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SUPPORTING INFORMATION

Lewis Acid Catalyzed Reactivity Switch: Pseudo Three-Component Annulation of Nitrosoarenes and (Epoxy)styrenes

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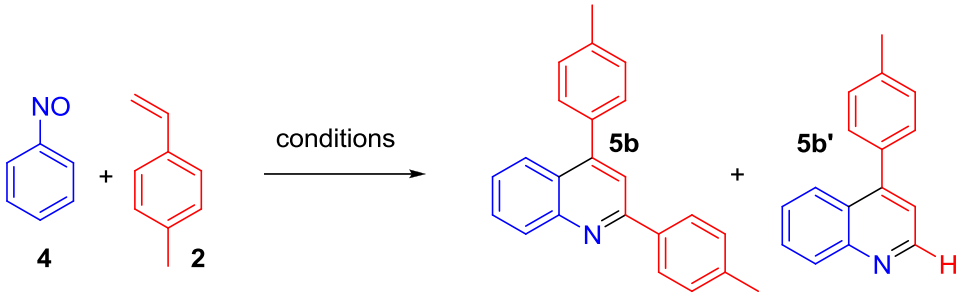
Experimental:

General: All reactions involving air- or moisture-sensitive reagents or intermediates were carried out in oven-dried glassware under an argon atmosphere. Dichloromethane (CH_2Cl_2) was freshly distilled from phosphorus (V) oxide (P_2O_5). Commercial grade DCE, xylene, benzene and toluene were distilled over CaH_2 before use. All other solvents and reagents were purified according to standard procedures or were used as received from Aldrich, Acros, Merck and Spectrochem. ^1H, ^{13}C NMR spectroscopy: *Bruker 600 MHz* and *Bruker 400 MHz* (at 298 K). Chemical shifts, δ (in ppm), are reported relative to TMS δ (^1H) 0.0 ppm, δ (^{13}C) 0.0 ppm) which was used as the inner reference. Otherwise the solvents residual proton resonance and carbon resonance ($CHCl_3$, δ (^1H) 7.26 ppm, δ (^{13}C) 77.23 ppm) were used for calibration. Column chromatography: Merck or Spectrochem silica gel 60-120 under gravity. IR: spectra were recorded on Perkin Elmer Instrument at normal temperature. MS (ESI-HRMS): Mass spectra were recorded on an Agilent Accurate-Mass Q-TOF LC/MS 6520, and peaks are given in *m/z* (% of basis peak). Nitrosoarenes were prepared from the reported method.

Table S1: Optimization of reaction conditions



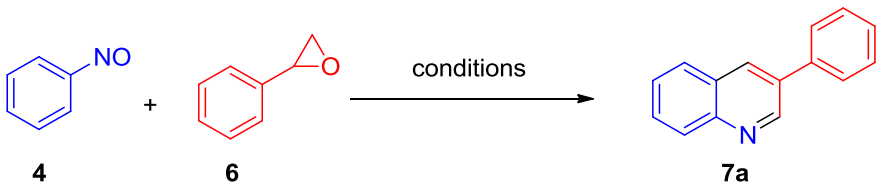
Entry	Conditions	Yield of **5b** (%)[d]	Yield of **5b'**(%)[d]
1.[a]	$Sc(OTf)_3$ (30 mol%), toluene, reflux, 24 h	36	11
2.[b]	$Sc(OTf)_3$ (30 mol%), toluene, reflux, 24 h	43	18
3.	$Sc(OTf)_3$ (30 mol%), toluene, reflux, 24 h	46	22
4.	$Sc(OTf)_3$ (30 mol%), toluene, reflux, 36 h	47	25
5.	$Sc(OTf)_3$ (15 mol%), toluene, reflux, 36 h	45	18
6.	$Sc(OTf)_3$ (15 mol%), DCE, reflux, 36 h	49	28
7.	$Sc(OTf)_3$ (15 mol%), DCM, reflux, 36 h	46	21
8.	$Yb(OTf)_3$ (15 mol%), DCE, reflux, 36 h	48	28
9.[c]	$Yb(OTf)_3$ (15 mol%), DCE, reflux, 36 h	44	25
10.	$Yb(OTf)_3$ (5 mol%), DCE, reflux, 36 h	34	15
11.	$Yb(OTf)_3$ (5 mol%), DCE, reflux, 72 h	34	12
12.	$Yb(OTf)_3$ (15 mol%), DCE, reflux, 72 h	42	22
13.	$Bi(OTf)_3$ (15 mol%), DCE, reflux, 36 h	36	19
14.	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 36 h	35	11
15.	TfOH (15 mol%), DCE, reflux, 36 h	33	21
16.	$FeCl_3$ (15 mol%), DCE, reflux, 36 h	-	-
17.	$Yb(OTf)_3$ (15 mol%), THF, reflux, 36 h	37	18
18.	$Yb(OTf)_3$ (15 mol%), EtOAc, reflux, 36 h	39	22
19.	$Yb(OTf)_3$ (15 mol%), benzene, reflux, 36 h	45	11

20.	$Yb(OTf)_3$ (15 mol%), CH_3CN, reflux, 36 h	46	19
21.	AcOH (15 mol%), DCE, reflux, 36 h	-	-
22.	p-NBA (15 mol%), DCE, reflux, 36 h	-	-

All reactions were carried out with 1 eq. (0.40 mmol) of nitrosobenzene, 2.2 eq. of 4-methyl styrene and solvent (3 mL). [a]1 eq. 4-methyl styrene was used. [b]2 eq. 4-methyl styrene was used. [c]4 eq. 4-methyl styrene was used. [d]Separated yield. p-NBA - para nitrobenzoic acid.

Accordingly, nitrosobenzene **4** was reacted with styrene **2** in the presence of 30 mol% of $Sc(OTf)_3$ in refluxing toluene for 24 h. As expected, the 2,4-diarylquinoline **5b** and 4-arylquinoline **5b'** were isolated as 3:1 ratio with a 47% combined yield (SI, Table S1). The better yield of the desired products was obtained by increasing the stoichiometry of styrene and the reaction time (entry 2-4). A significant decrease in the yield was observed on lowering the catalyst loading to 15 mol% (entry 5). However, the best yield of the desired quinoline was observed when the reaction with reduced catalyst loading was carried out in refluxing DCE instead of refluxing toluene (entry 6). A similar result was obtained when $Yb(OTf)_3$ was used as the catalyst. Further screening of reaction conditions was carried out using $Yb(OTf)_3$, which is cost-effective than $Sc(OTf)_3$ (entry 8-12, 17-20). Although the lower yield of the desired product was obtained in the presence of a catalytic amount of TfOH, the use of other acids like AcOH and dinitrobenzoic acid failed to provide the quinolines. Other solvents such as THF, EtOAc, CH_3CN, etc. were also found to be suitable for this reaction.

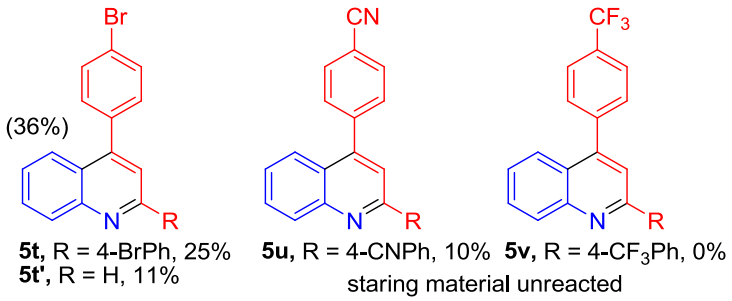
Table S2. Screening of reaction conditions.



4 **6** **7a**

entry	conditions	Yield (%)[c]
1[a]	$Cu(OTf)_2$ (15 mol%), toluene, reflux, 24 h	39
2	$Cu(OTf)_2$ (15 mol%), toluene, reflux, 24 h	55
3	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 24 h	62
4	$Sc(OTf)_3$ (15 mol%), DCE, reflux, 24 h	64
5	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 36 h	61
6	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 72 h	56
7	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 12 h	51
8[b]	$Cu(OTf)_2$ (15 mol%), DCE, reflux, 24 h	61
9	$Yb(OTf)_3$ (15 mol%), DCE, reflux, 24 h	53
10	$CuBr_2$ (15 mol%), DCE, reflux, 24 h	-
11	$Cu(OTf)_2$ (15 mol%), benzene, reflux, 24 h	42
12	$Cu(OTf)_2$ (15 mol%), THF, reflux, 24 h	37

All reactions were carried out 0.33 mmol (1 eq.) of nitrosobenzene, 2 eq. of styrene epoxide and solvent (3 mL). [a]1 eq. epoxide was used. [b]2.5 eq. epoxide was used. [c]Separated yield.

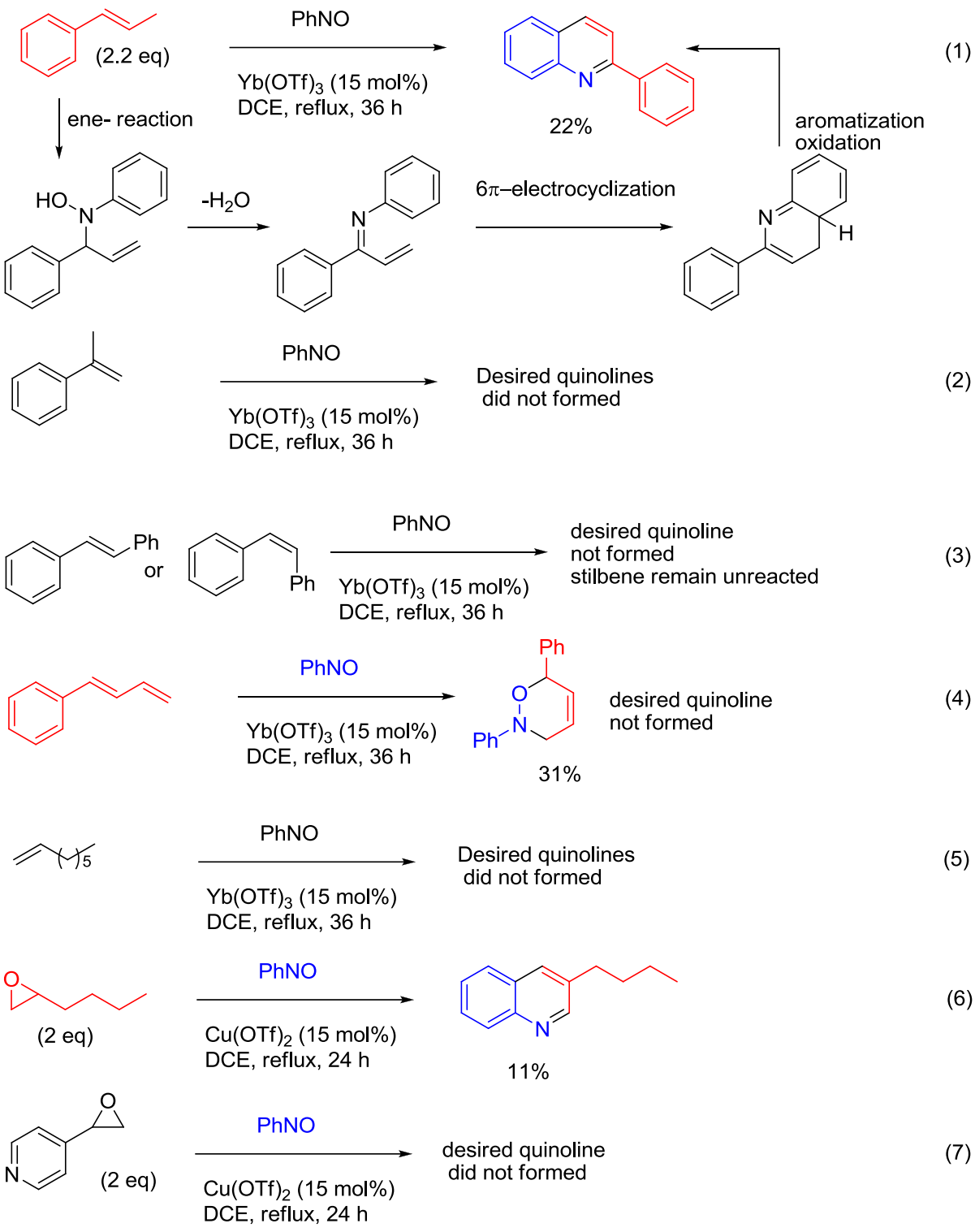


5t, R = 4-BrPh, 25%
5t', R = H, 11%

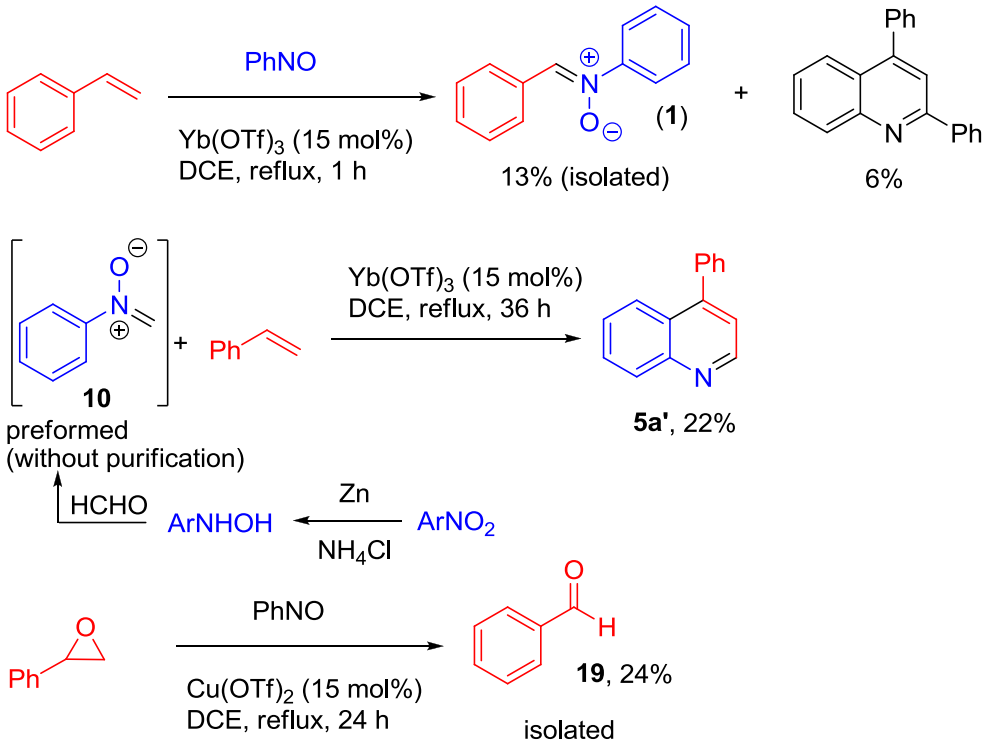
5u, R = 4-CNPh, 10%

5v, R = 4-CF_3Ph, 0%
staring material unreacted

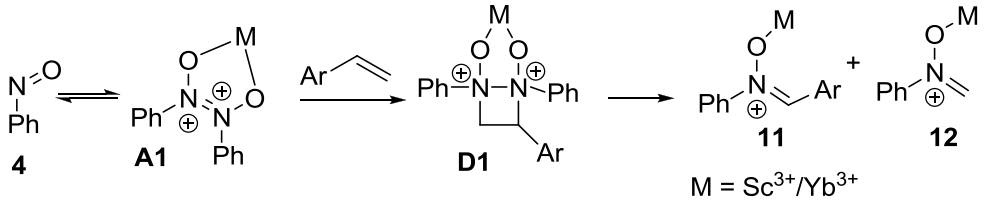
Scheme S1: Additional substrates



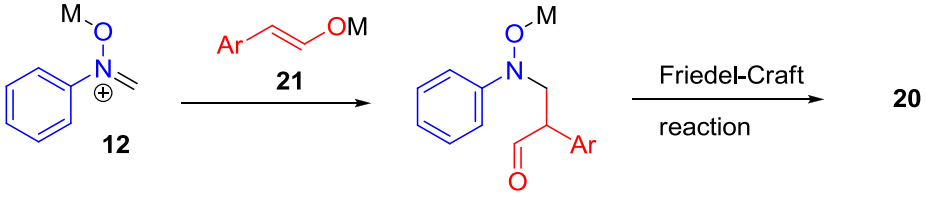
Scheme S2: Attempted reactions with various additional alkenes and epoxide.



Scheme S3: Additional controlled experiments.



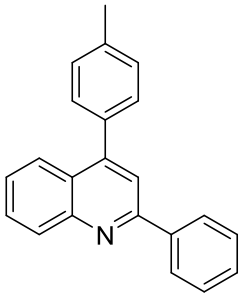
Scheme S4: Proposed mechanism for the formation of nitrone from nitrosoarene and styrene



Scheme S5: Probable stepwise pathway to form intermediate **20**.

Procedure for the Synthesis of 2-phenyl-4-(p-tolyl)quinoline (3) :

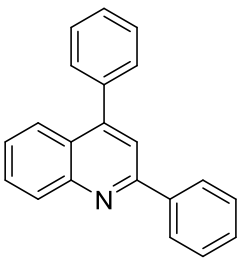
2-phenyl-4-(p-tolyl)quinoline (3):[a] Freshly prepared (*Z*)-N,1-diphenylmethanimine oxide (79 mg, 0.40 mmol) and $Sc(OTf)_3$ (29 mg, 0.06 mmol) were successively added to a solution of 4-methyl styrene (57 mg, 0.48 mmol) in dry DCE (3 mL). Then the reaction mixture was refluxed for 36 h under argon atmosphere. Then the solvent was evaporated under reduced pressure. The reaction mixture was diluted with water (1X20 mL) and the reaction mixture was extracted with DCM (3X20 mL). The organic layer was washed with brine solution (1X30 mL) and evaporated under vaccum. The crude mixture was subjected to column chromatography (silica gel; EtOAc : hexane, 1:30) gave **3** as yellow gum (0.10 g, 87%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.28 (d, *J* = 8.4 Hz, 1H), 8.20 (d, *J* = 7.2 Hz, 2H), 7.95 (d, *J* = 7.6 Hz, 1H), 7.82 (s, 1H), 7.76 - 7.72 (m, 1H), 7.56 - 7.52 (m, 2H), 7.49 - 7.47 (m, 4H), 7.37 (d, *J* = 8.0 Hz, 2H), 2.49 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{22}H_{18}N$ ($[M+H]^+$): 296.1434, Found: 296.1432.



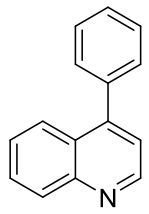
General Procedure for the Synthesis of mono and di substituted quinolines (I):

Freshly prepared nitrosoarenes (1 equiv.) and $Yb(OTf)_3$ (15 mol%) were successively added to a solution of styrene derivatives (2.2 equiv.) in dry DCE (3 mL). Then the reaction mixture was refluxed for 36 h under argon atmosphere. The reactions were carried out under an argon environment; however, without strictly maintaining the oxygen-free conditions. Then the solvent was evaporated under reduced pressure. The reaction mixture was diluted with water (1x20 mL) and the reaction mixture was extracted with DCM (3X20 mL). The organic layer was washed with brine solution (1X30 mL) and evaporated under vaccum. The crude mixture was subjected to column chromatography (silica gel) to afford analytically pure products.

2,4-diphenylquinoline (5a)[b] **and 4-phenylquinoline (5a')**[i]**:** According to GP I, nitrosobenzene (43 mg, 0.40 mmol), styrene (92 mg, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5a** as yellow gum (48 mg, 43%) and (silica gel; EtOAc : hexane, 1:7) gave **5a'** as yellow gum (21 mg, 25%). Analytical data for **5a:** ^{1}H NMR (400 MHz, $CDCl_3$) δ =

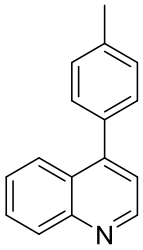


8.33 (d, *J* = 8.4 Hz, 1H), 8.23 - 8.18 (m, 2H), 7.92 (d, *J* = 8.4 Hz, 1H), 7.83 (s, 1H), 7.78 - 7.74 (m, 1H), 7.58 - 7.46 (m, 9H) ppm. HRMS: Exact mass calculated for $C_{21}H_{16}N$ ($[M+H]^+$): 282.1277, Found: 282.1285.



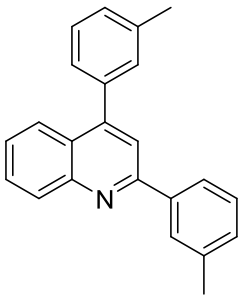
Analytical data for **5a':** ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.96 (d, *J* = 3.6 Hz, 1H), 8.32 (d, *J* = 8.4 Hz, 1H), 7.97 (d, *J* = 8.4 Hz, 1H), 7.82 - 7.78 (m, 1H), 7.59 - 7.52 (m, 6H), 7.43 (d, *J* = 4.4 Hz, 1H) ppm. HRMS: Exact mass calculated for $C_{15}H_{12}N$ ($[M+H]^+$): 206.0964, Found:206.0974.

2,4-di-p-tolylquinoline (5b)[c] and 4-(p-tolyl)quinoline (5b')[j]: According to GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-methyl styrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5b** as yellow gum (59 mg, 48%) and (silica gel; EtOAc : hexane, 1:7) gave **5b'** as yellow gum (25 mg, 28%). Analytical data for **5b:** ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.27 (d, *J* = 8.0 Hz, 1H), 8.11 (d, *J* = 8.4 Hz, 2H), 7.94 - 7.92 (m, 1H), 7.80 (s, 1H), 7.75 - 7.71 (m, 1H), 7.48 - 7.45 (m, 3H), 7.38 - 7.33 (m, 4H), 2.49 (s, 3H), 2.44 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{23}H_{20}N$ ($[M+H]^+$): 310.1590, Found: 310.1604.

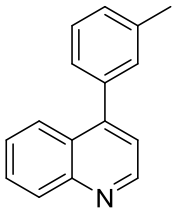


Analytical data for **5b':** ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.94 (d, *J* = 4.8 Hz, 1H), 8.31 (d, *J* = 8.4 Hz, 1H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.81 - 7.76 (m, 1H), 7.58 - 7.54 (m, 1H), 7.44 - 7.40 (m, 3H), 7.36 (d, *J* = 7.6 Hz, 2H), 2.48 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1127.

2,4-di-m-tolylquinoline (5c) and 4-(m-tolyl)quinoline (5c')[k]: According to GP I, nitrosobenzene (43 mg, 0.40 mmol), 3-methyl styrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5c** as yellow gum (40 mg, 32%) and (silica gel; EtOAc : hexane, 1:7) gave **5c'** as yellow gum (17 mg, 19%). Analytical data for **5c**: FT-IR: $\tilde{\nu}$ = 2960, 2927, 2857, 1670, 1593, 1548, 1488, 1353, 1261, 1096, 876, 766 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.26 (d, *J* = 8.8 Hz, 1H), 8.04 (s, 1H), 7.97 (d, *J* = 7.6 Hz,

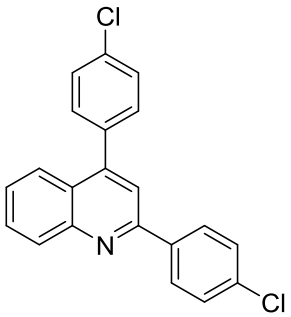


1H), 7.92 (d, *J* = 8.4 Hz, 1H), 7.81 (s, 1H), 7.76 - 7.72 (m, 1H), 7.50 - 7.42 (m, 3H), 7.40 - 7.32 (m, 3H), 7.29 (d, *J* = 7.6 Hz, 1H), 2.48 (s, 6H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 157.3, 149.5, 149.0, 139.8, 138.7, 138.6, 138.5, 130.4, 130.3, 130.2, 129.7, 129.3, 128.9, 128.7, 128.5, 126.9, 126.4, 126.0, 125.9, 124.9, 119.7, 21.82, 21.75 ppm. HRMS: Exact mass calculated for $C_{23}H_{20}N$ ($[M+H]^+$): 310.1590, Found: 310.1590.

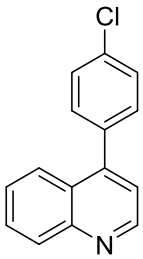


Analytical data for **5c'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.96 (d, *J* = 4.8 Hz, 1H), 8.41 (d, *J* = 8.4 Hz, 1H), 8.01 (d, *J* = 8.4 Hz, 1H), 7.86 - 7.81 (m, 1H), 7.63 - 7.59 (m, 1H), 7.48 - 7.44 (m, 2H), 7.37 - 7.32 (m, 3H), 2.47 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1122.

2,4-bis(4-chlorophenyl)quinoline (5d)[d] and 4-(4-chlorophenyl)quinoline (5d')[l]: According to

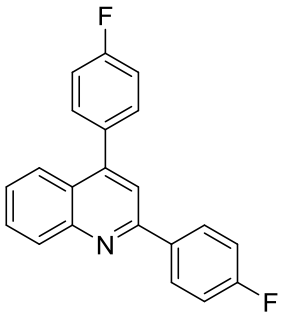


GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-chloro styrene (0.12 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5d** as yellow gum (45 mg, 32%) and (silica gel; EtOAc : hexane, 1:7) gave **5d'** as yellow gum (21mg, 22%). Analytical data for **5d**: FT-IR: $\tilde{\nu}$ = 2962, 2925, 2855, 1596, 1544, 1487, 1420, 1357, 1091, 1014, 830, 765 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (d, *J* = 8.4 Hz, 1H), 8.15 (d, *J* = 8.4 Hz, 2H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.78 - 7.74 (m, 2H), 7.55 - 7.49 (m, 7H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 155.5, 149.2, 148.0, 137.0, 136.5, 136.4, 135.2, 131.0, 130.6, 129.6, 129.4, 129.3, 129.2, 127.3, 125.8, 125.6, 119.3 ppm. HRMS: Exact mass calculated for $C_{21}H_{14}NCl_2$ ($[M+H]^+$): 350.0498, Found: 350.0497.

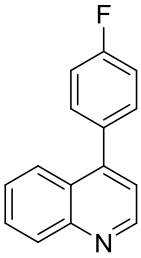


Analytical data for **5d'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.97 (d, *J* = 4.4 Hz, 1H), 8.37 (d, *J* = 8.4 Hz, 1H), 7.93 (d, *J* = 8.4 Hz, 1H), 7.85 - 7.81 (m, 1H), 7.62 - 7.58 (m, 1H), 7.56 - 7.54 (m, 2H), 7.48 - 7.46 (m, 2H), 7.43 (d, *J* = 4.4 Hz, 1H) ppm. HRMS: Exact mass calculated for $C_{15}H_{11}NCl$ ($[M+H]^+$): 240.0575, Found: 240.0576.

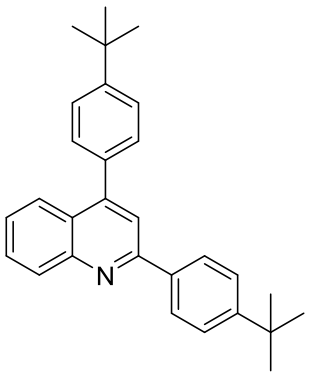
2,4-bis(4-fluorophenyl)quinoline (5e)[e] and 4-(4-fluorophenyl)quinoline (5e')[m]: According to GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-fluoro styrene (0.11 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5e** as yellow gum (47 mg, 37%) and (silica gel; EtOAc : hexane, 1:7) gave **5e'** as yellow gum (22 mg, 24%). Analytical data for **5e**: ^{1}H NMR (600 MHz, $CDCl_3$) δ = 8.27 - 8.23 (m, 1H), 8.21 - 8.16 (m, 2H), 7.87 - 7.83 (m, 1H), 7.77 - 7.75 (m, 2H), 7.55 - 7.49 (m, 3H), 7.27 - 7.20 (m, 4H) ppm. HRMS: Exact mass calculated for $C_{21}H_{14}NF_2$ ($[M+H]^+$): 318.1089, Found: 318.1090.

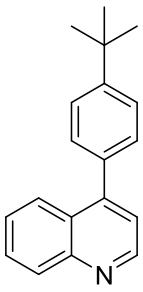


Analytical data for **5e'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.96 (d, *J* = 4.8 Hz, 1H), 8.34 (d, *J* = 8.4 Hz, 1H), 7.93 (d, *J* = 8.4 Hz, 1H), 7.83 - 7.79 (m, 1H), 7.61 - 7.57 (m, 1H), 7.53 - 7.49 (m, 2H), 7.41 (d, *J* = 4.4 Hz, 1H), 7.28 - 7.27 (m, 1H), 7.26 - 7.24 (m, 1H) ppm. HRMS: Exact mass calculated for $C_{15}H_{11}NF$ ($[M+H]^+$): 224.0870, Found:224.0871.



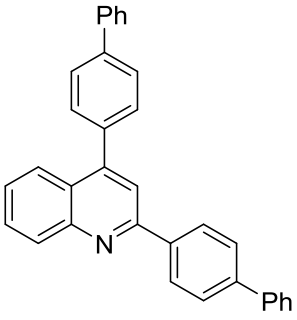
2,4-bis(4-(*tert*-butyl)phenyl)quinoline (5f) and 4-(4-(tert-butyl)phenyl)quinoline (5f'): According to GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-*tert* butyl styrene (0.14 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:40) gave **5f** as yellow gum (38 mg, 24%) and (silica gel; EtOAc : hexane, 1:10) gave **5f'** as yellow gum (22 mg, 21%). Analytical data for **5f**: FT-IR: $\tilde{\nu}$ = 2961, 2930, 2867, 1660, 1591, 1497, 1363, 1268, 1018, 838, 765, 701 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (d, *J* = 8.4 Hz, 1H), 8.13 (d, *J* = 8.4 Hz, 2H), 7.97 (d, *J* = 8.4 Hz, 1H), 7.83 (s, 1H), 7.74 - 7.70 (m, 1H), 7.59 - 7.57 (m, 3H), 7.55 - 7.51 (m, 3H), 7.48 - 7.45 (m, 1H), 1.44 (s, 9H), 1.39 (s, 9H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 157.2, 152.7, 151.7, 149.2, 149.1, 137.2, 135.8, 130.3, 129.5, 127.5, 126.2, 126.04, 125.99, 125.7, 119.5, 34.98, 34.96, 31.6, 31.5 ppm. Total count of 13C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{29}H_{32}N$ ($[M+H]^+$): 394.2529, Found: 394.2533.





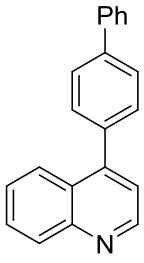
Analytical data for **5f'**: FT-IR: $\tilde{\nu}$ = 2960, 2930, 2866, 1611, 1585, 1501, 1462, 1389, 1201, 1056, 873, 747 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.93 (d, *J* = 4.4 Hz, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 8.00 (d, *J* = 8.4 Hz, 1H), 7.74 - 7.70 (m, 1H), 7.56 - 7.54 (m, 2H), 7.52 - 7.48 (m, 1H), 7.47 - 7.45 (m, 2H), 7.34 (d, *J* = 4.4 Hz, 1H), 1.41 (s, 9H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.8, 150.2, 149.0, 148.8, 135.3, 130.0, 129.51, 129.45, 127.1, 126.7, 126.3, 125.7, 121.5, 35.0, 31.6 ppm. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found: 262.1595.

2,4-di([1,1'-biphenyl]-4-yl)quinoline (5g) and 4-([1,1'-biphenyl]-4-yl)quinoline (5g'):



According to GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-vinyl biphenyl (0.16 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5g** as yellow gum (58 mg, 33%) and (silica gel; EtOAc : hexane, 1:10) gave **5g'** as yellow gum (24 mg, 21%). Analytical data for **5g**: FT-IR: $\tilde{\nu}$ = 2927, 2860, 1628, 1600, 1449, 1299, 1076, 907, 844, 734 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.32 - 8.29 (m, 3H), 8.02 - 8.00 (m, 1H), 7.92 (s, 1H), 7.81 - 7.75 (m, 5H), 7.73 - 7.67 (m, 6H), 7.54 - 7.47 (m, 5H), 7.44 - 7.37 (m, 2H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 156.7, 149.1, 149.0, 142.3, 141.6, 140.8, 140.7, 138.7, 137.5, 130.4, 130.3, 129.9, 129.2, 129.1, 128.2, 127.9, 127.81, 127.79, 127.6, 127.41, 127.37, 126.6, 126.0, 125.9, 119.5 ppm. HRMS: Exact mass calculated for $C_{33}H_{24}N$ ($[M+H]^+$): 434.1903, Found: 434.1910.

Analytical data for **5g'**: FT-IR: $\tilde{\nu}$ = 2957, 2920, 2847, 1633, 1596, 1486, 1388, 1261, 1007, 839, 766 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.97 (d, *J* = 4.8 Hz, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 8.03 (d, *J* = 9.2 Hz, 1H), 7.79 - 7.75 (m, 3H), 7.71 - 7.69 (m, 2H), 7.62 - 7.60 (m, 2H), 7.58 - 7.54 (m, 1H), 7.52 - 7.49 (m, 2H), 7.43 - 7.39 (m, 2H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 149.7, 149.0, 148.3, 141.8, 140.6, 136.9, 130.2, 129.9, 129.7, 129.2, 128.0, 127.6, 127.4, 127.1, 127.0, 126.2, 121.5 ppm. HRMS: Exact mass calculated for $C_{21}H_{16}N$ ($[M+H]^+$): 282.1277, Found: 282.1270.



6-methyl-2,4-diphenylquinoline (5h)[b] and 6-methyl-4-phenylquinoline (5h')[n]: According to GP I, 1-methyl-4-nitrosobenzene (48 mg, 0.40 mmol), styrene (92 mg, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) was reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5h** as yellow gum (34 mg, 29%) and (silica gel; EtOAc : hexane, 1:7) gave **5h'** as yellow gum (17 mg, 19%). Analytical data for **5h'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.21 - 8.17 (m, 3H), 7.78 (s, 1H), 7.66 (s, 1H), 7.60 - 7.51 (m, 8H), 7.48 - 7.44 (m, 1H), 2.48 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{22}H_{18}N$ ($[M+H]^+$): 296.1434, Found:296.1438.

Analytical data for **5h'**: ^{1}H NMR (600 MHz, $CDCl_3$) δ = 8.88 (d, *J* = 4.2 Hz, 1H), 8.22 (d, *J* = 9.0 Hz, 1H), 7.70 (s, 1H), 7.63 - 7.62 (m, 1H), 7.57 - 7.51 (m, 5H), 7.38 (d, *J* = 4.2 Hz, 1H), 2.49 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1123.

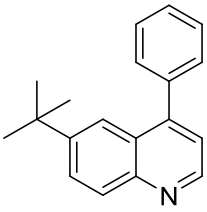
6-ethyl-2,4-diphenylquinoline (5i)[f] and 6-ethyl-4-phenylquinoline (5i')[o]: According to GP I, 1-ethyl-4-nitrosobenzene (54 mg, 0.40 mmol), styrene (92 mg, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5i** as yellow gum (44 mg, 36%) and (silica gel; EtOAc : hexane, 1:7) gave **5i'** as yellow gum (19 mg, 20%). Analytical data for **5i**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (d, *J* = 8.4 Hz, 1H), 8.19 (d, *J* = 7.2 Hz, 2H), 7.79 (s, 1H), 7.68 (s, 1H), 7.64 - 7.62 (m, 1H), 7.58 - 7.51 (m, 7H), 7.48 - 7.45 (m, 1H), 2.78 (q, *J* = 7.6 Hz, 2H), 1.27 (t, *J* = 7.6 Hz, 3H) ppm. HRMS: Exact mass calculated for $C_{23}H_{20}N$ ($[M+H]^+$): 310.1590, Found: 310.1591.

Analytical data for **5i'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.88 (d, *J* = 4.4 Hz, 1H), 8.21 (d, *J* = 8.8 Hz, 1H), 7.71 (s, 1H), 7.66 - 7.64 (m, 1H), 7.56 -7.51 (m, 5H), 7.36 (d, *J* = 4.8 Hz, 1H), 2.78 (q, *J* = 7.6 Hz, 2H), 1.26 (t, *J* = 7.6 Hz, 3H) ppm. HRMS: Exact mass calculated for $C_{17}H_{16}N$ ($[M+H]^+$): 234.1277, Found: 234.1285.

6-isopropyl-2,4-diphenylquinoline (5j) and 6-isopropyl-4-phenylquinoline (5j')[p]: According to GP I, 1-isopropyl-4-nitrosobenzene (60 mg, 0.40 mmol), styrene (92 mg, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5j** as yellow gum (48 mg, 37%) and (silica gel; EtOAc : hexane, 1:7) gave **5j'** as yellow gum (20 mg, 20%). Analytical data for **5j**: FT-IR: $\tilde{\nu}$ = 2960, 2930, 2867, 1623, 1589, 1491, 1027, 835, 693 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$) δ = 8.20 - 8.16 (m, 3H), 7.78 (s, 1H), 7.70 (s, 1H), 7.67 - 7.66 (m, 1H), 7.59 - 7.56 (m, 4H), 7.54 - 7.51 (m, 3H), 7.47 - 7.45 (m, 1H), 3.06 - 3.01 (m, 1H), 1.29 (d, *J* = 7.2 Hz, 6H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 156.4, 148.9, 147.9, 147.2, 140.0, 138.8, 130.3, 129.8, 129.3, 129.2, 129.0, 128.8, 128.5, 127.7, 125.8, 122.1, 119.7, 34.6, 24.1 ppm. HRMS: Exact mass calculated for $C_{24}H_{22}N$ ($[M+H]^+$): 324.1747, Found: 324.1749.

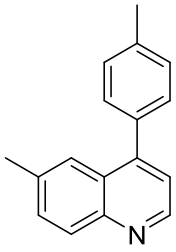
Analytical data for **5j'**: ^1H NMR (400 MHz, $CDCl_3$) δ = 8.88 (d, *J* = 4.8 Hz, 1H), 8.22 (d, *J* = 8.8 Hz, 1H), 7.74 (s, 1H), 7.71 – 7.68 (m, 1H), 7.56 – 7.52 (m, 5H), 7.36 (d, *J* = 4.4 Hz, 1H), 3.07 – 3.05 (m, 1H), 1.28 (d, *J* = 6.8 Hz, 6H) ppm. HRMS: Exact mass calculated for $C_{18}H_{18}N$ ($[M+H]^+$): 248.1434, Found: 248.1432.

6-(*tert*-butyl)-2,4-diphenylquinoline (5k)[g] and 6-(*tert*butyl)-4-phenylquinoline (5k')[p]: According to GP I, 1-*tert* butyl-4-nitrosobenzene (65 mg, 0.40 mmol), styrene (92 mg, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5k** as yellow gum (55 mg, 41%) and (silica gel; EtOAc : hexane, 1:7) gave **5k'** as yellow gum (19 mg, 18%). Analytical data for **5k**: ^1H NMR (400 MHz, $CDCl_3$) δ = 8.21 (d, *J* = 8.8 Hz, 1H), 8.19 - 8.17 (m, 2H), 7.87 - 7.83 (m, 2H), 7.79 (s, 1H), 7.60 - 7.51 (m, 7H), 7.48 - 7.44 (m, 1H), 1.35 (s, 9H) ppm. HRMS: Exact mass calculated for $C_{25}H_{24}N$ ($[M+H]^+$): 338.1903, Found: 338.1921.



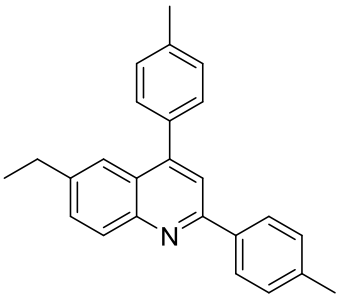
Analytical data for **5k'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.89 (d, *J* = 4.8 Hz, 1H), 8.25 (d, *J* = 8.8 Hz, 1H), 7.92 - 7.87 (m, 2H), 7.56 - 7.53 (m, 5H), 7.39 (d, *J* = 4.8 Hz, 1H), 1.34 (s, 9H) ppm. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found: 262.1594.

6-methyl-2,4-di-p-tolylquinoline (5l)^{h} and 6-methyl-4-(p-tolyl)quinoline (5l')^{n}: According to GP I, 1-methyl-4-nitrosobenzene (48 mg, 0.4 mmol), 4-methylstyrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) was reacted for 36 h in dry DCE (3 mL) and column chromatography (silica gel; EtOAc : hexane, 1:30) gave **5l** as yellow gum (58 mg, 45%) and (silica gel; EtOAc : hexane, 1:7) gave **5l'** as yellow gum (22 mg, 24%). Analytical data for **5l**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.18 (d, *J* = 8.4 Hz, 1H), 8.08 (d, *J* = 8.0 Hz, 2H), 7.75 (s, 1H), 7.67 (s, 1H), 7.58 - 7.55 (m, 1H), 7.47 - 7.45 (m, 2H), 7.38 - 7.36 (m, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 2.49 (s, 3H), 2.48 (s, 3H), 2.43 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{24}H_{22}N$ ($[M+H]^+$): 324.1747, Found: 324.1757.



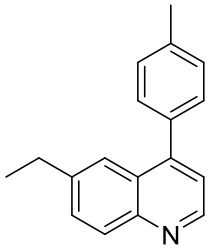
Analytical data for **5l'**: ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.85 (d, *J* = 4.4 Hz, 1H), 8.12 (d, *J* = 8.4 Hz, 1H), 7.71 (s, 1H), 7.59 - 7.56 (m, 1H), 7.42 - 7.40 (m, 2H), 7.36 - 7.34 (m, 2H), 7.31 (d, *J* = 4.8 Hz, 1H), 2.48 (s, 6H) ppm. HRMS: Exact mass calculated for $C_{17}H_{16}N$ ($[M+H]^+$): 234.1277, Found: 234.1287.

6-ethyl-2,4-di-p-tolylquinoline (5m) and 6-ethyl-4-(p-tolyl)quinoline (5m'): According to GP I, 1-ethyl-4-nitrosobenzene (54 mg, 0.4 mmol), 4-methylstyrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5m** as yellow gum (62 mg, 46%) and (silica gel; EtOAc : hexane, 1:7) gave **5m'** as yellow gum (26 mg, 26%). Analytical data for **5m**: FT-IR: $\tilde{\nu}$ = 2963, 2922, 2870, 1613, 1588, 1494, 1358, 1211, 1183, 1090, 890, 725 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.21 (d, *J* = 8.8 Hz, 1H), 8.09 (d, *J* = 8.0 Hz, 2H), 7.75 (s, 1H), 7.70 (d, *J* = 1.2 Hz, 1H), 7.62 - 7.59 (m, 1H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.37 (d, *J* = 7.6 Hz, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 2.77 (q, *J* = 7.6 Hz, 2H), 2.50 (s, 3H), 2.43 (s, 3H), 1.27 (t, *J* = 7.6 Hz, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.0, 149.5, 147.0, 142.8, 139.8, 138.6, 136.3, 135.7, 131.1, 129.8, 129.7,

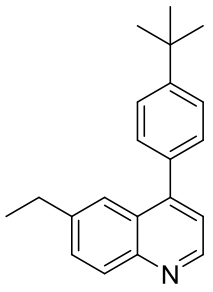


129.5, 129.4, 127.8, 126.0, 123.5, 119.6, 29.3, 21.56, 21.54, 15.8 ppm. HRMS: Exact mass calculated for $C_{25}H_{24}N$ ($[M+H]^+$): 338.1903, Found:338.1903.

Analytical data for **5m':** FT-IR: $\tilde{\nu}$ = 2964, 2927, 2872, 1615, 1584, 1454, 1372, 1260, 1184, 1021, 817, 723 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$) δ = 8.86 (d, *J* = 4.8 Hz, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.75 (s, 1H), 7.64 (d, *J* = 8.4 Hz, 1H), 7.42 (d, *J* = 7.8 Hz, 2H), 7.37 - 7.34 (m, 3H), 2.78 (q, *J* = 7.8 Hz, 2H), 2.48 (s, 3H), 1.26 (t, *J* = 7.8 Hz, 3H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 149.2, 148.4, 146.7, 143.3, 138.7, 135.2, 131.1, 129.63, 129.55, 129.1, 127.1, 123.8, 121.5, 29.4, 21.5, 15.8 ppm. HRMS: Exact mass calculated for $C_{18}H_{18}N$ ($[M+H]^+$): 248.1434, Found: 248.1434.



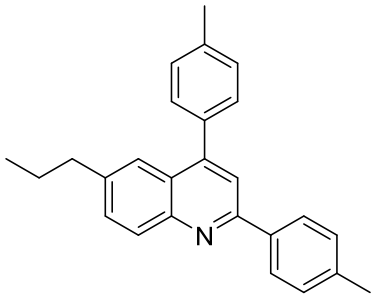
2,4-bis(4-(*tert*-butyl)phenyl)-6-ethylquinoline (5n) and 4-(4-(*tert*-butyl)phenyl)-6-ethylquinoline (5n'): According to GP I, 1-ethyl-4-nitrosobenzene (54 mg, 0.4 mmol), 4-*tert*-butylstyrene (0.14 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:40) gave **5n** as yellow gum (57 mg, 34%) and (silica gel; EtOAc : hexane, 1:10) gave **5n'** as yellow gum (24 mg, 21%). Analytical data for **5n**: FT-IR: $\tilde{\nu}$ = 2962, 2904, 2868, 1589, 1460, 1394, 1261, 1186, 1081, 965, 892, 799 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.16 (d, *J* = 8.8 Hz, 1H), 8.10 (d, *J* = 8.4 Hz, 2H), 7.77 (s, 1H), 7.74 (s, 1H), 7.61 - 7.57 (m, 3H), 7.55 - 7.51 (m, 4H), 2.78 (q, *J* = 7.6 Hz, 2H), 1.44 (s, 9H), 1.38 (s, 9H), 1.28 (t, *J* = 7.6 Hz, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.4, 152.5, 151.6, 148.6, 147.9, 142.4, 137.4, 136.0, 130.6, 130.2, 129.5, 127.4, 126.0, 125.9, 125.7, 123.6, 119.6, 35.0, 34.9, 31.6, 31.5, 29.4, 15.9 ppm. HRMS: Exact mass calculated for $C_{31}H_{36}N$ ($[M+H]^+$): 422.2822, Found:422.2851.



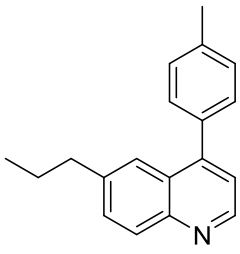
Analytical data for **5n'**: FT-IR: $\tilde{\nu}$ = 2962, 2929, 2868, 1611, 1582, 1501, 1455, 1363, 1260, 1102, 1018, 891, 736 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.86 (d, *J* = 4.4 Hz, 1H), 8.09 (d, *J* = 8.8 Hz, 1H), 7.76 (s, 1H), 7.61 - 7.59 (m, 1H), 7.57 - 7.55 (m, 2H), 7.48 - 7.46 (m, 2H), 7.29 (d, *J* = 4.4 Hz, 1H), 2.78 (q, *J* = 7.6 Hz, 2H), 1.42 (s, 9H), 1.27 (t, *J* = 7.6 Hz, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.6, 149.3, 148.2, 147.7, 142.9, 135.5, 130.6, 129.8, 129.5, 127.0,

125.7, 123.8, 121.7, 35.0, 31.6, 29.4, 15.9 ppm. HRMS: Exact mass calculated for $C_{21}H_{24}N$ ($[M+H]^+$): 290.1903, Found: 290.1900.

6-propyl-2,4-di-p-tolylquinoline (5o) and 6-propyl-4-(p-tolyl)quinoline (5o'): According to



GP I, 1-propyl-4-nitrosobenzene (60 mg, 0.4 mmol), 4-methylstyrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5o** as yellow gum (55 mg, 39%) and (silica gel; EtOAc : hexane, 1:10) gave **5o'** as yellow gum (20 mg, 19%). Analytical data for **5o**: FT-IR: $\tilde{\nu}$ = 2960, 2925, 2870, 1618, 1590, 1496, 1361, 1261, 1018, 820, 669 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.15 (d, *J* = 8.8 Hz, 1H), 8.08 (d, *J* = 8.4 Hz, 2H), 7.75 (s, 1H), 7.68 (d, *J* = 1.6 Hz, 1H), 7.59 - 7.56 (m, 1H), 7.47 (d, *J* = 8.0 Hz, 2H), 7.37 (d, *J* = 7.6 Hz, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 2.71(t, *J* = 7.6 Hz, 2H), 2.50 (s, 3H), 2.43 (s, 3H), 1.73 - 1.64 (m, 2H), 0.95 (t, *J* = 7.6 Hz, 3H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 156.3, 148.7, 147.8, 140.9, 139.3, 138.4, 137.3, 136.0, 131.1, 129.9, 129.73, 129.68, 129.5, 127.6, 125.9, 124.2, 119.5, 38.4, 24.8, 21.6, 14.1 ppm. Total count of 13C is less than expected due to the merging of signals in the aliphatic region. HRMS: Exact mass calculated for $C_{26}H_{26}N$ ($[M+H]^+$): 352.2060, Found:352.2056.



Analytical data for **5o':** FT-IR: $\tilde{\nu}$ = 2958, 2923, 2854, 1615, 1585, 1501, 1456, 1260, 1184, 1089, 858, 724 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$) δ = 8.86 (d, *J* = 4.8 Hz, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 7.74 (s, 1H), 7.64 (d, *J* = 8.4 Hz, 1H), 7.43 (d, *J* = 7.8 Hz, 2H), 7.38 - 7.37 (m, 3H), 2.72(t, *J* = 7.2 Hz, 2H), 2.49 (s, 3H), 1.70 -1.64 (m, 2H), 0.94 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 150.1, 147.6, 145.7, 142.2, 139.0, 135.0, 132.0, 129.6, 128.3, 127.1, 124.6, 121.5, 38.4, 24.7, 21.6, 14.0 ppm. Total count of 13C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found:262.1596.

6-isopropyl-2,4-di-p-tolylquinoline (5p) and 6-isopropyl-4-(p-tolyl)quinoline (5p'): According to GP I, 1-isopropyl-4-nitrosobenzene (60 mg, 0.4 mmol), 4-methylstyrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5p** as yellow gum (59 mg, 42%) and (silica gel; EtOAc : hexane, 1:7) gave **5p'** as yellow gum (30 mg, 29%). Analytical data for **5p**: FT-IR: $\tilde{\nu}$ = 2960, 2922, 2867, 1613, 1593, 1548, 1456, 1358, 1266, 821, 751 cm^{-1}. ^1H NMR (600 MHz, $CDCl_3$) δ = 8.17 (d, *J* = 8.4 Hz, 1H), 8.08 (d, *J* = 7.8 Hz, 2H), 7.76 (s, 1H), 7.73 (s, 1H), 7.66 - 7.64 (m, 1H), 7.49 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 7.8 Hz, 2H), 7.33 (d, *J* = 7.8 Hz, 2H), 3.06 - 3.01 (m, 1H), 2.50 (s, 3H), 2.44 (s, 3H), 1.29 (d, *J* = 7.2 Hz, 6H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 156.3, 148.8, 147.9, 146.9, 139.3, 138.4, 137.3, 136.0, 130.1, 129.72, 129.67, 129.5, 129.1, 127.6, 125.8, 122.2, 119.5, 34.6, 24.1, 21.6 ppm. Total count of 13C is less than expected due to the merging of signals in the aliphatic region. HRMS: Exact mass calculated for $C_{26}H_{26}N$ ($[M+H]^+$): 352.2060, Found: 352.2072.

Analytical data for **5p'**: FT-IR: $\tilde{\nu}$ = 2960, 2925, 2867, 1618, 1584, 1501, 1457, 1385, 1185, 1043, 859, 818, 684 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.86 (d, *J* = 4.4 Hz, 1H), 8.18 (d, *J* = 8.8 Hz, 1H), 7.77 (d, *J* = 1.6 Hz, 1H), 7.69 - 7.66 (m, 1H), 7.44 - 7.42 (m, 2H), 7.37 - 7.32 (m, 3H), 3.07 – 3.00 (m, 1H), 2.48 (s, 3H), 1.28 (d, *J* = 6.8 Hz, 6H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 149.4, 148.4, 147.8, 146.7, 138.8, 135.2, 129.7, 129.6, 129.1, 127.1, 122.5, 121.5, 34.6, 24.1, 21.6 ppm. Total count of 13C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found: 262.1591.

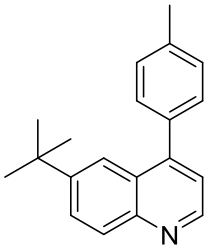
2,4-bis(4-(*tert*-butyl)phenyl)-6-isopropylquinoline (5q) and 4-(4-(*tert*-butyl)phenyl)-6-isopropylquinoline (5q'): According to GP I, 1-isopropyl-4-nitrosobenzene (60 mg, 0.4 mmol), 4-*tert*-butylstyrene (0.14 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:40) gave **5q** as yellow gum (81 mg, 47%) and (silica gel; EtOAc : hexane, 1:10) gave **5q'** as yellow gum (21mg, 17%). Analytical data for **5q**: FT-IR: $\tilde{\nu}$ = 2962, 2902, 2867, 1610, 1590, 1463, 1368, 1273, 1113, 1016, 838, 750, 604 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.17 (d, *J* = 8.4 Hz, 1H), 8.09 (d, *J* = 8.4 Hz, 2H), 7.77 - 7.76 (m, 2H), 7.66 - 7.63 (m, 1H), 7.60 - 7.58 (m, 2H), 7.55 - 7.52 (m, 4H), 3.09 - 3.02 (m, 1H), 1.44 (s, 9H), 1.38 (s, 9H), 1.30 (d, *J* = 7.2 Hz, 6H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.4, 152.5, 151.6, 148.7, 148.1, 146.9, 137.4, 136.0, 130.3, 129.5, 128.9, 127.4, 126.0, 125.7, 125.9, 122.3, 119.7, 35.0, 34.9, 34.6, 31.6, 31.5, 24.2 ppm. HRMS: Exact mass calculated for $C_{32}H_{38}N$ ($[M+H]^+$): 436.2999, Found: 436.2992.

Analytical data for **5q'**: FT-IR: $\tilde{\nu}$ = 2961, 2905, 2870, 1613, 1583, 1501, 1460, 1363, 1267, 1106, 1021, 838, 750 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.86 (d, *J* = 4.4 Hz, 1H), 8.11 (d, *J* = 8.8 Hz, 1H), 7.79 (d, *J* = 2.0 Hz, 1H), 7.66 - 7.63 (m, 1H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.48 - 7.46 (m, 2H), 7.29 (d, *J* = 4.4 Hz, 1H), 3.08 - 3.01 (m, 1H), 1.43 (s, 9H), 1.29 (d, *J* = 7.2 Hz, 6H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.7, 149.4, 148.2, 147.9, 147.4, 135.5, 130.0, 129.5, 128.9, 127.0, 125.7, 122.5, 121.7, 35.0, 34.6, 31.6, 24.2 ppm. HRMS: Exact mass calculated for $C_{22}H_{26}N$ ($[M+H]^+$): 304.2060, Found: 304.2064.

