# Palladium-Catalyzed Ligand-Promoted Site-Selective Cyanomethylation of Unactivated C($sp^3$)−H Bonds with Acetonitrile

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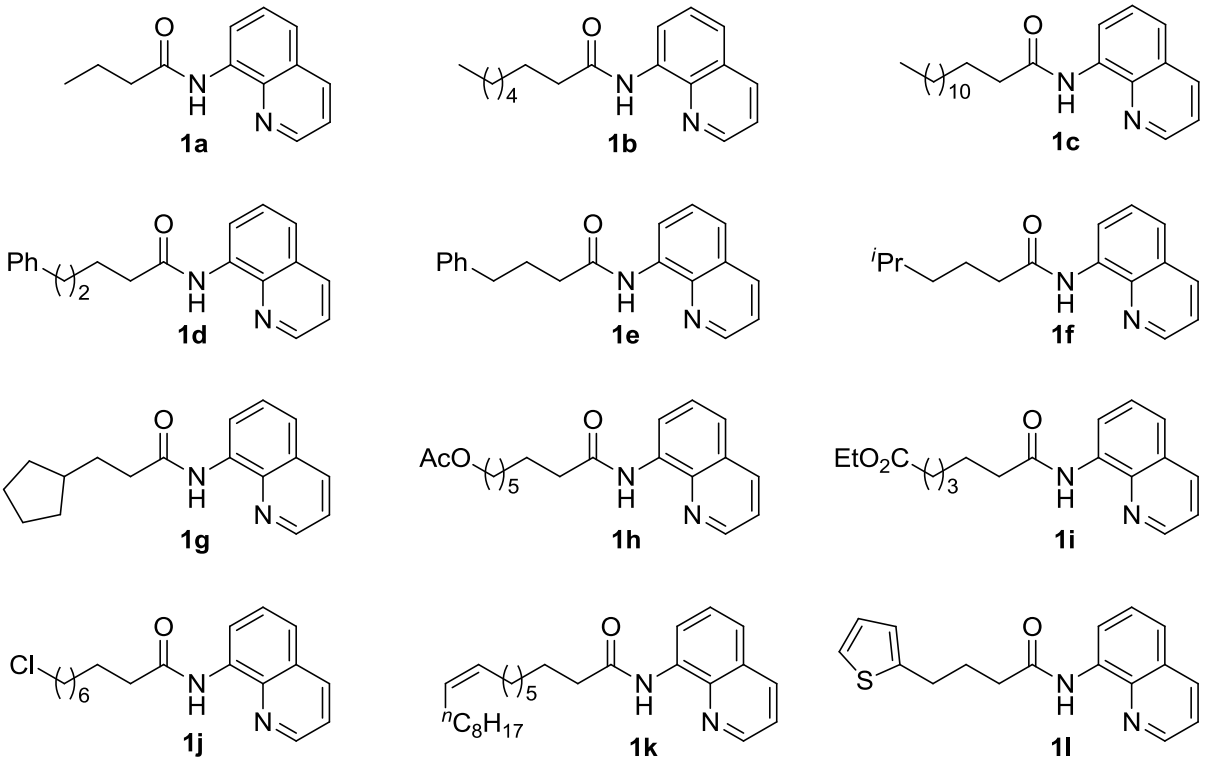
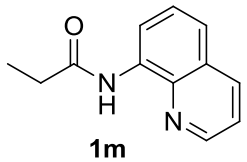
## General Information

$^{1}H$ and $^{13}C$ NMR were recorded on a Bruker 500 MHz NMR Fourier transform spectrometer (500 MHz and 125 MHz, respectively) using tetramethylsilane as an internal reference, and chemical shifts ($\delta$) and coupling constants ($J$) were expressed in ppm and Hz, respectively. Infrared spectra were obtained using a Thermo Nicolet IR 330 spectrometer. Mass (MS) analysis was obtained using Agilent 1100 series LC/MSD system with Electrospray Ionization (ESI). All the solvents and commercially available reagents were purchased from commercial sources and used directly. Starting materials **1a**-1**g**, **1k-1m**, **3a**-**3h**, **3k**, [$D_3$]-**3d** and **5** were prepared according to literature procedures.[1] **1h-1j**, **3i** and **3j** were prepared based on reported reaction protocol.[2]

## Structures of Starting Materials





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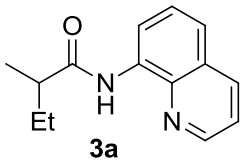

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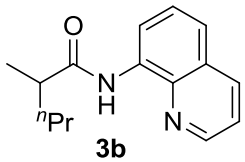

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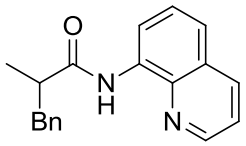

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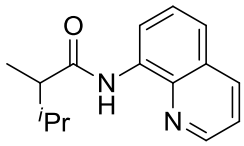

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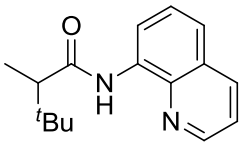

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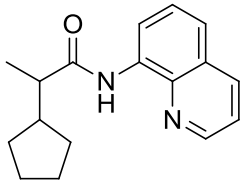

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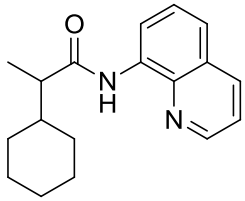

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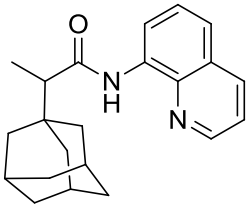

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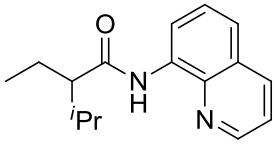

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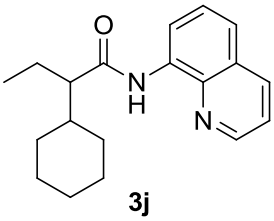

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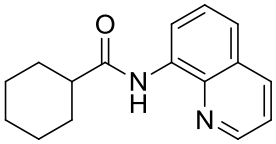

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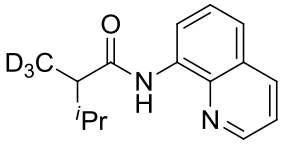
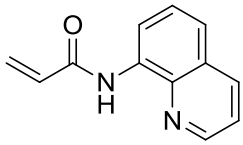
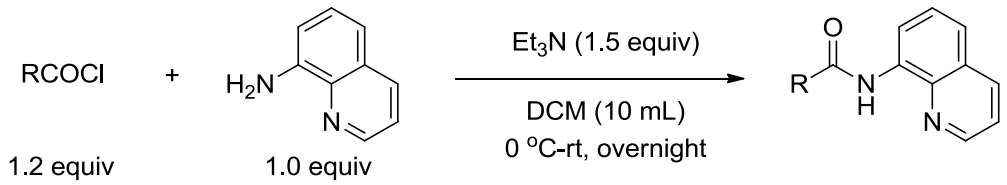


**[D$_3$]-3d**



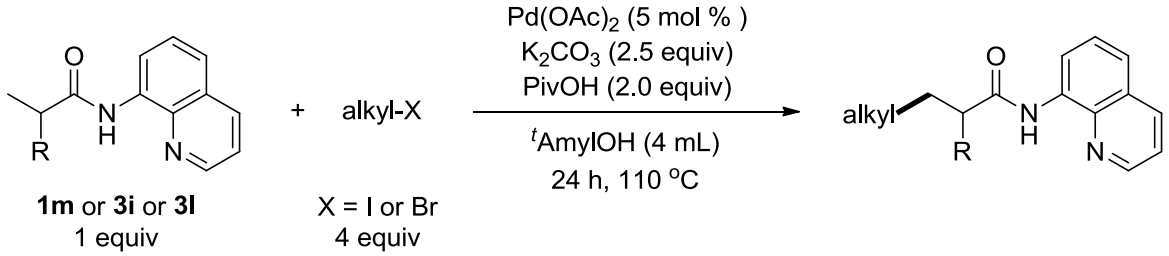
**5**

**General Procedure A for the Preparation of Starting Materials (1a-1g, 1k-1m, 3a-3h, 3k, [$D_3$]-3d and 5)**



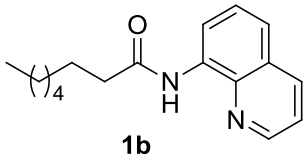

The acid chloride (6.0 mmol) was added dropwise to a solution of 8-aminoquinoline (0.721 g, 5.0 mmol) and $Et_3N$ (1.0 mL, 7.5 mmol) in $CH_2Cl_2$ (10 mL) at 0 °C under nitrogen. The resulting mixture was stirred overnight at room temperature. Then the mixture was diluted with $CH_2Cl_2$ (10 mL), washed successively with water, saturated aqueous $NaHCO_3$, and brine. The organic layer was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The residue was purified by flash column chromatography on silica gel eluting with EtOAc/hexanes (1/30-1/5, v/v) to afford corresponding 8-aminoquinolinyl amide.[1]

**General Procedure B for the Preparation of Starting Materials (1h-1j, 3i and 3j)**



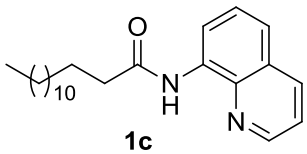

A 35 mL tube was charged with acetamide **1m** or **3i** or **3l** (601 mg, 3.0 mmol), alkyl halide (12 mmol) $Pd(OAc)_2$ (33.6 mg, 0.15 mmol), $K_2CO_3$ (1.037 g, 7.5 mmol), PivOH (613 mg, 6.0 mmol) and *tert*-Amyl alcohol (4.0 mL). The reaction mixture was stirred at 110 ˚C for 24 h. Then the mixture was cooled to room temperature, diluted with EtOAc (10 mL), filtered through a celite pad, and concentrated in vacuo. The residue was purified by chromatography on silica gel eluting with EtOAc/hexanes to give the desired product.[2]

**Analytical Data of Starting Materials (1b, 1c, 1h-1j, 1l, 3c, 3i, 3j, [$D_3$]-3d)**



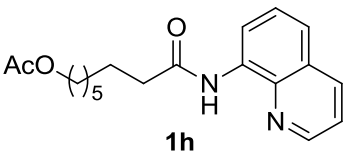
**1b**

Compound **1b**, pale yellow oil. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.86 (t, $J$ = 6.9 Hz, 3H), 1.20-1.45 (m, 8H), 1.72-1.86 (m, 2H), 2.52 (t, $J$ = 7.6 Hz, 2H), 7.38 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.43 (dd, $J$ = 8.2, 1.3 Hz, 1H), 7.45-7.54 (m, 1H), 8.08 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.75 (dd, $J$ = 4.2, 1.6 Hz, 1H), 8.78 (dd, $J$ = 7.6, 1.2 Hz, 1H), 9.78 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.1, 22.6, 25.7, 29.1, 29.3, 31.7, 38.3, 116.4, 121.3, 121.5, 127.4, 127.9, 134.6, 136.3, 138.3, 148.1, 171.9; IR (neat) $v$ 3356, 3044, 2953, 2927, 2854, 1689, 1525, 1486, 1424, 1386, 1325, 1163, 826, 791 cm$^{-1}$; Ms (ESI): $m/z$ = 271.2 $[M+H]^+$.



**1c**

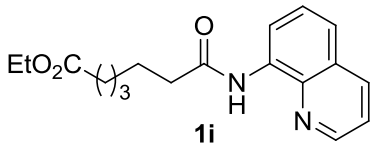
Compound **1c**, white solid. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.86 (t, $J$ = 7.0 Hz, 3H), 1.18-1.44 (m, 20H), 1.77-1.85 (m, 2H), 2.52 (t, $J$ = 7.5 Hz, 2H), 7.37 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.41 (dd, $J$ = 8.3, 1.3 Hz, 1H), 7.44-7.51 (m, 1H), 8.07 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.74 (dd, $J$ = 4.2, 1.7 Hz, 1H), 8.78 (dd, $J$ = 7.6, 1.1 Hz, 1H), 9.78 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.1, 22.7, 25.7, 29.33, 29.38, 29.44, 29.53, 29.65, 29.67, 29.70, 31.9, 38.2, 116.4, 121.3, 121.5, 127.4, 127.9, 134.6, 136.3, 138.3, 148.0, 171.8; IR (neat) $v$ 3358, 3048, 2959, 2852, 1697, 1521, 1486, 1424, 1386, 1325, 1165, 826, 791, 679 cm$^{-1}$; Ms (ESI): $m/z$ = 355.2 $[M+H]^+$.



**1h**

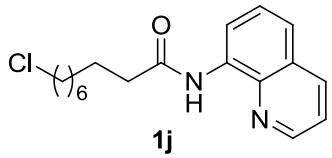
Compound **1h**, colorless oil. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.33-1.49 (m, 6H), 1.57-1.71 (m, 2H), 1.78-1.88 (m, 2H), 2.03 (s, 3H), 2.56 (t, $J$ = 7.5 Hz, 2H), 4.05 (t,

$J$ = 6.7 Hz, 2H), 7.45 (dd, $J$ = 8.3, 4.3 Hz, 1H), 7.49 (dd, $J$ = 8.2, 1.3 Hz, 1H), 7.51-7.56 (m, 1H), 8.16 (dd, $J$ = 8.3, 1.5 Hz, 1H), 8.73-8.84 (m, 2H), 9.80 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.1, 25.7, 25.9, 28.7, 29.2, 29.3, 38.3, 64.7, 116.6, 121.5, 121.7, 127.6, 128.1, 134.7, 136.5, 138.5, 148.2, 171.4, 171.9; IR (neat) $\nu$ 3356, 3047, 2933, 2857, 1735, 1689, 1525, 1486, 1425, 1386, 1325, 1242, 1164, 1041, 827, 793, 680 cm$^{-1}$; Ms (ESI): $m/z$ = 329.1 $[M+H]^+$.



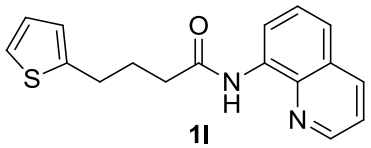

**1i**

Compound **1i**, pale yellow solid. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.20 (t, $J$ = 7.1 Hz, 3H), 1.37-1.49 (m, 2H), 1.60-1.72 (m, 2H), 1.73-1.85 (m, 2H), 2.28 (t, $J$ = 7.5 Hz, 2H), 2.52 (t, $J$ = 7.5 Hz, 2H), 4.08 (q, $J$ = 7.1 Hz, 2H), 7.38 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.42 (dd, $J$ = 8.2, 1.3 Hz, 1H), 7.44-7.53 (m, 1H), 8.08 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.63-8.80 (m, 2H), 9.76 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.3, 24.7, 25.3, 28.7, 34.2, 37.9, 60.2, 116.4, 121.4, 121.6, 127.4, 127.9, 134.5, 136.3, 138.3, 148.1, 171.5, 173.6; IR (neat) $\nu$ 3354, 2978, 2937, 2865, 1732, 1684, 1524, 1486, 1387, 1163, 1031, 829, 795 cm$^{-1}$; Ms (ESI): $m/z$ = 315.1 $[M+H]^+$.



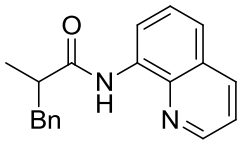

**1j**

Compound **1j**, pale yellow solid. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.30-1.45 (m, 8H), 1.68-1.87 (m, 4H), 2.55 (t, $J$ = 7.5 Hz, 2H), 3.51 (t, $J$ = 6.8 Hz, 2H), 7.44 (dd, $J$ = 8.1, 4.1 Hz, 1H), 7.46-7.56 (m, 2H), 8.14 (d, $J$ = 8.2 Hz, 1H), 8.69-8.85 (m, 2H), 9.80 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 25.7, 26.9, 28.8, 29.25, 29.31, 32.7, 38.3, 45.2, 116.5, 121.4, 121.7, 127.5, 128.0, 134.6, 136.5, 138.4, 148.2, 171.9; IR (neat) $\nu$ 3355, 2930, 1688, 1525, 1485, 1424, 1385, 1325, 1260, 1166, 826, 792, 758, 680 cm$^{-1}$; Ms (ESI): $m/z$ = 319.2 $[M+H]^+$.



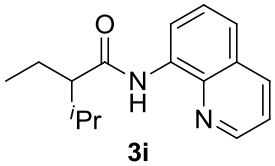
**1l**

Compound **1l**, pale yellow solid. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 2.13-2.24 (m, 2H), 2.63 (t, $J$ = 7.4 Hz, 2H), 3.00 (t, $J$ = 7.3 Hz, 2H), 6.78-6.89 (m, 1H), 6.94 (dd, $J$ = 5.1, 3.4 Hz, 1H), 7.14 (dd, $J$ = 5.1, 1.2 Hz, 1H), 7.46 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.50 (dd, $J$ = 8.3, 1.5 Hz, 1H), 7.52-7.63 (m, 1H), 8.16 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.65-8.90 (m, 2H), 9.80 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 27.5, 29.3, 37.1, 116.6, 121.5, 121.7, 123.4, 124.8, 126.9, 127.5, 128.0, 134.6, 136.5, 138.4, 144.4, 148.2, 171.3; IR (neat) $v$ 3351, 3066, 2934, 2851, 1685, 1522, 1485, 1424, 1385, 1259, 1163, 826, 792, 696 cm$^{-1}$; Ms (ESI): $m/z$ = 297.1 $[M+H]^+$.



**3c**

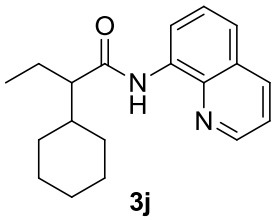
Compound **3c**, colorless oil. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.32 (d, $J$ = 6.8 Hz, 3H), 2.79 (dd, $J$ = 13.3, 7.4 Hz, 1H), 2.82-2.92 (m, 1H), 3.20 (dd, $J$ = 13.3, 6.9 Hz, 1H), 7.07-7.15 (m, 1H), 7.15-7.25 (m, 4H), 7.29 (dd, $J$ = 8.1, 4.1 Hz, 1H), 7.37 (d, $J$ = 8.2 Hz, 1H), 7.40-7.51 (m, 1H), 7.98 (d, $J$ = 8.2 Hz, 1H), 8.60-8.72 (m, 1H), 8.73-8.87 (m, 1H), 9.77 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 17.7, 40.2, 44.7, 116.3, 121.3, 121.4, 126.2, 127.2, 127.7, 128.3, 129.0, 134.4, 136.1, 138.2, 139.5, 147.9, 174.3; IR (neat) $v$ 3354, 3027, 2969, 2931, 1684, 1522, 1485, 1454, 1387, 1324, 1240, 1161, 1079, 912, 856, 792 cm$^{-1}$; Ms (ESI): $m/z$ = 291.1 $[M+H]^+$.



**3i**

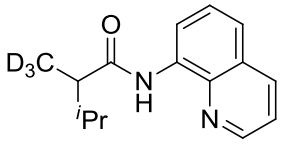
Compound **3i**, colorless oil. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.99 (t, $J$ =7.4 Hz, 3H), 1.03 (d, $J$ = 6.7 Hz, 3H), 1.05 (d, $J$ = 6.7 Hz, 3H), 1.68-1.84 (m, 2H), 1.95-2.06 (m, 1H), 2.08-2.15 (m, 1H), 7.44 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.48 (dd, $J$ = 8.2, 1.4 Hz, 1H), 7.52-7.57 (m, 1H), 8.15 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.81 (dd, $J$ = 4.3, 1.7 Hz,

1H), 8.85 (dd, *J* = 7.5, 1.4 Hz, 1H), 9.82 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.5, 20.6, 21.1, 23.5, 31.1, 58.4, 116.5, 121.4, 121.6, 127.6, 128.1, 134.6, 136.4, 138.6, 148.3, 174.5; IR (neat) *v* 3359, 2962, 2932, 2873, 1684, 1525, 1485, 1424, 1386, 1324, 1172, 826, 792, 757, 669, 603 cm$^{-1}$; Ms (ESI): *m*/*z* = 257.1 $[M+H]^+$.




**3j**

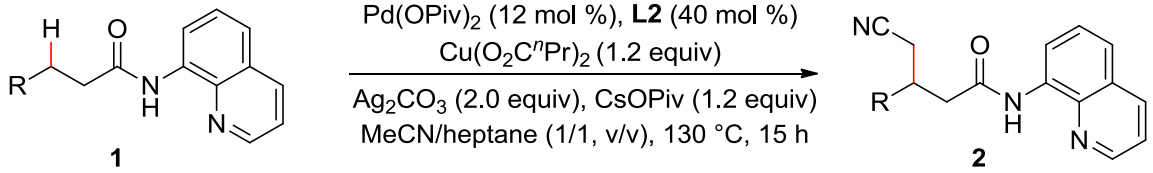
Compound **3j**, colorless oil. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.98 (t, *J* =7.4 Hz, 3H), 1.02-1.32 (m, 5H), 1.59-1.84 (m, 7H), 1.87-1.97 (m, 1H), 2.09-2.19 (m, 1H), 7.42 (dd, *J* = 8.1, 4.1 Hz, 1H), 7.47 (d, *J* = 8.0, 1H), 7.49-7.57 (m, 1H), 8.12 (d, *J* = 8.2 Hz, 1H), 8.80 (d, *J* = 3.1 Hz, 1H), 8.86 (dd, *J* = 7.4, 0.8 Hz, 1H), 9.82 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 12.4, 23.1, 26.4, 26.50, 26.53, 31.0, 31.4, 40.6, 57.5, 116.5, 121.4, 121.6, 127.5, 128.0, 134.5, 136.4, 138.5, 148.2, 174.5; IR (neat) *v* 3359, 2927, 2851, 1684, 1524, 1485, 1424, 1384, 1323, 1259, 1165, 826, 792, 757, 676 cm$^{-1}$; Ms (ESI): *m*/*z* = 297.1 $[M+H]^+$.




[$D_3$]-**3d**

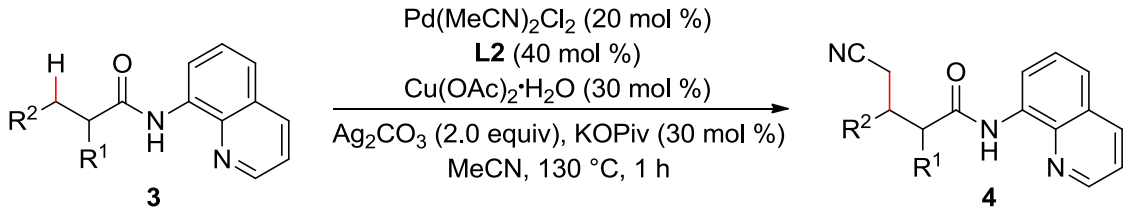
Compound [$D_3$]-**3d**, white solid. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.02 (d, *J* =6.8 Hz, 3H), 1.04 (d, *J* =6.8 Hz, 3H), 1.97-2.11 (m, 1H), 2.32 (d, *J* =7.9 Hz, 1H), 7.44 (dd, *J* = 8.3, 4.2 Hz, 1H), 7.48 (dd, *J* = 8.2, 1.3 Hz, 1H), 7.50-7.59 (m, 1H), 8.07-8.20 (m, 1H), 8.71-8.88 (m, 2H), 9.83 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 19.7, 21.3, 31.8, 49.8, 116.5, 121.4, 121.7, 127.6, 128.1, 134.7, 136.5, 138.6, 148.3, 175.3; IR (neat) *v* 3357, 2961, 2872, 1685, 1524, 1485, 1424, 1385, 1324, 1168, 826, 791 cm$^{-1}$; Ms (ESI): *m*/*z* = 246.1 $[M+H]^+$.

## General Procedure for Palladium-Catalyzed Site-Selective Cyanomethylation of Linear Aliphatic Amides



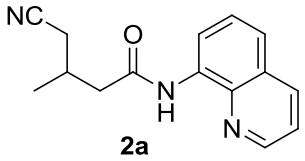

A 35 mL sealed tube was charged with amide **1** (0.3 mmol), $Pd(OPiv)_2$ (11.1 mg, 0.036 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (22.1 mg, 0.12 mmol), $Cu(O_2C^nPr)_2$ (85.6 mg, 0.36 mmol), $Ag_2CO_3$ (165.5 mg, 0.6 mmol), CsOPiv (84.3 mg, 0.36 mmol), MeCN (1.5 mL) and heptane (1.5 mL). After sealed, the reaction mixture was stirred at 130 ˚C for 15 h. Then the mixture was cooled to room temperature, quenched with aqueous NaOH (1 M, 2 mL), and extracted with EtOAc (3×10 mL). The combined organic phase was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with EtOAc/hexanes (1/10-1/3, v/v) to provide the desired product **2**.

## General Procedure for Palladium-Catalyzed Site-Selective Cyanomethylation of α-Substituted Aliphatic Amides



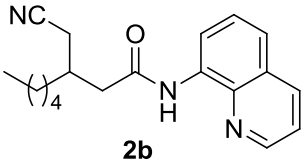

A 35 mL sealed tube was charged with amide **3** (0.3 mmol), $Pd(MeCN)_2Cl_2$ (15.6 mg, 0.06 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (22.1 mg, 0.12 mmol), $Cu(OAc)_2 \cdot H_2O$ (18.0 mg, 0.09 mmol), $Ag_2CO_3$ (165.5 mg, 0.6 mmol), KOPiv (12.6 mg, 0.09 mmol), and MeCN (2.0 mL). After sealed, the reaction mixture was stirred at 130 ˚C for 1 h. Then the mixture was cooled to room temperature, quenched with aqueous NaOH (1 M, 2 mL), and extracted with EtOAc (3×10 mL). The combined organic phase was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with EtOAc/hexanes (1/15-1/6, v/v) to provide the desired product **4**.

## Analytical Data of Products



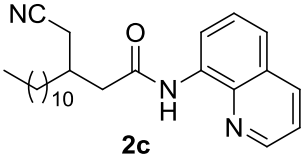

**2a**

Compound **2a**, colorless oil, yield: 72%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.25 (d, $J$ = 6.0 Hz, 3H), 2.53-2.72 (m, 5H), 7.47 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.50-7.58 (m, 2H), 8.11-8.23 (m, 1H), 8.67-8.77 (m, 1H), 8.77-8.87 (m, 1H), 9.85 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 19.6, 24.2, 27.9, 43.4, 116.7, 118.4, 121.9, 122.0, 127.5, 128.1, 134.3, 136.5, 138.4, 148.4, 169.3; IR (neat) $\nu$ 3347, 3049, 2964, 2931, 2245, 1684, 1527, 1486, 1423, 1327, 1166, 827, 793, 759, 685 cm$^{-1}$; Ms (ESI): $m/z$ = 254.1 $[M+H]^+$.




**2b**

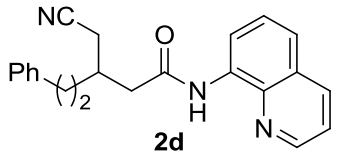
Compound **2b**, colorless oil, yield: 52%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.89 (t, $J$ = 7.0 Hz, 3H), 1.27-1.48 (m, 6H), 1.51-1.61 (m, 2H), 2.39-2.50 (m, 1H), 2.57-2.67 (m, 3H), 2.73 (dd, $J$ = 15.4, 5.6 Hz, 1H), 7.46 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.49-7.57 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.67-8.77 (m, 1H), 8.81 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.1, 21.8, 22.6, 26.5, 31.8, 32.3, 33.4, 41.4, 116.7, 118.5, 121.8, 121.9, 127.5, 128.1, 134.3, 136.5, 138.4, 148.4, 169.5; IR (neat) $\nu$ 3347, 2955, 2929, 2857, 2244, 1685, 1527, 1489, 1425, 1386, 1326, 1164, 827, 793, 758, 685 cm$^{-1}$; Ms (ESI): $m/z$ = 310.2 $[M+H]^+$.




**2c**

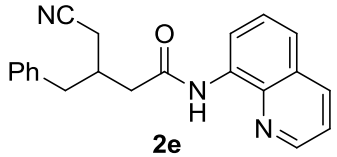
Compound **2c**, white solid, yield: 50%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.88 (t, $J$ = 7.0 Hz, 3H), 1.17-1.44 (m, 18H), 1.50-1.61 (m, 2H), 2.38-2.51 (m, 1H), 2.55-2.68 (m, 3H), 2.73 (dd, $J$ = 15.4, 5.6 Hz, 1H), 7.46 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.49-7.57 (m, 2H), 8.16 (dd, $J$ = 8.2, 1.6 Hz, 1H), 8.67-8.77 (m, 1H), 8.81 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.2, 21.8, 22.8, 26.9, 29.5,

29.60, 29.61, 29.67, 29.73, 29.74, 32.0, 32.3, 33.5, 41.5, 116.6, 118.5, 121.8, 121.9, 127.4, 128.1, 134.3, 136.5, 138.4, 148.4, 169.5; IR (neat) $\nu$ 3342, 3044, 2925, 2854, 2246, 1685, 1527, 1486, 1465, 1425, 1388, 1326, 1164, 827, 792, 757 $cm^{-1}$; Ms (ESI): $m/z$ = 394.2 $[M+H]^+$.



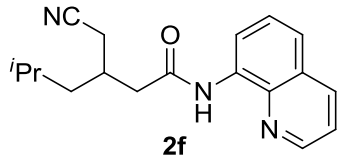
**2d**

Compound **2d**, white solid, yield: 70%. $^1H$ NMR (500 MHz, $CDCl_3$) $\delta$ 1.85-2.00 (m, 2H), 2.44-2.56 (m, 1H), 2.60-2.85 (m, 6H), 7.15-7.25 (m, 3H), 7.26-7.32 (m, 2H), 7.47 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.50-7.59 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.67-8.77 (m, 1H), 8.82 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.88 (brs, 1H); $^{13}C$ NMR (125 MHz, $CDCl_3$) $\delta$ 21.8, 31.9, 33.2, 35.1, 41.3, 116.7, 118.3, 121.9, 122.0, 126.3, 127.4, 128.1, 128.4, 128.7, 134.2, 136.5, 138.4, 141.0, 148.4, 169.2; IR (neat) $\nu$ 3345, 3055, 3026, 2927, 2858, 2244, 1684, 1526, 1486, 1425, 1388, 1326, 1166, 827, 793, 754 $cm^{-1}$; Ms (ESI): $m/z$ = 344.1 $[M+H]^+$.



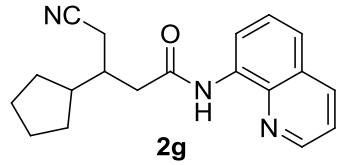
**2e**

Compound **2e**, white solid, yield: 54%. $^1H$ NMR (500 MHz, $CDCl_3$) $\delta$ 2.47 (dd, $J$ = 16.9, 4.1 Hz, 1H), 2.58 (dd, $J$ = 17.0, 4.3 Hz, 1H), 2.65-2.83 (m, 4H), 2.87-2.98 (m, 1H), 7.20-7.28 (m, 3H), 7.28-7.35 (m, 2H), 7.46 (dd, $J$ = 8.3, 4.3 Hz, 1H), 7.49-7.59 (m, 2H), 8.16 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.67-8.77 (m, 1H), 8.81 (dd, $J$ = 4.3, 1.7 Hz, 1H), 9.86 (brs, 1H); $^{13}C$ NMR (125 MHz, $CDCl_3$) $\delta$ 21.3, 34.2, 39.5, 40.8, 116.7, 118.3, 121.9, 122.0, 127.0, 127.4, 128.1, 128.9, 129.3, 134.3, 136.5, 138.3, 138.4, 148.4, 169.2; IR (neat) $\nu$ 3346, 3060, 3022, 2925, 2851, 2246, 1684, 1527, 1485, 1424, 1325, 1261, 1160, 827, 792, 748, 702 $cm^{-1}$; Ms (ESI): $m/z$ = 330.1 $[M+H]^+$.



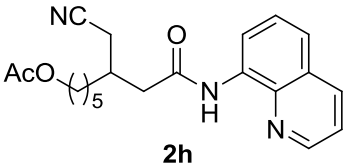

**2f**

Compound **2f**, colorless oil, yield: 66%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.95 (d, $J$ = 6.8 Hz, 3H), 0.96 (d, $J$ = 6.8 Hz, 3H), 1.35-1.51 (m, 2H), 1.64-1.76 (m, 1H), 2.48-2.75 (m, 5H), 7.46 (dd, $J$ = 8.3, 4.3 Hz, 1H), 7.49-7.59 (m, 2H), 8.10-8.20 (m, 1H), 8.68-8.77 (m, 1H), 8.77-8.85 (m, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.9, 22.3, 22.9, 25.2, 29.9, 41.4, 42.6, 116.6, 118.4, 121.8, 121.9, 127.4, 128.0, 134.2, 136.5, 138.3, 148.4, 169.4; IR (neat) $\nu$ 3347, 2957, 2870, 2244, 1684, 1527, 1486, 1425, 1326, 1166, 827, 793, 758, 684 cm$^{-1}$; Ms (ESI): $m/z$ = 296.1 $[M+H]^+$.




**2g**

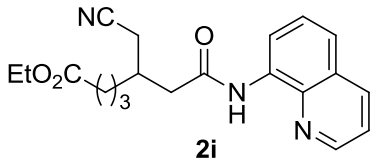
Compound **2g**, colorless oil, yield: 40%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.15-1.30 (m, 2H), 1.57-1.73 (m, 4H), 1.87-2.07 (m, 3H), 2.14-2.31 (m, 1H), 2.59-2.70 (m, 2H), 2.74 (dd, $J$ = 17.1, 4.6 Hz, 1H), 2.87 (dd, $J$ = 15.6, 3.9 Hz, 1H), 7.47 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.50-7.60 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.68-8.77 (m, 1H), 8.82 (dd, $J$ = 4.3, 1.7 Hz, 1H), 9.89 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.4, 25.34, 25.37, 30.9, 31.1, 37.7, 40.3, 43.4, 116.7, 118.7, 121.86, 121.92, 127.5, 128.1, 134.4, 136.5, 138.4, 148.5, 169.8; IR (neat) $\nu$ 3346, 2951, 2868, 2238, 1685, 1527, 1485, 1425, 1388, 1326, 827, 793 cm$^{-1}$; Ms (ESI): $m/z$ = 308.3 $[M+H]^+$.




**2h**

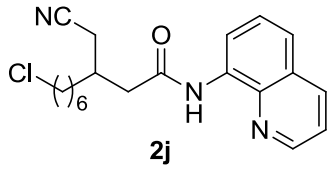
Compound **2h**, pale yellow oil, yield: 61%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.35-1.46 (m, 4H), 1.55-1.67 (m, 4H), 2.04 (s, 3H), 2.40-2.51 (m, 1H), 2.57-2.67 (m, 2H), 2.69 (dd, $J$ = 15.6, 8.1 Hz, 1H), 2.77 (dd, $J$ = 15.6, 5.6 Hz, 1H), 4.05 (t, $J$ = 6.6 Hz, 2H), 7.54-7.66 (m, 3H), 8.33 (dd, $J$ = 8.2, 1.5 Hz, 1H), 8.64-8.75 (m, 1H), 8.93 (dd, $J$ = 4.4, 1.5 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.0, 21.8, 25.9, 26.4, 28.5, 32.2, 33.3, 41.0, 64.4, 118.5, 119.9, 121.8, 122.8, 128.0,

128.4, 133.0, 136.8, 139.0, 147.6, 170.0, 171.1; IR (neat) *v* 3345, 2933, 2859, 2241, 1734, 1684, 1527, 1486, 1425, 1387, 1325, 1243, 1163, 1135, 1043, 828, 794, 761 $cm^{-1}$; Ms (ESI): *m*/*z* = 368.1 $[M+H]^+$.



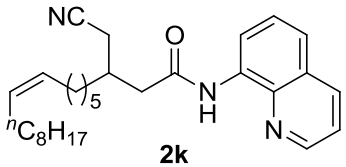

**2i**

Compound **2i**, pale yellow oil, yield: 63%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.23 (t, *J* = 7.1 Hz, 3H), 1.54-1.64 (m, 2H), 1.65-1.77 (m, 2H), 2.33 (t, *J* = 7.2 Hz, 2H), 2.40-2.50 (m, 1H), 2.57-2.67 (m, 3H), 2.73 (dd, *J* = 15.5, 5.4 Hz, 1H), 4.11 (q, *J* = 7.1 Hz, 2H), 7.41-7.46 (m, 1H), 7.47-7.54 (m, 2H), 8.11-8.17 (m, 1H), 8.66-8.73 (m, 1H), 8.75-8.83 (m, 1H), 9.85 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.3, 21.7, 22.1, 32.0, 32.8, 34.0, 41.0, 60.5, 116.6, 118.2, 121.8, 121.9, 127.3, 128.0, 134.2, 136.4, 138.3, 148.4, 169.2, 173.2; IR (neat) *v* 3346, 2981, 2936, 2869, 2245, 1732, 1684, 1526, 1486, 1425, 1326, 1181, 1030, 953, 828, 794, 761 $cm^{-1}$; Ms (ESI): *m*/*z* = 354.1 $[M+H]^+$.



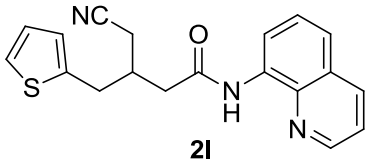

**2j**

Compound **2j**, pale yellow solid, yield: 70%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.31-1.50 (m, 6H), 1.53-1.62 (m, 2H), 1.70-1.82 (m, 2H), 2.38-2.51 (m, 1H), 2.56-2.68 (m, 3H), 2.73 (dd, *J* = 15.4, 5.7 Hz, 1H), 3.51 (t, *J* = 6.7 Hz, 2H), 7.47 (dd, *J* = 8.2, 4.2 Hz, 1H), 7.50-7.62 (m, 2H), 8.17 (dd, *J* = 8.3, 1.6 Hz, 1H), 8.64-8.77 (m, 1H), 8.81 (dd, *J* = 4.1, 1.5 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.9, 26.75, 26.84, 28.9, 32.3, 32.6, 33.4, 41.4, 45.1, 116.7, 118.4, 121.9, 122.0, 127.5, 128.1, 134.3, 136.5, 138.4, 148.4, 169.4; IR (neat) *v* 3344, 2931, 2856, 2244, 1684, 1523, 1425, 1425, 1387, 1324, 1162, 826, 792, 758, 641 $cm^{-1}$; Ms (ESI): *m*/*z* = 358.2 $[M+H]^+$.



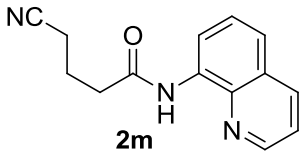

**2k**

Compound **2k**, colorless oil, yield: 52%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.85 (t, $J$ = 7.0 Hz, 3H), 1.20-1.41 (m, 18H), 1.51-1.62 (m, 2H), 1.85-2.10 (m, 4H), 2.39-2.49 (m, 1H), 2.55-2.68 (m, 3H), 2.73 (dd, $J$ = 15.5, 5.6 Hz, 1H), 5.27-5.41 (m, 2H), 7.46 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.49-7.58 (m, 2H), 8.16 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.73 (dd, $J$ = 6.4, 2.6 Hz, 1H), 8.81 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.2, 21.8, 22.8, 26.8, 27.2, 27.4, 29.2, 29.4, 29.5, 29.6, 29.7, 29.9, 32.0, 32.3, 33.4, 41.4, 116.6, 118.4, 121.8, 121.9, 127.4, 128.1, 129.6, 130.3, 134.3, 136.5, 138.4, 148.4, 169.5; IR (neat) $\nu$ 3348, 3004, 2926, 2854, 2245, 1688, 1527, 1486, 1425, 1388, 1326, 1164, 827, 792, 757, 689 cm$^{-1}$; Ms (ESI): $m/z$ = 448.2 $[M+H]^+$.




**2l**

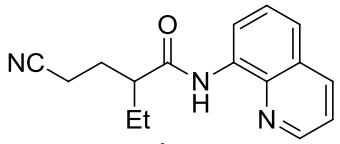
Compound **2l**, colorless oil, yield: 41%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 2.53-2.61 (m, 1H), 2.61-2.68 (m, 1H), 2.68-2.84 (m, 3H), 3.07 (dd, $J$ = 14.8, 7.5 Hz, 1H), 3.16 (dd, $J$ = 14.8, 5.7 Hz, 1H), 6.90-6.94 (m, 1H), 6.96 (dd, $J$ = 5.1, 3.4 Hz, 1H), 7.20 (dd, $J$ = 5.1, 1.2 Hz, 1H), 7.47 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.50-7.59 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.69-8.77 (m, 1H), 8.81 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 21.2, 33.5, 34.5, 40.4, 116.7, 118.1, 121.9, 122.0, 124.7, 126.6, 127.3, 127.4, 128.1, 134.2, 136.5, 138.4, 140.3, 148.4, 168.9; IR (neat) $\nu$ 3343, 3066, 2924, 2851, 2245, 1658, 1527, 1486, 1388, 1326, 1261, 1164, 827, 792, 757, 700 cm$^{-1}$; Ms (ESI): $m/z$ = 336.0 $[M+H]^+$.




**2m**

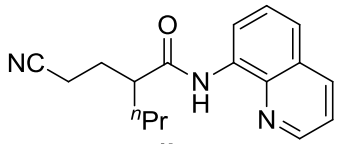
Compound **2m**, colorless oil, yield: 57%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 2.10-2.22 (m, 2H), 2.57 (t, $J$ = 7.0 Hz, 2H), 2.76 (t, $J$ = 7.0 Hz, 2H), 7.46 (dd, $J$ = 8.2, 4.1 Hz,

1H), 7.49-7.59 (m, 2H), 8.16 (d, *J* = 8.3 Hz, 1H), 8.67-8.77 (m, 1H), 8.77-8.84 (m, 1H), 9.85 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 16.8, 21.2, 35.7, 116.6, 119.4, 121.8, 121.9, 127.4, 128.1, 134.3, 136.5, 138.4, 148.4, 169.6; IR (neat) *v* 3347, 3049, 2941, 2246, 1685, 1527, 1486, 1425, 1387, 1325, 1160, 827, 792, 759, 681 cm$^{-1}$; Ms (ESI): *m*/*z* = 240.1 $[M+H]^+$.



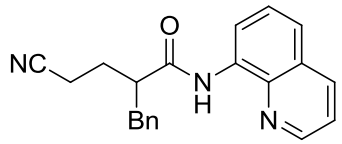

**4a**

Compound **4a**, colorless oil, yield: 51%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.04 (t, *J* = 7.4 Hz, 3H), 1.64-1.77 (m, 1H), 1.81-1.95 (m, 2H), 2.12-2.25 (m, 1H), 2.37-2.56 (m, 2H), 2.58-2.69 (m, 1H), 7.46 (dd, *J* = 8.3, 4.2 Hz, 1H), 7.50-7.59 (m, 2H), 8.16 (dd, *J* = 8.3, 1.7 Hz, 1H), 8.70-8.80 (m, 1H), 8.82 (dd, *J* = 4.2, 1.6 Hz, 1H), 9.96 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 11.8, 15.5, 26.2, 27.9, 48.9, 116.7, 119.5, 121.8, 122.0, 127.4, 128.0, 134.2, 136.5, 138.5, 148.5, 172.7; IR (neat) *v* 3347, 3049, 2965, 2934, 2876, 2245, 1684, 1525, 1486, 1425, 1379, 1324, 1162, 827, 759, 686, 605 cm$^{-1}$; Ms (ESI): *m*/*z* = 268.2 $[M+H]^+$.



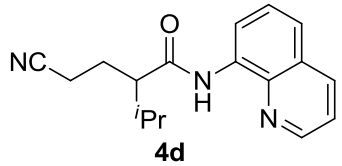

**4b**

Compound **4b**, colorless oil, yield: 55%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.96 (t, *J* = 7.3 Hz, 3H), 1.40-1.52 (m, 2H), 1.53-1.65 (m, 1H), 1.77-1.86 (m, 1H), 1.87-1.97 (m, 1H), 2.13-2.25 (m, 1H), 2.38-2.56 (m, 2H), 2.65-2.75 (m, 1H), 7.47 (dd, *J* = 8.3, 4.2 Hz, 1H), 7.49-7.58 (m, 2H), 8.16 (dd, *J* = 8.3, 1.6 Hz, 1H), 8.70-8.80 (m, 1H), 8.83 (dd, *J* = 4.2, 1.6 Hz, 1H), 9.96 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.2, 15.5, 20.7, 28.2, 35.3, 47.4, 116.7, 119.5, 121.9, 122.0, 127.4, 128.0, 134.2, 136.5, 138.5, 148.5, 172.8; IR (neat) *v* 3347, 2958, 2932, 2872, 2241, 1684, 1526, 1486, 1425, 1324, 1162, 827, 792, 758, 685, 607 cm$^{-1}$; Ms (ESI): *m*/*z* = 282.1 $[M+H]^+$.



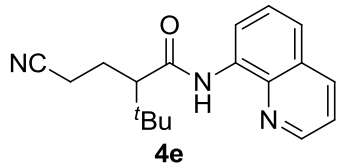

**4c**

Compound **4c**, pale yellow oil, yield: 50%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.87-1.98 (m, 1H), 2.17-2.28 (m, 1H), 2.38-2.47 (m, 1H), 2.47-2.56 (m, 1H), 2.85-3.03 (m, 2H), 3.16 (dd, $J$ = 13.1, 7.4 Hz, 1H), 7.10-7.18 (m, 1H), 7.19-7.30 (m, 4H), 7.43 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.48-7.58 (m, 2H), 8.14 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.65-8.80 (m, 2H), 9.78 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 15.5, 27.7, 39.4, 49.4, 116.8, 119.3, 121.8, 122.1, 126.9, 127.4, 128.0, 128.8, 129.1, 134.0, 136.4, 138.3, 138.4, 148.3, 171.9; IR (neat) $v$ 3344, 3061, 2928, 2856, 2246, 1684, 1527, 1486, 1425, 1324, 1161, 827, 792, 730, 701, 607 cm$^{-1}$; Ms (ESI): $m/z$ = 330.1 $[M+H]^+$.




**4d**

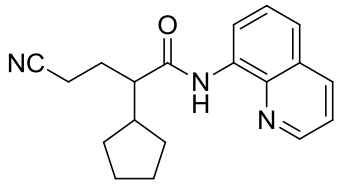
Compound **4d**, colorless oil, yield: 66%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.06 (d, $J$ = 7.3 Hz, 3H), 1.08 (d, $J$ = 7.3 Hz, 3H), 1.90-2.01 (m, 1H), 2.01-2.12 (m, 1H), 2.14-2.26 (m, 1H), 2.33-2.57 (m, 3H), 7.46 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.49-7.59 (m, 2H), 8.16 (dd, $J$ = 8.2, 1.7 Hz, 1H), 8.71-8.80 (m, 1H), 8.82 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 15.8, 20.2, 20.8, 25.6, 31.3, 54.3, 116.7, 119.6, 121.9, 122.0, 127.4, 128.1, 134.1, 136.5, 138.5, 148.5, 172.2; IR (neat) $v$ 3348, 2963, 2874, 2245, 1683, 1526, 1486, 1425, 1388, 1323, 1161, 827, 792, 758, 697, 606 cm$^{-1}$; Ms (ESI): $m/z$ = 282.1 $[M+H]^+$.




**4e**

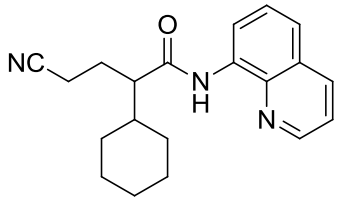
Compound **4e**, colorless oil, yield: 60%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.11 (s, 9H), 1.86-2.00 (m, 1H), 2.22-2.36 (m, 2H), 2.36-2.45 (m, 1H), 2.45-2.56 (m, 1H), 7.47 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.49-7.59 (m, 2H), 8.17 (dd, $J$ = 8.2, 1.6 Hz, 1H), 8.72-8.81 (m, 1H), 8.83 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (125

MHz, $CDCl_3$) $\delta$ 16.3, 24.1, 28.2, 33.7, 58.0, 116.7, 119.6, 121.9, 122.0, 127.4, 128.1, 134.1, 136.5, 138.6, 148.6, 171.8; IR (neat) $\nu$ 3351, 3049, 2926, 2872, 2245, 1683, 1526, 1486, 1425, 1370, 1324, 1157, 827, 758, 652, 605 $cm^{-1}$; Ms (ESI): $m/z$ = 296.1 $[M+H]^+$.



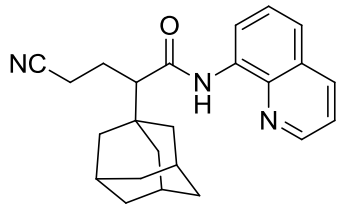

**4f**

Compound **4f**, colorless oil, yield: 60%. $^1H$ NMR (500 MHz, $CDCl_3$) $\delta$ 1.24-1.42 (m, 2H), 1.47-1.75 (m, 4H), 1.77-1.87 (m, 1H), 1.88-2.06 (m, 2H), 2.09-2.26 (m, 2H), 2.35-2.57 (m, 3H), 7.47 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.50-7.60 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.71-8.80 (m, 1H), 8.83 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.96 (brs, 1H); $^{13}C$ NMR (125 MHz, $CDCl_3$) $\delta$ 15.7, 24.95, 25.04, 27.5, 30.9, 31.4, 43.3, 53.4, 116.8, 119.6, 121.9, 122.1, 127.4, 128.1, 134.2, 136.5, 138.5, 148.6, 172.7; IR (neat) $\nu$ 3348, 2953, 2869, 2245, 1684, 1525, 1486, 1425, 1387, 1324, 1162, 827, 793, 758, 688 $cm^{-1}$; Ms (ESI): $m/z$ = 208.1 $[M+H]^+$.



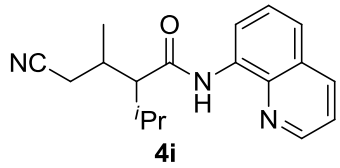

**4g**

Compound **4g**, colorless oil, yield: 63%. $^1H$ NMR (500 MHz, $CDCl_3$) $\delta$ 1.05-1.33 (m, 5H), 1.60-1.82 (m, 5H), 1.87-1.95 (m, 1H), 1.96-2.06 (m, 1H), 2.13-2.24 (m, 1H), 2.33-2.43 (m, 1H), 2.43-2.55 (m, 2H), 7.47 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.50-7.59 (m, 2H), 8.17 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.73-8.81 (m, 1H), 8.83 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.93 (brs, 1H); $^{13}C$ NMR (125 MHz, $CDCl_3$) $\delta$ 15.7, 25.6, 26.3, 26.4, 30.8, 31.2, 40.7, 53.8, 116.7, 119.6, 121.9, 122.0, 127.4, 128.1, 134.1, 136.5, 138.5, 148.6, 172.4; IR (neat) $\nu$ 3348, 2928, 2852, 2241, 1684, 1526, 1486, 1424, 1380, 1323, 1160, 827, 792, 758 $cm^{-1}$; Ms (ESI): $m/z$ = 322.2 $[M+H]^+$.



