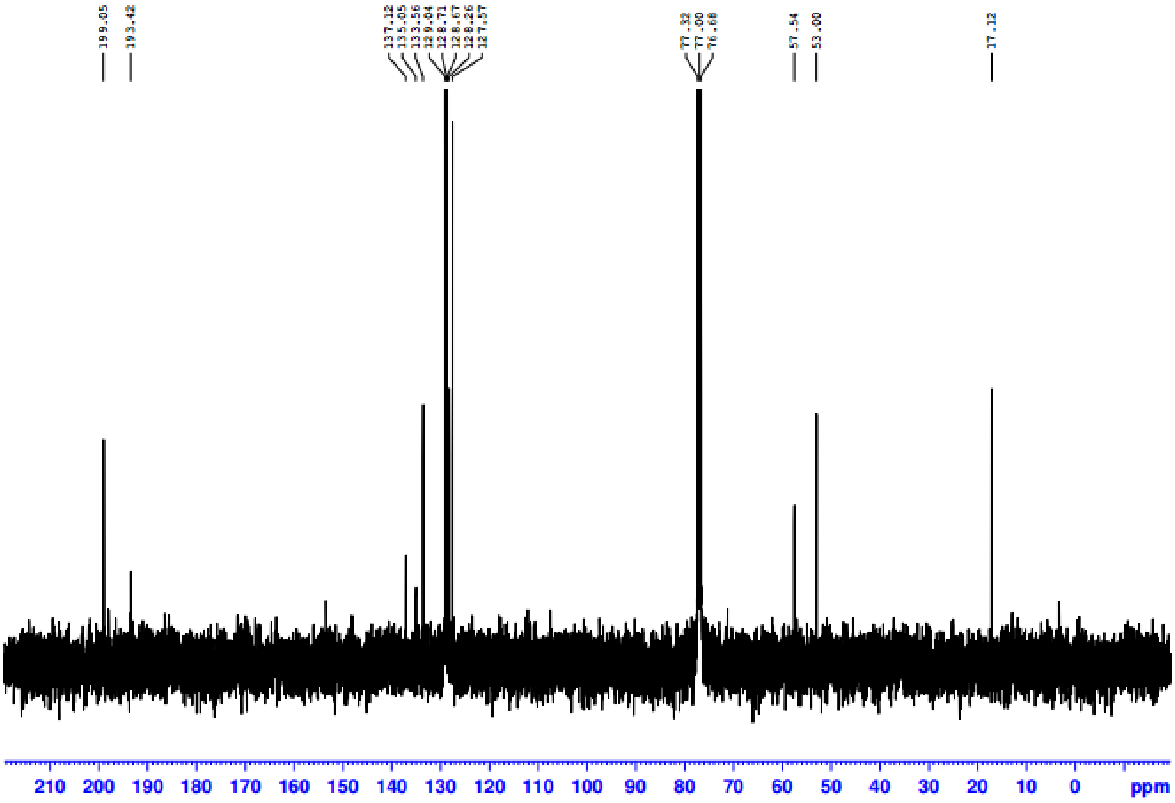
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17.12
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200
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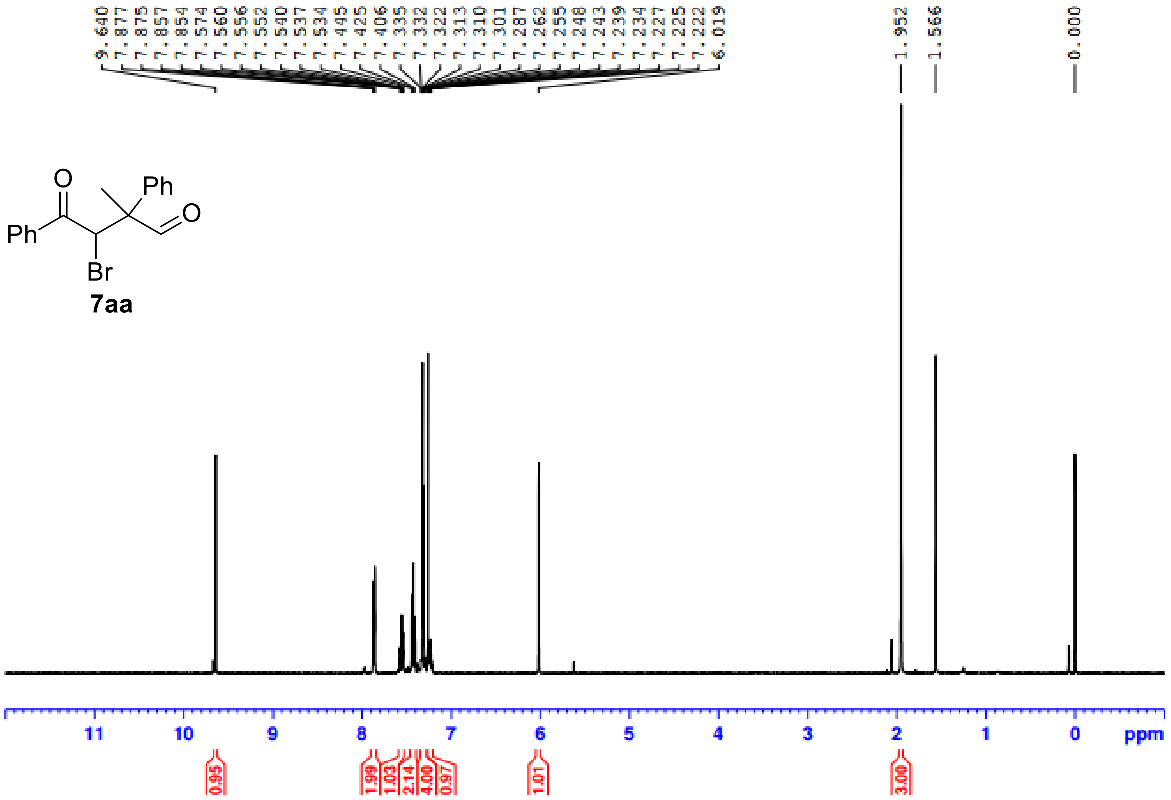
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7.243
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Ph