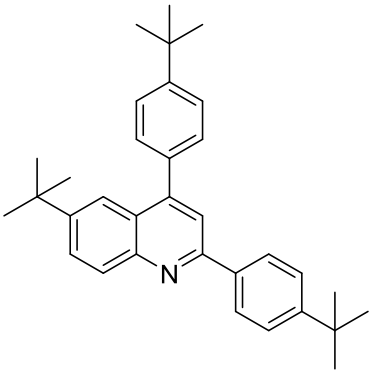
6-*tert*-butyl-2,4-di-p-tolylquinoline (5r) and 6-*tert*-butyl-4-(p-tolyl)quinoline (5r'): According to GP I, 1-*tert*-butyl-4-nitrosobenzene (65 mg, 0.4 mmol), 4-methylstyrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **5r** as yellow gum (65 mg, 45%) and (silica gel; EtOAc : hexane, 1:7) gave **5r'** as yellow gum (24 mg, 22%). Analytical data for **5r**: FT-IR: $\tilde{\nu}$ =

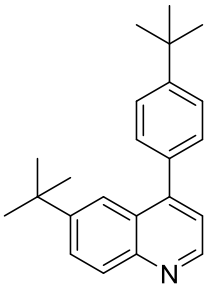
2962, 2927, 2867, 1615, 1590, 1544, 1462, 1389, 1260, 1114, 1020, 820, 746 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.23 (d, *J* = 8.8 Hz, 1H), 8.09 (d, *J* = 8.4 Hz, 2H), 7.91 (d, *J* = 2.0 Hz, 1H), 7.85 - 7.82 (m, 1H), 7.77 (s, 1H), 7.50 (d, *J* = 8.0 Hz, 2H), 7.39 - 7.32 (m, 4H), 2.50 (s, 3H), 2.44 (s, 3H), 1.36 (s, 9H) ppm . ^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.3, 149.7, 149.3, 146.9, 139.7, 138.6, 136.6, 135.8, 129.8, 129.6, 129.5, 129.3, 128.8, 127.7, 125.5, 120.9, 119.6, 35.3, 31.4, 21.6 ppm. Total count of 13C is less than expected due to the merging of signals in the aliphatic region. HRMS: Exact mass calculated for $C_{27}H_{28}N$ ($[M+H]^+$): 366.2216, Found:366.2219.

Analytical data for **5r'**: FT-IR: $\tilde{\nu}$ = 2962, 2869, 1614, 1583, 1500, 1372, 1260, 1185, 1022, 859, 817, 724 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.87 (s, 1H), 8.15 (d, *J* = 8.8 Hz, 1H), 7.93 (s, 1H), 7.85 - 7.82 (m, 1H), 7.45 - 7.43 (m, 2H), 7.36 - 7.31 (m, 3H), 2.48 (s, 3H), 1.35 (s, 9H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 149.7, 149.2, 149.0, 146.9, 138.6, 135.4, 129.7, 129.5, 129.1, 128.6, 126.6, 121.6, 121.1, 35.3, 31.4, 21.5 ppm. HRMS: Exact mass calculated for $C_{20}H_{22}N$ ($[M+H]^+$): 276.1747, Found: 276.1751.



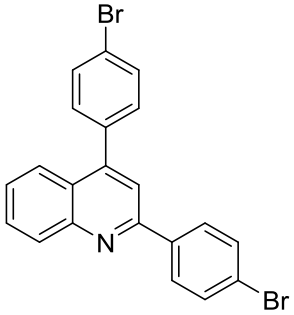
2,4-bis(4-(*tert*-butyl)phenyl)-6-*tert*-butylquinoline (5s) and 4-(4-(*tert*-butyl)phenyl)-6-*tert*-butylquinoline (5s'): According to GP I, 1-*tert*-butyl-4-nitrosobenzene (65 mg, 0.4 mmol), 4-*tert*-butylstyrene (0.14 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:40) gave **5s** as yellow gum (76 mg, 42%) and (silica gel; EtOAc : hexane, 1:10) gave **5s'** as yellow gum (20 mg, 16%). Analytical data for **5s**: FT-IR: $\tilde{\nu}$ = 2961, 2905, 2868, 1589, 1514, 1493, 1393, 1201, 1110, 1017, 894, 834, 669 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (d, *J* = 8.4 Hz, 2H), 8.11 (d, *J* = 8.4 Hz, 2H), 7.95 (d, *J* = 2.0 Hz, 2H), 7.85 - 7.82 (m, 1H), 7.79 (s, 1H), 7.61 - 7.54 (m, 6H), 1.44 (s, 9H), 1.39 (s, 9H), 1.38 (s, 9H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 156.5, 152.6, 151.6, 149.1, 147.4, 137.2, 135.9, 129.6, 129.5, 128.5, 127.5, 126.0, 125.7, 125.4, 120.8, 119.7, 35.3, 35.0, 34.9, 31.6, 31.5, 31.4 ppm. Total count of 13C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{33}H_{40}N$ ($[M+H]^+$): 450.3155, Found: 450.3172.



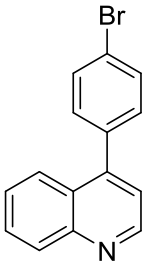


Analytical data for **5s'**: FT-IR: $\tilde{\nu}$ = 2962, 2909, 2870, 1613, 1583, 1500, 1372, 1266, 1111, 1023, 839, 771 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.87 (d, *J* = 4.4 Hz, 1H), 8.11 (d, *J* = 9.2 Hz, 1H), 7.96 (d, *J* = 2.0 Hz, 1H), 7.84 - 7.81 (m, 1H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.49 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 4.4 Hz, 1H), 1.43 (s, 9H), 1.36 (s, 9H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.7, 149.52, 149.45, 148.6, 147.4, 135.5, 129.49, 129.45, 128.4, 126.6, 125.7, 121.7, 121.1, 35.3, 35.0, 31.6, 31.4 ppm. HRMS: Exact mass calculated for $C_{23}H_{28}N$ ($[M+H]^+$): 318.2216, Found: 318.2206.

2,4-bis(4-bromophenyl)quinoline (5t) and 4-(4-bromophenyl)quinoline (5t')[q]: According to



GP I, nitrosobenzene (43 mg, 0.40 mmol), 4-bromo styrene (0.16 g, 0.88 mmol) and $Yb(OTf)_3$ (74 mg, 0.12 mmol) were reacted for 48 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:40) gave **5t** as yellow gum (43 mg, 25%) and (silica gel; EtOAc : hexane, 1:10) gave **5t'** as yellow gum (12 mg, 11%). Analytical data for **5t:** FT-IR = 2958, 2924, 2851, 1596, 1542, 1485, 1355, 1072, 825, 764, 578, 470 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.24 (d, *J* = 8.4 Hz, 1H), 8.08 (d, *J* = 8.8 Hz, 2H), 7.84 (d, *J* = 8.4 Hz, 1H), 7.78 – 7.74 (m, 2H), 7.71 – 7.65 (m, 4H), 7.51 (t, *J* = 8.0 Hz, 1H), 7.43 (d, *J* = 8.4 Hz, 2H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.7, 148.8,



148.6, 138.3, 137.2, 132.3, 132.1, 131.3, 130.2, 129.4, 127.1, 125.7, 125.5, 124.4, 123.2, 119.0 ppm. Total count of ^{13}C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{21}H_{14}Br_2N$ ([M+H]+): 437.9488, Found: 437.9484.

Analytical data for **5t':** ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.96 (s, 1H), 8.28 (d, *J* = 8.4 Hz, 1H), 7.90 (d, *J* = 7.6 Hz, 1H), 7.79 (t, *J* = 7.6 Hz, 1H), 7.69 (d, *J* = 8.4 Hz, 2H), 7.58 – 7.54 (m, 1H), 7.41 – 7.38 (m, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 149.0, 148.8, 136.7, 132.2, 131.3, 130.4, 129.2, 127.6, 125.9, 123.5, 121.4 ppm. Total count of 13C is less than expected due to the merging of signals in the aromatic region.

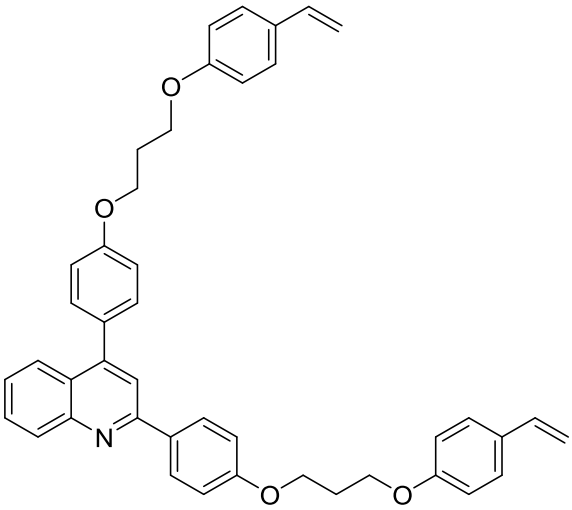
4,4'-(quinoline-2,4-diyl)dibenzonitrile (5u): According to GP II, nitrosobenzene (43 mg, 0.40 mmol), 4-cyano styrene (0.11 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 5 days in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **5u** as yellow gum (13 mg, 10%). Analytical data for **5u:** FT-IR = 2960, 2930, 2852, 2228, 1595, 1499, 1451, 1278, 1188, 1076, 844, 747, 699 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.35 – 8.32 (m, 3H), 7.89 – 7.78 (m, 7H), 7.69 (d, *J* = 8.4 Hz, 2H), 7.61 – 7.57 (m, 1H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 154.6, 148.4, 142.7, 132.9, 132.8, 131.0, 130.5, 130.4, 128.5, 128.2, 119.1, 118.8, 118.5, 113.5, 113.1 ppm. Total count of ^{13}C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{23}H_{14}N_3$ ($[M+H]^+$): 332.1182, Found: 332.1177.

4,4'-(propane-1,3-diylbis(oxy))dibenzaldehyde:[r] 4-hydroxy benzaldehyde (1.47 g, 12.05 mmol) was added to the solution of 1,3-dibromoprpoape (1.0 g, 5.00 mmol) in DMF (5 mL) followed by the addition of K_2CO_3 (2.08 g, 15.07 mmol). The reaction mixture was heated at 100 °C for 12 h. After that, the reaction mixture was cooled down to room temperature. The reaction mixture was diluted with cold water (70 mL) and extracted with DCM (3 X 50 mL). The organic layer was washed with brine solution (1 X 50 mL), dried over anhydrous Na_2SO_4 and evaporated under vaccum to provide 4,4'-(propane-1,3-diylbis(oxy))dibenzaldehyde as a light yellow solid (1.28 g, 90%) which was used for the next step. ^1H NMR (600 MHz, $CDCl_3$) δ = 9.87 (s, 2H), 7.82 (d, *J* = 8.4 Hz, 4H), 7.01 (d, *J* = 9.0 Hz, 4H), 4.25 (t, *J* = 6.0 Hz, 4H), 2.36 - 2.32 (m, 2H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 191.0, 163.9, 132.2, 130.2, 114.9, 64.7, 29.1 ppm.

1,3-bis(4-vinylphenoxy)propane (6): Methyltriphenylphosphonium iodide (2.19 g, 5.41 mmol) and sodium hydride (60% in mineral oil) (0.81 g (0.49 g), 20.29 mmol) were taken in 100 mL R.B. under argon. A solution of 4,4'-(propane-1,3-diylbis(oxy))dibenzaldehyde (1.28 g, 4.51 mmol) in dry THF (20 mL) was added slowly to the mixture at 0 °C. Then the reaction mixture was stirred at room temperature for 12 h. Then the reaction was quenched with cold water (50 mL) and the mixture was extracted with DCM (3 X 50 mL). The organic layer was washed with

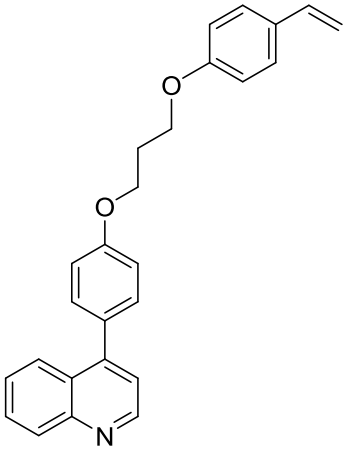
brine solution (1X50 mL), dried over anhydrous Na_2SO_4 and evaporated under vaccum. The column chromatography of the crude product (silica gel; EtOAc : hexane, 1:50) gave **6** as white solid (0.33 g, 26%). FT-IR: $\tilde{\nu}$ = 2955, 2922, 2853, 1603, 1509, 1468, 1378, 1289, 1242, 1176, 1065, 992, 903, 836 cm-1. ^{1}H NMR (600 MHz, $CDCl_3$) δ = 7.34 (d, *J* = 8.4 Hz, 4H), 6.87 (d, *J* = 9.0 Hz, 4H), 6.69 - 6.64 (m, 2H), 5.61 (d, *J* = 17.4 Hz, 2H), 5.13 (d, *J* = 10.8 Hz, 2H), 4.17 (t, *J* = 6.0 Hz, 4H), 2.29 - 2.25 (m, 2H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 158.8, 136.4, 130.7, 127.6, 114.7, 111.8, 64.6, 29.5 ppm.

2,4-bis(4-(3-(4-vinylphenoxy)propoxy)phenyl)quinoline (7a) and 4-(4-(3-(4-vinylphenoxy)propoxy)phenyl)quinoline (7b):

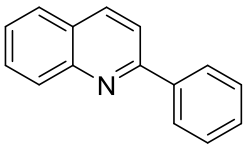


Nitrosobenzene (43 mg, 0.40 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were successively added to a solution of styrene derivative **6** (0.25 g, 0.88 mmol) in dry DCE (3 mL). Then the reaction mixture was refluxed for 36 h under argon atmosphere. Then the solvent was evaporated under reduced pressure. The reaction mixture was diluted with water (20 mL) and the mixture was extracted with DCM (3 X 20 mL). The combined organic layer was washed with brine solution (1 X 30 mL), dried over anhydrous Na_2SO_4 and evaporated under vaccum. Column chromatography of the crude product (silica gel; EtOAc : hexane, 1:10) gave **7a** as yellow gum (75 mg, 30%) and (silica gel; EtOAc : hexane, 1:4) gave **7b** as yellow gum (34 mg, 22%). Analytical data for **7a**: FT-IR: $\tilde{\nu}$ = 2958, 2923, 2879, 2848, 1606, 1544, 1509, 1498, 1401, 1288, 1175, 1059, 833 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.25 (d, *J* = 8.0 Hz, 1H), 8.16 (d, *J* = 8.8 Hz, 2H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.75 (s, 1H), 7.73 - 7.70 (m, 1H), 7.49 (d, *J* = 8.8 Hz, 2H), 7.47 - 7.43 (m, 1H), 7.37 - 7.34 (m, 4H), 7.10 - 7.05 (m, 4H), 6.91 - 6.88 (m, 4H), 6.70 - 6.62 (m, 2H), 5.64 - 5.59 (m, 2H), 5.15 - 5.11 (m, 2H), 4.29 - 4.18 (m, 8H), 2.37 - 2.28 (m, 4H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 160.6, 159.5, 158.8, 156.3, 136.41, 136.38, 131.0, 130.82, 130.78, 130.7, 130.0, 129.4, 127.6, 126.3, 126.0, 125.9, 119.2, 115.1, 114.9, 114.73, 114.72, 111.9, 111.8, 64.81, 64.80, 64.65, 64.56, 29.52, 29.50 ppm. Total count of ^{13}C is less than expected due to the merging of signals in the aromatic region. HRMS: Exact mass calculated for $C_{43}H_{40}NO_4$ ($[M+H]^+$): 634.2952, Found: 634.2945.

Analytical data for **7b:** FT-IR: $\tilde{\nu}$ = 2961, 2905, 2870, 1613, 1583, 1501, 1460, 1363, 1267, 1106, 1021, 838, 750 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ = 8.92 (d, *J* = 4.8 Hz, 1H), 8.29 (d, *J* = 8.4 Hz, 1H), 8.01 (d, *J* = 8.4 Hz, 1H), 7.80 - 7.76 (m, 1H), 7.58 - 7.54 (m, 1H), 7.46 (d, *J* = 8.4 Hz, 2H), 7.40 - 7.34 (m, 3H), 7.09 (d, *J* = 8.4 Hz, 2H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.70 - 6.63 (m, 1H), 5.62 (d, *J* = 17.6 Hz, 1H), 5.13 (d, *J* = 10.8 Hz, 1H), 4.29 - 4.20 (m, 4H), 2.36 - 2.30 (m, 2H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 159.8, 158.8, 148.6, 147.2, 136.4, 131.1, 130.8, 130.4, 130.0, 128.8, 128.7, 127.6, 127.3, 127.2, 126.3, 121.4, 115.0, 114.7, 111.9, 64.8, 64.5, 29.5 ppm. HRMS: Exact mass calculated for $C_{26}H_{24}NO_2$ ($[M+H]^+$): 382.1802, Found: 382.1818.



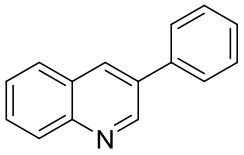
2-phenylquinoline (7c):[s]According to GP I, nitrosobenzene (43 mg, 0.40 mmol), trans β- methyl styrene (0.10 g, 0.88 mmol) and $Yb(OTf)_3$ (37 mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave **7c** as yellow gum (18 mg, 22%) ^1H NMR (400 MHz, $CDCl_3$) δ = 8.23 (d, *J* = 8.4 Hz, 1H), 8.19 – 8.16 (m, 3H), 7.89 (d, *J* = 8.4 Hz, 1H), 7.84 (d, *J* = 8.0 Hz, 1H), 7.76 – 7.71 (m 1H), 7.56 – 7.52 (m, 3H), 7.49 – 7.45 (m, 1H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 157.6, 148.5, 139.9, 137.0, 129.94, 129.88, 129.5, 129.1, 127.8, 127.7, 127.4, 126.5, 119.3 ppm.



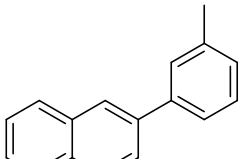
General Procedure for the Synthesis of 3-substituted quinolines (II):

Freshly prepared nitrosoarenes (1 equiv.) and $Cu(OTf)_2$ (15 mol%) were successively added to a solution of styrene oxide derivatives (2 equiv.) in dry DCE (3 mL). Then the reaction mixture was refluxed for 20 - 28 h under argon atmosphere. Then the solvent was evaporated under reduced pressure. The reaction mixture was diluted with water (1X20 mL) and the reaction mixture was extracted with DCM (3X20 mL). The organic layer was washed with brine solution (1X30 mL) and evaporated under vaccum. The crude mixture was subjected to column chromatography (silica gel) to afford analytically pure products.

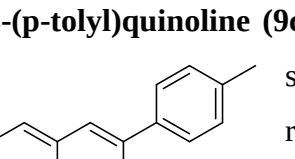
3-phenylquinoline (9a):[t] According to GP II, nitrosobenzene (35 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9a** as yellow gum (42 mg, 62%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.19 (d, *J* = 2.4 Hz, 1H), 8.32 (d, *J* = 2.0 Hz, 1H), 8.17 (d, *J* = 8.4 Hz, 1H), 7.89 (d, *J* = 8.0 Hz, 1H), 7.75 - 7.71 (m, 3H), 7.61 - 7.57 (m, 1H), 7.55 - 7.51 (m, 2H), 7.46 - 7.43 (m, 1H) ppm. HRMS: Exact mass calculated for $C_{15}H_{12}N$ ($[M+H]^+$): 206.0964, Found: 206.0974.



3-(m-tolyl)quinoline (9b):[u] According to GP II, nitrosobenzene (35 mg, 0.33 mmol), 3-methylstyrene oxide (88 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 20 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9b** as yellow gum (39 mg, 54%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.19 (d, *J* = 2.0 Hz, 1H), 8.37 (d, *J* = 2.0 Hz, 1H), 8.21 (d, *J* = 8.4 Hz, 1H), 7.91 (d, *J* = 7.6 Hz, 1H), 7.77 - 7.74 (m, 1H), 7.63 -7.60 (m, 1H), 7.53 - 7.51 (m, 2H), 7.45 - 7.41 (m, 1H), 7.28 (s, 1H), 2.48 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1114.



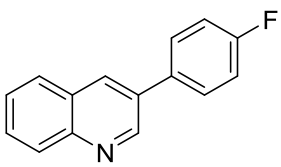
3-(p-tolyl)quinoline (9c):[u] According to GP II, nitrosobenzene (35 mg, 0.33 mmol), 4-methyl styrene oxide (88 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 20 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9c** as yellow gum (49 mg, 68%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.19 (d, *J* = 1.2 Hz, 1H), 8.36 (d, *J* = 1.6 Hz, 1H), 8.22 (d, *J* = 8.4 Hz, 1H), 7.91 (d, *J* = 8.0 Hz, 1H), 7.77 - 7.73 (m, 1H), 7.63 - 7.59 (m, 3H), 7.35 (d, *J* = 7.6 Hz, 2H), 2.45 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1122.



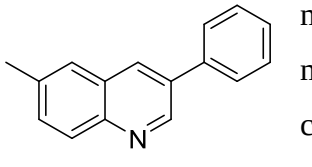
3-(4-chlorophenyl)quinoline (9d):[t] According to GP II, nitrosobenzene (35 mg, 0.33 mmol), 4-chlorostyrene oxide (0.10 g, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 20 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9d** as yellow gum (44 mg, 56%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.15 (d, *J* = 2.0 Hz, 1H), 8.33 (d, *J* = 2.0 Hz, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.90 (d, *J* = 8.0 Hz,

1H), 7.78 - 7.74 (m, 1H), 7.66 - 7.60 (m, 3H), 7.52 - 7.49 (m, 2H) ppm. HRMS: Exact mass calculated for $C_{15}H_{11}NCl$ ($[M+H]^+$): 240.0575, Found: 240.0578.

3-(4-fluorophenyl)quinoline (9e):[t] According to GP II, nitrosobenzene (35 mg, 0.33 mmol), 4-fluorostyrene oxide (91 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 15 mol %, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9e** as yellow gum (45 mg, 61%). ^1H NMR (400 MHz, $CDCl_3$) δ = 9.16 (d, *J* = 2.0 Hz, 1H), 8.36 (s, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.80 - 7.76 (m, 1H), 7.70 - 7.62 (m, 3H), 7.24 - 7.22 (m, 2H) ppm. HRMS: Exact mass calculated for $C_{15}H_{11}NF$ ($[M+H]^+$): 224.0870, Found: 224.0869.

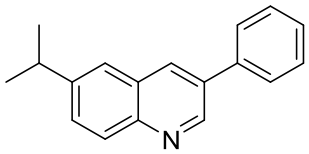


6-methyl-3-phenylquinoline (9f):[t] According to GP II, 1-methyl-4-nitrosobenzene (40 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9f** as yellow gum (45 mg, 62%). ^1H NMR (400 MHz, $CDCl_3$) δ = 9.12 (d, *J* = 2.0 Hz, 1H), 8.30 (d, *J* = 2.0 Hz, 1H), 8.12 (d, *J* = 8.4 Hz, 1H), 7.72 - 7.68 (m, 3H), 7.61 - 7.58 (m, 1H), 7.56 - 7.52 (m, 2H), 7.47 - 7.43 (m, 1H), 2.58 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1124.

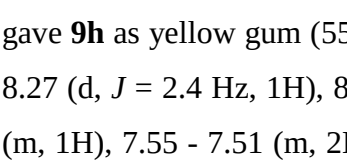


6-ethyl-3-phenylquinoline (9g):[t] According to GP II, 1-ethyl-4-nitrosobenzene (45 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 20 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9g** as yellow gum (42 mg, 55%). ^1H NMR (400 MHz, $CDCl_3$) δ = 9.13 (d, *J* = 2.0 Hz, 1H), 8.32 (d, *J* = 2.0 Hz, 1H), 8.14 (d, *J* = 8.4 Hz, 1H), 7.73 - 7.69 (m, 3H), 7.64 - 7.61 (m, 1H), 7.55 - 7.52 (m, 2H), 7.47 - 7.43 (m, 1H), 2.88 (q, *J* = 7.6 Hz, 2H), 1.36 (t, *J* = 7.6 Hz, 3H) ppm. HRMS: Exact mass calculated for $C_{17}H_{16}N$ ($[M+H]^+$): 234.1277, Found: 234.1280.

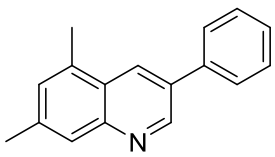
6-isopropyl-3-phenylquinoline (9h):[t] According to GP II, 1-isopropyl-4-nitrosobenzene (49 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9h** as yellow gum (55 mg, 67%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.12 (d, *J* = 2.0 Hz, 1H), 8.27 (d, *J* = 2.4 Hz, 1H), 8.08 (d, *J* = 8.4 Hz, 1H), 7.72 - 7.71 (m, 2H), 7.68 (s, 1H), 7.65 - 7.63 (m, 1H), 7.55 - 7.51 (m, 2H), 7.45 - 7.42 (m, 1H), 3.16 - 3.09 (m, 1H), 1.37 (d, *J* = 6.8 Hz, 6H) ppm. HRMS: Exact mass calculated for $C_{18}H_{18}N$ ($[M+H]^+$): 248.1434, Found: 248.1429.



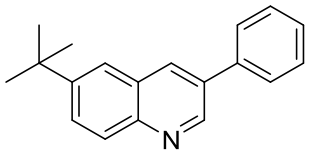
3-phenyl-6-propylquinoline (9i): According to GP II, 1-nitroso-4-propylbenzene (49 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 22 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9i** as yellow gum (57 mg, 70%). FT-IR: $\tilde{\nu}$ = 2959, 2929, 2871, 1600, 1494, 1455, 1349, 1260, 1026, 800, 627 cm^{-1}. ^{1}H NMR (600 MHz, $CDCl_3$) δ = 9.13 (d, *J* = 1.8 Hz, 1H), 8.33(d, *J* = 1.2 Hz, 1H), 8.15 (d, *J* = 8.4 Hz, 1H), 7.71 (d, *J* = 7.8 Hz, 2H), 7.68 (s, 1H), 7.62 - 7.61 (m, 1H), 7.55 - 7.53 (m, 2H), 7.47 - 7.44 (m, 1H), 2.81 (t, *J* = 7.8 Hz, 2H), 1.79 - 1.75 (m, 2H), 1.00 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR (151 MHz, $CDCl_3$) δ = 148.1, 144.9, 142.5, 137.7, 134.21, 134.15, 132.0, 129.5, 128.5, 128.4, 128.1, 127.6, 126.6, 38.2, 24.5, 14.0 ppm. HRMS: Exact mass calculated for $C_{18}H_{18}N$ ($[M+H]^+$): 248.1434, Found: 248.1433.



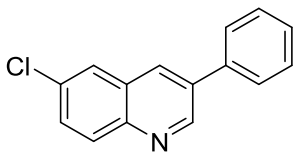
5,7-dimethyl-3-phenylquinoline (9j):[t] According to GP II, 1,3-dimethyl-5-nitrosobenzene (45 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 28 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9j** as yellow gum (45 mg, 58%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.13 (d, *J* = 2.4 Hz, 1H), 8.44 (d, *J* = 2.0 Hz, 1H), 7.82 (s, 1H), 7.73 - 7.71 (m, 2H), 7.56 - 7.52 (m, 2H), 7.46 - 7.42 (m, 1H), 7.28 (s, 1H), 2.72 (s, 3H), 2.55 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{17}H_{16}N$ ($[M+H]^+$): 234.1277, Found: 234.1280.



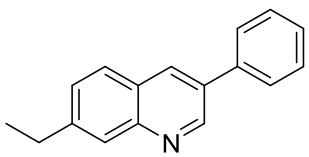
6-(*tert*-butyl)-3-phenylquinoline (9k):[v] According to GP II, 1-(*tert*-butyl)-4-nitrosobenzene (54 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9k** as yellow gum (56 mg, 65%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.13 (s, 1H), 8.35 (d, *J* = 1.6 Hz, 1H), 8.15 (d, *J* = 8.8 Hz, 1H), 7.86 - 7.83 (m, 2H), 7.73 - 7.71 (m, 2H), 7.55 - 7.52 (m, 2H), 7.47 - 7.43 (m, 1H), 1.45 (s, 9H) ppm. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found: 262.1593.



6-chloro-3-phenylquinoline (9l):[u] According to GP II, 1-chloro-4-nitrosobenzene (47 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9l** as yellow gum (29 mg, 37%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.17 (d, *J* = 2.0 Hz, 1H), 8.23 (d, *J* = 2.0 Hz, 1H), 8.10 (d, *J* = 9.2 Hz, 1H), 7.87 (d, *J* = 2.4 Hz, 1H), 7.71 - 7.65 (m, 3H), 7.56 - 7.52 (m, 2H), 7.48 - 7.44 (m, 1H) ppm. HRMS: Exact mass calculated for $C_{15}H_{11}NCl$ ($[M+H]^+$): 240.0575, Found: 240.0574.



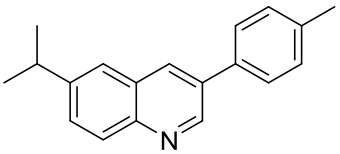
7-ethyl-3-phenylquinoline (9m):[w] According to GP II, 1-ethyl-3-nitrosobenzene (45 mg, 0.33 mmol), styrene oxide (79 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9m** as yellow gum (41 mg, 53%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.15 (d, *J* = 2.4 Hz, 1H), 8.35 (d, *J* = 2.0 Hz, 1H), 8.02 (s, 1H), 7.84 (d, *J* = 8.4 Hz, 1H), 7.72 - 7.70 (m, 2H), 7.55 - 7.43 (m, 4H), 2.90 (q, *J* = 7.6 Hz, 2H), 1.37 (t, *J* = 7.6 Hz, 3H) ppm. HRMS: Exact mass calculated for $C_{17}H_{16}N$ ($[M+H]^+$): 234.1277, Found: 234.1279.



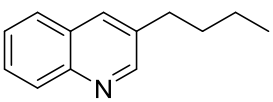
6-ethyl-3-(p-tolyl)quinoline (9n): According to GP II, 1-ethyl-4-nitrosobenzene (45 mg, 0.33 mmol), 4-methyl styrene oxide (88 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 20 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9n** as yellow gum (52 mg, 64%). FT-IR: $\tilde{\nu}$ = 2964, 2927, 2871, 1604, 1516, 1455, 1374, 1261, 1040, 914, 834, 724 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.11 (d, *J* = 2.0 Hz, 1H), 8.29 (d,

J = 2.0 Hz, 1H), 8.13 (d, *J* = 8.4 Hz, 1H), 7.67 (s, 1H), 7.63 - 7.60 (m, 3H), 7.34 (d, *J* = 8.0 Hz, 2H), 2.87 (q, *J* = 7.6 Hz, 2H), 2.44 (s, 3H), 1.36 (t, *J* = 7.6 Hz, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 148.1, 144.8, 143.9, 138.5, 134.8, 134.1, 133.8, 131.5, 130.2, 128.6, 128.2, 127.4, 125.7, 29.1, 21.4, 15.5 ppm. HRMS: Exact mass calculated for $C_{18}H_{18}N$ ($[M+H]^+$): 248.1434, Found: 248.1435.

6-isopropyl-3-(p-tolyl)quinoline (9o): According to GP II, 1-isopropyl-4-nitrosobenzene (49 mg, 0.33 mmol), 4-methyl styrene oxide (88 mg, 0.66 mmol) and $Cu(OTf)_2$ (18 mg, 0.05 mmol) were reacted for 22 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9o** as yellow gum (57 mg, 66%). FT-IR: $\tilde{\nu}$ = 2960, 2927, 2872, 1607, 1516, 1256, 1128, 817, 748 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.12 (d, *J* = 2.4 Hz, 1H), 8.36 (d, *J* = 2.0 Hz, 1H), 8.19 (d, *J* = 8.4 Hz, 1H), 7.71 – 7.67 (m, 2H), 7.61 (d, *J* = 8.4 Hz, 2H), 7.35 (d, *J* = 7.6 Hz, 2H), 3.17 - 3.10 (m, 1H), 2.44 (s, 3H), 1.37 (d, *J* = 6.8 Hz, 6H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 148.9, 147.4, 144.0, 138.8, 134.7, 134.4, 134.2, 130.7, 130.3, 128.7, 127.6, 127.4, 124.3, 34.4, 24.0, 21.4 ppm. HRMS: Exact mass calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found: 262.1592.



3-butylquinoline (9p):[s] According to GP II, nitrosobenzene (43 mg, 0.4 mmol), 1,2-epoxyhexane (80 mg, 0.8 mmol) and $Cu(OTf)_2$ (22 mg, 0.06 mmol) were reacted for 24 h in dry DCE (3 mL) and column chromatography of the crude product (neutral alumina; EtOAc : hexane, 1:30) gave **9p** as yellow gum (8 mg, 11%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.78 (d, *J* = 2.0 Hz, 1H), 8.11 (d, *J* = 8.4 Hz, 1H), 7.95 (s, 1H), 7.78 (d, *J* = 8.4 Hz, 1H), 7.67 (t, *J* = 8.0 Hz, 1H), 7.53 (t, *J* = 8.0 Hz, 1H), 2.83 – 2.67 (m, 2H), 1.77 – 1.67 (m, 2H), 1.44 – 1.38 (m, 2H), 1.00 – 0.94 (m, 3H) ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.8, 146.4, 135.7, 134.9, 129.0, 128.9, 128.5, 127.5, 126.9, 33.4, 33.1, 22.5, 14.1 ppm.

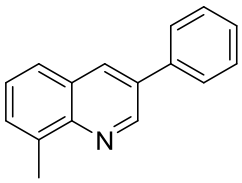


General Procedure for preparation of nitrone 10 and its reaction with 2-phenylacetaldehyde or styrene oxide (GP III): Formalin (37%, 1eq) solution was added to a mixture of nitrobenzene derivatives (1eq), ethanol, water and NH_4Cl (1eq). After the mixture was stirred 15 min, Zn powder (2 eq) was added under 0 ^{o}C. The reaction mixture was stirred overnight at room temperature. Then the solid was filtered, the filtrate was extracted with DCM (3X30 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated in vacuo. The crude product was

dissolved in DCE. 2-phenylacetaldehyde (1eq) or styrene epoxide (1 eq) and $Cu(OTf)_2$ (15 mol%) were added and the mixture was refluxed for 24 h. Then the solvent was evaporated under reduced pressure. The reaction mixture was diluted with water and the reaction mixture was extracted with DCM. The organic layer was washed with brine solution and evaporated under vaccum. The crude mixture was subjected to column chromatography (silica gel) to afford analytically pure products.

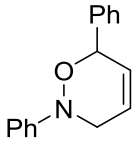
3-phenylquinoline (9a): According to the GP III: 37% aq. Formalin (0.11 g (40 mg), 1.35 mmol), nitrobenzene (0.17 g, 1.35 mmol), ethanol (5 mL), water (5 mL) and NH_4Cl (72 mg, 1.35 mmol), Zn powder (0.18 g, 2.70 mmol), 2-phenylacetaldehyde (0.16 g, 1.35 mmol) and $Cu(OTf)_2$ (73 mg, 0.20 mmol) were reacted for 24 h in dry DCE (5 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9a** as yellow gum (0.14 g, 52%) and styrene oxide (0.16 g, 1.35 mmol) and $Cu(OTf)_2$ (73 mg, 0.20 mmol) were reacted for 24 h in dry DCE (5 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9a** as yellow gum (0.20 g, 73%).

8-methyl-3-phenylquinoline (9q):[x] According to the GP III: 37% aq. Formalin (0.11 g (40 mg),



1.35 mmol), 1-methy-2-nitrobenzene (0.19 g, 1.35 mmol), ethanol (5 mL), water (5 mL) and NH_4Cl(72 mg, 1.35 mmol), Zn powder (0.18 g, 2.70 mmol), 2-phenylacetaldehyde (0.16 g, 1.35 mmol) and $Cu(OTf)_2$ (73 mg, 0.20 mmol) were reacted for 24 h in dry DCE (5 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:7) gave **9q** as yellow gum (92 mg, 31%). Analytical data for **9q:** ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.25 (s, 1H), 8.34 (d, *J* = 2.0 Hz, 1H), 7.77 – 7.72 (m, 3H), 7.61 – 7.52 (m, 3H), 7.50 – 7.43 (m, 2H), 2.88 (s, 3H) ppm. HRMS: Exact mass calculated for $C_{16}H_{14}N$ ($[M+H]^+$): 220.1121, Found: 220.1135.

2,6-diphenyl-3,6-dihydro-2H-1,2-oxazine:[y] According to GP I, nitrosobenzene (43 mg, 0.4



mmol), phenylbutadiene (0.11 g, 0.88 mmol) and $Yb(OTf)_3$ (37mg, 0.06 mmol) were reacted for 36 h in dry DCE (3 mL) and column chromatography of the crude product (silica gel; EtOAc : hexane, 1:30) gave oxazine as yellow gum (29 mg, 31%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.40 – 7.38 (m, 2H), 7.32 – 7.25 (m, 3H), 7.22 – 7.18 (m, 2H), 7.04 – 7.02 (m, 2H), 6.89 (t, *J* = 7.2 Hz, 1H), 6.08 – 5.99 (m, 2H), 5.55 – 5.54 (m, 1H), 3.93 – 3.79 (m, 2H)

ppm. ^{13}C NMR (101 MHz, $CDCl_3$) δ = 150.5, 139.1, 129.2, 129.0, 128.7, 128.6, 128.4, 124.0, 122.4, 116.0, 80.1, 51.8 ppm.

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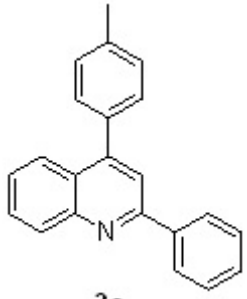
7.260

2.490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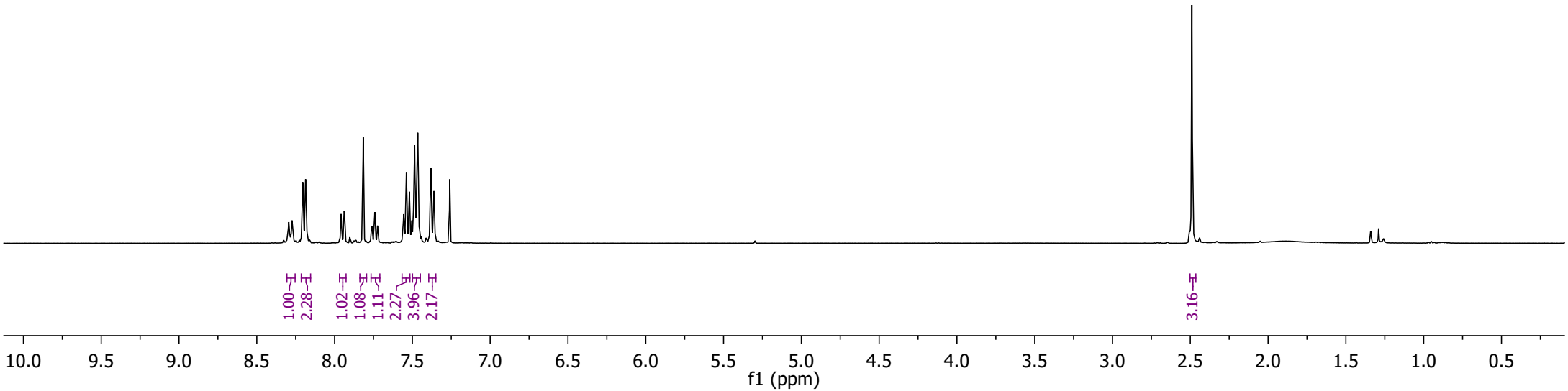
3a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7.5
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4.0
3.5
3.0
2.5
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0.5
f1 (ppm)


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8.183
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7.913
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7.776
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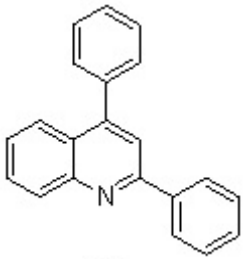
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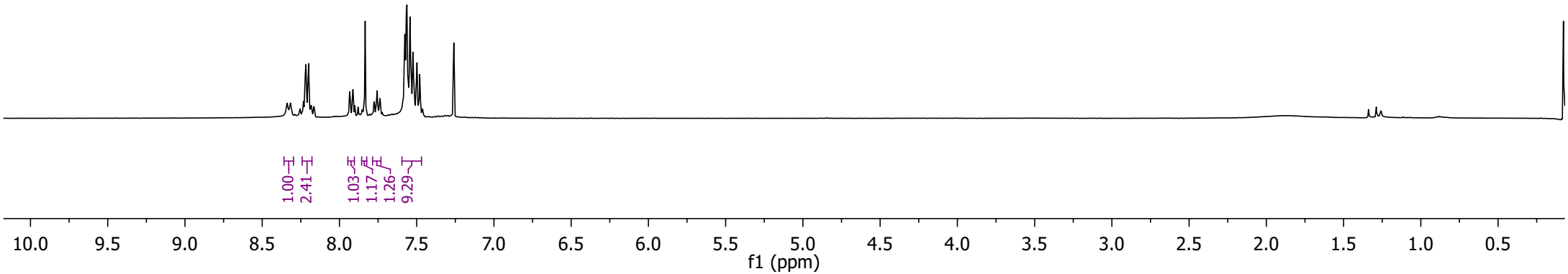
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6.0
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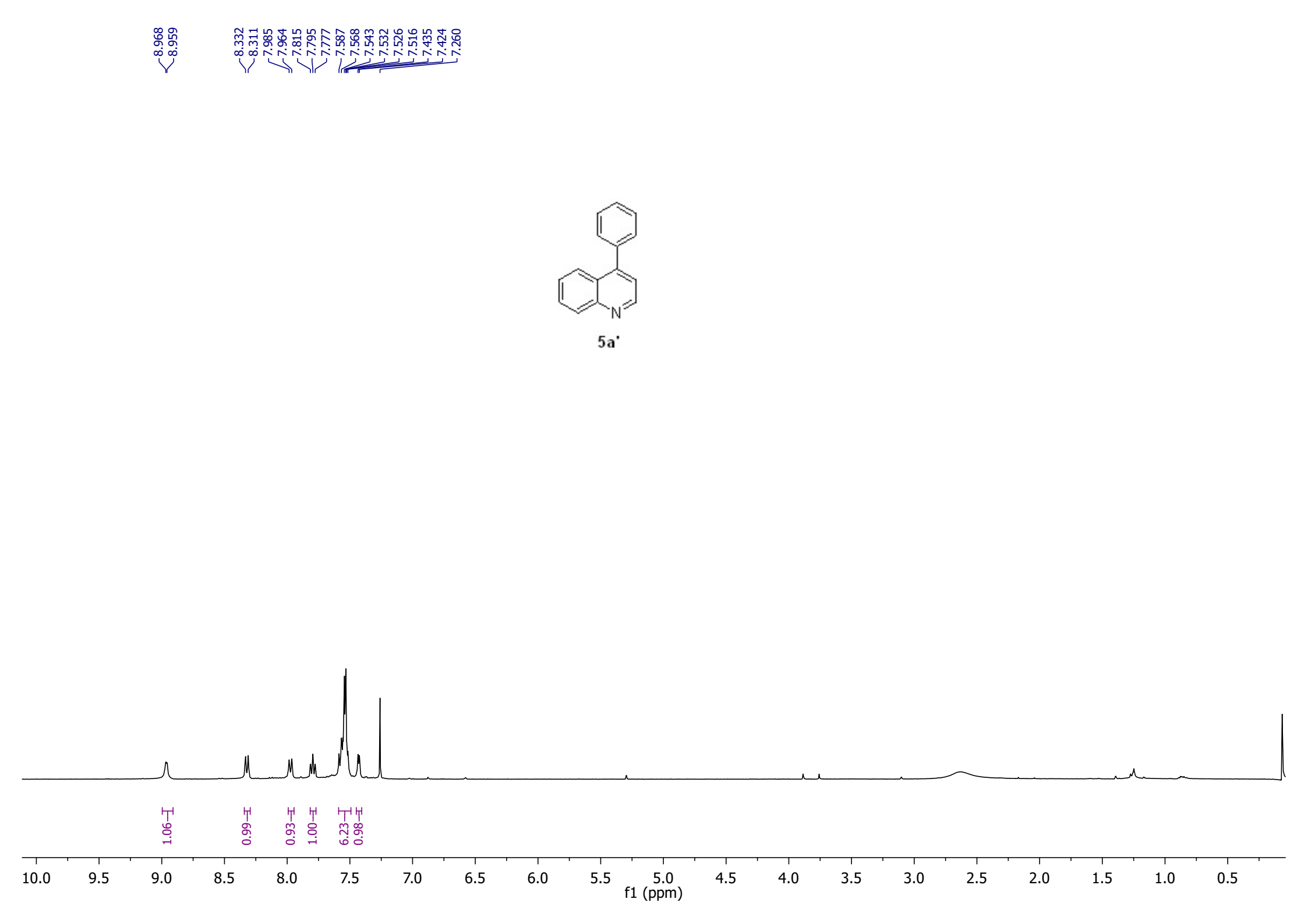
f1 (ppm)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7.532
7.526
7.516
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7.260
N
5a'
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f1 (ppm)


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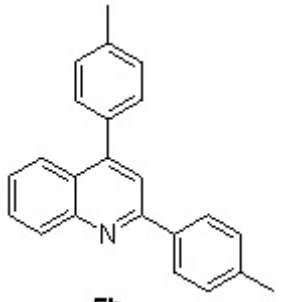
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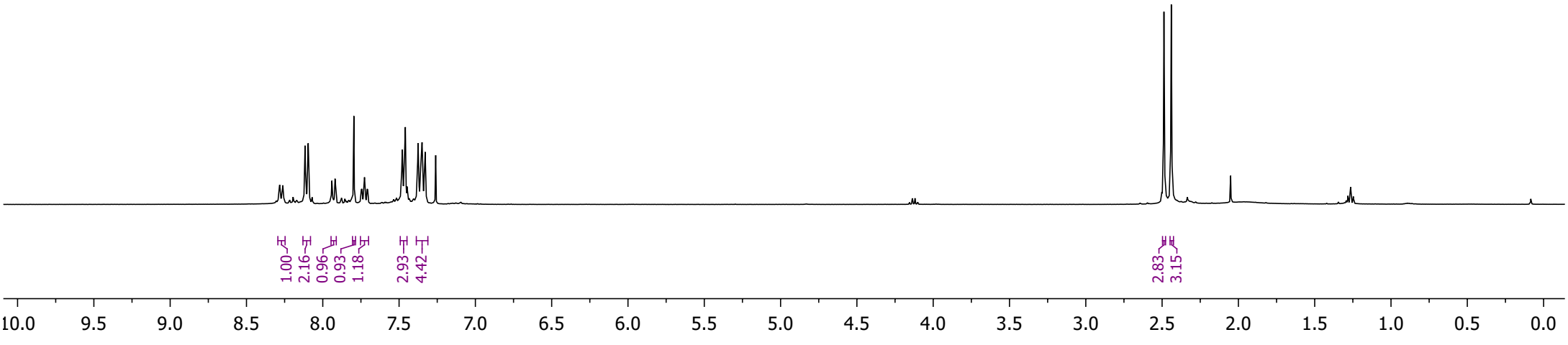
5b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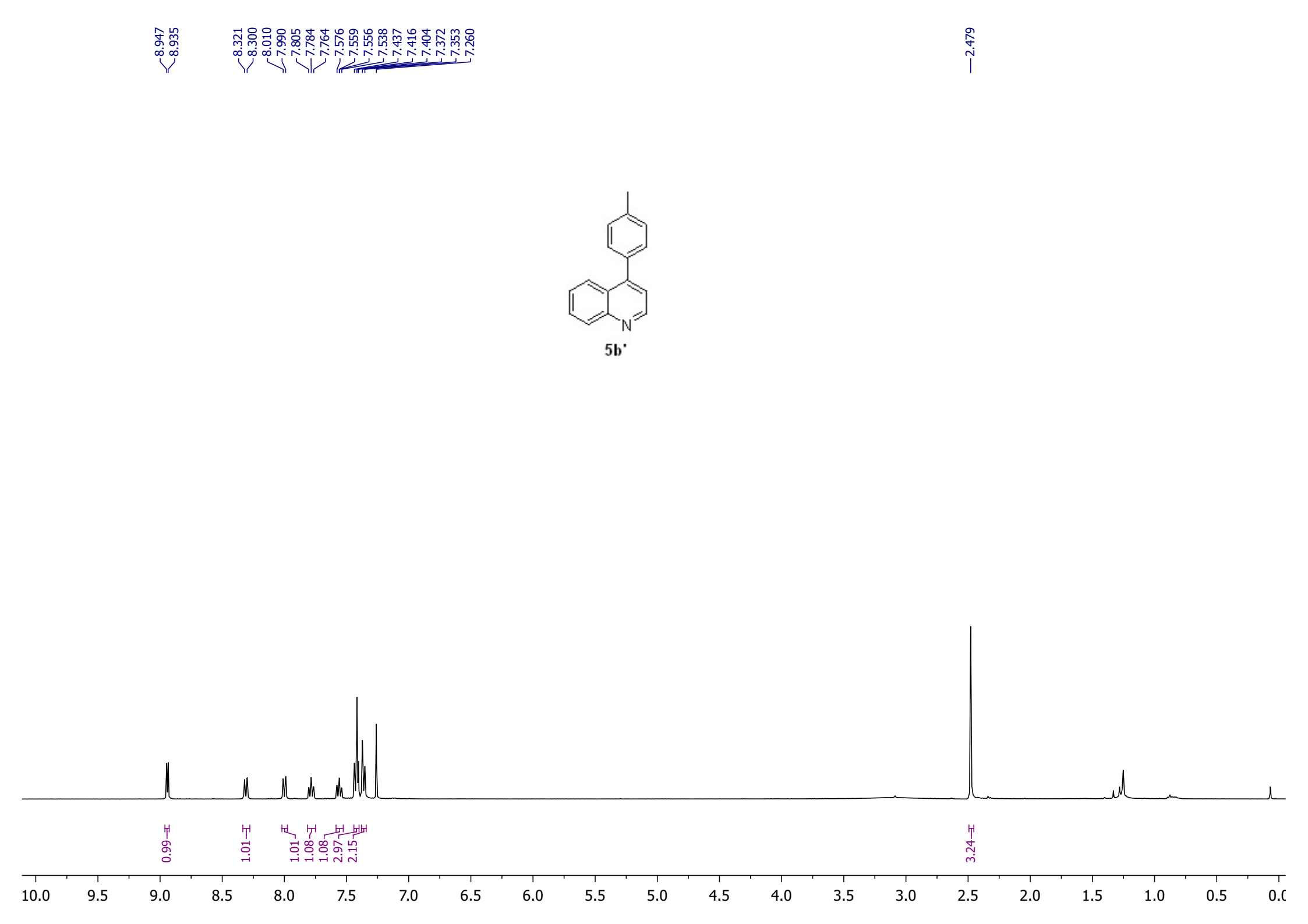
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N
5b'
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1.01
1.08
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3.24
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9.5
9.0
8.5
8.0
7.5
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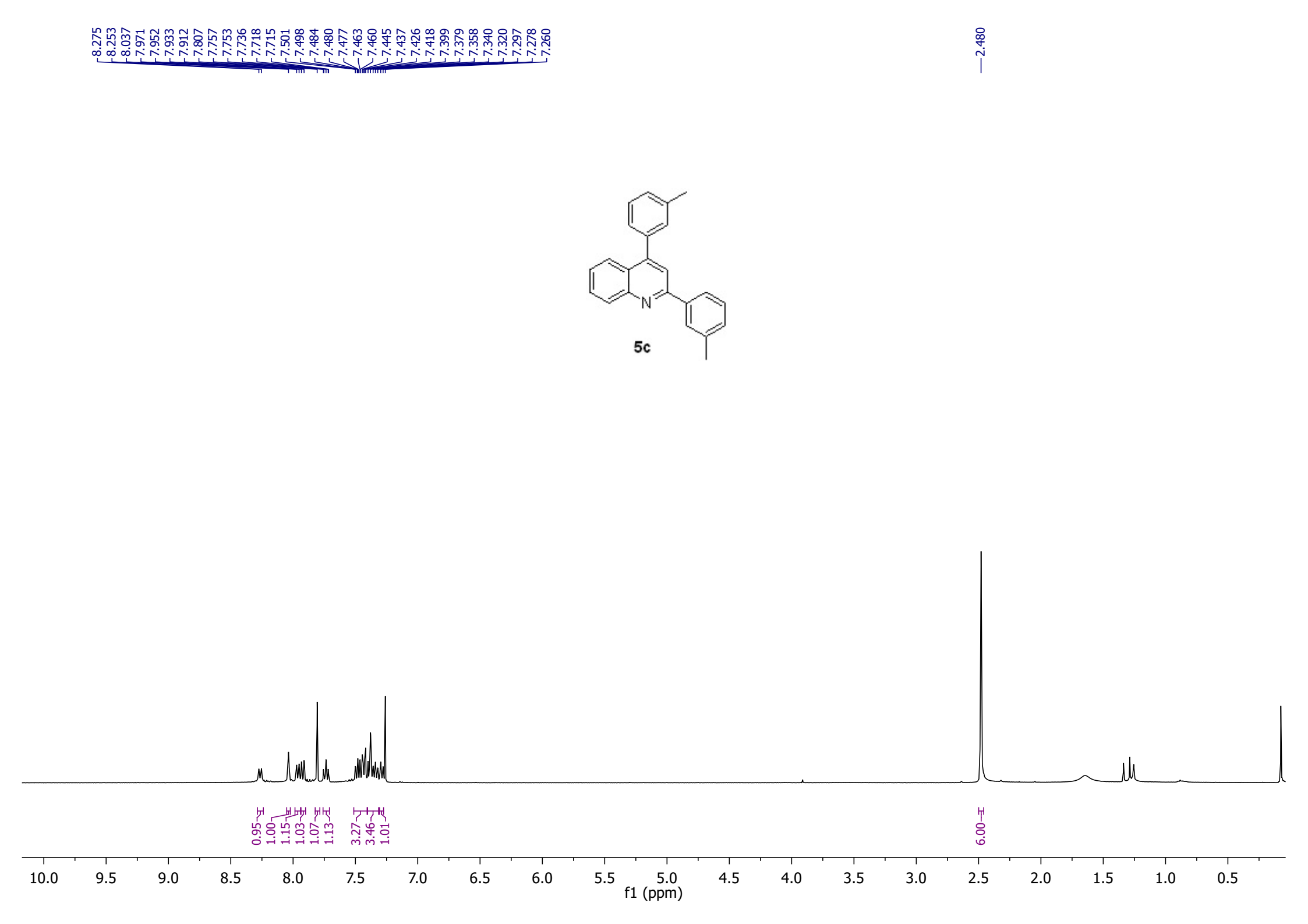
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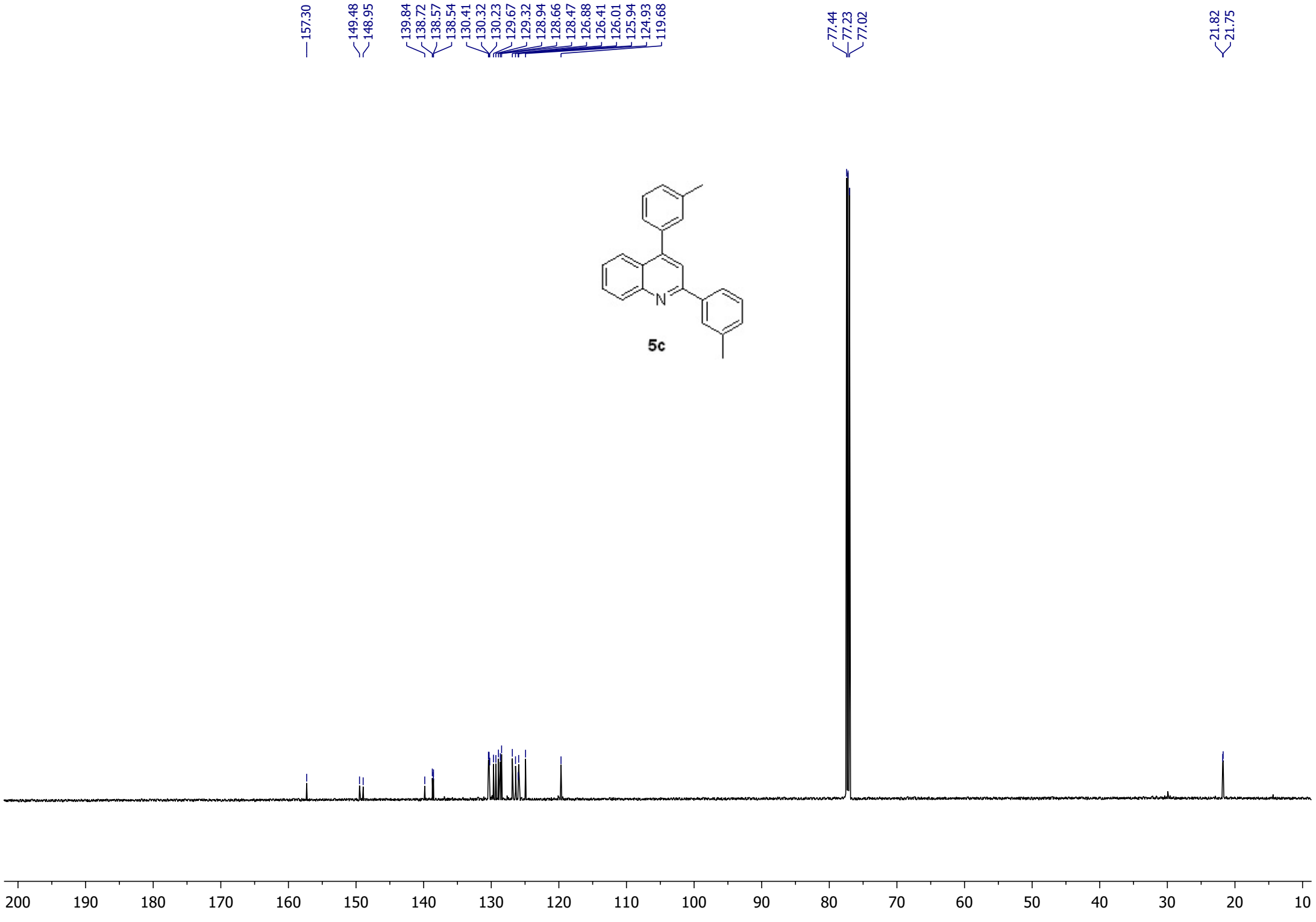
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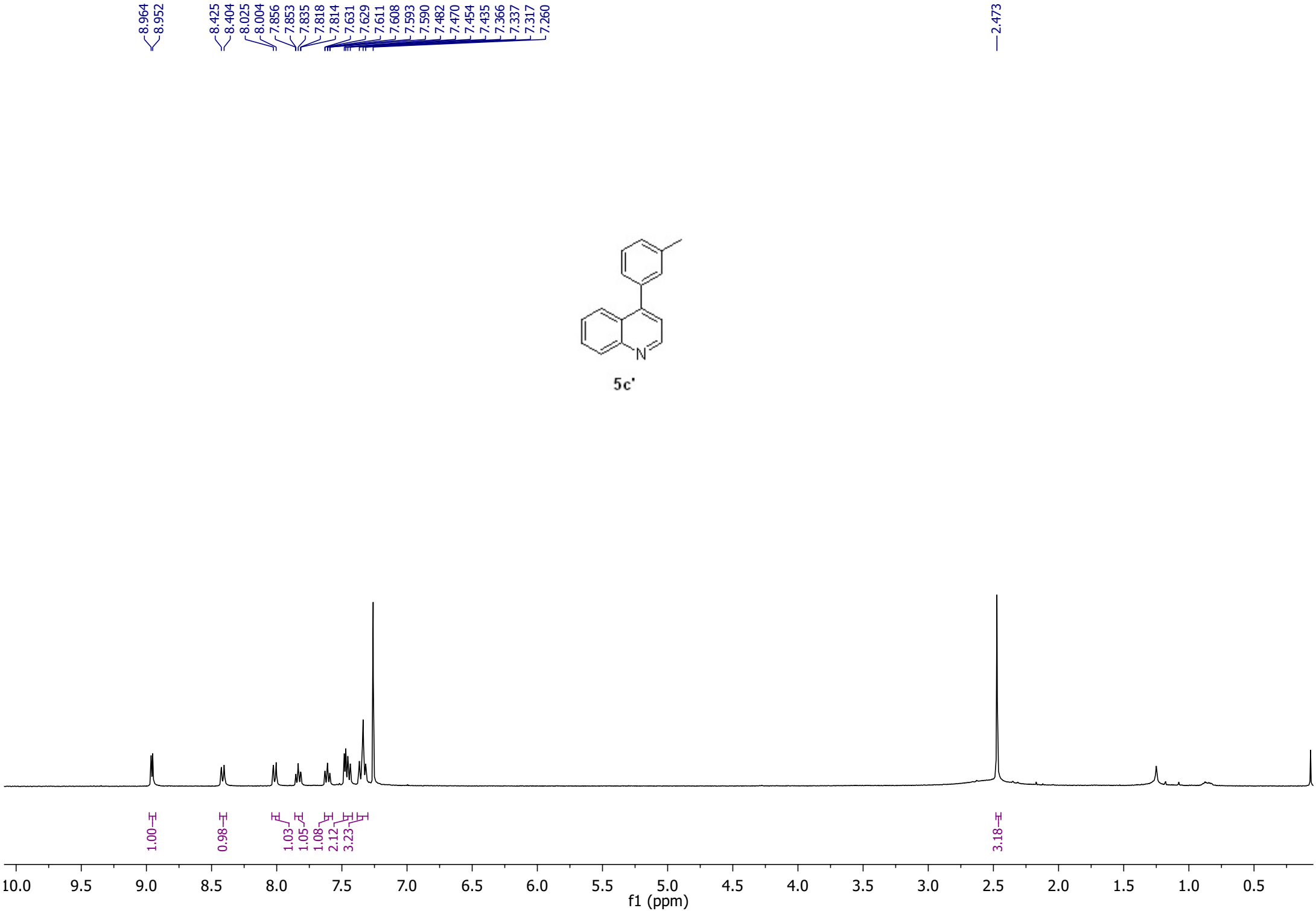
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f1 (ppm)


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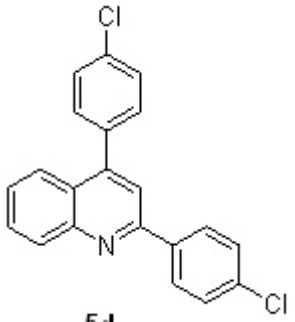
Cl
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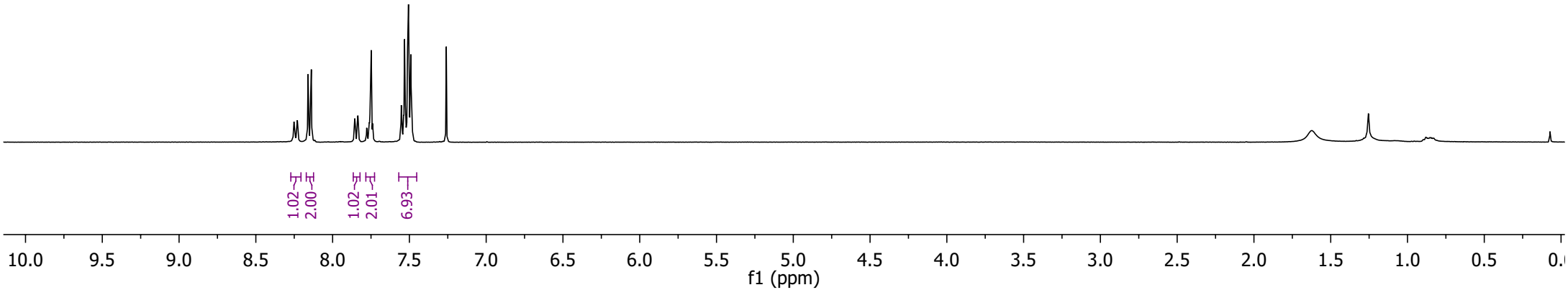
Cl

5d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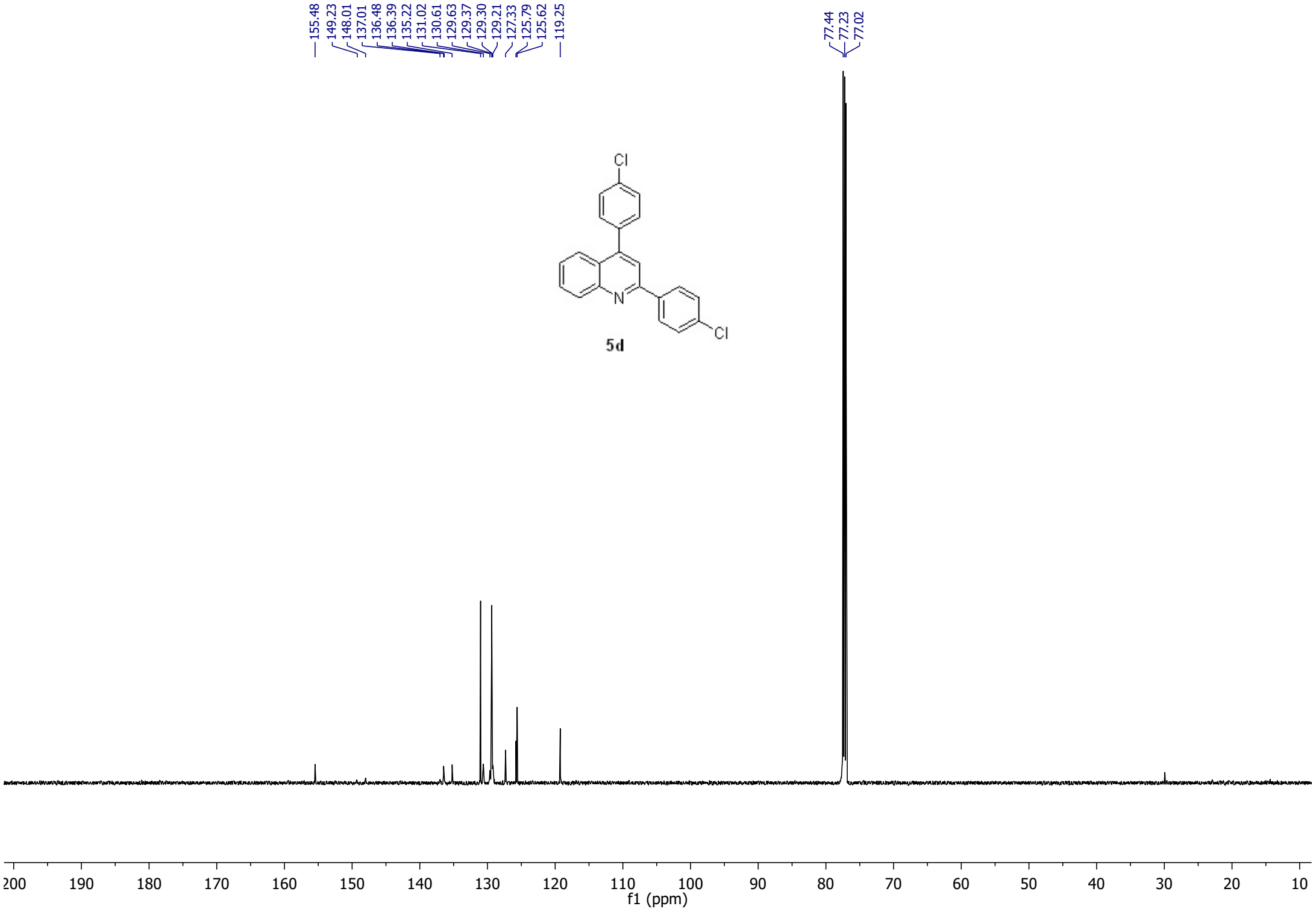
f1 (ppm)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137.01
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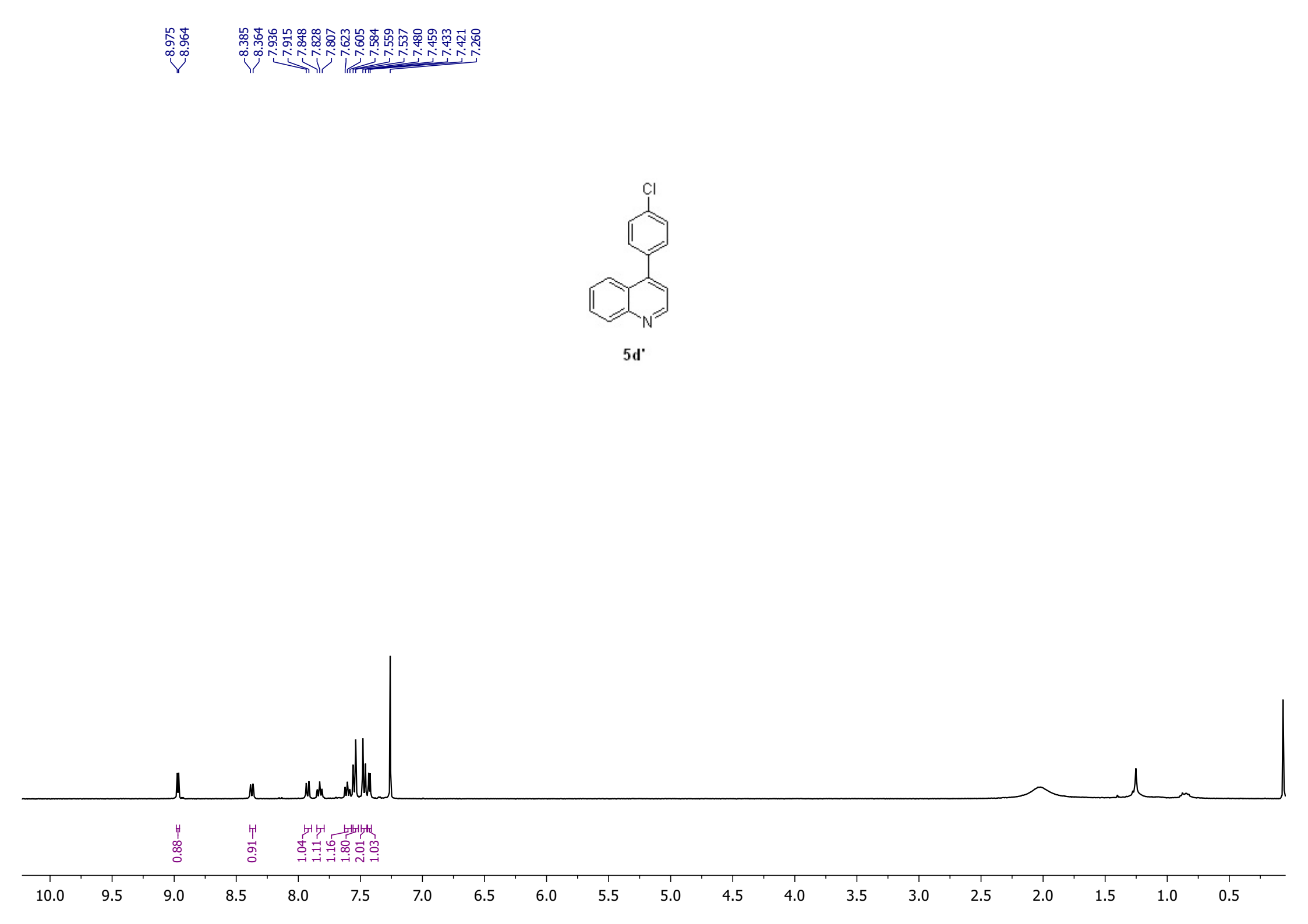
130.61
129.63
129.37
129.30
129.21
127.33
125.79
125.62
119.25
77.44
77.23
77.02
Cl
N
Cl
5d
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.807
7.623
7.605
7.584
7.559
7.537
7.480
7.459
7.433
7.421
7.260
Cl
N
5d'
0.88
0.91
1.04
1.11
1.16
1.80
2.01
1.03
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5


8.267
8.253
8.245
8.231
8.207
8.198
8.192
8.183
8.170
8.165
8.156
7.867
7.853
7.847
7.833
7.770
7.756
7.746
7.549
7.540
7.535
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7.517
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7.491
7.271
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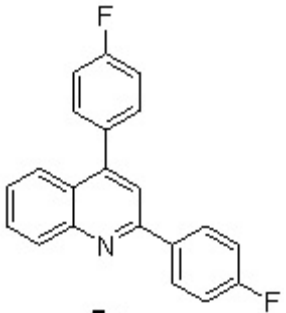
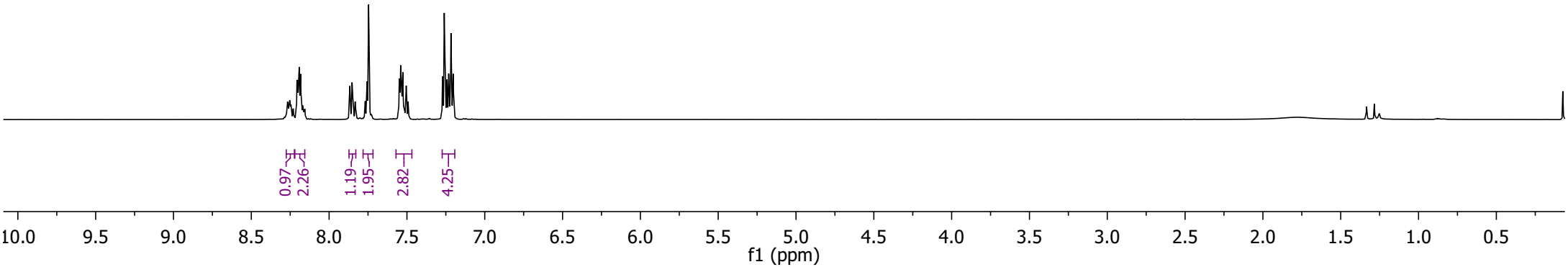
7.257
7.243
7.232
7.217
7.203


F
N
F

5e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9.5
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8.5
8.0
7.5
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6.5
6.0
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4.0
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3.0
2.5
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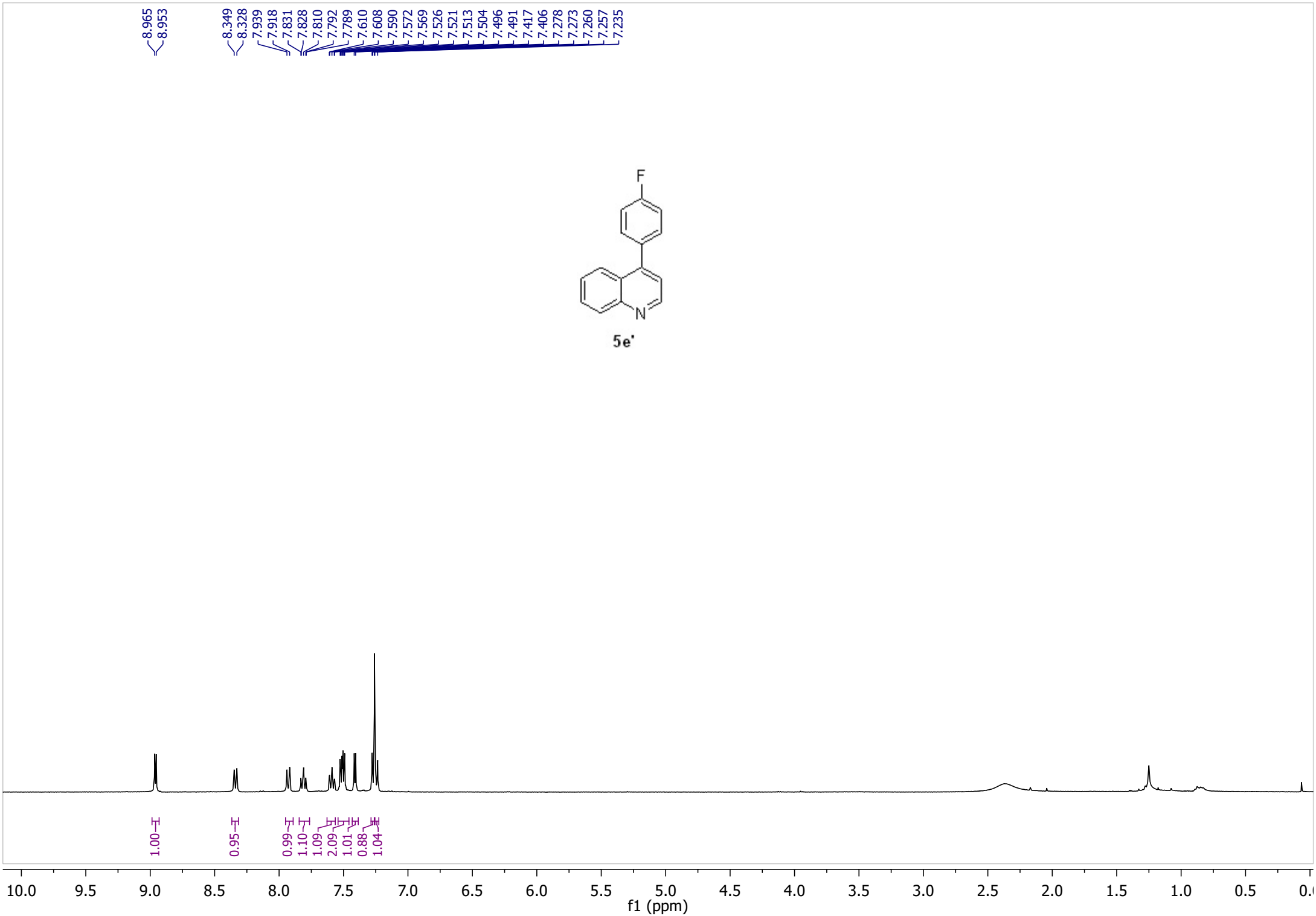
1.5
1.0
0.5
f1 (ppm)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7.789
7.610
7.608
7.590
7.572
7.569
7.526
7.521
7.513
7.504
7.496
7.491
7.417
7.406
7.278
7.273
7.260
7.257
7.235
F
N
5e'
1.00
0.95
0.99
1.10
1.09
2.09
1.01
0.88
1.04
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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3.0
2.5
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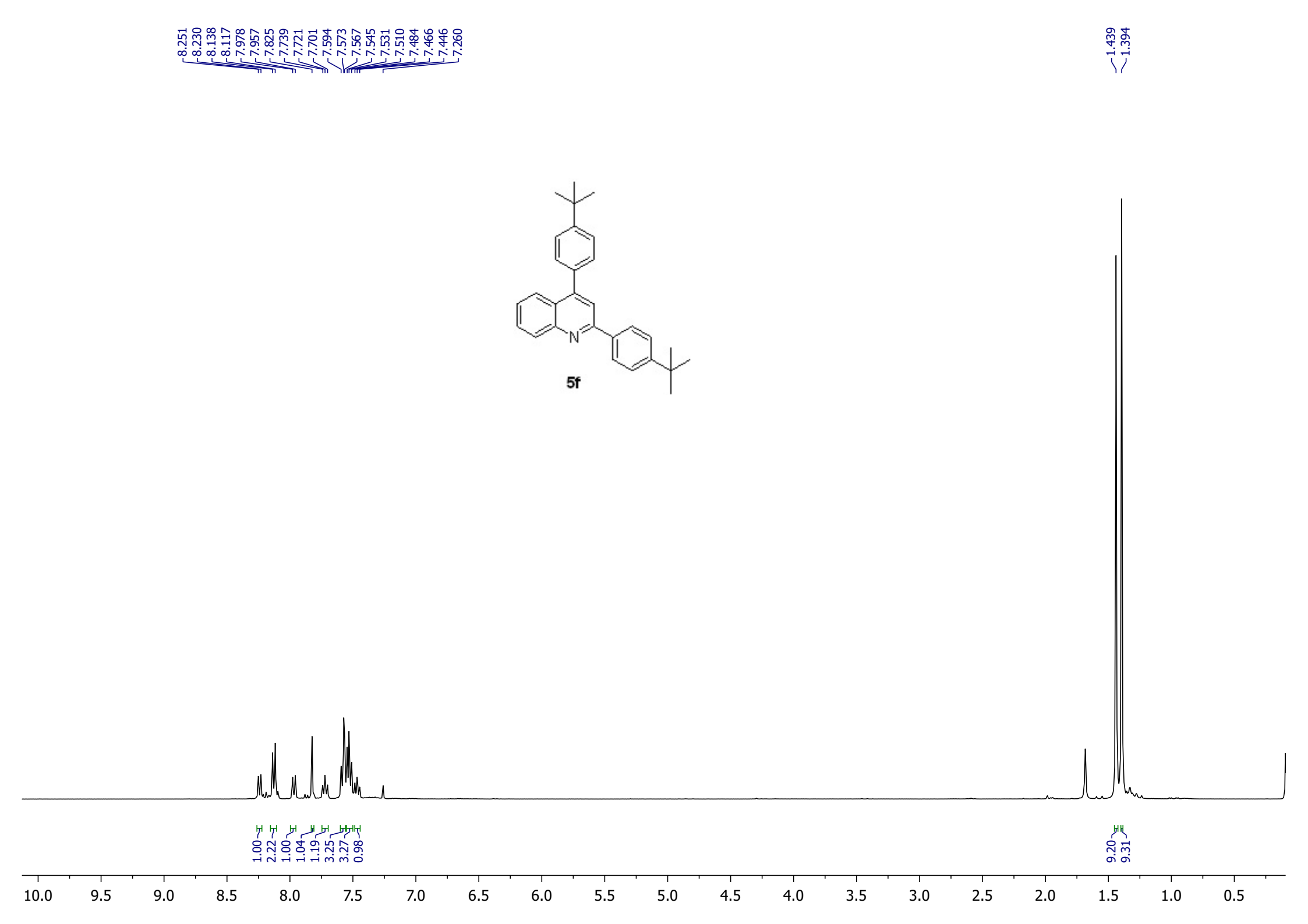
1.5
1.0
0.5
f1 (ppm)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7.739
7.721
7.701
7.594
7.573
7.567
7.545
7.531
7.510
7.484
7.466
7.446
7.260
1.439
1.394
5f
1.00
2.22
1.00
1.04
1.19
3.25
3.27
0.98
9.20
9.31
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
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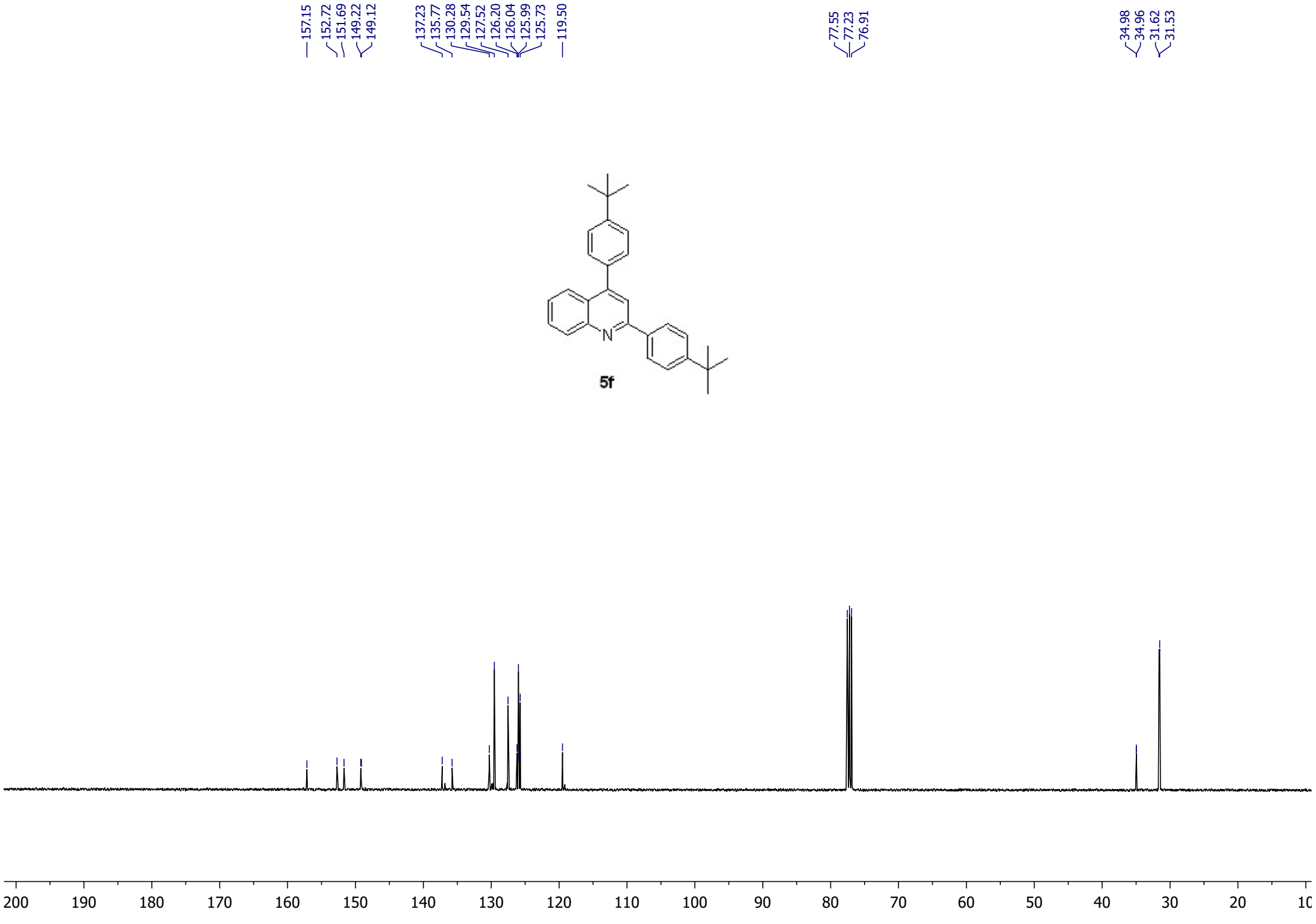
1.5
1.0
0.5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152.72
151.69
149.22
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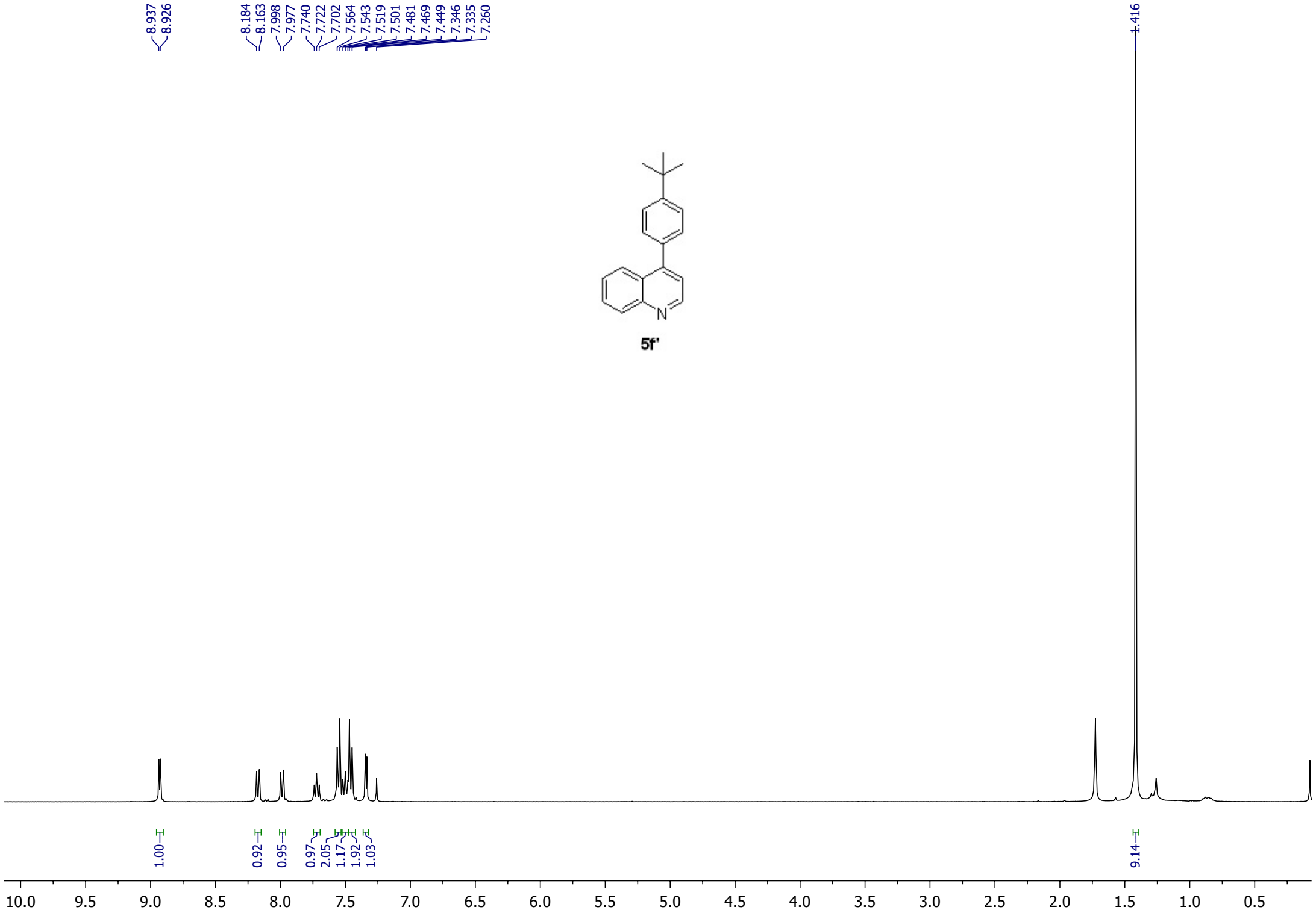
137.23
135.77
130.28
129.54
127.52
126.20
126.04
125.99
125.73
119.50
77.55
77.23
76.91
34.98
34.96
31.62
31.53
N
5f
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10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8.184
8.163
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7.977
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7.722
7.702
7.564
7.543
7.519
7.501
7.481
7.469
7.449
7.346
7.335
7.260
1.416
N
5f'
1.00
0.92
0.95
0.97
2.05
1.17
1.92
1.03
9.14
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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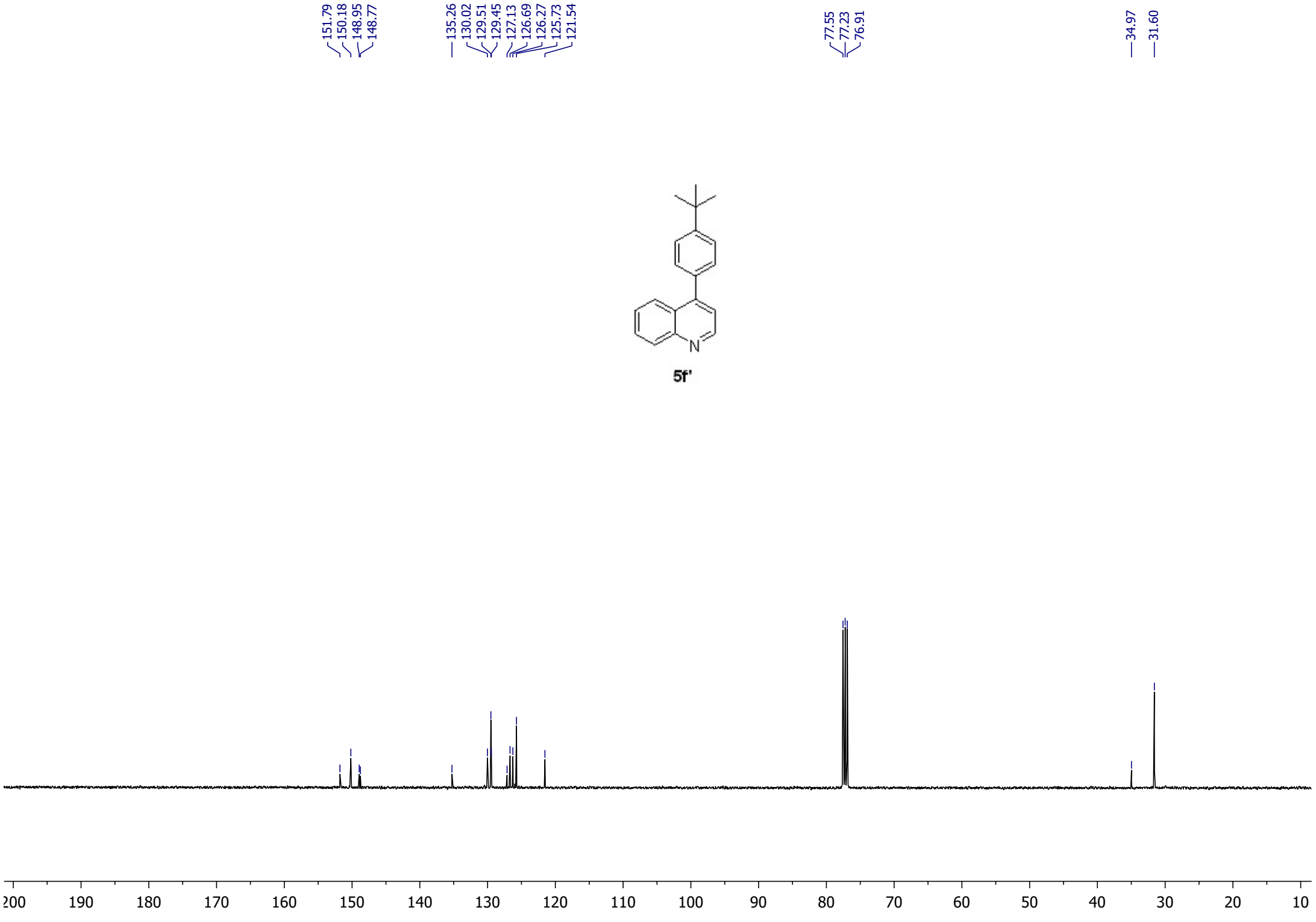
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5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130.02
129.51
129.45
127.13
126.69
126.27
125.73
121.54
77.55
77.23
76.91
34.97
31.60
N
5f'
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10


8.320
8.315
8.298
8.294
8.019
8.017
7.998
7.996
7.923
7.813
7.808
7.792
7.773
7.768
7.754
7.750
7.727
7.724
7.707
7.704
7.685
7.665
7.536
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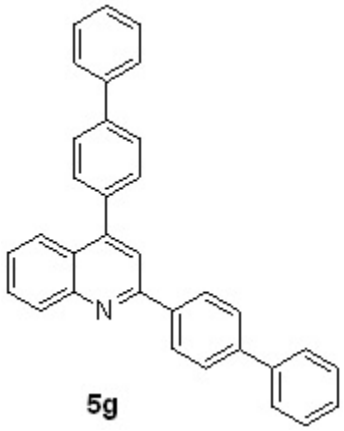
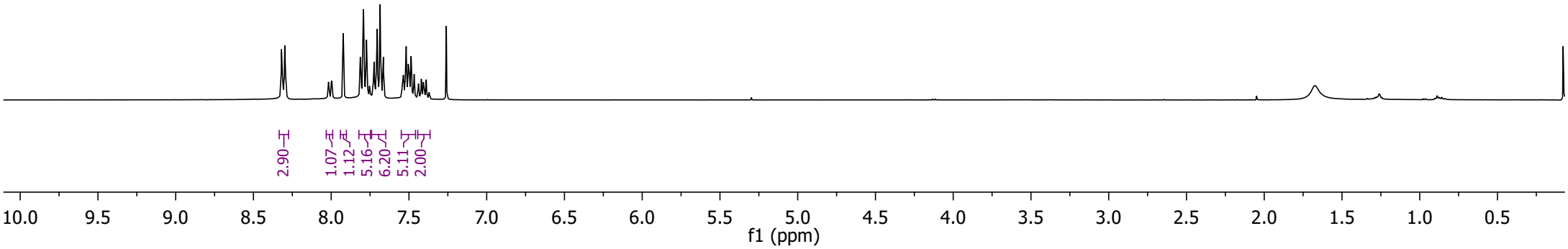
7.389
7.370
7.260


N

5g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1.12
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5.11
2.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
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4.0
3.5
3.0
2.5
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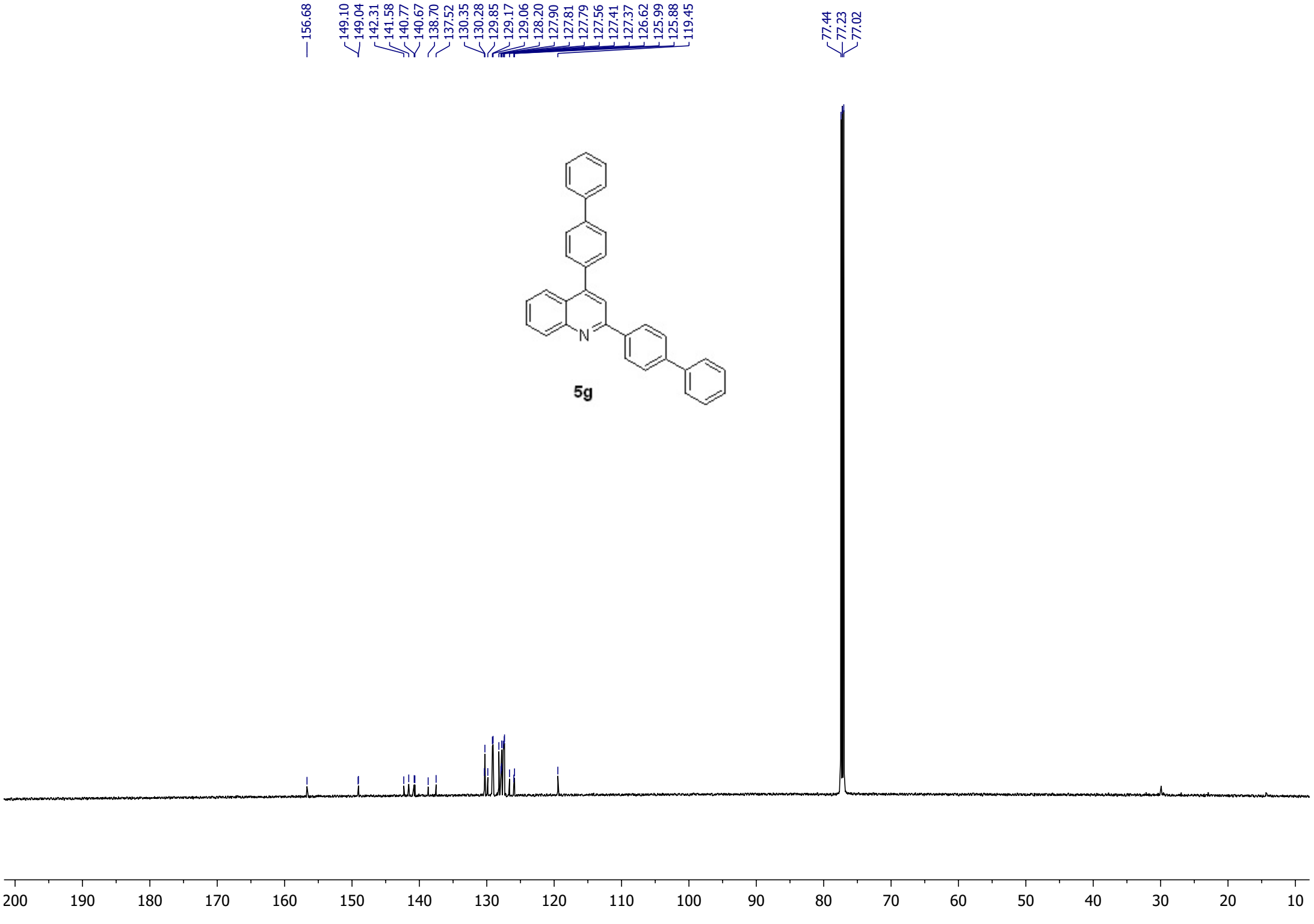
1.5
1.0
0.5
f1 (ppm)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129.17
129.06
128.20
127.90
127.81
127.79
127.56
127.41
127.37
126.62
125.99
125.88
119.45
77.44
77.23
77.02
N
5g
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10


8.978
8.966
8.254
8.233
8.040
8.017
7.785
7.780
7.769
7.764
7.754
7.750
7.706
7.702
7.685
7.618
7.613
7.601
7.597
7.577
7.575
7.560
7.557
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7.524
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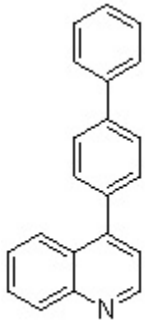
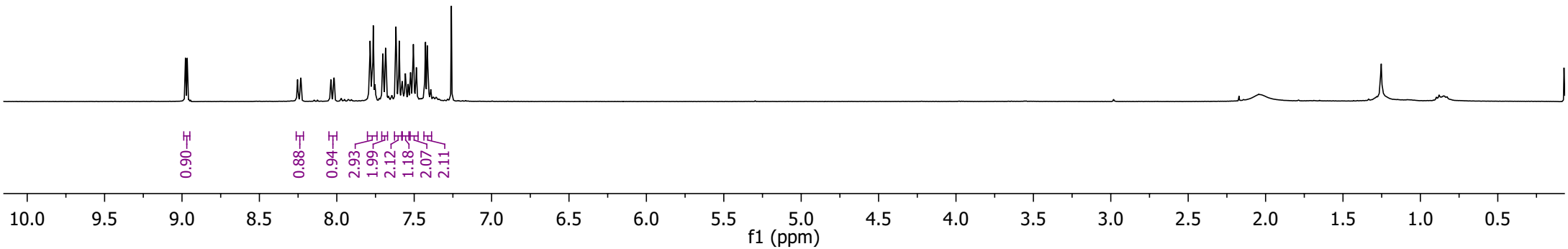
7.260