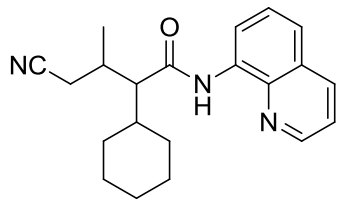
**4h**

Compound **4h**, colorless oil, yield: 59%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.57-1.70 (m, 9H), 1.81-1.90 (m, 3H), 1.92-2.05 (m, 4H), 2.21-2.34 (m, 3H), 2.45-2.55 (m, 1H), 7.47 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.51-7.59 (m, 2H), 8.17 (dd, $J$ = 8.2, 1.6 Hz, 1H), 8.75-8.83 (m, 1H), 8.84 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.92 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 16.3, 22.5, 28.7, 35.6, 36.9, 40.3, 59.4, 116.7, 119.6, 121.9, 122.0, 127.4, 128.1, 134.1, 136.5, 138.6, 148.6, 171.4; IR (neat) $\nu$ 3348, 3048, 2904, 2848, 2241, 1683, 1526, 1485, 1425, 1323, 1157, 827, 792, 754 cm$^{-1}$; Ms (ESI): $m/z$ = 374.3 $[M+H]^+$.



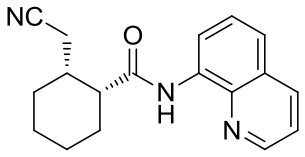
**4i**

Compound **4i**, colorless oil, yield: 40%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.04 (d, $J$ = 6.6 Hz, 3H), 1.10 (d, $J$ = 6.8 Hz, 3H), 1.26 (d, $J$ = 6.8 Hz, 3H), 2.08-2.21 (m, 1H), 2.23-2.31 (m, 1H), 2.39-2.51 (m, 1H), 2.57 (dd, $J$ = 17.0, 8.6 Hz, 1H), 2.64 (dd, $J$ = 17.0, 4.1 Hz, 1H), 7.46 (dd, $J$ = 8.2, 4.2 Hz, 1H), 7.49-7.58 (m, 2H), 8.16 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.71-8.79 (m, 1H), 8.81 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.88 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 18.2, 19.4, 21.1, 21.5, 28.1, 30.5, 59.5, 116.7, 119.4, 121.8, 122.0, 127.4, 128.1, 134.0, 136.5, 138.5, 148.5, 171.8; IR (neat) $\nu$ 3350, 2963, 2933, 2876, 2244, 1680, 1526, 1486, 1425, 1378, 1324, 1167, 827, 793, 758, 679 cm$^{-1}$; Ms (ESI): $m/z$ = 296.1 $[M+H]^+$.



**4j**

Compound **4j**, colorless oil, yield: 45%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.06-1.34 (m, 8H), 1.60-1.90 (m, 6H), 2.25-2.35 (m, 1H), 2.40-2.53 (m, 1H), 2.55-2.68 (m, 2H), 7.47 (dd, $J$ = 8.3, 4.3 Hz, 1H), 7.50-7.60 (m, 2H), 8.17 (dd, $J$ = 8.2, 1.5 Hz, 1H), 8.70-8.79 (m, 1H), 8.81 (dd, $J$ = 4.1, 1.4 Hz, 1H), 9.87 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 18.3, 21.2, 26.36, 26.42, 26.6, 29.6, 30.1, 31.5, 37.6, 58.9, 116.7, 119.5, 121.8, 122.0, 127.4, 128.1, 134.0, 136.5, 138.5, 148.5, 172.0; IR (neat) $\nu$ 3350, 3054, 2929, 2852, 2249, 1679, 1525, 1485, 1425, 1325, 1165, 827, 792 cm$^{-1}$; Ms (ESI): $m/z$ = 336.1 $[M+H]^+$.

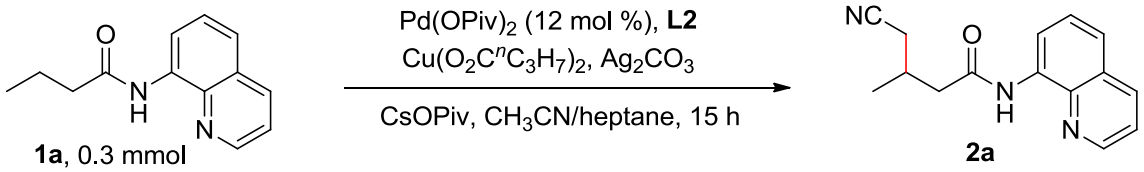



**4k**

Compound **4k**, colorless oil, yield: 41%. $^{1}$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.32-1.48 (m, 3H), 1.61-1.71 (m, 1H), 1.77-1.92 (m, 2H), 1.93-2.06 (m, 1H), 2.07-2.27 (m, 2H), 2.32-2.54 (m, 3H), 7.46 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.50-7.60 (m, 2H), 8.16 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.70-8.79 (m, 1H), 8.82 (dd, $J$ = 4.2, 1.7 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 22.9, 25.35, 25.39, 30.87, 30.90, 35.7, 51.3, 116.7, 118.4, 121.9, 122.0, 127.4, 128.1, 134.3, 136.5, 138.5, 148.5, 172.9; IR (neat) $\nu$ 3346, 3042, 2931, 2857, 2244, 1683, 1526, 1486, 1425, 1388, 1325, 1163, 931, 827, 792, 668, 600 cm$^{-1}$; Ms (ESI): $m/z$ = 294.1 $[M+H]^+$.

## Experimental Date of Further Optimization Studies

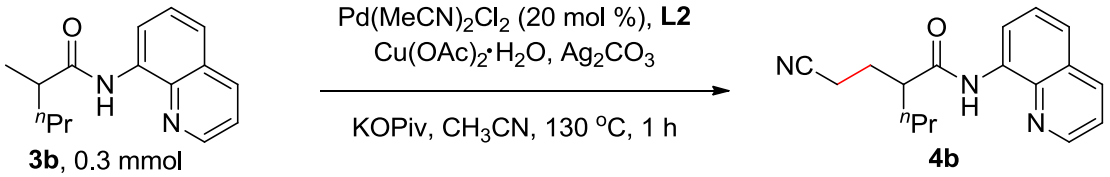
**Table S1** Experimental date of further optimization studies for **1a**




| entry | [Cu] (equiv) | [Ag] (equiv) | [Cs] (equiv) | **L2** (mol %) | $CH_3CN$/heptane (mL/mL) | temp ($^oC$) | yield[a] (%) |
|---|---|---|---|---|---|---|---|
| 1 | 1.2 | 2.0 | 1.2 | 40 | 1.5/1.5 | 130 | 76 |
| 2 | 2.0 | 2.0 | 1.2 | 40 | 1.5/1.5 | 130 | 62 |
| 3 | 0.5 | 2.0 | 1.2 | 40 | 1.5/1.5 | 130 | 8 |
| 4 | 1.2 | 3.0 | 1.2 | 40 | 1.5/1.5 | 130 | 74 |
| 5 | 1.2 | 1.0 | 1.2 | 40 | 1.5/1.5 | 130 | 50 |
| 6 | 1.2 | 2.0 | 2.0 | 40 | 1.5/1.5 | 130 | 29 |
| 7 | 1.2 | 2.0 | 0.5 | 40 | 1.5/1.5 | 130 | 64 |
| 8 | 1.2 | 2.0 | 1.2 | 50 | 1.5/1.5 | 130 | 76 |
| 9 | 1.2 | 2.0 | 1.2 | 30 | 1.5/1.5 | 130 | 59 |
| 10 | 1.2 | 2.0 | 1.2 | 40 | 2.0/1.0 | 130 | 74 |
| 11 | 1.2 | 2.0 | 1.2 | 40 | 1.0/2.0 | 130 | 73 |
| 12 | 1.2 | 2.0 | 1.2 | 40 | 1.5/1.5 | 150 | 74 |
| 13 | 1.2 | 2.0 | 1.2 | 40 | 1.5/1.5 | 110 | 61 |
| 14 | 1.2 | 2.0 | 1.2 | 40 | 0.8/0.8 | 130 | 61 |
| 15 | 1.2 | 2.0 | 1.2 | 40 | 3.0/3.0 | 130 | 75 |
| 16[b] | 40 | 2.0 | 1.2 | 40 | 1.5/1.5 | 130 | 67 |
| 17[c] | 40 | 2.0 | 1.2 | 40 | 1.5/1.5 | 130 | 85 |

[a] Yields are based on **1a**, determined by $^1$H-NMR using dibromomethane as the internal standard. [b] $Pd(OPiv)_2$ (10 mol %). [c] $Pd(OPiv)_2$ (15 mol %).

**Table S2** Experimental date of further optimization studies for **3b**




**3b**, 0.3 mmol

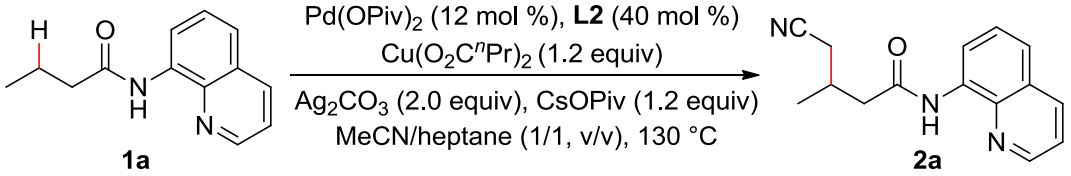
**4b**

| entry | [Cu] (equiv) | [Ag] (equiv) | [K] (equiv) | **L2** (mol %) | $CH_3CN$ (mL) | temp ($^oC$) | yield[a] (%) |
|---|---|---|---|---|---|---|---|
| 1 | 0.3 | 2.0 | 0.3 | 40 | 2 | 130 | 60 |
| 2 | 0.4 | 2.0 | 0.3 | 40 | 2 | 130 | 56 |
| 3 | 0.2 | 2.0 | 0.3 | 40 | 2 | 130 | 50 |
| 4 | 0 | 2.0 | 0.2 | 40 | 2 | 130 | trace |
| 5 | 0.3 | 3.0 | 0.3 | 40 | 2 | 130 | 59 |
| 6 | 0.3 | 1.5 | 0.3 | 40 | 2 | 130 | 54 |
| 7 | 0.3 | 2.0 | 0.4 | 40 | 2 | 130 | 56 |
| 8 | 0.3 | 2.0 | 0.1 | 40 | 2 | 130 | 58 |
| 9 | 0.3 | 2.0 | 0 | 40 | 2 | 130 | 52 |
| 10 | 0.3 | 2.0 | 0.3 | 50 | 2 | 130 | 60 |
| 11 | 0.3 | 2.0 | 0.3 | 30 | 2 | 130 | 50 |
| 12 | 0.3 | 2.0 | 0.3 | 40 | 2 | 150 | 51 |
| 13 | 0.3 | 2.0 | 0.3 | 40 | 2 | 110 | 29 |
| 14 | 0.3 | 2.0 | 0.3 | 40 | 4 | 130 | 42 |
| 15 | 0.3 | 2.0 | 0.3 | 40 | 1 | 130 | 60 |
| 16[b] | 0.3 | 2.0 | 0.3 | 40 | 2 | 130 | 59 |

[a] Yields are based on **1a**, determined by $^1$H-NMR using dibromomethane as the internal standard.
[b] 15 h.

## Control Experiments on Cyanomethylation of 1a

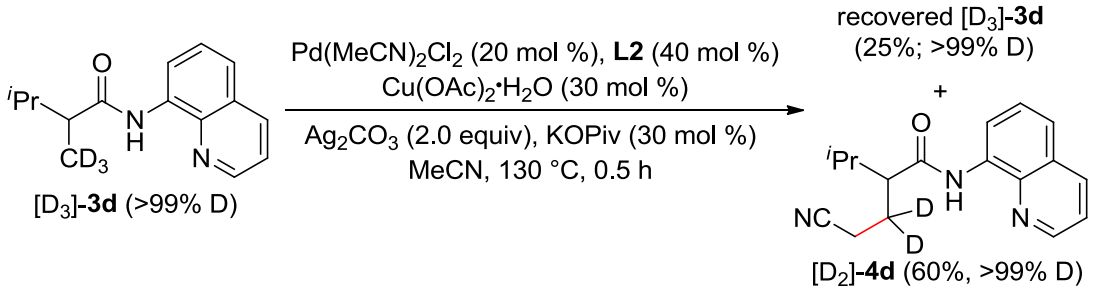
**Table S3** Control Experiments on Cyanomethylation of **1a**




| entry | change from the 'standard conditions'[a] | yield of **2a** (%)[b] |
|---|---|---|
| 1 | none | 76 |
| 2 | no $Pd(OPiv)_2$ | 0 |
| 3 | no $Cu(O_2C^nPr)_2$ | trace |
| 4 | 0.5 equiv $Cu(O_2C^nPr)_2$ | 8 |
| 5 | 0.5 equiv $Cu(O_2C^nPr)_2$, $O_2$ (1 atm) | 8 |
| 6 | no $Ag_2CO_3$ | trace |
| 7 | no $Ag_2CO_3$, 2 equiv $Cu(O_2C^nPr)_2$ | trace |
| 8 | no $Ag_2CO_3$, $O_2$ (1 atm) | trace |
| 9 | 0.3 equiv $Ag_2CO_3$, $O_2$ (1 atm) | 12 |

[a] **1a** (0.3 mmol), $Pd(OPiv)_2$ (0.036 mmol), **L2** (0.12 mmol), $Cu(O_2C^nPr)_2$ (0.36 mmol), $Ag_2CO_3$ (0.6 mmol), CsOPiv (0.36 mmol), MeCN (1.5 mL), heptane (1.5 mL), air (1 atm), 130 °C, 15 h. [b] Yields are based on **1a**, determined by $^1$H-NMR using dibromomethane as the internal standard.

## Deuterium Labeling Experiment

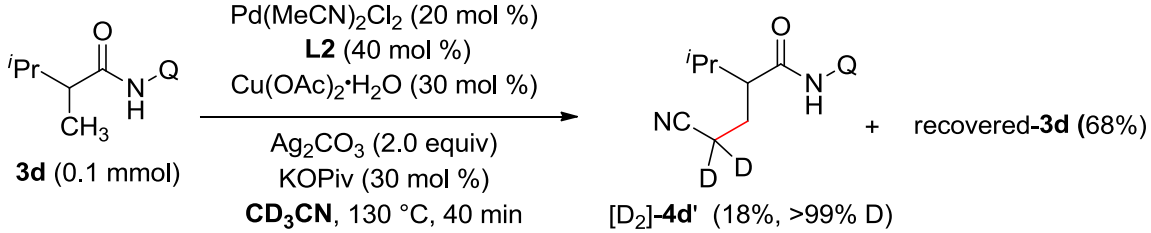



A 35 mL sealed tube was charged with amide [$D_3$]-**3d** (73.6 mg, 0.3 mmol), $Pd(MeCN)_2Cl_2$ (15.6 mg, 0.06 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (22.1 mg, 0.12 mmol), $Cu(OAc)_2 \cdot H_2O$ (18.0 mg, 0.09 mmol), $Ag_2CO_3$ (165.5 mg, 0.6 mmol), KOPiv (12.6 mg, 0.09 mmol), and MeCN (2.0 mL). After sealed, the reaction

mixture was stirred at 130 ˚C for 0.5 h. Then the mixture was cooled to room temperature, quenched with aqueous NaOH (1 M, 2 mL), and extracted with EtOAc (3×10 mL). The combined organic phase was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with EtOAc/hexanes (1/10-1/6) to provide the recovered [$D_3$]-**3d** and desired product [$D_2$]-**4d**. The ratio of deuterium was determined by $^1$H NMR.

[$D_2$]-**4d**, colorless oil, yield: 60%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.06 (d, $J$ = 6.5 Hz, 3H), 1.07 (d, $J$ = 6.5 Hz, 3H), 2.00-2.11 (m, 1H), 2.38 (d, $J$ = 17.0 Hz, 1H), 2.44 (d, $J$ = 7.2 Hz, 1H), 2.49 (d, $J$ = 17.0 Hz, 1H), 7.46 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.48-7.59 (m, 2H), 8.16 (dd, $J$ = 8.2, 1.4 Hz, 1H), 8.72-8.80 (m, 1H), 8.82 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.95 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 15.6 (t, $J$ = 5.6 Hz), 20.2 (d, $J$ = 2.9 Hz), 20.7 (d, $J$ = 2.7 Hz), 31.2, 54.1 (d, $J$ = 4.7 Hz), 116.8, 119.6, 121.8, 122.0, 127.4, 128.0, 134.1, 136.5, 138.4, 148.4, 172.3; IR (neat) $\nu$ 3348, 2962, 2928, 2874, 2239, 1683, 1526, 1486, 1425, 1387, 1324, 1168, 827, 792 cm$^{-1}$; Ms (ESI): $m/z$ = 284.1 $[M+H]^+$.

Recovered [$D_3$]-**4d**, colorless oil, yield: 25%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.03 (d, $J$ = 6.7 Hz, 3H), 1.04 (d, $J$ = 6.7 Hz, 3H), 1.97-2.13 (m, 1H), 2.32 (d, $J$ = 7.7 Hz, 1H), 7.44 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.49 (dd, $J$ = 8.3, 1.4 Hz, 1H), 7.51-7.60 (m, 1H), 8.15 (dd, $J$ = 8.3, 1.7 Hz, 1H), 8.71-8.88 (m, 2H), 9.84 (brs, 1H).

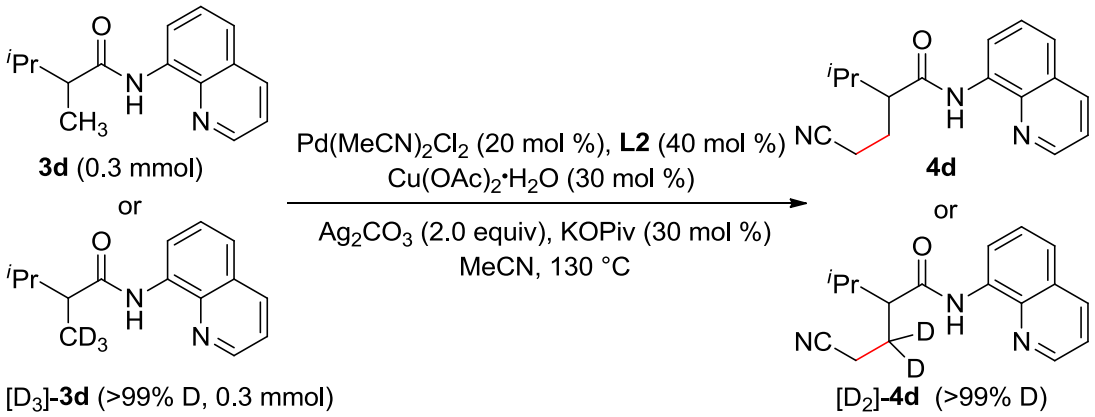



A 10 mL sealed tube was charged with amide **3d** (0.1 mmol), $Pd(MeCN)_2Cl_2$ (5.2 mg, 0.02 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (7.4 mg, 0.04 mmol), $Cu(OAc)_2 \cdot H_2O$ (6.0 mg, 0.03 mmol), $Ag_2CO_3$ (55.2 mg, 0.2 mmol), KOPiv (4.2 mg, 0.03 mmol), and MeCN or $CD_3CN$ (0.7 mL). After sealed, the reaction mixture was stirred at 130 ˚C for 40 min. Then the mixture was cooled to room temperature, quenched with aqueous NaOH (1 M, 1 mL), and extracted with

EtOAc (3×5 mL). The combined organic phase was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The residue was purified by chromatography on silica gel eluting with EtOAc/hexanes (1/8) to provide the recovered **3d** and desired product [$D_2$]-**4d′**. The ratio of deuterium was determined by $^1$H NMR.

[$D_2$]-**4d′**, colorless oil, yield: 18%. $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 1.07 (d, $J$ = 6.8 Hz, 3H), 1.08 (d, $J$ = 6.8 Hz, 3H), 1.96 (dd, $J$ = 13.6, 2.8 Hz, 1H), 2.00-2.13 (m, 1H), 2.19 (dd, $J$ = 13.4, 11.2 Hz, 1H), 2.39-2.50 (m, 1H), 7.47 (dd, $J$ = 8.3, 4.2 Hz, 1H), 7.50-7.60 (m, 2H), 8.17 (dd, $J$ = 8.2, 1.6 Hz, 1H), 8.71-8.81 (m, 1H), 8.83 (dd, $J$ = 4.2, 1.6 Hz, 1H), 9.94 (brs, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 20.3, 20.8, 25.4, 31.3, 54.3, 116.7, 119.6, 121.9, 122.0, 127.4, 128.1, 134.2, 136.5, 138.6, 148.6, 172.3; IR (neat) $\nu$ 3348, 2963, 2246, 1683, 1526, 1486, 1425, 1387, 1324, 1169, 827, 792 cm$^{-1}$; Ms (ESI): $m/z$ = 284.1 $[M+H]^+$.

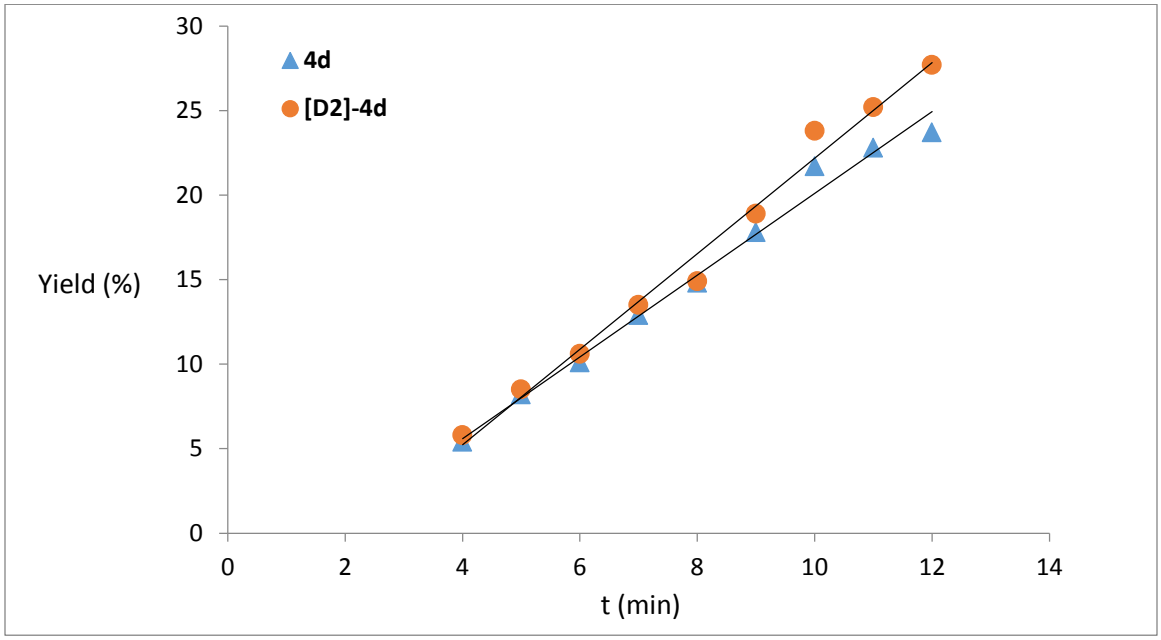
## Parallel KIE Experiments




A 35 mL sealed tube was charged with amide **3d** or [$D_3$]-**3d** (0.3 mmol), $Pd(MeCN)_2Cl_2$ (15.6 mg, 0.06 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (22.1 mg, 0.12 mmol), $Cu(OAc)_2 \cdot H_2O$ (18.0 mg, 0.09 mmol), $Ag_2CO_3$ (165.5 mg, 0.6 mmol), KOPiv (12.6 mg, 0.09 mmol), and MeCN (2.0 mL). After sealed, the reaction mixture was stirred at 130 ˚C for the indicated time. The reaction was stopped by rapid cooling and analyzed by GC using benzophenone as the internal standard. The average GC yield was calculated after calibrating the response of GC based on three runs of each reaction.

| Time (min) | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|
| Yield **4d** (%) | 5.4 | 8.2 | 10.1 | 12.9 | 14.8 | 17.8 | 21.7 | 22.8 | 23.7 |

| Time (min) | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|
| Yield of [$D_2$]-**4d** (%) | 5.8 | 8.5 | 10.6 | 13.5 | 14.9 | 18.9 | 23.8 | 25.2 | 27.7 |

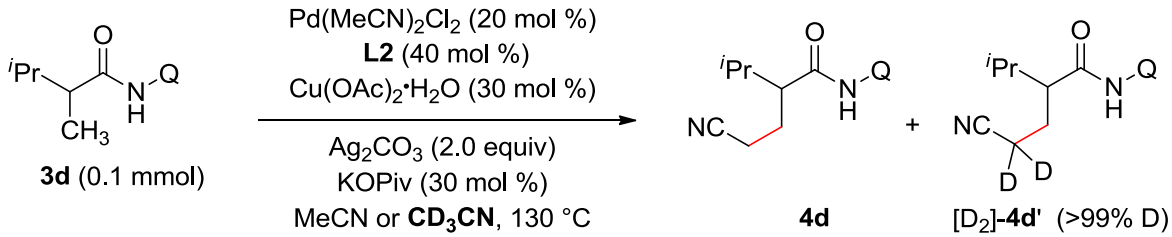



Equation for **4d**: $y = 2.4183x - 4.08$ $R^2 = 0.9871$

Equation for [$D_2$]-**4d**: $y = 2.825x - 6.0556$ $R^2 = 0.9872$

$k_H/k_D = 2.4183/2.825 \approx 0.9$

KIE value determined from parallel reactions is 0.9.

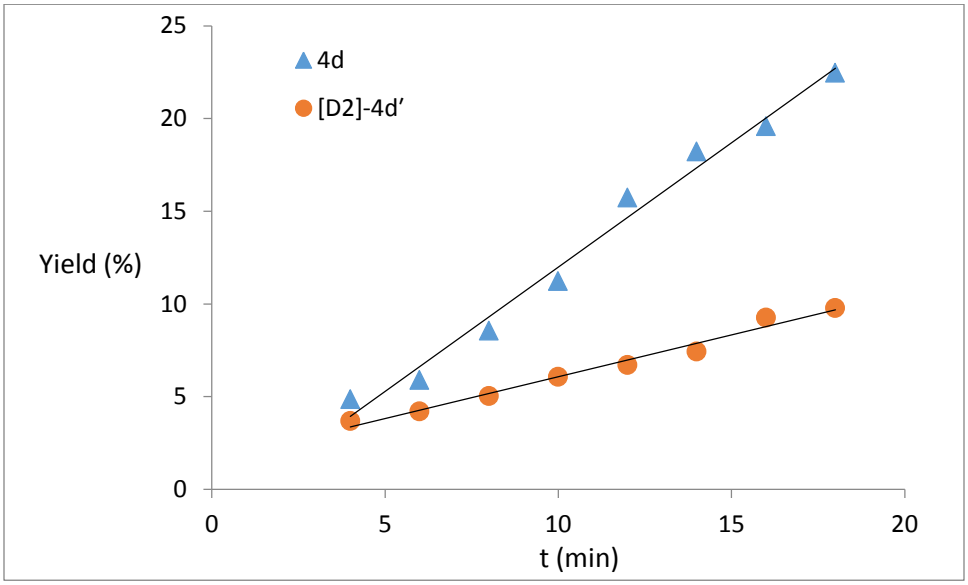



A 10 mL sealed tube was charged with amide **3d** (0.1 mmol), $Pd(MeCN)_2Cl_2$ (5.2 mg, 0.02 mmol), 5,5'-dimethyl-2,2'-bipyridine (**L2**) (7.4 mg, 0.04 mmol), $Cu(OAc)_2 \cdot H_2O$ (6.0 mg, 0.03 mmol), $Ag_2CO_3$ (55.2 mg, 0.2 mmol), KOPiv (4.2 mg, 0.03 mmol), and MeCN or $CD_3CN$ (0.7 mL). After sealed, the reaction

mixture was stirred at 130 ˚C for the indicated time. The reaction was stopped by rapid cooling and analyzed by GC using benzophenone as the internal standard. The average GC yield was calculated after calibrating the response of GC based on three runs of each reaction.

| Time (min) | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|---|---|
| Yield **4d** (%) | 4.9 | 5.9 | 8.6 | 11.2 | 15.7 | 18.2 | 19.6 | 22.5 |

| Time (min) | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|---|---|---|
| Yield of [$D_2$]-**4d′** (%) | 3.7 | 4.2 | 5.0 | 6.1 | 6.7 | 7.4 | 9.3 | 9.8 |



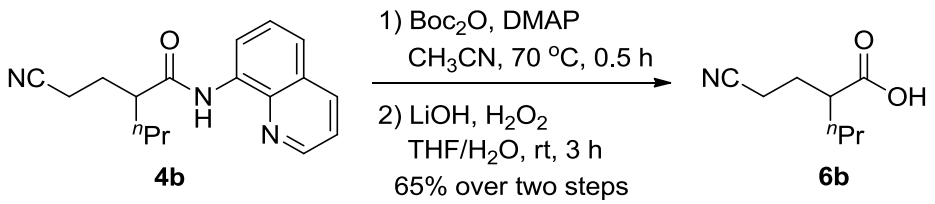

Equation for **4d**: $y = 1.3407 - 1.4259$ $R^2 = 0.9848$

Equation for [$D_2$]-**4d′**: $y = 0.4508x + 1.5627$ $R^2 = 0.9818$

$k_H/k_D = 1.3407/0.4259 \approx 3.0$

KIE value determined from parallel reactions is 3.0.

**Experimental Procedure for the Removal of the Directing Group of 4b**



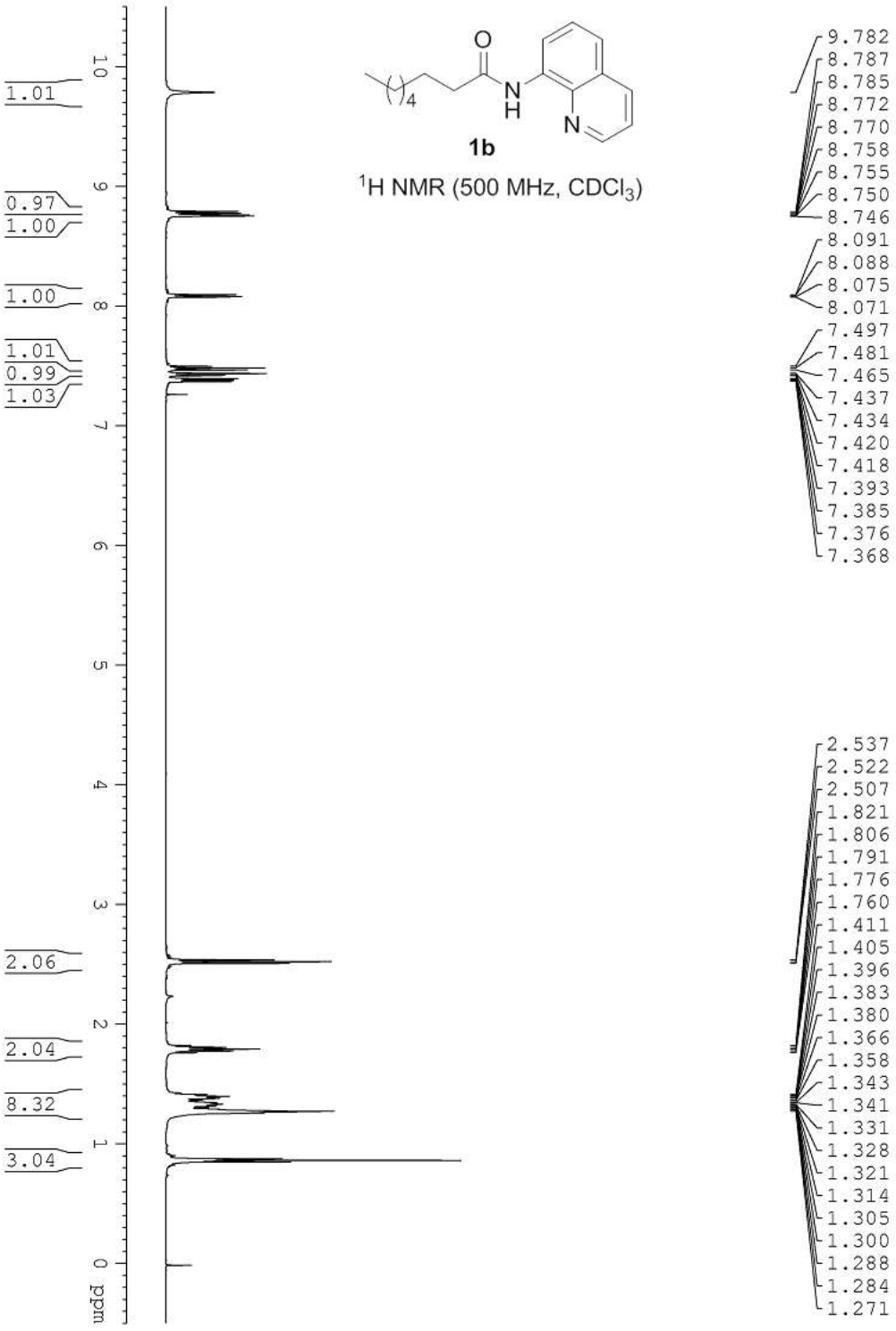

A solution of compound **4b** (84.4 mg, 0.3 mmol), $Boc_2O$ (654 mg, 3 mmol) and DMAP (100 mg, 0.9 mmol) in $CH_3CN$ (2 mL) was stirred at 70 °C for 0.5 h. The resulting mixture was concentrated under reduced pressure and purified by chromatography on silica gel eluting with EtOAc/hexanes (1/3) to provide the boc-protecting amide as yellow oil (108 mg, 94% yield). $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.95 (t, $J$ = 7.3 Hz, 3H), 1.22 (s, 9H), 1.40-1.60 (m, 3H), 1.80-1.91 (m, 1H), 1.94-2.04 (m, 1H), 2.10-2.22 (m, 1H), 2.48-2.69 (m, 2H), 4.00 (brs, 1H), 7.41 (dd, $J$ = 8.3, 4.1 Hz, 1H), 7.49 (dd, $J$ = 7.3, 1.3 Hz, 1H), 7.52-7.61 (m, 1H), 7.82 (dd, $J$ = 8.2, 1.2 Hz, 1H), 8.17 (dd, $J$ = 8.3, 1.6 Hz, 1H), 8.87 (dd, $J$ = 4.1, 1.6 Hz, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 14.3, 15.0, 20.4, 27.7, 28.4, 34.8, 43.8, 83.1, 120.3, 121.7, 126.2, 128.3, 128.7, 129.0, 136.1, 137.2, 144.1, 150.5, 152.8, 178.4; IR (neat) $\nu$ 2960, 2934, 2245, 1738, 1699, 1596, 1500, 1369, 1292, 1255, 1155, 1125, 1042, 854, 792 cm$^{-1}$; Ms (ESI): $m/z$ = 382.2 $[M+H]^+$.

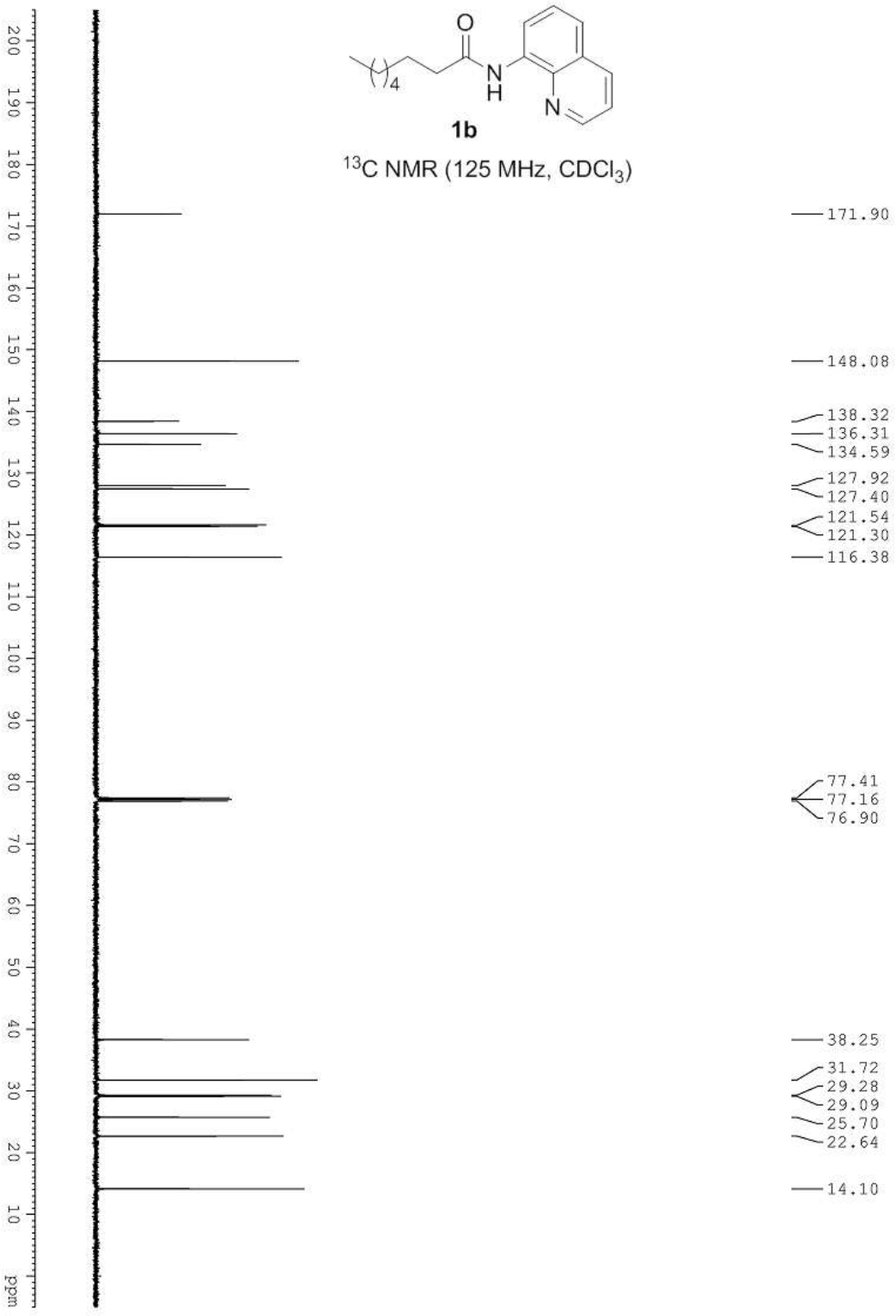
To a solution of the boc-protecting amide (76.2 mg, 0.2 mmol) in THF/$H_2O$ (2 mL, 3:1) was added LiOH·$H_2O$ (9.6 mg, 0.4 mmol) and 30% $H_2O_2$ (1.0 mmol) at 0 °C. Ater the reaction was stirred at room temperature for 3 h, $Na_2SO_3$ (252 mg, 2 mmol) was added. The reaction mixture was diluted with EtOAc (4 mL), acidified with 0.5 M aqueous HCl, and extracted with EtOAc. The organic layer was dried over anhydrous $Na_2SO_4$ and concentrated under reduced pressure. The resulting residue was purified by chromatography on silica gel eluting with EtOAc/hexanes (1/8-1/1) to provide the acid product 6**b** as pale yellow oil (21.5 mg, 69% yield). $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 0.93 (t, $J$ = 7.3 Hz, 3H), 1.31-1.44 (m, 2H), 1.46-1.56 (m, 1H), 1.62-1.73 (m, 1H), 1.79-1.89 (m, 1H), 1.95-2.06 (m, 1H), 2.32-2.50 (m, 2H), 2.50-2.61 (m 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 13.9, 15.5, 20.3, 27.3, 34.0, 43.9, 119.1, 180.6; IR (neat) $\nu$ 2960, 2929, 2874, 2248, 1734, 1707, 1528, 1456, 1164; Ms (ESI): $m/z$ = 154.2 $[M-H]^-$.

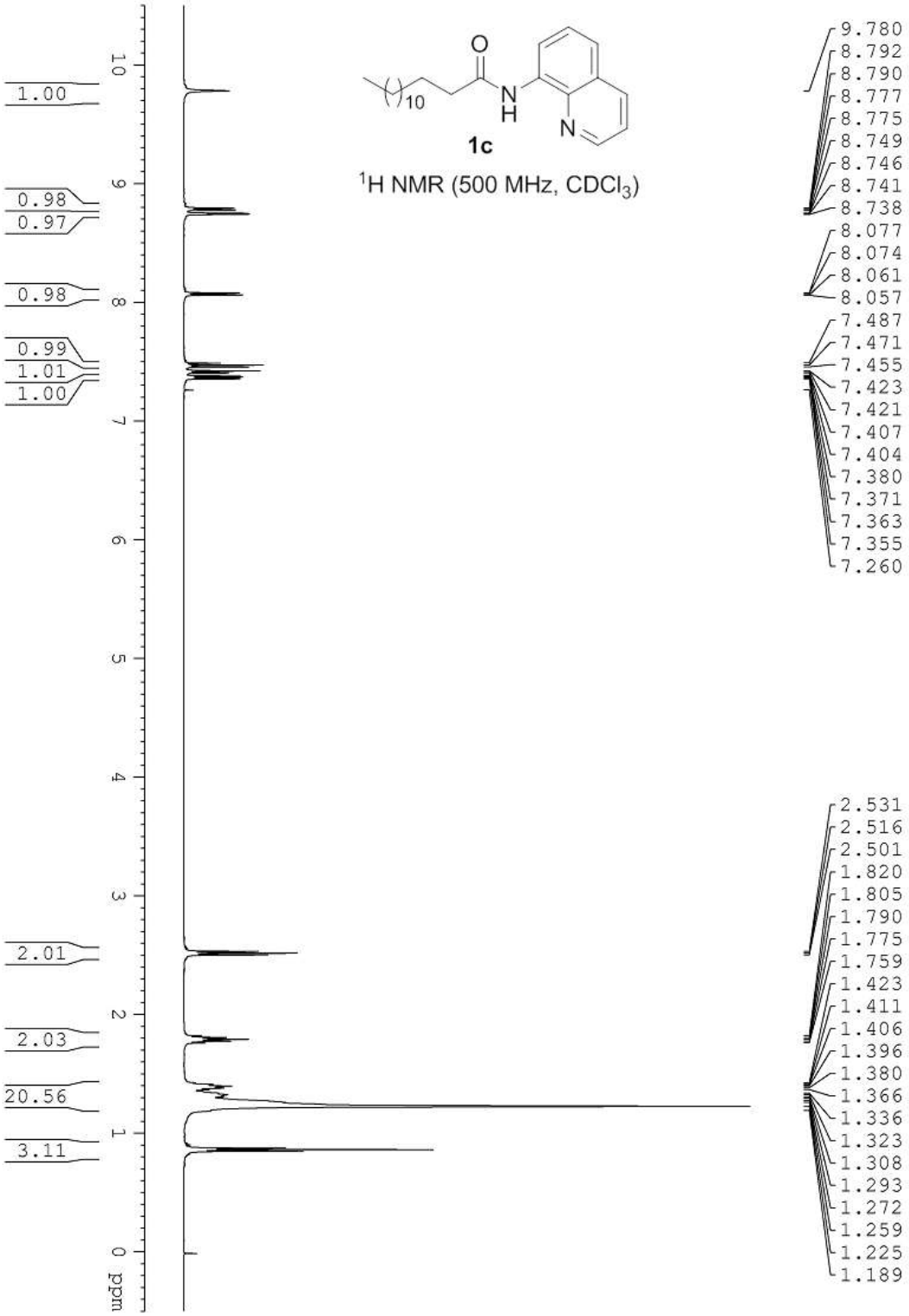
## References

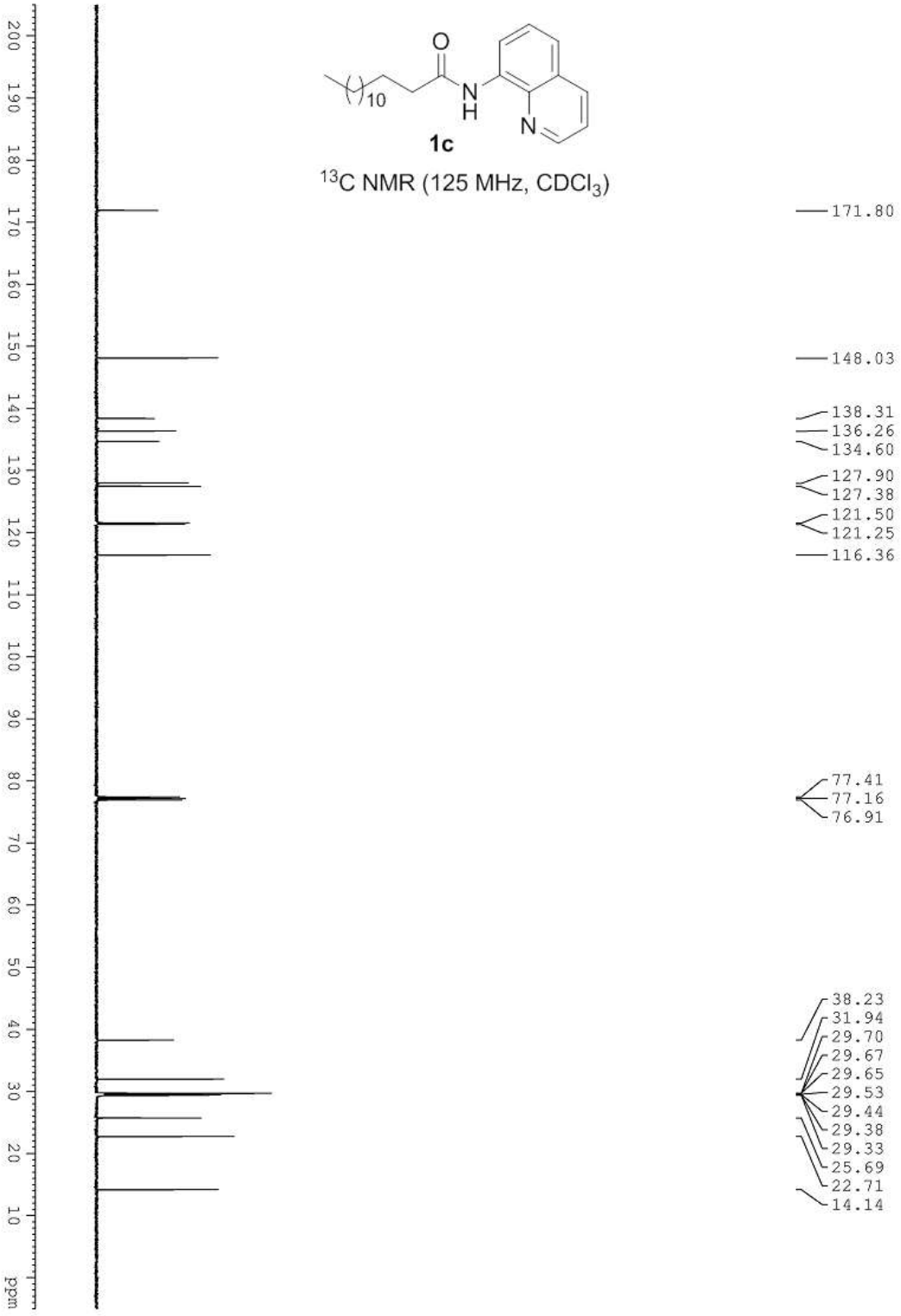

1. X. Wu, Y. Zhao and H. Ge, *J. Am. Chem. Soc.*, 2014, **136**, 1789.
2. E. T. Nadres, G. I. F. Santos, D. Shabashov and O. Daugulis, *J. Org. Chem*., 2013, **78**, 9689.