O
Ph
Br
11
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9
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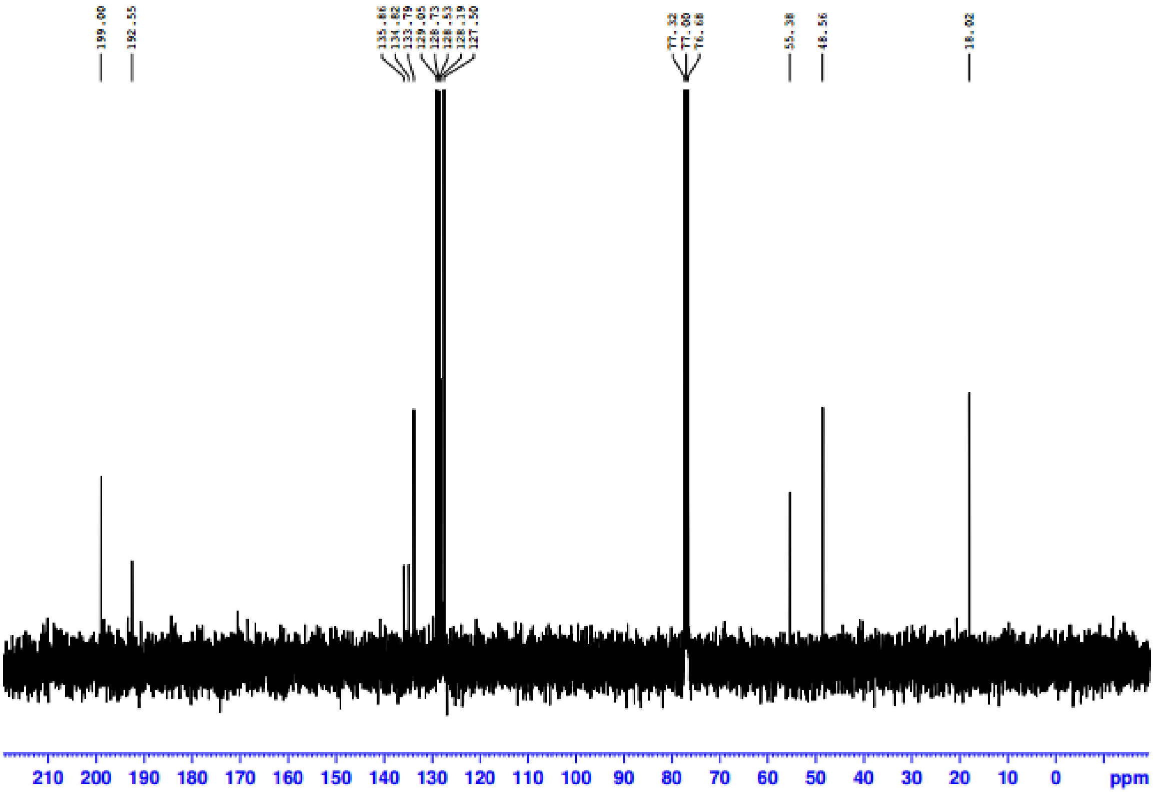
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200
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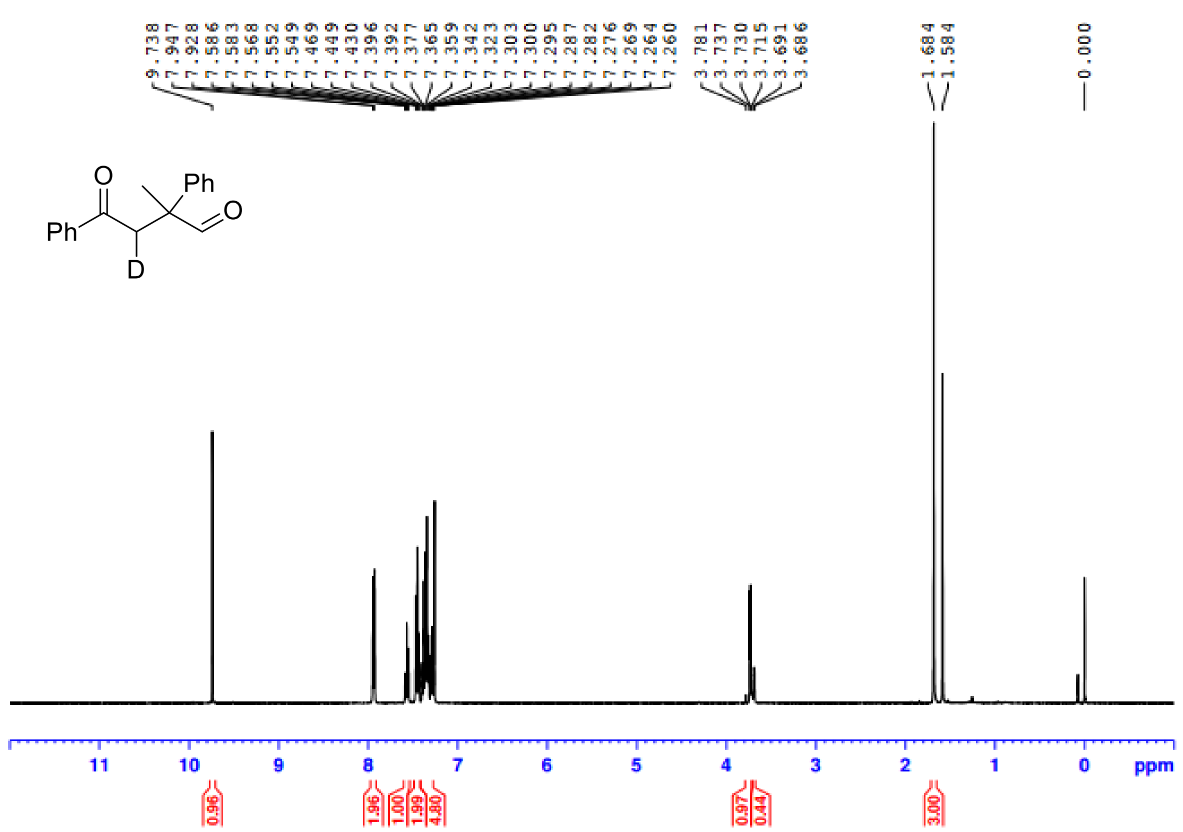
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7.359