N

5g'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1.18
2.07
2.11
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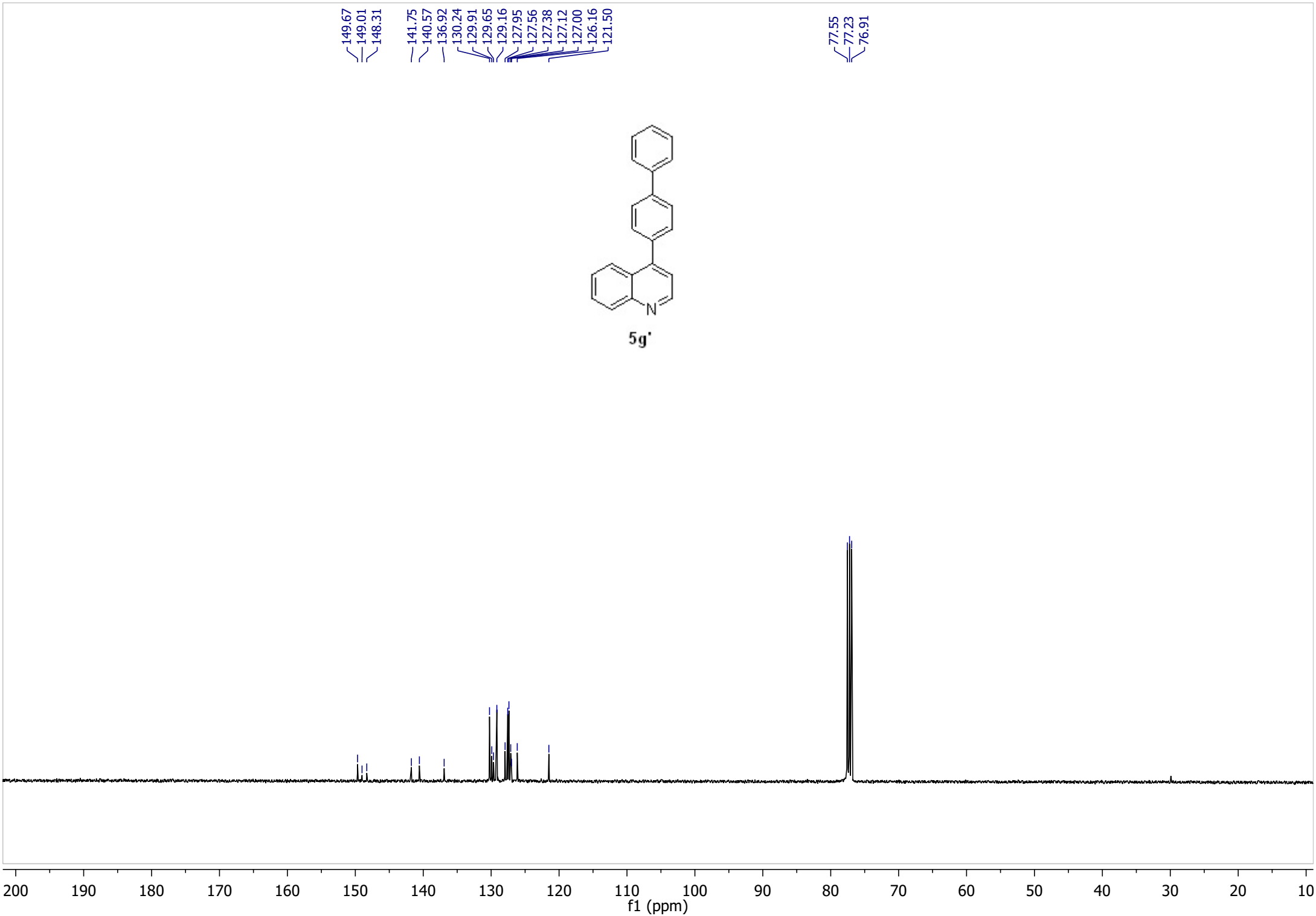
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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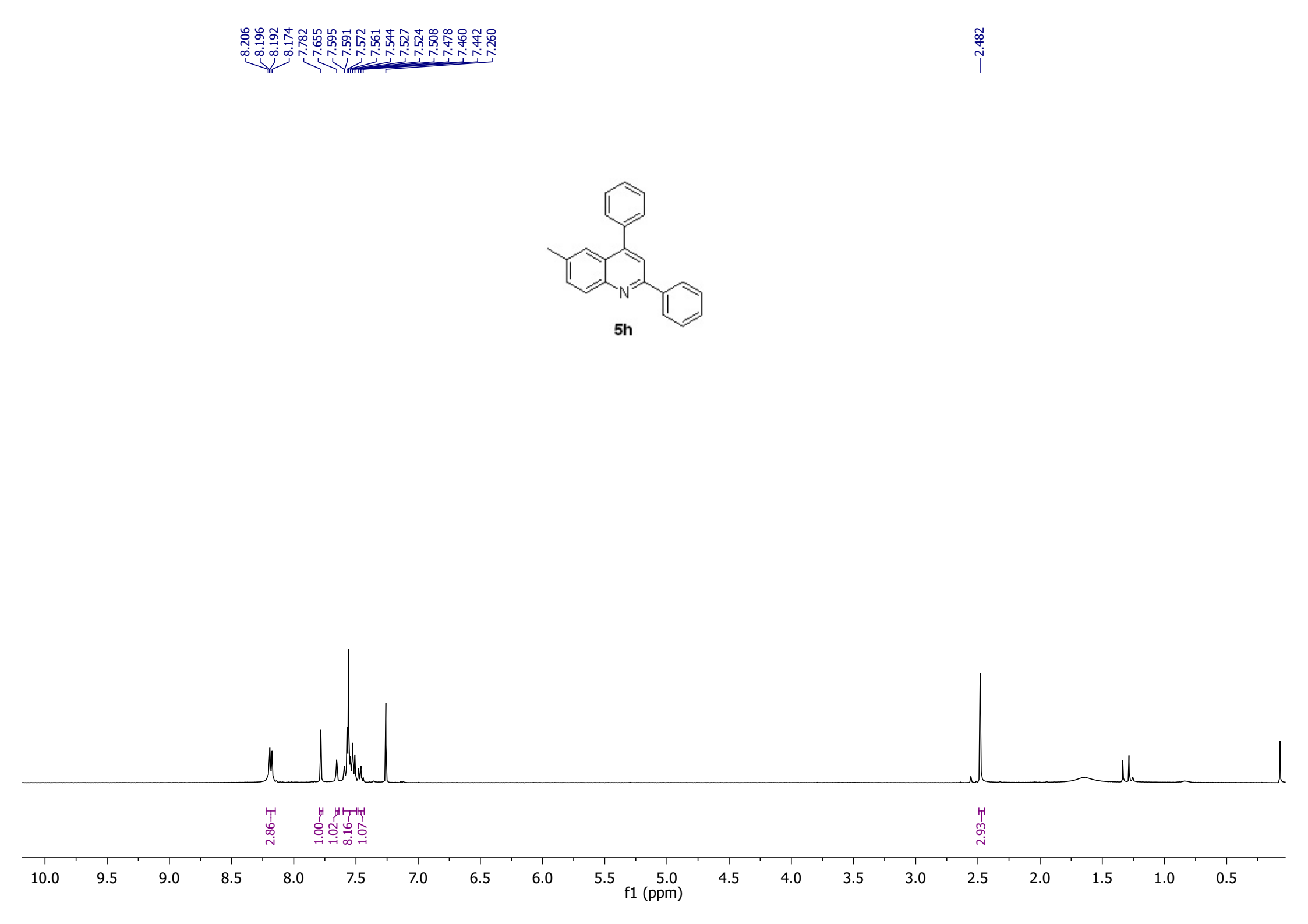
129.16
127.95
127.56
127.38
127.12
127.00
126.16
121.50
77.55
77.23
76.91
N
5g'
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.544
7.527
7.524
7.508
7.478
7.460
7.442
7.260
2.482
N
5h
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1.00
1.02
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1.07
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7.5
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6.5
6.0
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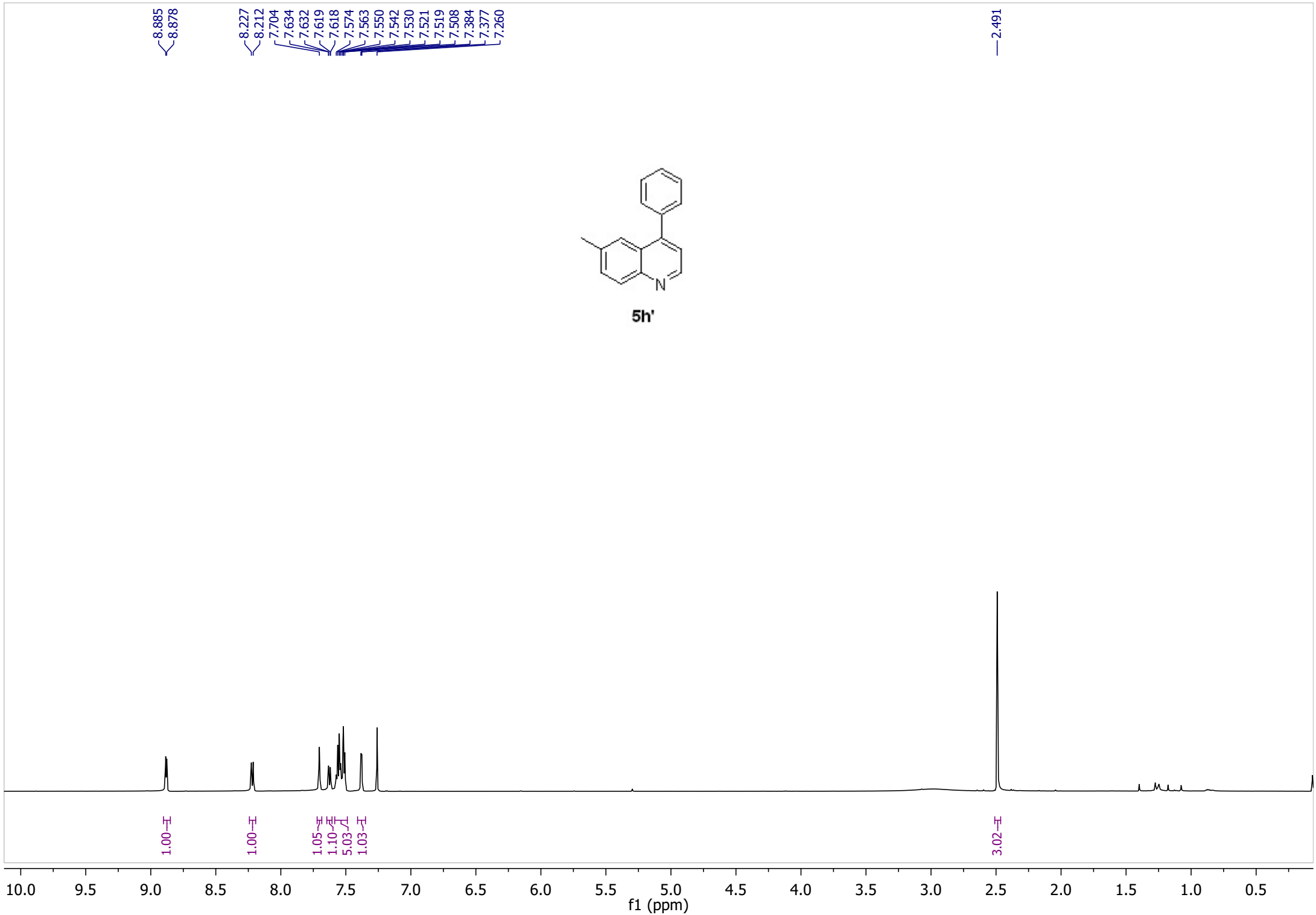
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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7.542
7.530
7.521
7.519
7.508
7.384
7.377
7.260
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N
5h'
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1.00
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1.10
5.03
1.03
3.02
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9.0
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8.0
7.5
7.0
6.5
6.0
5.5
5.0
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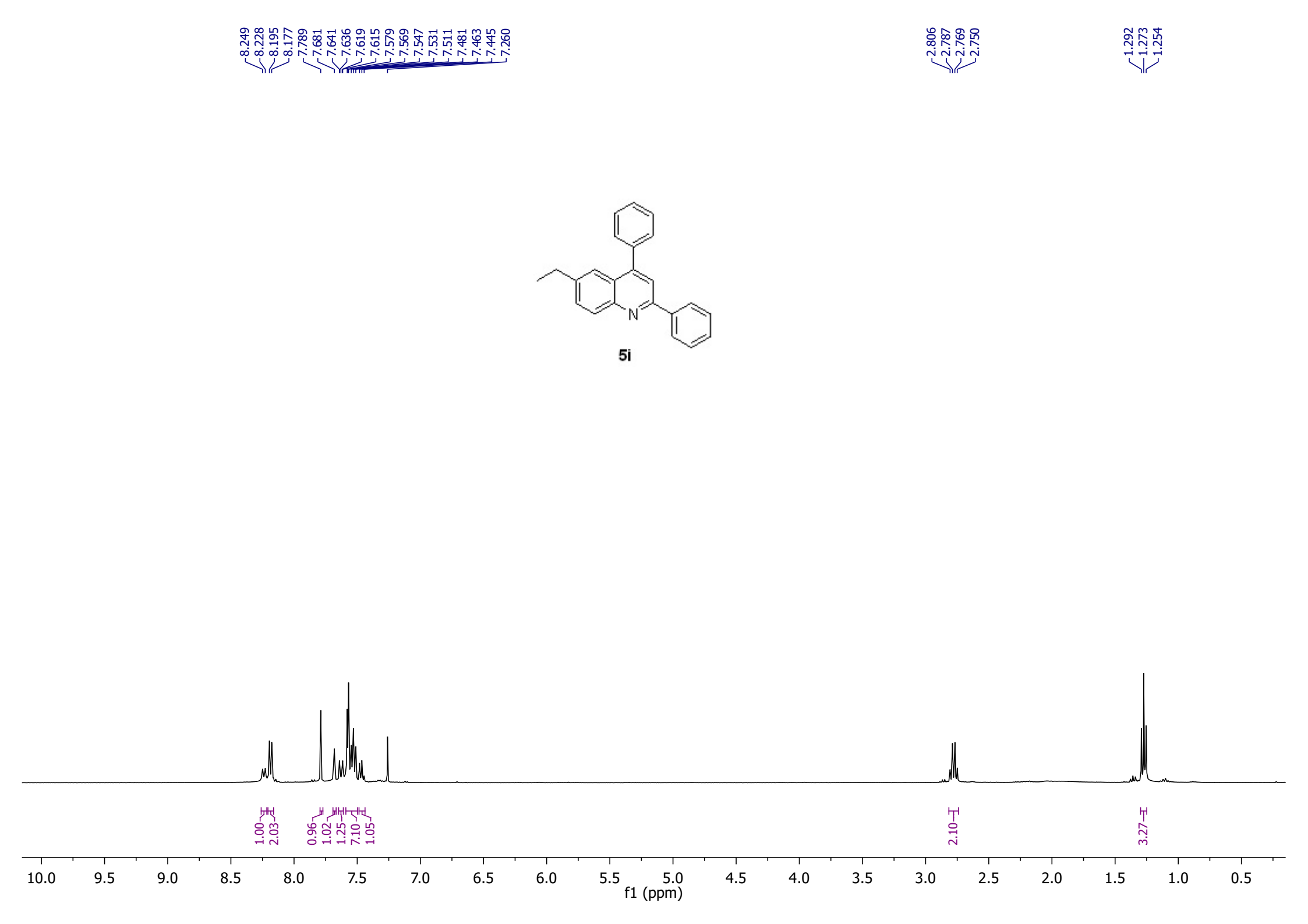
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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7.569
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7.531
7.511
7.481
7.463
7.445
7.260
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2.787
2.769
2.750
1.292
1.273
1.254
N
5i
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2.03
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1.05
2.10
3.27
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9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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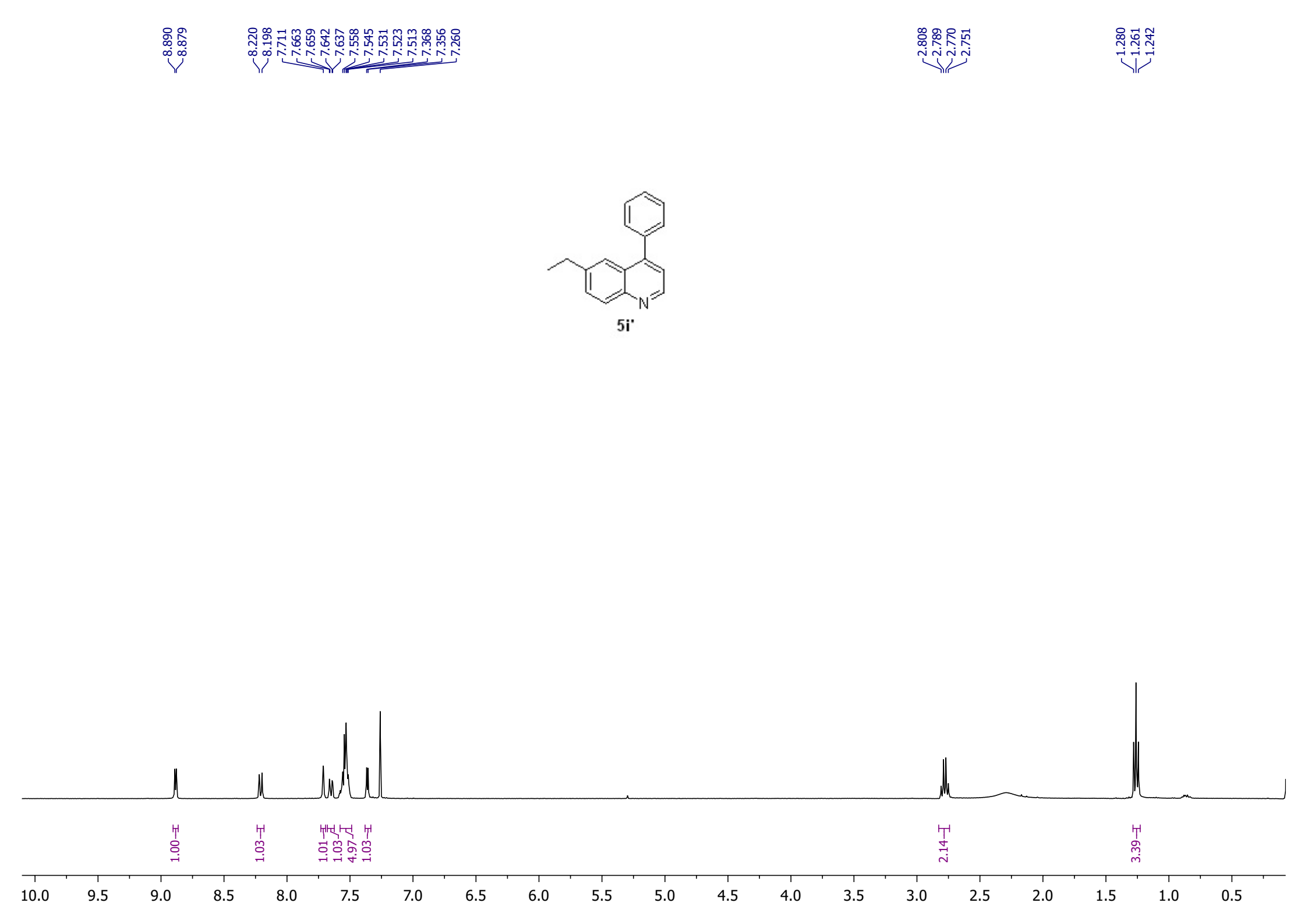
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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7.558
7.545
7.531
7.523
7.513
7.368
7.356
7.260
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2.789
2.770
2.751
1.280
1.261
1.242
N
5i'
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1.01
1.03
4.97
1.03
2.14
3.39
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9.0
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8.0
7.5
7.0
6.5
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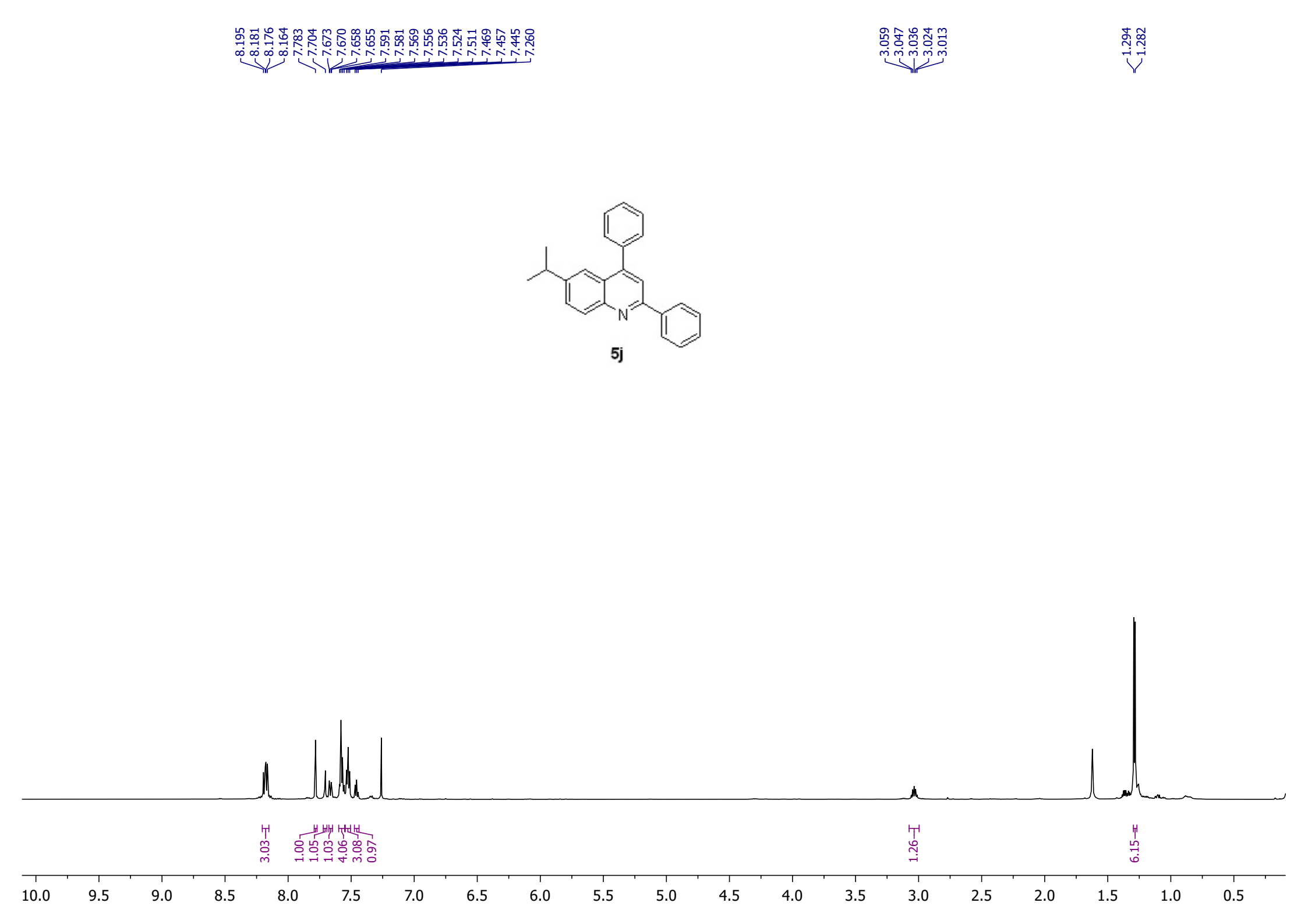
0.5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7.536
7.524
7.511
7.469
7.457
7.445
7.260
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3.047
3.036
3.024
3.013
1.294
1.282
N
5j
3.03
1.00
1.05
1.03
4.06
3.08
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1.26
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7.5
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6.5
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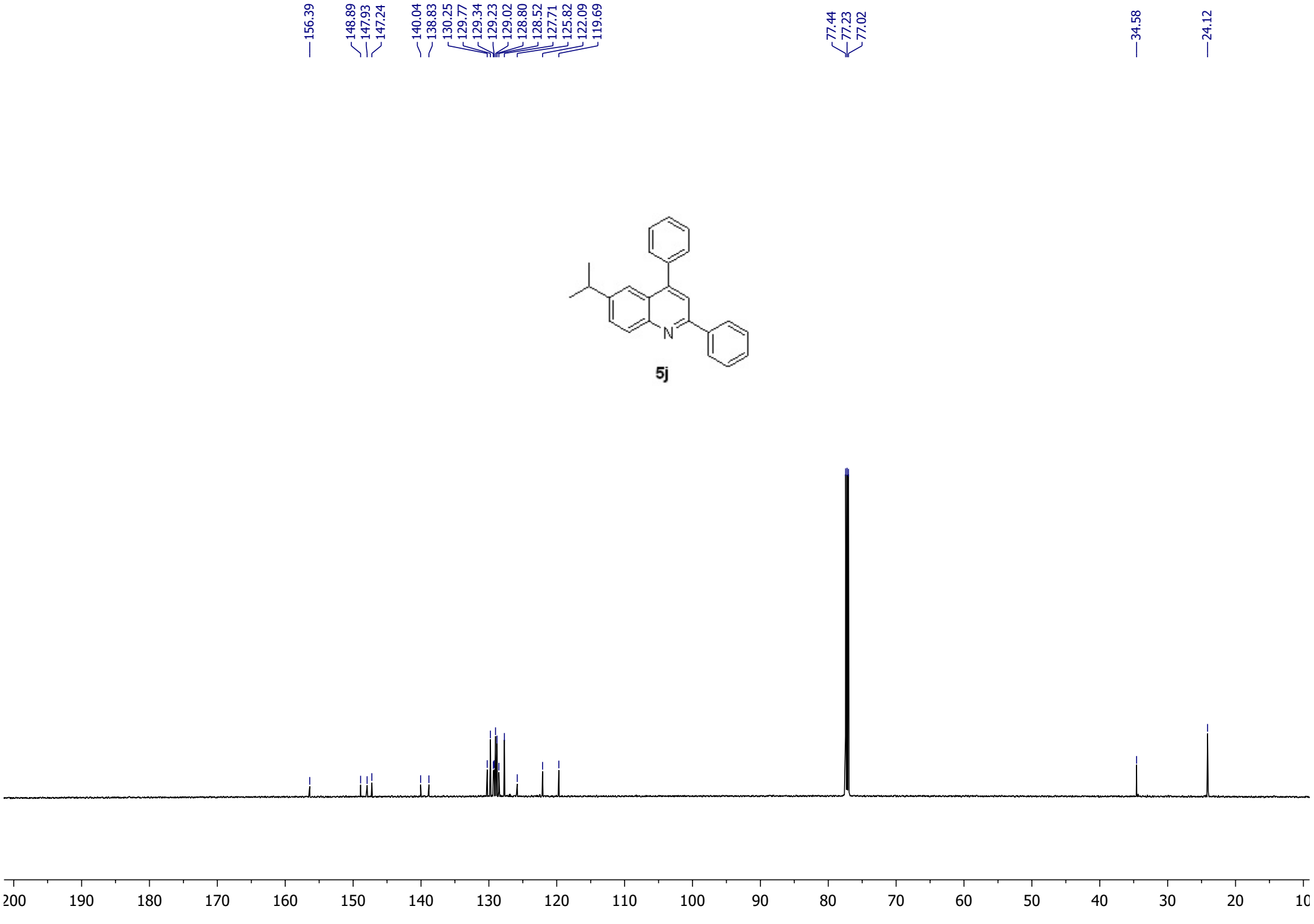
1.0
0.5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125.82
122.09
119.69
77.44
77.23
77.02
34.58
24.12
N
5j
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160
150
140
130
120
110
100
90
80
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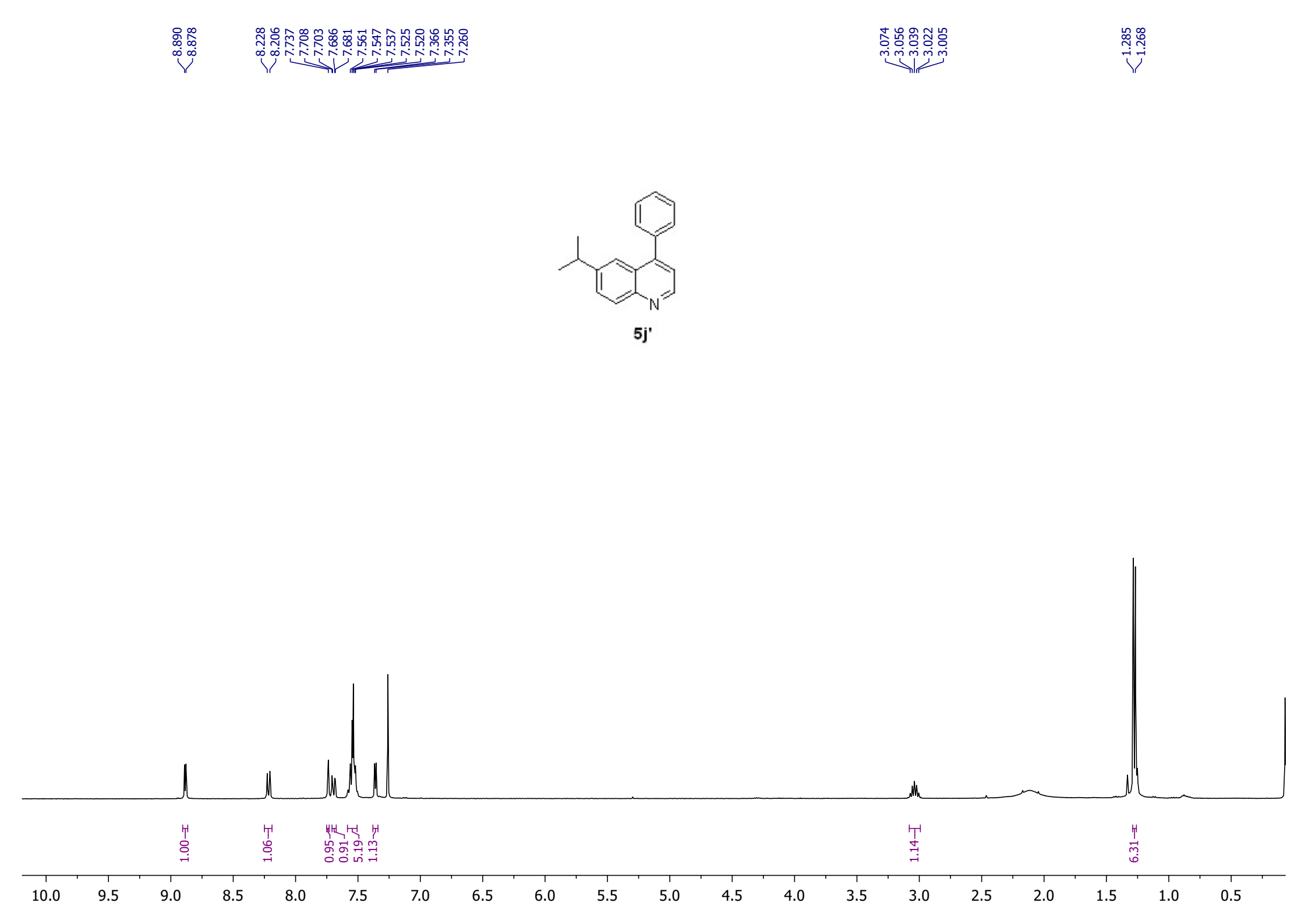
30
20
10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7.520
7.366
7.355
7.260
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3.056
3.039
3.022
3.005
1.285
1.268
N
5j'
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1.06
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0.91
5.19
1.13
1.14
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8.5
8.0
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7.0
6.5
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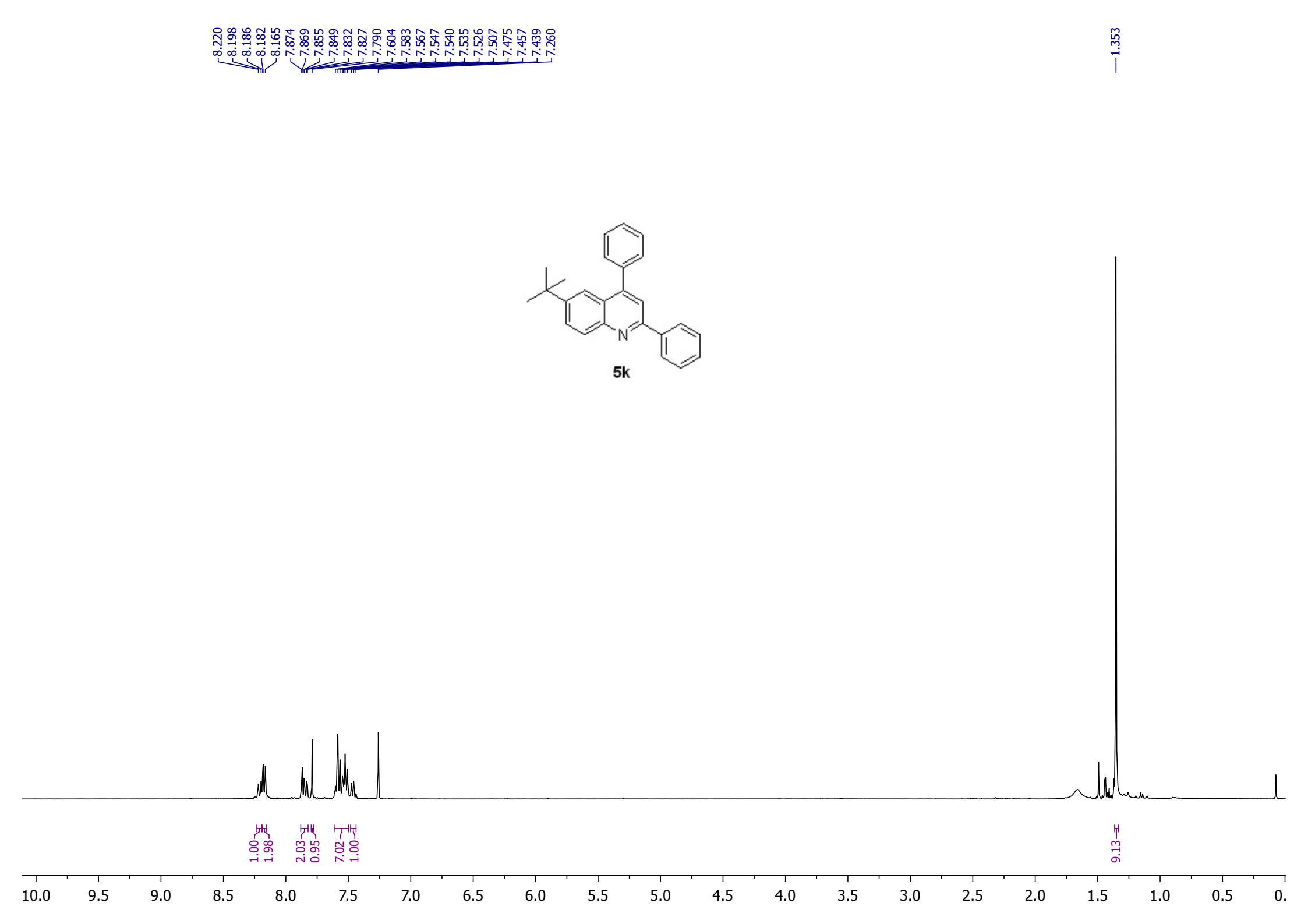
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7.567
7.547
7.540
7.535
7.526
7.507
7.475
7.457
7.439
7.260
1.353
5k
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7.02
1.00
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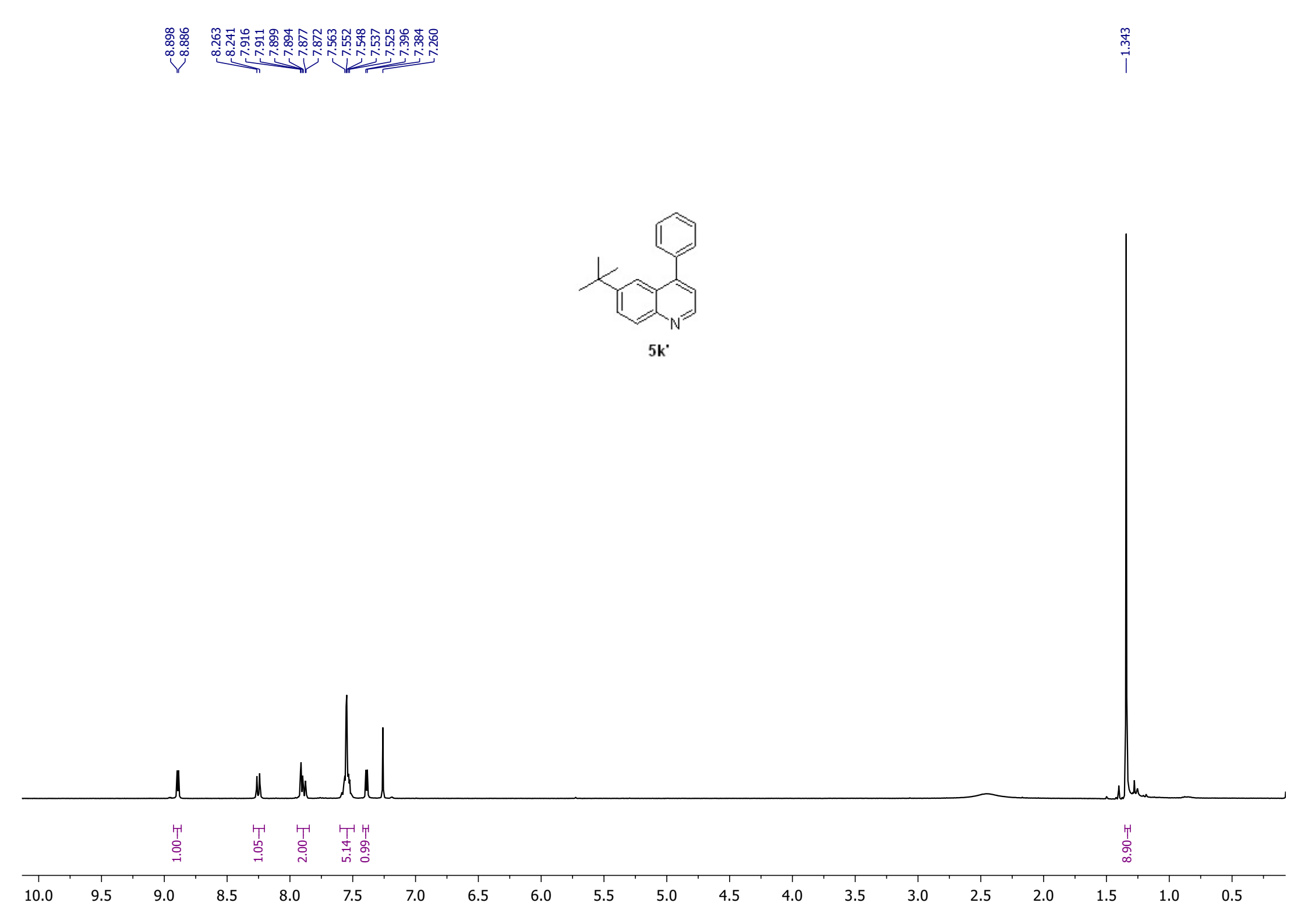
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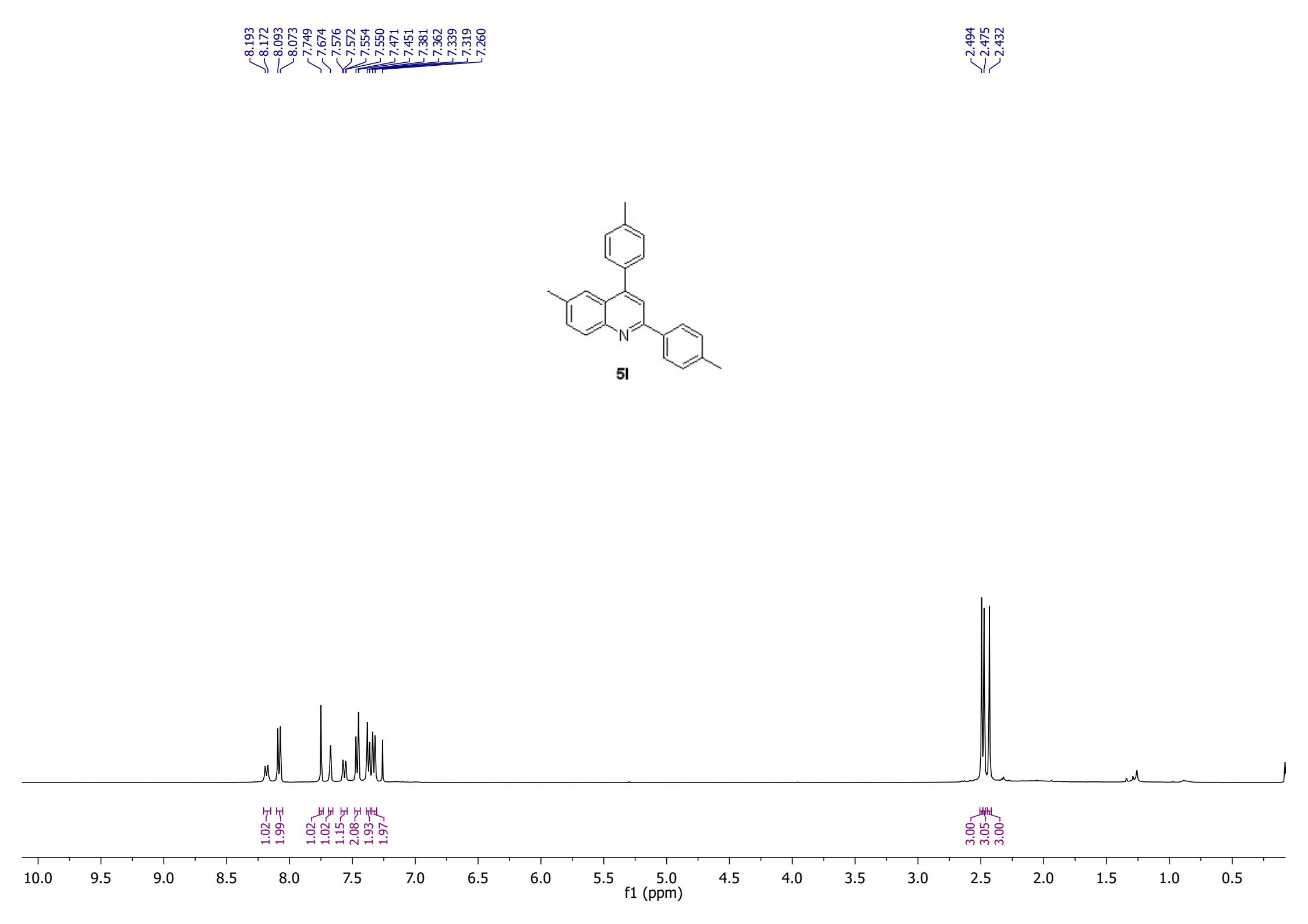
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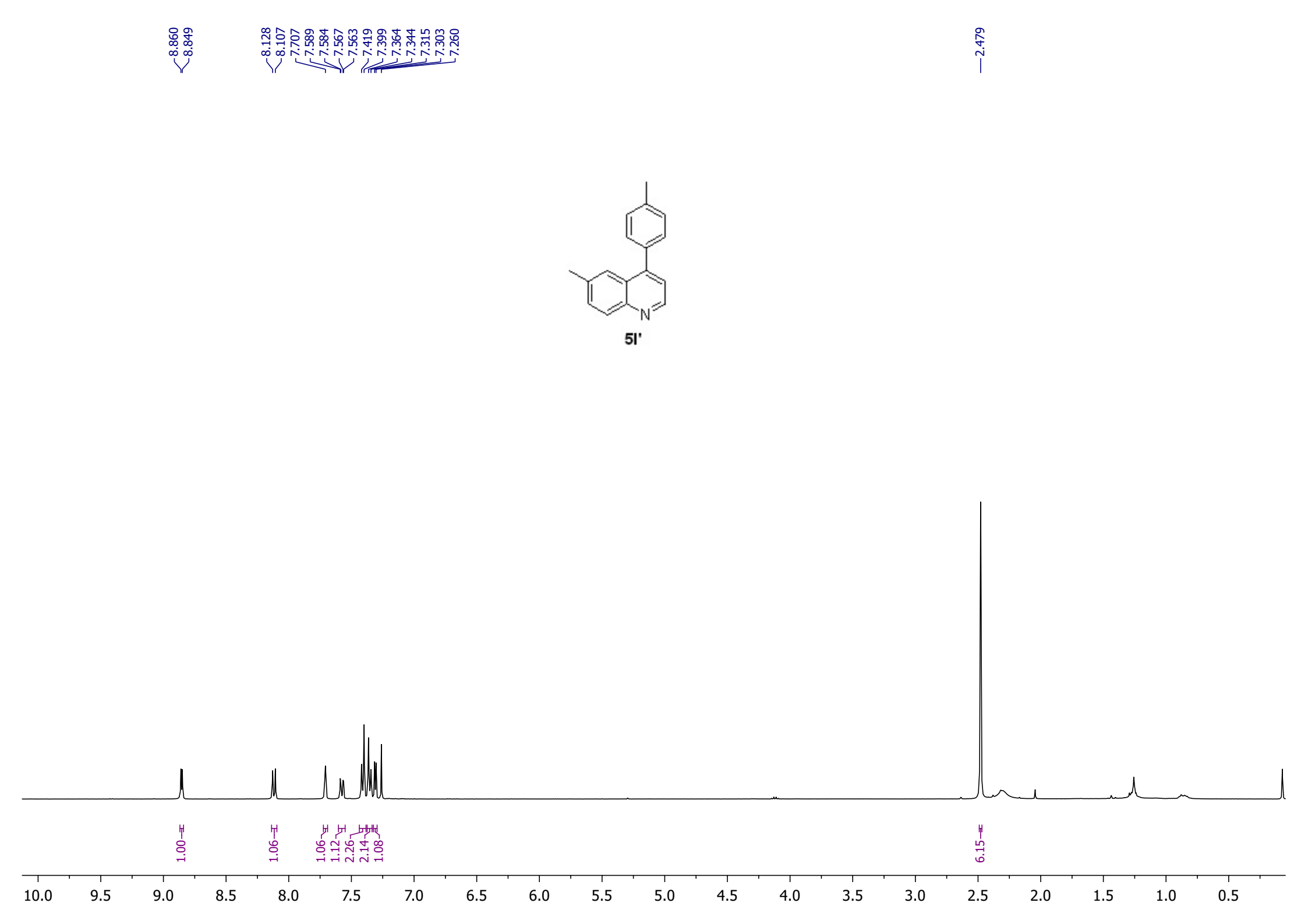
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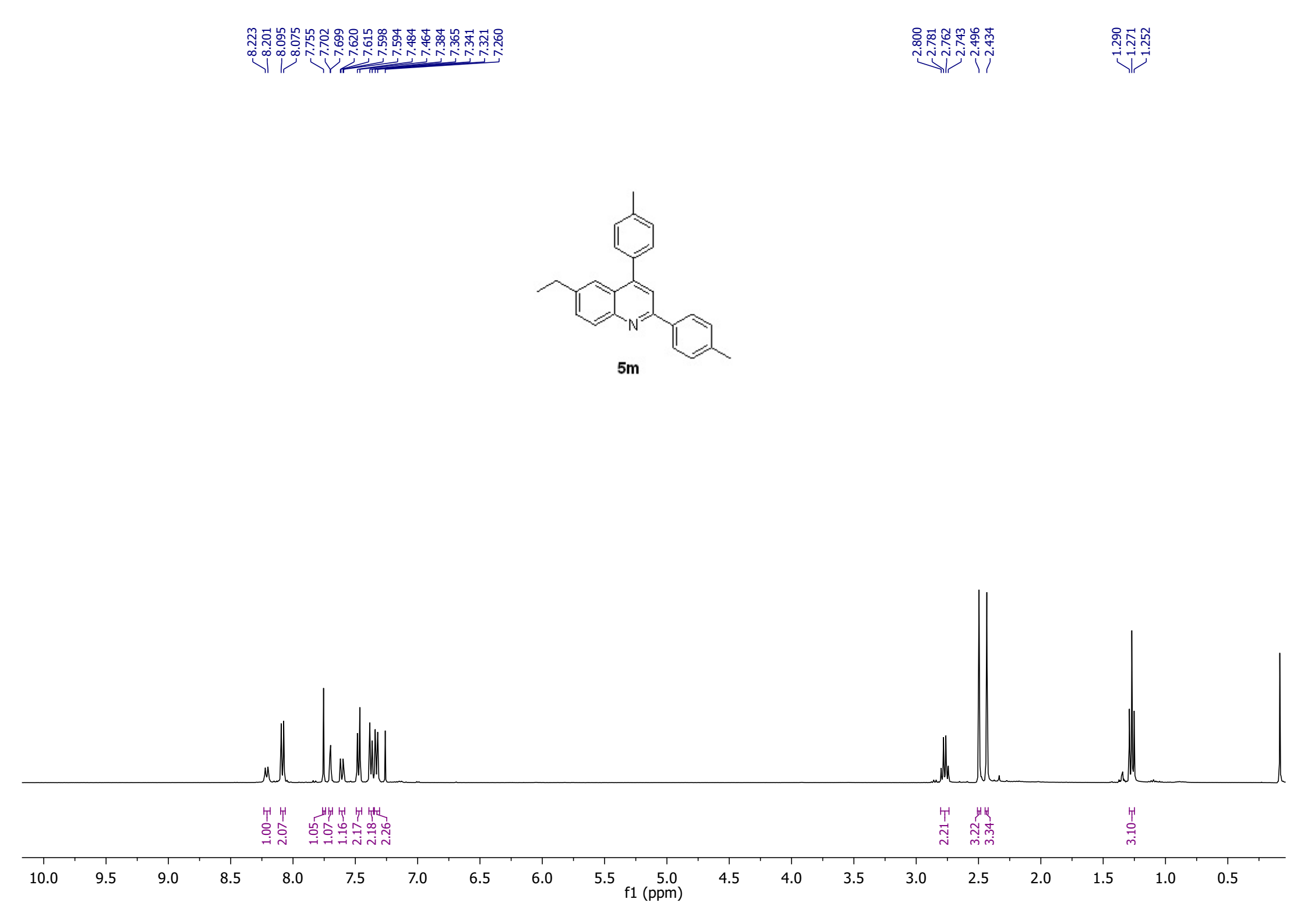
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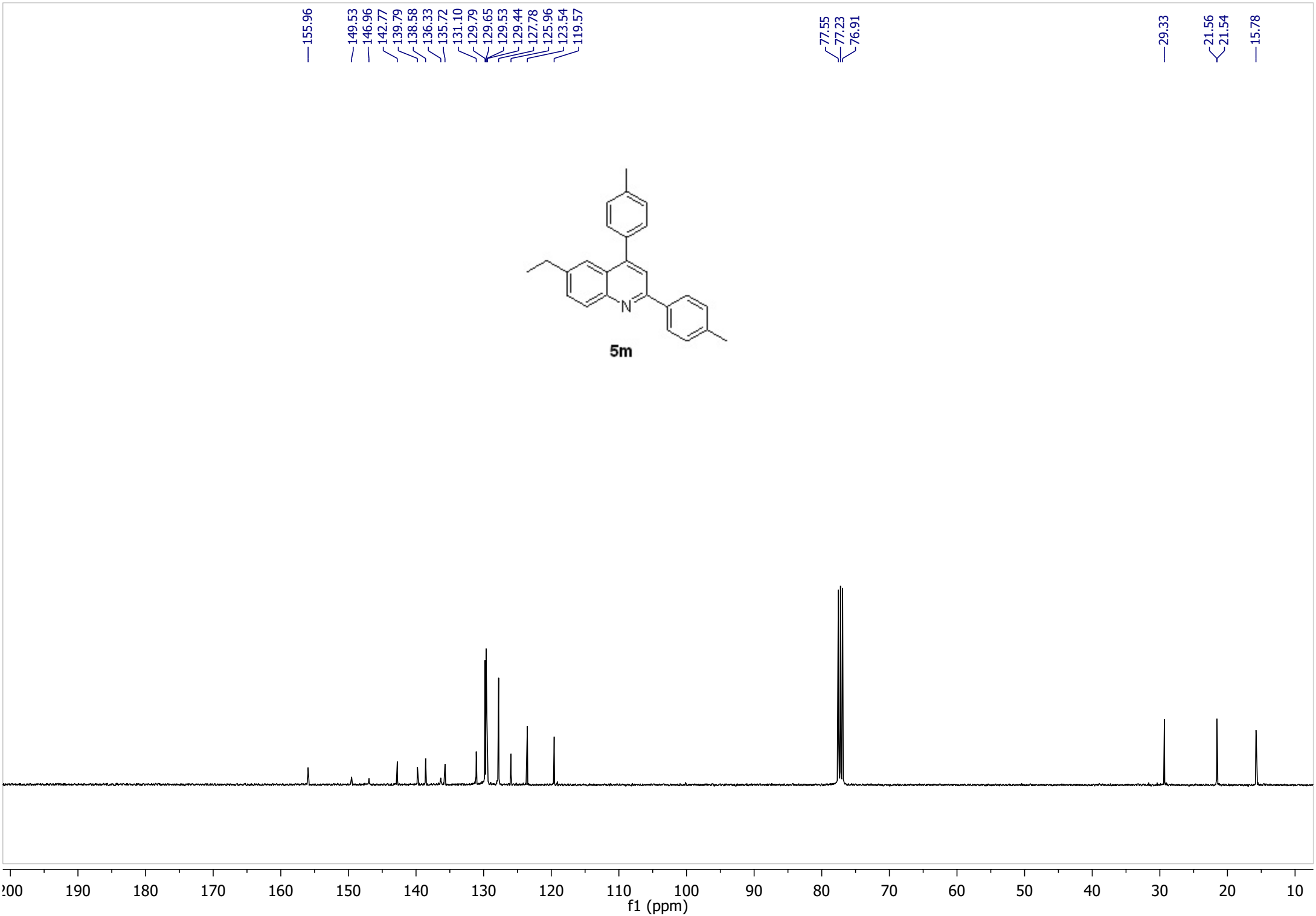
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123.54
119.57
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77.23
76.91
29.33
21.56
21.54
15.78
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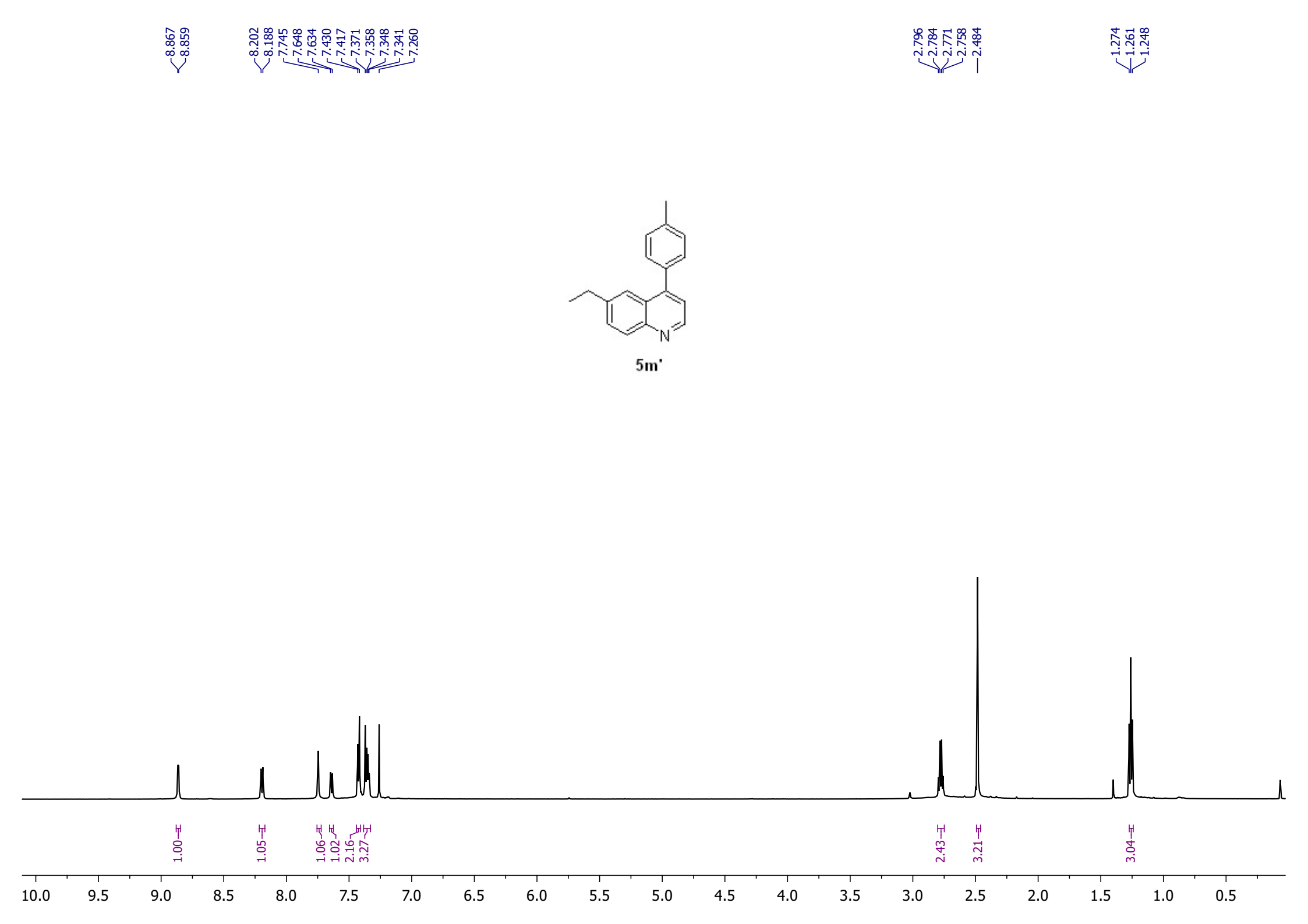
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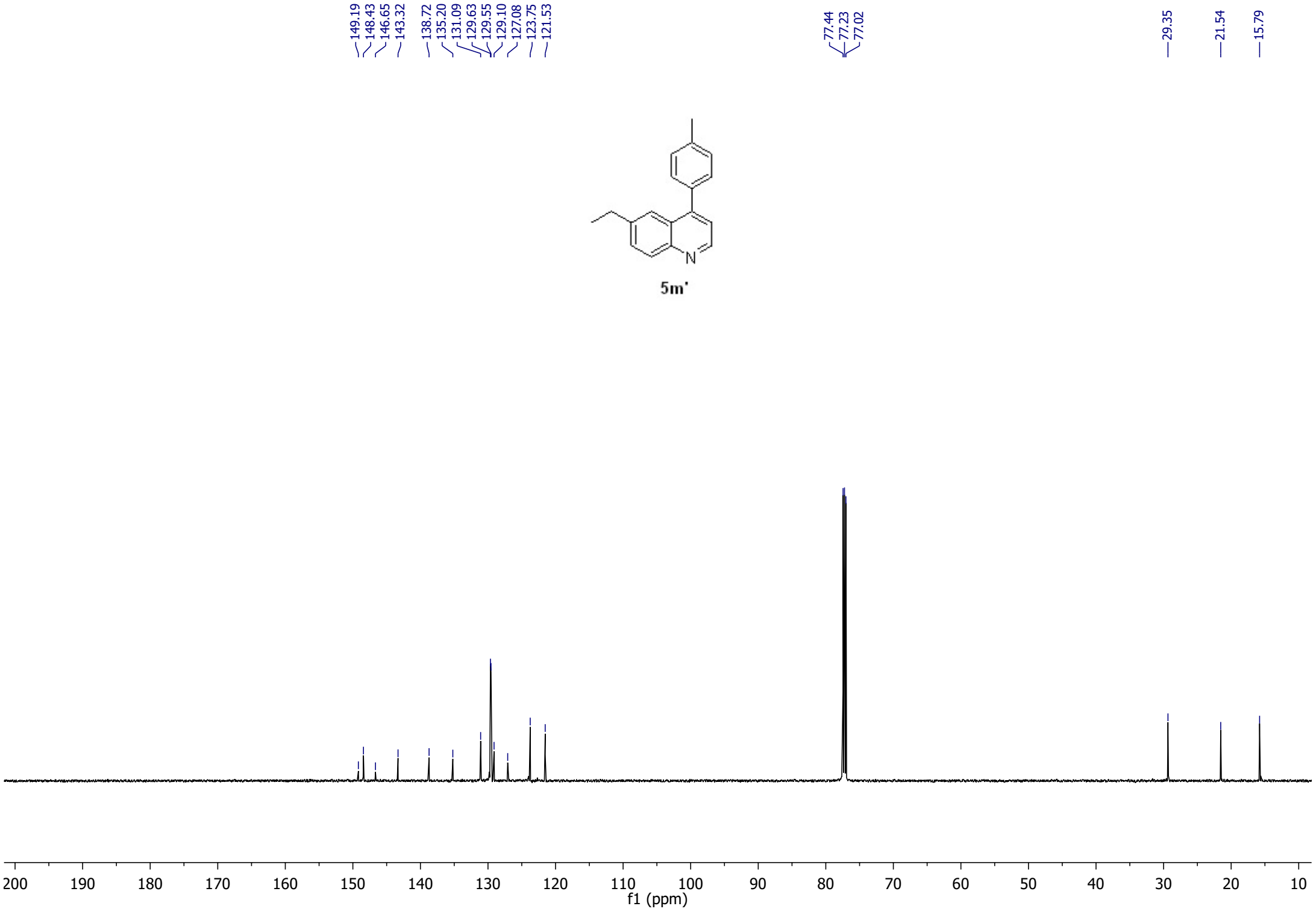
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15.79
N
5m'
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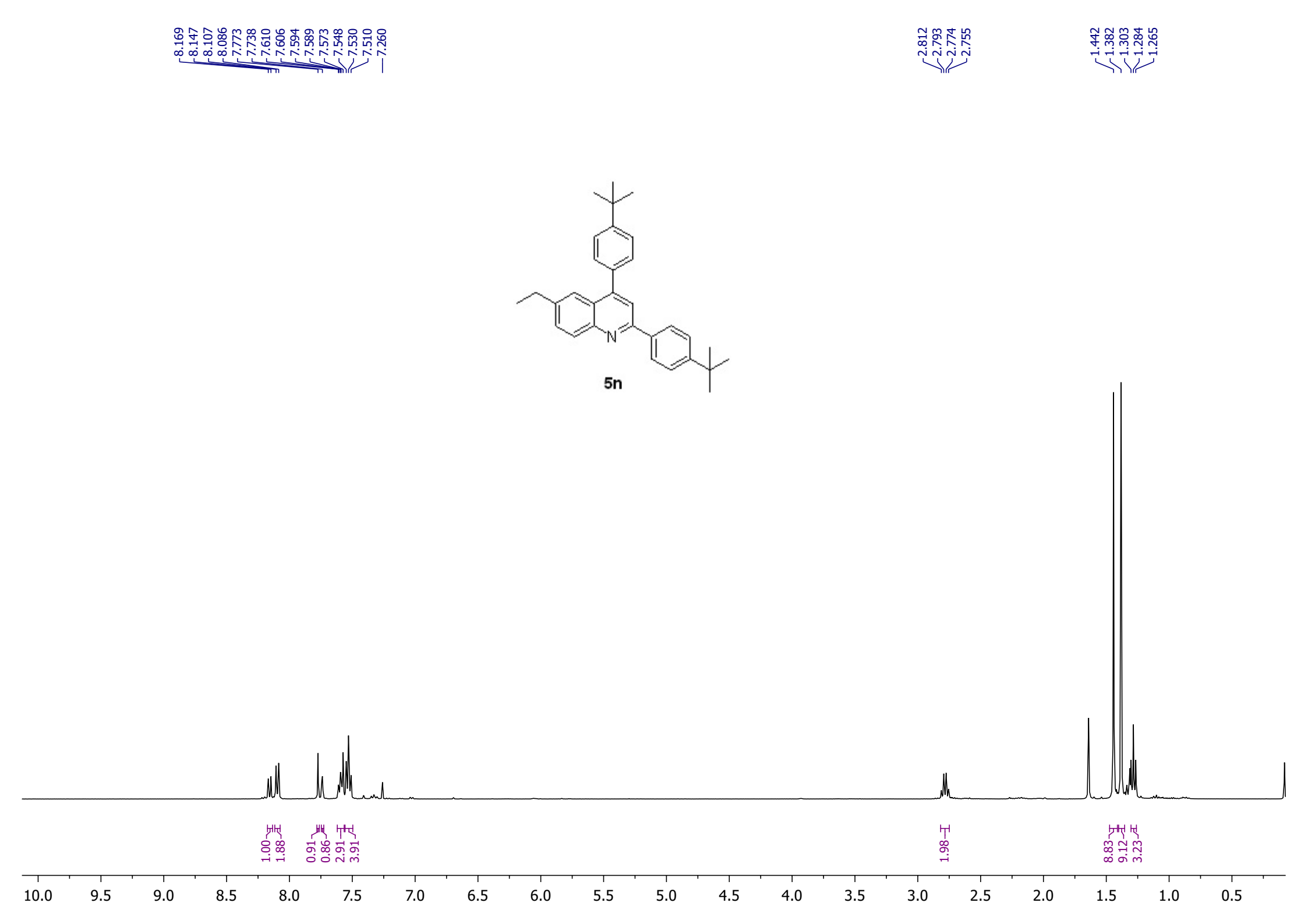
f1 (ppm)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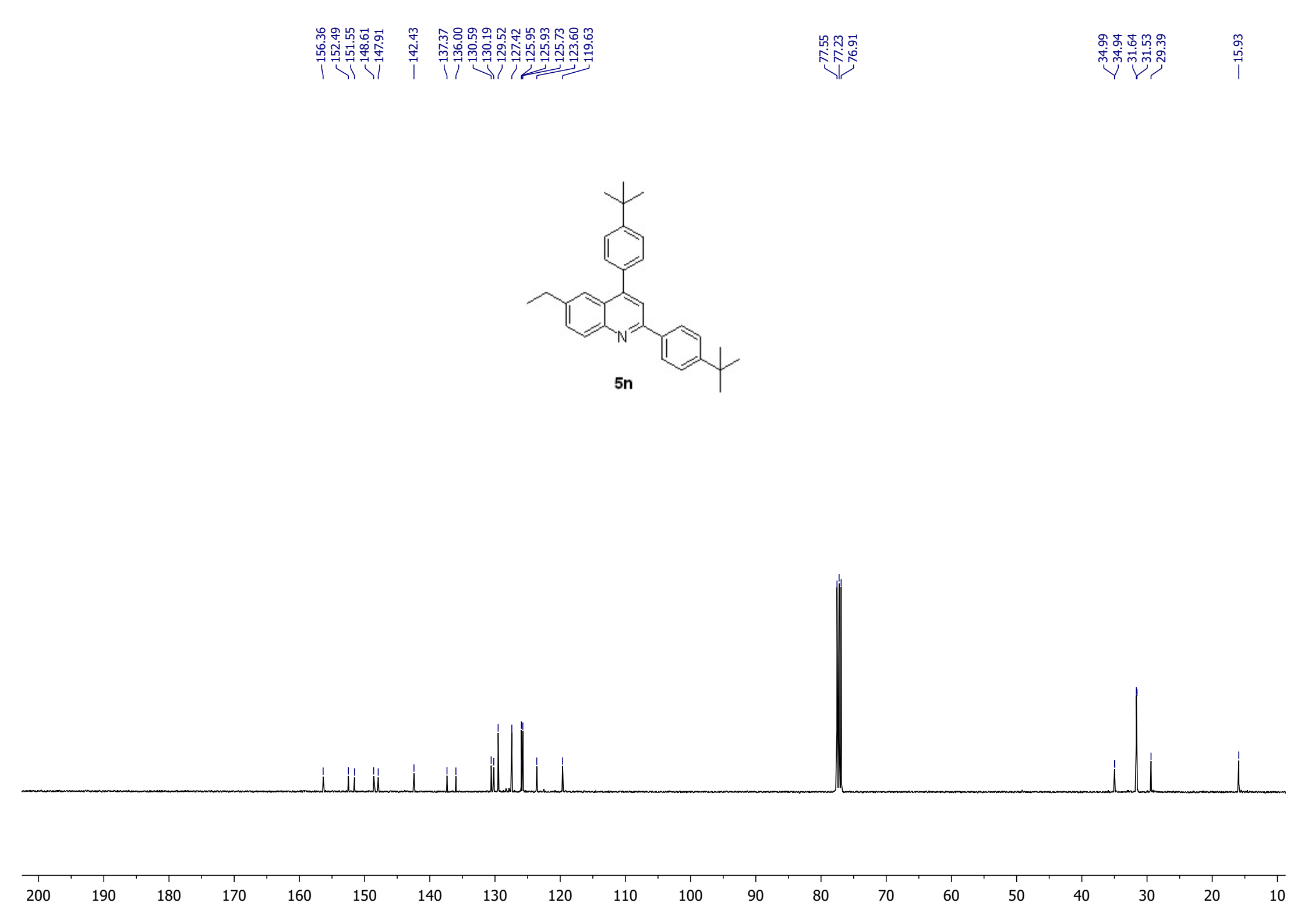
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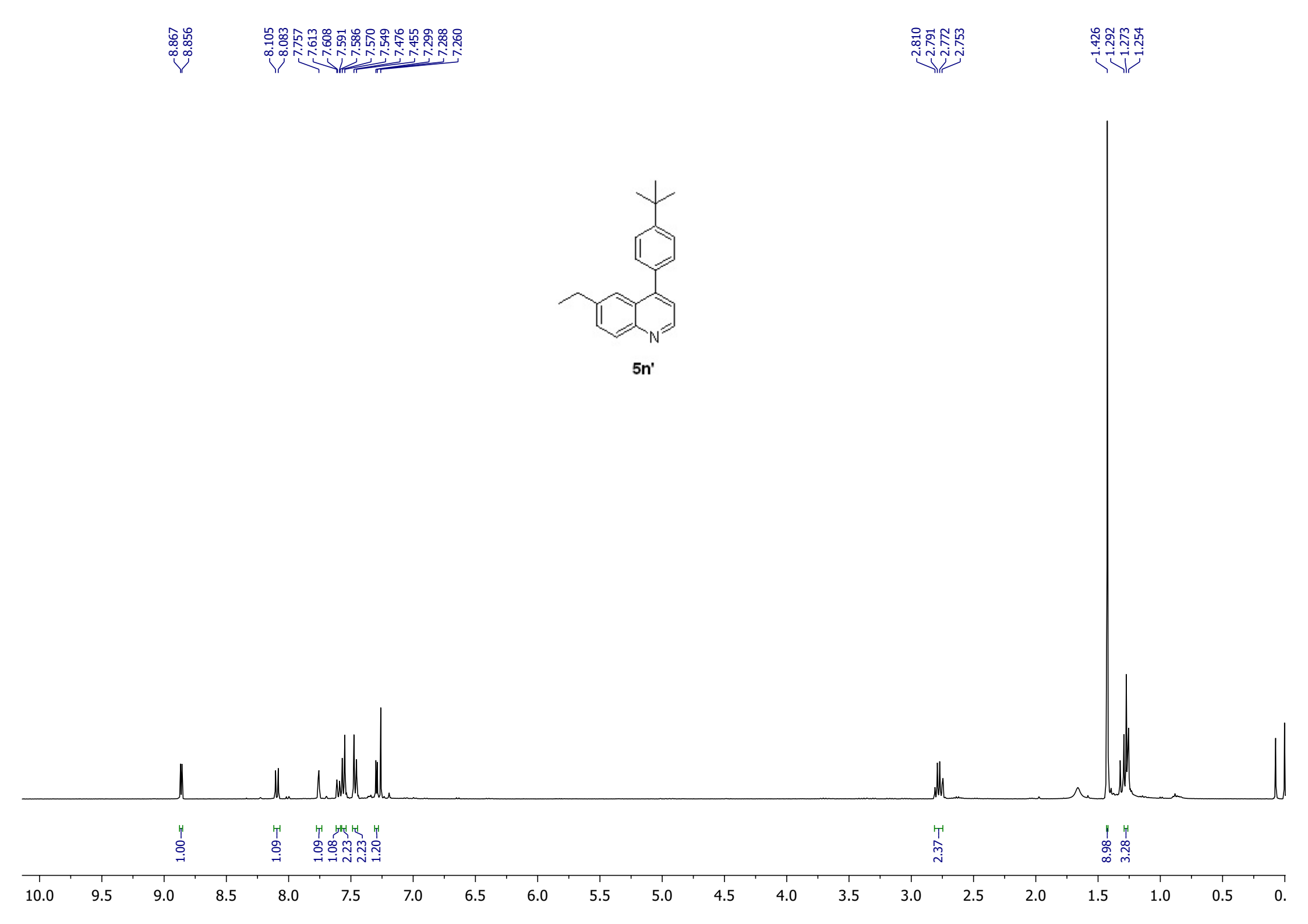
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1.09
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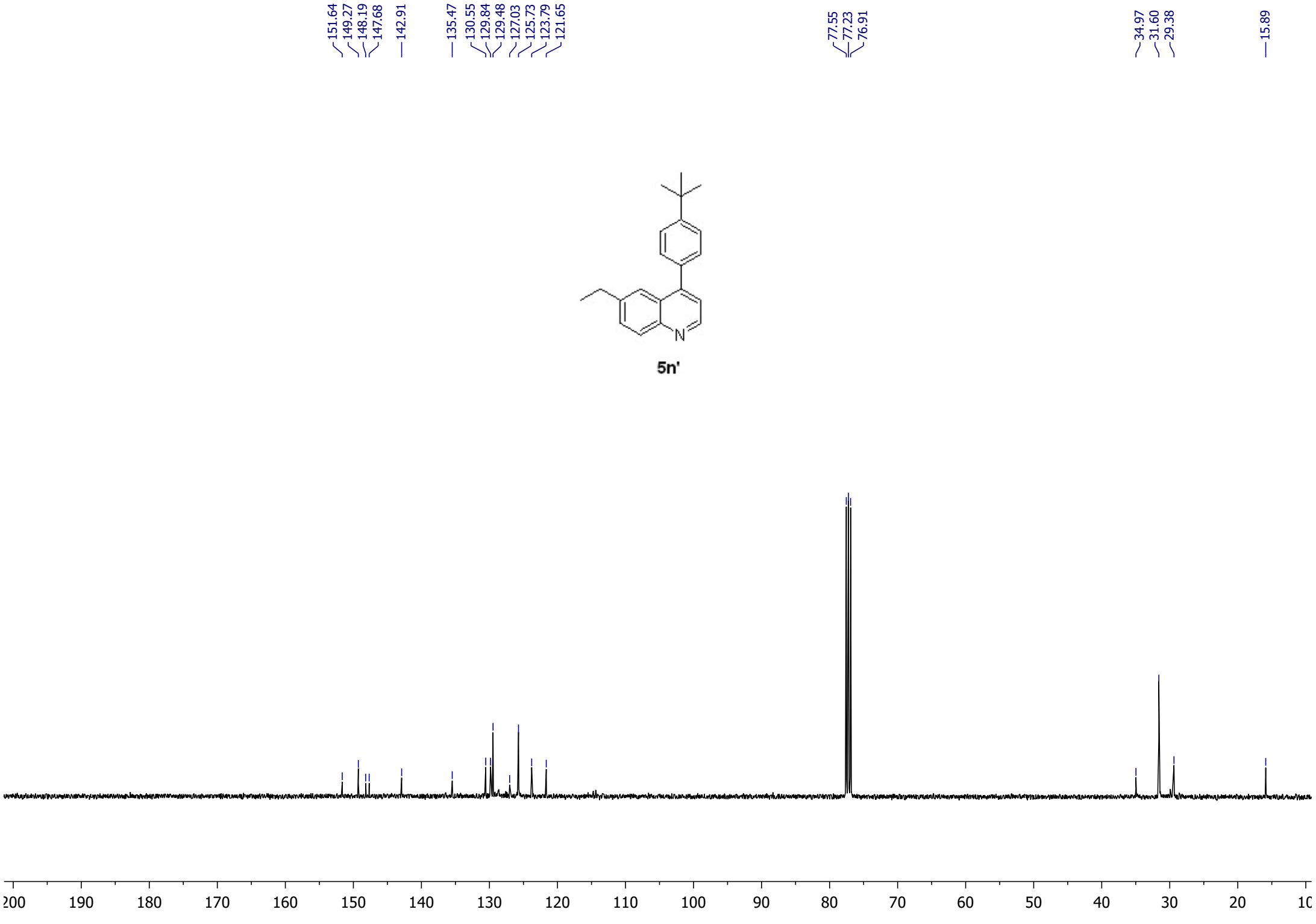
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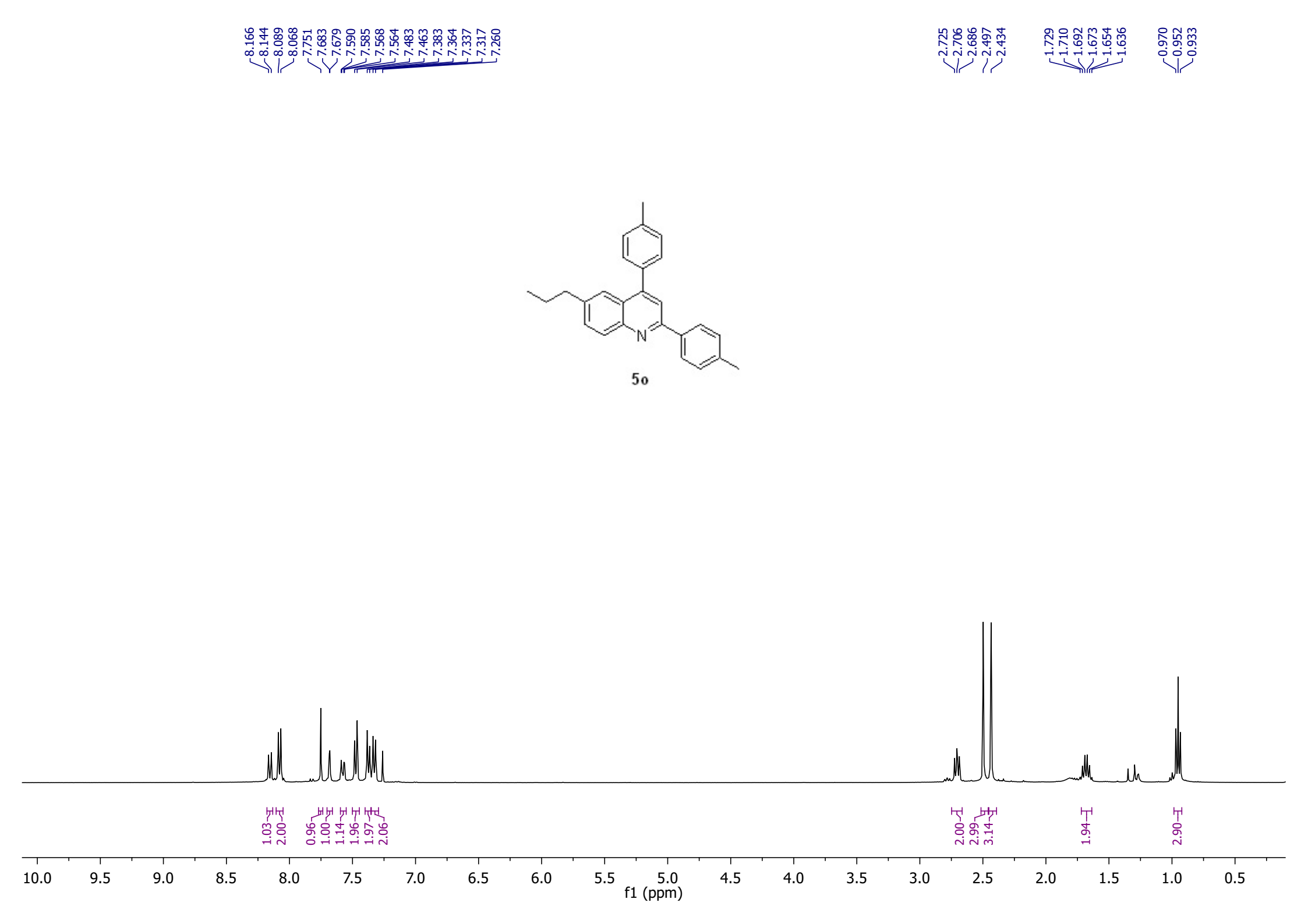
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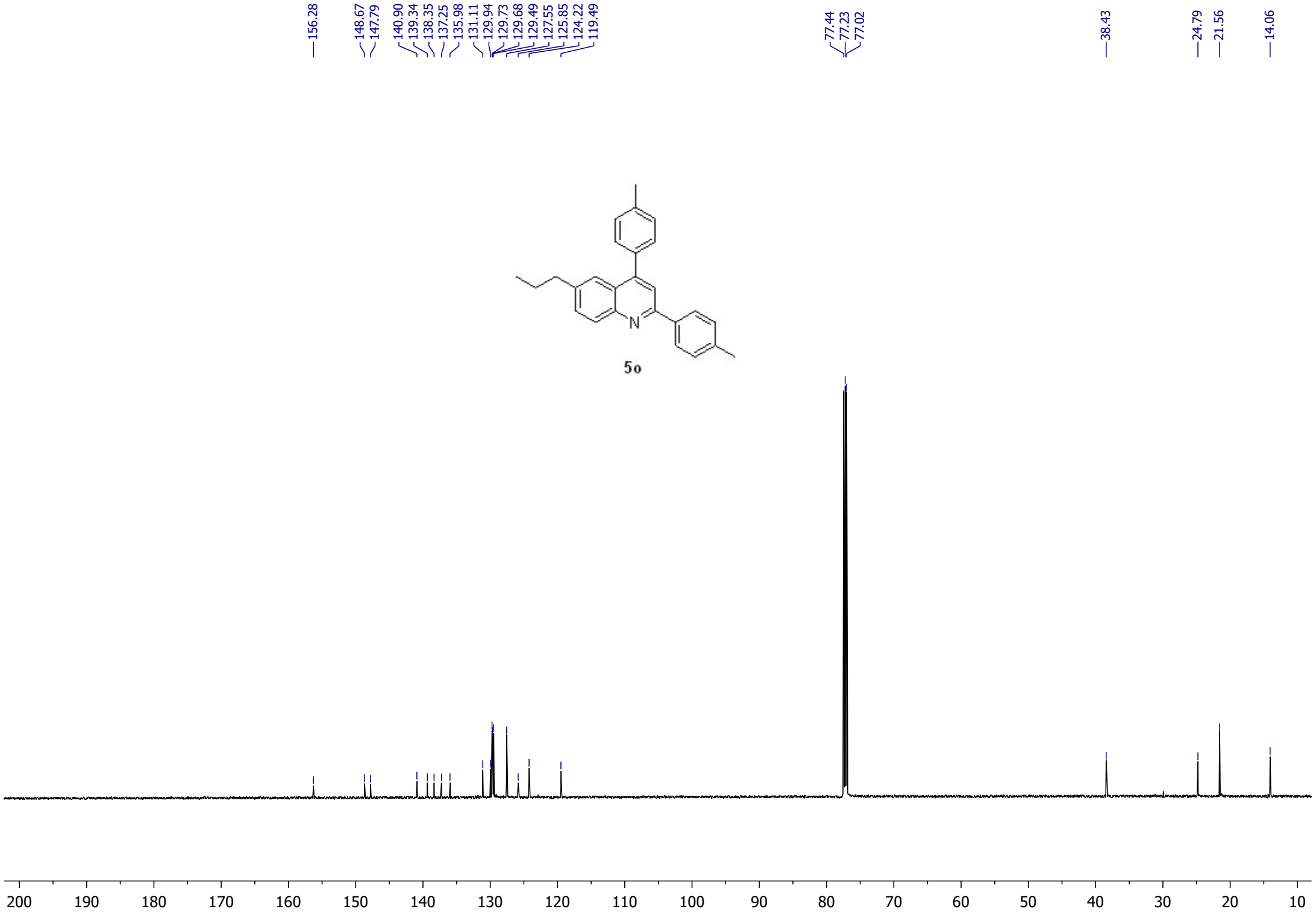
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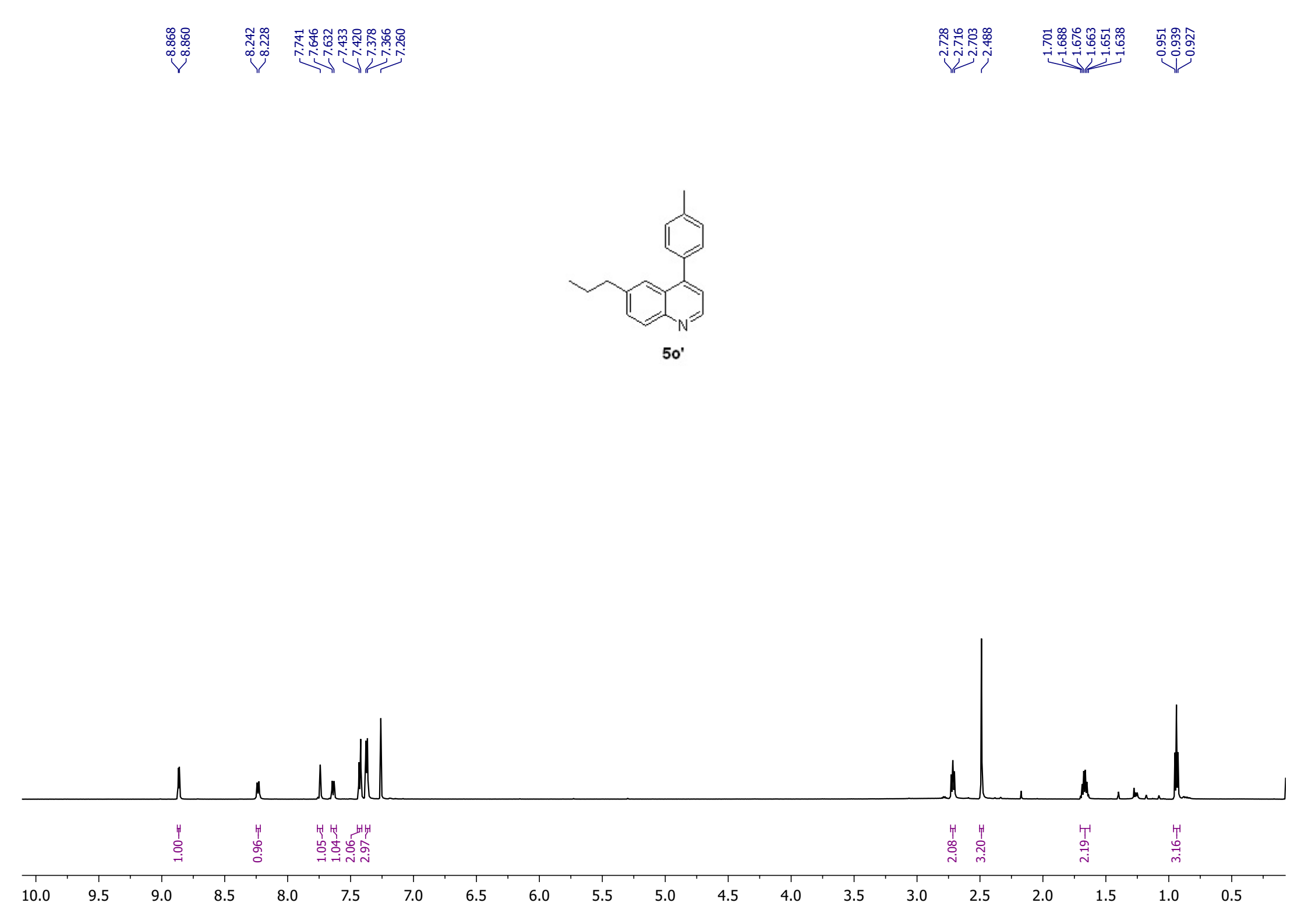
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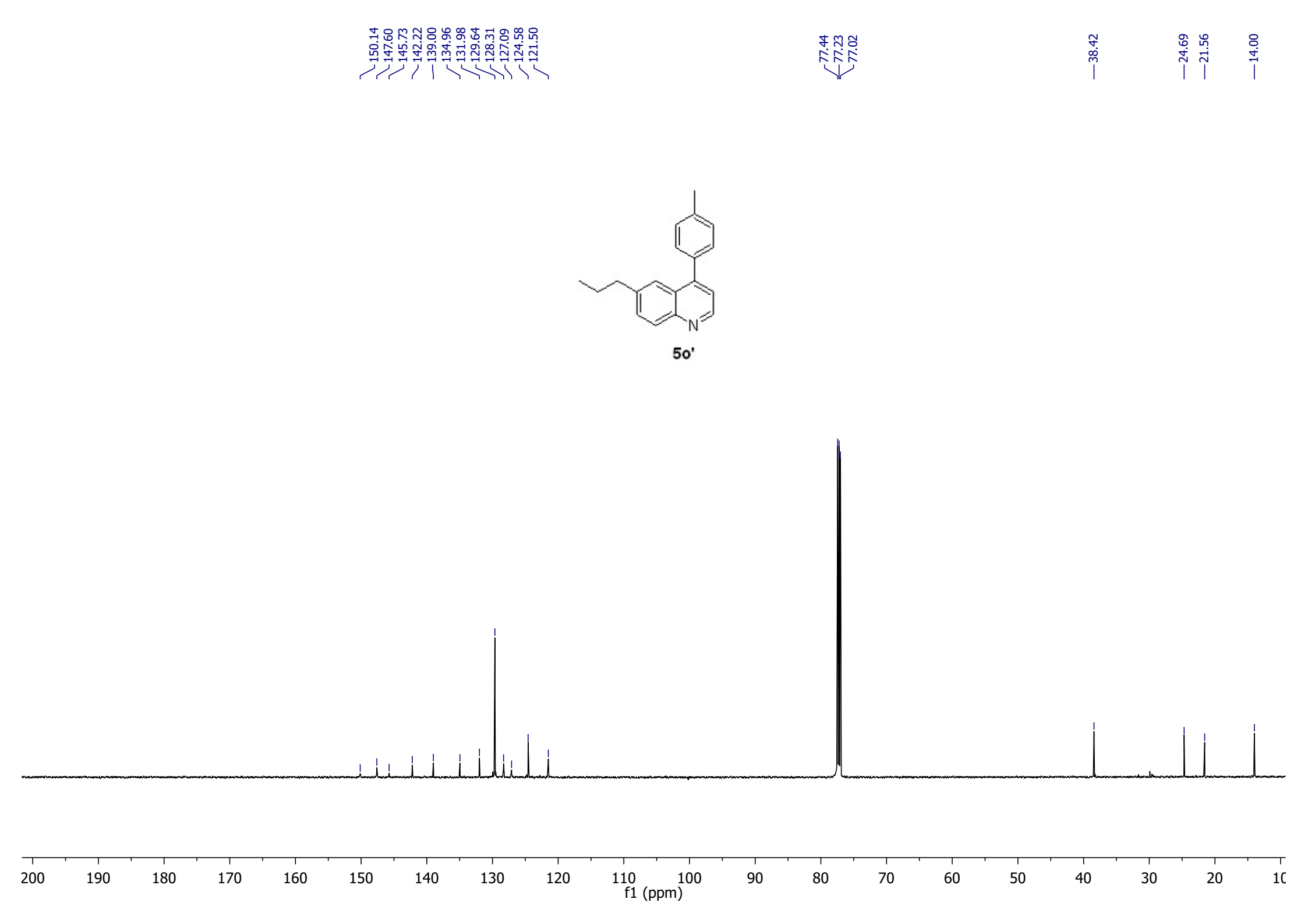
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77.23
77.02
38.42
24.69
21.56
14.00
N
5o'
200
190
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120
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100
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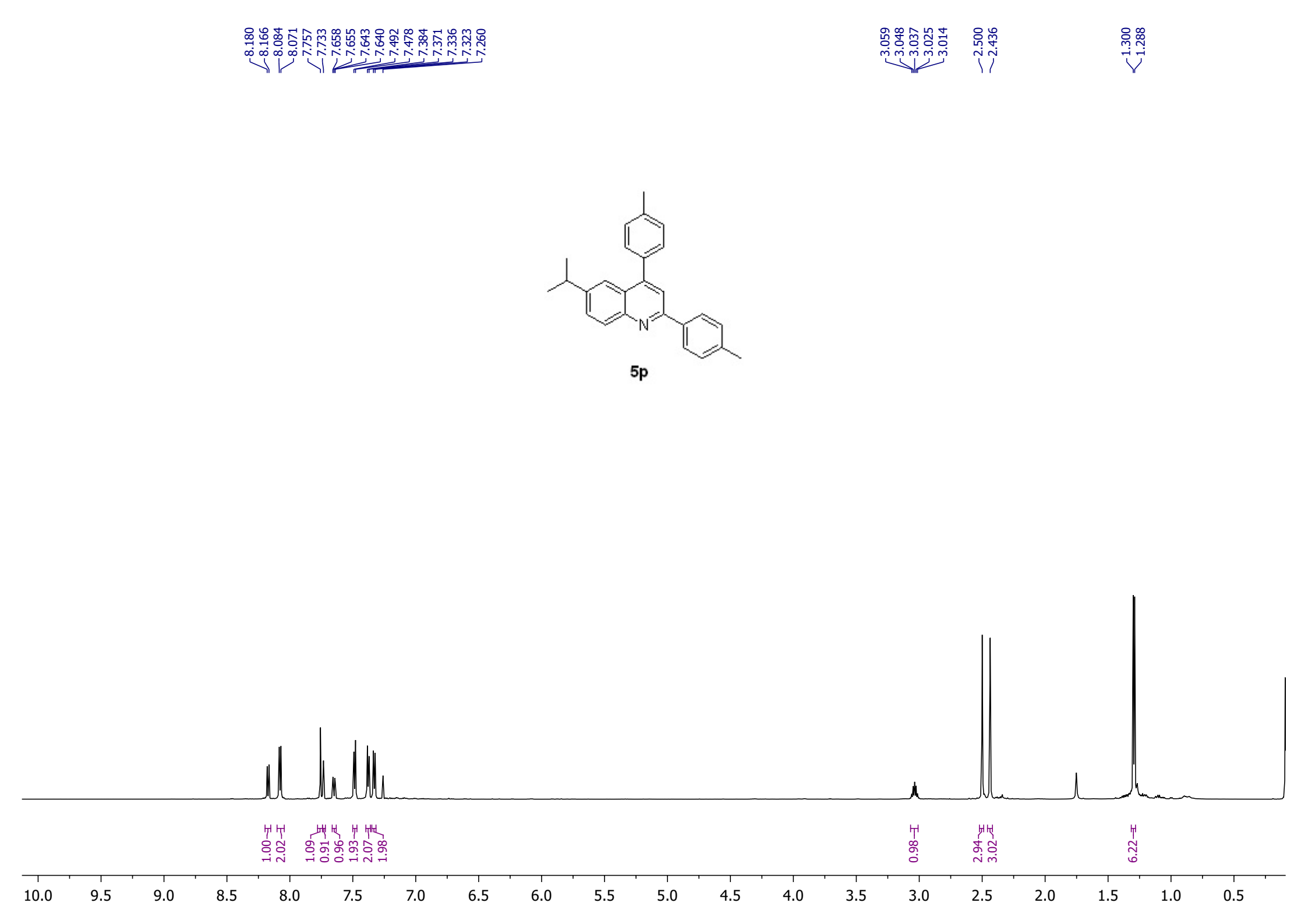
f1 (ppm)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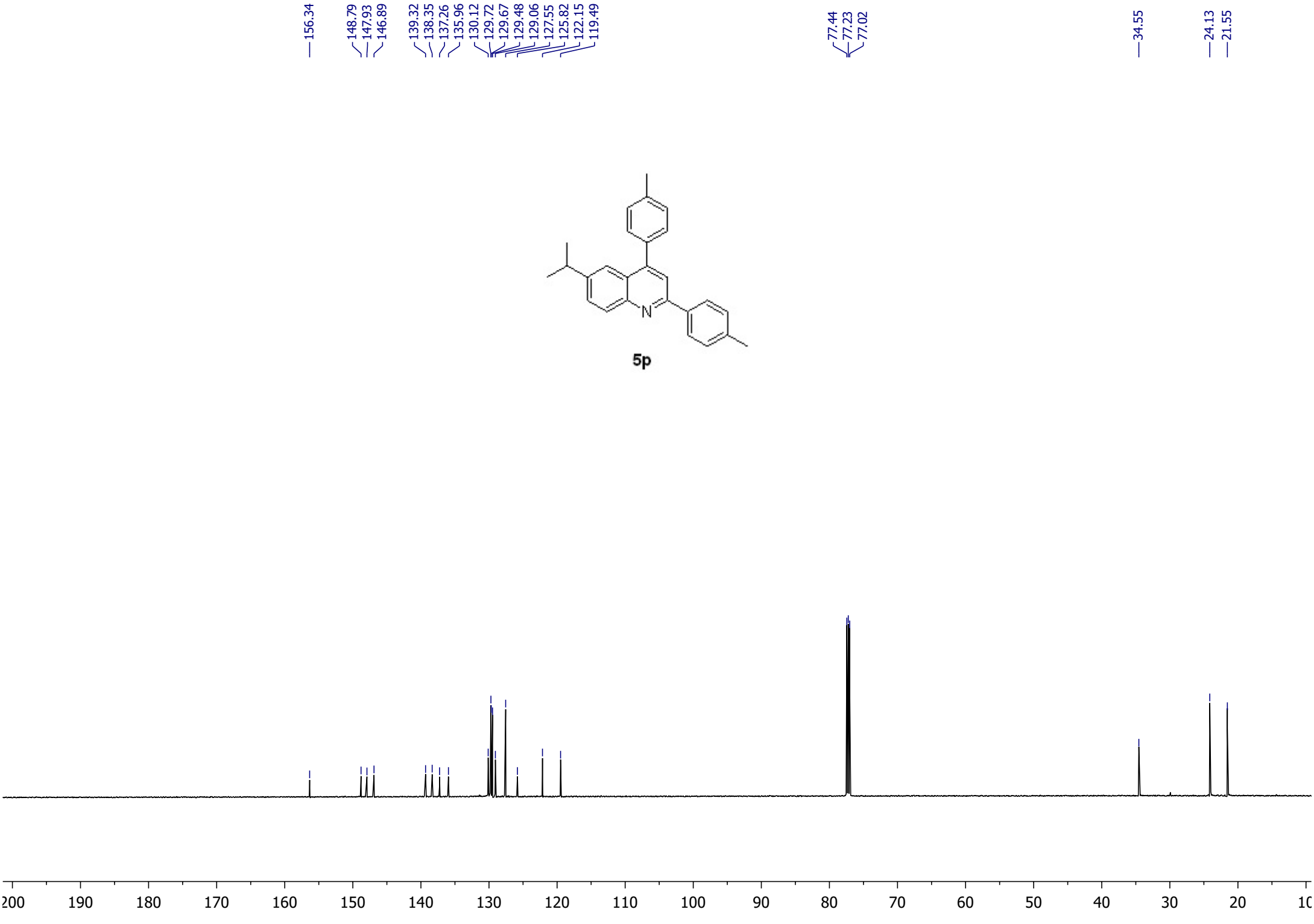
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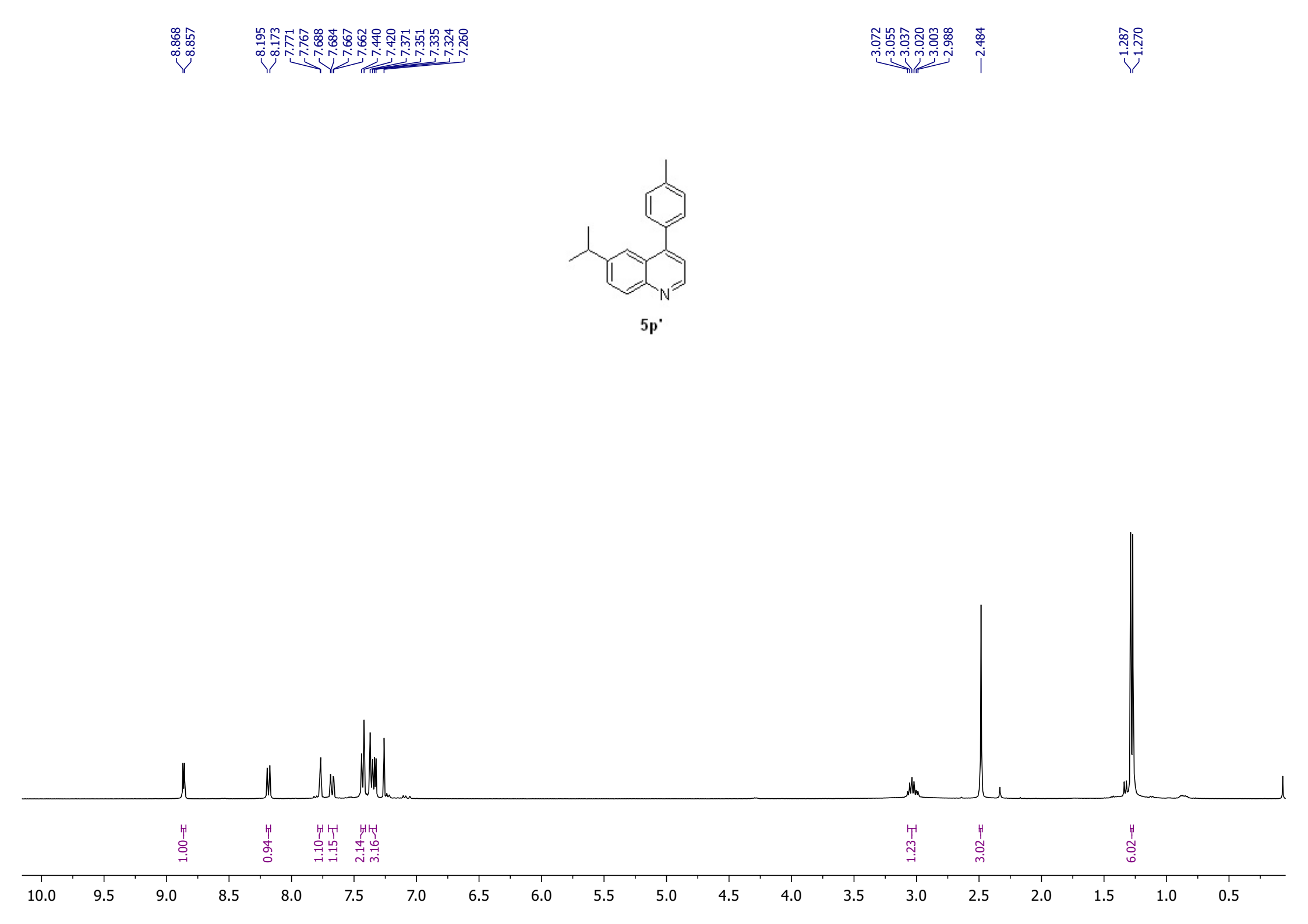
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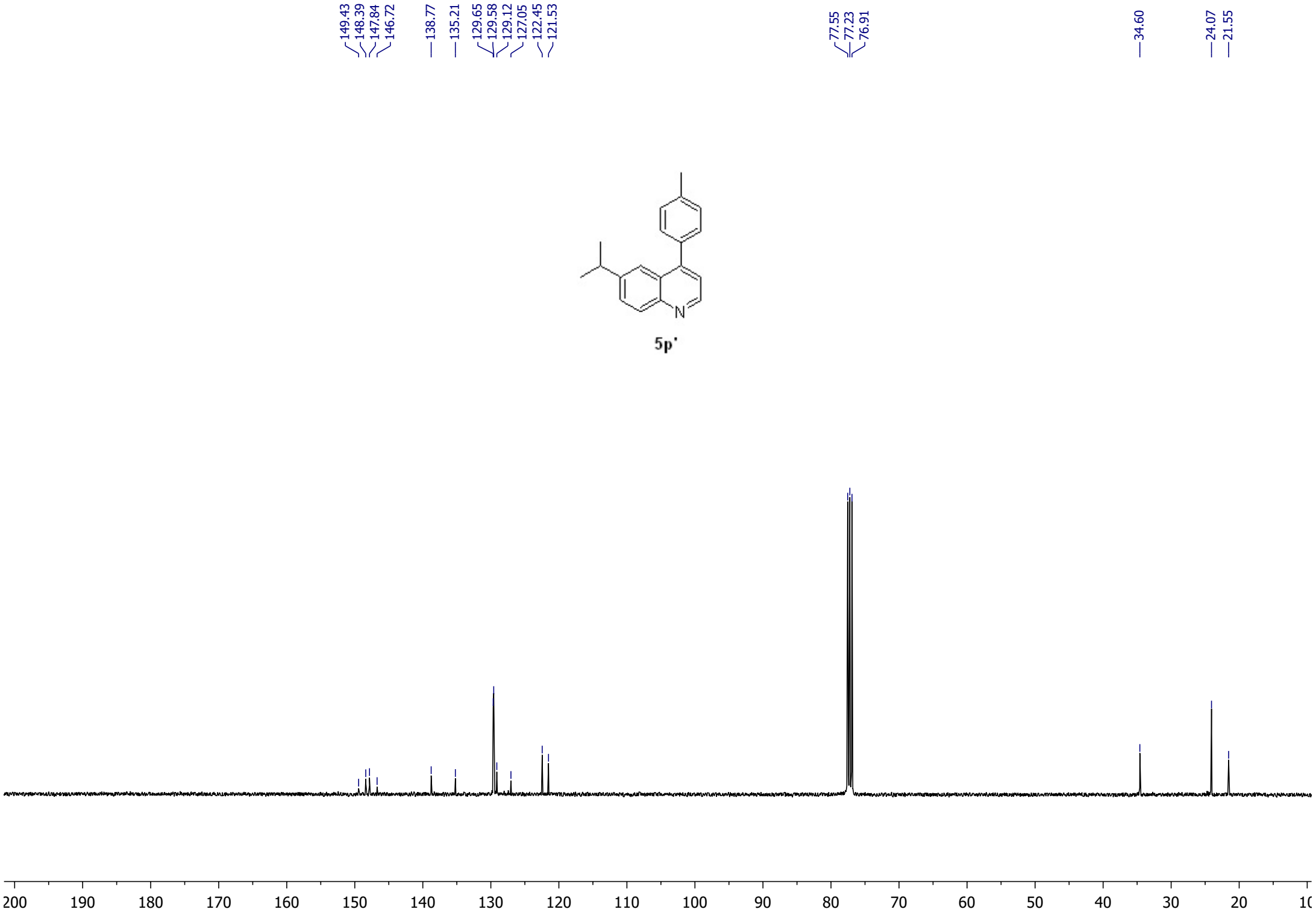
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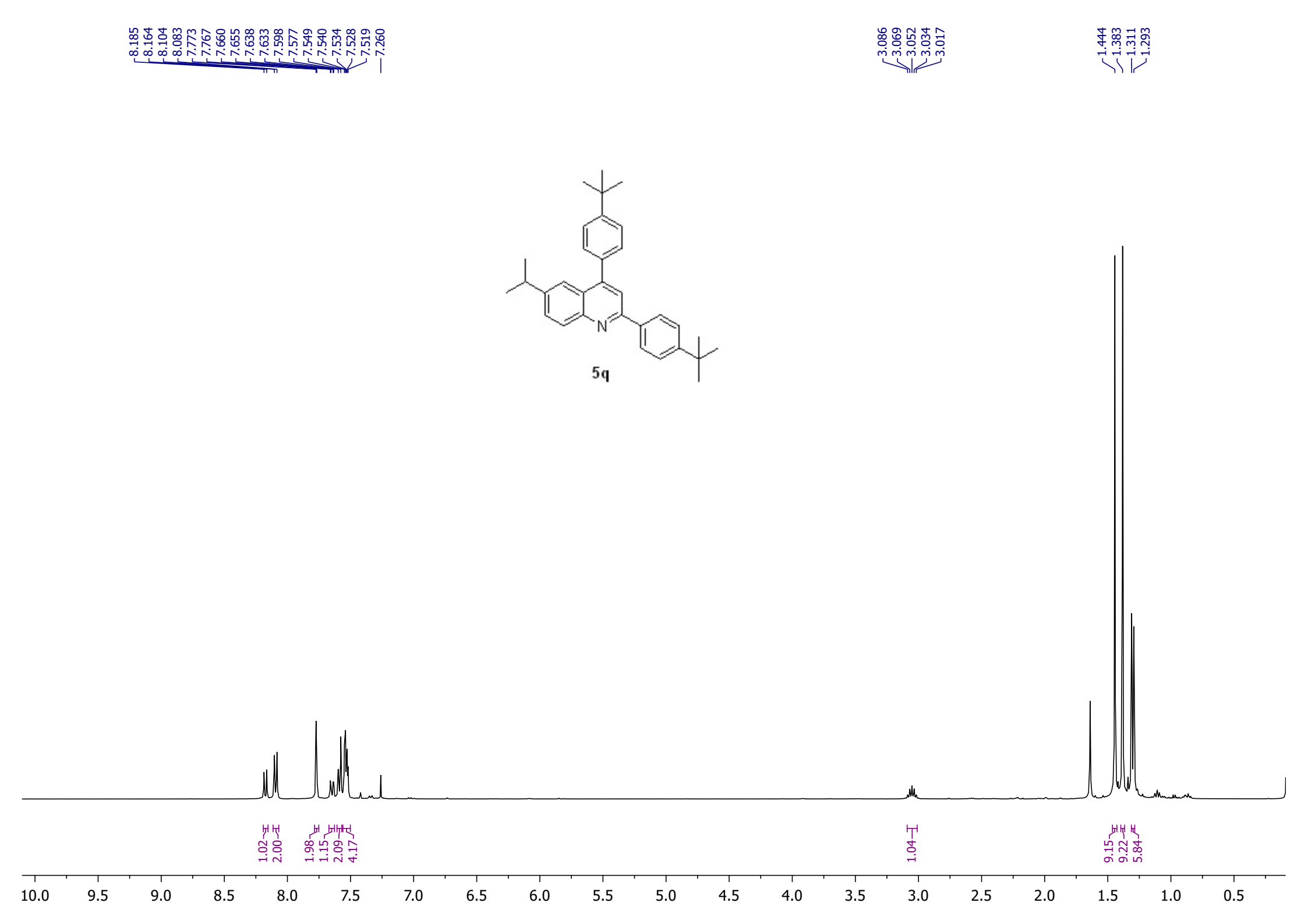
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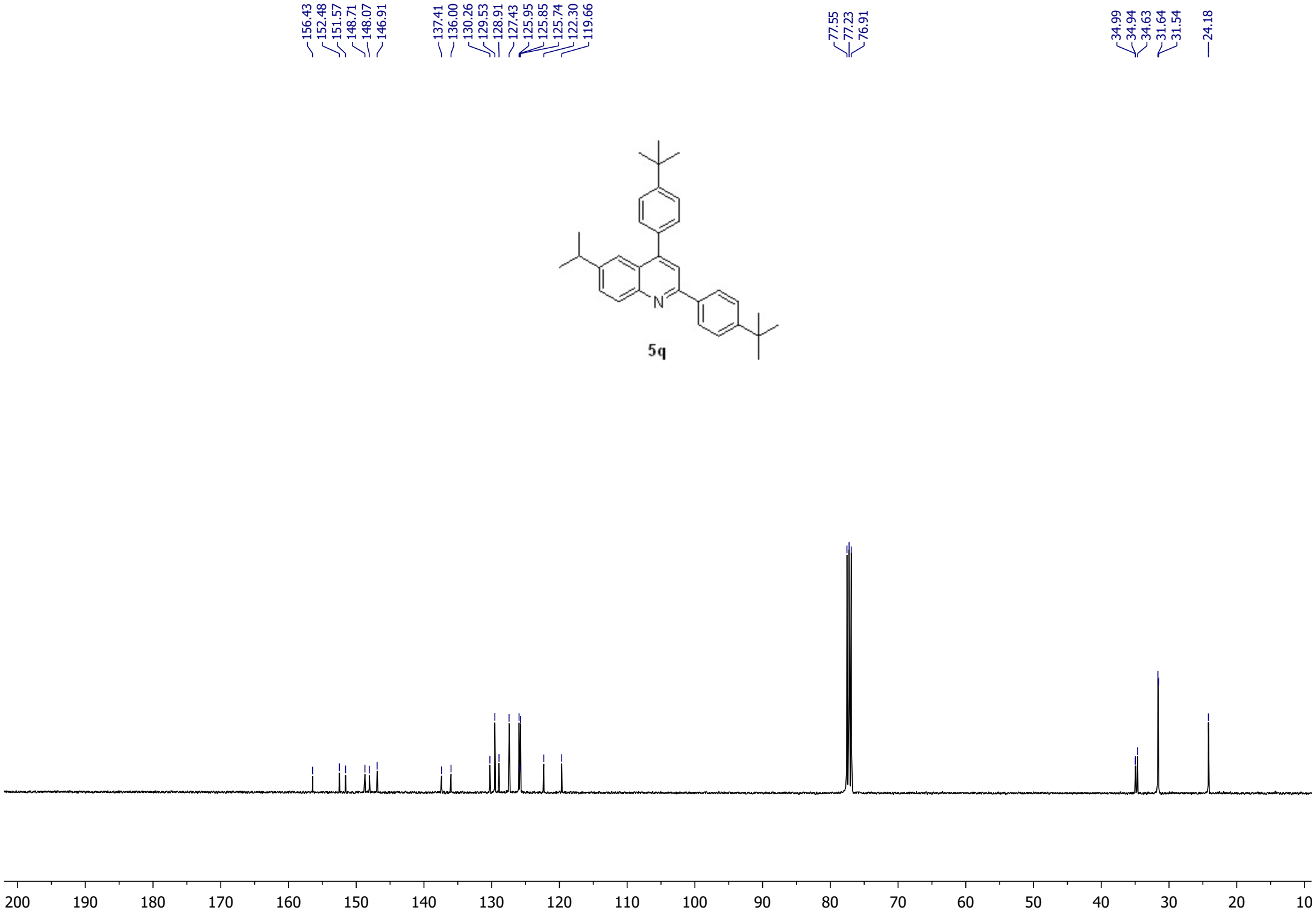
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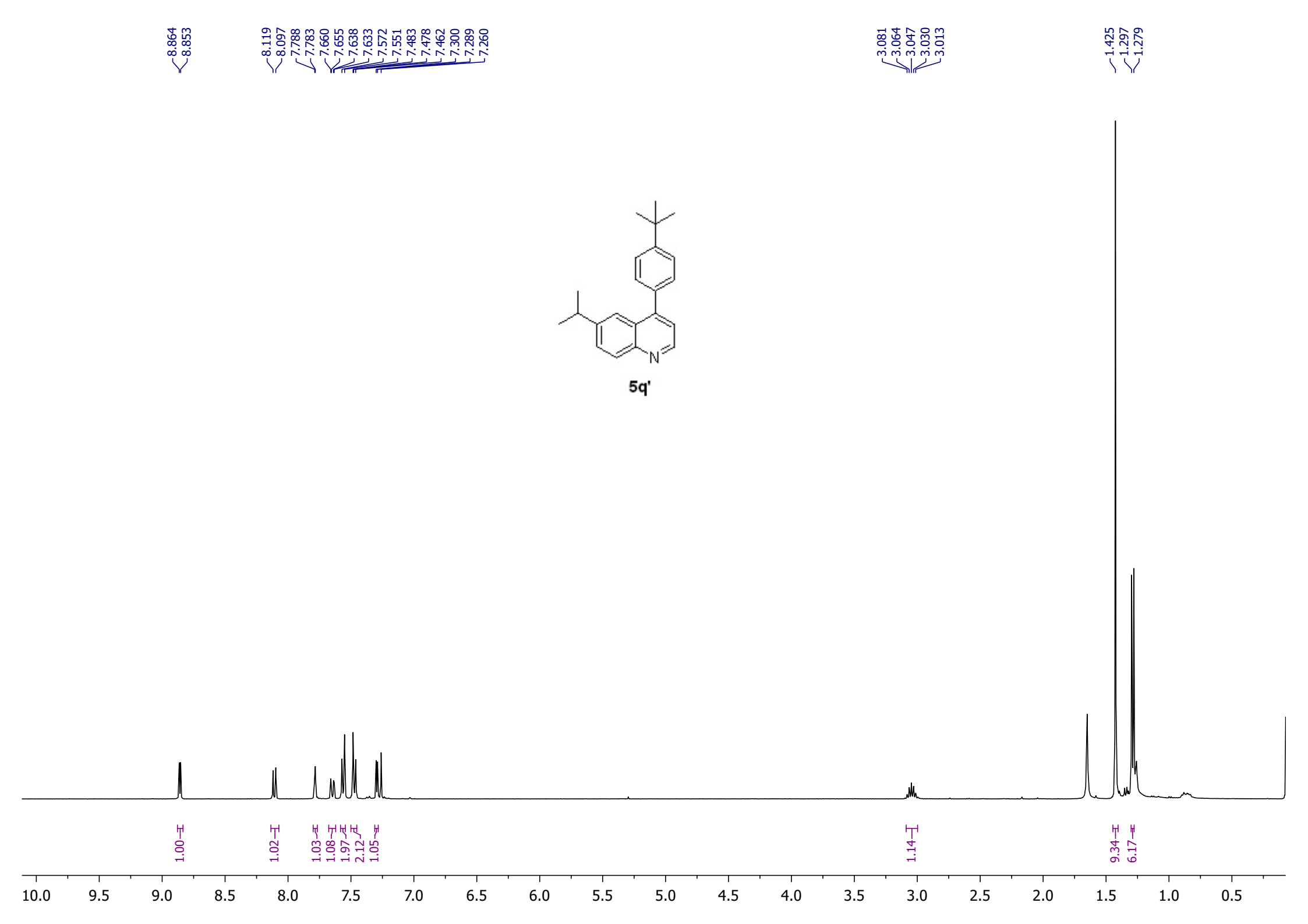
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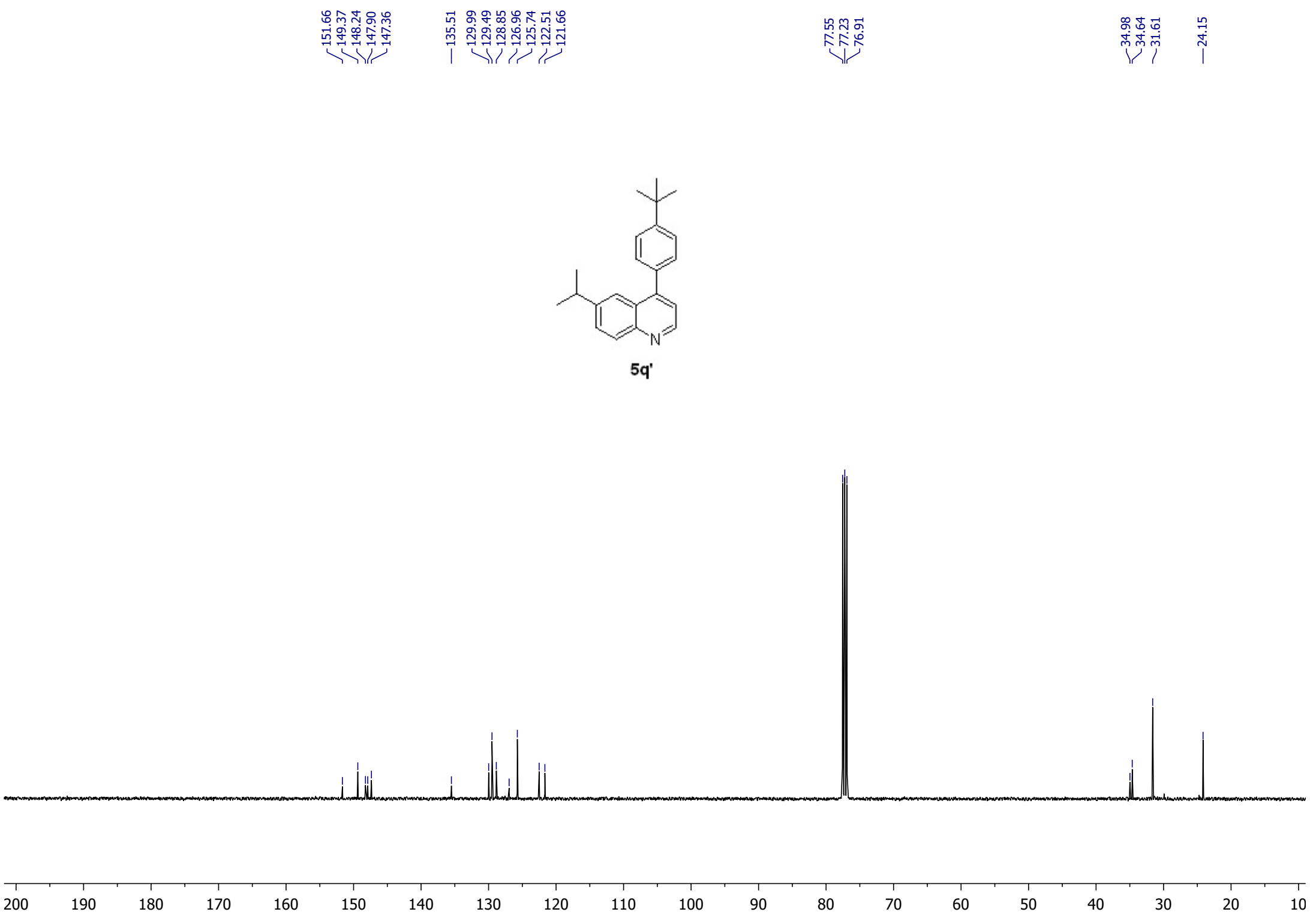
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N
5q'
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150
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80
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40
30
20
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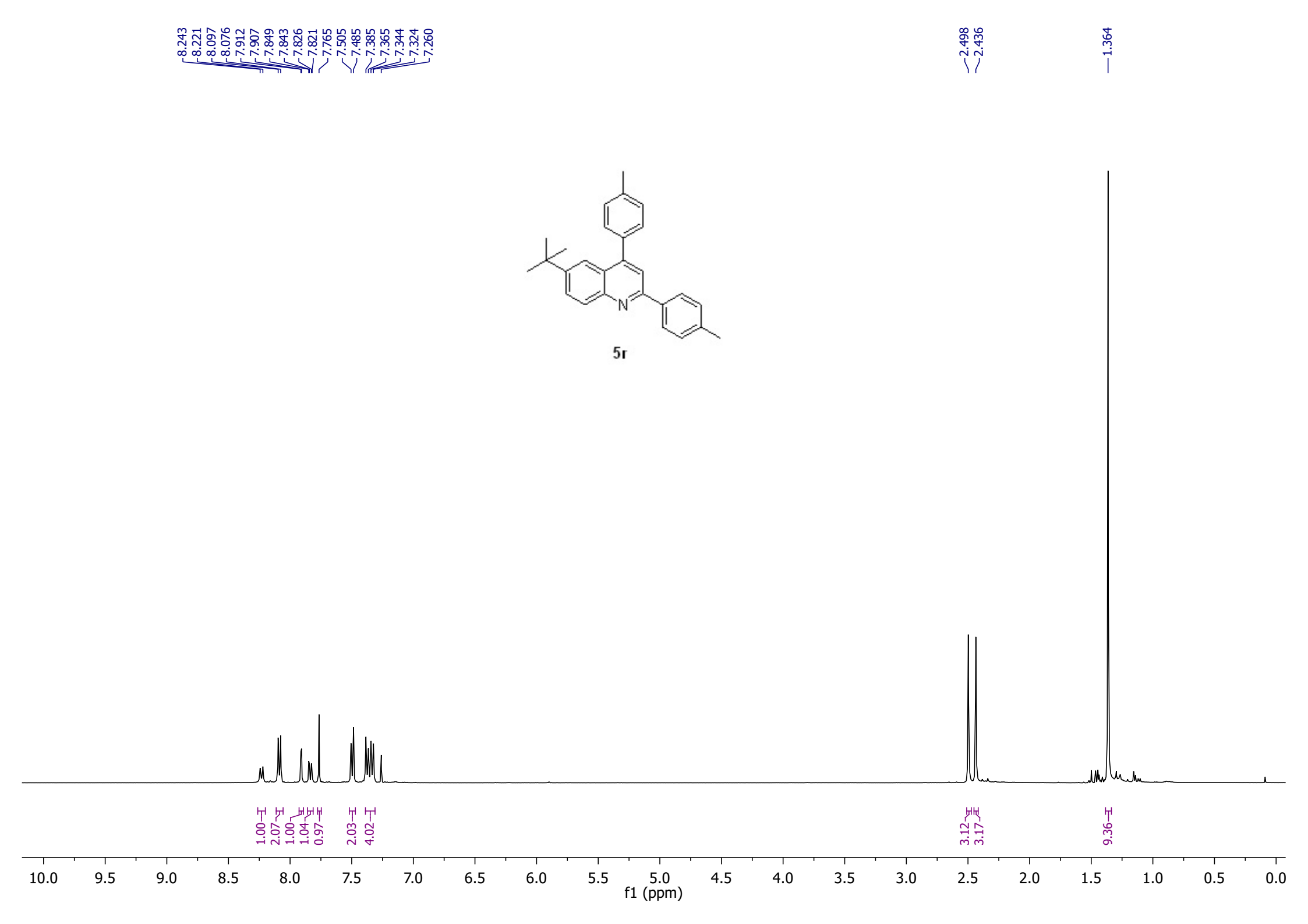
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7.821
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7.505
7.485
7.385
7.365
7.344
7.324
7.260
2.498
2.436
1.364
N
5r
1.00
2.07
1.00
1.04
0.97
2.03
4.02
3.12
3.17
9.36
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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2.5
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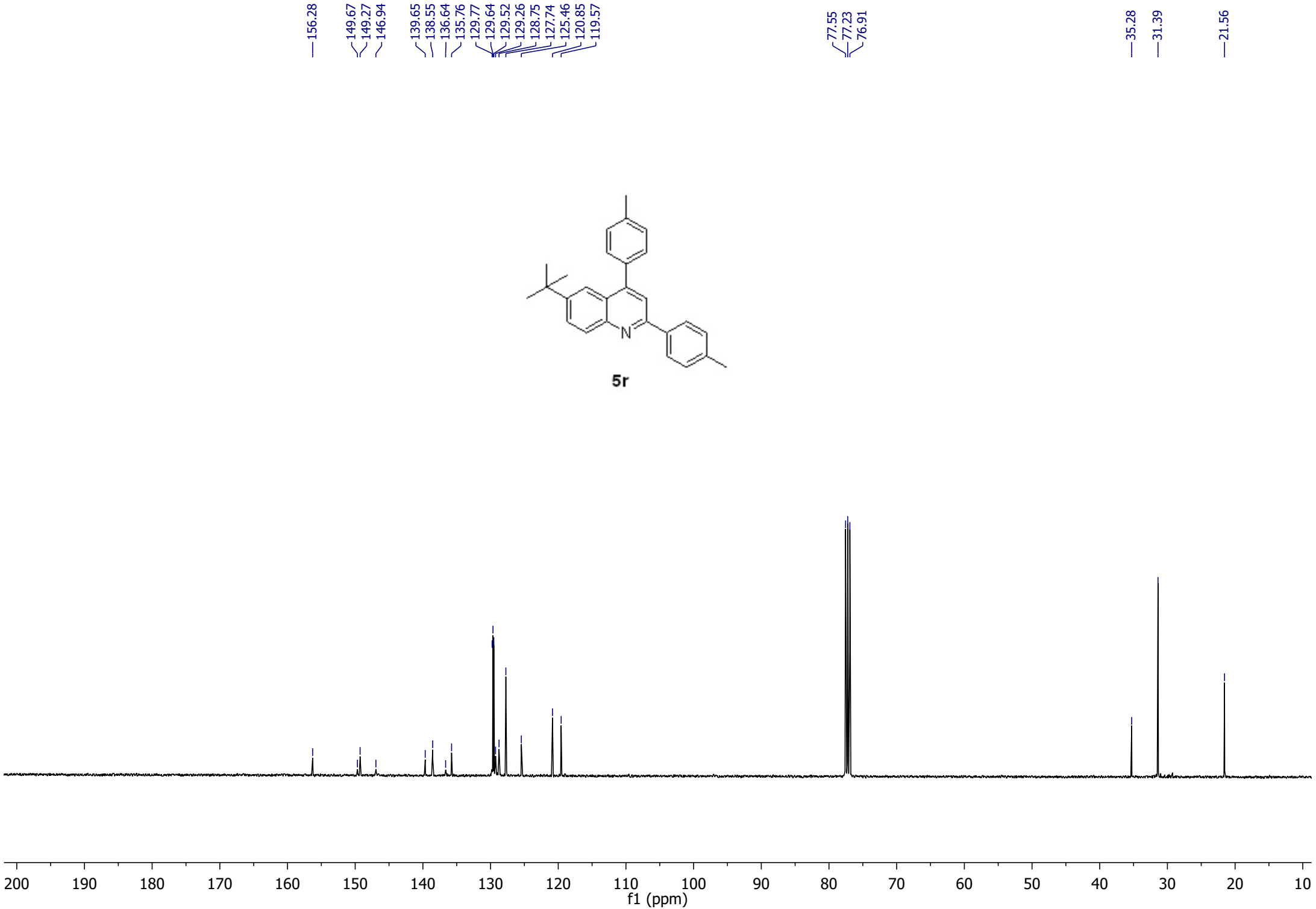
f1 (ppm)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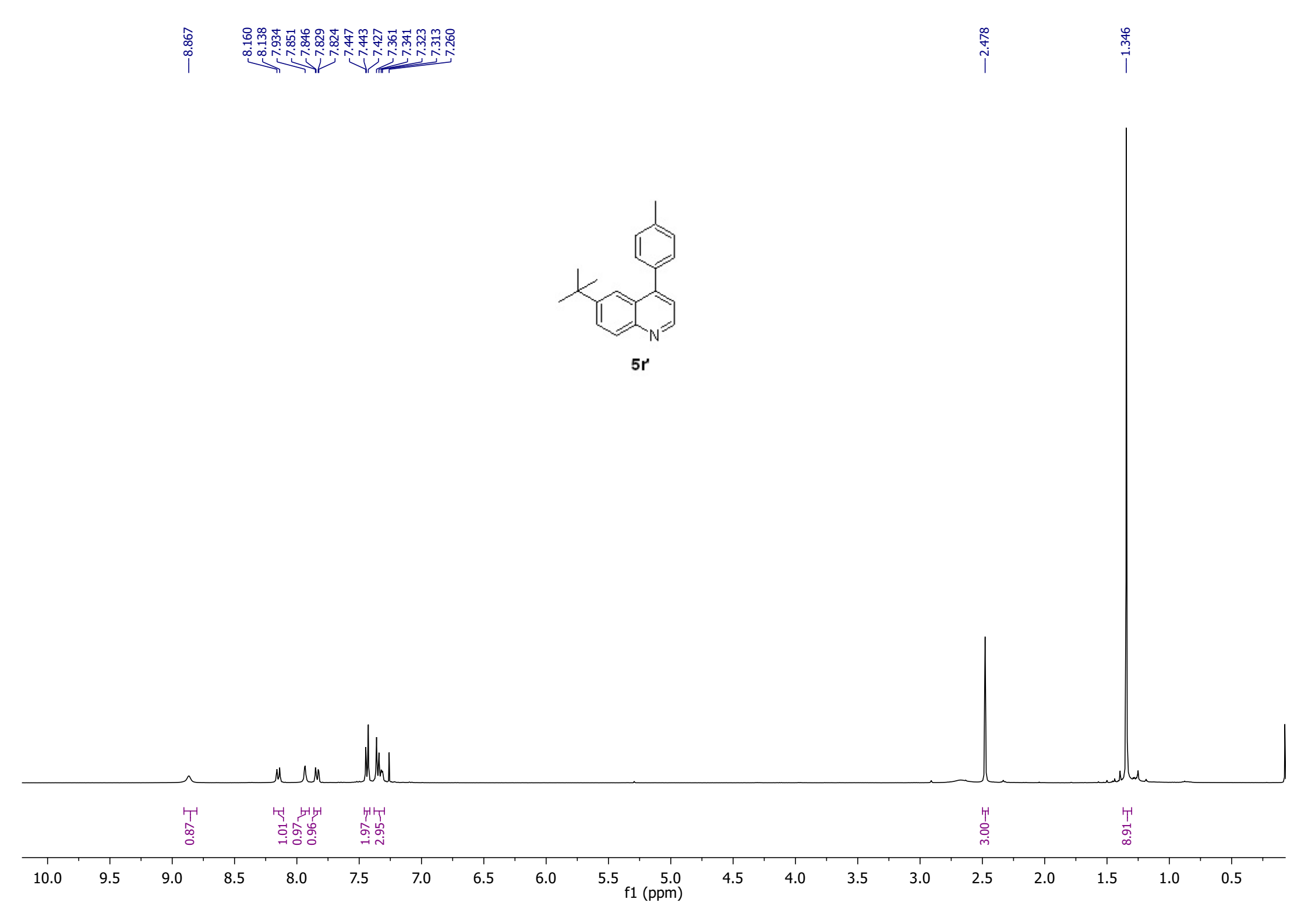
135.76
129.77
129.64
129.52
129.26
128.75
127.74
125.46
120.85
119.57
77.55
77.23
76.91
35.28
31.39
21.56
N
5r
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.824
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7.443
7.427
7.361
7.341
7.323
7.313
7.260
2.478
1.346
N
5r'
0.87
1.01
0.97
0.96
1.97
2.95
3.00
8.91
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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4.0
3.5
3.0
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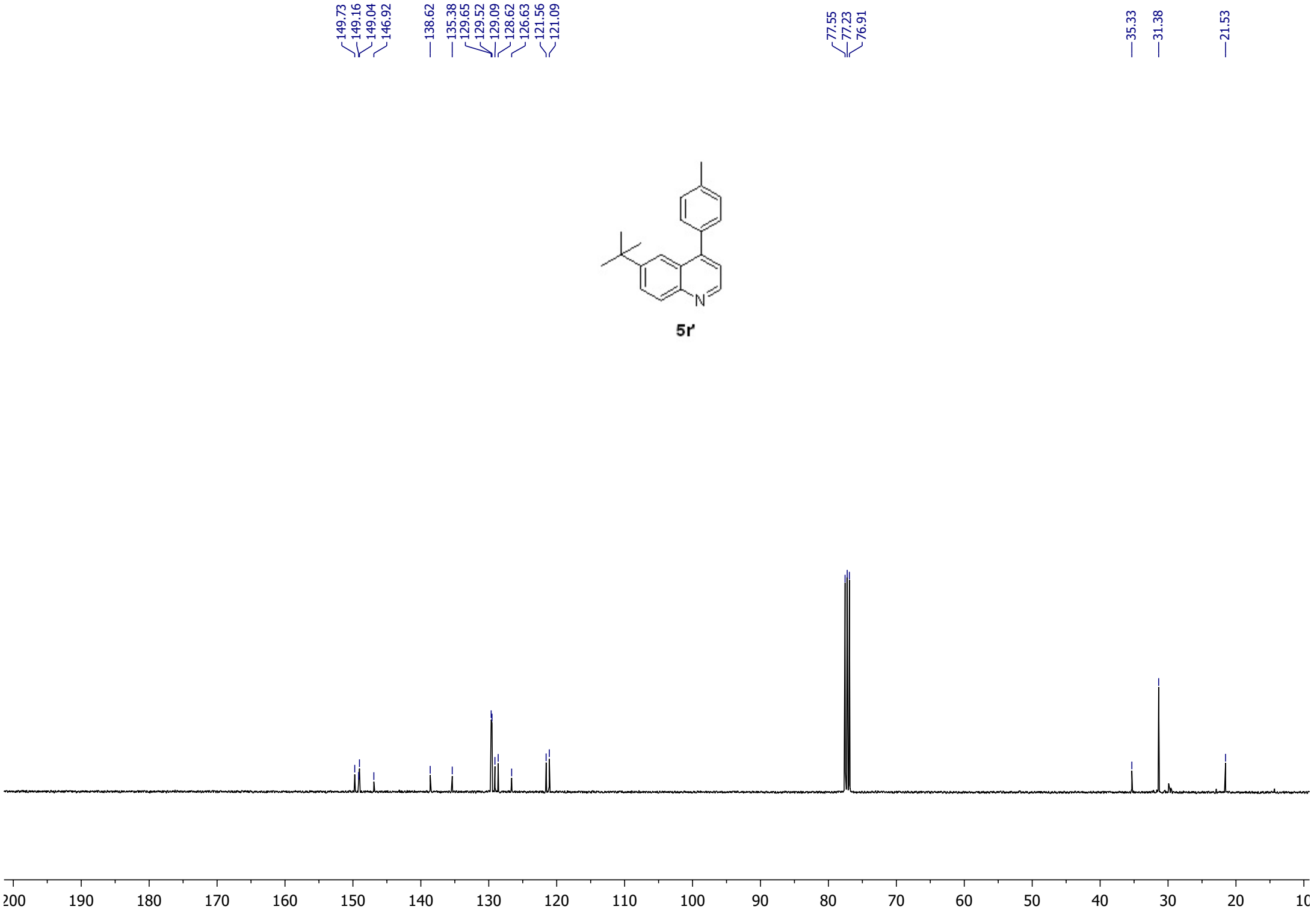
2.0
1.5
1.0
0.5
f1 (ppm)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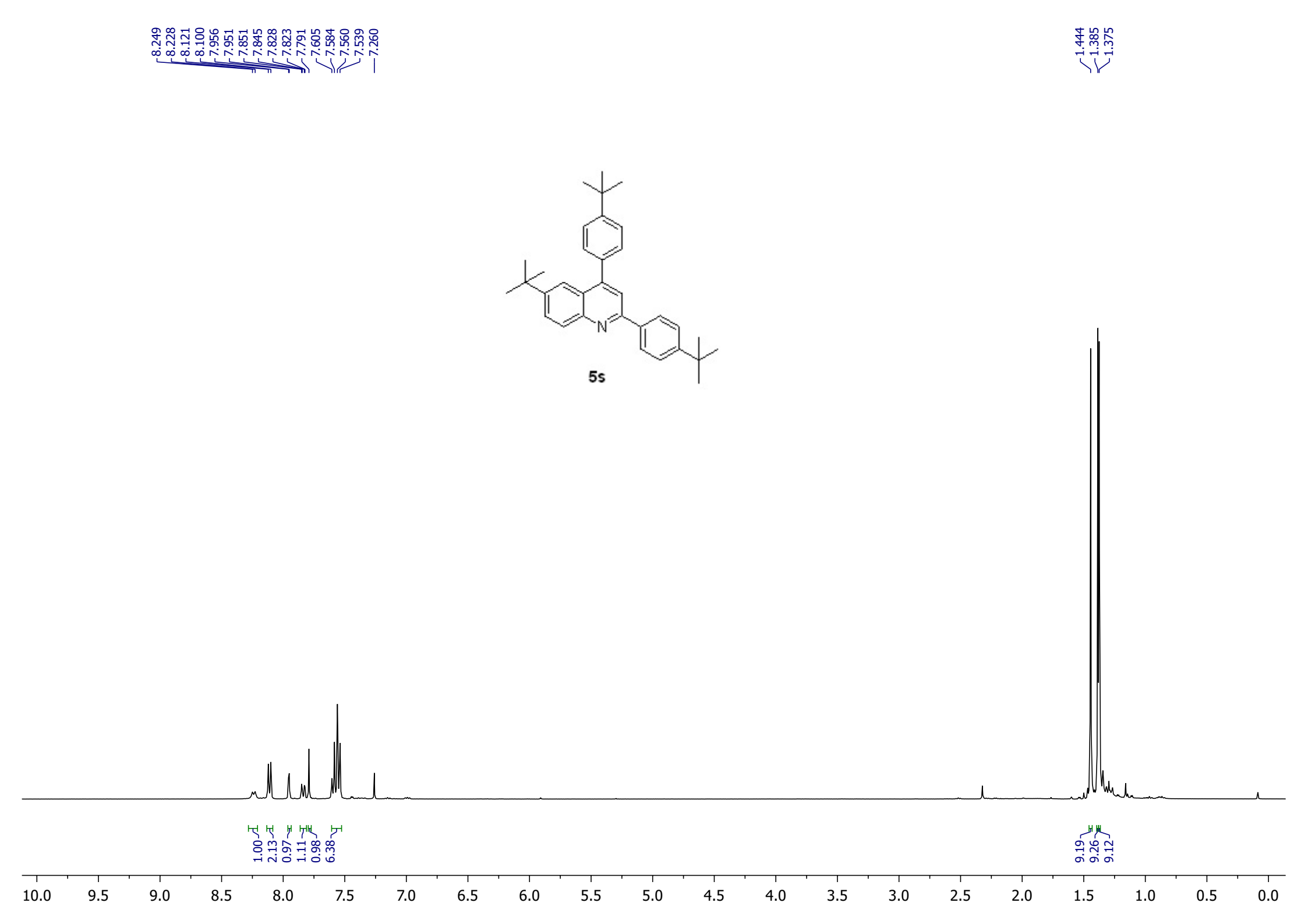
135.38
129.65
129.52
129.09
128.62
126.63
121.56
121.09
77.55
77.23
76.91
35.33
31.38
21.53
N
5r'
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10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7.851
7.845
7.828
7.823
7.791
7.605
7.584
7.560
7.539
7.260
1.444
1.385
1.375
N
5s
1.00
2.13
0.97
1.11
0.98
6.38
9.19
9.26
9.12
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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3.0
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2.0
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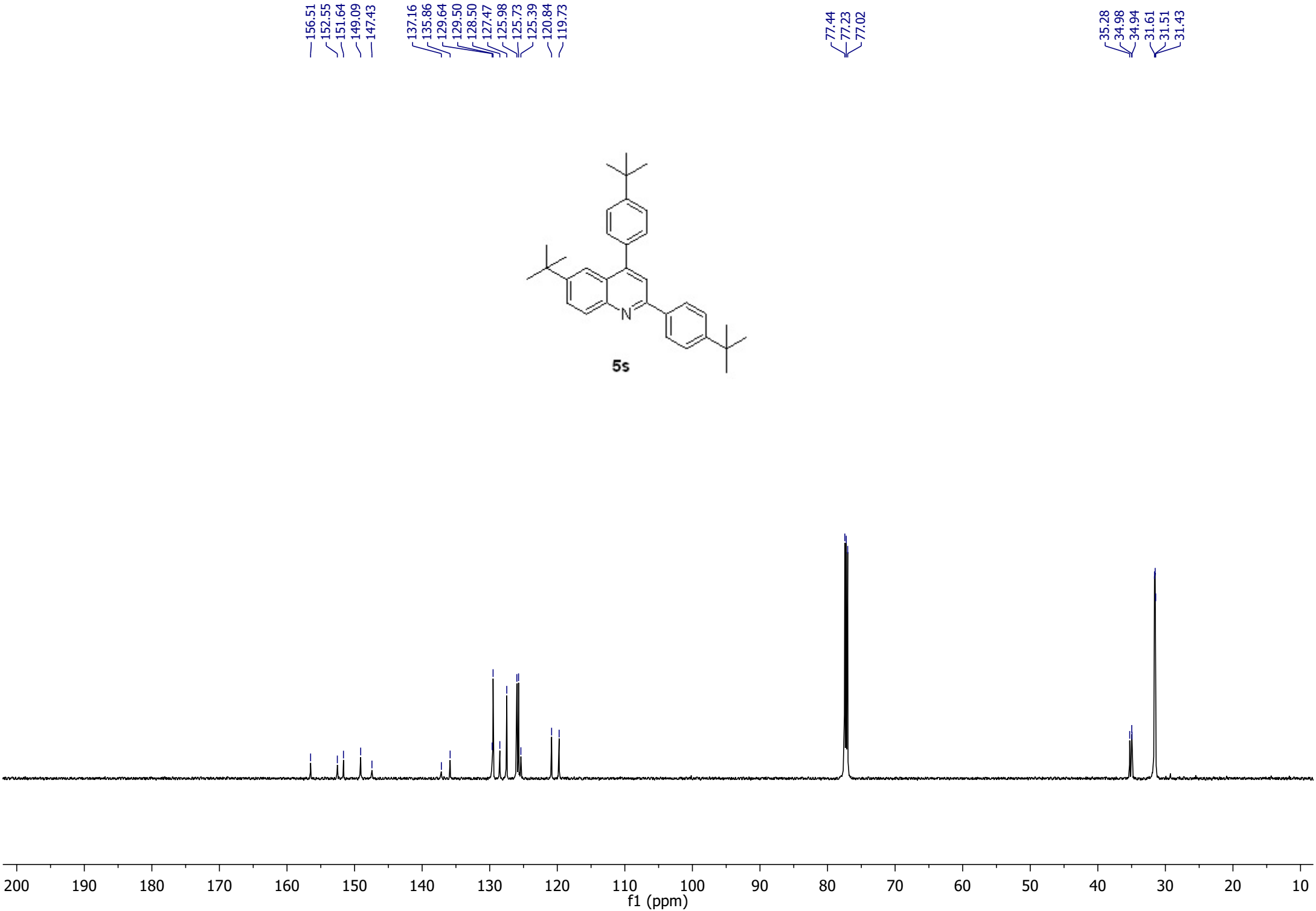
0.5
0.0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129.64
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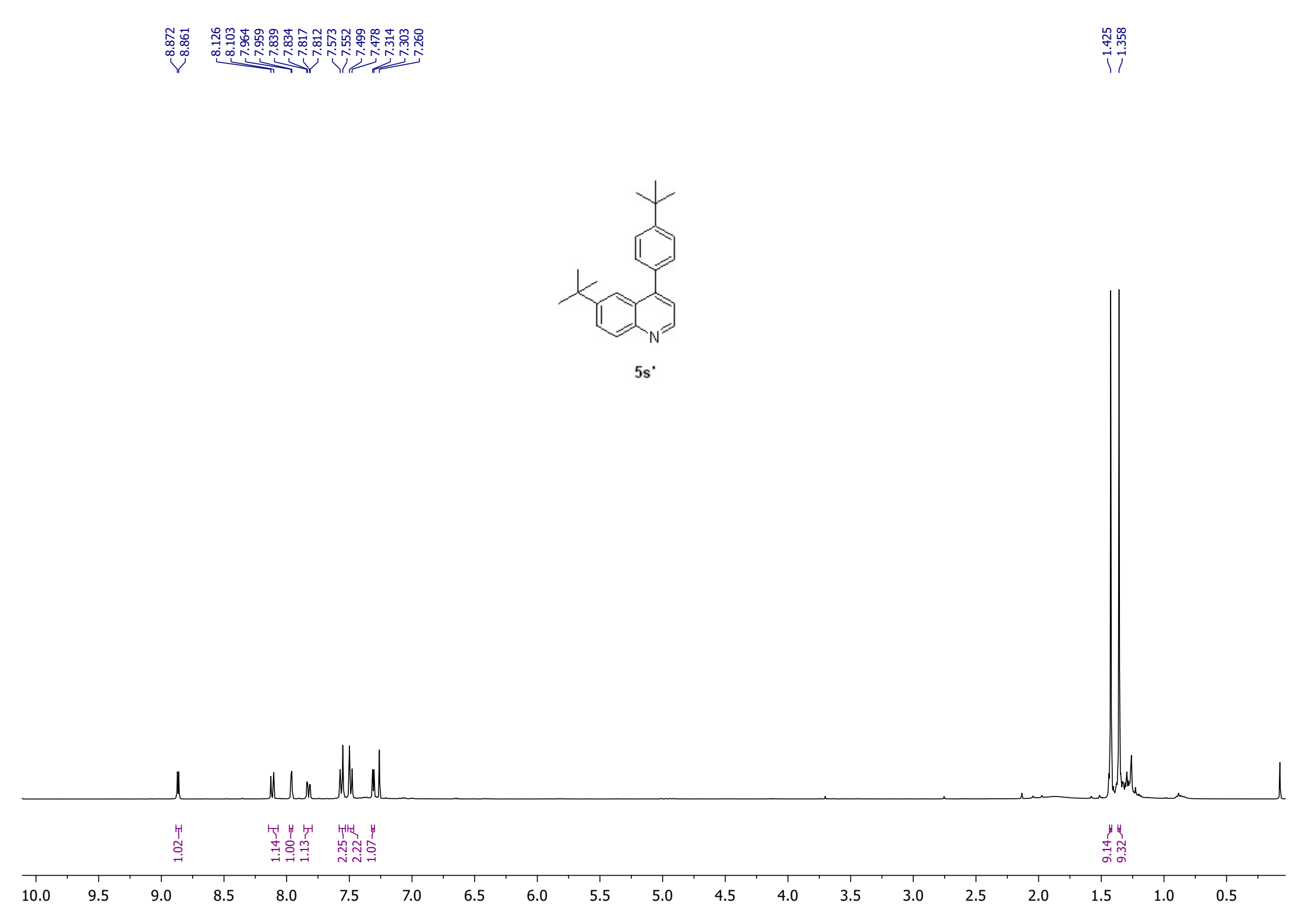
128.50
127.47
125.98
125.73
125.39
120.84
119.73
77.44
77.23
77.02
35.28
34.98
34.94
31.61
31.51
31.43
N
5s
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.959
7.839
7.834
7.817
7.812
7.573
7.552
7.499
7.478
7.314
7.303
7.260
1.425
1.358
N
5s'
1.02
1.14
1.00
1.13
2.25
2.22
1.07
9.14
9.32
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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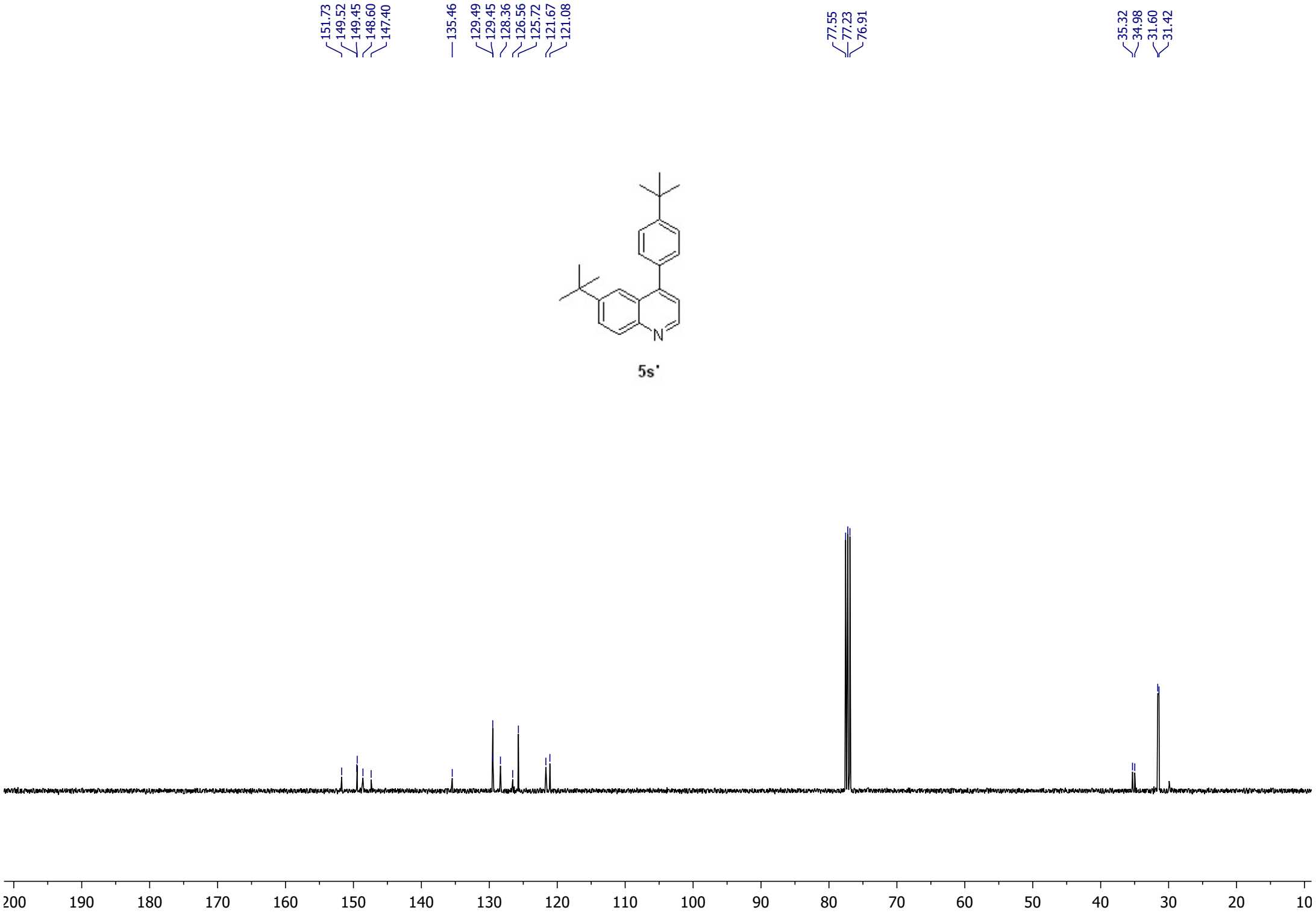
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5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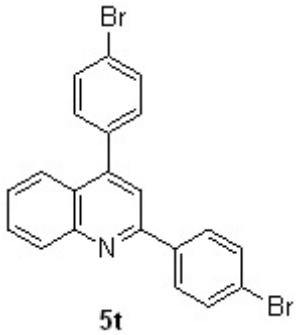
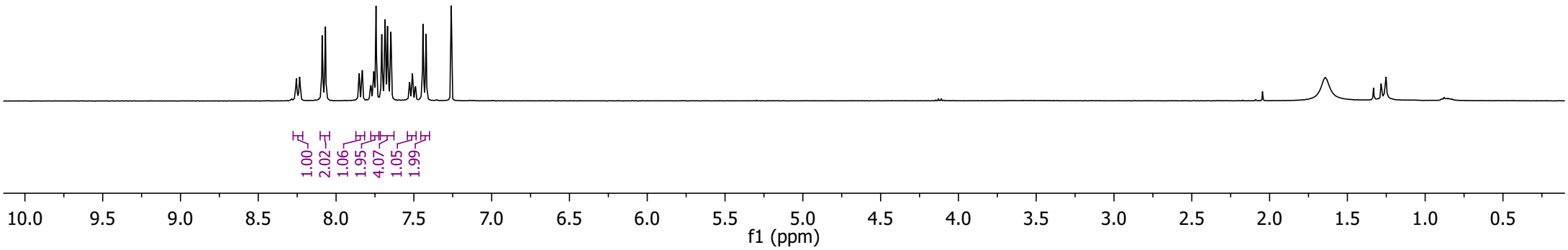
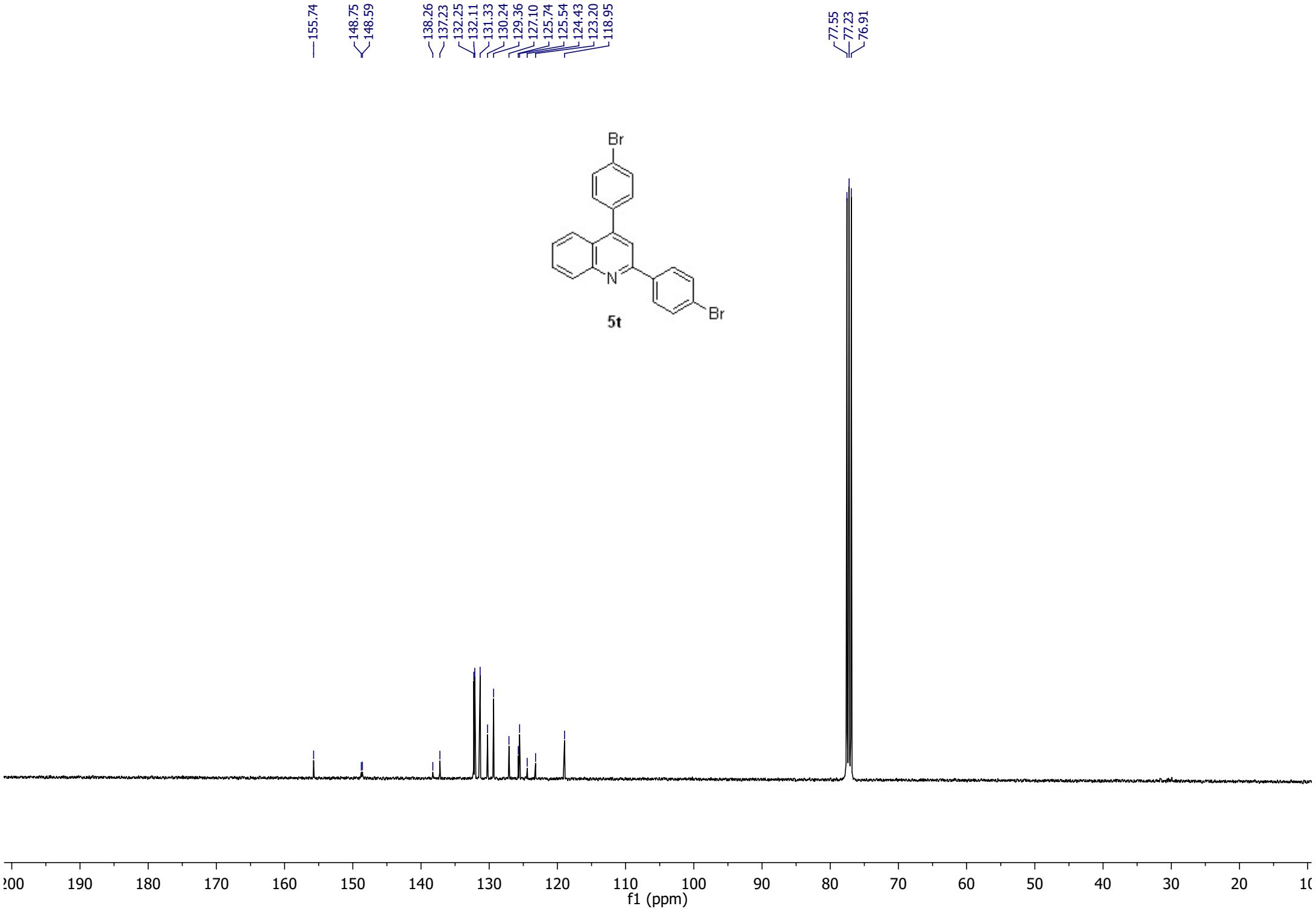
135.46
129.49
129.45
128.36
126.56
125.72
121.67
121.08
77.55
77.23
76.91
35.32
34.98
31.60
31.42
N
5s'
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10


8.255
8.234
8.090
8.068
7.852
7.831
7.778
7.758
7.743
7.706
7.685
7.669
7.648
7.527
7.509
7.489
7.442
7.421
7.260


Br
N
Br

5t


1.00
2.02
1.06
1.95
4.07
1.05
1.99
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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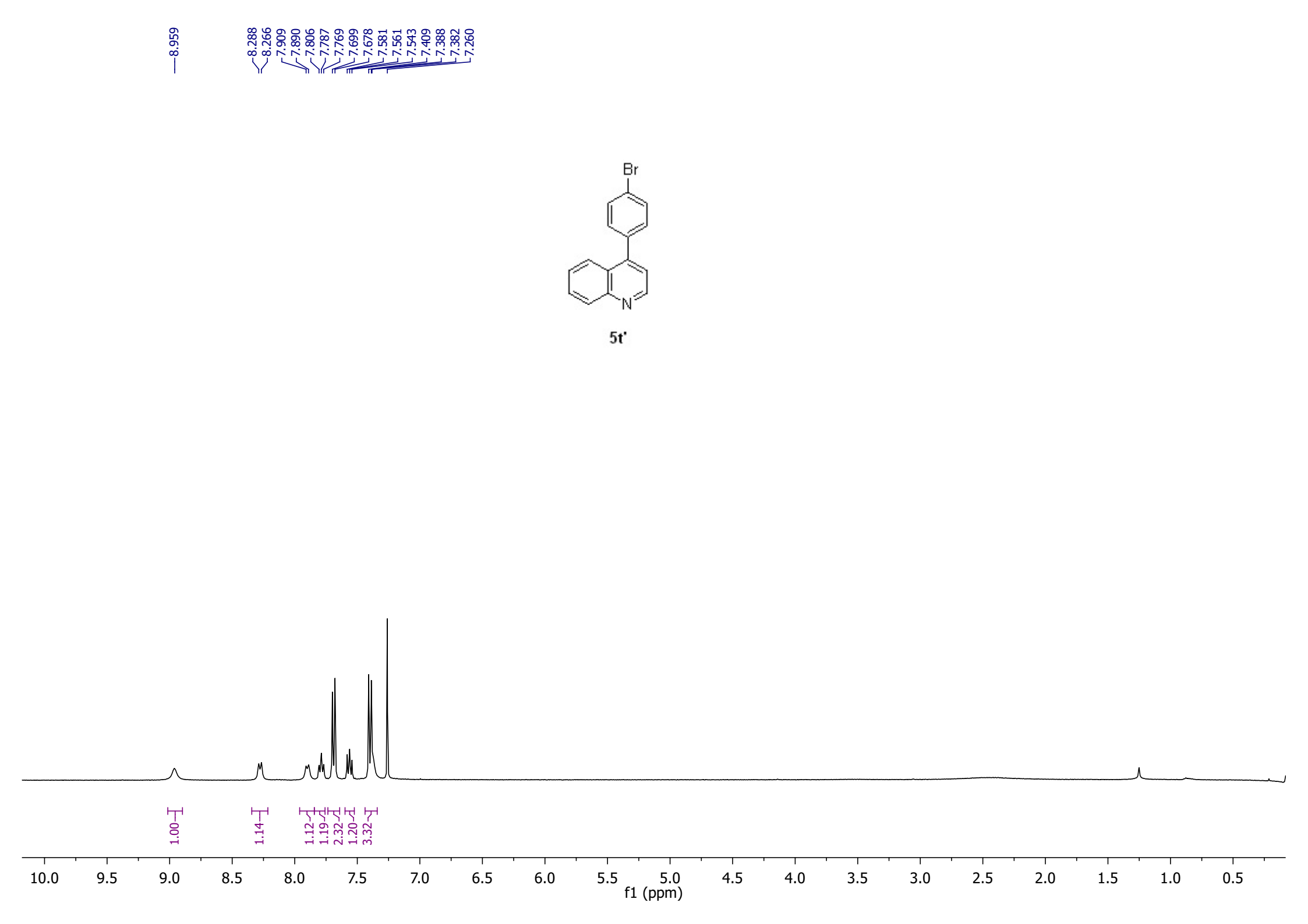
137.23
132.25
132.11
131.33
130.24
129.36
127.10
125.74
125.54
124.43
123.20
118.95
77.55
77.23
76.91
Br
N
Br
5t
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.806
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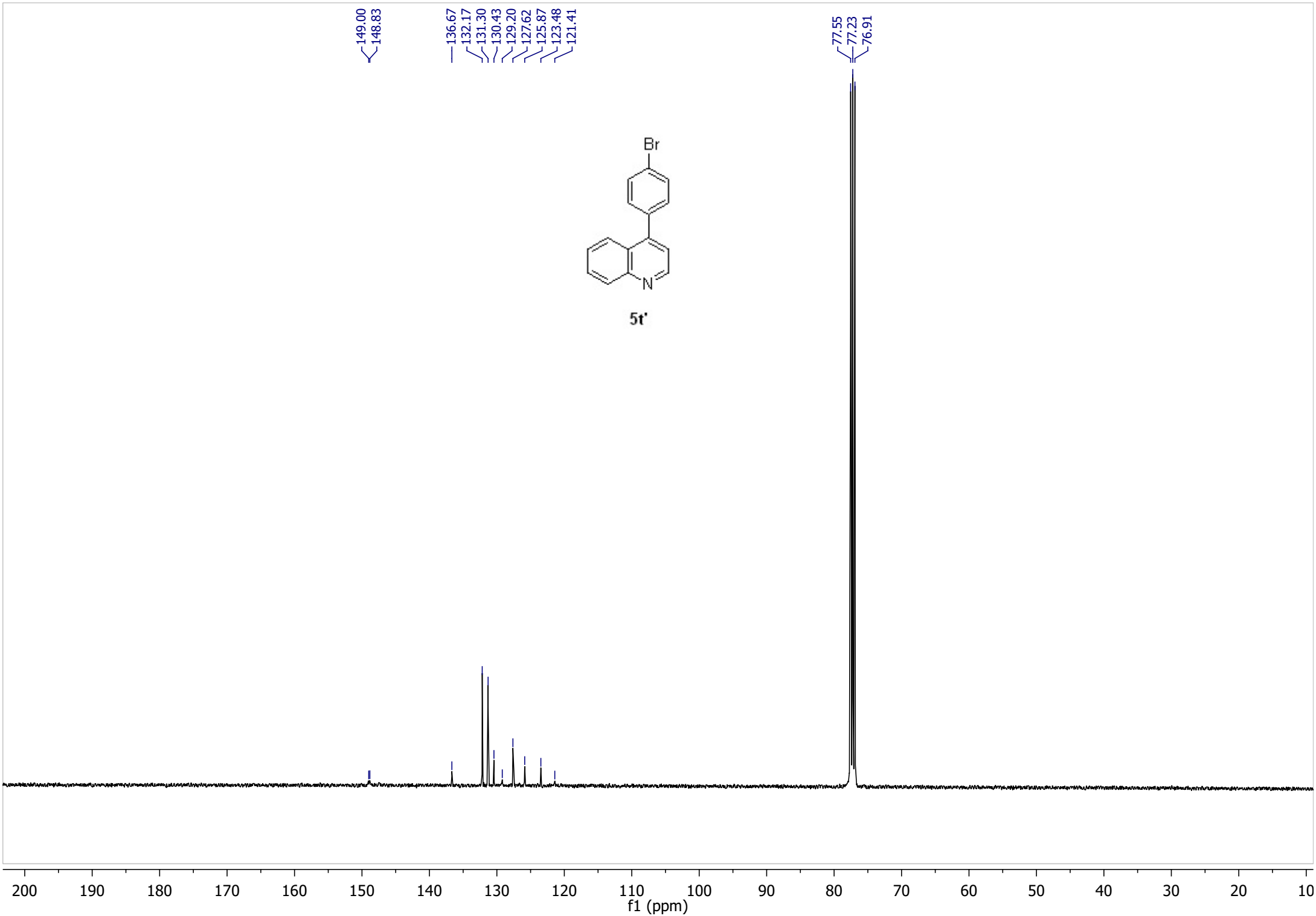
7.769
7.699
7.678
7.581
7.561
7.543
7.409
7.388
7.382
7.260
Br
N
1.00
1.14
1.12
1.19
2.32
1.20
3.32
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

5t'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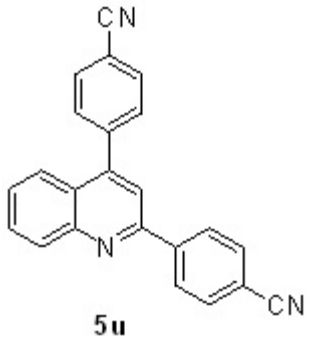
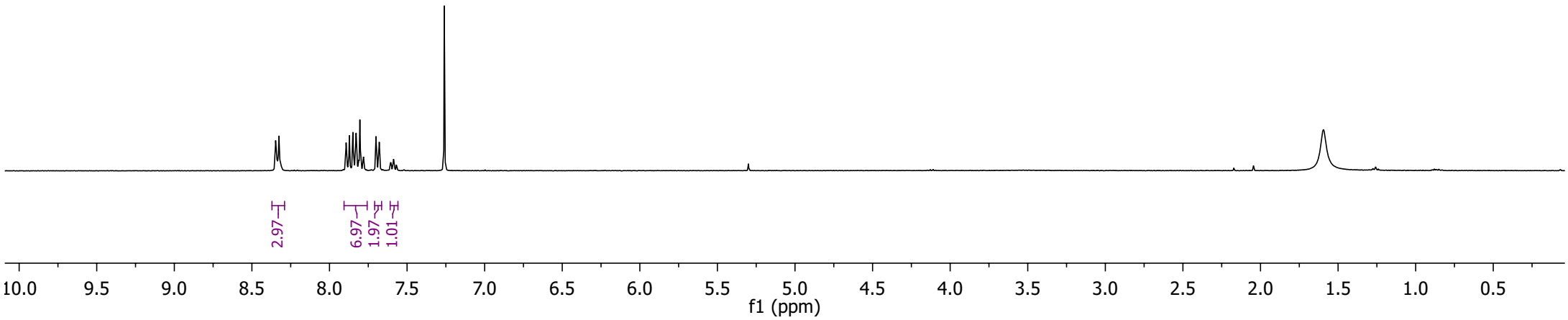
148.83
136.67
132.17
131.30
130.43
129.20
127.62
125.87
123.48
121.41
77.55
77.23
76.91
Br
N
5t'
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


8.347
8.343
8.326
8.318
7.893
7.872
7.849
7.828
7.810
7.804
7.781
7.700
7.679
7.607
7.604
7.590
7.587
7.584
7.569
7.566
7.260


CN
N
CN

5u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6.97
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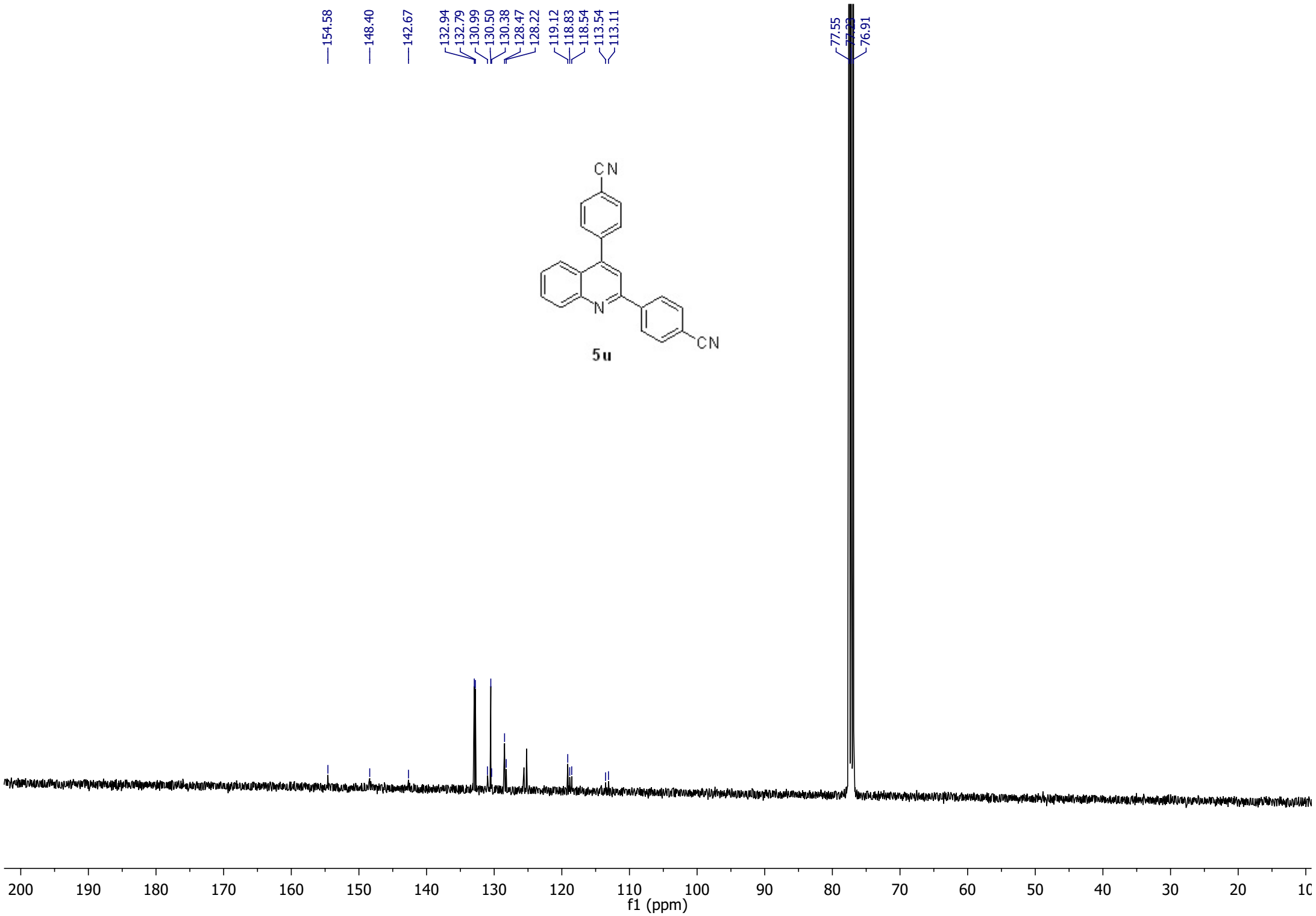
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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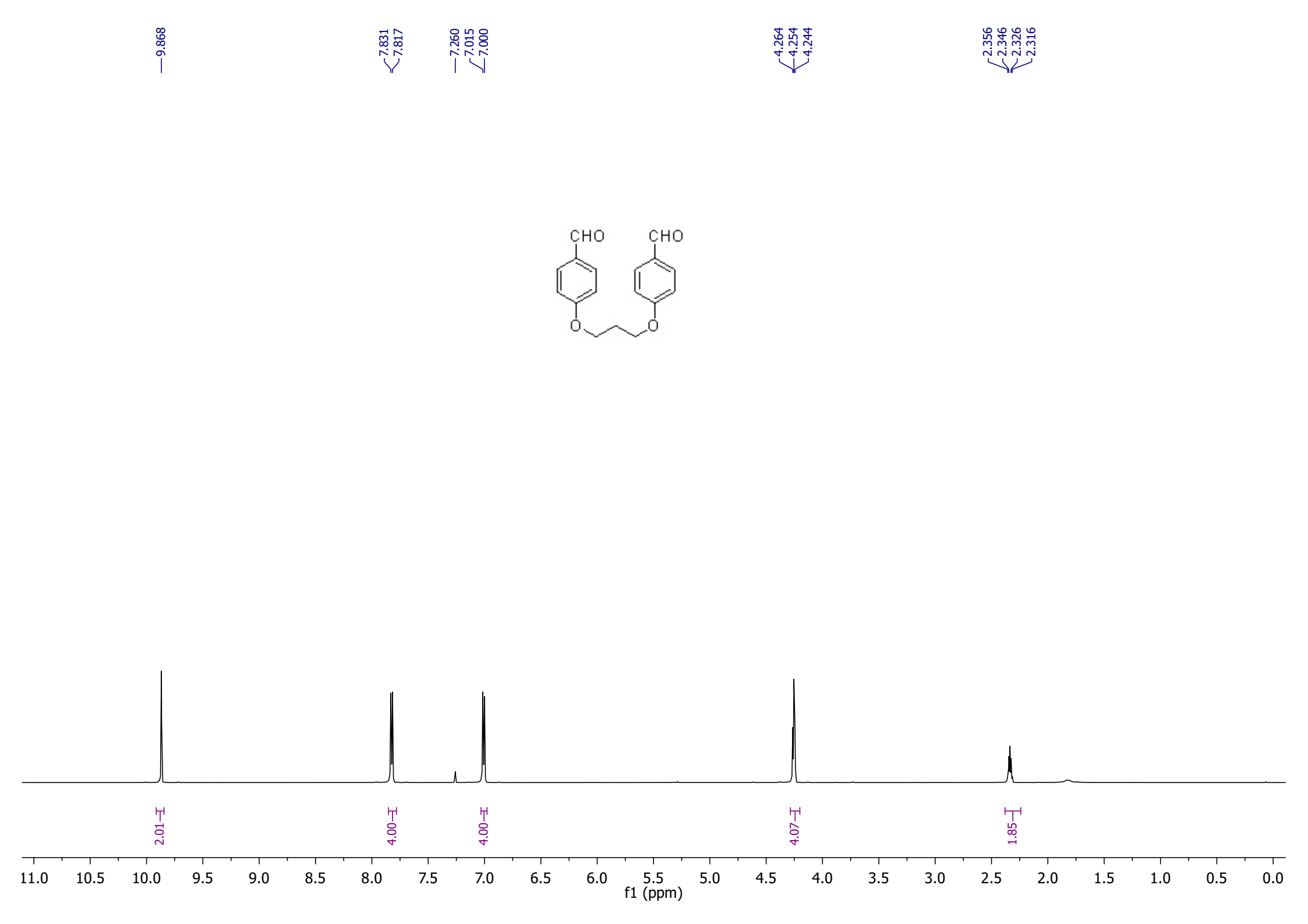
130.38
128.47
128.22
119.12
118.83
118.54
113.54
113.11
77.55
77.23
76.91
CN
N
CN
5u
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.817
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4.254
4.244
2.356
2.346
2.326
2.316
CHO
CHO
O
O
2.01
4.00
4.00
4.07
1.85
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
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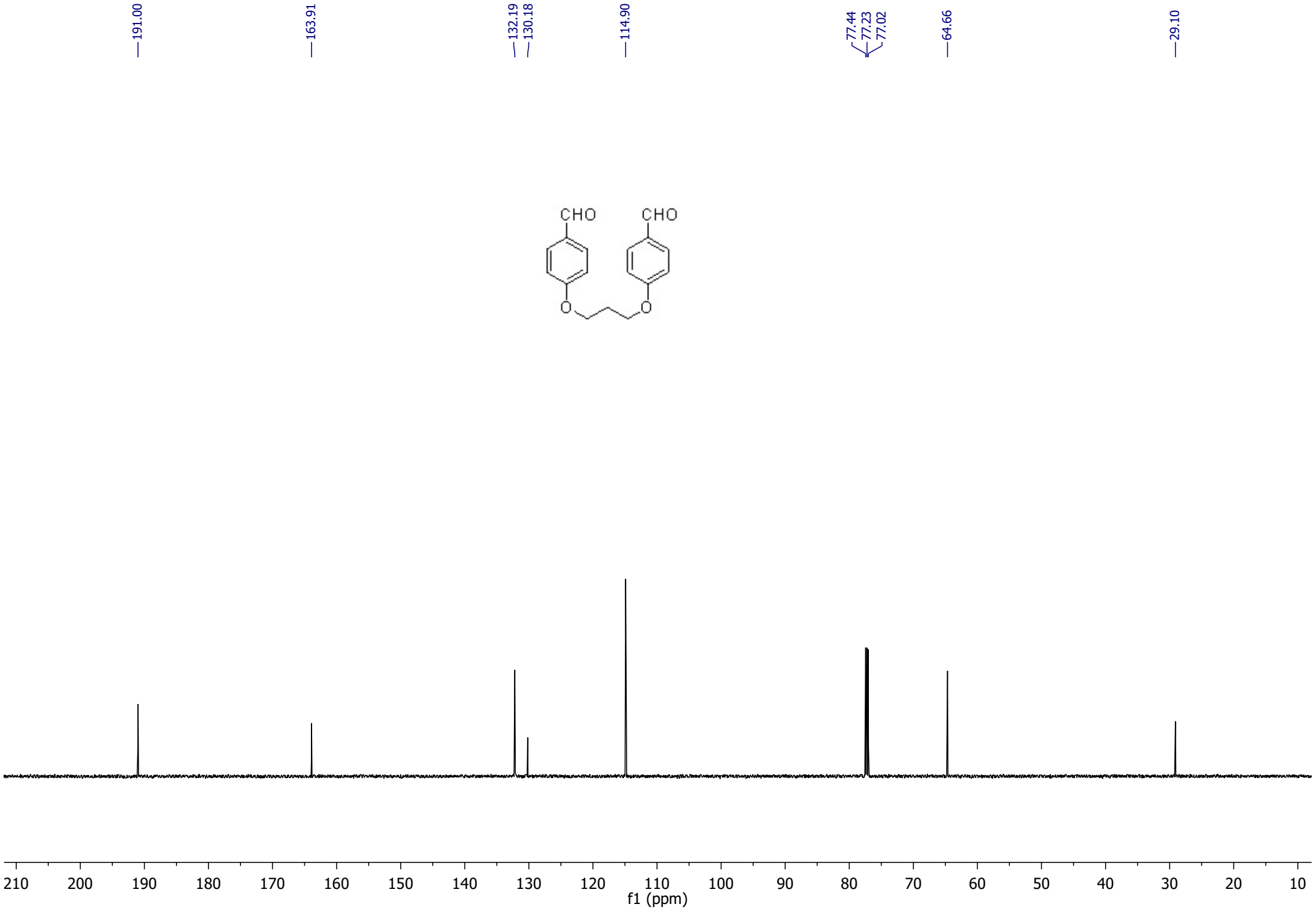
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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130.18
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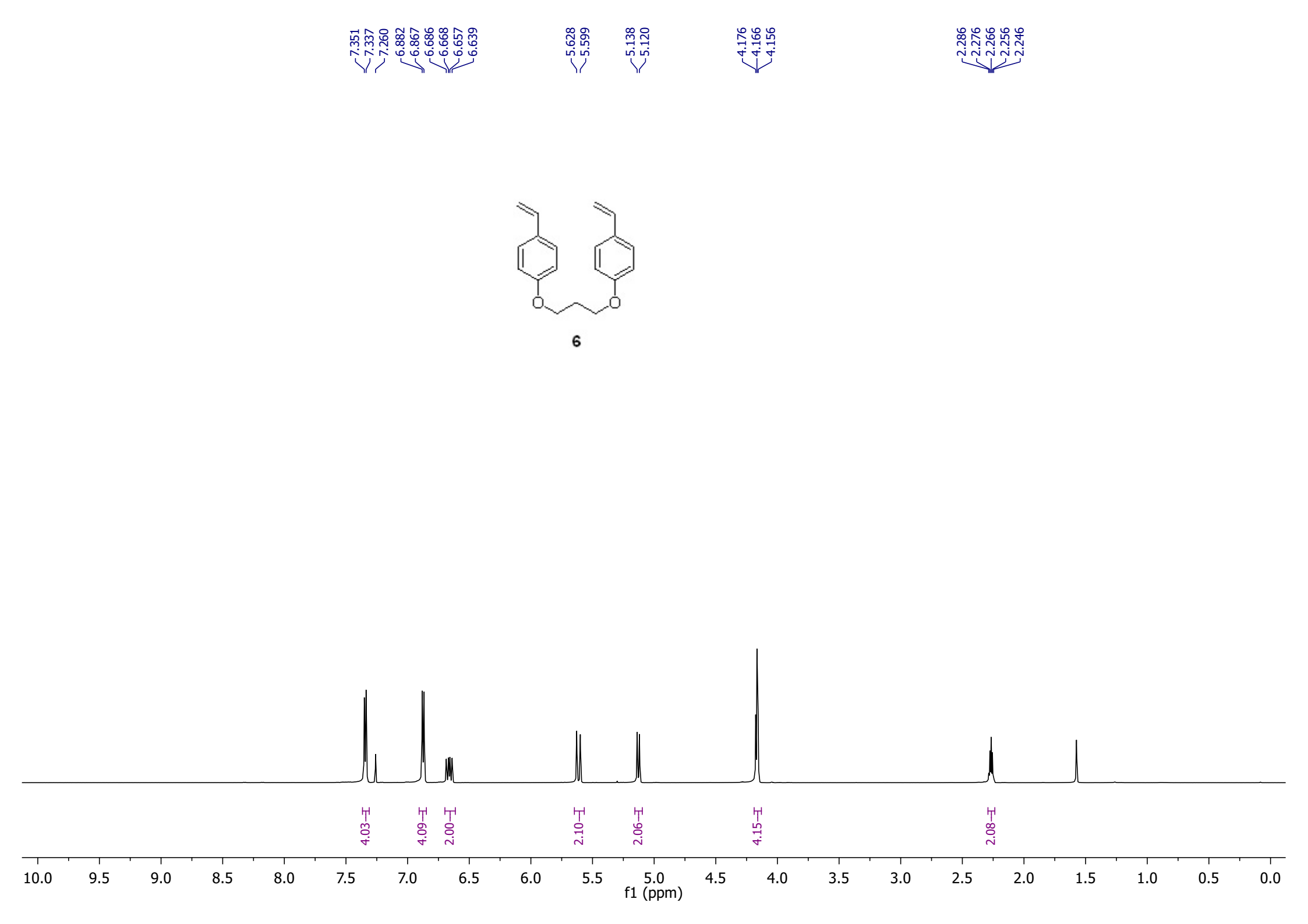
77.44
77.23
77.02
64.66
29.10
CHO
CHO
O
O
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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6.657
6.639
5.628
5.599
5.138
5.120
4.176
4.166
4.156
2.286
2.276
2.266
2.256
2.246
6
4.03
4.09
2.00
2.10
2.06
4.15
2.08
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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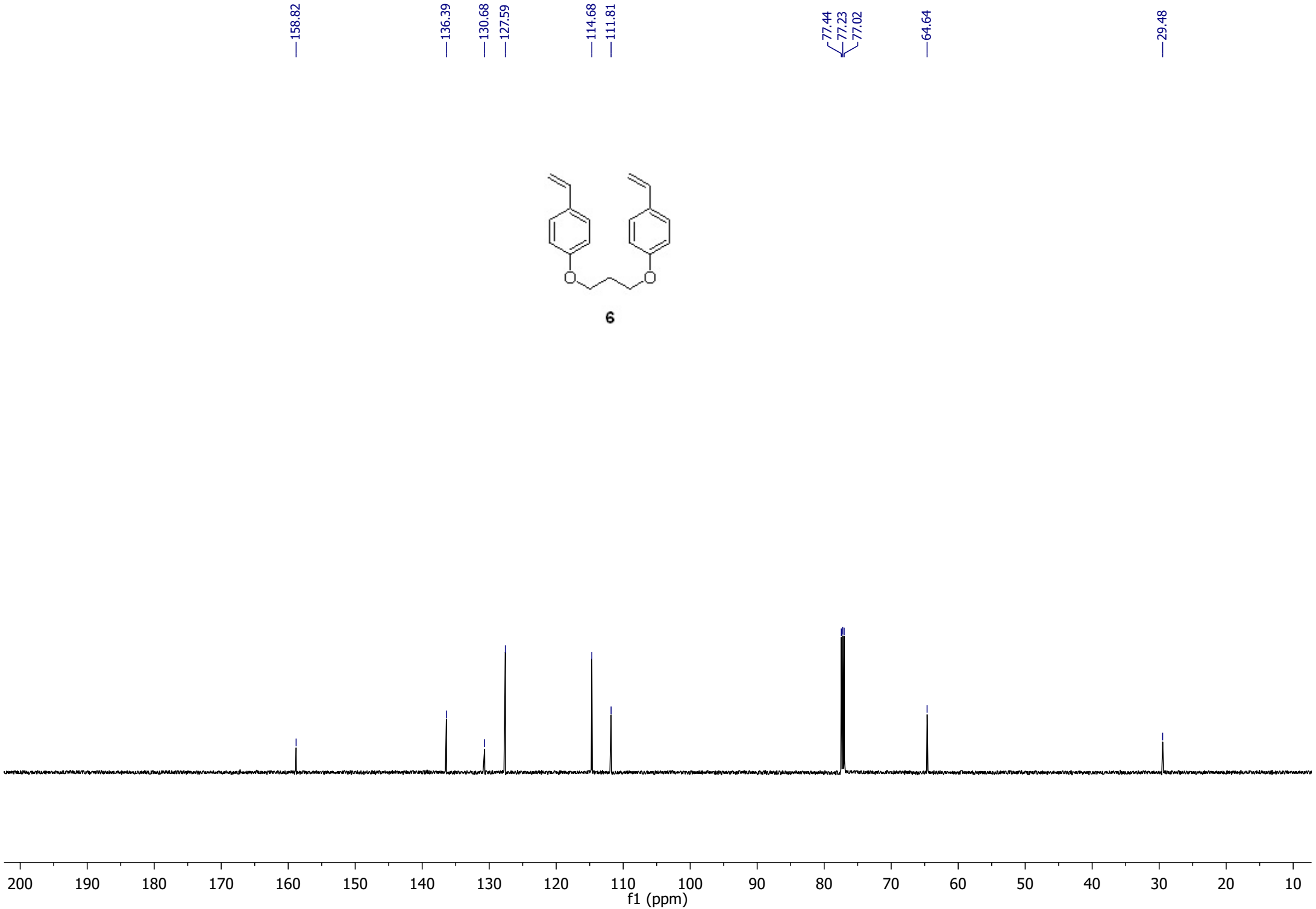
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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64.64
29.48
6
200
190
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170
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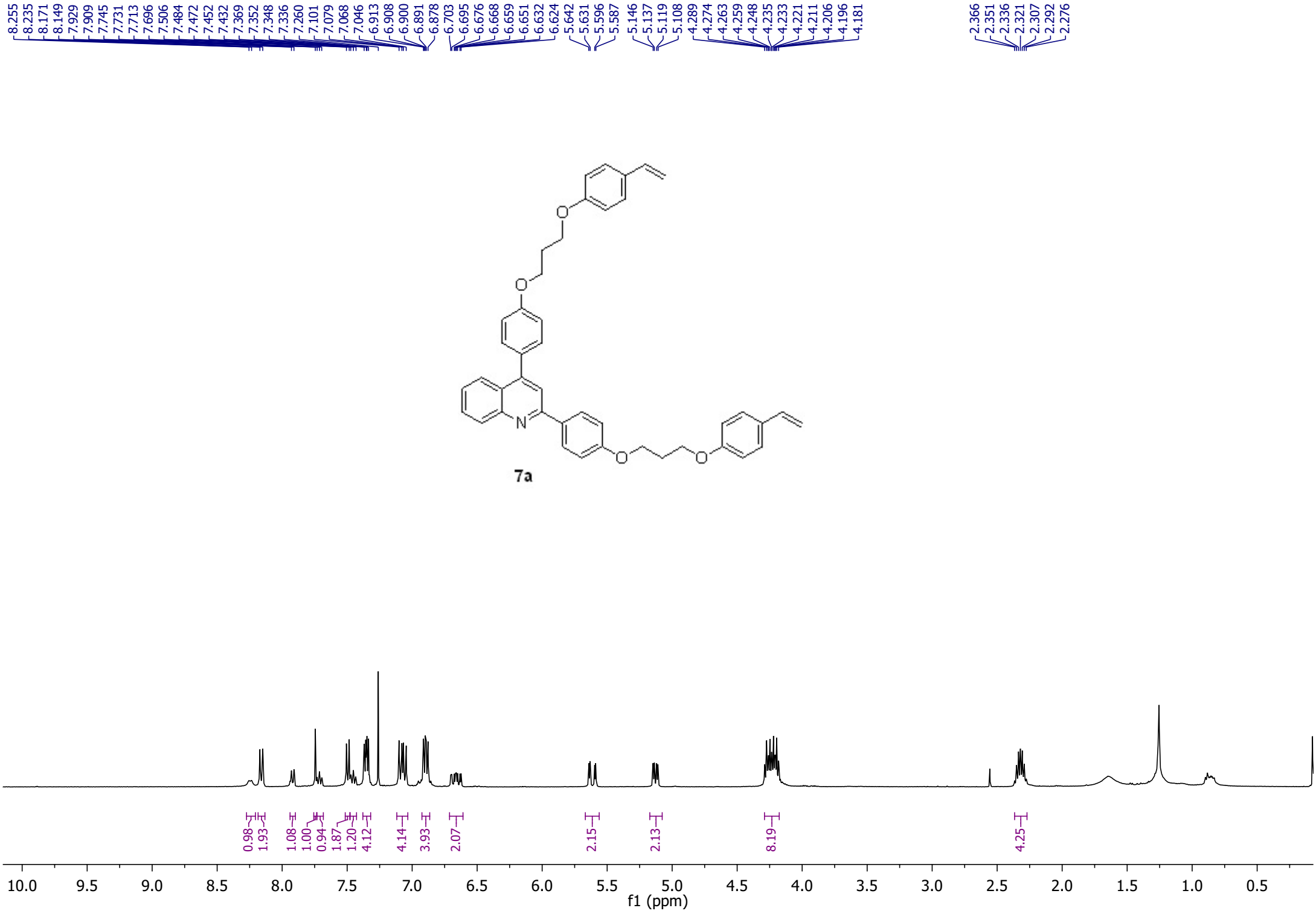
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.472
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7.432
7.369
7.352
7.348
7.336
7.260
7.101
7.079
7.068
7.046
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6.908
6.900
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6.676
6.668
6.659
6.651
6.632
6.624
5.642
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5.596
5.587
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4.196
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O
O
N
O
O
7a
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1.08
1.00
0.94
1.87
1.20
4.12
4.14
3.93
2.07
2.15
2.13
8.19
4.25
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
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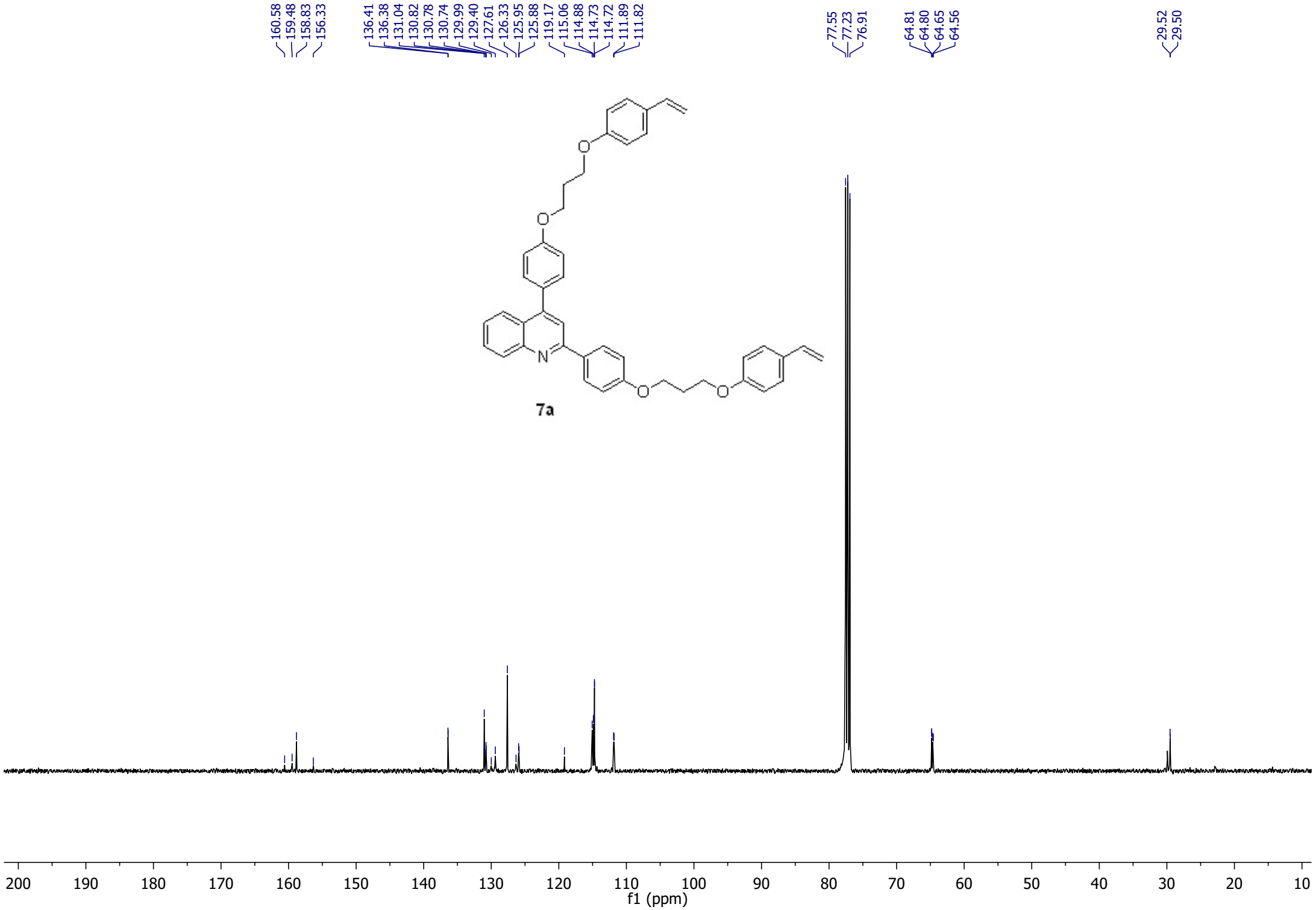
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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130.78
130.74
129.99
129.40
127.61
126.33
125.95
125.88
119.17
115.06
114.88
114.73
114.72
111.89
111.82
77.55
77.23
76.91
64.81
64.80
64.65
64.56
29.52
29.50
O
O
N
O
O
7a
200
190
180
170
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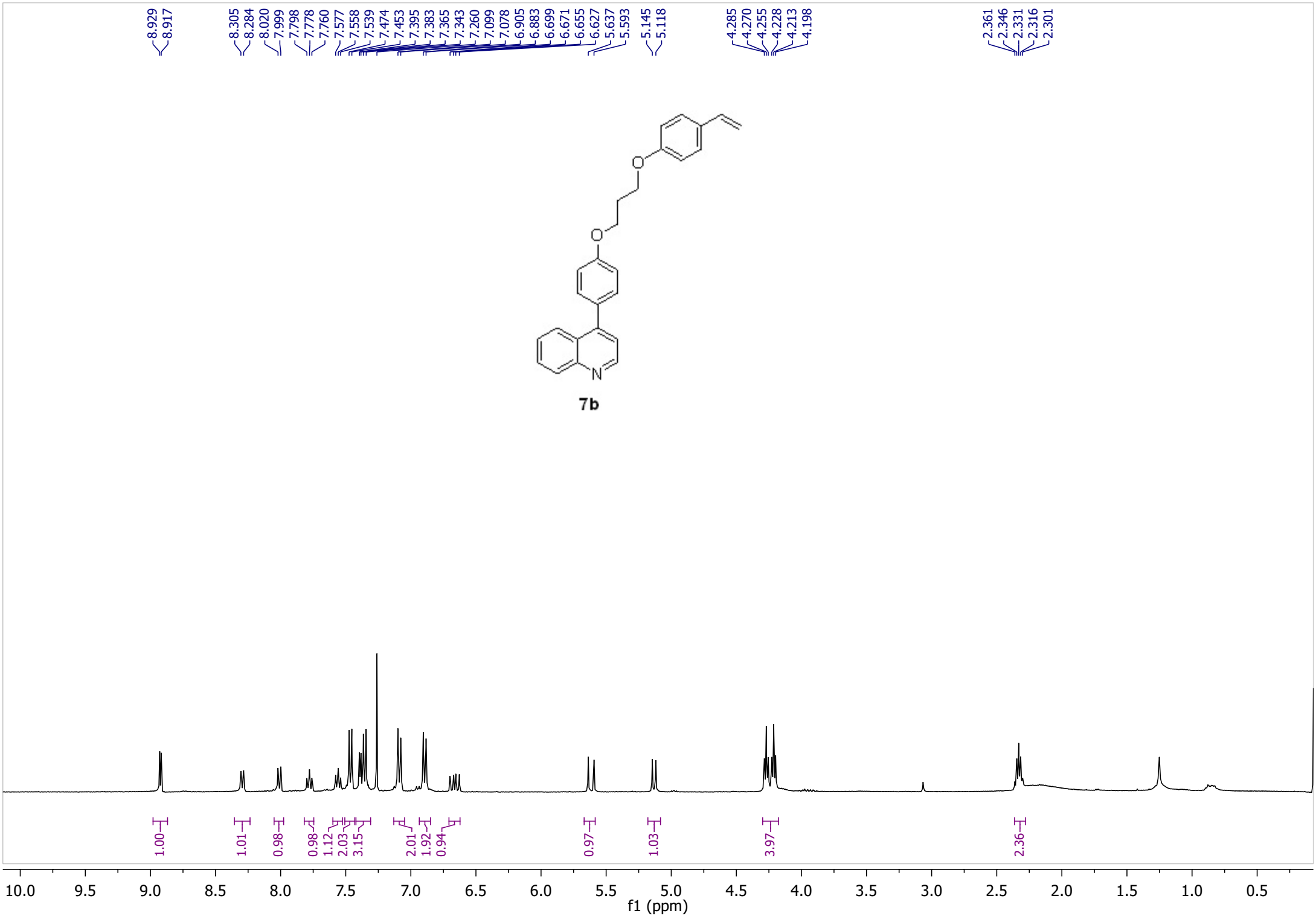
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.577
7.558
7.539
7.474
7.453
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7.383
7.365
7.343
7.260
7.099
7.078
6.905
6.883
6.699
6.671
6.655
6.627
5.637
5.593
5.145
5.118
4.285
4.270
4.255
4.228
4.213
4.198
2.361
2.346
2.331
2.316
2.301
O
O
N
7b
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1.01
0.98
0.98
1.12
2.03
3.15
2.01
1.92
0.94
0.97
1.03
3.97
2.36
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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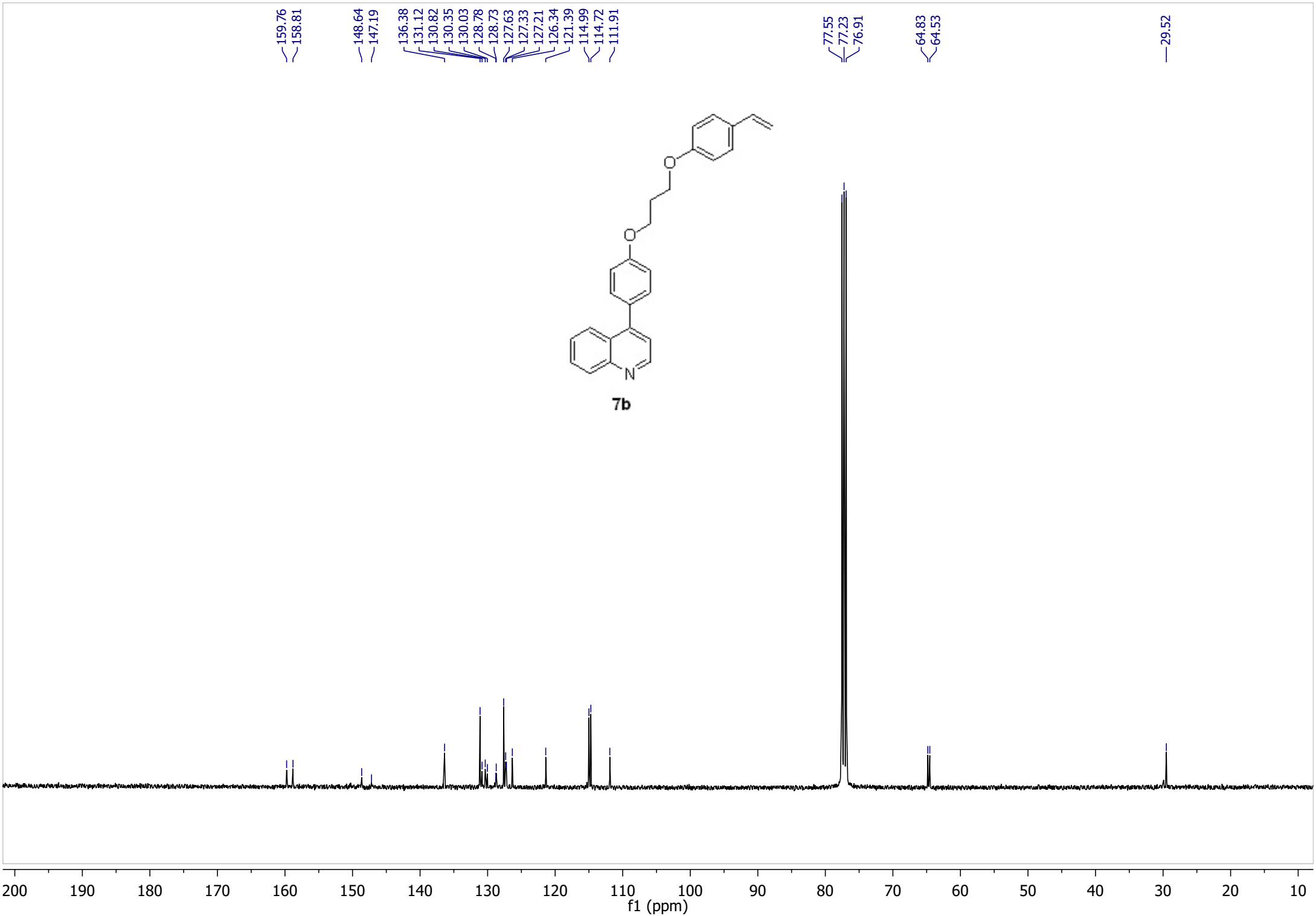
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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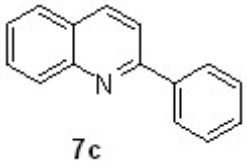
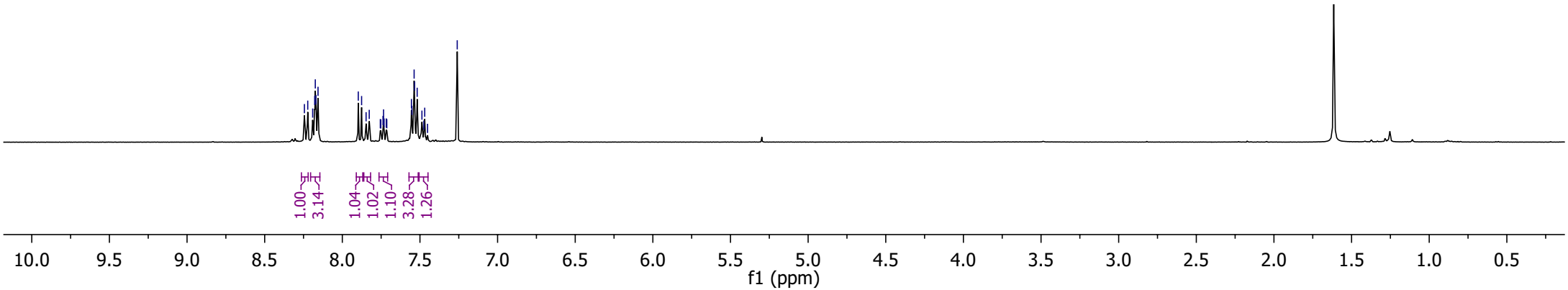
127.33
127.21
126.34
121.39
114.99
114.72
111.91
77.55
77.23
76.91
64.83
64.53
29.52
O
O
N
7b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


8.244
8.223
8.191
8.178
8.174
8.170
8.156
7.897
7.876
7.847
7.827
7.755
7.752
7.738
7.734
7.731
7.717
7.714
7.555
7.552
7.538
7.534
7.518
7.487
7.475
7.469
7.451
7.260


N

7c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1.04
1.02
1.10
3.28
1.26
10.0
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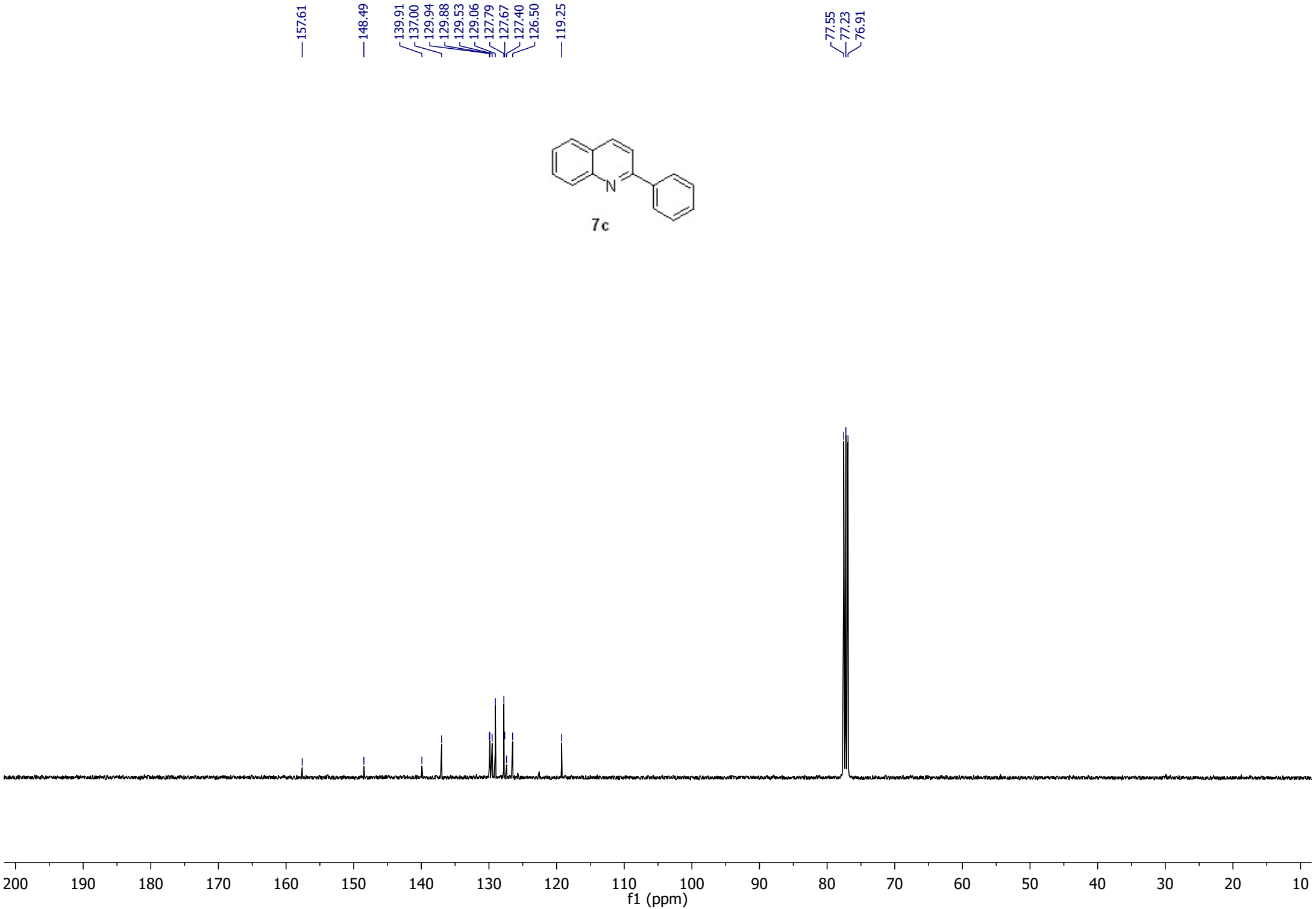
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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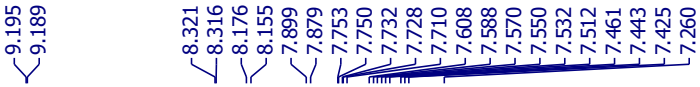
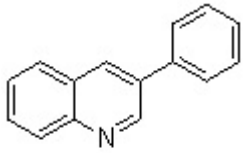
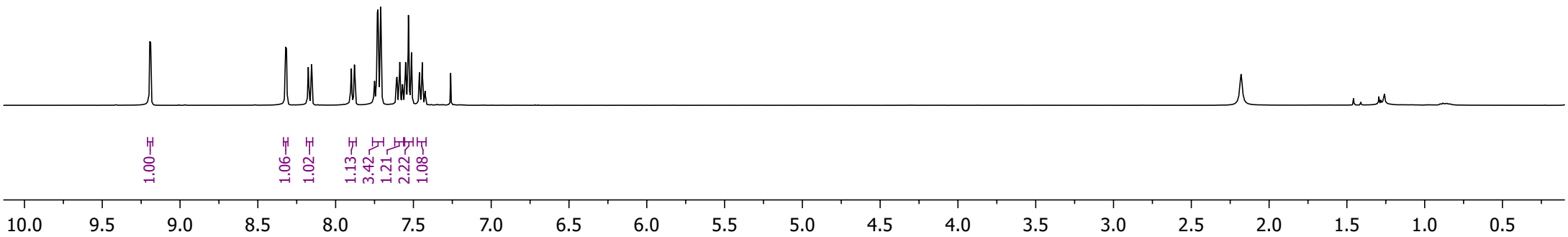
148.49
139.91
137.00
129.94
129.88
129.53
129.06
127.79
127.67
127.40
126.50
119.25
77.55
77.23
76.91
N
7c
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


9.195
9.189
8.321
8.316
8.176
8.155
7.899
7.879
7.753
7.750
7.732
7.728
7.710
7.608
7.588
7.570
7.550
7.532
7.512
7.461
7.443
7.425
7.260


N

9a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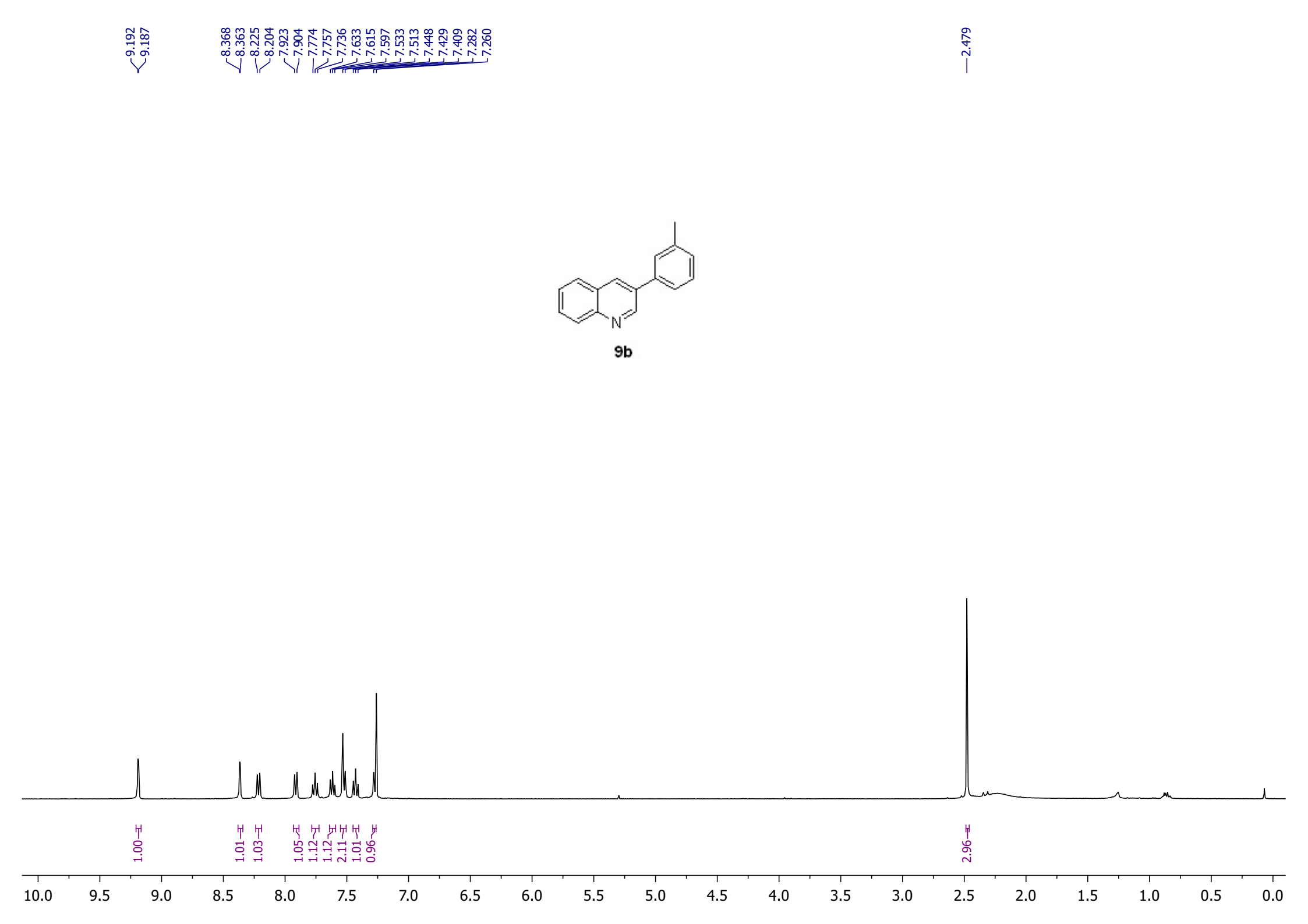
1.06
1.02
1.13
3.42
1.21
2.22
1.08
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5


9.192
9.187
8.368
8.363
8.225
8.204
7.923
7.904
7.774
7.757
7.736
7.633
7.615
7.597
7.533
7.513
7.448
7.429
7.409
7.282
7.260
2.479
N
9b
1.00
1.01
1.03
1.05
1.12
1.12
2.11
1.01
0.96
2.96
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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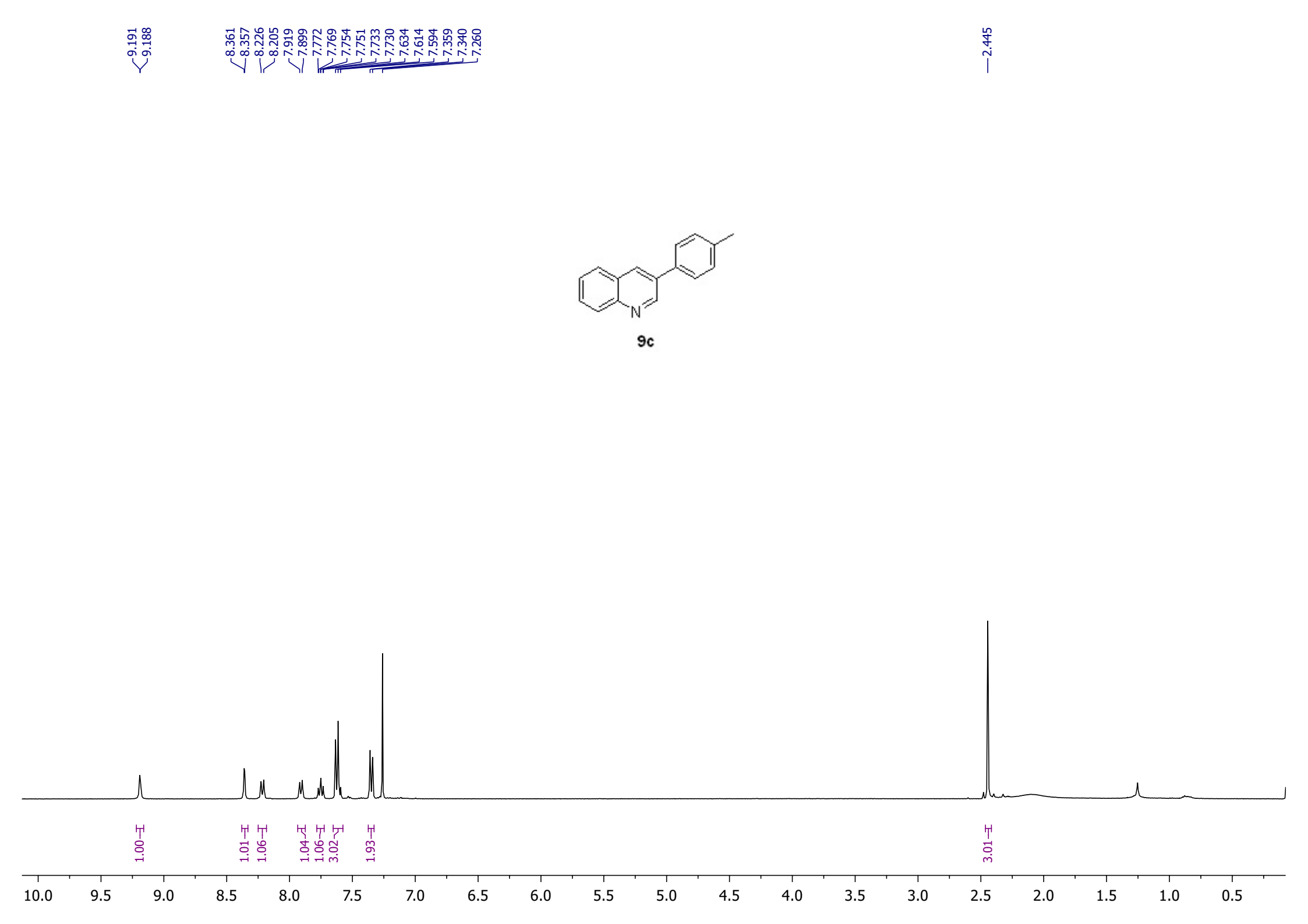
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0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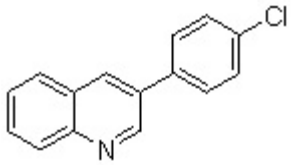
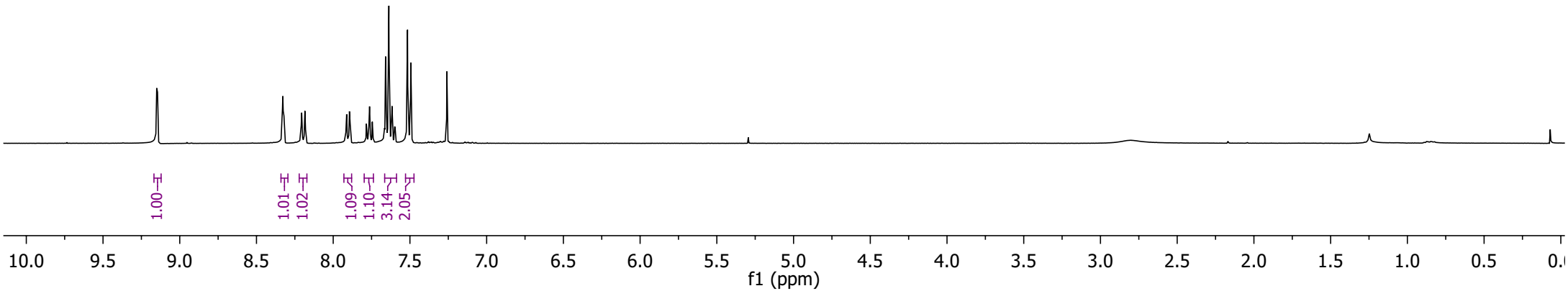
9.188
8.361
8.357
8.226
8.205
7.919
7.899
7.772
7.769
7.754
7.751
7.733
7.730
7.634
7.614
7.594
7.359
7.340
7.260
2.445
N
9c
1.00
1.01
1.06
1.04
1.06
3.02
1.93
3.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5


9.150
9.145
8.328
8.323
8.205
8.184
7.914
7.894
7.784
7.780
7.763
7.746
7.742
7.659
7.654
7.642
7.637
7.617
7.597
7.516
7.511
7.499
7.494
7.260


Cl
N

9d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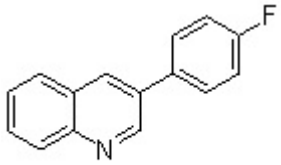
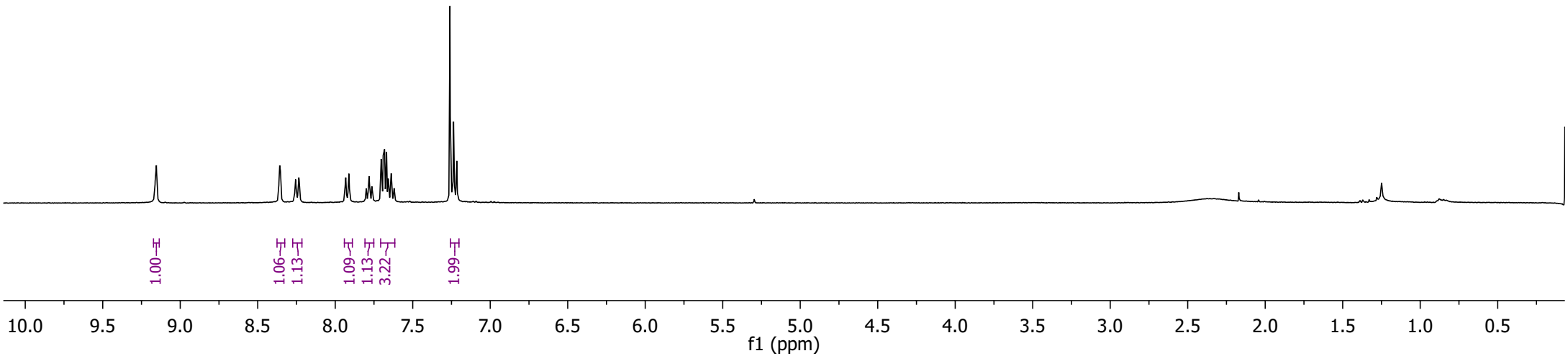
1.01
1.02
1.09
1.10
3.14
2.05
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


9.159
9.154
8.358
8.256
8.235
7.932
7.912
7.802
7.800
7.782
7.764
7.761
7.704
7.699
7.691
7.687
7.682
7.669
7.658
7.639
7.620
7.260
7.237
7.215


F
N

9e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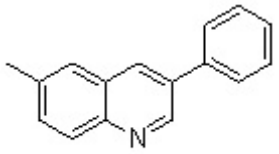
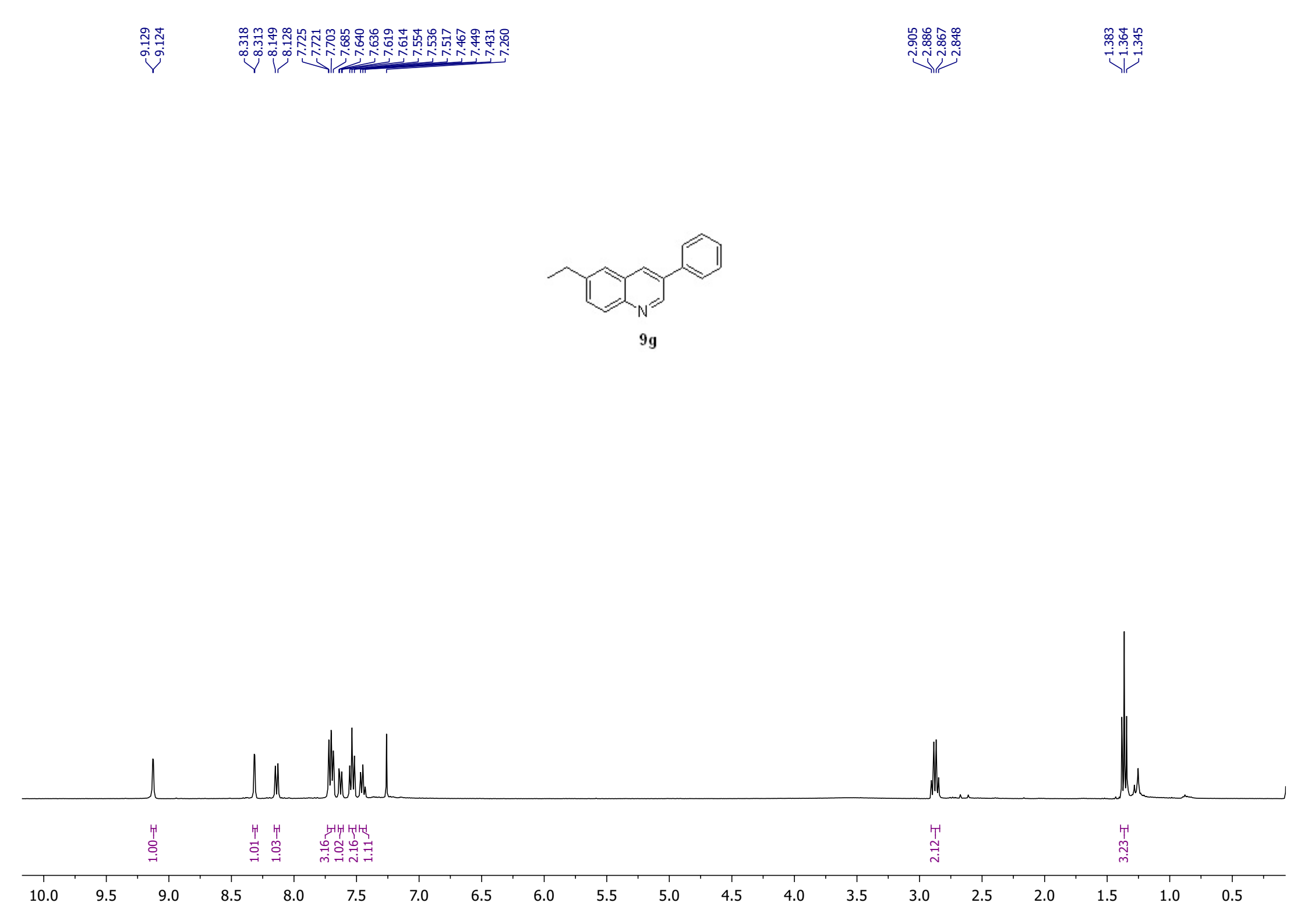
1.06
1.13
1.09
1.13
3.22
1.99
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)



9f

9.122
9.117
8.299
8.294
8.134
8.113
7.719
7.717
7.698
7.676
7.609
7.604
7.587
7.583
7.555
7.537
7.517
7.469
7.451
7.432
7.260
2.576
1.00
1.00
1.04
3.15
1.09
2.09
1.14
3.05
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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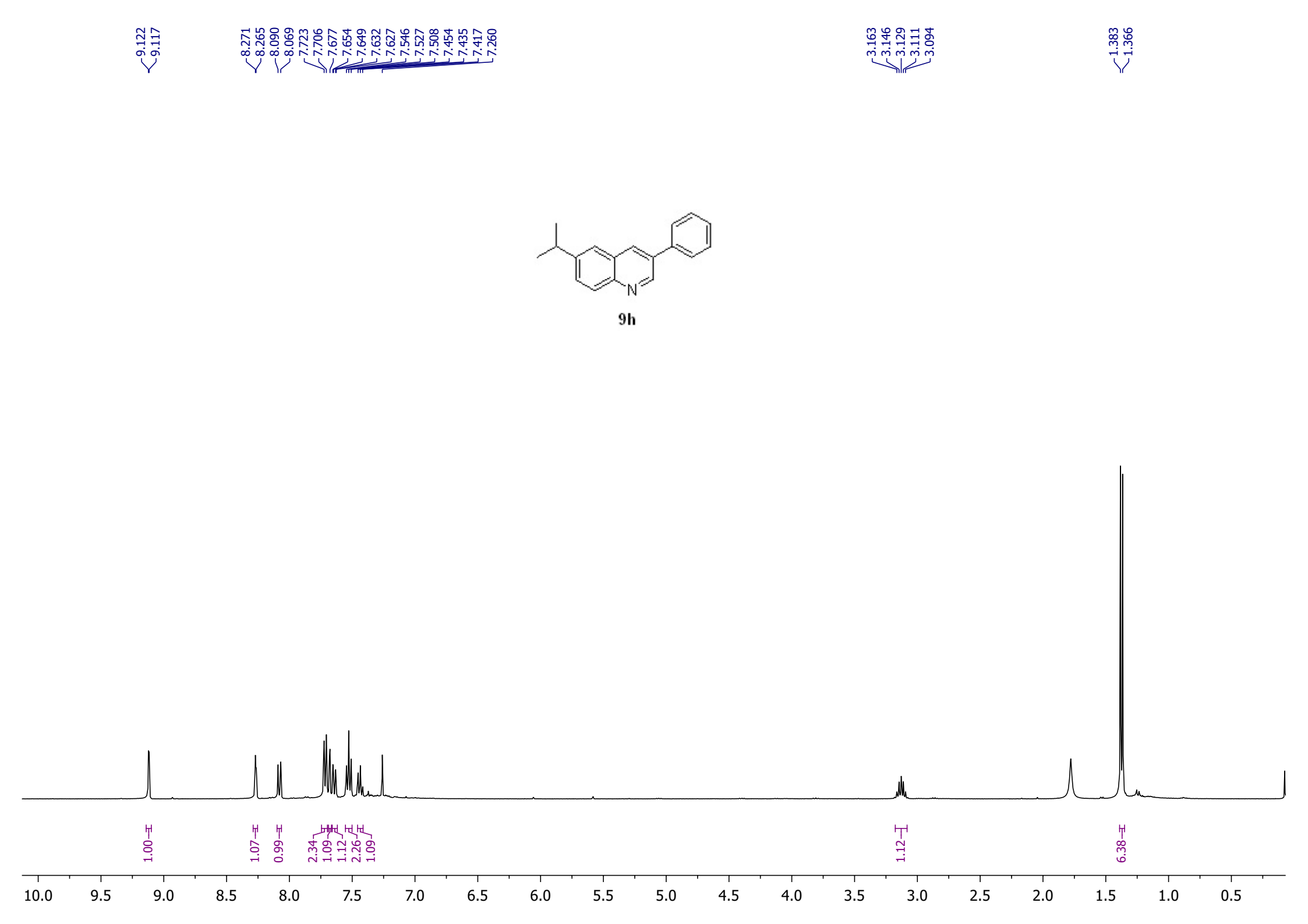
9.124
8.318
8.313
8.149
8.128
7.725
7.721
7.703
7.685
7.640
7.636
7.619
7.614
7.554
7.536
7.517
7.467
7.449
7.431
7.260
2.905
2.886
2.867
2.848
1.383
1.364
1.345
N
9g
1.00
1.01
1.03
3.16
1.02
2.16
1.11
2.12
3.23
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5


9.122
9.117
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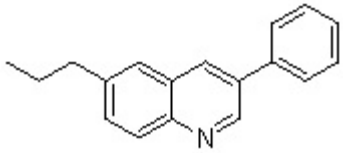
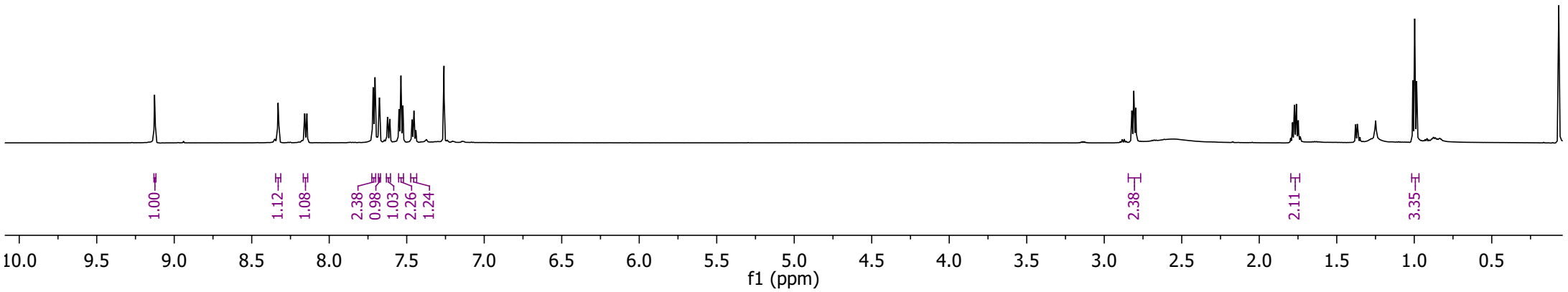
8.265
8.090
8.069
7.723
7.706
7.677
7.654
7.649
7.632
7.627
7.546
7.527
7.508
7.454
7.435
7.417
7.260
3.163
3.146
3.129
3.111
3.094
1.383
1.366
N
9h
1.00
1.07
0.99
2.34
1.09
1.12
2.26
1.09
1.12
6.38
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5


N

9i


9.127
9.124
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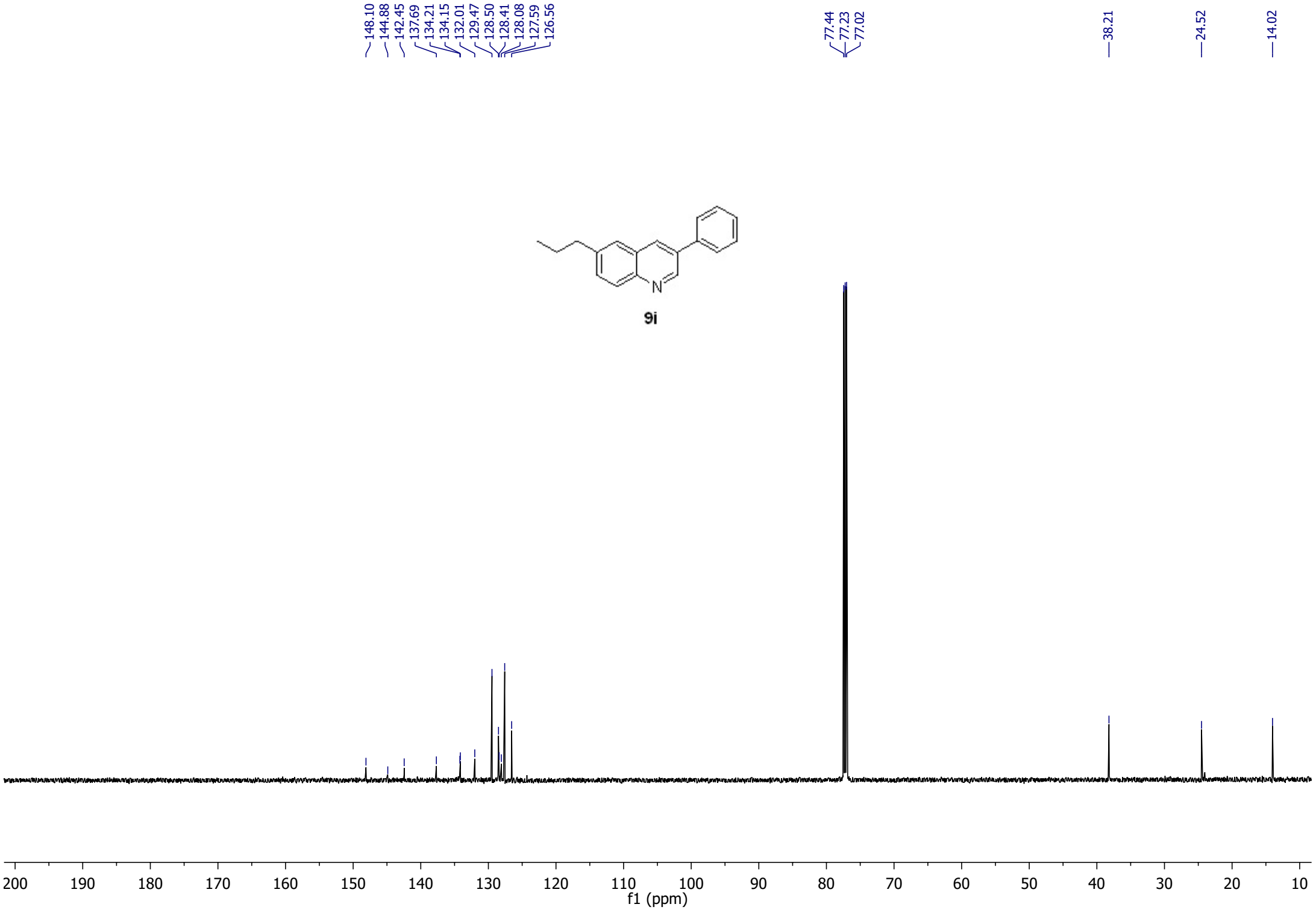
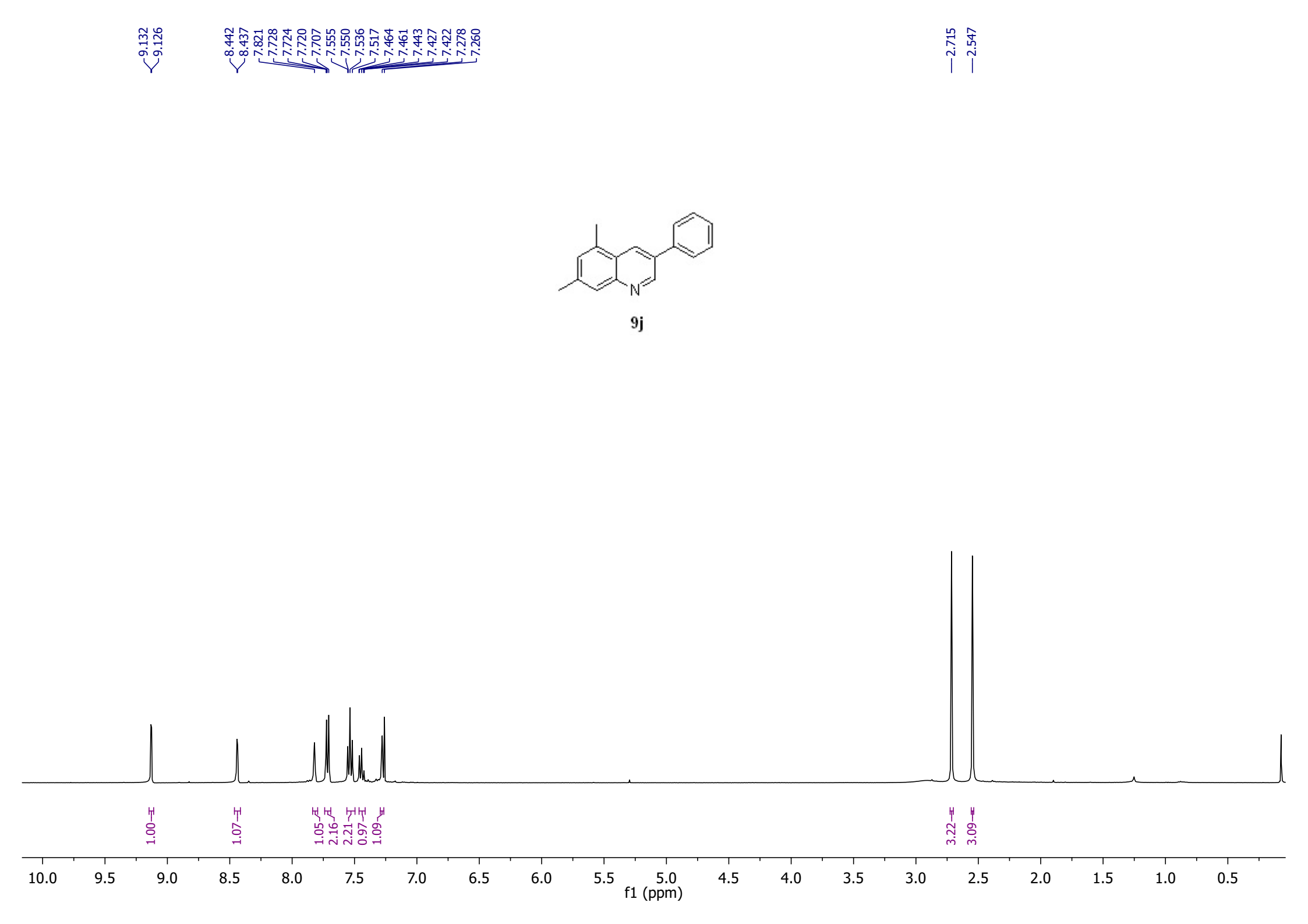
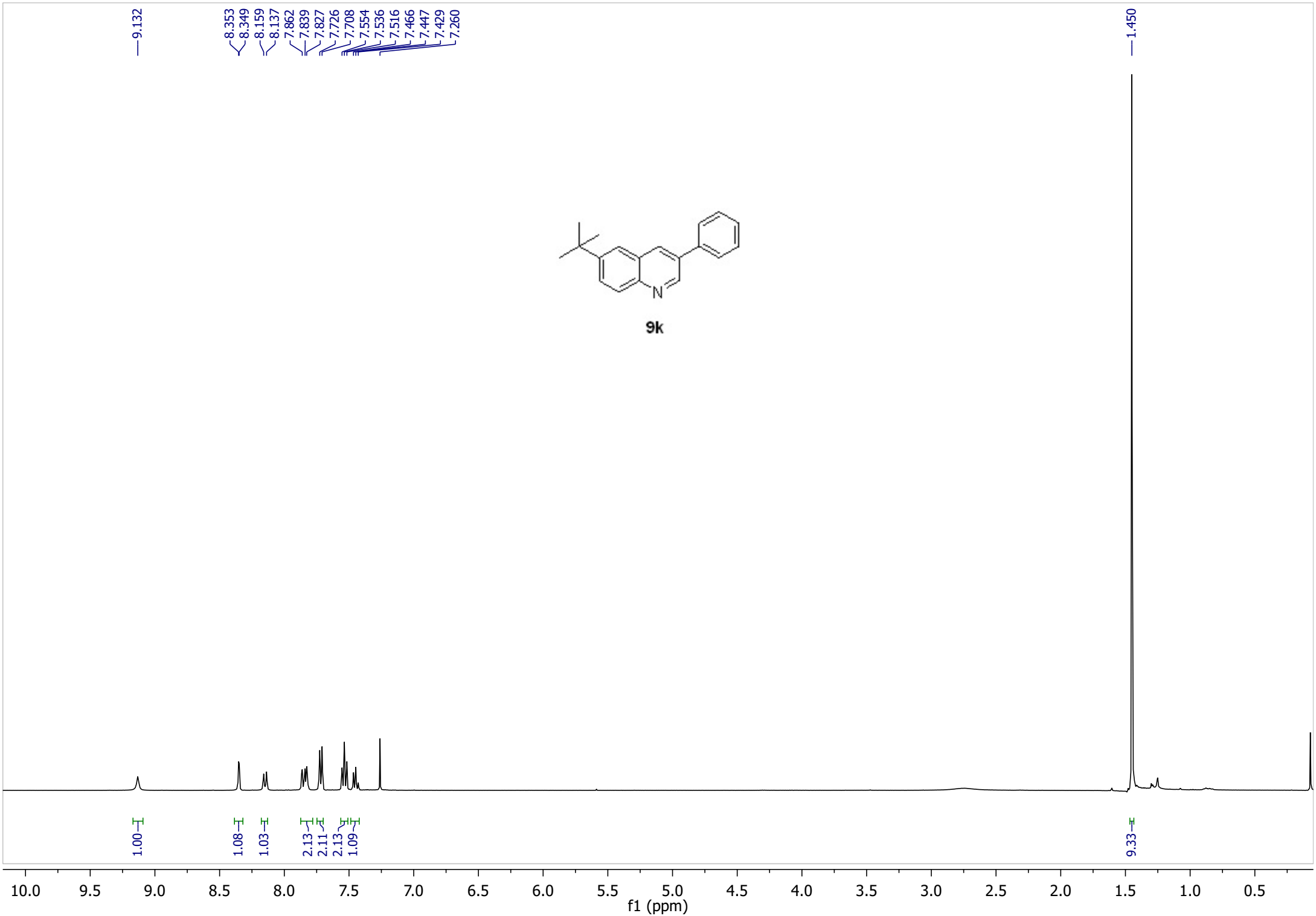
8.328
8.158
8.144
7.717
7.704
7.676
7.624
7.622
7.610
7.607
7.550
7.537
7.525
7.465
7.453
7.441
7.260
2.822
2.809
2.796
1.785
1.773
1.760
1.748
1.009
0.997
0.985
1.00
1.12
1.08
2.38
0.98
1.03
2.26
1.24
2.38
2.11
3.35
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


148.10
144.88
142.45
137.69
134.21
134.15
132.01
129.47
128.50
128.41
128.08
127.59
126.56
77.44
77.23
77.02
38.21
24.52
14.02
N
9i
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


9.132
9.126
8.442
8.437
7.821
7.728
7.724
7.720
7.707
7.555
7.550
7.536
7.517
7.464
7.461
7.443
7.427
7.422
7.278
7.260
2.715
2.547
N
1.00
1.07
1.05
2.16
2.21
0.97
1.09
3.22
3.09
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

9j


9.132
8.353
8.349
8.159
8.137
7.862
7.839
7.827
7.726
7.708
7.554
7.536
7.516
7.466
7.447
7.429
7.260
1.450
N
9k
1.00
1.08
1.03
2.13
2.11
2.13
1.09
9.33
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


9.172
9.167
8.231
8.226
8.115
8.092
7.875
7.869
7.713
7.709
7.692
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7.654
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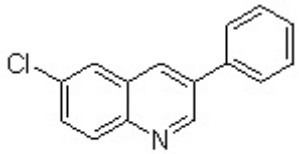
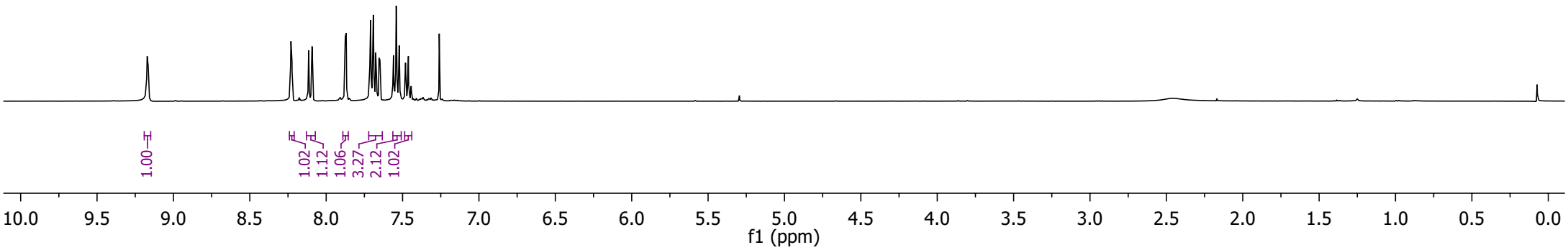
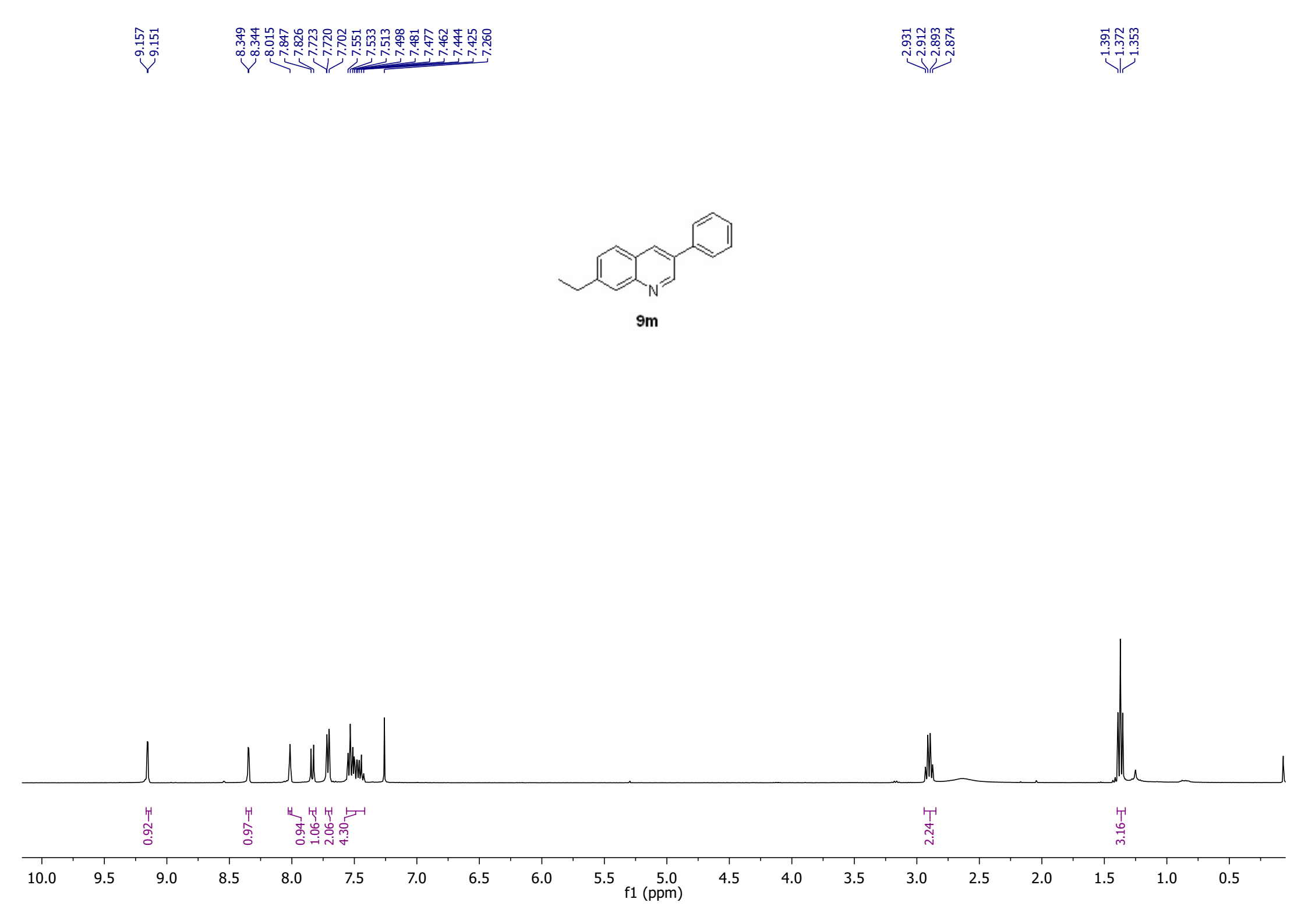
7.542
7.522
7.481
7.462
7.444
7.260


Cl
N

9l


1.00
1.02
1.12
1.06
3.27
2.12
1.02
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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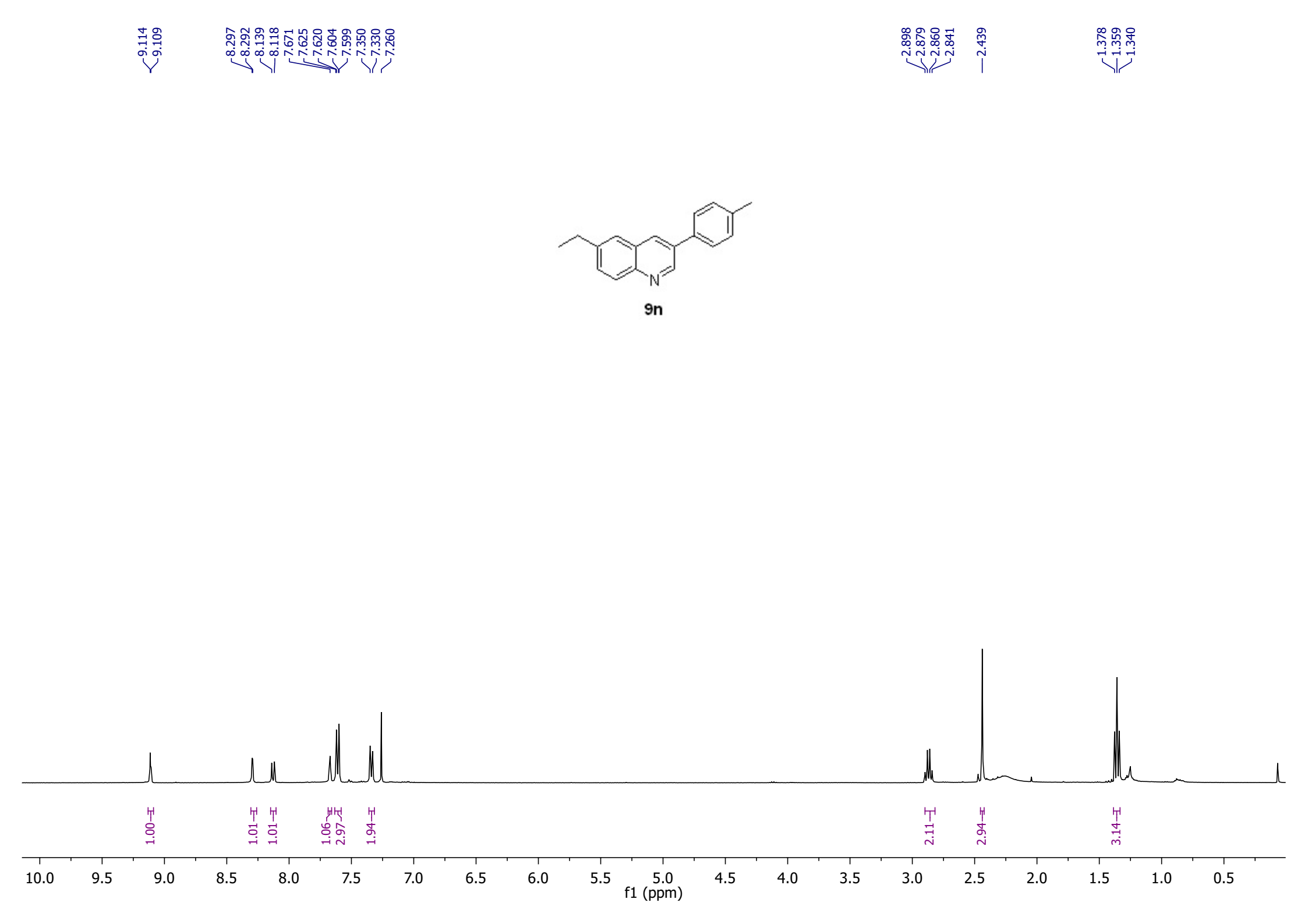
9.151
8.349
8.344
8.015
7.847
7.826
7.723
7.720
7.702
7.551
7.533
7.513
7.498
7.481
7.477
7.462
7.444
7.425
7.260
2.931
2.912
2.893
2.874
1.391
1.372
1.353
N
9m
0.92
0.97
0.94
1.06
2.06
4.30
2.24
3.16
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


9.114
9.109
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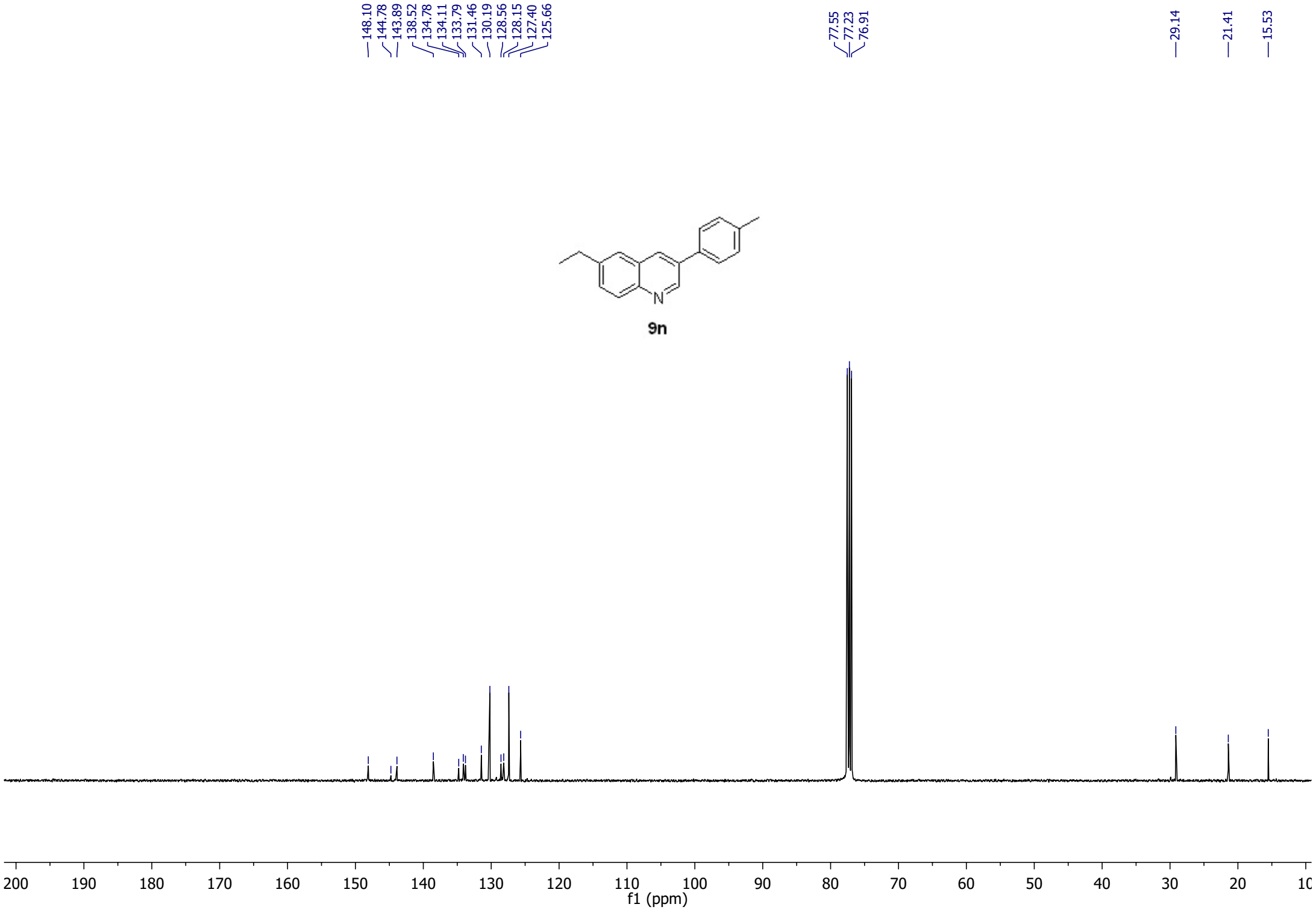
8.292
8.139
8.118
7.671
7.625
7.620
7.604
7.599
7.350
7.330
7.260
2.898
2.879
2.860
2.841
2.439
1.378
1.359
1.340
N
9n
1.00
1.01
1.01
1.06
2.97
1.94
2.11
2.94
3.14
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


148.10
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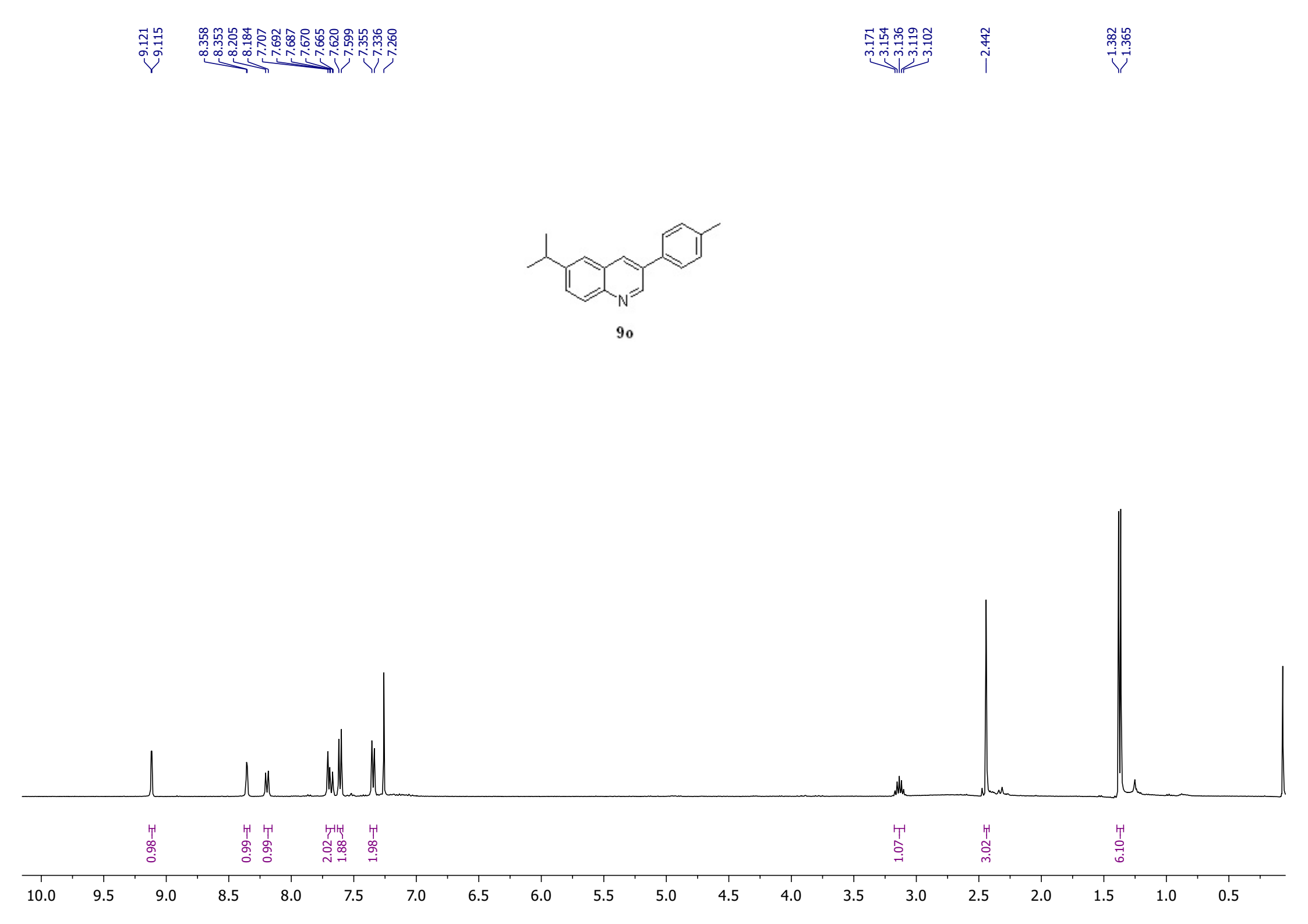
134.78
134.11
133.79
131.46
130.19
128.56
128.15
127.40
125.66
77.55
77.23
76.91
29.14
21.41
15.53
N
9n
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


9.121
9.115
8.358
8.353
8.205
8.184
7.707
7.692
7.687
7.670
7.665
7.620
7.599
7.355
7.336
7.260
3.171
3.154
3.136
3.119
3.102
2.442
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1.365
N
0.98
0.99
0.99
2.02
1.88
1.98
1.07
3.02
6.10
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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2.0
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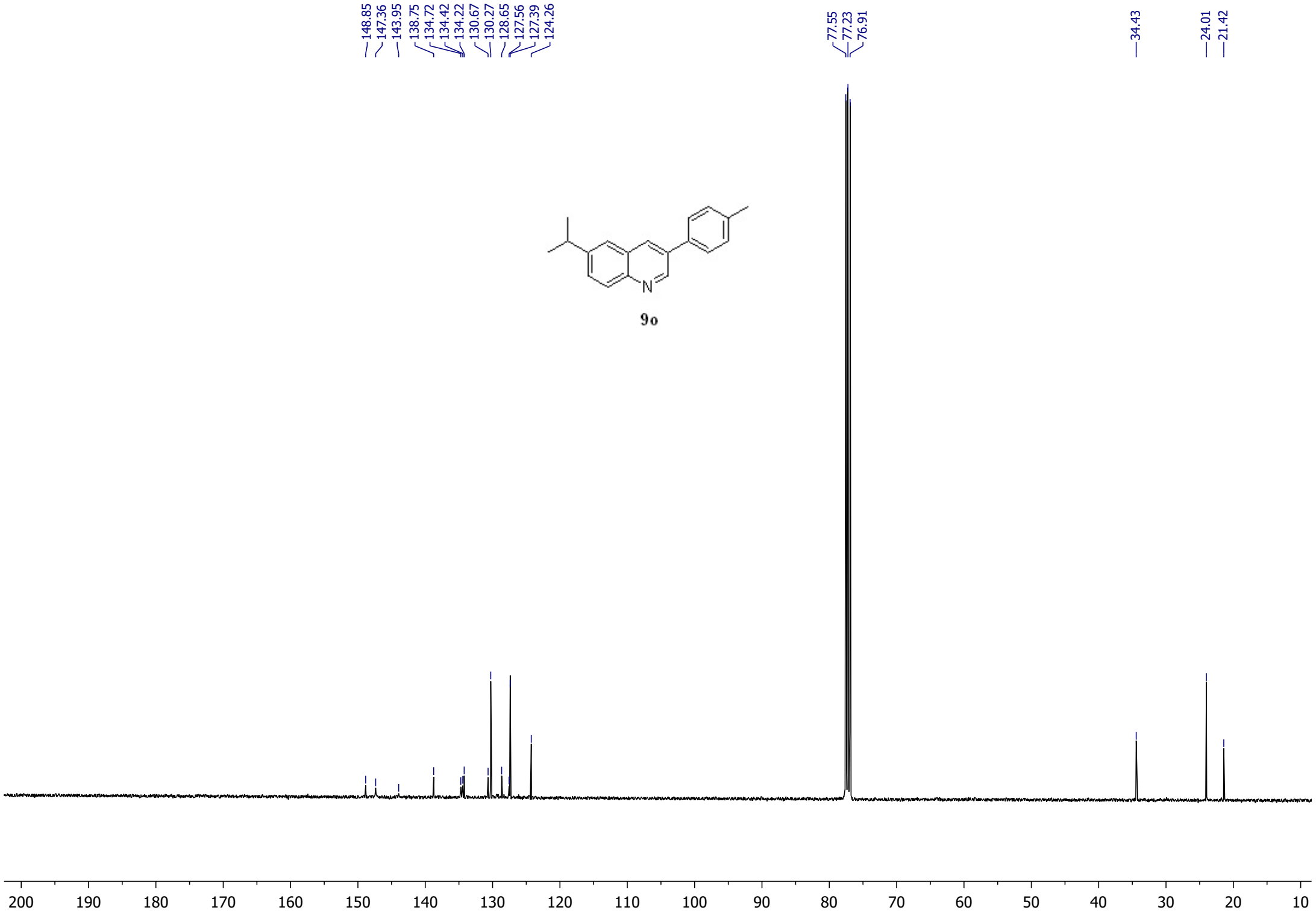
9o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130.27
128.65
127.56
127.39
124.26
77.55
77.23
76.91
34.43
24.01
21.42
N
200
190
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170
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140
130
120
110
100
90
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70
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40
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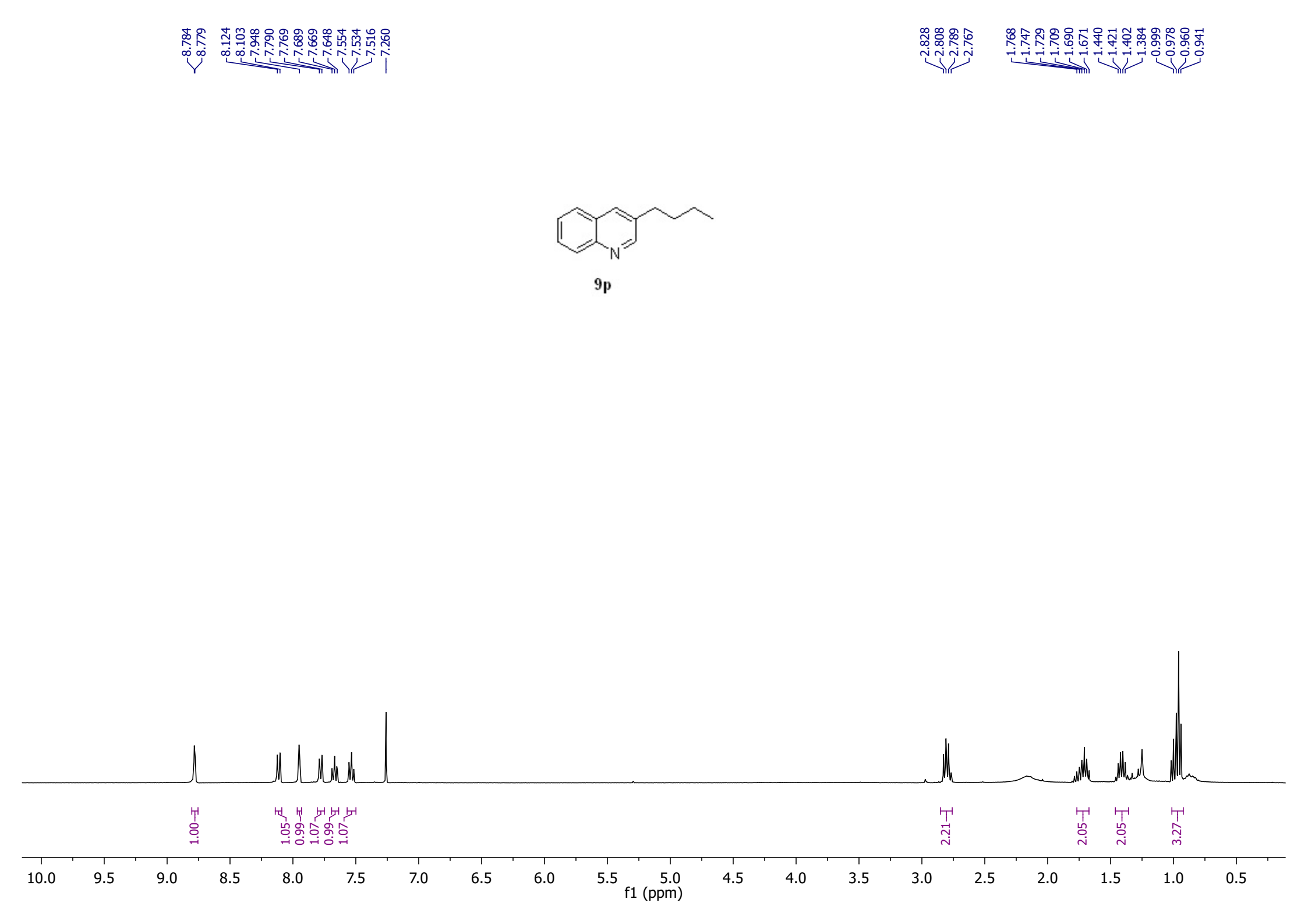
10

9o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7.948
7.790
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7.554
7.534
7.516
7.260
2.828
2.808
2.789
2.767
1.768
1.747
1.729
1.709
1.690
1.671
1.440
1.421
1.402
1.384
0.999
0.978
0.960
0.941
N
9p
1.00
1.05
0.99
1.07
0.99
1.07
2.21
2.05
2.05
3.27
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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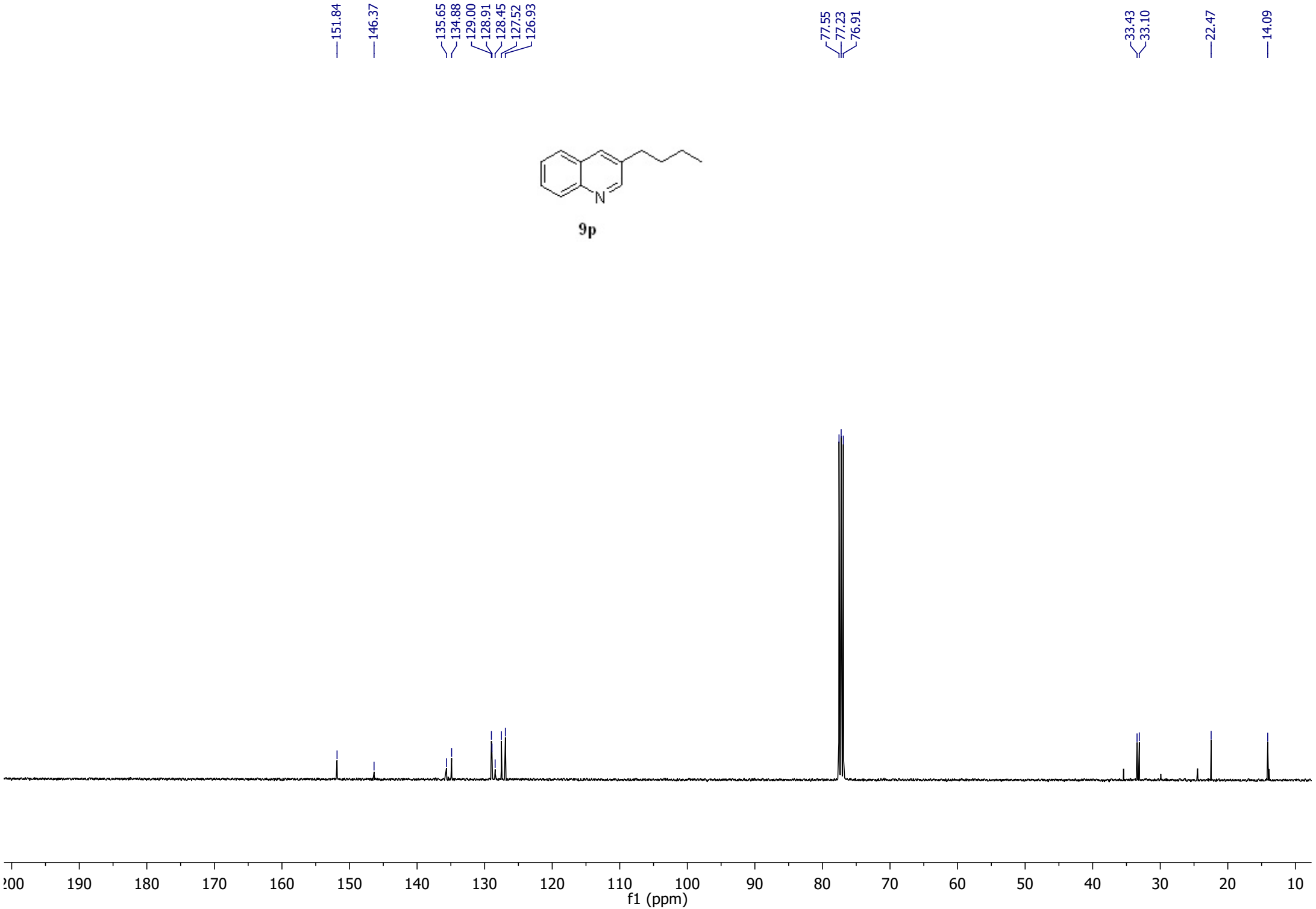
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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128.91
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127.52
126.93
77.55
77.23
76.91
33.43
33.10
22.47
14.09
N
9p
200
190
180
170
160
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140
130
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80
70
60
50
40
30
20
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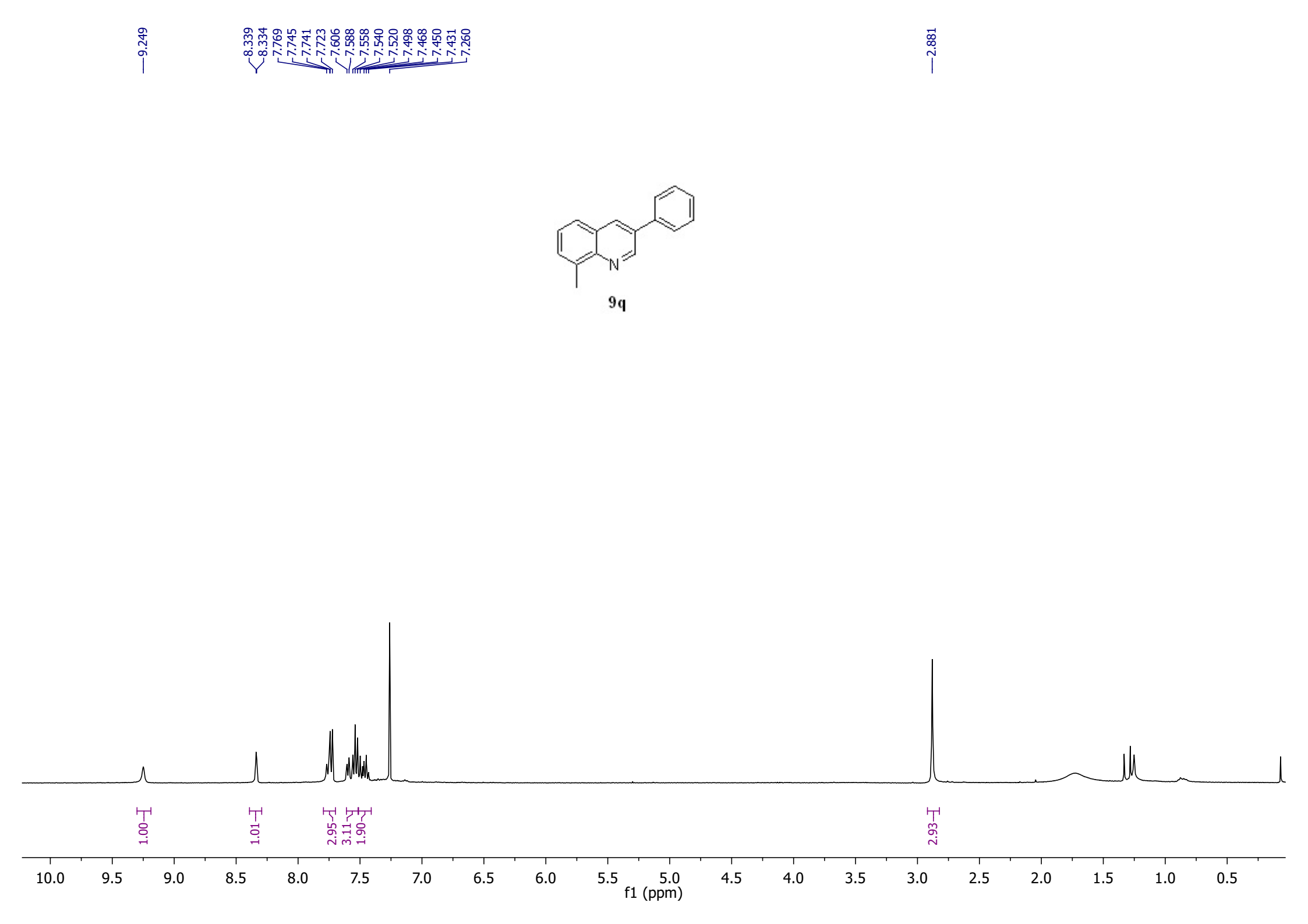
f1 (ppm)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7.558
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7.520
7.498
7.468
7.450
7.431
7.260
2.881
N
9q
1.00
1.01
2.95
3.11
1.90
2.93
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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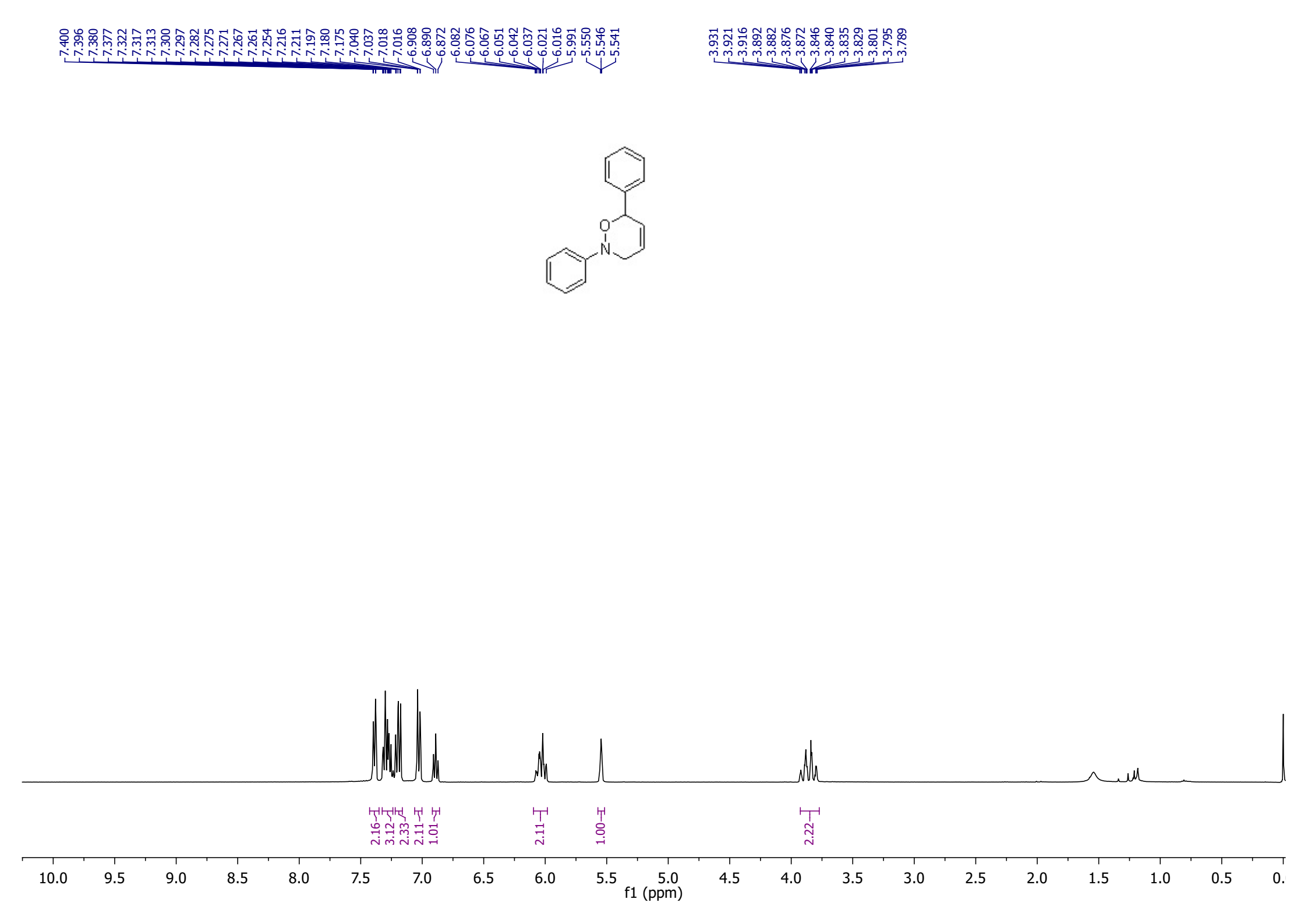
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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7.300
7.297
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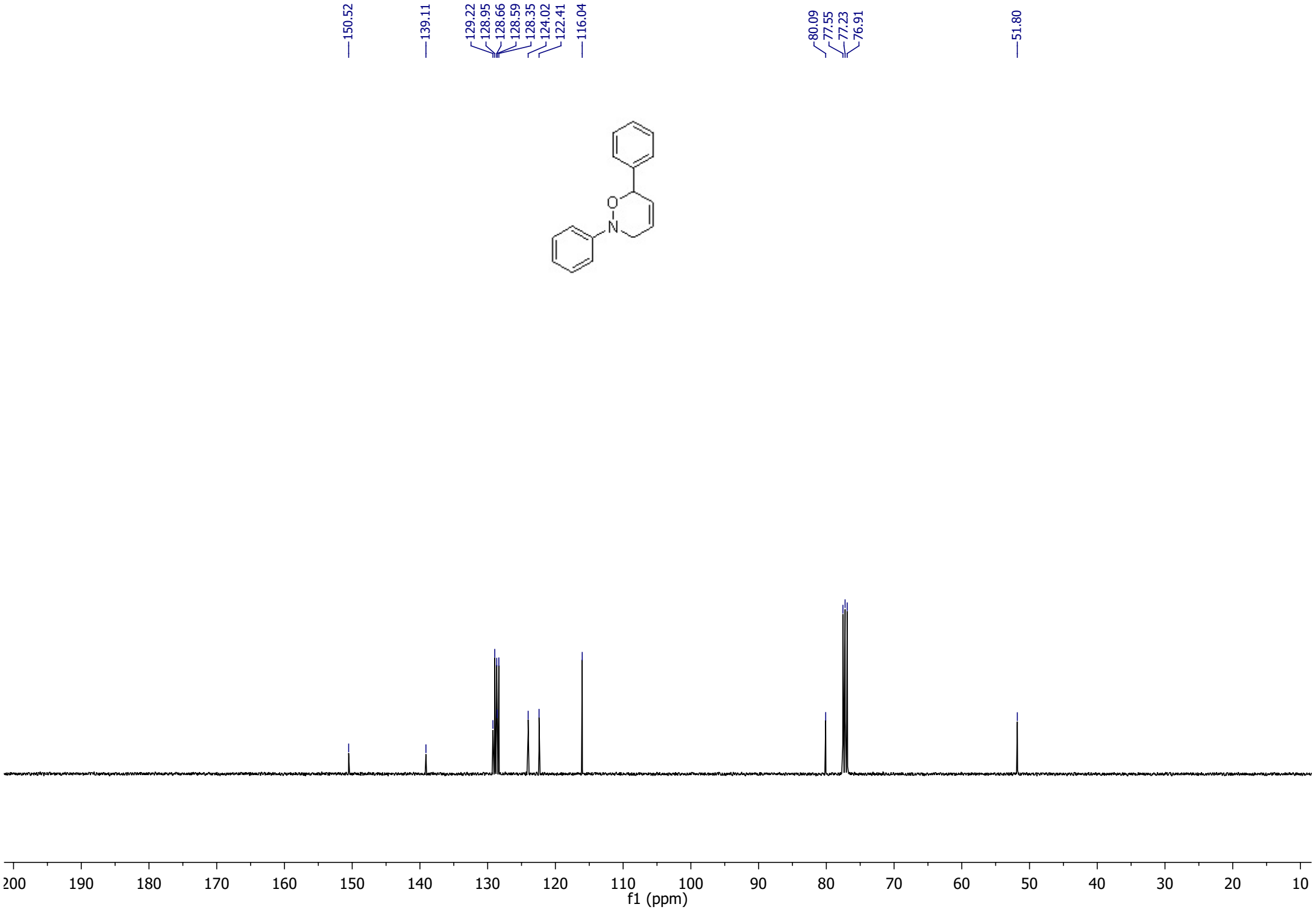
7.271
7.267
7.261
7.254
7.216
7.211
7.197
7.180
7.175
7.040
7.037
7.018
7.016
6.908
6.890
6.872
6.082
6.076
6.067
6.051
6.042
6.037
6.021
6.016
5.991
5.550
5.546
5.541
3.931
3.921
3.916
3.892
3.882
3.876
3.872
3.846
3.840
3.835
3.829
3.801
3.795
3.789
O
N
2.16
3.12
2.33
2.11
1.01
2.11
1.00
2.22
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


150.52
139.11
129.22
128.95
128.66
128.59
128.35
124.02
122.41
116.04
80.09
77.55
77.23
76.91
51.80
O
N
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)