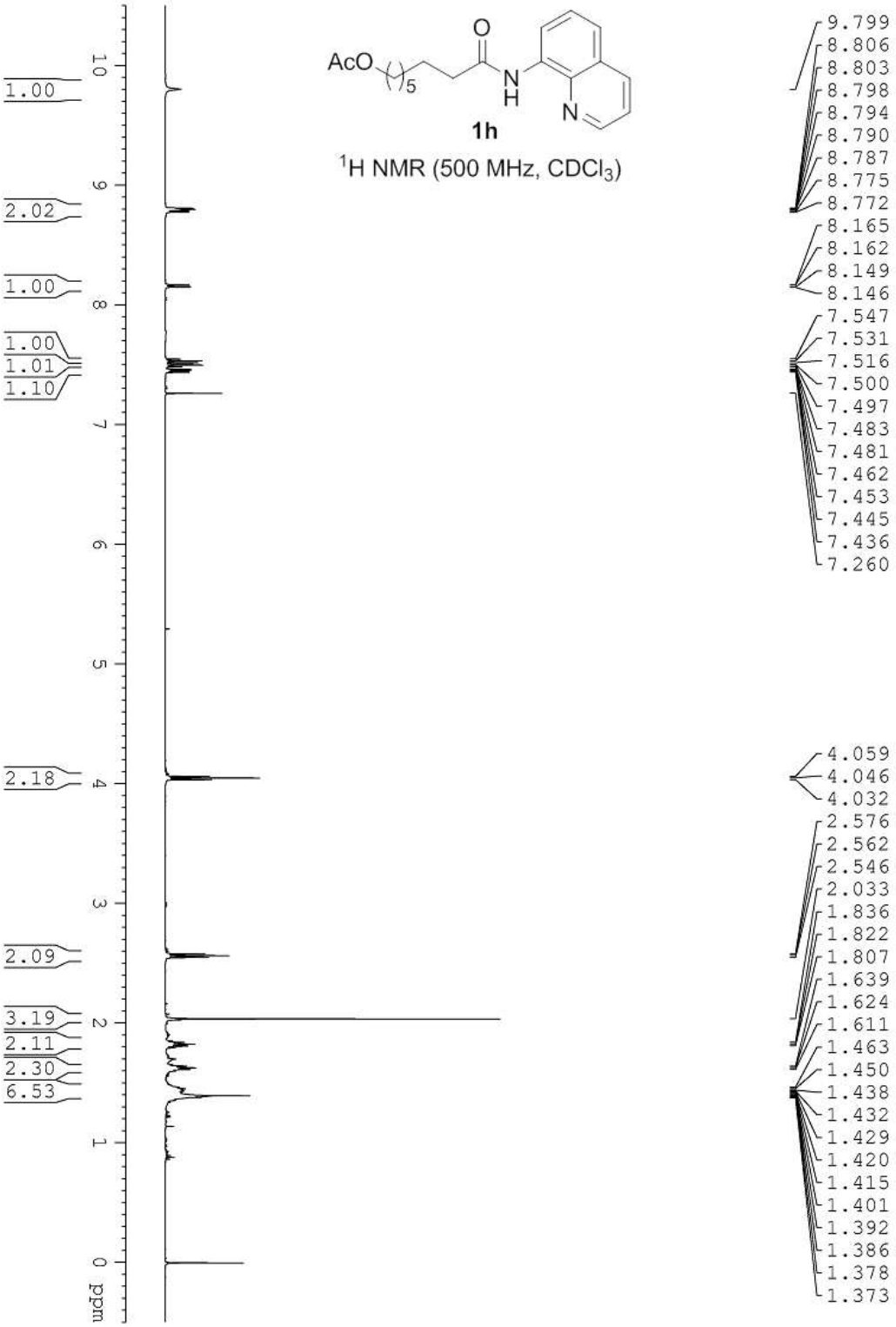
## Copies of NMR Spectrum




O
N
H
N
4
1b
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.90
148.08
138.32
136.31
134.59
127.92
127.40
121.54
121.30
116.38
77.41
77.16
76.90
38.25
31.72
29.28
29.09
25.70
22.64
14.10
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


1c
$^1$H NMR (500 MHz, $CDCl_3$)
9.780
8.792
8.790
8.777
8.775
8.749
8.746
8.741
8.738
8.077
8.074
8.061
8.057
7.487
7.471
7.455
7.423
7.421
7.407
7.404
7.380
7.371
7.363
7.355
7.260
2.531
2.516
2.501
1.820
1.805
1.790
1.775
1.759
1.423
1.411
1.406
1.396
1.380
1.366
1.336
1.323
1.308
1.293
1.272
1.259
1.225
1.189
1.00
0.98
0.97
0.98
0.99
1.01
1.00
2.01
2.03
20.56
3.11
ppm


O
N
H
N
10
1c
$^{13}$C NMR (125 MHz, CDCl$_3$)
171.80
148.03
138.31
136.26
134.60
127.90
127.38
121.50
121.25
116.36
77.41
77.16
76.91
38.23
31.94
29.70
29.67
29.65
29.53
29.44
29.38
29.33
25.69
22.71
14.14
ppm


AcO
5
O
N
H
N
1h
1H NMR (500 MHz, CDCl3)
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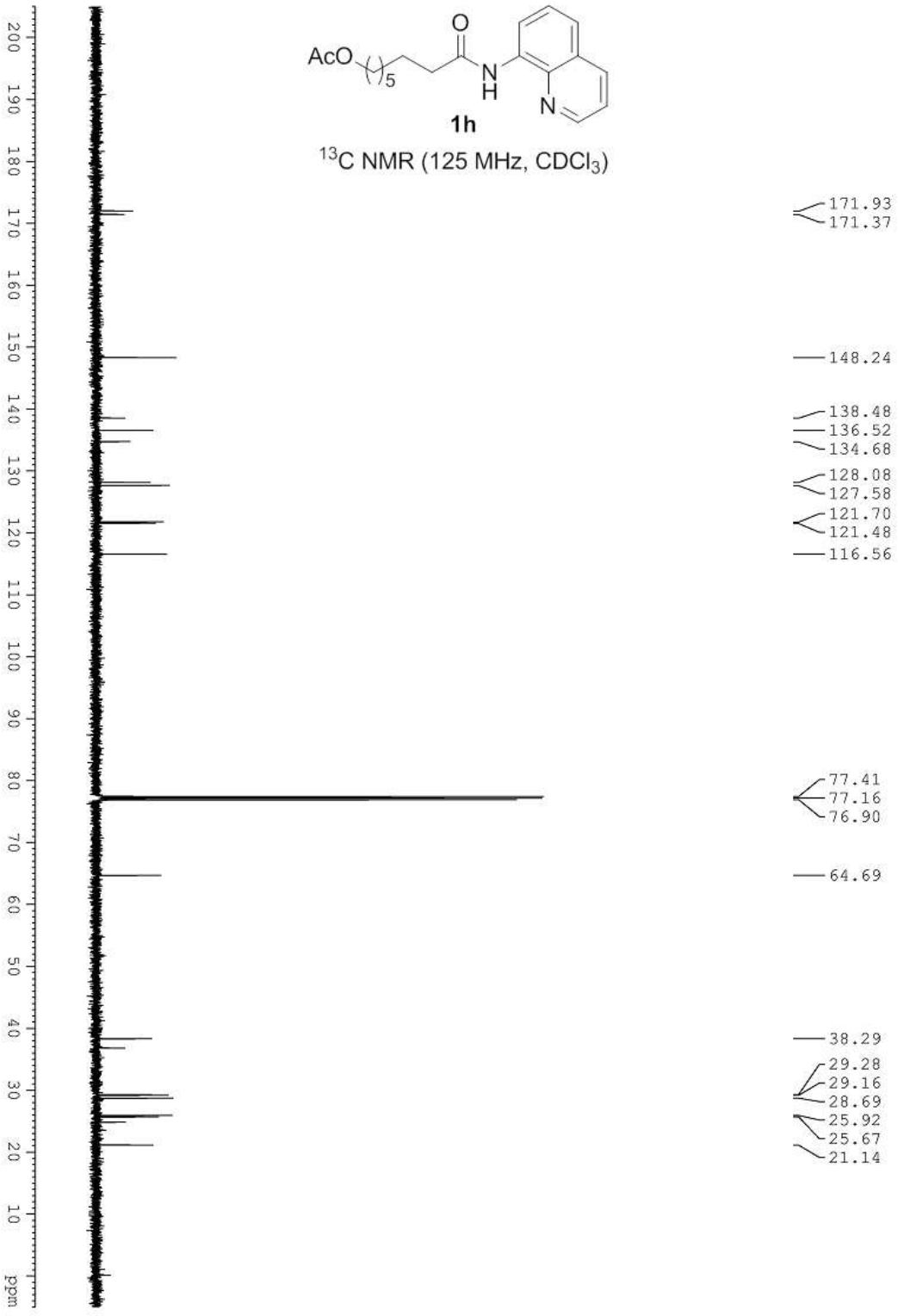
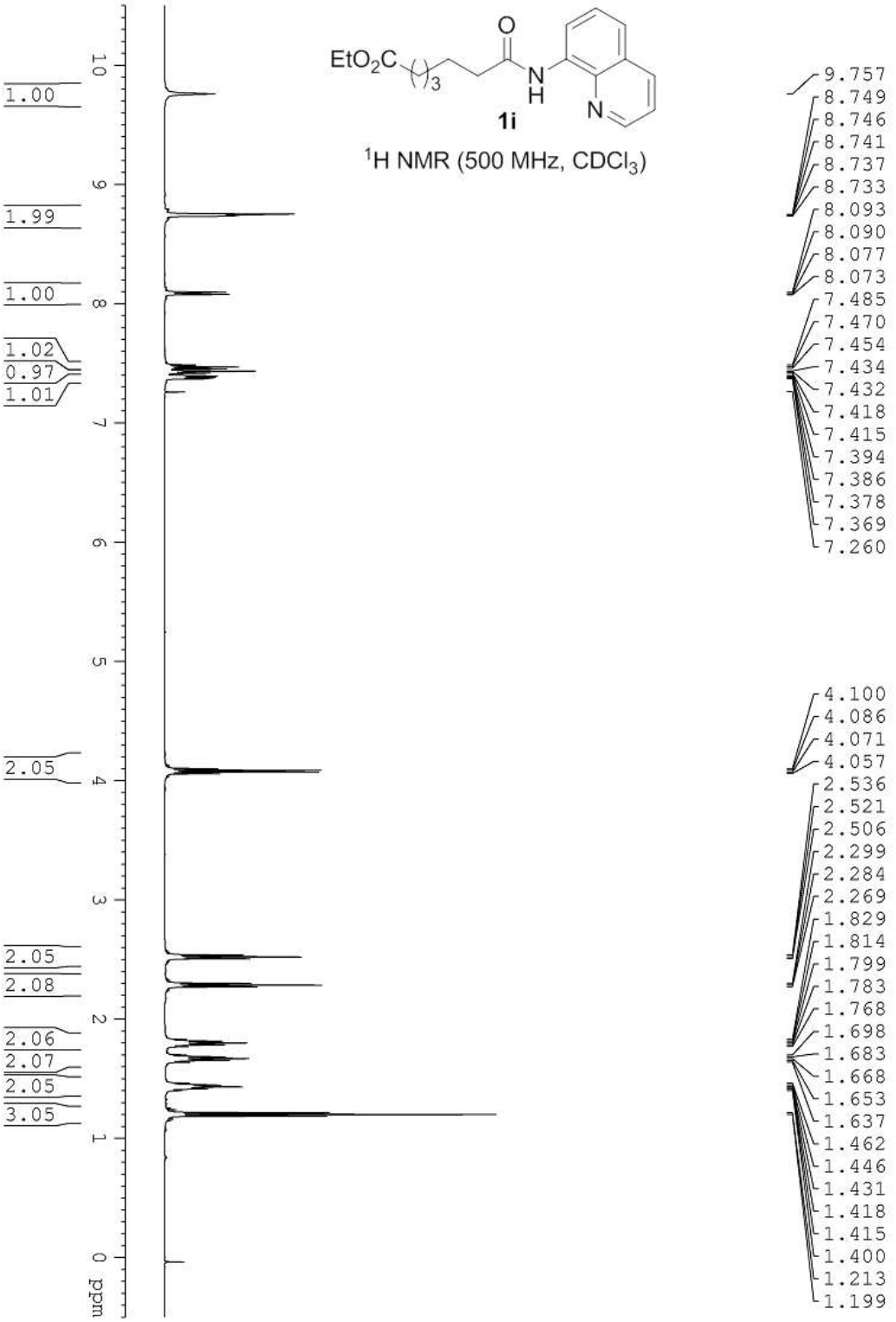
2.02
1.00
1.00
1.01
1.10
2.18
2.09
3.19
2.11
2.30
6.53
ppm
9.799
8.806
8.803
8.798
8.794
8.790
8.787
8.775
8.772
8.165
8.162
8.149
8.146
7.547
7.531
7.516
7.500
7.497
7.483
7.481
7.462
7.453
7.445
7.436
7.260
4.059
4.046
4.032
2.576
2.562
2.546
2.033
1.836
1.822
1.807
1.639
1.624
1.611
1.463
1.450
1.438
1.432
1.429
1.420
1.415
1.401
1.392
1.386
1.378
1.373


AcO
5
O
N
H
N
1h
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.93
171.37
148.24
138.48
136.52
134.68
128.08
127.58
121.70
121.48
116.56
77.41
77.16
76.90
64.69
38.29
29.28
29.16
28.69
25.92
25.67
21.14
ppm


EtO2C
3
O
N
H
N
1i
1H NMR (500 MHz, CDCl3)
1.00
1.99
1.00
1.02
0.97
1.01
2.05
2.05
2.08
2.06
2.07
2.05
3.05
ppm
9.757
8.749
8.746
8.741
8.737
8.733
8.093
8.090
8.077
8.073
7.485
7.470
7.454
7.434
7.432
7.418
7.415
7.394
7.386
7.378
7.369
7.260
4.100
4.086
4.071
4.057
2.536
2.521
2.506
2.299
2.284
2.269
1.829
1.814
1.799
1.783
1.768
1.698
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1.431
1.418
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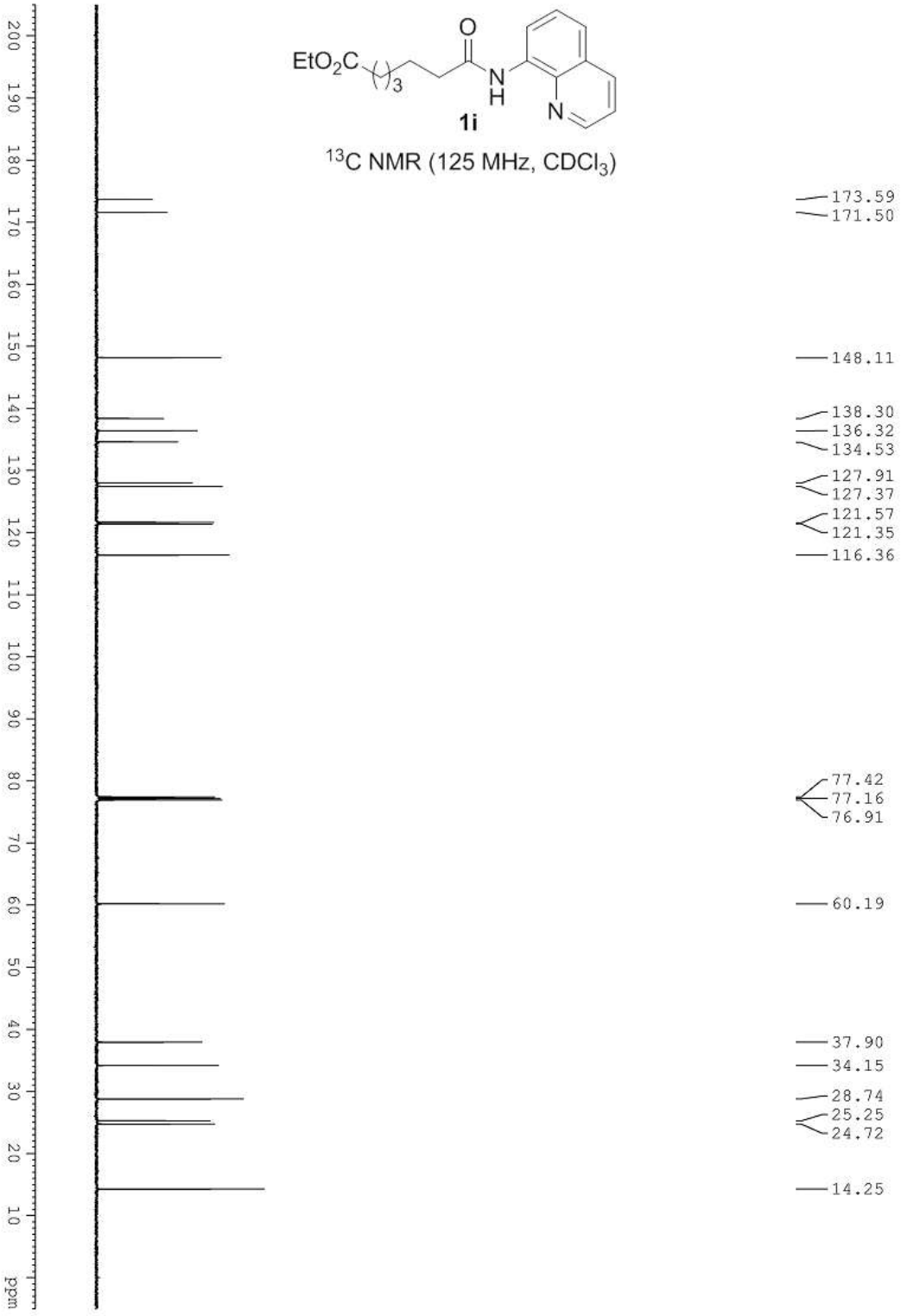
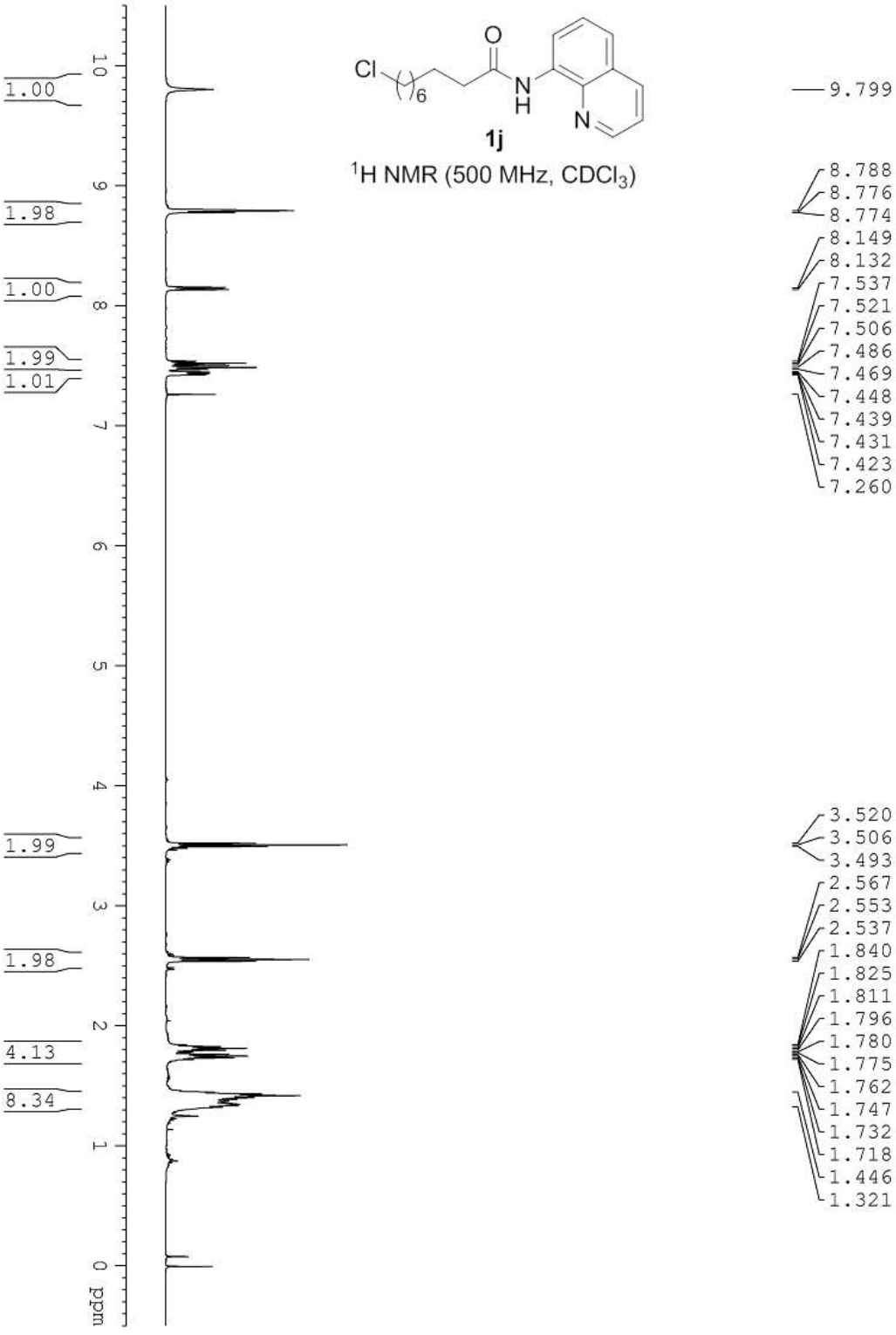
1.400
1.213
1.199


EtO2C
3
O
N
H
N
1i
13C NMR (125 MHz, CDCl3)
173.59
171.50
148.11
138.30
136.32
134.53
127.91
127.37
121.57
121.35
116.36
77.42
77.16
76.91
60.19
37.90
34.15
28.74
25.25
24.72
14.25
ppm


Cl
6
O
N
H
N
1j
1H NMR (500 MHz, CDCl3)
1.00
1.98
1.00
1.99
1.01
1.99
1.98
4.13
8.34
9.799
8.788
8.776
8.774
8.149
8.132
7.537
7.521
7.506
7.486
7.469
7.448
7.439
7.431
7.423
7.260
3.520
3.506
3.493
2.567
2.553
2.537
1.840
1.825
1.811
1.796
1.780
1.775
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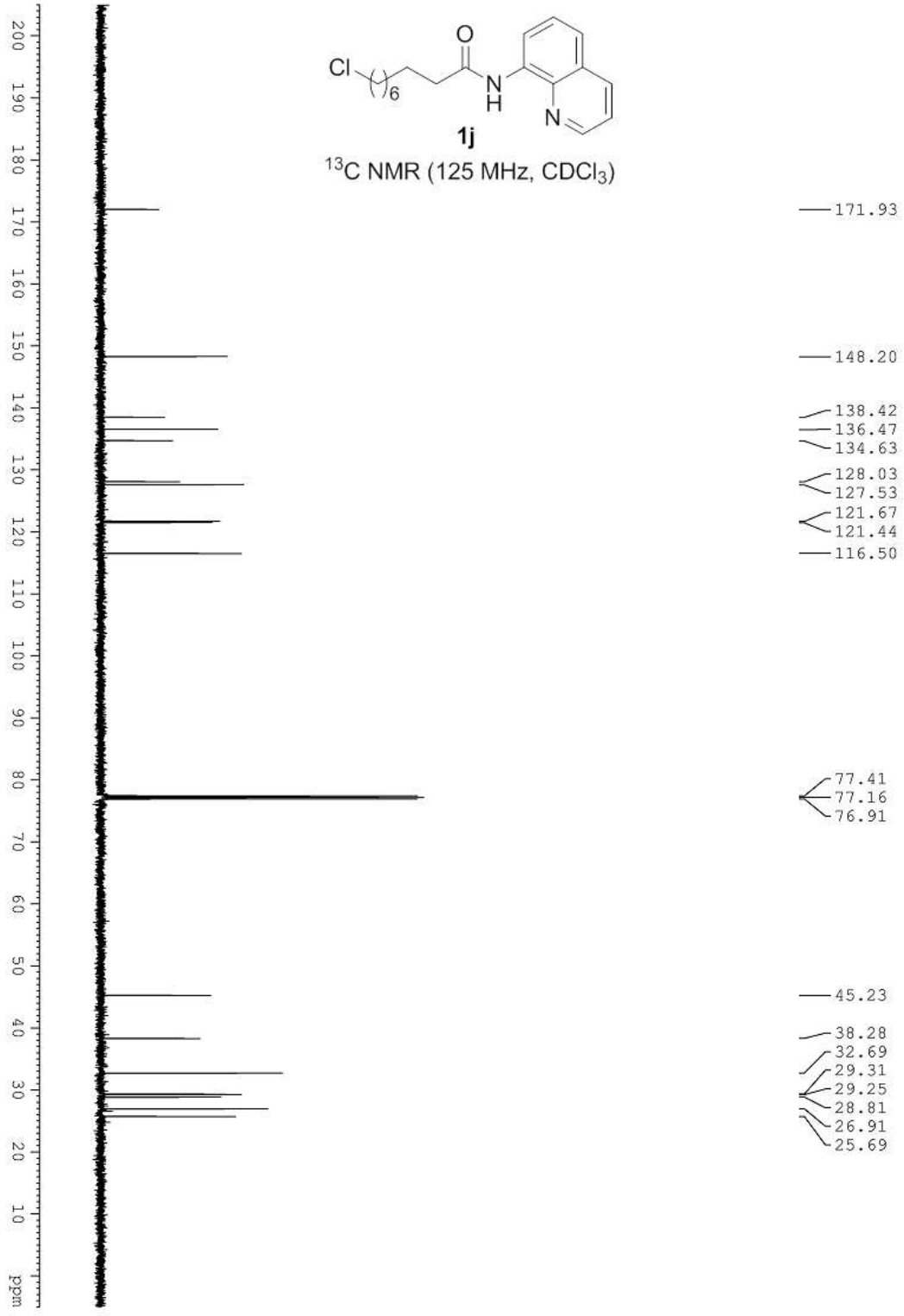
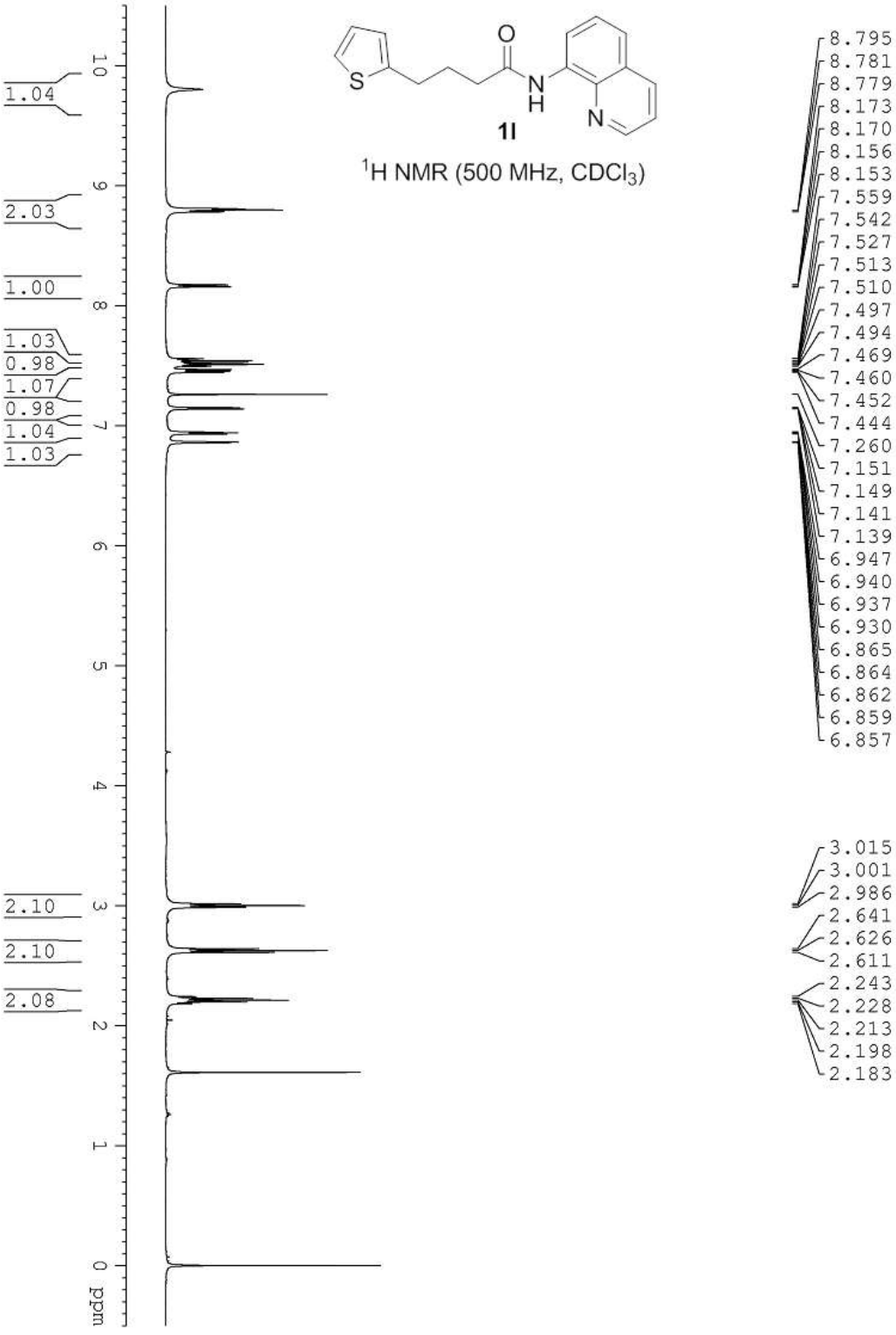
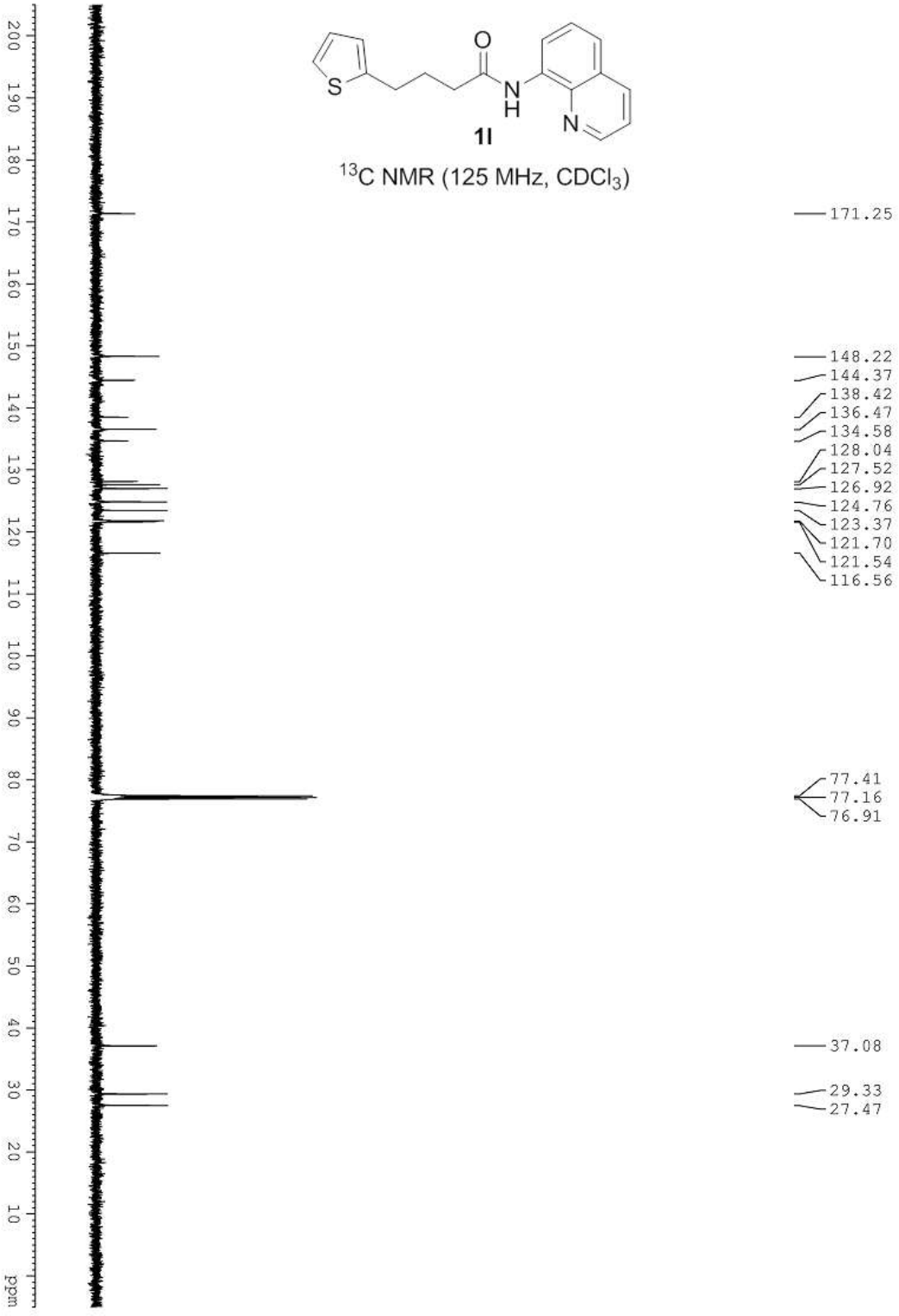
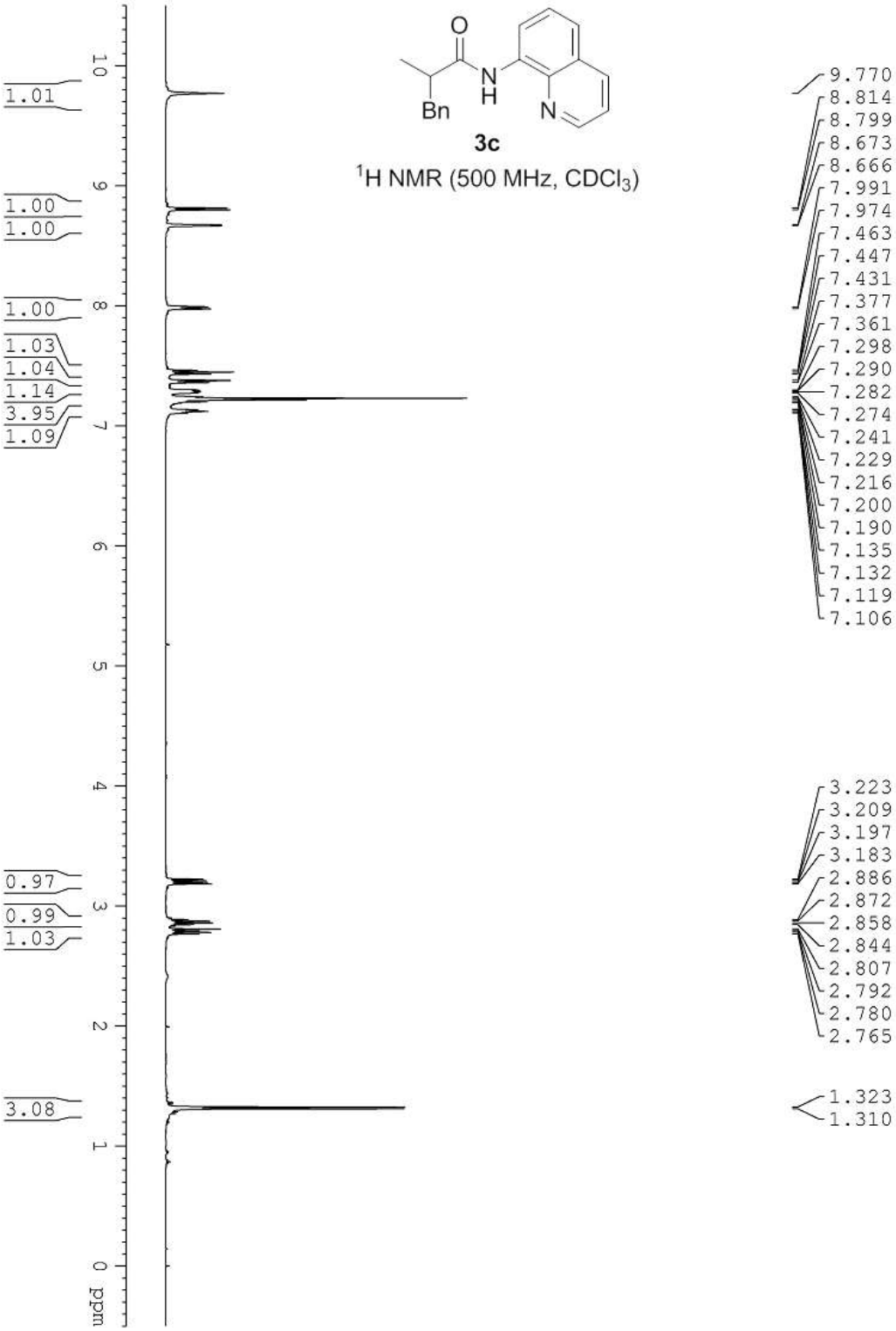
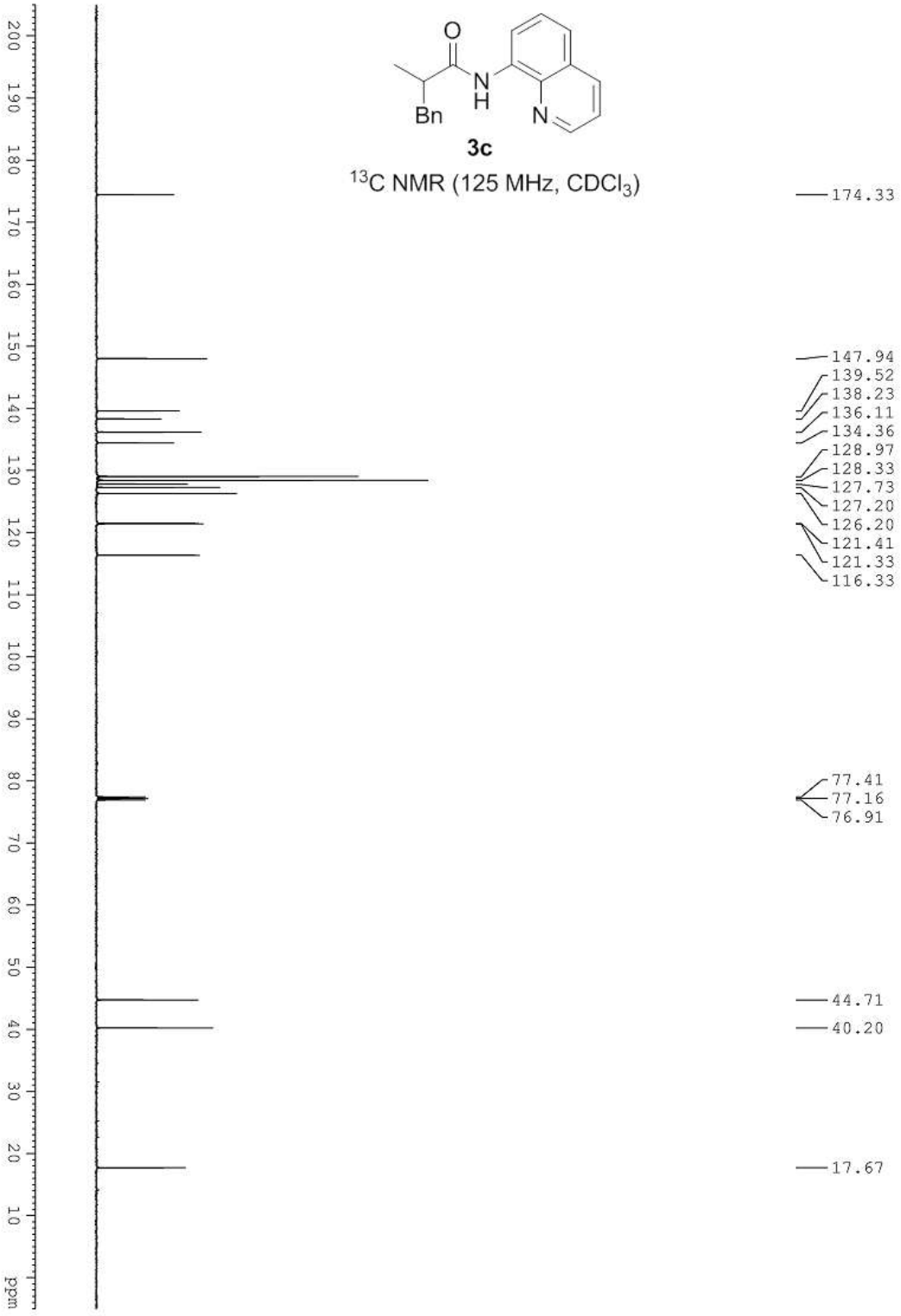
1.747
1.732
1.718
1.446
1.321
ppm

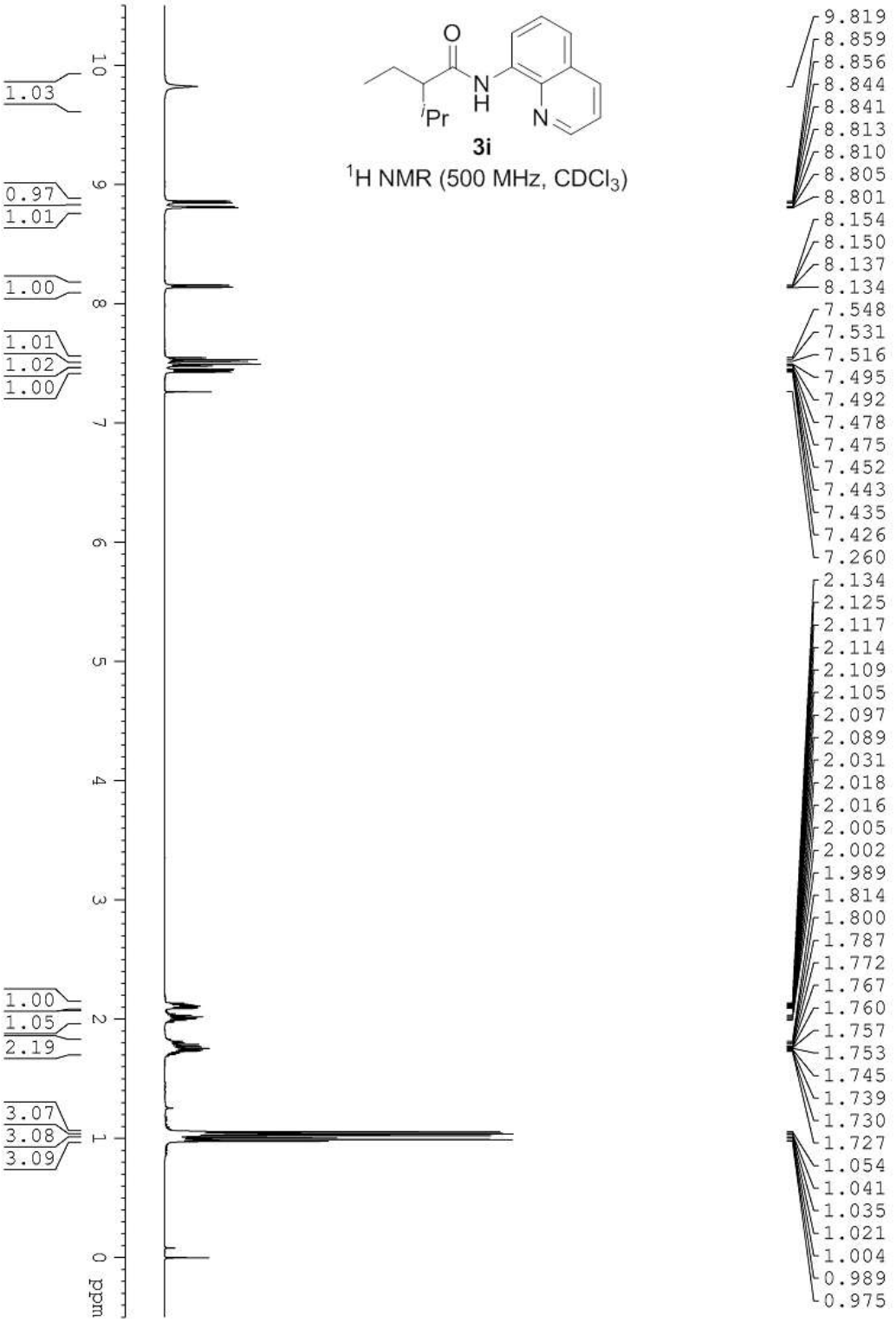

Cl
6
O
N
H
N
1j
13C NMR (125 MHz, CDCl3)
171.93
148.20
138.42
136.47
134.63
128.03
127.53
121.67
121.44
116.50
77.41
77.16
76.91
45.23
38.28
32.69
29.31
29.25
28.81
26.91
25.69
ppm

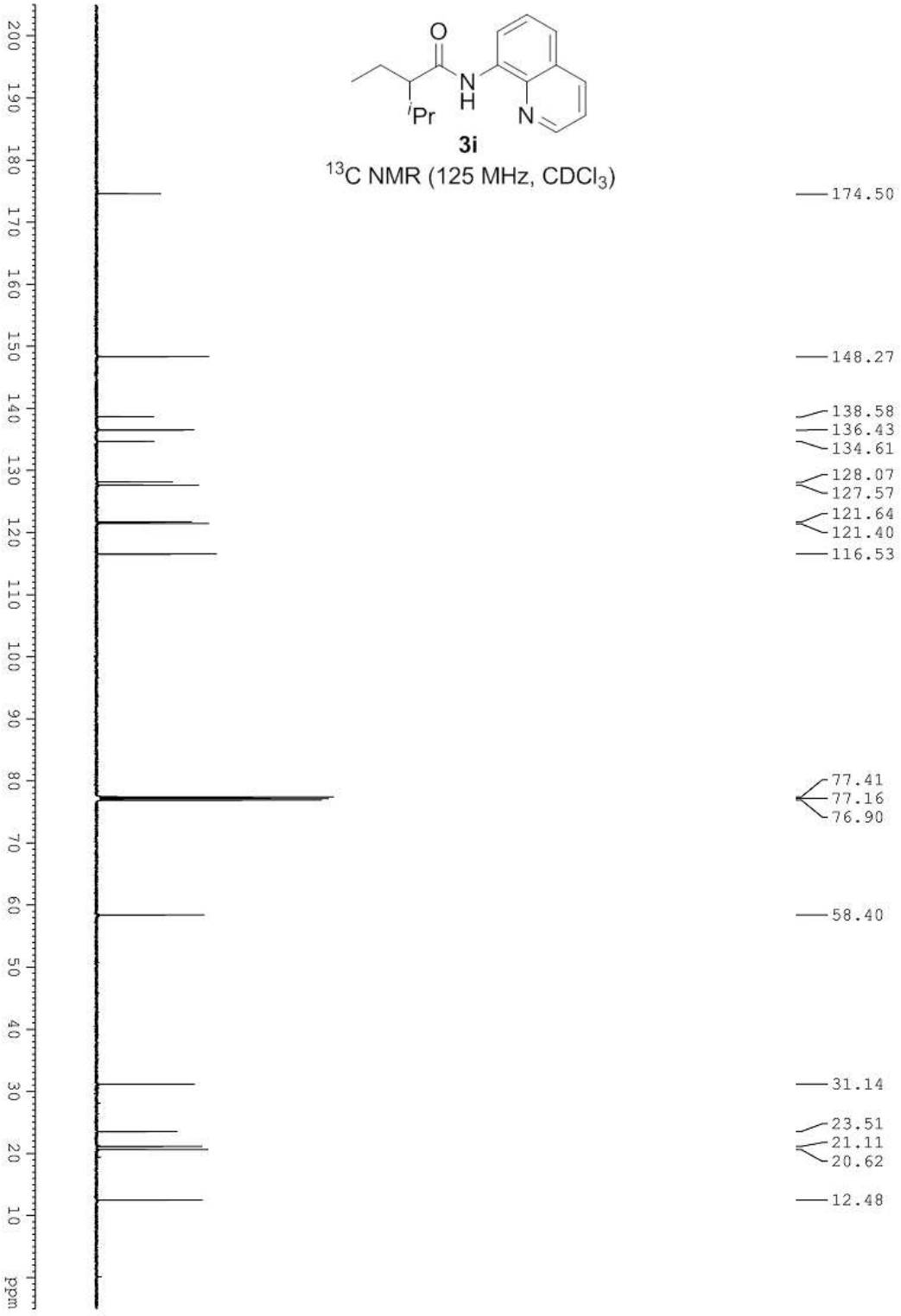

1.04
2.03
1.00
1.03
0.98
1.07
0.98
1.04
1.03
2.10
2.10
2.08
ppm
1l
$^1$H NMR (500 MHz, CDCl$_3$)
8.795
8.781
8.779
8.173
8.170
8.156
8.153
7.559
7.542
7.527
7.513
7.510
7.497
7.494
7.469
7.460
7.452
7.444
7.260
7.151
7.149
7.141
7.139
6.947
6.940
6.937
6.930
6.865
6.864
6.862
6.859
6.857
3.015
3.001
2.986
2.641
2.626
2.611
2.243
2.228
2.213
2.198
2.183

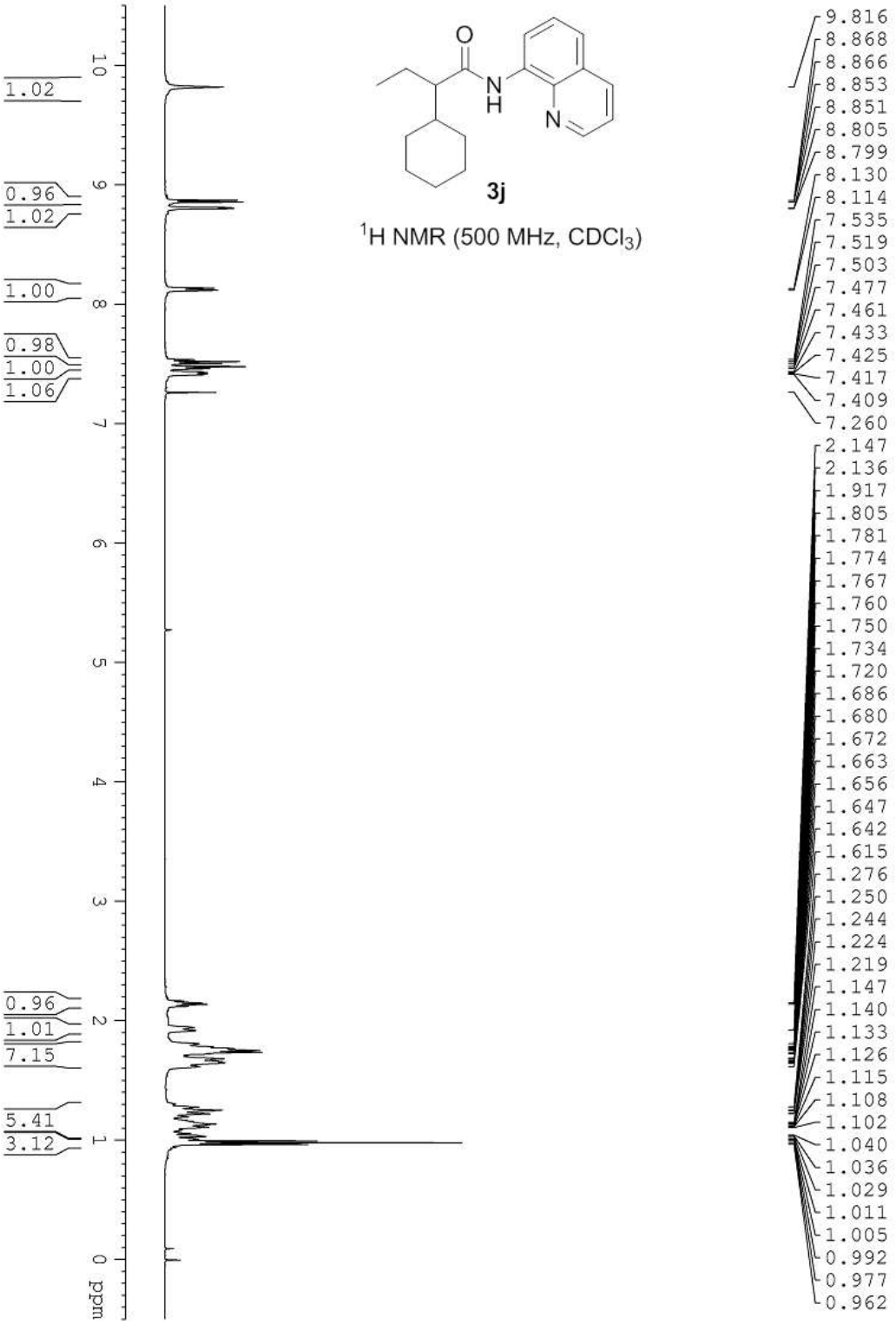

O
S
N
H
N
1l
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.25
148.22
144.37
138.42
136.47
134.58
128.04
127.52
126.92
124.76
123.37
121.70
121.54
116.56
77.41
77.16
76.91
37.08
29.33
27.47
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

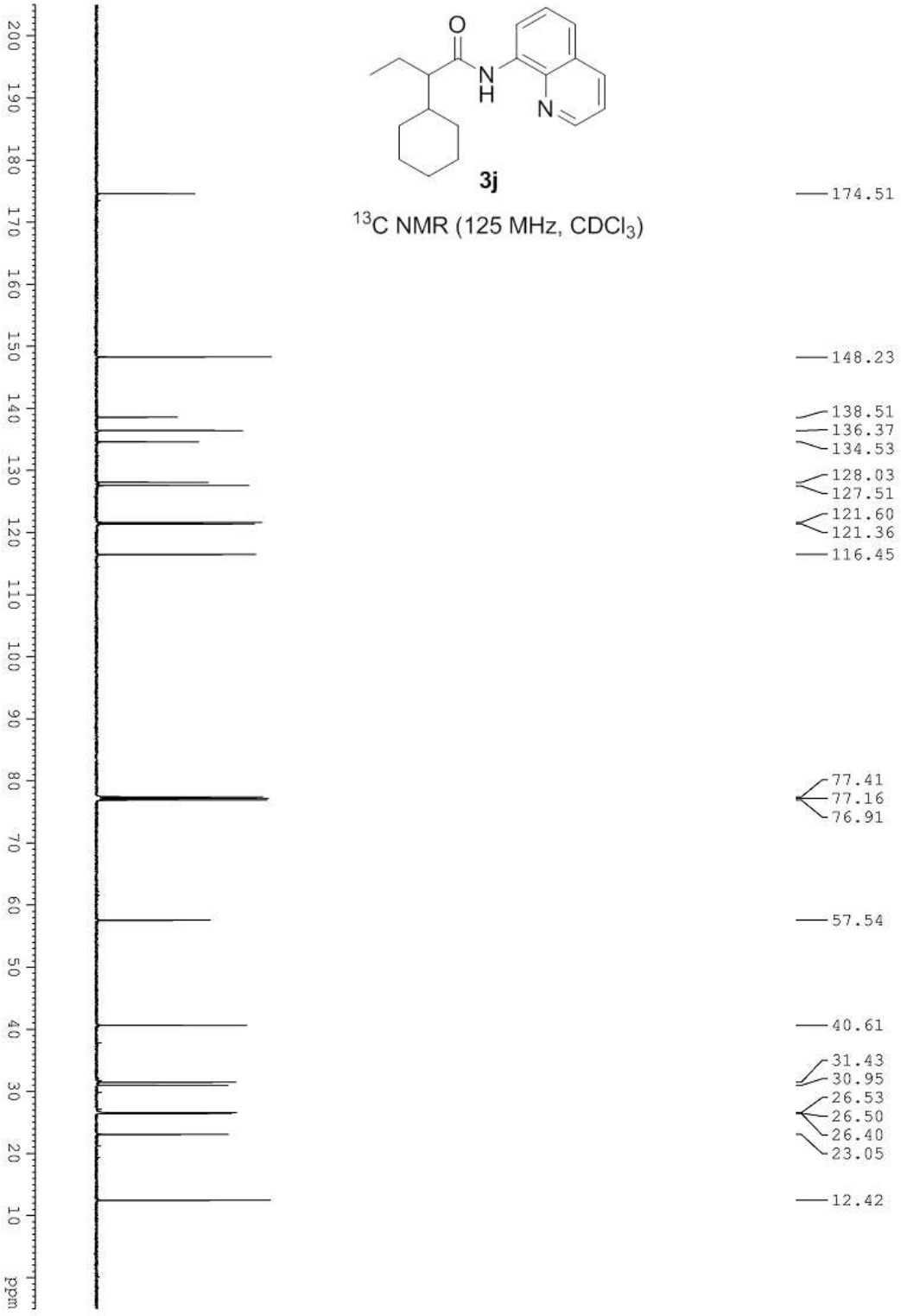

3c
$^1$H NMR (500 MHz, $CDCl_3$)
1.01
1.00
1.00
1.00
1.03
1.04
1.14
3.95
1.09
0.97
0.99
1.03
3.08
9.770
8.814
8.799
8.673
8.666
7.991
7.974
7.463
7.447
7.431
7.377
7.361
7.298
7.290
7.282
7.274
7.241
7.229
7.216
7.200
7.190
7.135
7.132
7.119
7.106
3.223
3.209
3.197
3.183
2.886
2.872
2.858
2.844
2.807
2.792
2.780
2.765
1.323
1.310
ppm

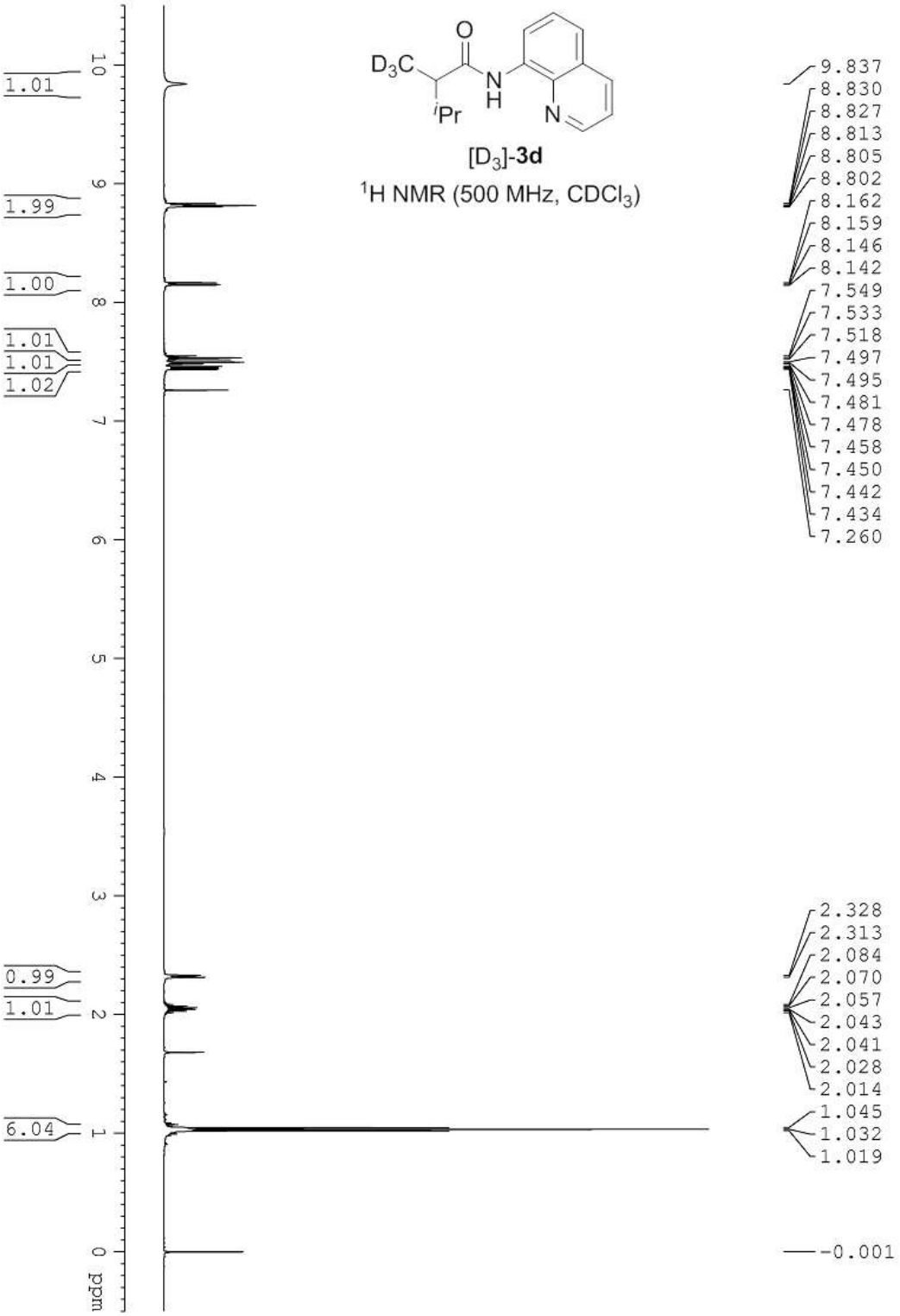

O
N
H
Bn
N
3c
$^{13}$C NMR (125 MHz, $CDCl_3$)
174.33
147.94
139.52
138.23
136.11
134.36
128.97
128.33
127.73
127.20
126.20
121.41
121.33
116.33
77.41
77.16
76.91
44.71
40.20
17.67
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

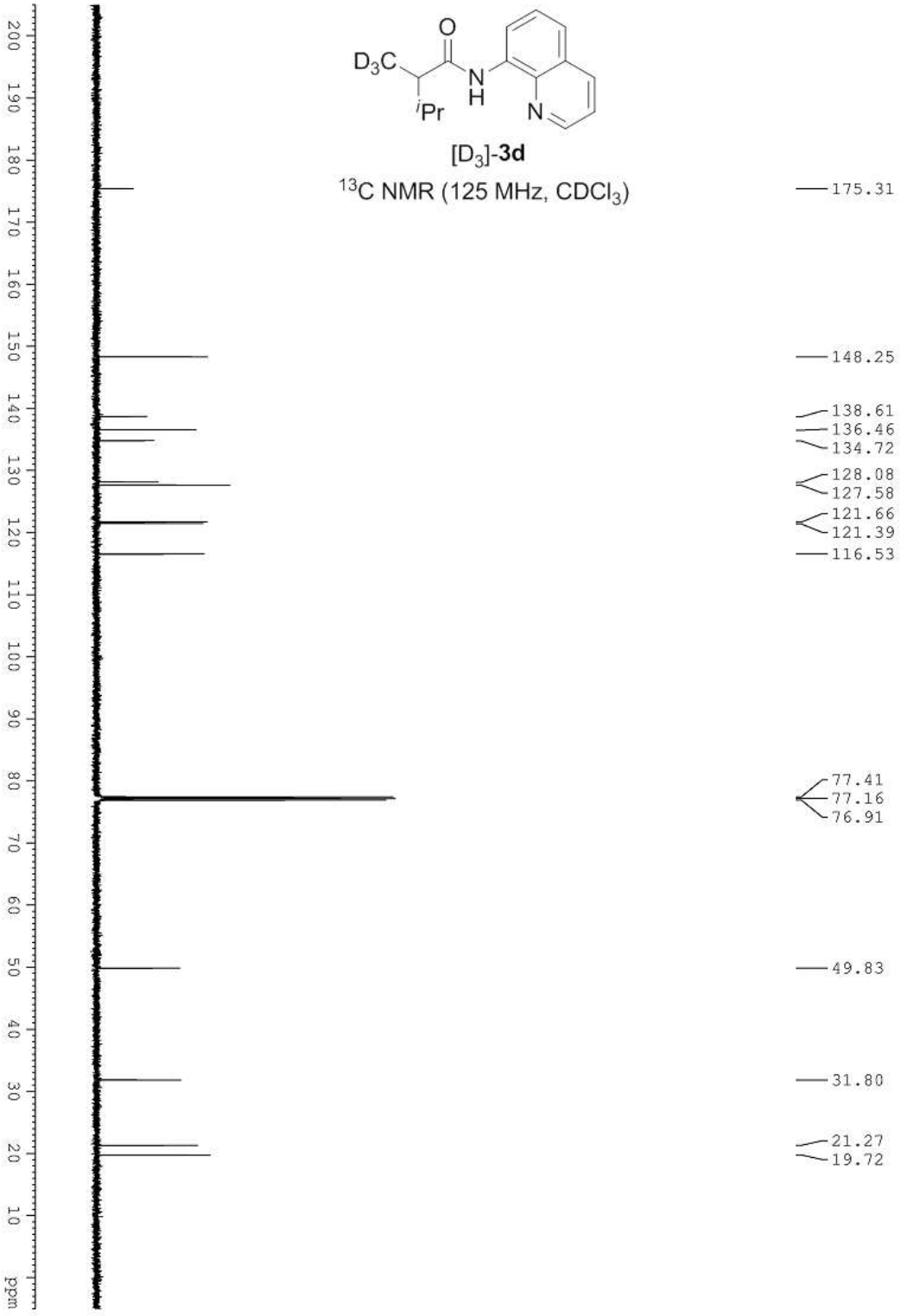

O
N
H
iPr
N
3i
1H NMR (500 MHz, CDCl3)
1.03
0.97
1.01
1.00
1.01
1.02
1.00
1.00
1.05
2.19
3.07
3.08
3.09
ppm
9.819
8.859
8.856
8.844
8.841
8.813
8.810
8.805
8.801
8.154
8.150
8.137
8.134
7.548
7.531
7.516
7.495
7.492
7.478
7.475
7.452
7.443
7.435
7.426
7.260
2.134
2.125
2.117
2.114
2.109
2.105
2.097
2.089
2.031
2.018
2.016
2.005
2.002
1.989
1.814
1.800
1.787
1.772
1.767
1.760
1.757
1.753
1.745
1.739
1.730
1.727
1.054
1.041
1.035
1.021
1.004
0.989
0.975

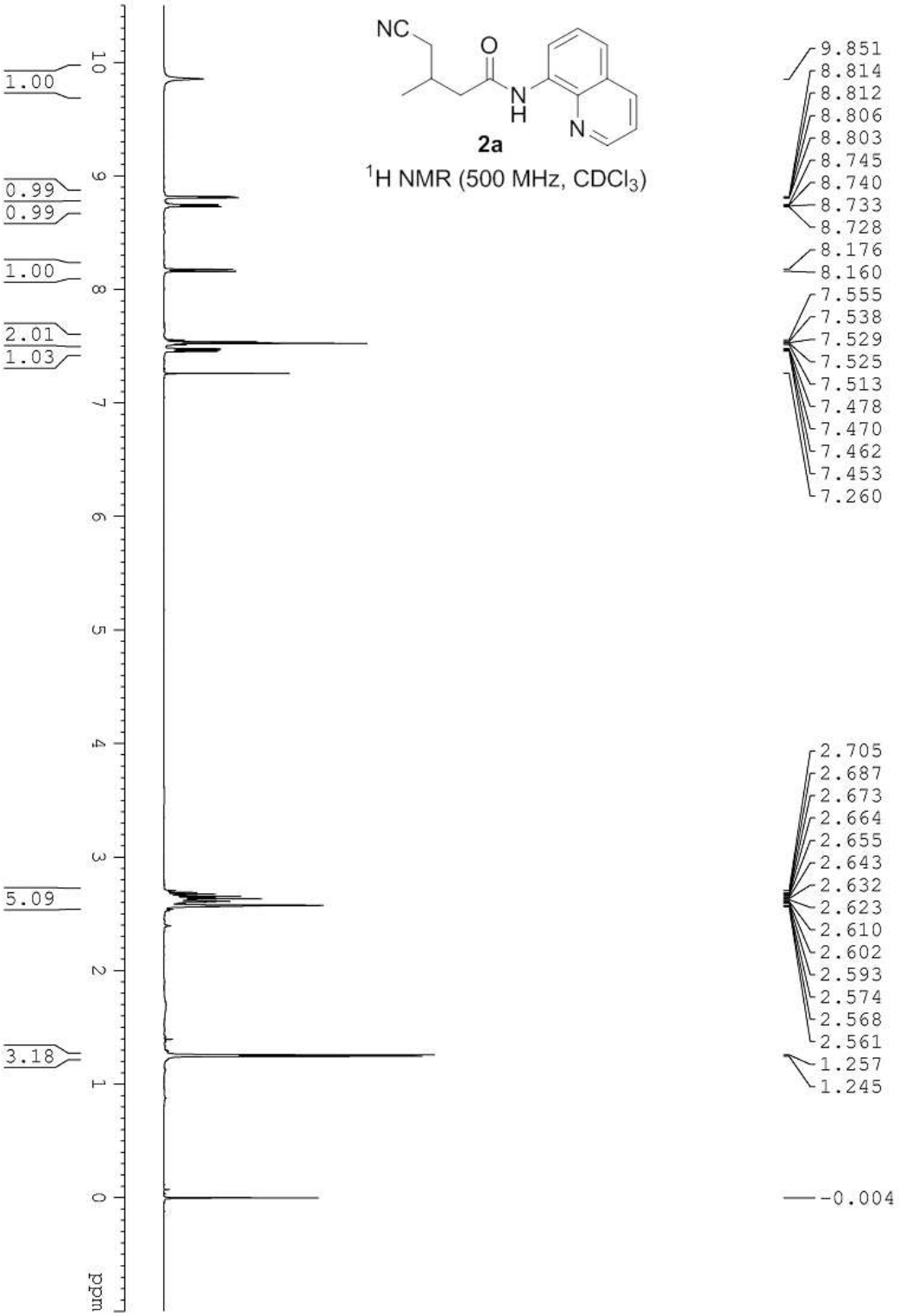

O
N
H
iPr
N
3i
13C NMR (125 MHz, CDCl3)
174.50
148.27
138.58
136.43
134.61
128.07
127.57
121.64
121.40
116.53
77.41
77.16
76.90
58.40
31.14
23.51
21.11
20.62
12.48
ppm

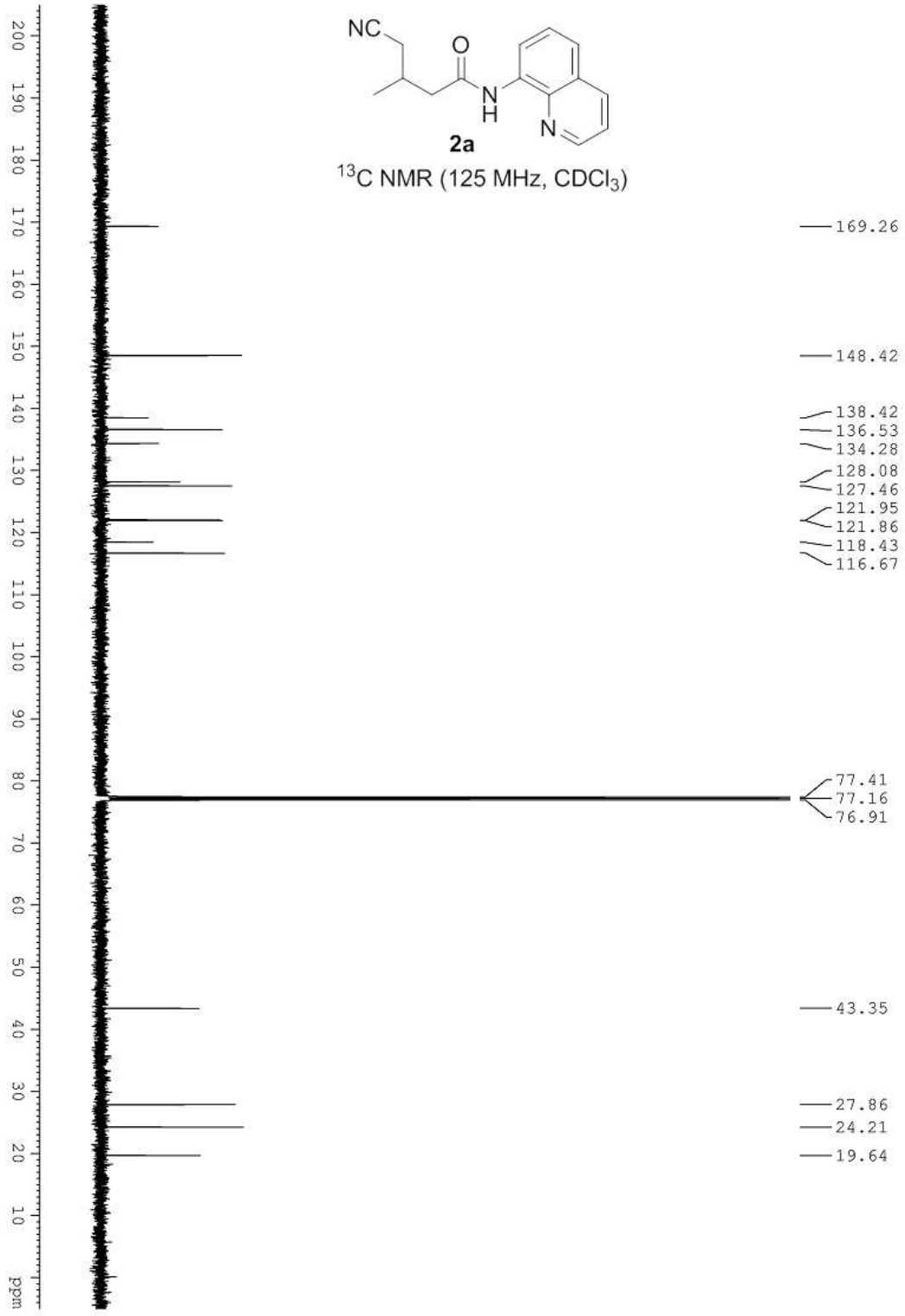

O
N
H
N
3j
$^1$H NMR (500 MHz, $CDCl_3$)
1.02
0.96
1.02
1.00
0.98
1.00
1.06
0.96
1.01
7.15
5.41
3.12
ppm
9.816
8.868
8.866
8.853
8.851
8.805
8.799
8.130
8.114
7.535
7.519
7.503
7.477
7.461
7.433
7.425
7.417
7.409
7.260
2.147
2.136
1.917
1.805
1.781
1.774
1.767
1.760
1.750
1.734
1.720
1.686
1.680
1.672
1.663
1.656
1.647
1.642
1.615
1.276
1.250
1.244
1.224
1.219
1.147
1.140
1.133
1.126
1.115
1.108
1.102
1.040
1.036
1.029
1.011
1.005
0.992
0.977
0.962

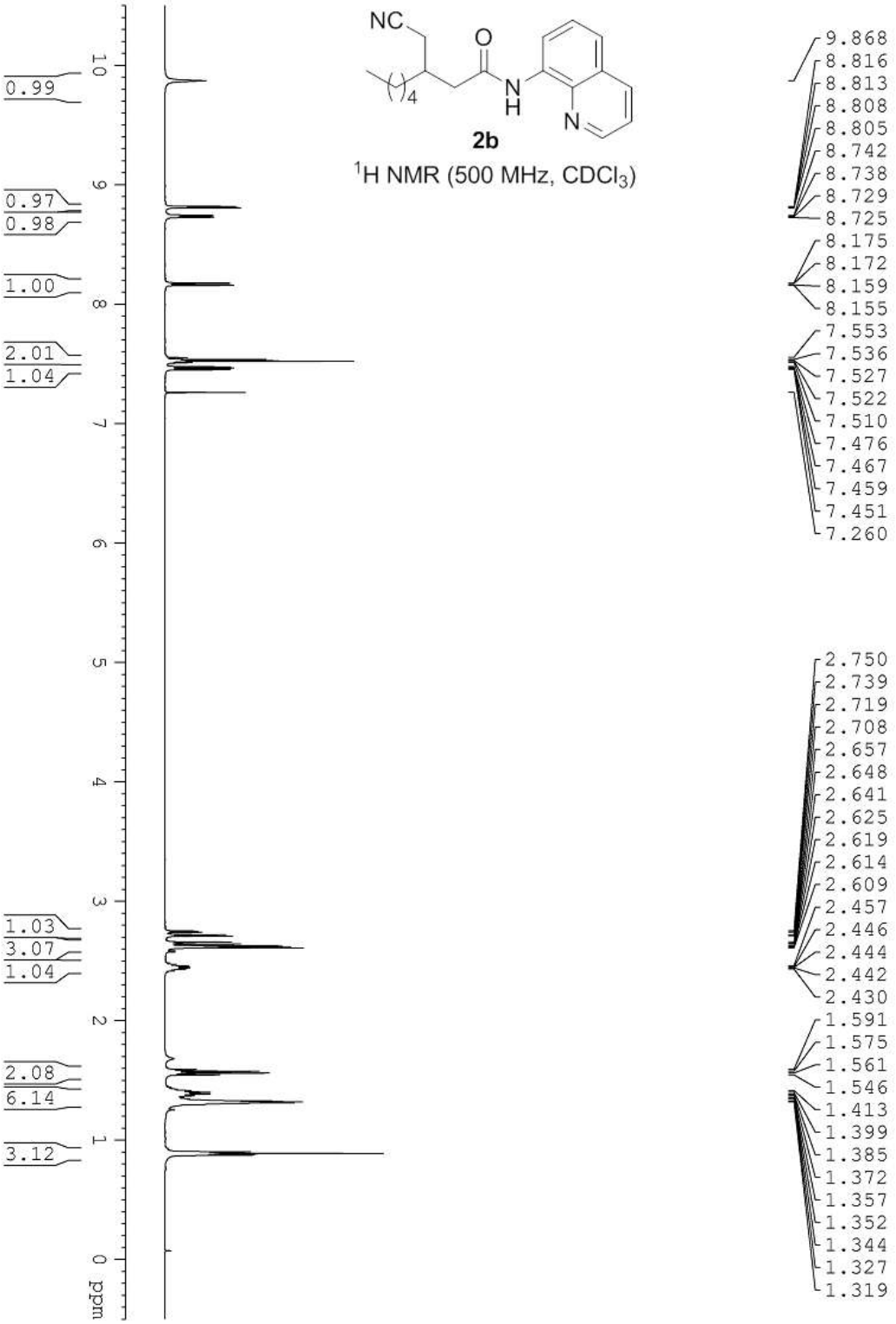

O
N
H
N
3j
$^{13}$C NMR (125 MHz, $CDCl_3$)
174.51
148.23
138.51
136.37
134.53
128.03
127.51
121.60
121.36
116.45
77.41
77.16
76.91
57.54
40.61
31.43
30.95
26.53
26.50
26.40
23.05
12.42
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

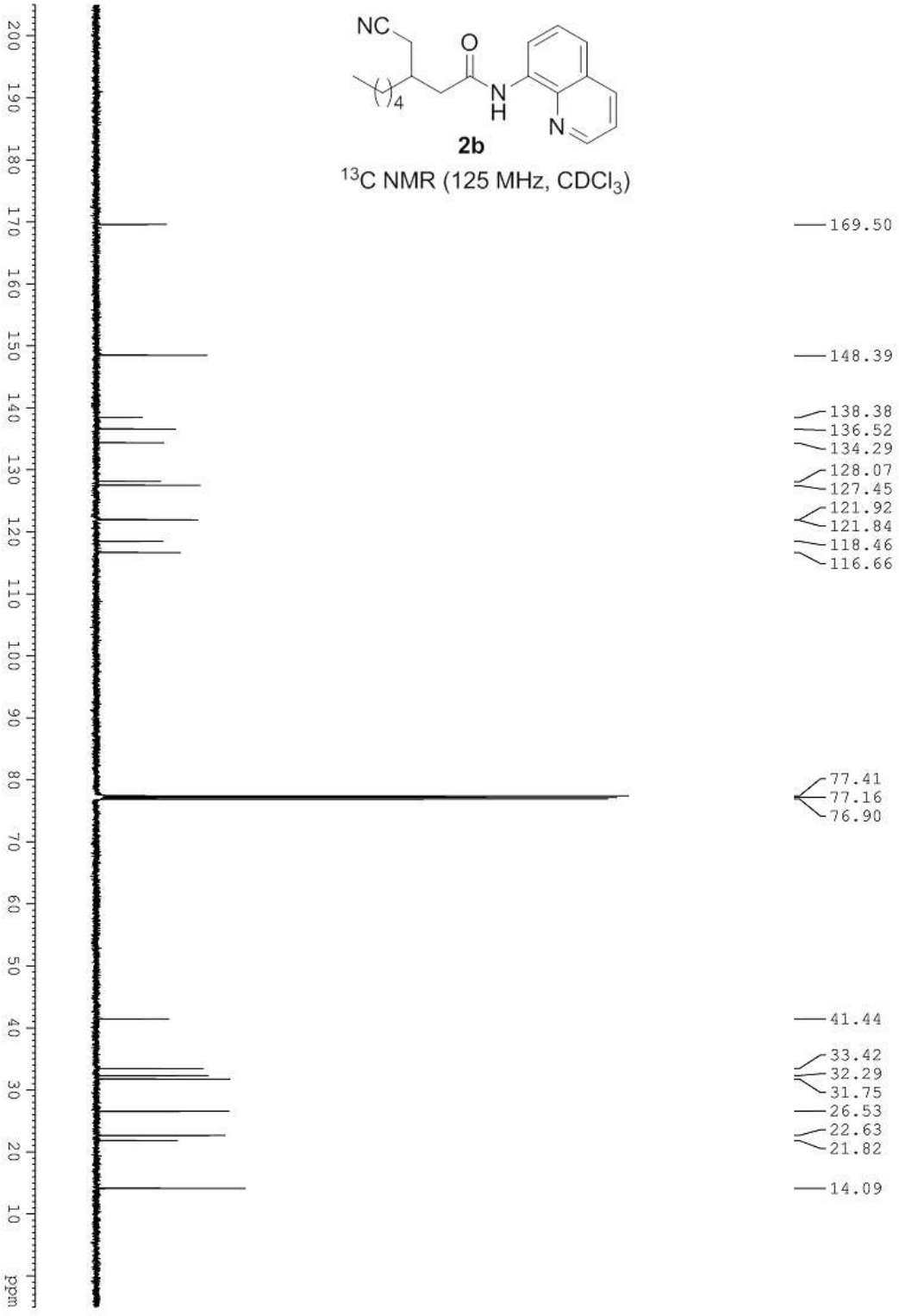

[D3]-3d
1H NMR (500 MHz, CDCl3)
1.01
1.99
1.00
1.01
1.01
1.02
0.99
1.01
6.04
9.837
8.830
8.827
8.813
8.805
8.802
8.162
8.159
8.146
8.142
7.549
7.533
7.518
7.497
7.495
7.481
7.478
7.458
7.450
7.442
7.434
7.260
2.328
2.313
2.084
2.070
2.057
2.043
2.041
2.028
2.014
1.045
1.032
1.019
-0.001
ppm

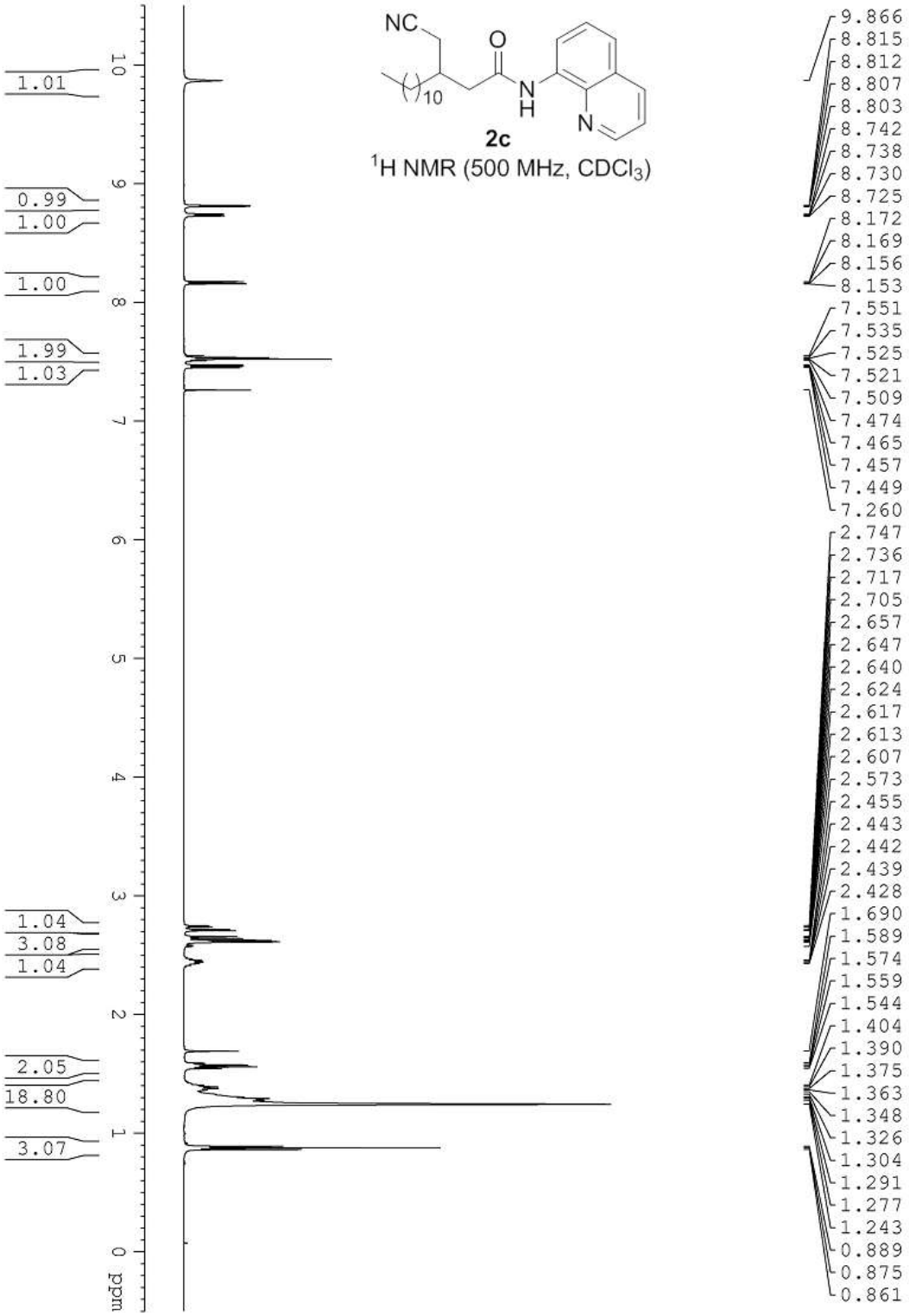

[D3]-3d
13C NMR (125 MHz, CDCl3)
175.31
148.25
138.61
136.46
134.72
128.08
127.58
121.66
121.39
116.53
77.41
77.16
76.91
49.83
31.80
21.27
19.72
ppm

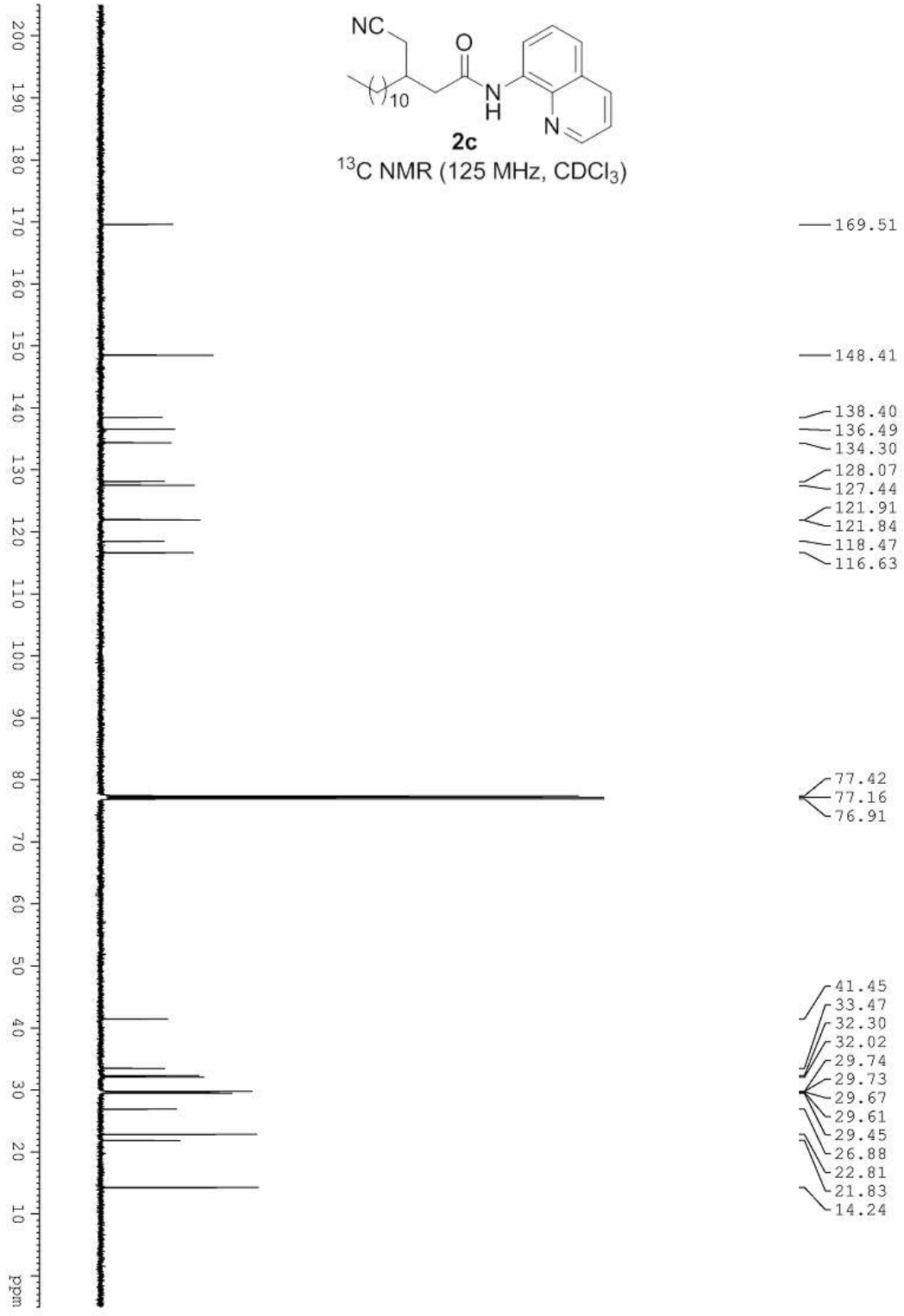

NC
O
N
H
N
2a
$^1$H NMR (500 MHz, $CDCl_3$)
9.851
8.814
8.812
8.806
8.803
8.745
8.740
8.733
8.728
8.176
8.160
7.555
7.538
7.529
7.525
7.513
7.478
7.470
7.462
7.453
7.260
2.705
2.687
2.673
2.664
2.655
2.643
2.632
2.623
2.610
2.602
2.593
2.574
2.568
2.561
1.257
1.245
-0.004
1.00
0.99
0.99
1.00
2.01
1.03
5.09
3.18
ppm

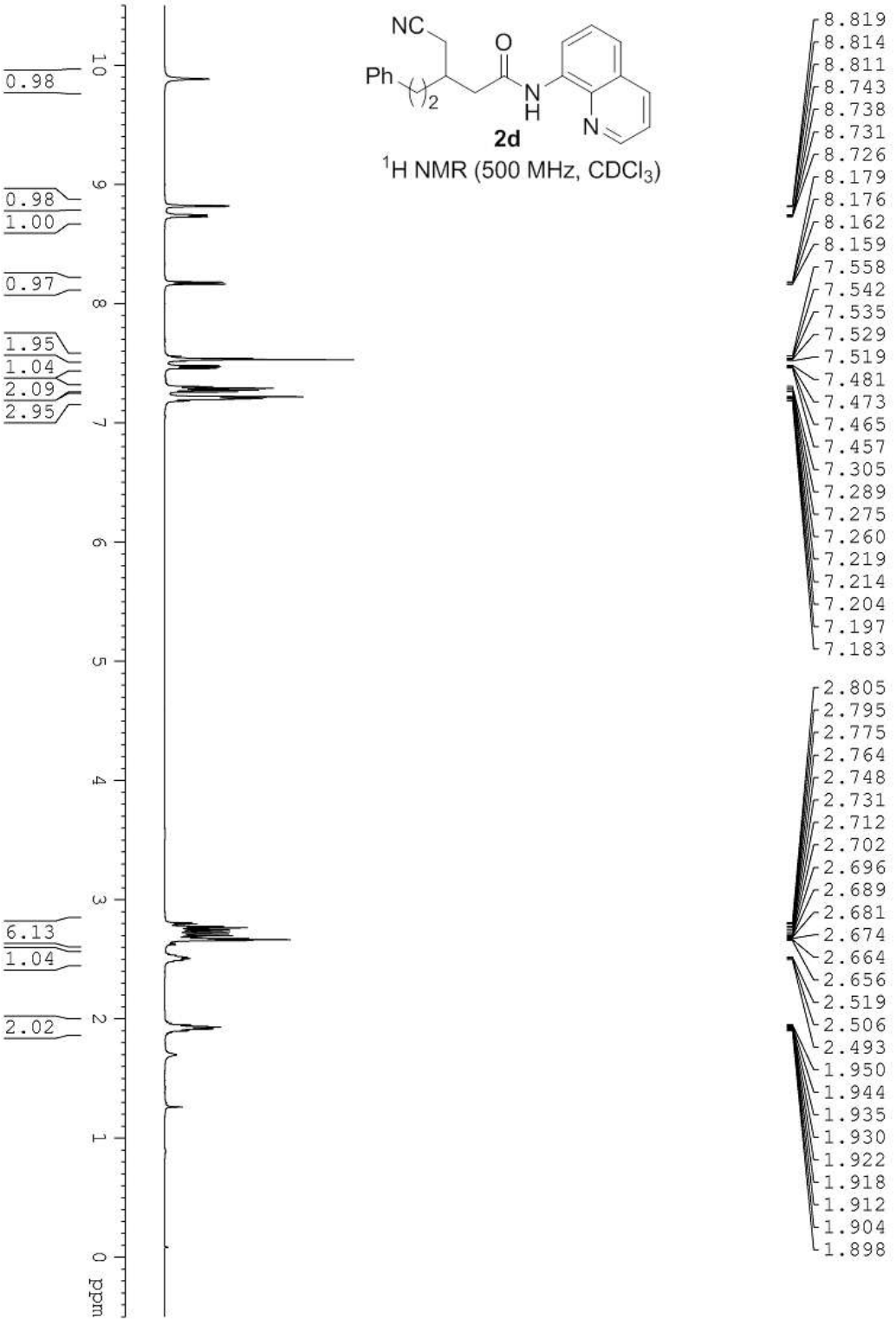

NC
O
N
H
N
2a
$^{13}$C NMR (125 MHz, $CDCl_3$)
169.26
148.42
138.42
136.53
134.28
128.08
127.46
121.95
121.86
118.43
116.67
77.41
77.16
76.91
43.35
27.86
24.21
19.64
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

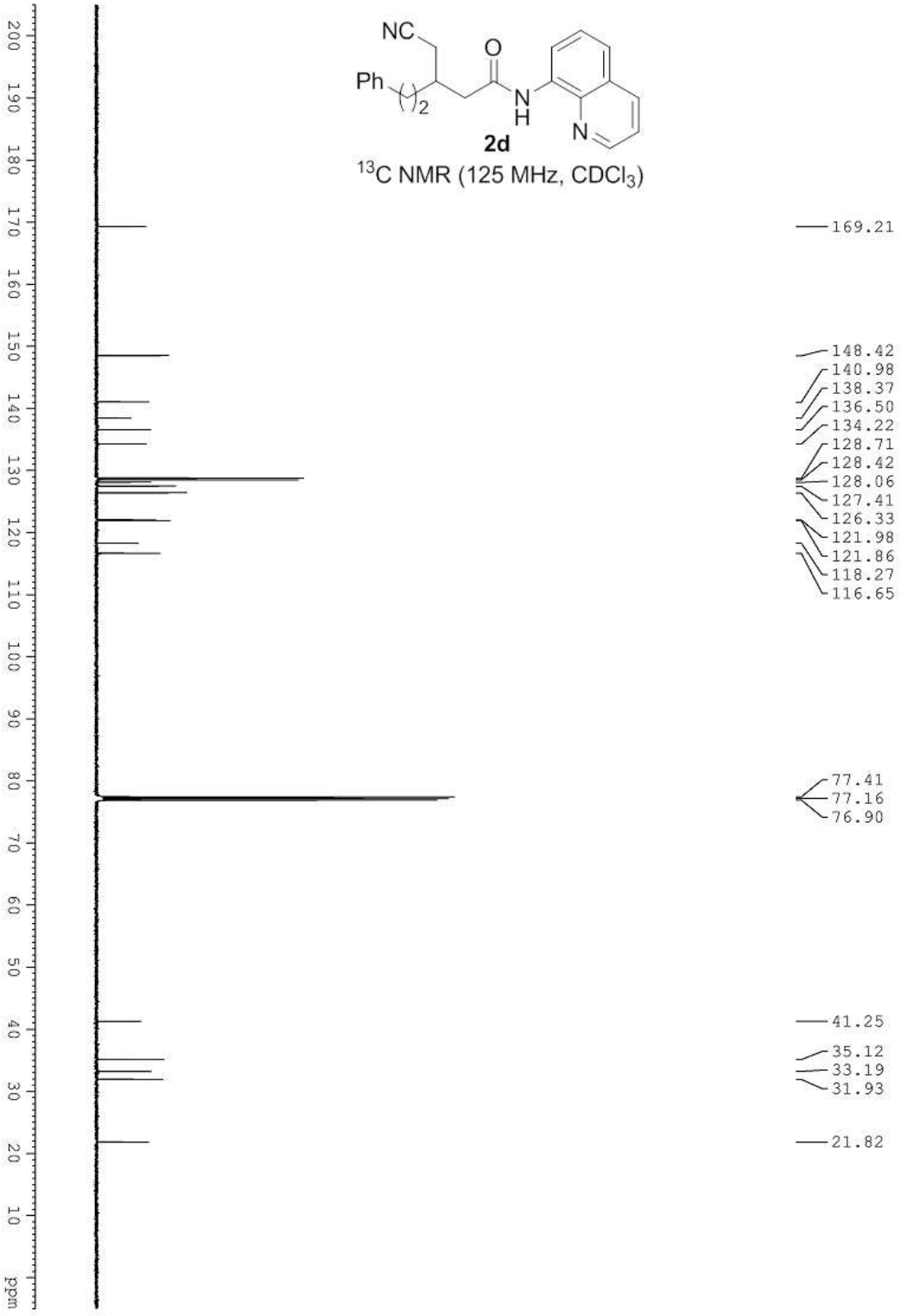

NC
O
N
H
N
4
2b
1H NMR (500 MHz, CDCl3)
0.99
0.97
0.98
1.00
2.01
1.04
1.03
3.07
1.04
2.08
6.14
3.12
9.868
8.816
8.813
8.808
8.805
8.742
8.738
8.729
8.725
8.175
8.172
8.159
8.155
7.553
7.536
7.527
7.522
7.510
7.476
7.467
7.459
7.451
7.260
2.750
2.739
2.719
2.708
2.657
2.648
2.641
2.625
2.619
2.614
2.609
2.457
2.446
2.444
2.442
2.430
1.591
1.575
1.561
1.546
1.413
1.399
1.385
1.372
1.357
1.352
1.344
1.327
1.319
ppm

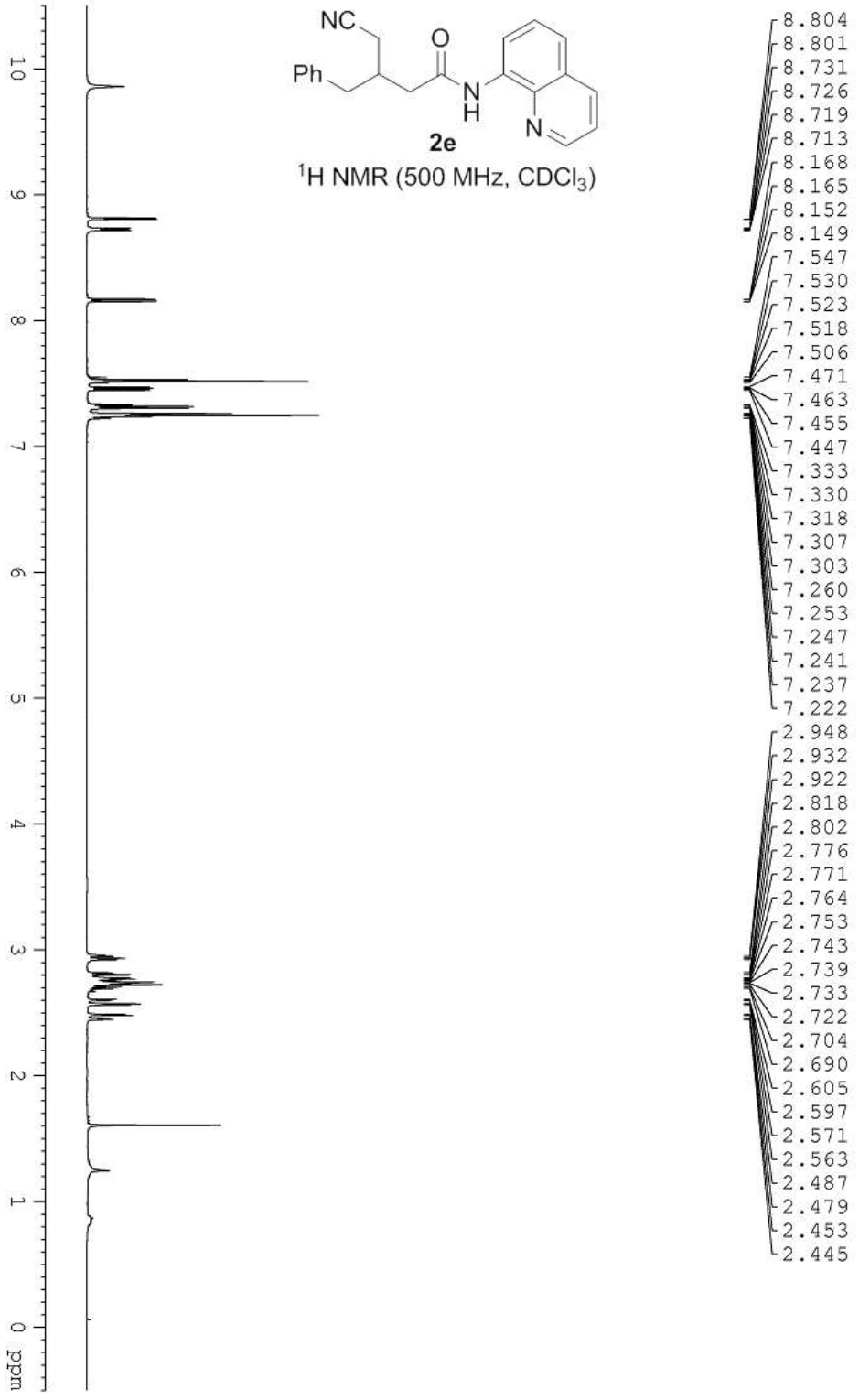

NC
O
N
H
N
4
2b
13C NMR (125 MHz, CDCl3)
169.50
148.39
138.38
136.52
134.29
128.07
127.45
121.92
121.84
118.46
116.66
77.41
77.16
76.90
41.44
33.42
32.29
31.75
26.53
22.63
21.82
14.09
ppm

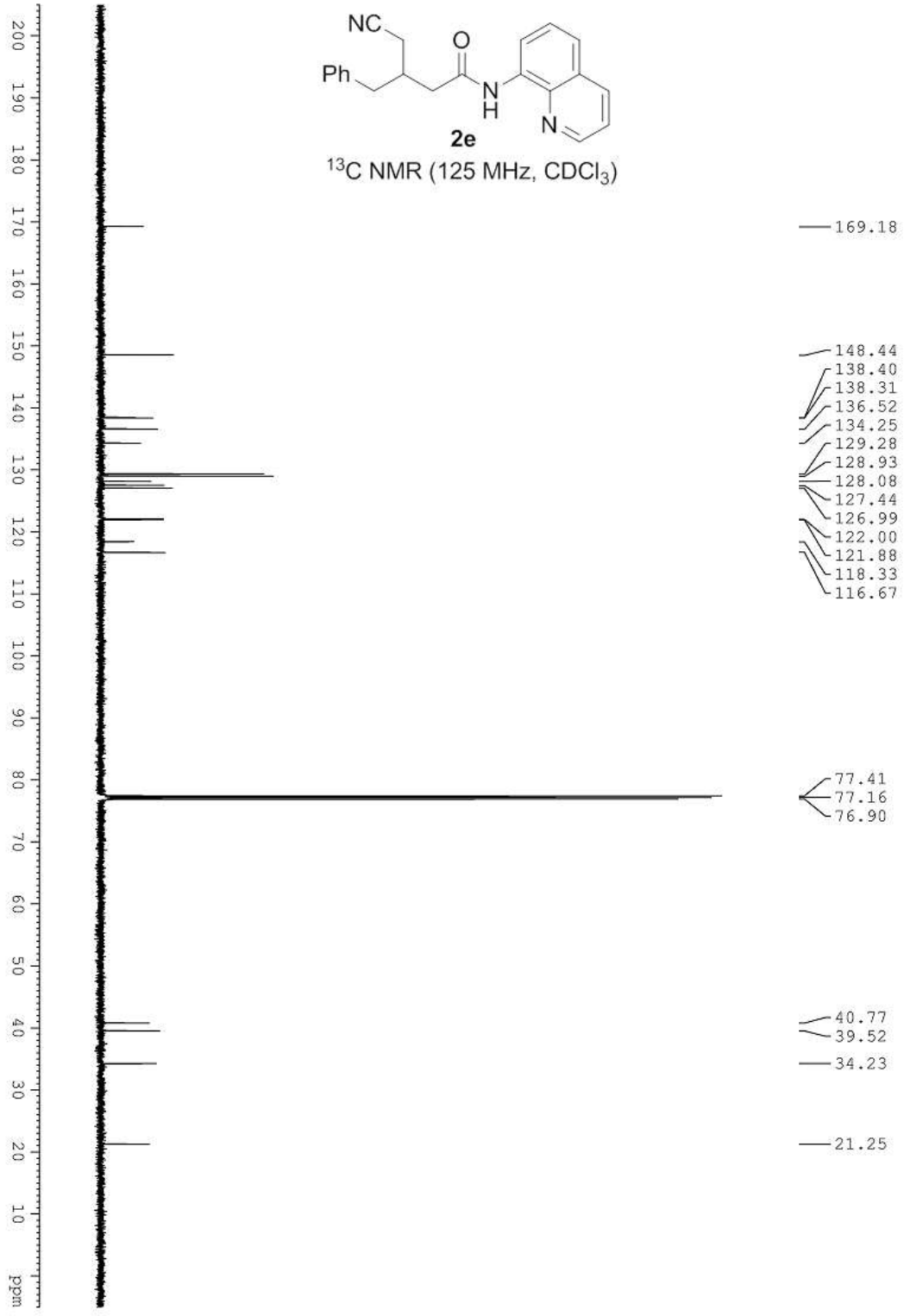

NC
O
N
H
10
N
2c
1H NMR (500 MHz, CDCl3)
1.01
0.99
1.00
1.00
1.99
1.03
1.04
3.08
1.04
2.05
18.80
3.07
ppm
9.866
8.815
8.812
8.807
8.803
8.742
8.738
8.730
8.725
8.172
8.169
8.156
8.153
7.551
7.535
7.525
7.521
7.509
7.474
7.465
7.457
7.449
7.260
2.747
2.736
2.717
2.705
2.657
2.647
2.640
2.624
2.617
2.613
2.607
2.573
2.455
2.443
2.442
2.439
2.428
1.690
1.589
1.574
1.559
1.544
1.404
1.390
1.375
1.363
1.348
1.326
1.304
1.291
1.277
1.243
0.889
0.875
0.861

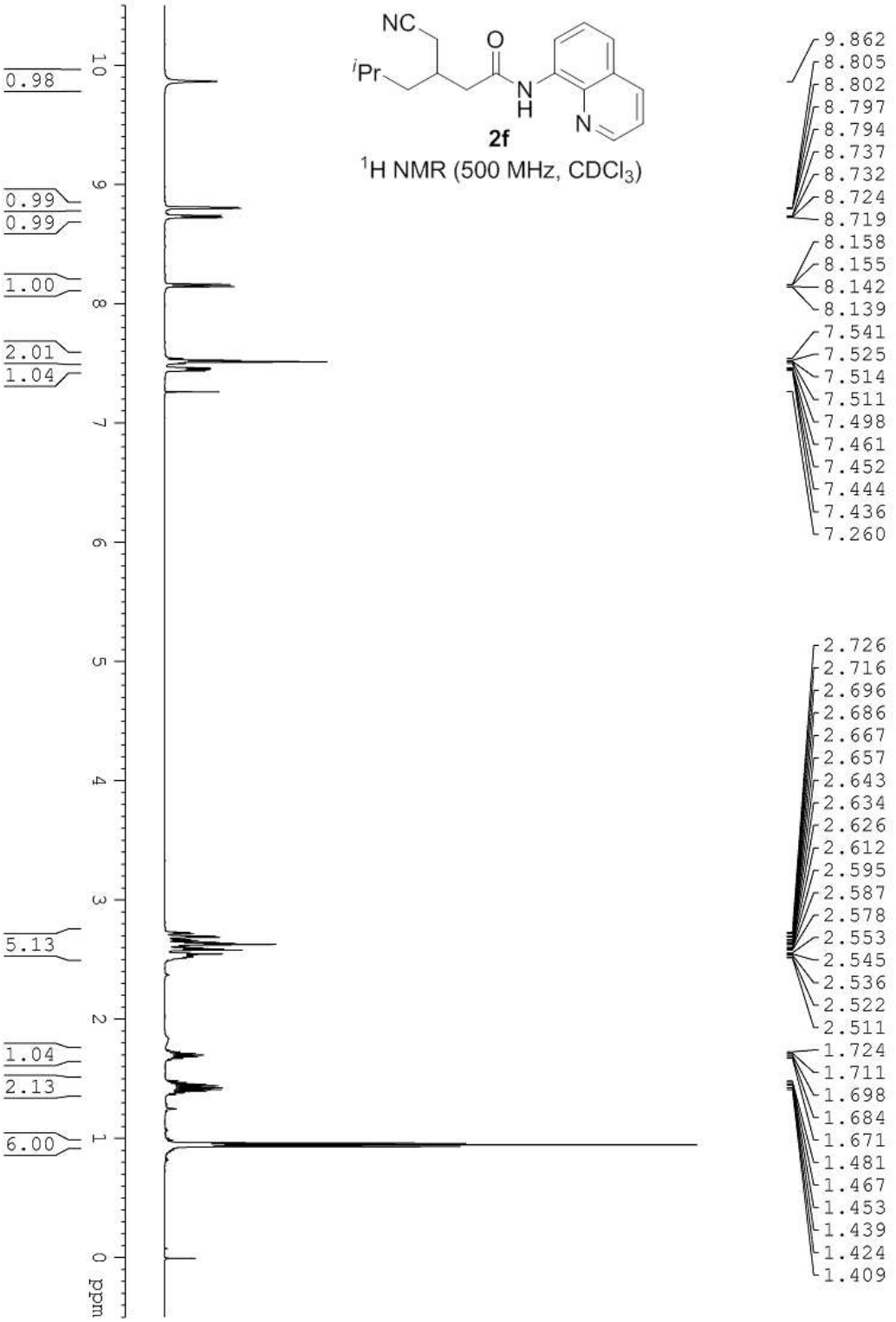

NC
O
N
H
10
N
2c
13C NMR (125 MHz, CDCl3)
169.51
148.41
138.40
136.49
134.30
128.07
127.44
121.91
121.84
118.47
116.63
77.42
77.16
76.91
41.45
33.47
32.30
32.02
29.74
29.73
29.67
29.61
29.45
26.88
22.81
21.83
14.24
ppm

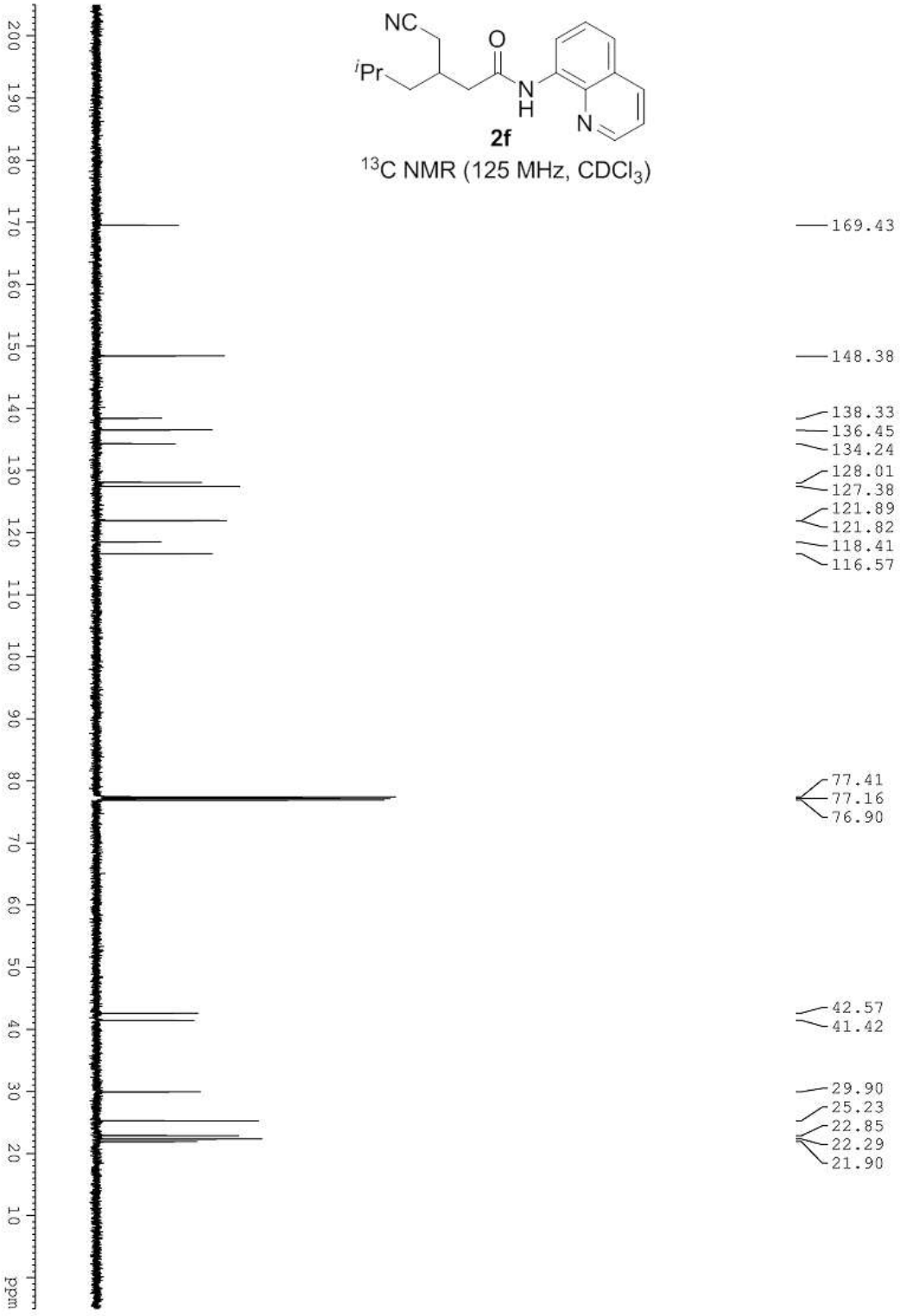

NC
O
Ph
2
N
H
N
2d
1H NMR (500 MHz, CDCl3)
0.98
0.98
1.00
0.97
1.95
1.04
2.09
2.95
6.13
1.04
2.02
ppm
8.819
8.814
8.811
8.743
8.738
8.731
8.726
8.179
8.176
8.162
8.159
7.558
7.542
7.535
7.529
7.519
7.481
7.473
7.465
7.457
7.305
7.289
7.275
7.260
7.219
7.214
7.204
7.197
7.183
2.805
2.795
2.775
2.764
2.748
2.731
2.712
2.702
2.696
2.689
2.681
2.674
2.664
2.656
2.519
2.506
2.493
1.950
1.944
1.935
1.930
1.922
1.918
1.912
1.904
1.898

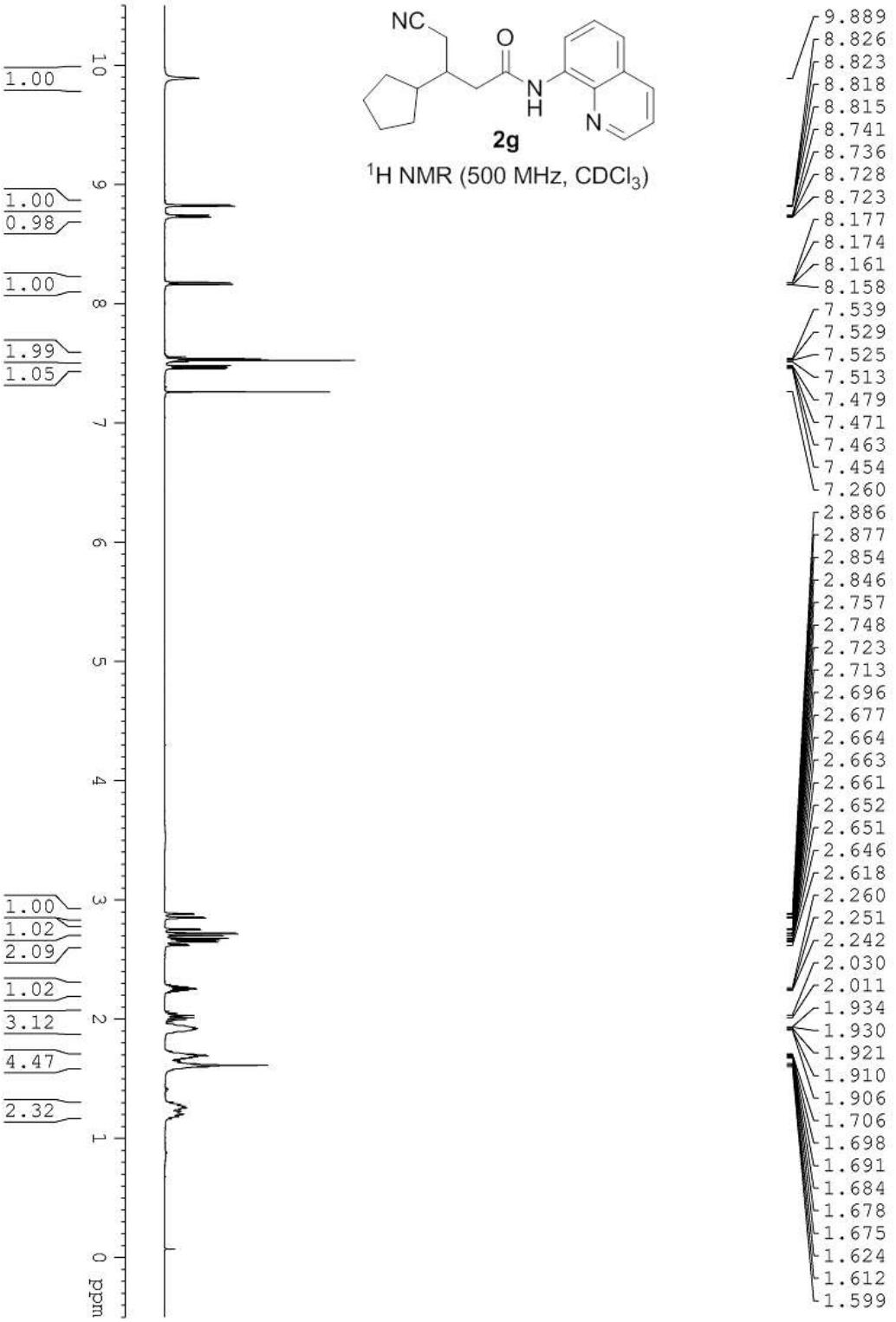

NC
O
Ph
2
N
H
N
2d
$^{13}$C NMR (125 MHz, CDCl$_3$)
169.21
148.42
140.98
138.37
136.50
134.22
128.71
128.42
128.06
127.41
126.33
121.98
121.86
118.27
116.65
77.41
77.16
76.90
41.25
35.12
33.19
31.93
21.82
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

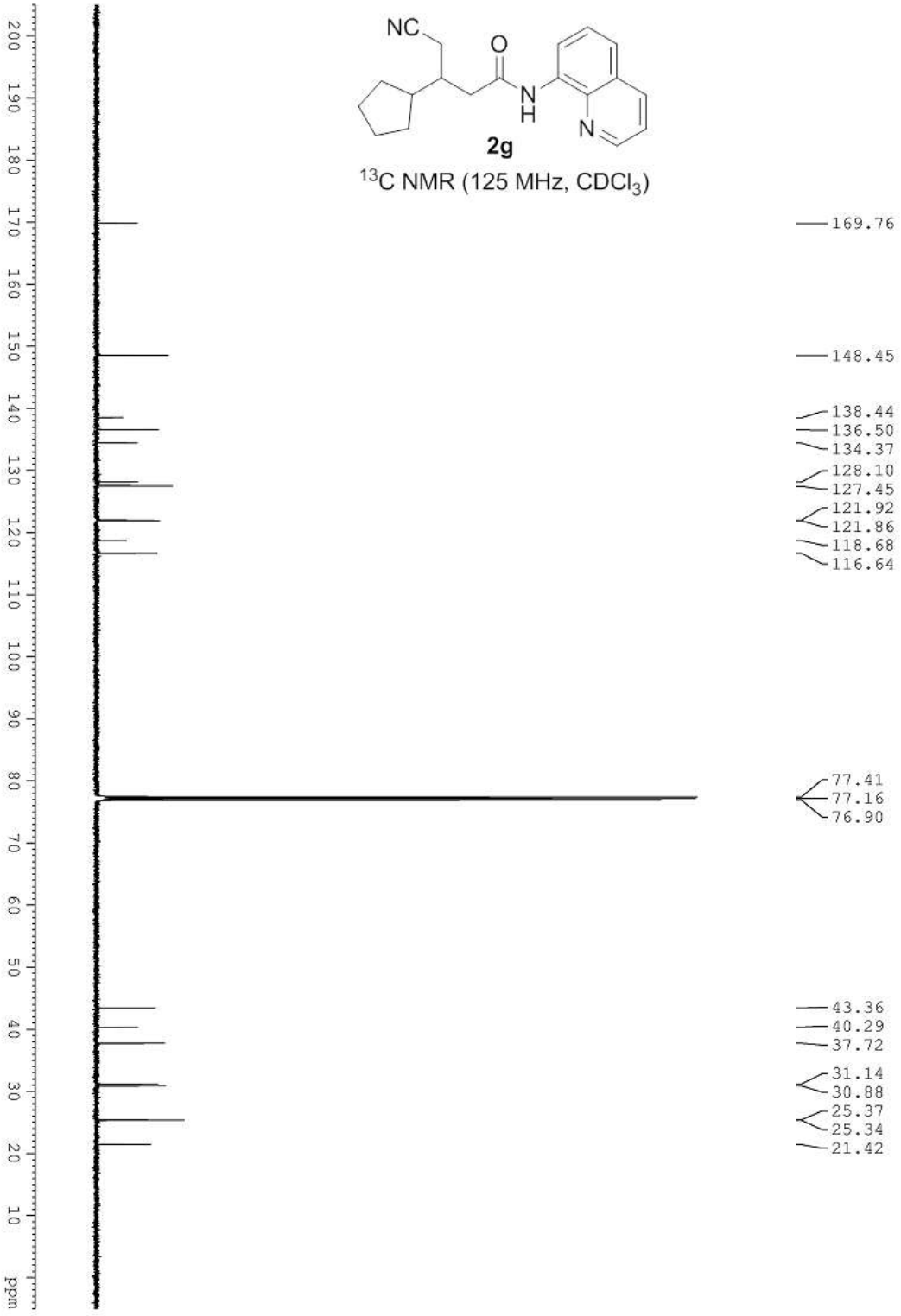

NC
O
Ph
N
H
N
2e
$^1$H NMR (500 MHz, $CDCl_3$)
8.804
8.801
8.731
8.726
8.719
8.713
8.168
8.165
8.152
8.149
7.547
7.530
7.523
7.518
7.506
7.471
7.463
7.455
7.447
7.333
7.330
7.318
7.307
7.303
7.260
7.253
7.247
7.241
7.237
7.222
2.948
2.932
2.922
2.818
2.802
2.776
2.771
2.764
2.753
2.743
2.739
2.733
2.722
2.704
2.690
2.605
2.597
2.571
2.563
2.487
2.479
2.453
2.445
10
9
8
7
6
5
4
3
2
1
0
ppm

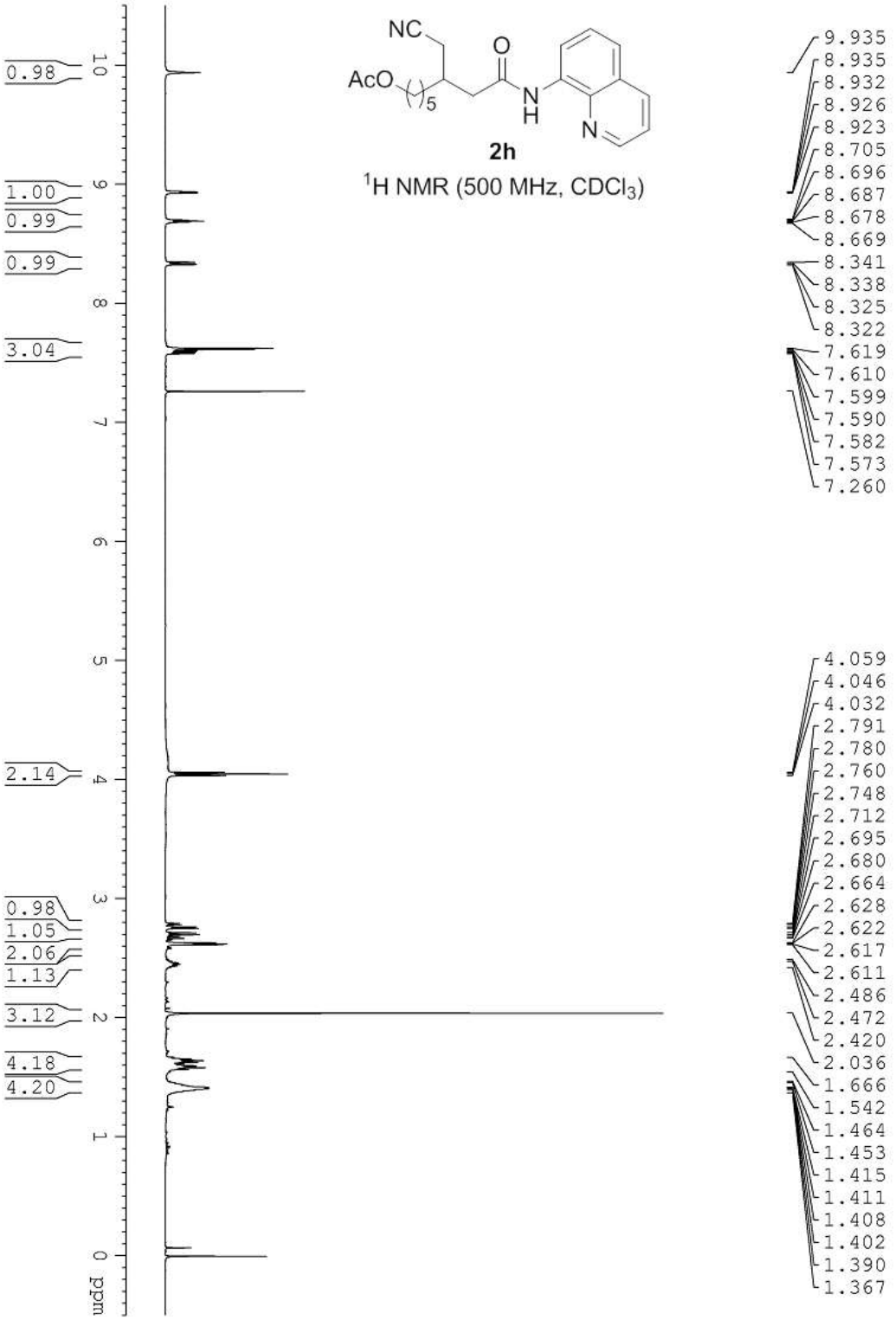

NC
O
Ph
N
H
N
2e
$^{13}$C NMR (125 MHz, $CDCl_3$)
169.18
148.44
138.40
138.31
136.52
134.25
129.28
128.93
128.08
127.44
126.99
122.00
121.88
118.33
116.67
77.41
77.16
76.90
40.77
39.52
34.23
21.25
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

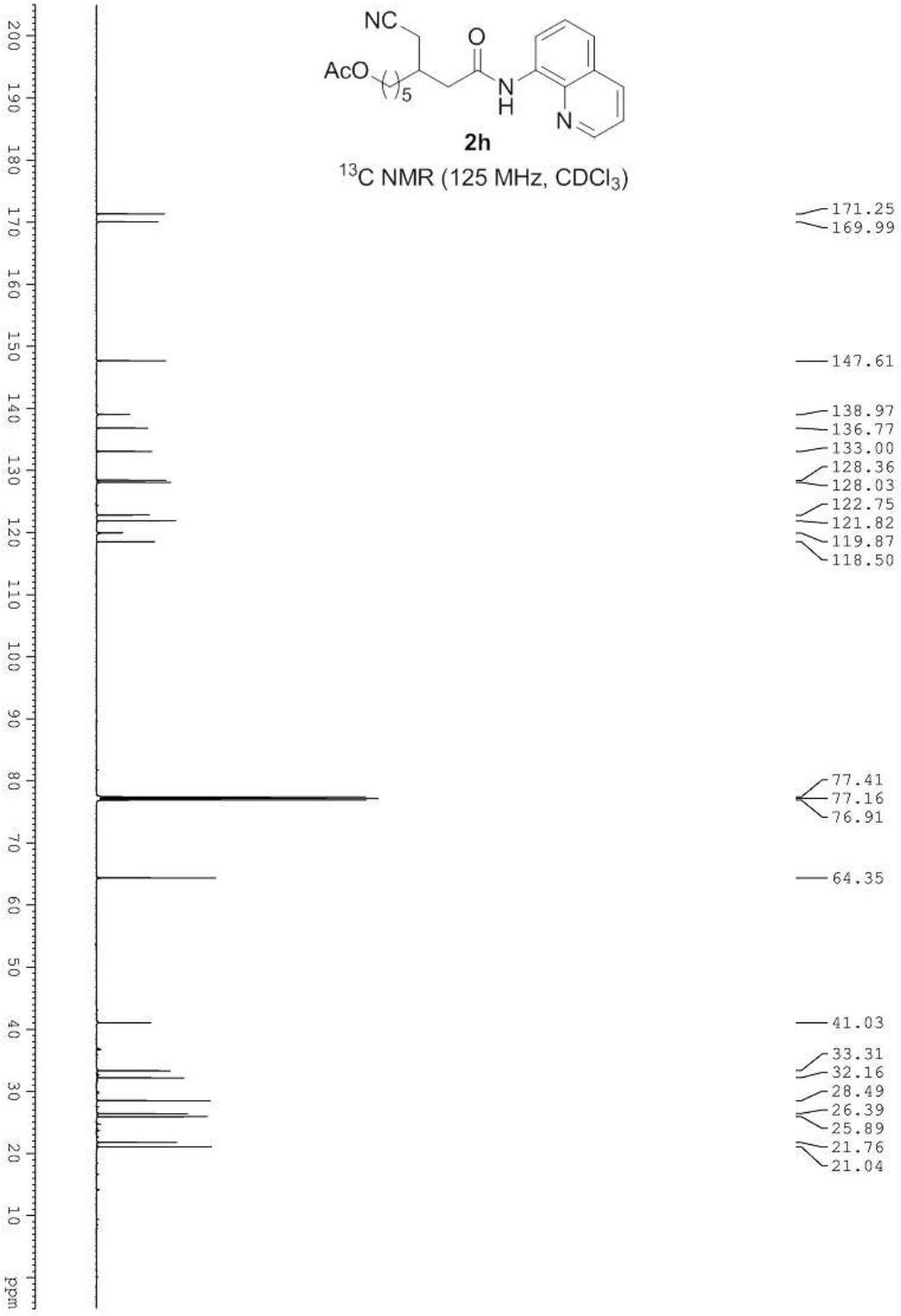

NC
O
iPr
N
H
N
2f
1H NMR (500 MHz, CDCl3)
9.862
8.805
8.802
8.797
8.794
8.737
8.732
8.724
8.719
8.158
8.155
8.142
8.139
7.541
7.525
7.514
7.511
7.498
7.461
7.452
7.444
7.436
7.260
2.726
2.716
2.696
2.686
2.667
2.657
2.643
2.634
2.626
2.612
2.595
2.587
2.578
2.553
2.545
2.536
2.522
2.511
1.724
1.711
1.698
1.684
1.671
1.481
1.467
1.453
1.439
1.424
1.409
0.98
0.99
0.99
1.00
2.01
1.04
5.13
1.04
2.13
6.00
ppm

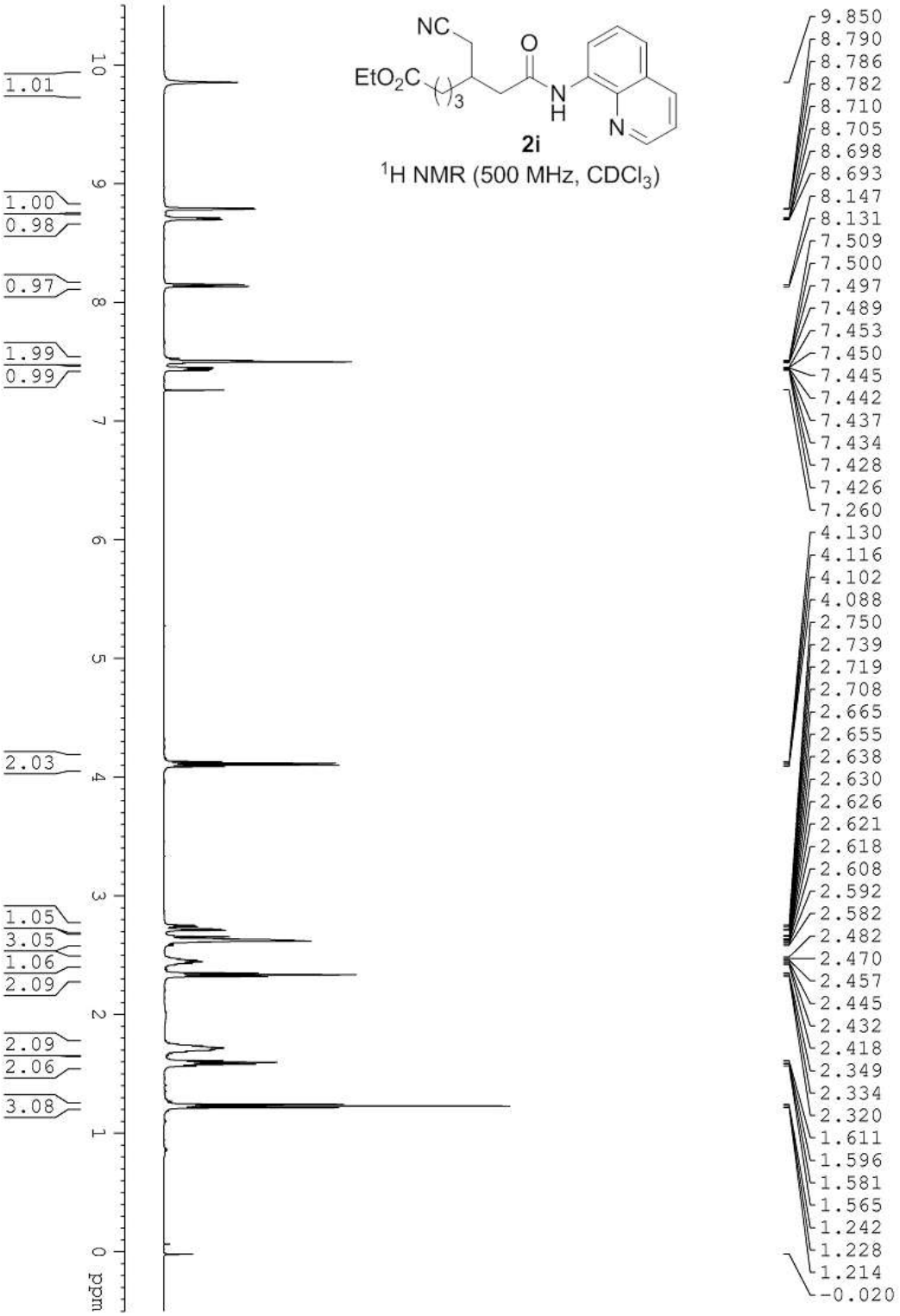

NC
O
iPr
N
H
N
2f
13C NMR (125 MHz, CDCl3)
169.43
148.38
138.33
136.45
134.24
128.01
127.38
121.89
121.82
118.41
116.57
77.41
77.16
76.90
42.57
41.42
29.90
25.23
22.85
22.29
21.90
ppm

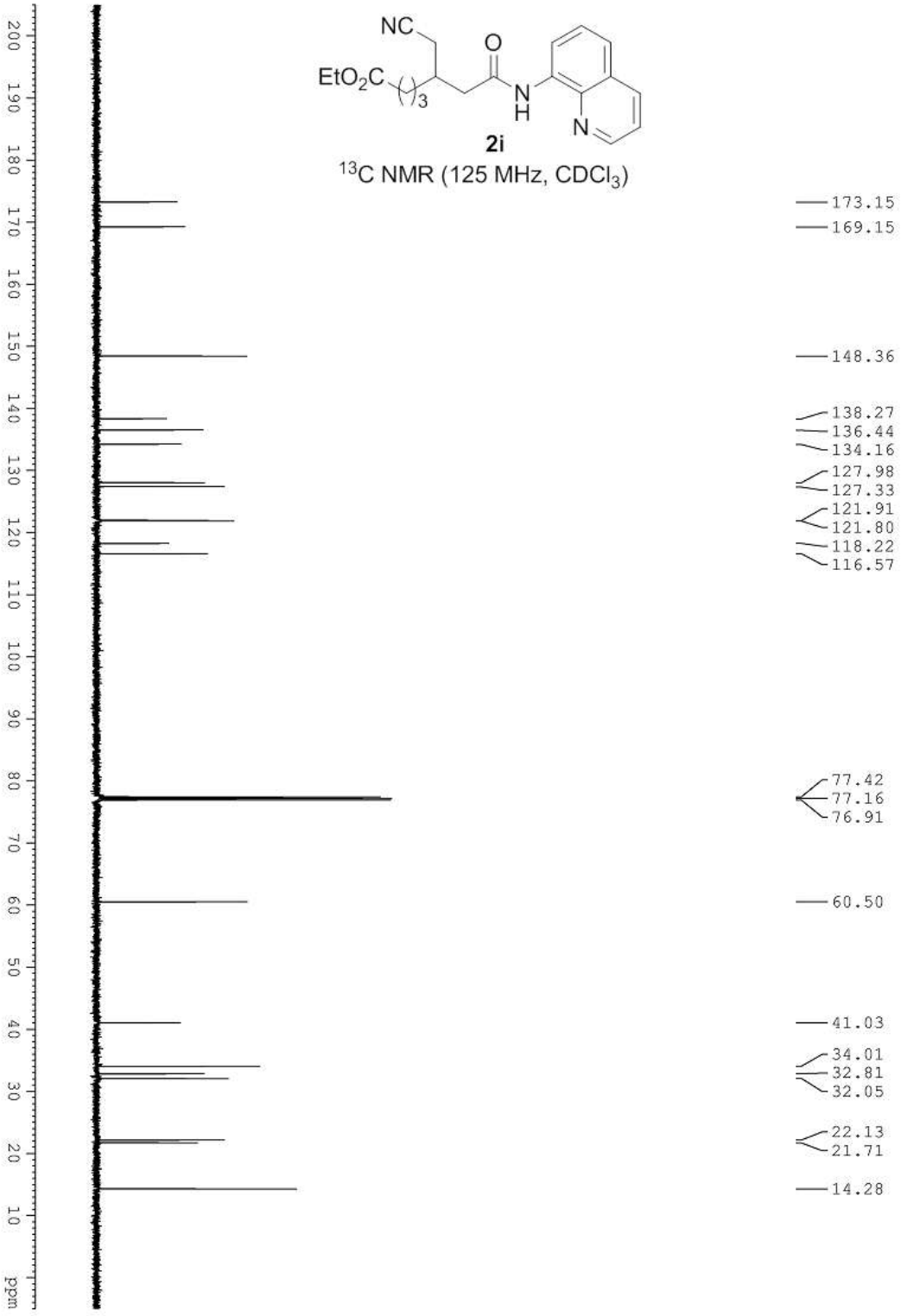

NC
O
N
H
N
2g
$^1$H NMR (500 MHz, $CDCl_3$)
1.00
1.00
0.98
1.00
1.99
1.05
1.00
1.02
2.09
1.02
3.12
4.47
2.32
ppm
9.889
8.826
8.823
8.818
8.815
8.741
8.736
8.728
8.723
8.177
8.174
8.161
8.158
7.539
7.529
7.525
7.513
7.479
7.471
7.463
7.454
7.260
2.886
2.877
2.854
2.846
2.757
2.748
2.723
2.713
2.696
2.677
2.664
2.663
2.661
2.652
2.651
2.646
2.618
2.260
2.251
2.242
2.030
2.011
1.934
1.930
1.921
1.910
1.906
1.706
1.698
1.691
1.684
1.678
1.675
1.624
1.612
1.599

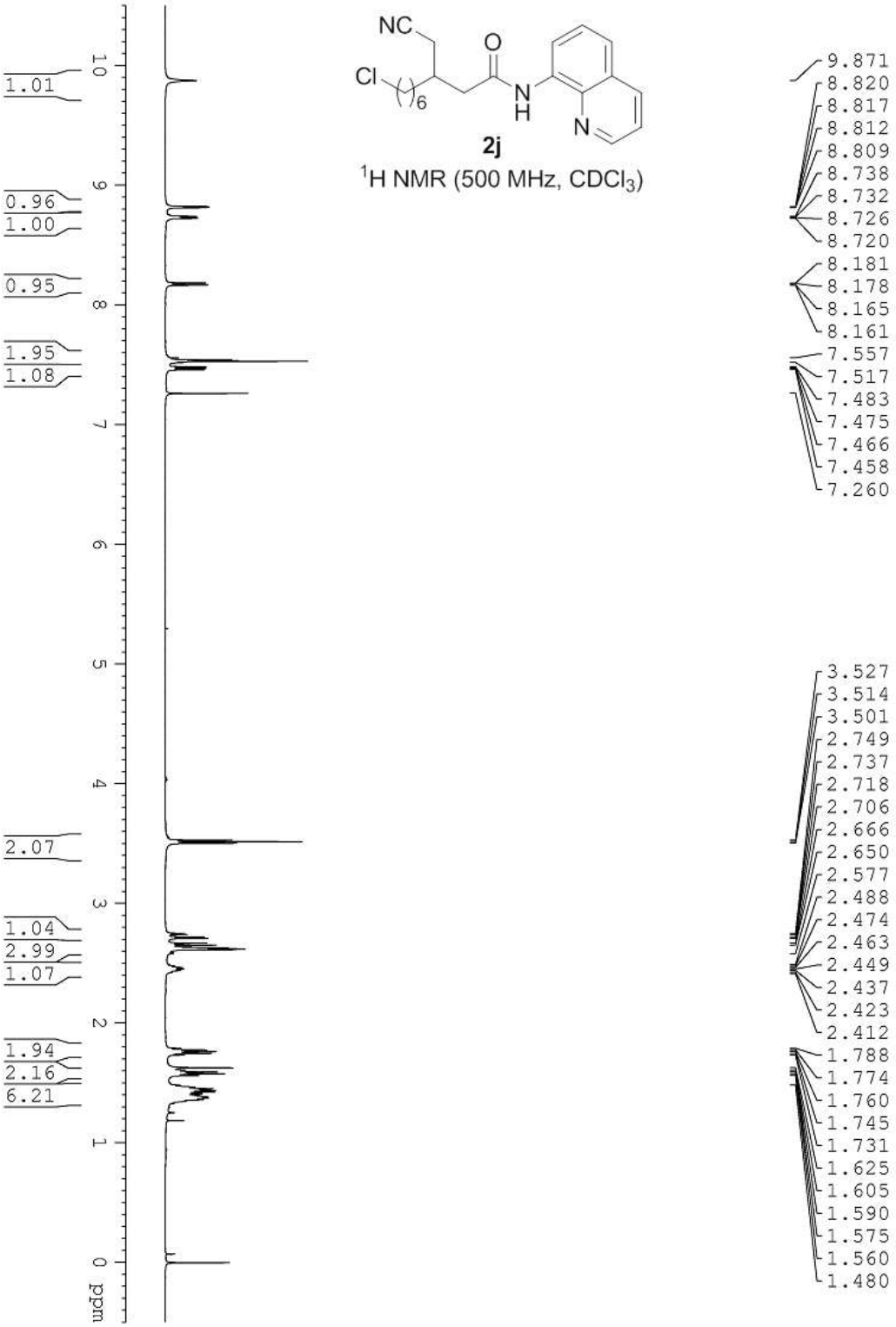

NC
O
N
H
N
2g
$^{13}$C NMR (125 MHz, $CDCl_3$)
169.76
148.45
138.44
136.50
134.37
128.10
127.45
121.92
121.86
118.68
116.64
77.41
77.16
76.90
43.36
40.29
37.72
31.14
30.88
25.37
25.34
21.42
ppm

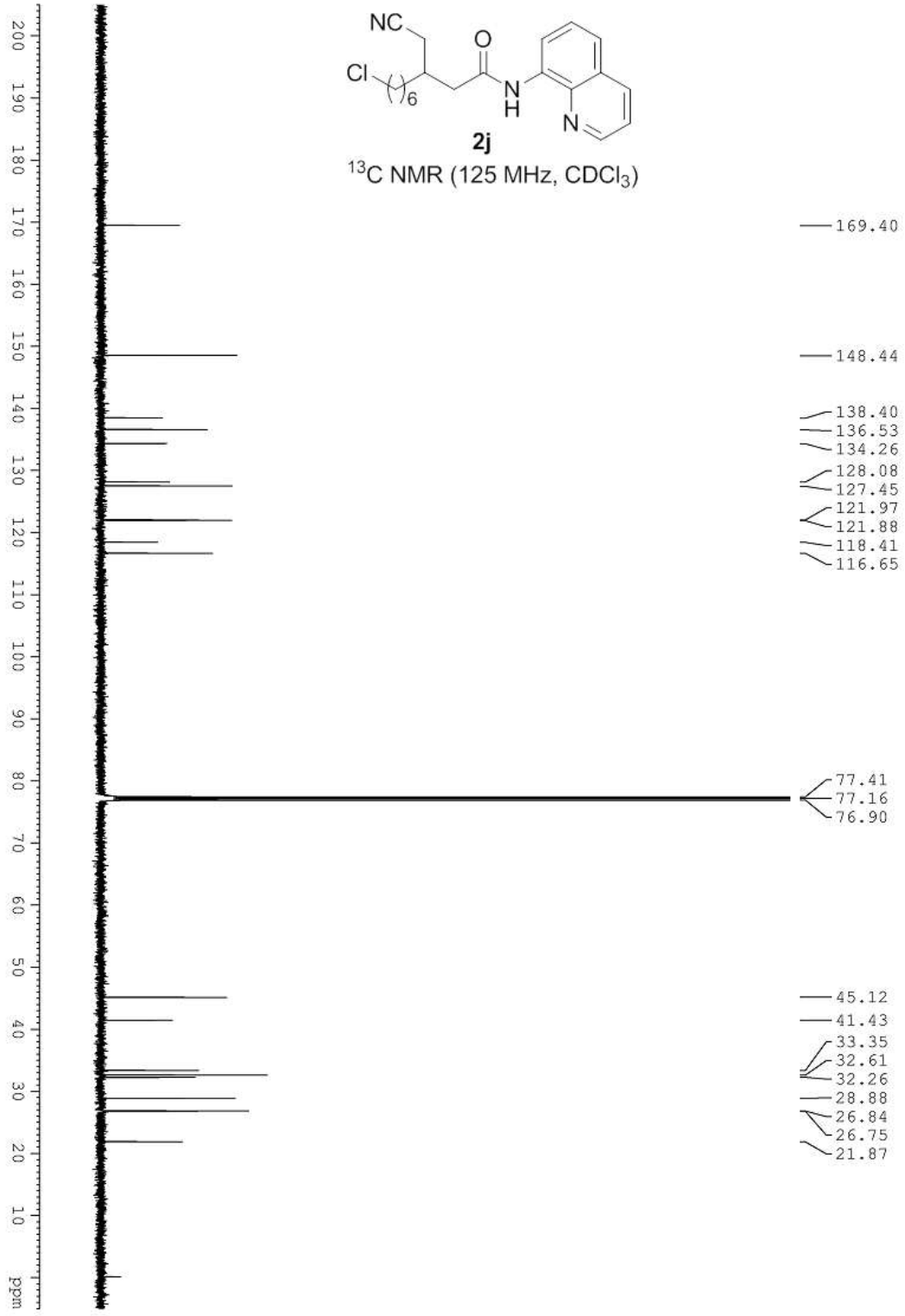

NC
O
AcO
5
N
H
N
2h
1H NMR (500 MHz, CDCl3)
9.935
8.935
8.932
8.926
8.923
8.705
8.696
8.687
8.678
8.669
8.341
8.338
8.325
8.322
7.619
7.610
7.599
7.590
7.582
7.573
7.260
4.059
4.046
4.032
2.791
2.780
2.760
2.748
2.712
2.695
2.680
2.664
2.628
2.622
2.617
2.611
2.486
2.472
2.420
2.036
1.666
1.542
1.464
1.453
1.415
1.411
1.408
1.402
1.390
1.367
0.98
1.00
0.99
0.99
3.04
2.14
0.98
1.05
2.06
1.13
3.12
4.18
4.20
ppm

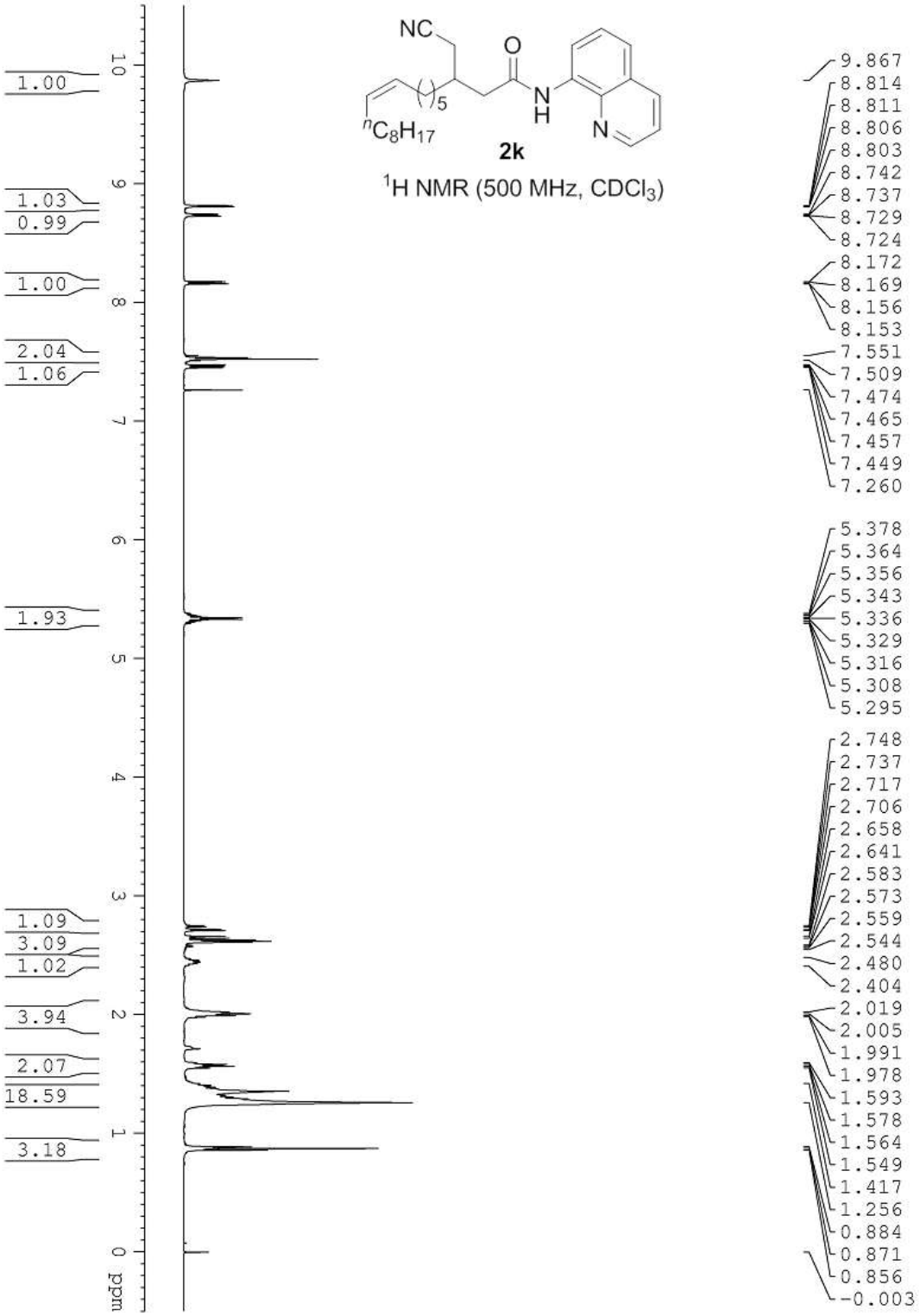

NC
O
AcO
5
N
H
N
2h
13C NMR (125 MHz, CDCl3)
171.25
169.99
147.61
138.97
136.77
133.00
128.36
128.03
122.75
121.82
119.87
118.50
77.41
77.16
76.91
64.35
41.03
33.31
32.16
28.49
26.39
25.89
21.76
21.04
ppm

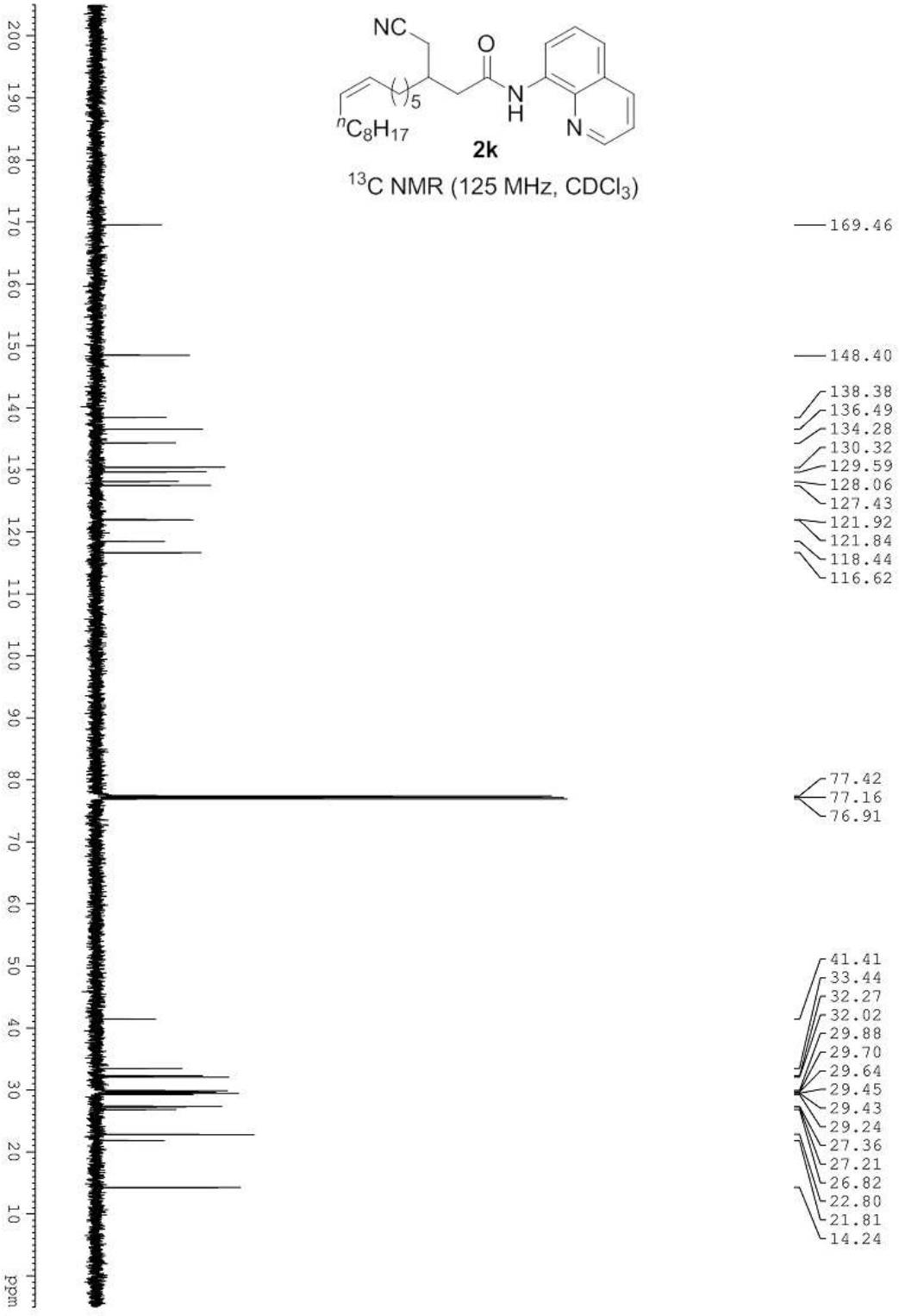

NC
O
EtO2C
3
N
H
N
2i
1H NMR (500 MHz, CDCl3)
1.01
1.00
0.98
0.97
1.99
0.99
2.03
1.05
3.05
1.06
2.09
2.09
2.06
3.08
ppm
9.850
8.790
8.786
8.782
8.710
8.705
8.698
8.693
8.147
8.131
7.509
7.500
7.497
7.489
7.453
7.450
7.445
7.442
7.437
7.434
7.428
7.426
7.260
4.130
4.116
4.102
4.088
2.750
2.739
2.719
2.708
2.665
2.655
2.638
2.630
2.626
2.621
2.618
2.608
2.592
2.582
2.482
2.470
2.457
2.445
2.432
2.418
2.349
2.334
2.320
1.611
1.596
1.581
1.565
1.242
1.228
1.214
-0.020

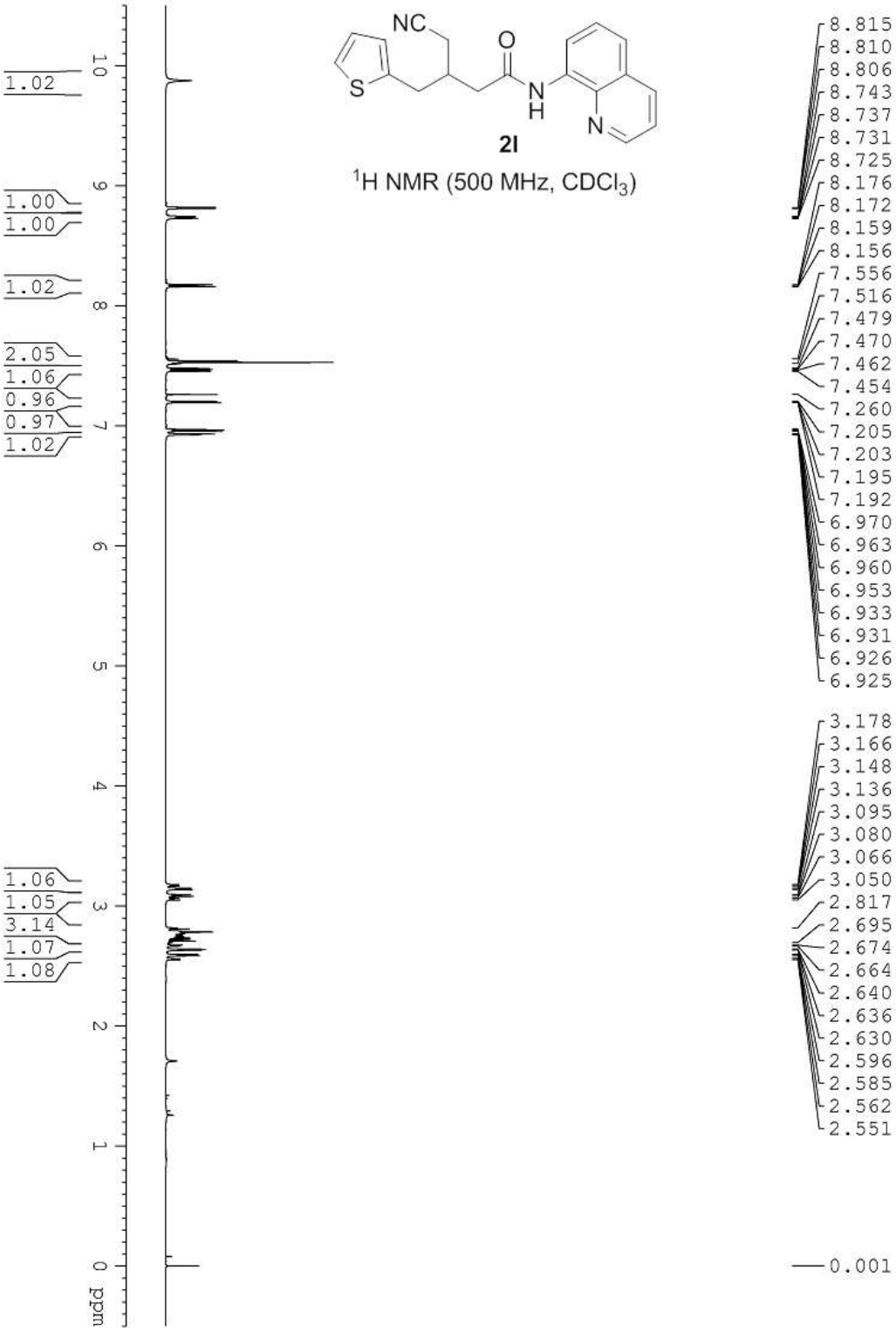

NC
O
EtO2C
3
N
H
N
2i
13C NMR (125 MHz, CDCl3)
173.15
169.15
148.36
138.27
136.44
134.16
127.98
127.33
121.91
121.80
118.22
116.57
77.42
77.16
76.91
60.50
41.03
34.01
32.81
32.05
22.13
21.71
14.28
ppm

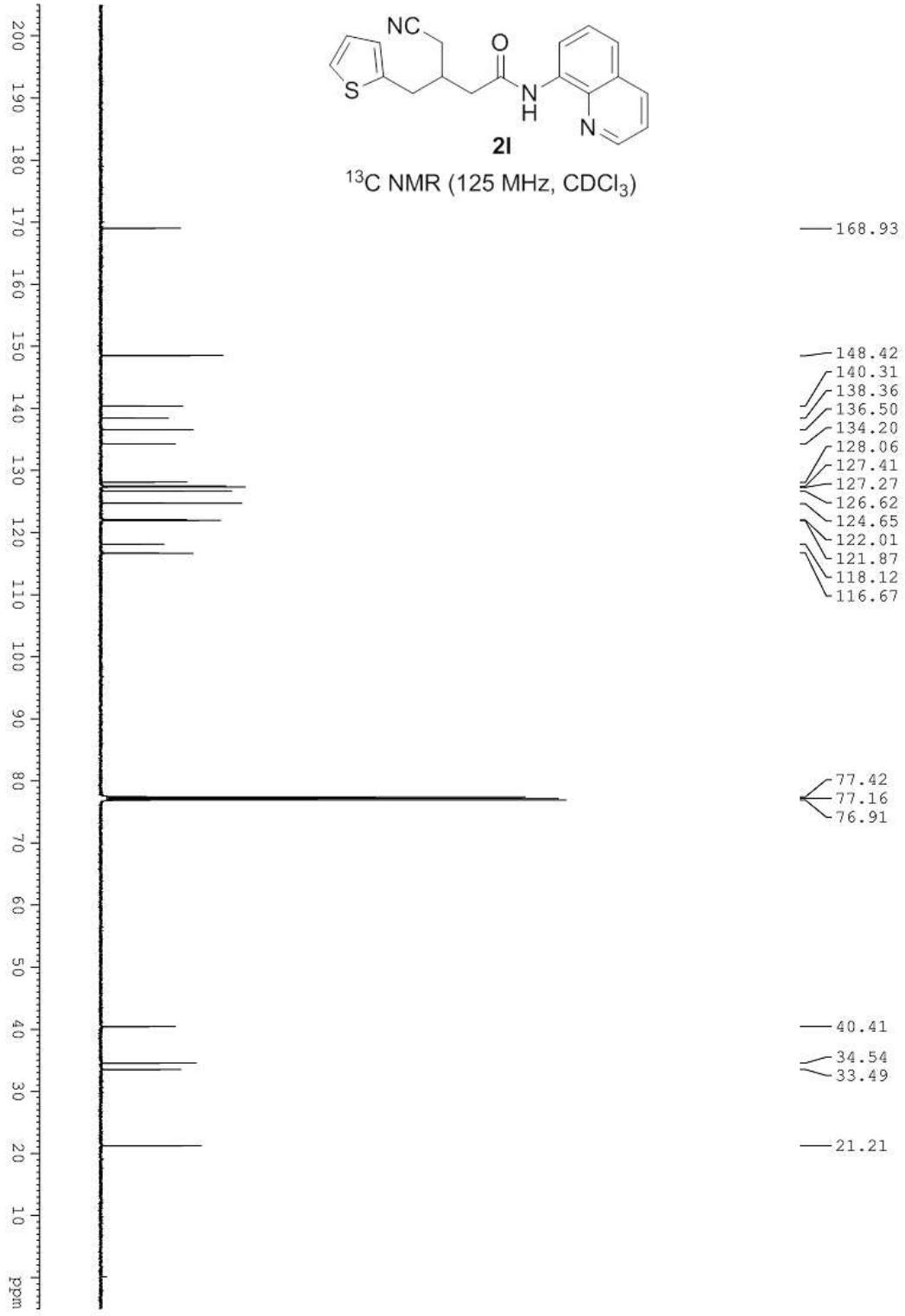

NC
O
Cl
6
N
H
N
2j
1H NMR (500 MHz, CDCl3)
1.01
0.96
1.00
0.95
1.95
1.08
2.07
1.04
2.99
1.07
1.94
2.16
6.21
ppm
9.871
8.820
8.817
8.812
8.809
8.738
8.732
8.726
8.720
8.181
8.178
8.165
8.161
7.557
7.517
7.483
7.475
7.466
7.458
7.260
3.527
3.514
3.501
2.749
2.737
2.718
2.706
2.666
2.650
2.577
2.488
2.474
2.463
2.449
2.437
2.423
2.412
1.788
1.774
1.760
1.745
1.731
1.625
1.605
1.590
1.575
1.560
1.480

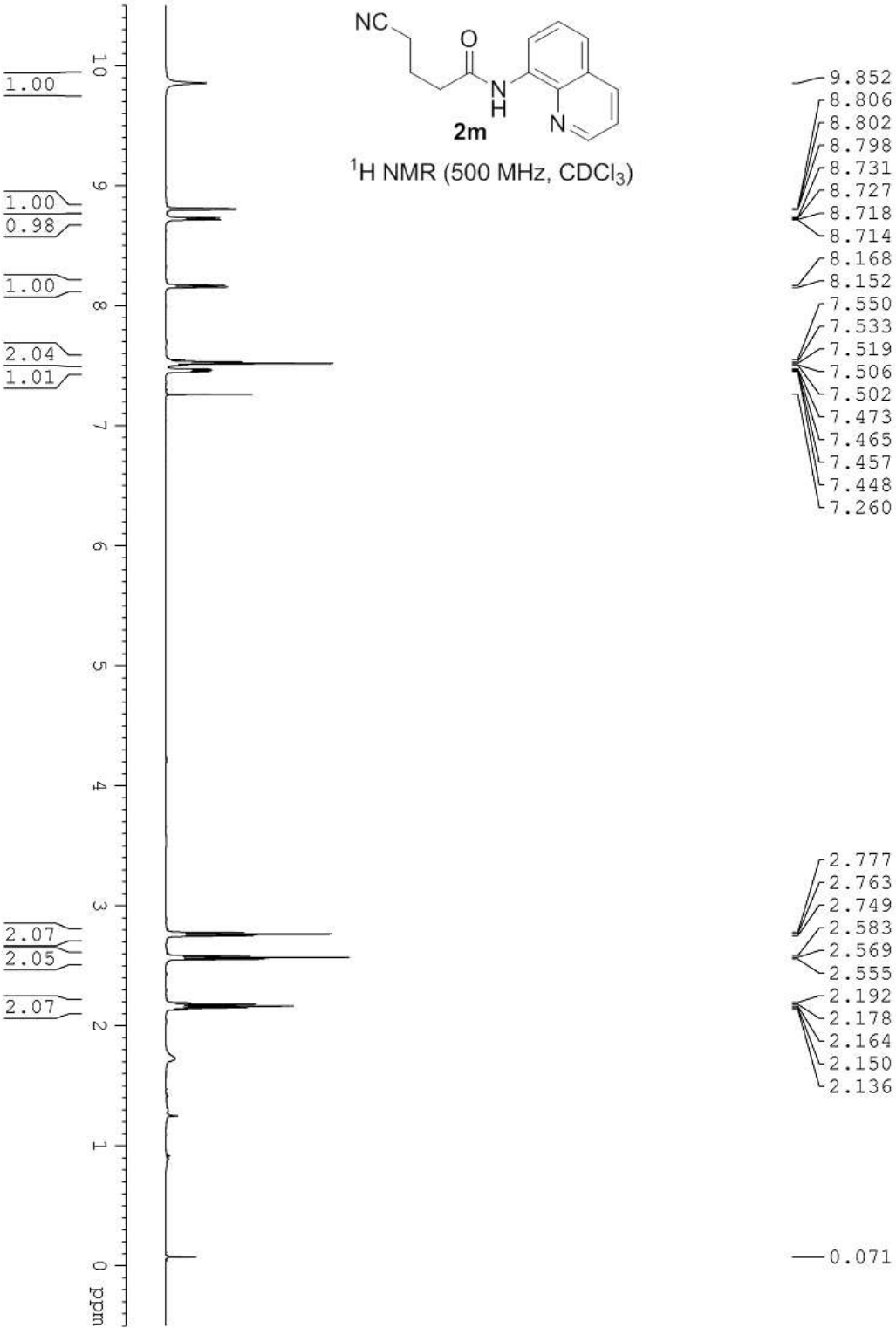

NC
O
Cl
6
N
H
N
2j
13C NMR (125 MHz, CDCl3)
169.40
148.44
138.40
136.53
134.26
128.08
127.45
121.97
121.88
118.41
116.65
77.41
77.16
76.90
45.12
41.43
33.35
32.61
32.26
28.88
26.84
26.75
21.87
ppm

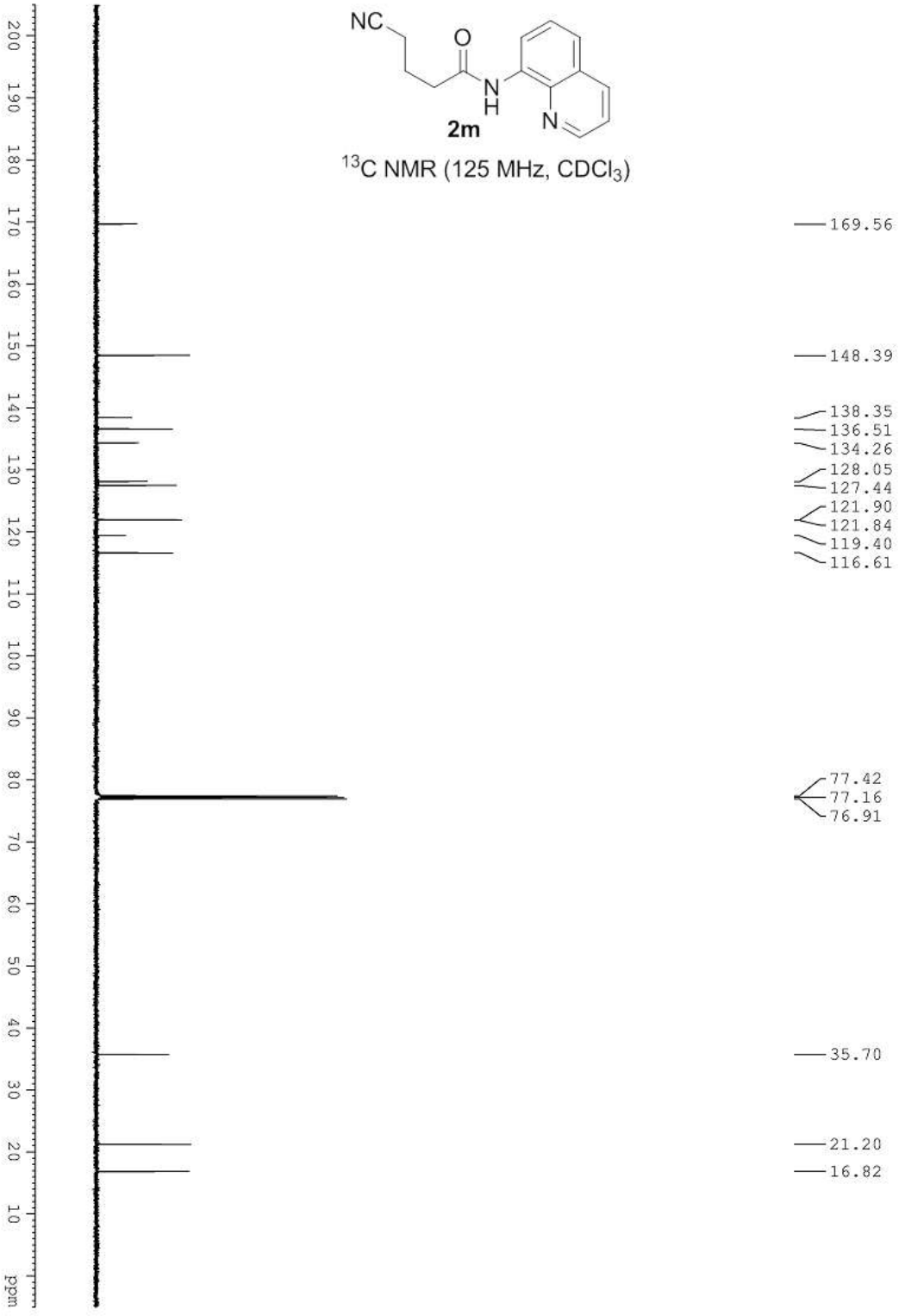

NC
O
N
H
N
5
$^n$C$_8$H$_{17}$
2k
$^1$H NMR (500 MHz, CDCl$_3$)
1.00
1.03
0.99
1.00
2.04
1.06
1.93
1.09
3.09
1.02
3.94
2.07
18.59
3.18
ppm
9.867
8.814
8.811
8.806
8.803
8.742
8.737
8.729
8.724
8.172
8.169
8.156
8.153
7.551
7.509
7.474
7.465
7.457
7.449
7.260
5.378
5.364
5.356
5.343
5.336
5.329
5.316
5.308
5.295
2.748
2.737
2.717
2.706
2.658
2.641
2.583
2.573
2.559
2.544
2.480
2.404
2.019
2.005
1.991
1.978
1.593
1.578
1.564
1.549
1.417
1.256
0.884
0.871
0.856
-0.003

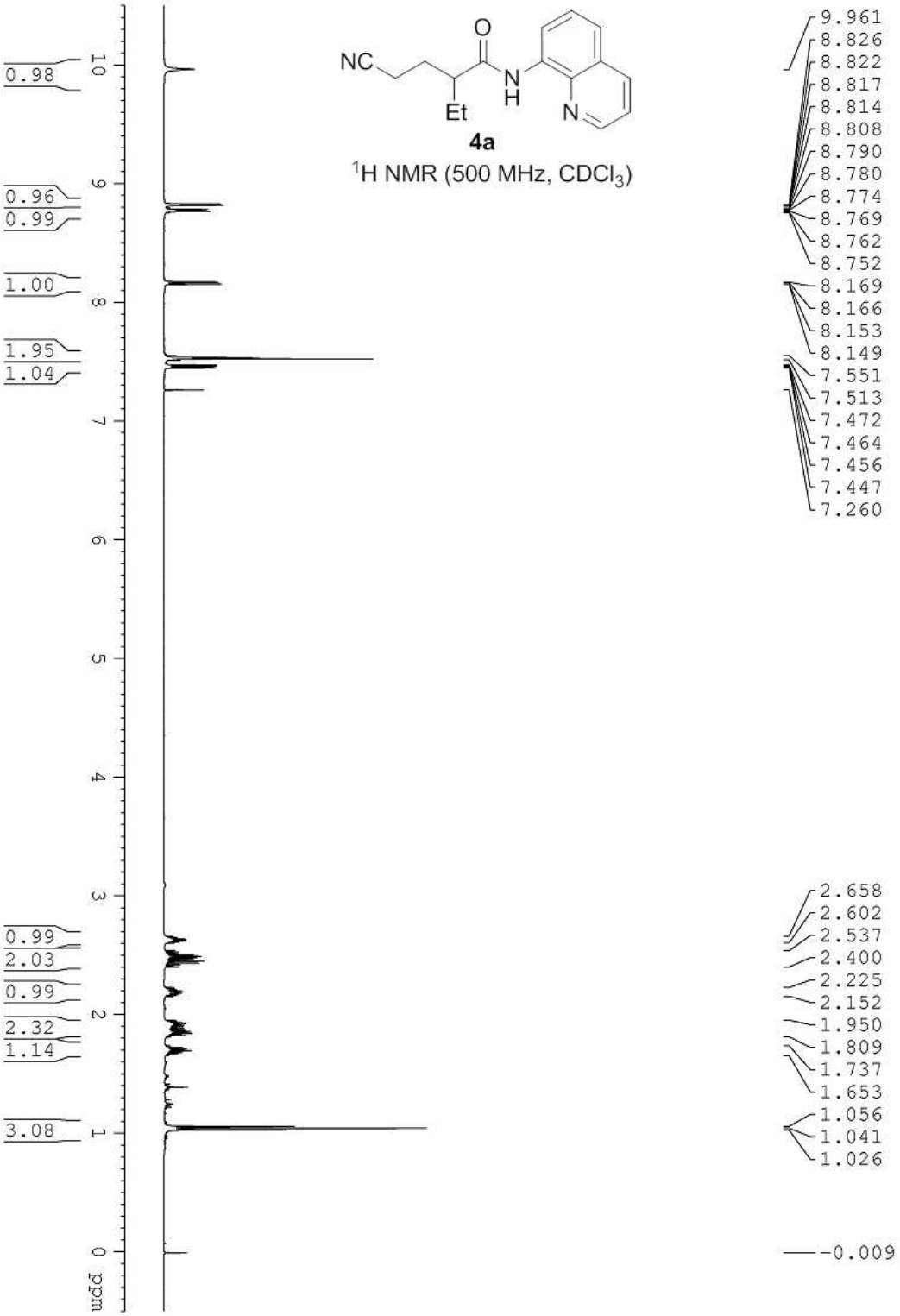

NC
O
N
H
N
$^{n}C_8H_{17}$
5
2k
$^{13}$C NMR (125 MHz, $CDCl_3$)
169.46
148.40
138.38
136.49
134.28
130.32
129.59
128.06
127.43
121.92
121.84
118.44
116.62
77.42
77.16
76.91
41.41
33.44
32.27
32.02
29.88
29.70
29.64
29.45
29.43
29.24
27.36
27.21
26.82
22.80
21.81
14.24
ppm

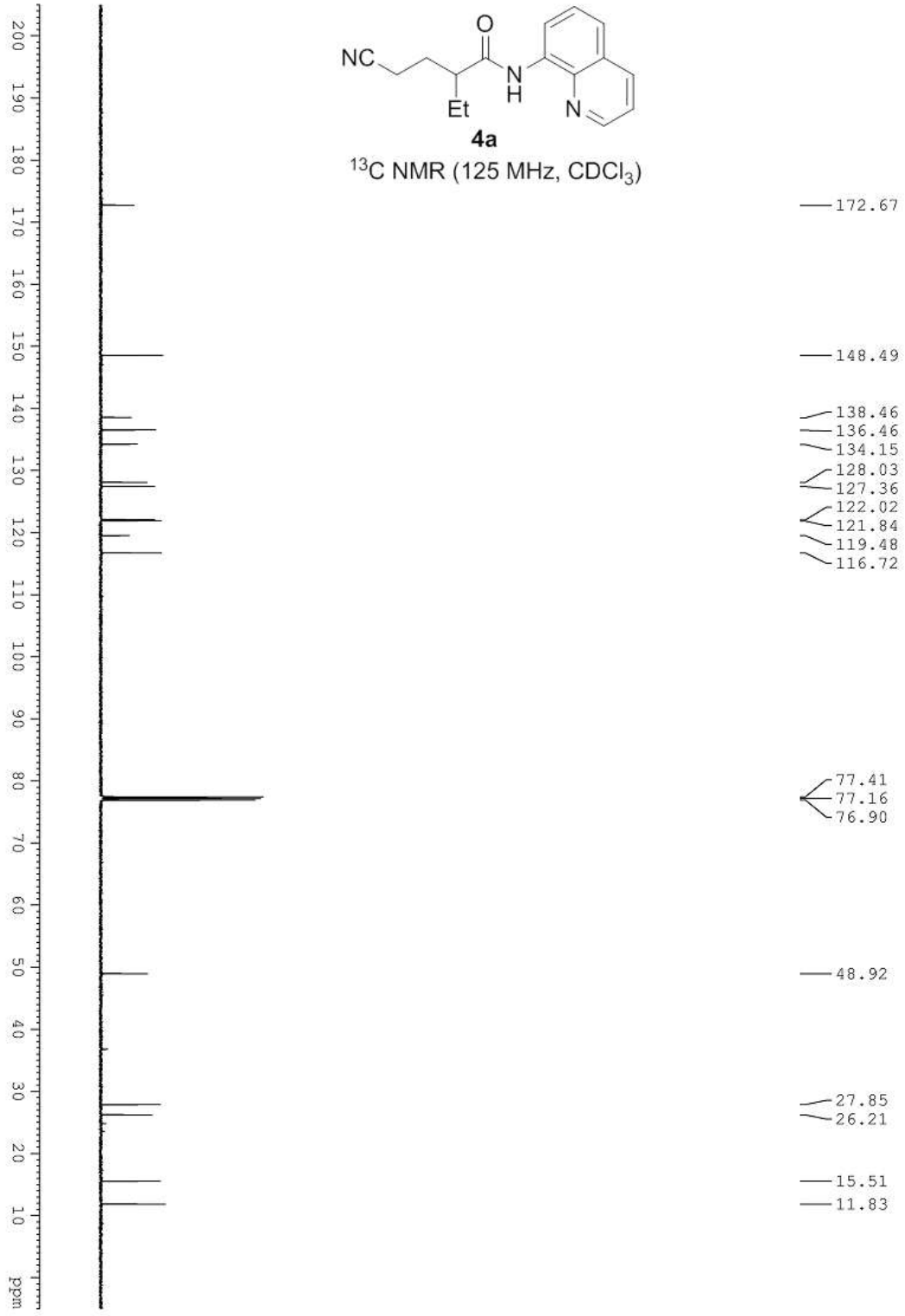

NC
O
S
N
H
N
2l
$^1$H NMR (500 MHz, $CDCl_3$)
1.02
1.00
1.00
1.02
2.05
1.06
0.96
0.97
1.02
1.06
1.05
3.14
1.07
1.08
8.815
8.810
8.806
8.743
8.737
8.731
8.725
8.176
8.172
8.159
8.156
7.556
7.516
7.479
7.470
7.462
7.454
7.260
7.205
7.203
7.195
7.192
6.970
6.963
6.960
6.953
6.933
6.931
6.926
6.925
3.178
3.166
3.148
3.136
3.095
3.080
3.066
3.050
2.817
2.695
2.674
2.664
2.640
2.636
2.630
2.596
2.585
2.562
2.551
0.001
ppm

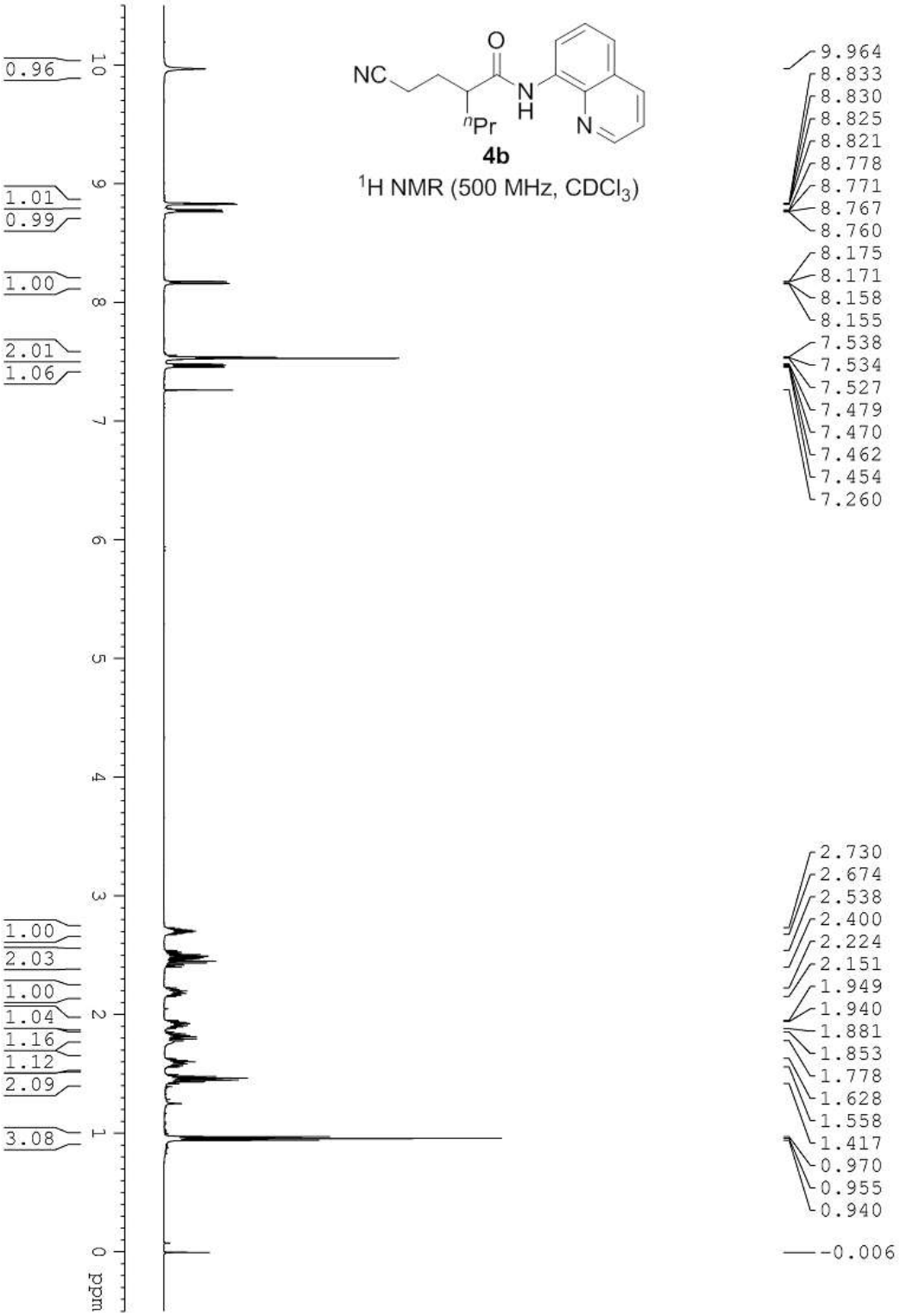

NC
O
S
N
H
N
2l
$^{13}$C NMR (125 MHz, $CDCl_3$)
168.93
148.42
140.31
138.36
136.50
134.20
128.06
127.41
127.27
126.62
124.65
122.01
121.87
118.12
116.67
77.42
77.16
76.91
40.41
34.54
33.49
21.21
ppm

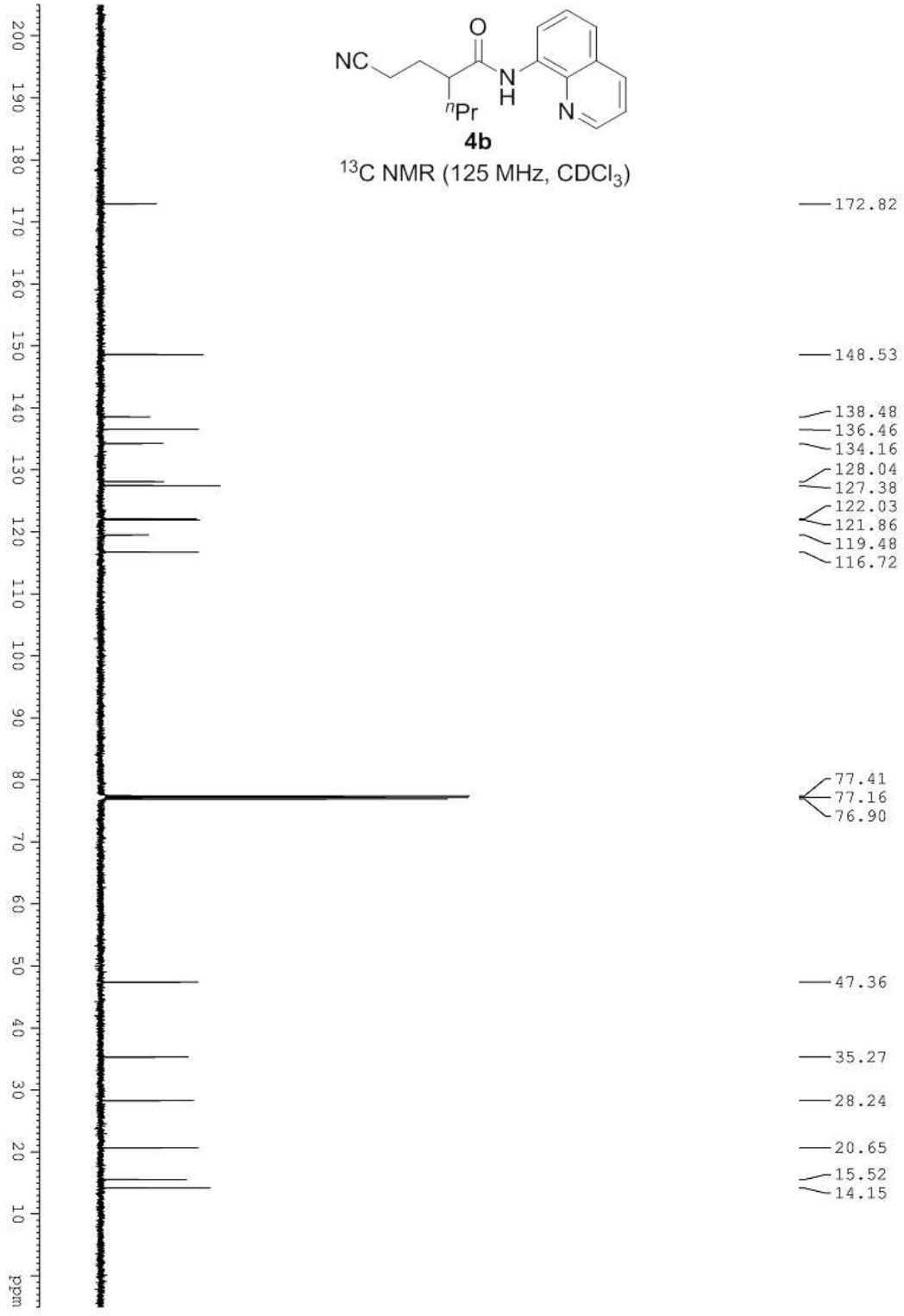

NC
O
N
H
N
2m
$^1$H NMR (500 MHz, $CDCl_3$)
1.00
1.00
0.98
1.00
2.04
1.01
2.07
2.05
2.07
9.852
8.806
8.802
8.798
8.731
8.727
8.718
8.714
8.168
8.152
7.550
7.533
7.519
7.506
7.502
7.473
7.465
7.457
7.448
7.260
2.777
2.763
2.749
2.583
2.569
2.555
2.192
2.178
2.164
2.150
2.136
0.071
ppm

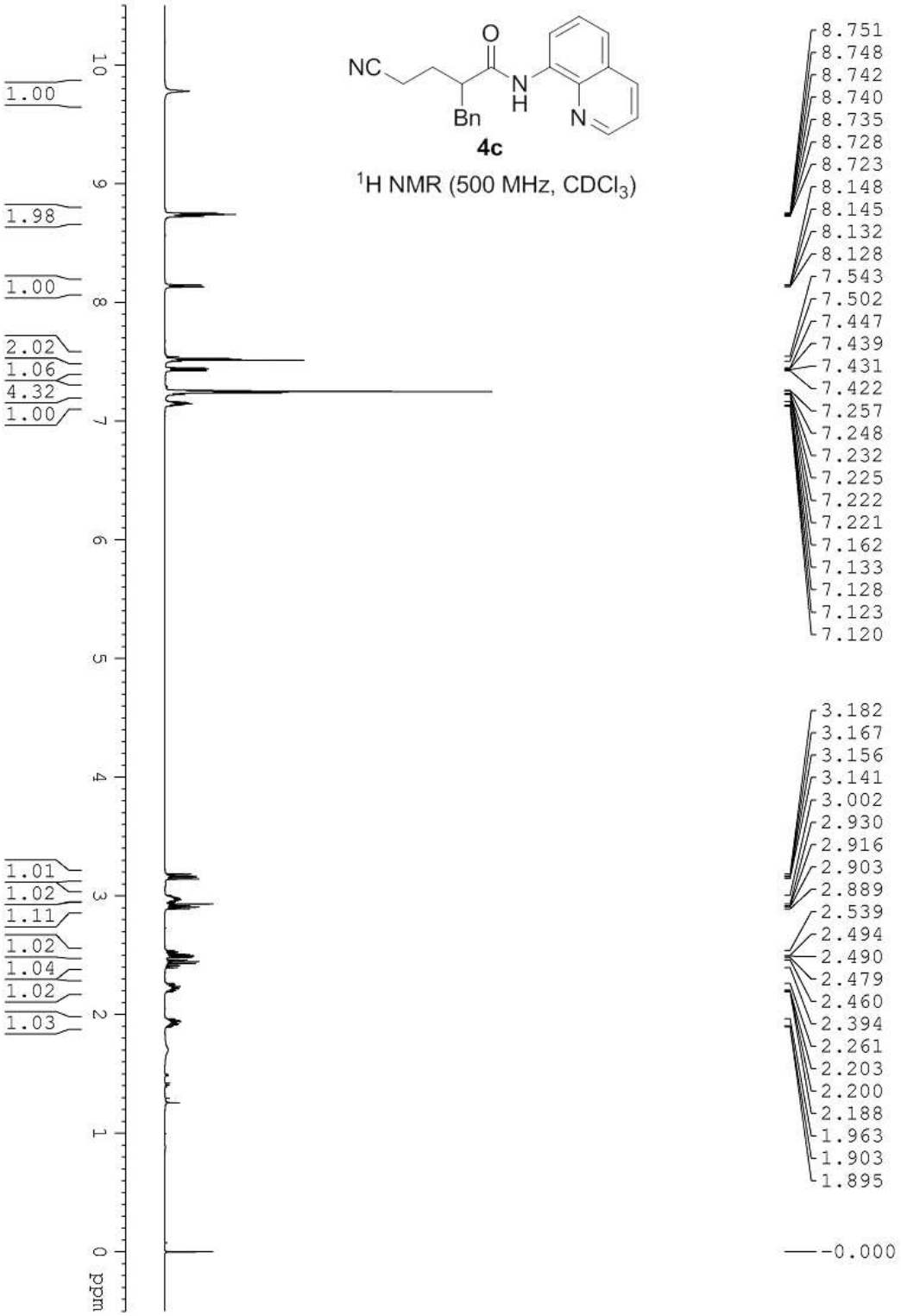

NC
O
N
H
N
2m
$^{13}$C NMR (125 MHz, $CDCl_3$)
169.56
148.39
138.35
136.51
134.26
128.05
127.44
121.90
121.84
119.40
116.61
77.42
77.16
76.91
35.70
21.20
16.82
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

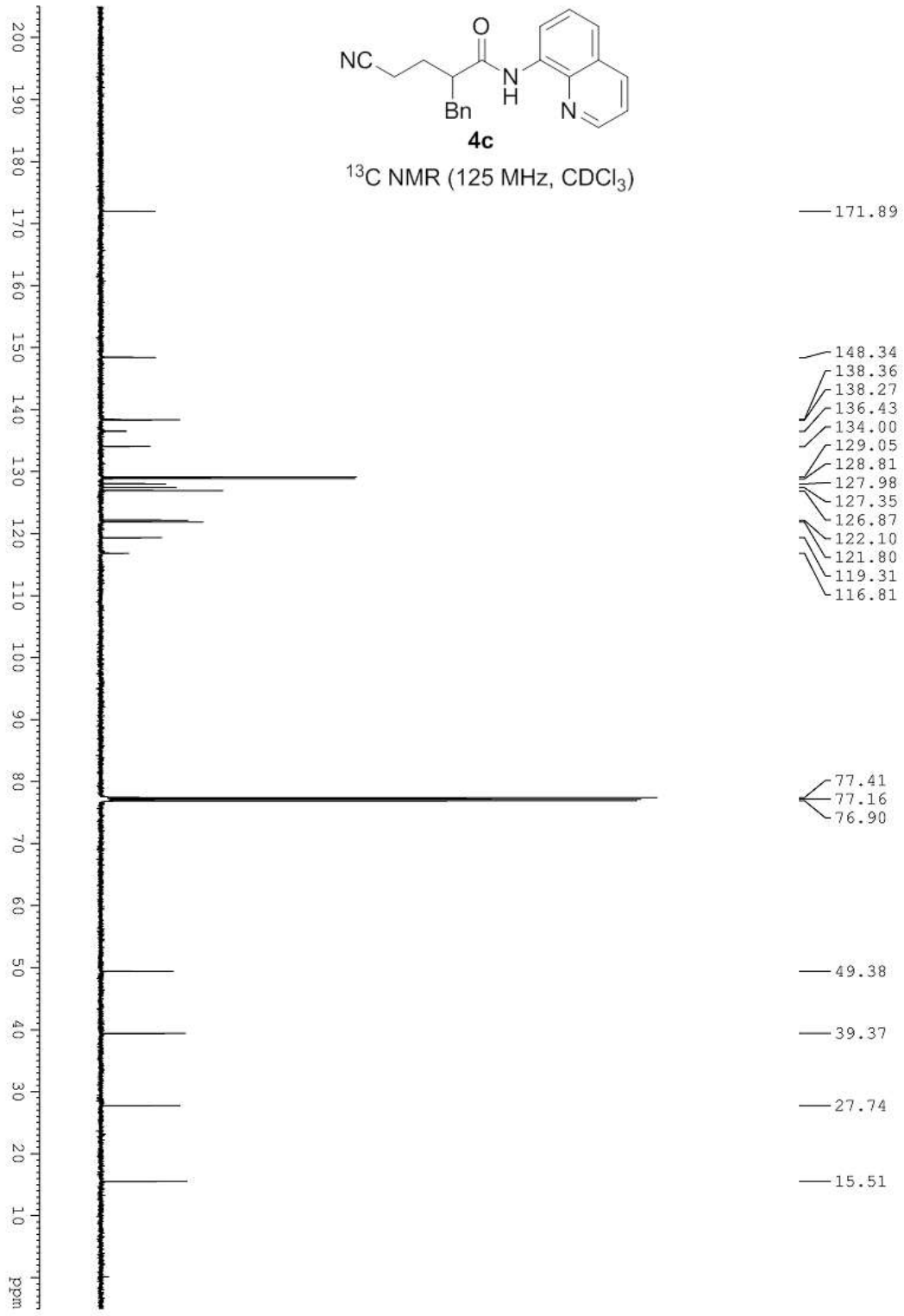

NC
O
N
H
Et
N
4a
$^1$H NMR (500 MHz, $CDCl_3$)
0.98
0.96
0.99
1.00
1.95
1.04
0.99
2.03
0.99
2.32
1.14
3.08
9.961
8.826
8.822
8.817
8.814
8.808
8.790
8.780
8.774
8.769
8.762
8.752
8.169
8.166
8.153
8.149
7.551
7.513
7.472
7.464
7.456
7.447
7.260
2.658
2.602
2.537
2.400
2.225
2.152
1.950
1.809
1.737
1.653
1.056
1.041
1.026
-0.009
ppm

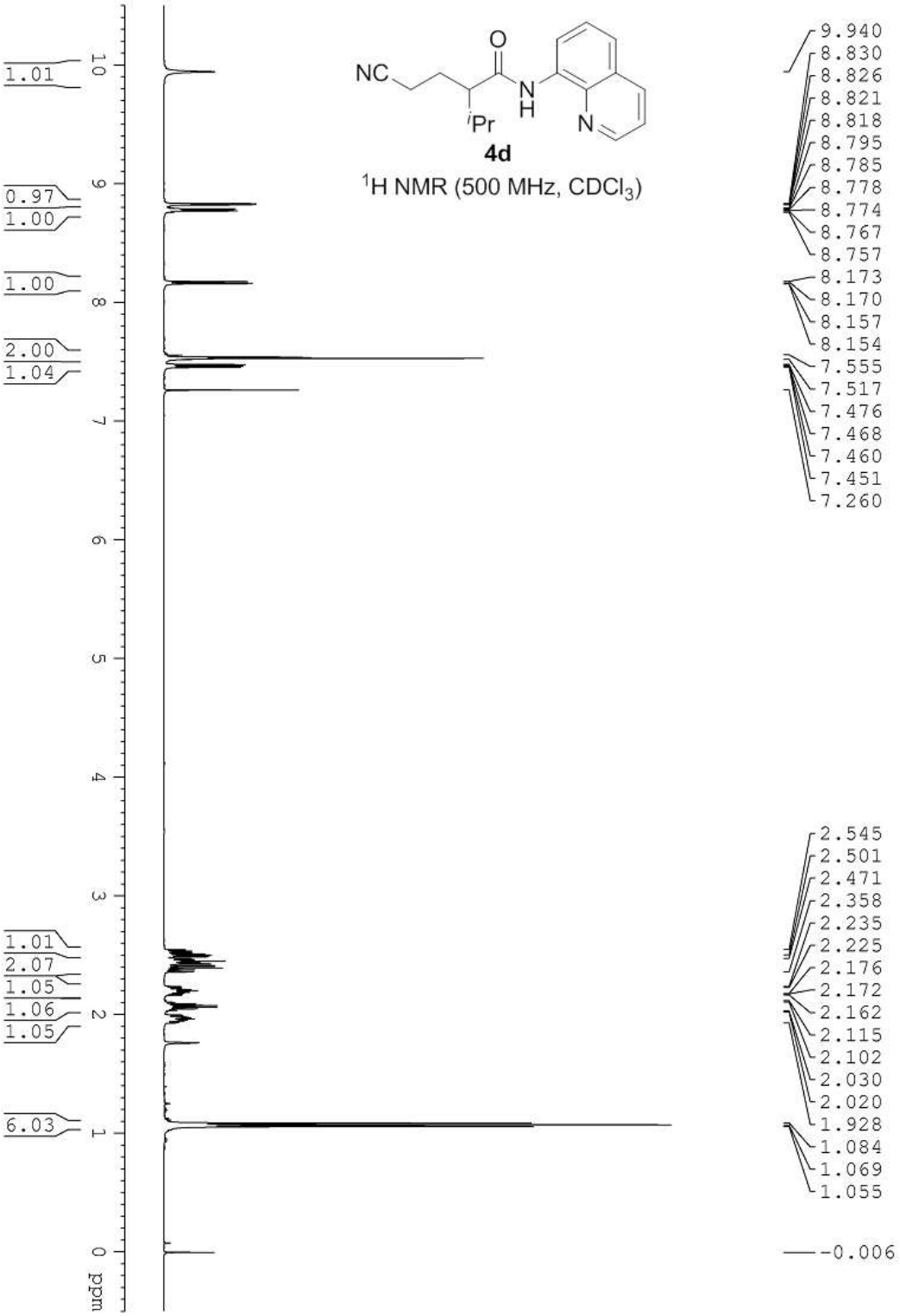

NC
O
N
H
Et
N
4a
$^{13}$C NMR (125 MHz, $CDCl_3$)
172.67
148.49
138.46
136.46
134.15
128.03
127.36
122.02
121.84
119.48
116.72
77.41
77.16
76.90
48.92
27.85
26.21
15.51
11.83
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

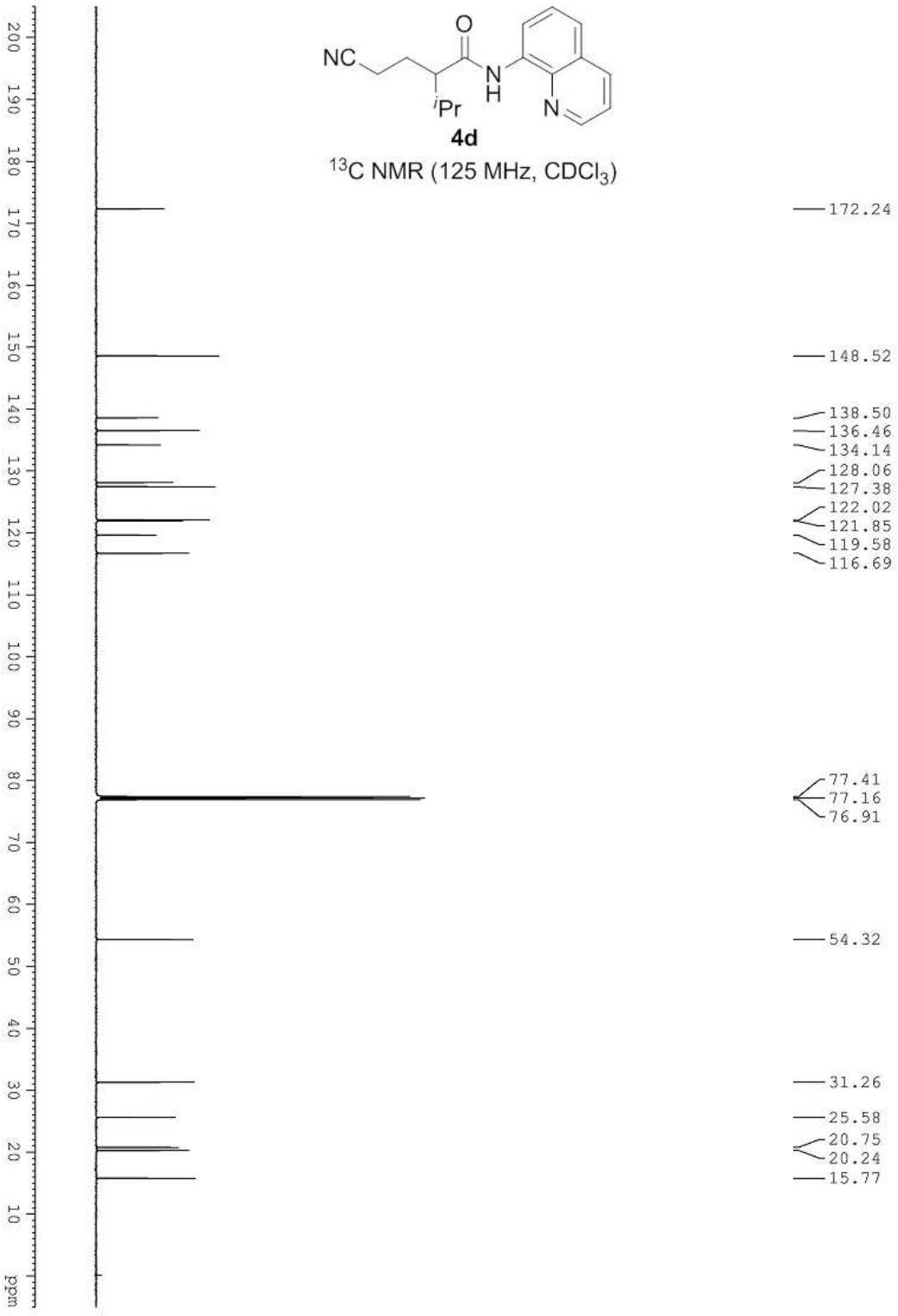

NC
O
N
H
nPr
N
4b
1H NMR (500 MHz, CDCl3)
9.964
8.833
8.830
8.825
8.821
8.778
8.771
8.767
8.760
8.175
8.171
8.158
8.155
7.538
7.534
7.527
7.479
7.470
7.462
7.454
7.260
2.730
2.674
2.538
2.400
2.224
2.151
1.949
1.940
1.881
1.853
1.778
1.628
1.558
1.417
0.970
0.955
0.940
-0.006
0.96
1.01
0.99
1.00
2.01
1.06
1.00
2.03
1.00
1.04
1.16
1.12
2.09
3.08
ppm

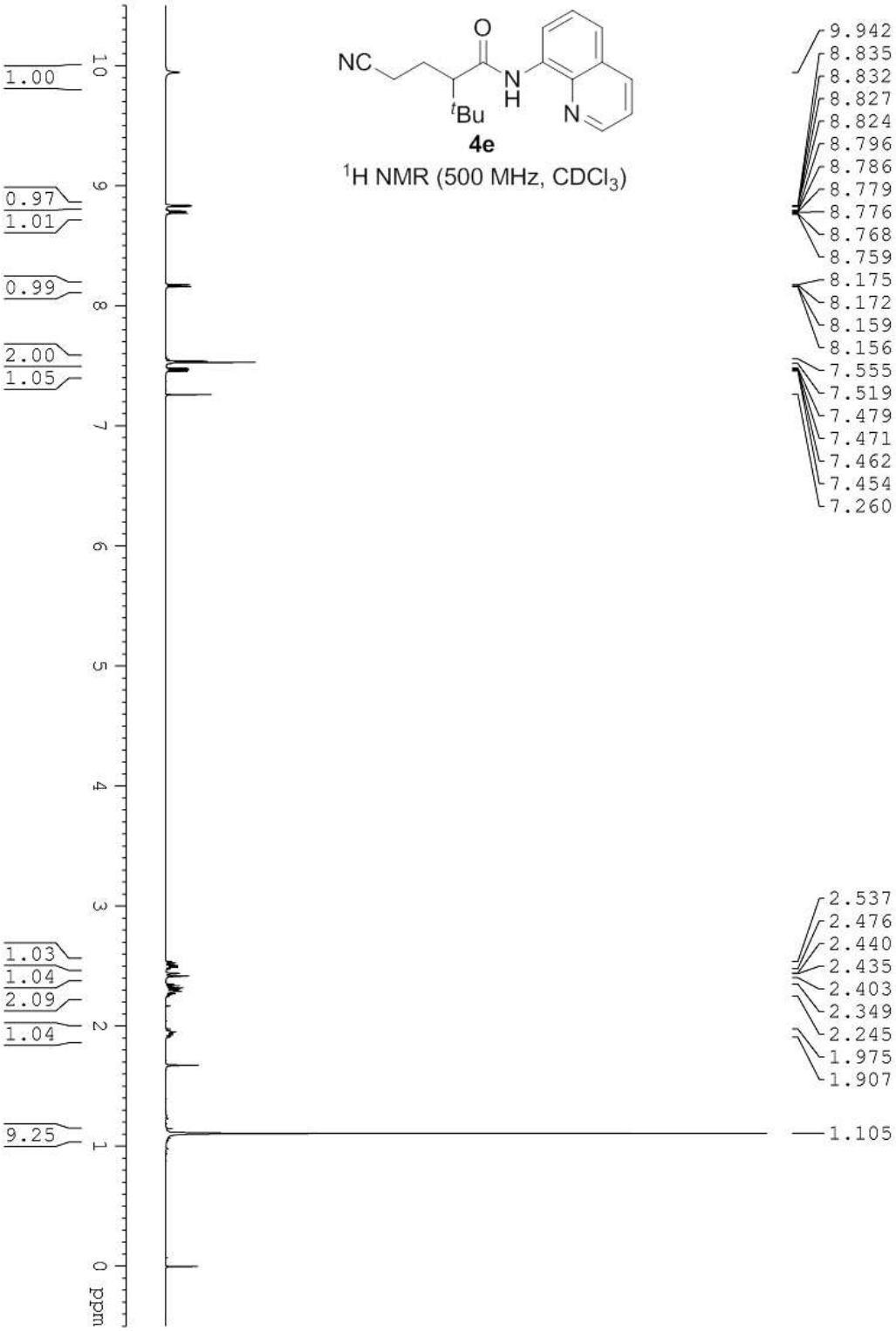

NC
O
N
H
nPr
N
4b
13C NMR (125 MHz, CDCl3)
172.82
148.53
138.48
136.46
134.16
128.04
127.38
122.03
121.86
119.48
116.72
77.41
77.16
76.90
47.36
35.27
28.24
20.65
15.52
14.15
ppm

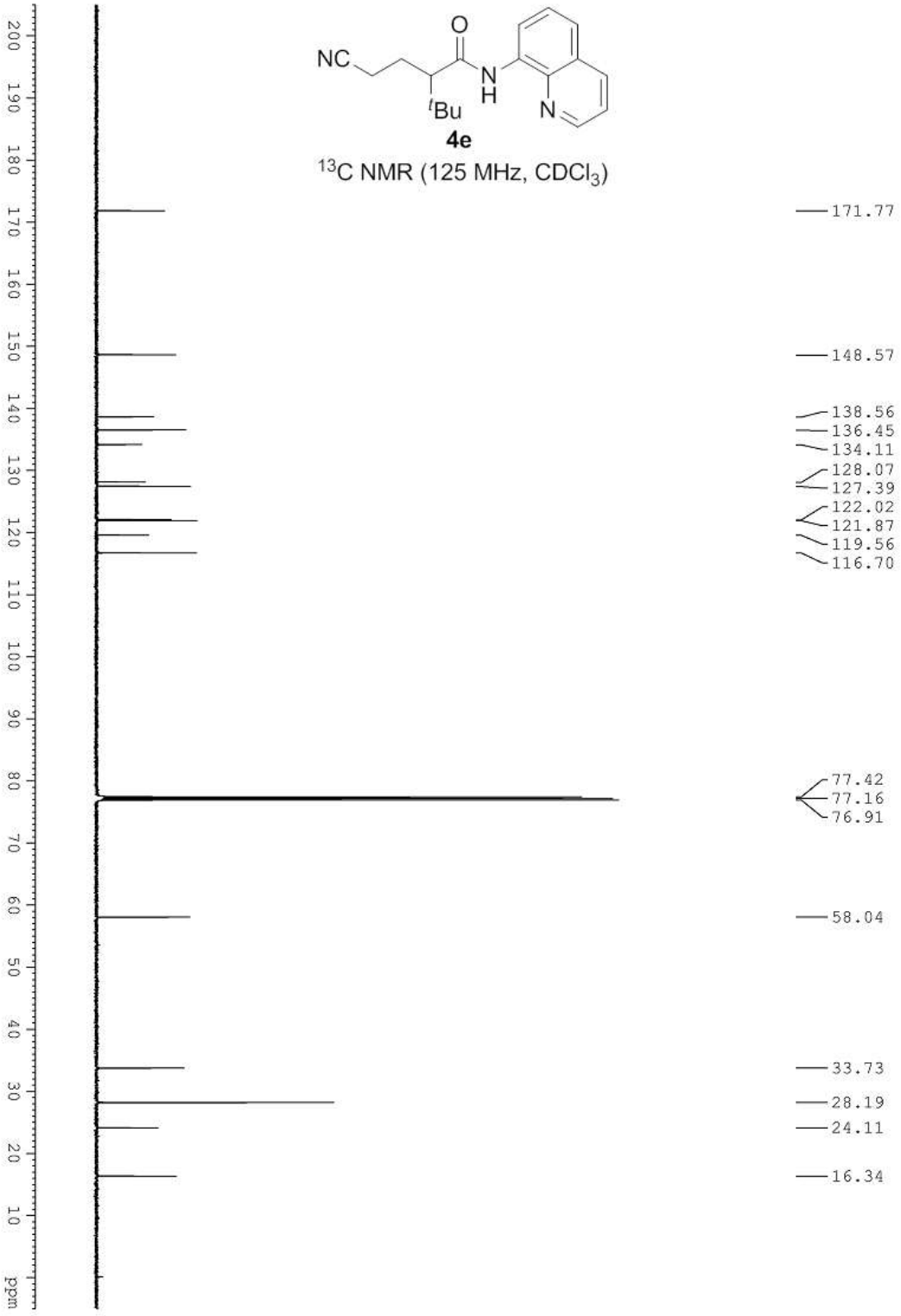

NC
O
N
H
Bn
N
4c
$^1$H NMR (500 MHz, $CDCl_3$)
1.00
1.98
1.00
2.02
1.06
4.32
1.00
1.01
1.02
1.11
1.02
1.04
1.02
1.03
8.751
8.748
8.742
8.740
8.735
8.728
8.723
8.148
8.145
8.132
8.128
7.543
7.502
7.447
7.439
7.431
7.422
7.257
7.248
7.232
7.225
7.222
7.221
7.162
7.133
7.128
7.123
7.120
3.182
3.167
3.156
3.141
3.002
2.930
2.916
2.903
2.889
2.539
2.494
2.490
2.479
2.460
2.394
2.261
2.203
2.200
2.188
1.963
1.903
1.895
0.000
ppm

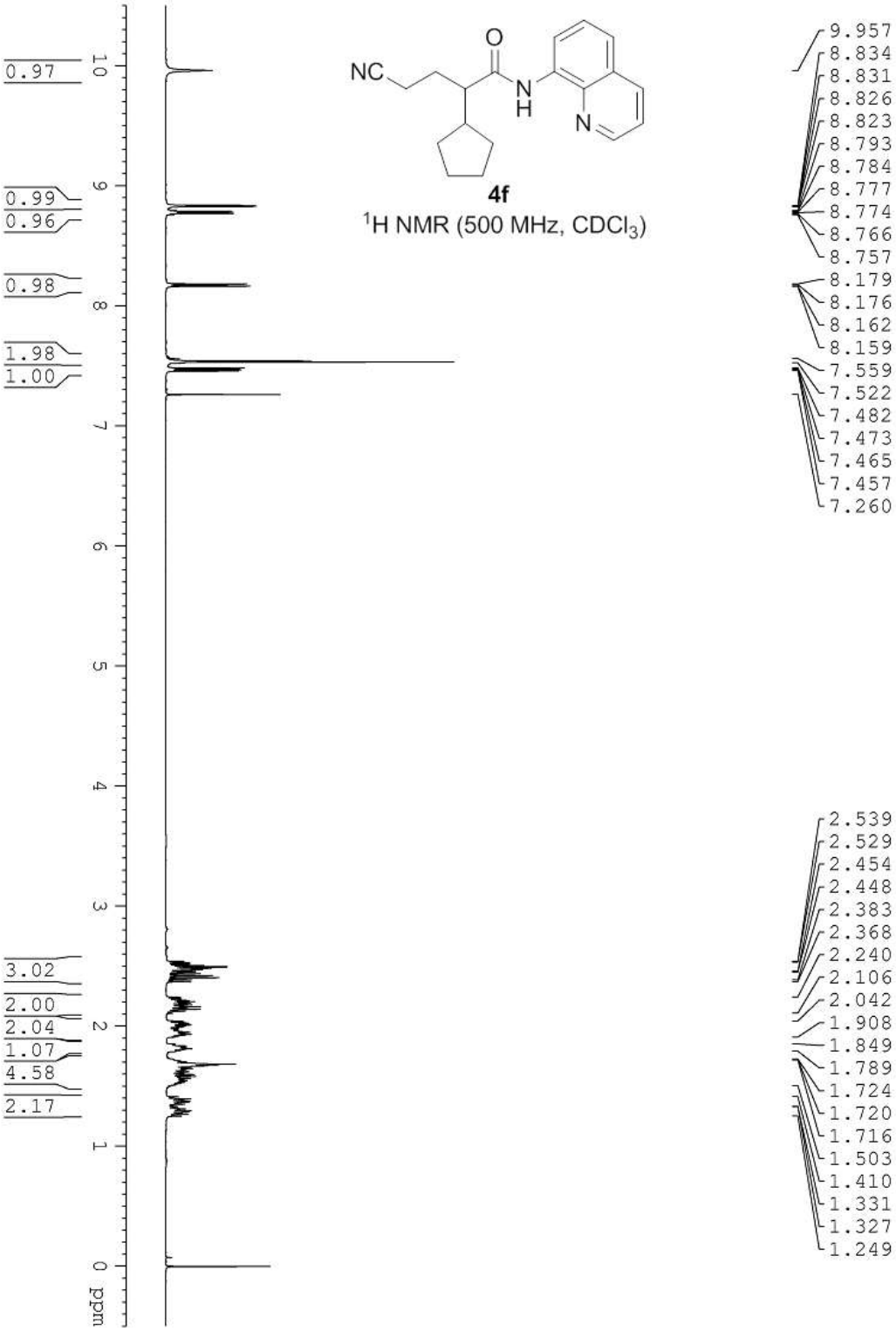

O
NC
N
H
Bn
N
4c
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.89
148.34
138.36
138.27
136.43
134.00
129.05
128.81
127.98
127.35
126.87
122.10
121.80
119.31
116.81
77.41
77.16
76.90
49.38
39.37
27.74
15.51
ppm

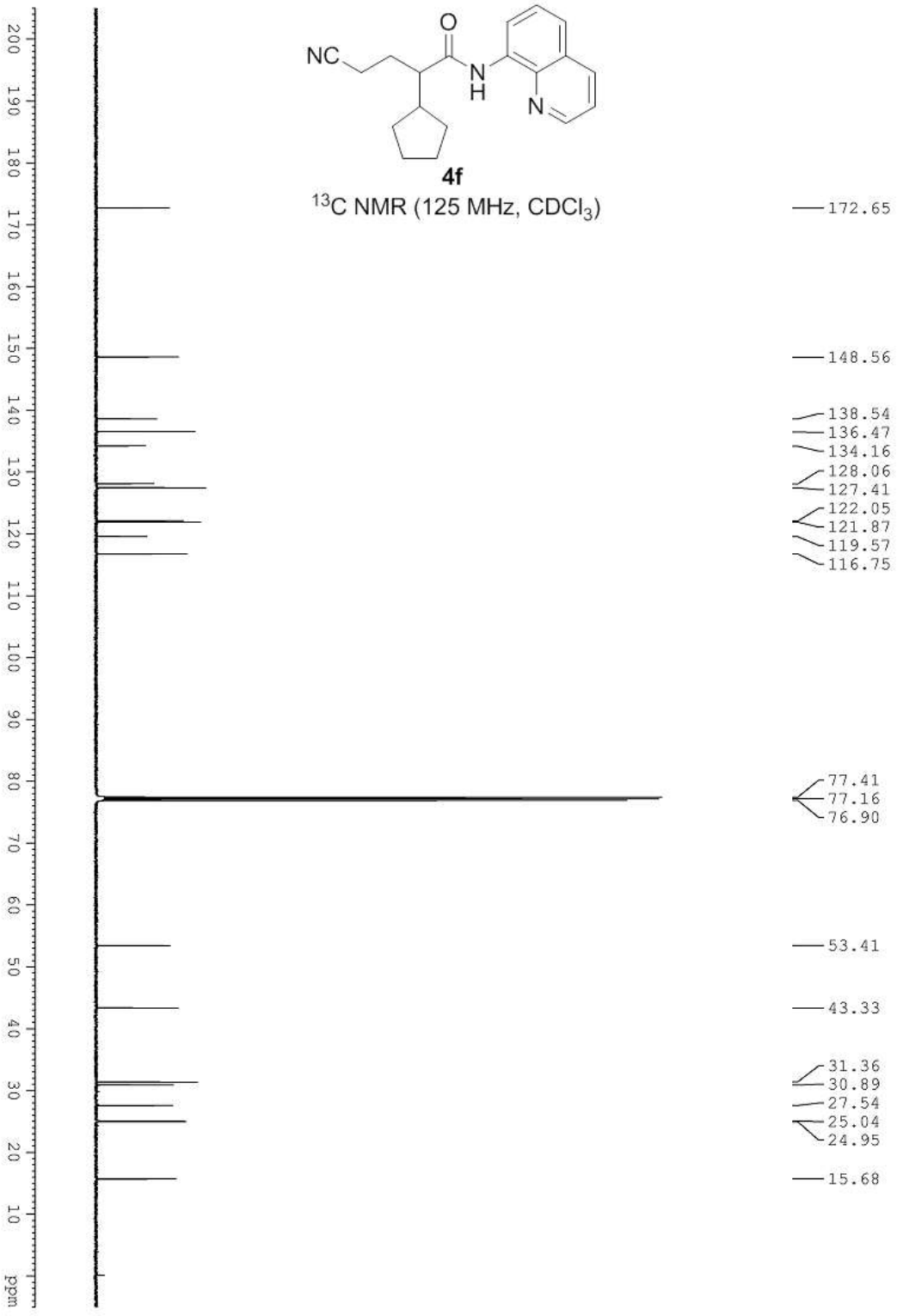

NC
O
N
H
iPr
N
4d
1H NMR (500 MHz, CDCl3)
1.01
0.97
1.00
1.00
2.00
1.04
1.01
2.07
1.05
1.06
1.05
6.03
9.940
8.830
8.826
8.821
8.818
8.795
8.785
8.778
8.774
8.767
8.757
8.173
8.170
8.157
8.154
7.555
7.517
7.476
7.468
7.460
7.451
7.260
2.545
2.501
2.471
2.358
2.235
2.225
2.176
2.172
2.162
2.115
2.102
2.030
2.020
1.928
1.084
1.069
1.055
-0.006
ppm

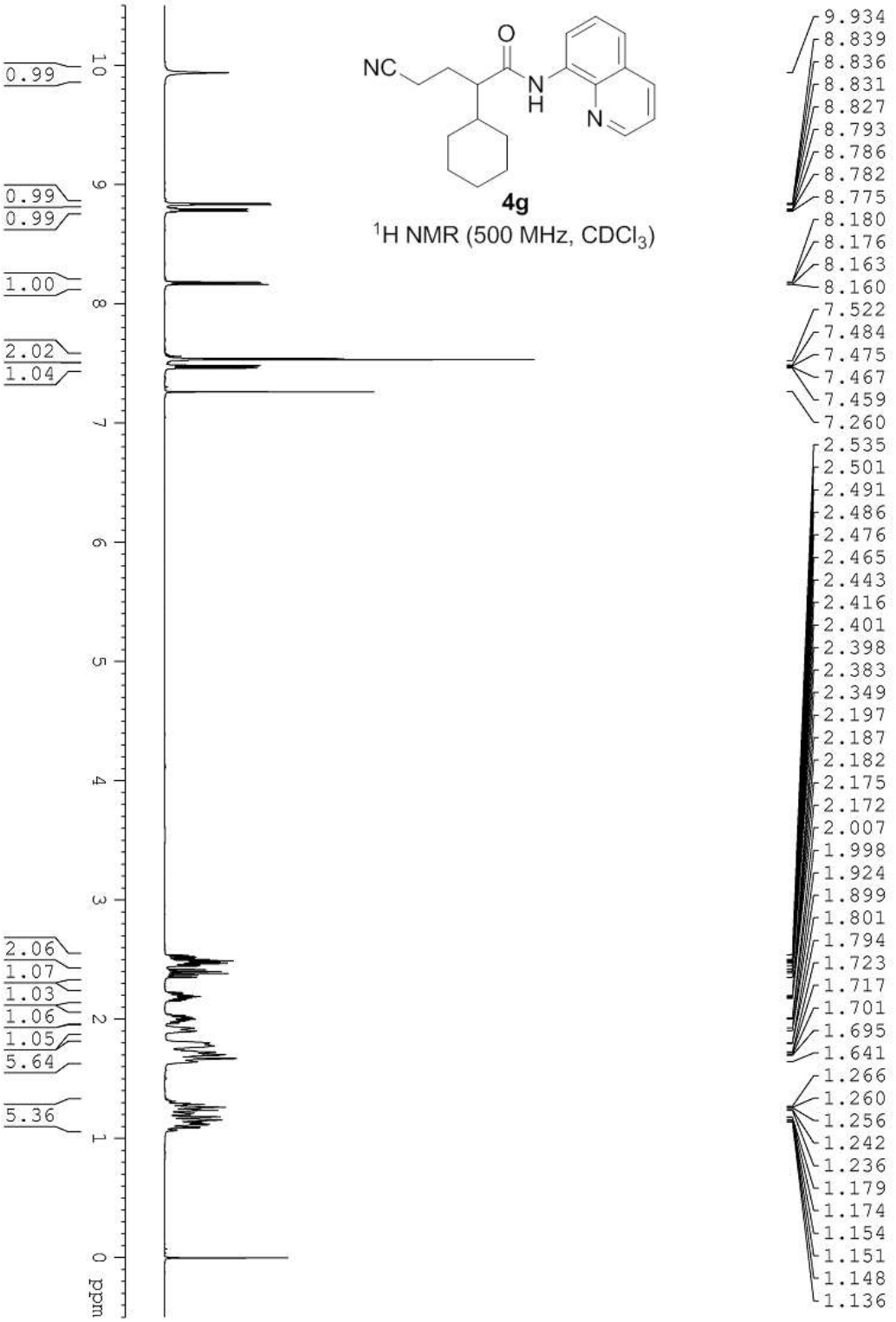

NC
O
N
H
iPr
N
4d
13C NMR (125 MHz, CDCl3)
172.24
148.52
138.50
136.46
134.14
128.06
127.38
122.02
121.85
119.58
116.69
77.41
77.16
76.91
54.32
31.26
25.58
20.75
20.24
15.77
ppm

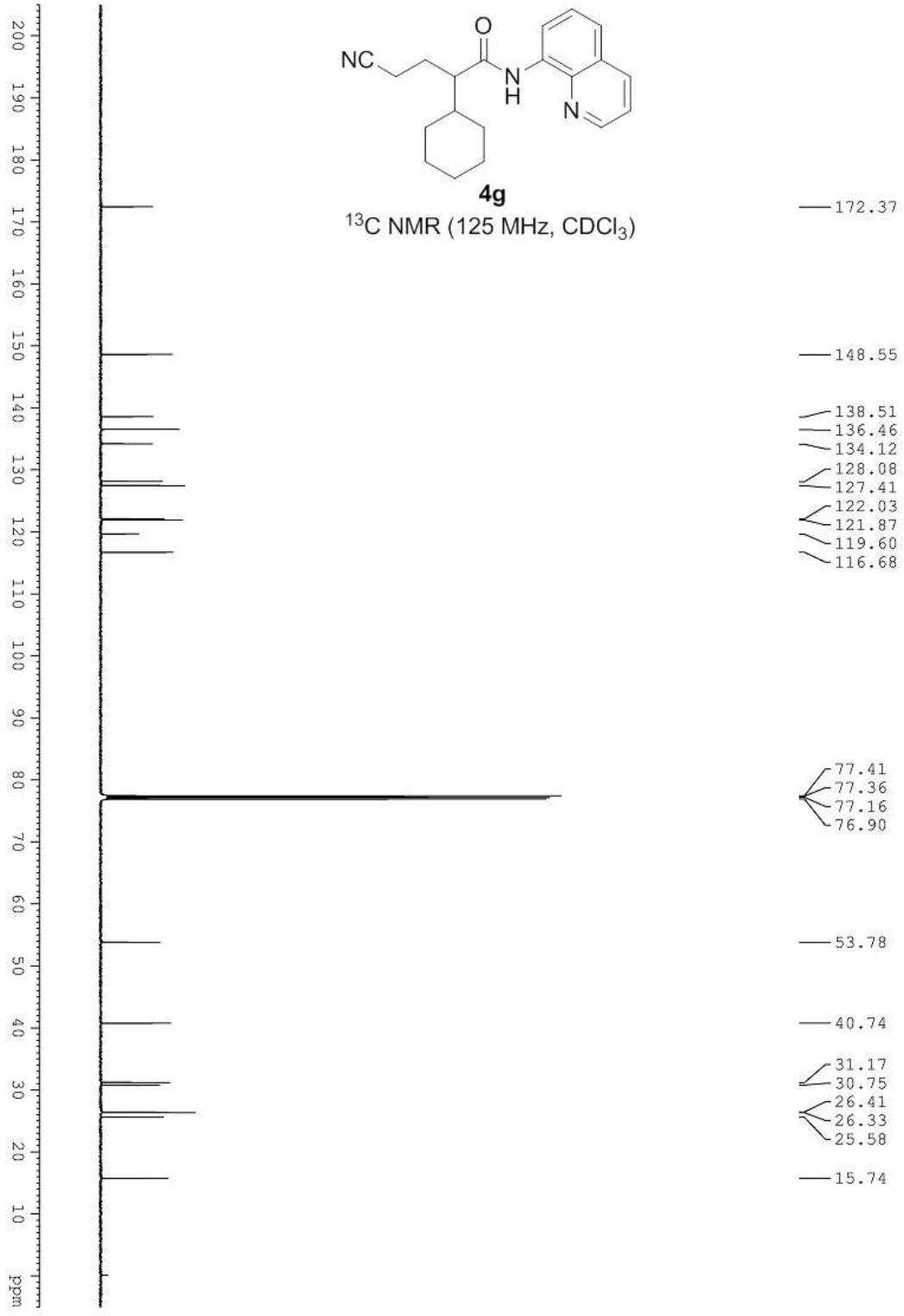

NC
O
N
H
tBu
N
4e
1H NMR (500 MHz, CDCl3)
9.942
8.835
8.832
8.827
8.824
8.796
8.786
8.779
8.776
8.768
8.759
8.175
8.172
8.159
8.156
7.555
7.519
7.479
7.471
7.462
7.454
7.260
2.537
2.476
2.440
2.435
2.403
2.349
2.245
1.975
1.907
1.105
1.00
0.97
1.01
0.99
2.00
1.05
1.03
1.04
2.09
1.04
9.25
ppm

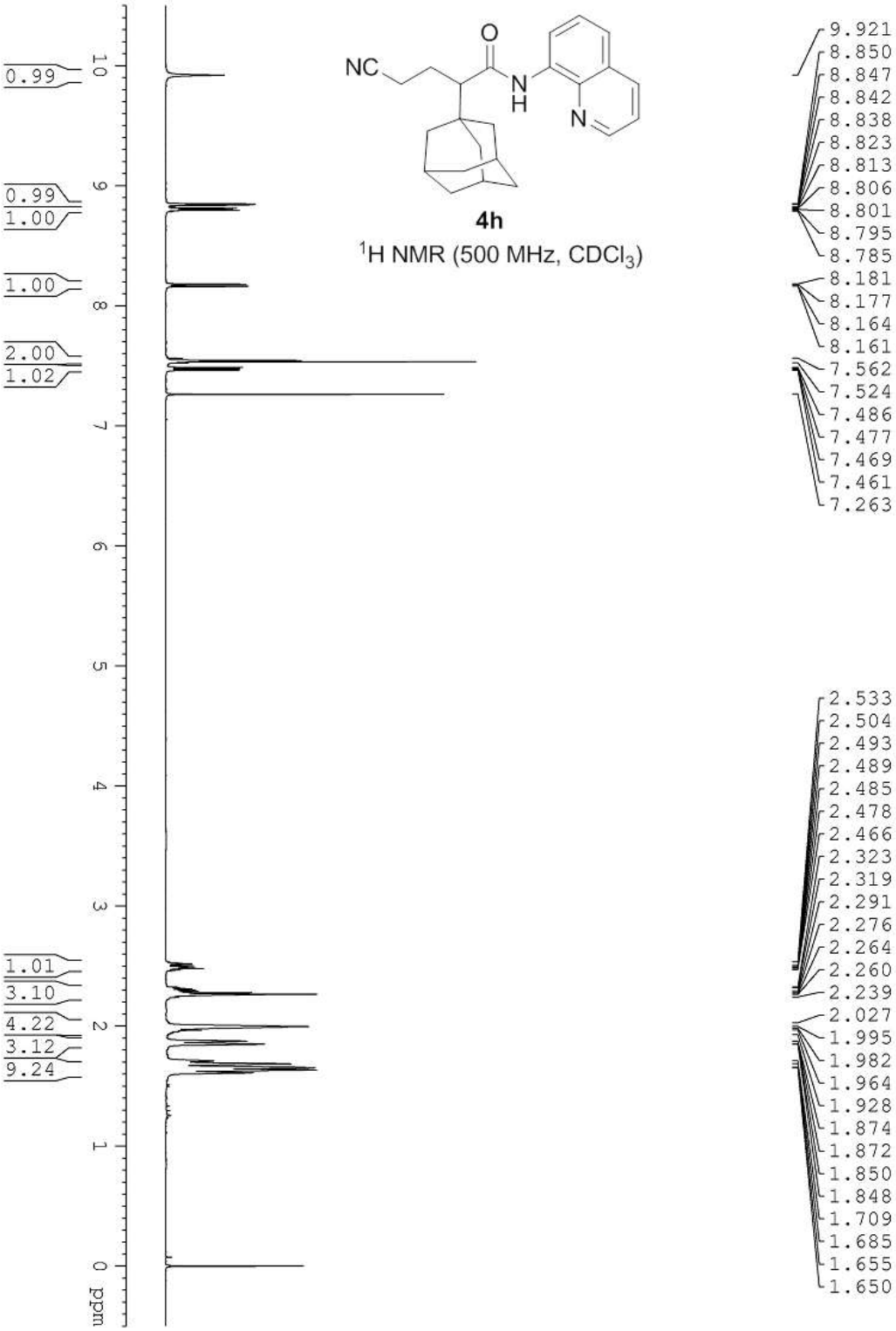

NC
O
N
H
tBu
N
4e
13C NMR (125 MHz, CDCl3)
171.77
148.57
138.56
136.45
134.11
128.07
127.39
122.02
121.87
119.56
116.70
77.42
77.16
76.91
58.04
33.73
28.19
24.11
16.34
ppm

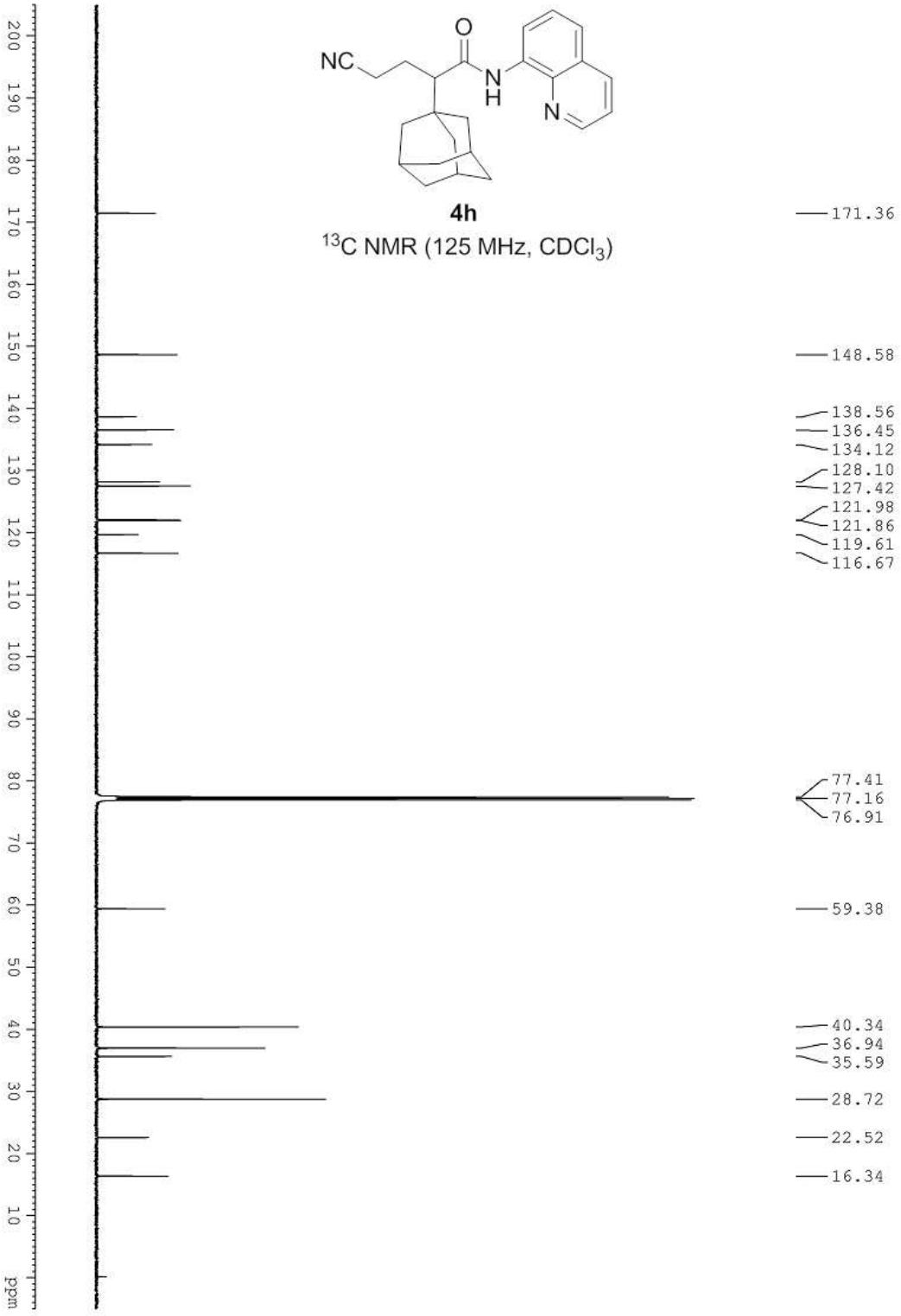

NC
O
N
H
N
4f
$^1$H NMR (500 MHz, $CDCl_3$)
0.97
0.99
0.96
0.98
1.98
1.00
3.02
2.00
2.04
1.07
4.58
2.17
ppm
9.957
8.834
8.831
8.826
8.823
8.793
8.784
8.777
8.774
8.766
8.757
8.179
8.176
8.162
8.159
7.559
7.522
7.482
7.473
7.465
7.457
7.260
2.539
2.529
2.454
2.448
2.383
2.368
2.240
2.106
2.042
1.908
1.849
1.789
1.724
1.720
1.716
1.503
1.410
1.331
1.327
1.249

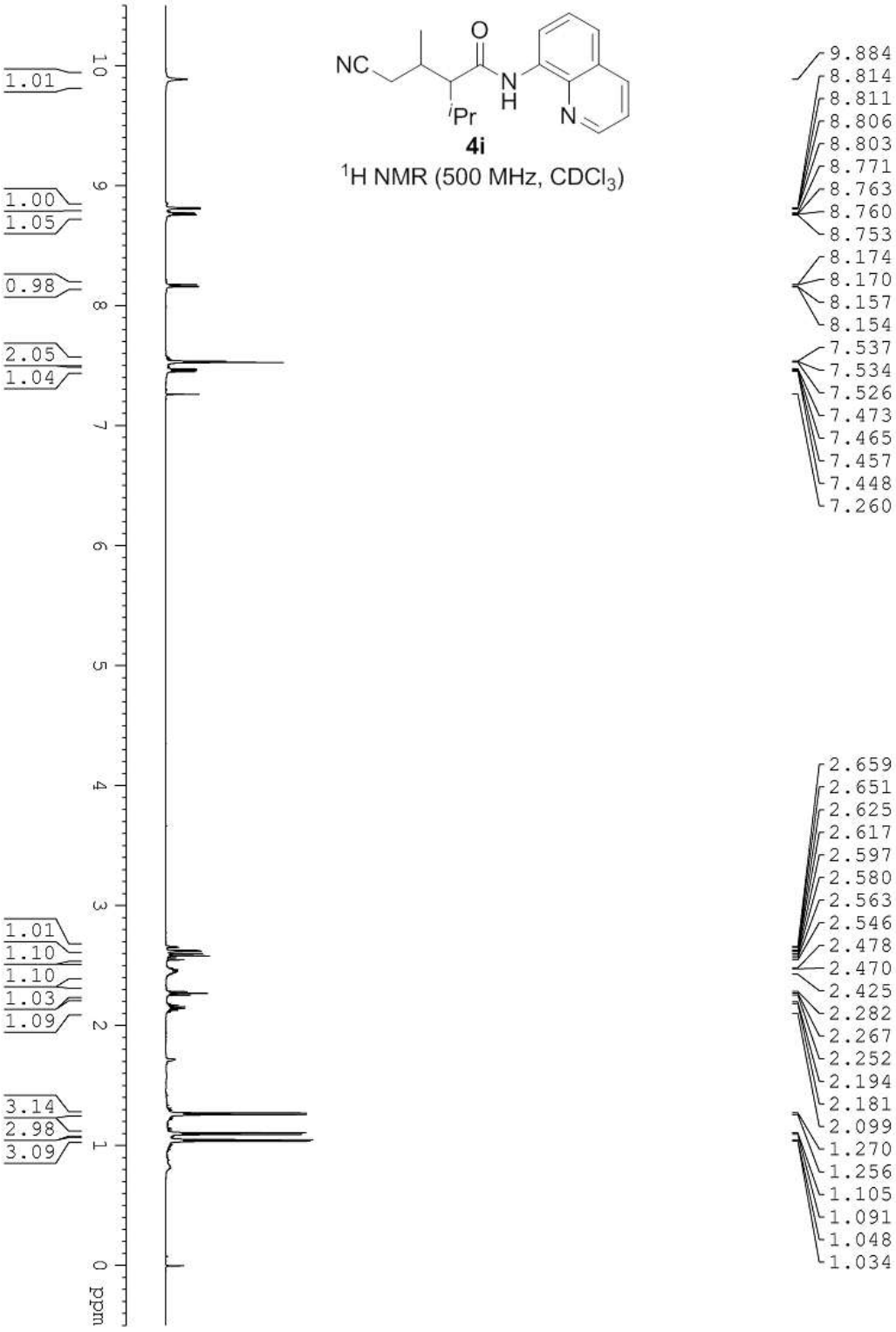

NC
O
N
H
N
4f
$^{13}$C NMR (125 MHz, $CDCl_3$)
172.65
148.56
138.54
136.47
134.16
128.06
127.41
122.05
121.87
119.57
116.75
77.41
77.16
76.90
53.41
43.33
31.36
30.89
27.54
25.04
24.95
15.68
ppm

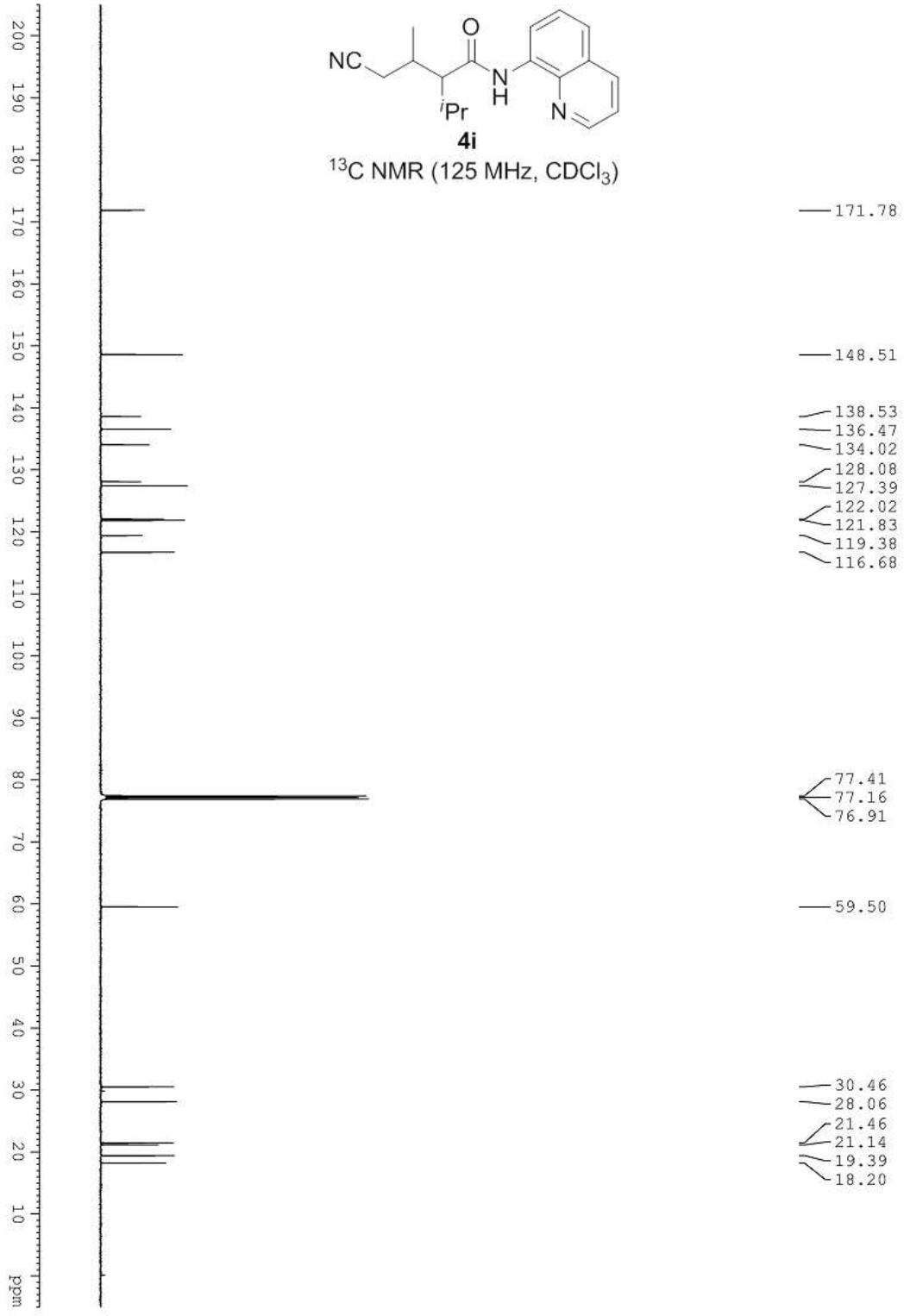

NC
O
N
H
N
4g
$^1$H NMR (500 MHz, $CDCl_3$)
0.99
0.99
0.99
1.00
2.02
1.04
2.06
1.07
1.03
1.06
1.05
5.64
5.36
ppm
9.934
8.839
8.836
8.831
8.827
8.793
8.786
8.782
8.775
8.180
8.176
8.163
8.160
7.522
7.484
7.475
7.467
7.459
7.260
2.535
2.501
2.491
2.486
2.476
2.465
2.443
2.416
2.401
2.398
2.383
2.349
2.197
2.187
2.182
2.175
2.172
2.007
1.998
1.924
1.899
1.801
1.794
1.723
1.717
1.701
1.695
1.641
1.266
1.260
1.256
1.242
1.236
1.179
1.174
1.154
1.151
1.148
1.136

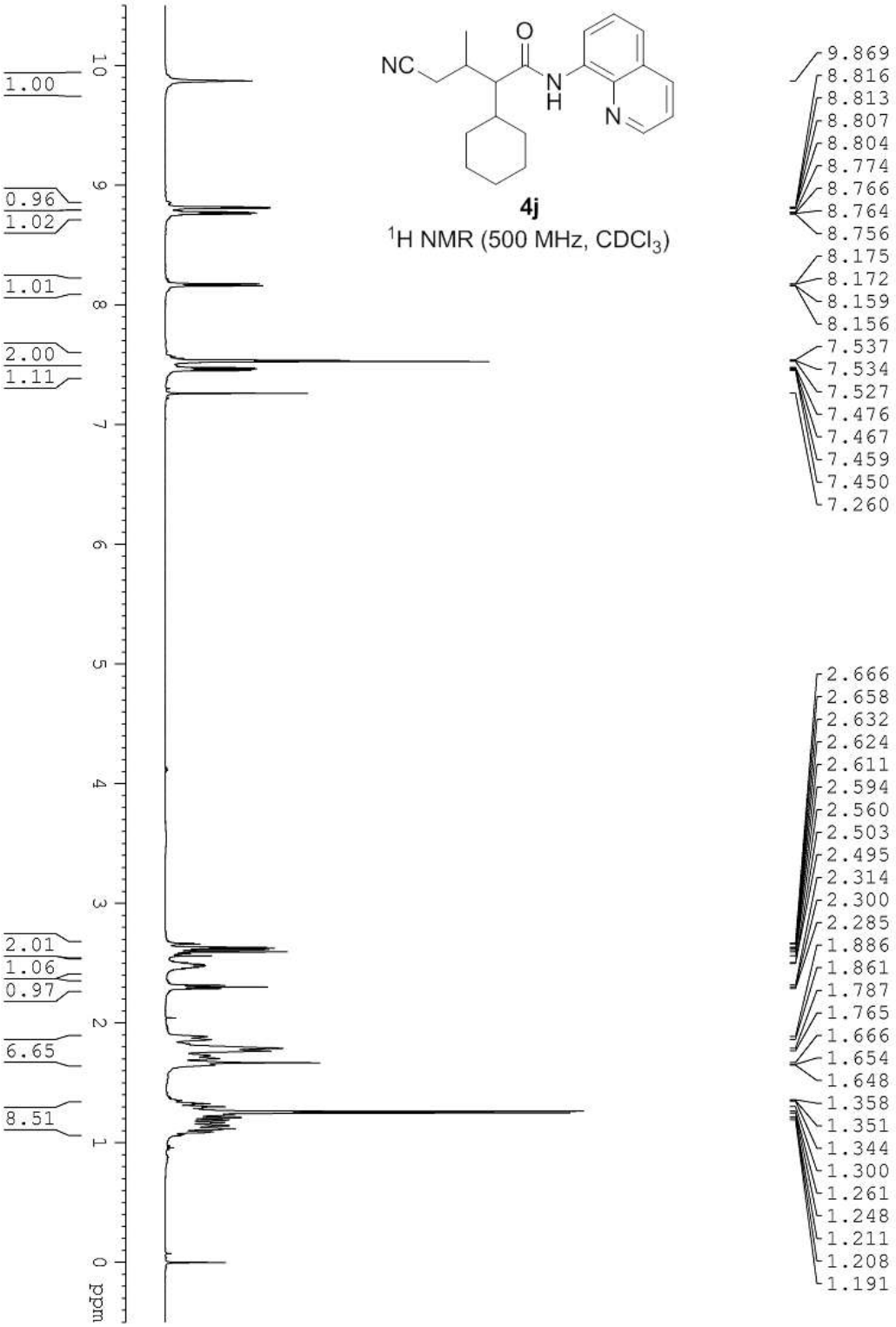

NC
O
N
H
N
4g
$^{13}$C NMR (125 MHz, $CDCl_3$)
172.37
148.55
138.51
136.46
134.12
128.08
127.41
122.03
121.87
119.60
116.68
77.41
77.36
77.16
76.90
53.78
40.74
31.17
30.75
26.41
26.33
25.58
15.74
ppm

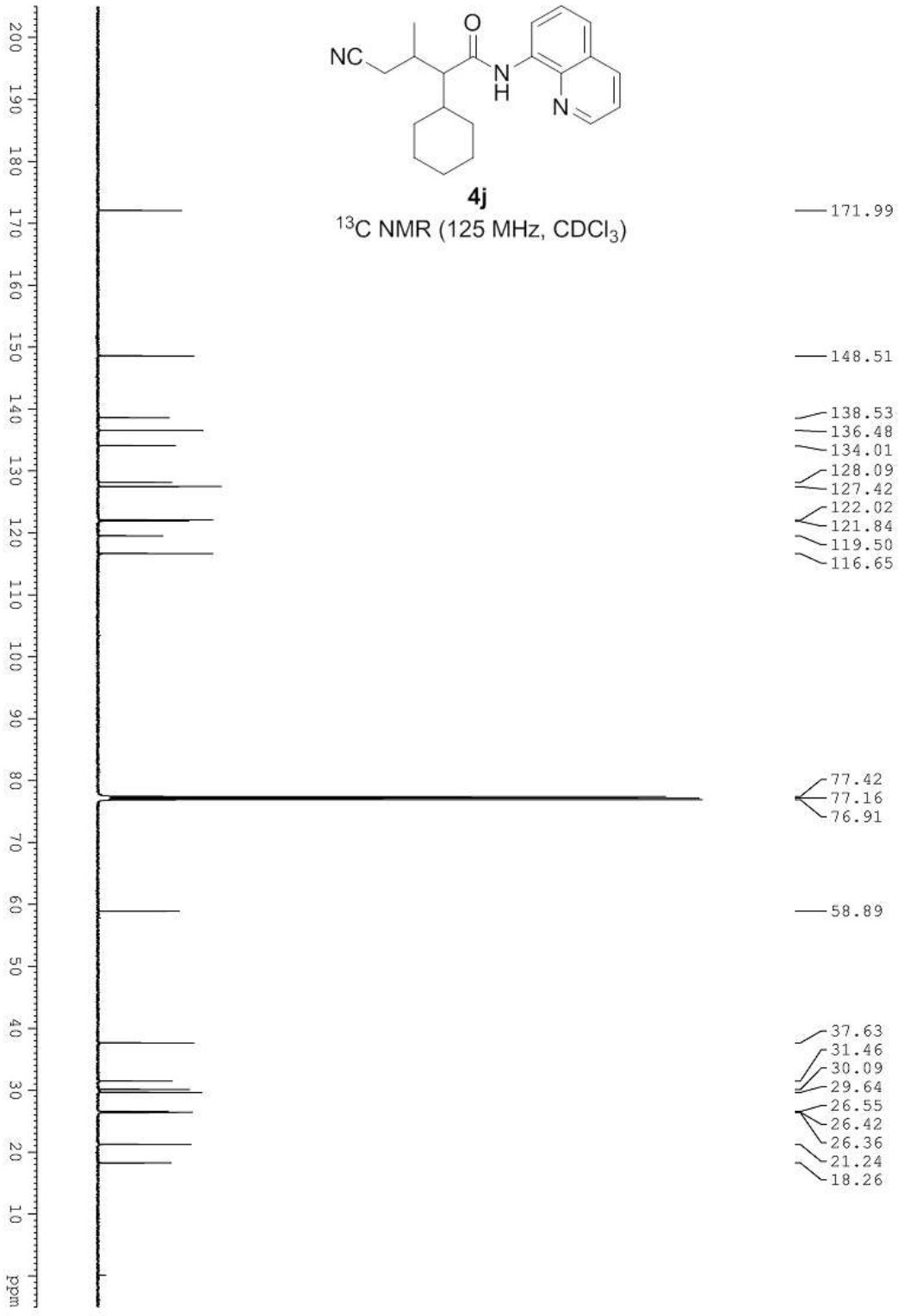

NC
O
N
H
N
4h
$^1$H NMR (500 MHz, $CDCl_3$)
0.99
0.99
1.00
1.00
2.00
1.02
1.01
3.10
4.22
3.12
9.24
9.921
8.850
8.847
8.842
8.838
8.823
8.813
8.806
8.801
8.795
8.785
8.181
8.177
8.164
8.161
7.562
7.524
7.486
7.477
7.469
7.461
7.263
2.533
2.504
2.493
2.489
2.485
2.478
2.466
2.323
2.319
2.291
2.276
2.264
2.260
2.239
2.027
1.995
1.982
1.964
1.928
1.874
1.872
1.850
1.848
1.709
1.685
1.655
1.650
ppm

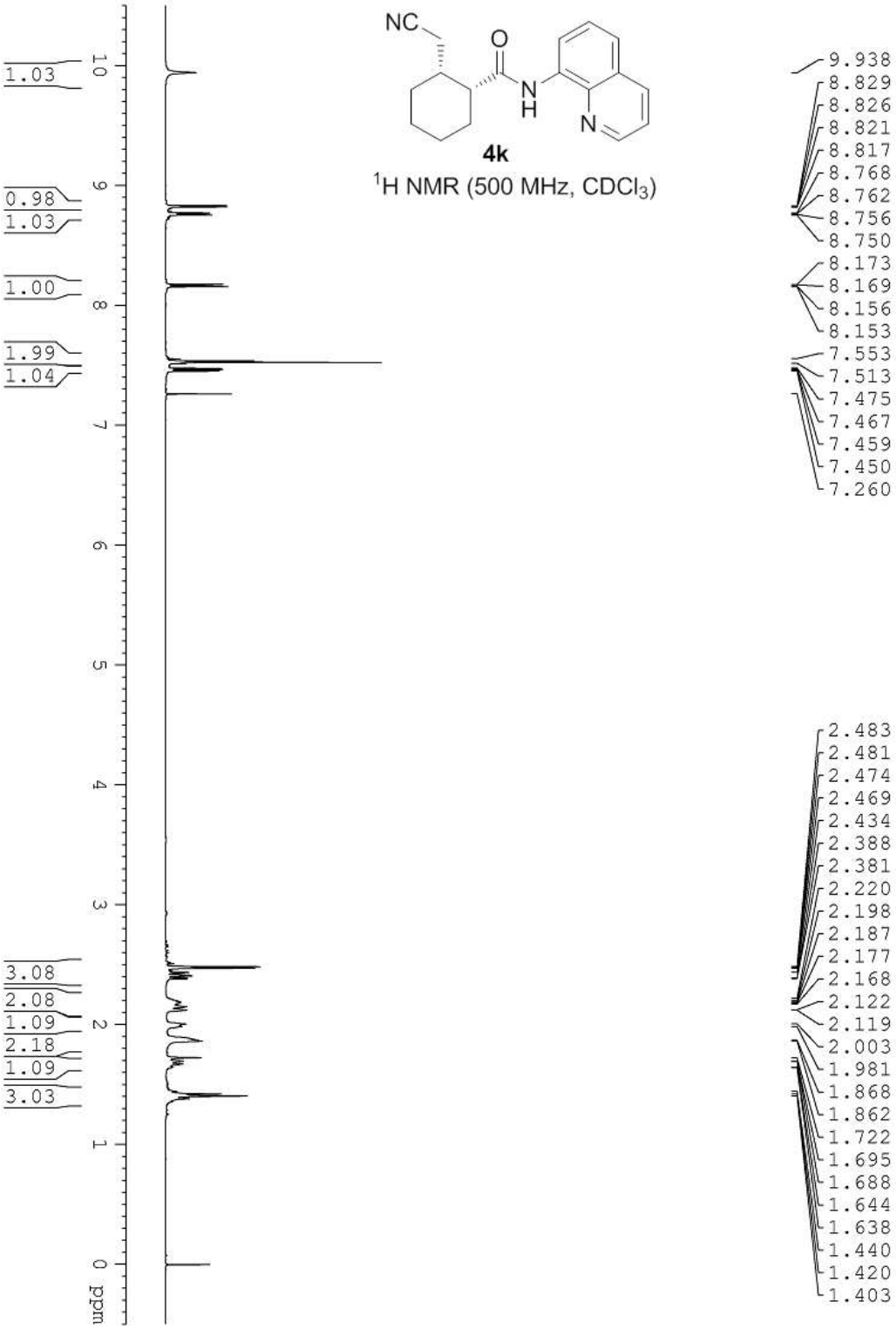

NC
O
N
H
N
4h
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.36
148.58
138.56
136.45
134.12
128.10
127.42
121.98
121.86
119.61
116.67
77.41
77.16
76.91
59.38
40.34
36.94
35.59
28.72
22.52
16.34
ppm

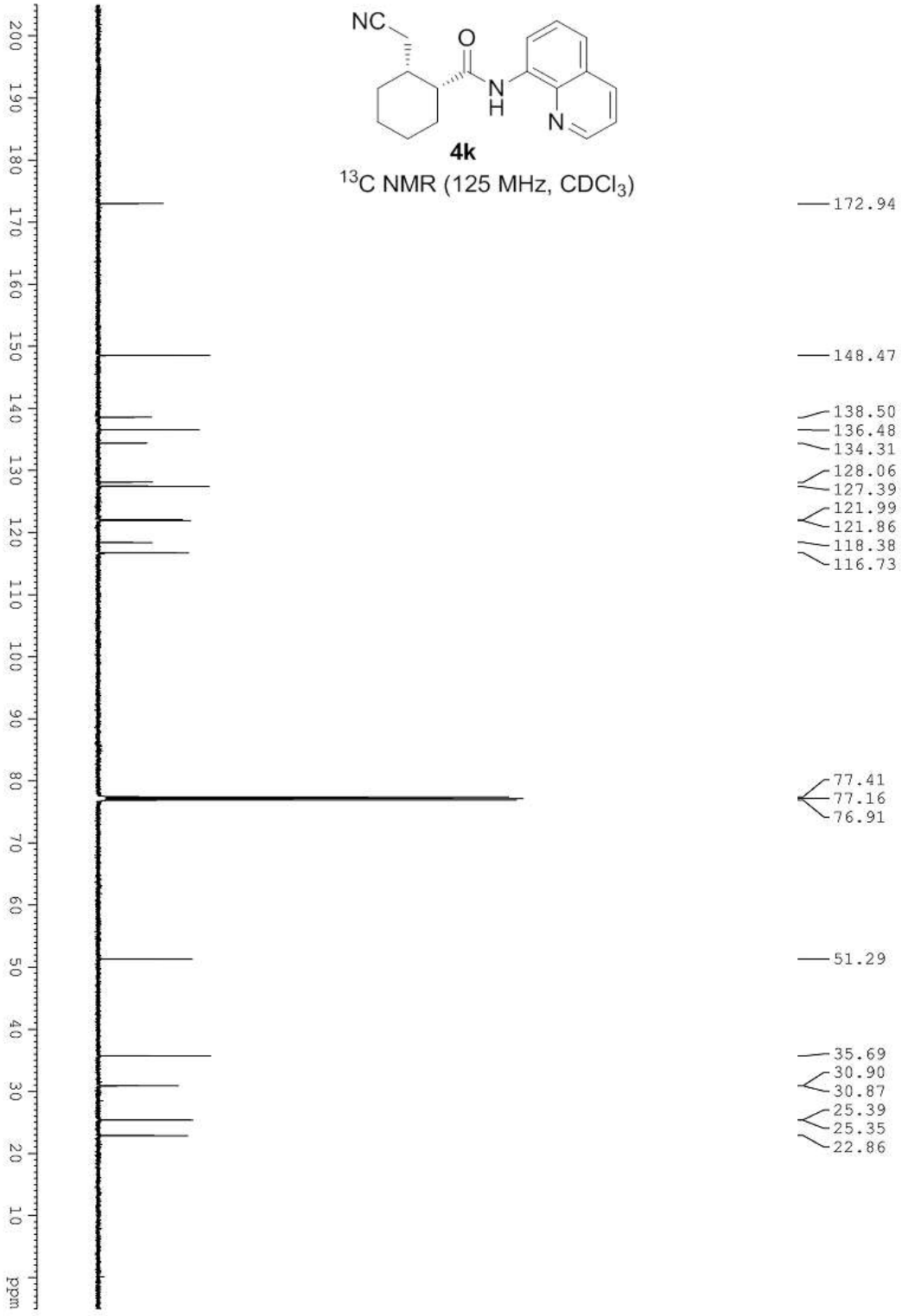

NC
O
N
H
iPr
N
4i
1H NMR (500 MHz, CDCl3)
9.884
8.814
8.811
8.806
8.803
8.771
8.763
8.760
8.753
8.174
8.170
8.157
8.154
7.537
7.534
7.526
7.473
7.465
7.457
7.448
7.260
2.659
2.651
2.625
2.617
2.597
2.580
2.563
2.546
2.478
2.470
2.425
2.282
2.267
2.252
2.194
2.181
2.099
1.270
1.256
1.105
1.091
1.048
1.034
1.01
1.00
1.05
0.98
2.05
1.04
1.01
1.10
1.10
1.03
1.09
3.14
2.98
3.09
ppm

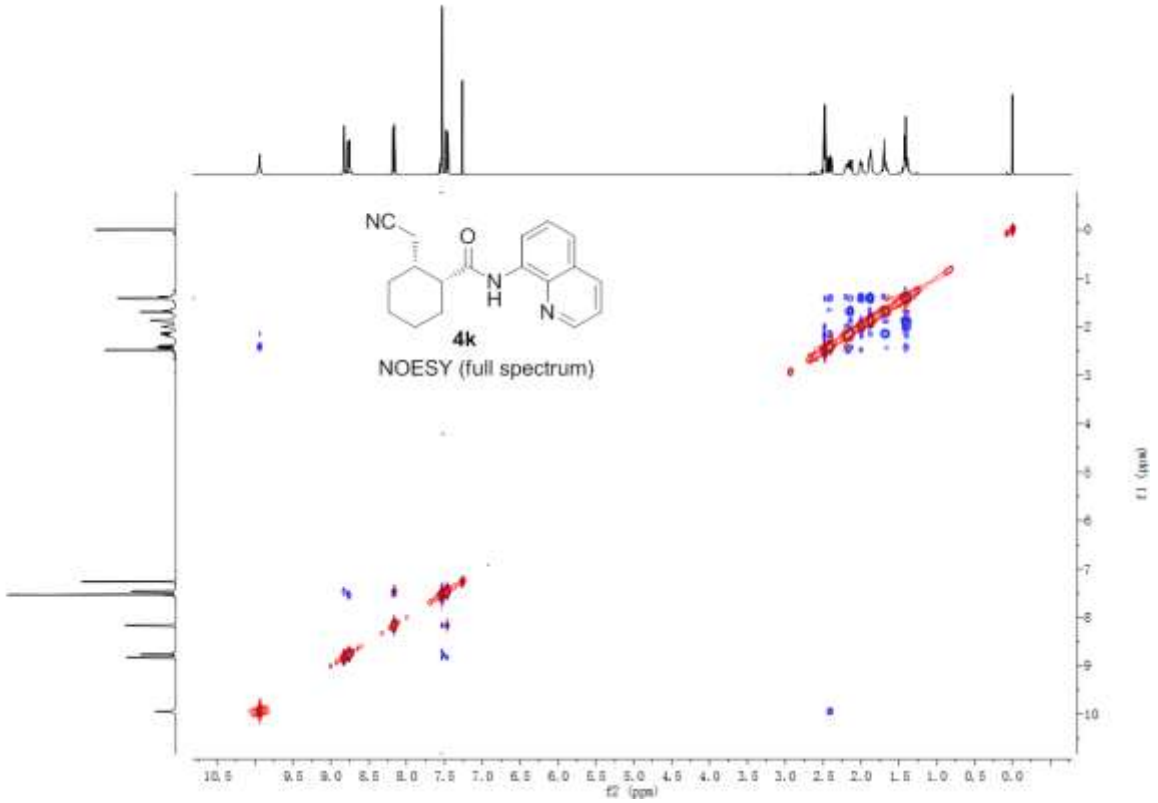

NC
O
N
H
iPr
N
4i
13C NMR (125 MHz, CDCl3)
171.78
148.51
138.53
136.47
134.02
128.08
127.39
122.02
121.83
119.38
116.68
77.41
77.16
76.91
59.50
30.46
28.06
21.46
21.14
19.39
18.20
ppm

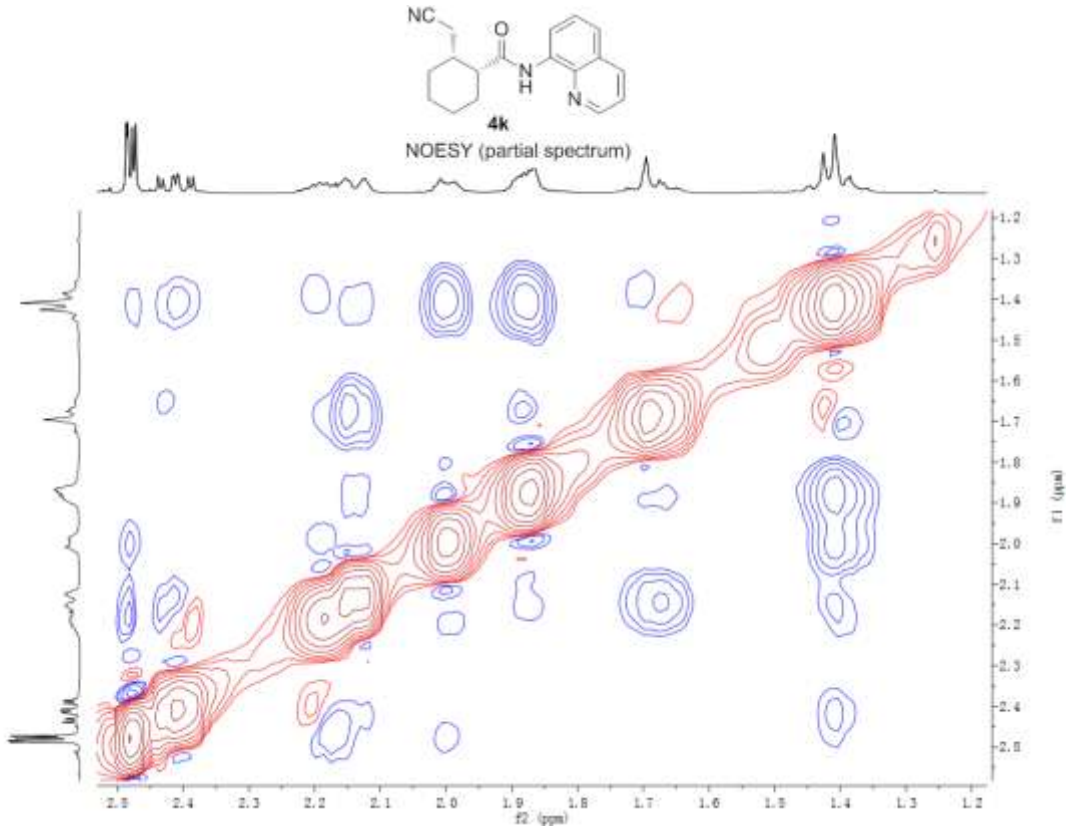

NC
O
N
H
N
4j
1H NMR (500 MHz, CDCl3)
1.00
0.96
1.02
1.01
2.00
1.11
2.01
1.06
0.97
6.65
8.51
9.869
8.816
8.813
8.807
8.804
8.774
8.766
8.764
8.756
8.175
8.172
8.159
8.156
7.537
7.534
7.527
7.476
7.467
7.459
7.450
7.260
2.666
2.658
2.632
2.624
2.611
2.594
2.560
2.503
2.495
2.314
2.300
2.285
1.886
1.861
1.787
1.765
1.666
1.654
1.648
1.358
1.351
1.344
1.300
1.261
1.248
1.211
1.208
1.191
ppm

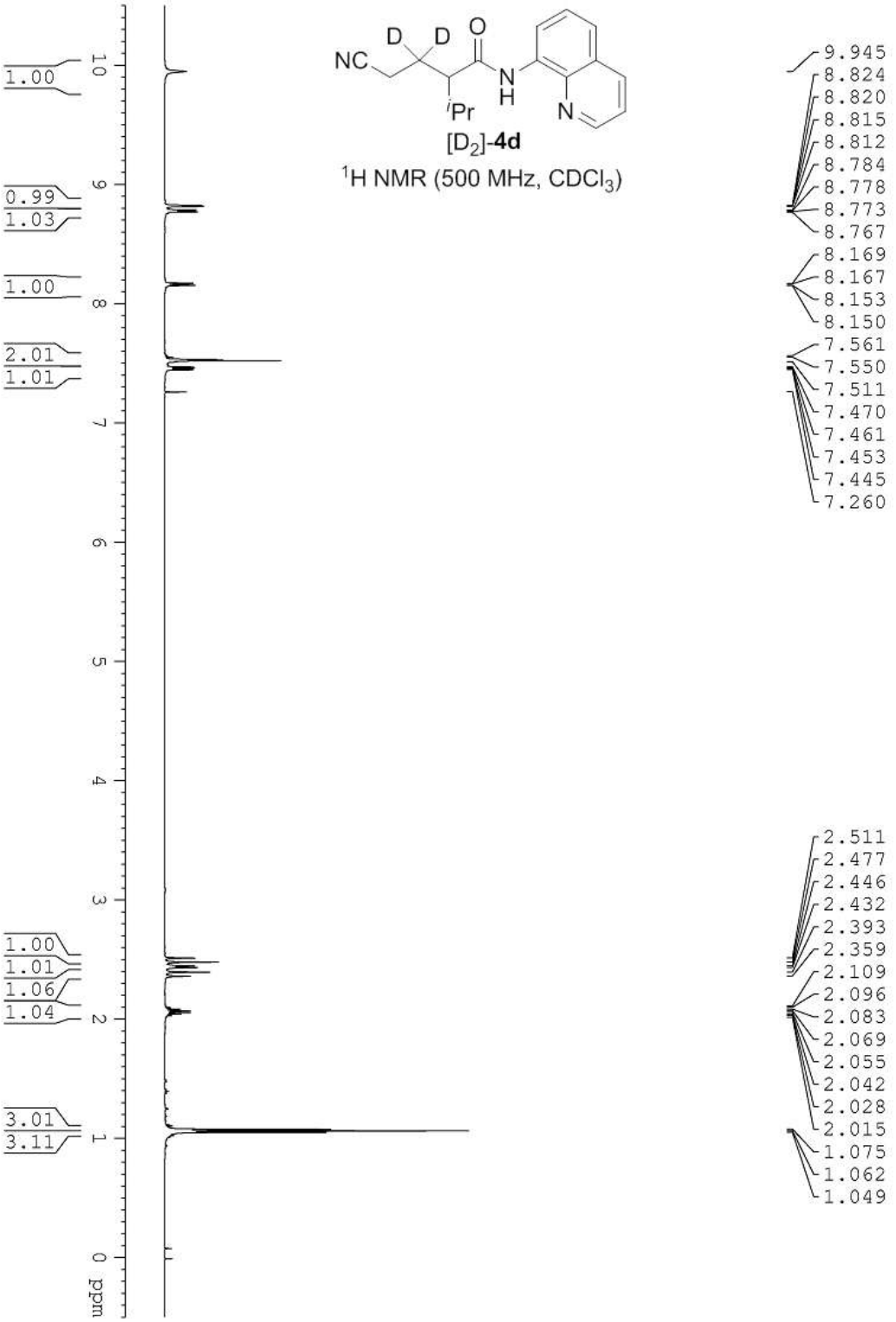

NC
O
N
H
N
4j
$^{13}$C NMR (125 MHz, $CDCl_3$)
171.99
148.51
138.53
136.48
134.01
128.09
127.42
122.02
121.84
119.50
116.65
77.42
77.16
76.91
58.89
37.63
31.46
30.09
29.64
26.55
26.42
26.36
21.24
18.26
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

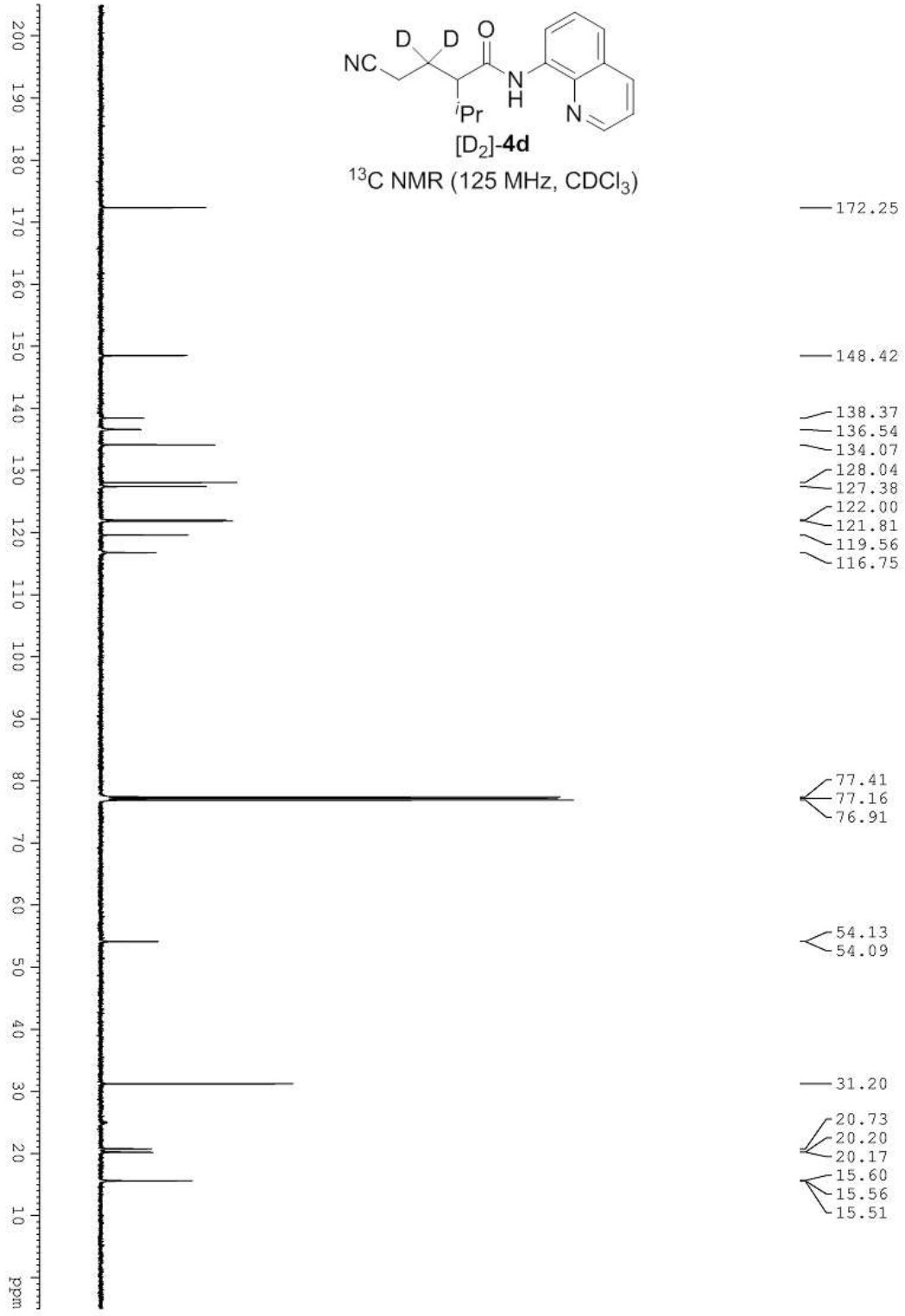

NC
O
N
H
N
4k
$^1$H NMR (500 MHz, $CDCl_3$)
1.03
0.98
1.03
1.00
1.99
1.04
3.08
2.08
1.09
2.18
1.09
3.03
9.938
8.829
8.826
8.821
8.817
8.768
8.762
8.756
8.750
8.173
8.169
8.156
8.153
7.553
7.513
7.475
7.467
7.459
7.450
7.260
2.483
2.481
2.474
2.469
2.434
2.388
2.381
2.220
2.198
2.187
2.177
2.168
2.122
2.119
2.003
1.981
1.868
1.862
1.722
1.695
1.688
1.644
1.638
1.440
1.420
1.403
10
9
8
7
6
5
4
3
2
1
0
ppm

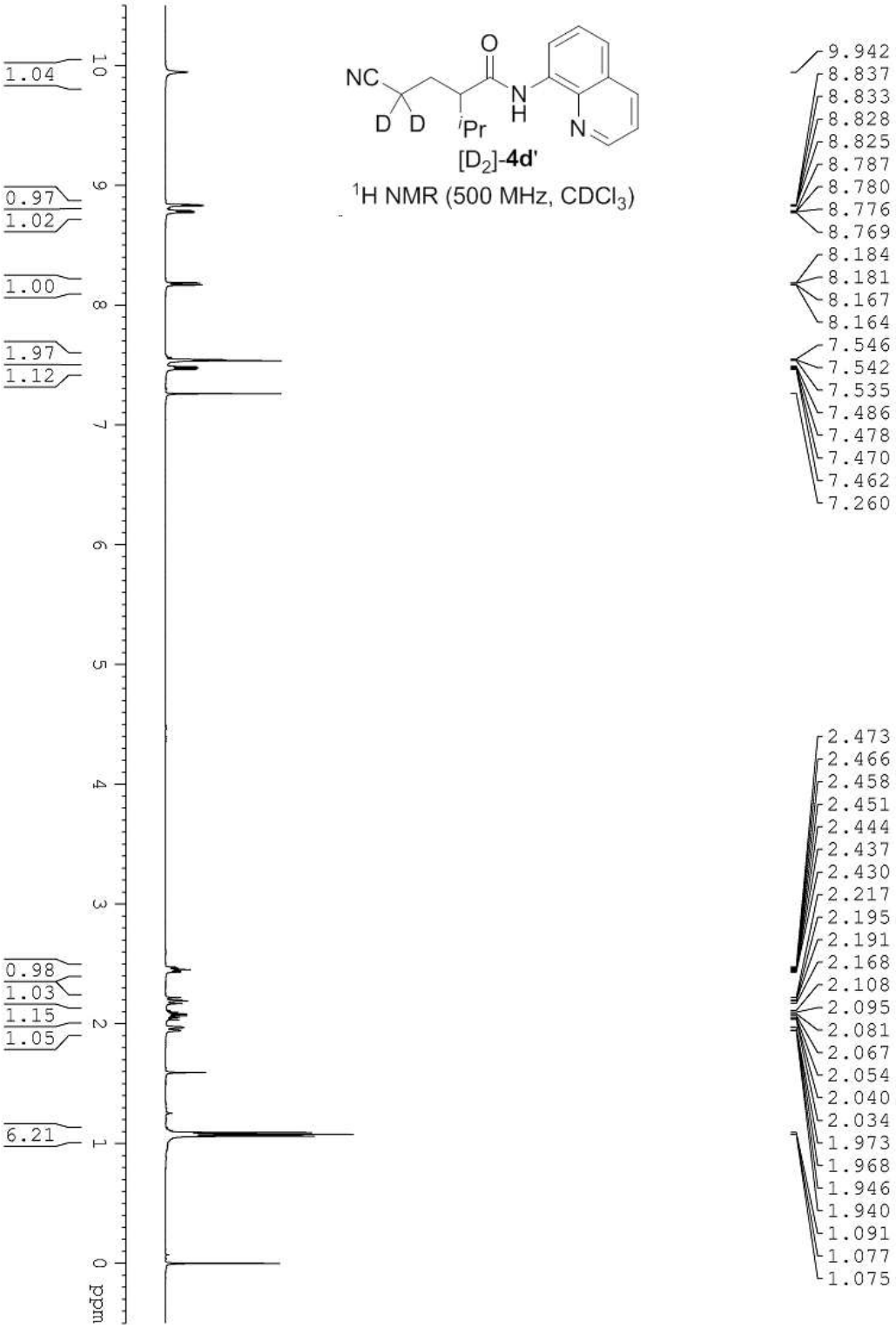

NC
O
N
H
N
4k
$^{13}$C NMR (125 MHz, $CDCl_3$)
172.94
148.47
138.50
136.48
134.31
128.06
127.39
121.99
121.86
118.38
116.73
77.41
77.16
76.91
51.29
35.69
30.90
30.87
25.39
25.35
22.86
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

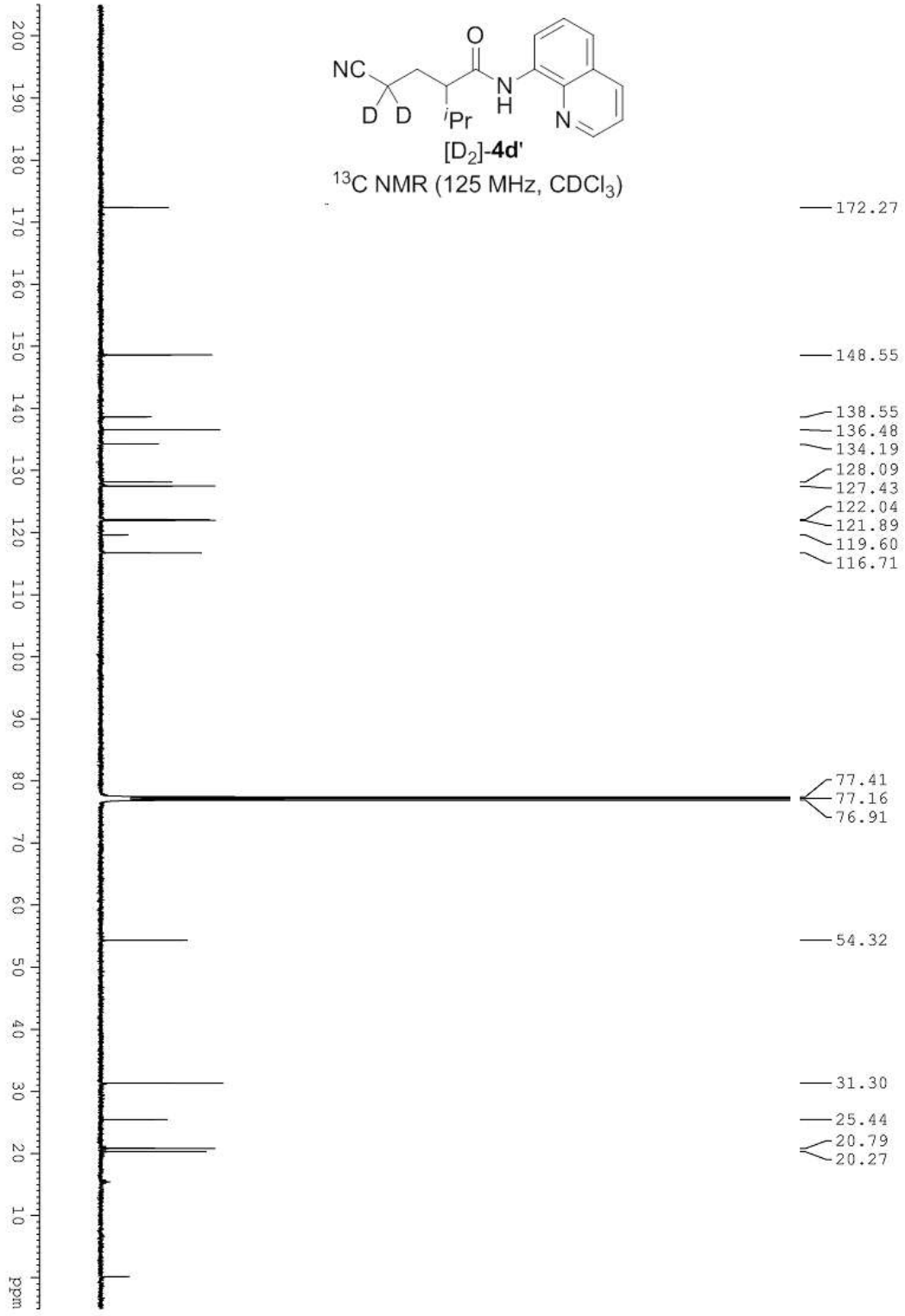

NC
O
N
H
N
4k
NOESY (full spectrum)
f2 (ppm)
f1 (ppm)

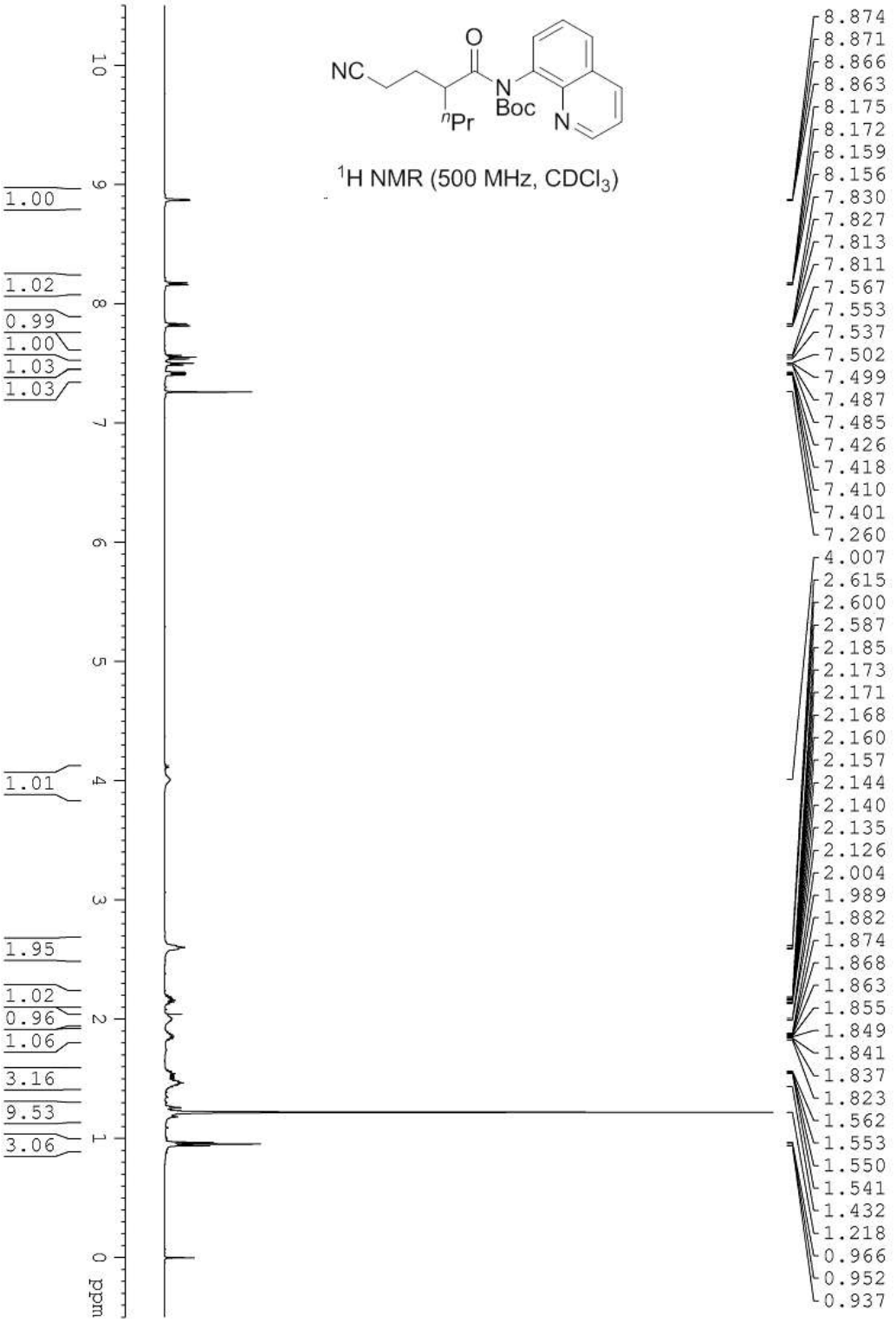

NC
O
N
H
N
4k
NOESY (partial spectrum)
f2 (ppm)
f1 (ppm)

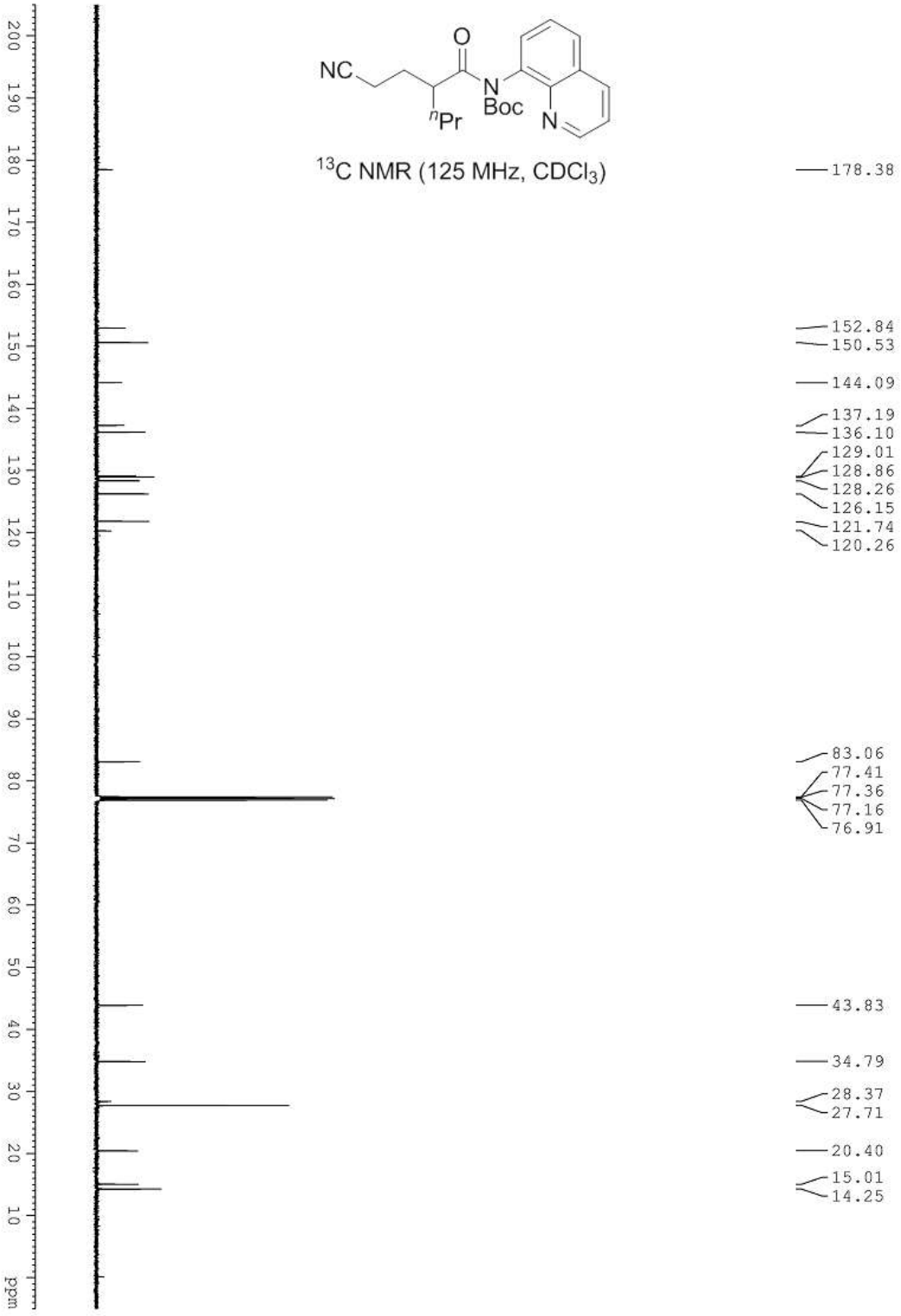

NC
D
D
O
N
H
iPr
N
[D2]-4d
1H NMR (500 MHz, CDCl3)
1.00
0.99
1.03
1.00
2.01
1.01
1.00
1.01
1.06
1.04
3.01
3.11
9.945
8.824
8.820
8.815
8.812
8.784
8.778
8.773
8.767
8.169
8.167
8.153
8.150
7.561
7.550
7.511
7.470
7.461
7.453
7.445
7.260
2.511
2.477
2.446
2.432
2.393
2.359
2.109
2.096
2.083
2.069
2.055
2.042
2.028
2.015
1.075
1.062
1.049
ppm

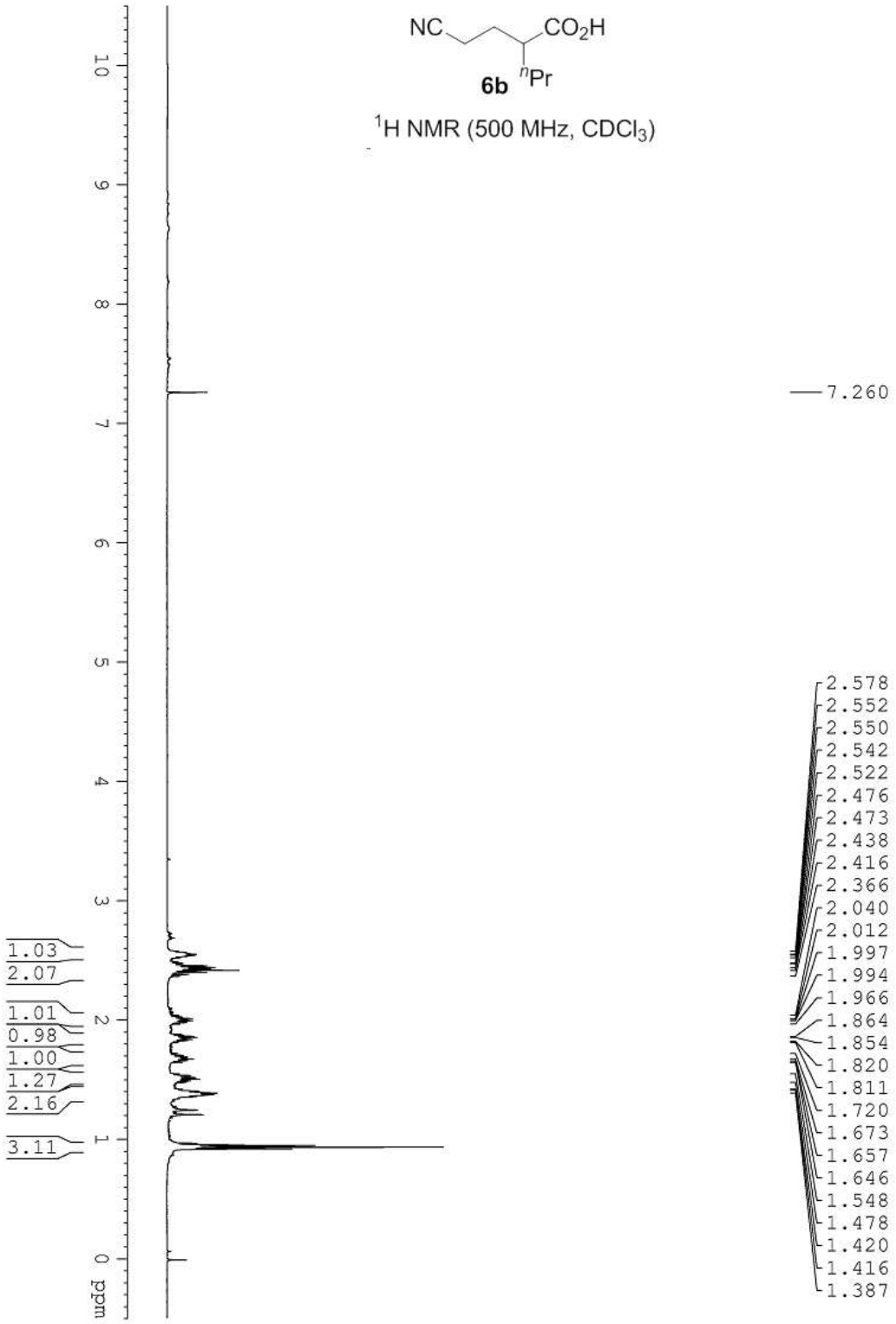

D
D
O
NC
N
H
iPr
N
[D2]-4d
13C NMR (125 MHz, CDCl3)
172.25
148.42
138.37
136.54
134.07
128.04
127.38
122.00
121.81
119.56
116.75
77.41
77.16
76.91
54.13
54.09
31.20
20.73
20.20
20.17
15.60
15.56
15.51
ppm

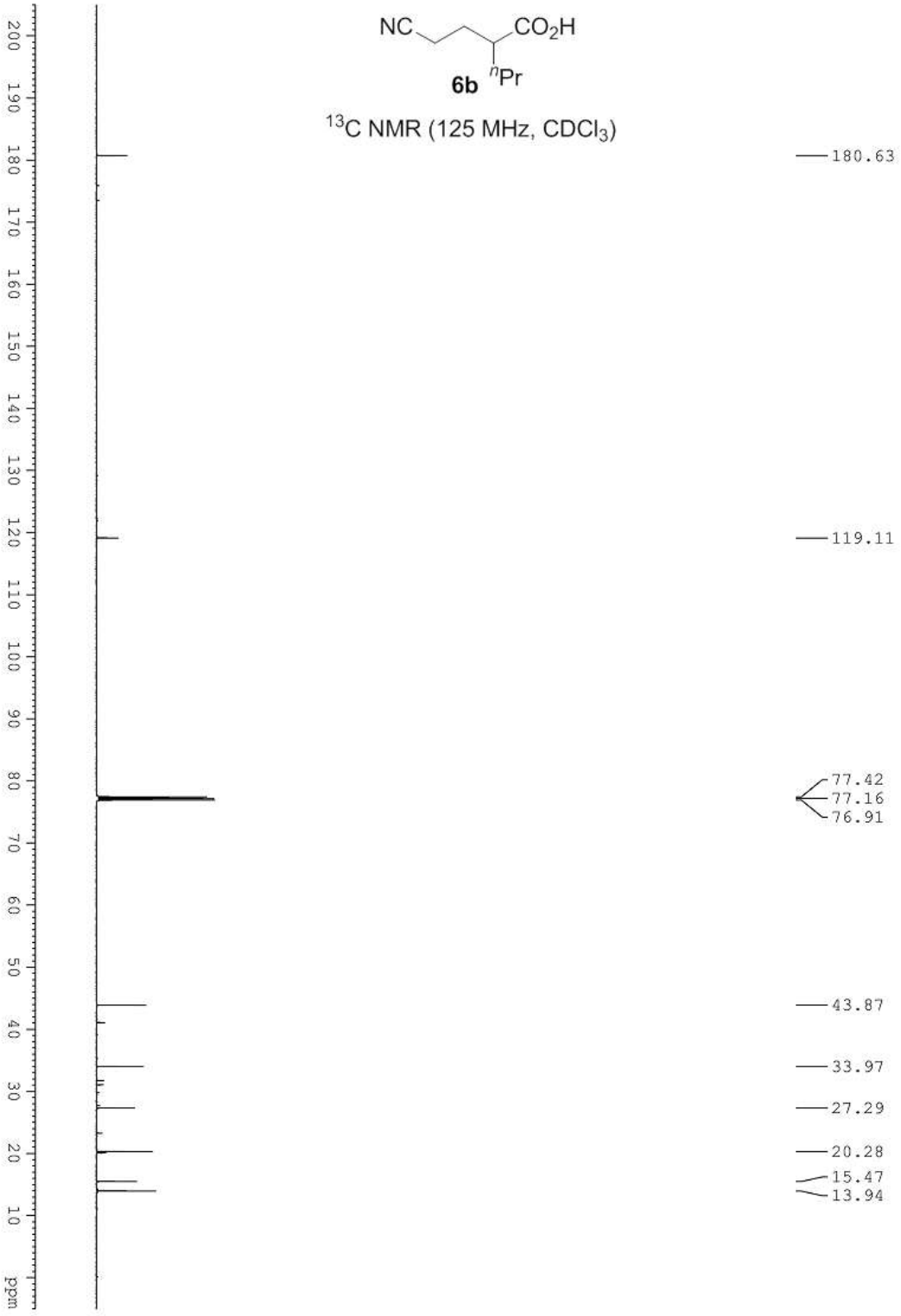

NC
D D
iPr
O
N
H
N
[D2]-4d'
1H NMR (500 MHz, CDCl3)
1.04
0.97
1.02
1.00
1.97
1.12
0.98
1.03
1.15
1.05
6.21
ppm
9.942
8.837
8.833
8.828
8.825
8.787
8.780
8.776
8.769
8.184
8.181
8.167
8.164
7.546
7.542
7.535
7.486
7.478
7.470
7.462
7.260
2.473
2.466
2.458
2.451
2.444
2.437
2.430
2.217
2.195
2.191
2.168
2.108
2.095
2.081
2.067
2.054
2.040
2.034
1.973
1.968
1.946
1.940
1.091
1.077
1.075


NC
D D
iPr
O
N
H
N
[D2]-4d'
13C NMR (125 MHz, CDCl3)
172.27
148.55
138.55
136.48
134.19
128.09
127.43
122.04
121.89
119.60
116.71
77.41
77.16
76.91
54.32
31.30
25.44
20.79
20.27
ppm


NC
O
N
Boc
N
nPr
1H NMR (500 MHz, CDCl3)
1.00
1.02
0.99
1.00
1.03
1.03
1.01
1.95
1.02
0.96
1.06
3.16
9.53
3.06
ppm
8.874
8.871
8.866
8.863
8.175
8.172
8.159
8.156
7.830
7.827
7.813
7.811
7.567
7.553
7.537
7.502
7.499
7.487
7.485
7.426
7.418
7.410
7.401
7.260
4.007
2.615
2.600
2.587
2.185
2.173
2.171
2.168
2.160
2.157
2.144
2.140
2.135
2.126
2.004
1.989
1.882
1.874
1.868
1.863
1.855
1.849
1.841
1.837
1.823
1.562
1.553
1.550
1.541
1.432
1.218
0.966
0.952
0.937


NC
O
N
Boc
N
nPr
13C NMR (125 MHz, CDCl3)
178.38
152.84
150.53
144.09
137.19
136.10
129.01
128.86
128.26
126.15
121.74
120.26
83.06
77.41
77.36
77.16
76.91
43.83
34.79
28.37
27.71
20.40
15.01
14.25
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm


NC
CO2H
nPr
6b
1H NMR (500 MHz, CDCl3)
7.260
2.578
2.552
2.550
2.542
2.522
2.476
2.473
2.438
2.416
2.366
2.040
2.012
1.997
1.994
1.966
1.864
1.854
1.820
1.811
1.720
1.673
1.657
1.646
1.548
1.478
1.420
1.416
1.387
1.03
2.07
1.01
0.98
1.00
1.27
2.16
3.11
ppm


NC
CO2H
nPr
6b
13C NMR (125 MHz, CDCl3)
180.63
119.11
77.42
77.16
76.91
43.87
33.97
27.29
20.28
15.47
13.94
ppm