7.342
7.323
7.303
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7.295
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7.276
7.269
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7.260
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3.691
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O
Ph
D
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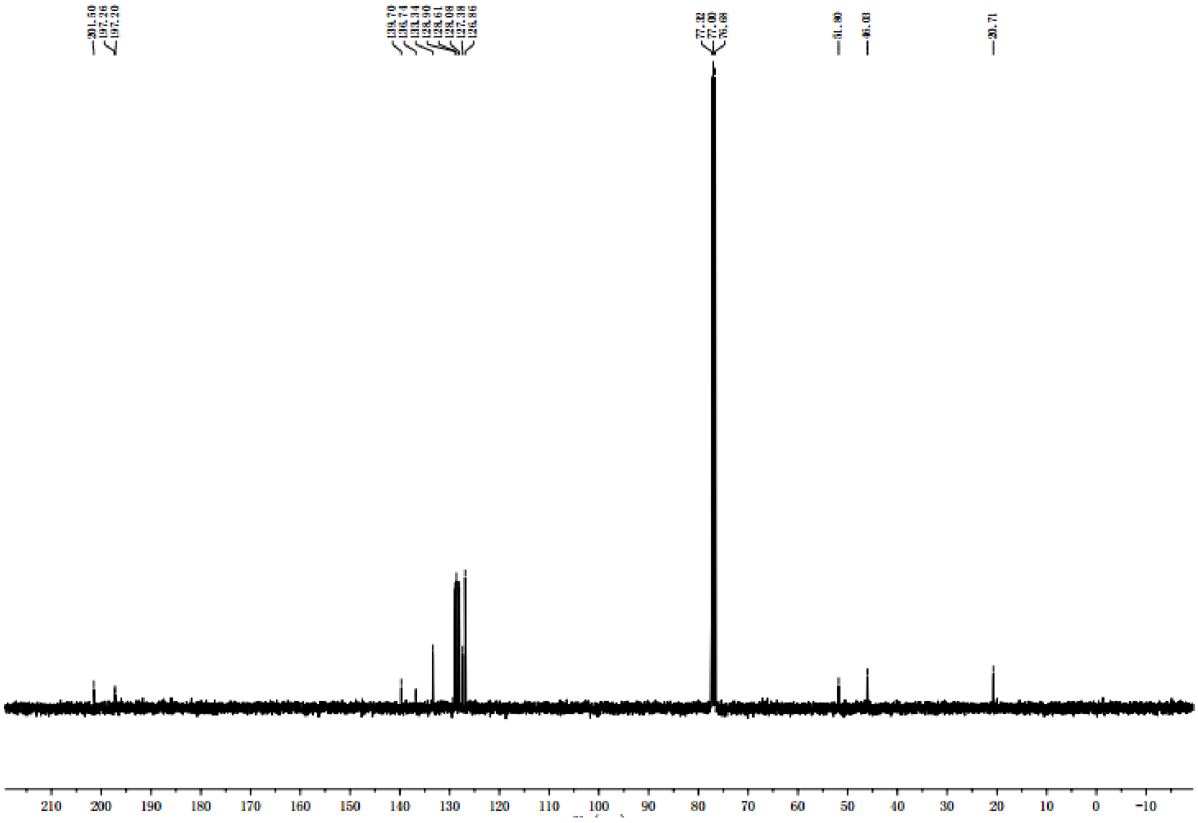
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76.68
51.90
46.03
20.71
210
200
190
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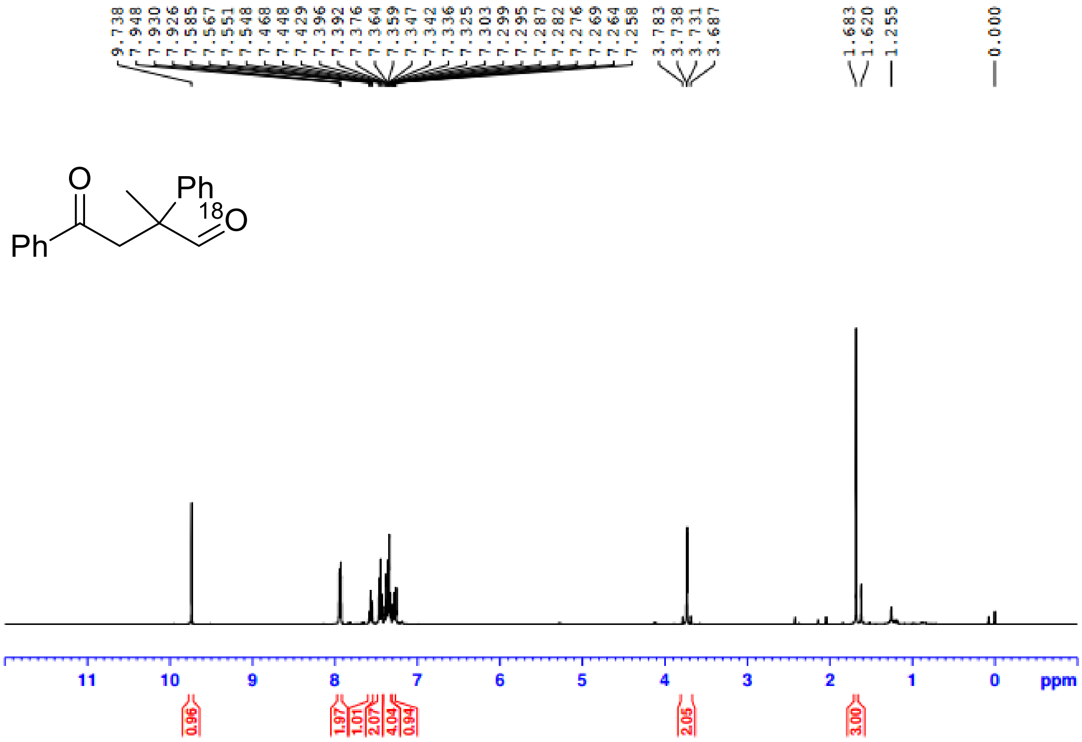
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7.429
7.396
7.392
7.376
7.364
7.359
7.347
7.342
7.336
7.325
7.303
7.299
7.295
