Rh(I)-Catalyzed Direct Arylation of Pyridines and Quinolines

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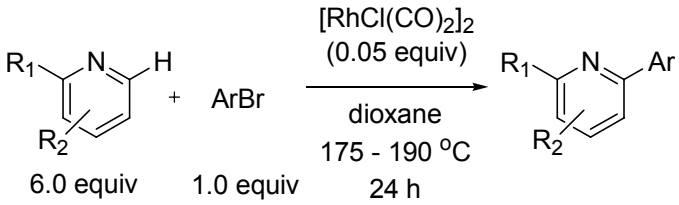
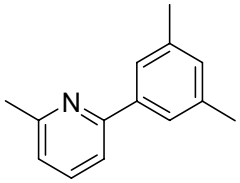
General Procedures. All reagents were degassed and handled under an inert nitrogen atmosphere using syringe and cannula techniques. Unless otherwise noted, all organic preparations were carried out in flame- or oven-dried glassware under a nitrogen atmosphere and all catalytic arylation reactions were assembled in a nitrogen-filled Vacuum Atmospheres inert atmosphere box. Flash column chromatography was carried out using a Biotage SP Flash Purification System (Biotage No. SP1-B1A) with Flash+ cartridges (Biotage No. FPK0-1107-16046, or FPL0-1118-15045) using hexanes/ethyl acetate gradients calculated using the TLC data recorded for each compound (vide infra). NMR spectroscopy (^{1}H, ^{13}C, and ^{19}F) was conducted using a Bruker AVQ-400 or AV-300 spectrometer at room temperature. Chemical shifts are reported in ppm relative to TMS as an internal standard ($Si(CH_3)_4$, 0.00 ppm) in $CDCl_3$, and coupling constants are reported in Hz. Mass spectrometry was performed by the University of California, Berkeley mass spectrometry facility using a VG ProSpec (EBE geometry) spectrometer equipped with an electron impact source (EI ionization). Reported tabular yields are the average of at least two experimental runs; yields reported in the following experimental procedures may vary slightly from those found in the tables.

Materials. Unless otherwise noted, all reagents were obtained from commercial suppliers and used without further purification. $[RhCl(CO)_2]_2$ was purchased from either Strem chemicals or Sigma-Aldrich and stored in the glove box. All liquid reagents were thoroughly degassed using three freeze-pump-thaw cycles prior to introduction to the glove box. 1, 4-Dioxane was obtained from a Seca Solvent System by GlassContour (solvent dried over alumina under a nitrogen atmosphere) prior to introduction to the glove box.

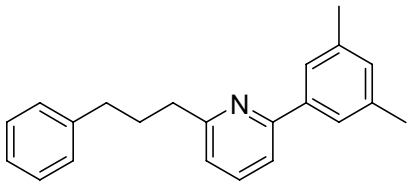


General Procedure for the Catalytic Direct Arylation of Pyridines and Quinolines. To a 15- or 25-mL sealable flame- or oven-dried Schlenk tube containing a stir bar was added $[RhCl(CO)_2]_2$ (0.0078 g, 0.0200 mmol), the heterocycle (2.400 mmol), the aryl bromide (0.400 mmol), and 1,4-dioxane (reaction diluted to a total concentration of 0.30 – 0.80 M). The volume of the heterocycle is not negligible at the concentrations used and must therefore be included in the concentration calculation. The reaction vessel was sealed, removed from the glove box, submerged to the neck in a silicone oil bath, heated at the indicated temperature with stirring for 24 h and then cooled to room temperature. The reaction mixture was transferred to a 60 mL separatory funnel using 3 x 5.0 mL of CH_2Cl_2 and 2.5 mL of MeOH, the reaction mixture was washed with saturated $NaHCO_3$ (1 x 20 mL), the aqueous layer was extracted with CH_2Cl_2 (3 x 10 mL). The organic extracts were combined, washed with

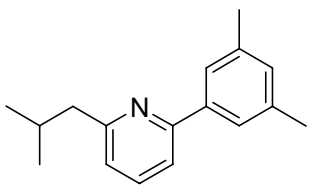
saturated NaCl (1 x 20 mL), dried over Na_2SO_4, filtered through glass wool and concentrated to dryness under reduced pressure. The crude product mixture was loaded onto a Biotage samplet using a minimal amount of CH_2Cl_2 (ca. 0.5 mL). This solvent was removed by placing the samplet under reduced pressure in a vacuum dessicator for ca. 15 min, and the samplet was loaded into a Biotage SP1 system. Eluting with an ethyl acetate/hexanes gradient calculated by the Biotage instrument from the R_f of the product in a specified ethyl acetate/hexanes mixture provided the desired product.



2-(3,5-Dimethylphenyl)-6-methyl-pyridine (1a). The reaction was conducted with 2-methylpyridine (0.2236 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 0.25 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0422 g, 53% yield of **1a** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.63 – 7.57 (m, 3 H), 7.49 – 7.47 (m, 1 H), 7.08 – 7.03 (m, 2 H), 2.62 (s, 3 H), 2.39 (s, 6 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 158.29, 157.44, 139.86, 138.24, 136.87, 130.50, 124.99, 121.54, 117.87, 24.90, 21.55. HRMS-EI (*m/z*): calculated for $C_{14}H_{15}N$: 197.1205; observed: 197.1200.

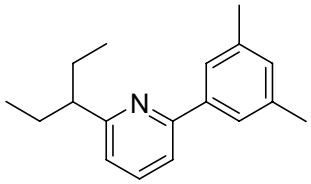


2-(3,5-Dimethylphenyl)-6-(3-phenylpropyl)-pyridine (1b). The reaction was conducted with 2-(3-phenylpropyl)-pyridine (0.4735 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 0.10 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0609 g, 51% yield of **1b** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.65 – 7.60 (m, 3 H), 7.51 – 7.49 (m, 1 H), 7.32 – 7.16 (m, 5 H), 7.07 – 7.04 (m, 2 H), 2.93 – 2.88 (m, 2 H), 2.76 – 2.71 (m, 2 H), 2.39 (s, 6 H), 2.20 – 2.10 (m, 2 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 161.83, 157.42, 142.52, 139.99, 138.28, 136.90, 130.54, 128.70, 128.45, 125.89, 125.05, 121.04, 118.15, 38.16, 35.75, 31.55, 21.63. HRMS-EI (*m/z*): calculated for $C_{22}H_{23}N$: 301.1831; observed: 301.1830.

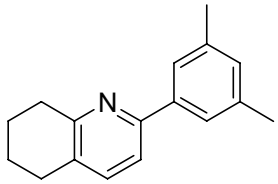


2-(3,5-Dimethylphenyl)-6-isobutyl-pyridine (1c). The reaction was conducted with 2-isobutylpyridine (0.3245 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene

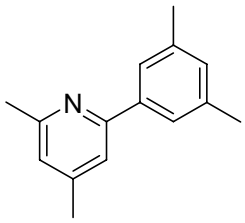
(0.0740 g, 0.400 mmol) and 0.12 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0749 g, 78% yield of **1c** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.63 – 7.57 (m, 3 H), 7.49 – 7.47 (m, 1 H), 7.03 – 7.00 (m, 2 H), 2.72 (d, *J* = 7.20 Hz, 2 H), 2.39 (s, 6 H), 2.26 – 2.17 (m, 1 H), 0.96 (d, *J* = 6.60 Hz, 6 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 161.28, 157.20, 139.92, 138.04, 136.41, 130.25, 124.85, 121.56, 117.85, 47.66, 28.99, 22.47, 21.41. HRMS-EI (*m/z*): calculated for $C_{17}H_{21}N$: 239.1674; observed: 239.1666.



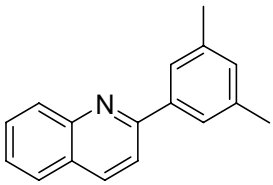
2-(3,5-Dimethylphenyl)-6-(1-ethylpropyl)-pyridine (1d). The reaction was conducted with 2-(1-ethylpropyl)-pyridine (0.3581 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 0.10 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0707 g, 70% yield of **1d** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.64 – 7.58 (m, 3 H), 7.50 – 7.47 (m, 1 H), 7.02 – 6.98 (m, 2 H), 2.66 – 2.57 (m, 1 H), 2.39 (s, 6 H), 1.85 – 1.68 (m, 4 H), 0.82 (t, *J* = 7.50 Hz, 6 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 164.84, 156.91, 140.08, 138.01, 136.26, 130.21, 124.84, 120.70, 117.77, 51.42, 28.10, 21.46, 12.13. HRMS-EI (*m/z*): calculated for $C_{18}H_{23}N$: 253.1831; observed: 253.1834.



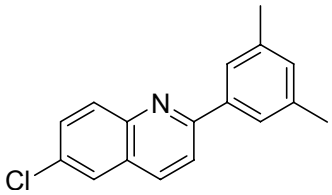
6-(3,5-Dimethylphenyl)-2,3-(cyclohexeno)-pyridine (1e). The reaction was conducted with 2,3-cyclohexenopyridine (0.3197 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 0.18 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0722 g, 76% yield of **1e** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.53 (br s, 2 H), 7.43 – 7.36 (m, 2 H), 7.00 (br s, 1 H), 3.01 – 2.97 (m, 2 H), 2.81 – 2.77 (m, 2 H), 2.37 (s, 6 H), 1.92 – 1.82 (m, 4 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 157.16, 155.14, 139.99, 138.18, 137.46, 130.60, 130.17, 124.82, 118.20, 32.99, 28.67, 23.36, 22.93, 21.57. HRMS-EI (*m/z*): calculated for $C_{17}H_{19}N$: 237.1518; observed: 237.1520.



2-(3,5-Dimethylphenyl)-4,6-(dimethyl)-pyridine (1f). The reaction was conducted with 2,4-dimethylpyridine (0.2573 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 0.25 mL of 1,4-dioxane at 190 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0570 g, 67% yield of **1f** as a white powder. mp 76 – 77 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.55 (s, 2 H), 7.31 (s, 1 H), 7.02 (s, 1 H), 6.91 (s, 1 H), 2.58 (s, 3 H), 2.38 (s, 6 H), 2.35 (s, 3 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 158.09, 157.43, 147.75, 140.01, 138.21, 130.39, 125.04, 122.62, 119.01, 24.72, 21.58, 21.20. HRMS-EI (*m/z*): calculated for $C_{15}H_{17}N$: 211.1361; observed: 211.1356.

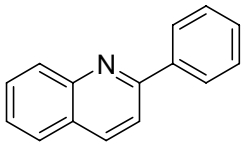


2-(3,5-Dimethylphenyl)-quinoline (1h). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0800 g, 86% yield of **1h** as a clear, colorless oil. ^{1}H NMR (400.13 MHz, $CDCl_3$): δ 8.34 – 8.12 (m, 2 H), 7.91 – 7.67 (m, 5 H), 7.49 – 7.45 (m, 1 H), 7.08 (br s, 1 H), 2.41 (s, 6 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 157.86, 148.38, 139.76, 138.48, 136.74, 131.17, 129.80, 129.70, 127.58, 127.28, 126.26, 125.57, 119.38, 21.62. HRMS-EI (*m/z*): calculated for $C_{17}H_{15}N$: 233.1205; observed: 233.1203.

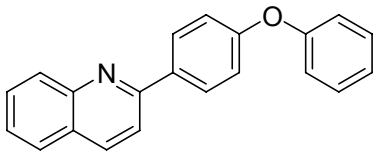


2-(3,5-Dimethylphenyl)-6-chloro-quinoline (1i). The reaction was conducted with 6-chloro-quinoline (0.3919 g, 2.400 mmol), 1-bromo-3,5-dimethyl-benzene (0.0740 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0695 g, 65% yield of **1i** as a pale yellow powder. mp 105 – 106 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.12 – 8.08 (m, 2 H), 7.89 – 7.86 (m, 1 H), 7.80 – 7.79 (m, 1 H), 7.75 (br s, 2 H), 7.66 – 7.63 (m, 1 H), 7.11 (br s, 1 H), 2.43 (s, 6 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 158.04, 146.73, 139.27,

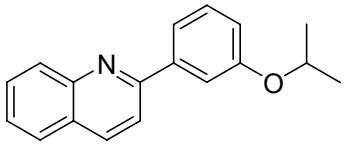
138.58, 135.79, 131.84, 131.43, 131.38, 130.59, 127.80, 126.25, 125.50, 120.14, 21.62. HRMS-EI (*m/z*): calculated for $C_{17}H_{14}ClN$: 267.0815; observed: 267.0812.



2-Phenyl-quinoline (1j). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), bromobenzene (0.0624 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0608 g, 74% yield of **1j** as a white powder. mp 83 – 84 °C (lit. 84 – 85 °C).[1] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.24 – 8.21 (m, 1 H), 8.19 – 8.15 (m, 3 H), 7.90 – 7.87 (m, 1 H), 7.84 – 7.82 (m, 1 H), 7.76 – 7.70 (m 1 H), 7.56 – 7.44 (m, 4 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 157.49, 148.43, 139.83, 136.93, 129.89, 129.81, 129.48, 129.01, 127.73, 127.63, 127.32, 126.43, 119.15. HRMS-EI (*m/z*): calculated for $C_{15}H_{11}N$: 205.0891; observed: 205.0894.



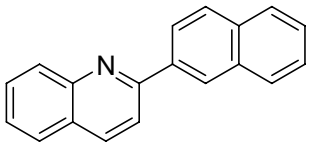
2-(4-Phenoxyphenyl)-quinoline (1k). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-phenoxy-benzene (0.0996 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0734 g, 62% yield of **1k** as a white powder. mp 83 – 84 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.22 – 8.14 (m, 4 H), 7.86 – 7.81 (m, 2 H), 7.75 – 7.69 (m, 1 H), 7.54 – 7.49 (m, 1 H), 7.40 – 7.34 (m, 2 H), 7.16 – 7.06 (m, 5 H). ^{13}C {^{1}H} NMR (75.48 MHz, $CDCl_3$): δ 158.74, 157.00, 156.78, 148.41, 136.92, 134.80, 130.00, 129.83, 129.76, 129.28, 127.62, 127.15, 126.30, 123.77, 119.36, 119.07, 118.80. HRMS-EI (*m/z*): calculated for $C_{21}H_{15}NO$: 297.1154; observed: 297.1150.



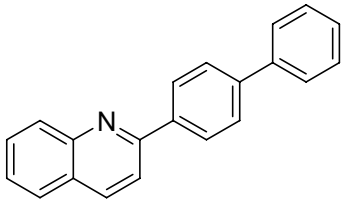
2-(3-Isopropoxyphenyl)-quinoline (1l). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-3-isopropoxy-benzene (0.0860 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0741 g, 70% yield of **1l** as a clear, colorless oil. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.22 – 8.16 (m, 2 H), 7.87 – 7.81 (m, 2 H), 7.75 – 7.68 (m, 3 H), 7.55 – 7.50 (m, 1 H), 7.44 – 7.39 (m, 1 H), 7.01 – 6.98 (m, 1 H), 4.71 (sept, *J* = 6.00 Hz, 1 H), 1.39 (d, *J* = 6.00 Hz, 6 H). ^{13}C {^{1}H} NMR (75.48 MHz, $CDCl_3$): δ 162.60,

[1] Cho, C. S.; Kim, B. T.; Choi, H.-J.; Kim, T.-J.; Shim, S. C. *Tetrahedron* **2003**, *59*, 7997.

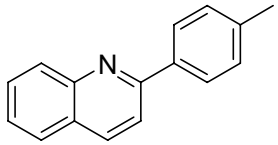
158.67, 157.51, 148.50, 141.47, 137.00, 130.12, 130.05, 129.90, 127.73, 126.56, 120.12, 119.40, 117.17, 115.35, 70.24, 22.41. HRMS-EI (*m/z*): calculated for $C_{18}H_{17}NO$: 263.1310; observed: 263.1315.



2-(2-Naphthyl)-quinoline (1m). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 2-bromonaphthalene (0.0828 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0772 g, 76% yield of **1m** as a white powder. mp 162 – 163 °C (lit. 162 – 163 °C).[1] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.62 (br s, 1 H), 8.39 – 8.36 (m, 1 H), 8.28 – 8.20 (m, 2 H), 8.06 – 7.98 (m, 3 H), 7.90 – 7.84 (m, 2 H), 7.78 – 7.72 (m, 1 H), 7.57 – 7.52 (m, 3 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 157.27, 148.51, 137.10, 136.95, 134.00, 133.65, 129.89, 129.00, 128.75, 127.89, 127.67, 127.37, 127.30, 126.88, 126.50, 125.23, 119.29. HRMS-EI (*m/z*): calculated for $C_{19}H_{13}N$: 255.1048; observed: 255.1043.



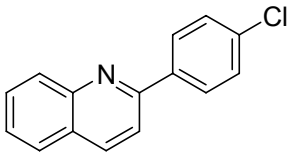
2-((1,1'-Biphenyl)-4-yl)-quinoline (1n). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-phenyl-benzene (0.0932 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0650 g, 58% yield of **1n** as a white powder. mp 175 – 177 °C (lit. 175 – 177 °C).[2] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.27 – 8.23 (m, 3 H), 8.20 – 8.17 (m, 1 H), 7.95 – 7.92 (m, 1 H), 7.85 – 7.83 (m, 1 H), 7.78 – 7.67 (m, 5 H), 7.56 – 7.45 (m, 3 H), 7.40 – 7.38 (m, 1 H). ^{13}C {^{1}H} NMR (75.48 MHz, $CDCl_3$): δ 157.04, 148.51, 142.22, 140.75, 138.69, 136.97, 129.92, 129.88, 129.04, 128.14, 127.77, 127.73, 127.67, 127.39, 127.32, 126.47, 119.05. HRMS-EI (*m/z*): calculated for $C_{21}H_{15}N$: 281.1205; observed: 281.1202.



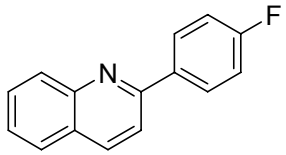
2-(4-Methylphenyl)-quinoline (1o). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-methyl-benzene (0.0684 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0608 g,

[2] Steinkopf, W. *Justus Liebigs Ann. Chem.* **1940**, *543*, 119.

69% yield of **1o** as a white powder. mp 82 – 83 °C (lit. 80 – 81 °C).[1] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.21 – 8.18 (m, 1 H), 8.17 – 8.14 (m, 1 H), 8.08 – 8.06 (m, 2 H), 7.88 – 7.85 (m, 1 H), 7.83 – 7.80 (m, 1 H), 7.74 – 7.68 (m, 1 H), 7.53 – 7.48 (m, 1 H), 7.34 – 7.32 (m, 2 H), 2.43 (s, 3 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 157.47, 148.44, 139.55, 137.02, 136.82, 129.82, 129.74, 129.48, 127.60, 127.25, 126.24, 119.01, 21.53. HRMS-EI (*m/z*): calculated for $C_{16}H_{13}N$: 219.1048; observed: 219.1043.

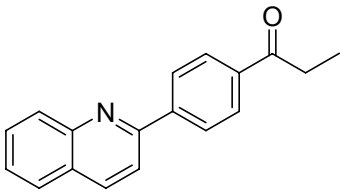


2-(4-Chlorophenyl)-quinoline (1p). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-chloro-benzene (0.0766 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0650 g, 68% yield of **1p** as a white powder. mp 111 – 112 °C (lit. 112 – 114 °C).[3] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.26 – 8.22 (m, 1 H), 8.17 – 8.11 (m, 3 H), 7.87 – 7.81 (m, 2 H), 7.78 – 7.71 (m, 1 H), 7.57 – 7.49 (m, 3 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 156.13, 148.38, 138.19, 137.12, 135.69, 130.01, 129.86, 129.18, 128.98, 127.66, 127.37, 126.67, 118.71. HRMS-EI (*m/z*): calculated for $C_{15}H_{10}ClN$: 239.0502; observed: 239.0500.

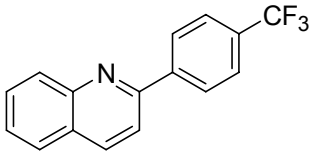


2-(4-Fluorophenyl)-quinoline (1q). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-fluoro-benzene (0.0700 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0630 g, 71% yield of **1q** as a white powder. mp 94 – 95 °C (lit. 92 – 93 °C).[1] ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.24 – 8.14 (m, 4 H), 7.85 – 7.82 (m, 2 H), 7.76 – 7.70 (m, 1 H), 7.56 – 7.50 (m, 1 H), 7.24 – 7.18 (m, 2 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 165.17, 162.70, 156.33, 148.36, 137.04, 135.95, 135.92, 129.94, 129.78, 129.59, 129.51, 127.64, 127.21, 126.49, 118.74, 116.03, 115.81. ^{19}F NMR (376.50 MHz, $CDCl_3$): δ -111.71. HRMS-EI (*m/z*): calculated for $C_{15}H_{10}FN$: 223.0797; observed: 223.0792.

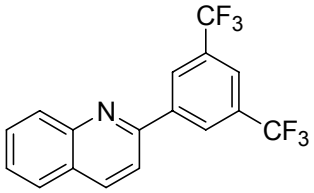
[3] Shi, D.; Rong, L.; Shi, C.; Zhuang, Q.; Wang, X.; Tu, S.; Hu, H. *Synthesis* **2005**, *5*, 717.



2-((Propriophenone)-4'-yl)-quinoline (1r). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 4'-bromopropriophenone (0.0852 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0757 g, 72% yield of **1r** as a white powder. mp 130 – 131 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.29 – 8.26 (m, 3 H), 8.21 – 8.18 (m, 1 H), 8.14 – 8.11 (m, 2 H), 7.94 – 7.91 (m, 1 H), 7.87 – 7.84 (m, 1 H), 7.79 – 7.74 (m, 1 H), 7.59 – 7.55 (m, 1 H), 3.08 (q, *J* = 7.20 Hz, 2 H), 1.27 (t, *J* = 7.20 Hz, 3 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 200.71, 156.11, 148.44, 143.75, 137.29, 137.18, 130.09, 130.02, 128.68, 127.83, 127.69, 127.56, 126.95, 119.10, 32.18, 8.42. HRMS-EI (*m/z*): calculated for $C_{18}H_{15}NO$: 261.1154; observed: 261.1150.



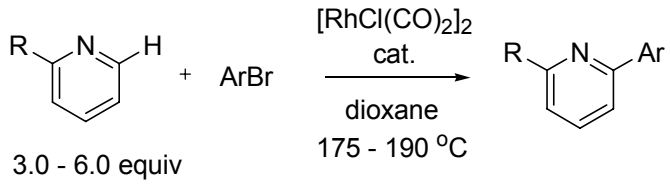
2-(4-(Trifluoromethyl)phenyl)-quinoline (1s). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-4-(trifluoromethyl)-benzene (0.0900 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0712 g, 65% yield of **1s** as a white powder. mp 124 – 126 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.30 – 8.26 (m, 3 H), 8.20 – 8.17 (m, 1 H), 7.91 – 7.84 (m, 2 H), 7.79 – 7.73 (m, 3 H), 7.59 – 7.54 (m, 1 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 155.80, 148.43, 143.09, 137.29, 131.38, 131.06, 130.17, 130.02, 128.00, 127.71, 127.60, 127.03, 125.93, 125.90, 125.75, 123.05, 118.93. ^{19}F NMR (376.50 MHz, $CDCl_3$): δ -61.75. HRMS-EI (*m/z*): calculated for $C_{16}H_{10}F_3N$: 273.0765; observed: 273.0766.

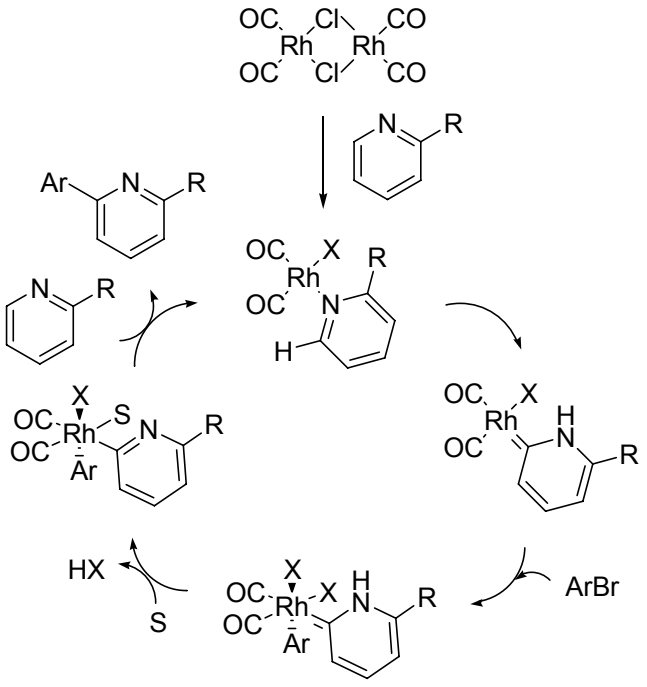


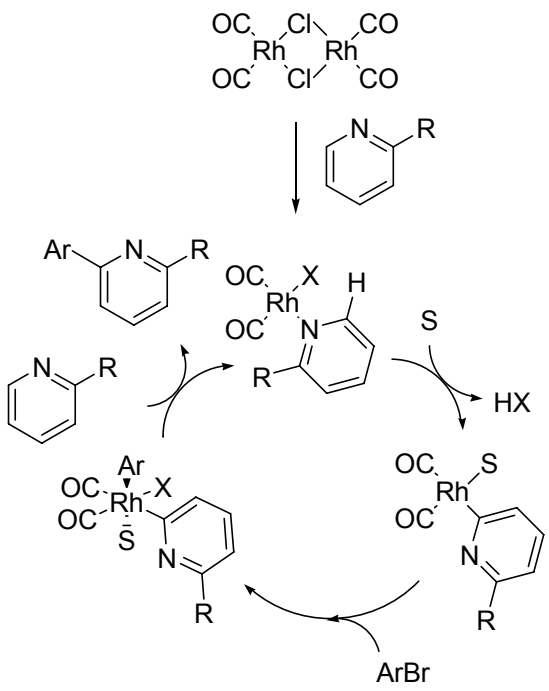
2-(3,5-Bis(trifluoromethyl)phenyl)-quinoline (1t). The reaction was conducted with quinoline (0.3100 g, 2.400 mmol), 1-bromo-3,5-bis(trifluoromethyl)-benzene (0.1172 g, 0.400 mmol) and 1.0 mL of 1,4-dioxane at 175 °C for 24 h. The crude mixture was purified by flash chromatography using an ethyl acetate/hexanes gradient to provide 0.0610 g, 45% yield of **1t** as a white powder. mp 95 – 96 °C. ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.66 (br s, 2 H), 8.33 – 8.31 (m, 1 H), 8.22 – 8.19 (m, 1 H), 7.96 – 7.86 (m, 3 H), 7.82 – 7.76 (m, 1 H), 7.63 – 7.57 (m, 1 H). ^{13}C {^{1}H} NMR (100.61 MHz, $CDCl_3$): δ 153.87, 148.43, 141.71, 137.77, 132.54,

132.21, 131.87, 130.54, 130.13, 127.79, 127.52, 125.00, 122.97, 122.29, 118.34. ^{19}F NMR (376.50 MHz, $CDCl_3$): δ -61.82. HRMS-EI (*m/z*): calculated for $C_{17}H_9F_6N$: 341.0639; observed: 341.0632.

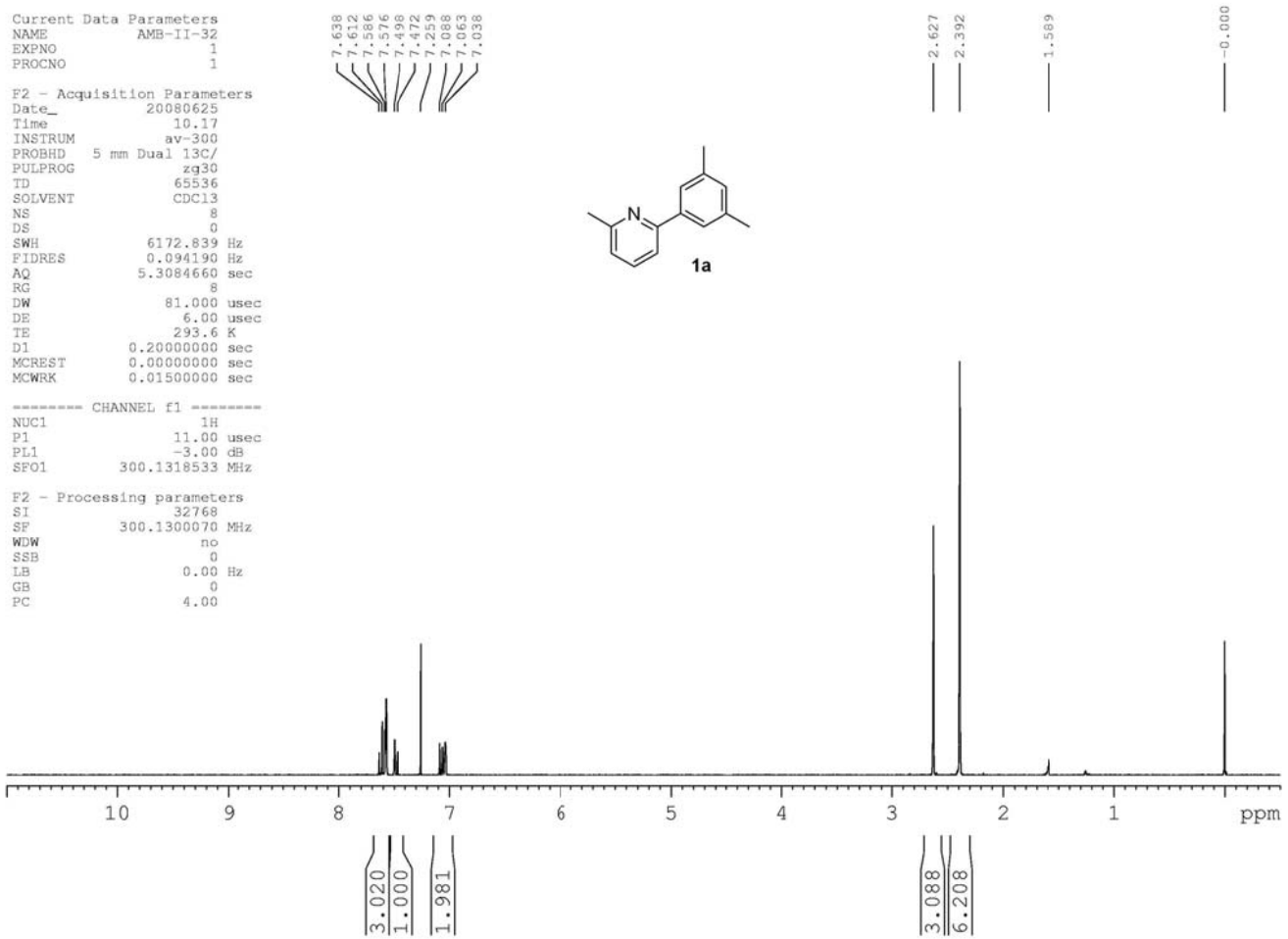
Mechanistic Possibilities. Presented below are two working mechanistic hypotheses for the Rh(I)-catalyzed direct arylation reaction.







S = solvent and/or *N*-bound heterocycle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FIDRES 0.094190 Hz
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RG 8
DW 81.000 usec
DE 6.00 usec
TE 293.6 K
D1 0.20000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
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PL1 -3.00 dB
SFO1 300.1318533 MHz
F2 - Processing parameters
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LB 0.00 Hz
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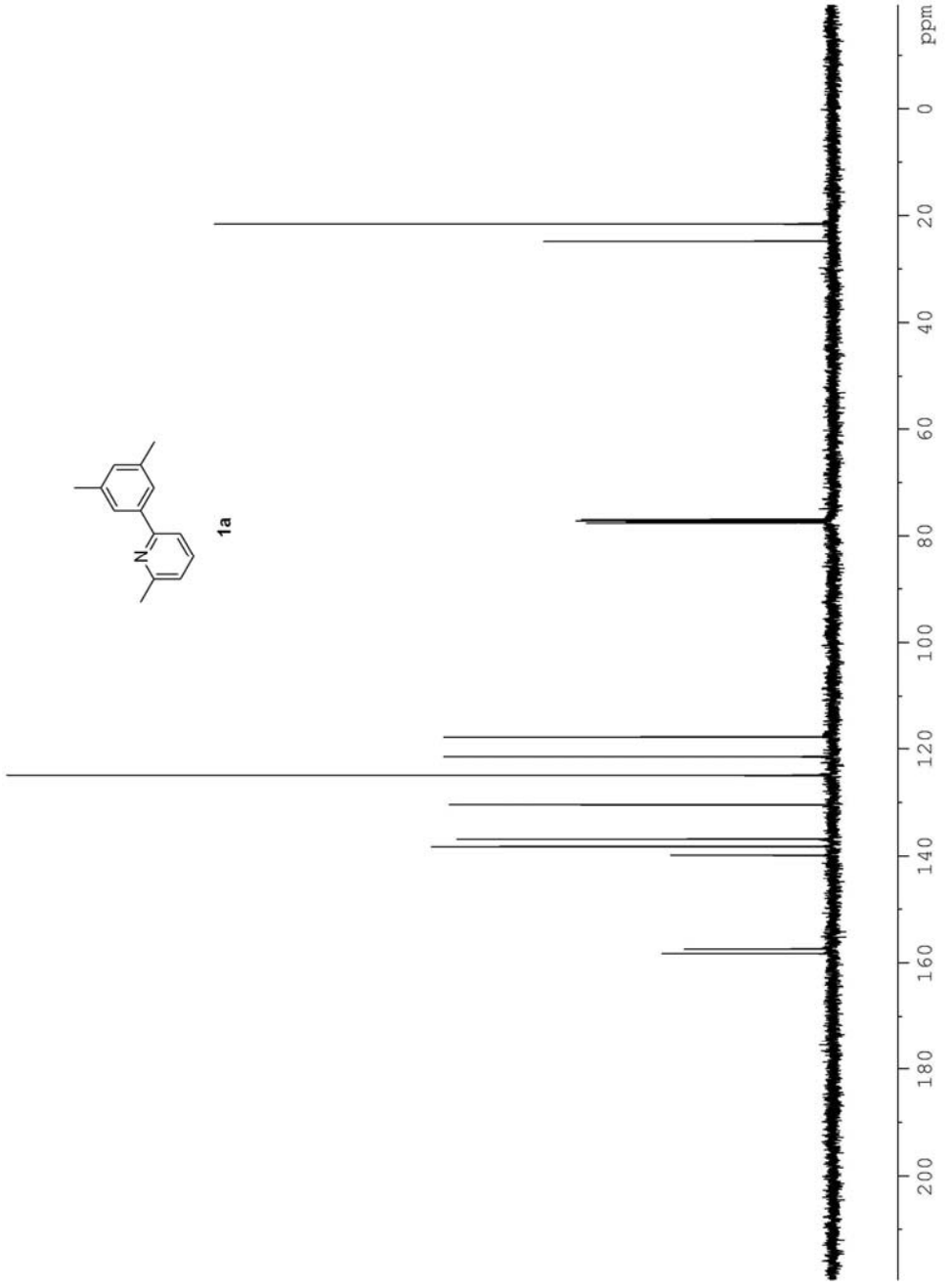
6.208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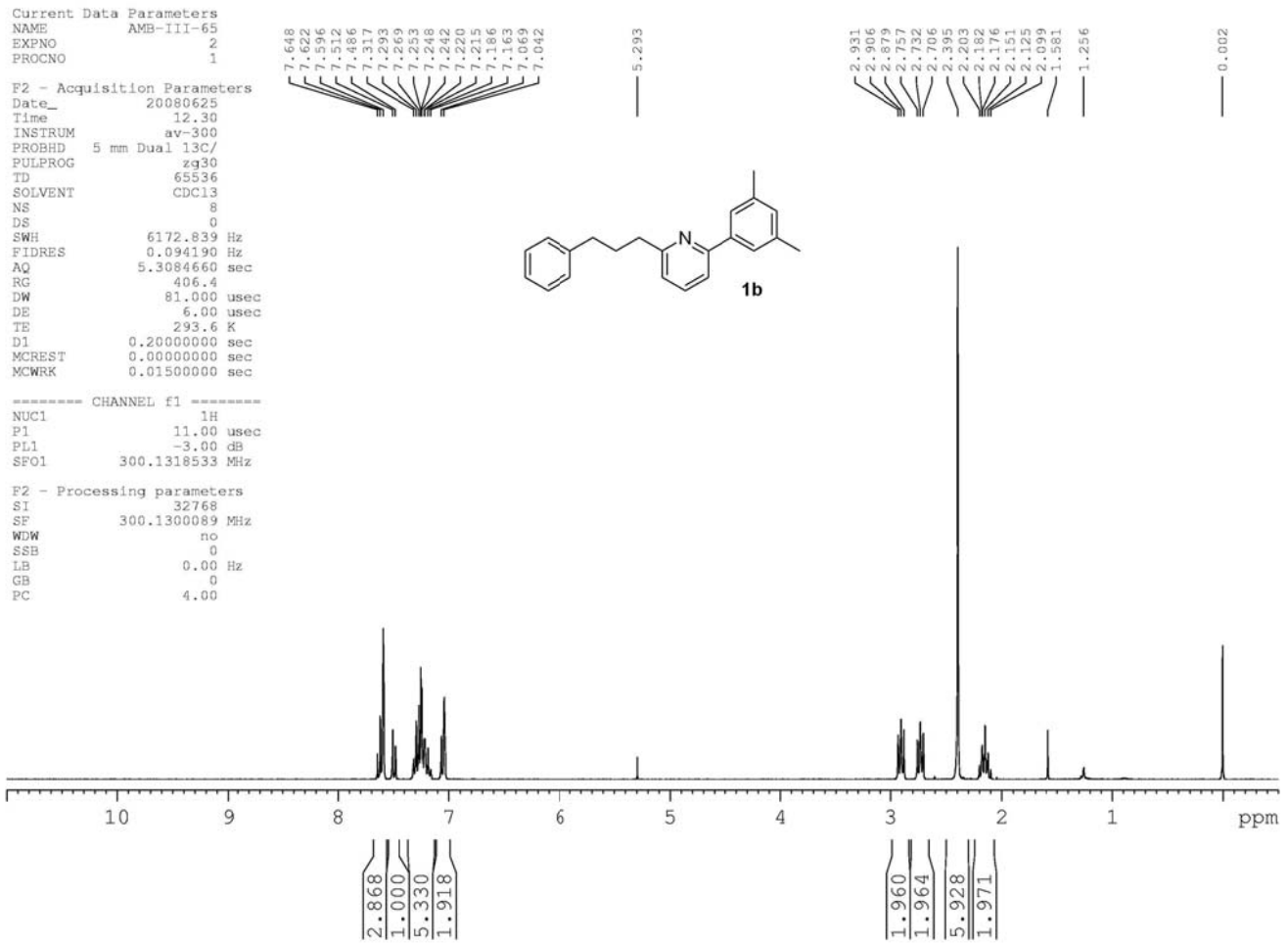
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MCWRK 0.01500000 sec
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PL1 -3.00 dB
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F2 - Processing parameters
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LB 0.00 Hz
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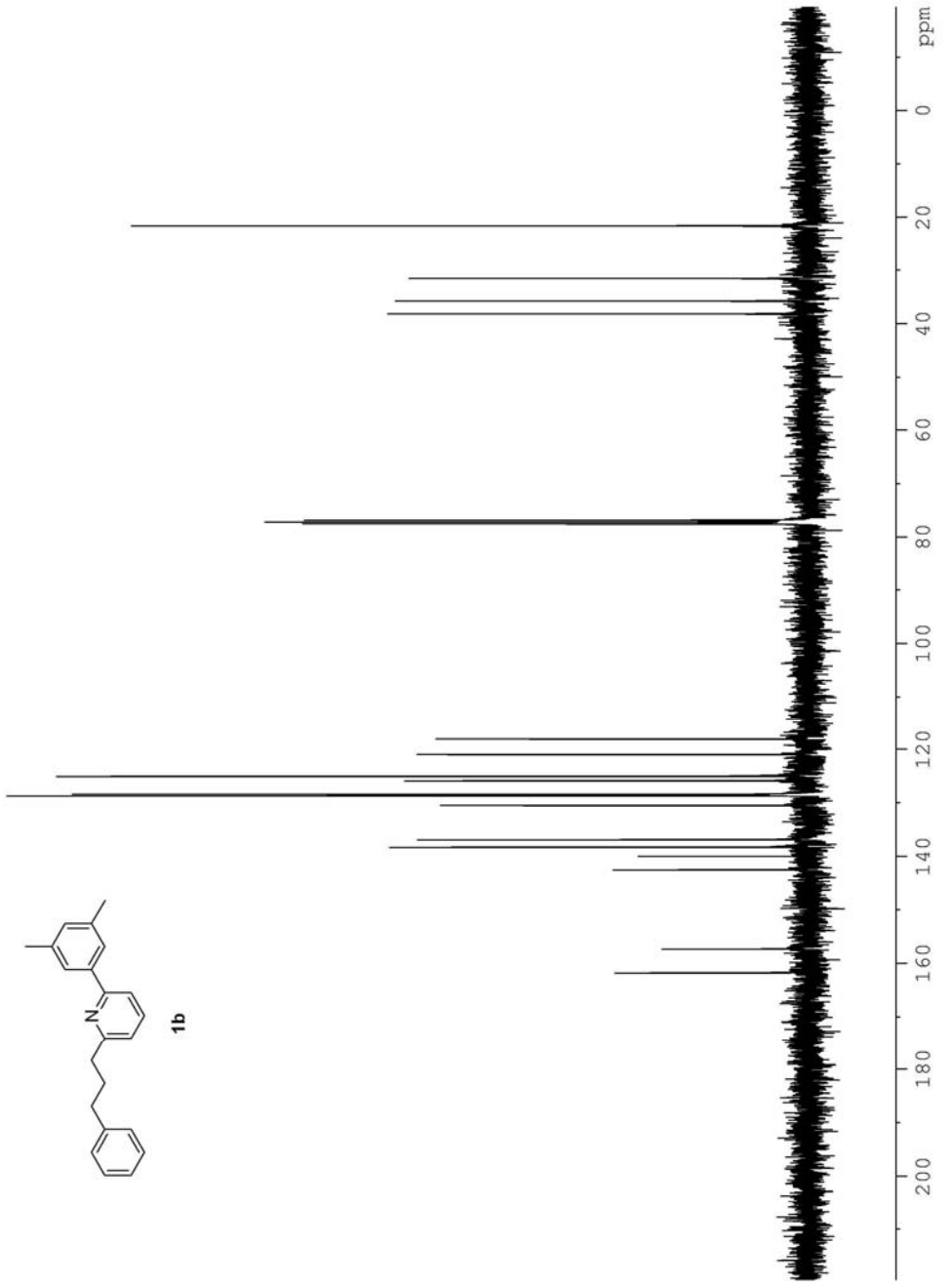
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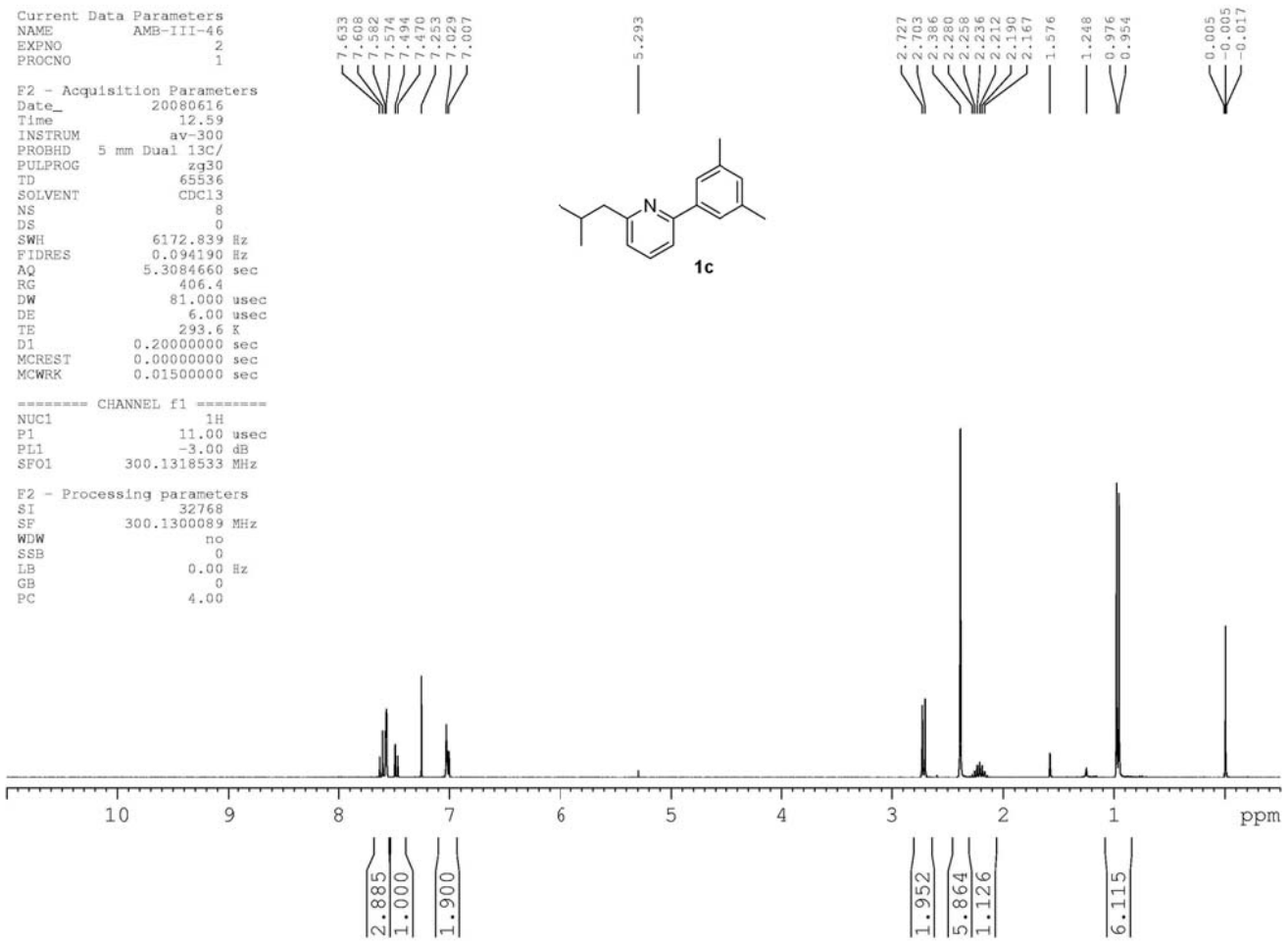
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RG 406.4
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TE 293.6 K
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======== CHANNEL f1 ========
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F2 - Processing parameters
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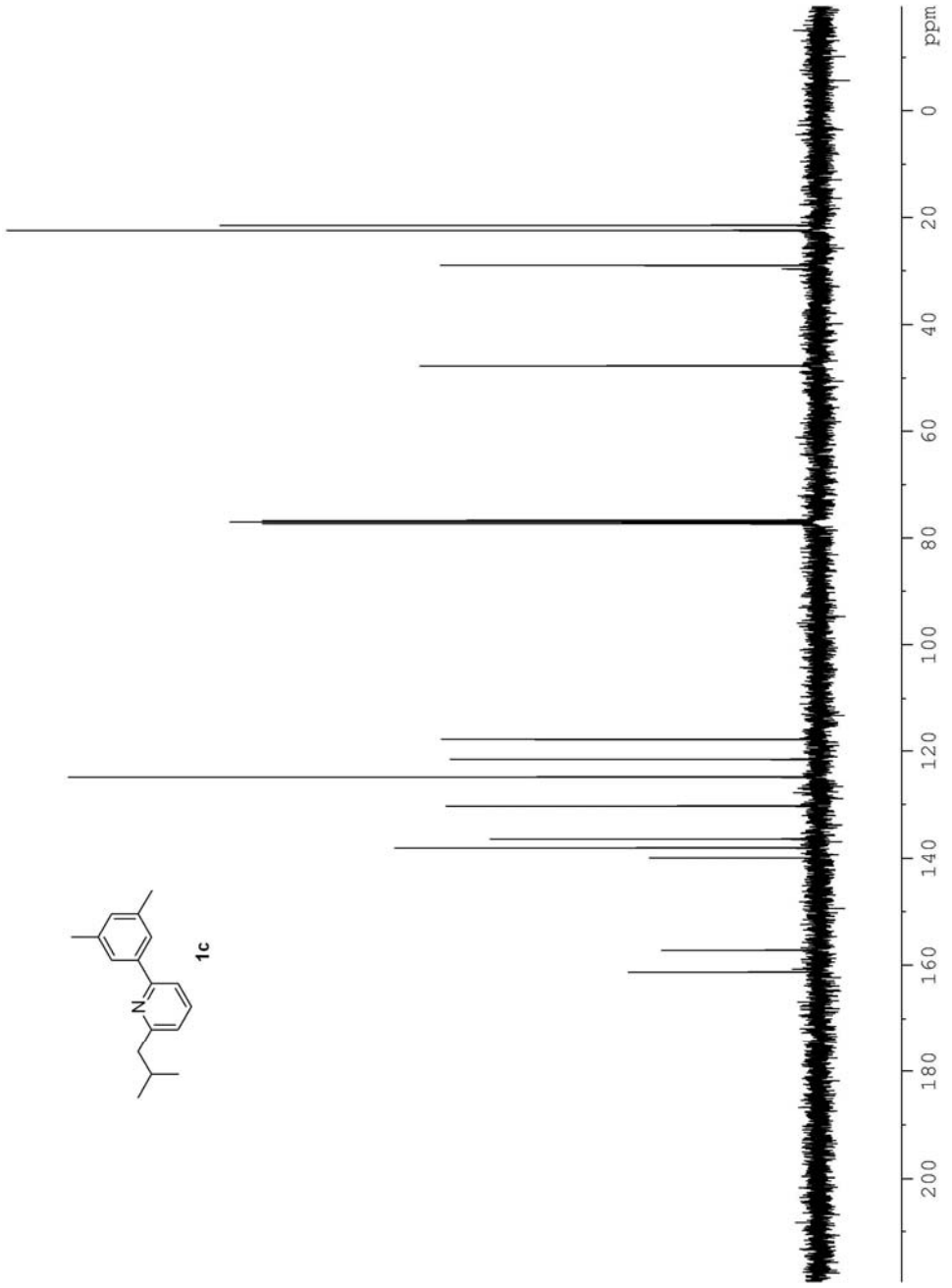
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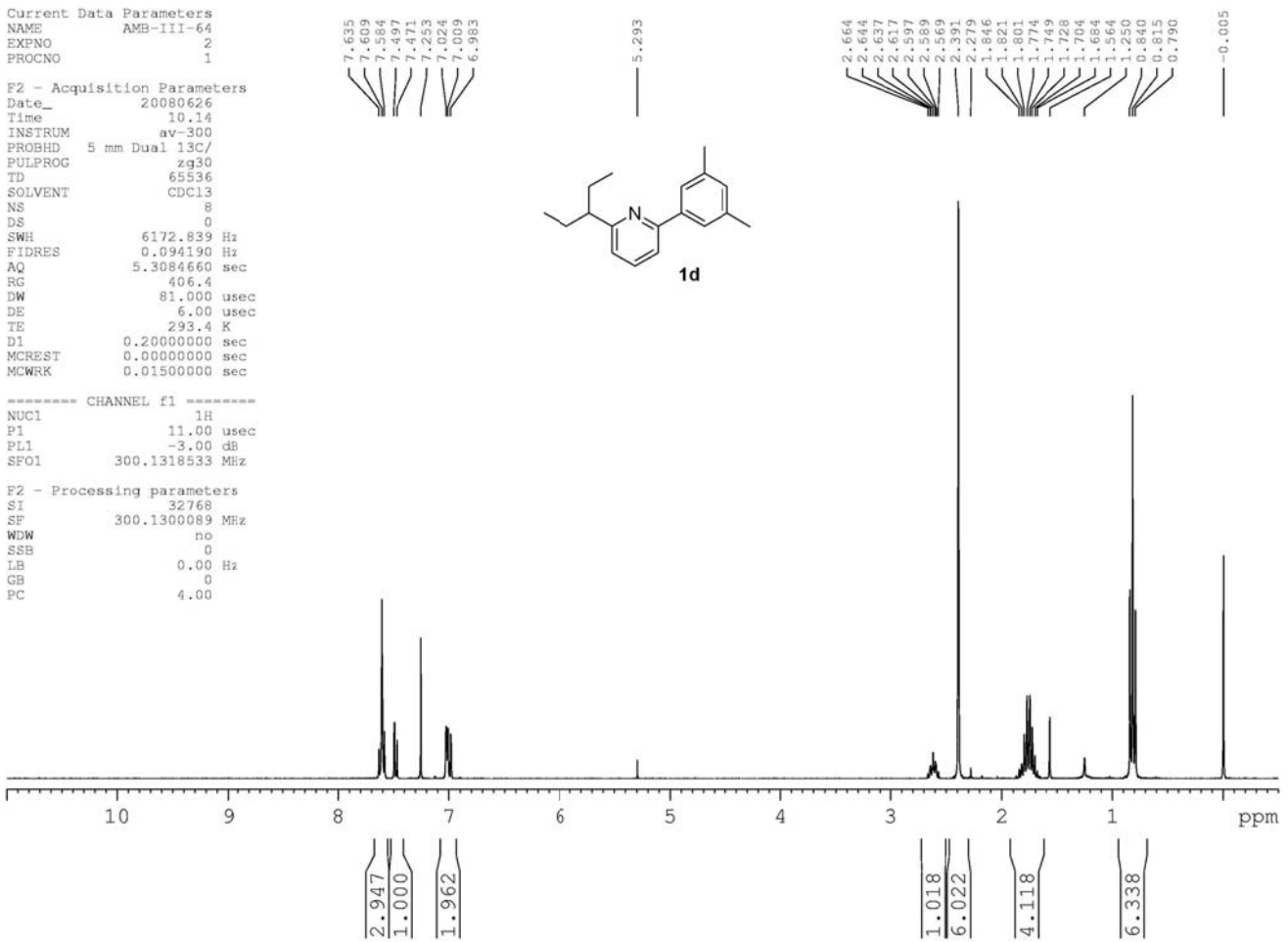
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TE 293.4 K
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SSB 0
LB 0.00 Hz
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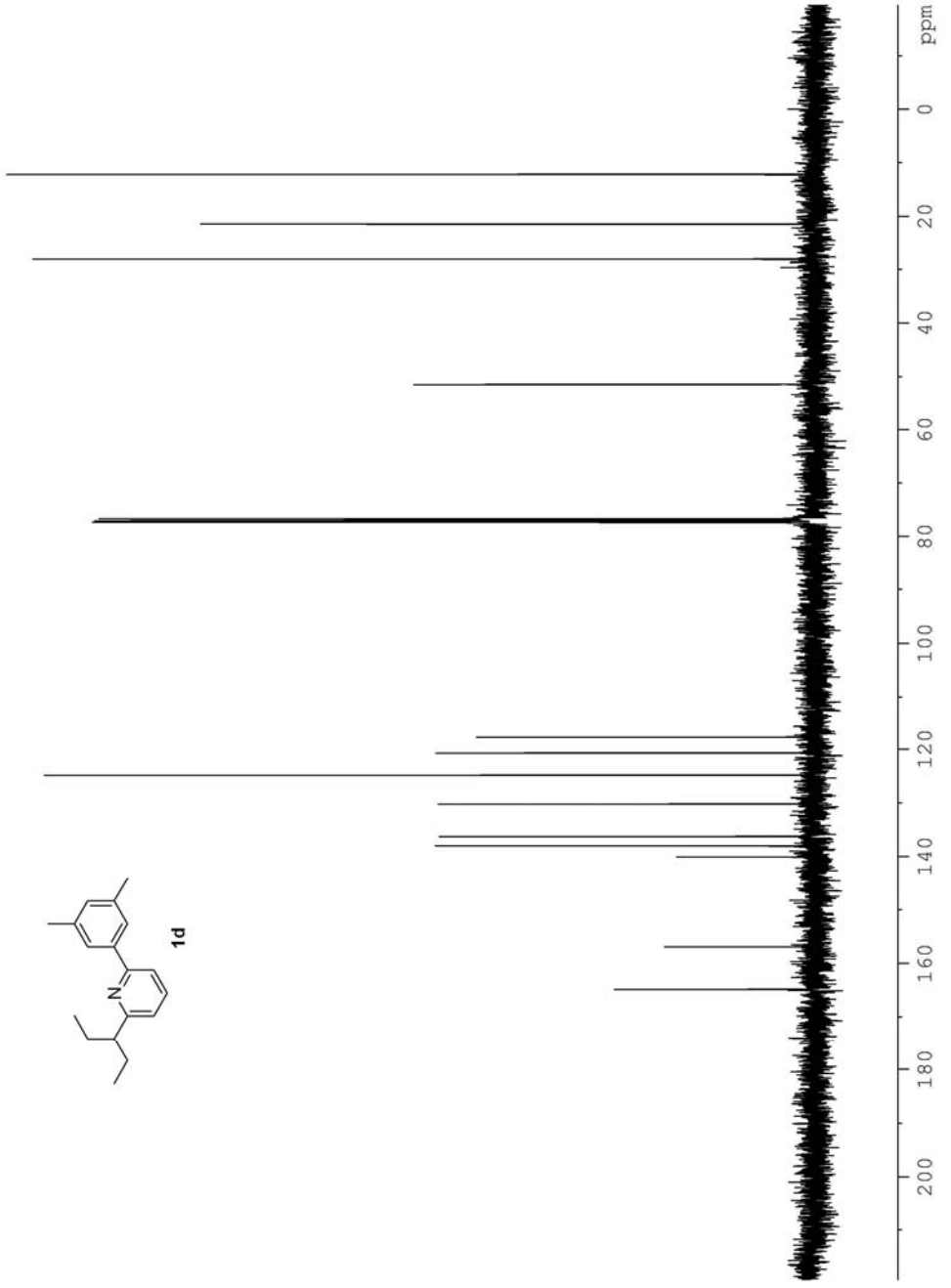
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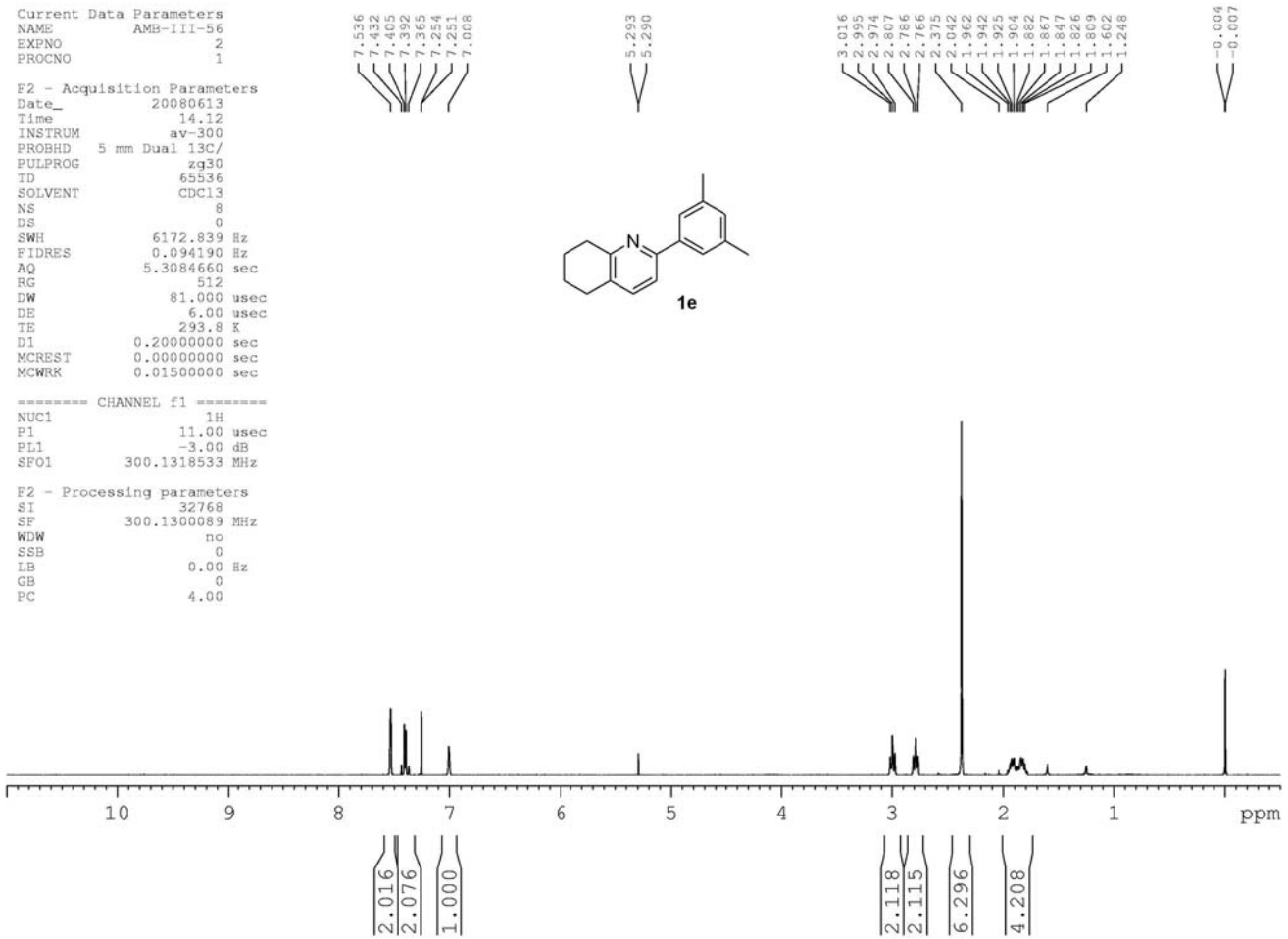
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FIDRES 0.094190 Hz
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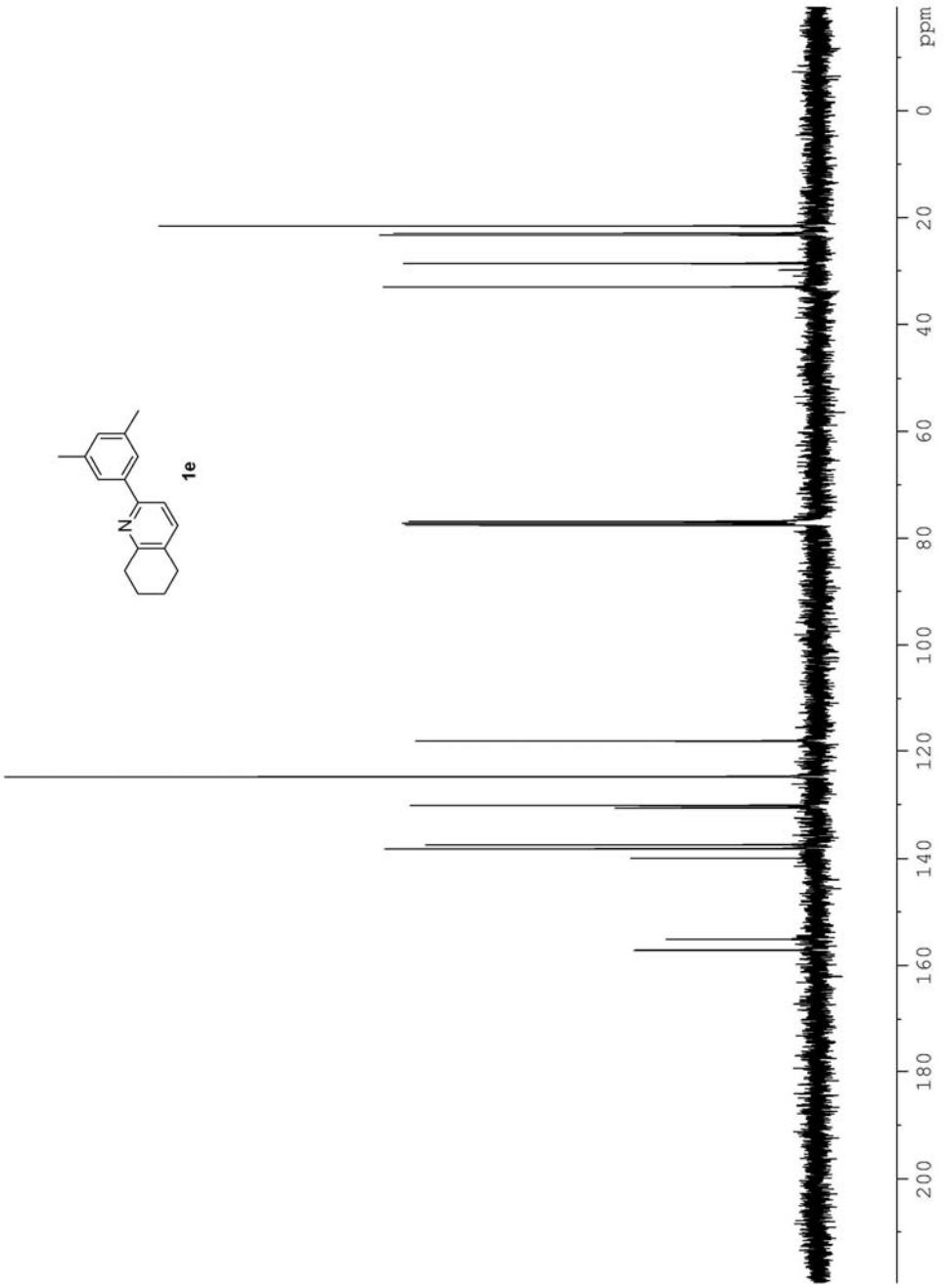
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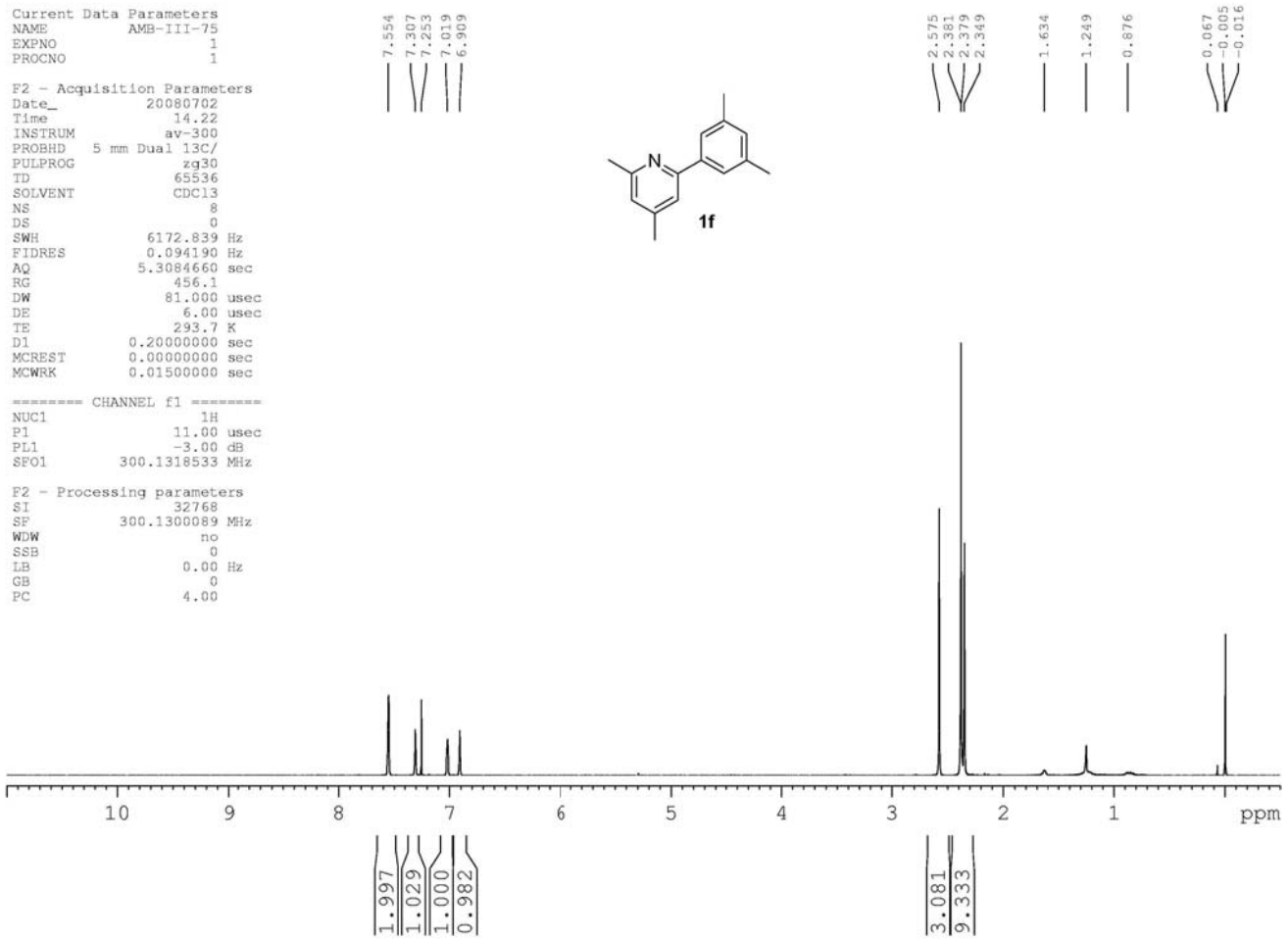
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MCREST 0.00000000 sec
MCWRK 0.01500000 sec
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SFO1 300.1318533 MHz
F2 - Processing parameters
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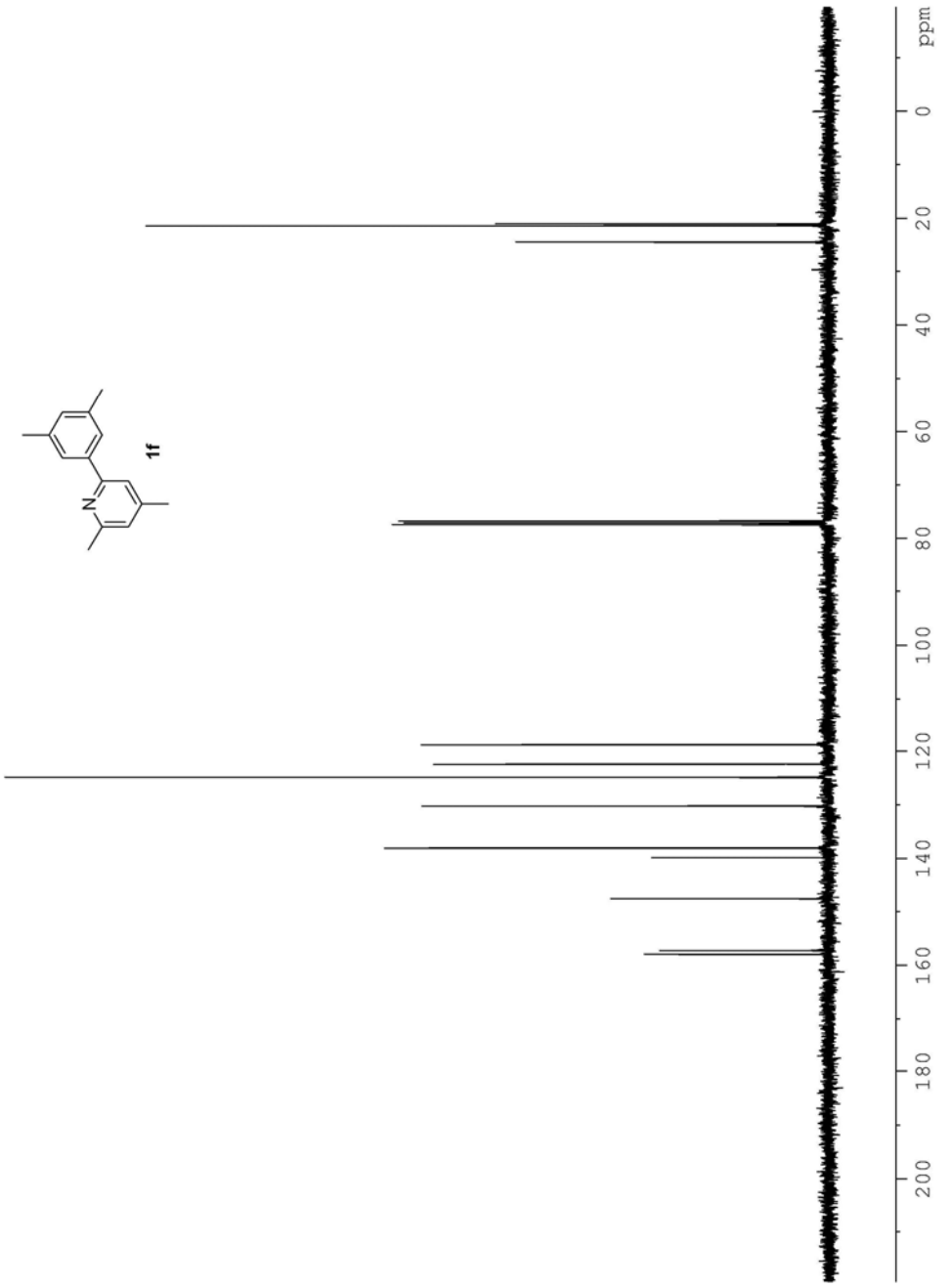
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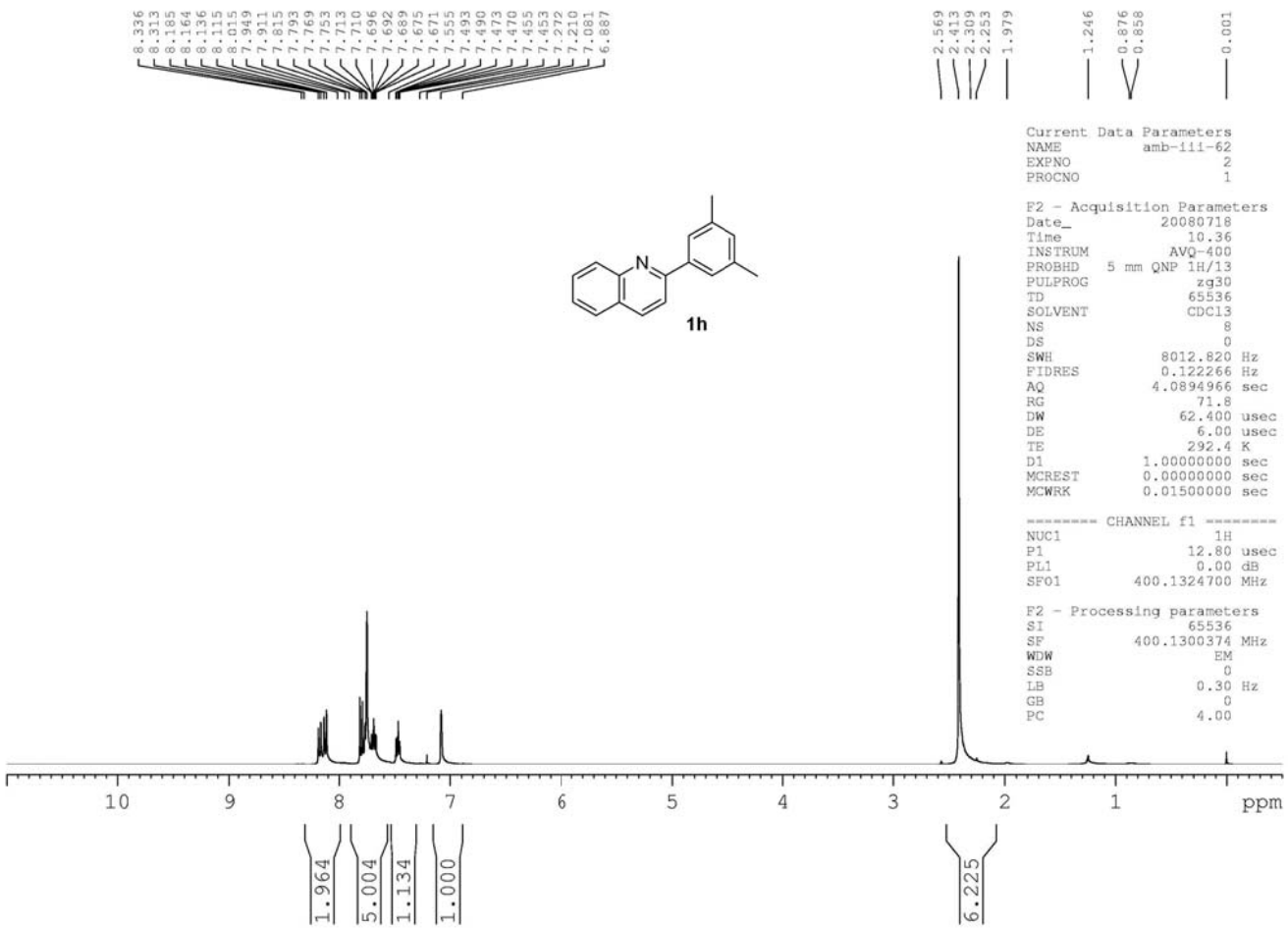
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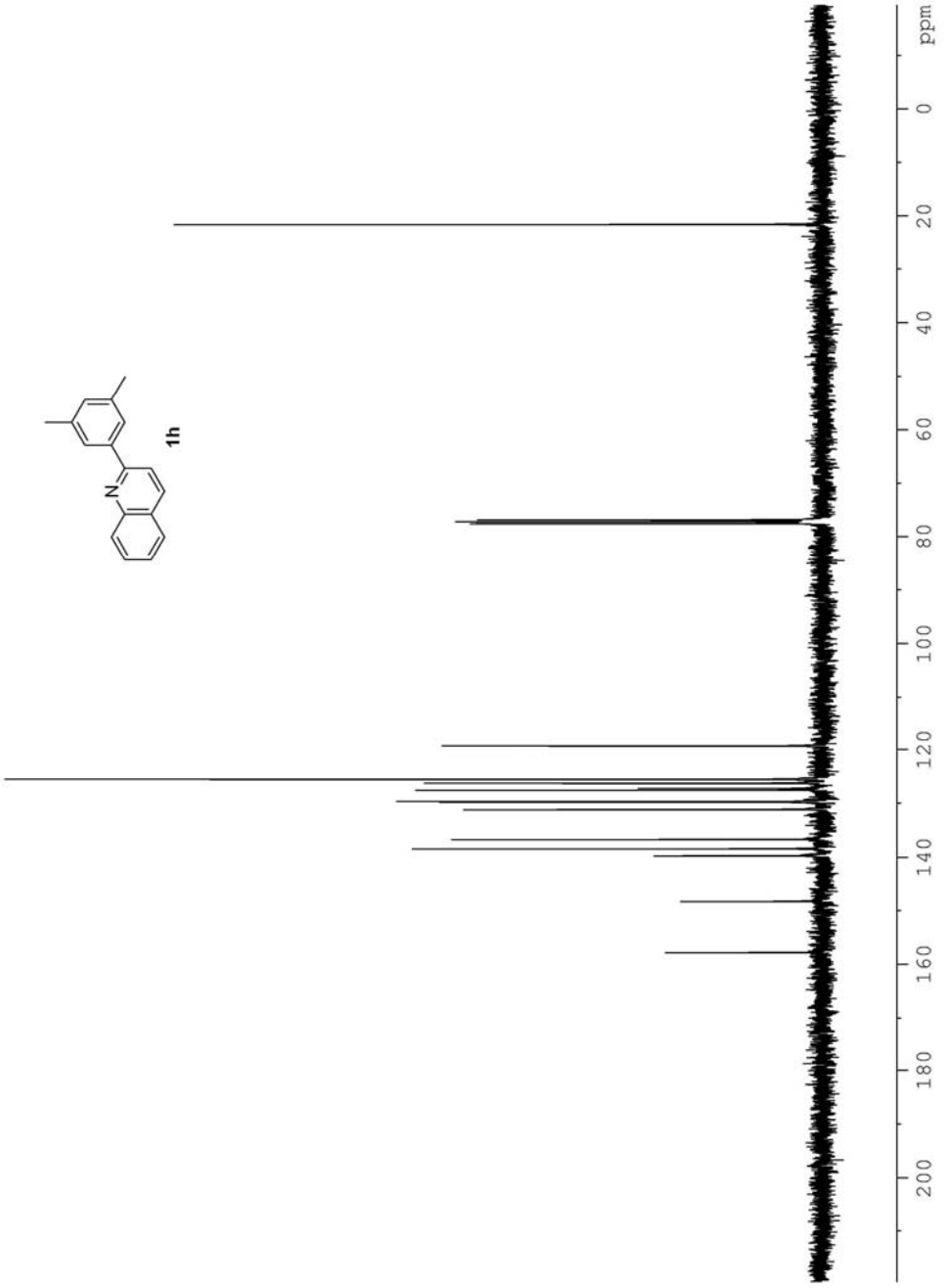
7.753
7.713
7.710
7.696
7.692
7.689
7.675
7.671
7.555
7.493
7.490
7.473
7.470
7.455
7.453
7.272
7.210
7.081
6.887
2.569
2.413
2.309
2.253
1.979
1.246
0.876
0.858
0.001
N
1h
Current Data Parameters
NAME amb-iii-62
EXPNO 2
PROCNO 1
F2 - Acquisition Parameters
Date_ 20080718
Time 10.36
INSTRUM AVQ-400
PROBHD 5 mm QNP 1H/13
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 8
DS 0
SWH 8012.820 Hz
FIDRES 0.122266 Hz
AQ 4.0894966 sec
RG 71.8
DW 62.400 usec
DE 6.00 usec
TE 292.4 K
D1 1.00000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
====== CHANNEL f1 ======
NUC1 1H
P1 12.80 usec
PL1 0.00 dB
SFO1 400.1324700 MHz
F2 - Processing parameters
SI 65536
SF 400.1300374 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 4.00
10
9
8
7
6
5
4
3
2
1
ppm
1.964
5.004
1.134
1.000
6.225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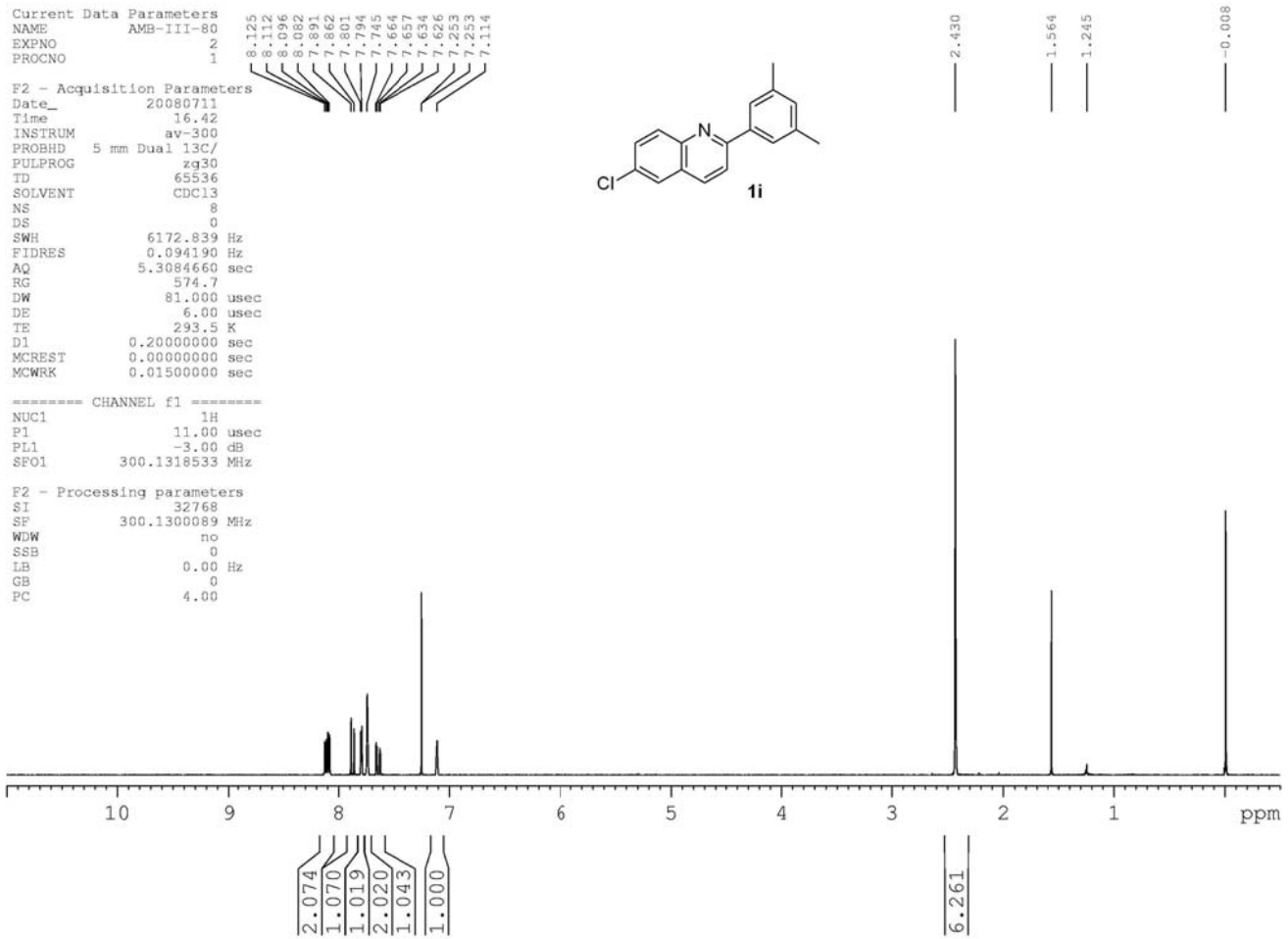
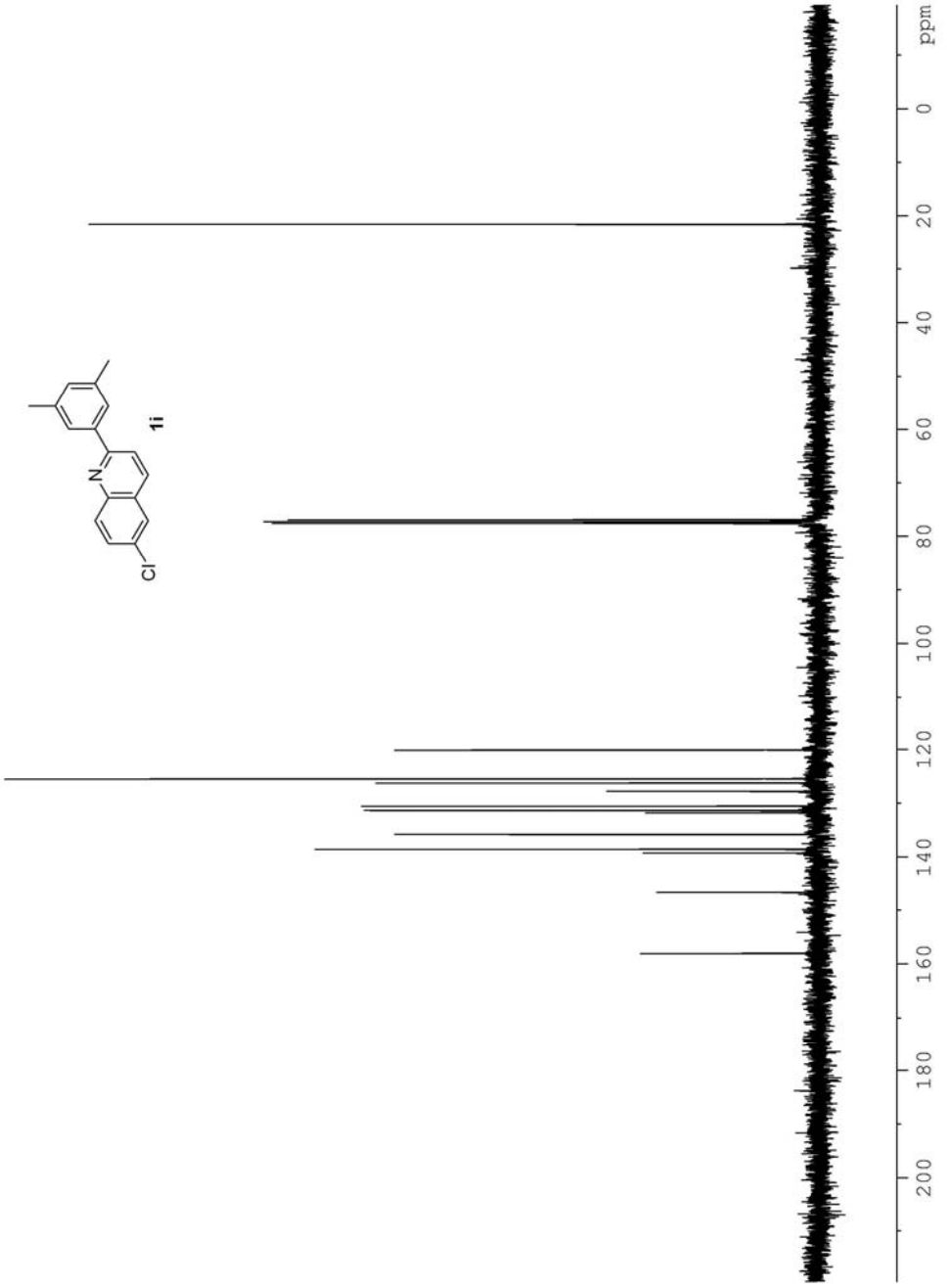
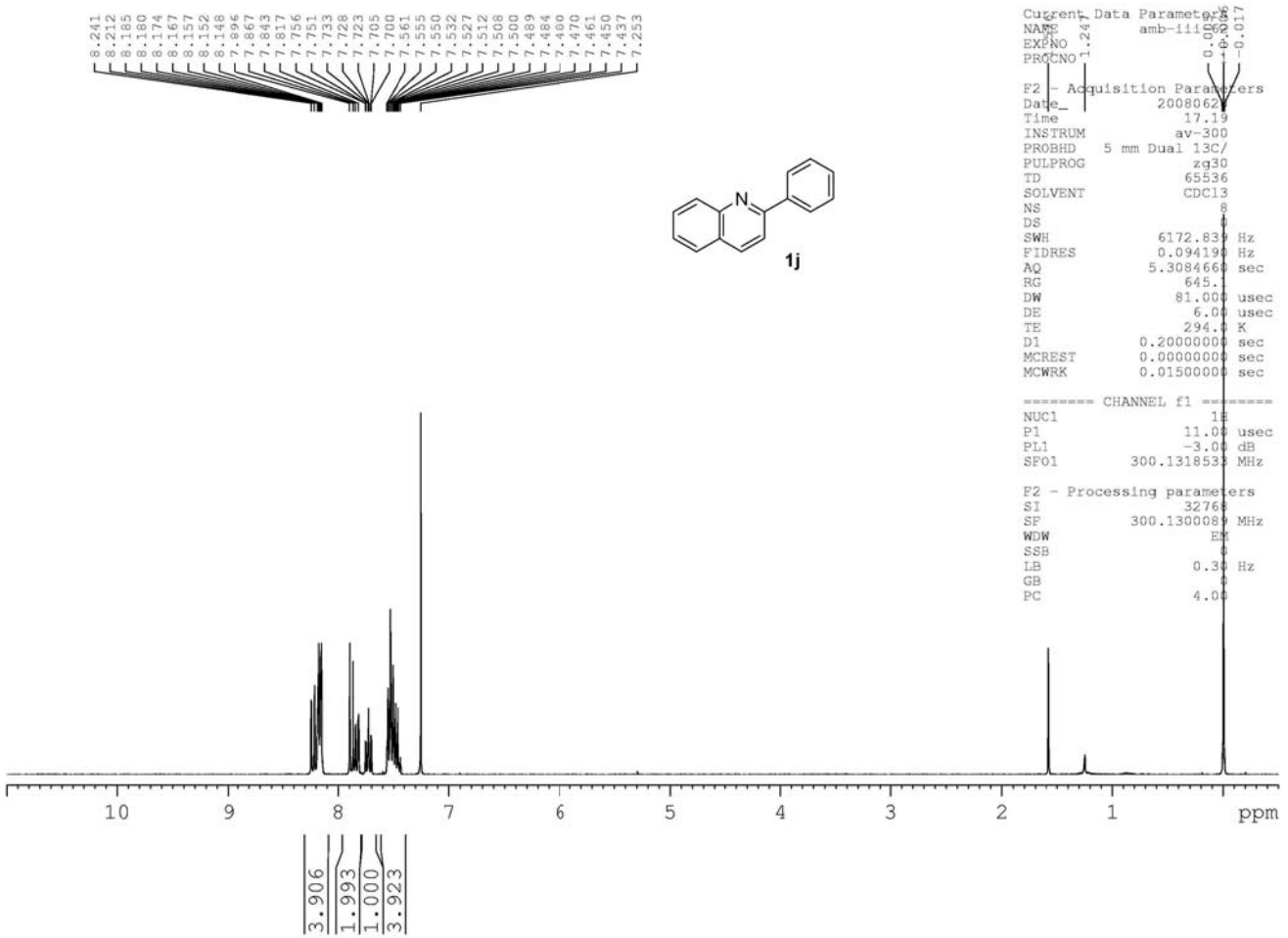
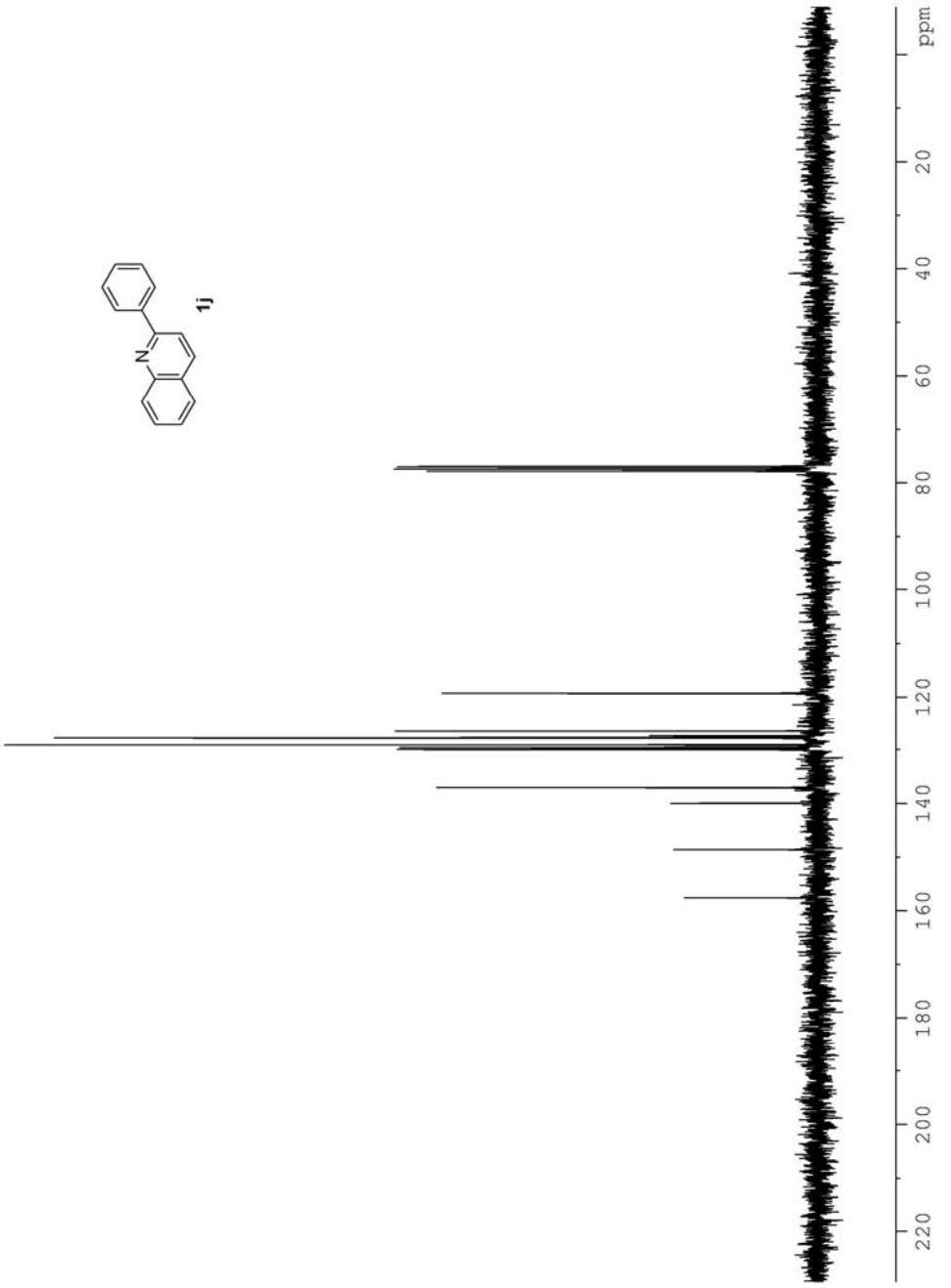
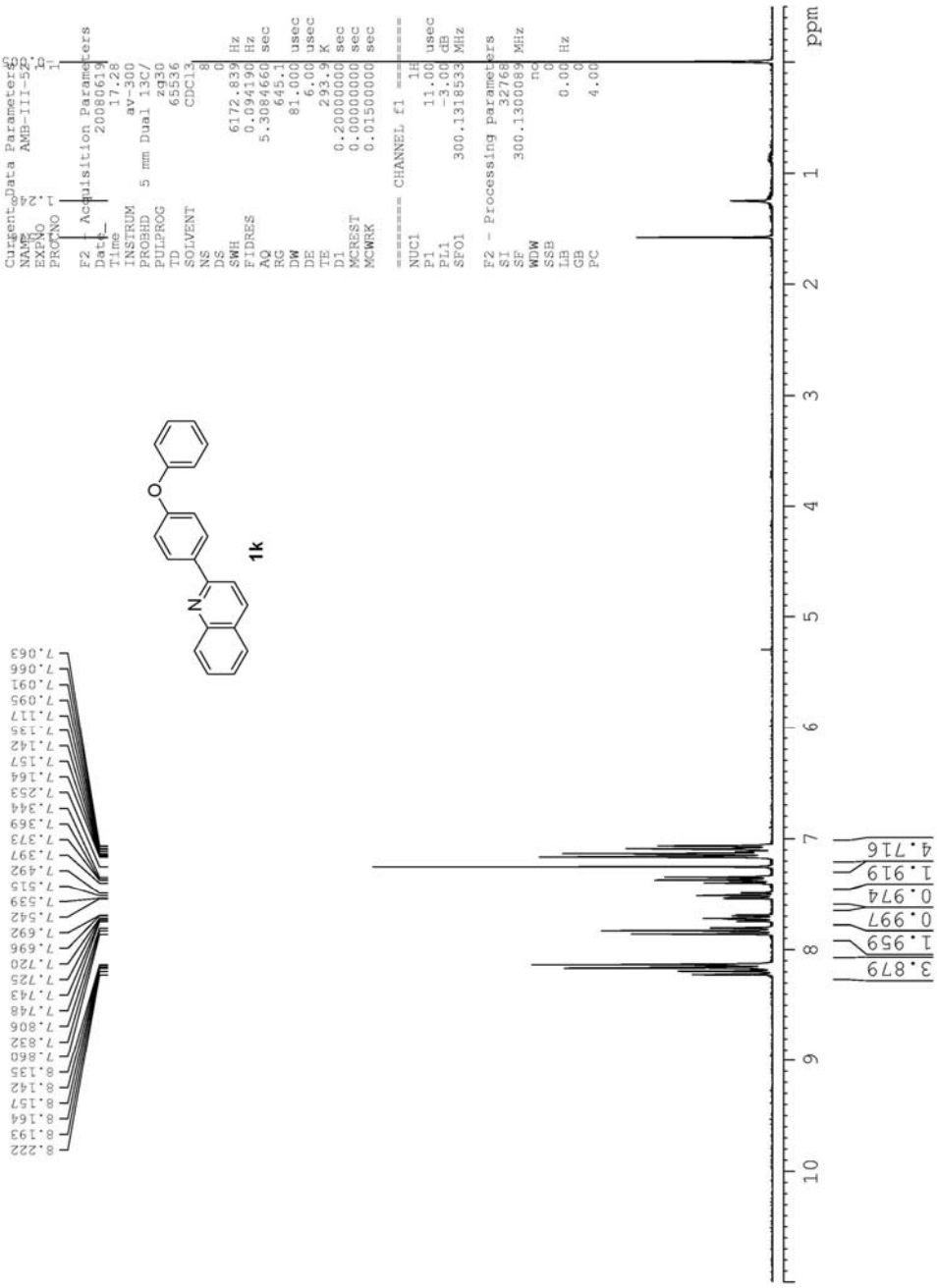
N
ppm
0
20
40
60
80
100
120
140
160
180
200

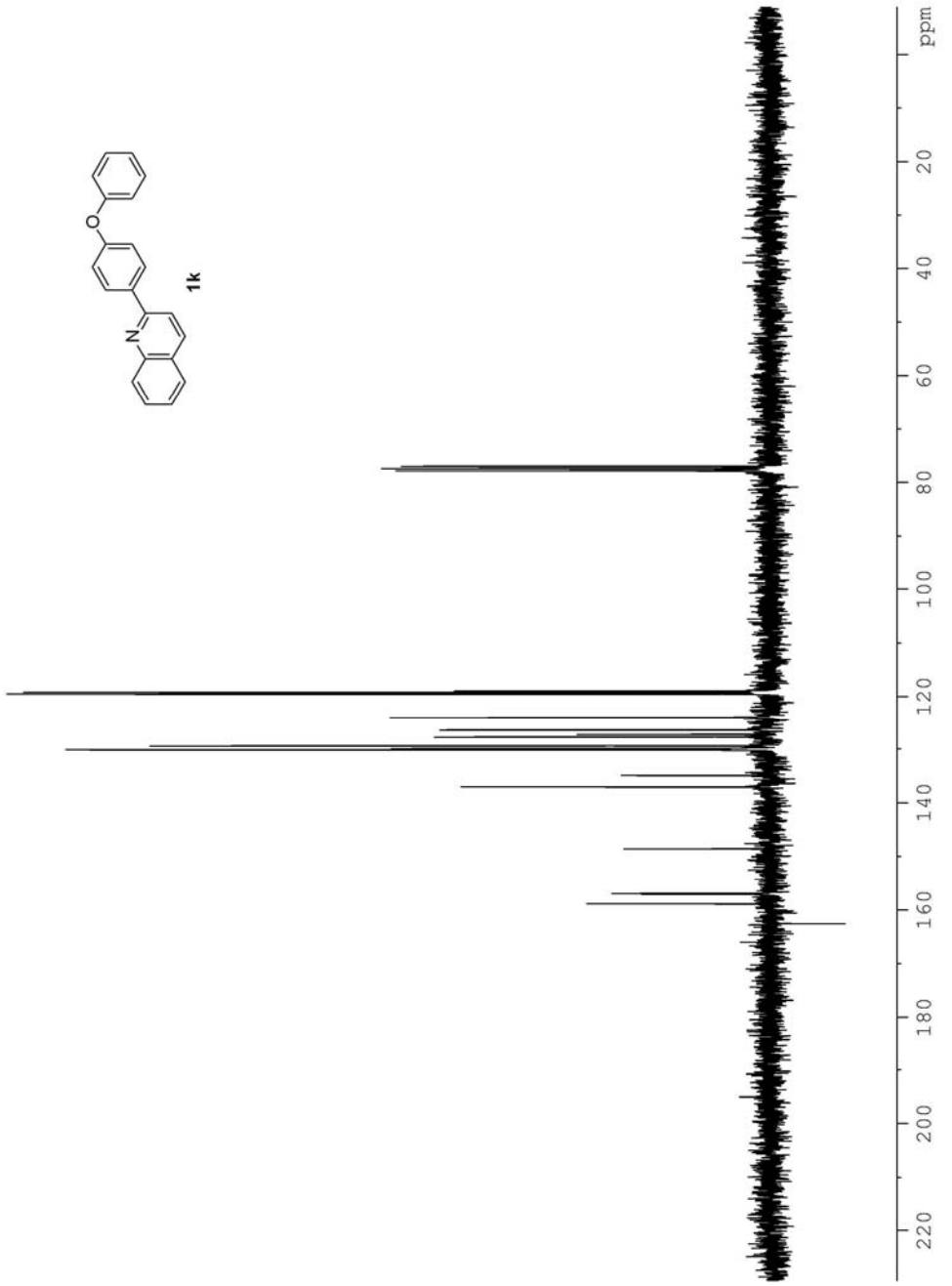

Current Data Parameters
NAME AMB-III-80
EXPNO 2
PROCNO 1
F2 - Acquisition Parameters
Date_ 20080711
Time 16.42
INSTRUM av-300
PROBHD 5 mm Dual 13C/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 8
DS 0
SWH 6172.839 Hz
FIDRES 0.094190 Hz
AQ 5.3084660 sec
RG 574.7
DW 81.000 usec
DE 6.00 usec
TE 293.5 K
D1 0.20000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
======== CHANNEL f1 ========
NUC1 1H
P1 11.00 usec
PL1 -3.00 dB
SFO1 300.1318533 MHz
F2 - Processing parameters
SI 32768
SF 300.1300089 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 4.00
8.125
8.112
8.096
8.082
7.891
7.862
7.801
7.794
7.745
7.664
7.657
7.634
7.626
7.253
7.253
7.114
2.430
1.564
1.245
-0.008
N
Cl
1i
10
9
8
7
6
5
4
3
2
1
ppm
2.074
1.070
1.019
2.020
1.043
1.000
6.261

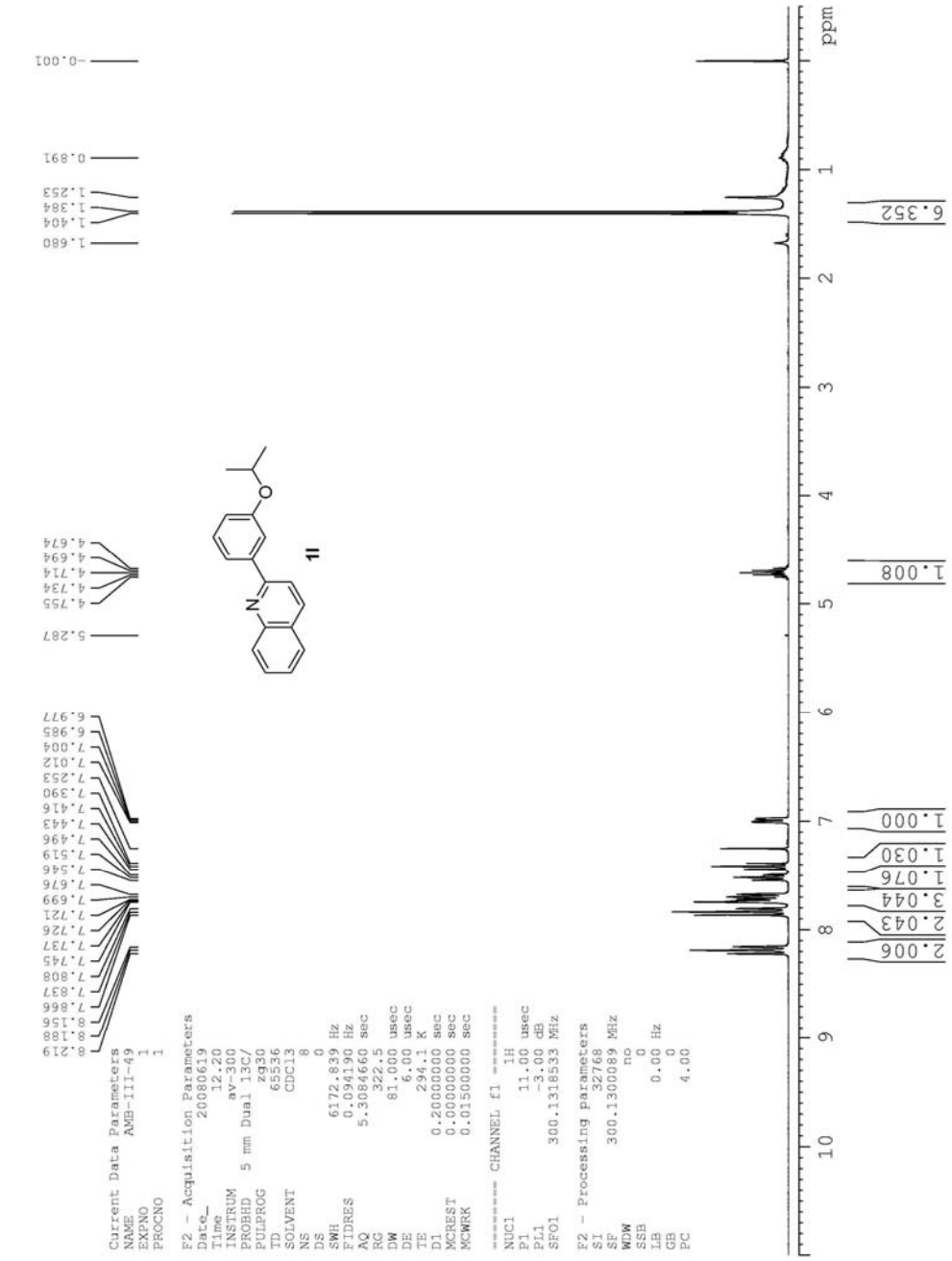

1i
N
Cl
ppm
0
20
40
60
80
100
120
140
160
180
200

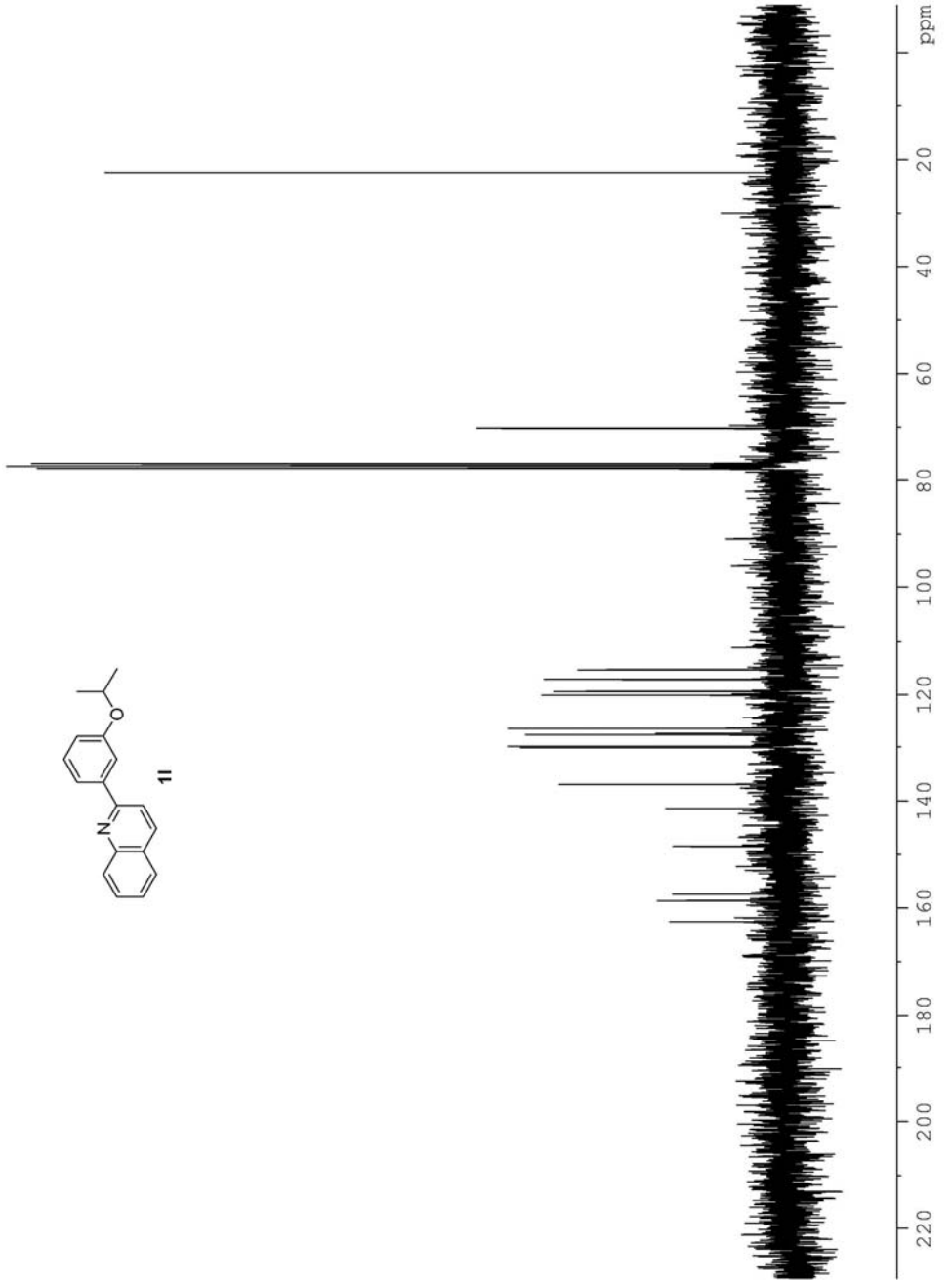

8.241
8.212
8.185
8.180
8.174
8.167
8.157
8.152
8.148
7.896
7.867
7.843
7.817
7.756
7.751
7.733
7.728
7.723
7.705
7.700
7.561
7.555
7.550
7.532
7.527
7.512
7.508
7.500
7.489
7.484
7.400
7.470
7.461
7.450
7.437
7.253
1.247
0.000
0.006
-0.017
N
1j
Current Data Parameters
NAME amb-iii-60
EXPNO 1
PROCNO 1
F2 - Acquisition Parameters
Date_ 20080627
Time 17.19
INSTRUM av-300
PROBHD 5 mm Dual 13C/
PULPROG zg30
TD 65536
SOLVENT CDCl3
NS 8
DS 0
SWH 6172.839 Hz
FIDRES 0.094190 Hz
AQ 5.3084660 sec
RG 645.1
DW 81.000 usec
DE 6.00 usec
TE 294.0 K
D1 0.20000000 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec
======== CHANNEL f1 ========
NUC1 1H
P1 11.00 usec
PL1 -3.00 dB
SF01 300.1318533 MHz
F2 - Processing parameters
SI 32768
SF 300.1300089 MHz
WDW EM
SSB 0
LB 0.30 Hz
GB 0
PC 4.00
10
9
8
7
6
5
4
3
2
1
ppm
3.906
1.993
1.000
3.923

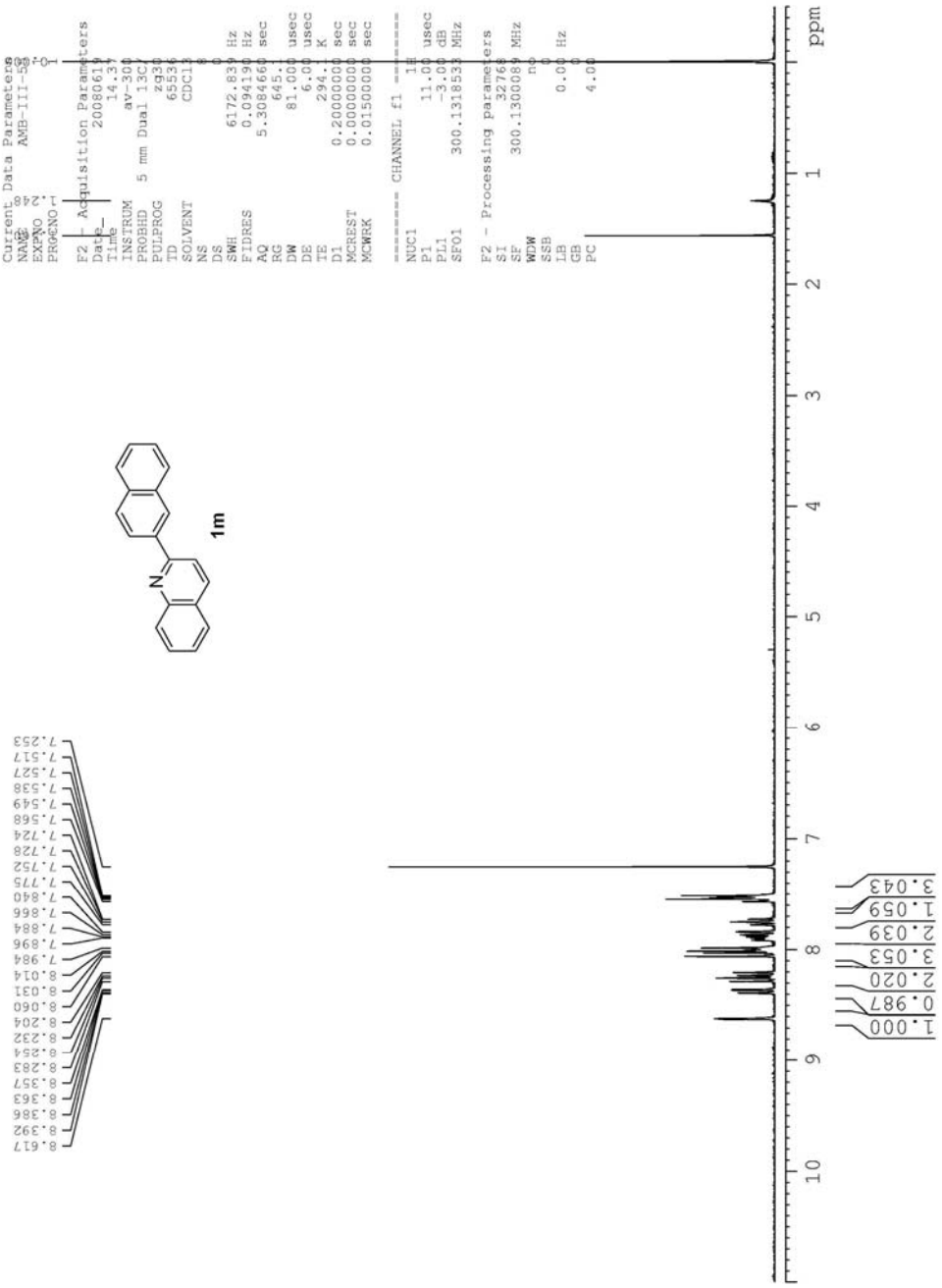

1j
N
ppm
220
200
180
160
140
120
100
80
60
40
20

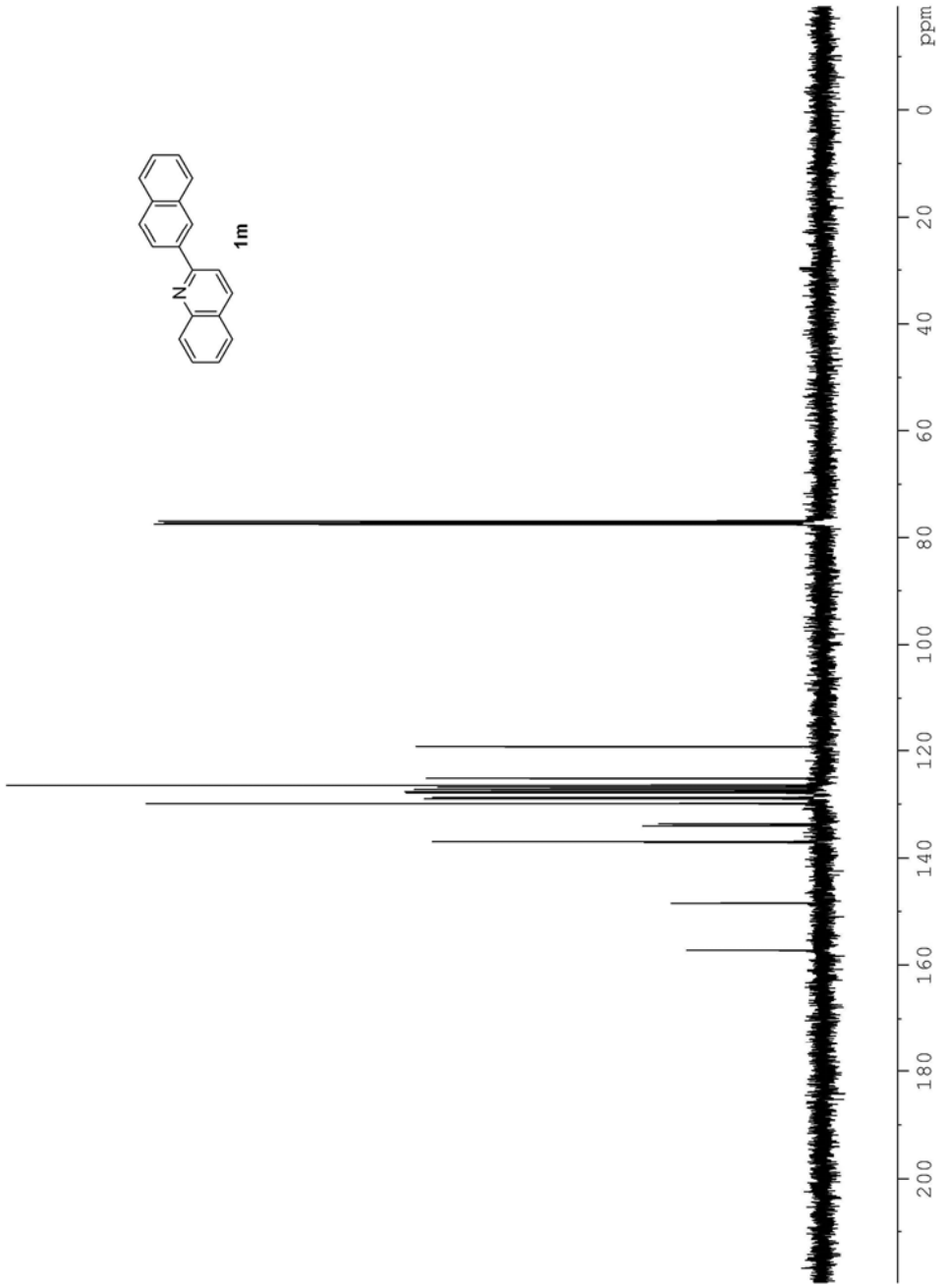

1k
ppm

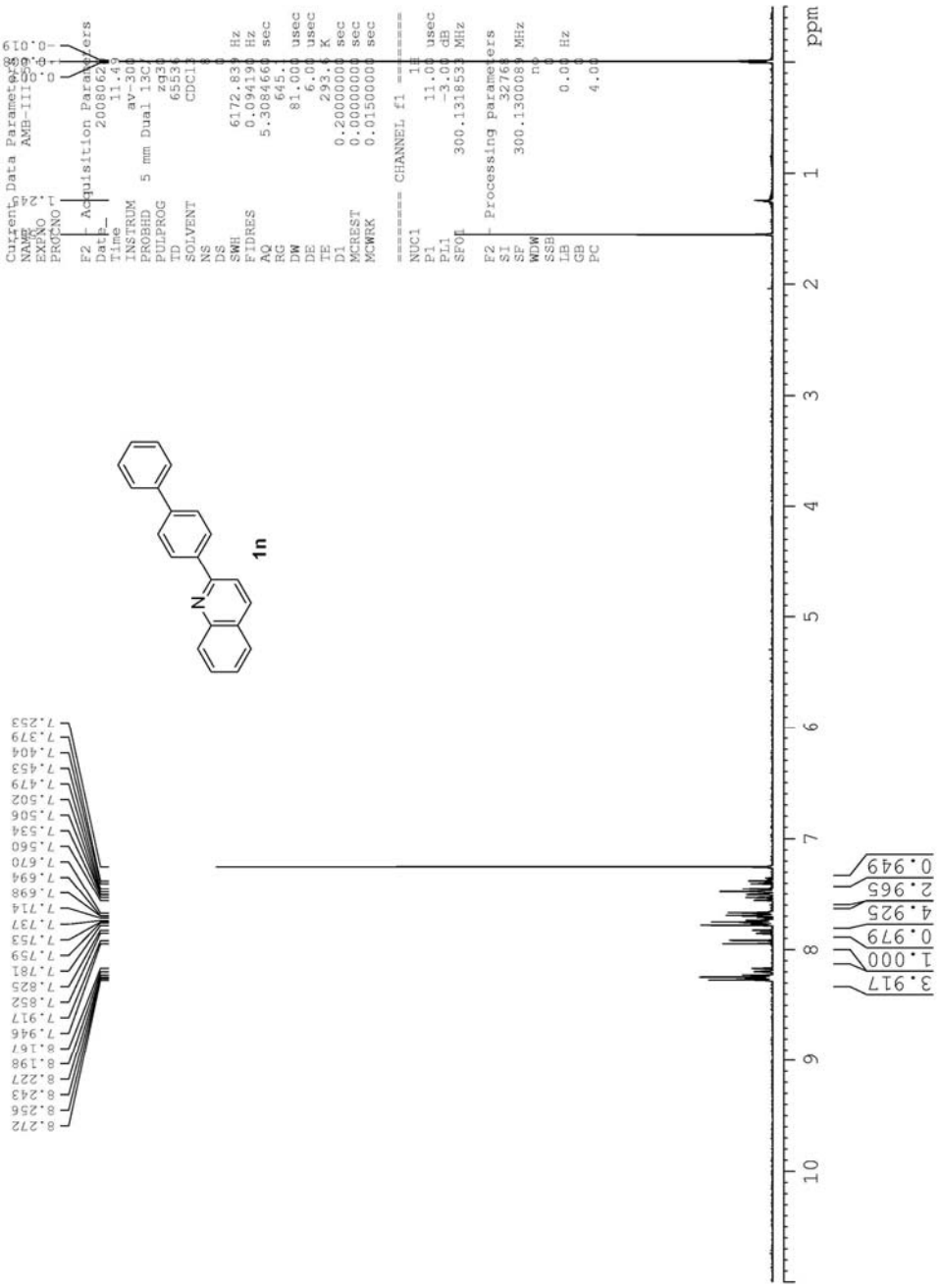

1k
O
N
220
200
180
160
140
120
100
80
60
40
20
ppm

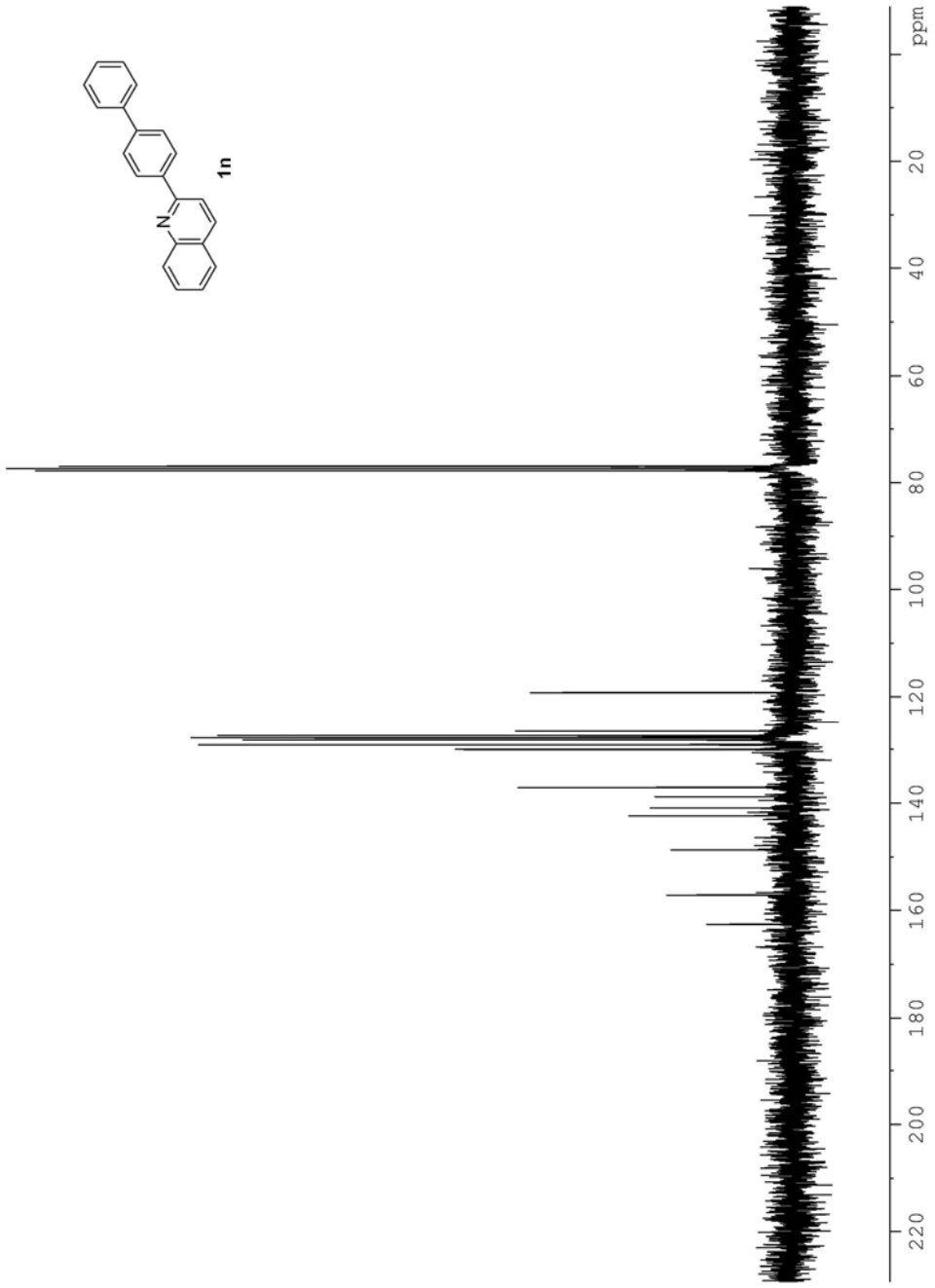

11
ppm


11
ppm
220
200
180
160
140
120
100
80
60
40
20


1m
ppm


1m
N
200
180
160
140
120
100
80
60
40
20
0
ppm


1n
ppm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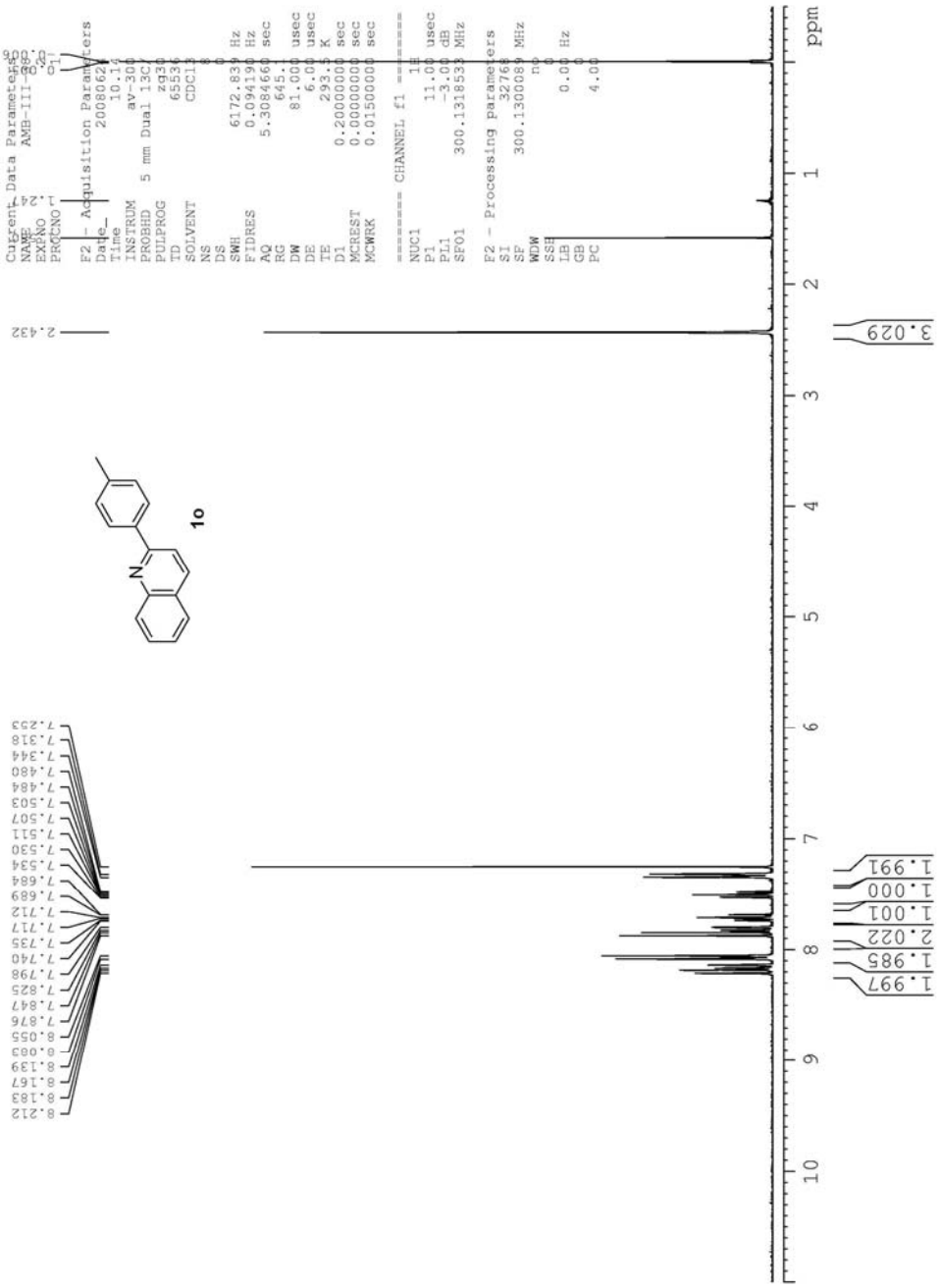
N
ppm
220
200
180
160
140
120
100
80
60
40
20


1o
ppm
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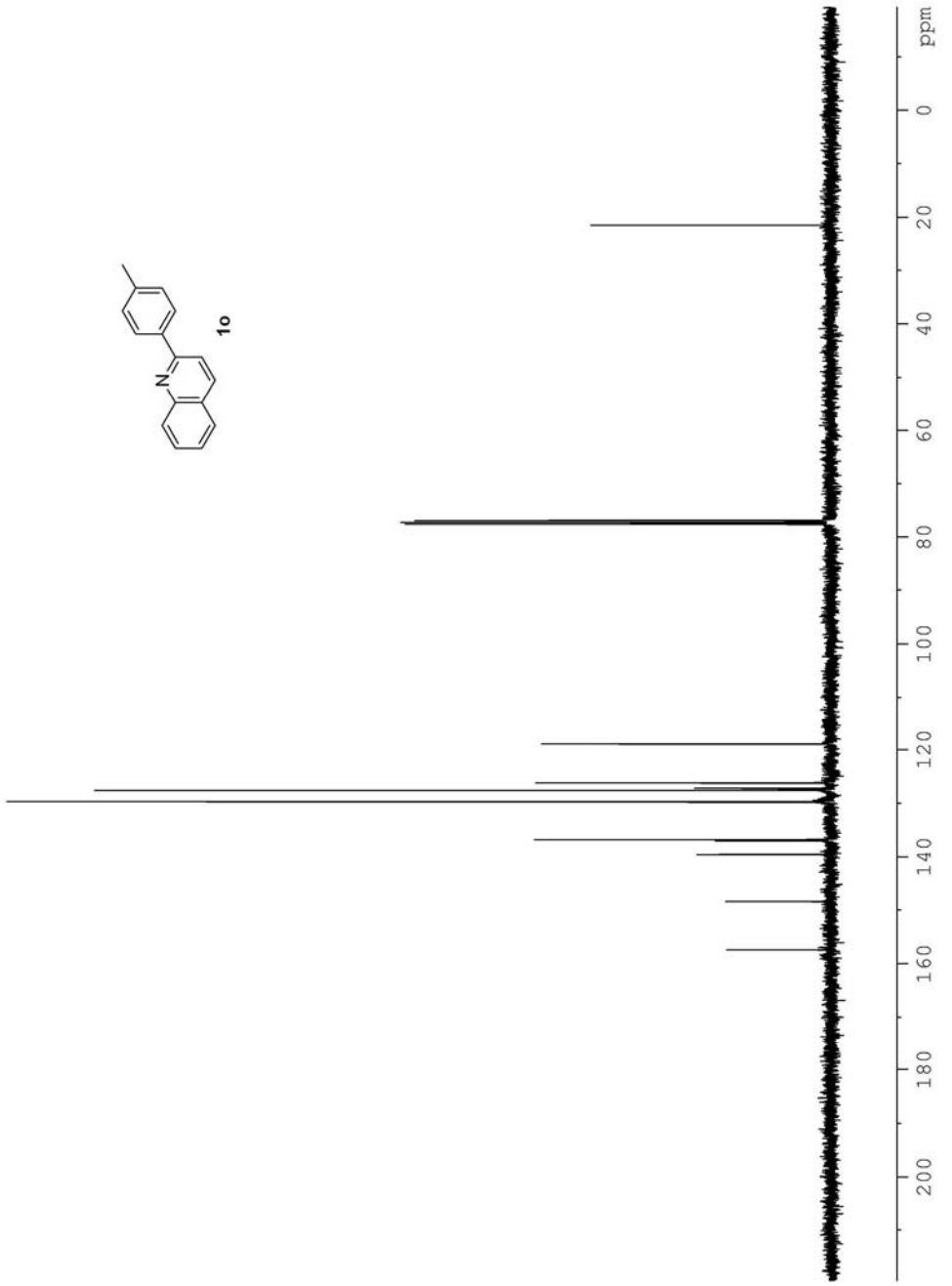
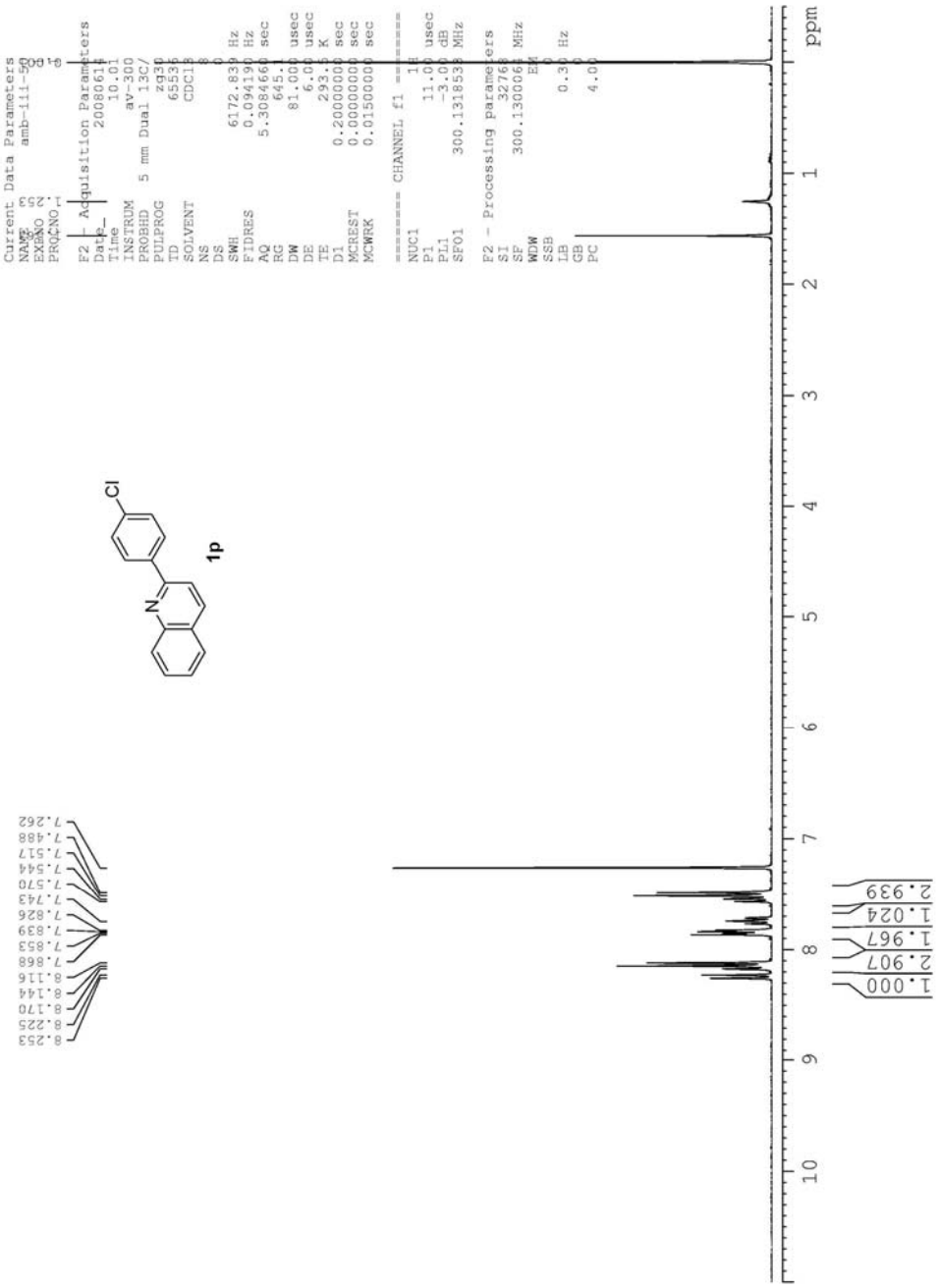
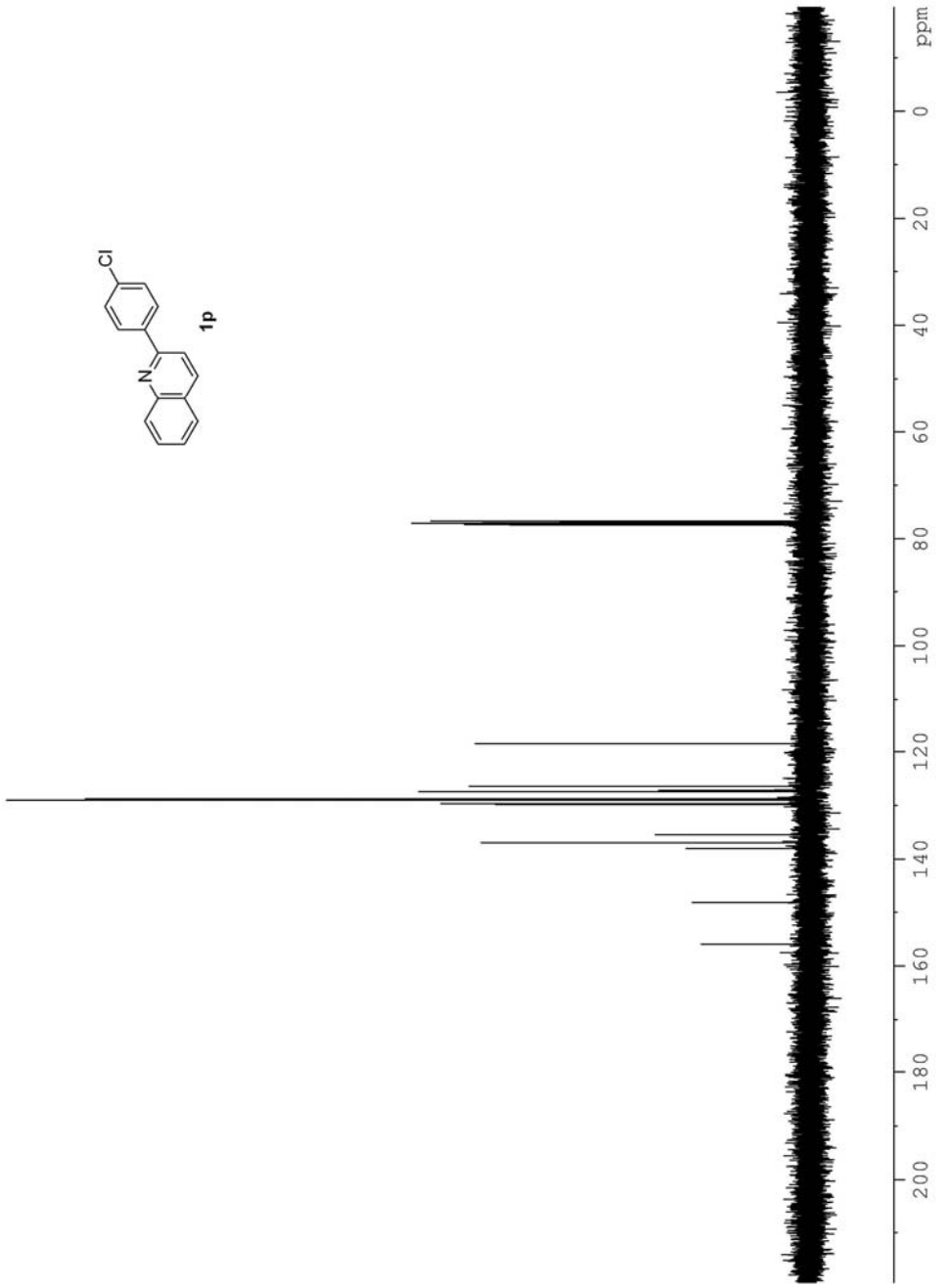
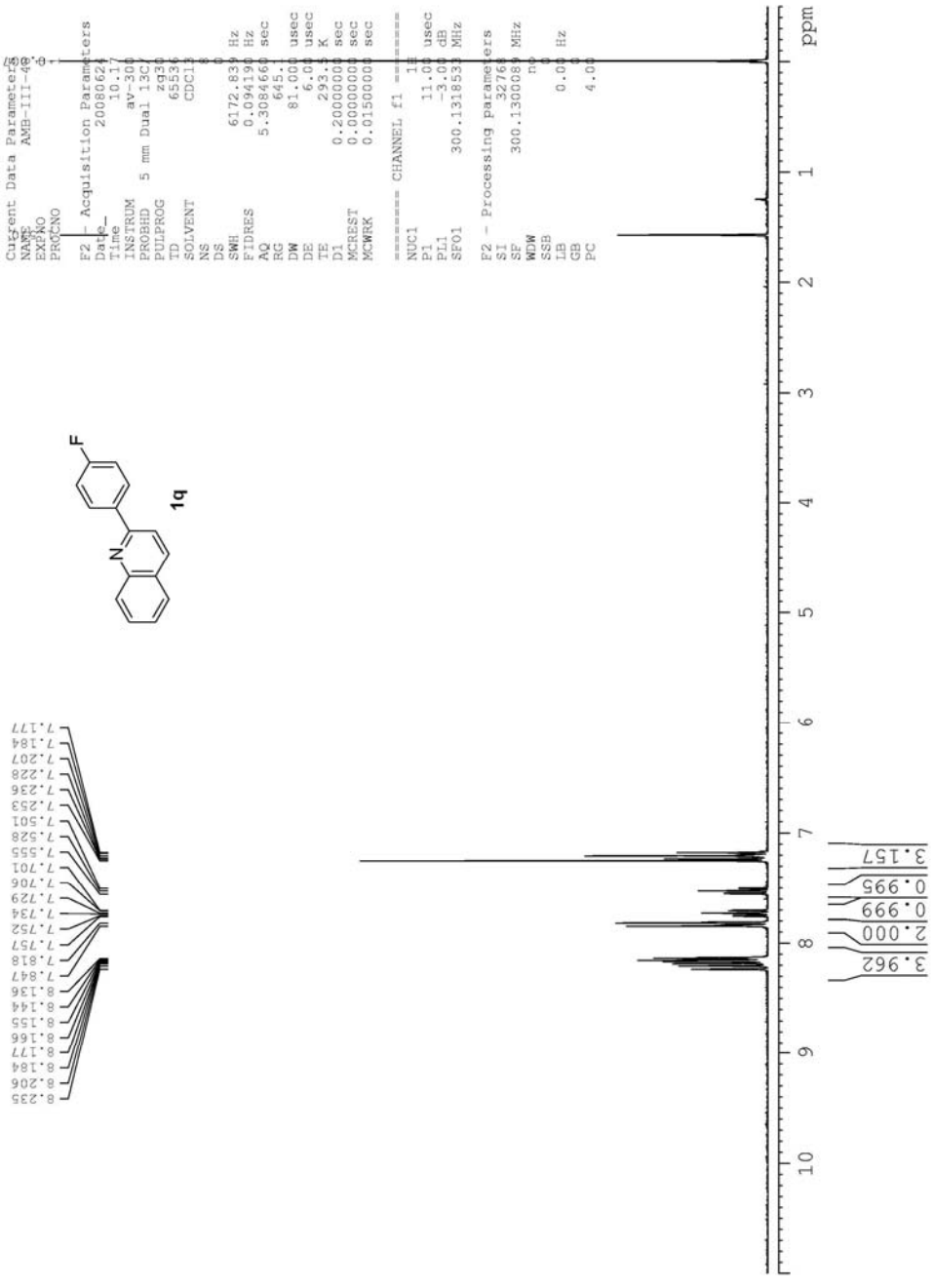
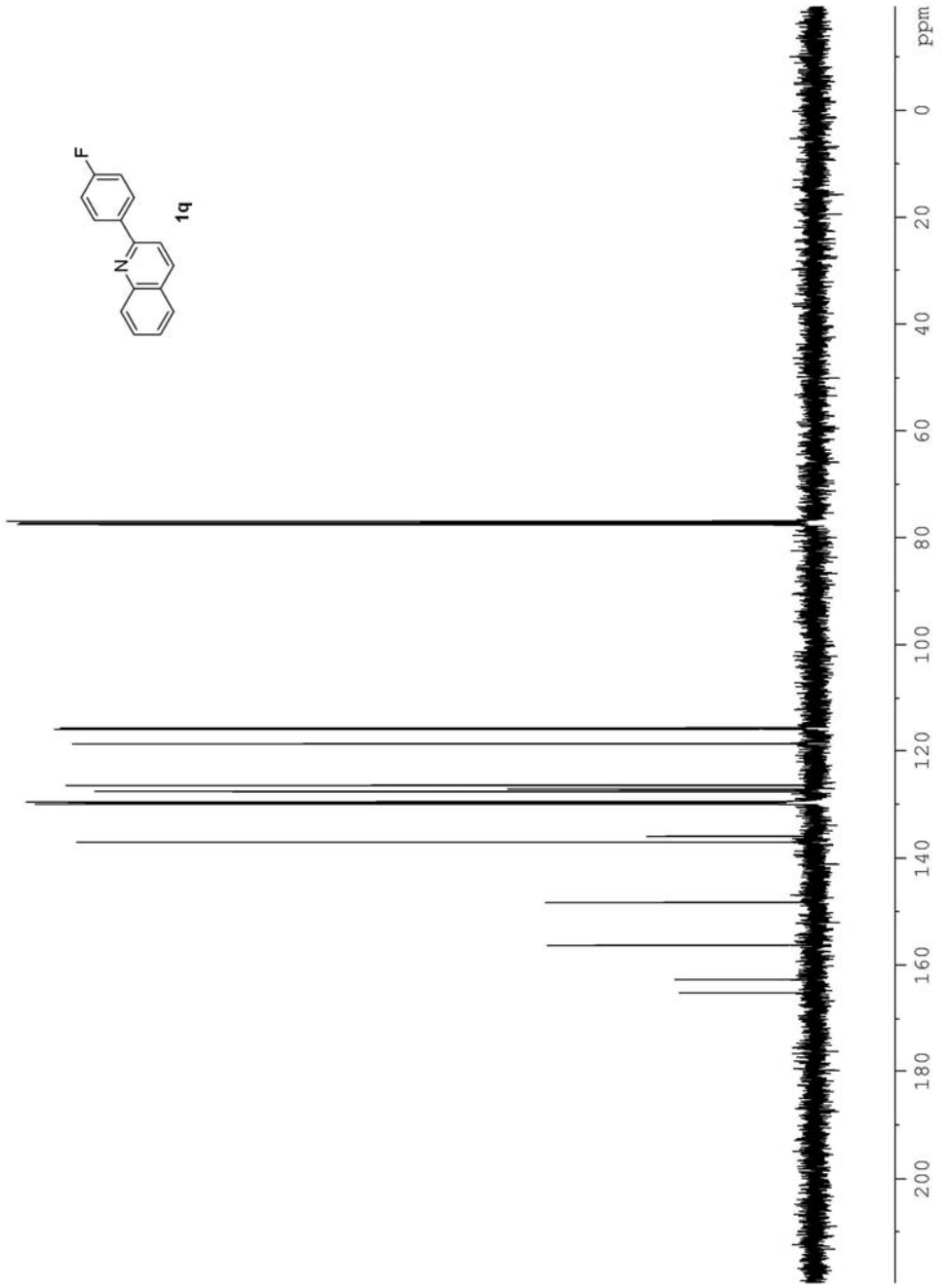
1.985
2.022
1.001
1.000
1.991
3.029
2.432

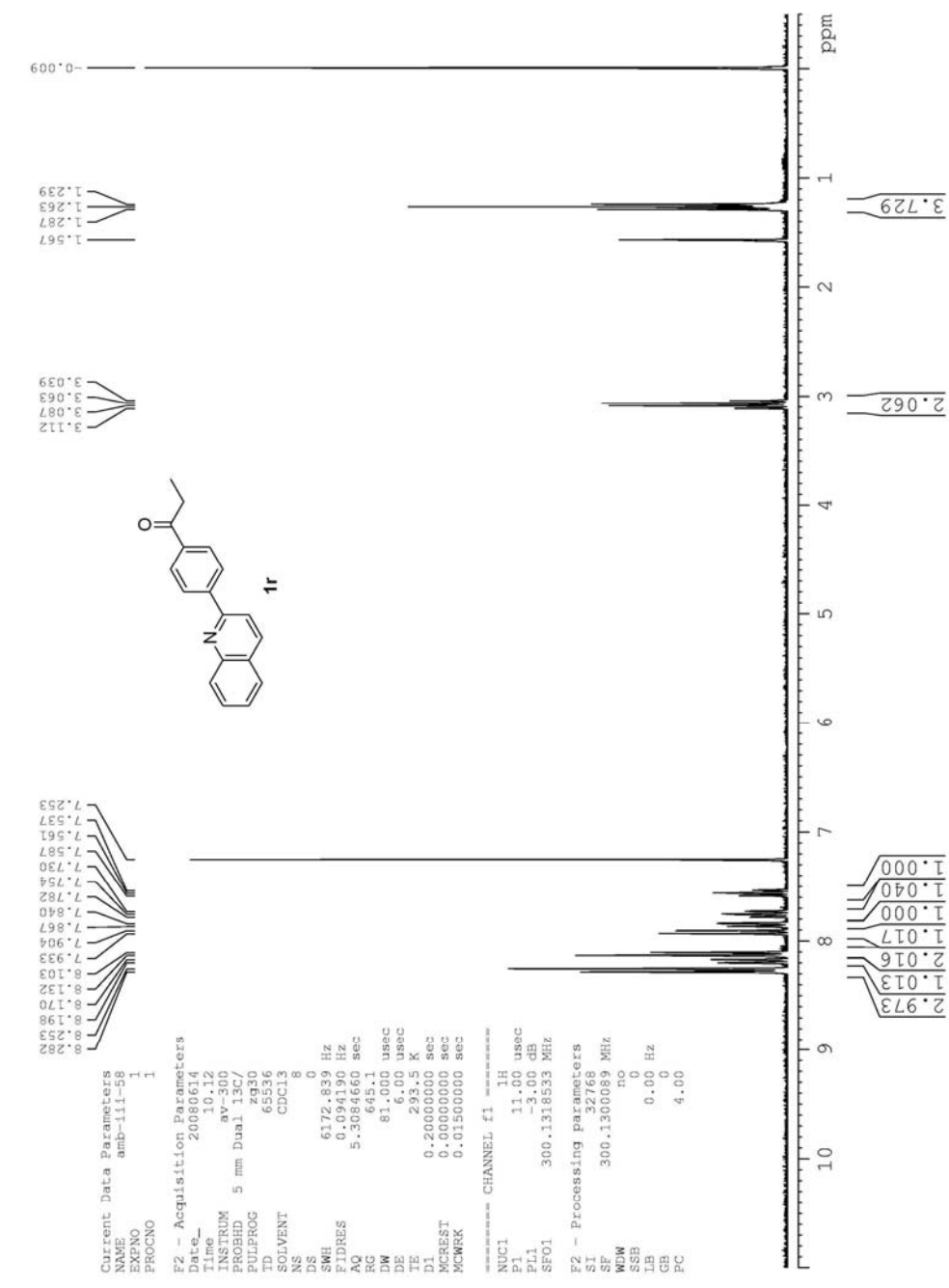

1o
N
200
180
160
140
120
100
80
60
40
20
0
ppm

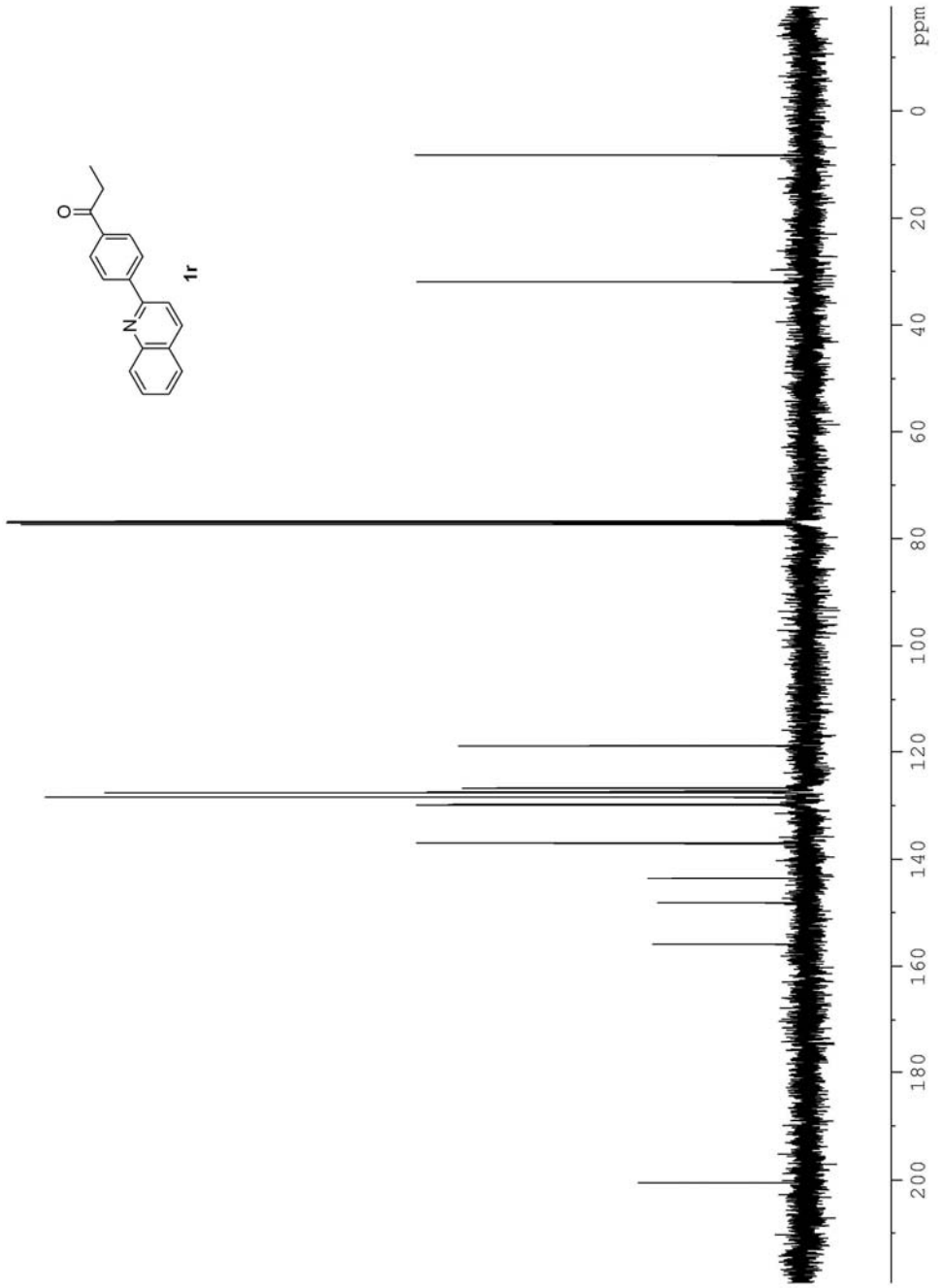

Cl
N
1p
ppm

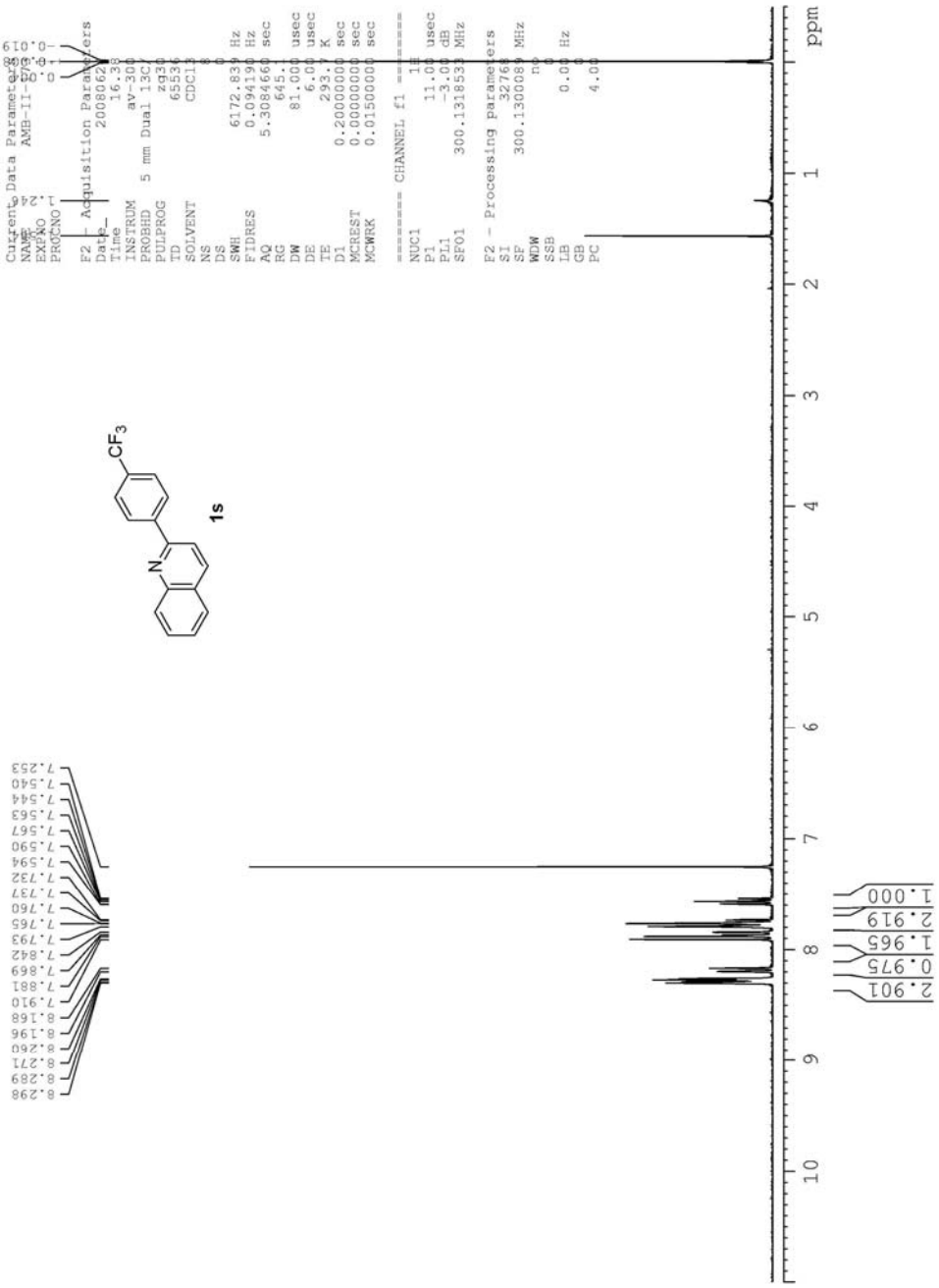

Cl
N
1p
200
180
160
140
120
100
80
60
40
20
0
ppm

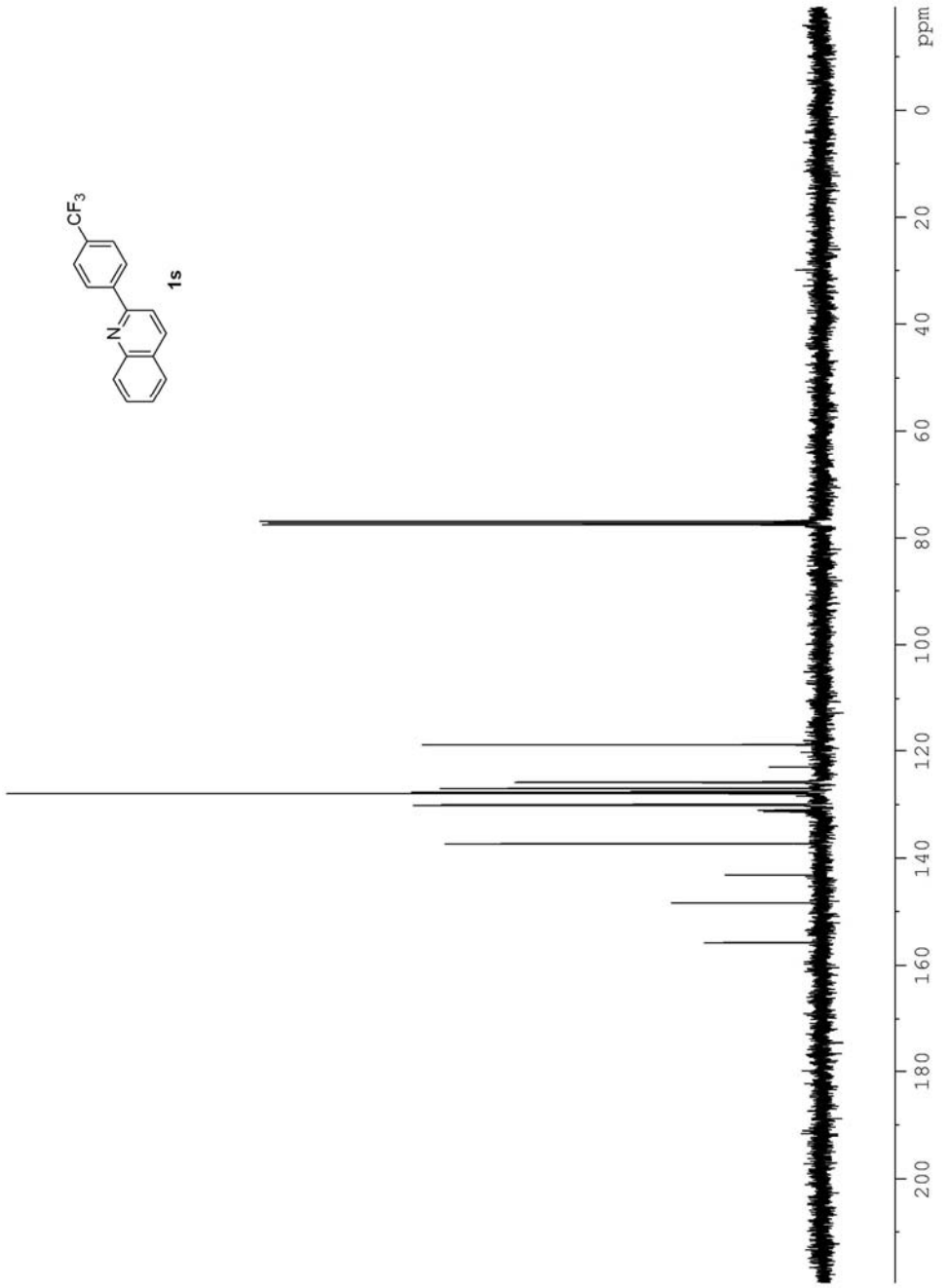

1q
F
N
ppm
3.962
2.000
0.999
0.995
3.157

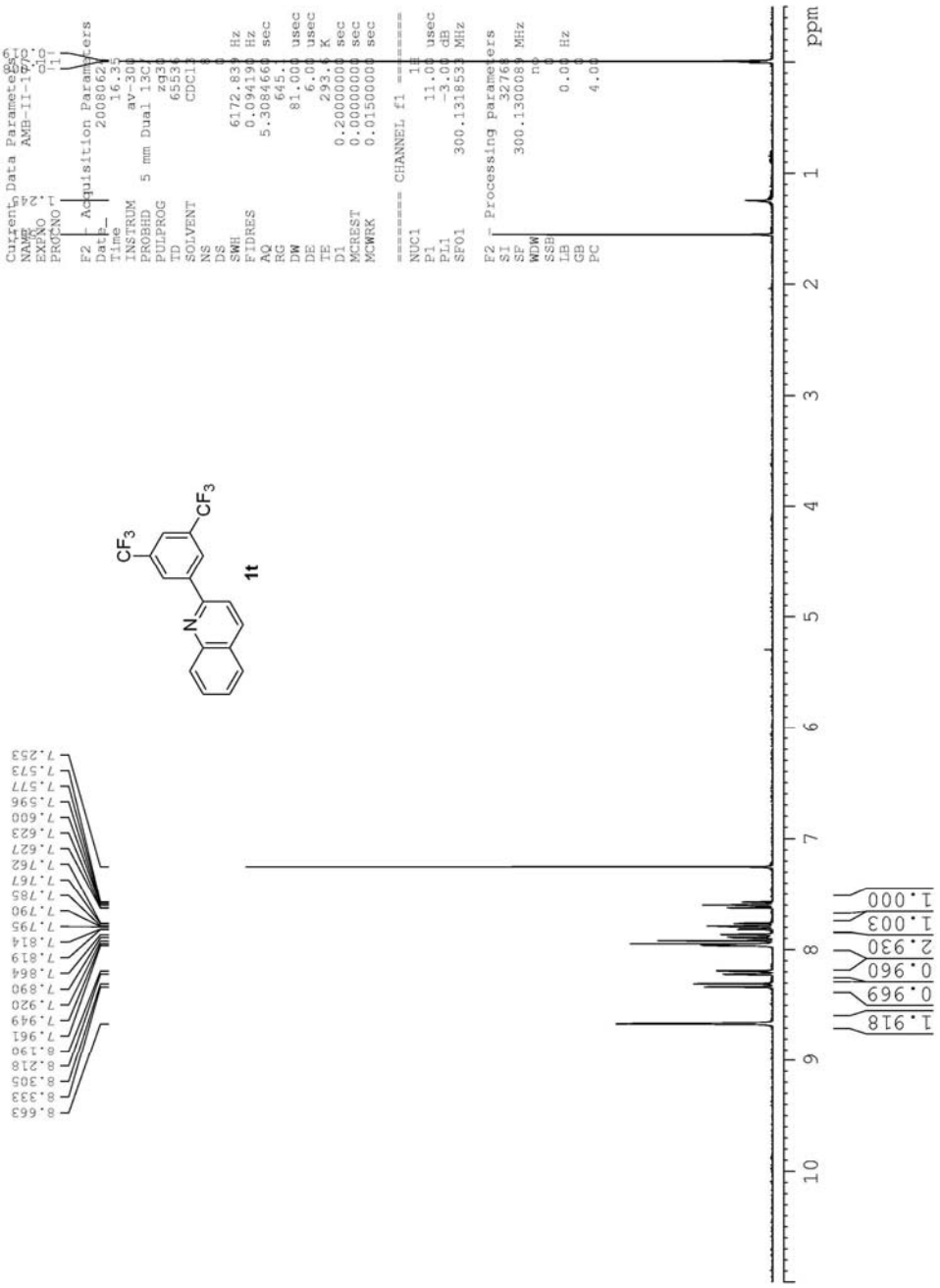

F
N
1q
200
180
160
140
120
100
80
60
40
20
0
ppm


1r
ppm


O
N
1r
ppm
0
20
40
60
80
100
120
140
160
180
200


1s
CF3
N
ppm


CF3
N
1s
200
180
160
140
120
100
80
60
40
20
0
ppm


1t
ppm

CF3
CF3
N
1t
200
180
160
140
120
100
80
60
40
20
0
ppm