7.287
7.282
7.276
7.269
7.264
7.258
3.783
3.738
3.731
3.687
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1.620
1.255
0.000
11
10
9
8
7
6
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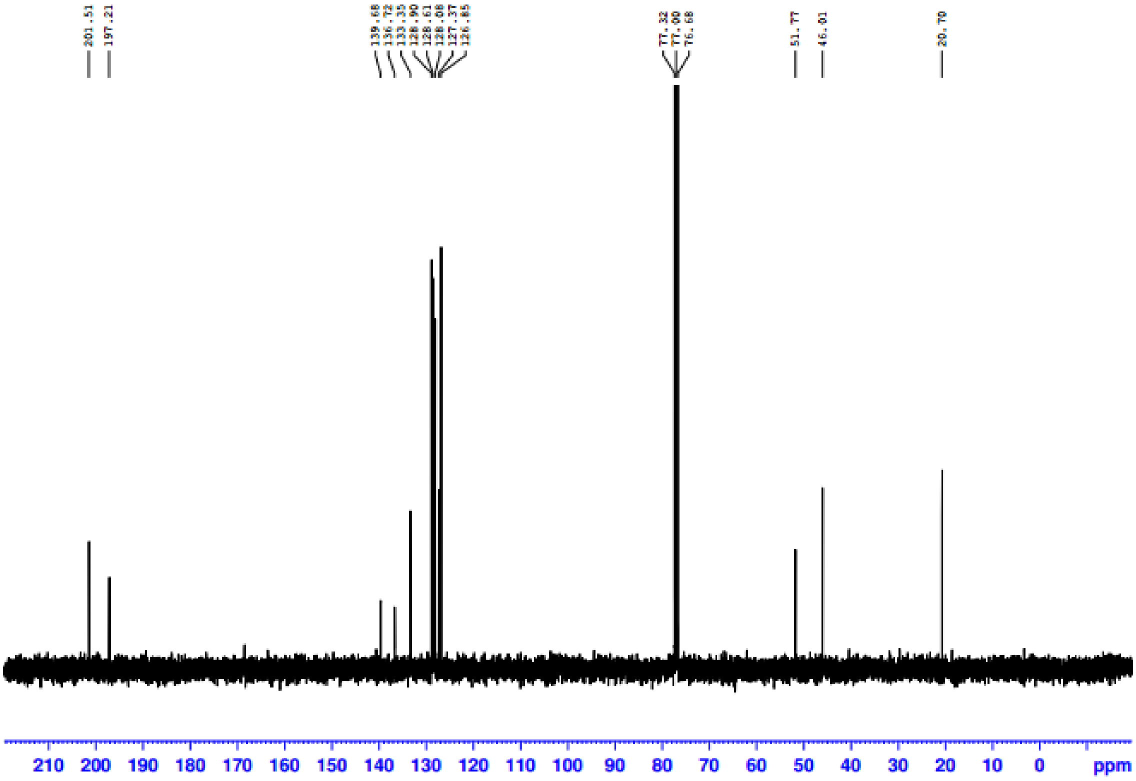
3.00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51.77
46.01
20.70
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm