Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Electronic Supplementary Information

Palladium-Catalyzed Chemoselective Anaerobic Oxidation of *N*-Heterocycle-Containing Alcohols

Masami Kuriyama, Sho Nakashima, Tsubasa Miyagi, Kanako Sato, Kosuke Yamamoto and Osamu Onomura**

Graduate School of Biomedical Sciences, Nagasaki University,
1-14 Bunkyo-machi, Nagasaki 852-8521, Japan

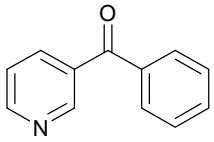
mkuriyam@nagasaki-u.ac.jp, onomura@nagasaki-u.ac.jp

Table of Contents

1. General. All melting points are not corrected. IR spectra were expressed in cm^{-1}. ^1H NMR spectra were taken at 500 and 400 MHz, while ^{13}C NMR spectra were taken at 100 MHz. Chemical shift values are expressed in ppm relative to internal or external TMS. Abbreviations are as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. A double-focusing magnetic sector mass spectrometer was used for low and high-resolution EI-MS and FAB-MS. The products were isolated by silica gel column chromatography. All reactions were performed under an argon atmosphere unless otherwise specified. Dioxane and toluene were distilled from sodium benzophenone ketyl under an argon atmosphere. Dry DMF was used as received. Alcohols **1d-k**, **1n-o**, **1q-u**, **3a**, **3e-g**, **3m-n**, **3q**, **5c**, and **3h**-*d* were prepared as new compounds. NHC·HCl **L1-4**[1], NHC-Pd complex **C2**[1], alcohols **1a**[2a], **1b**[2b], **1c**[2c], **1l**[2d], **1p**[2d], **1v**[2e], **3b**[3a], **3c**[3b], **3i-j**[3b], **3k**[3c], **3o**[3d], **3r**[3e], **3s-t**[3f], **3u-v**[3g], **5b**[4] and aryl chloride **7**[5] were prepared as previously reported. In the case of alcohols **3c-d**, **3m**, and **3s-u**, their *trans*-isomers were used as starting materials.

2. Typical procedure for the palladium-catalyzed chemoselective anaerobic oxidation of *N*-heterocycle-containing alcohols. Under an argon atmosphere, a reaction tube was charged with **L2** (8.66 mg, 0.02 mmol), $[Pd(allyl)Cl]_2$ (1.83 mg, 0.005 mmol), and Cs_2CO_3 (326 mg, 1.0 mmol). After toluene (2.0 mL) was added, the mixture was stirred at 80 ºC for 15 min. Then, alcohol **1a** (185 mg, 1.0 mmol) and 2-chlorotoluene (152 mg, 1.2 mmol) were added at room temperature, and the reaction mixture was stirred at 90 ºC for 16 h. After water was added at room temperature, the resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography gave desired product **2a**.

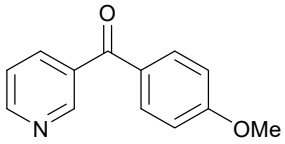
Phenyl(pyridin-3-yl)methanone (2a)[6a]



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 182 mg of the product (0.99 mmol, 99% yield) as white solids of mp 41-42 °C. ^1H-NMR (400 MHz, $CDCl_3$): δ 7.45-7.55 (m, 3H), 7.63-7.67 (m, 1H), 7.82-7.85 (m, 2H), 8.13 (dt, J = 1.7, 8.1 Hz, 1H), 8.82 (dd, J = 1.7, 4.9 Hz, 1H), 9.00 (d, J = 1.7 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 123.2 (CH), 128.5 (CH), 129.9 (CH),

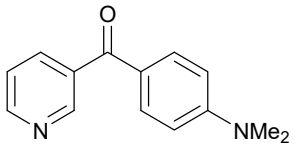
133.0 (C), 133.1 (CH), 136.5 (C), 137.1 (CH), 150.7 (CH), 152.6 (CH), 194.8 (C). IR (ATR): 650, 700, 1030, 1600, 1650 cm^{-1}. EIMS *m/z*: 183 (M^+).

4-Methoxyphenyl(pyridin-3-yl)methanone (2b)[6b]



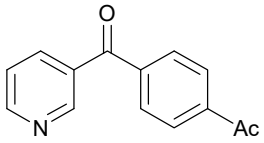
Silica gel column chromatography (hexane/AcOEt = 1/2) gave 200 mg of the product (0.94 mmol, 94% yield) as white solids of mp 99-99.5 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.91 (s, 3H), 6.88-7.02 (m, 2H), 7.45 (ddd, *J* = 1.0, 4.9, 7.8 Hz, 1H), 7.83-7.86 (m, 2H), 8.08 (dt, *J* = 2.2, 7.8 Hz, 1H), 8.80 (dd, *J* = 1.7, 4.9 Hz, 1H), 8.96 (d, *J* = 2.2 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 55.5 (CH_3), 113.9 (CH), 123.3 (CH), 129.4 (C), 132.5 (CH), 133.9 (C), 136.9 (CH), 150.6 (CH), 152.4 (CH), 163.8 (C), 193.5 (C). IR (ATR): 710, 1010, 1150, 1580, 1640 cm^{-1}. EIMS *m/z*: 213 (M^+).

4-(Dimethylamino)phenyl(pyridin-3-yl)methanone (2c)



Silica gel column chromatography (hexane/AcOEt = 1/2) gave 209 mg of the product (0.92 mmol, 92% yield) as yellow solids of mp 96-97 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.10 (s, 6H), 6.70 (d, *J* = 9.0 Hz, 2H), 7.42 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.80 (d, *J* = 9.0 Hz, 2H), 8.04 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.76 (dd, *J* = 1.5, 4.9 Hz, 1H), 8.93 (d, *J* = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 39.9 (CH_3), 110.7 (CH), 123.1 (CH), 124.0 (C), 132.7 (CH), 134.9 (C), 136.7 (CH), 150.3 (CH), 151.7 (CH), 153.6 (C), 192.8 (C). IR (ATR): 710, 810, 1150, 1580, 1630 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{14}N_2O$ (M^+): 226.1106. Found: 226.1102.

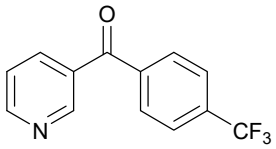
4-Acetylphenyl(pyridin-3-yl)methanone (2d)



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 205 mg of the product (0.91 mmol, 91% yield) as white solids of mp 110-110.5 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.69 (s, 3H), 7.49

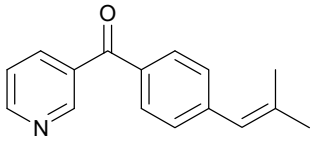
(dd, *J* = 4.9, 7.3 Hz, 1H), 7.90 (d, *J* = 8.3 Hz, 2H), 8.10 (d, *J* = 8.3 Hz, 2H), 8.14 (d, *J* = 7.8 Hz, 1H), 8.85 (d, *J* = 3.9 Hz, 1H), 9.01 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 26.7 (CH_3), 123.5 (CH), 128.4 (CH), 130.0 (CH), 132.5 (C), 137.1 (CH), 140.1 (C), 140.2 (C), 151.0 (CH), 153.3 (CH), 194.2 (C), 197.4 (C). IR (ATR): 710, 860, 1250, 1650, 1690 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{11}NO_2$ (M^+): 225.0790. Found: 225.0792.

4-(Trifluoromethyl)phenyl(pyridin-3-yl)methanone (2e)[6c]



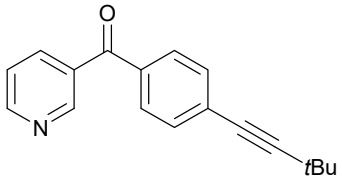
Silica gel column chromatography (hexane/AcOEt = 1/1) gave 248 mg of the product (0.99 mmol, 99% yield) as white solids of mp 53-54 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.49 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.80 (d, *J* = 7.8 Hz, 2H), 7.93 (d, *J* = 7.8 Hz, 2H), 8.14 (d, *J* = 7.8 Hz, 1H), 8.86 (d, *J* = 3.9 Hz, 1H), 9.01 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 123.5 (q, *J* = 273.1 Hz, C), 123.6 (CH), 125.7 (q, *J* = 4.1 Hz, CH), 130.2 (CH), 132.4 (C), 134.4 (q, *J* = 33.1 Hz, C), 137.2 (CH), 139.7 (C), 151.0 (CH), 153.5 (CH), 193.9 (C). IR (ATR): 700, 860, 1110, 1650 cm^{-1}. EIMS *m/z*: 251 (M^+).

(4-(2-Methylprop-1-enyl)phenyl)(pyridin-3-yl)methanone (2f)



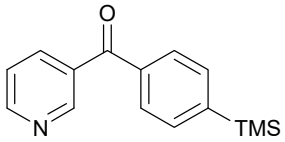
Silica gel column chromatography (hexane/AcOEt = 7/3) gave 235 mg of the product (0.99 mmol, 99% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.93 (s, 3H), 1.96 (s, 3H), 6.33 (s, 1H), 7.36 (d, *J* = 8.3 Hz, 2H), 7.46 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.79 (d, *J* = 8.3 Hz, 2H), 8.12 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.81 (dd, *J* = 2.0, 4.9 Hz, 1H), 9.00 (d, *J* = 2.0 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 19.6 (CH_3), 27.1 (CH_3), 123.3 (CH), 124.4 (CH), 128.8 (CH), 130.1 (CH), 133.5 (C), 133.9 (C), 137.1 (CH), 138.9 (C), 144.0 (C), 150.8 (CH), 152.6 (CH), 194.5 (C). IR (ATR): 710, 870, 1580, 1650 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{16}H_{15}NO$ (M^+): 237.1154. Found: 237.1154.

(4-(3,3-Dimethylbut-1-ynyl)phenyl)(pyridin-3-yl)methanone (2g)



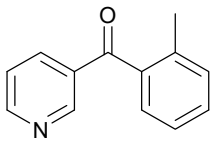
Silica gel column chromatography (hexane/AcOEt = 3/1) gave 252 mg of the product (0.96 mmol, 96% yield) as white solids of mp 77-78 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.34 (s, 9H), 7.44-7.48 (m, 1H), 7.50-7.53 (m, 2H), 7.74-7.77 (m, 2H), 8.10 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.82 (dd, *J* = 2.0, 4.9 Hz, 1H), 8.97-8.98 (m, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.0 (C), 30.7 (CH_3), 78.5 (C), 102.8 (C), 123.4 (CH), 129.5 (C), 129.9 (CH), 131.7 (CH), 133.2 (C), 135.1 (C), 137.1 (CH), 150.9 (CH), 152.9 (CH), 194.3 (C). IR (ATR): 710, 850, 1580, 1650, 2200 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{18}H_{17}NO$ (M^+): 263.1310. Found: 263.1310.

4-(Trimethylsilyl)phenyl(pyridin-3-yl)methanone (2h)



Silica gel column chromatography (hexane/AcOEt = 4/1) gave 249 mg of the product (0.98 mmol, 98% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 0.32 (s, 9H), 7.46 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.67 (d, *J* = 8.3 Hz, 2H), 7.78 (d, *J* = 8.3 Hz, 2H), 8.13 (d, *J* = 7.8 Hz, 1H), 8.81-8.83 (m, 1H), 9.01 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ −1.47 (CH_3), 123.4 (CH), 129.0 (CH), 133.2 (C), 133.5 (CH), 136.8 (C), 137.2 (CH), 147.5 (C), 151.0 (CH), 152.9 (CH), 195.2 (C). IR (ATR): 730, 830, 1580, 1660 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{17}NOSi$ (M^+): 255.1079. Found: 255.1080.

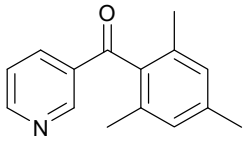
2-Methylphenyl(pyridin-3-yl)methanone (2i)[6d]



Silica gel column chromatography (hexane/AcOEt = 1/2) gave 195 mg of the product (0.99 mmol, 99% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.38 (s, 3H), 7.29 (d, *J* = 7.8 Hz, 1H), 7.34 (d, *J* = 4.9 Hz, 2H), 7.42-7.46 (m, 2H), 8.13-8.15 (m, 1H), 8.80 (dd, *J* = 1.5, 4.9 Hz, 1H), 8.95

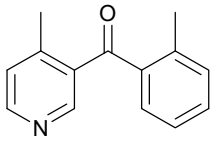
(s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 20.0 (CH_3), 123.4 (CH), 125.4 (CH), 128.9 (CH), 131.0 (CH), 131.4 (CH), 133.3 (C), 137.1 (CH), 137.25 (C), 137.32 (C), 151.5 (CH), 153.3 (CH), 197.0 (C). IR (ATR): 700, 730, 920, 1270, 1660 cm^{-1}. EIMS *m/z*: 197 (M^+).

2,4,6-Trimethylphenyl(pyridin-3-yl)methanone (2j)



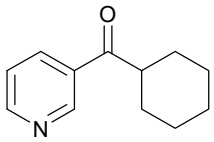
Silica gel column chromatography (hexane/AcOEt = 1/1) gave 200 mg of the product (0.89 mmol, 89% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.09 (s, 6H), 2.34 (s, 3H), 6.92 (s, 2H), 7.43 (dd, *J* = 4.9, 7.8 Hz, 1H), 8.14 (d, *J* = 7.8 Hz, 1H), 8.80 (d, *J* = 3.4 Hz, 1H), 8.91 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 19.3 (CH_3), 21.1 (CH_3), 123.8 (CH), 128.6 (CH), 132.6 (C), 134.2 (C), 135.7 (C), 136.4 (CH), 139.2 (C), 151.2 (CH), 153.9 (CH), 199.6 (C). IR (ATR): 700, 900, 1270, 1580, 1680 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{15}NO$ (M^+): 225.1154. Found: 225.1152.

2-Methylphenyl(4-methylpyridin-3-yl)methanone (2k)



Silica gel column chromatography (hexane/AcOEt = 2/1) gave 193 mg of the product (0.91 mmol, 91% yield) as an orange oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.46 (s, 3H), 2.48 (s, 3H), 7.22-7.25 (m, 2H), 7.32 (d, *J* = 9.3 Hz, 2H), 7.44 (t, *J* = 7.3 Hz, 1H), 8.50 (s, 1H), 8.57 (d, *J* = 4.9 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 20.1 (CH_3), 20.6 (CH_3), 125.7 (CH), 126.3 (CH), 130.5 (CH), 131.8 (CH), 135.0 (C), 138.0 (C), 138.5 (C), 147.5 (C), 150.8 (CH), 151.4 (CH), 198.7 (C). IR (ATR): 730, 920, 1270, 1590, 1660 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{13}NO$ (M^+): 211.0997. Found: 211.0993.

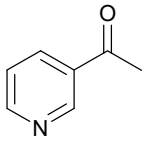
Cyclohexyl(pyridin-3-yl)methanone (2l)[6e]



Silica gel column chromatography (hexane/AcOEt = 1/2) gave 169 mg of the product (0.89 mmol,

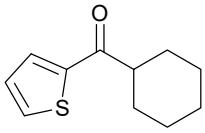
89% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.22-1.33 (m, 1H), 1.36-1.56 (m, 4H), 1.73-1.78 (m, 1H), 1.84-1.93 (m, 4H), 3.23 (tt, *J* = 3.4, 11.2 Hz, 1H), 7.41-7.44 (m, 1H), 8.22 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.77 (dd, *J* = 2.0, 4.9 Hz, 1H), 9.16 (d, *J* = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 25.5 (CH_2), 25.6 (CH_2), 28.9 (CH_2), 45.9 (CH), 123.6 (CH), 131.4 (C), 135.6 (CH), 149.7 (CH), 153.1 (CH), 202.6 (C). IR (ATR): 710, 970, 1580, 1680 cm^{-1}. EIMS *m/z*: 189 (M^+).

1-(Pyridin-3-yl)ethanone (2m)



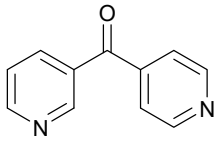
Silica gel column chromatography (hexane/AcOEt = 1/1) gave 111 mg of the product (0.92 mmol, 92% yield) as a brown oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.66 (s, 3H), 7.42-7.45 (m, 1H), 8.23-8.26 (m, 1H), 8.80 (dd, *J* = 1.5, 4.9 Hz, 1H), 9.18 (d, *J* = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 26.6 (CH_3), 123.6 (CH), 132.2 (C), 135.4 (CH), 150.0 (CH), 153.6 (CH), 196.8 (C). IR (ATR): 810, 1020, 1590, 1680 cm^{-1}. HRMS (EI) *m/z* calcd for C_7H_7NO (M^+): 121.0528. Found: 121.0528.

Cyclohexyl(thiophen-2-yl)methanone (2n)[6f]



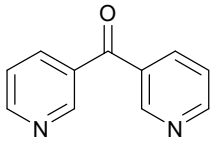
Silica gel column chromatography (hexane/AcOEt = 19/1) gave 158 mg of the product (0.81 mmol, 81% yield) as a colorless oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.22-1.42 (m, 3H), 1.51-1.60 (m, 2H), 1.73 (d, *J* = 11.7 Hz, 1H), 1.84-1.93 (m, 4H), 3.10 (tt, *J* = 3.4, 11.7 Hz, 1H), 7.12-7.14 (m, 1H), 7.62 (d, *J* = 4.9 Hz, 1H), 7.72 (d, *J* = 3.4 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 25.68 (CH_2), 25.71 (CH_2), 29.5 (CH_2), 47.4 (CH), 128.0 (CH), 131.4 (CH), 133.4 (CH), 144.0 (C), 196.9 (C). IR (ATR): 710, 760, 1200, 1410, 1650 cm^{-1}. EIMS *m/z*: 194 (M^+).

Pyridin-3-yl(pyridin-4-yl)methanone (2o)



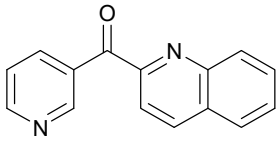
Silica gel column chromatography (AcOEt/MeOH = 20/1) gave 170 mg of the product (0.92 mmol, 92% yield) as white solids of mp 120-121 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.50 (dd, *J* = 4.9, 8.1 Hz, 1H), 7.60-7.62 (m, 2H), 8.15-8.17 (m, 1H), 8.86-8.89 (m, 3H), 9.02 (d, *J* = 2.2 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 122.6 (CH), 123.6 (CH), 131.5 (C), 137.1 (CH), 143.1 (C), 150.7 (CH), 151.0 (CH), 153.8 (CH), 193.7 (C). IR (ATR): 710, 1020, 1160, 1590, 1660 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_8N_2O$ (M^+): 184.0637. Found: 184.0615.

Dipyridin-3-ylmethanone (2p)[6g]



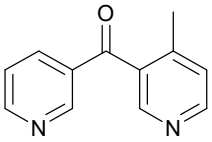
Silica gel column chromatography (AcOEt/MeOH = 20/1) gave 160 mg of the product (0.87 mmol, 87% yield) as white solids of mp 114-115 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.50 (dd, *J* = 4.9, 7.8 Hz, 2H), 8.15 (dt, *J* = 2.0, 7.8 Hz, 2H), 8.87 (dd, *J* = 1.5, 4.9 Hz, 2H), 9.03 (d, *J* = 1.5 Hz, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 123.6 (CH), 132.4 (C), 137.1 (CH), 151.0 (CH), 153.6 (CH), 193.4 (C). IR (ATR): 700, 730, 810, 1580, 1650 cm^{-1}. EIMS *m/z*: 184 (M^+).

Pyridin-3-yl(quinolin-2-yl)methanone (2q)



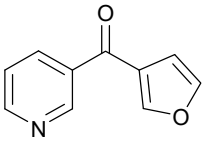
Silica gel column chromatography (AcOEt) gave 233 mg of the product (0.99 mmol, 99% yield) as white solids of mp 119-120 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 7.48-7.50 (m, 1H), 7.68-7.71 (m, 1H), 7.80-7.83 (m, 1H), 7.93 (d, *J* = 7.6 Hz, 1H), 8.21 (d, *J* = 8.6 Hz, 1H), 8.23 (d, *J* = 8.6 Hz, 1H), 8.39 (d, *J* = 8.6 Hz, 1H), 8.59 (dt, *J* = 2.0, 8.1 Hz, 1H), 8.84 (dd, *J* = 1.7, 4.9 Hz, 1H), 9.55 (d, *J* = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 120.4 (CH), 123.1 (CH), 127.7 (CH), 128.9 (CH), 129.1 (C), 130.3 (CH), 130.6 (CH), 132.0 (C), 137.4 (CH), 138.6 (CH), 146.7 (C), 152.7 (CH), 152.9 (CH), 153.4 (C), 192.1 (C). IR (ATR): 700, 770, 850, 1660 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{10}N_2O$ (M^+): 234.0793. Found: 234.0794.

4-Methylpyridin-3-yl(pyridin-3-yl)methanone (2r)



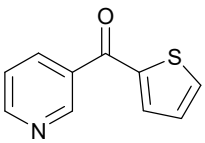
Silica gel column chromatography (AcOEt/MeOH = 20/1) gave 172 mg of the product (0.87 mmol, 87% yield) as white solids of mp 83-84 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.43 (s, 3H), 7.30 (d, *J* = 5.4 Hz, 1H), 7.48 (dd, *J* = 4.9, 7.8 Hz, 1H), 8.15 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.59 (s, 1H), 8.64 (d, *J* = 5.4 Hz, 1H), 8.86 (dd, *J* = 2.0, 4.6 Hz, 1H), 8.97 (d, *J* = 2.0 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 19.6 (CH_3), 123.6 (CH), 126.2 (CH), 132.7 (C), 133.3 (C), 136.9 (CH), 147.1 (C), 149.4 (CH), 151.3 (CH), 151.6 (CH), 153.9 (CH), 194.8 (C). IR (ATR): 700, 750, 1580, 1660 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{12}H_{10}N_2O$ (M^+): 198.0793. Found: 198.0790.

Furan-3-yl(pyridin-3-yl)methanone (2s)



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 143 mg of the product (0.83 mmol, 83% yield) as white solids of mp 110-111 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 6.93 (d, *J* = 1.2 Hz, 1H), 7.46 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.55-7.56 (m, 1H), 7.97 (s, 1H), 8.15 (dt, *J* = 2.0, 7.8 Hz, 1H), 8.82 (dd, *J* = 1.5, 4.9 Hz, 1H), 9.08 (d, *J* = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 109.9 (CH), 123.6 (CH), 126.4 (C), 134.3 (C), 136.2 (CH), 144.5 (CH), 148.8 (CH), 149.8 (CH), 153.1 (CH), 187.5 (C). IR (ATR): 710, 740, 870, 1590, 1650 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{10}H_7NO_2$ (M^+): 173.0477. Found: 173.0457.

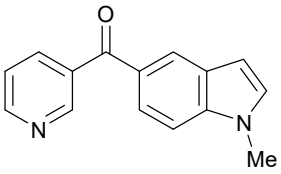
Pyridin-3-yl(thiophen-2-yl)methanone (2t)[6h]



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 185 mg of the product (0.98 mmol, 98% yield) as white solids of mp 92-93 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.21 (t, *J* = 4.4 Hz, 1H), 7.47 (dd, *J* = 4.9, 7.8 Hz, 1H), 7.67 (d, *J* = 3.7 Hz, 1H), 7.80 (d, *J* = 4.9 Hz, 1H), 8.15-8.17 (m, 1H), 8.81 (dd, *J* = 1.2, 4.9 Hz, 1H), 9.10 (d, *J* = 1.7 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ

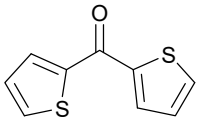
123.5 (CH), 128.3 (CH), 133.8 (C), 135.16 (CH), 135.20 (CH), 136.5 (CH), 143.0 (C), 150.0 (CH), 152.8 (CH), 186.3 (C). IR (ATR): 700, 730, 820, 850, 1630 cm^{-1}. EIMS *m/z*: 189 (M^+).

1-Methyl-1*H*-indol-5-yl(pyridin-3-yl)methanone (2u)



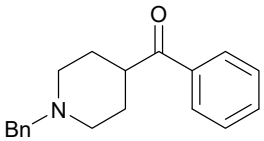
Silica gel column chromatography (hexane/AcOEt = 1/1) gave 232 mg of the product (0.98 mmol, 98% yield) as white solids of mp 115-116 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.87 (s, 3 H), 6.61-6.62 (m, 1 H), 7.17 (d, *J* = 3.4 Hz, 1 H), 7.43 (d, *J* = 8.3 Hz, 1 H), 7.44-7.48 (m, 1 H), 7.84 (dd, *J* = 2.0, 8.8 Hz, 1 H), 8.12-8.14 (m, 2 H), 8.80 (dd, *J* = 2.0, 4.9 Hz, 1 H), 9.01-9.02 (m, 1 H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 33.0 (CH_3), 103.1 (CH), 109.4 (CH), 123.2 (CH), 123.6 (CH), 125.6 (CH), 127.8 (C), 128.5 (C), 130.8 (CH), 134.7 (C), 137.1 (CH), 139.3 (C), 150.8 (CH), 152.1 (CH), 195.2 (C). IR (ATR): 740, 890, 1020, 1100, 1640 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{12}N_2O$ (M^+): 236.0950. Found: 236.0945.

Dithiophen-2-ylmethanone (2v)[6i]



Silica gel column chromatography (hexane/AcOEt = 5/1) gave 171 mg of the product (0.88 mmol, 88% yield) as white solids of mp 87-88 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 7.19 (dd, *J* = 3.9, 4.9 Hz, 2H), 7.70 (dd, *J* = 1.2, 4.9 Hz, 2H), 7.91 (dd, *J* = 1.2, 3.9 Hz, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 128.0 (CH), 133.2 (CH), 133.5 (CH), 143.0 (C), 178.9 (C). IR (ATR): 730, 780, 1050, 1220, 1610 cm^{-1}. EIMS *m/z*: 194 (M^+).

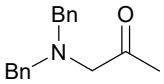
1-Benzylpiperidin-4-yl(phenyl)methanone (4a)



Silica gel column chromatography (hexane/AcOEt = 1/2) gave 254 mg of the product (0.91 mmol,

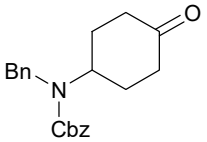
91% yield) as pale yellow solids of mp 90-91 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.83-1.90 (m, 4H), 2.10-2.16 (m, 2H), 2.96-2.99 (m, 2H), 3.21-3.27 (m, 1H), 3.55 (s, 2H), 7.24-7.27 (m, 1H), 7.30-7.35 (m, 4H), 7.44-7.47 (m, 2H), 7.53-7.57 (m, 1H), 7.92-7.94 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.7 (CH_2), 43.6 (CH), 53.1 (CH_2), 63.2 (CH_2), 127.0 (CH), 128.20 (CH), 128.24 (CH), 128.7 (CH), 129.1 (CH), 132.9 (CH), 136.2 (C), 138.4 (C), 202.9 (C). IR (ATR): 700, 730, 980, 1200, 1680 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{19}H_{21}NO$ (M^+): 279.1623. Found: 279.1631.

1-(Dibenzylamino)propan-2-one (4b)[7a]



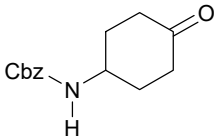
Silica gel column chromatography (hexane/AcOEt = 10/1) gave 235 mg of the product (0.93 mmol, 93% yield) as a colorless oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.11 (s, 3H), 3.19 (s, 2H), 3.67 (s, 4H), 7.25-7.29 (m, 2H), 7.32-7.35 (m, 4H), 7.38-7.40 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 27.5 (CH_3), 58.6 (CH_2), 63.4 (CH_2), 127.3 (CH), 128.4 (CH), 129.0 (CH), 138.7 (C), 209.2 (C). IR (ATR): 700, 740, 1490, 1710 cm^{-1}. EIMS *m/z*: 253 (M^+).

***N*-Benzyl-*N*-benzyloxycarbonyl-4-aminocyclohexanone (4c)**



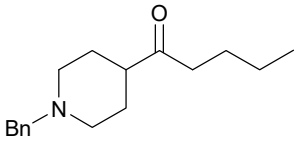
As a starting material, *trans*-4-(benzylamino)cyclohexanol[3b] was used. After heated for 16 h, 1 N NaOH solution (1.2 mL) and benzyl chloroformate (205 mg, 1.2 mmol) were added at 0 °C. The resulting mixture was stirred at room temperature for 2 h. After water was added, the mixture was acidified with 10% HCl solution to pH 1 and extracted with AcOEt. The combined organic layers were washed with brine and dried over $MgSO_4$. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 2/1) gave 320 mg of the product (0.95 mmol, 95% yield) as white solids of mp 112-114 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.84-1.92 (m, 2H), 1.95-2.04 (m, 2H), 2.32-2.47 (m, 4H), 4.42-4.56 (m, 3H), 5.13-5.27 (m, 2H), 7.15-7.41 (m, 10H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 29.5 (CH_2), 39.7 (CH_2), 46.9 (CH_2), 54.4 (CH), 67.2 (CH_2), 126.6 (CH), 127.0 (CH), 127.9 (CH), 128.0 (CH), 128.4 (CH), 136.4 (C), 138.9 (C), 156.1 (C), 209.4 (C). IR (ATR): 700, 740, 1220, 1680, 1720 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{21}H_{23}NO_3$ (M^+): 337.1678. Found: 337.1670.

_N_-Benzyloxycarbonyl-4-aminocyclohexanone (4d)[7b]



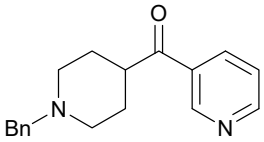
As a starting material, *trans*-4-aminocyclohexanol was used. After heated for 16 h, 1 N NaOH solution (1.2 mL) and benzyl chloroformate (205 mg, 1.2 mmol) were added at 0 °C. The resulting mixture was stirred at room temperature for 2 h. After water was added, the mixture was acidified with 10% HCl solution to pH 1 and extracted with AcOEt. The combined organic layers were washed with brine and dried over $MgSO_4$. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 1/1) gave 176 mg of the product (0.71 mmol, 71% yield) as white solids of mp 81-82 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.66-1.74 (m, 2H), 2.21-2.28 (m, 2H), 2.37-2.47 (m, 4H), 3.99 (brs, 1H), 4.73-4.86 (m, 1H), 5.11 (s, 2H), 7.31-7.39 (m, 5H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 31.9 (CH_2), 38.7 (CH_2), 47.8 (CH), 66.7 (CH_2), 128.1 (CH), 128.2 (CH), 128.5 (CH), 136.3 (C), 155.7 (C), 209.8 (C). IR (ATR): 690, 1230, 1690, 1720, 3340 cm^{-1}. EIMS *m/z*: 247 (M^+).

1-(1-Benzylpiperidin-4-yl)pentan-1-one (4e)



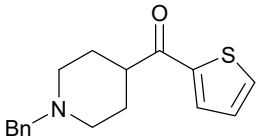
Silica gel column chromatography (hexane/AcOEt = 1/2) gave 238 mg of the product (0.92 mmol, 92% yield) as a brown oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 0.90 (t, *J* = 7.3 Hz, 3H), 1.25-1.34 (m, 2H), 1.50-1.58 (m, 2H), 1.62-1.72 (m, 2H), 1.77-1.80 (m, 2H), 2.00 (dt, *J* = 2.0, 11.2 Hz, 2H), 2.29 (tt, *J* = 3.9, 11.2 Hz, 1H), 2.43 (t, *J* = 7.3 Hz, 2H), 2.89-2.92 (m, 2H), 3.50 (s, 2H), 7.23-7.26 (m, 1H), 7.30-7.32 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 13.8 (CH_3), 22.3 (CH_2), 25.6 (CH_2), 27.7 (CH_2), 40.0 (CH_2), 48.7 (CH), 53.0 (CH_2), 63.1 (CH_2), 127.0 (CH), 128.2 (CH), 129.1 (CH), 138.4 (C), 213.4 (C). IR (ATR): 700, 730, 980, 1130, 1710 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{17}H_{25}NO$ (M^+): 259.1936. Found: 259.1935.

(1-Benzylpiperidin-4-yl)(pyridin-3-yl)methanone (4f)



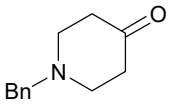
Silica gel column chromatography (AcOEt) gave 267 mg of the product (0.95 mmol, 95% yield) as pale yellow solids of mp 64-66 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.84-1.91 (m, 4H), 2.12-2.17 (m, 2H), 2.96-3.00 (m, 2H), 3.18-3.24 (m, 1H), 3.55 (s, 2H), 7.24-7.28 (m, 1H), 7.30-7.34 (m, 4H), 7.42 (dd, *J* = 4.9, 8.1 Hz, 1H), 8.21 (dt, *J* = 2.0, 8.1 Hz, 1H), 8.77 (dd, *J* = 1.7, 4.7 Hz, 1H), 9.14 (d, *J* = 2.0 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.4 (CH_2), 44.1 (CH), 52.8 (CH_2), 63.1 (CH_2), 123.7 (CH), 127.0 (CH), 128.2 (CH), 129.0 (CH), 131.3 (C), 135.7 (CH), 138.2 (C), 149.7 (CH), 153.3 (CH), 201.6 (C). IR (ATR): 700, 810, 980, 1590, 1680 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{18}H_{20}N_2O$ (M^+): 280.1576. Found: 280.1587.

(1-Benzylpiperidin-4-yl)(thiophen-2-yl)methanone (4g)



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 238 mg of the product (0.83 mmol, 83% yield) as pale yellow solids of mp 94-96 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.84-1.97 (m, 4H), 2.11 (dt, *J* = 2.9, 11.2 Hz, 2H), 2.97-3.00 (m, 2H), 3.04-3.12 (m, 1H), 3.54 (s, 2H), 7.12-7.14 (m, 1H), 7.27-7.34 (m, 5H), 7.63 (d, *J* = 4.9 Hz, 1H), 7.72 (d, *J* = 3.9 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.9 (CH_2), 45.4 (CH), 53.0 (CH_2), 63.1 (CH_2), 127.0 (CH), 128.1 (CH), 128.2 (CH), 129.1 (CH), 131.5 (CH), 133.5 (CH), 138.4 (C), 143.7 (C), 195.8 (C). IR (ATR): 700, 750, 950, 1420, 1650 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{17}H_{19}NOS$ (M^+): 285.1187. Found: 285.1183.

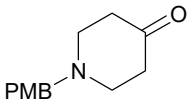
1-Benzylpiperidin-4-one (4h)[3b]



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 166 mg of the product (0.88 mmol, 88% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.46 (t, *J* = 6.1 Hz, 4H), 2.75 (t, *J* = 6.1 Hz, 4H), 3.63 (s, 2H), 7.26-7.30 (m, 1H), 7.32-7.37 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ

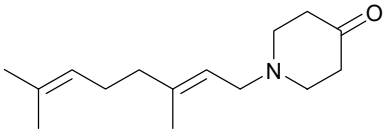
41.2 (CH_2), 52.8 (CH_2), 61.9 (CH_2), 127.3 (CH), 128.4 (CH), 128.9 (CH), 138.1 (C), 209.4 (C). IR (ATR): 700, 740, 1070, 1190, 1710 cm^{-1}. EIMS *m/z*: 189 (M^+).

1-(4-Methoxybenzyl)piperidin-4-one (4i)[3b]



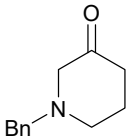
Silica gel column chromatography (hexane/AcOEt = 1/2) gave 187 mg of the product (0.85 mmol, 85% yield) as a pale brown oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.45 (t, *J* = 6.1 Hz, 4H), 2.73 (t, *J* = 6.1 Hz, 4H), 3.56 (s, 2H), 3.81 (s, 3H), 6.86-6.89 (m, 2H), 7.26-7.27 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 41.2 (CH_2), 52.7 (CH_2), 55.2 (CH_3), 61.3 (CH_2), 113.7 (CH), 130.10 (C), 130.13 (CH), 158.9 (C), 209.5 (C). IR (ATR): 800, 1030, 1240, 1510, 1710 cm^{-1}. EIMS *m/z*: 219 (M^+).

***N*-Geranylpiperidin-4-one (4j)**[3b]



Silica gel column chromatography (AcOEt) gave 190 mg of the product (0.81 mmol, 81% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.60 (s, 3H), 1.65 (s, 3H), 1.67 (s, 3H), 2.04-2.14 (m, 4H), 2.47 (t, *J* = 6.1 Hz, 4H), 2.74 (t, *J* = 6.1 Hz, 4H), 3.08 (d, *J* = 6.9 Hz, 2H), 5.07-5.10 (m, 1H), 5.28-5.31 (m, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 16.2 (CH_3), 17.6 (CH_3), 25.6 (CH_3) 26.2 (CH_2), 39.7 (CH_2), 41.3 (CH_2), 52.9 (CH_2), 54.9 (CH_2), 120.8 (CH), 124.0 (CH), 131.7 (C), 139.4 (C), 209.4 (C). IR (ATR): 760, 1080, 1120, 1210, 1720 cm^{-1}. EIMS *m/z*: 235 (M^+).

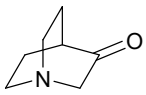
1-Benzylpiperidin-3-one (4k)[7c]



Silica gel column chromatography (hexane/AcOEt = 1/2) gave 178 mg of the product (0.94 mmol, 94% yield) as a pale yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.92-1.98 (m, 2H), 2.37 (t, *J* = 7.3 Hz, 2H), 2.65 (t, *J* = 5.4 Hz, 2H), 3.01 (s, 2H), 3.59 (s, 2H), 7.25-7.35 (m, 5H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 23.8 (CH_2), 38.6 (CH_2), 51.4 (CH_2), 62.5 (CH_2), 64.5 (CH_2), 127.4 (CH), 128.4

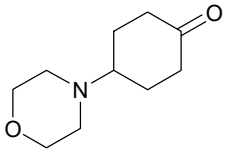
(CH), 129.0 (CH), 137.2 (C), 207.2 (C). IR (ATR): 700, 740, 980, 1720 cm^{-1}. EIMS *m/z*: 189 (M^+).

Quinuclidin-3-one (4l)[3b]



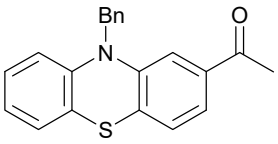
Silica gel column chromatography (AcOEt/MeOH = 3/1) gave 104 mg of the product (0.83 mmol, 83% yield) as white solids of mp 131-132 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.94-2.06 (m, 4H), 2.45-2.48 (m, 1H), 2.88-2.96 (m, 2H), 2.99-3.06 (m, 2H), 3.30 (s, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 25.5 (CH_2), 39.5 (CH), 46.8 (CH_2), 62.7 (CH_2), 219.8 (C). IR (ATR): 1720 cm^{-1}. EIMS *m/z*: 125 (M^+).

4-Morpholinocyclohexanone (4m)



Silica gel column chromatography (CH_2Cl_2/MeOH = 20/1) gave 162 mg of the product (0.88 mmol, 88% yield) as a colorless oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.83-1.92 (m, 2H), 2.01-2.07 (m, 2H), 2.27-2.34 (m, 2H), 2.47-2.64 (m, 7H), 3.73-3.75 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 27.7 (CH_2), 38.5 (CH_2), 50.0 (CH_2), 60.1 (CH), 67.2 (CH_2), 211.1 (C). IR (ATR): 820, 960, 1120, 1710 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{10}H_{17}NO_2$ (M^+): 183.1259. Found: 183.1259.

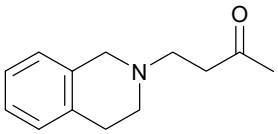
1-(10-Benzyl-10*H*-phenothiazin-2-yl)ethanone (4n)



Silica gel column chromatography (hexane/AcOEt = 2/1) gave 305 mg of the product (0.92 mmol, 92% yield) as a yellow amorphous. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.38 (s, 3H), 5.11 (s, 2H), 6.69 (d, *J* = 8.1 Hz, 1H), 6.89 (dt, *J* = 1.0, 7.3 Hz, 1H), 7.00-7.03 (m, 1H), 7.08 (dd, *J* = 1.5, 7.3 Hz, 1H), 7.13 (d, *J* = 8.1 Hz, 1H), 7.20 (d, *J* = 1.5 Hz, 1H), 7.23-7.26 (m, 1H), 7.30-7.34 (m, 4H), 7.42 (dd, *J* = 1.5, 8.1 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 26.2 (CH_3), 52.4 (CH_2), 114.4 (CH), 115.8 (CH), 122.3 (C), 122.9 (CH), 126.5 (CH), 126.6 (CH), 126.9 (CH), 127.2 (CH), 127.7 (CH), 128.8 (CH), 130.6 (C), 136.1 (C), 136.2 (C), 144.0 (C), 144.6 (C), 197.2 (C). IR (ATR): 690, 730,

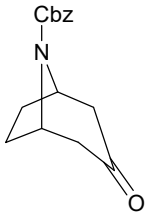
1590, 1670 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{21}H_{17}NOS$ (M^+): 331.1031. Found: 331.1027.

4-(3,4-Dihydroisoquinolin-2(1*H*)-yl)butan-2-one (4o)[7d]



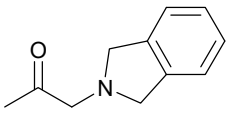
Silica gel column chromatography (hexane/AcOEt = 1/2) gave 191 mg of the product (0.94 mmol, 94% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.20 (s, 3H), 2.72-2.76 (m, 4H), 2.82-2.91 (m, 2H), 2.89 (t, *J* = 5.9 Hz, 2H), 3.64 (s, 2H), 7.00-7.02 (m, 1H), 7.08-7.14 (m, 3H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.8 (CH_2), 30.0 (CH_3), 41.4 (CH_2), 50.7 (CH_2), 52.3 (CH_2), 55.8 (CH_2), 125.6 (CH), 126.1 (CH), 126.5 (CH), 128.6 (CH), 134.0 (C), 134.4 (C), 207.8 (C). IR (ATR): 740, 940, 1100, 1710 cm^{-1}. EIMS *m/z*: 203 (M^+).

***N*-Benzyloxycarbonyl-8-aza-bicyclo[3.2.1]octan-3-one (4p)**[7e]



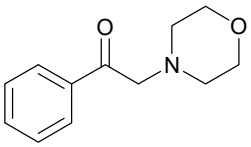
As a starting material, nortropine was used. After heated for 16 h, 1 N NaOH solution (1.2 mL) and benzyl chloroformate (205 mg, 1.2 mmol) were added at 0 °C. The resulting mixture was stirred at room temperature for 2 h. After water was added, the mixture was acidified with 10% HCl solution to pH 1 and extracted with AcOEt. The combined organic layers were washed with brine and dried over $MgSO_4$. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 3/1) gave 233 mg of the product (0.90 mmol, 90% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.67-1.72 (m, 2H), 2.10-2.12 (m, 2H), 2.36 (d, *J* = 15.9 Hz, 2H), 2.60-2.73 (m, 2H), 4.52-4.66 (m, 2H), 5.20 (s, 2H), 7.32-7.38 (m, 5H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.5 (CH_2), 29.3 (CH_2), 48.6 (CH_2), 49.1 (CH_2), 53.1 (CH), 67.2 (CH_2), 128.1 (CH), 128.2 (CH), 128.6 (CH), 136.4 (C), 153.7 (C), 208.0 (C). IR (ATR): 700, 730, 1090, 1190, 1690 cm^{-1}. EIMS *m/z*: 259 (M^+).

1-(Isoindolin-2-yl)propan-2-one (4q)



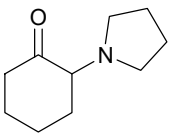
Silica gel column chromatography (hexane/AcOEt = 1/1) gave 150 mg of the product (0.86 mmol, 86% yield) as red-brown solids of mp 44-45 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.21 (s, 3H), 3.63 (s, 2H), 4.06 (s, 4H), 7.19-7.22 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 27.4 (CH_3), 59.1 (CH_2), 65.6 (CH_2), 122.2 (CH), 126.8 (CH), 139.7 (C), 206.8 (C). IR (ATR): 750, 870, 1150, 1720 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{13}NO$ (M^+): 175.0997. Found: 175.0998.

2-Morpholino-1-phenylethanone (4r)



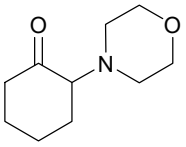
Silica gel column chromatography (hexane/AcOEt = 2/1) gave 185 mg of the product (0.90 mmol, 90% yield) as yellow solids of mp 49-51 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.61-2.63 (m, 4H), 3.78-3.80 (m, 4H), 3.82 (s, 2H), 7.45-7.48 (m, 2H), 7.56-7.60 (m, 1H), 7.99-8.01 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 53.7 (CH_2), 64.5 (CH_2), 66.7 (CH_2), 128.0 (CH), 128.5 (CH), 133.3 (CH), 135.9 (C), 196.1 (C). IR (ATR): 690, 750, 1110, 1220, 1690 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{12}H_{15}NO_2$ (M^+): 205.1103. Found: 205.1100.

2-(Pyrrolidin-1-yl)cyclohexanone (4s)[7f]



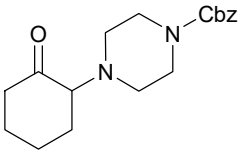
As a starting material, *trans*-2-(pyrrolidin-1-yl)cyclohexanol[3f] was used. Silica gel column chromatography (CH_2Cl_2/MeOH = 10/1) gave 136 mg of the product (0.81 mmol, 81% yield) as a yellow oil. ^{1}H-NMR (500 MHz, CD_2Cl_2): δ 1.55-1.63 (m, 1H), 1.72-1.77 (m, 4H), 1.80-1.85 (m, 2H), 1.87-1.99 (m, 3H), 2.18-2.23 (m, 1H), 2.49-2.58 (m, 5H), 2.81-2.83 (m, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 22.8 (CH_2), 23.4 (CH_2), 28.3 (CH_2), 33.2 (CH_2), 40.7 (CH_2), 51.0 (CH_2), 72.2 (CH), 211.7 (C). IR (ATR): 1710 cm^{-1}. EIMS *m/z*: 167 (M^+).

2-Morpholinocyclohexanone (4t)



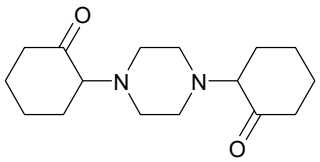
As a starting material, *trans*-2-morpholinocyclohexanol[3f] was used. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 165 mg of the product (0.91 mmol, 91% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.57-1.65 (m, 1H), 1.76-2.05 (m, 5H), 2.23-2.28 (m, 1H), 2.45-2.49 (m, 2H), 2.57-2.61 (m, 1H), 2.62-2.67 (m, 2H), 2.94-2.97 (m, 1H), 3.71-3.78 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 22.7 (CH_2), 28.0 (CH_2), 29.6 (CH_2), 40.9 (CH_2), 50.1 (CH_2), 67.0 (CH_2), 72.6 (CH), 211.4 (C). IR (ATR): 1120, 1710 cm^{-1}. HRMS (FAB) *m/z* calcd for $C_{10}H_{17}NO_2$ (M^+): 183.1259. Found: 183.1245.

***N*-Benzyloxycarbonyl-2-(piperazin-1-yl)cyclohexanone (4u)**



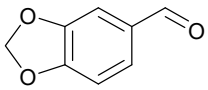
As a starting material, *trans*-2-(piperazin-1-yl)cyclohexanol[3g] was used. After heated for 16 h, 1 N NaOH solution (1.2 mL) and benzyl chloroformate (205 mg, 1.2 mmol) were added at 0 °C. The resulting mixture was stirred at room temperature for 2 h. After water was added, the mixture was extracted with AcOEt. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 1/1) gave 255 mg of the product (0.81 mmol, 81% yield) as a brown oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.58-1.65 (m, 1H), 1.71-1.87 (m, 2H), 1.90-2.06 (m, 3H), 2.23-2.28 (m, 1H), 2.46-2.71 (m, 5H), 3.02-3.05 (m, 1H), 3.53 (t, *J* = 4.8 Hz, 4H), 5.13 (s, 2H), 7.29-7.38 (m, 5H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 23.3 (CH_2), 27.8 (CH_2), 29.7 (CH_2), 41.2 (CH_2), 43.9 (CH_2), 49.1 (CH_2), 67.0 (CH_2), 72.1 (CH), 127.9 (CH), 128.0 (CH), 128.5 (CH), 136.7 (C), 155.2 (C), 211.0 (C). IR (ATR): 700, 1120, 1240, 1700 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{18}H_{24}N_2O_3$ (M^+): 316.1787. Found: 316.1796.

1,4-Bis(2-ketocyclohexyl)piperadine (4v)



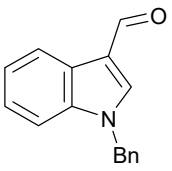
As a starting material, the diastereomeric mixture of 2,2'-(piperazine-1,4-diyl)biscyclohexanol[3g] was used, and the product was analyzed as a diastereomeric mixture because of the difficulty of separation. Silica gel column chromatography (CH_2Cl_2/MeOH = 20/1) gave 274 mg of the product (0.98 mmol, 98% yield) as pale yellow solids of mp 110-112 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.55-1.63 (m, 2H), 1.76-2.02 (m, 10H), 2.21-2.26 (m, 2H), 2.48-2.51 (m, 4H), 2.57-2.63 (m, 2H), 2.67-2.70 (m, 4H), 2.94-2.98 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 22.6 (CH_2), 22.7 (CH_2), 28.1 (CH_2), 29.7 (CH_2), 29.8 (CH_2), 40.80 (CH_2), 40.84 (CH_2), 49.7 (CH_2), 72.39 (CH), 72.43 (CH), 211.7 (C), 211.8 (C). IR (ATR): 860, 940, 1120, 1700, 1710 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{16}H_{26}N_2O_2$ (M^+): 278.1994. Found: 278.1997.

Piperonal (6a)[8a]



Silica gel column chromatography (hexane/Et_2O = 1/1) gave 140 mg of the product (0.93 mmol, 93% yield) as white solids of mp 35-37 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 6.08 (s, 2H), 6.94 (d, *J* = 8.1 Hz, 1H), 7.35 (d, *J* = 1.5 Hz, 1H), 7.42 (dd, *J* = 1.5, 8.1 Hz, 1H), 9.82 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 102.1 (CH_2), 106.9 (CH), 108.3 (CH), 128.6 (CH), 131.9 (C), 148.7 (C), 153.1 (C), 190.3 (CH). IR (ATR): 810, 930, 1100, 1670 cm^{-1}. EIMS *m/z*: 150 (M^+).

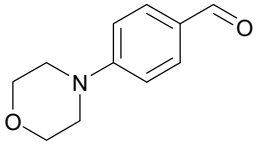
1-Benzyl-1*H*-indole-3-carbaldehyde (6b)[8b]



Silica gel column chromatography (hexane/AcOEt = 2/1) gave 196 mg of the product (0.83 mmol, 83% yield) as white solids of mp 108-110 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 5.36 (s, 2H), 7.19 (d, *J* = 6.6 Hz, 2H), 7.29-7.38 (m, 6H), 7.71 (s, 1H), 8.32-8.34 (m, 1H), 10.01 (s, 1H). ^{13}C-NMR (100

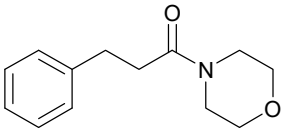
MHz, $CDCl_3$): δ 50.8 (CH_2), 110.4 (CH), 118.5 (C), 122.1 (CH), 123.1 (CH), 124.2 (CH), 125.5 (C), 127.2 (CH), 128.4 (CH), 129.1 (CH), 135.3 (C), 137.5 (C), 138.5 (CH), 184.7 (CH). IR (ATR): 730, 1170, 1650 cm^{-1}. EIMS *m/z*: 235 (M^+).

4-Morpholinobenzaldehyde (6c)[8c]



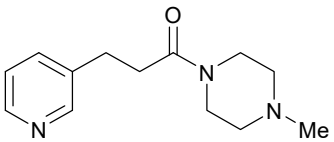
Silica gel column chromatography (hexane/AcOEt = 2/1) gave 190 mg of the product (0.99 mmol, 99% yield) as white solids of mp 60-62 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 3.35-3.37 (m, 4H), 3.85-3.87 (m, 4H), 6.93 (d, *J* = 8.8 Hz, 2H), 7.78 (d, *J* = 8.8 Hz, 2H), 9.81 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 47.2 (CH_2), 66.4 (CH_2), 113.4 (CH), 127.7 (C), 131.8 (CH), 155.2 (C), 190.6 (CH). IR (ATR): 810, 1120, 1650 cm^{-1}. EIMS *m/z*: 191 (M^+).

1-Morpholino-3-phenylpropan-1-one (6d)[8d]



Silica gel column chromatography (hexane/AcOEt = 1/1) gave 177 mg of the product (0.81 mmol, 81% yield) as a colorless oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.62 (t, *J* = 7.8 Hz, 2H), 2.99 (t, *J* = 7.8 Hz, 2H), 3.36 (t, *J* = 4.9 Hz, 2H), 3.51 (t, *J* = 4.9 Hz, 2H), 3.61-3.66 (m, 4H), 7.20-7.23 (m, 3H), 7.28-7.32 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 31.4 (CH_2), 34.7 (CH_2), 41.9 (CH_2), 45.9 (CH_2), 66.4 (CH_2), 66.8 (CH_2), 126.3 (CH), 128.5 (CH), 128.6 (CH), 141.1 (C), 170.9 (C). IR (ATR): 700, 850, 1110, 1220, 1640 cm^{-1}. EIMS *m/z*: 219 (M^+).

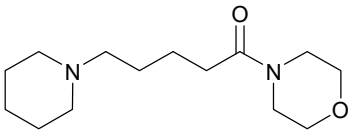
1-(4-Methylpiperazin-1-yl)-3-(pyridin-3-yl)propan-1-one (6e)



Silica gel column chromatography (CH_2Cl_2/MeOH = 9/1) gave 180 mg of the product (0.77 mmol, 77% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.29 (s, 3H), 2.30-2.32 (m, 2H), 2.34-2.36 (m, 2H), 2.63 (t, *J* = 7.8 Hz, 2H), 2.99 (t, *J* = 7.8 Hz, 2H), 3.41-3.43 (m, 2H), 3.63-3.65

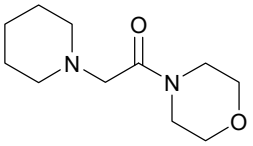
(m, 2H), 7.21 (dd, J = 4.7, 7.8 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 8.46-8.47 (m, 1H), 8.49 (d, J = 1.5 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 27.9 (CH_2), 33.8 (CH_2), 41.1 (CH_2), 44.9 (CH_2), 45.5 (CH_3), 54.2 (CH_2), 54.5 (CH_2), 123.0 (CH), 135.7 (CH), 136.3 (C), 147.3 (CH), 149.6 (CH), 169.6 (C). IR (ATR): 710, 800, 1290, 1640 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{13}H_{19}N_3O$ (M^+): 233.1528. Found: 233.1523.

1-Morpholino-5-(piperidin-1-yl)pentan-1-one (6f)



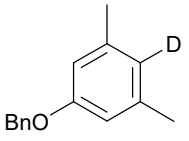
Silica gel column chromatography (CH_2Cl_2/MeOH = 4/1) gave 210 mg of the product (0.83 mmol, 83% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ1.41-1.45 (m, 2H), 1.52-1.59 (m, 5 H), 1.61-1.67 (m, 3H), 2.29-2.35 (m, 8H), 3.46-3.48 (m, 2H), 3.60-3.62 (m, 2H), 3.66-3.68 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 23.2 (CH_2), 24.3 (CH_2), 25.8 (CH_2), 26.5 (CH_2), 32.8 (CH_2), 41.7 (CH_2), 45.9 (CH_2), 54.5 (CH_2), 58.8 (CH_2), 66.6 (CH_2), 66.8 (CH_2), 171.7 (C). IR (ATR): 850, 1110, 1640 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{26}N_2O_2$ (M^+): 254.1994. Found: 254.1996.

1-Morpholino-2-(piperidin-1-yl)ethanone (6g)



Silica gel column chromatography (CH_2Cl_2/MeOH = 20/1) gave 179 mg of the product (0.84 mmol, 84% yield) as a pale yellow oil. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.43-1.44 (m, 2H), 1.54-1.59 (m, 4H), 2.39-2.44 (m, 4H), 3.12 (s, 2H), 3.60-3.61 (m, 2H), 3.65-3.68 (m, 6H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 23.6 (CH_2), 25.7 (CH_2), 41.9 (CH_2), 46.0 (CH_2), 54.1 (CH_2), 62.2 (CH_2), 66.8 (CH_2), 66.9 (CH_2), 168.6 (C). IR (ATR): 860, 1110, 1270, 1640 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{20}N_2O_2$ (M^+): 212.1525. Found: 212.1526.

1-Benzyloxy-4-deuterio-3,5-dimethylbenzene (8)[5]



This reaction was conducted on 0.5 mmol scale. Silica gel column chromatography (hexane/Et_2O = 100/1) gave 100 mg of the product (0.47 mmol, 94% yield) as a colorless oil. 98% D (D content was judged with the peak at 6.62 ppm (a deuterated site) compared to the peak at 7.30-7.44 ppm by ^{1}H-NMR). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.29 (s, 6H), 5.03 (s, 2H), 6.62 (s, 2H), 7.30-7.44 (m, 5H). ^{2}H-NMR (61 MHz, CH_2Cl_2): δ 6.70 (brs). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 21.3 (CH_3), 69.8 (CH_2), 112.6 (CH), 122.4 (t, $J_{C\text{-}D}$ = 23.2 Hz, C), 127.5 (CH), 127.9 (CH), 128.6 (CH), 137.4 (C), 139.2 (C), 159.0 (C). IR (ATR): 690, 1150, 1590 cm^{-1}. EIMS *m/z*: 213 (M^+).

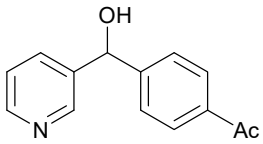
3. Synthesis of alcohols.

Method A.[9a] To a suspension of Mg (243 mg, 10 mmol) in THF (5 mL) was added an aryl bromide (10 mmol) in THF (5 mL) at room temperature. After the mixture was refluxed for 30 min, an aldehyde (9.5 mmol) was added at 0 ºC. The reaction mixture was stirred at room temperature for 1 h, and then brine was added. The resulting mixture was extracted with AcOEt. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration and purification through silica gel column chromatography gave the desired product.

Method B.[9b] To a solution of an aryl bromide (6.2 mmol) in Et_2O (20 mL) was added *n*BuLi (1.6 M in hexane, 4.2 mL, 6.7 mmol) at −78 ºC. The resulting suspension was stirred for 1 h, and then an aldehyde (5.6 mmol) in Et_2O (2.5 mL) was added. After stirring for 30 min, the reaction mixture was allowed to warm gradually to 0 ºC, and then brine was added. The resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography gave the desired product.

Method C.[9c] Mg (1.09 g, 45 mmol) and a chip of iodine were charged in a two-necked flask, and then THF (40 mL) and an aryl bromide (30 mmol) were added. After the reaction mixture was refluxed for 6 h and cooled to room temperature, an aldehyde (10 mmol) was added dropwise. The mixture was stirred at room temperature for 14 h, and then brine was added. The resulting mixture was extracted with AcOEt. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration and purification through silica gel column chromatography gave the desired product.

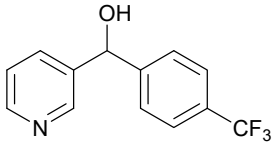
4-Acetylphenyl(pyridin-3-yl)methanol (1d)



In the first step, [4-(2-methyl-1,3-dioxolan-2-yl)phenyl](pyridin-3-yl)methanol[10a] was prepared on the basis of Method B. To a solution of 2-(4-iodophenyl)-2-methyl-1,3-dioxolane[10b] (2.38 g, 8.2 mmol) in THF (49 mL) was added *n*BuLi (1.55 M in hexane, 5.3 mL, 8.2 mmol) at −78 ºC. After the mixture was stirred for 30 min, 3-pyridinecarboxaldehyde (877 mg, 8.2 mmol) was added. The reaction mixture was warmed to room temperature over 1 h, and then brine was added. The resulting mixture was extracted with Et_2O. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration gave the crude product (1.06 g), which was used for the next step without further purification.

To the crude product (1.06 g) was added 2 N HCl (18 mL). The mixture was stirred at 80 ºC for 12 h. The reaction mixture was cooled to room temperature and neutralized with 0.5 M NaOH. The resulting mixture was extracted with CH_2Cl_2. After the combined organic layers were dried over Na_2SO_4, concentration and reprecipitation from CH_2Cl_2 and hexane gave 438 mg of desired product **1d** (1.9 mmol, 24% yield in two steps) as white solids of mp 171-172 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.59 (brs, 1H), 2.60 (s, 3H), 5.95 (d, *J* = 2.9 Hz, 1H), 7.26-7.29 (m, 1H), 7.50 (d, *J* = 8.1 Hz, 2H), 7.68 (dt, *J* = 1.7, 7.8 Hz, 1H), 7.94-7.97 (m, 2H), 8.53 (dd, *J* = 1.7, 4.9 Hz, 1H), 8.63 (d, *J* = 2.5 Hz, 1H). ^{13}C-NMR (100 MHz, DMSO-*d*$_6$): δ 26.7 (CH_3), 71.8 (CH), 123.7 (CH), 126.4 (CH), 128.5 (CH), 134.3 (CH), 135.8 (C), 140.5 (C), 147.8 (CH), 148.3 (CH), 150.2 (C), 197.7 (C). IR (ATR): 720, 800, 1270, 1670, 3120 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{13}NO_2$ (M^+): 227.0946. Found: 227.0945.

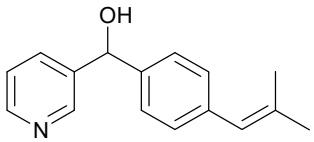
4-(Trifluoromethyl)phenyl(pyridin-3-yl)methanol (1e)



This alcohol was prepared with Method C from 3-bromopyridine and 4-(trifluoromethyl)benzaldehyde. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 2.47 g of the product (9.8 mmol, 98% yield) as white solids of mp 81-82 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.78 (d, *J* = 3.4 Hz, 1H), 5.94 (d, *J* = 3.4 Hz, 1H), 7.27-7.30 (m, 1H), 7.52 (d, *J* = 7.8 Hz, 2H), 7.63 (d, *J* = 7.8 Hz,

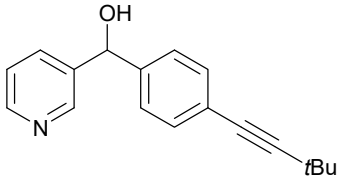
2H), 7.67 (d, *J* = 7.8 Hz, 1H), 8.52 (d, *J* = 3.9 Hz, 1H), 8.62 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 73.0 (CH), 123.8 (CH), 124.0 (q, *J* = 272.3 Hz, C), 125.6 (q, *J* = 4.1 Hz, CH), 126.7 (CH), 130.0 (q, *J* = 32.3 Hz, C), 134.9 (CH), 139.6 (C), 147.3 (C), 147.7 (CH), 148.3 (CH). IR (ATR): 710, 1320, 1410, 3170 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{13}H_{10}F_3NO$ (M^+): 253.0714. Found: 253.0722.

(4-(2-Methylprop-1-enyl)phenyl)(pyridin-3-yl)methanol (1f)



This alcohol was prepared with Method C from 1-bromo-4-(2-methylprop-1-enyl)benzene and 3-pyridinecarboxaldehyde (2.5 mmol). Silica gel column chromatography (hexane/AcOEt = 1/1) gave 465 mg of the product (1.9 mmol, 78% yield) as white solids of mp 97-98 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.85 (d, *J* = 1.5 Hz, 3H), 1.90 (d, *J* = 1.5 Hz, 3H), 2.49 (brs, 1H), 5.88 (s, 1H), 6.24 (s, 1H), 7.22 (d, *J* = 8.3 Hz, 2H), 7.25-7.28 (m, 1H), 7.31 (d, *J* = 8.3 Hz, 2H), 7.72 (dt, *J* = 1.5, 8.3 Hz, 1H), 8.50 (d, *J* = 3.9 Hz, 1H), 8.64 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 19.3 (CH_3), 26.8 (CH_3), 73.7 (CH), 123.5 (CH), 124.6 (CH), 126.3 (CH), 129.0 (CH), 134.4 (CH), 136.0 (C), 138.4 (C), 139.7 (C), 140.6 (C), 148.1 (CH), 148.3 (CH). IR (ATR): 780, 1060, 1510, 3140 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{16}H_{17}NO$ (M^+): 239.1310. Found: 239.1310.

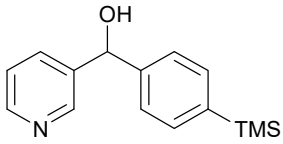
(4-(3,3-Dimethylbut-1-ynyl)phenyl)(pyridin-3-yl)methanol (1g)



This alcohol was prepared with Method C from 1-bromo-4-(3,3-dimethylbut-1-ynyl)benzene and 3-pyridinecarboxaldehyde (4.4 mmol). The crude was triturated in hexane and recrystallized from hexane/AcOEt (2/1), giving 818 mg of the product (3.1 mmol, 70% yield) as white solids of mp 166-167 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.31 (s, 9H), 2.53 (brs, 1H), 5.86 (s, 1H), 7.24-7.26 (m, 1H), 7.28 (d, *J* = 8.3 Hz, 2H), 7.38 (d, *J* = 8.3 Hz, 2H), 7.65 (d, *J* = 8.3 Hz, 1H), 8.50 (d, *J* = 4.4 Hz, 1H), 8.60 (s, 1H). ^{13}C-NMR (100 MHz, DMSO-d_6): δ 27.5 (C), 30.7 (CH_3), 71.8 (CH), 78.8 (C), 98.4 (C), 121.9 (C), 123.5 (CH), 126.4 (CH), 131.3 (CH), 134.0 (CH), 140.7 (C), 144.7 (C), 148.0 (CH), 148.3 (CH). IR (ATR): 710, 1060, 1480, 3130 cm^{-1}. HRMS (EI) *m/z* calcd for

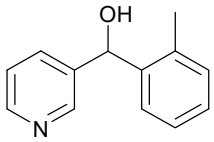
$C_{18}H_{19}NO$ (M^+): 265.1467. Found: 265.1467.

4-(Trimethylsilyl)phenyl(pyridin-3-yl)methanol (1h)



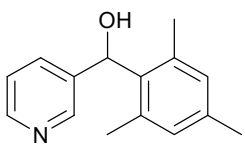
This alcohol was prepared with Method C from (4-bromophenyl)trimethylsilane and 3-pyridinecarboxaldehyde (9.5 mmol). Silica gel column chromatography (hexane/AcOEt = 1/1) gave 1.79 g of the product (6.9 mmol, 73% yield) as white solids of mp 115-116 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 0.26 (s, 9H), 2.41 (s, 1H), 5.88 (s, 1H), 7.25-7.28 (m, 1H), 7.36 (d, *J* = 7.8 Hz, 2H), 7.52 (d, *J* = 7.8 Hz, 2H), 7.72 (d, *J* = 7.8 Hz, 1H), 8.51 (d, *J* = 3.4 Hz, 1H), 8.64 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ −1.3 (CH_3), 73.9 (CH), 123.5 (CH), 125.9 (CH), 133.8 (CH), 134.4 (CH), 139.6 (C), 140.3 (C), 143.7 (C), 148.1 (CH), 148.4 (CH). IR (ATR): 840, 1100, 1580, 3170 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{19}NOSi$ (M^+): 257.1236. Found: 257.1234.

2-Methylphenyl(pyridin-3-yl)methanol (1i)



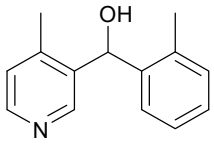
This alcohol was prepared with Method B from 3-bromopyridine and *o*-tolualdehyde. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 923 mg of the product (4.6 mmol, 83% yield) as white solids of mp 131-133 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.22 (d, *J* = 3.4 Hz, 1H), 2.28 (s, 3H), 6.08 (d, *J* = 3.4 Hz, 1H), 7.17-7.29 (m, 4H), 7.48-7.50 (m, 1H), 7.64 (d, *J* = 7.8 Hz, 1H), 8.52 (d, *J* = 3.4 Hz, 1H), 8.62 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 19.2 (CH_3), 71.0 (CH), 123.4 (CH), 126.4 (CH), 126.5 (CH), 127.9 (CH), 130.8 (CH), 134.8 (CH), 135.3 (C), 138.8 (C), 140.8 (C), 148.4 (CH), 148.6 (CH). IR (ATR): 720, 760, 820, 1580, 3130 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{13}H_{13}NO$ (M^+): 199.0997. Found: 199.1001.

2,4,6-Trimethylphenyl(pyridin-3-yl)methanol (1j)



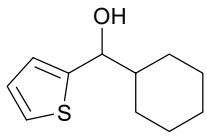
This alcohol was prepared with Method A from mesityl bromide and 3-pyridinecarboxaldehyde. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 1.72 g of the product (7.6 mmol, 80% yield) as white solids of mp 133-135 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.24 (s, 7H), 2.29 (s, 3H), 6.36 (s, 1H), 6.88 (s, 2H), 7.21-7.24 (m, 1H), 7.61 (d, *J* = 7.8 Hz, 1H), 8.48 (d, *J* = 4.4 Hz, 1H), 8.52 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 20.3 (CH_3), 20.7 (CH_3), 68.6 (CH), 123.0 (CH), 130.1 (CH), 133.6 (CH), 135.9 (C), 136.8 (C), 137.4 (C), 139.6 (C), 147.1 (CH), 147.2 (CH). IR (ATR): 710, 760, 850, 1020, 3170 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{17}NO$ (M^+): 227.1310. Found: 227.1319.

2-Methylphenyl(4-methylpyridin-3-yl)methanol (1k)



This alcohol was prepared with Method B from 3-bromo-4-methylpyridine and *o*-tolualdehyde. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 706 mg of the product (3.3 mmol, 59% yield) as white solids of mp 192-193 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.16 (d, *J* = 3.9 Hz, 1H), 2.25 (s, 3H), 2.31 (s, 3H), 6.18 (d, *J* = 3.9 Hz 1H), 7.08 (d, *J* = 4.9 Hz, 1H), 7.19-7.28 (m, 4H), 8.42 (d, *J* = 4.9 Hz, 1H), 8.52 (s, 1H). ^{13}C-NMR (100 MHz, DMSO-*d*$_6$): δ 18.1 (CH_3), 18.7 (CH_3), 67.3 (CH), 125.2 (CH), 125.8 (CH), 126.7 (CH), 127.2 (CH), 130.3 (CH), 135.3 (C), 137.6 (C), 141.3 (C), 144.8 (C), 148.07 (CH), 148.12 (CH). IR (ATR): 740, 750, 1040, 1600, 3120 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{15}NO$ (M^+): 213.1154. Found: 213.1155.

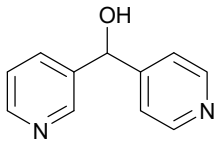
Cyclohexyl(thiophen-2-yl)methanol (1n)



This alcohol was prepared with Method C from 2-bromothiophene and cyclohexanecarboxaldehyde (5 mmol). Silica gel column chromatography (hexane/AcOEt = 12/1) gave 736 mg of the product (3.8 mmol, 75% yield) as a pale yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 0.92-1.32 (m, 5H), 1.47-1.51 (m, 1H), 1.62-1.71 (m, 3H), 1.76-1.80 (m, 1H), 1.95 (d, *J* = 3.4 Hz, 1H), 2.02-2.05 (m, 1H), 4.64 (dd, *J* = 3.4, 7.3 Hz, 1H), 6.94-6.98 (m, 2H), 7.25 (d, *J* = 1.0, 4.9 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 25.8 (CH_2), 25.9 (CH_2), 26.3 (CH_2), 28.8 (CH_2), 29.2 (CH_2), 45.5 (CH), 75.1

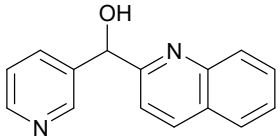
(CH), 124.3 (CH), 124.4 (CH), 126.4 (CH), 147.7 (C). IR (ATR): 690, 830, 1000, 1450, 3380 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{16}OS$ (M^+): 196.0922. Found: 196.0925.

Pyridin-3-yl(pyridin-4-yl)methanol (1o)



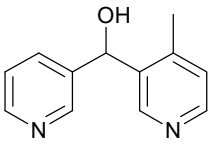
This alcohol was prepared with Method B from 3-bromopyridine and 4-pyridinecarboxaldehyde. Silica gel column chromatography (AcOEt/MeOH = 10/1) gave 664 mg of the product (3.6 mmol, 64% yield) as pale yellow solids of mp 109-110 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 5.00 (brs, 1H), 5.82 (s, 1H), 7.26-7.28 (m, 1H), 7.31 (d, *J* = 5.6 Hz, 2H), 7.66 (d, *J* = 7.8 Hz, 1H), 8.45-8.46 (m, 1H), 8.48 (d, *J* = 5.6 Hz, 2H), 8.53 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 72.1 (CH), 121.4 (CH), 123.8 (CH), 134.8 (CH), 139.1 (C), 147.9 (CH), 148.8 (CH), 149.4 (CH), 152.9 (C). IR (ATR): 710, 1060, 1480, 1600, 3160 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{10}N_2O$ (M^+): 186.0793. Found: 186.0770.

Pyridin-3-yl(quinolin-2-yl)methanol (1q)



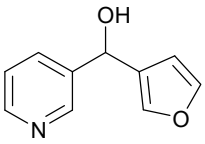
This alcohol was prepared with Method B from 3-bromopyridine and 2-quinolinecarboxaldehyde. Silica gel column chromatography with AcOEt gave 978 mg of the product (4.1 mmol, 74% yield) as pale yellow solids of mp 105-107 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 5.91 (d, *J* = 3.9 Hz, 1H), 6.12 (d, *J* = 3.9 Hz, 1H), 7.18 (d, *J* = 8.6 Hz, 1H), 7.24-7.27 (m, 1H), 7.57-7.60 (m, 1H), 7.68 (dt, *J* = 2.0, 8.1 Hz, 1H), 7.77-7.80 (m, 1H), 7.83 (d, *J* = 8.1 Hz, 1H), 8.11 (d, *J* = 8.6 Hz, 1H), 8.15 (d, *J* = 8.3 Hz, 1H), 8.55 (dd, *J* = 1.5, 4.9 Hz, 1H), 8.74 (d, *J* = 2.2 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 73.0 (CH), 118.9 (CH), 123.7 (CH), 126.8 (CH), 127.5 (C), 127.6 (CH), 128.8 (CH), 130.1 (CH), 134.9 (CH), 137.4 (CH), 138.4 (C), 146.1 (C), 148.8 (CH), 149.3 (CH), 159.8 (C). IR (ATR): 710, 750, 820, 1070, 3090 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{12}N_2O$ (M^+): 236.0950. Found: 236.0948.

4-Methylpyridin-3-yl(pyridin-3-yl)methanol (1r)



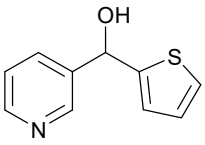
This alcohol was prepared with Method B from 3-bromo-4-methylpyridine and 3-pyridinecarboxaldehyde (3.37 mmol). Silica gel column chromatography (AcOEt/MeOH = 20/1) gave 618 mg of the product (3.1 mmol, 92% yield) as a brown gum. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 2.22 (s, 3H), 6.04 (s, 1H), 7.08 (d, *J* = 5.4 Hz, 1H), 7.27-7.30 (m, 1H), 7.64-7.66 (m, 1H), 8.38 (d, *J* = 5.4 Hz, 1H), 8.50 (dd, *J* = 1.5, 4.9 Hz, 1H), 8.56 (d, *J* = 2.0 Hz, 1H), 8.64 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 18.8 (CH_3), 69.5 (CH), 123.6 (CH), 125.8 (CH), 134.8 (CH), 137.4 (C), 138.4 (C), 145.6 (C), 147.5 (CH), 148.1 (CH), 148.2 (CH), 148.3 (CH). IR (ATR): 710, 1020, 1580, 1600, 3120 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{12}H_{12}N_2O$ (M^+): 200.0950. Found: 200.0950.

Furan-3-yl(pyridin-3-yl)methanol (1s)



This alcohol was prepared with Method B from 3-bromopyridine and 3-furaldehyde. Silica gel column chromatography (hexane/AcOEt = 1/2) gave 960 mg of the product (5.5 mmol, 98% yield) as a yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 4.83 (brs, 1H), 5.87 (s, 1H), 6.95 (d, *J* = 4.9 Hz, 1H), 7.16 (d, *J* = 1.7 Hz, 1H), 7.21-7.28 (m, 2H), 7.71 (d, *J* = 7.8 Hz, 1H), 8.32 (d, *J* = 4.6 Hz, 1H), 8.43 (s, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 66.4 (CH), 109.0 (CH), 123.5 (CH), 128.6 (C), 134.6 (CH), 139.5 (C), 139.6 (CH), 143.6 (CH), 147.5 (CH), 148.0 (CH). IR (ATR): 710, 1020, 1500, 1580, 3140 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{10}H_9NO_2$ (M^+): 175.0633. Found: 175.0608.

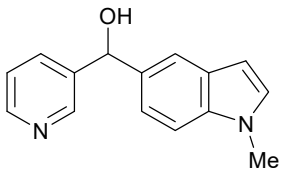
Pyridin-3-yl(thiophen-2-yl)methanol (1t)



This alcohol was prepared with Method B from 3-bromopyridine and 2-thiophenecarboxaldehyde. Silica gel column chromatography (hexane/AcOEt = 1/1) gave 910 mg of the product (4.8 mmol, 85% yield) as white solids of mp 58-59 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 6.12 (s, 1H), 6.92 (dt,

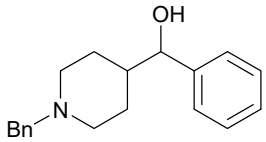
J = 1.0, 3.4 Hz, 1H), 6.97 (dd, *J* = 3.4, 4.9 Hz, 1H), 7.28-7.32 (m, 2H), 7.79-7.82 (m, 1H), 8.51 (dd, *J* = 1.7, 4.9 Hz, 1H), 8.63 (d, *J* = 2.2 Hz, 1H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 69.7 (CH), 123.6 (CH), 124.9 (CH), 125.6 (CH), 126.7 (CH), 134.5 (CH), 139.6 (C), 147.6 (CH), 147.8 (C), 148.3 (CH). IR (ATR): 710, 820, 1030, 1420, 3110 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{10}H_9NOS$ (M^+): 191.0405. Found: 191.0400.

1-Methyl-1*H*-indol-5-yl(pyridin-3-yl)methanol (1u)



This alcohol was prepared with Method B from 5-bromo-1-methylindole[10c] and 3-pyridinecarboxaldehyde (10 mmol). Silica gel column chromatography (hexane/AcOEt = 1/4) and recrystallization from Et_2O gave 428 mg of the product (1.8 mmol, 18% yield) as white solids of mp 126-127 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 3.79 (s, 3 H), 6.00 (s, 1 H), 6.47 (d, *J* = 2.9 Hz, 1 H), 7.08 (d, *J* = 2.9 Hz, 1 H), 7.19 (dd, *J* = 1.5, 8.3 Hz, 1 H), 7.23 - 7.26 (m, 1 H), 7.31 (d, *J* = 8.8 Hz, 1 H), 7.63 (d, *J* = 1.5 Hz, 1 H), 7.72 - 7.75 (m, 1 H), 8.49 (dd, *J* = 1.5, 4.9 Hz, 1 H), 8.68 (d, *J* = 2.4 Hz, 1 H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 32.8 (CH_3), 74.6 (CH), 101.2 (CH), 109.6 (CH), 119.2 (CH), 120.6 (CH), 123.2 (CH), 128.4 (C), 129.6 (CH), 134.2 (CH), 134.5 (C), 136.4 (C), 140.1 (C), 148.18 (CH), 148.23 (CH). IR (ATR): 710, 790, 1030, 1600, 3130 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{15}H_{14}N_2O$ (M^+): 238.1106. Found: 238.1109.

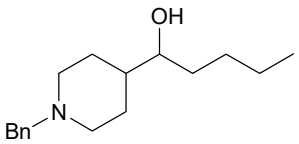
(1-Benzylpiperidin-4-yl)(phenyl)methanol (3a)



This alcohol was prepared on the basis of Method A. To a suspension of Mg (608 mg, 25 mmol) in THF (50 mL) was added bromobenzene (3.93 g, 25 mmol) in THF (25 mL) at room temperature. After refluxing for 30 min, *N*-benzylpiperidine-4-carbaldehyde (2.54 g, 12.5 mmol) in THF (25 mL) was added at room temperature. The reaction mixture was refluxed for 14 h. After brine was added, the resulting mixture was extracted with AcOEt. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration and purification through silica gel column chro-

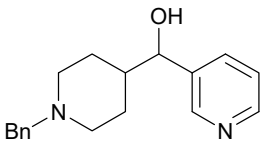
matography (AcOEt/MeOH = 19/1) and recrystallization (hexane/ AcOEt = 1/1) gave 1.80 g of the product (6.4 mmol, 51% yield) as white solids of mp 109-111 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.22-1.32 (m, 2H), 1.38-1.46 (m, 1H), 1.57-1.65 (m, 1H), 1.82-1.99 (m, 4H), 2.80-2.84 (m, 1H), 2.92-2.96 (m, 1H), 3.46 (s, 2H), 4.38 (d, *J* = 7.8 Hz, 1H), 7.21-7.36 (m, 10H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.3 (CH_2), 28.5 (CH_2), 43.1 (CH), 53.38 (CH_2), 53.42 (CH_2), 63.3 (CH_2), 78.7 (CH), 126.7 (CH), 126.9 (CH), 127.5 (CH), 128.1 (CH), 128.2 (CH), 129.3 (CH), 138.2 (C), 143.5 (C). IR (ATR): 690, 740, 970, 1030, 3340 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{19}H_{23}NO$ (M^+): 281.1780. Found: 281.1774.

1-(1-Benzylpiperidin-4-yl)pentan-1-ol (3e)



To a solution of *n*BuLi (1.63 M in hexane, 2.1 mL, 3.5 mmol) in THF (750 μL) was added *N*-benzylpiperidine-4-carbaldehyde (711 mg, 3.5 mmol) in THF (1.9 mL) at −78 ºC.[11] After the reaction mixture was stirred at −78 ºC for 1 h and at room temperature for 20 h, brine was added. The resulting mixture was extracted with Et_2O. The combined organic layers were washed with brine and dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (AcOEt) gave 368 mg of the product (1.4 mmol, 40% yield) as a pale yellow oil. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 0.90 (t, *J* = 6.8 Hz, 3H), 1.30-1.59 (m, 11H), 1.75-1.78 (m, 1H), 1.92 (t, *J* = 11.2 Hz, 2H), 2.94 (t, *J* = 8.8 Hz, 2H), 3.35-3.41 (m, 1H), 3.49 (s, 2H), 7.22-7.26 (m, 1H), 7.29-7.32 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 14.0 (CH_3), 22.7 (CH_2), 27.4 (CH_2), 27.9 (CH_2), 28.3 (CH_2), 33.8 (CH_2), 41.8 (CH), 53.7 (CH_2), 63.4 (CH_2), 75.5 (CH), 126.9 (CH), 128.2 (CH), 129.3 (CH), 138.6 (C). IR (ATR): 700, 740, 970, 1110, 3380 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{17}H_{27}NO$ (M^+): 261.2093. Found: 261.2088.

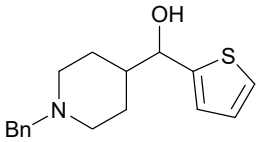
1-Benzylpiperidin-4-yl(pyridin-3-yl)methanol (3f)



This alcohol was prepared with Method C from 3-bromopyridine and 1-benzyl-4-formylpiperidine. Silica gel column chromatography (hexane/AcOEt = 1/2) and recrystallization (hexane/AcOEt =

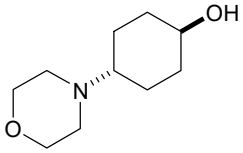
1/1) gave 592 mg of the product (2.1 mmol, 21% yield) as pale yellow solids of mp 143-146 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.26-1.35 (m, 2H), 1.38-1.46 (m, 1H), 1.59-1.67 (m, 1H), 1.81-1.96 (m, 3H), 2.08-2.14 (m, 1H), 2.83-2.86 (m, 1H), 2.94-2.96 (m, 1H), 3.47 (s, 2H), 4.45 (d, *J* = 7.3 Hz, 1H), 7.22-7.31 (m, 6H), 7.65 (dt, *J* = 1.7, 7.8 Hz, 1H), 8.51-8.52 (m, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.1 (CH_2), 28.3 (CH_2), 43.1 (CH), 53.2 (CH_2), 53.3 (CH_2), 63.2 (CH_2), 75.9 (CH), 123.4 (CH), 127.0 (CH), 128.1 (CH), 129.2 (CH), 134.5 (CH), 138.1 (C), 139.2 (C), 148.2 (CH), 148.5 (CH). IR (ATR): 700, 740, 820, 970, 3130 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{18}H_{22}N_2O$ (M^+): 282.1732. Found: 282.1732.

1-Benzylpiperidin-4-yl(thiophen-2-yl)methanol (3g)



This alcohol was prepared with Method C from 2-bromothiophene and 1-benzyl-4-formylpiperidine. Silica gel column chromatography (hexane/AcOEt = 1/4) gave 2.25 g of the product (7.8 mmol, 78% yield) as pale yellow solids of mp 101-103 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.26-1.48 (m, 3H), 1.61-1.67 (m, 1H), 1.87-2.05 (m, 4H), 2.86 (d, *J* = 11.2 Hz, 1H), 2.95 (d, *J* = 11.2 Hz, 1H), 3.49 (s, 2H), 4.65 (d, *J* = 7.8 Hz, 1H), 6.95-6.97 (m, 2H), 7.22-7.26 (m, 2H), 7.30-7.31 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 28.3 (CH_2), 28.5 (CH_2), 43.7 (CH), 53.3 (CH_2), 63.2 (CH_2), 74.4 (CH), 124.4 (CH), 124.5 (CH), 126.4 (CH), 127.0 (CH), 128.1 (CH), 129.3 (CH), 138.1 (C), 147.7 (C). IR (ATR): 690, 730, 970, 3330 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{17}H_{21}NOS$ (M^+): 287.1344. Found: 287.1347.

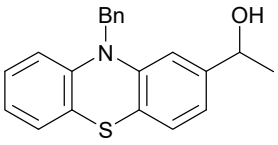
***trans*-4-Morpholinocyclohexanol (3m)**



While the mixture of *trans*-4-aminocyclohexanol (921 mg, 8.0 mmol) and Na_2CO_3 (1.87 g, 17.6 mmol) in CH_3CN (32 mL) was refluxed, 2-bromoethyl ether (2.23 g, 9.6 mmol) was added.[12a] The reaction mixture was refluxed for 12 h. After brine was added, the resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (CH_2Cl_2/MeOH = 9/1) gave 578 mg of the product (3.1

mmol, 39% yield) as pale brown solids of mp 113-114 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.25-1.34 (m, 4H), 1.39 (brs, 1H), 1.93-1.96 (m, 2H), 2.00-2.05 (m, 2H), 2.17-2.20 (m, 1H), 2.54-2.55 (m, 4H), 3.56-3.62 (m, 1H), 3.70-3.72 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 26.3 (CH_2), 34.3 (CH_2), 49.8 (CH_2), 62.6 (CH), 67.2 (CH_2), 70.2 (CH). IR (ATR): 690, 1070, 1110, 3140 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{10}H_{19}NO_2$ (M^+): 185.1416. Found: 185.1405.

1-(10-Benzyl-10*H*-phenothiazin-2-yl)ethanol (3n)

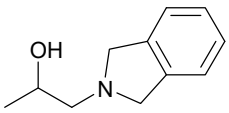


To a solution of 2-acetylphenothiazine (7.2 g, 30 mmol) in MeOH (188 mL) was added $NaBH_4$ (1.4 g, 37.5 mmol) slowly at 0 °C. The reaction mixture was stirred at room temperature for 2 h, and then concentrated and diluted with H_2O (20 mL). After the resulting mixture was extracted with CH_2Cl_2, the combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 2/1) gave 5.10 g of 1-(10*H*-phenothiazin-2-yl)ethanol (**3n'**) (21 mmol, 70% yield) as white solids of mp 144-146 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.45 (d, *J* = 6.6 Hz, 3H), 1.72 (d, *J* = 3.4 Hz, 1H), 4.75-4.80 (m, 1H), 5.83 (brs, 1H), 6.55 (d, *J* = 7.8 Hz, 1H), 6.63 (d, *J* = 1.2 Hz, 1H), 6.80-6.84 (m, 2H), 6.94-7.01 (m, 3H). ^{13}C-NMR (100 MHz, DMSO-d_6): δ 25.7 (CH_3), 67.6 (CH), 111.6 (CH), 114.1 (C), 114.5 (CH), 116.6 (C), 119.0 (CH), 121.7 (CH), 125.8 (CH), 126.3 (CH), 127.5 (CH), 142.0 (C), 142.3 (C), 147.3 (C). IR (ATR): 740, 870, 1300, 3310 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{14}H_{13}NOS$ (M^+): 243.0718. Found: 243.0728.

To a solution of 1-(10*H*-phenothiazin-2-yl)ethanol (**3n'**) (2.40 g, 10 mmol) in toluene (20 mL) was added DIPEA (3.23 g, 25 mmol). Then, benzyl bromide (1.88 g, 11 mmol) was added at 0 °C, and the reaction mixture was refluxed for 6 h. After saturated $NaHCO_3$ solution (10 ml) was added, the resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 2/1) gave 2.81 g of the product (8.4 mmol, 84% yield) as white solids of mp 52-53 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.29 (d, *J* = 6.4 Hz, 3H), 1.60 (brs, 1H), 4.66 (q, *J* = 6.4 Hz, 1H), 5.10 (s, 2H), 6.66-6.68 (m, 2H), 6.85-6.88 (m, 2H), 6.97-7.00 (m, 1H), 7.05 (d, *J* = 7.6 Hz, 1H), 7.09 (dd, *J* = 1.5, 7.6 Hz, 1H), 7.22-7.24 (m, 1H), 7.29-7.34 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 24.8 (CH_3), 52.4 (CH_2), 70.0 (CH), 112.8 (CH), 115.6 (CH), 119.5 (CH), 122.5 (C), 122.6 (CH), 123.5

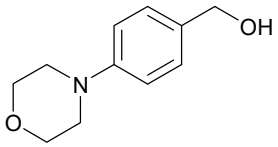
(C), 126.77 (CH), 126.84 (CH), 126.9 (CH), 127.1 (CH), 127.3 (CH), 128.7 (CH), 136.7 (C), 144.6 (C), 144.8 (C), 145.3 (C). IR (ATR): 690, 730, 810, 1220, 3320 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{21}H_{19}NOS$ (M^+): 333.1187. Found: 333.1188.

1-(Isoindolin-2-yl)propan-2-ol (3q)



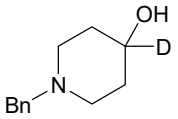
The mixture of 1,2-bis(chloromethyl)benzene (1.75 g, 10 mmol), 1-amino-2-propanol (751 mg, 10 mmol), and K_2CO_3 (1.66 g, 12 mmol) in CH_3CN (33 mL) was refluxed for 4 h.[12b] After brine was added, the resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (hexane/ AcOEt = 1/1) gave 842 mg of the product (4.8 mmol, 48% yield) as pale brown solids of mp 61-62 °C. ^{1}H-NMR (400 MHz, $CDCl_3$): δ 1.20 (d, *J* = 6.3 Hz, 3H), 2.68-2.70 (m, 2H), 3.85-3.93 (m, 1H), 3.91-3.95 (m, 2H), 4.08-4.12 (m, 2H), 7.21-7.23 (m, 4H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 20.0 (CH_3), 59.0 (CH_2), 63.5 (CH_2), 64.4 (CH), 122.2 (CH), 126.8 (CH), 139.8 (C). IR (ATR): 760, 1070, 3280 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{15}NO$ (M^+): 177.1154. Found: 177.1166.

(4-Morpholinophenyl)methanol (5c)



To a solution of 4-(4-formylphenyl)morpholine (1.90 g, 10 mmol) in MeOH (10 mL) was added $NaBH_4$ (378 mg, 10 mmol) slowly at 0 °C. The mixture was stirred at 0 °C for 2 h. After brine was added, the resulting mixture was extracted with AcOEt. The combined organic layers were dried over Na_2SO_4. Concentration and purification through silica gel column chromatography (hexane/ AcOEt = 1/2) gave 1.89 g of the product (9.8 mmol, 98% yield) as white solids of mp 83-85 °C. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.49 (t, *J* = 5.9 Hz, 1H), 3.15-3.17 (m, 4H), 3.86-3.88 (m, 4H), 4.61 (d, *J* = 5.9 Hz, 2H), 6.91 (d, *J* = 8.6 Hz, 2H), 7.29 (d, *J* = 8.6 Hz, 2H). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 49.2 (CH_2), 64.8 (CH_2), 66.7 (CH_2), 115.7 (CH), 128.3 (CH), 132.6 (C), 150.8 (C). IR (ATR): 810, 1120, 1210, 3200 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{11}H_{15}NO_2$ (M^+): 193.1103. Found: 193.1106.

1-Benzyl-4-deuteriopiperidin-4-ol (3h-*d*)



To a suspension of lithium aluminum deuteride (115 mg, 2.7 mmol) in THF (9 mL) was added 1-benzyl-4-piperidinone (1.04 g, 5.5 mmol) in THF (9 mL) was added at 0 °C. After the reaction mixture was stirred at 0 °C for 30 min, water (115 μL), 15% NaOH solution (115 μL), and water (345 μL) were added slowly. The resulting mixture was filtered through Celite. Concentration and purification through silica gel column chromatography (hexane/AcOEt = 1/2) gave 1.02 g of the product (5.3 mmol, 96% yield) as yellow solids of mp 40-41 °C. >99% D (D content was judged with the peak at 3.67 ppm (a deuterated site) compared to the peak at 3.50 ppm by ^{1}H-NMR). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.34 (brs, 1H), 1.56-1.61 (m, 2H), 1.86-1.89 (m, 2H), 2.12-2.16 (m, 2H), 2.74-2.76 (m, 2H), 3.50 (s, 2H), 7.23-7.25 (m, 1H), 7.31-7.32 (m, 4H). ^{2}H-NMR (61 MHz, $CHCl_3$): δ 3.68 (brs). ^{13}C-NMR (100 MHz, $CDCl_3$): δ 34.1 (CH_2), 50.9 (CH_2), 62.8 (CH_2), 67.2 (t, $J_{C\text{-}D}$ = 21.5 Hz, C), 126.9 (CH), 128.1 (CH), 129.1 (CH), 138.2 (C). IR (ATR): 700, 740, 1080, 1340, 3140 cm^{-1}. HRMS (EI) *m/z* calcd for $C_{12}H_{16}DNO$ (M^+): 192.1373. Found: 192.1378.

References

1 M. Kuriyama, S. Matsuo, M. Shinozawa and O. Onomura, *Org. Lett*., 2013, **15**, 2716-2719.

2 (a) Y. Nishigaya, K. Umei, D. Watanabe, Y. Kohno and S. Seto, *Tetrahedron*, 2016, **72**, 1566-1572; (b) B. Ágai, A. Nádor, Á. Proszenyák, G. Tárkányi and F. Faigl, *Tetrahedron*, 2003, **59**, 7897-7900; (c) A. Harikrishnan, J. Sanjeevi and C. R. Ramanathan, *Org. Biomol. Chem*., 2015, **13**, 3633-3647; (d) F. Sauter, P. Stanetty, W. Sittenthaler and R. Waditsehatka, *Monatsh. Chem*., 1988, **119**, 1427-1438; (e) I. Gupta and M. Ravikanth, *J. Org. Chem*., 2004, **69**, 6796-6811.

3 (a) I. Cepanec, M. Litvić, H. Mikuldaš, A. Bartolinčić and V. Vinković, *Tetrahedron*, 2003, **59**, 2435-2439; (b) Y. Sasano, S. Nagasawa, M. Yamazaki, M. Shibuya, J. Park and Y. Iwabuchi, *Angew. Chem. Int. Ed*., 2014, **53**, 3236-3240; (c) M. B. Skaddan, M. R. Kilbourn, S. E. Snyder, P. S. Sherman, T. J. Desmond and K. A. Frey, *J. Med. Chem.*, 2000, **43**, 4552-4562; (d) M. L. Deb, S. S. Dey, I. Bento, M. T. Barros and C. D. Maycock, *Angew. Chem. Int. Ed*., 2013, **52**, 9791-9795; (e) C. E. Harris, G. B. Fisher, D. Beardsley, L. Lee, C. T. Goralski, L. W. Nicholson and B. Singaram, *J. Org. Chem*., 1994, **59**, 7746-7751; (f) J. Agarwal, A. Duley, R. Rani and R. K. Peddinti, *Synthesis*, 2009, 2790-2796; (g) B. L. Griggs, G. A. Lawrance, M. Maeder, M. J. Robertson and P. Turner, *Inorg. Chim. Acta*, 2007, **360**, 2403-2410.

4 S. Wu, L. Wang, W. Guo, X. Liu, J. Liu, X. Wei and B. Fang, *J. Med. Chem*., 2011, **54**, 2668-2679.

5 M. Kuriyama, N. Hamaguchi, G. Yano, K. Tsukuda, K. Sato and O. Onomura, *J. Org. Chem*., 2016, **81**, 8934-8946.

6 (a) X. Qi, L.-B. Jiang, H.-P. Li and X.-F. Wu, *Chem. Eur. J*., 2015, **21**, 17650-17656; (b) X. Wang, R.-X. Chen, Z.-F. Wei, C.-Y. Zhang, H.-Y. Tu and A.-D. Zhang, *J. Org. Chem*., 2016, **81**, 238-249; (c) S. Dohi, K. Moriyama and H. Togo, *Tetrahedron*, 2012, **68**, 6557-6564; (d) E. Maerten, M. Sauthier, A. Mortreux and Y. Castanet, *Tetrahedron*, 2007, **63**, 682-689; (e) A. Takemiya and J. F. Hartwig, *J. Am. Chem. Soc*., 2006, **128**, 14800-14801; (f) T. Kondo, M. Akazome, Y. Tsuji and Y. Watanabe, *J. Org. Chem*., 1990, **55**, 1286-1291; (g) X.-D. Chen and T. C. W. Mak, *J. Mol. Struct*., 2005, **743**, 1-6; (h) P. Jakobsen, P. Madsen and H. Andersen, *Eur. J. Med. Chem*., 2003, **38**, 357-362; (i) L. Ren and N. Jiao, *Chem. Asian J*., 2014, **9**, 2411-2414.

7 (a) X. Dai, J. Rabeach, H. Yuan, A. Breckner, X. Cui and F. Shi, *ChemSusChem*, 2016, **9**, 3133-3138; (b) M. Shibuya, Y. Osada, Y. Sasano, M. Tomizawa and Y. Iwabuchi, *J. Am. Chem. Soc*., 2011, **133**, 6497-6500; (c) W.-X. Huang, B. Wu, X. Gao, M.-W. Chen, B. Wang and Y.-G. Zhou, *Org. Lett*., 2015, **17**, 1640-1643; (d) G. Zhang, S. Wang, Y. Ma, W. Kong and R. Wang, *Adv. Synth. Catal*., 2013, **355**, 874-879; (e) S. Vlahovic, N. Schädel, S. Tussetschläger and S. Laschat, *Eur. J. Org. Chem*., 2013, 1580-1590; (f) D. M. S. Schietroma, M. R. Monaco, V. Bucalossi, P. E. Walter, P. Gentile and M. Bella, *Org. Biomol. Chem*., 2012, **10**, 4692-4695.

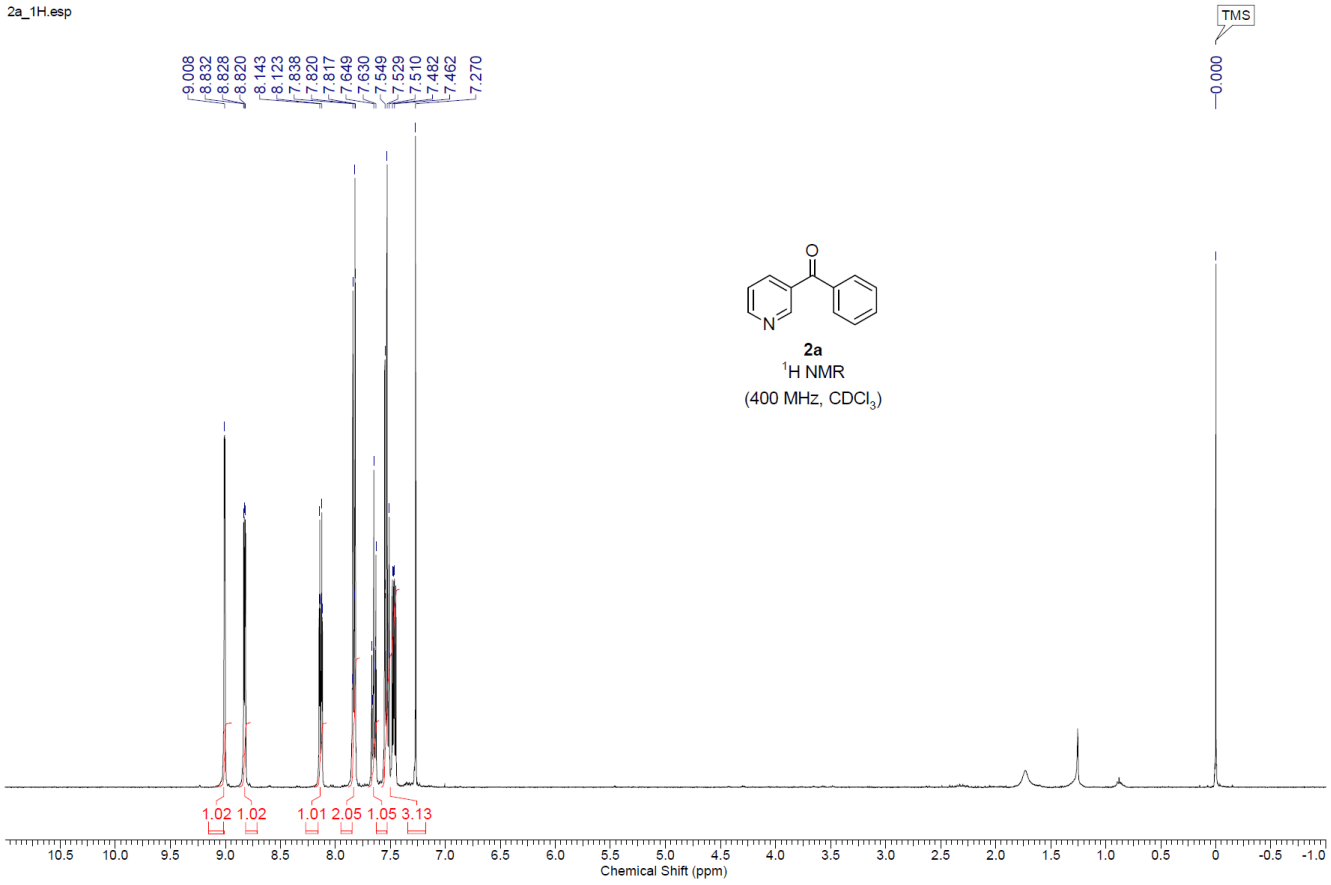
8 (a) X. Jiang, J. Zhang and S. Ma, *J. Am. Chem. Soc*., 2016, **138**, 8344-8347; (b) J.-L. Shih, T. S. Nguyen and J. A. May, *Angew. Chem. Int. Ed*., 2015, **54**, 9931-9935; (c) P. Magdolen, M. Mečiarová and Š. Toma, *Tetrahedron*, 2001, **57**, 4781-4785; (d) N. Deibl and R. Kempe, *J. Am. Chem. Soc*., 2016, **138**, 10786-10789.

9 (a) F. Shibahara, R. Sugiura, E. Yamaguchi, A. Kitagawa and T. Murai, *J. Org. Chem*., 2009, **74**, 3566-3568; (b) C. J. Dinsmore, J. M. Bergman, D. C. Beshore, B. W. Trotter, K. K. Nanda, R. Isaacs, L. S. Payne, L. A. Neilson, Z. Wu, M. T. Bilodeau, P. J. Manley and A. E. Balitza, PCT Int. Appl., WO2006/015159, 2016; (c) P. T. Weiser, C.-Y. Chang, D. P. McDonnell and R. N. Hanson, *Bioorg. Med. Chem.*, 2014, **22**, 917-926.

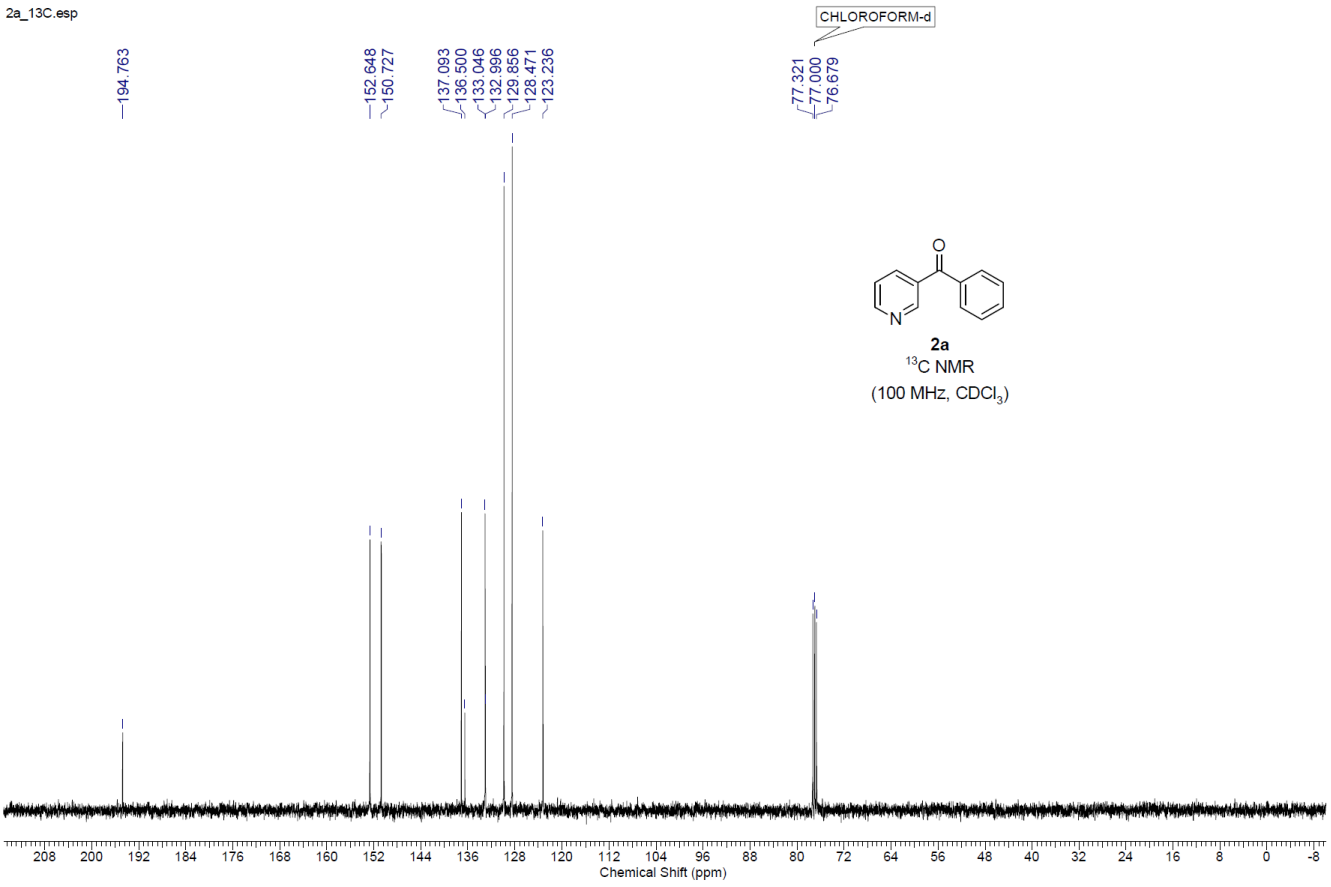
10 (a) F. Mühlthau, D. Stadler, A. Goeppert, G. A. Olah, G. K. S. Prakash and T. Bach, *J. Am. Chem. Soc.*, 2006, **128**, 9668-9675; (b) K. Sekine, T. Mawatari and T. Yamada, *Synlett* 2015, **26**, 2447-2450; (c) T. W. Greulich, C. G. Daniliuc and A. Studer, *Org. Lett*., 2015, **17**, 254-257.

11 P. R. Blakemore, S. P. Marsden and H. D. Vater, *Org. Lett*., 2006, **8**, 773-776.

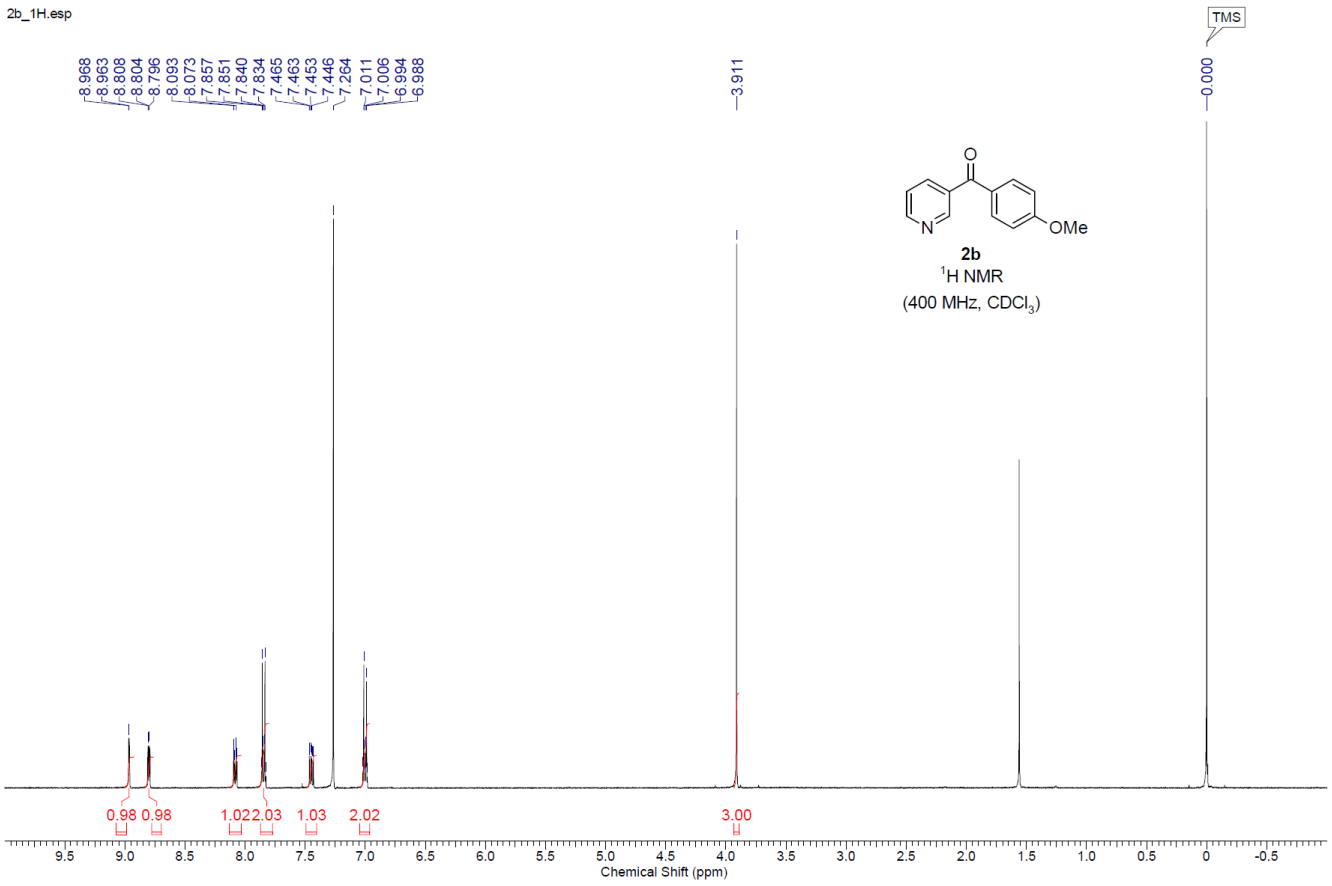
12 (a) G. M. Dobrikov, V. Valcheva, M. Stoilova-Disheva, G. Momekov, P. Tzvetkova, A. Chimov and V. Dimitrov, *Eur. J. Med. Chem*., 2012, **48**, 45-56; (b) T.-K. Yang, S.-L. Tseng, T. Liu and N.-K. Chen, U.S. Pat. Appl. Publ., US 20040181057, September 16, 2004.

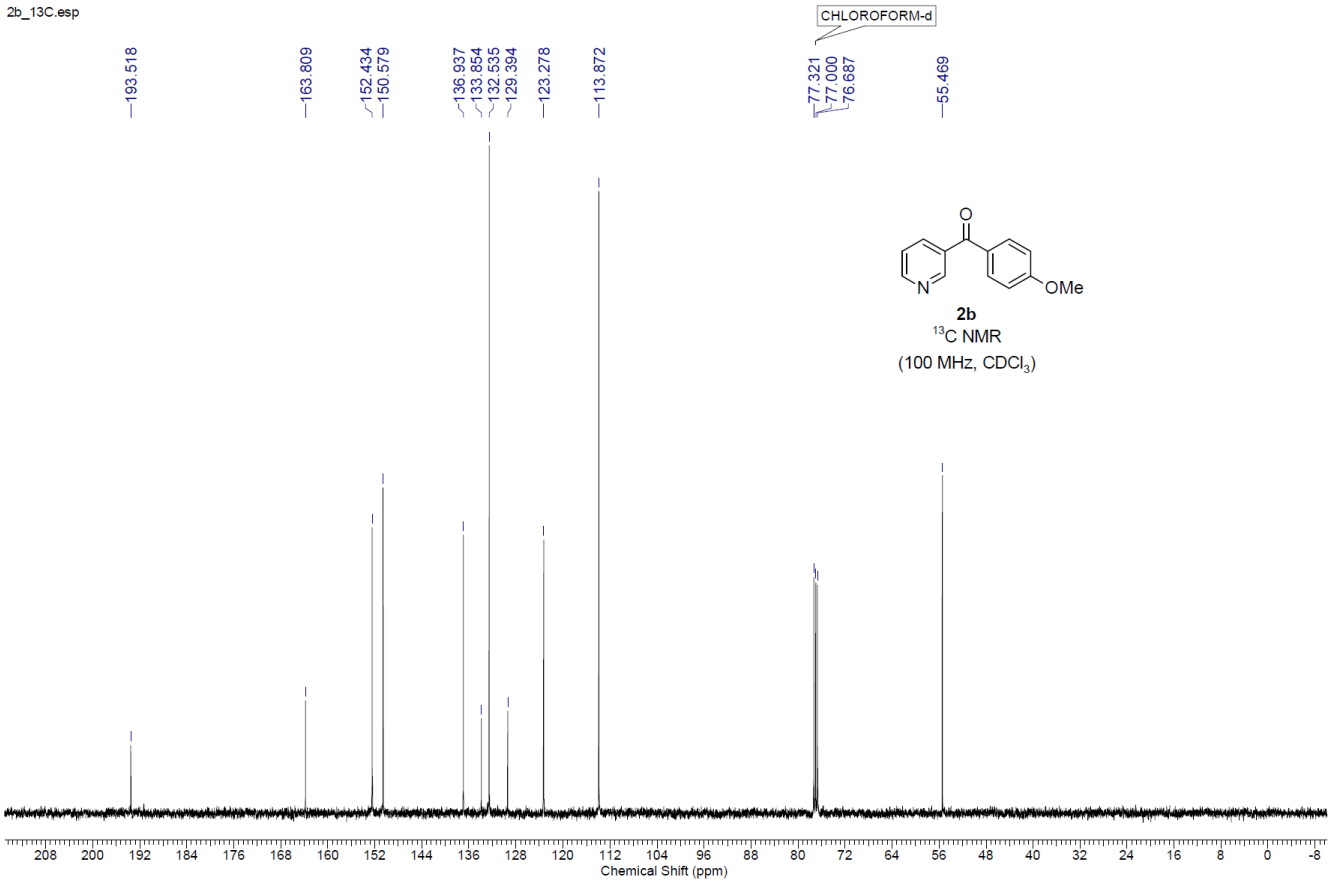


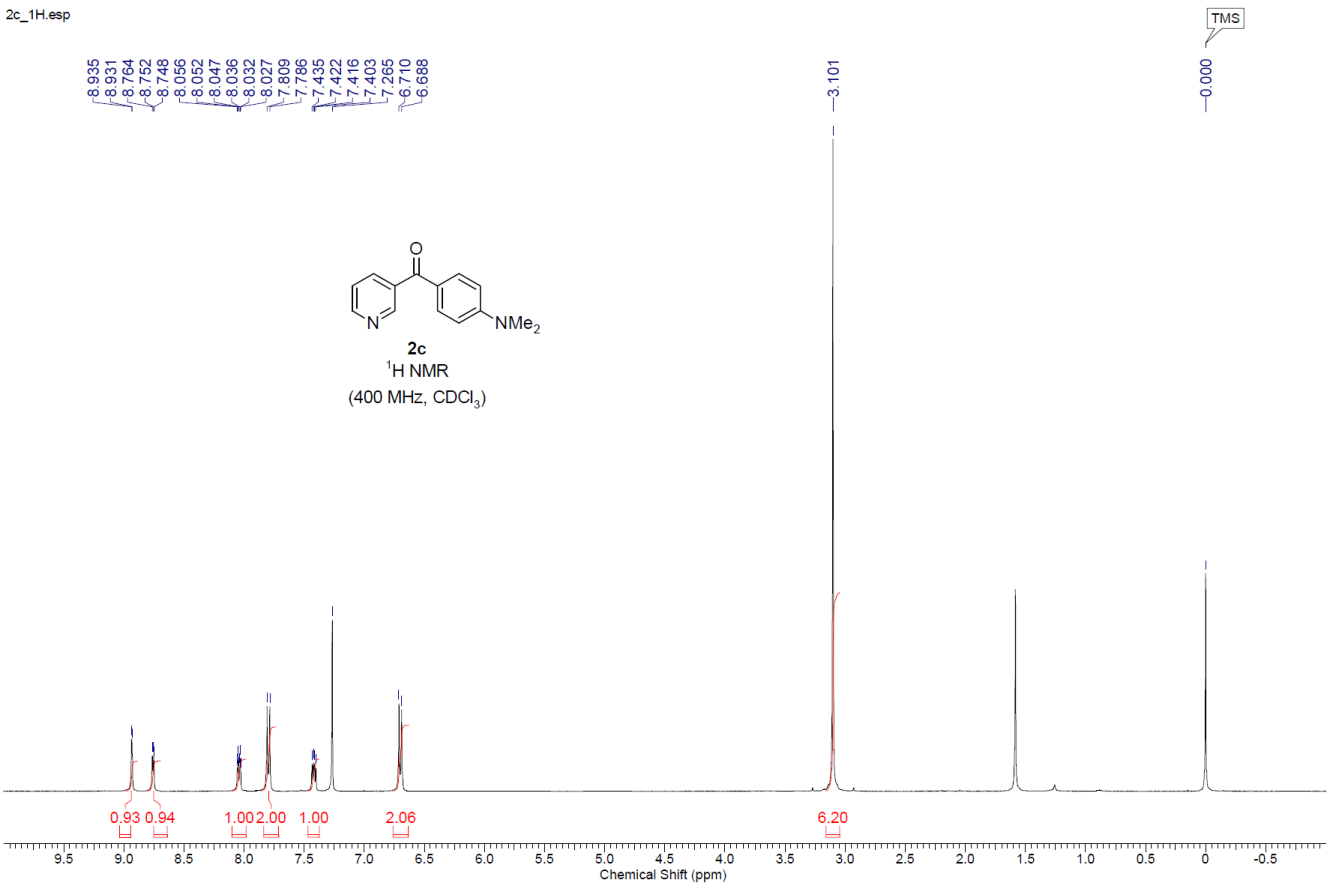
2a
^{1}H NMR
(400 MHz, $CDCl_3$)

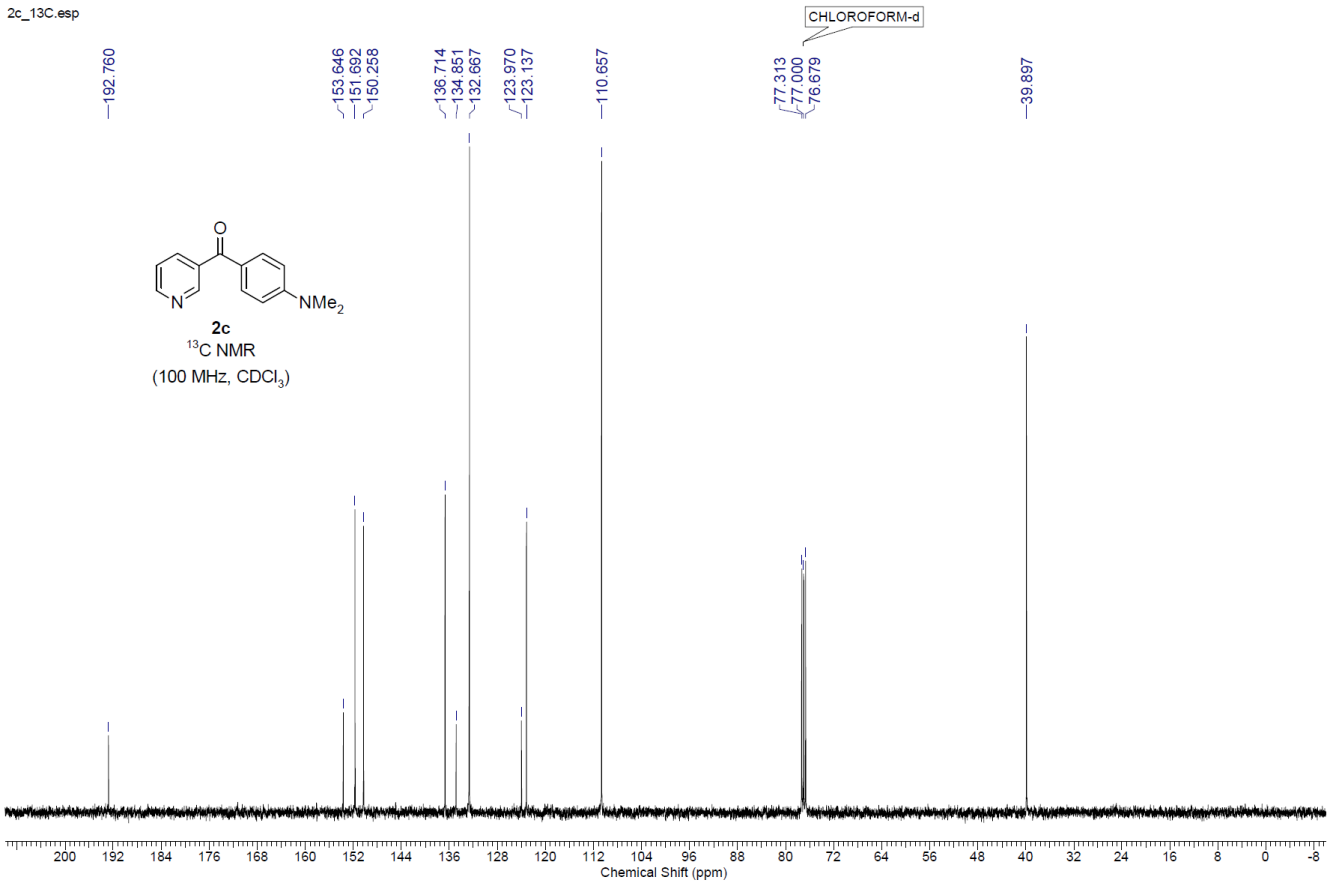


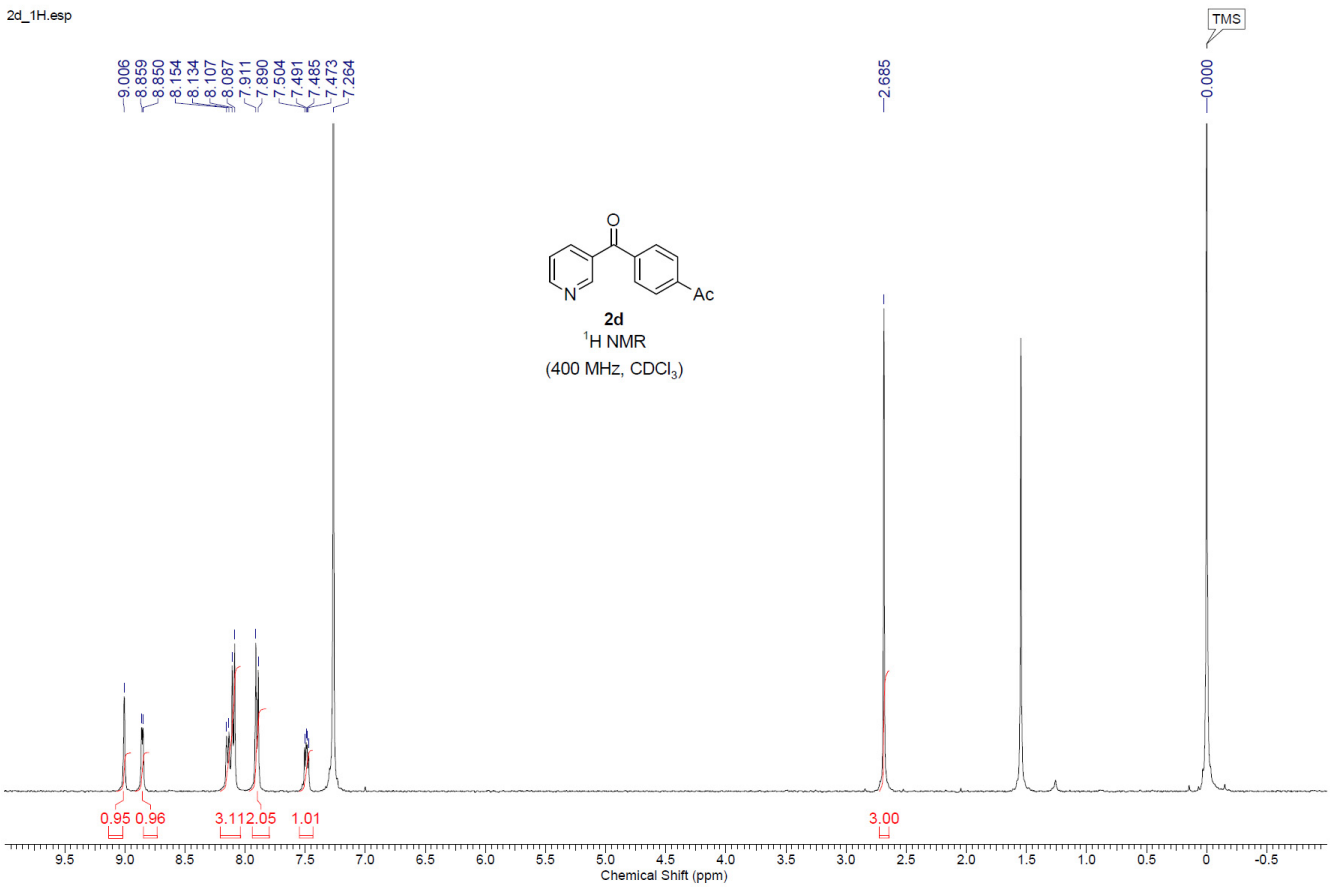
2a
^{13}C NMR
(100 MHz, $CDCl_3$)

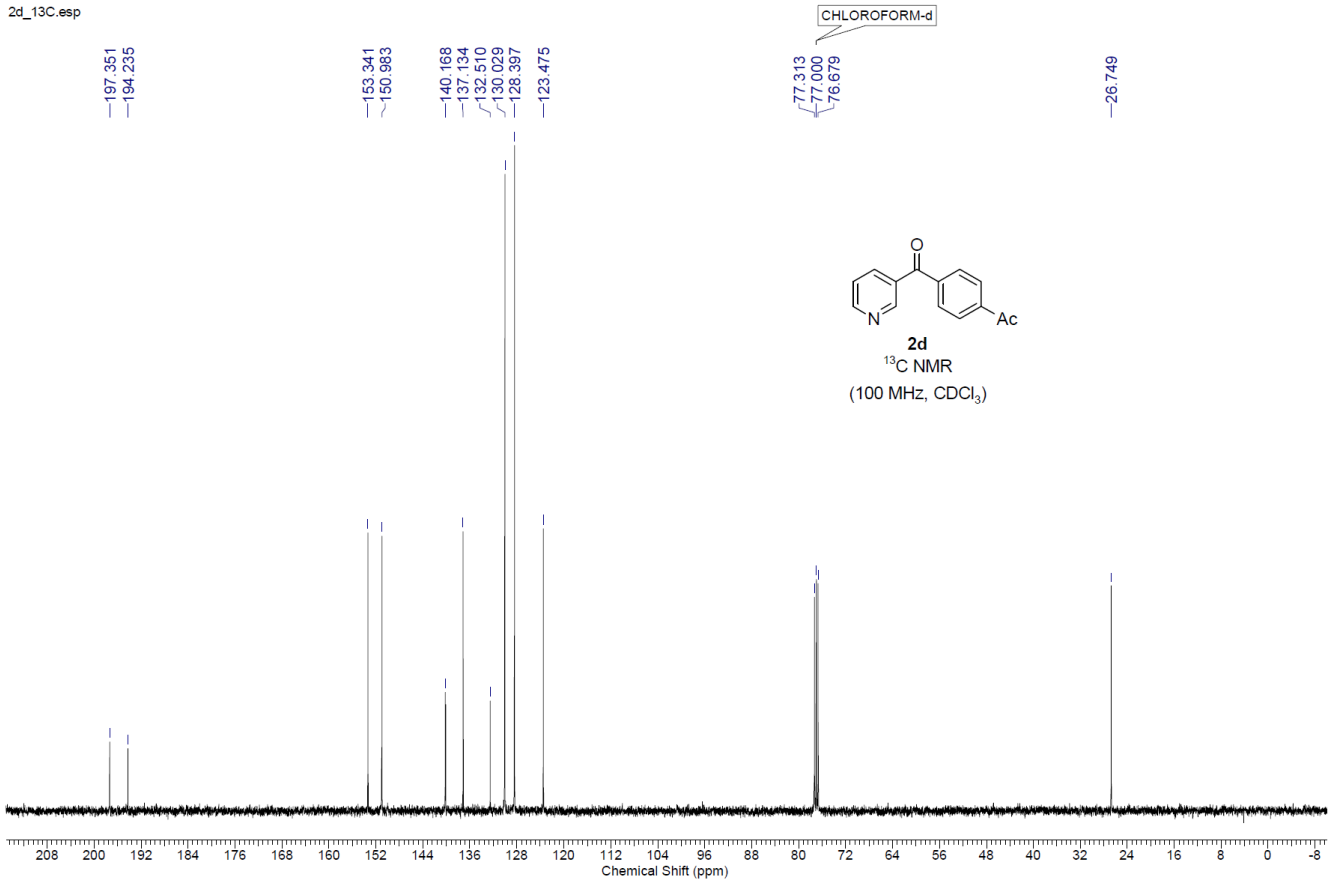

2b_1H.esp
8.968
8.963
8.808
8.804
8.796
8.093
8.073
7.857
7.851
7.840
7.834
7.465
7.463
7.453
7.446
7.264
7.011
7.006
6.994
6.988
3.911
TMS
0.000
O
N
OMe
2b
1H NMR
(400 MHz, CDCl3)
0.98 0.98 1.02 2.03 1.03 2.02 3.00
Chemical Shift (ppm)

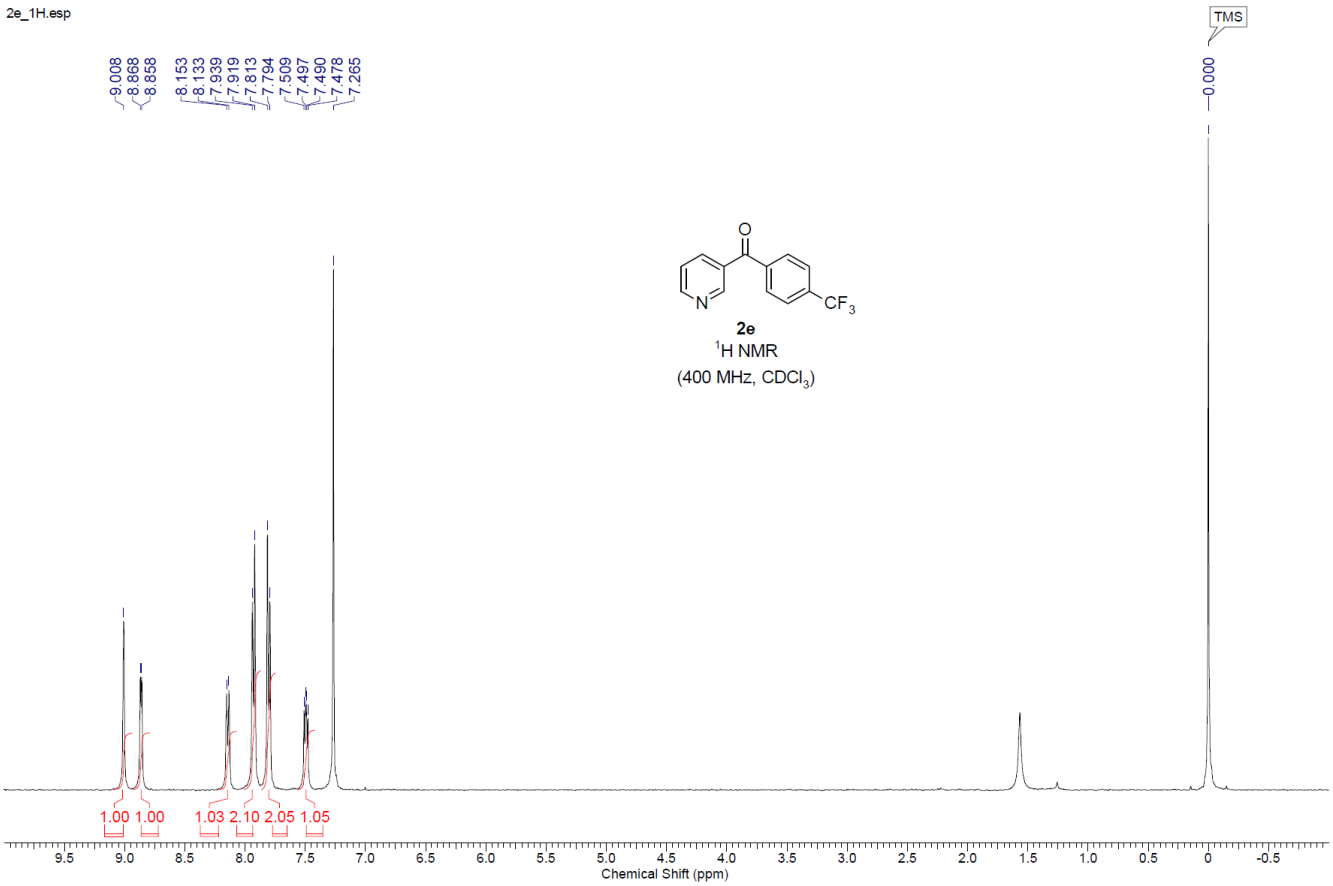

2b_13C.esp
193.518
163.809
152.434
150.579
136.937
133.854
132.535
129.394
123.278
113.872
CHLOROFORM-d
77.321
77.000
76.687
55.469
O
N
OMe
2b
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

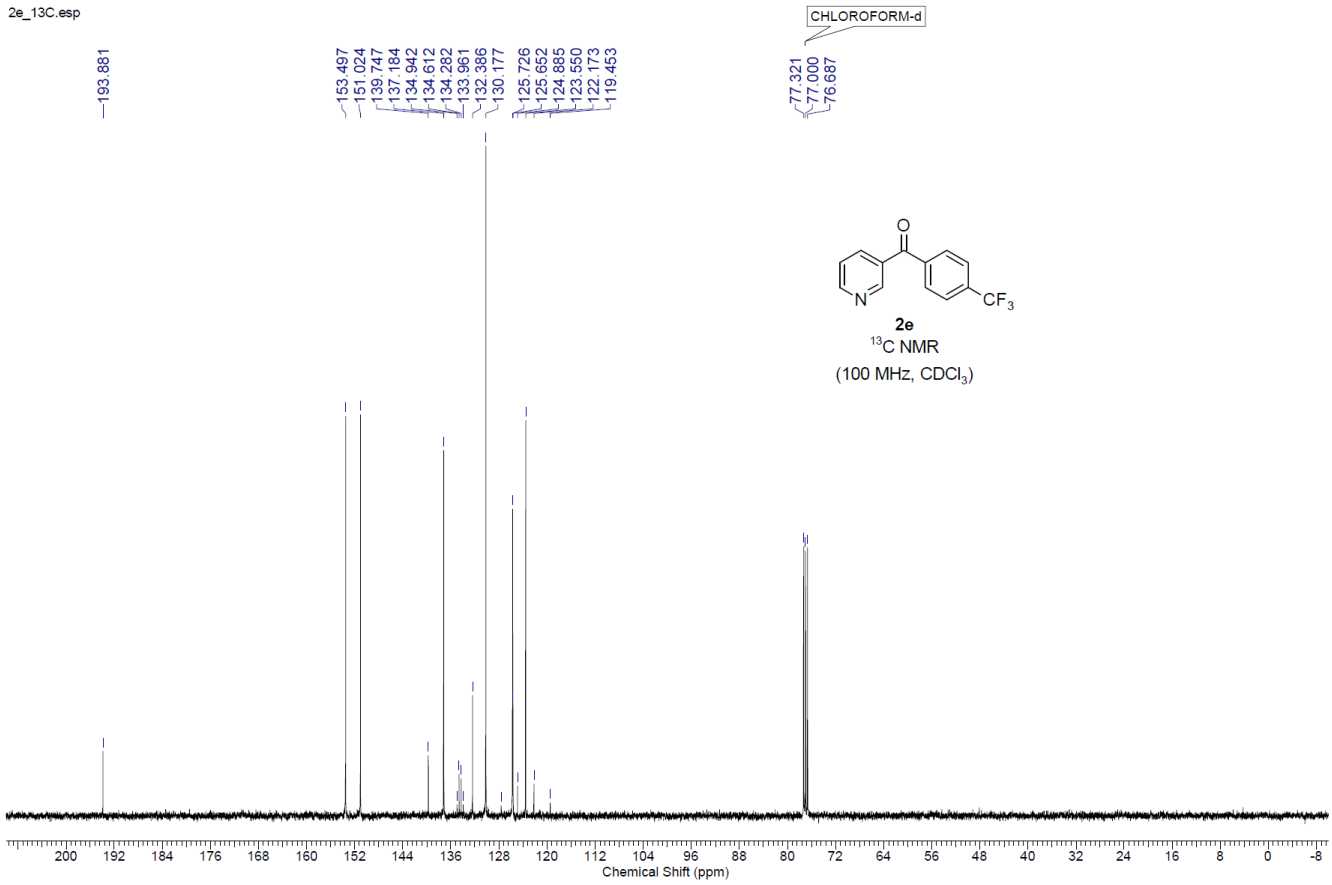

2c_1H.esp
TMS
8.935
8.931
8.764
8.752
8.748
8.056
8.052
8.047
8.036
8.032
8.027
7.809
7.786
7.435
7.422
7.416
7.403
7.265
6.710
6.688
3.101
0.000
O
N
NMe2
2c
1H NMR
(400 MHz, CDCl3)
0.93 0.94 1.00 2.00 1.00 2.06 6.20
Chemical Shift (ppm)

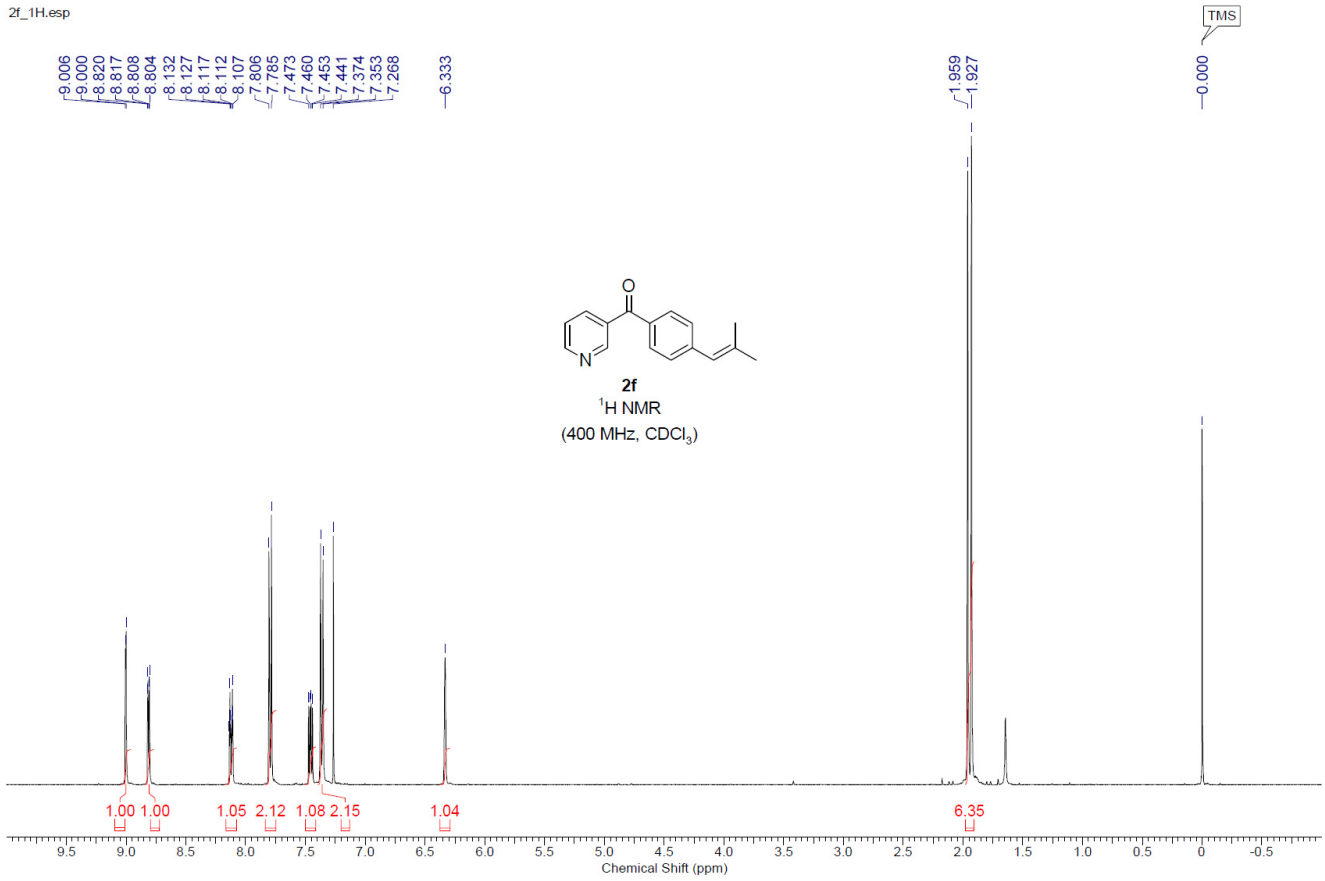

2c_13C.esp
CHLOROFORM-d
192.760
153.646
151.692
150.258
136.714
134.851
132.667
123.970
123.137
110.657
77.313
77.000
76.679
39.897
O
N
NMe2
2c
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

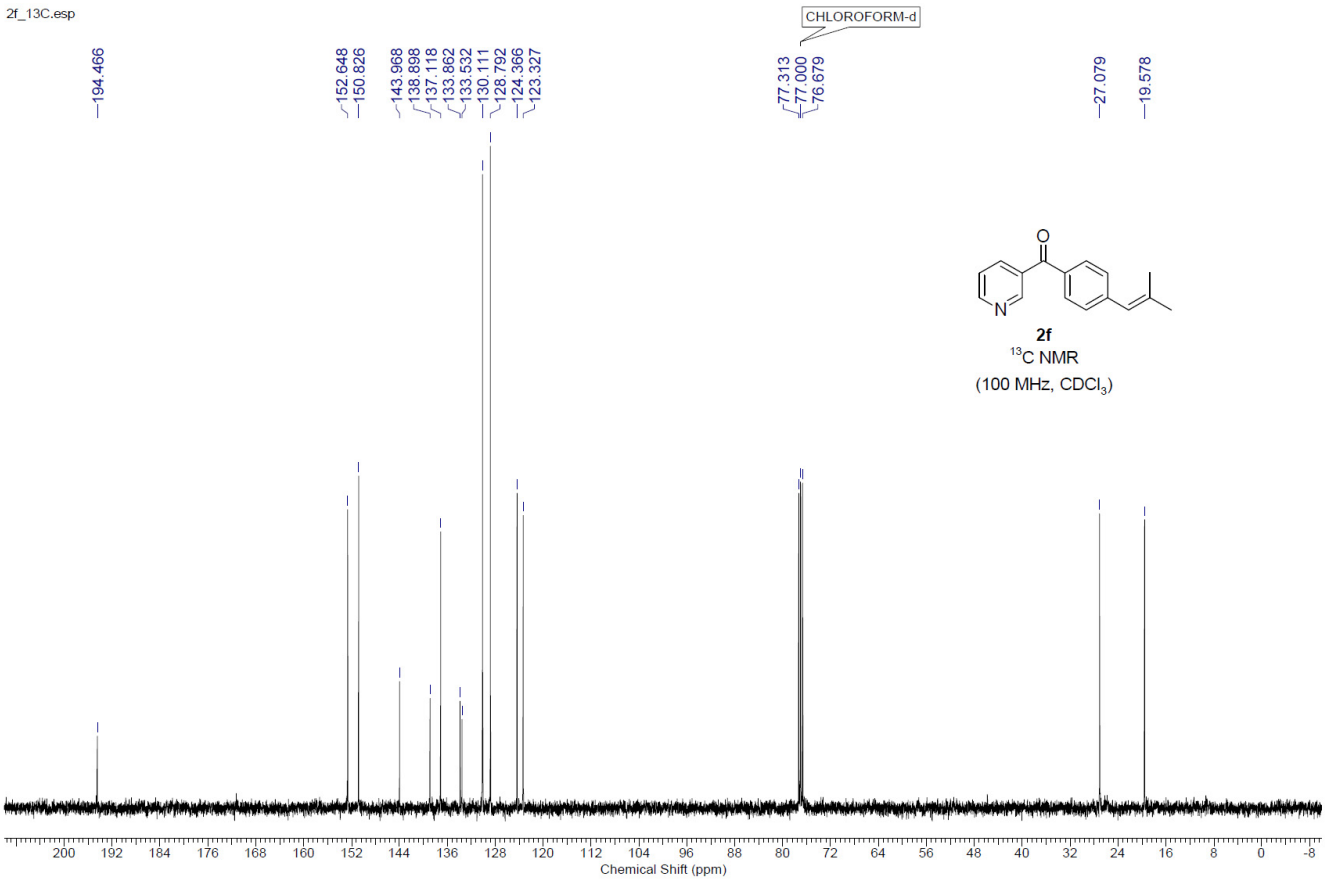

2d_1H.esp
TMS
9.006
8.859
8.850
8.154
8.134
8.107
8.087
7.911
7.890
7.504
7.491
7.485
7.473
7.264
2.685
0.000
O
N
Ac
2d
1H NMR
(400 MHz, CDCl3)
0.95 0.96
3.11 2.05
1.01
3.00
Chemical Shift (ppm)

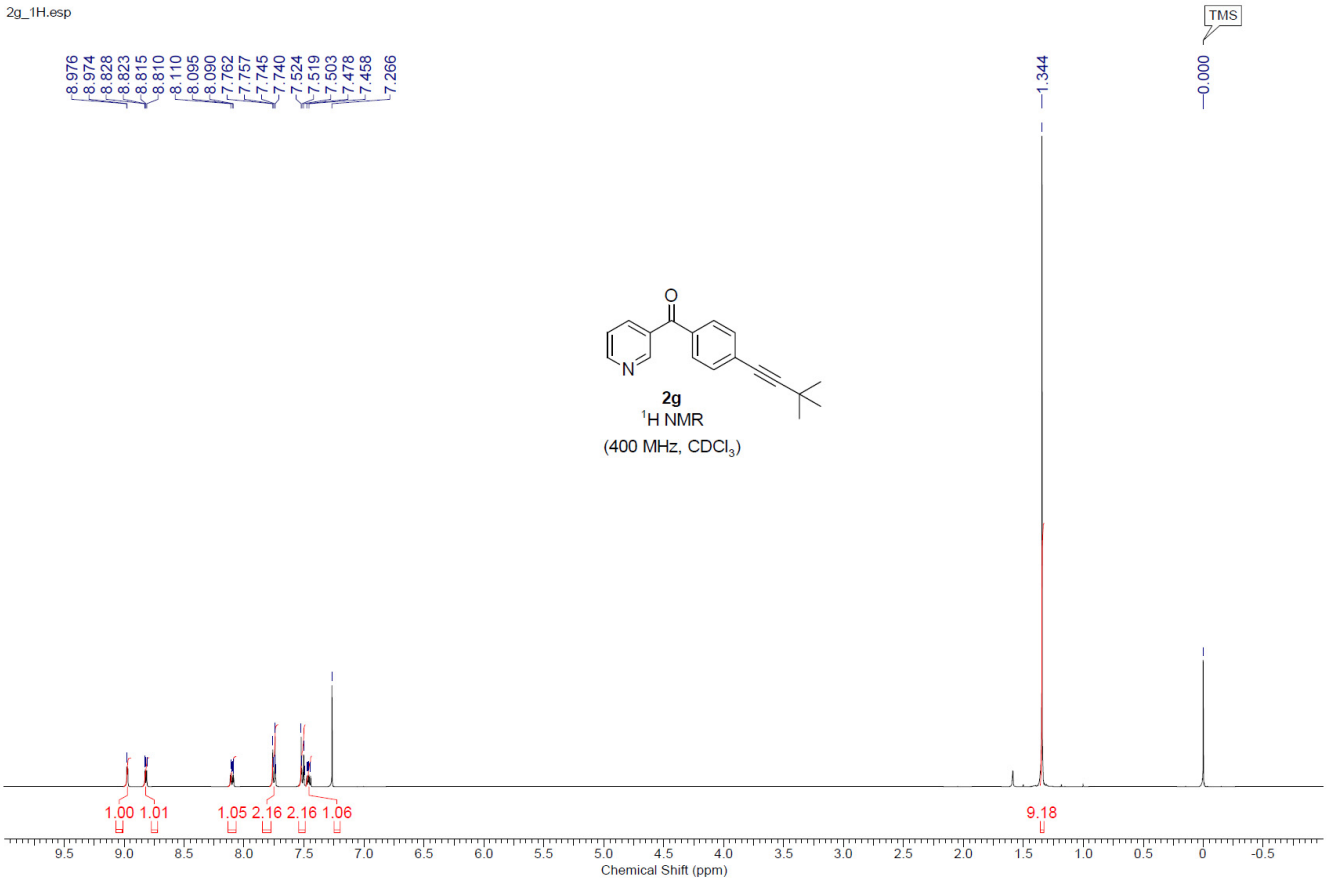

2d_13C.esp
CHLOROFORM-d
197.351
194.235
153.341
150.983
140.168
137.134
132.510
130.029
128.397
123.475
77.313
77.000
76.679
26.749
O
N
Ac
2d
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

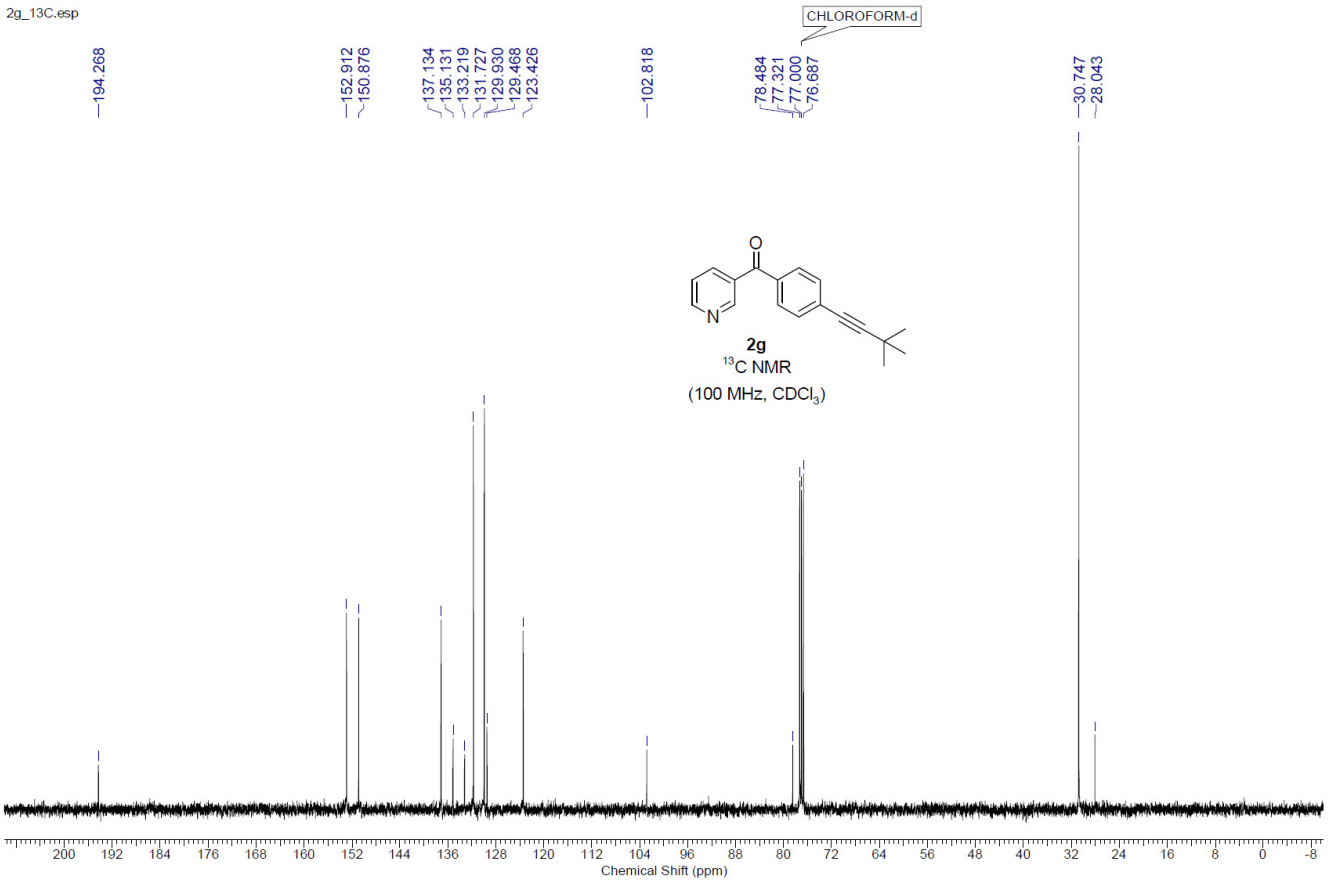

2e_1H.esp
9.008
8.868
8.858
8.153
8.133
7.939
7.919
7.813
7.794
7.509
7.497
7.490
7.478
7.265
TMS
0.000
O
N
CF3
2e
1H NMR
(400 MHz, CDCl3)
1.00 1.00 1.03 2.10 2.05 1.05
Chemical Shift (ppm)

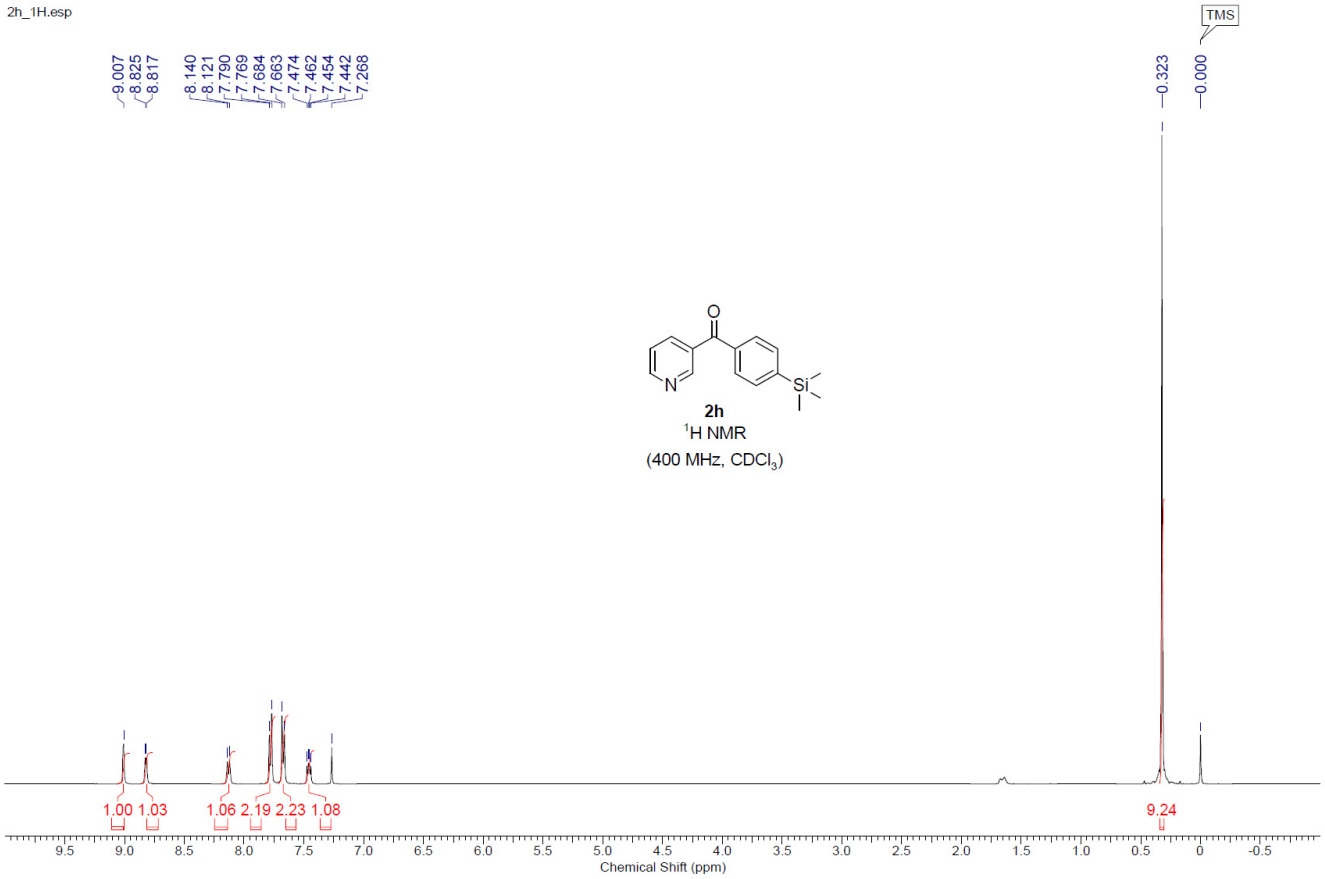

2e_13C.esp
193.881
153.497
151.024
139.747
137.184
134.942
134.612
134.282
133.961
132.386
130.177
125.726
125.652
124.885
123.550
122.173
119.453
CHLOROFORM-d
77.321
77.000
76.687
O
N
CF3
2e
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

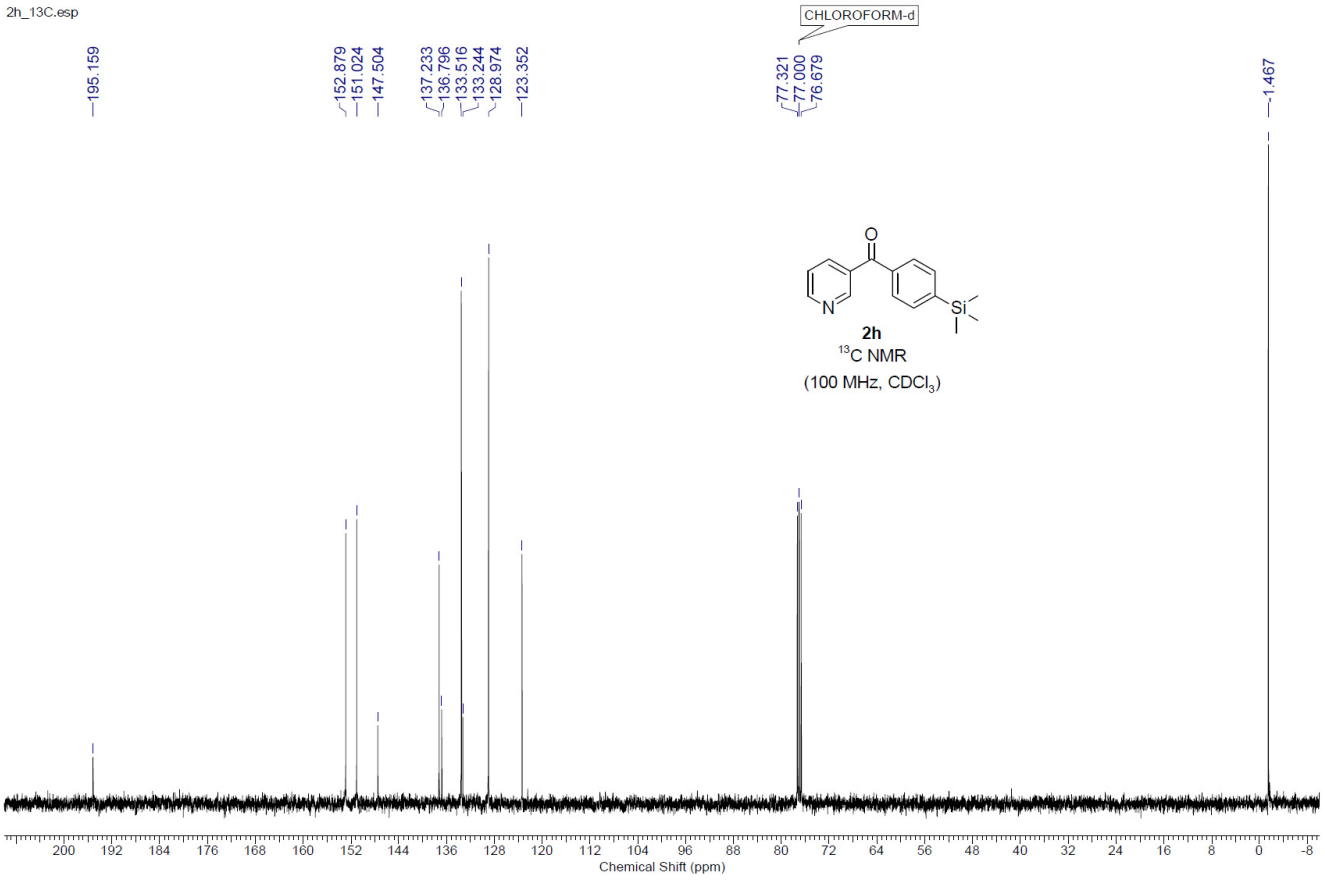

2f_1H.esp
TMS
9.006
9.000
8.820
8.817
8.808
8.804
8.132
8.127
8.117
8.112
8.107
7.806
7.785
7.473
7.460
7.453
7.441
7.374
7.353
7.268
6.333
1.959
1.927
0.000
O
N
2f
1H NMR
(400 MHz, CDCl3)
1.00 1.00 1.05 2.12 1.08 2.15 1.04 6.35
Chemical Shift (ppm)

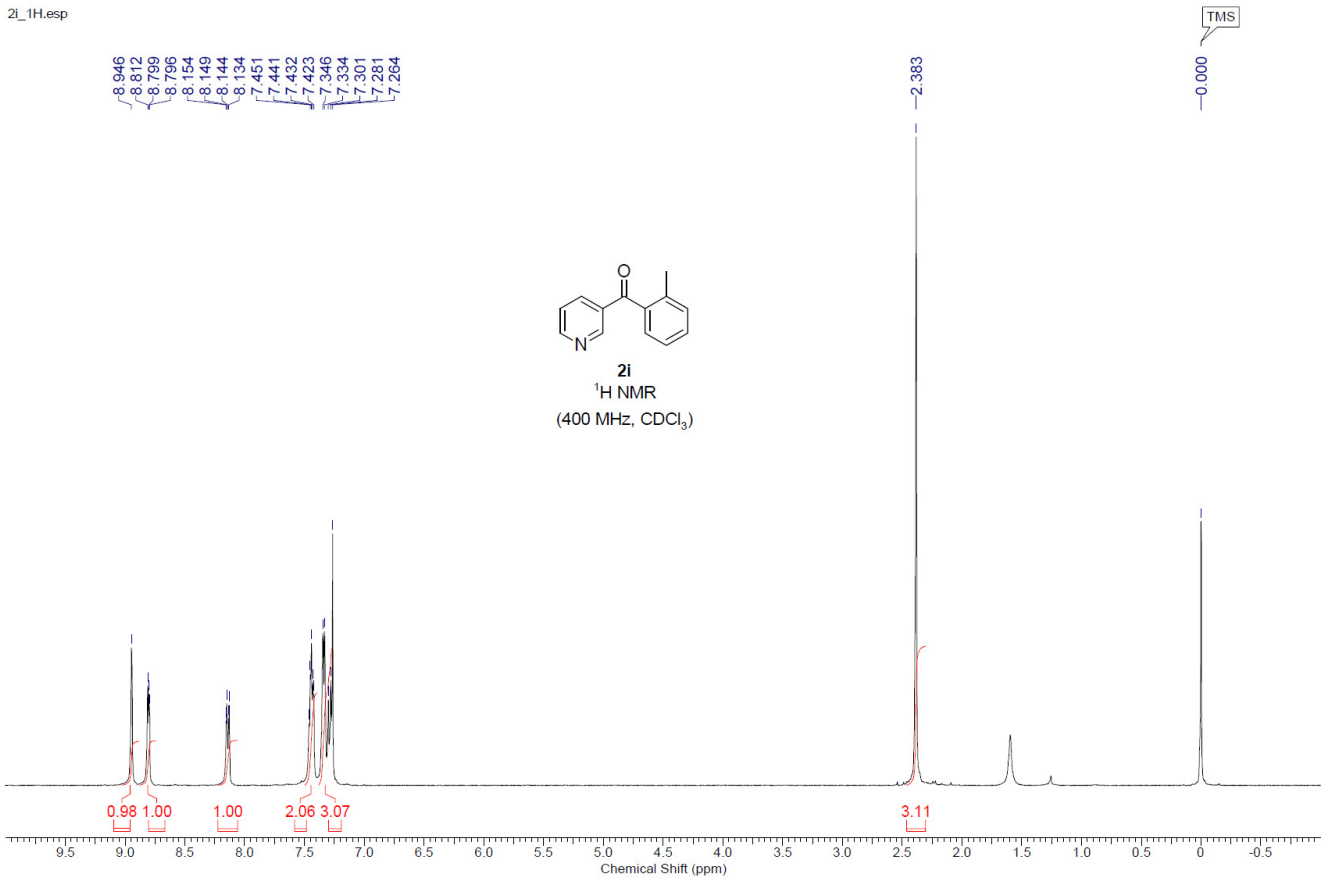

2f_13C.esp
CHLOROFORM-d
194.466
152.648
150.826
143.968
138.898
137.118
133.862
133.532
130.111
128.792
124.366
123.327
77.313
77.000
76.679
27.079
19.578
O
N
2f
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

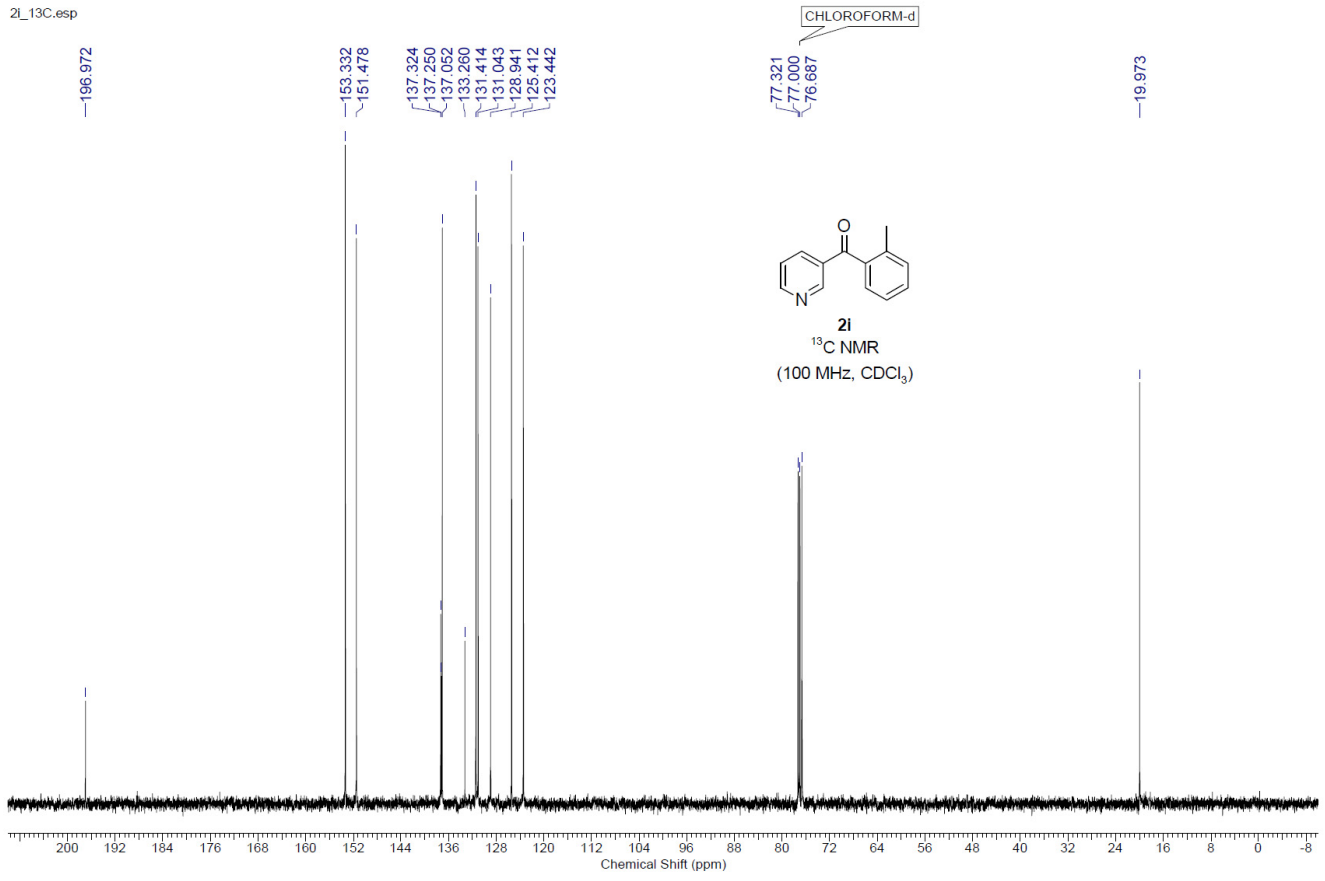

2g_1H.esp
TMS
8.976
8.974
8.828
8.823
8.815
8.810
8.110
8.095
8.090
7.762
7.757
7.745
7.740
7.524
7.519
7.503
7.478
7.458
7.266
1.344
0.000
2g
1H NMR
(400 MHz, CDCl3)
1.00 1.01 1.05 2.16 2.16 1.06
9.18
Chemical Shift (ppm)

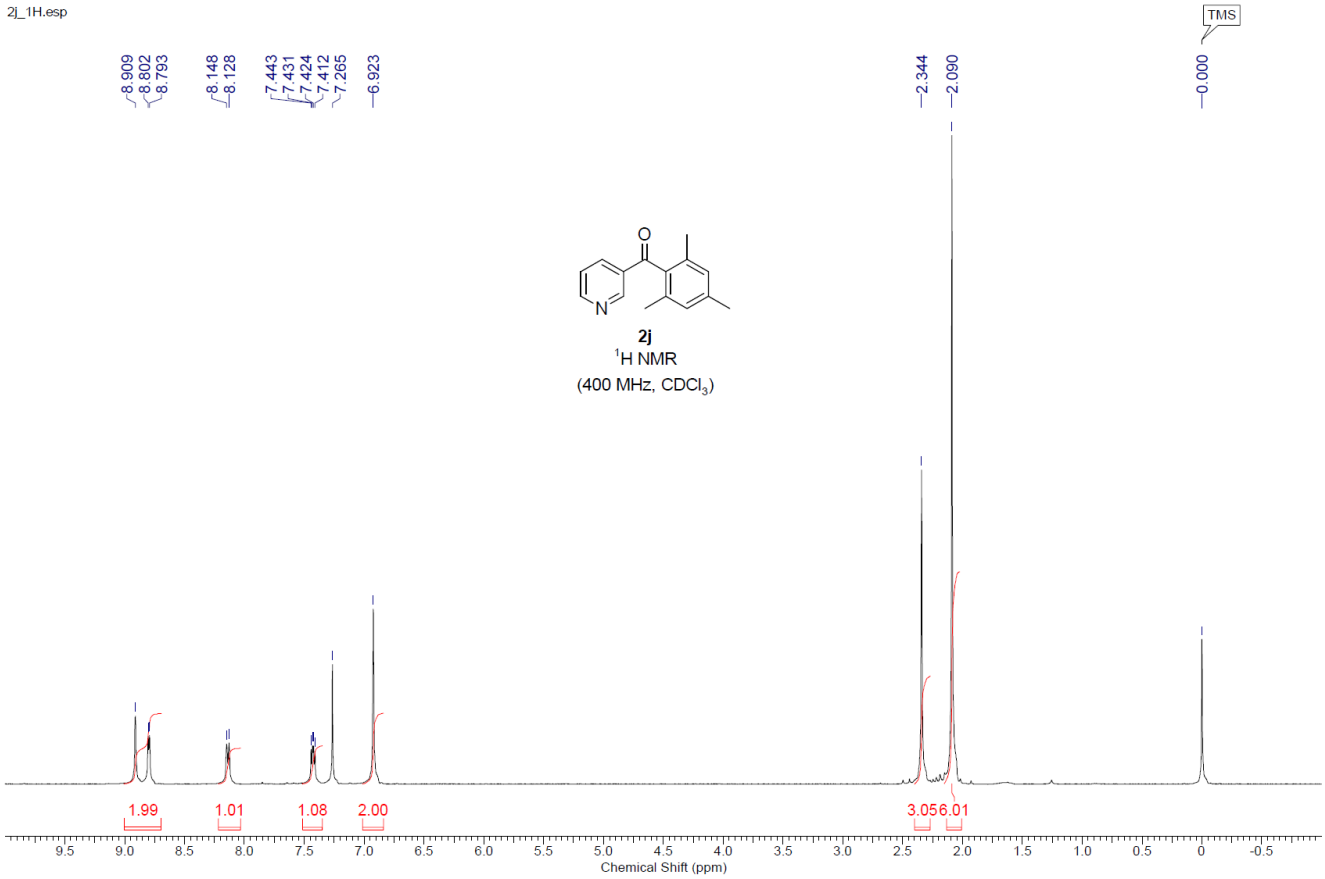

2g_13C.esp
CHLOROFORM-d
194.268
152.912
150.876
137.134
135.131
133.219
131.727
129.930
129.468
123.426
102.818
78.484
77.321
77.000
76.687
30.747
28.043
2g
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

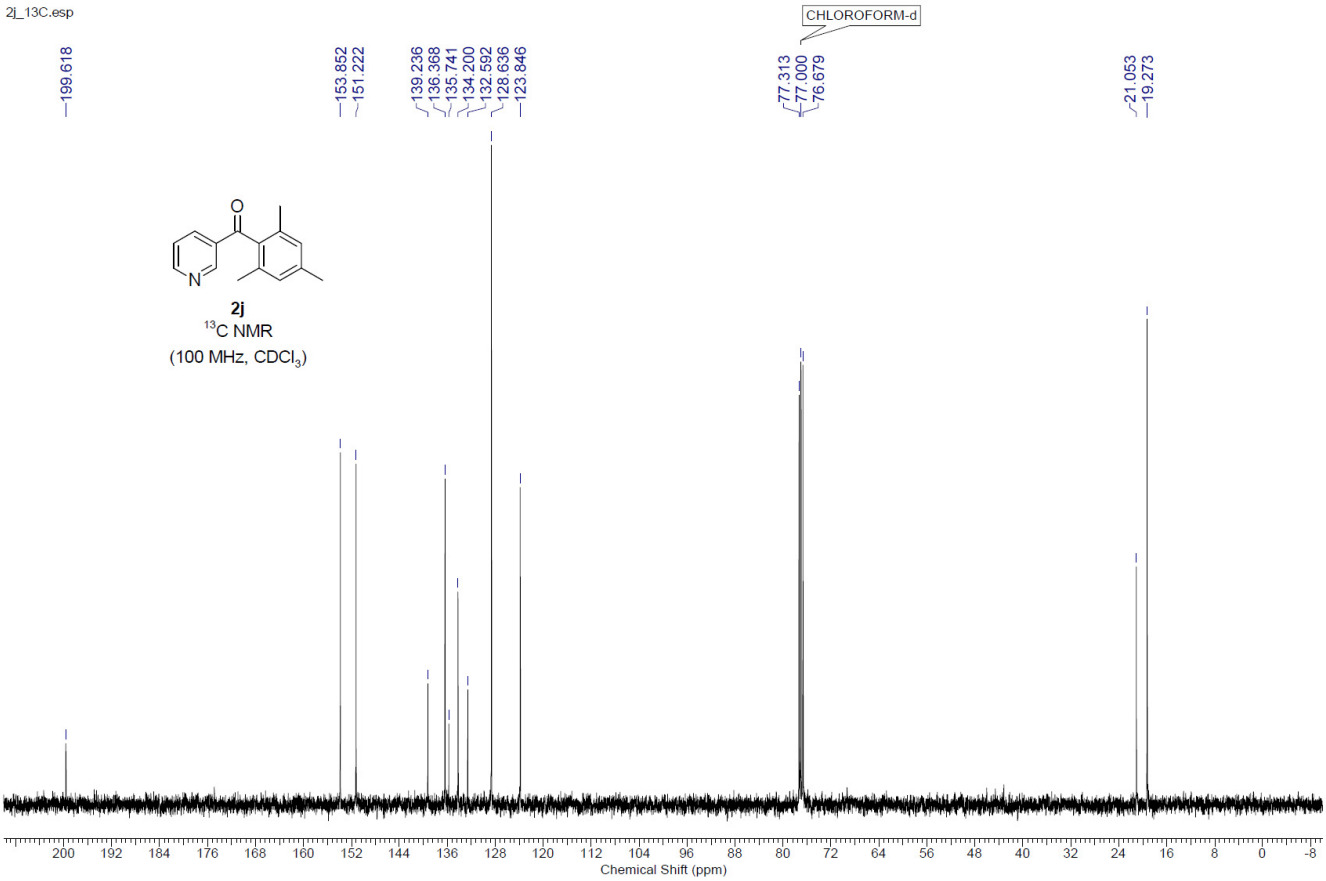

2h_1H.esp
TMS
9.007
8.825
8.817
8.140
8.121
7.790
7.769
7.684
7.663
7.474
7.462
7.454
7.442
7.268
0.323
0.000
2h
1H NMR
(400 MHz, CDCl3)
1.00 1.03 1.06 2.19 2.23 1.08
9.24
Chemical Shift (ppm)

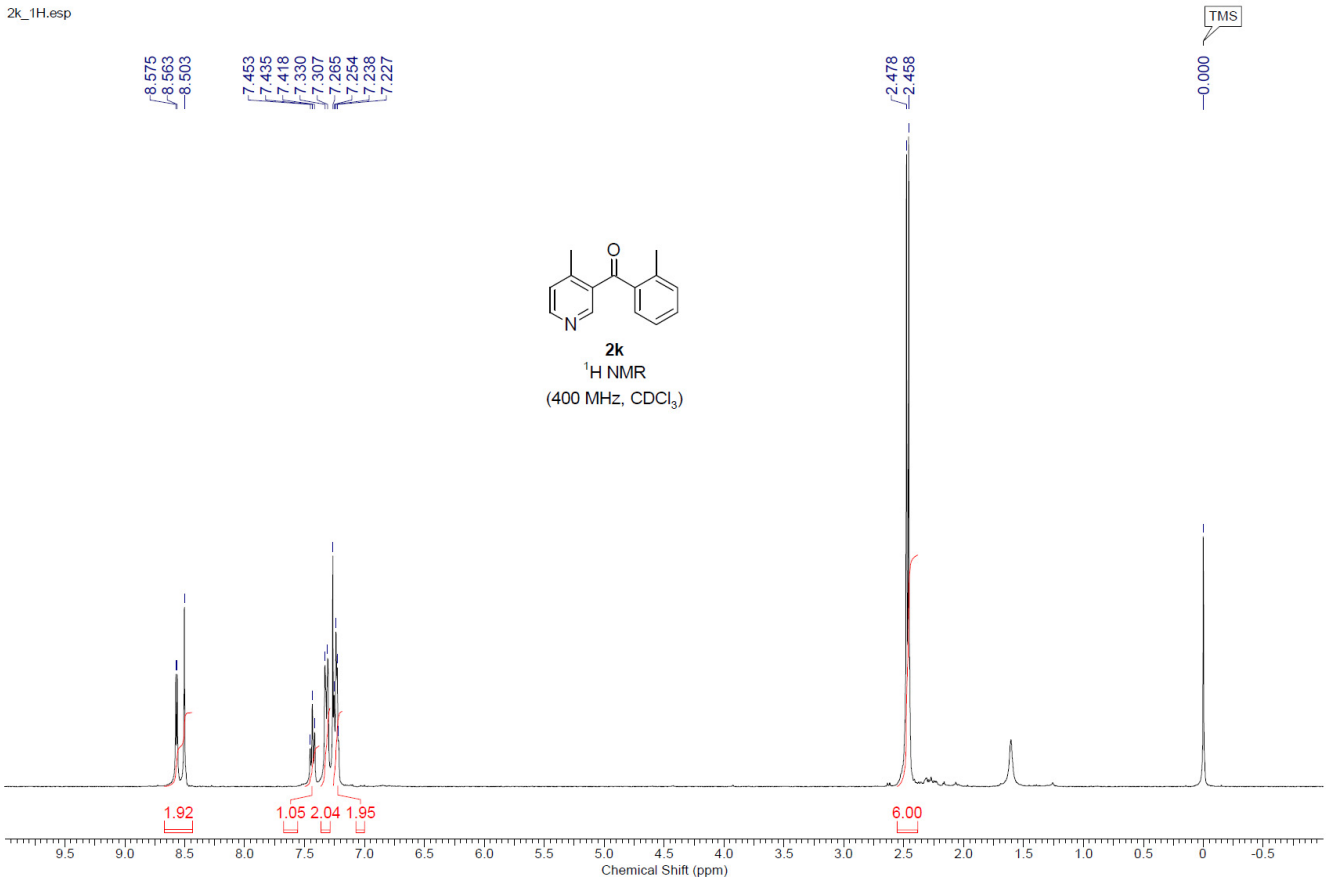

2h_13C.esp
CHLOROFORM-d
195.159
152.879
151.024
147.504
137.233
136.796
133.516
133.244
128.974
123.352
77.321
77.000
76.679
1.467
2h
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

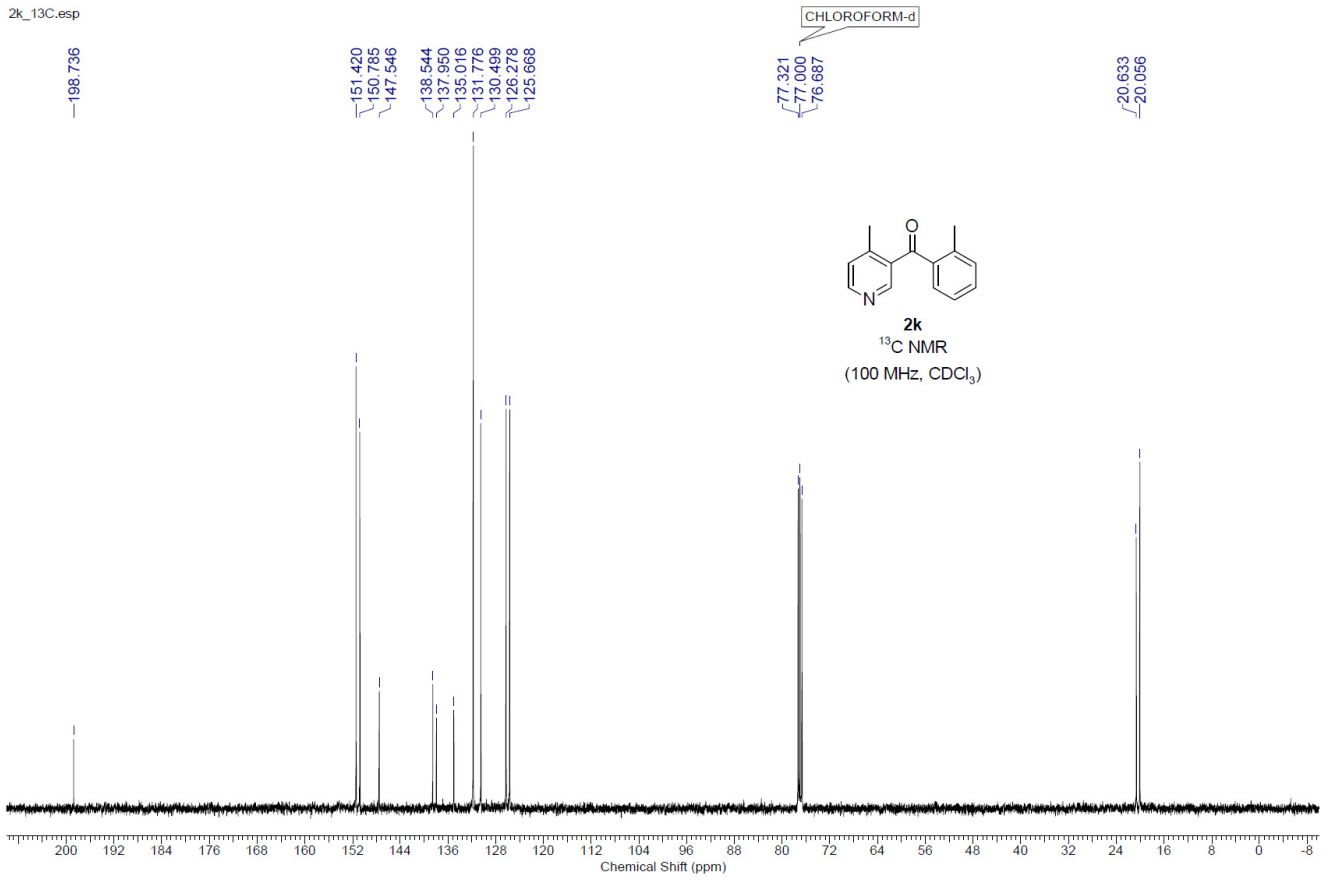

2i_1H.esp
TMS
8.946
8.812
8.799
8.796
8.154
8.149
8.144
8.134
7.451
7.441
7.432
7.423
7.346
7.334
7.301
7.281
7.264
2.383
0.000
2i
1H NMR
(400 MHz, CDCl3)
0.98 1.00 1.00 2.06 3.07
3.11
Chemical Shift (ppm)

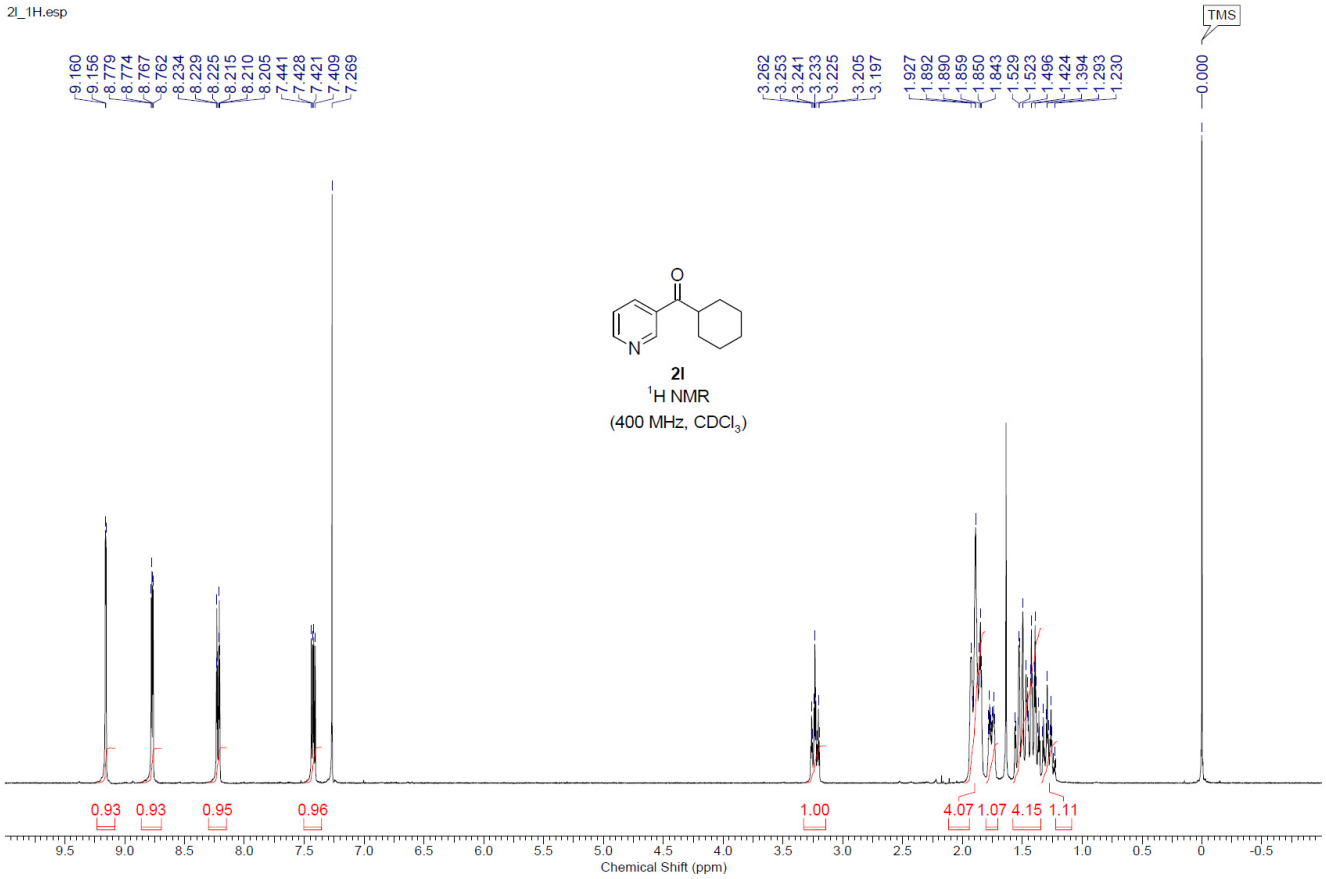

2i_13C.esp
CHLOROFORM-d
196.972
153.332
151.478
137.324
137.250
137.052
133.260
131.414
131.043
128.941
125.412
123.442
77.321
77.000
76.687
19.973
2i
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

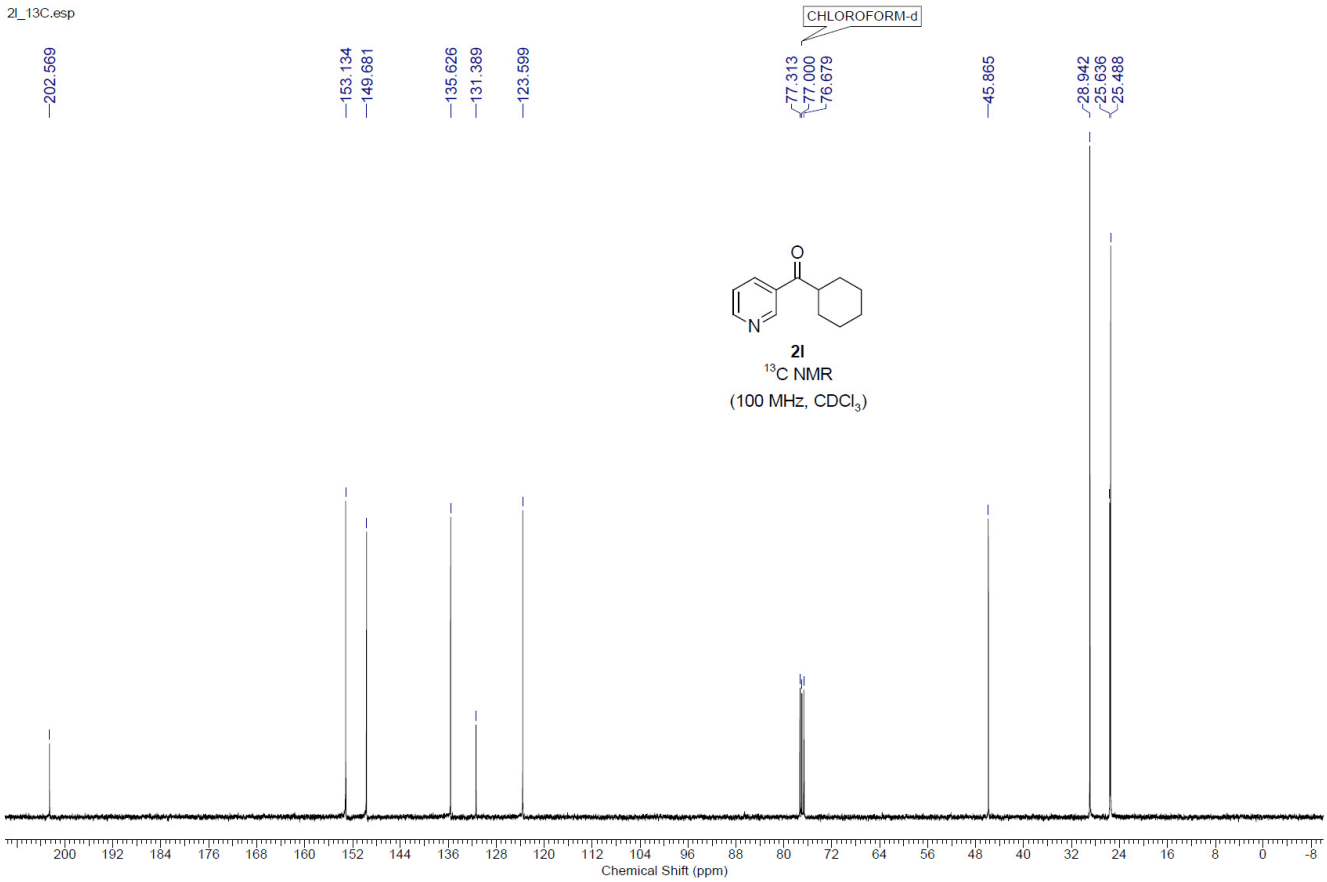

2j_1H.esp
TMS
8.909
8.802
8.793
8.148
8.128
7.443
7.431
7.424
7.412
7.265
6.923
2.344
2.090
0.000
O
N
2j
1H NMR
(400 MHz, CDCl3)
1.99
1.01
1.08
2.00
3.05
6.01
Chemical Shift (ppm)

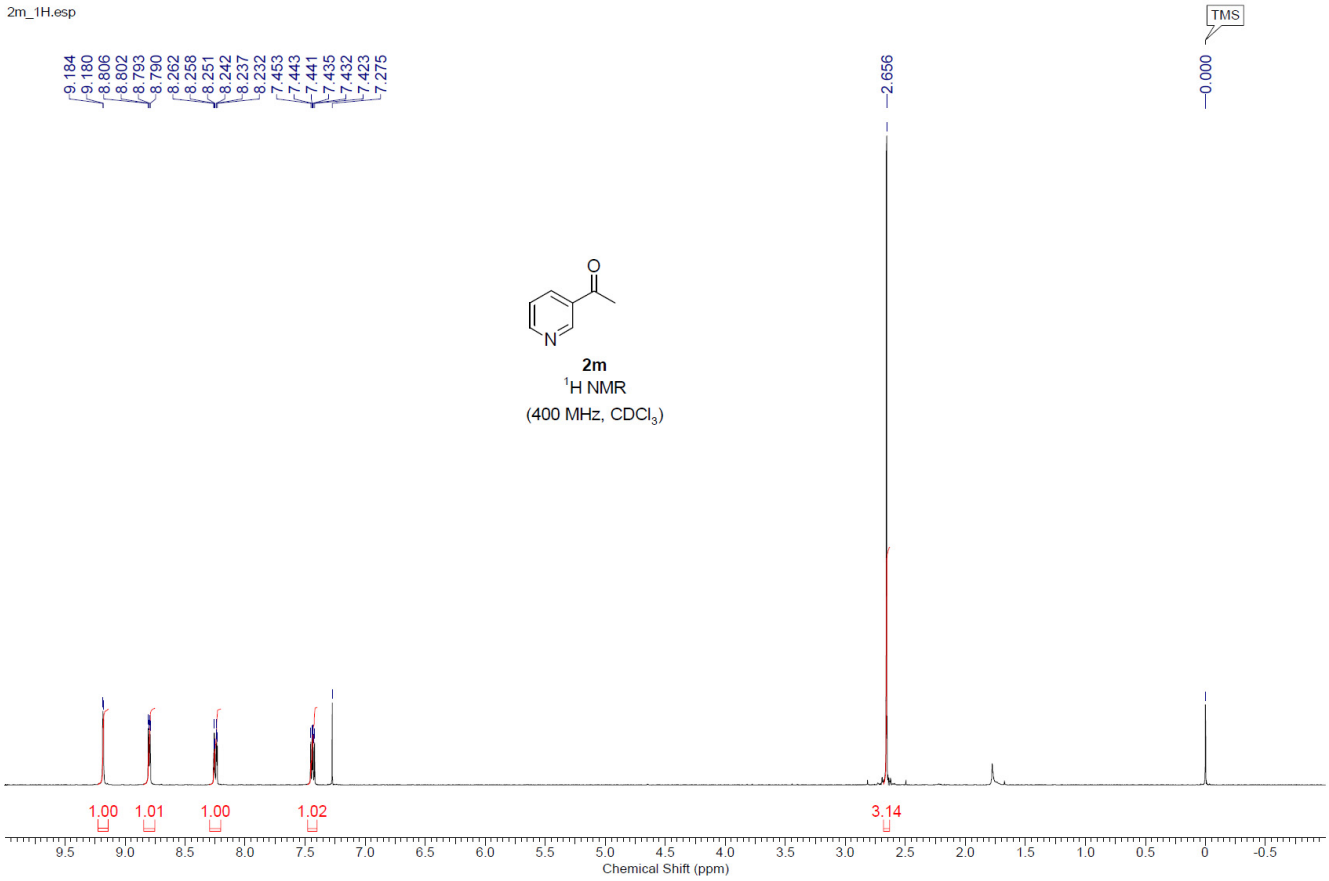

2j_13C.esp
CHLOROFORM-d
199.618
153.852
151.222
139.236
136.368
135.741
134.200
132.592
128.636
123.846
77.313
77.000
76.679
21.053
19.273
O
N
2j
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

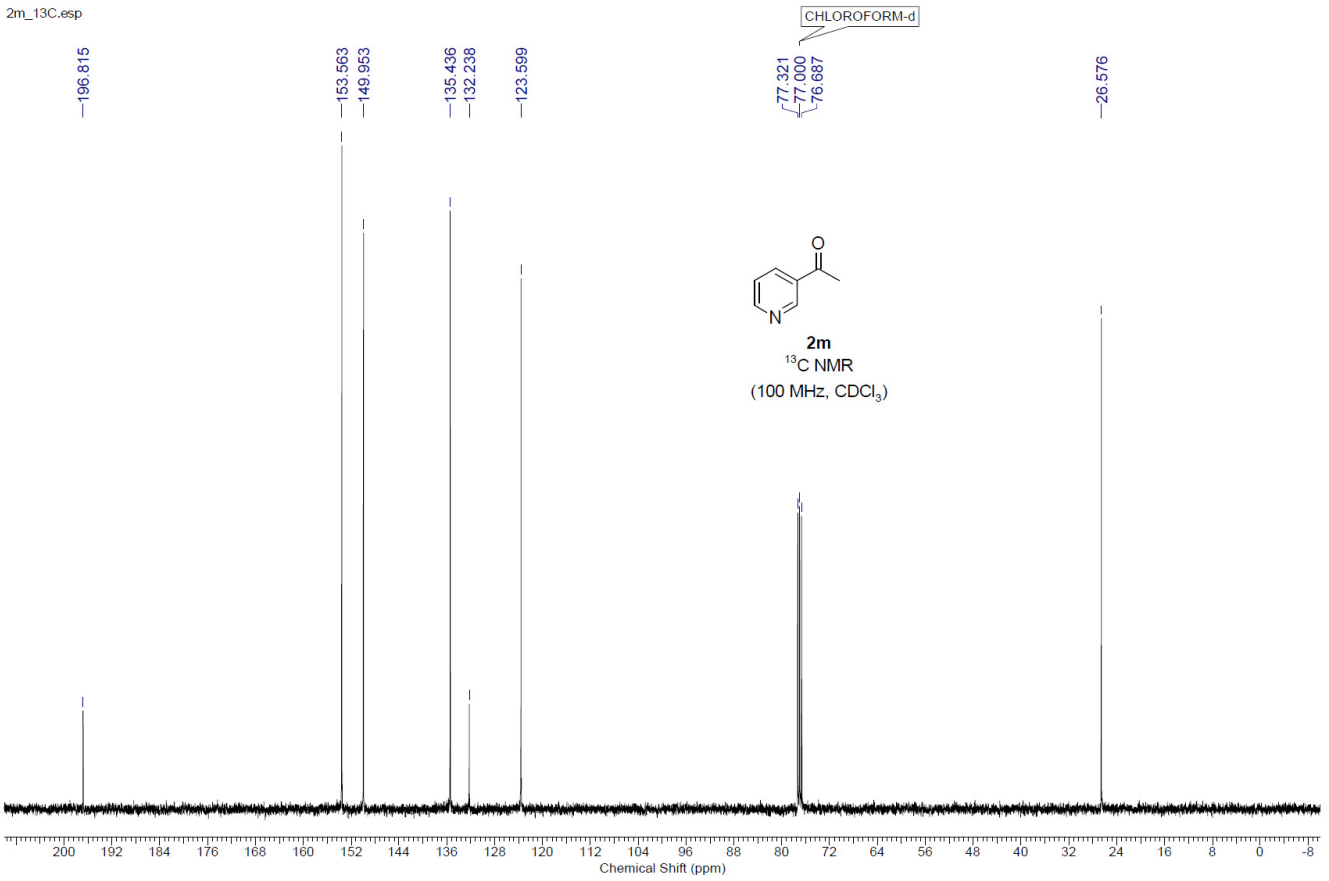

2k_1H.esp
TMS
8.575
8.563
8.503
7.453
7.435
7.418
7.330
7.307
7.265
7.254
7.238
7.227
2.478
2.458
0.000
O
N
2k
1H NMR
(400 MHz, CDCl3)
1.92
1.05
2.04
1.95
6.00
Chemical Shift (ppm)

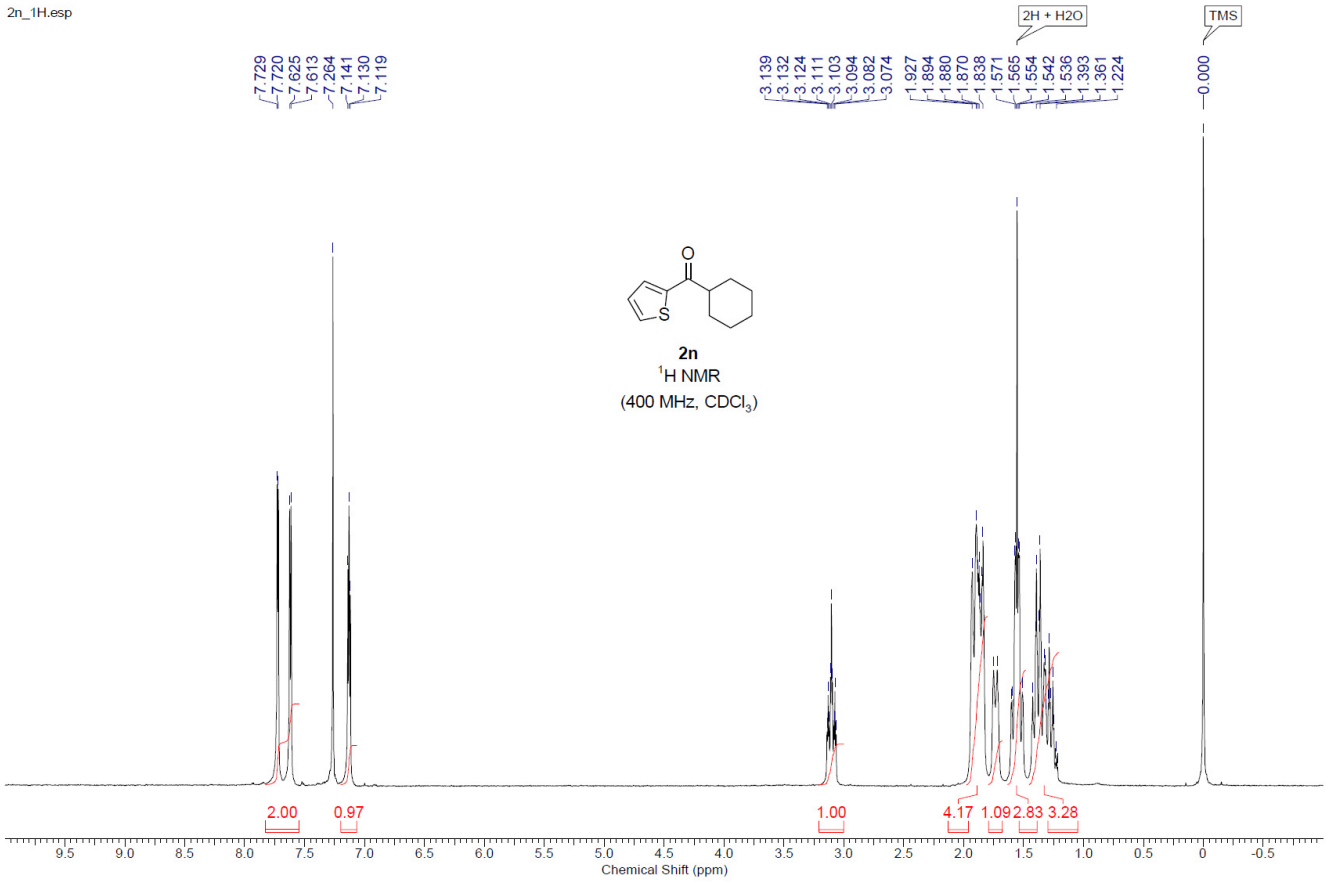

2k_13C.esp
CHLOROFORM-d
198.736
151.420
150.785
147.546
138.544
137.950
135.016
131.776
130.499
126.278
125.668
77.321
77.000
76.687
20.633
20.056
O
N
2k
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

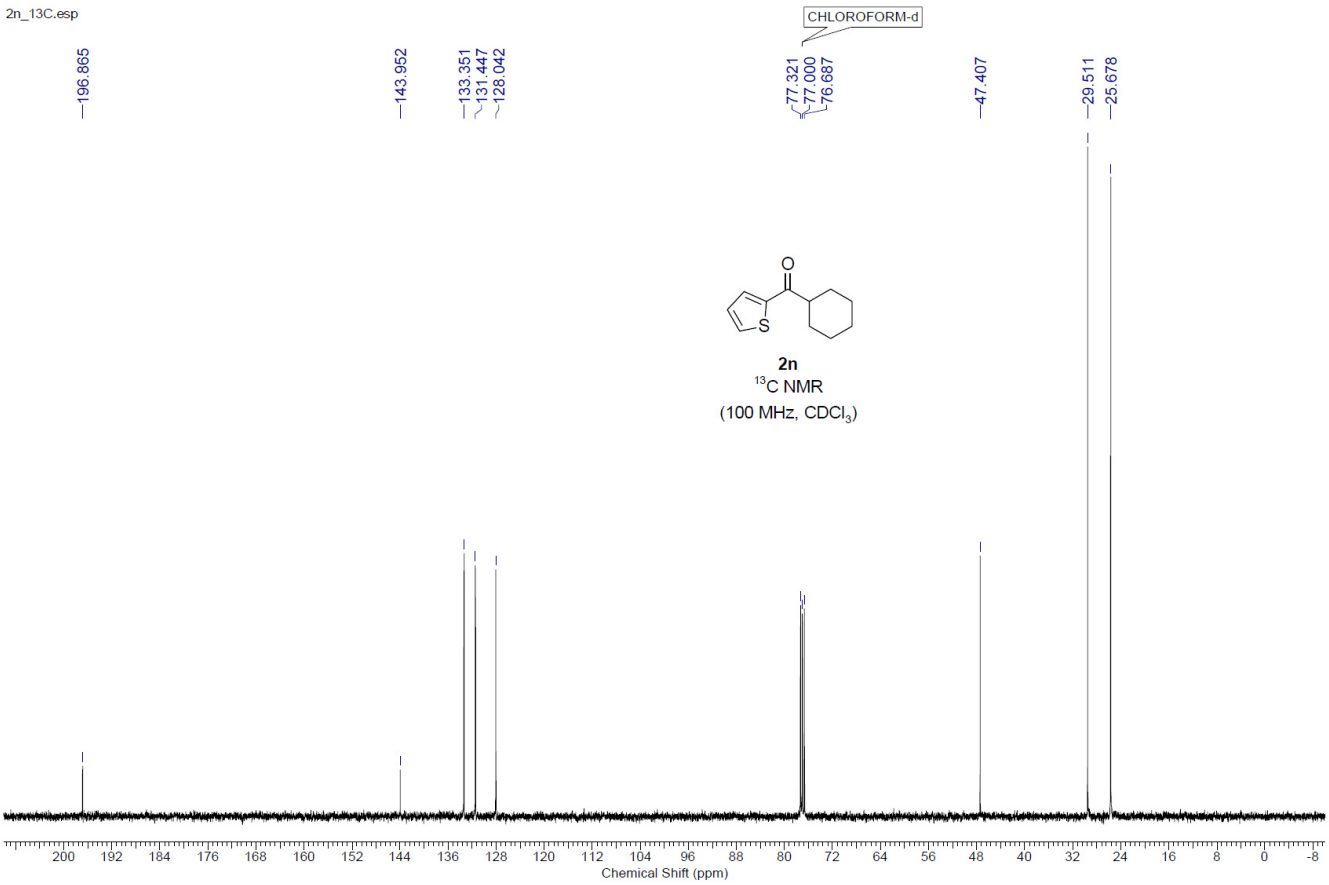

2l_1H.esp
TMS
9.160
9.156
8.779
8.774
8.767
8.762
8.234
8.229
8.225
8.215
8.210
8.205
7.441
7.428
7.421
7.409
7.269
3.262
3.253
3.241
3.233
3.225
3.205
3.197
1.927
1.892
1.890
1.859
1.850
1.843
1.529
1.523
1.496
1.424
1.394
1.293
1.230
0.000
O
N
2l
1H NMR
(400 MHz, CDCl3)
0.93
0.93
0.95
0.96
1.00
4.07
1.07
4.15
1.11
Chemical Shift (ppm)

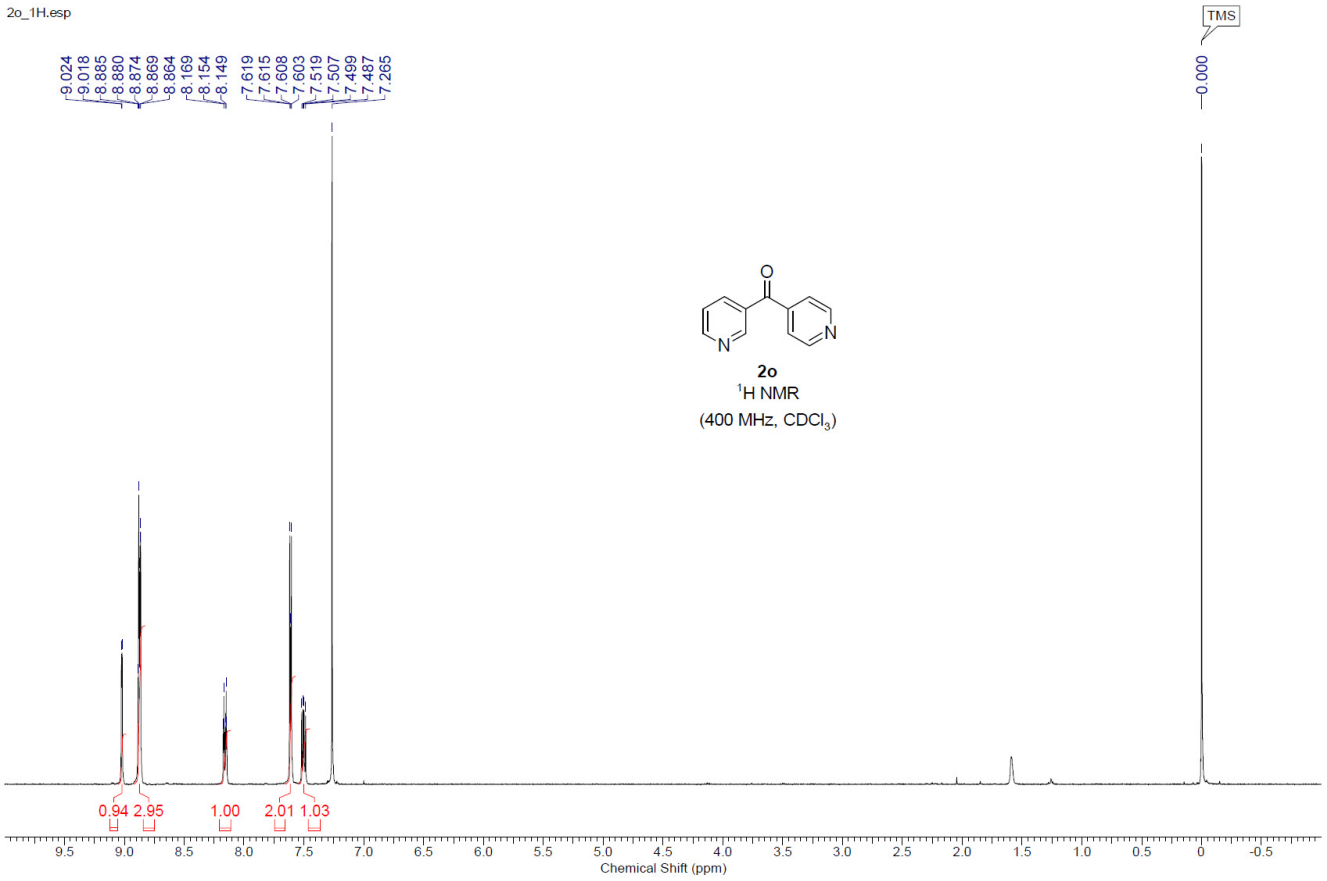

2l_13C.esp
CHLOROFORM-d
202.569
153.134
149.681
135.626
131.389
123.599
77.313
77.000
76.679
45.865
28.942
25.636
25.488
O
N
2l
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


2m_1H.esp
TMS
9.184
9.180
8.806
8.802
8.793
8.790
8.262
8.258
8.251
8.242
8.237
8.232
7.453
7.443
7.441
7.435
7.432
7.423
7.275
2.656
0.000
O
N
2m
1H NMR
(400 MHz, CDCl3)
1.00
1.01
1.00
1.02
3.14
Chemical Shift (ppm)


2m_13C.esp
CHLOROFORM-d
196.815
153.563
149.953
135.436
132.238
123.599
77.321
77.000
76.687
26.576
O
N
2m
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


2n_1H.esp
2H + H2O
TMS
7.729
7.720
7.625
7.613
7.264
7.141
7.130
7.119
3.139
3.132
3.124
3.111
3.103
3.094
3.082
3.074
1.927
1.894
1.880
1.870
1.838
1.571
1.565
1.554
1.542
1.536
1.393
1.361
1.224
0.000
2n
1H NMR
(400 MHz, CDCl3)
2.00
0.97
1.00
4.17
1.09
2.83
3.28
Chemical Shift (ppm)

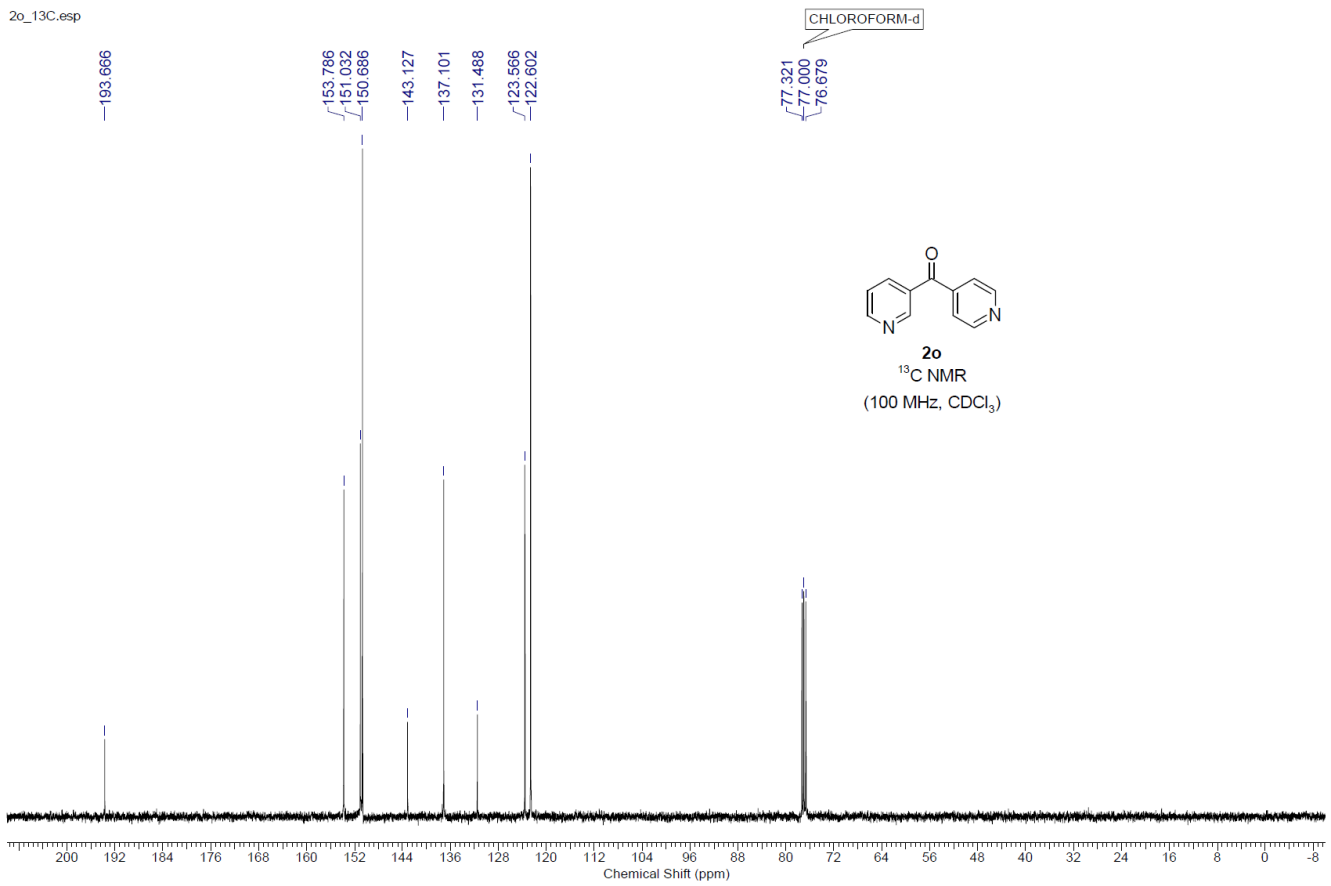

2n_13C.esp
CHLOROFORM-d
196.865
143.952
133.351
131.447
128.042
77.321
77.000
76.687
47.407
29.511
25.678
2n
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)



2o

^{1}H NMR

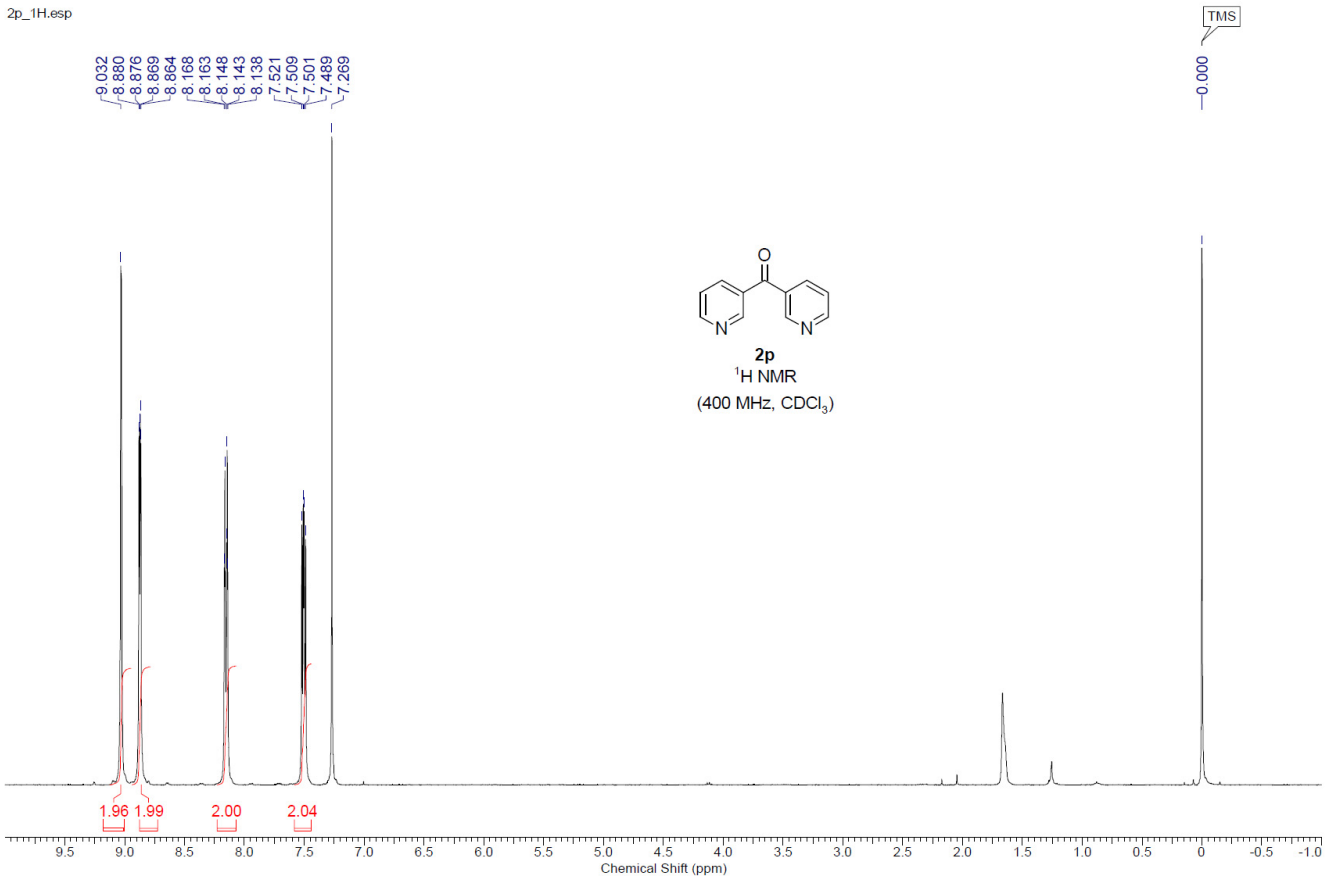
(400 MHz, $CDCl_3$)

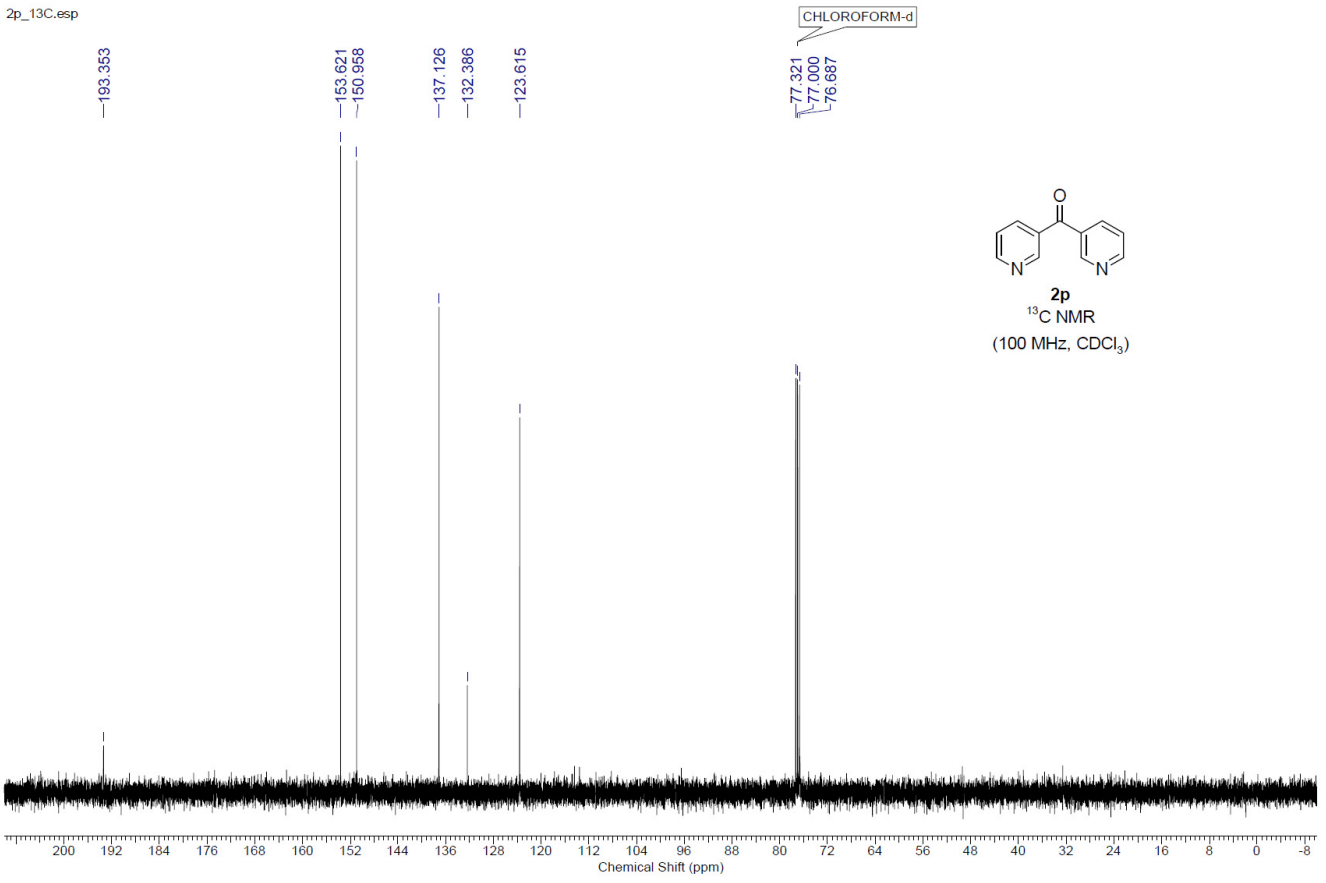


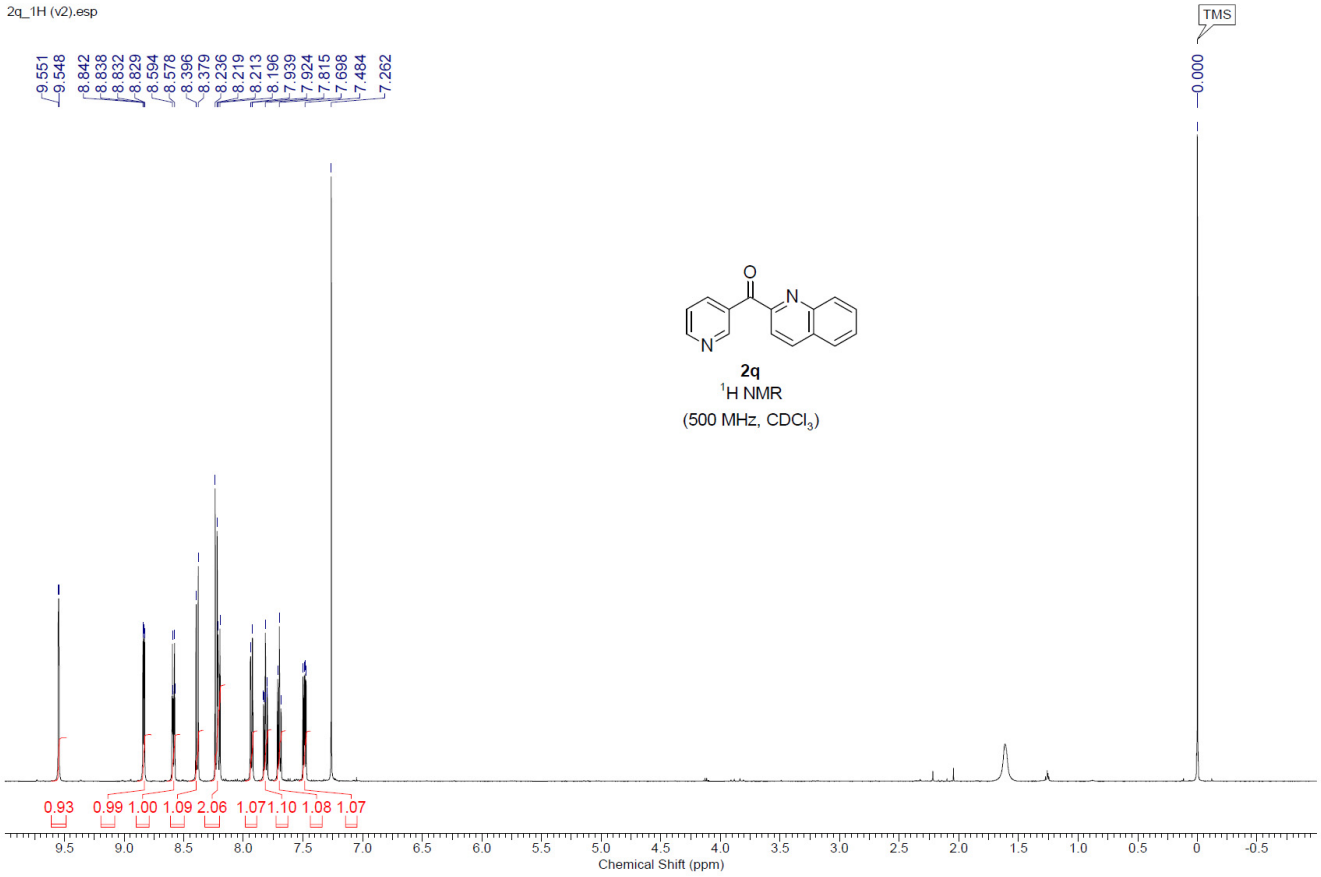
2o

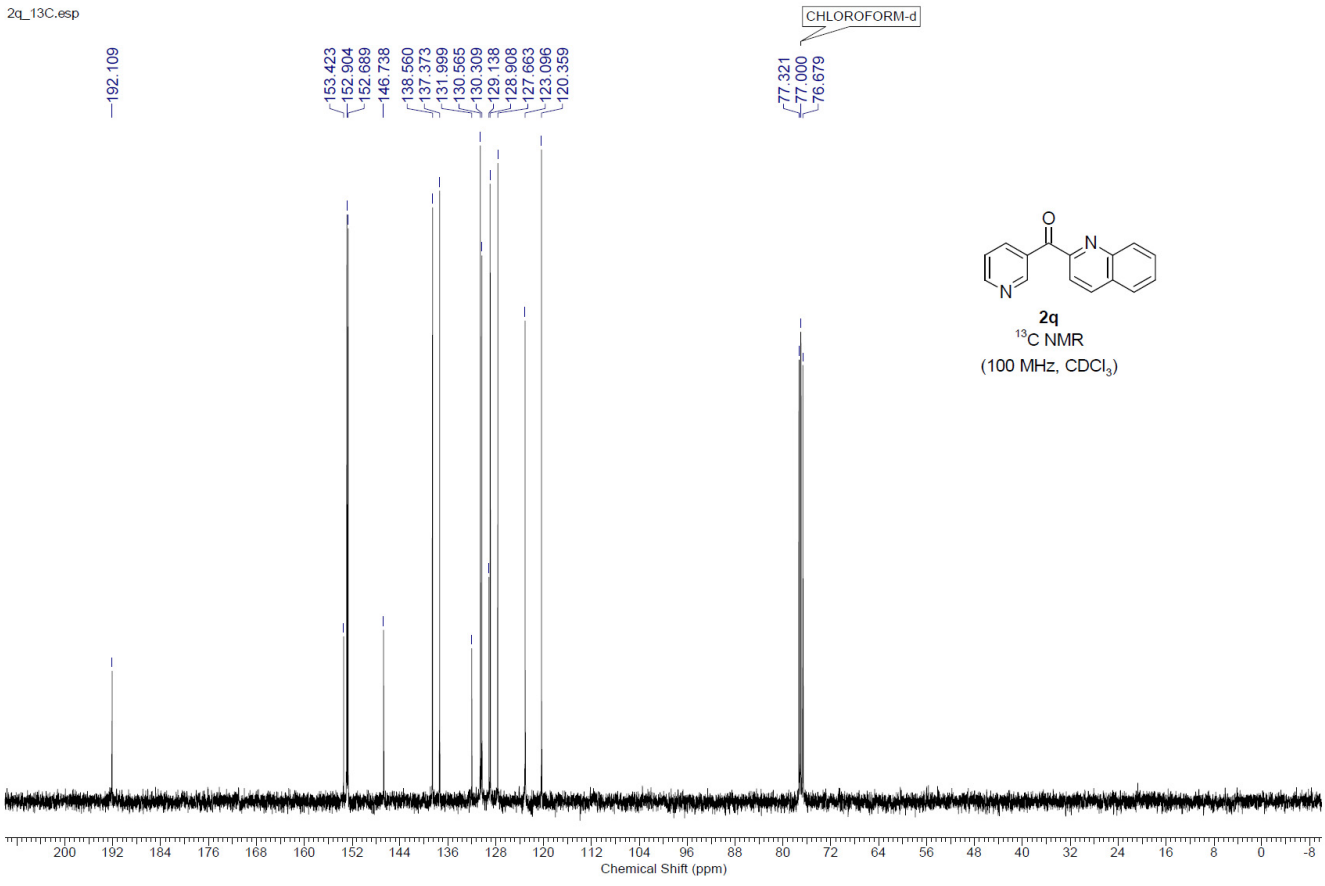
^{13}C NMR

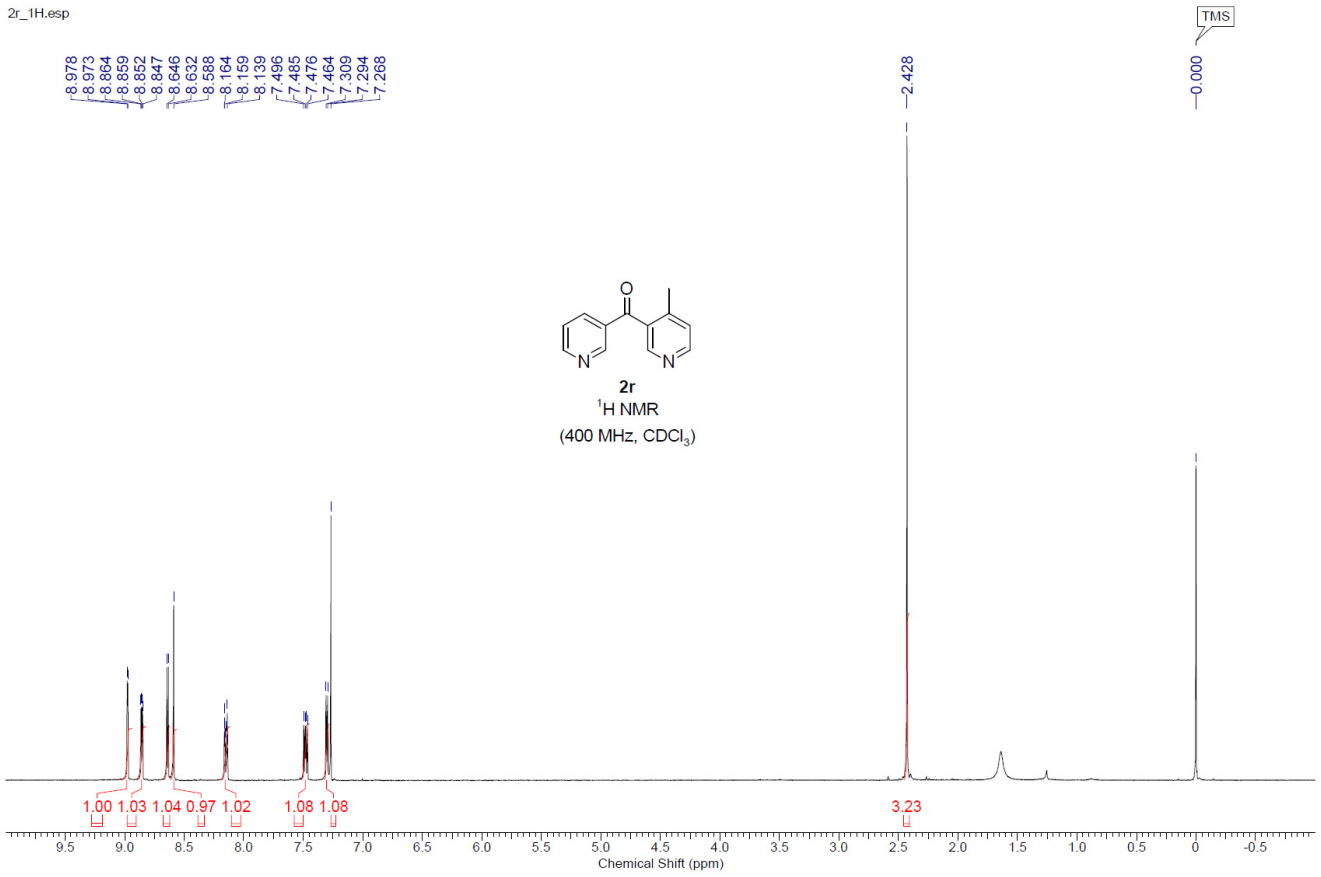
(100 MHz, $CDCl_3$)

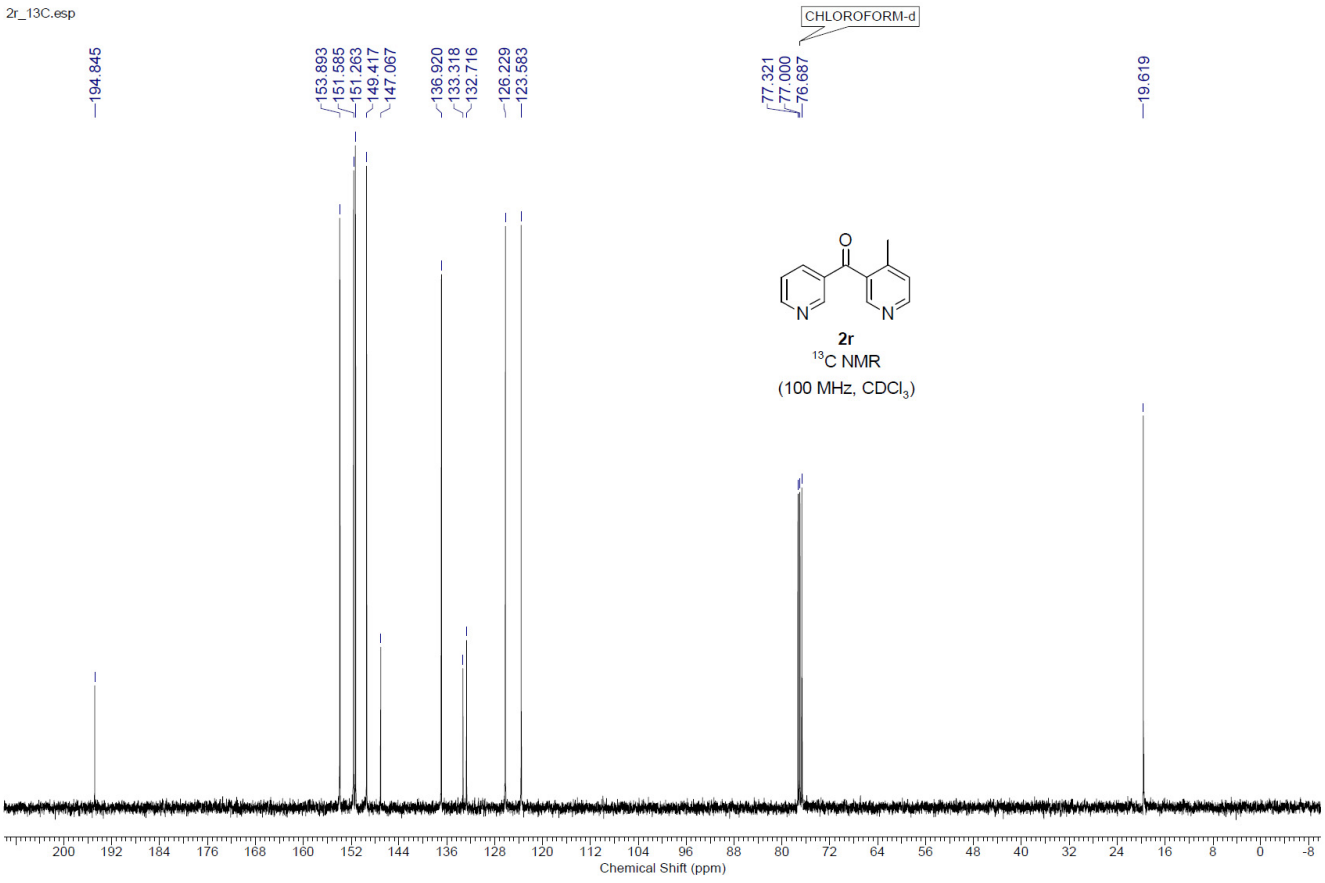

2p_1H.esp
TMS
9.032
8.880
8.876
8.869
8.864
8.168
8.163
8.148
8.143
8.138
7.521
7.509
7.501
7.489
7.269
0.000
1.96
1.99
2.00
2.04
Chemical Shift (ppm)
2p
1H NMR
(400 MHz, CDCl3)

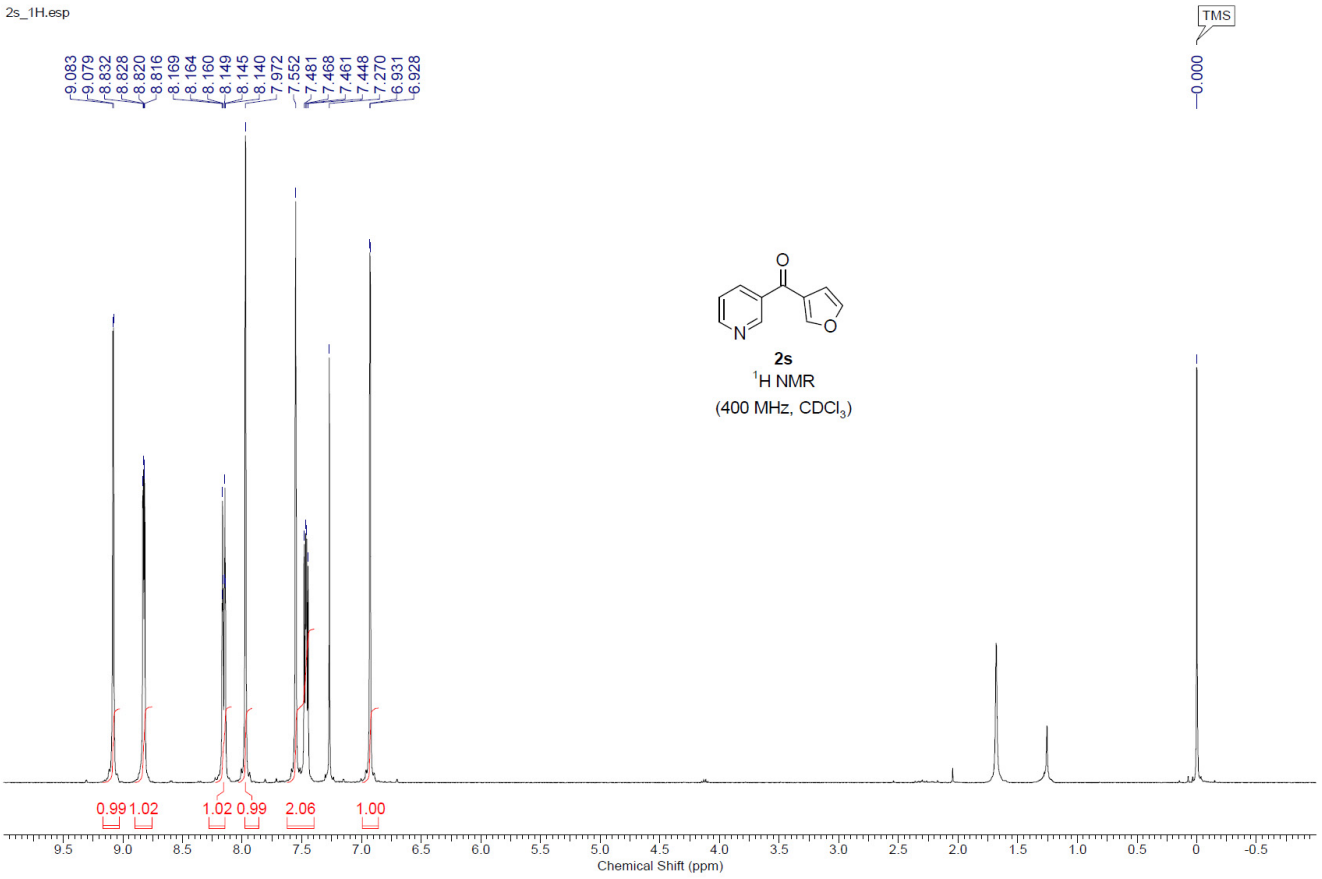

2p_13C.esp
CHLOROFORM-d
193.353
153.621
150.958
137.126
132.386
123.615
77.321
77.000
76.687
Chemical Shift (ppm)
2p
13C NMR
(100 MHz, CDCl3)


2q_1H (v2).esp
TMS
9.551
9.548
8.842
8.838
8.832
8.829
8.594
8.578
8.396
8.379
8.236
8.219
8.213
8.196
7.939
7.924
7.815
7.698
7.484
7.262
0.000
2q
1H NMR
(500 MHz, CDCl3)
0.93
0.99
1.00
1.09
2.06
1.07
1.10
1.08
1.07
Chemical Shift (ppm)

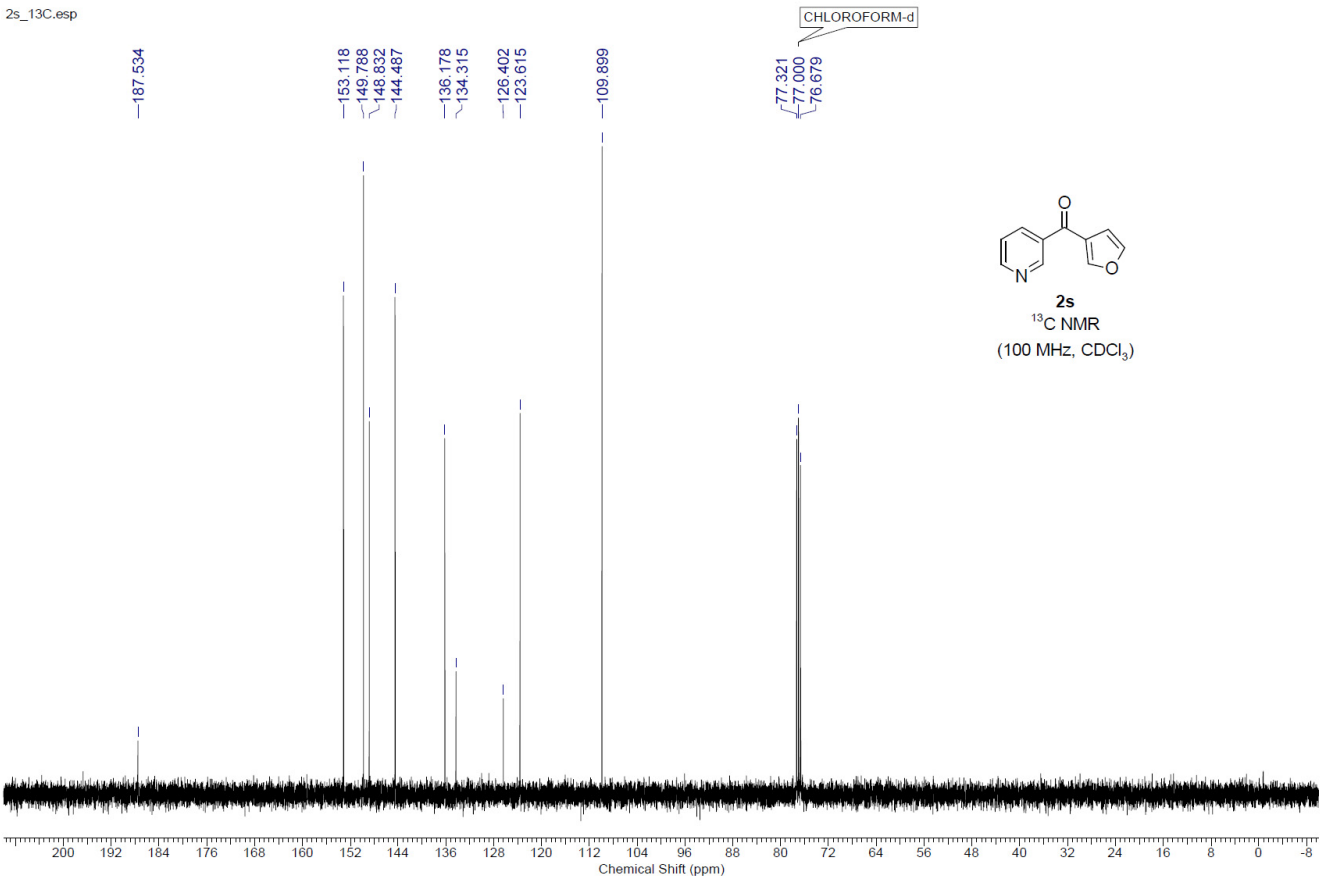

2q_13C.esp
CHLOROFORM-d
192.109
153.423
152.904
152.689
146.738
138.560
137.373
131.999
130.565
130.309
129.138
128.908
127.663
123.096
120.359
77.321
77.000
76.679
2q
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


2r_1H.esp
TMS
8.978
8.973
8.864
8.859
8.852
8.847
8.646
8.632
8.588
8.164
8.159
8.139
7.496
7.485
7.476
7.464
7.309
7.294
7.268
2.428
0.000
2r
1H NMR
(400 MHz, CDCl3)
1.00 1.03 1.04 0.97 1.02 1.08 1.08
3.23
Chemical Shift (ppm)

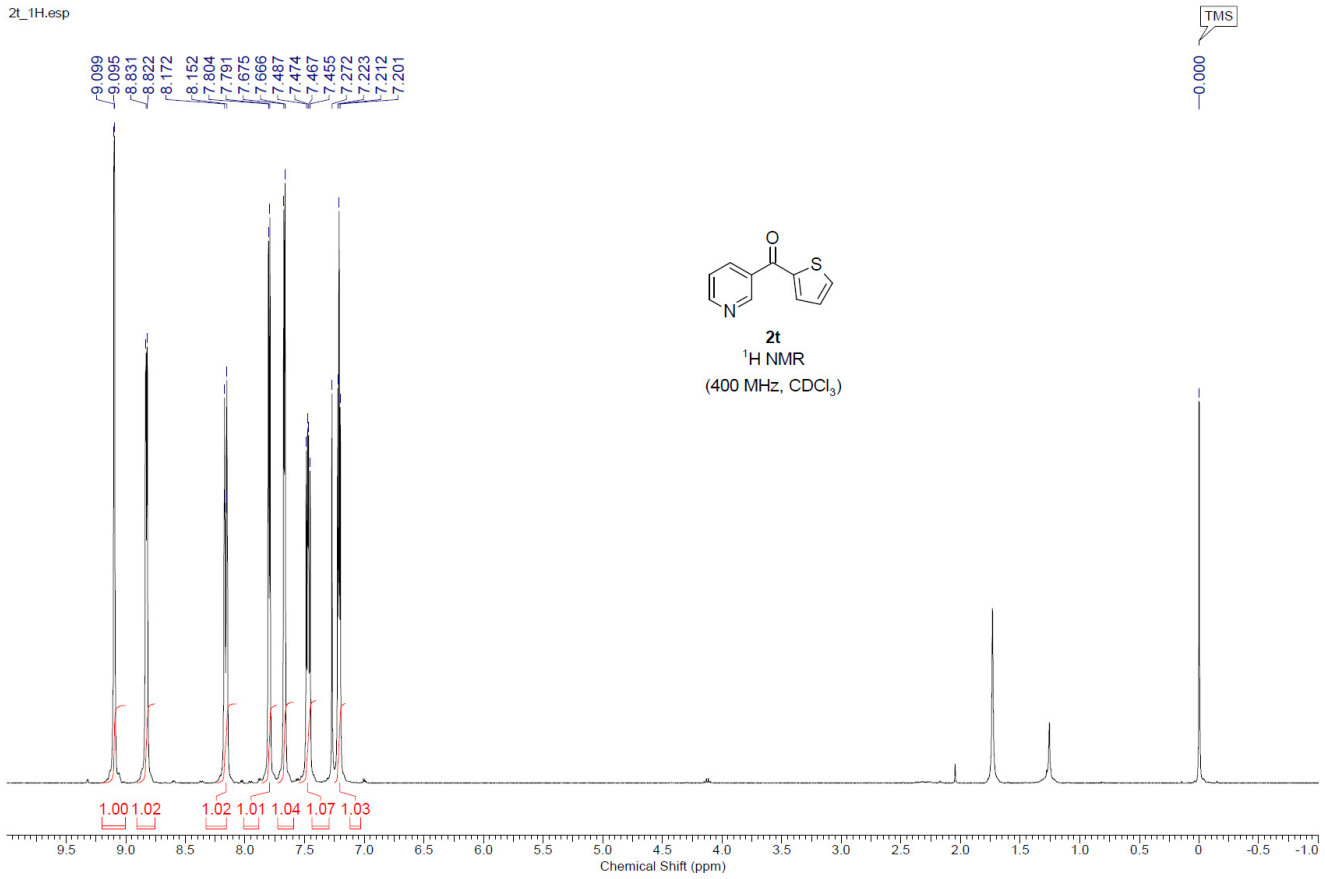

2r_13C.esp
CHLOROFORM-d
194.845
153.893
151.585
151.263
149.417
147.067
136.920
133.318
132.716
126.229
123.583
77.321
77.000
76.687
19.619
2r
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)



2s
^{1}H NMR
(400 MHz, $CDCl_3$)



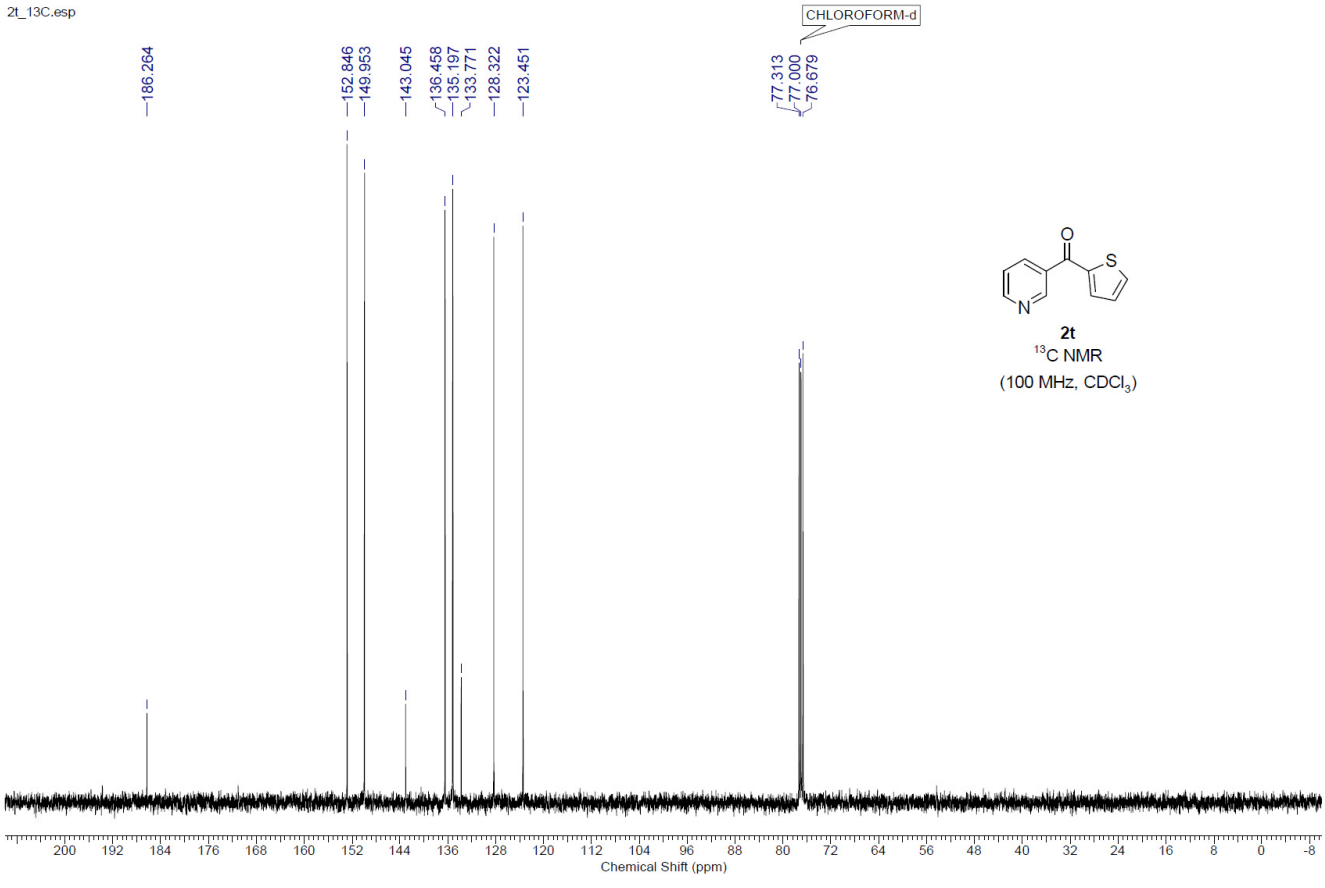
2s
^{13}C NMR
(100 MHz, $CDCl_3$)



2t

^{1}H NMR

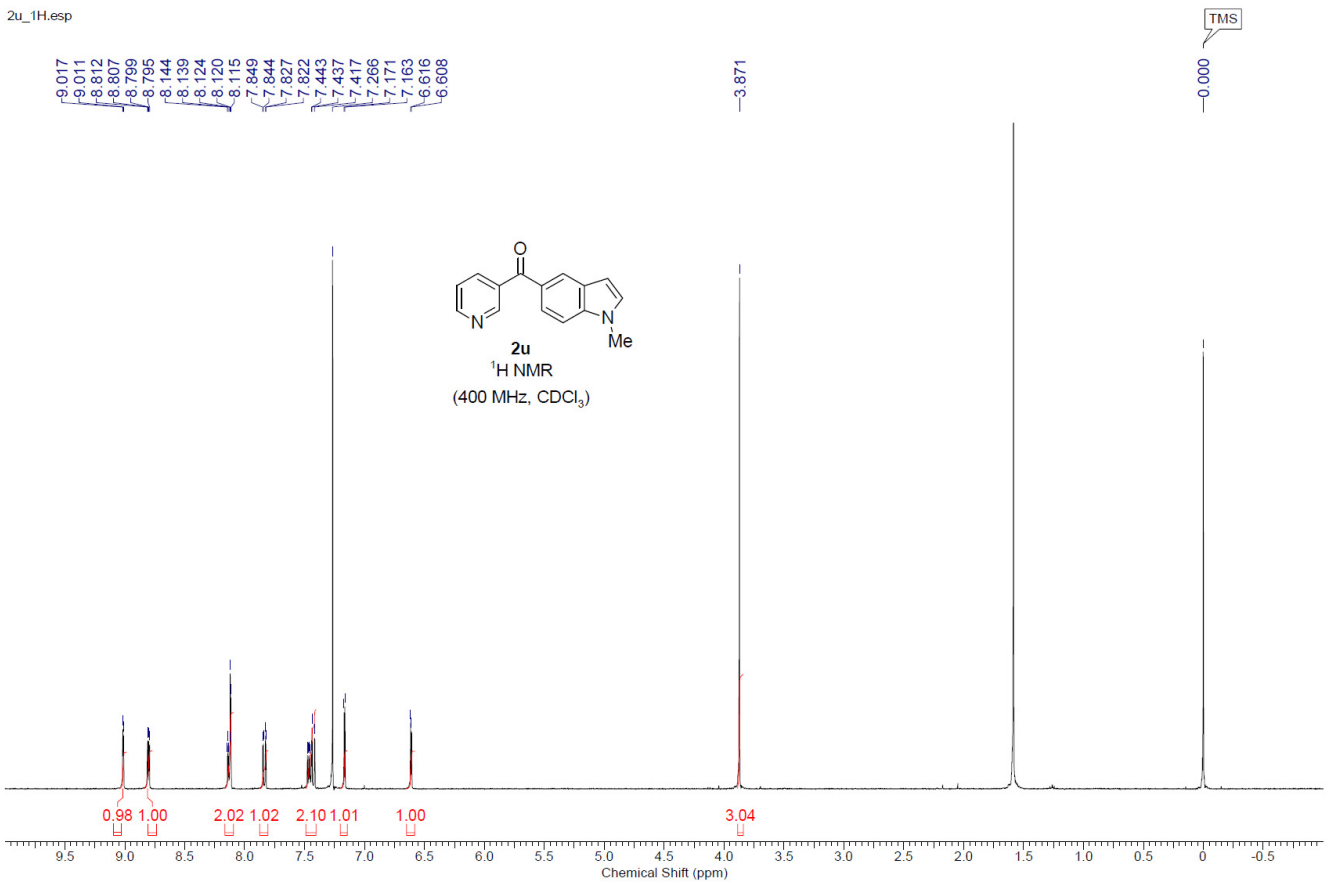
(400 MHz, $CDCl_3$)

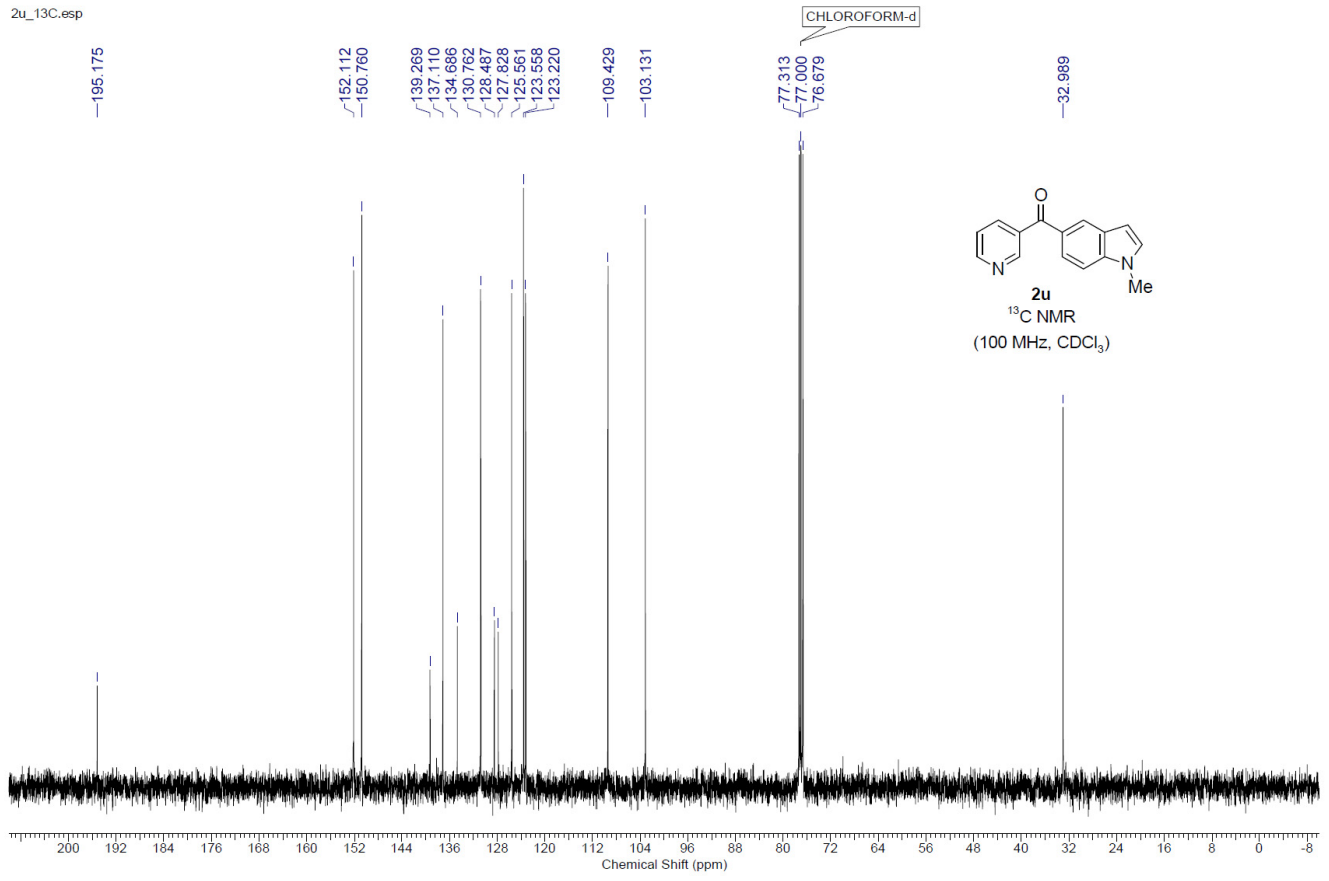


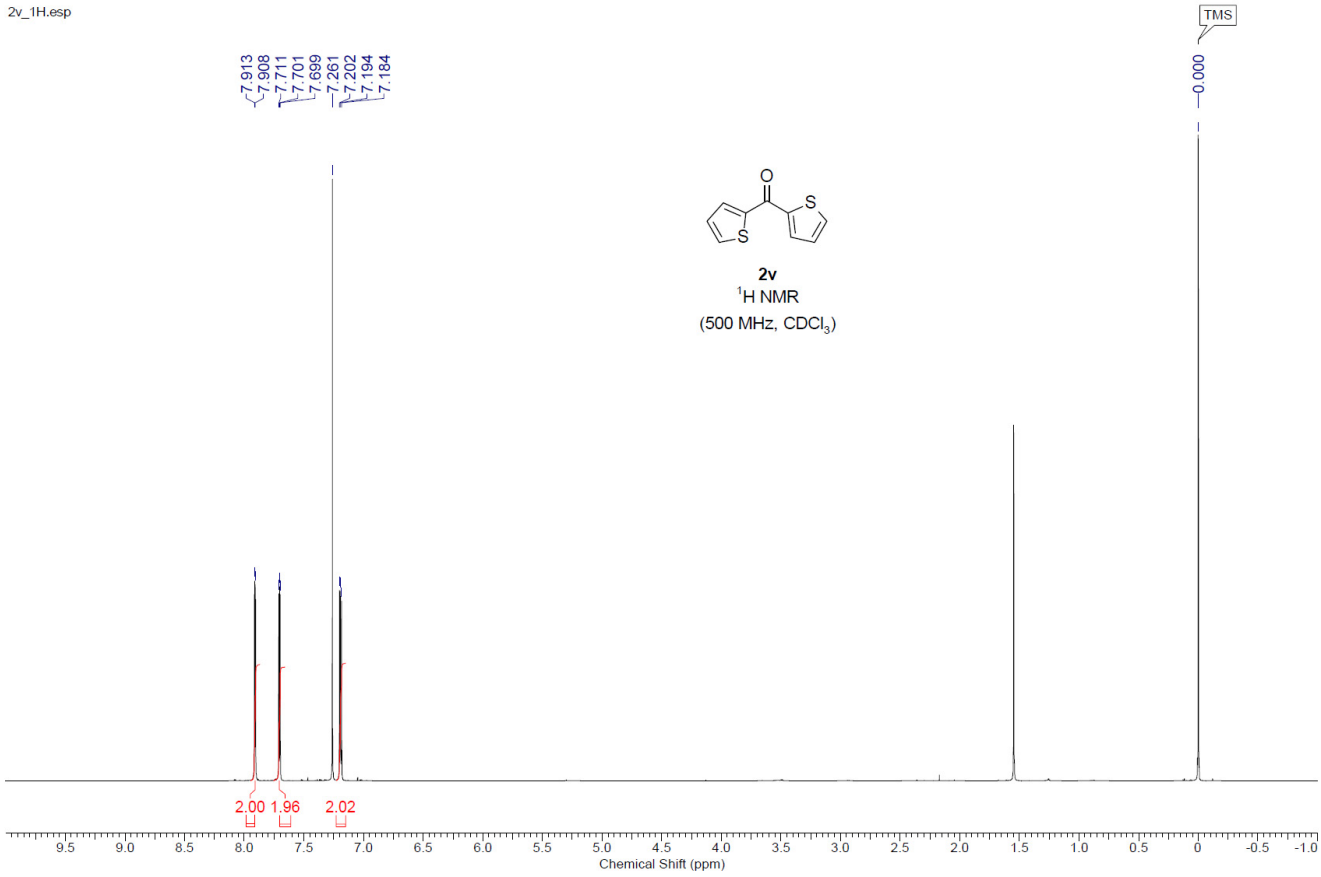
2t

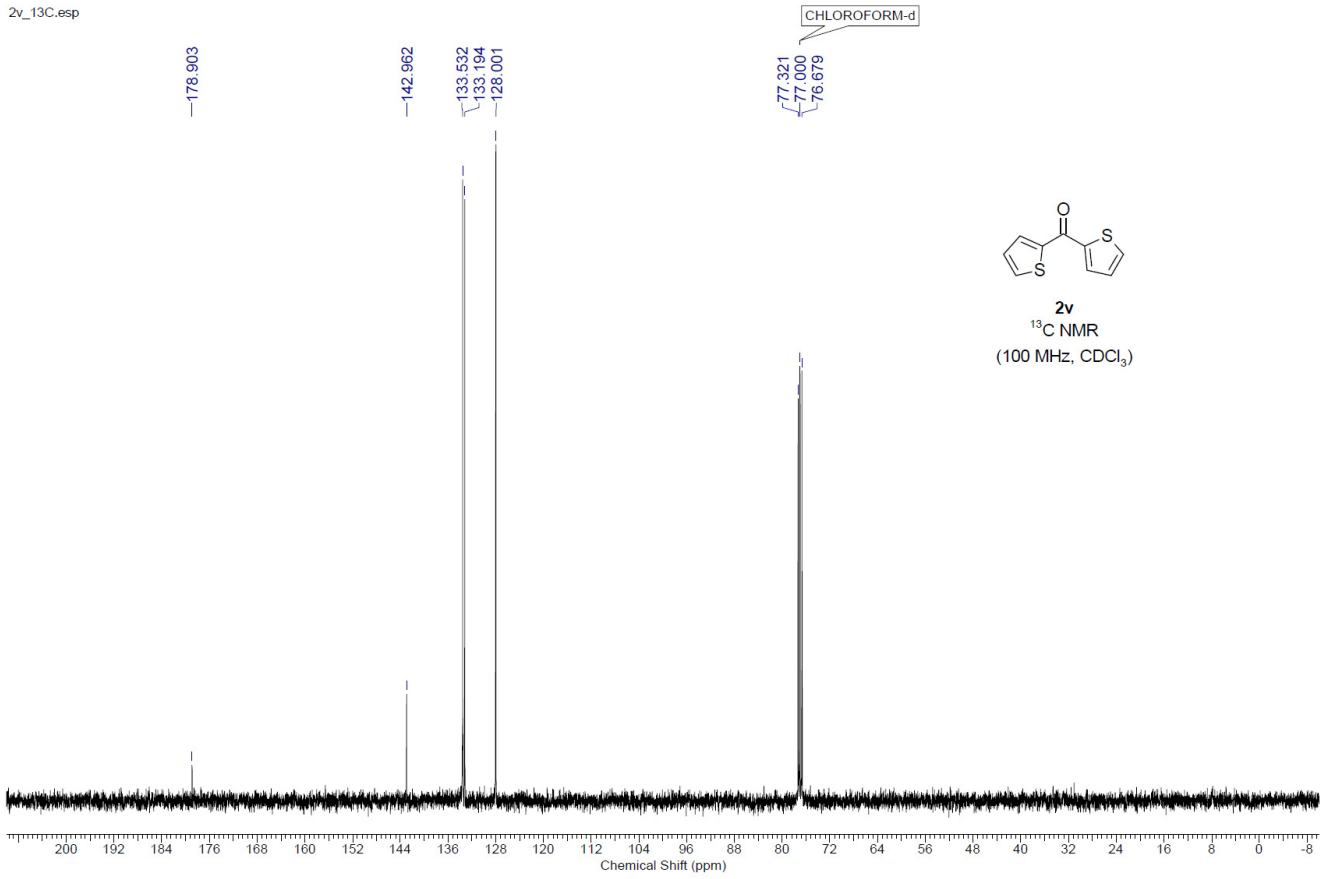
^{13}C NMR

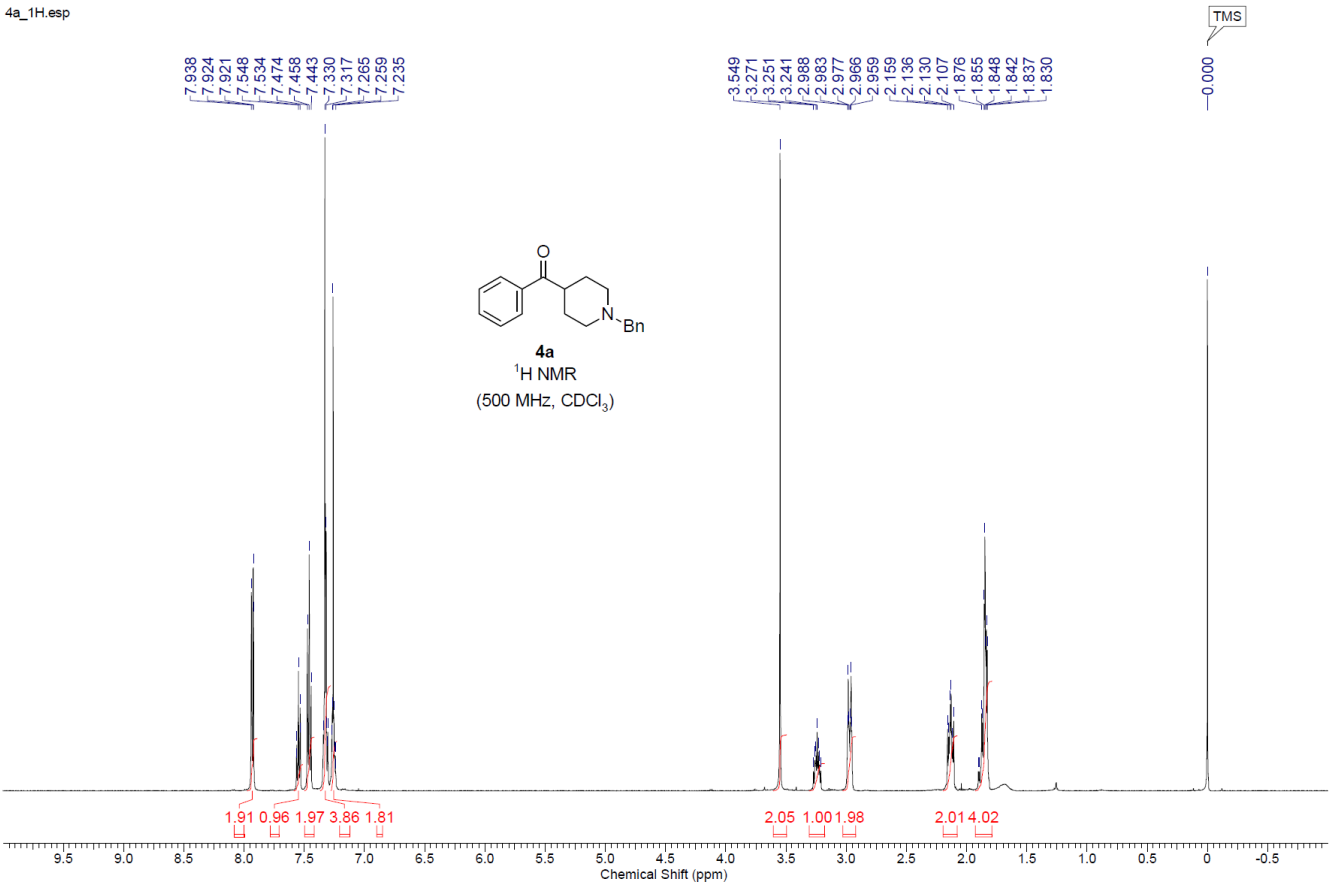
(100 MHz, $CDCl_3$)


2u_1H.esp
TMS
9.017
9.011
8.812
8.807
8.799
8.795
8.144
8.139
8.124
8.120
8.115
7.849
7.844
7.827
7.822
7.443
7.437
7.417
7.266
7.171
7.163
6.616
6.608
3.871
0.000
O
N
N
Me
2u
1H NMR
(400 MHz, CDCl3)
0.98 1.00 2.02 1.02 2.10 1.01 1.00 3.04
Chemical Shift (ppm)

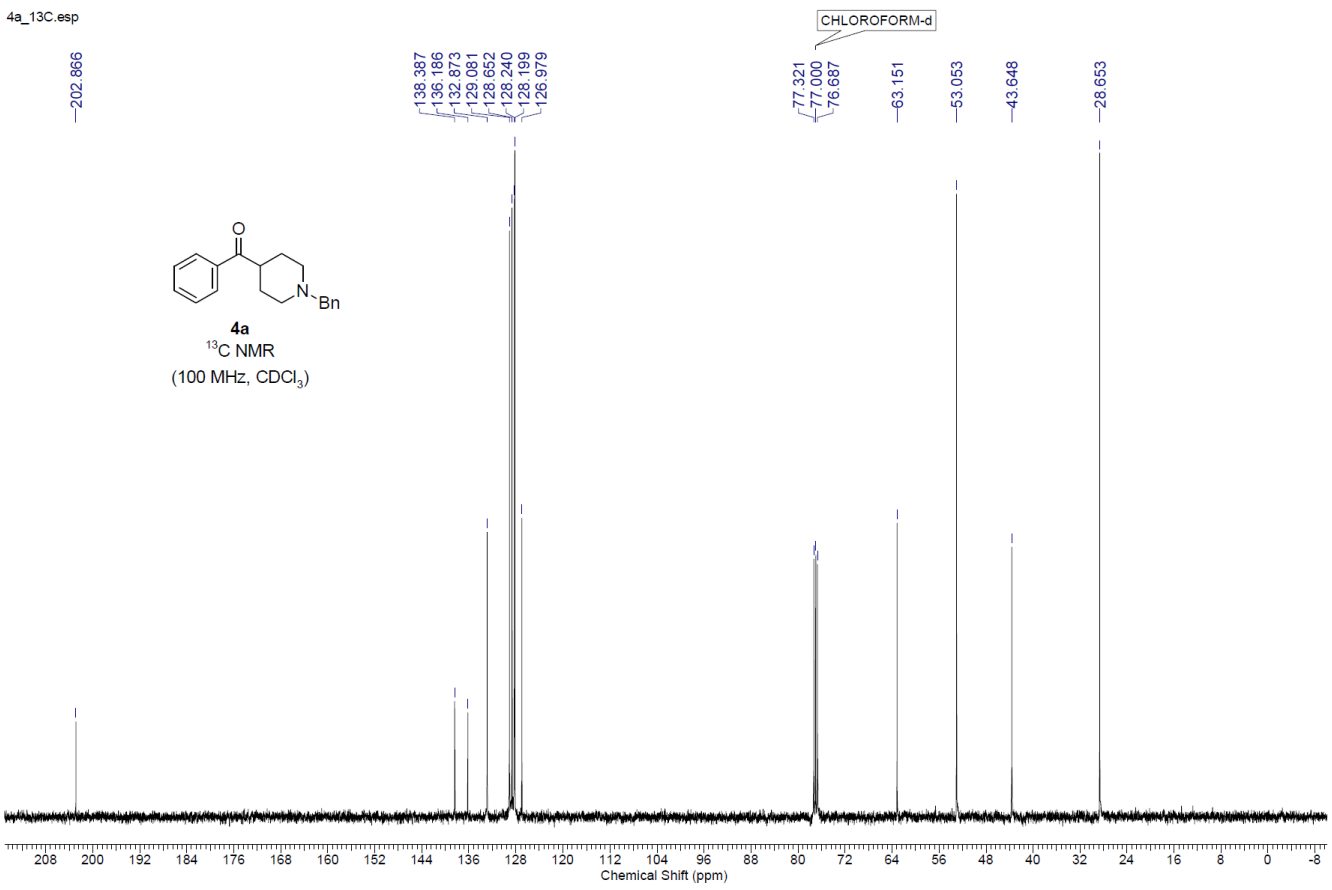

2u_13C.esp
CHLOROFORM-d
195.175
152.112
150.760
139.269
137.110
134.686
130.762
128.487
127.828
125.561
123.558
123.220
109.429
103.131
77.313
77.000
76.679
32.989
O
N
N
Me
2u
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


2v_1H.esp
7.913
7.908
7.711
7.701
7.699
7.261
7.202
7.194
7.184
TMS
0.000
O
S
S
2v
1H NMR
(500 MHz, CDCl3)
2.00 1.96 2.02
Chemical Shift (ppm)

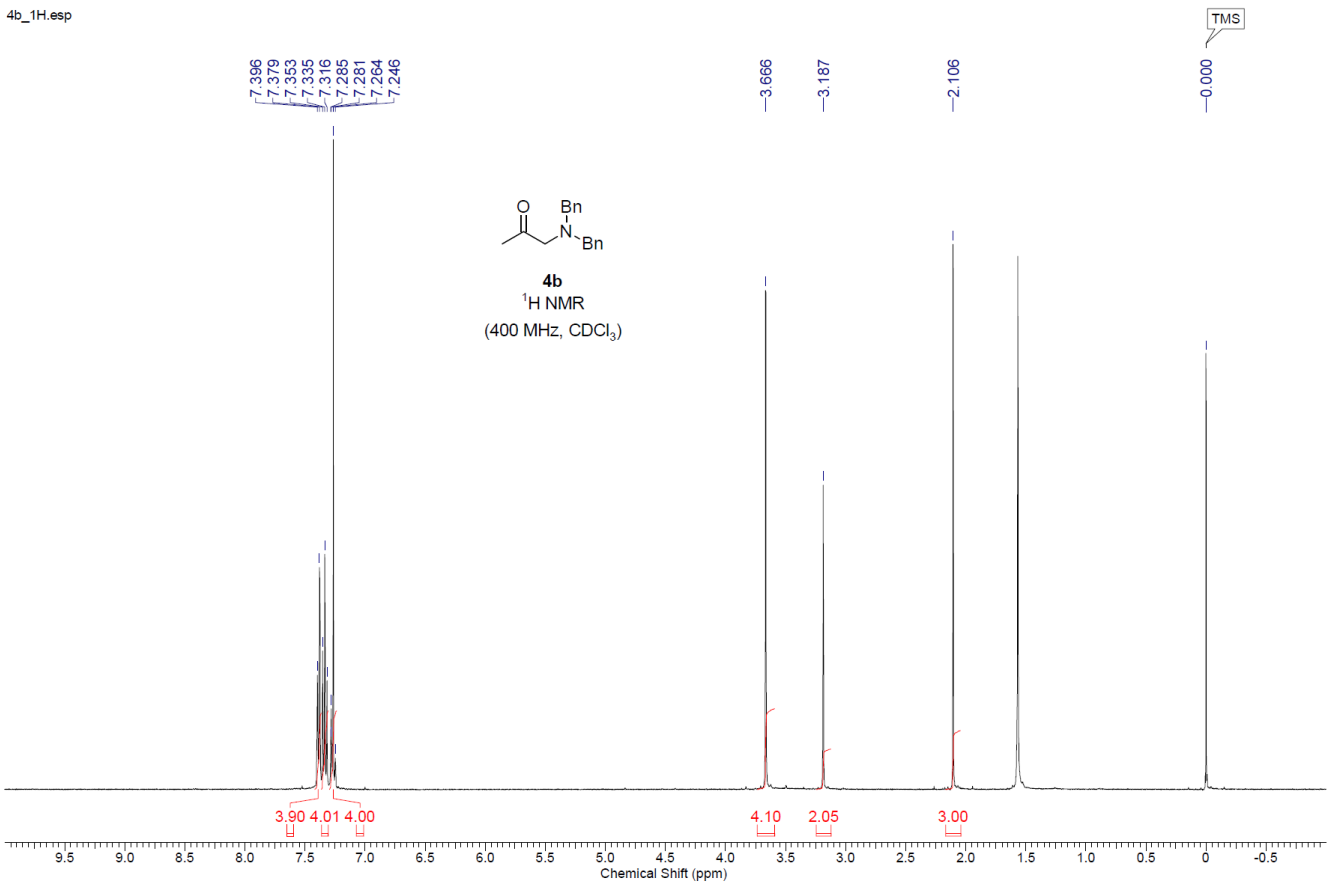

2v_13C.esp
178.903
142.962
133.532
133.194
128.001
CHLOROFORM-d
77.321
77.000
76.679
O
S
S
2v
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

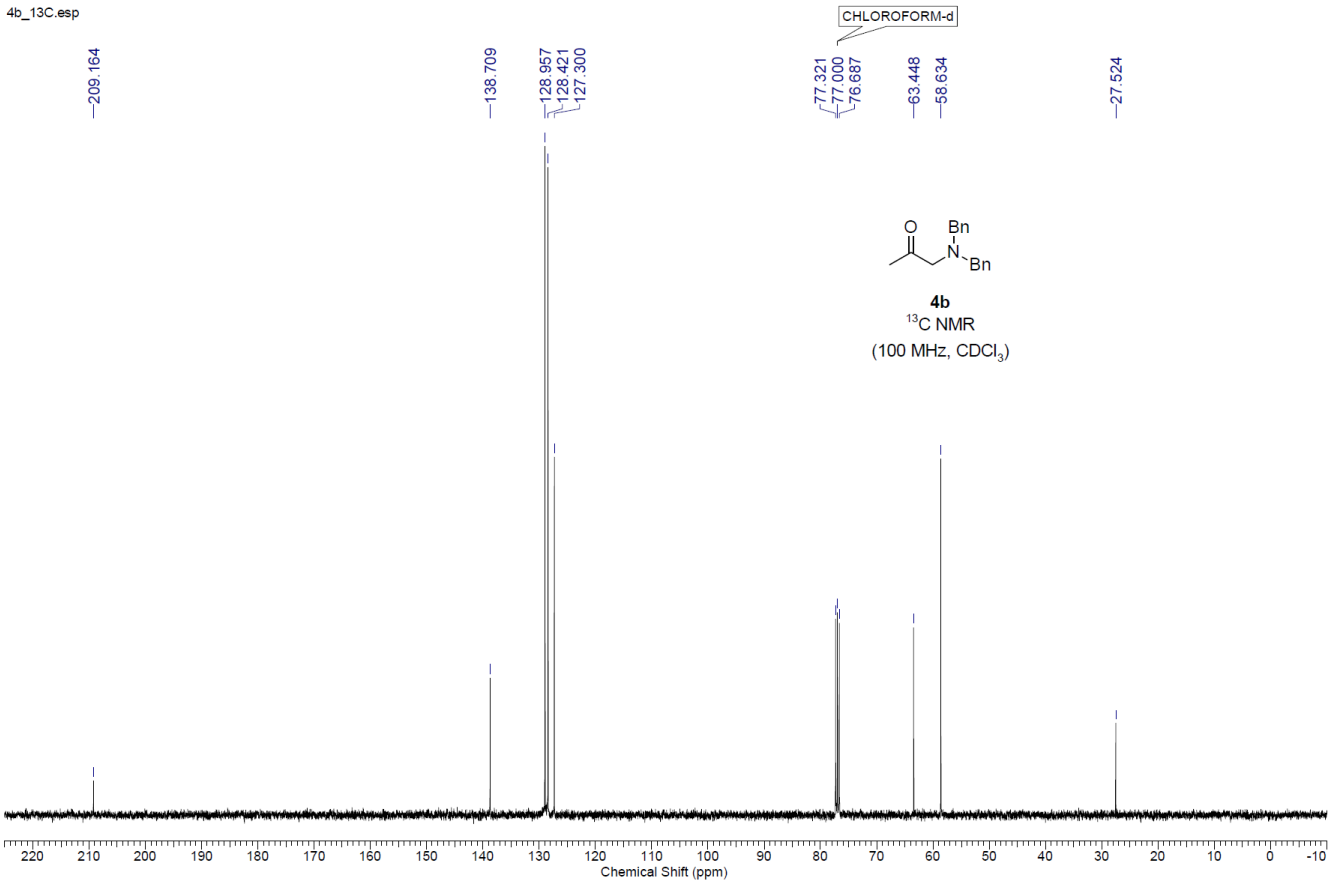


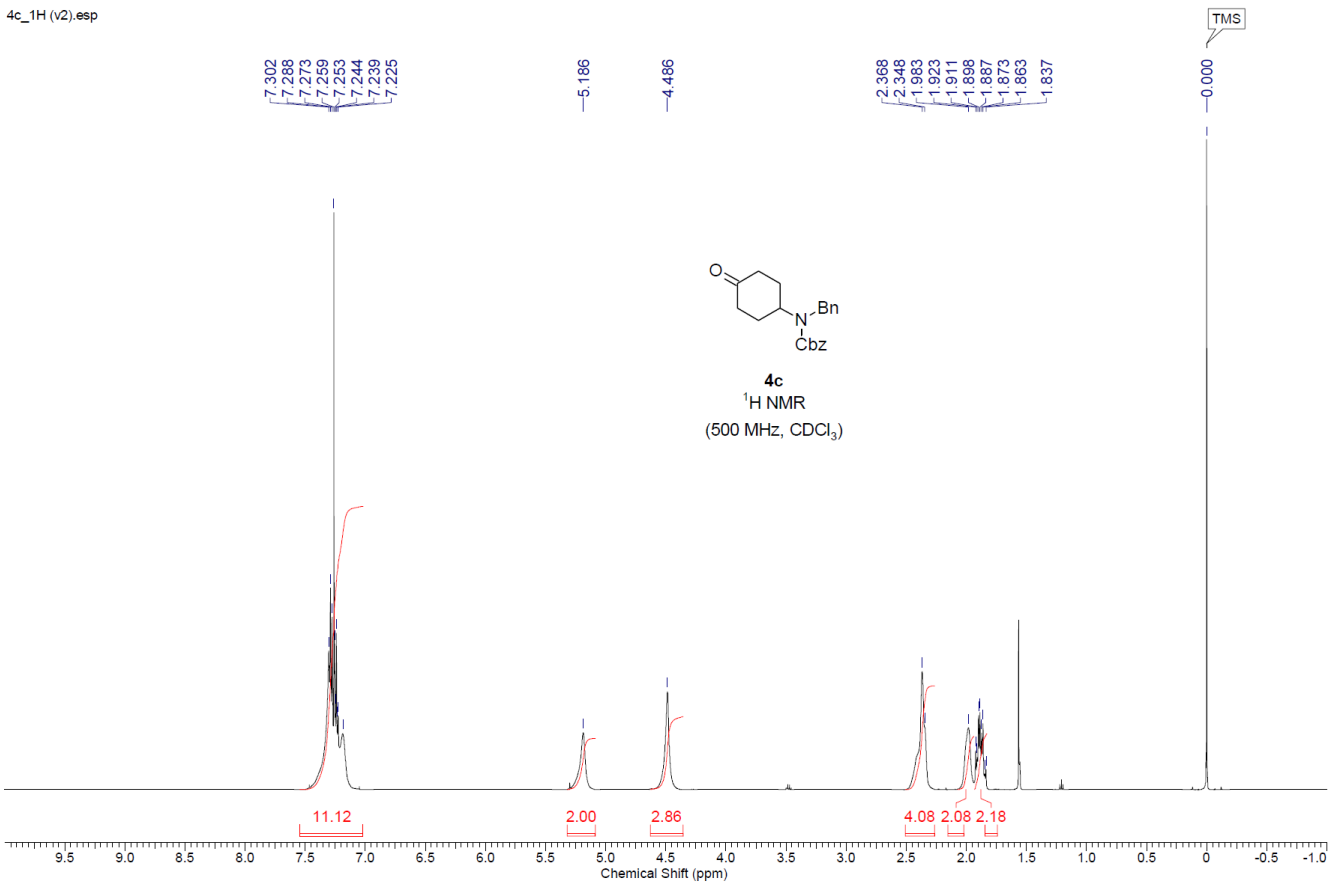
4a
^{1}H NMR
(500 MHz, $CDCl_3$)

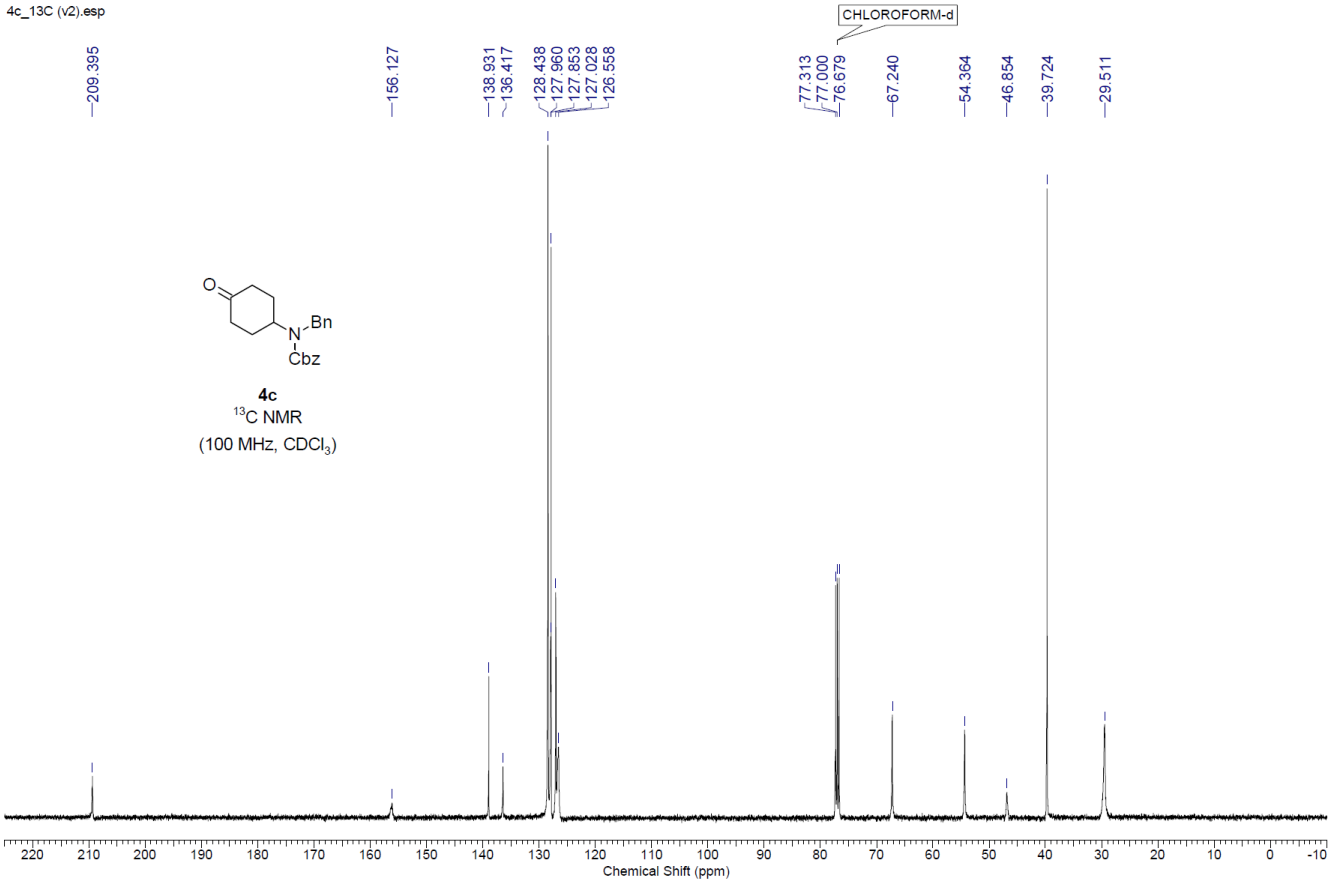


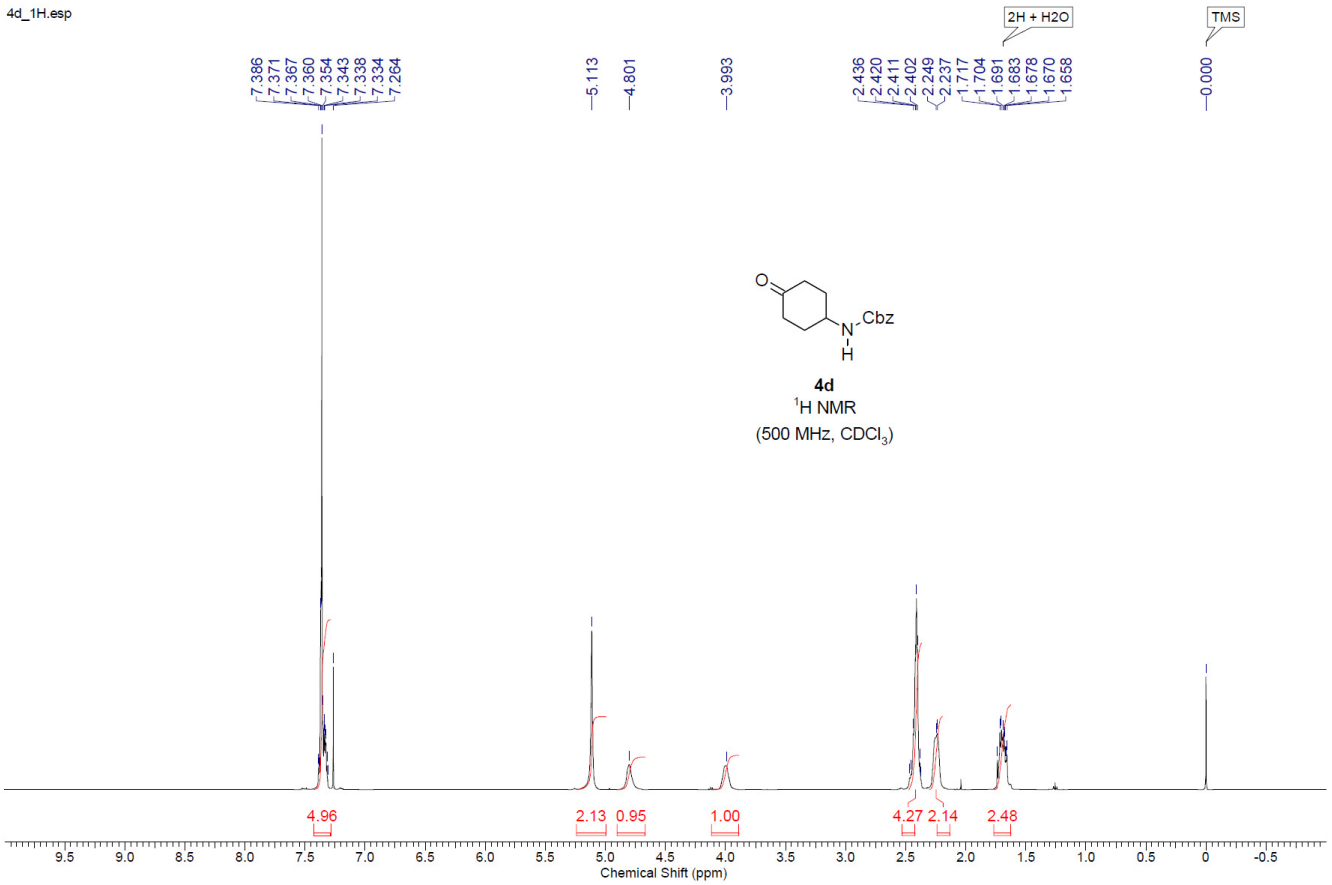
4a
^{13}C NMR
(100 MHz, $CDCl_3$)

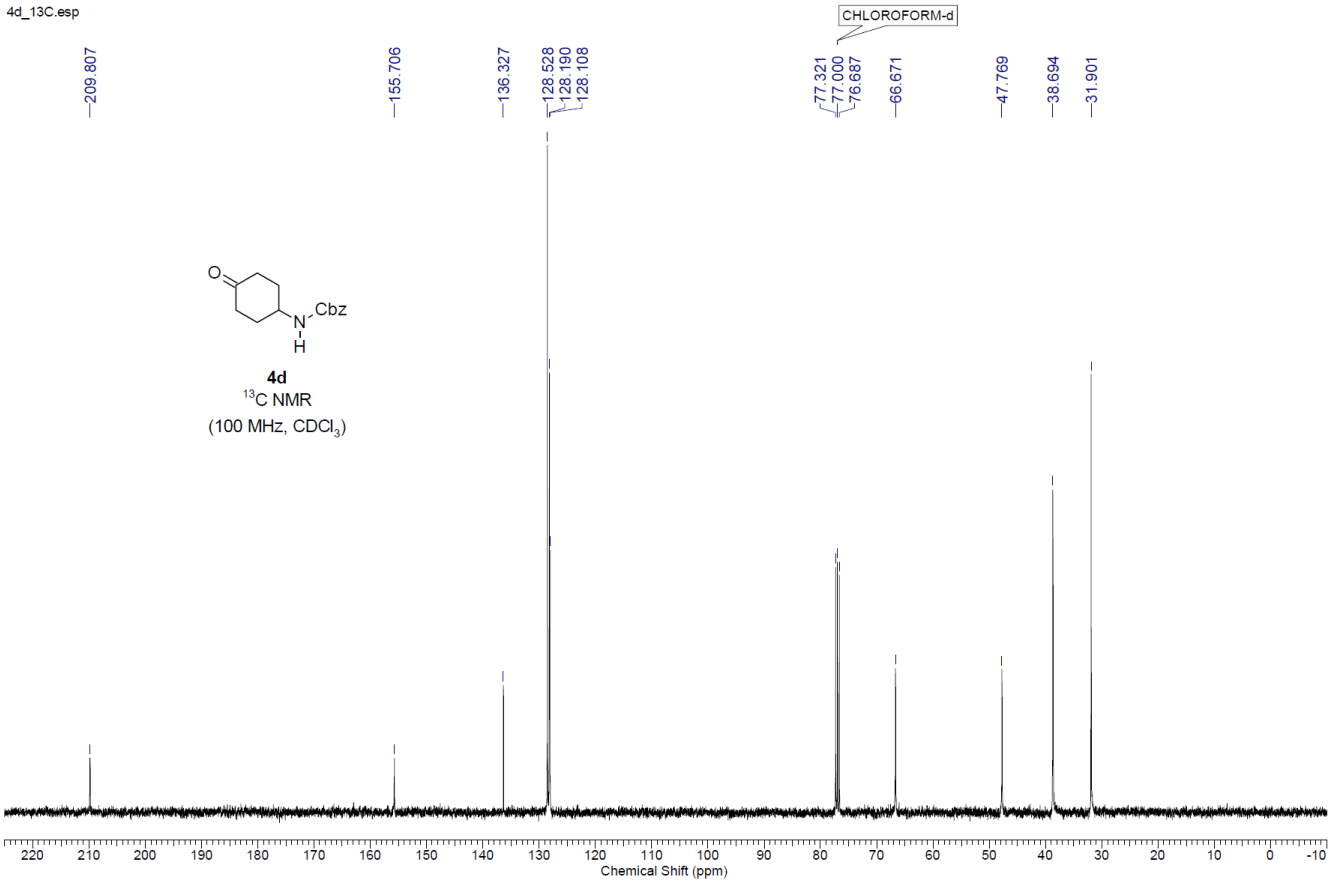

4b_1H.esp
TMS
7.396
7.379
7.353
7.335
7.316
7.285
7.281
7.264
7.246
3.666
3.187
2.106
0.000
O
Bn
N
Bn
4b
1H NMR
(400 MHz, CDCl3)
3.90 4.01 4.00
4.10
2.05
3.00
Chemical Shift (ppm)

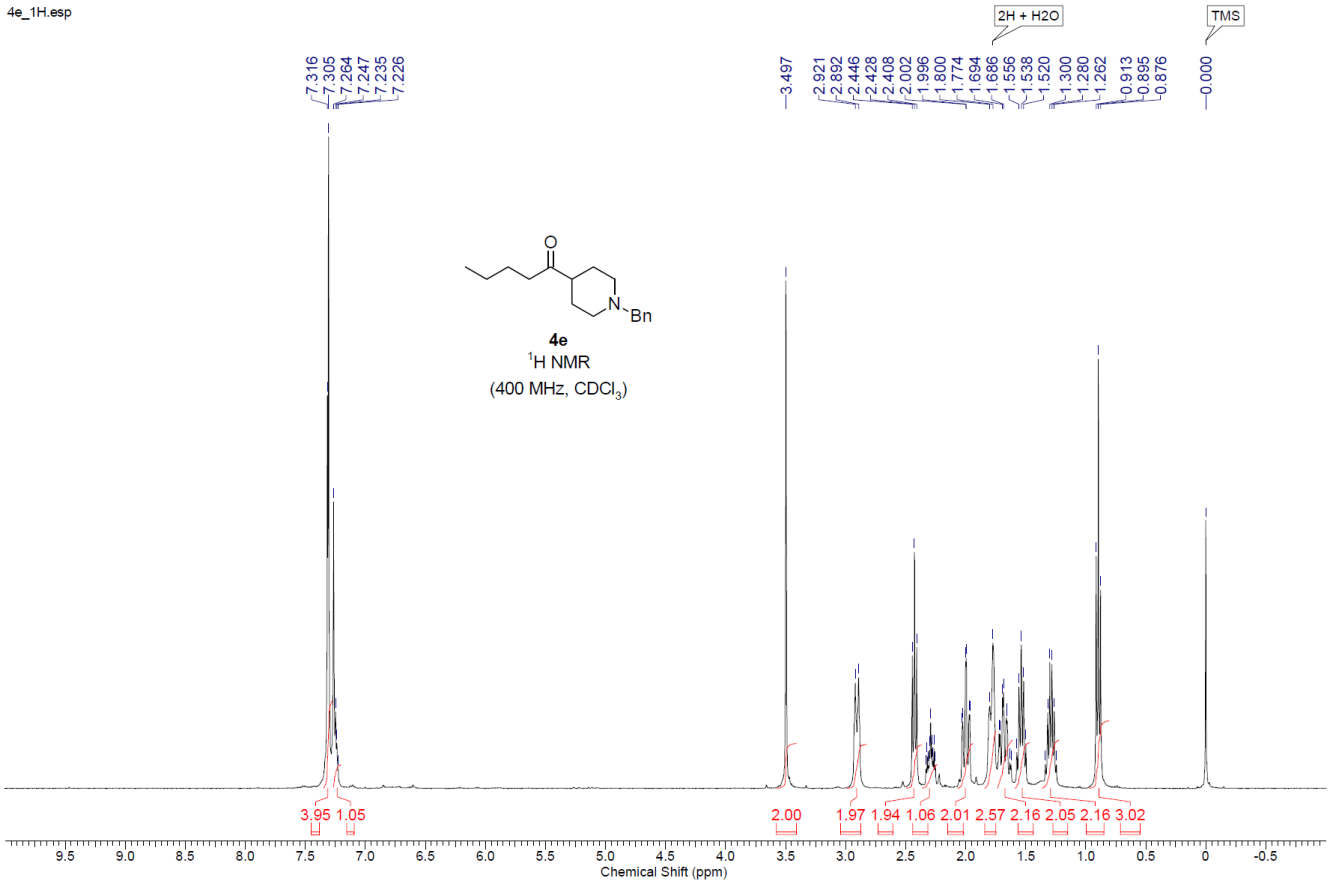

4b_13C.esp
CHLOROFORM-d
209.164
138.709
128.957
128.421
127.300
77.321
77.000
76.687
63.448
58.634
27.524
O
Bn
N
Bn
4b
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

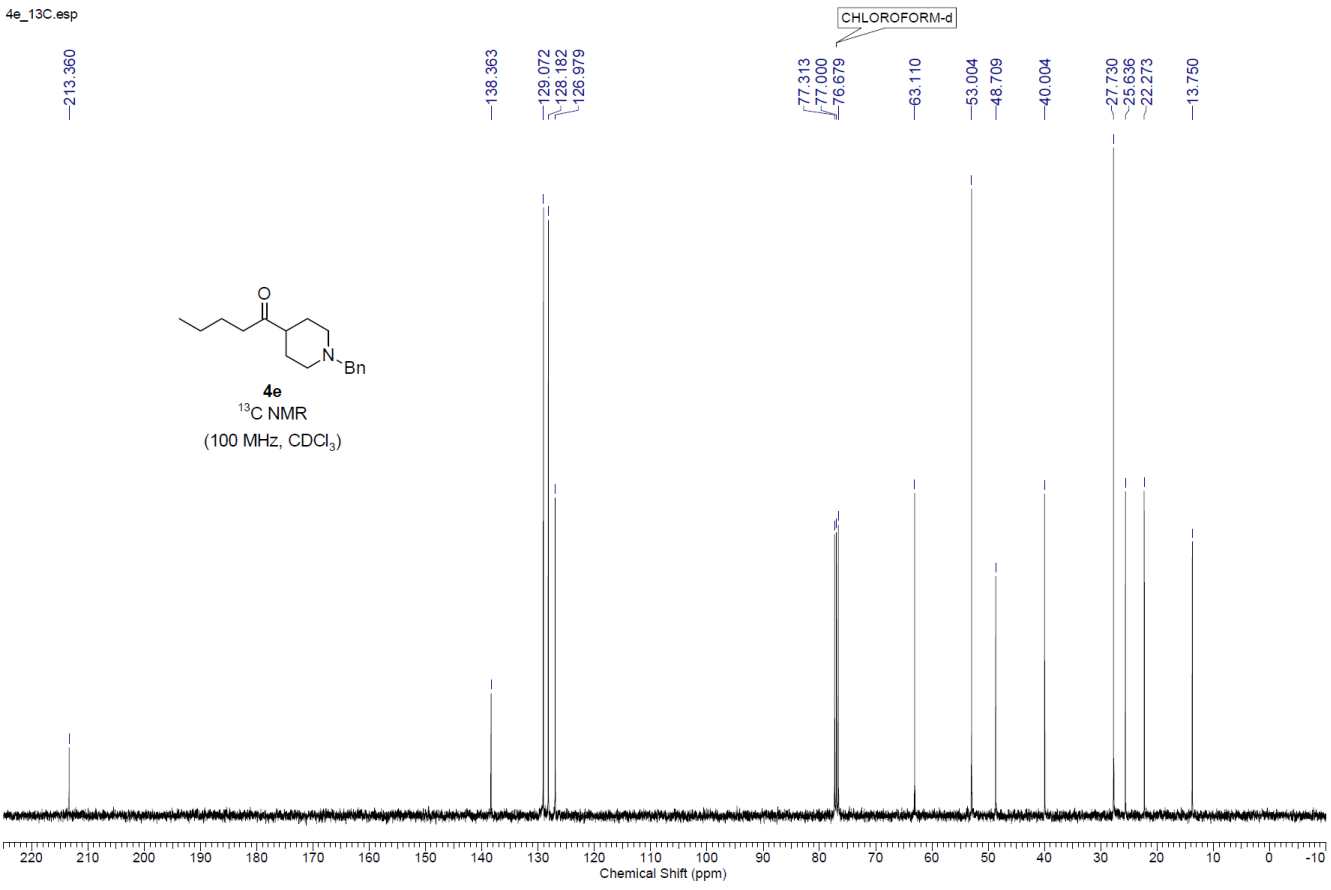

4c_1H (v2).esp
TMS
7.302
7.288
7.273
7.259
7.253
7.244
7.239
7.225
5.186
4.486
2.368
2.348
1.983
1.923
1.911
1.898
1.887
1.873
1.863
1.837
0.000
Bn
N
Cbz
4c
1H NMR
(500 MHz, CDCl3)
11.12
2.00
2.86
4.08
2.08
2.18
Chemical Shift (ppm)

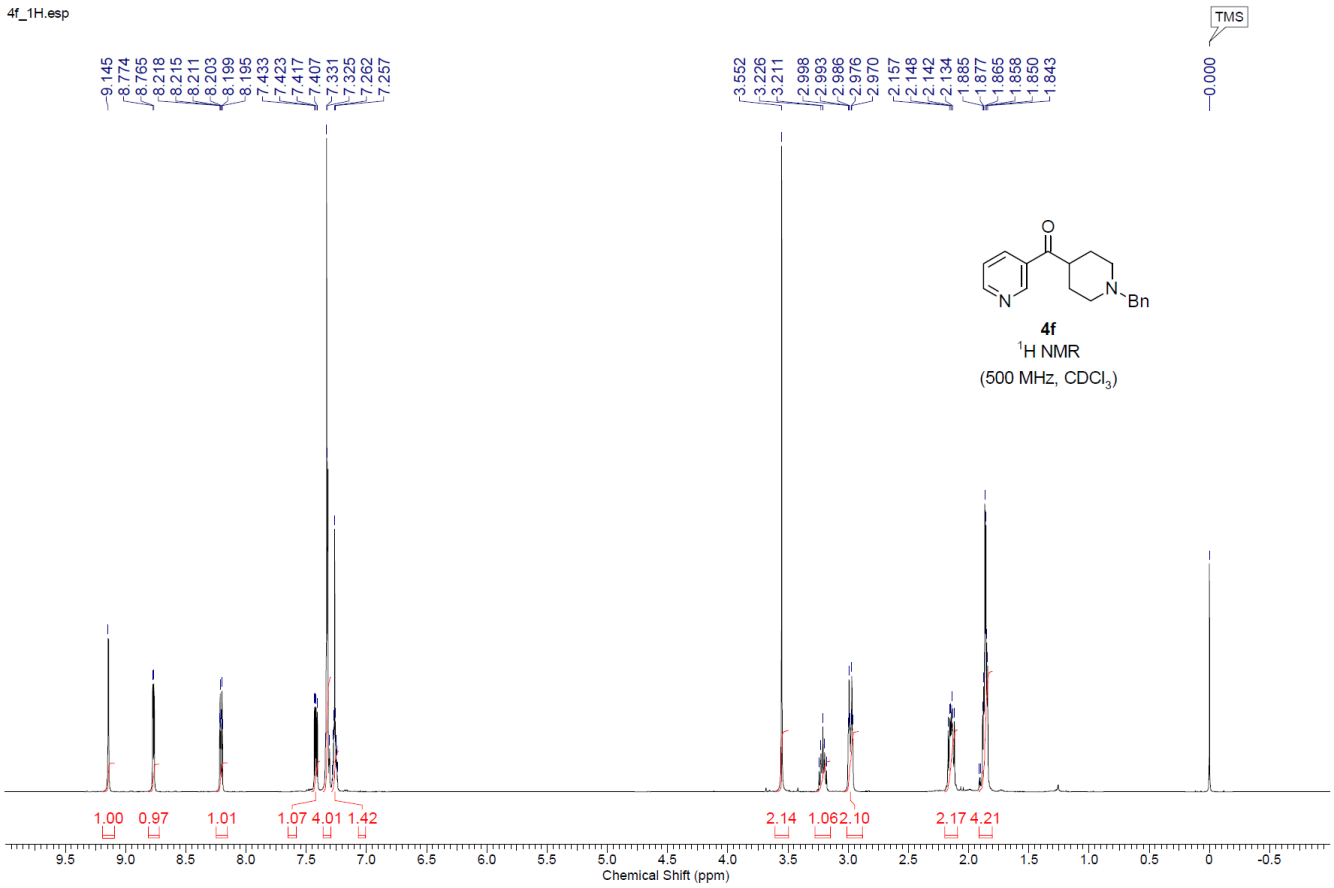

4c_13C (v2).esp
CHLOROFORM-d
209.395
156.127
138.931
136.417
128.438
127.960
127.853
127.028
126.558
77.313
77.000
76.679
67.240
54.364
46.854
39.724
29.511
Bn
N
Cbz
4c
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

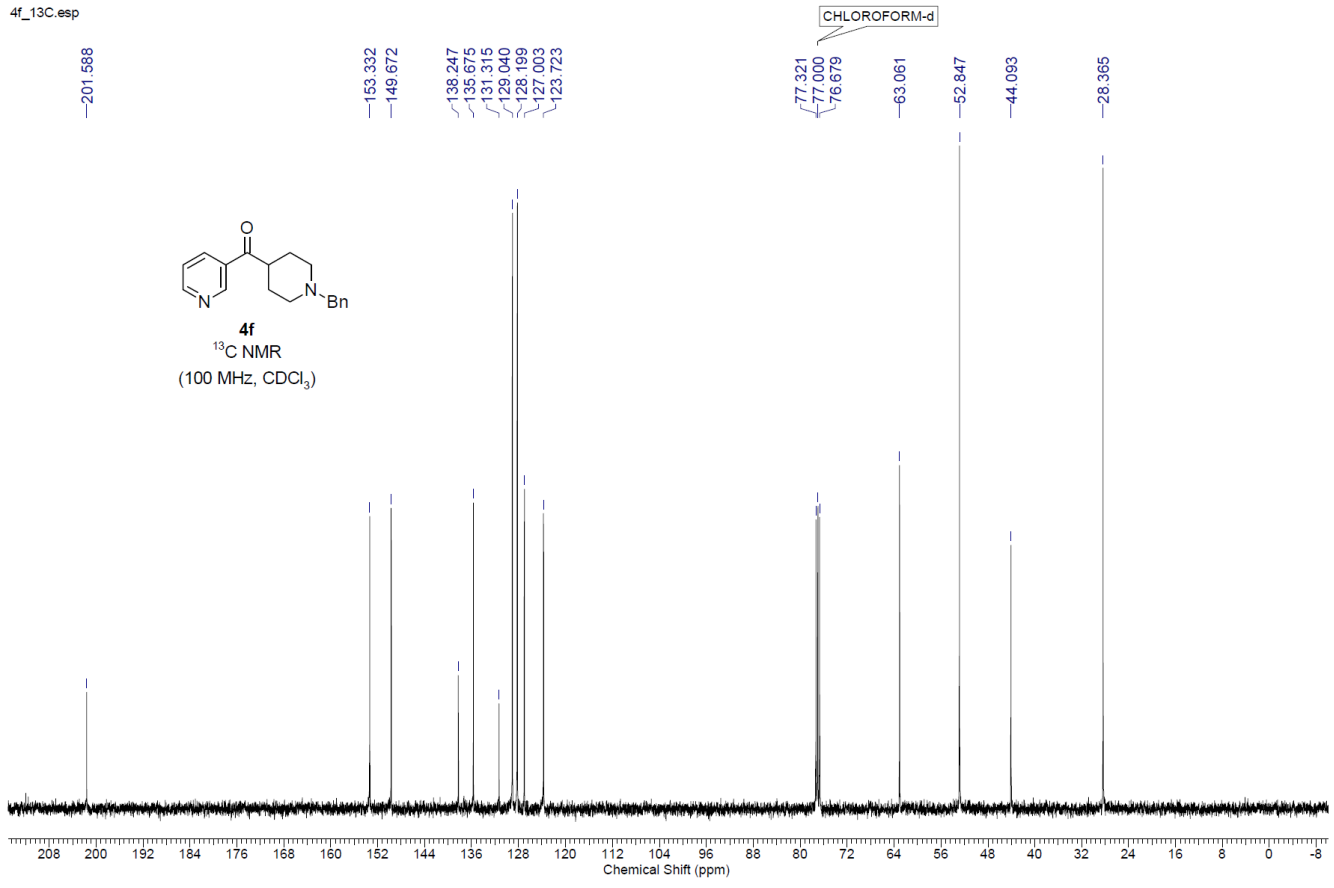

4d_1H.esp
2H + H2O
TMS
7.386
7.371
7.367
7.360
7.354
7.343
7.338
7.334
7.264
5.113
4.801
3.993
2.436
2.420
2.411
2.402
2.249
2.237
1.717
1.704
1.691
1.683
1.678
1.670
1.658
0.000
Cbz
N
H
4d
1H NMR
(500 MHz, CDCl3)
4.96
2.13
0.95
1.00
4.27
2.14
2.48
Chemical Shift (ppm)

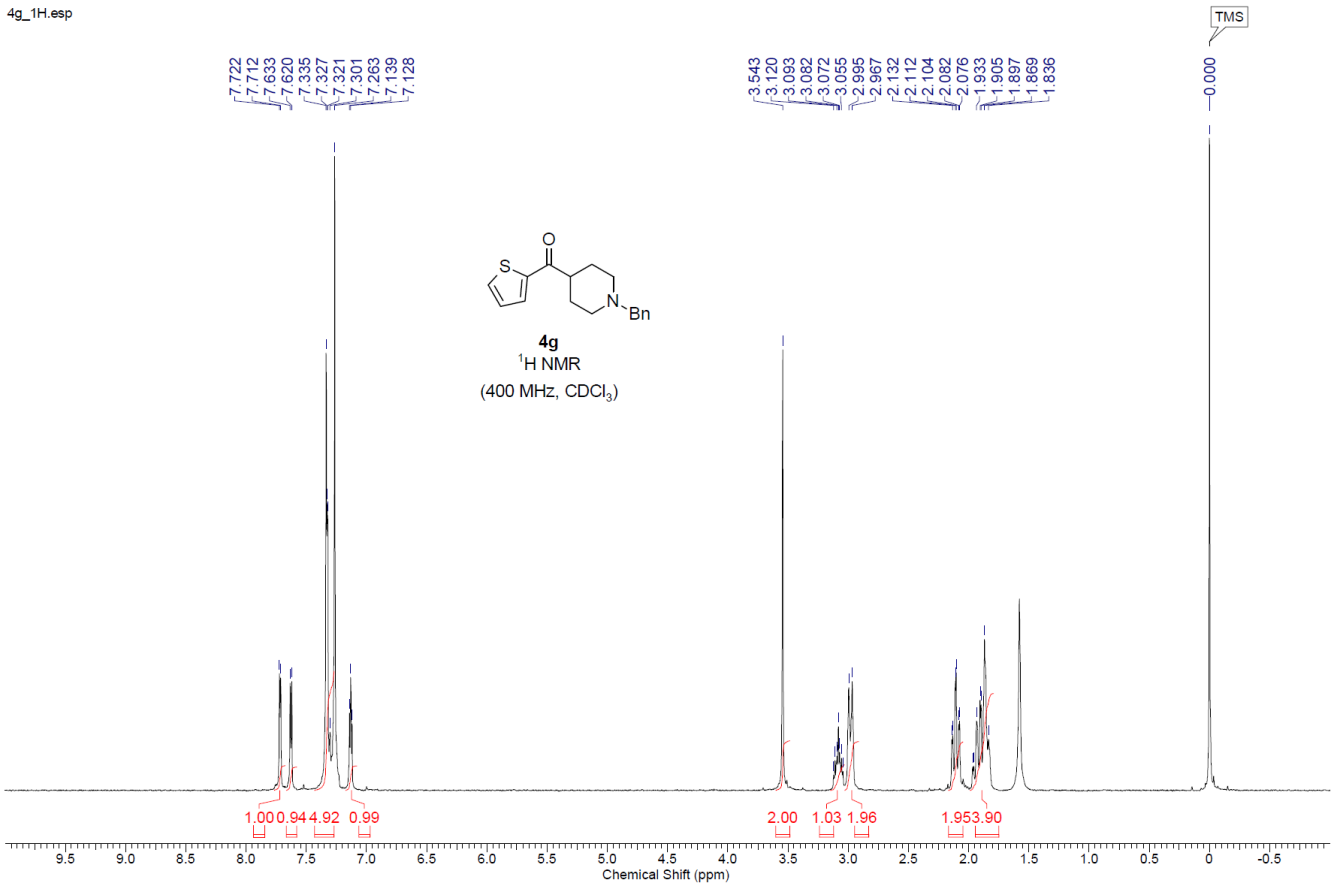

4d_13C.esp
CHLOROFORM-d
209.807
155.706
136.327
128.528
128.190
128.108
77.321
77.000
76.687
66.671
47.769
38.694
31.901
Cbz
N
H
4d
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4e_1H.esp
2H + H2O
TMS
7.316
7.305
7.264
7.247
7.235
7.226
3.497
2.921
2.892
2.446
2.428
2.408
2.002
1.996
1.800
1.774
1.694
1.686
1.556
1.538
1.520
1.300
1.280
1.262
0.913
0.895
0.876
0.000
O
N
Bn
4e
1H NMR
(400 MHz, CDCl3)
3.95 1.05
2.00
1.97 1.94 1.06 2.01 2.57 2.16 2.05 2.16 3.02
Chemical Shift (ppm)

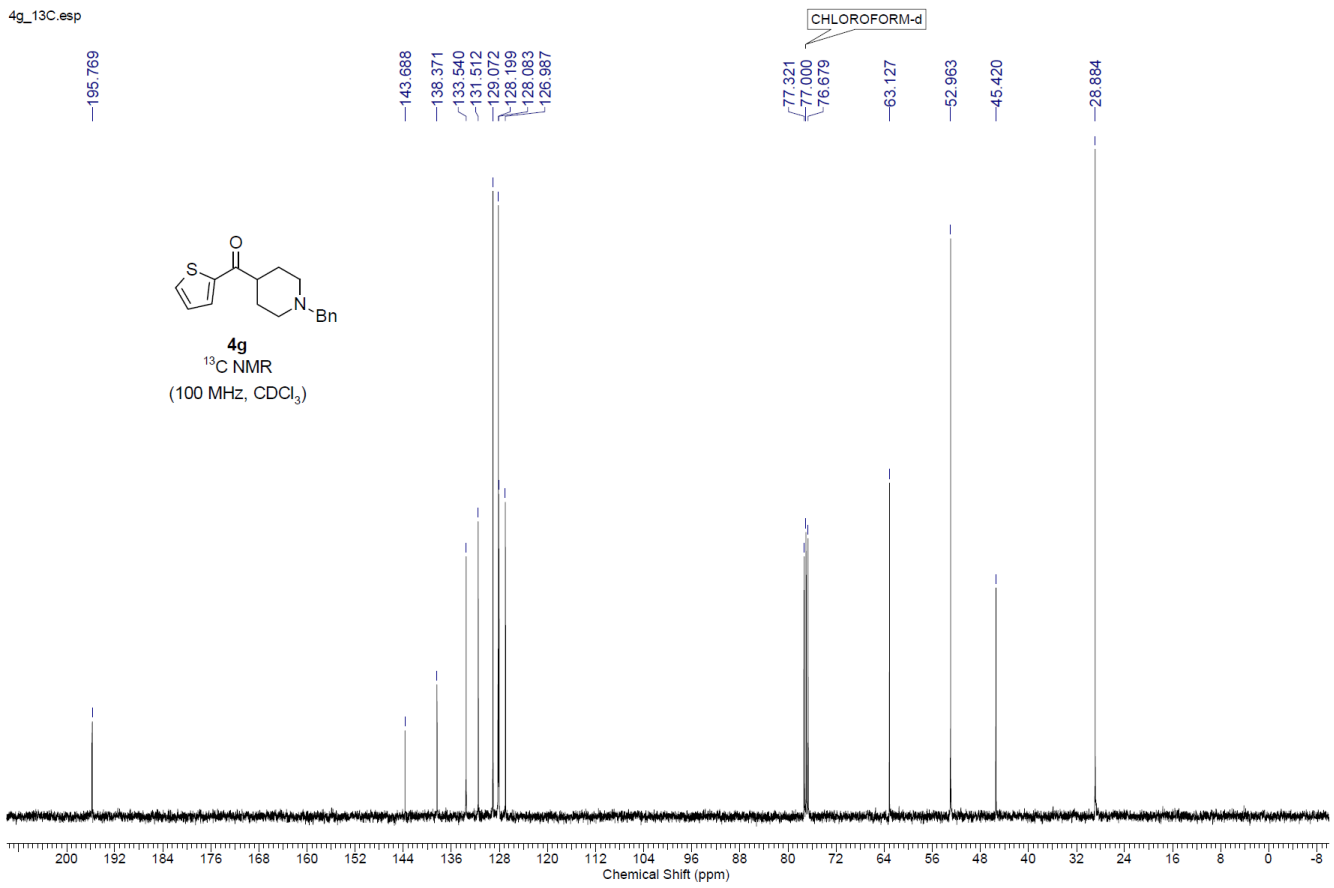

4e_13C.esp
CHLOROFORM-d
213.360
138.363
129.072
128.182
126.979
77.313
77.000
76.679
63.110
53.004
48.709
40.004
27.730
25.636
22.273
13.750
O
N
Bn
4e
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4f_1H.esp
TMS
9.145
8.774
8.765
8.218
8.215
8.211
8.203
8.199
8.195
7.433
7.423
7.417
7.407
7.331
7.325
7.262
7.257
3.552
3.226
3.211
2.998
2.993
2.986
2.976
2.970
2.157
2.148
2.142
2.134
1.885
1.877
1.865
1.858
1.850
1.843
0.000
1.00
0.97
1.01
1.07
4.01
1.42
2.14
1.06
2.10
2.17
4.21
Chemical Shift (ppm)
4f
1H NMR
(500 MHz, CDCl3)

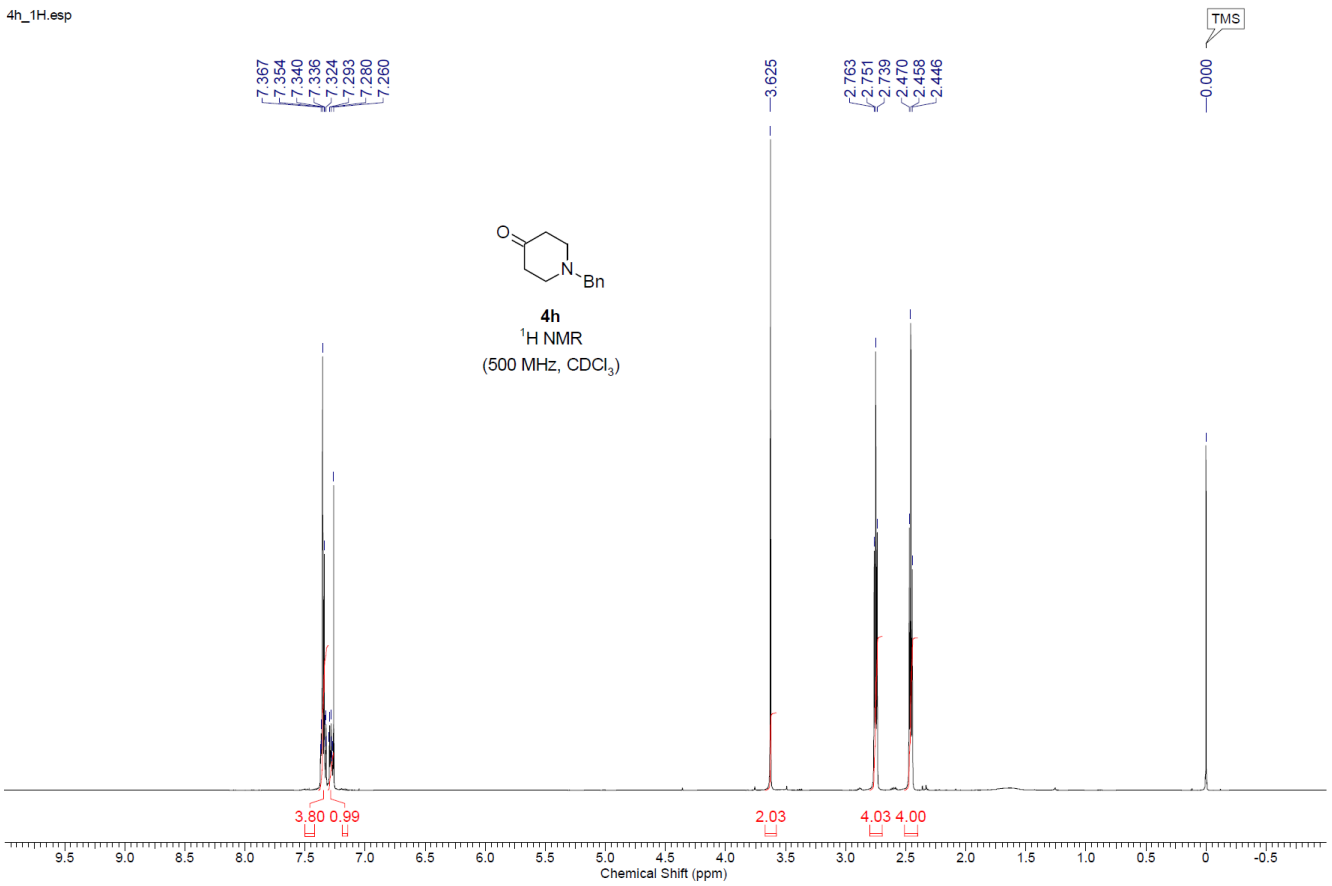

4f_13C.esp
CHLOROFORM-d
201.588
153.332
149.672
138.247
135.675
131.315
129.040
128.199
127.003
123.723
77.321
77.000
76.679
63.061
52.847
44.093
28.365
Chemical Shift (ppm)
4f
13C NMR
(100 MHz, CDCl3)

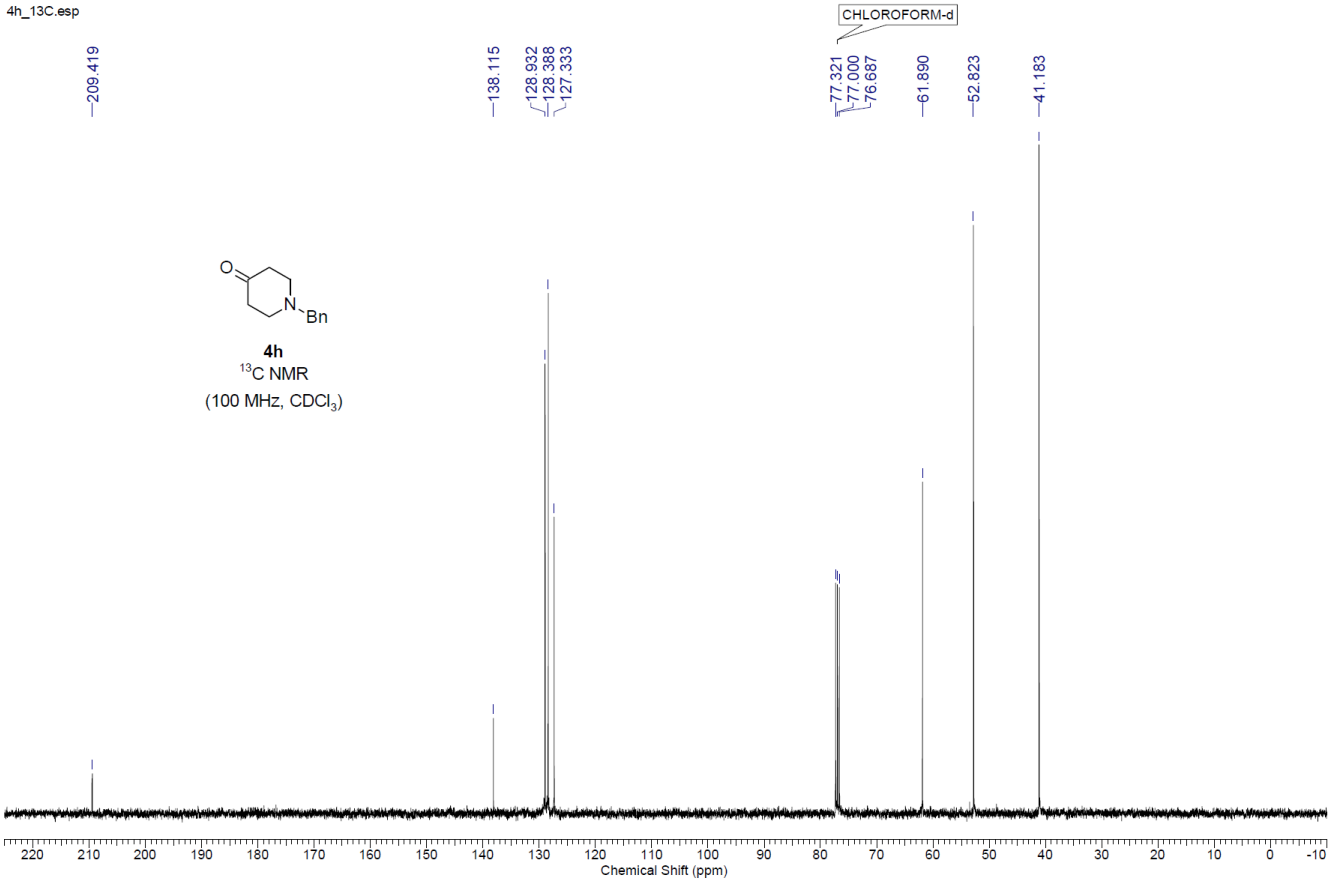


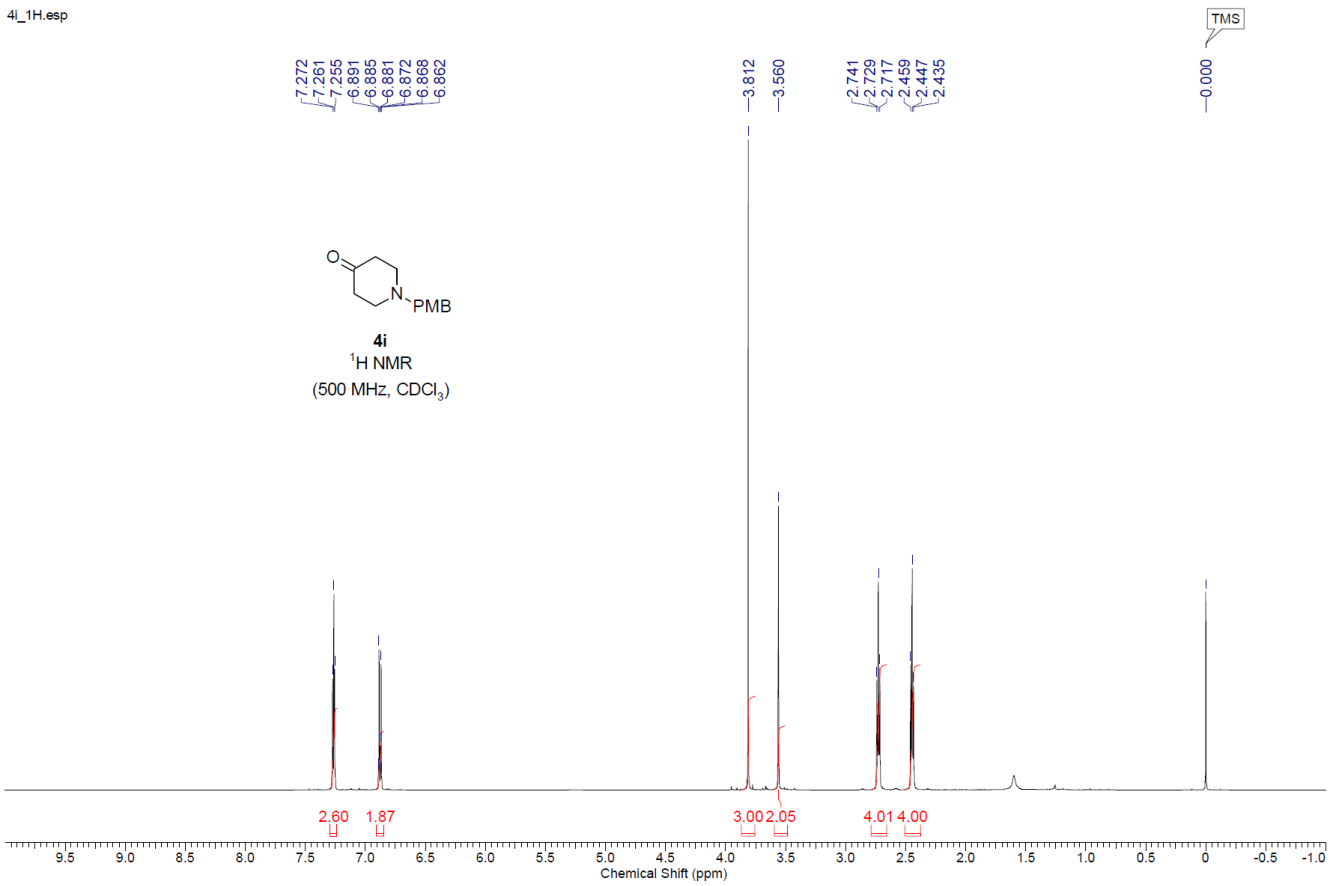
4g
^{1}H NMR
(400 MHz, $CDCl_3$)

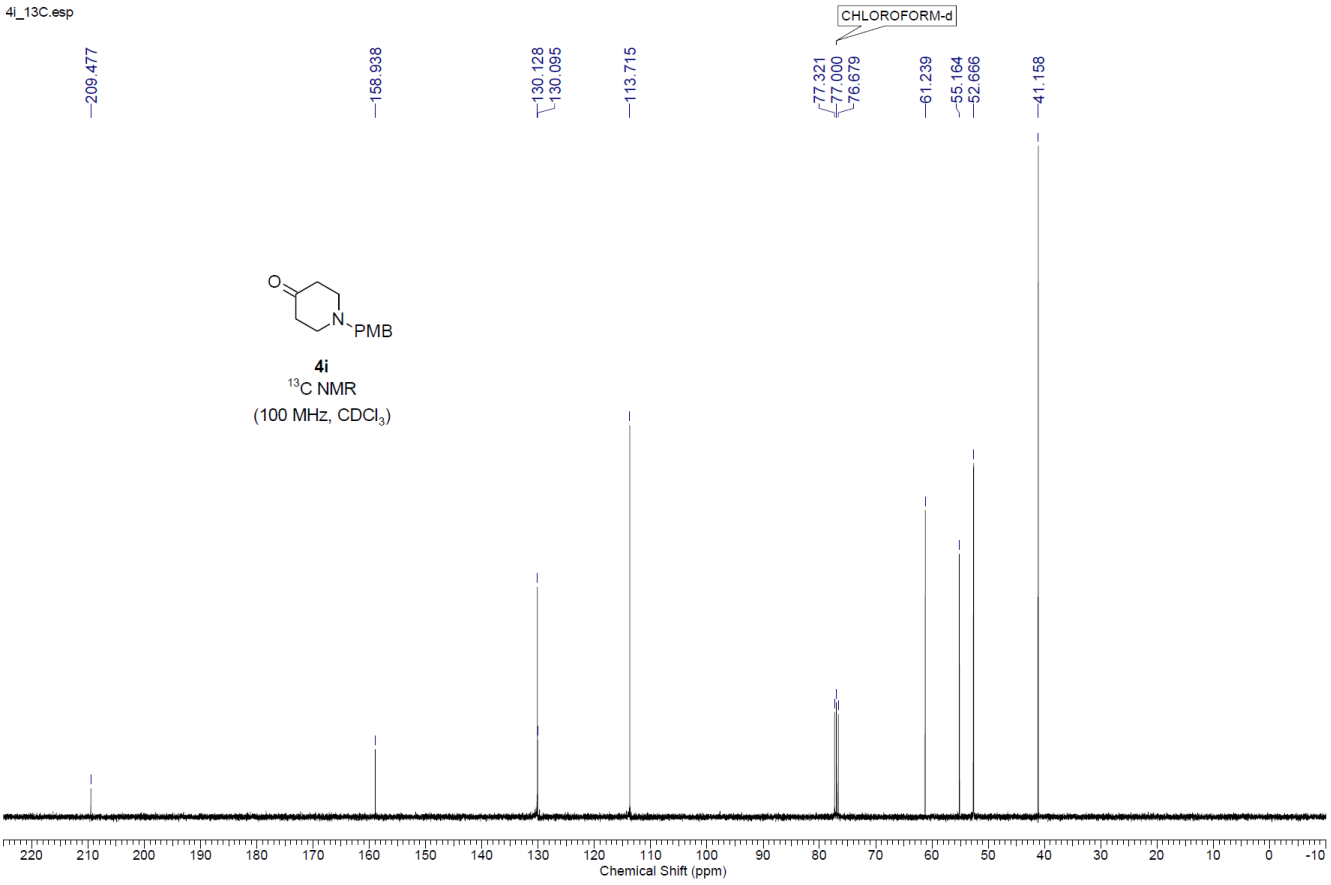


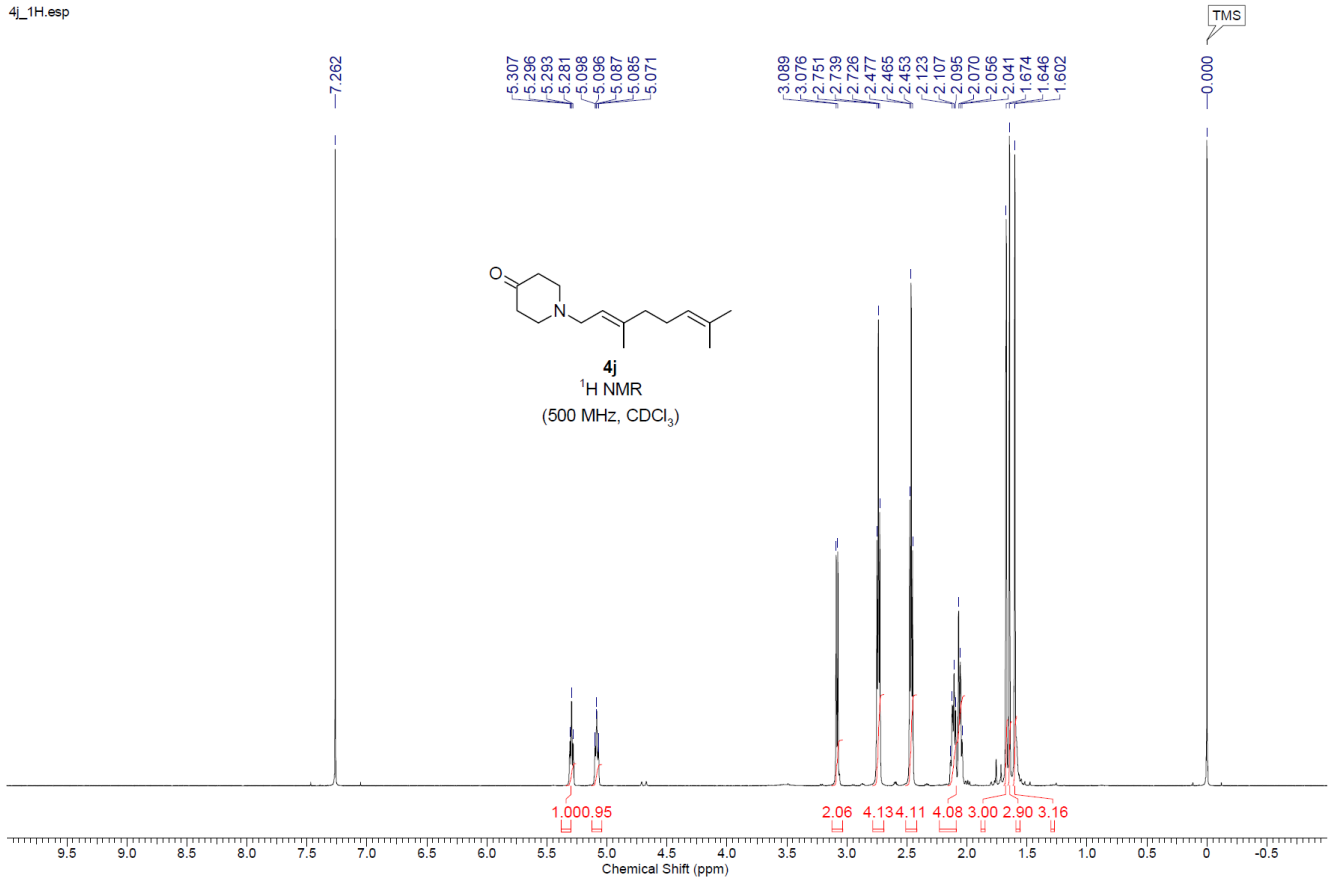
4g
^{13}C NMR
(100 MHz, $CDCl_3$)

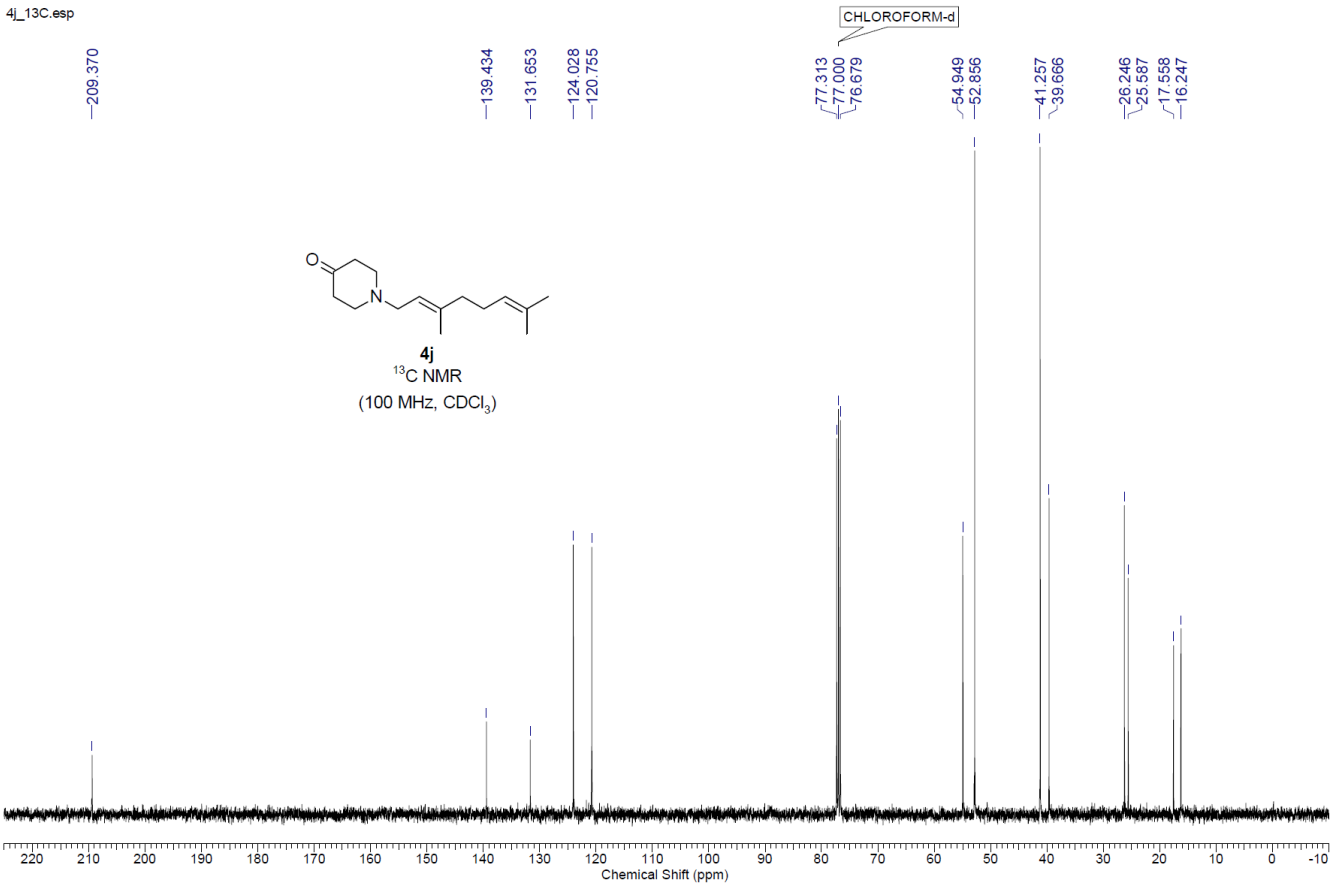

4h_1H.esp
TMS
7.367
7.354
7.340
7.336
7.324
7.293
7.280
7.260
3.625
2.763
2.751
2.739
2.470
2.458
2.446
0.000
O
N
Bn
4h
1H NMR
(500 MHz, CDCl3)
3.80 0.99
2.03
4.03 4.00
Chemical Shift (ppm)

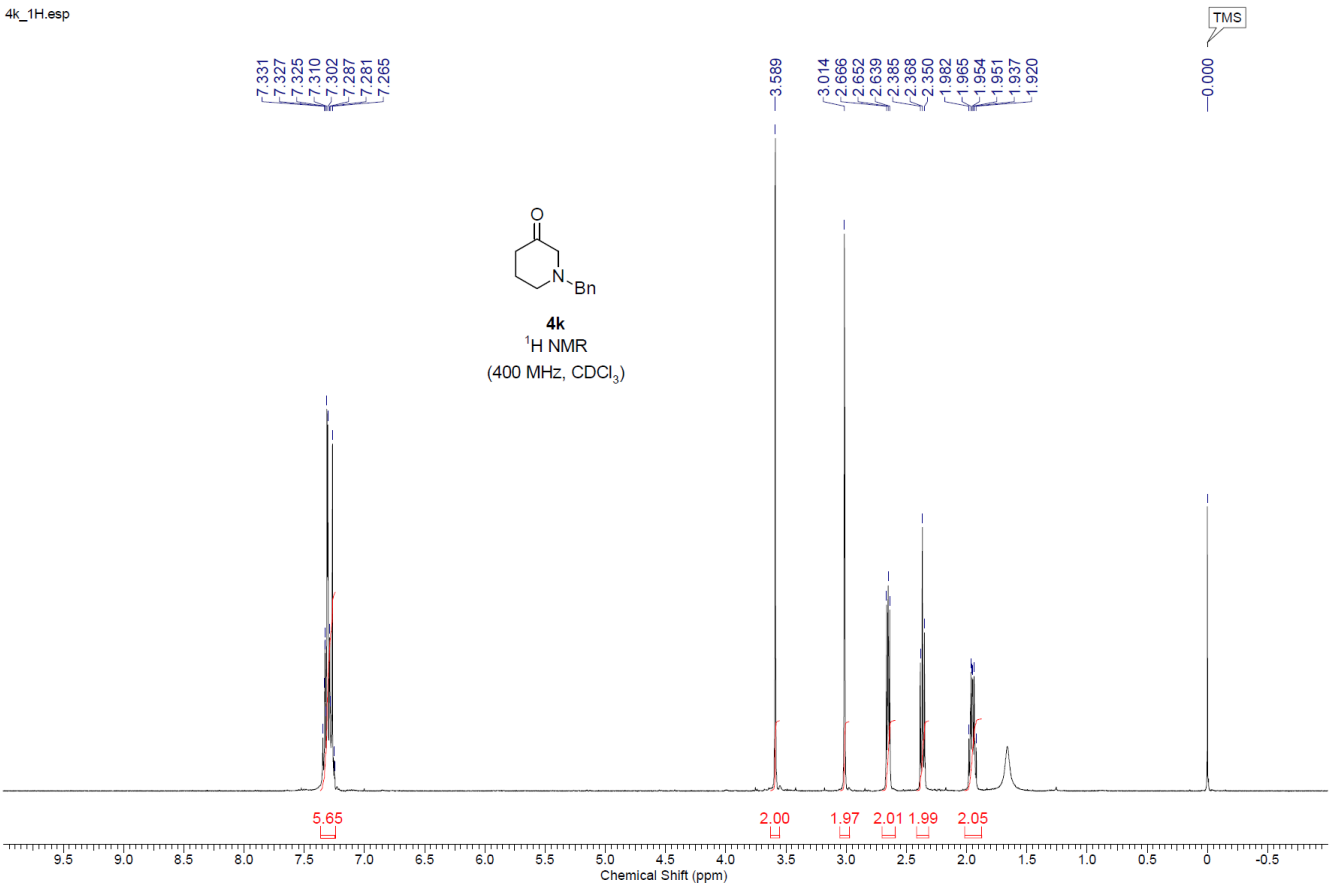

4h_13C.esp
CHLOROFORM-d
209.419
138.115
128.932
128.388
127.333
77.321
77.000
76.687
61.890
52.823
41.183
O
N
Bn
4h
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

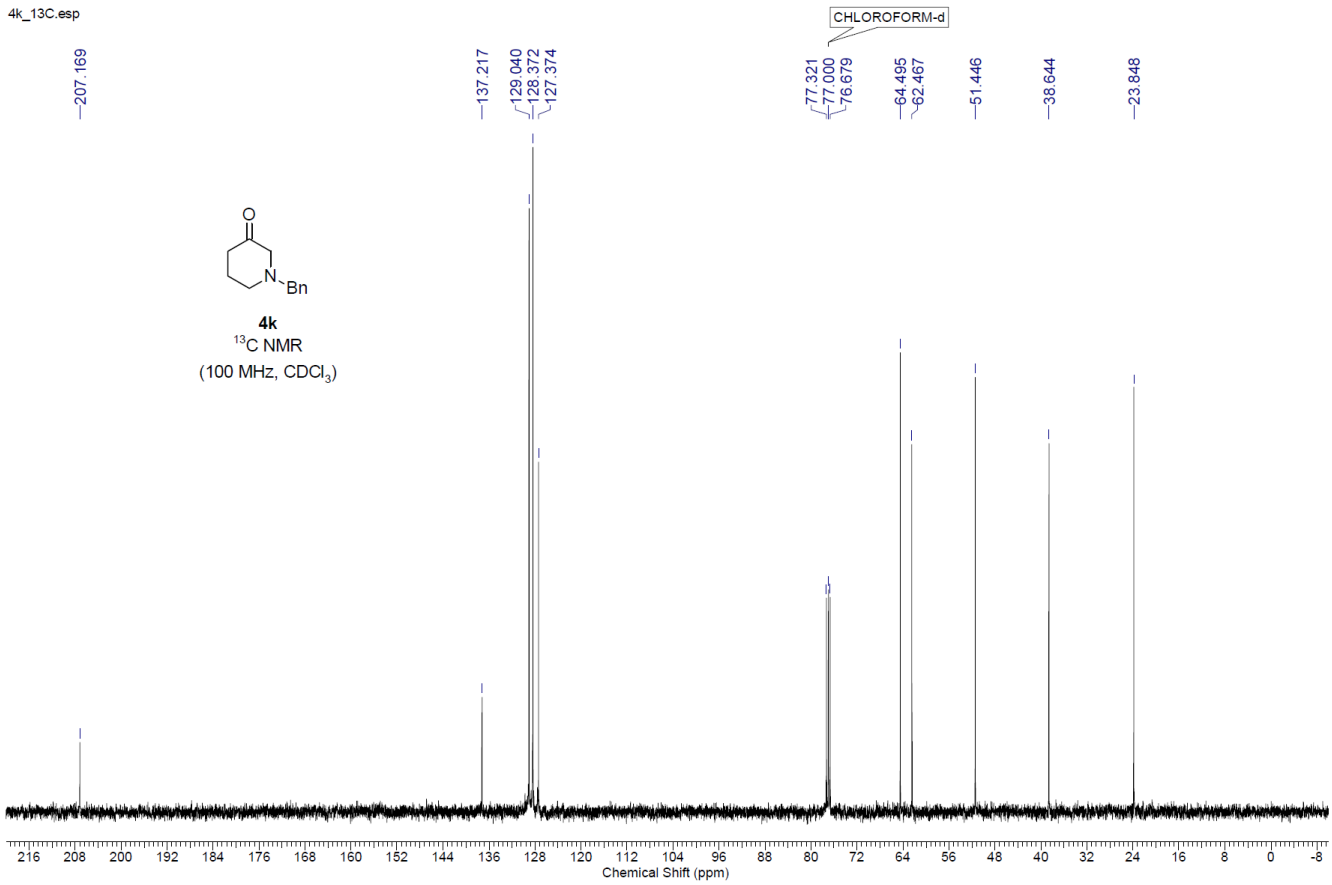

4i_1H.esp
TMS
7.272
7.261
7.255
6.891
6.885
6.881
6.872
6.868
6.862
3.812
3.560
2.741
2.729
2.717
2.459
2.447
2.435
0.000
O
N
PMB
4i
1H NMR
(500 MHz, CDCl3)
2.60
1.87
3.00
2.05
4.01
4.00
Chemical Shift (ppm)

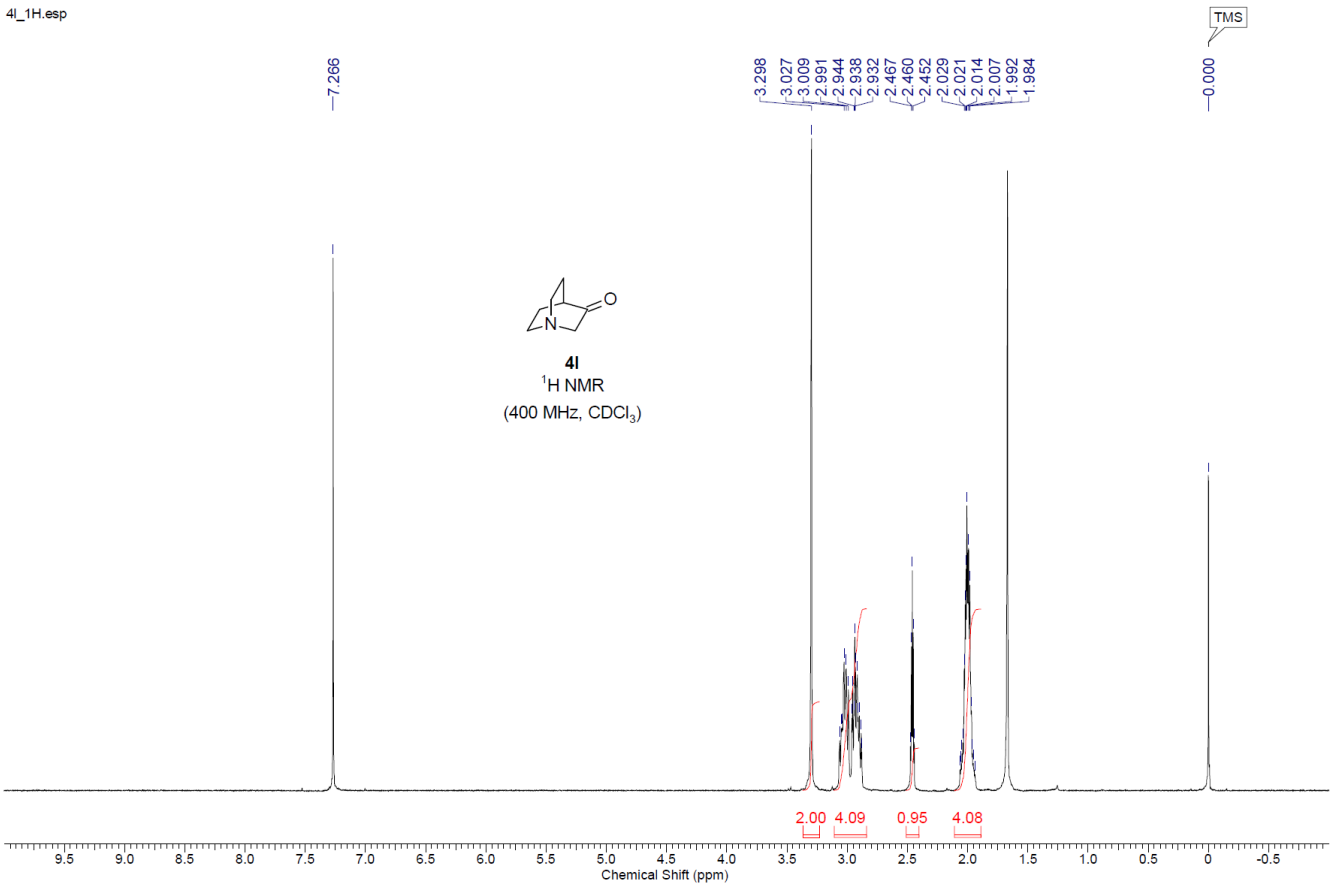

4i_13C.esp
CHLOROFORM-d
209.477
158.938
130.128
130.095
113.715
77.321
77.000
76.679
61.239
55.164
52.666
41.158
O
N
PMB
4i
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4j_1H.esp
TMS
7.262
5.307
5.296
5.293
5.281
5.098
5.096
5.087
5.085
5.071
3.089
3.076
2.751
2.739
2.726
2.477
2.465
2.453
2.123
2.107
2.095
2.070
2.056
2.041
1.674
1.646
1.602
0.000
4j
1H NMR
(500 MHz, CDCl3)
1.00 0.95
2.06 4.13 4.11 4.08 3.00 2.90 3.16
Chemical Shift (ppm)


4j_13C.esp
CHLOROFORM-d
209.370
139.434
131.653
124.028
120.755
77.313
77.000
76.679
54.949
52.856
41.257
39.666
26.246
25.587
17.558
16.247
4j
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4k_1H.esp
TMS
7.331
7.327
7.325
7.310
7.302
7.287
7.281
7.265
3.589
3.014
2.666
2.652
2.639
2.385
2.368
2.350
1.982
1.965
1.954
1.951
1.937
1.920
0.000
O
N
Bn
4k
1H NMR
(400 MHz, CDCl3)
5.65
2.00
1.97
2.01
1.99
2.05
Chemical Shift (ppm)

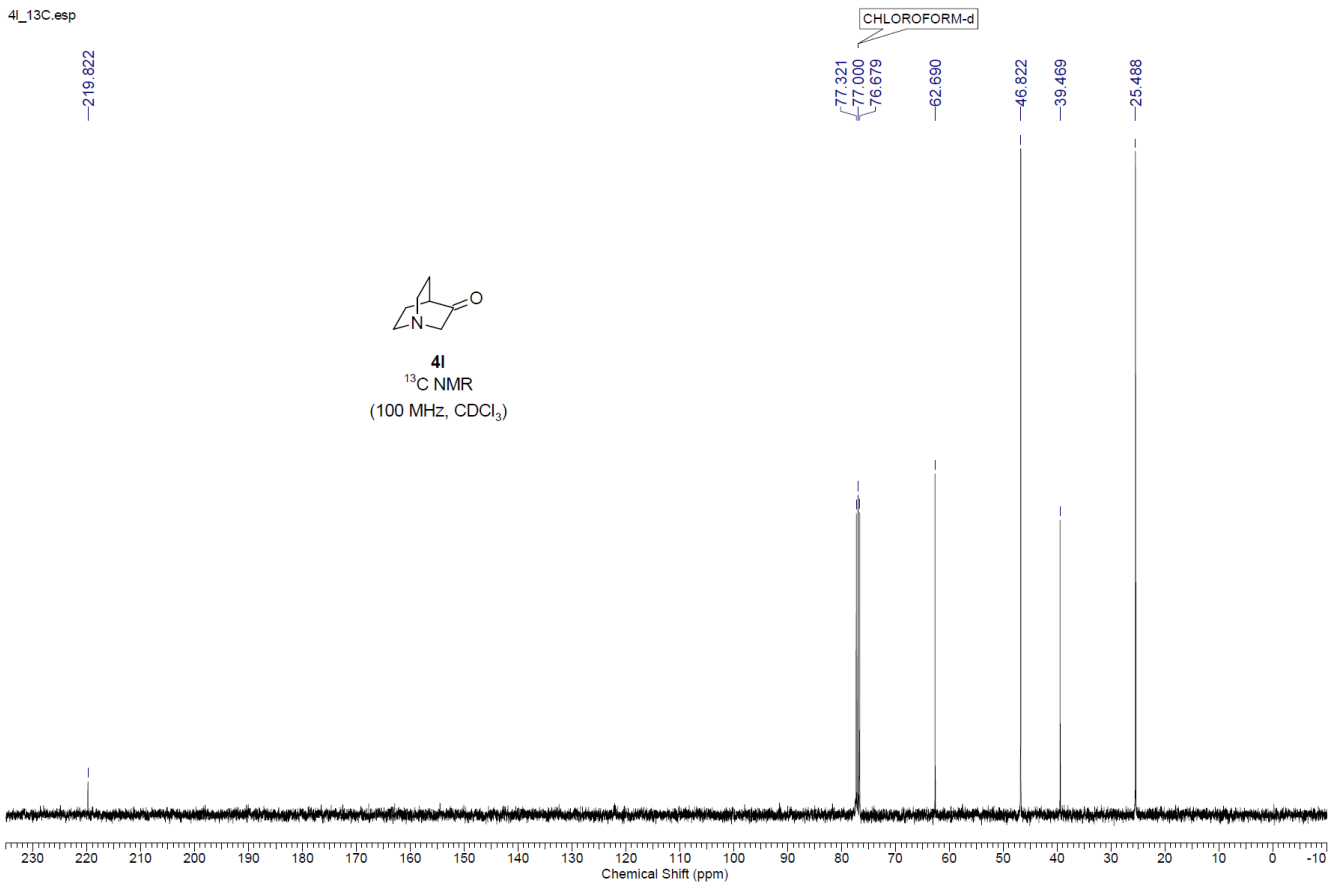

4k_13C.esp
CHLOROFORM-d
207.169
137.217
129.040
128.372
127.374
77.321
77.000
76.679
64.495
62.467
51.446
38.644
23.848
O
N
Bn
4k
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)



4l

^{1}H NMR

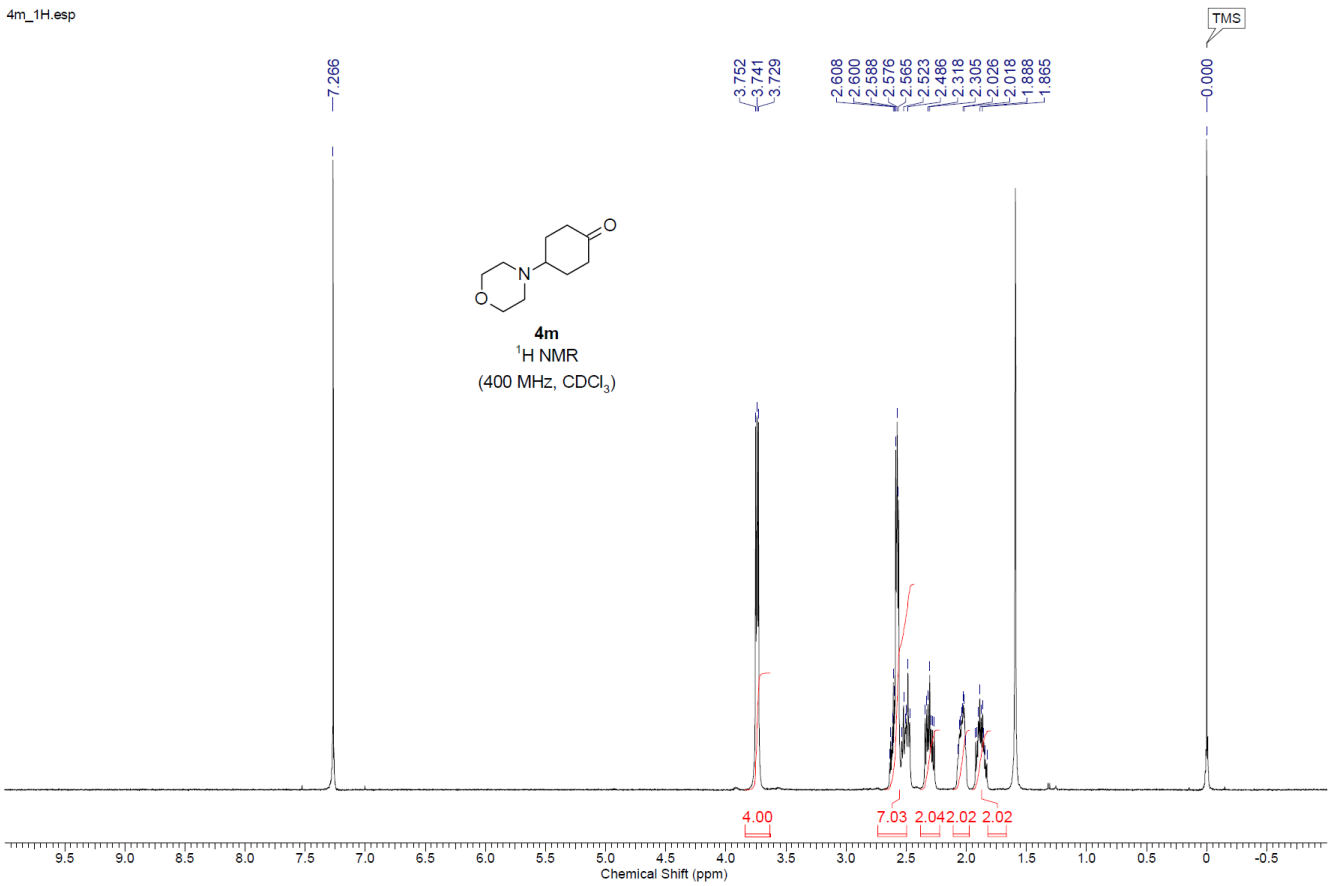
(400 MHz, $CDCl_3$)



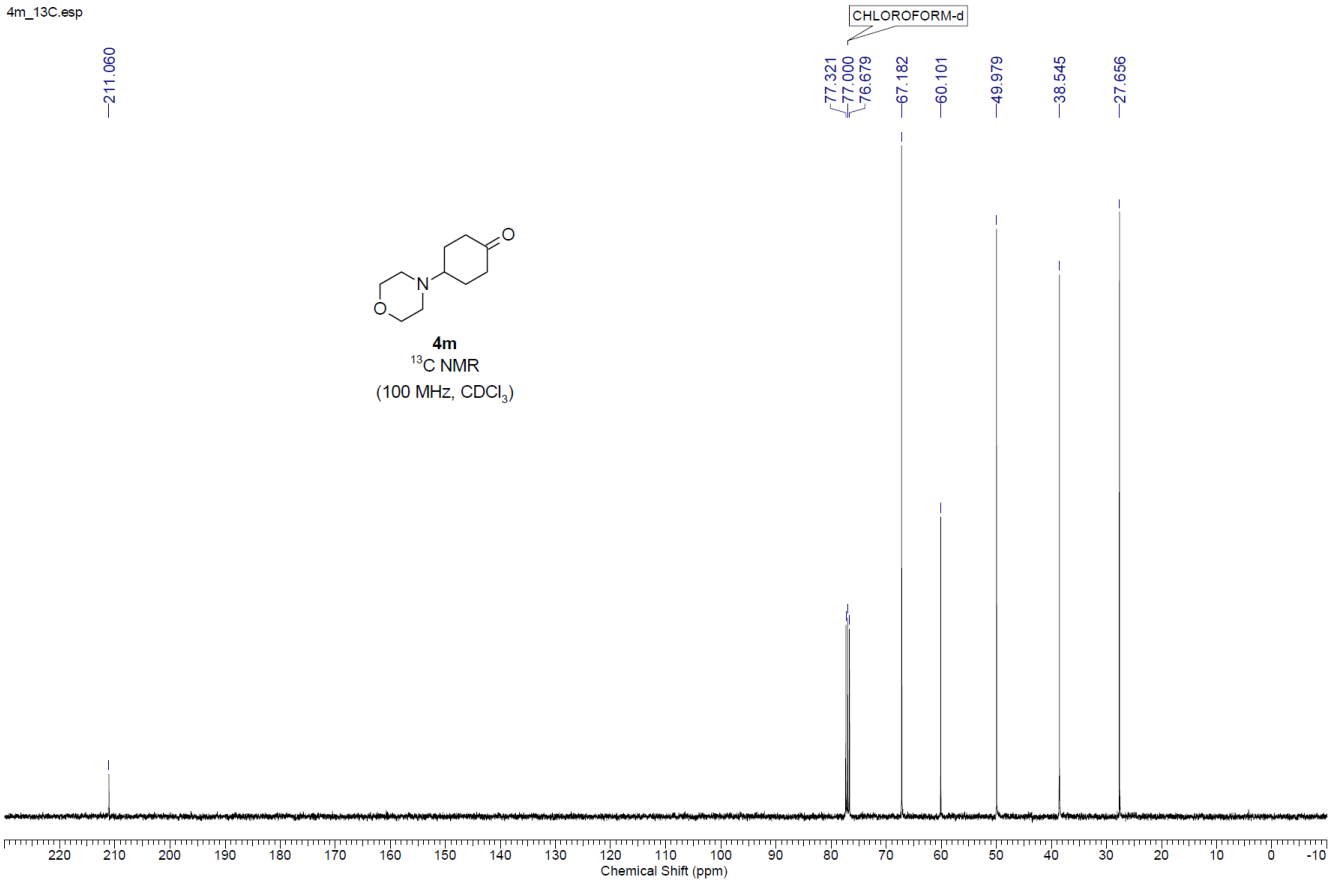
4l

^{13}C NMR

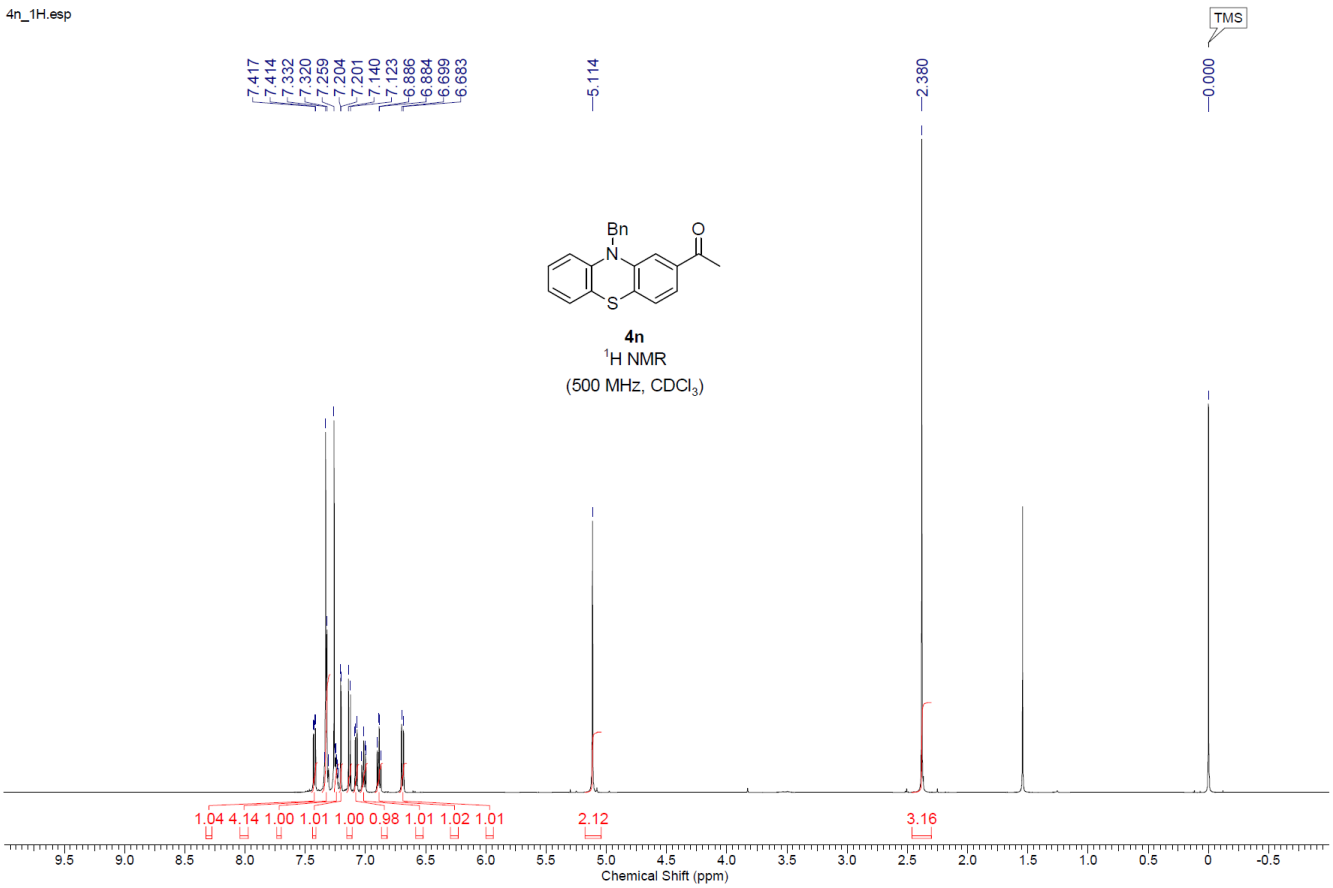
(100 MHz, $CDCl_3$)

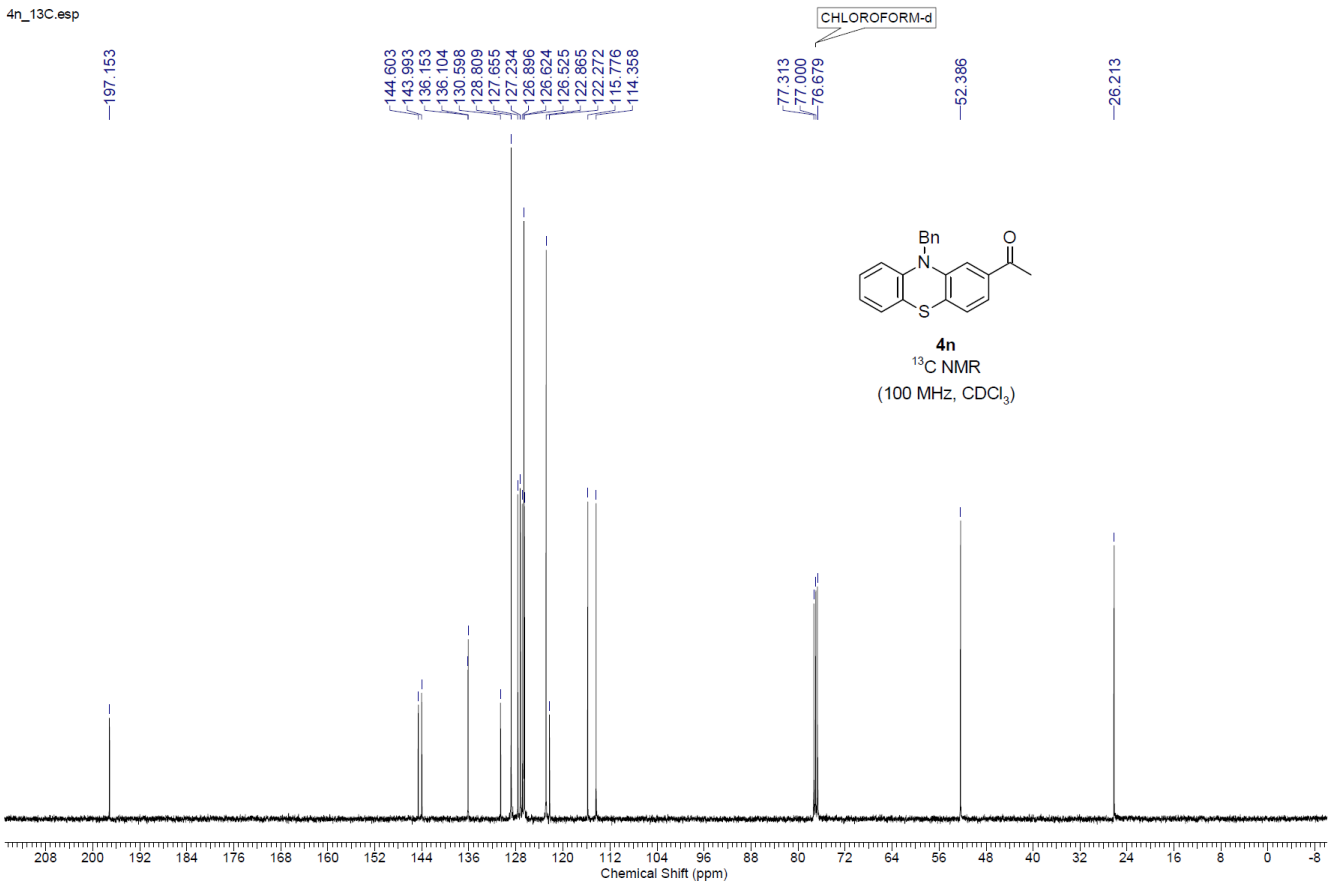


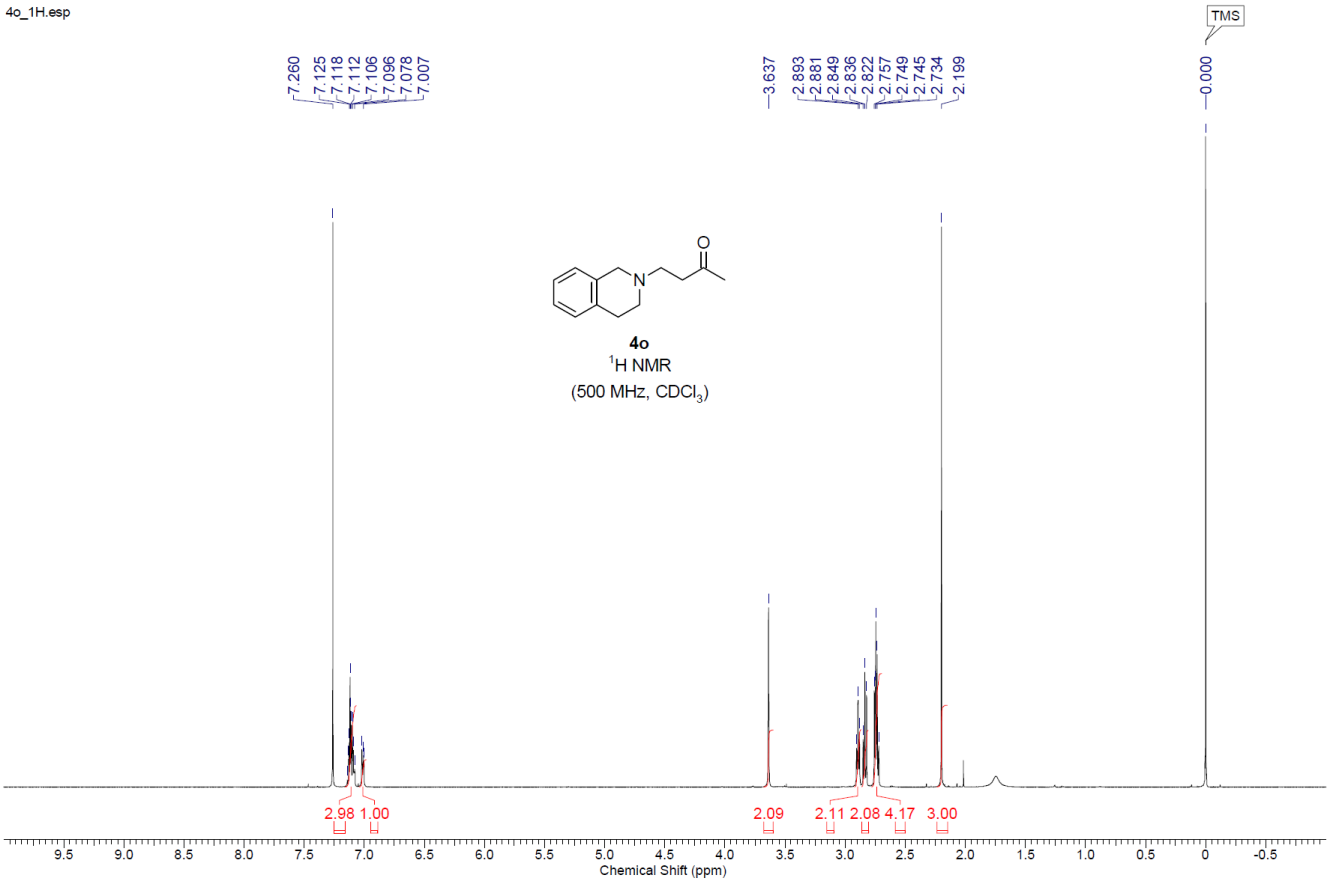
4m
^{1}H NMR
(400 MHz, $CDCl_3$)

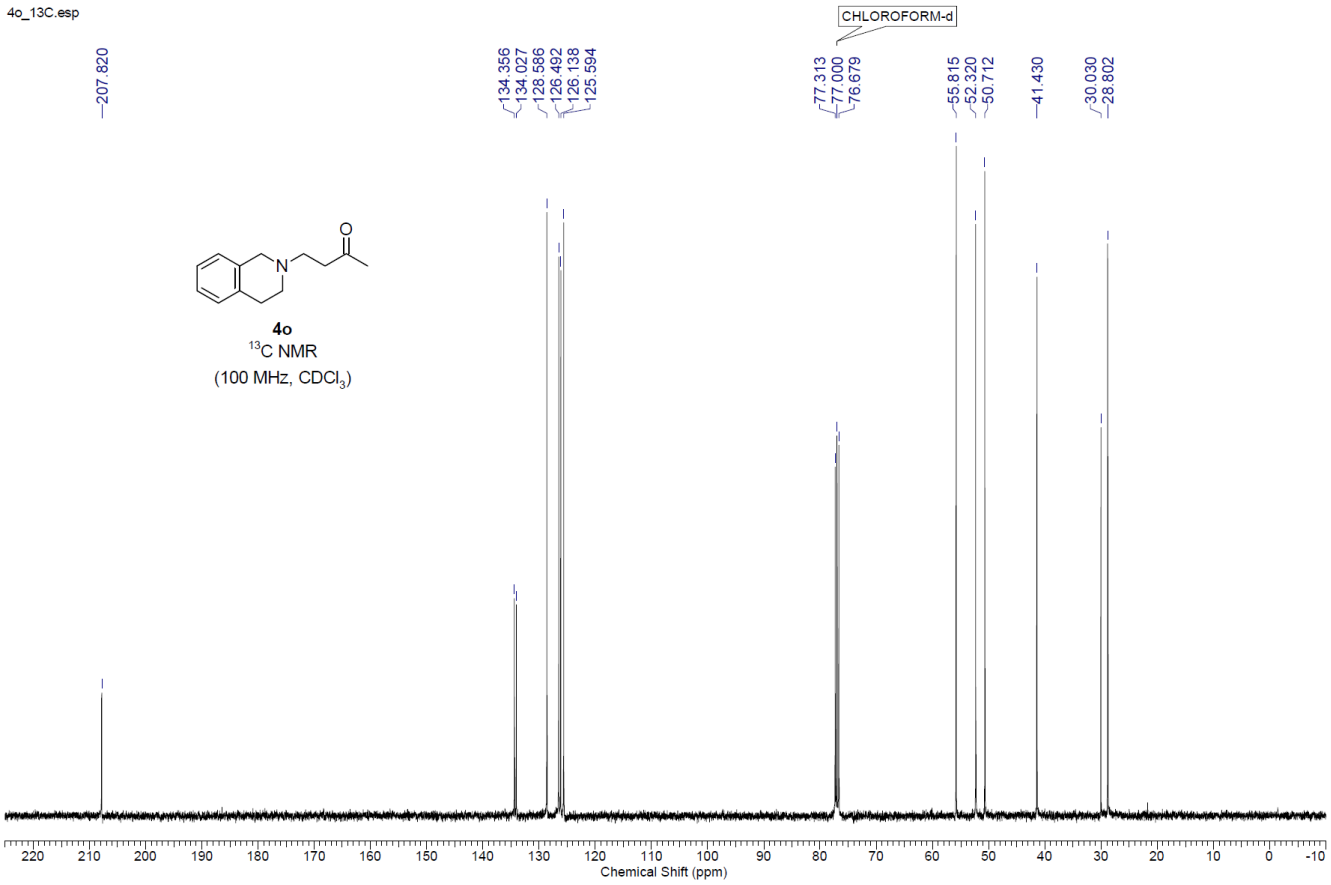


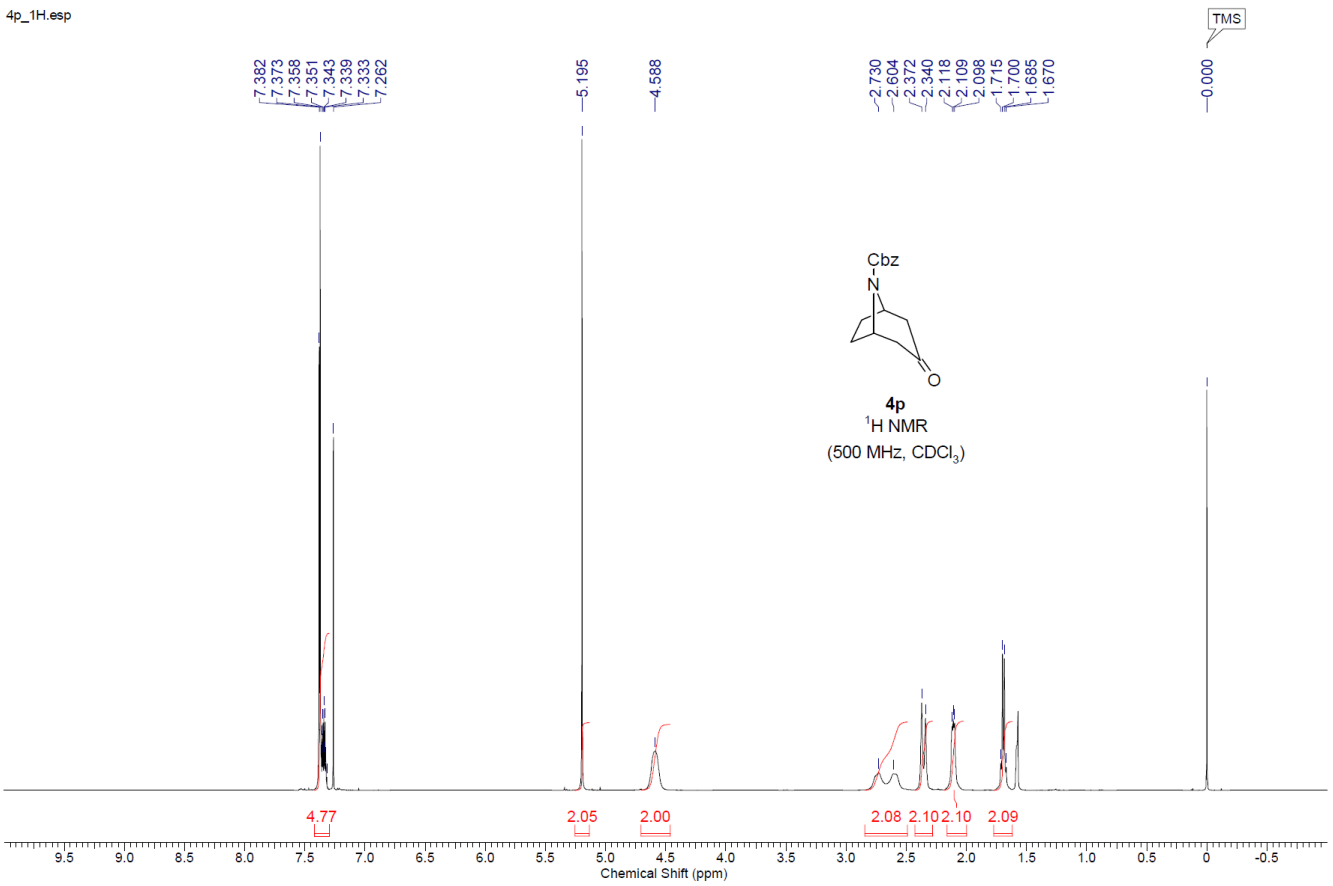
4m
^{13}C NMR
(100 MHz, $CDCl_3$)

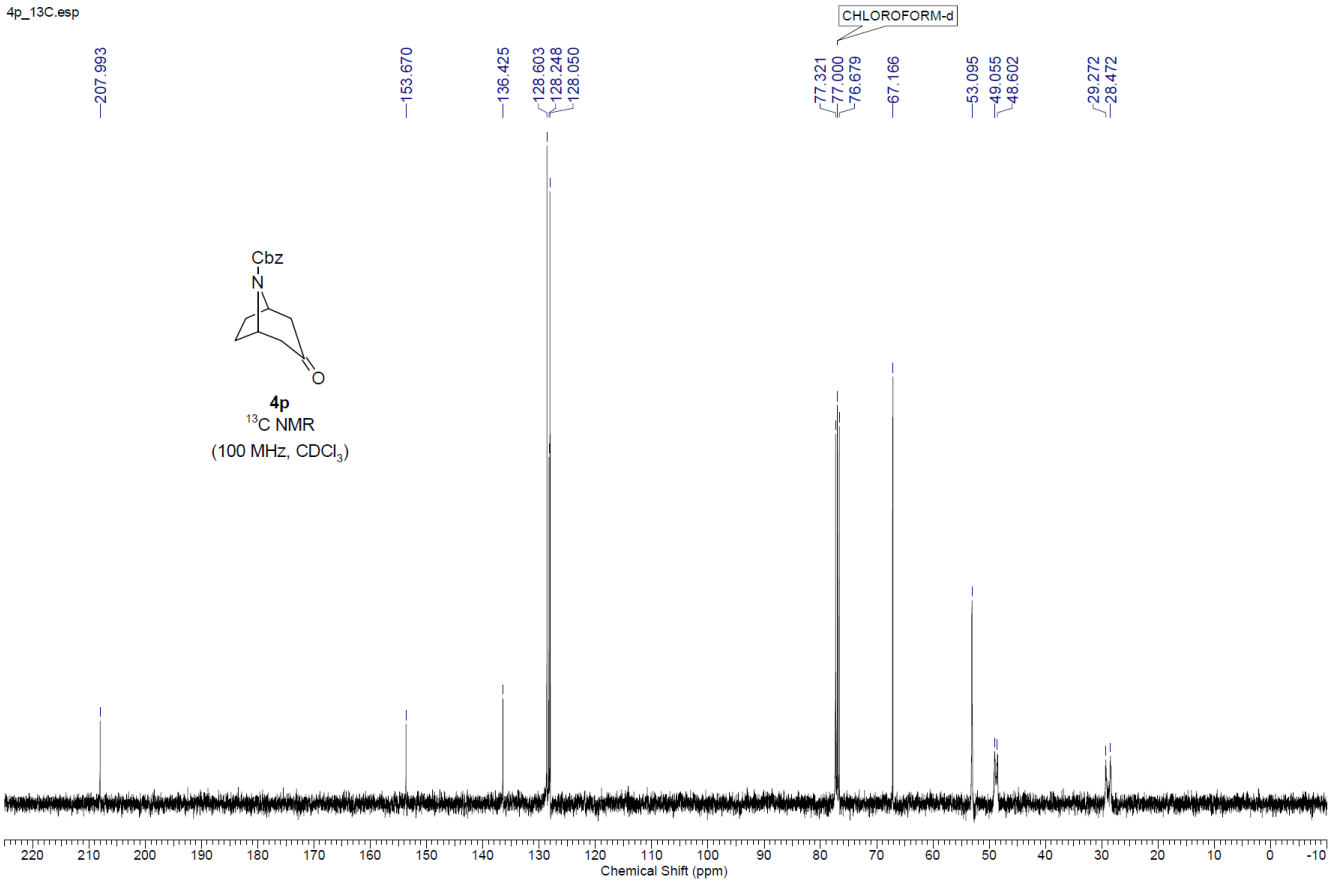

4n_1H.esp
TMS
7.417
7.414
7.332
7.320
7.259
7.204
7.201
7.140
7.123
6.886
6.884
6.699
6.683
5.114
2.380
0.000
Bn
N
O
S
4n
1H NMR
(500 MHz, CDCl3)
1.04 4.14 1.00 1.01 1.00 0.98 1.01 1.02 1.01
2.12
3.16
Chemical Shift (ppm)

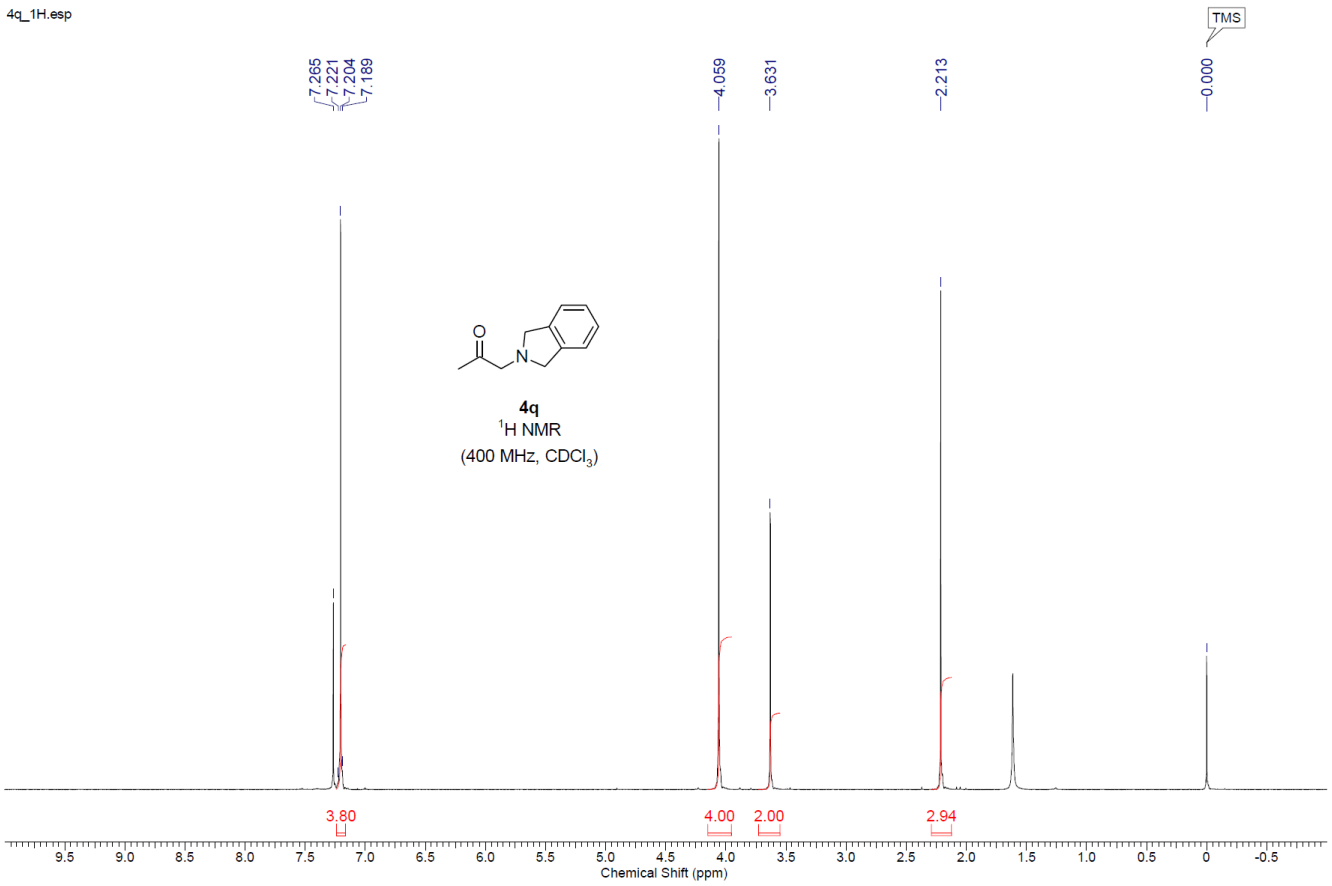

4n_13C.esp
CHLOROFORM-d
197.153
144.603
143.993
136.153
136.104
130.598
128.809
127.655
127.234
126.896
126.624
126.525
122.865
122.272
115.776
114.358
77.313
77.000
76.679
52.386
26.213
Bn
N
O
S
4n
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

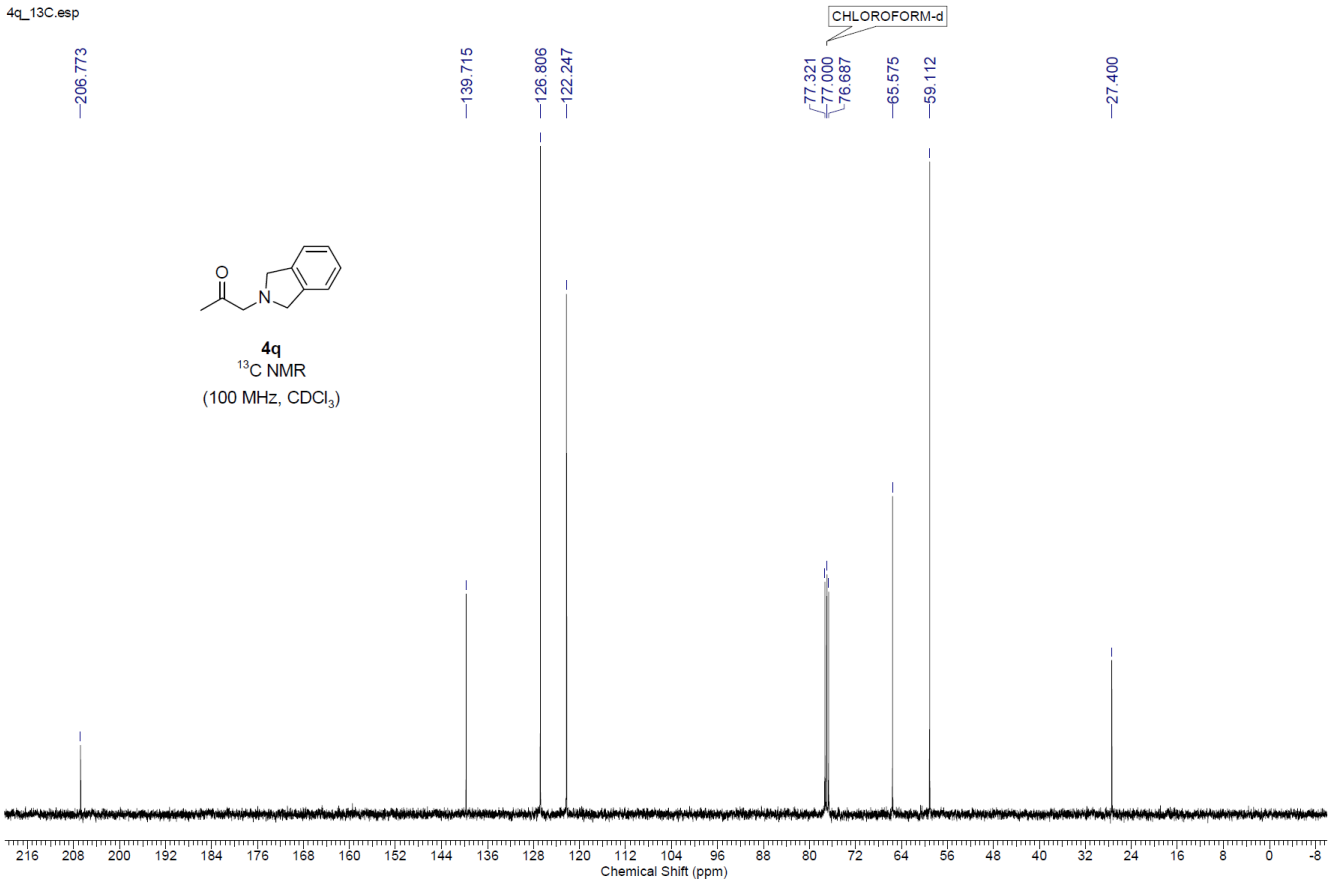

4o_1H.esp
TMS
7.260
7.125
7.118
7.112
7.106
7.096
7.078
7.007
3.637
2.893
2.881
2.849
2.836
2.822
2.757
2.749
2.745
2.734
2.199
0.000
O
N
4o
1H NMR
(500 MHz, CDCl3)
2.98 1.00
2.09
2.11 2.08 4.17 3.00
Chemical Shift (ppm)

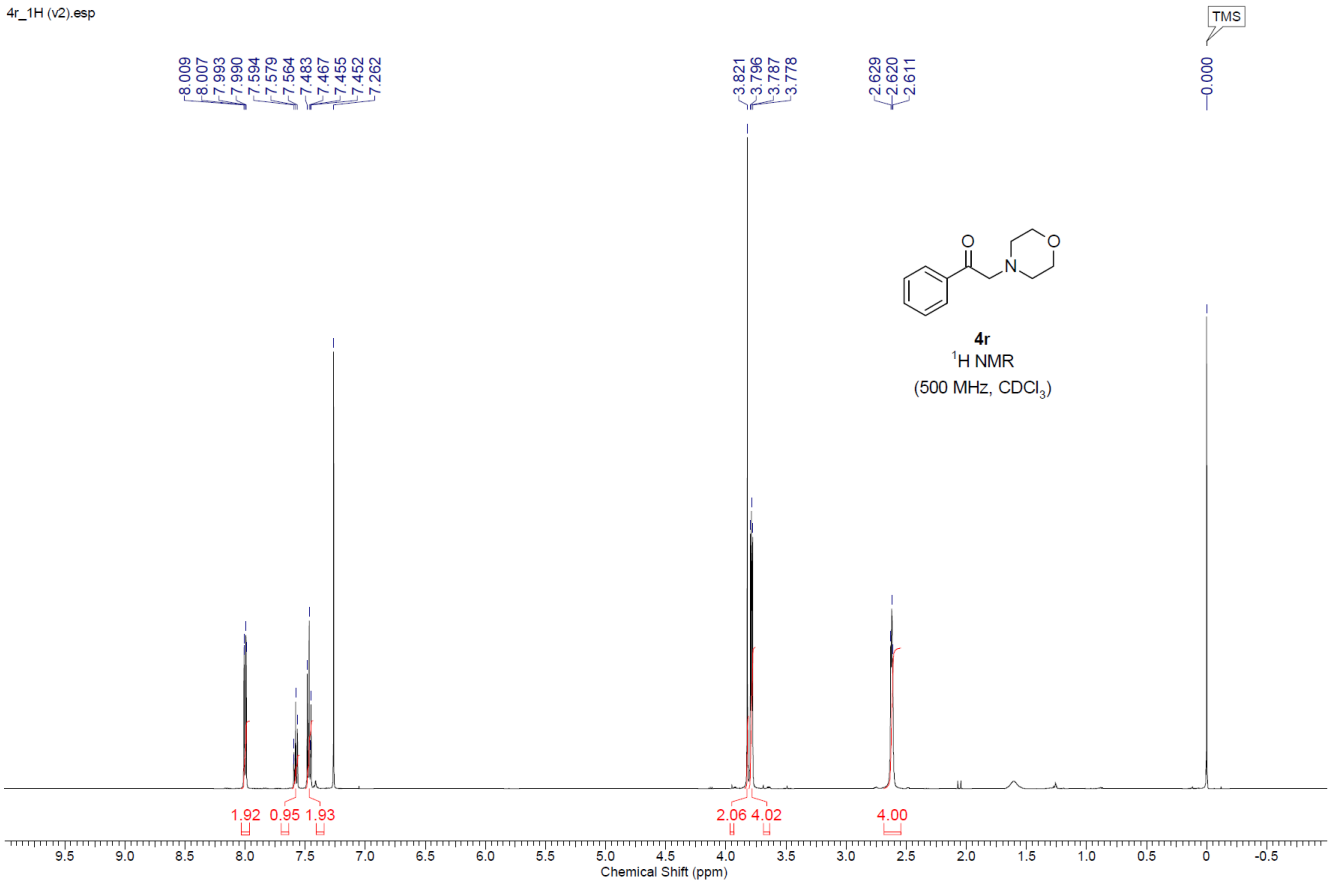

4o_13C.esp
CHLOROFORM-d
207.820
134.356
134.027
128.586
126.492
126.138
125.594
77.313
77.000
76.679
55.815
52.320
50.712
41.430
30.030
28.802
O
N
4o
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

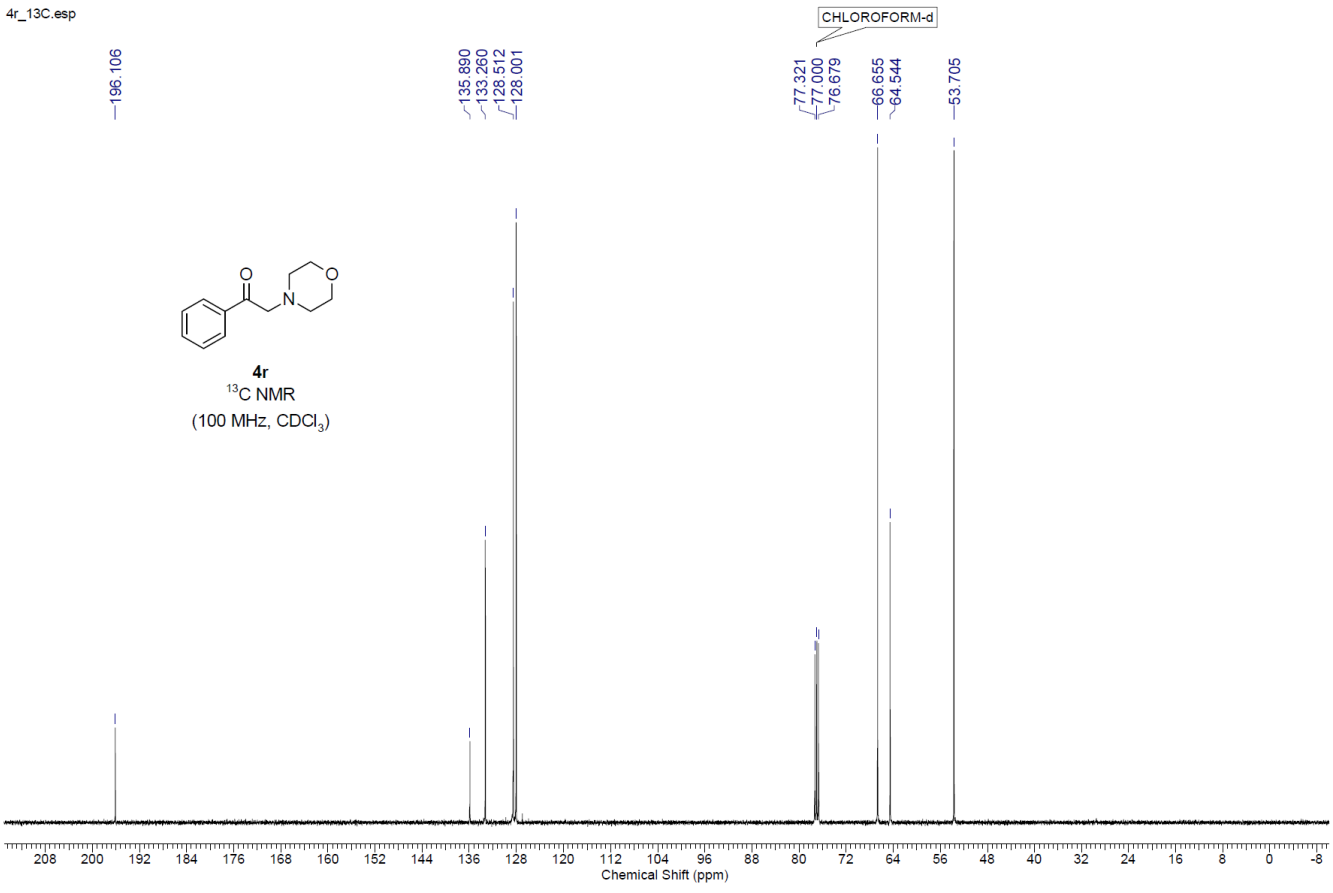

4p_1H.esp
TMS
7.382
7.373
7.358
7.351
7.343
7.339
7.333
7.262
5.195
4.588
2.730
2.604
2.372
2.340
2.118
2.109
2.098
1.715
1.700
1.685
1.670
0.000
Cbz
N
O
4p
1H NMR
(500 MHz, CDCl3)
4.77
2.05
2.00
2.08
2.10
2.10
2.09
Chemical Shift (ppm)

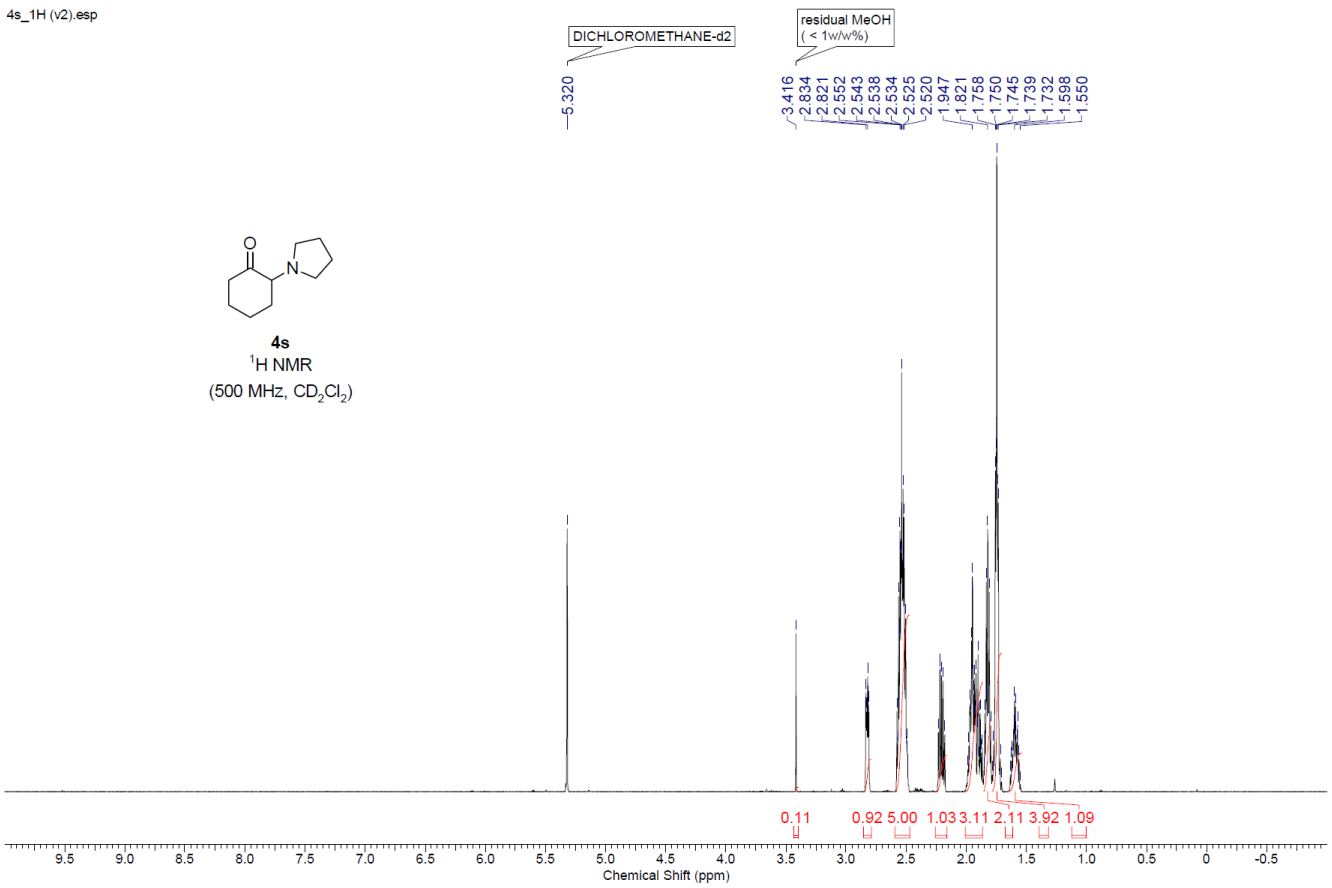

4p_13C.esp
CHLOROFORM-d
207.993
153.670
136.425
128.603
128.248
128.050
77.321
77.000
76.679
67.166
53.095
49.055
48.602
29.272
28.472
Cbz
N
O
4p
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

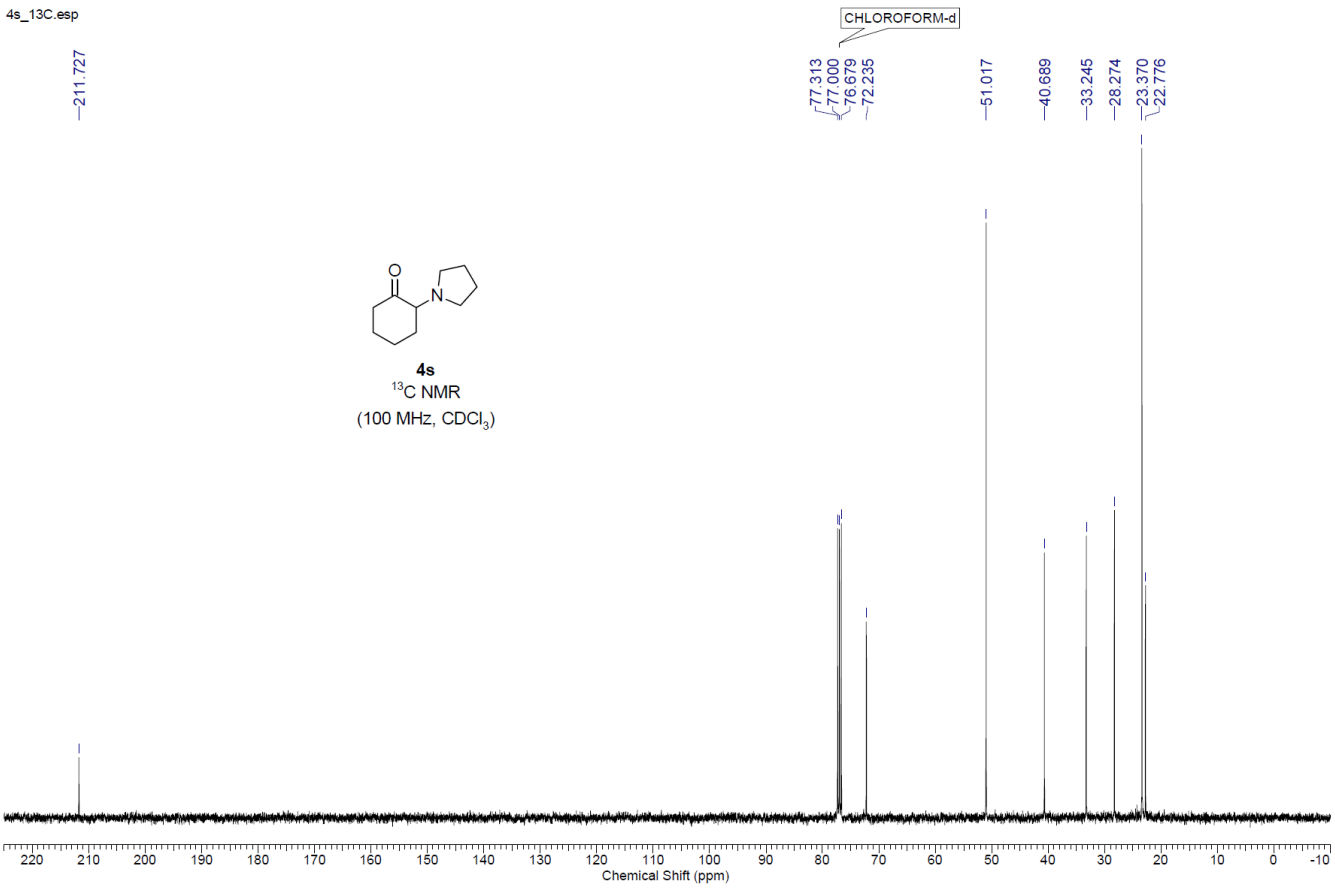

4q_1H.esp
TMS
7.265
7.221
7.204
7.189
4.059
3.631
2.213
0.000
O
N
4q
1H NMR
(400 MHz, CDCl3)
3.80
4.00
2.00
2.94
Chemical Shift (ppm)

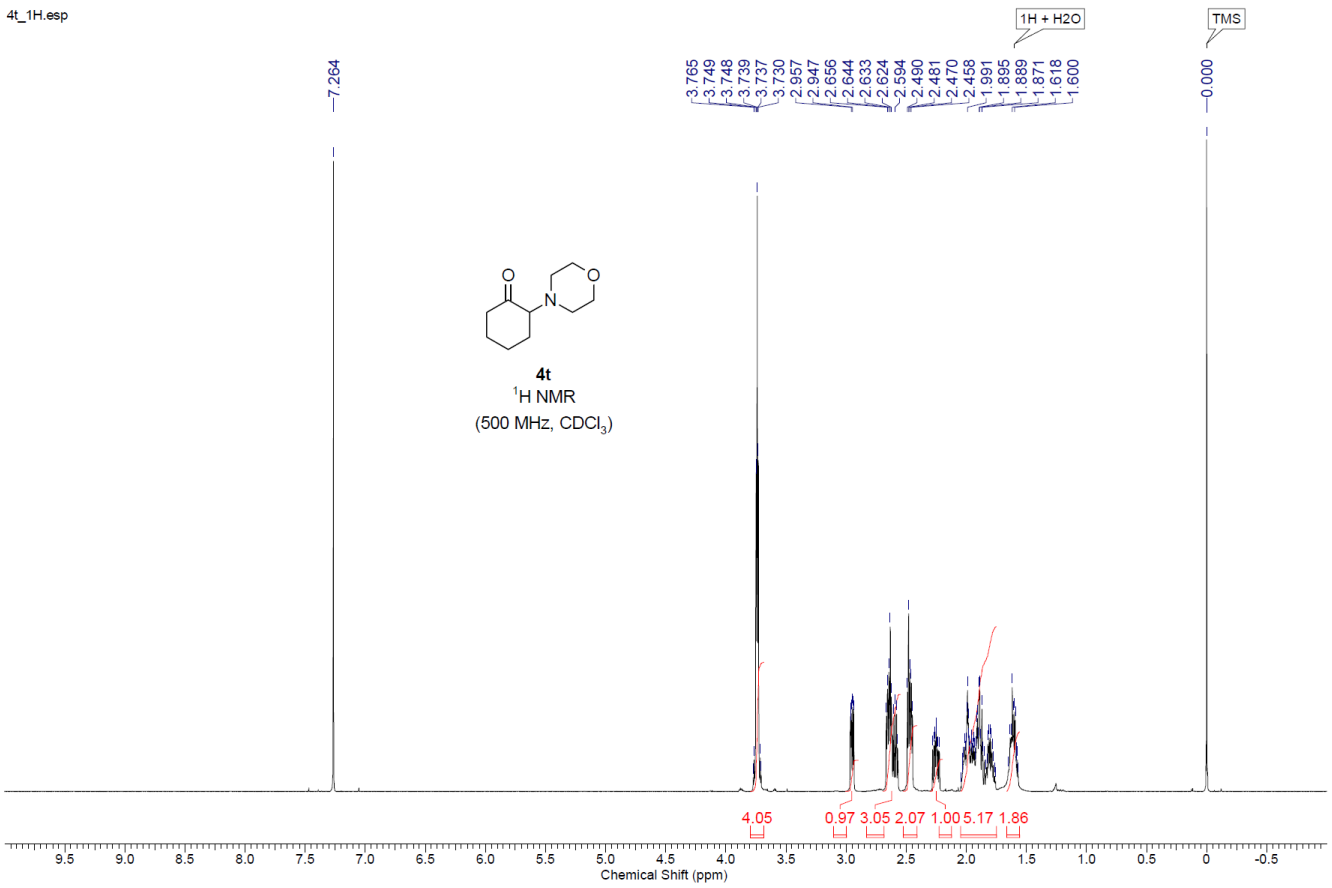

4q_13C.esp
CHLOROFORM-d
206.773
139.715
126.806
122.247
77.321
77.000
76.687
65.575
59.112
27.400
O
N
4q
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4r_1H (v2).esp
TMS
8.009
8.007
7.993
7.990
7.594
7.579
7.564
7.483
7.467
7.455
7.452
7.262
3.821
3.796
3.787
3.778
2.629
2.620
2.611
0.000
4r
1H NMR
(500 MHz, CDCl3)
1.92
0.95
1.93
2.06
4.02
4.00
Chemical Shift (ppm)

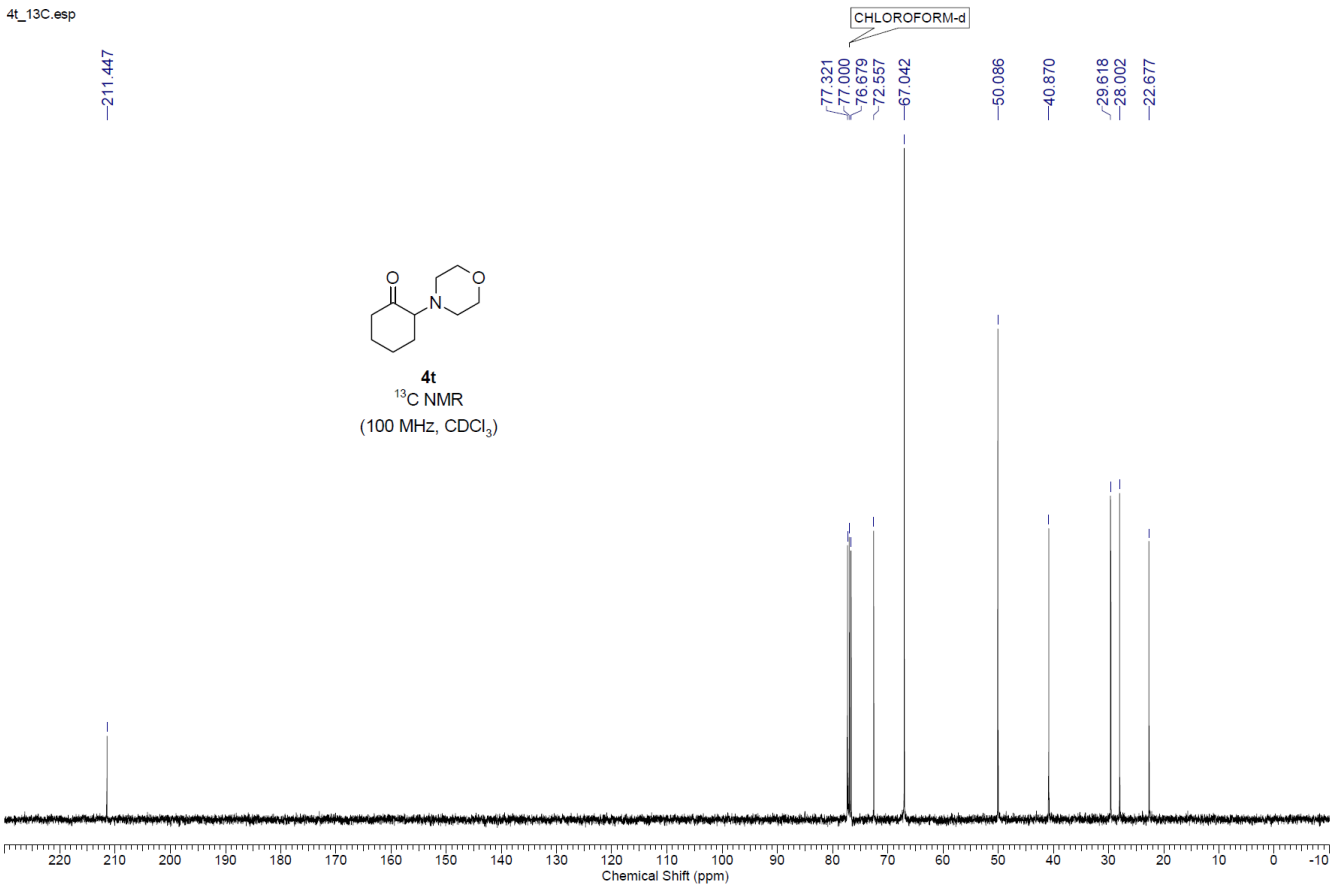

4r_13C.esp
CHLOROFORM-d
196.106
135.890
133.260
128.512
128.001
77.321
77.000
76.679
66.655
64.544
53.705
4r
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


4s_1H (v2).esp
DICHLOROMETHANE-d2
residual MeOH
(< 1w/w%)
5.320
3.416
2.834
2.821
2.552
2.543
2.538
2.534
2.525
2.520
1.947
1.821
1.758
1.750
1.745
1.739
1.732
1.598
1.550
4s
1H NMR
(500 MHz, CD2Cl2)
0.11
0.92
5.00
1.03
3.11
2.11
3.92
1.09
Chemical Shift (ppm)

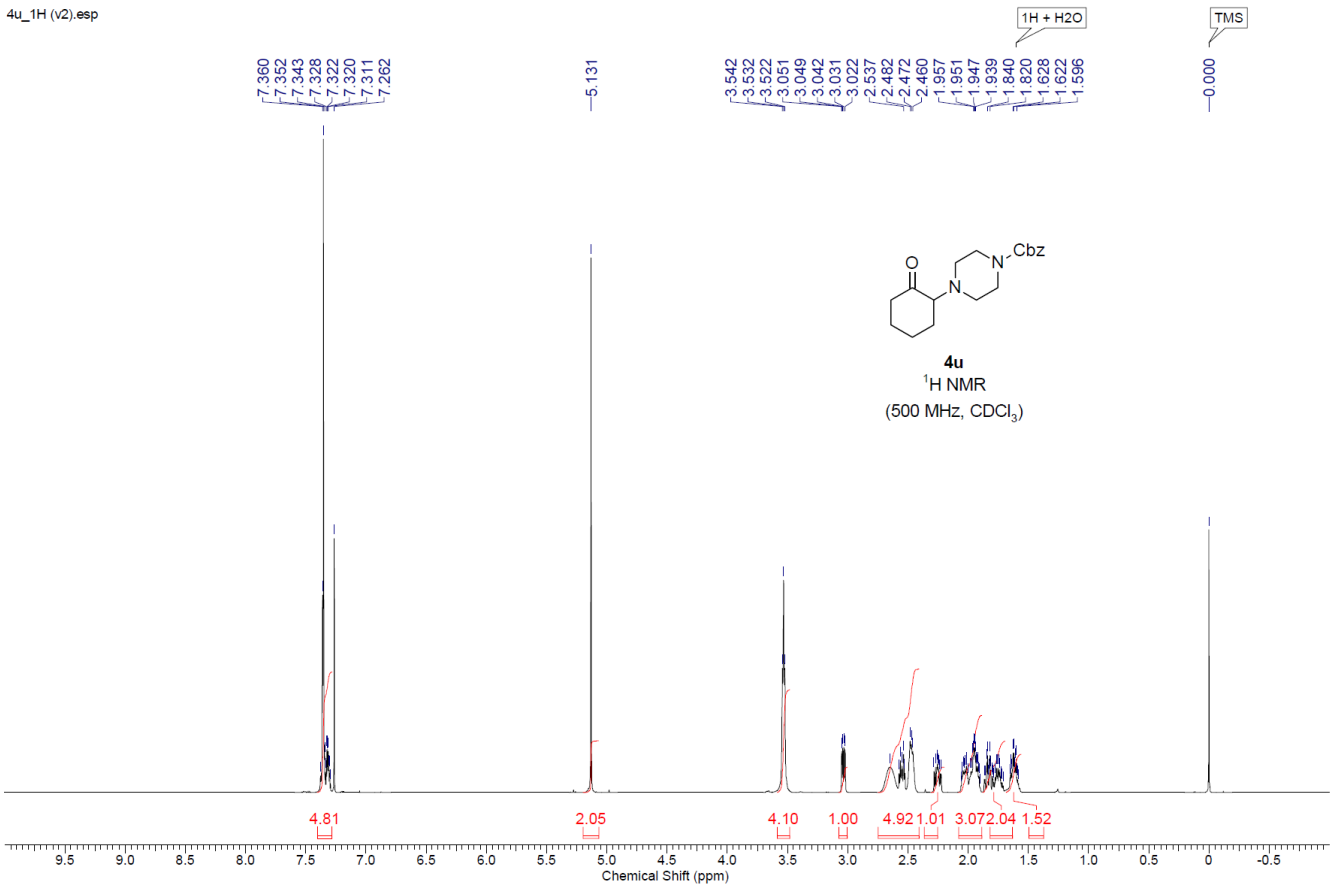

4s_13C.esp
CHLOROFORM-d
211.727
77.313
77.000
76.679
72.235
51.017
40.689
33.245
28.274
23.370
22.776
4s
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

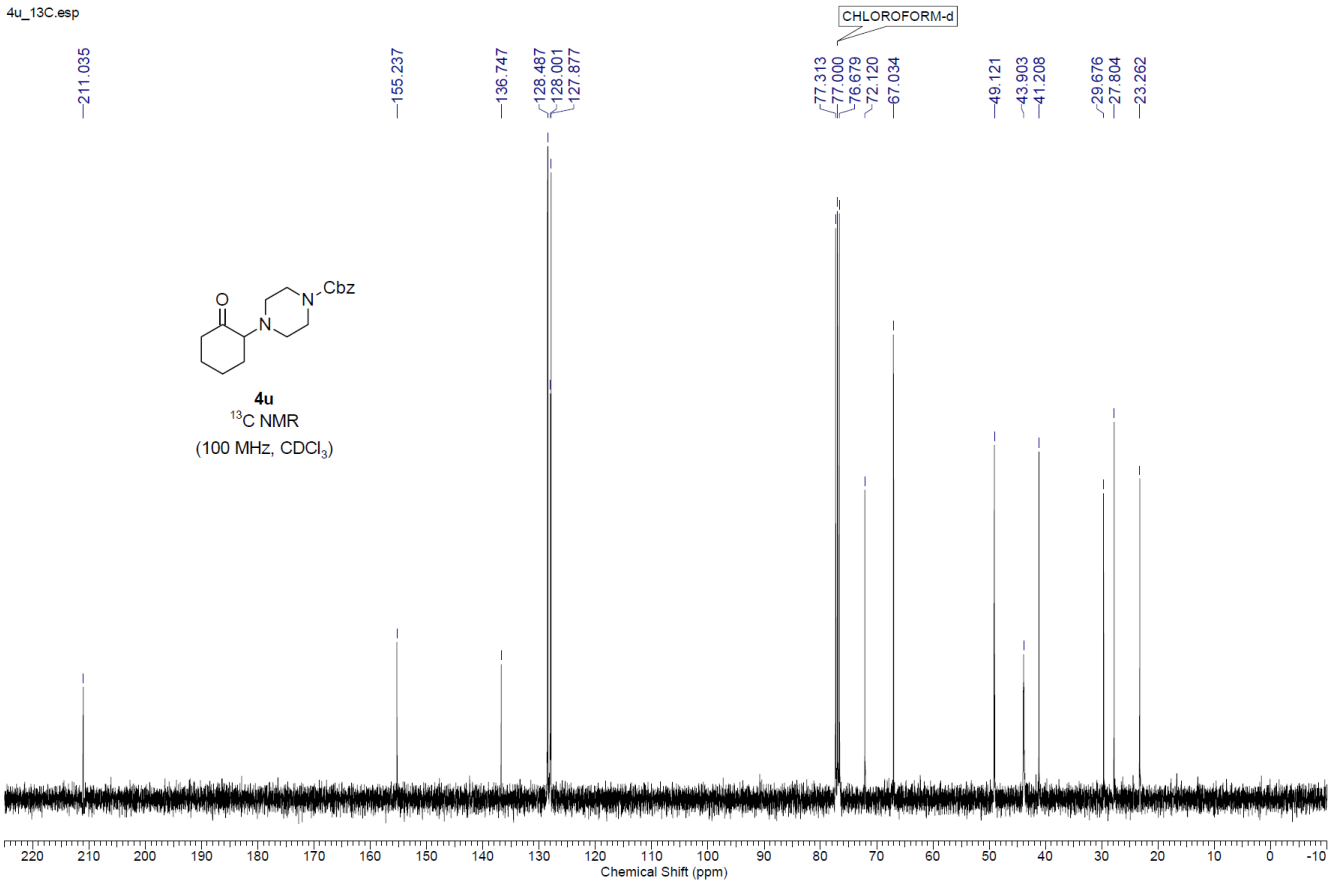


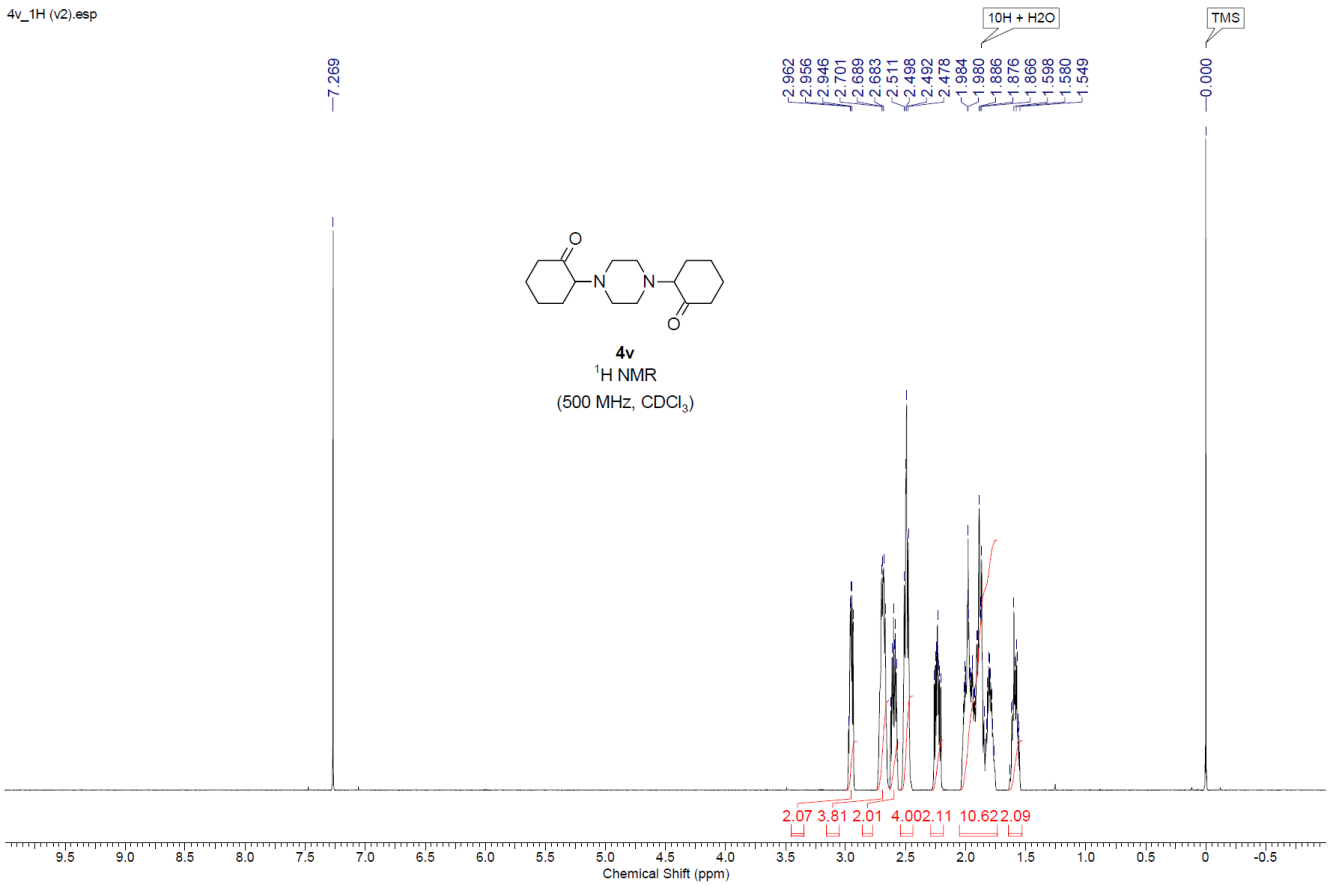
4t
^{1}H NMR
(500 MHz, $CDCl_3$)



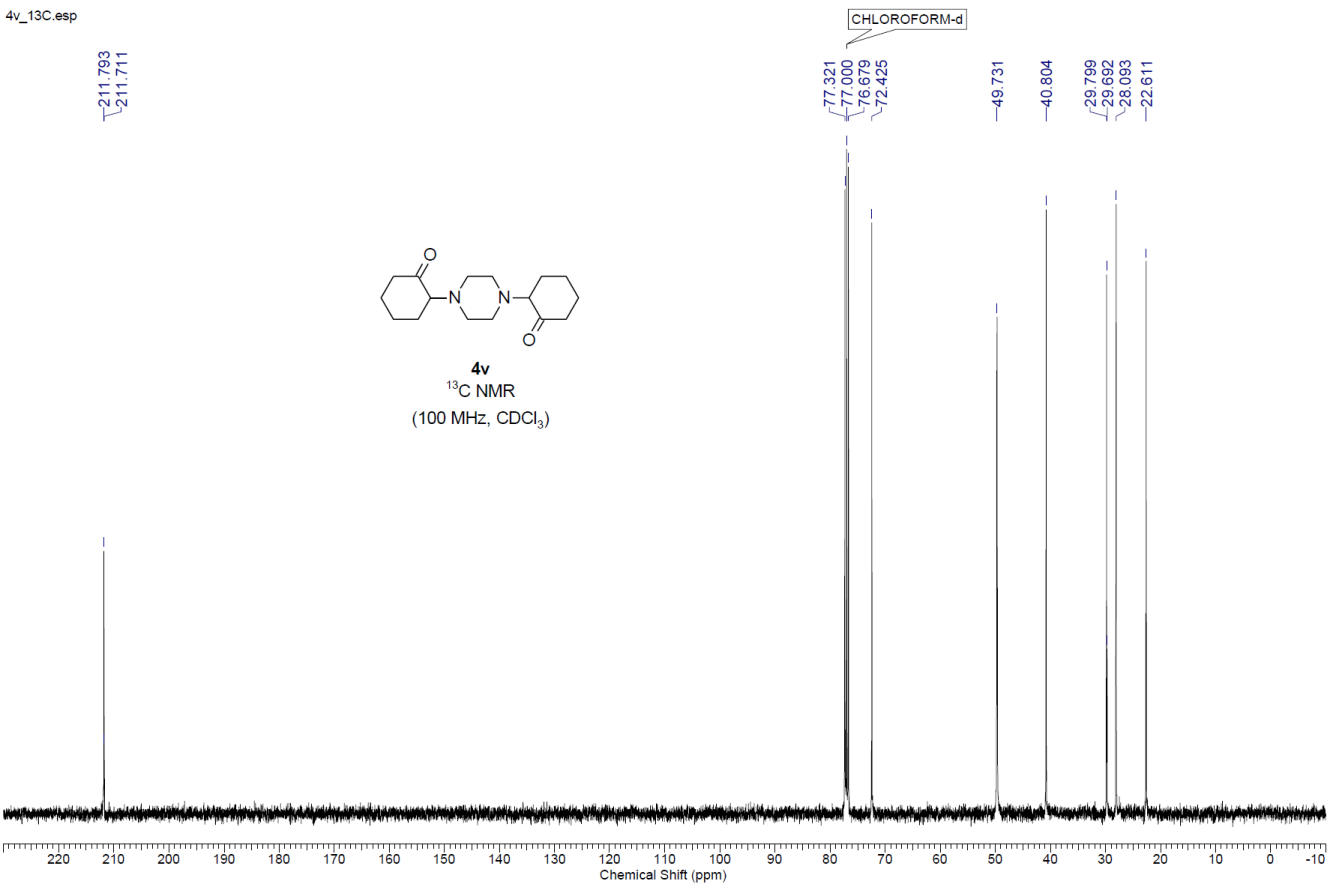
4t
^{13}C NMR
(100 MHz, $CDCl_3$)


4u_1H (v2).esp
1H + H2O
TMS
7.360
7.352
7.343
7.328
7.322
7.320
7.311
7.262
5.131
3.542
3.532
3.522
3.051
3.049
3.042
3.031
3.022
2.537
2.482
2.472
2.460
1.957
1.951
1.947
1.939
1.840
1.820
1.628
1.622
1.596
0.000
Cbz
4u
1H NMR
(500 MHz, CDCl3)
4.81
2.05
4.10
1.00
4.92
1.01
3.07
2.04
1.52
Chemical Shift (ppm)

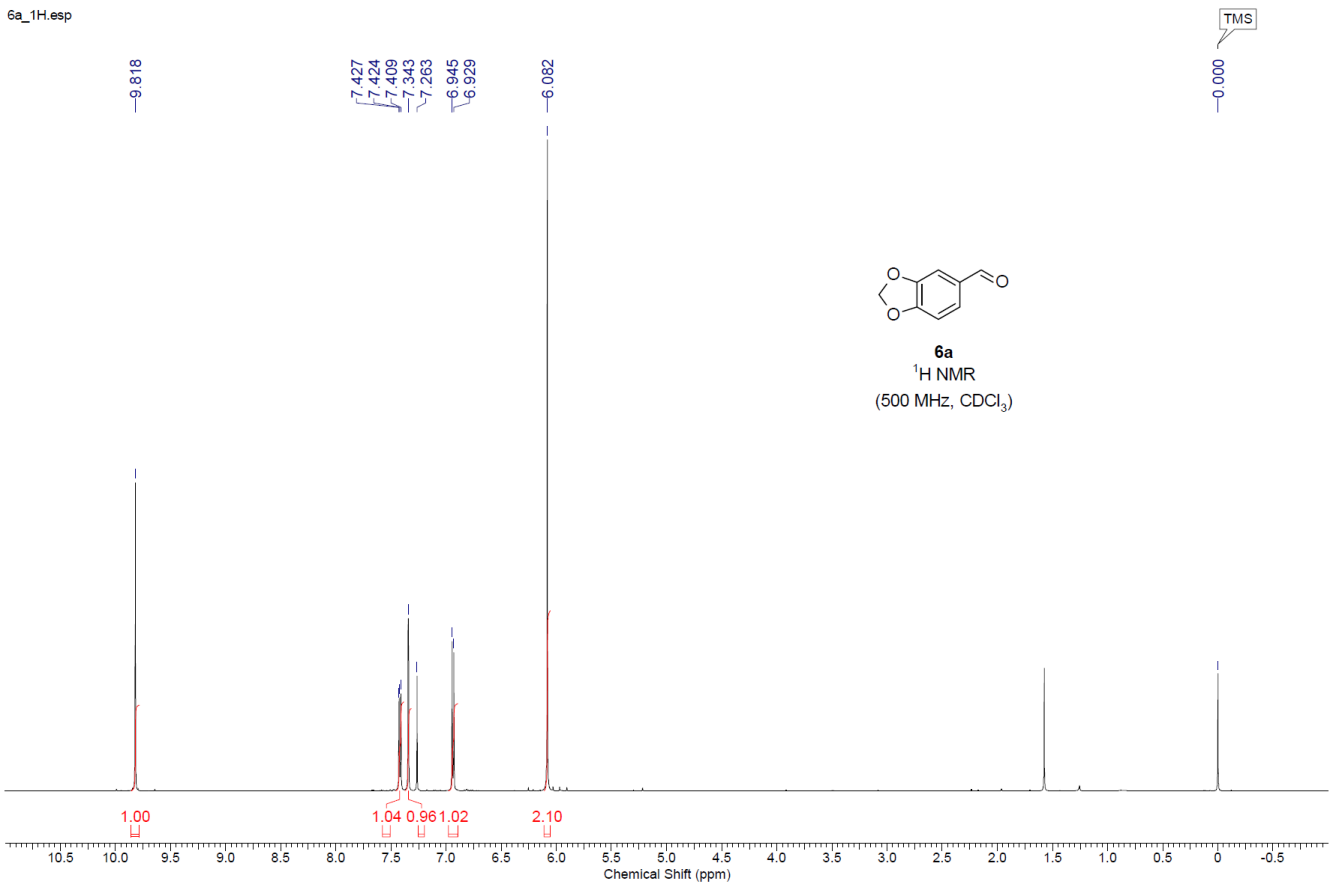

4u_13C.esp
CHLOROFORM-d
211.035
155.237
136.747
128.487
128.001
127.877
77.313
77.000
76.679
72.120
67.034
49.121
43.903
41.208
29.676
27.804
23.262
Cbz
4u
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

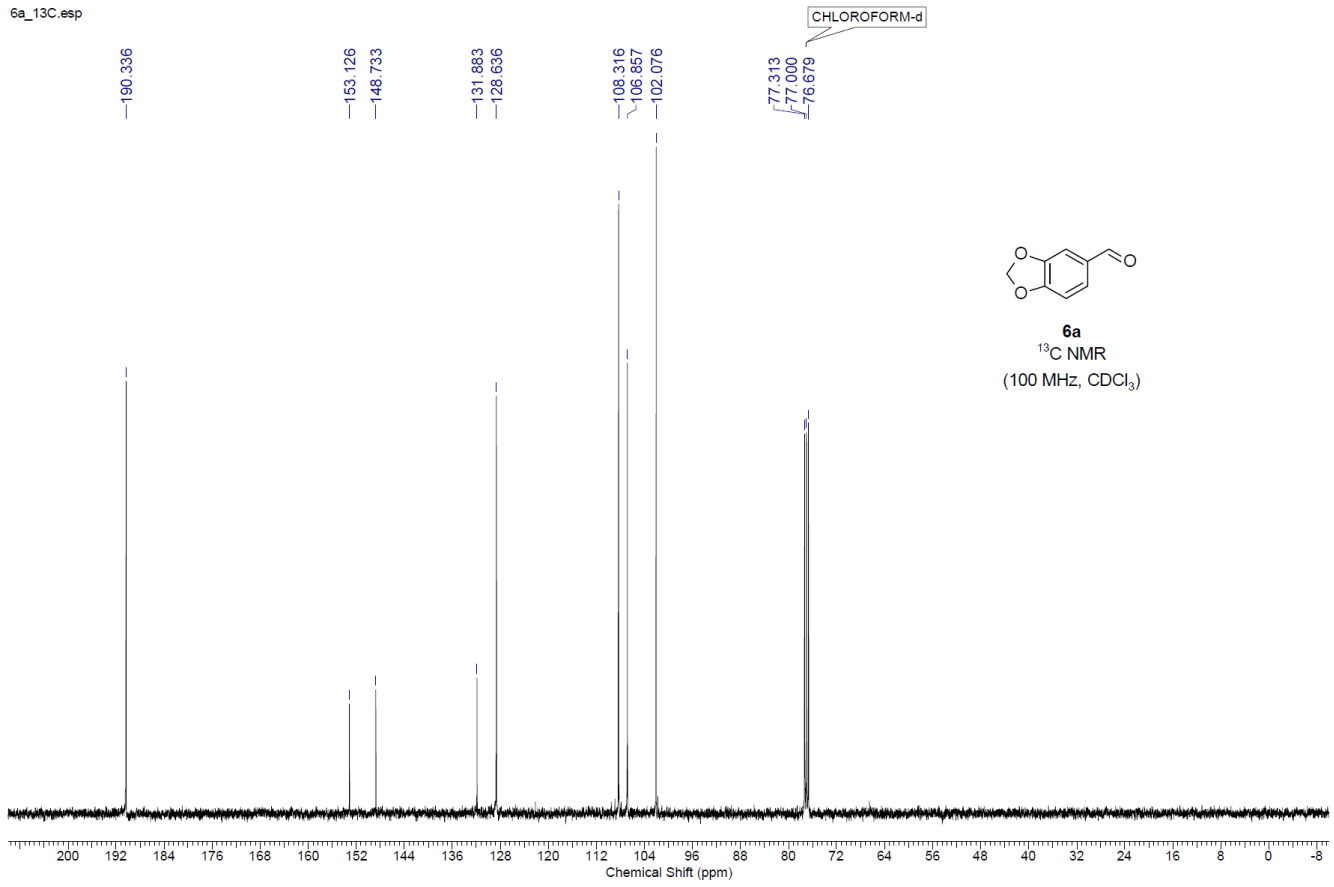


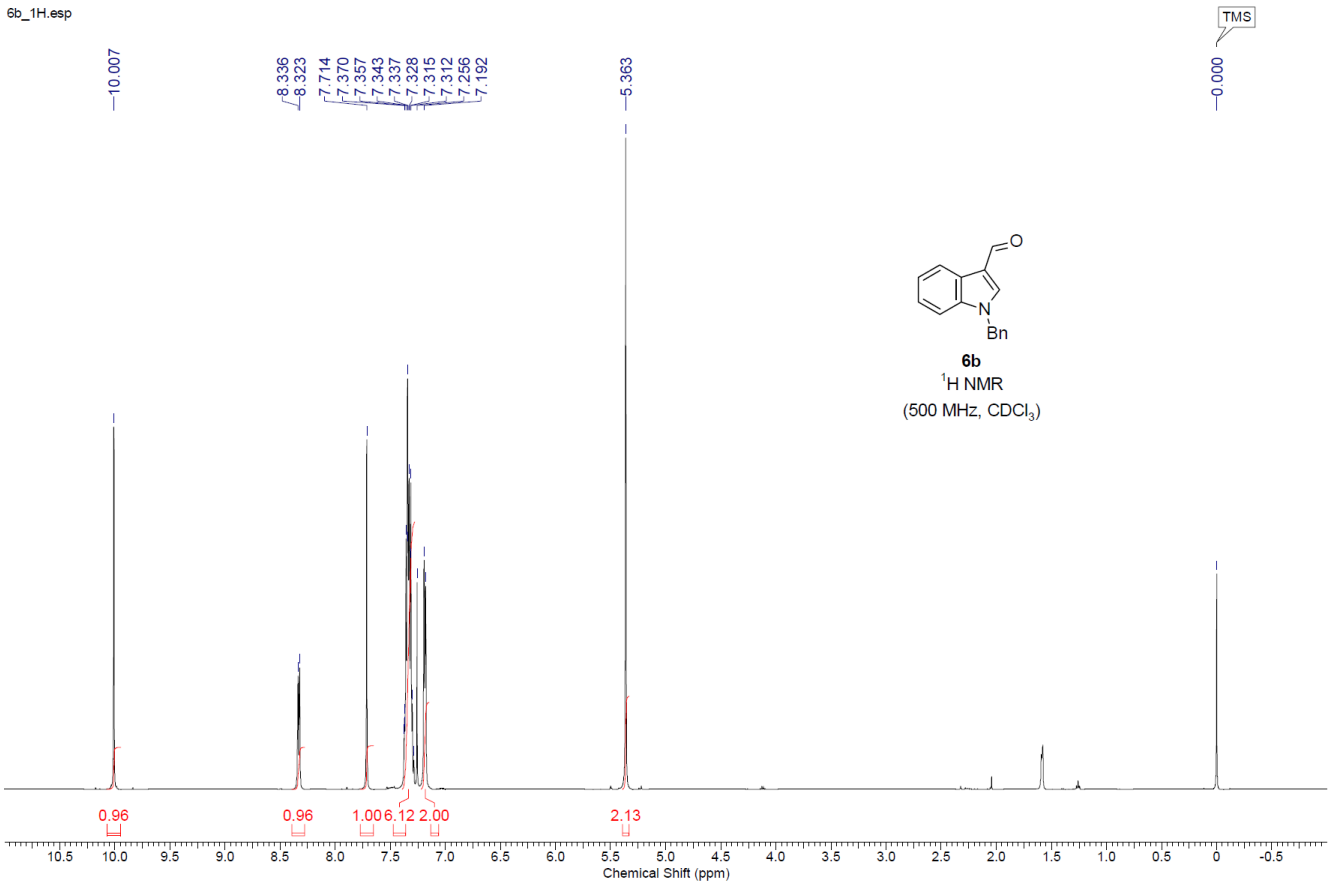
4v
^{1}H NMR
(500 MHz, $CDCl_3$)

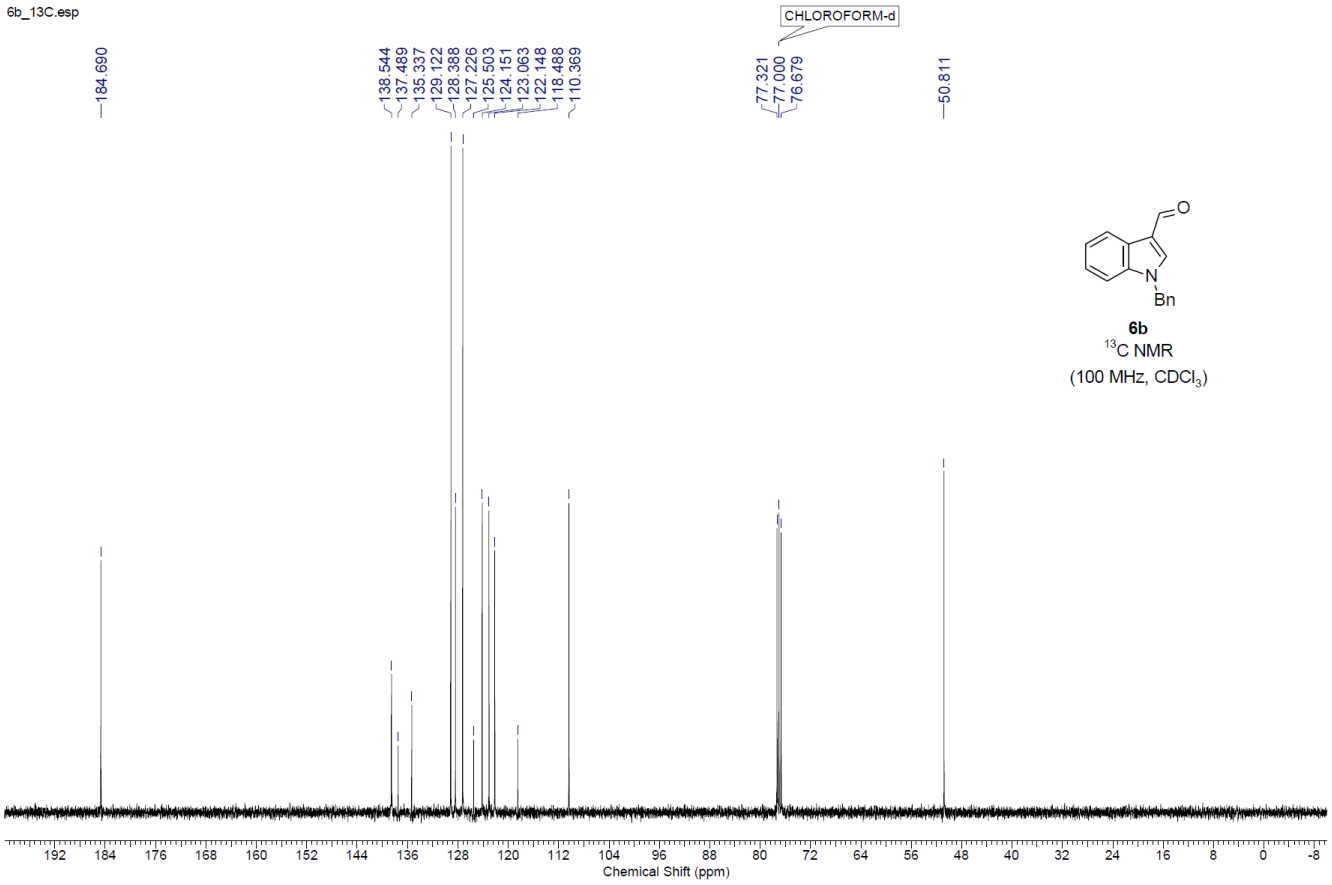


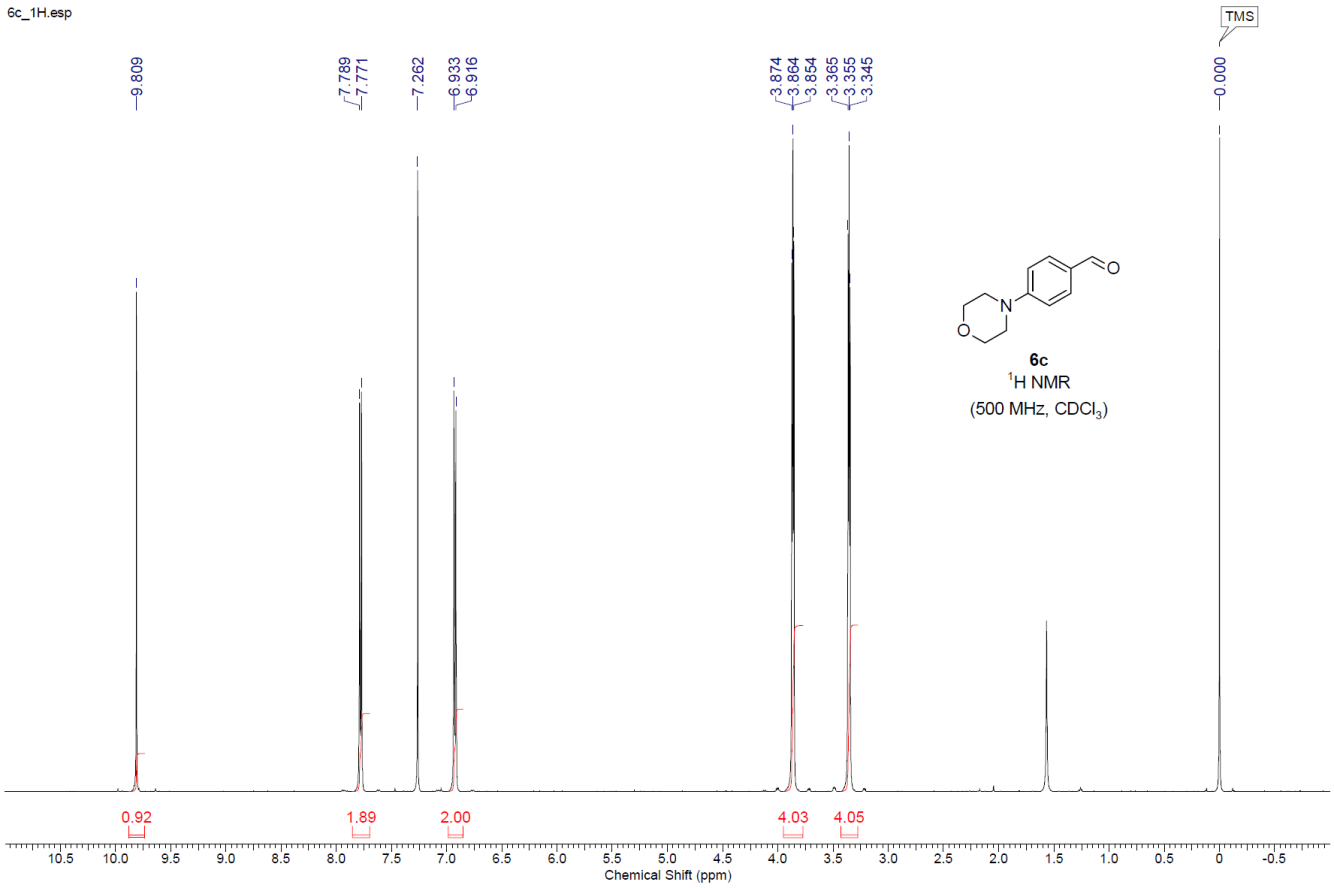
4v
^{13}C NMR
(100 MHz, $CDCl_3$)

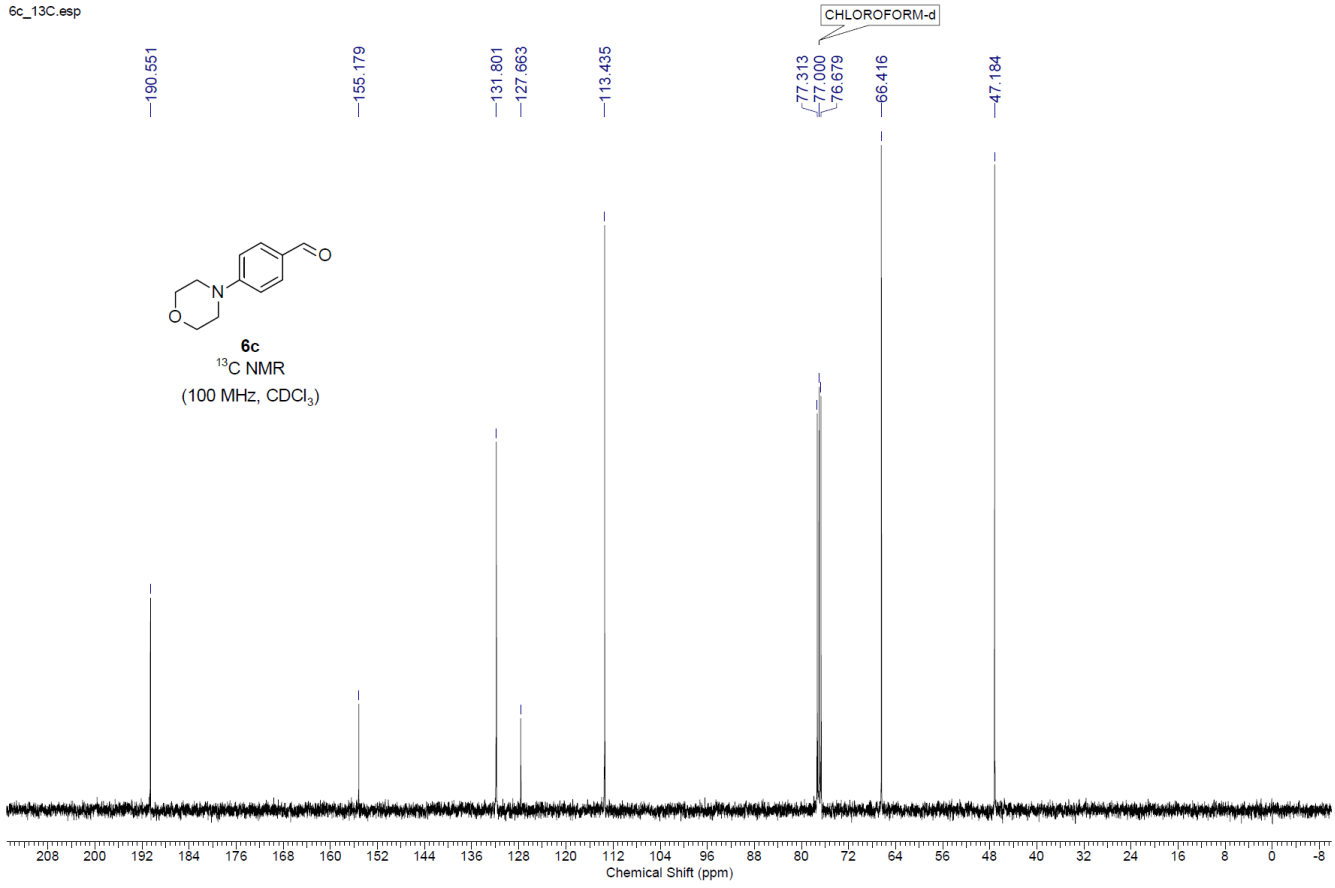

6a_1H.esp
TMS
9.818
7.427
7.424
7.409
7.343
7.263
6.945
6.929
6.082
0.000
1.00
1.04
0.96
1.02
2.10
Chemical Shift (ppm)
6a
1H NMR
(500 MHz, CDCl3)

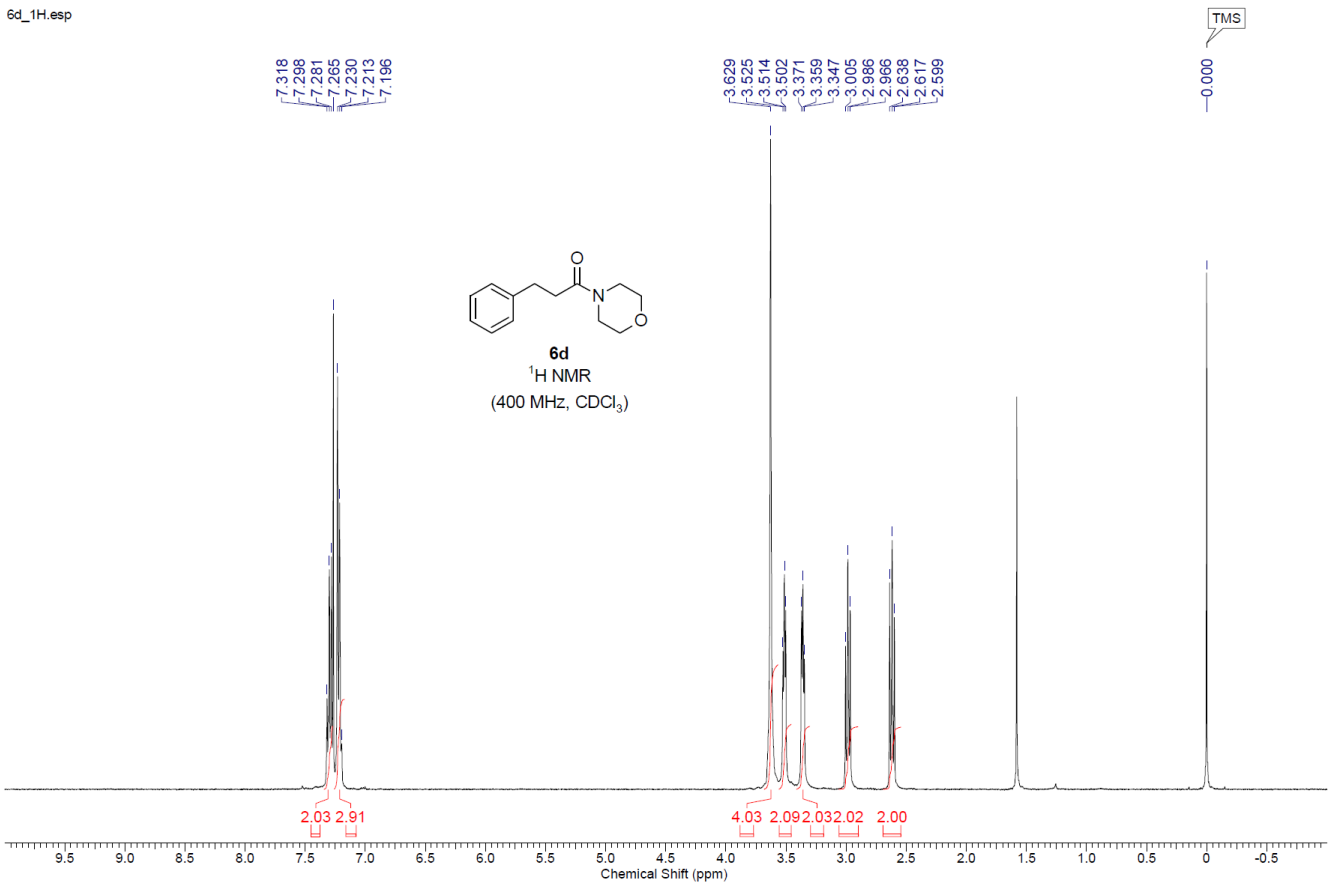

6a_13C.esp
CHLOROFORM-d
190.336
153.126
148.733
131.883
128.636
108.316
106.857
102.076
77.313
77.000
76.679
Chemical Shift (ppm)
6a
13C NMR
(100 MHz, CDCl3)

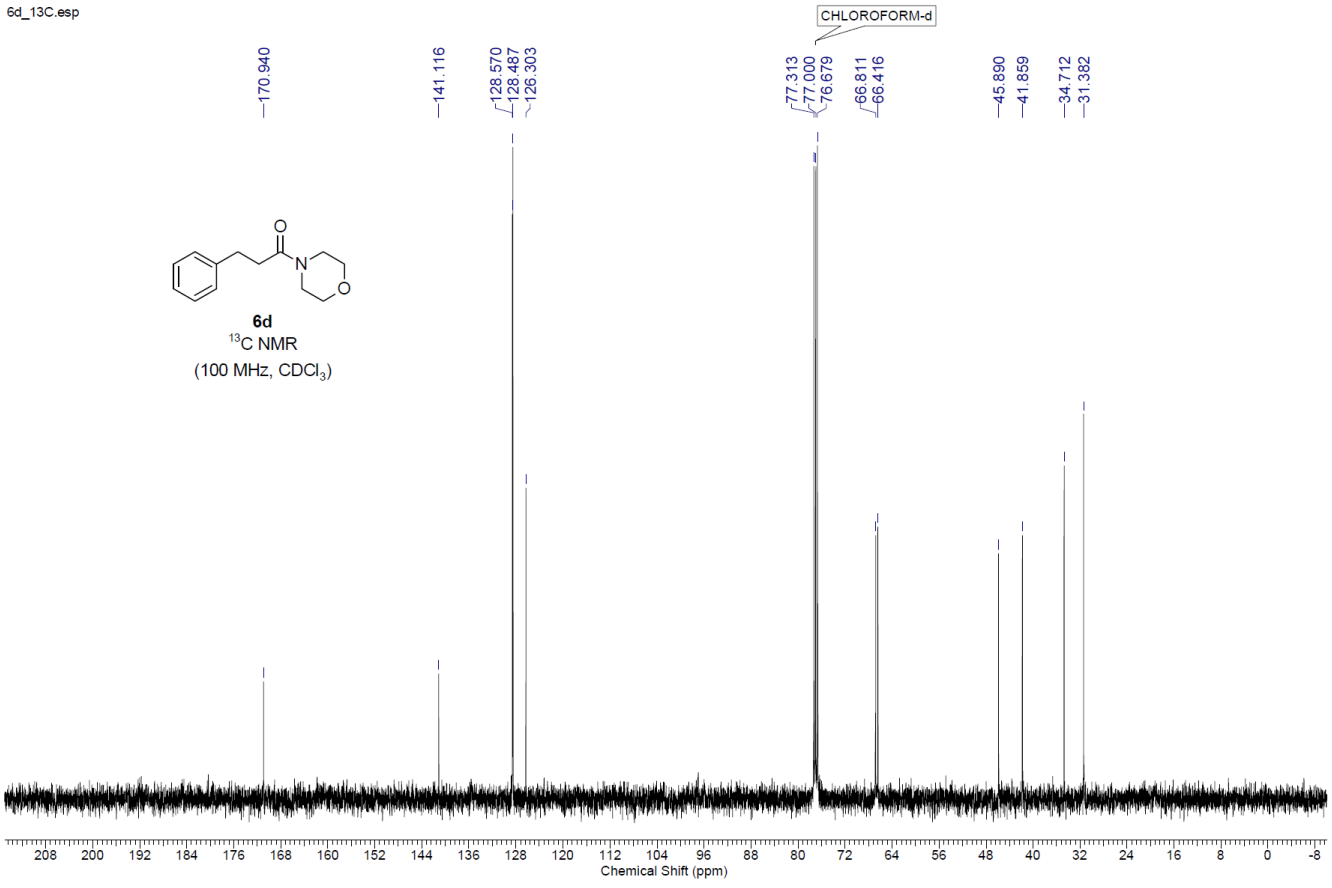

6b_1H.esp
TMS
10.007
8.336
8.323
7.714
7.370
7.357
7.343
7.337
7.328
7.315
7.312
7.256
7.192
5.363
0.000
O
N
Bn
6b
1H NMR
(500 MHz, CDCl3)
0.96
0.96
1.00
6.12
2.00
2.13
Chemical Shift (ppm)

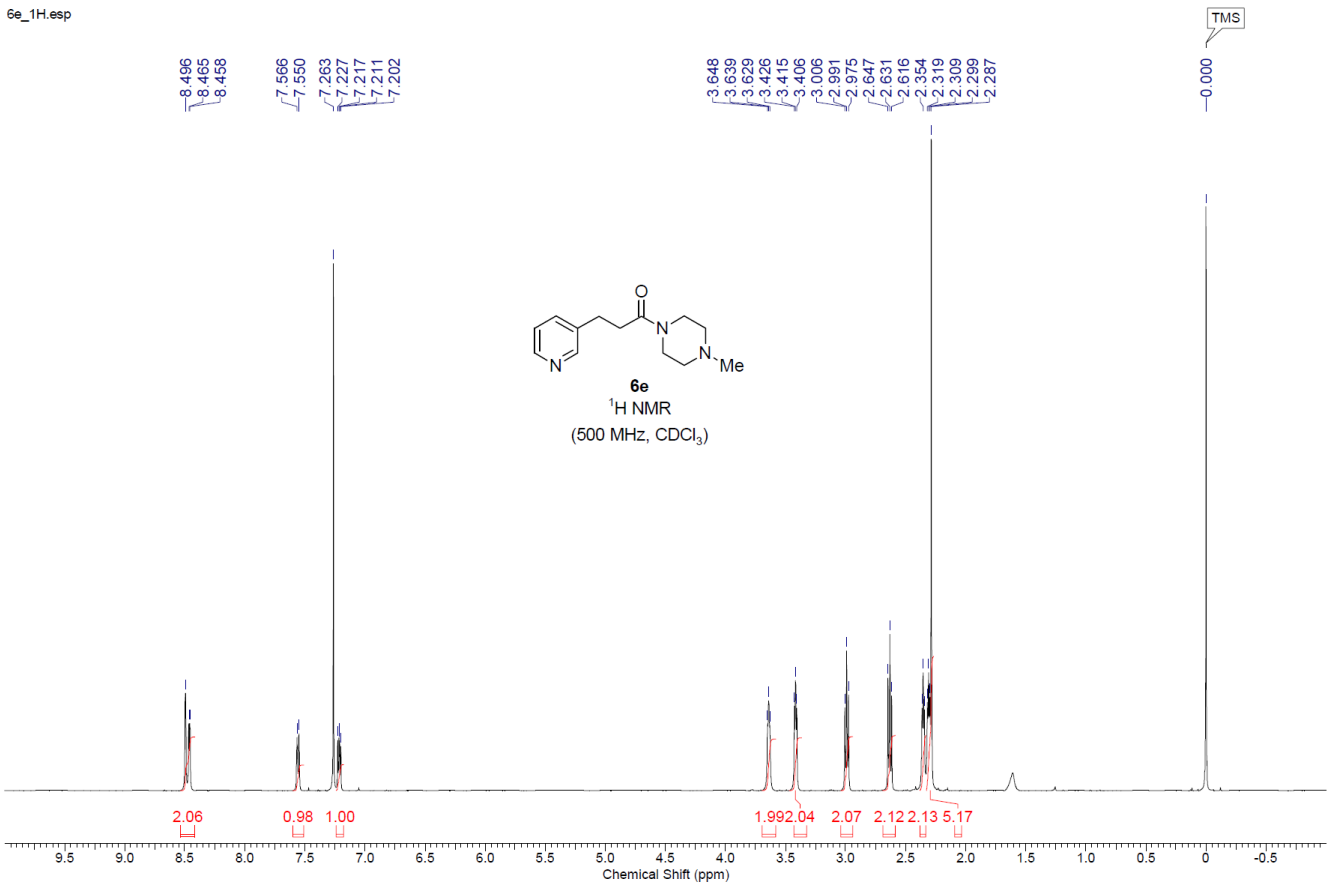

6b_13C.esp
CHLOROFORM-d
184.690
138.544
137.489
135.337
129.122
128.388
127.226
125.503
124.151
123.063
122.148
118.488
110.369
77.321
77.000
76.679
50.811
O
N
Bn
6b
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

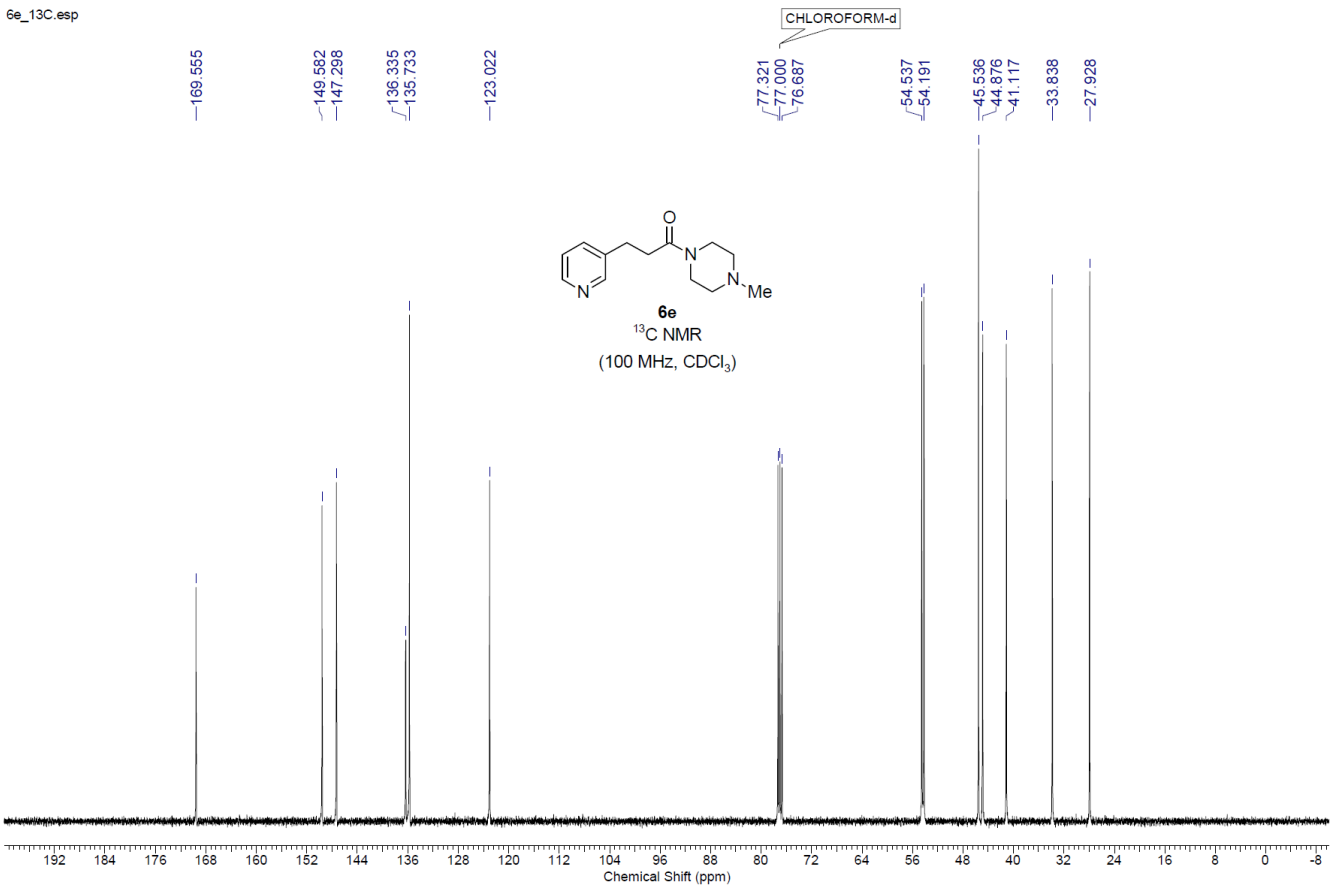

6c_1H.esp
TMS
9.809
7.789
7.771
7.262
6.933
6.916
3.874
3.864
3.854
3.365
3.355
3.345
0.000
0.92
1.89
2.00
4.03
4.05
Chemical Shift (ppm)
6c
1H NMR
(500 MHz, CDCl3)

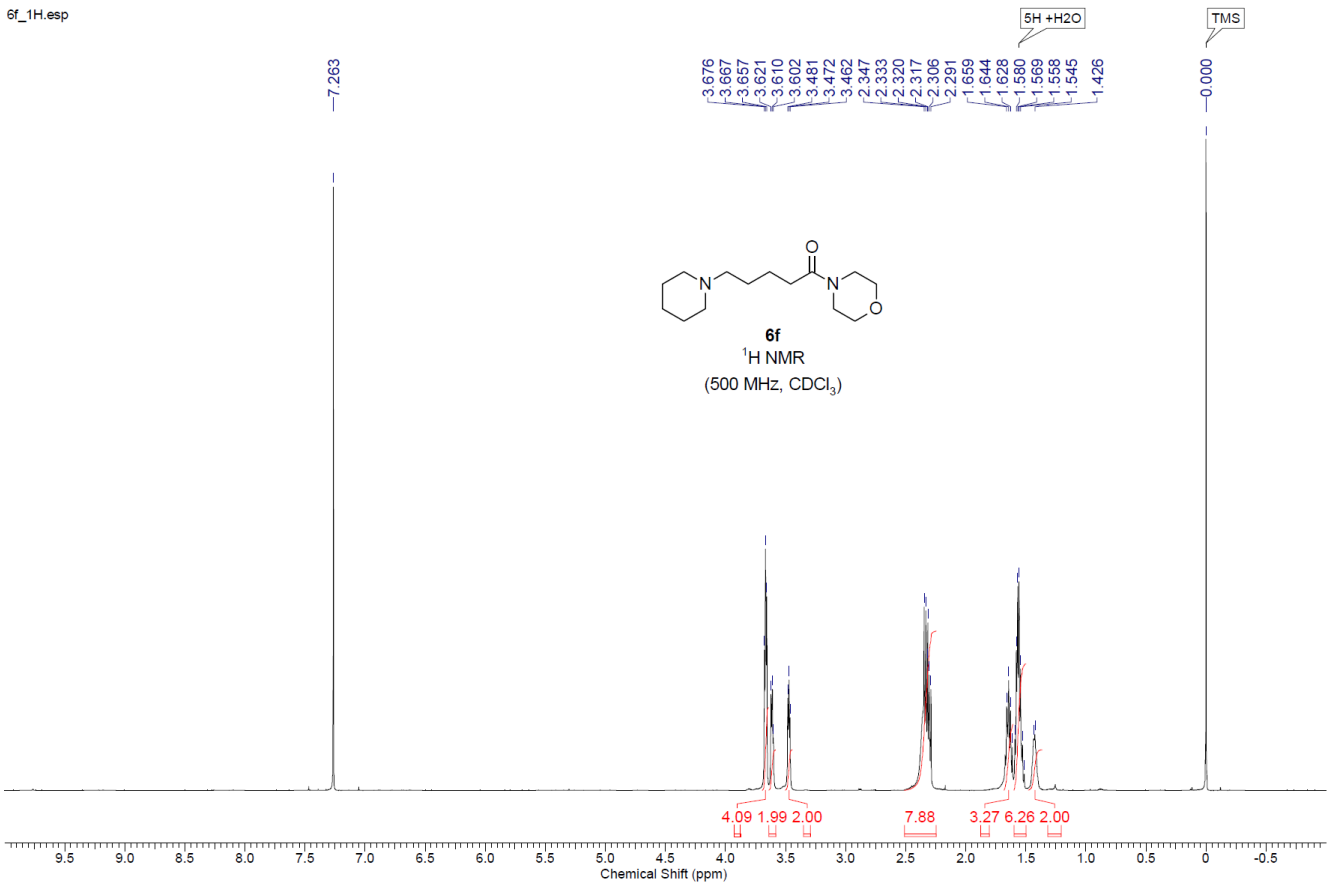

6c_13C.esp
CHLOROFORM-d
190.551
155.179
131.801
127.663
113.435
77.313
77.000
76.679
66.416
47.184
Chemical Shift (ppm)
6c
13C NMR
(100 MHz, CDCl3)

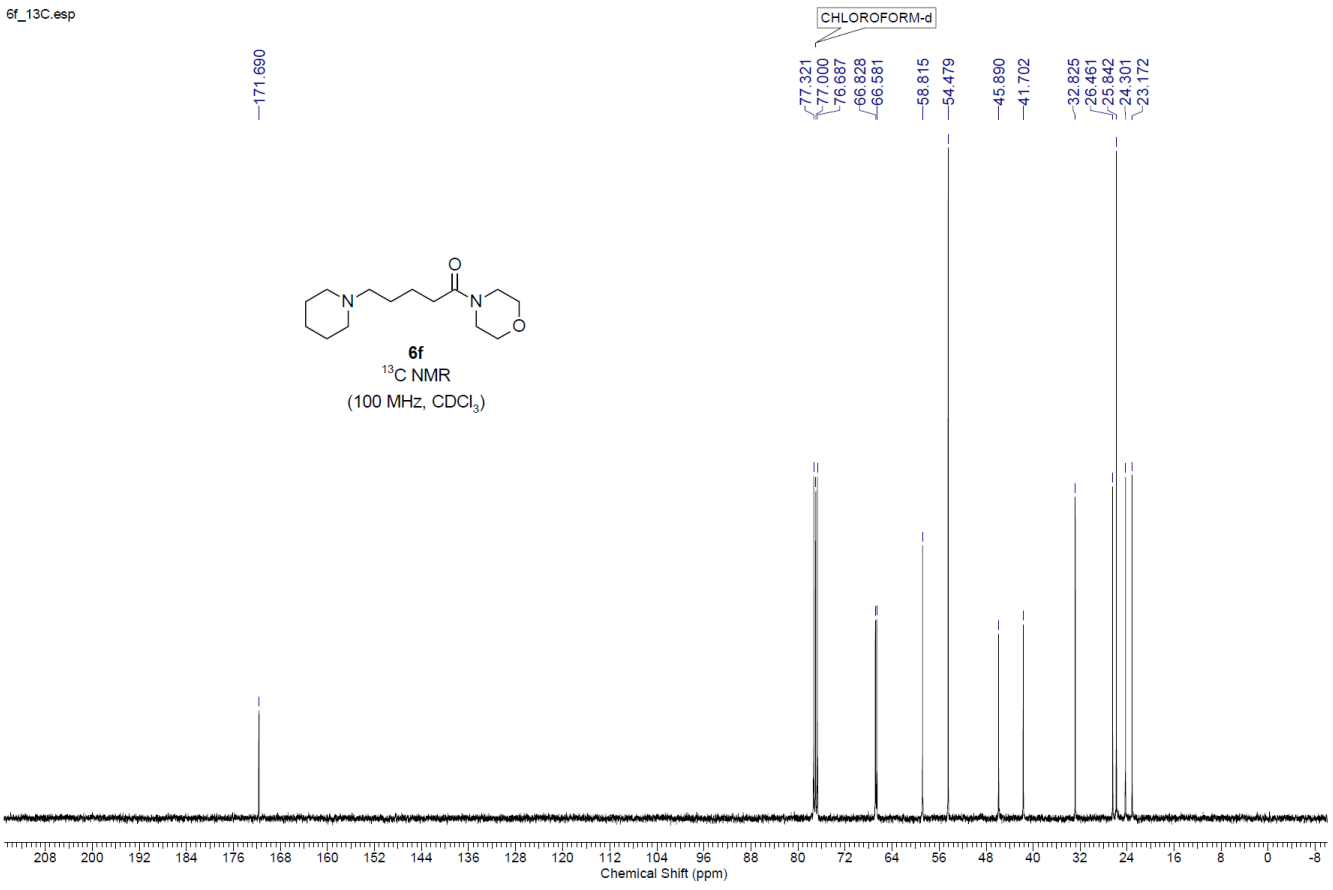

6d_1H.esp
TMS
7.318
7.298
7.281
7.265
7.230
7.213
7.196
3.629
3.525
3.514
3.502
3.371
3.359
3.347
3.005
2.986
2.966
2.638
2.617
2.599
0.000
6d
1H NMR
(400 MHz, CDCl3)
2.03 2.91
4.03 2.09 2.03 2.02 2.00
Chemical Shift (ppm)

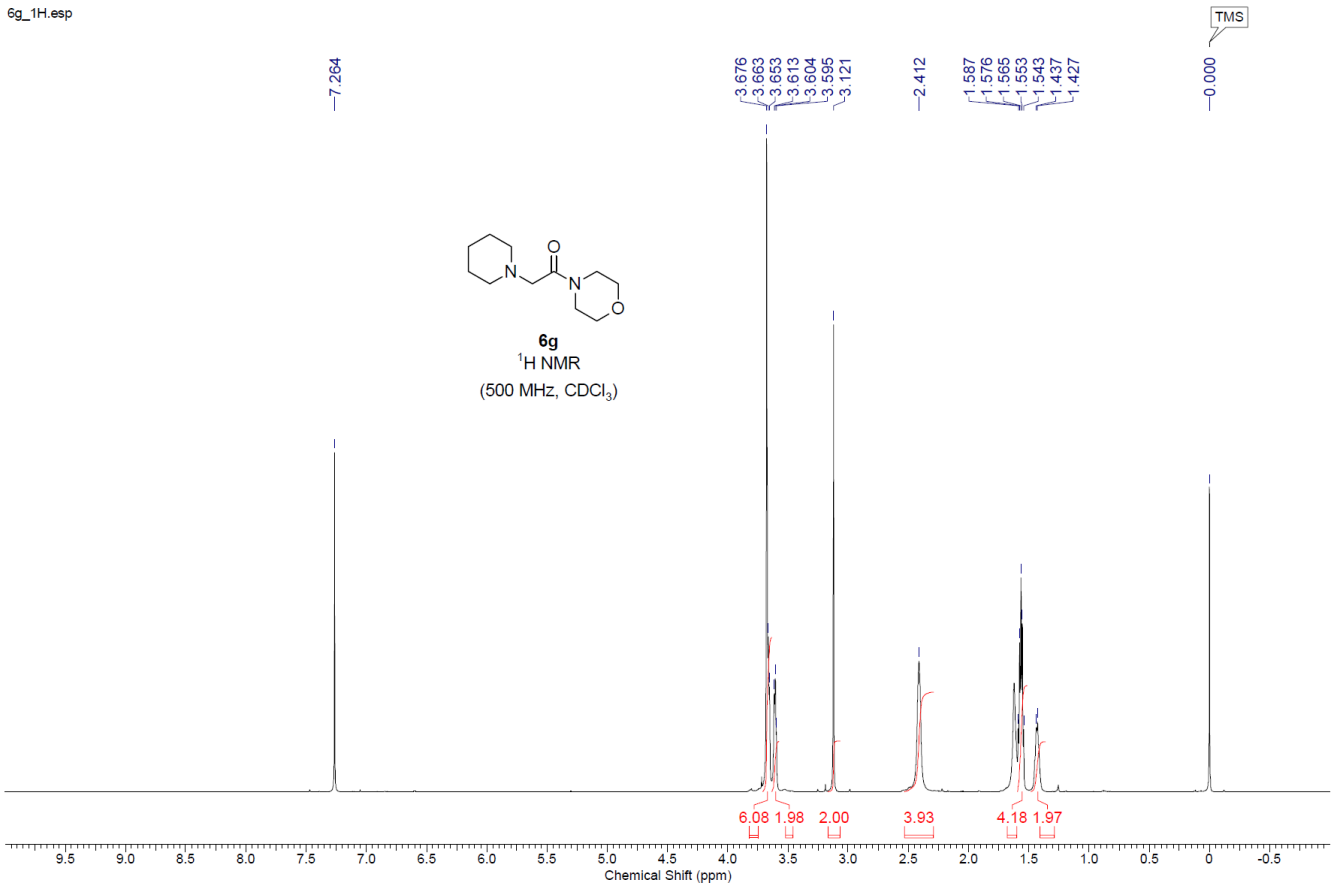

6d_13C.esp
CHLOROFORM-d
170.940
141.116
128.570
128.487
126.303
77.313
77.000
76.679
66.811
66.416
45.890
41.859
34.712
31.382
6d
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

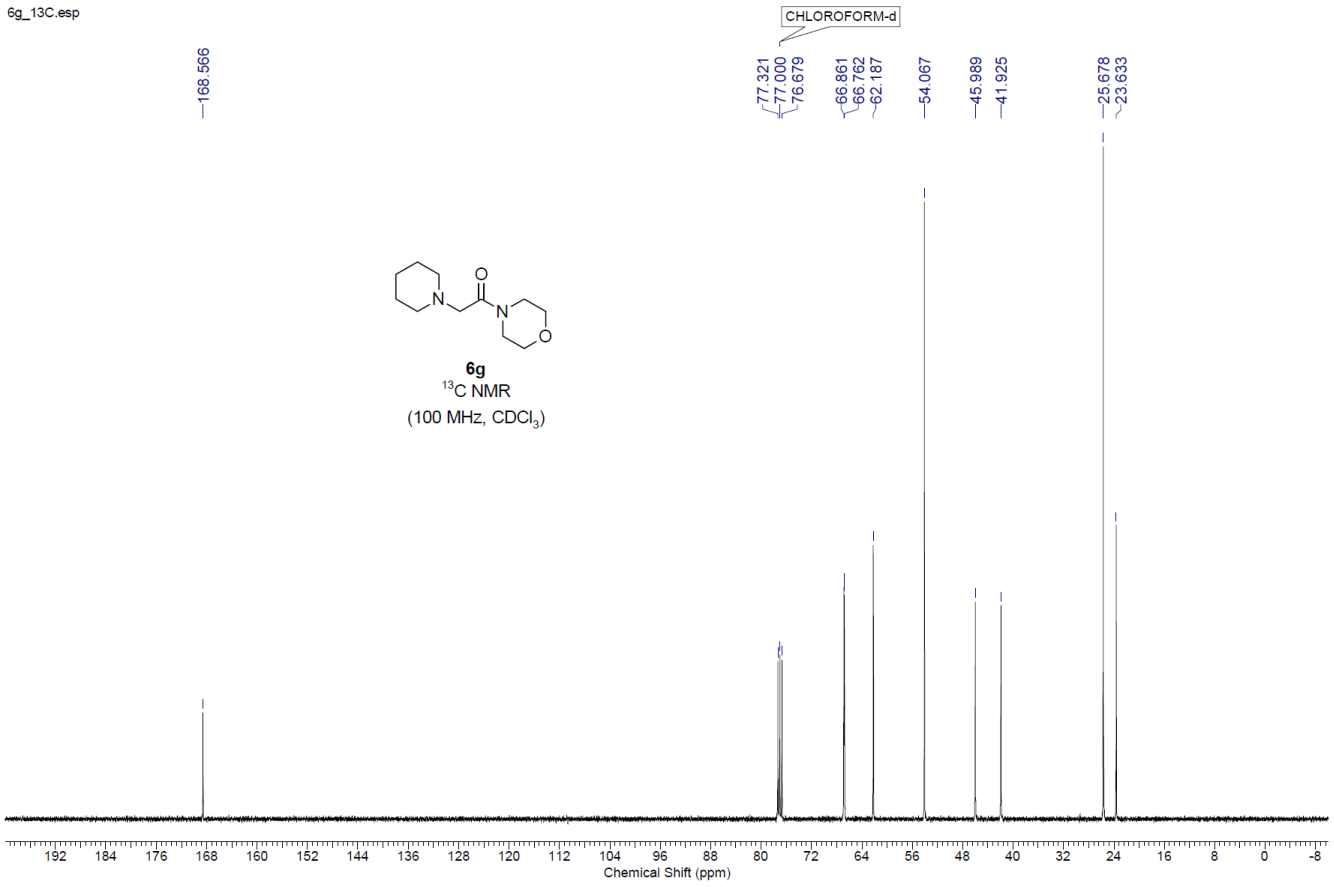

6e_1H.esp
TMS
8.496
8.465
8.458
7.566
7.550
7.263
7.227
7.217
7.211
7.202
3.648
3.639
3.629
3.426
3.415
3.406
3.006
2.991
2.975
2.647
2.631
2.616
2.354
2.319
2.309
2.299
2.287
0.000
O
N
N
Me
6e
1H NMR
(500 MHz, CDCl3)
2.06
0.98
1.00
1.99
2.04
2.07
2.12
2.13
5.17
Chemical Shift (ppm)

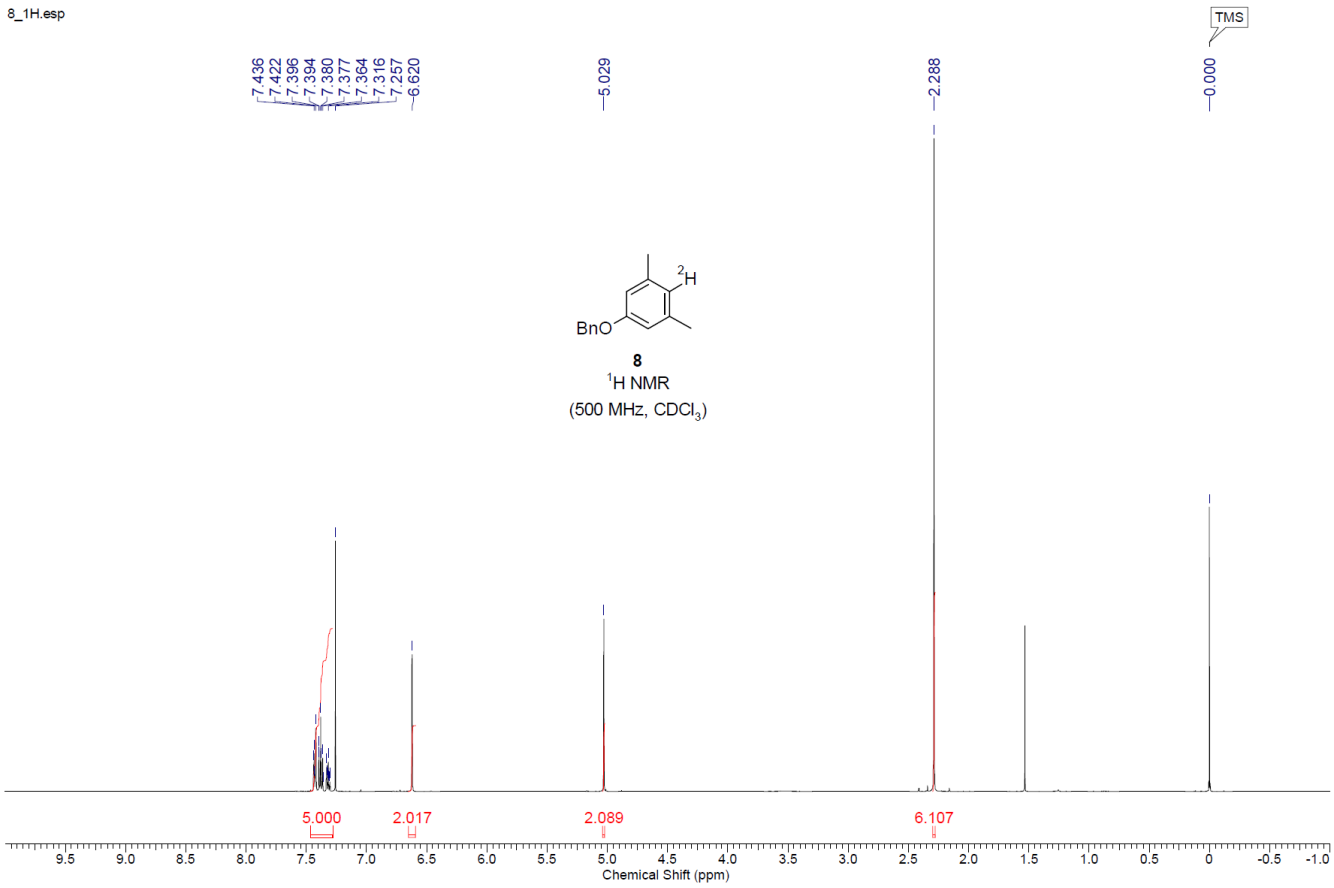

6e_13C.esp
CHLOROFORM-d
169.555
149.582
147.298
136.335
135.733
123.022
77.321
77.000
76.687
54.537
54.191
45.536
44.876
41.117
33.838
27.928
O
N
N
Me
6e
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

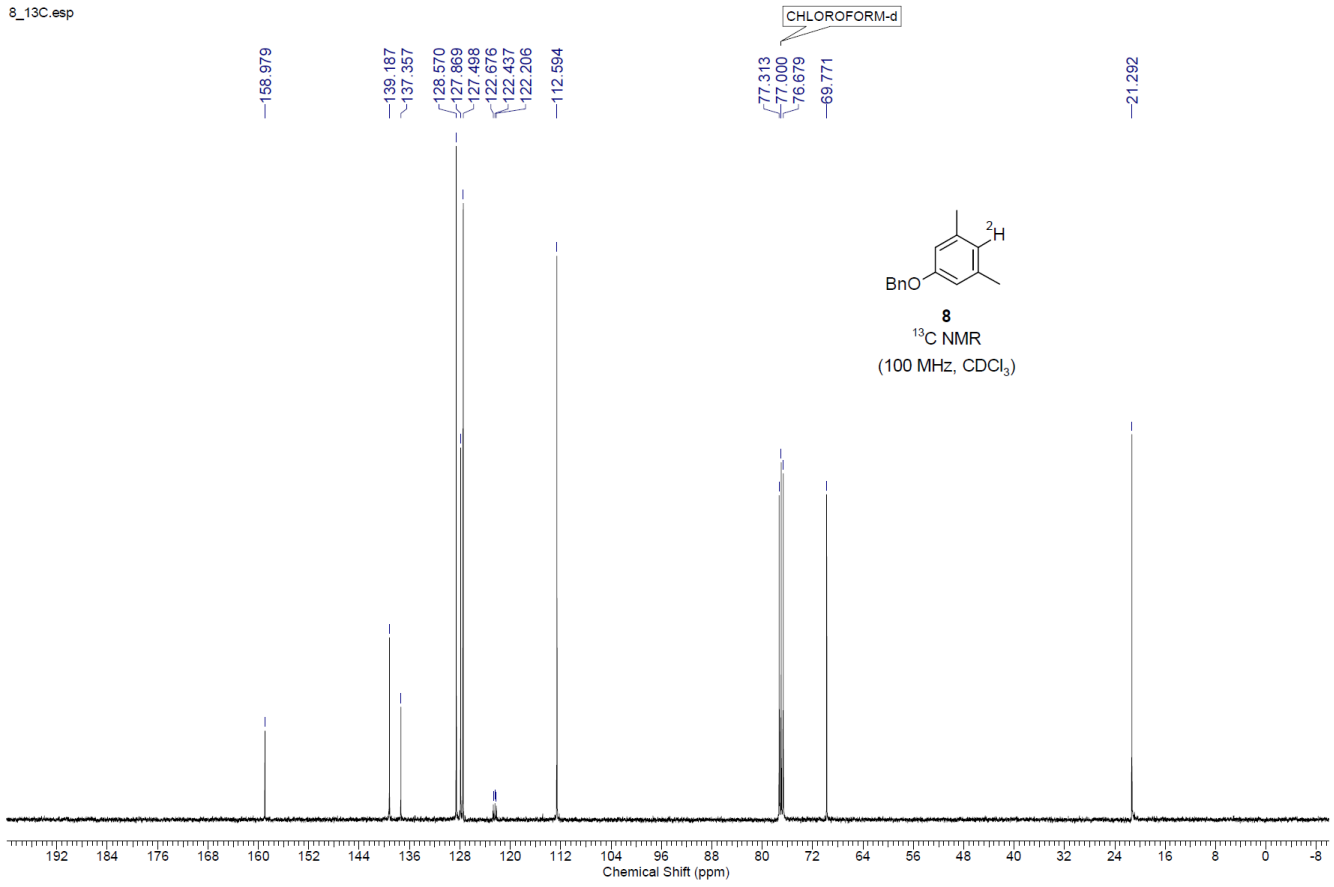

6f_1H.esp
5H +H2O
TMS
7.263
3.676
3.667
3.657
3.621
3.610
3.602
3.481
3.472
3.462
2.347
2.333
2.320
2.317
2.306
2.291
1.659
1.644
1.628
1.580
1.569
1.558
1.545
1.426
0.000
6f
1H NMR
(500 MHz, CDCl3)
4.09 1.99 2.00
7.88
3.27 6.26 2.00
Chemical Shift (ppm)

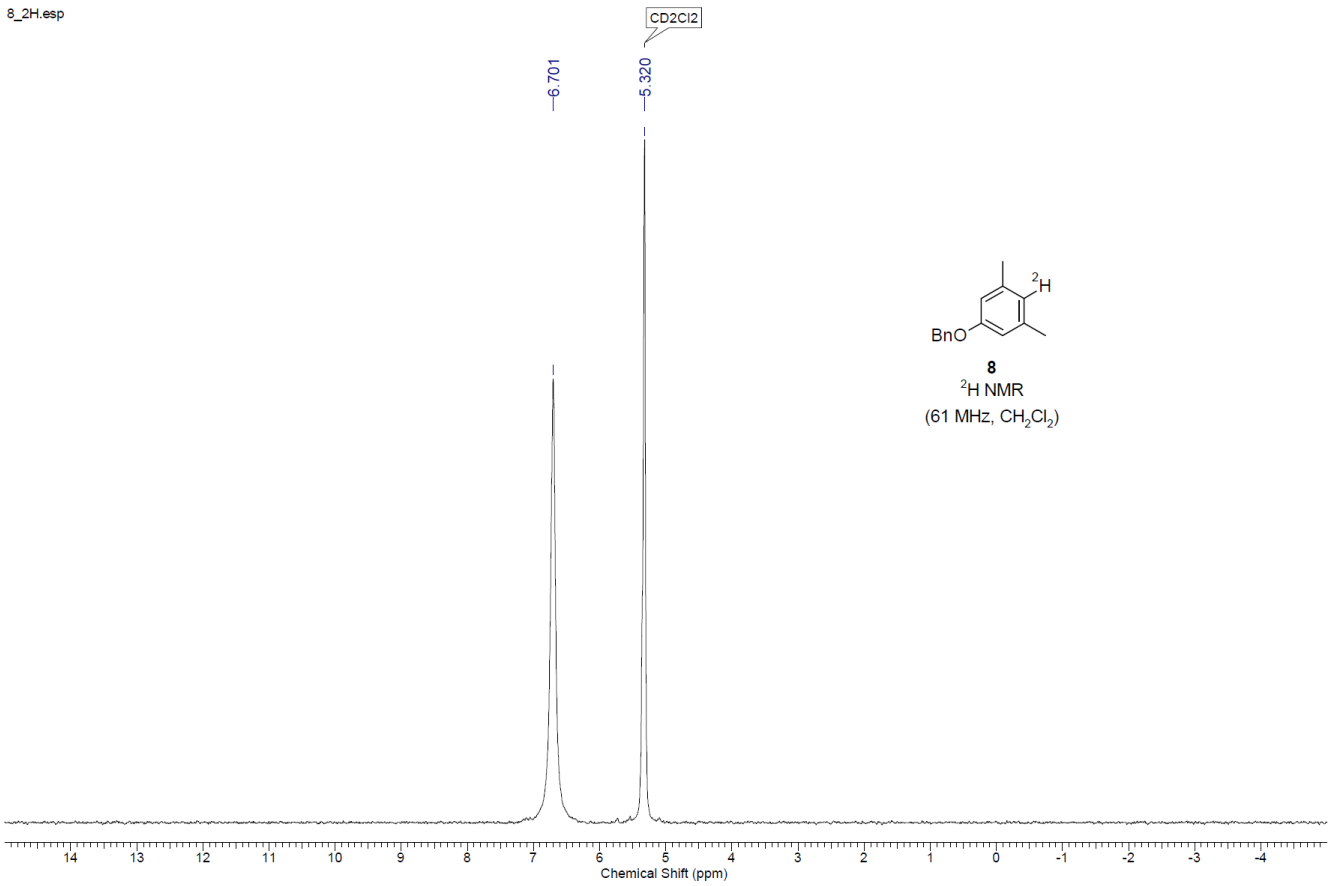

6f_13C.esp
CHLOROFORM-d
171.690
77.321
77.000
76.687
66.828
66.581
58.815
54.479
45.890
41.702
32.825
26.461
25.842
24.301
23.172
6f
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


6g_1H.esp
TMS
7.264
3.676
3.663
3.653
3.613
3.604
3.595
3.121
2.412
1.587
1.576
1.565
1.553
1.543
1.437
1.427
0.000
6g
1H NMR
(500 MHz, CDCl3)
6.08 1.98 2.00 3.93 4.18 1.97
Chemical Shift (ppm)


6g_13C.esp
CHLOROFORM-d
168.566
77.321
77.000
76.679
66.861
66.762
62.187
54.067
45.989
41.925
25.678
23.633
6g
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


8_1H.esp
TMS
7.436
7.422
7.396
7.394
7.380
7.377
7.364
7.316
7.257
6.620
5.029
2.288
0.000
BnO
2H
8
1H NMR
(500 MHz, CDCl3)
5.000
2.017
2.089
6.107
Chemical Shift (ppm)

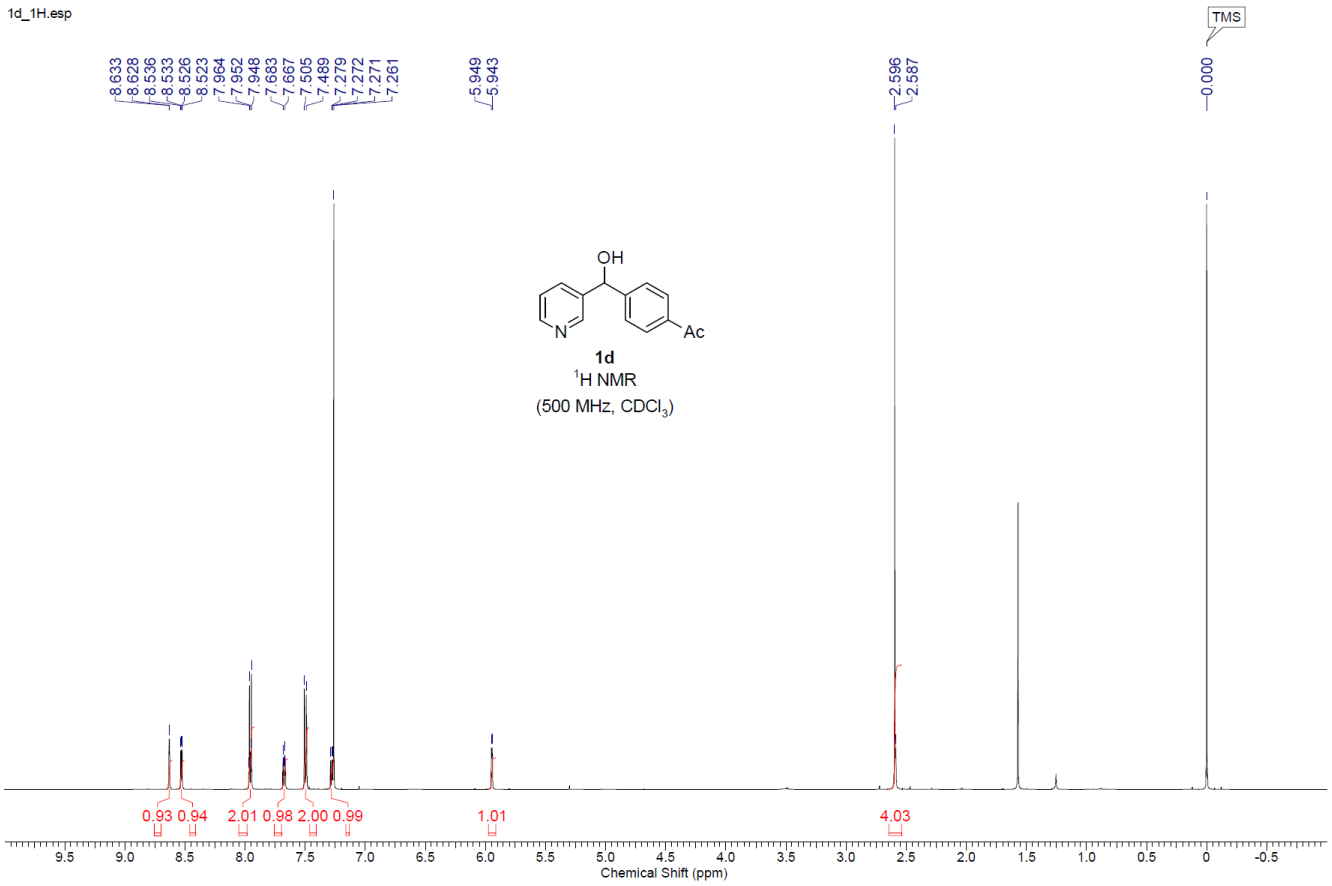

8_13C.esp
CHLOROFORM-d
158.979
139.187
137.357
128.570
127.869
127.498
122.676
122.437
122.206
112.594
77.313
77.000
76.679
69.771
21.292
BnO
2H
8
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

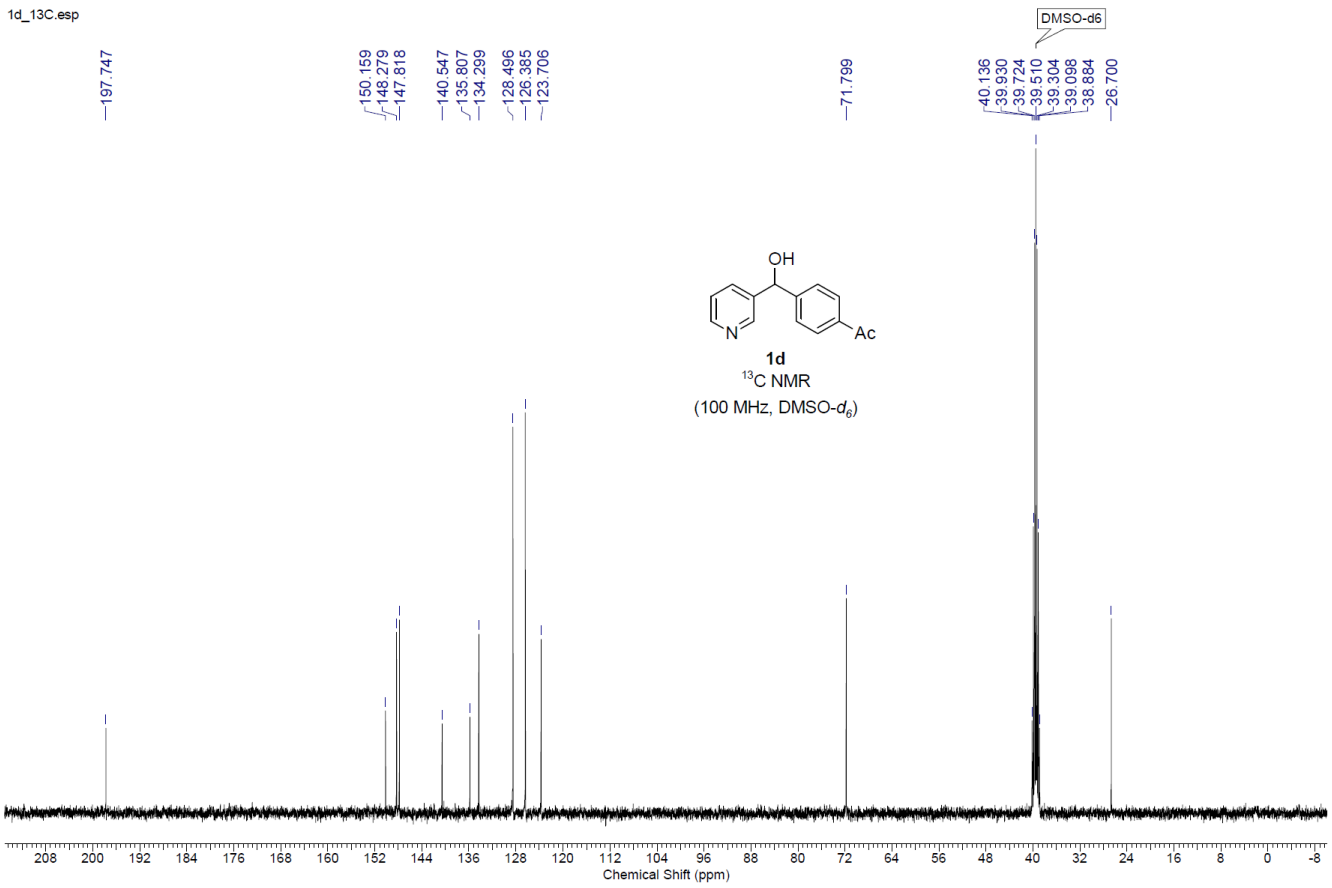


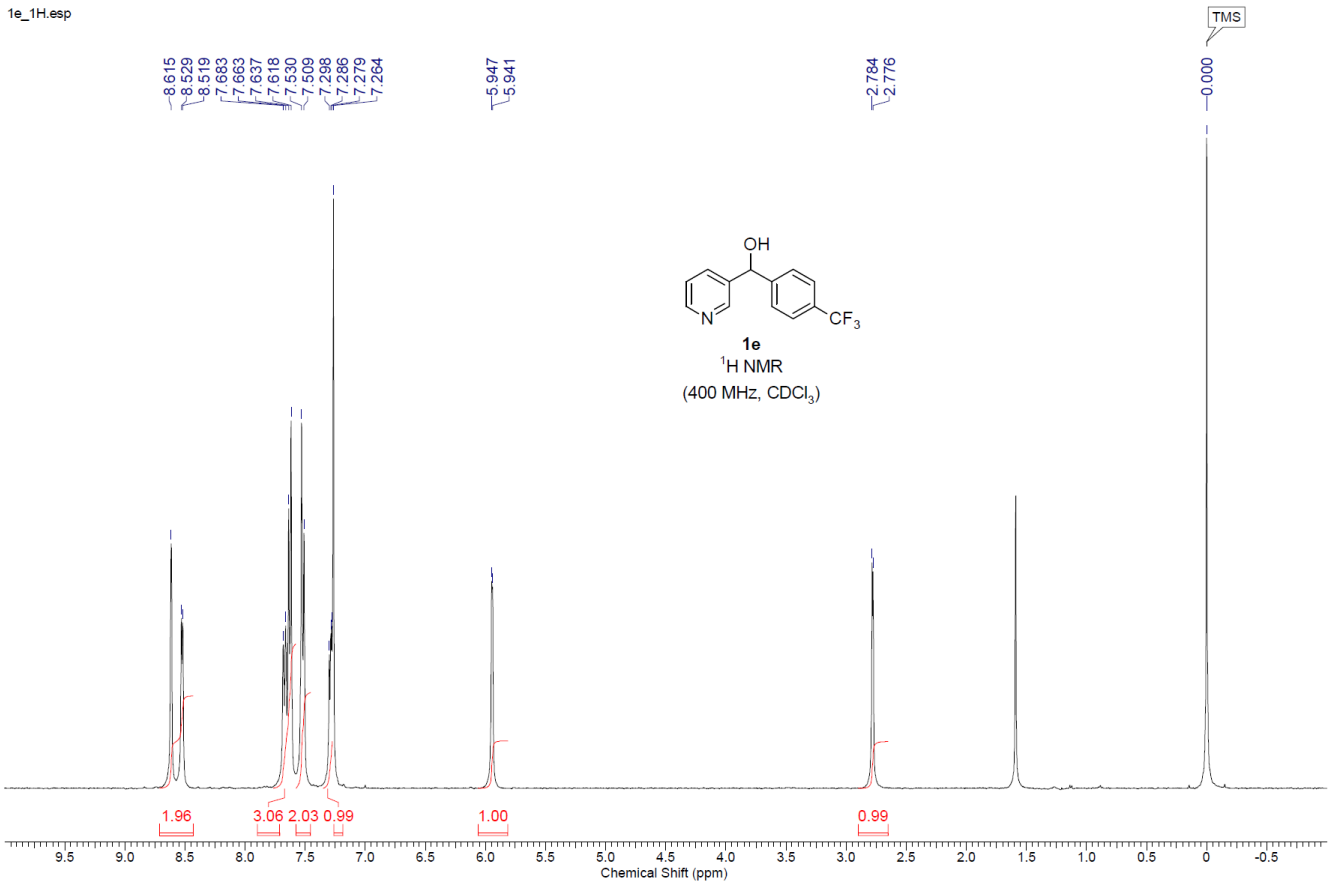
8

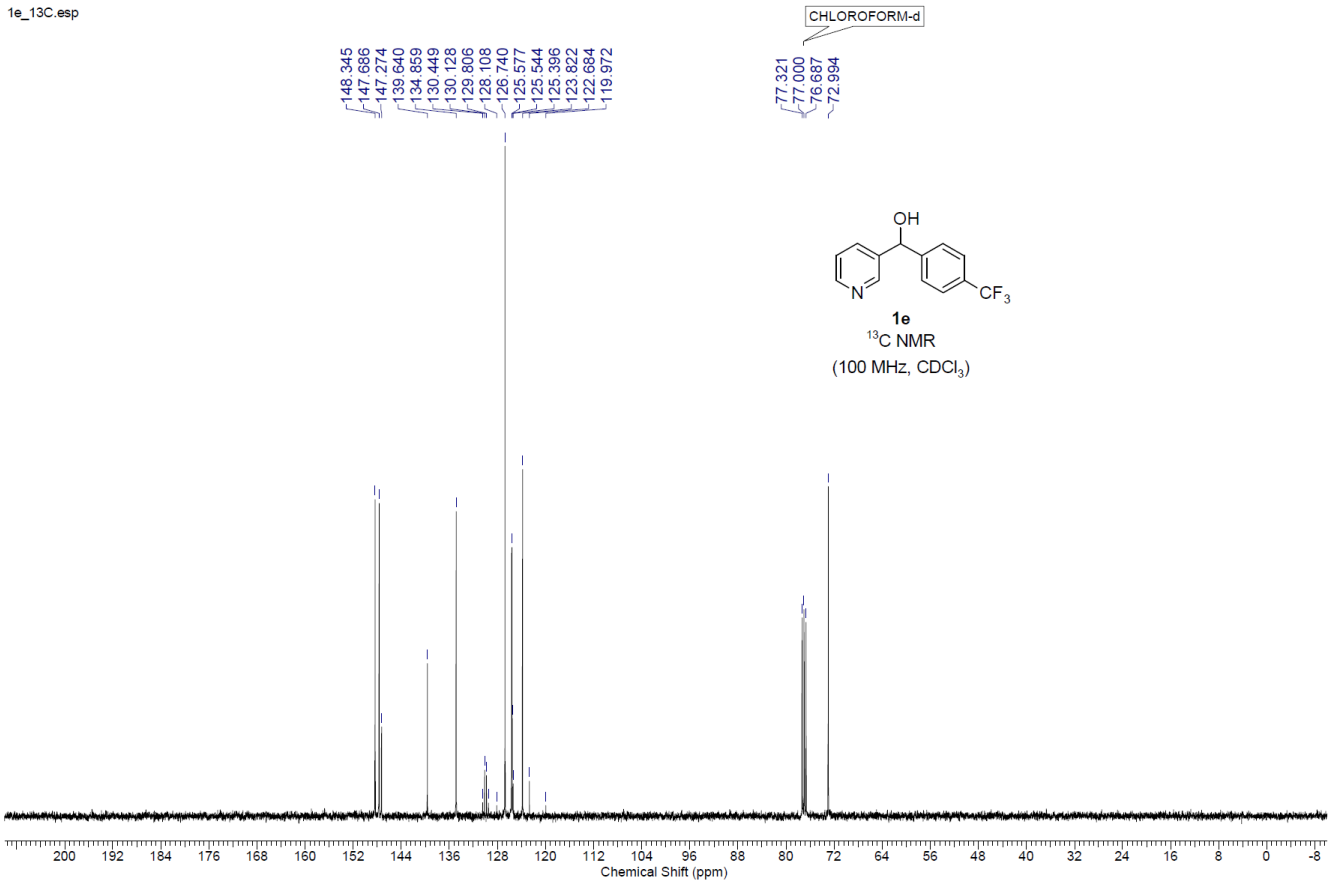
^{2}H NMR

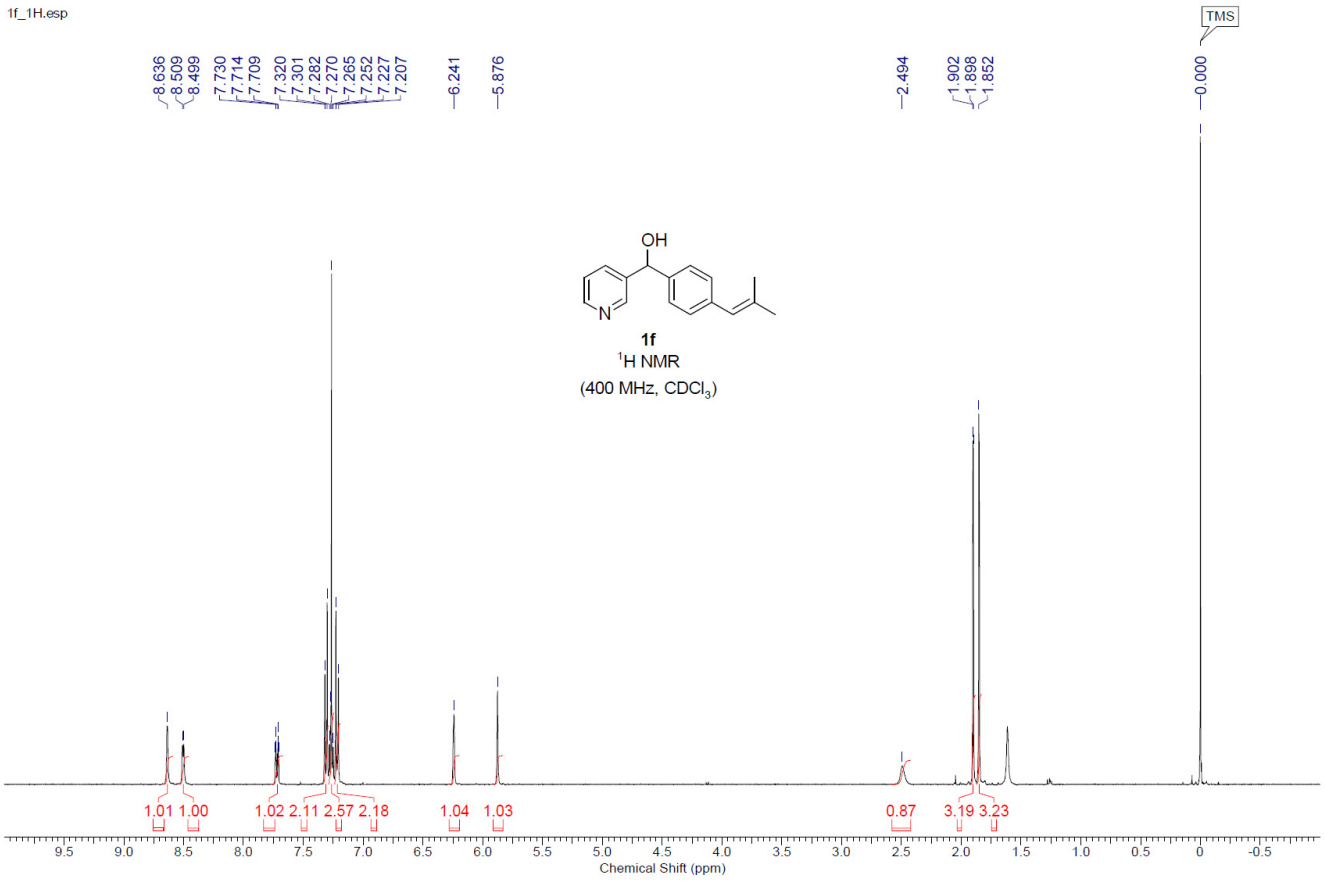
(61 MHz, CH_2Cl_2)

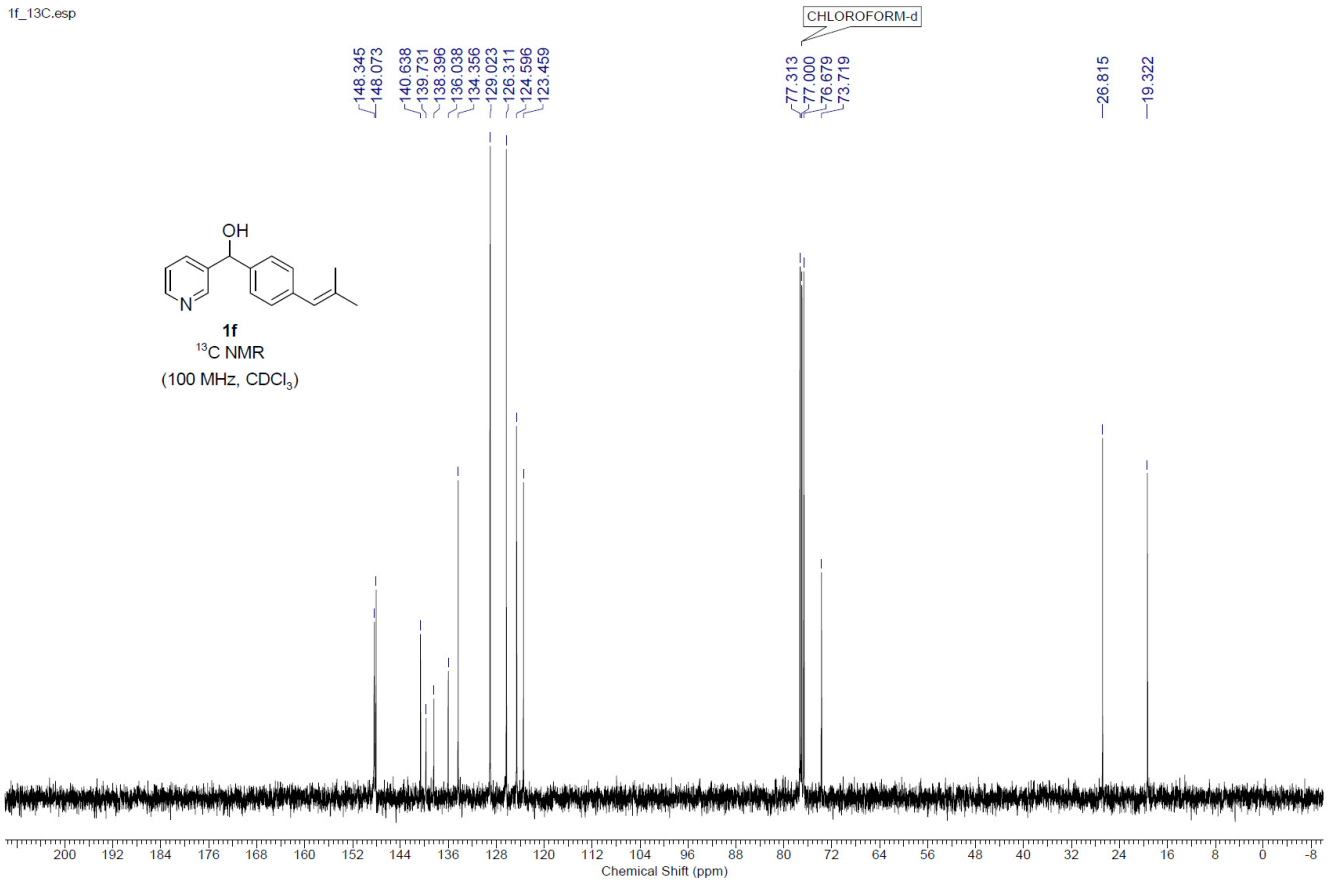

1d_1H.esp
TMS
8.633
8.628
8.536
8.533
8.526
8.523
7.964
7.952
7.948
7.683
7.667
7.505
7.489
7.279
7.272
7.271
7.261
5.949
5.943
2.596
2.587
0.000
OH
N
Ac
1d
1H NMR
(500 MHz, CDCl3)
0.93 0.94 2.01 0.98 2.00 0.99 1.01 4.03
Chemical Shift (ppm)

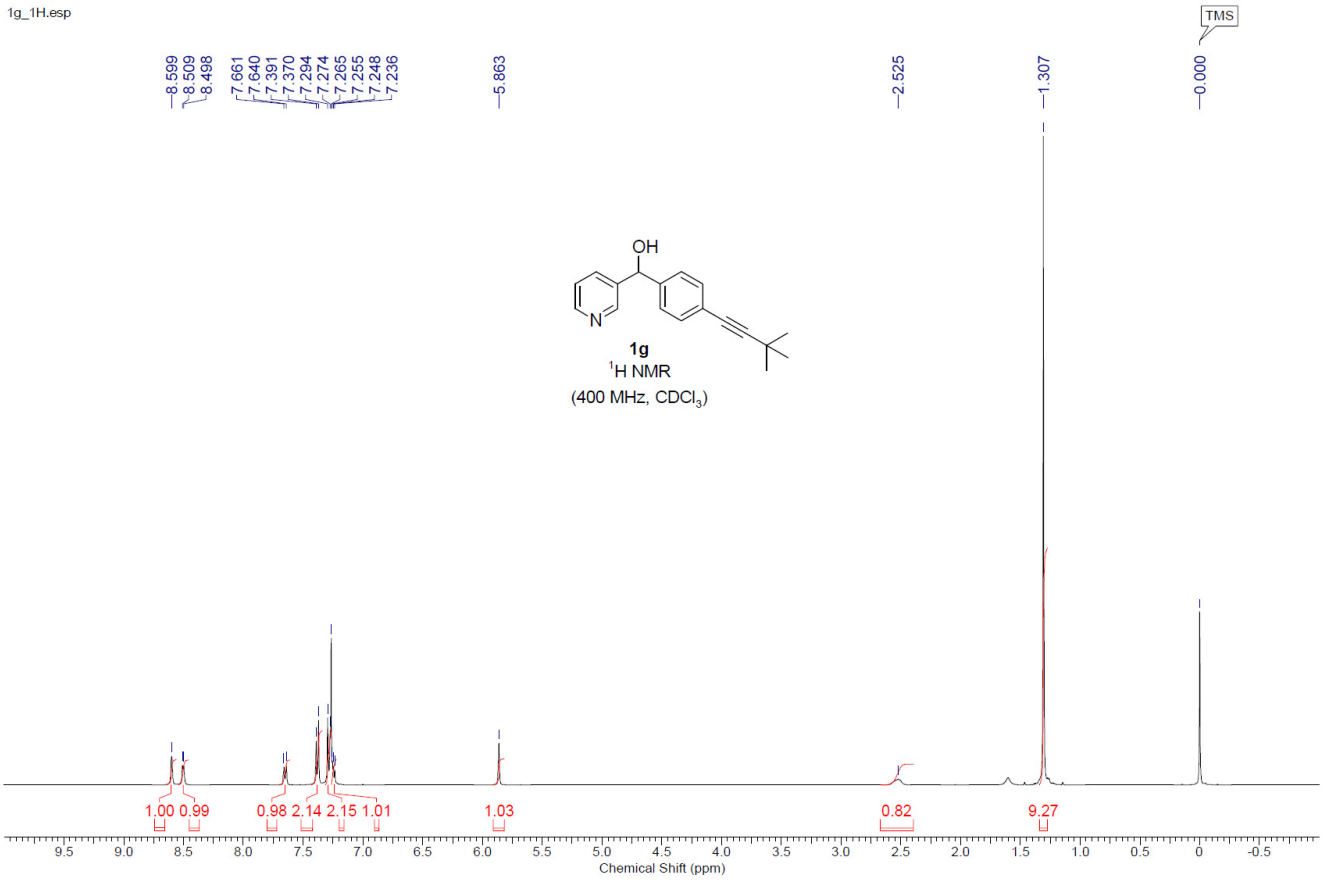

1d_13C.esp
DMSO-d6
197.747
150.159
148.279
147.818
140.547
135.807
134.299
128.496
126.385
123.706
71.799
40.136
39.930
39.724
39.510
39.304
39.098
38.884
26.700
OH
N
Ac
1d
13C NMR
(100 MHz, DMSO-d6)
Chemical Shift (ppm)

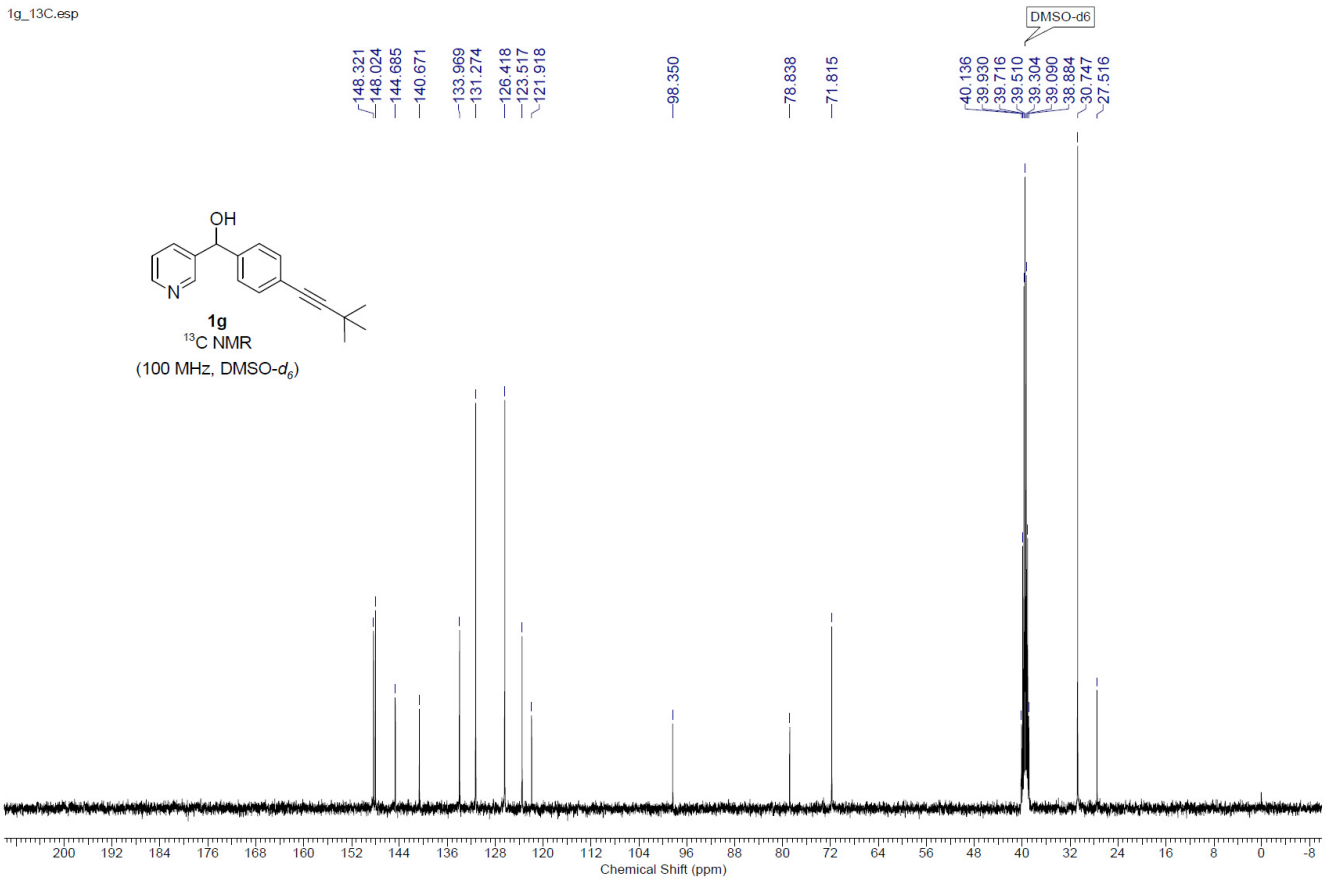

1e_1H.esp
TMS
8.615
8.529
8.519
7.683
7.663
7.637
7.618
7.530
7.509
7.298
7.286
7.279
7.264
5.947
5.941
2.784
2.776
0.000
OH
N
CF3
1e
1H NMR
(400 MHz, CDCl3)
1.96
3.06
2.03
0.99
1.00
0.99
Chemical Shift (ppm)

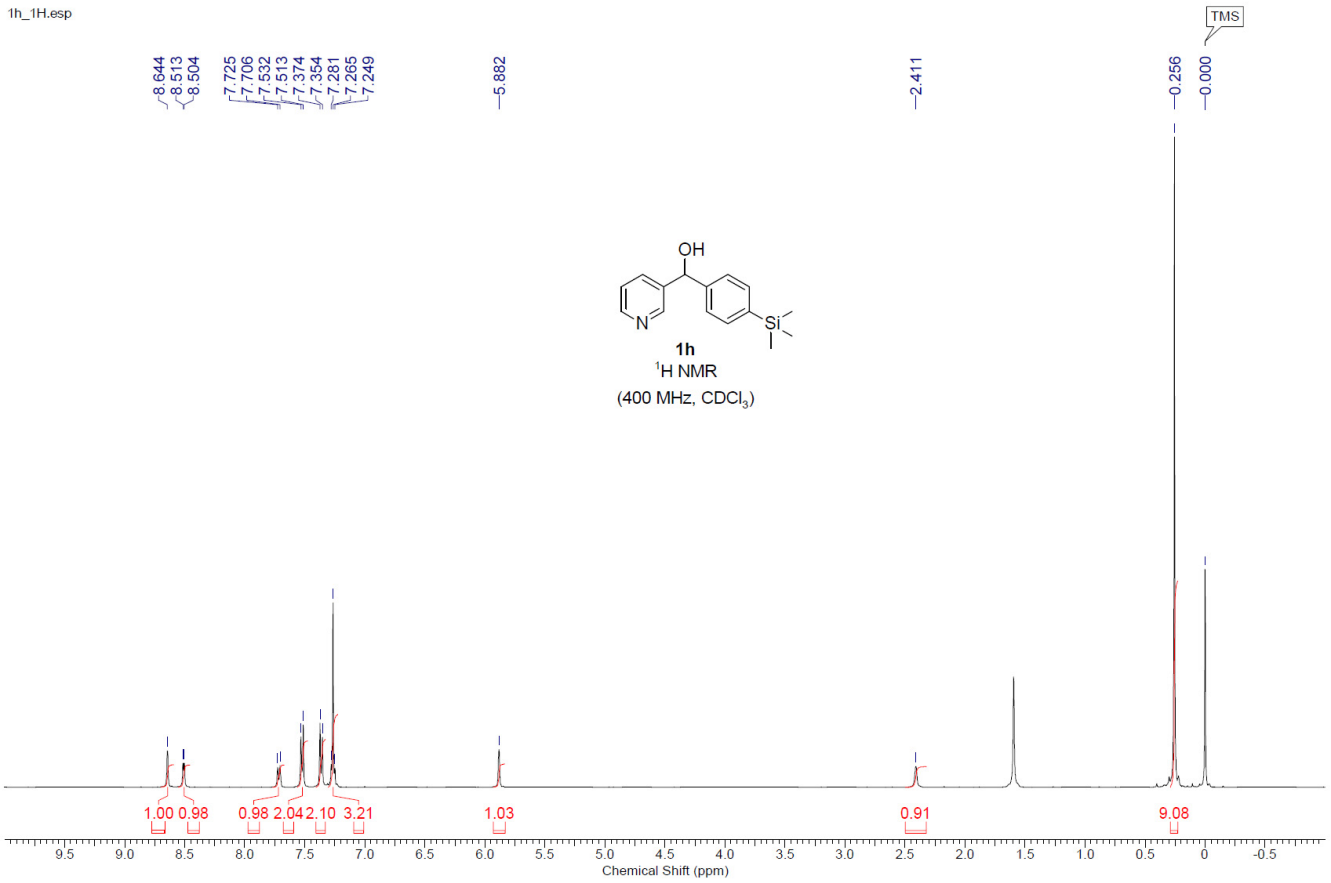

1e_13C.esp
CHLOROFORM-d
148.345
147.686
147.274
139.640
134.859
130.449
130.128
129.806
128.108
126.740
125.577
125.544
125.396
123.822
122.684
119.972
77.321
77.000
76.687
72.994
OH
N
CF3
1e
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

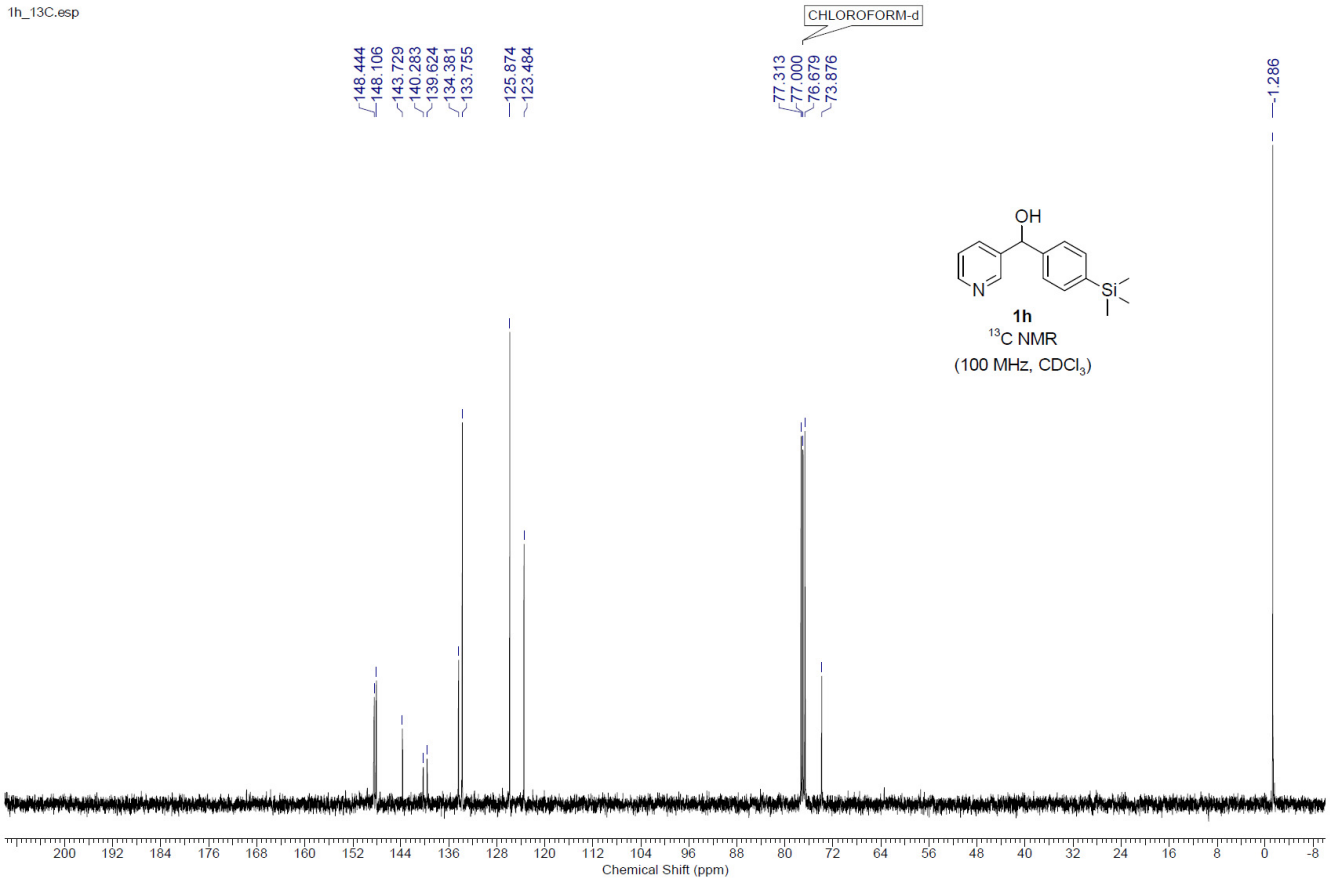

1f_1H.esp
TMS
8.636
8.509
8.499
7.730
7.714
7.709
7.320
7.301
7.282
7.270
7.265
7.252
7.227
7.207
6.241
5.876
2.494
1.902
1.898
1.852
0.000
OH
N
1f
1H NMR
(400 MHz, CDCl3)
1.01 1.00 1.02 2.11 2.57 2.18 1.04 1.03 0.87 3.19 3.23
Chemical Shift (ppm)

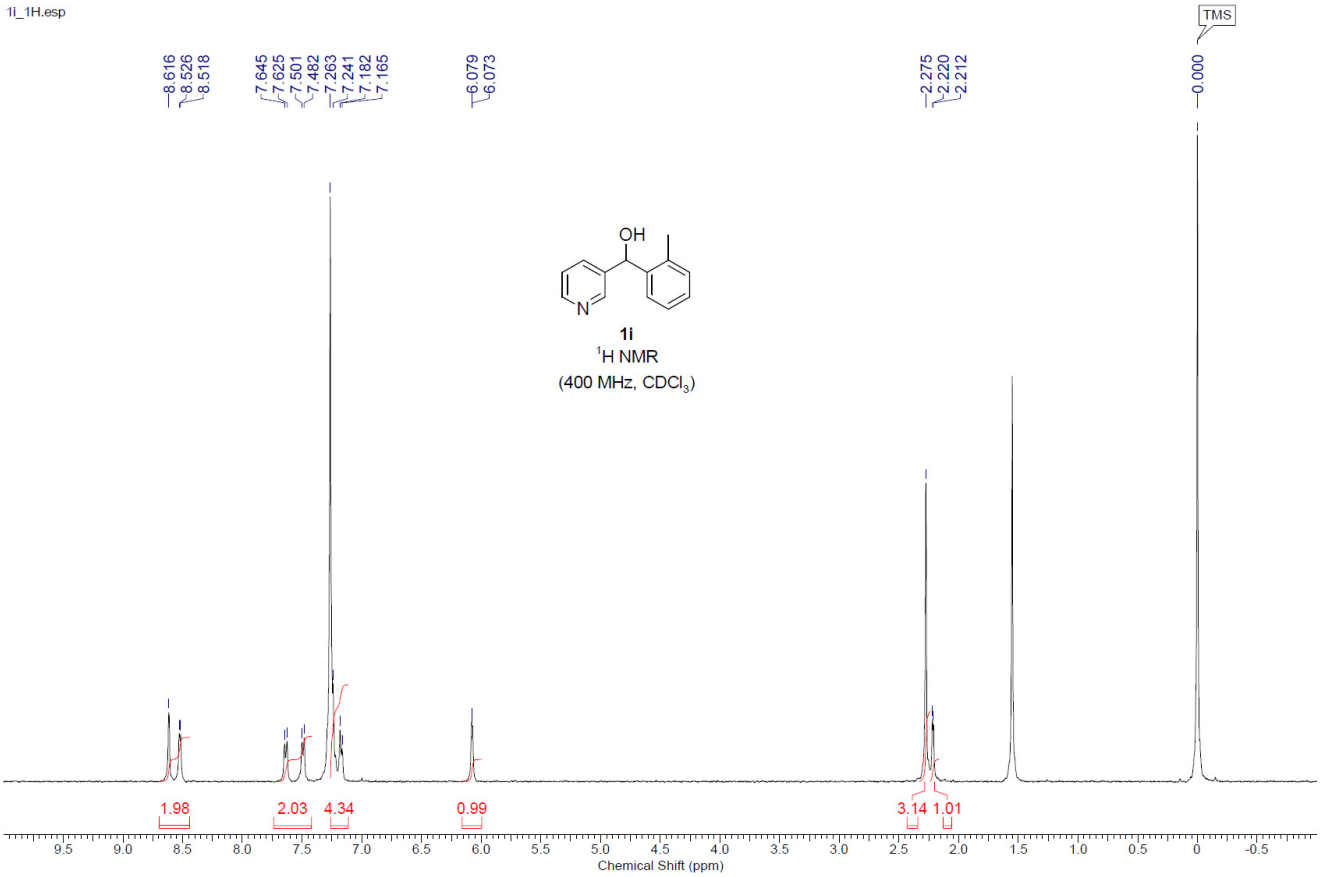

1f_13C.esp
CHLOROFORM-d
148.345
148.073
140.638
139.731
138.396
136.038
134.356
129.023
126.311
124.596
123.459
77.313
77.000
76.679
73.719
26.815
19.322
OH
N
1f
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

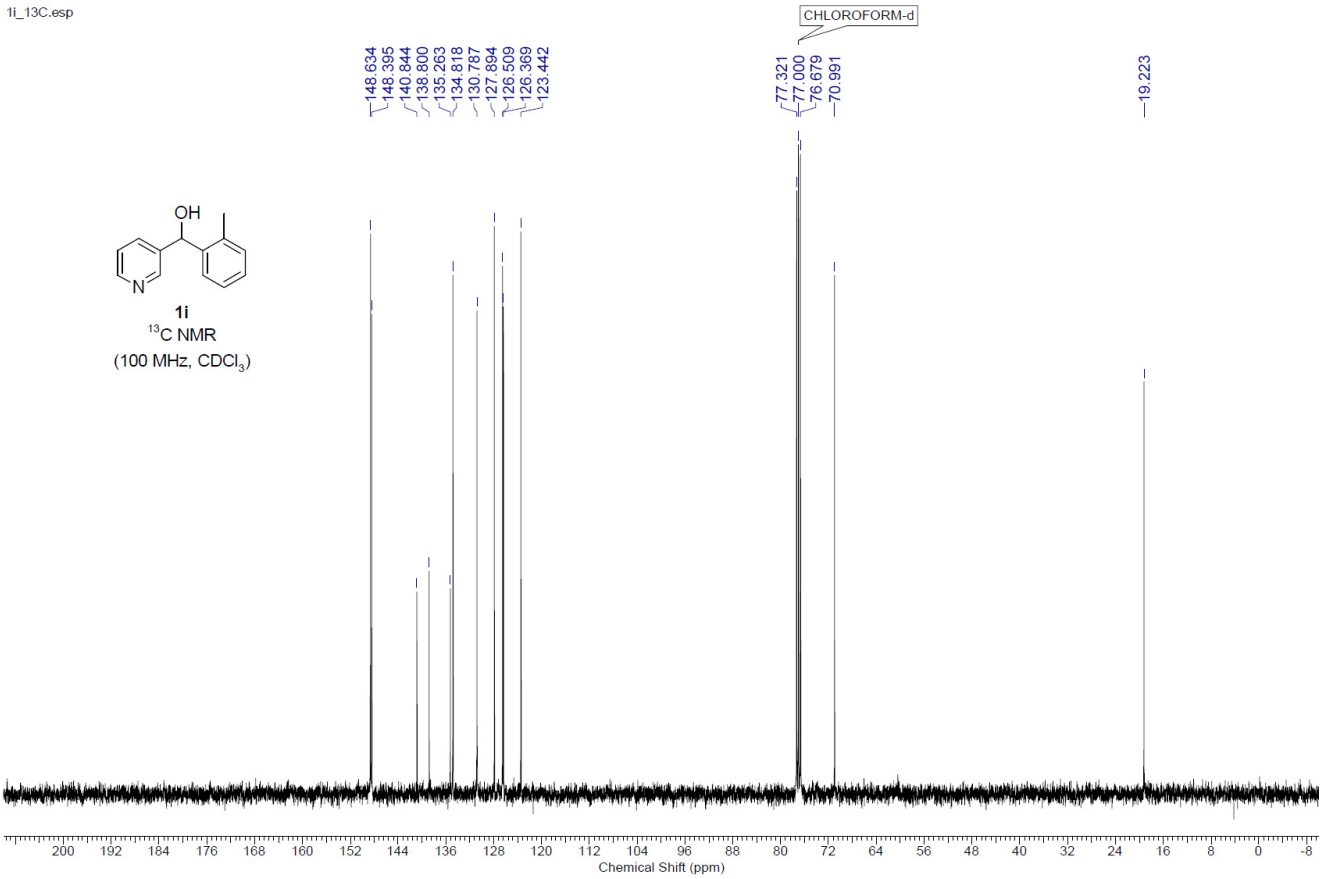

1g_1H.esp
TMS
8.599
8.509
8.498
7.661
7.640
7.391
7.370
7.294
7.274
7.265
7.255
7.248
7.236
5.863
2.525
1.307
0.000
OH
N
1g
1H NMR
(400 MHz, CDCl3)
1.00 0.99
0.98 2.14 2.15 1.01
1.03
0.82
9.27
Chemical Shift (ppm)

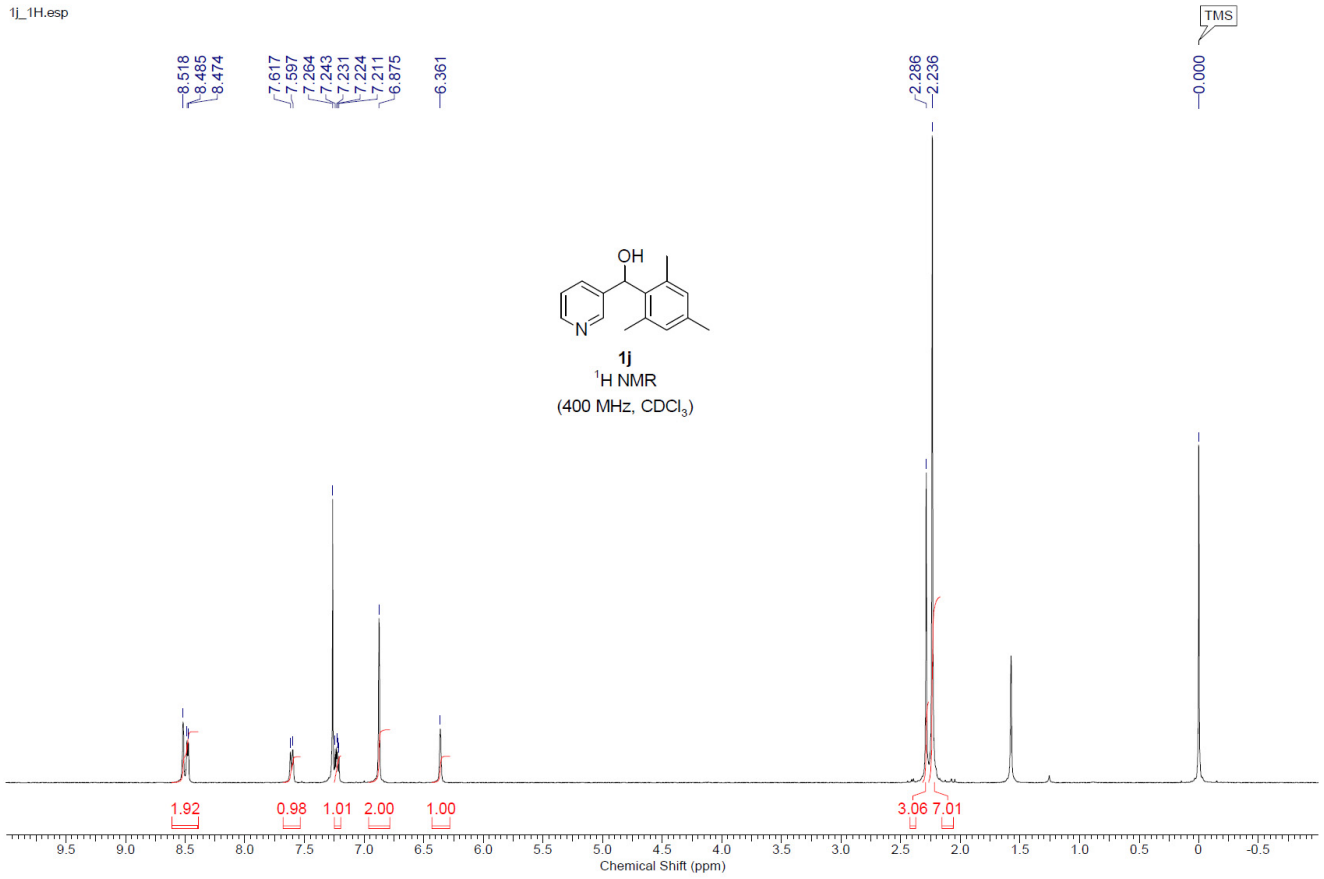

1g_13C.esp
DMSO-d6
148.321
148.024
144.685
140.671
133.969
131.274
126.418
123.517
121.918
98.350
78.838
71.815
40.136
39.930
39.716
39.510
39.304
39.090
38.884
30.747
27.516
OH
N
1g
13C NMR
(100 MHz, DMSO-d6)
Chemical Shift (ppm)

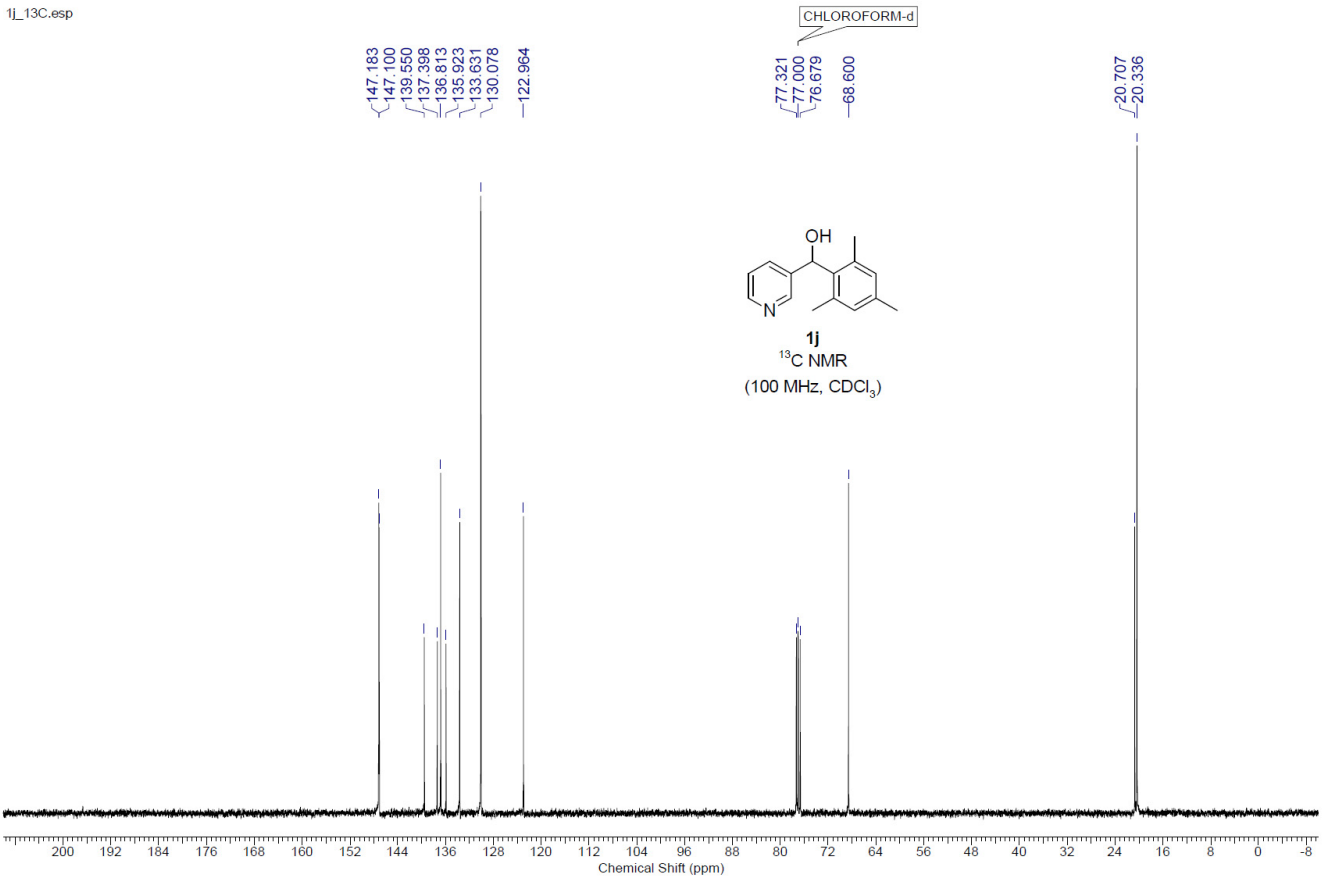

1h_1H.esp
TMS
8.644
8.513
8.504
7.725
7.706
7.532
7.513
7.374
7.354
7.281
7.265
7.249
5.882
2.411
0.256
0.000
OH
N
Si
1h
1H NMR
(400 MHz, CDCl3)
1.00 0.98 0.98 2.04 2.10 3.21 1.03 0.91 9.08
Chemical Shift (ppm)

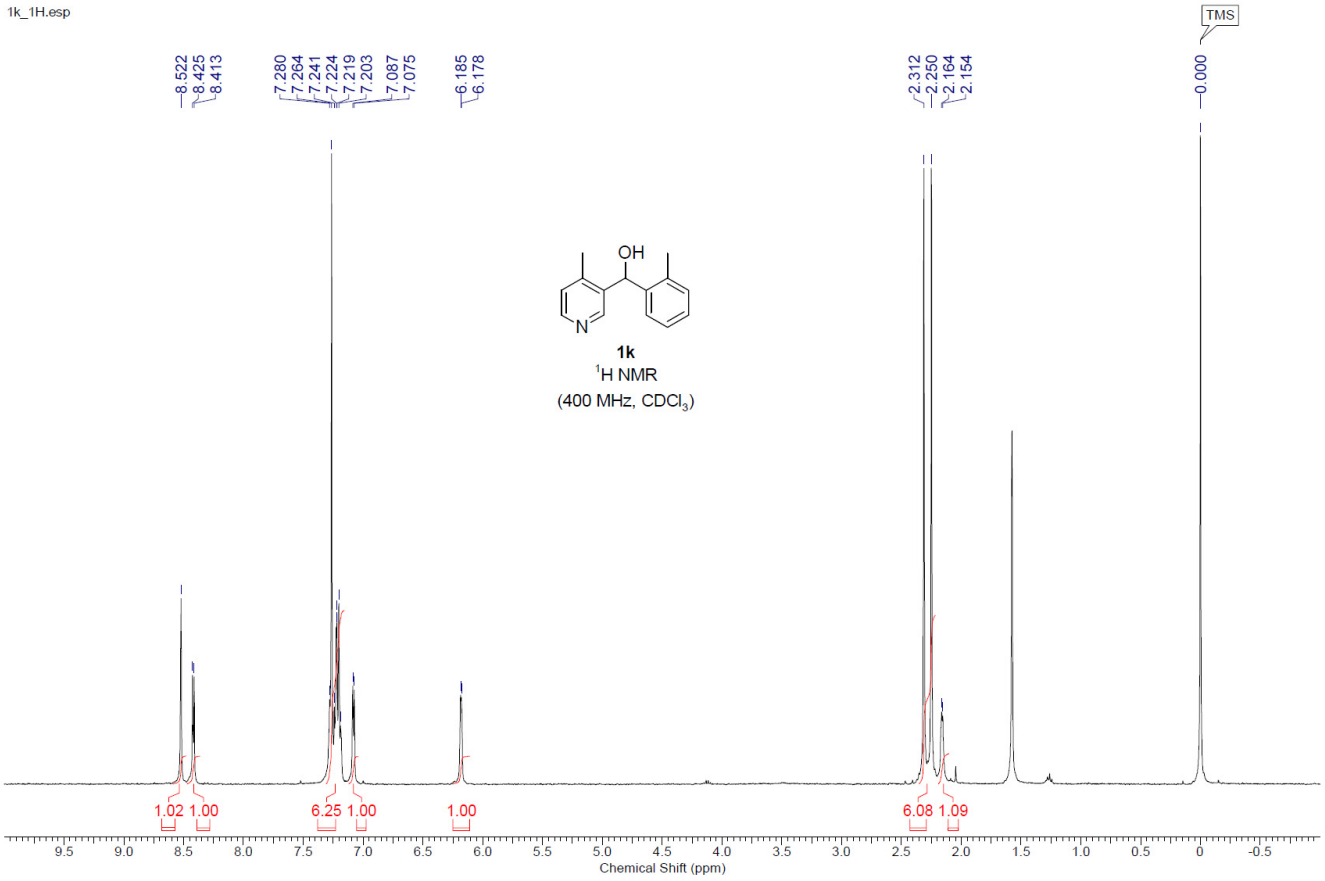

1h_13C.esp
CHLOROFORM-d
148.444
148.106
143.729
140.283
139.624
134.381
133.755
125.874
123.484
77.313
77.000
76.679
73.876
1.286
OH
N
Si
1h
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

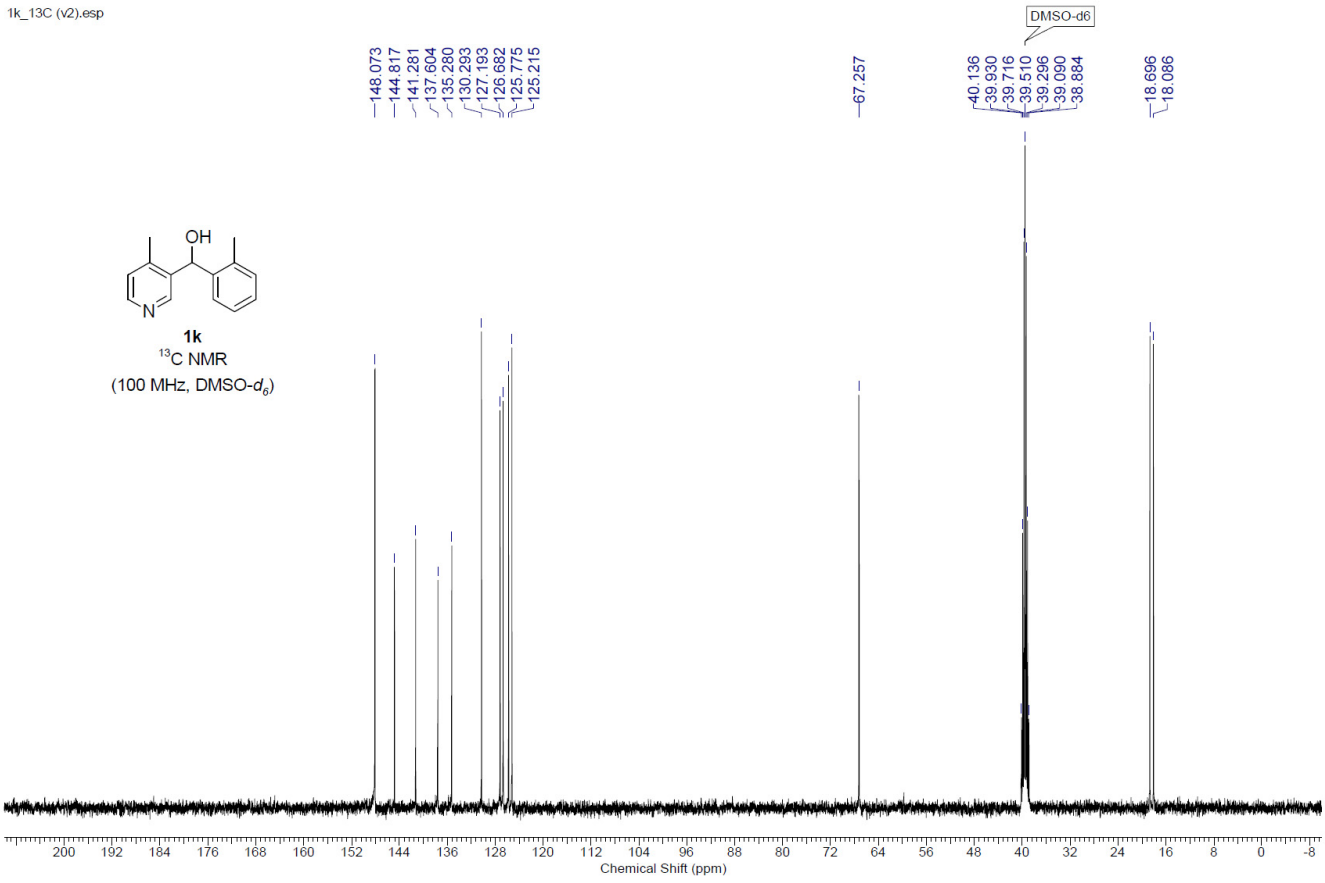

1i_1H.esp
TMS
8.616
8.526
8.518
7.645
7.625
7.501
7.482
7.263
7.241
7.182
7.165
6.079
6.073
2.275
2.220
2.212
0.000
OH
N
1i
1H NMR
(400 MHz, CDCl3)
1.98
2.03
4.34
0.99
3.14
1.01
Chemical Shift (ppm)

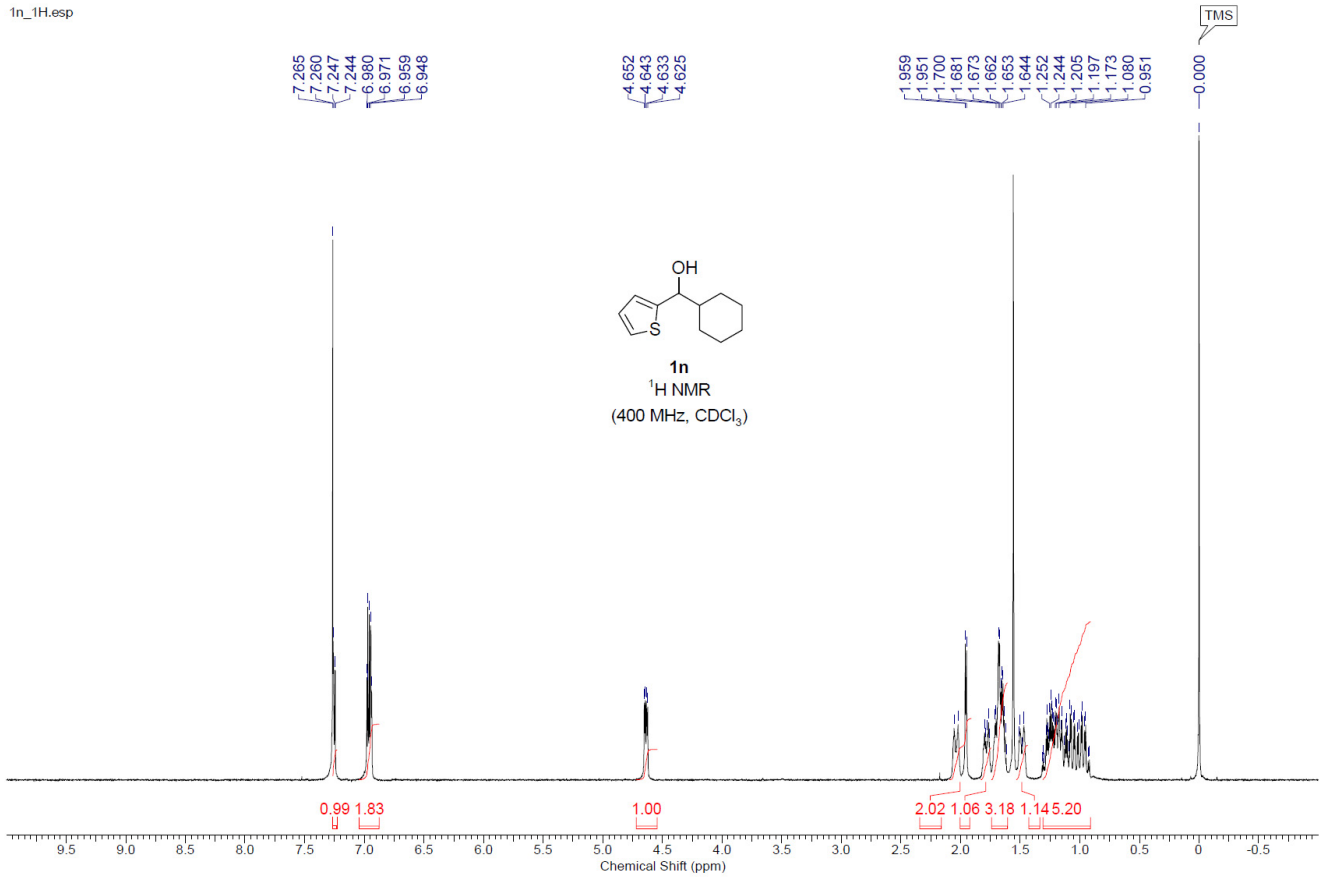

1i_13C.esp
CHLOROFORM-d
148.634
148.395
140.844
138.800
135.263
134.818
130.787
127.894
126.509
126.369
123.442
77.321
77.000
76.679
70.991
19.223
OH
N
1i
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

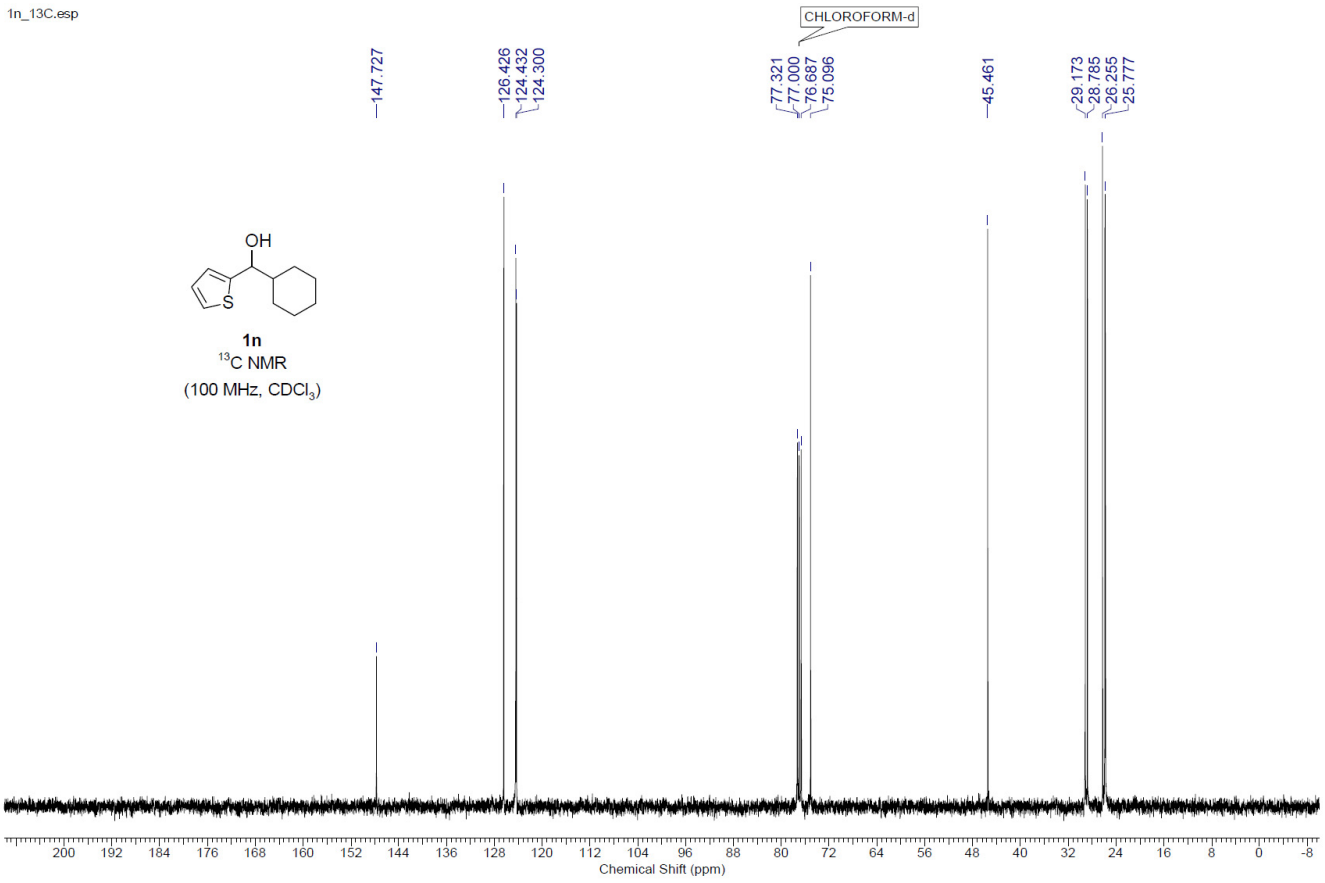

1j_1H.esp
TMS
8.518
8.485
8.474
7.617
7.597
7.264
7.243
7.231
7.224
7.211
6.875
6.361
2.286
2.236
0.000
OH
N
1j
1H NMR
(400 MHz, CDCl3)
1.92
0.98
1.01
2.00
1.00
3.06
7.01
Chemical Shift (ppm)

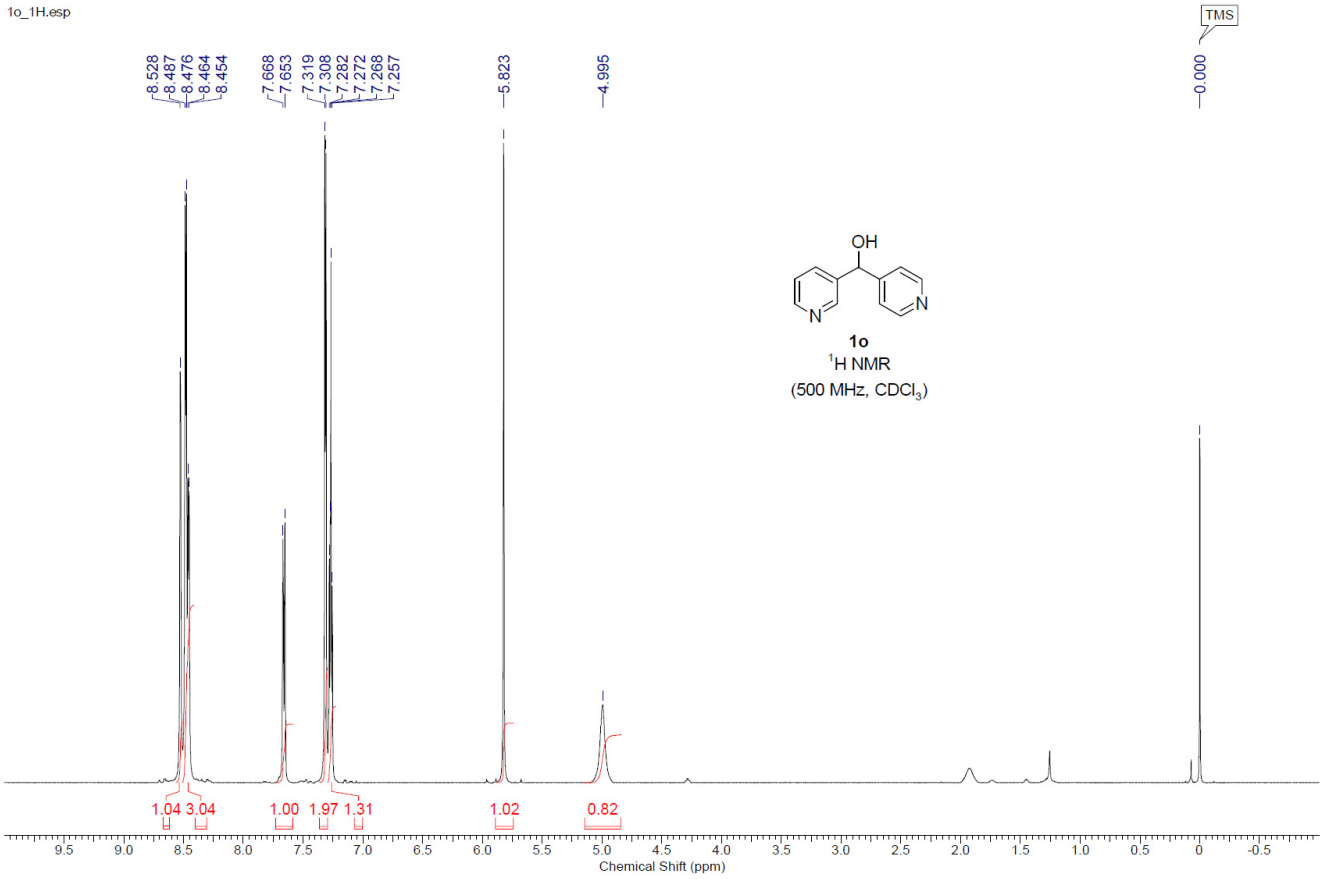

1j_13C.esp
CHLOROFORM-d
147.183
147.100
139.550
137.398
136.813
135.923
133.631
130.078
122.964
77.321
77.000
76.679
68.600
20.707
20.336
OH
N
1j
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

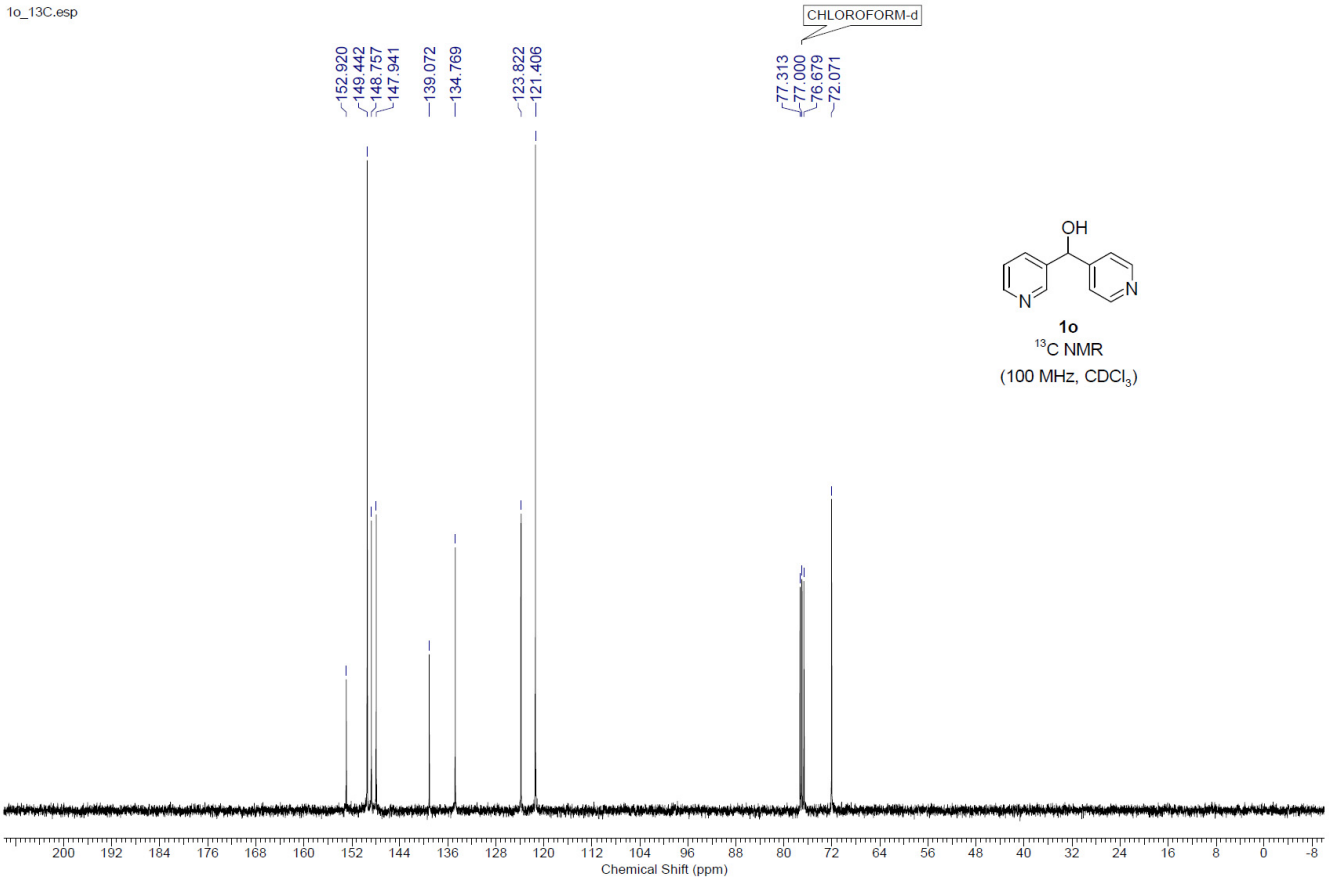

1k_1H.esp
TMS
8.522
8.425
8.413
7.280
7.264
7.241
7.224
7.219
7.203
7.087
7.075
6.185
6.178
2.312
2.250
2.164
2.154
0.000
OH
N
1k
1H NMR
(400 MHz, CDCl3)
1.02 1.00
6.25 1.00
1.00
6.08 1.09
Chemical Shift (ppm)

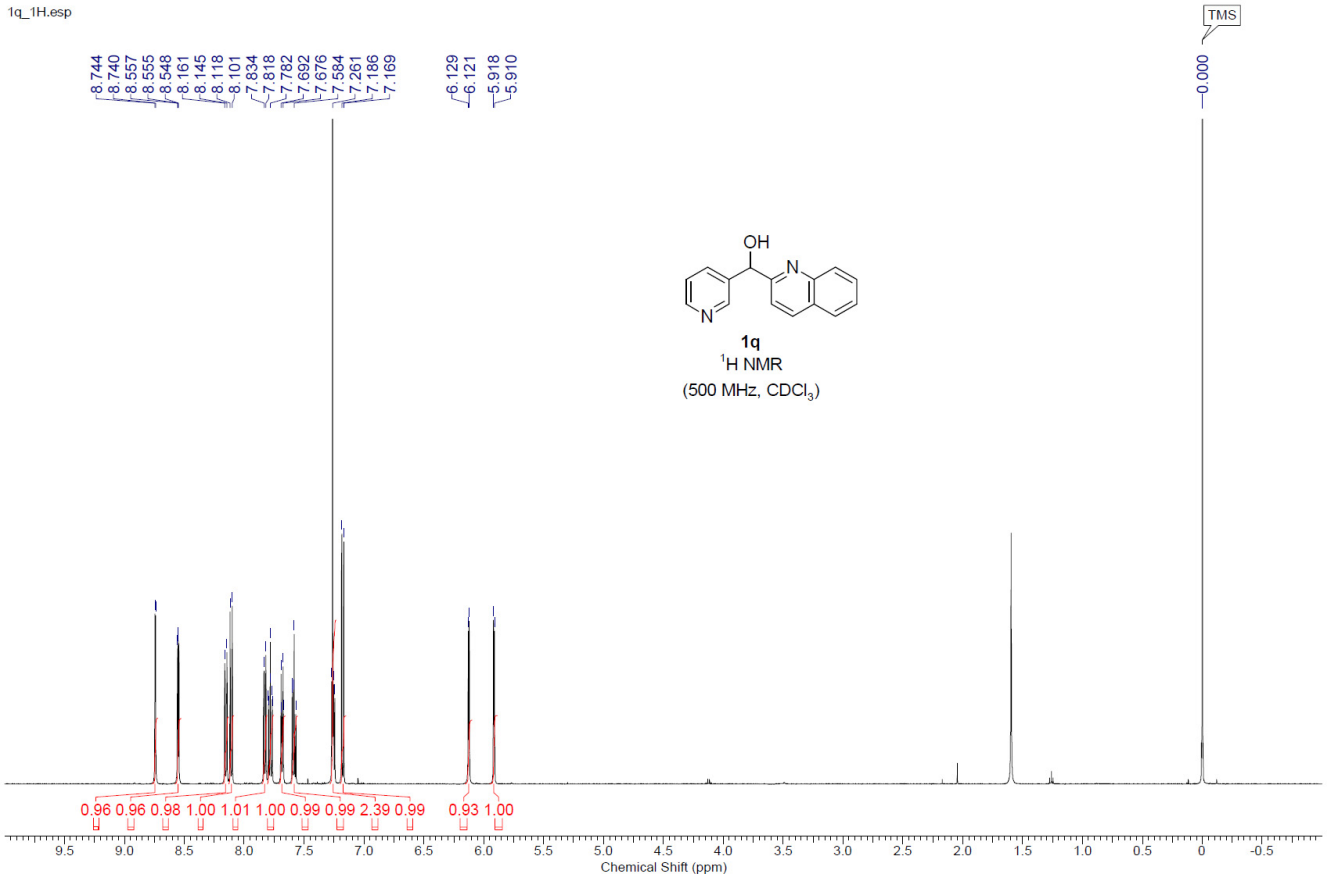

1k_13C (v2).esp
DMSO-d6
148.073
144.817
141.281
137.604
135.280
130.293
127.193
126.682
125.775
125.215
67.257
40.136
39.930
39.716
39.510
39.296
39.090
38.884
18.696
18.086
OH
N
1k
13C NMR
(100 MHz, DMSO-d6)
Chemical Shift (ppm)

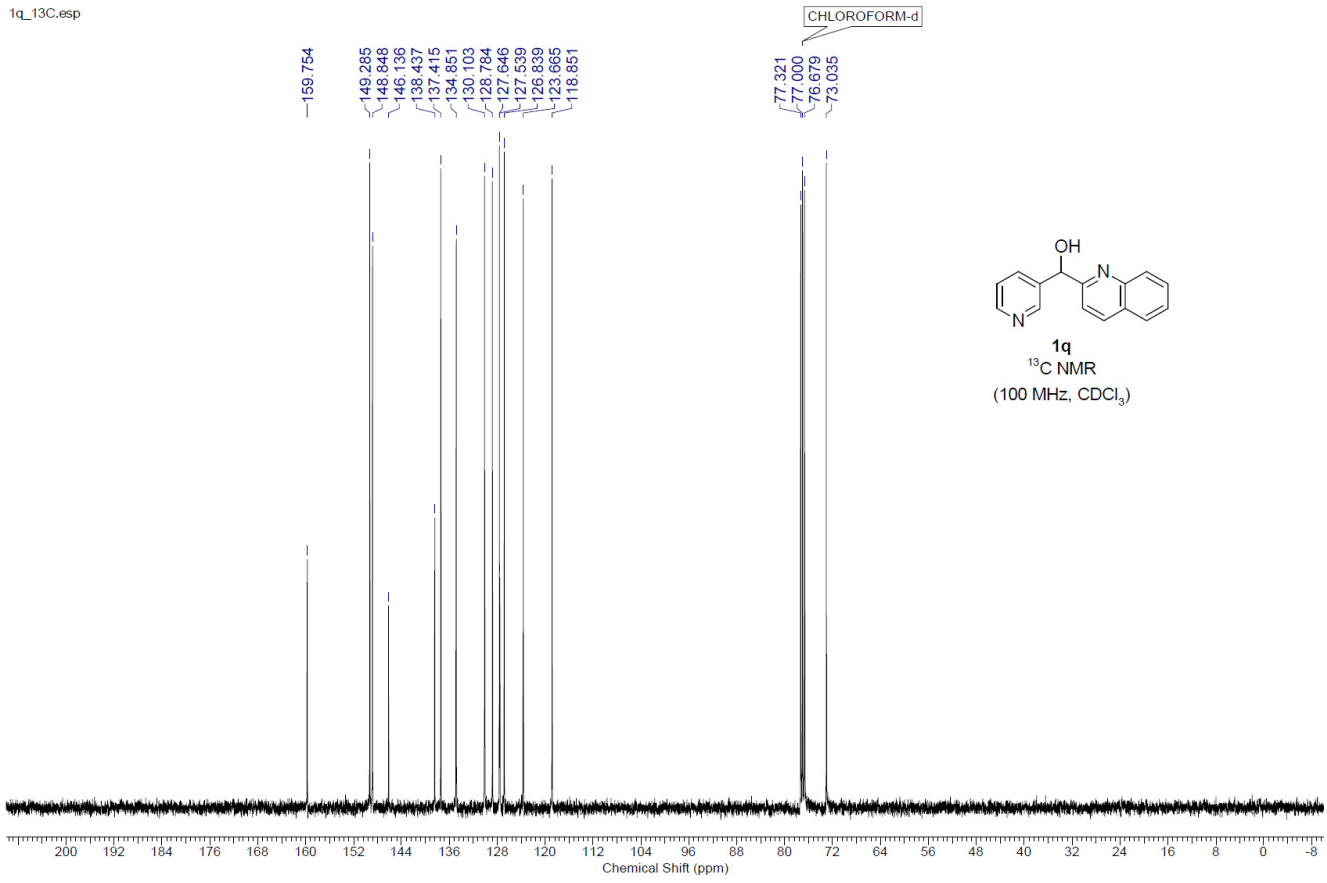

1n_1H.esp
TMS
7.265
7.260
7.247
7.244
6.980
6.971
6.959
6.948
4.652
4.643
4.633
4.625
1.959
1.951
1.700
1.681
1.673
1.662
1.653
1.644
1.252
1.244
1.205
1.197
1.173
1.080
0.951
0.000
OH
S
1n
1H NMR
(400 MHz, CDCl3)
0.99 1.83
1.00
2.02 1.06 3.18 1.14 5.20
Chemical Shift (ppm)

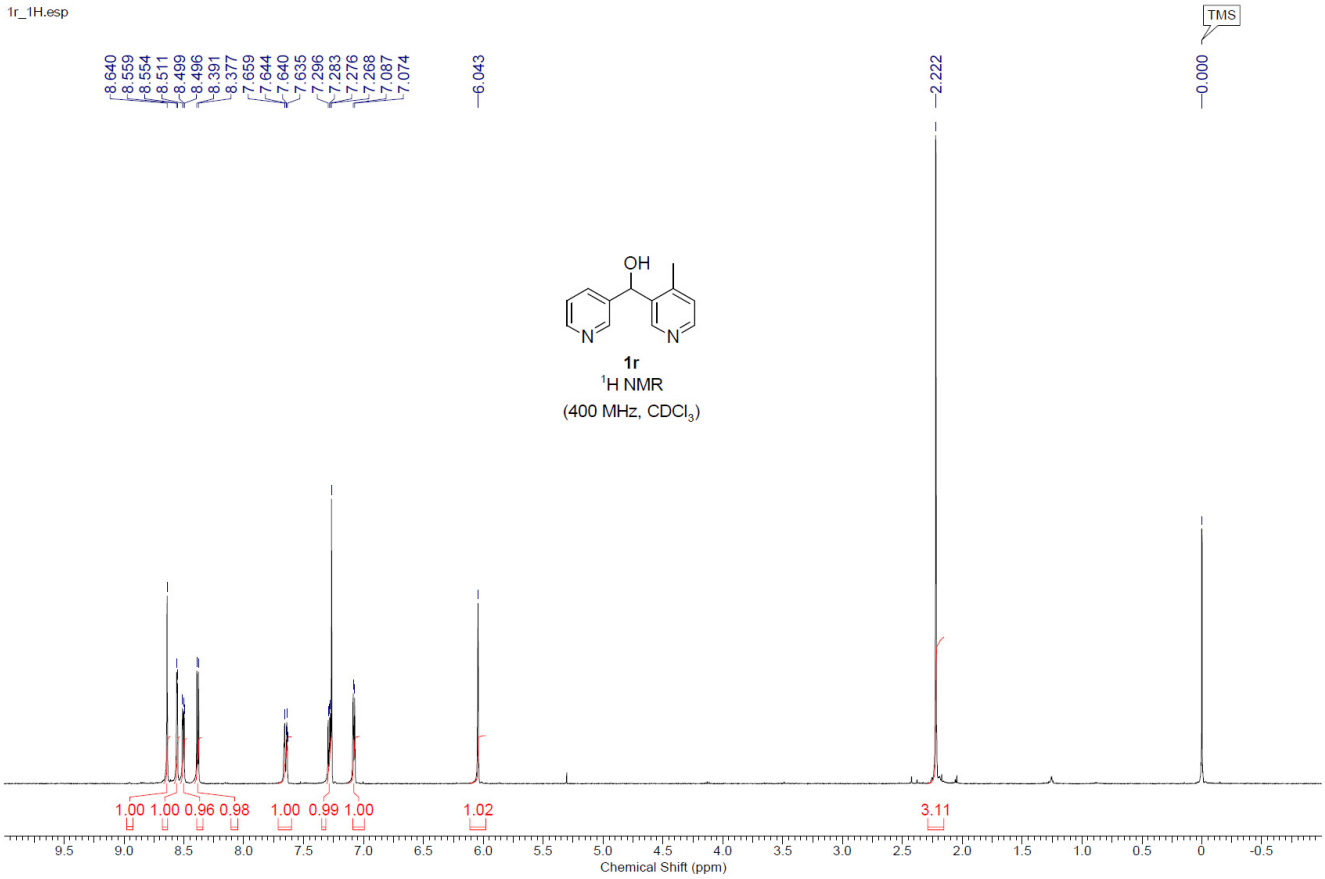

1n_13C.esp
CHLOROFORM-d
147.727
126.426
124.432
124.300
77.321
77.000
76.687
75.096
45.461
29.173
28.785
26.255
25.777
OH
S
1n
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

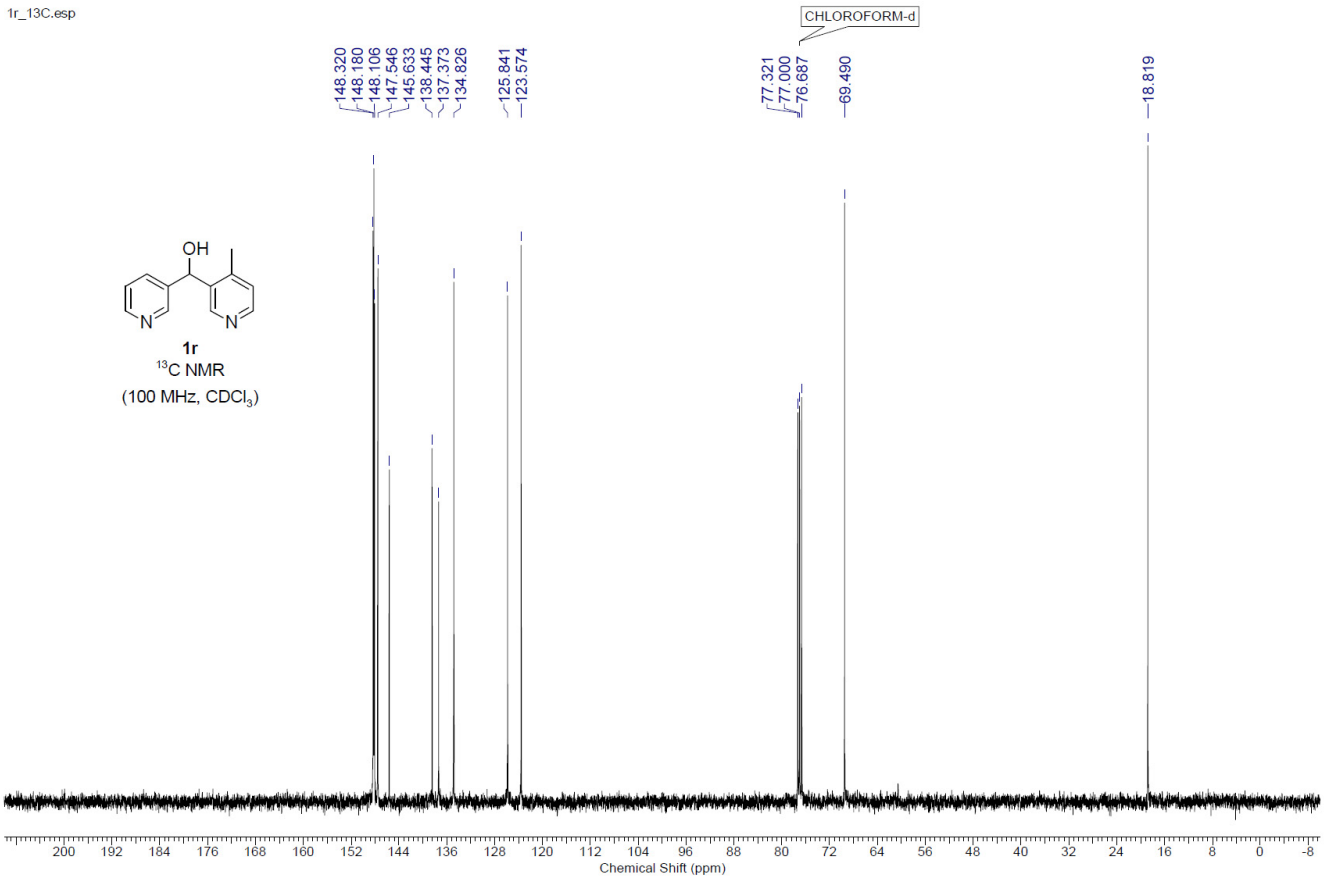

1o_1H.esp
TMS
8.528
8.487
8.476
8.464
8.454
7.668
7.653
7.319
7.308
7.282
7.272
7.268
7.257
5.823
4.995
0.000
OH
N
N
1o
1H NMR
(500 MHz, CDCl3)
1.04 3.04
1.00
1.97 1.31
1.02
0.82
Chemical Shift (ppm)

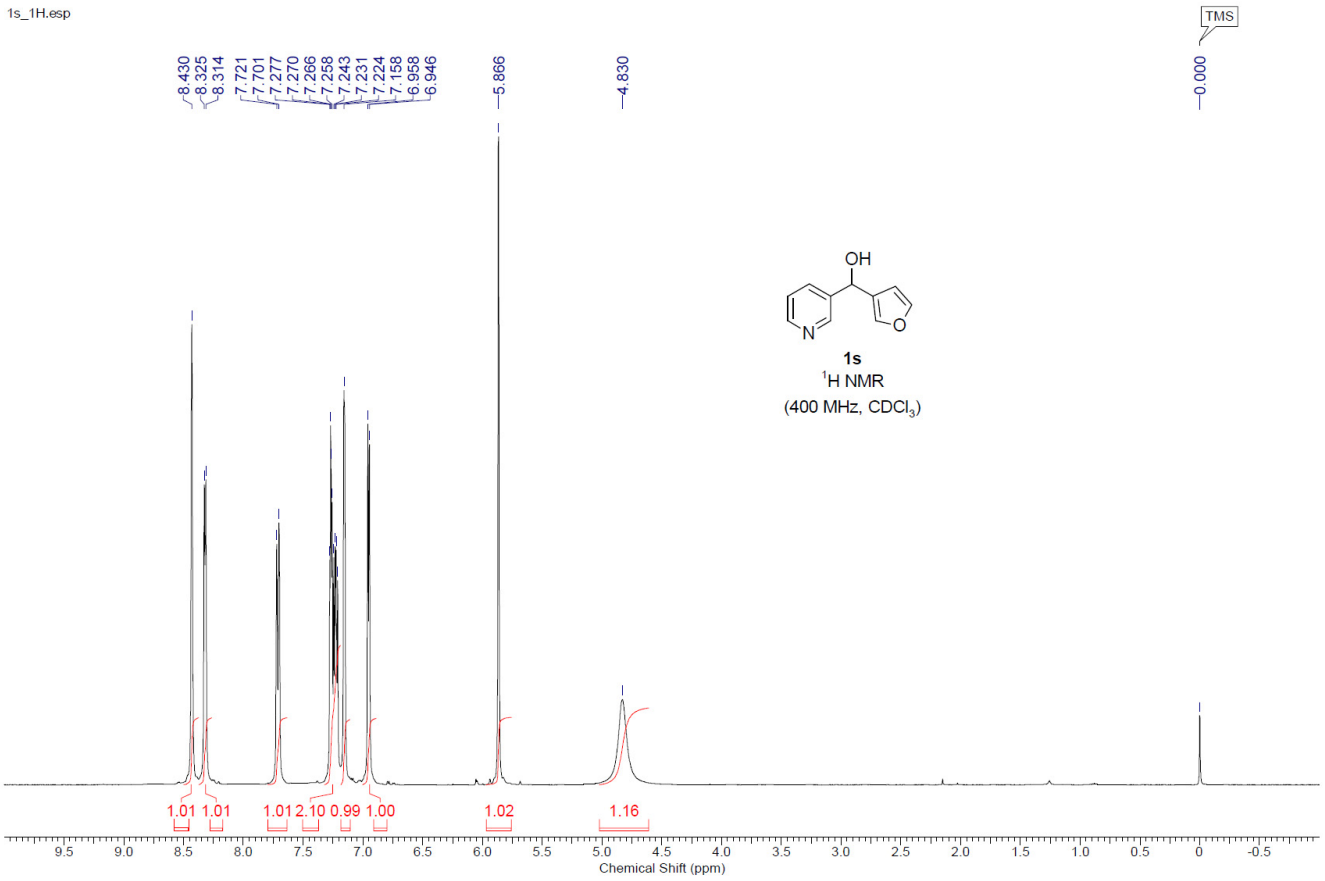

1o_13C.esp
CHLOROFORM-d
152.920
149.442
148.757
147.941
139.072
134.769
123.822
121.406
77.313
77.000
76.679
72.071
OH
N
N
1o
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

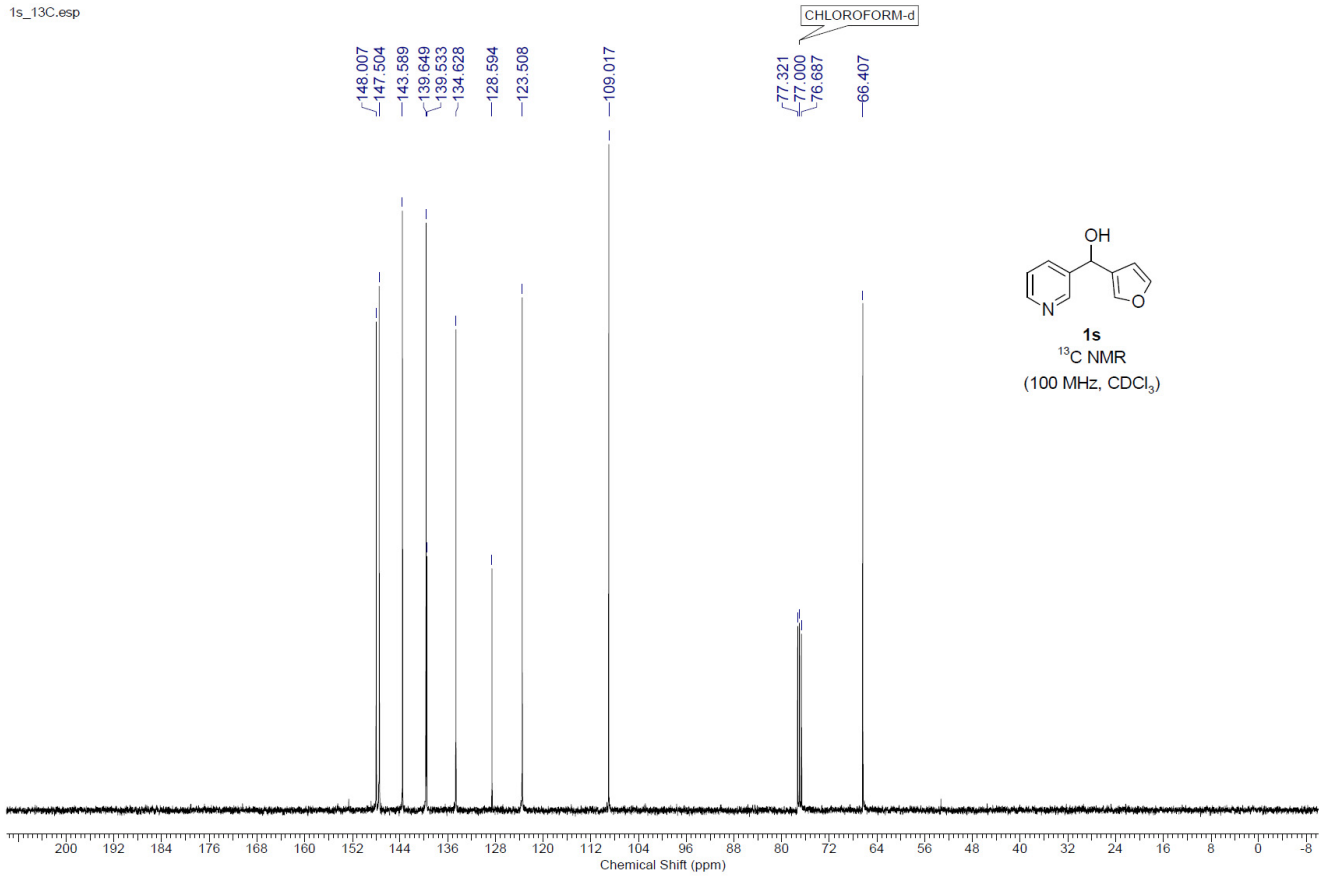

1q_1H.esp
TMS
8.744
8.740
8.557
8.555
8.548
8.161
8.145
8.118
8.101
7.834
7.818
7.782
7.692
7.676
7.584
7.261
7.186
7.169
6.129
6.121
5.918
5.910
0.000
OH
N
N
1q
1H NMR
(500 MHz, CDCl3)
0.96 0.96 0.98 1.00 1.01 1.00 0.99 0.99 2.39 0.99 0.93 1.00
Chemical Shift (ppm)

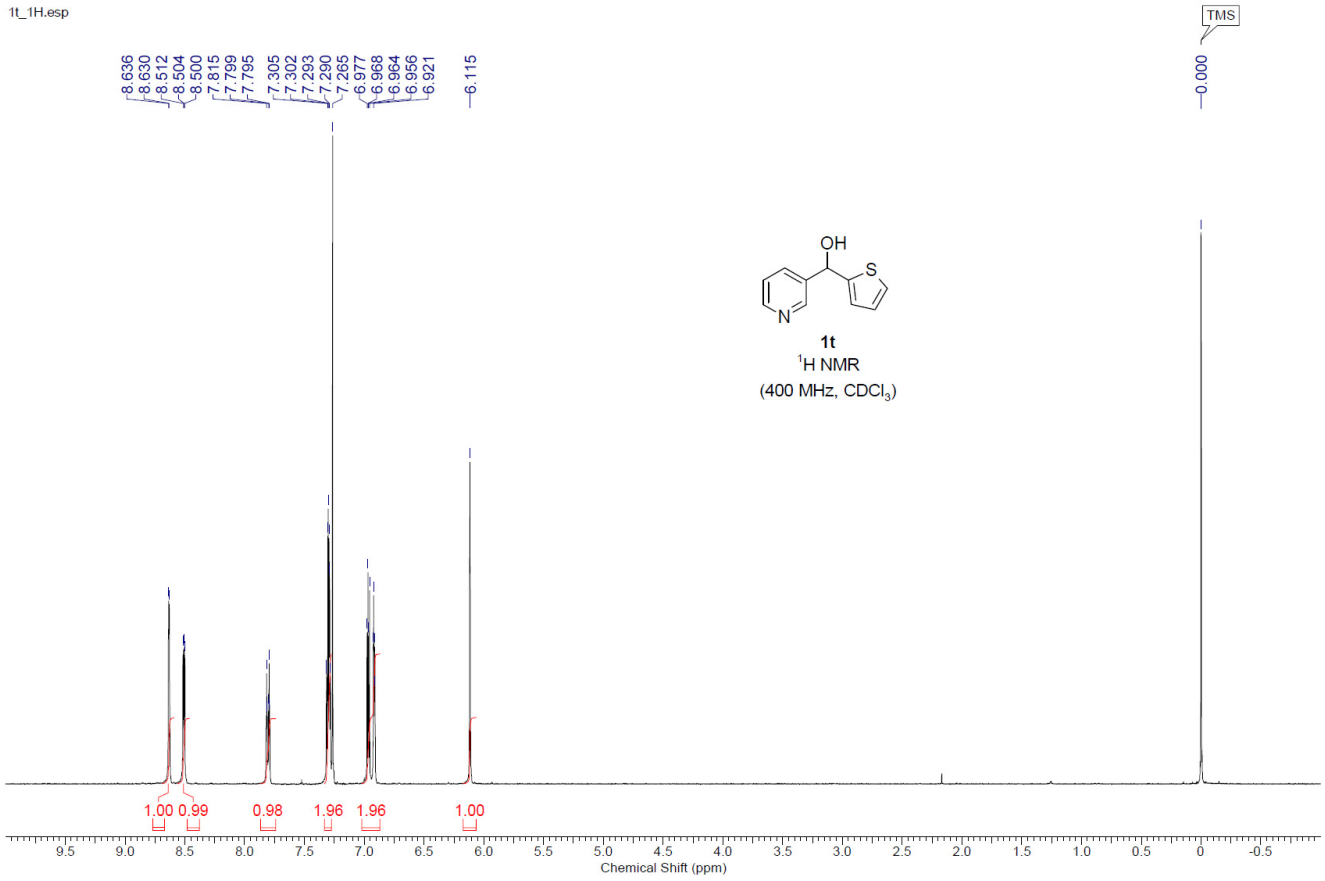

1q_13C.esp
CHLOROFORM-d
159.754
149.285
148.848
146.136
138.437
137.415
134.851
130.103
128.784
127.646
127.539
126.839
123.665
118.851
77.321
77.000
76.679
73.035
OH
N
N
1q
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

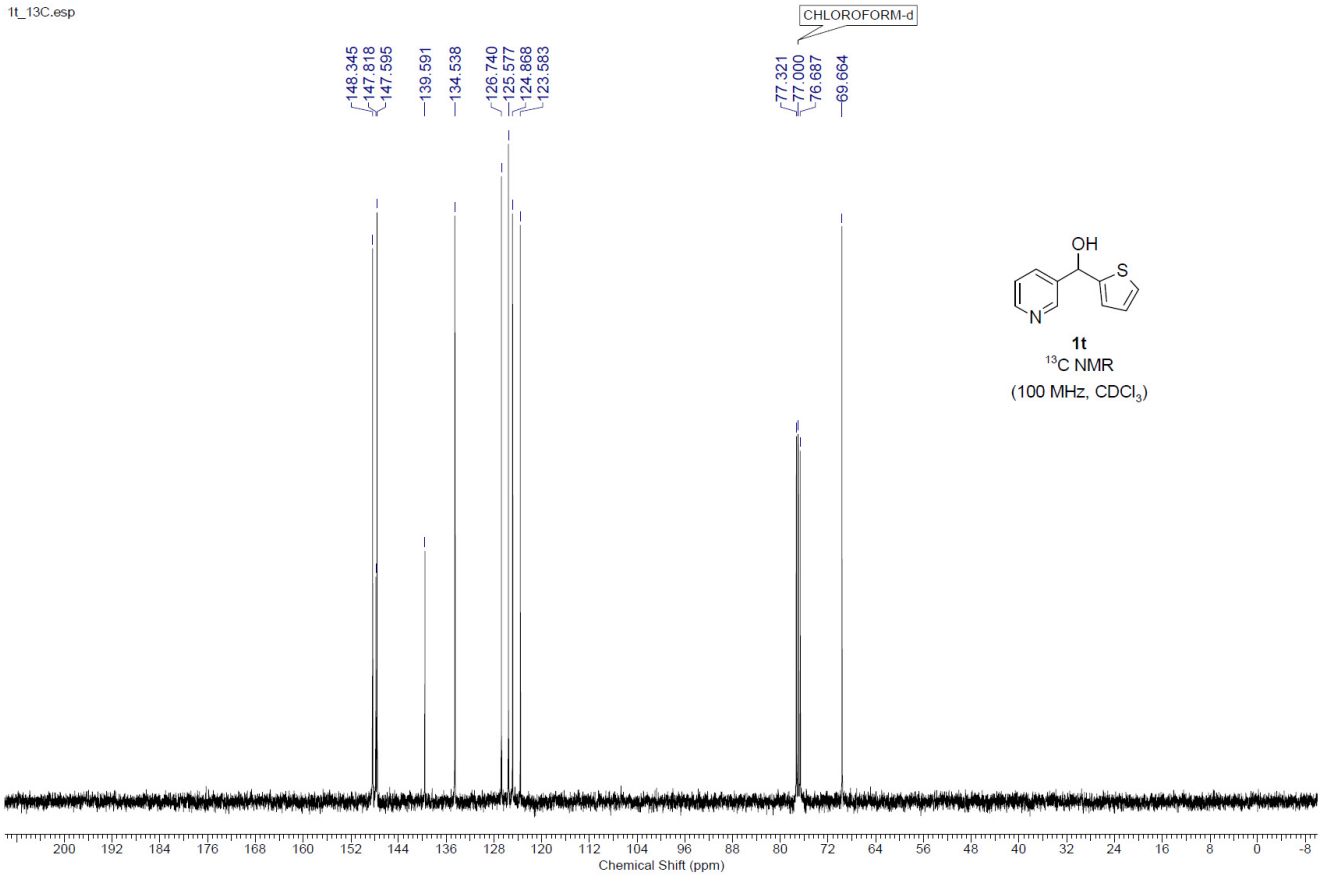

1r_1H.esp
TMS
8.640
8.559
8.554
8.511
8.499
8.496
8.391
8.377
7.659
7.644
7.640
7.635
7.296
7.283
7.276
7.268
7.087
7.074
6.043
2.222
0.000
OH
N
N
1r
1H NMR
(400 MHz, CDCl3)
1.00 1.00 0.96 0.98 1.00 0.99 1.00 1.02 3.11
Chemical Shift (ppm)

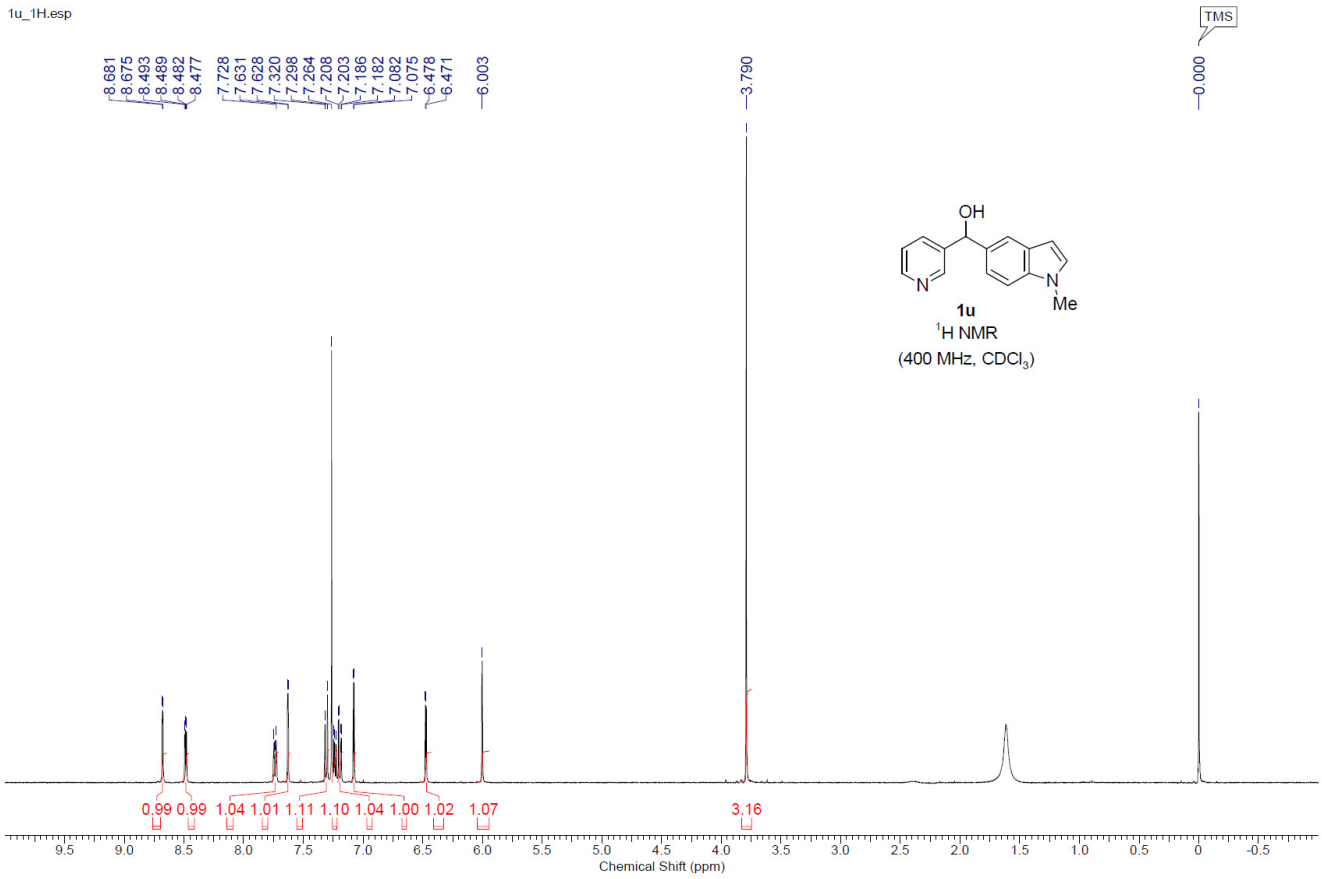

1r_13C.esp
CHLOROFORM-d
148.320
148.180
148.106
147.546
145.633
138.445
137.373
134.826
125.841
123.574
77.321
77.000
76.687
69.490
18.819
OH
N
N
1r
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

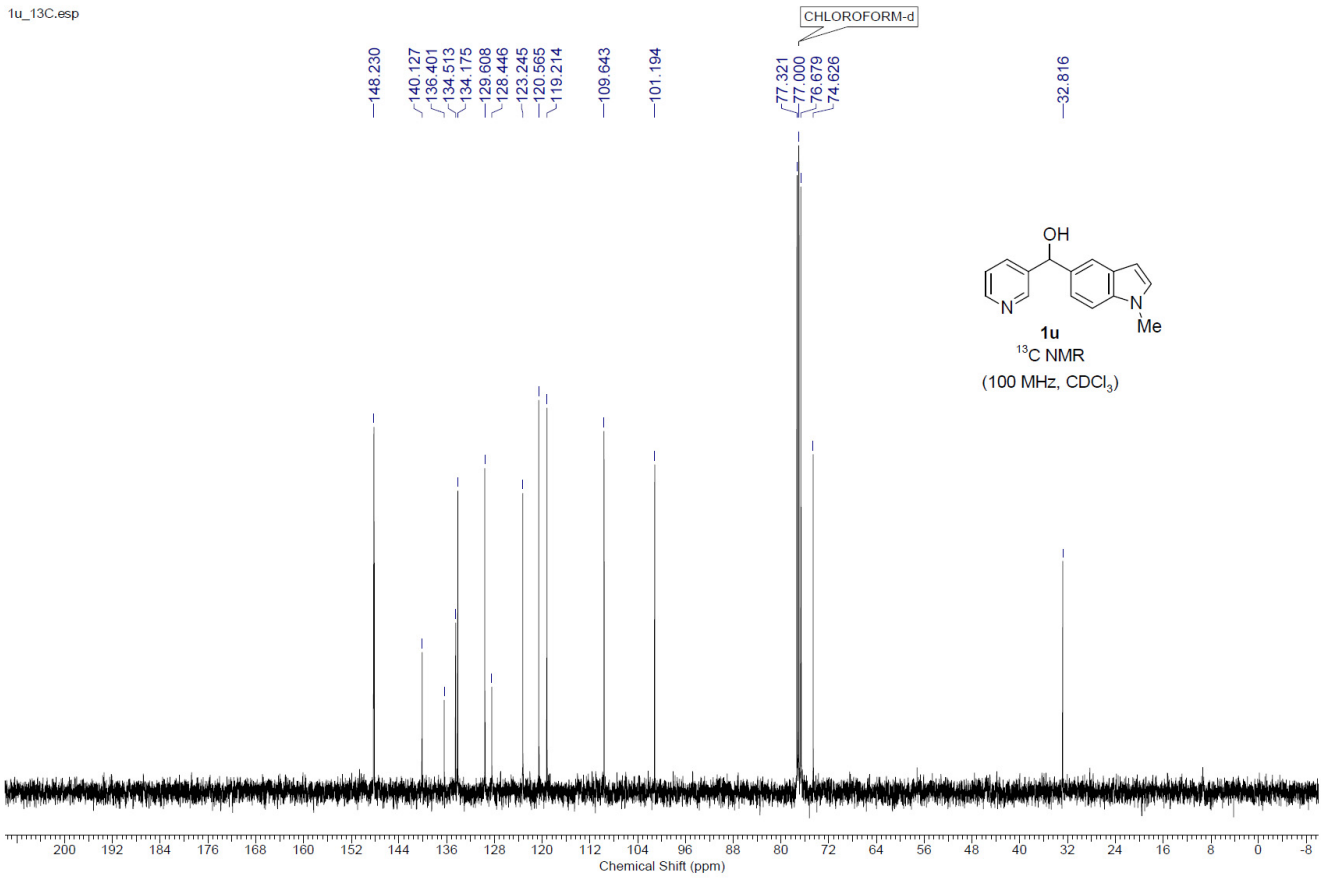

1s_1H.esp
TMS
8.430
8.325
8.314
7.721
7.701
7.277
7.270
7.266
7.258
7.243
7.231
7.224
7.158
6.958
6.946
5.866
4.830
0.000
OH
N
O
1s
1H NMR
(400 MHz, CDCl3)
1.01 1.01 1.01 2.10 0.99 1.00 1.02 1.16
Chemical Shift (ppm)

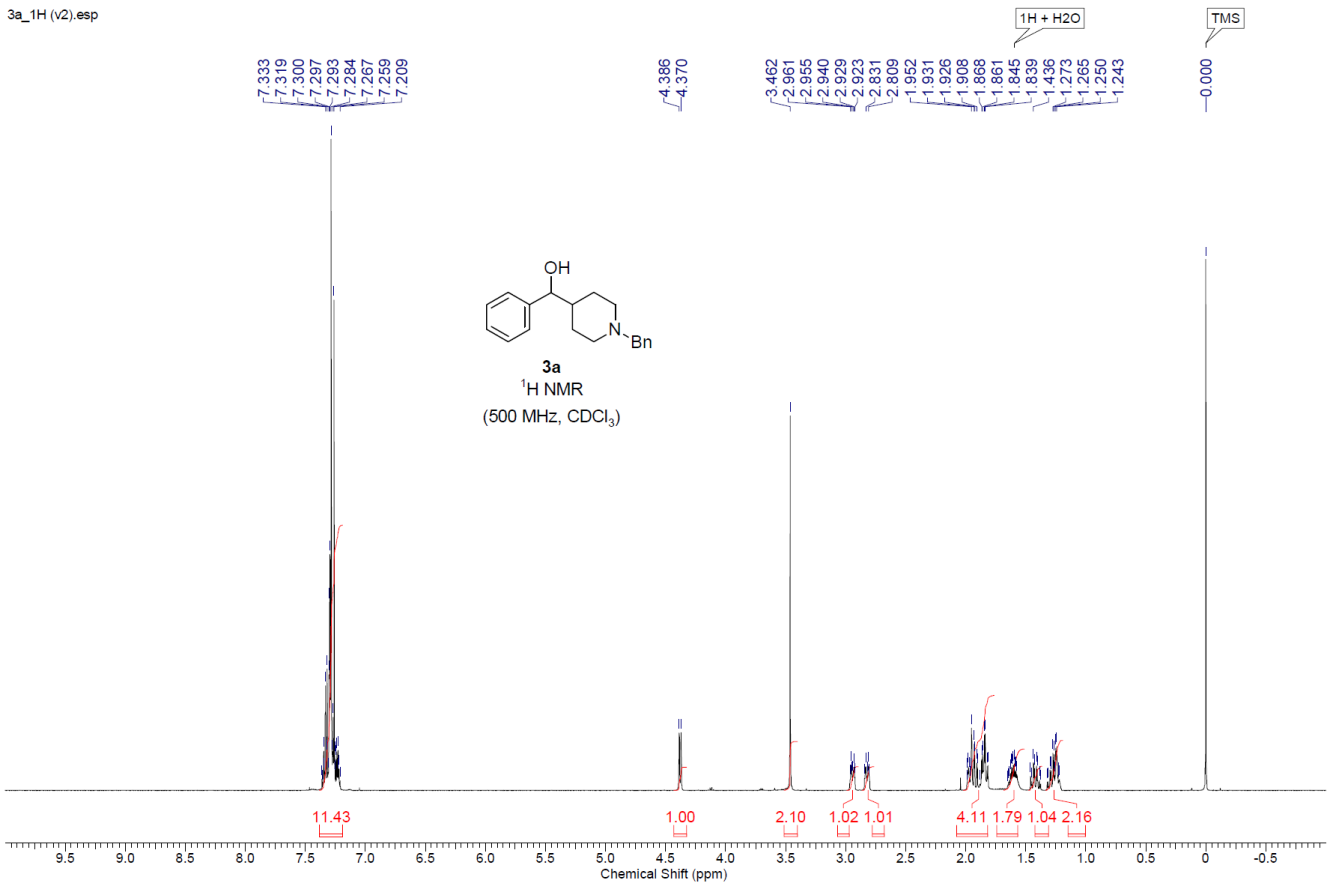

1s_13C.esp
CHLOROFORM-d
148.007
147.504
143.589
139.649
139.533
134.628
128.594
123.508
109.017
77.321
77.000
76.687
66.407
OH
N
O
1s
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

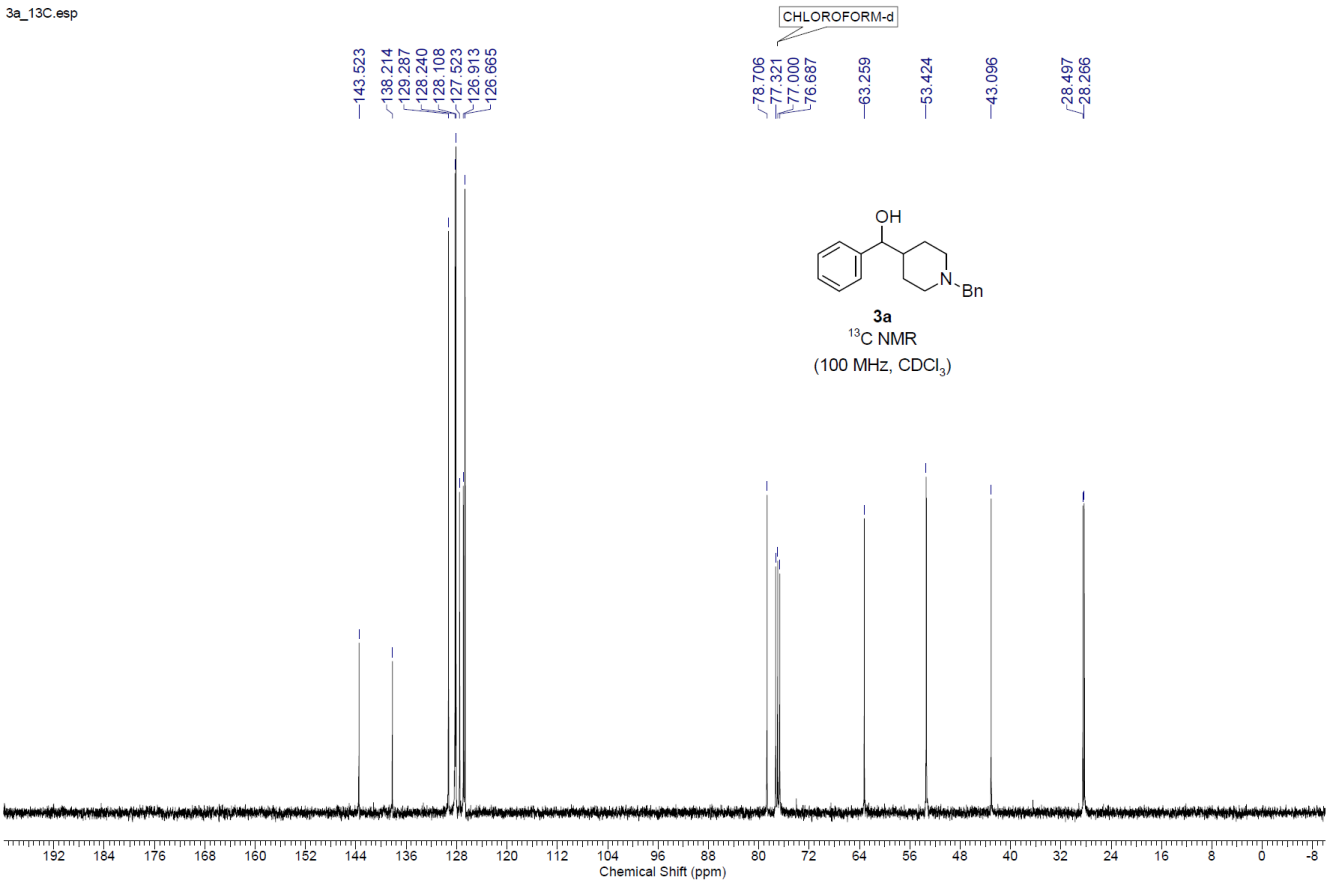

1t_1H.esp
TMS
8.636
8.630
8.512
8.504
8.500
7.815
7.799
7.795
7.305
7.302
7.293
7.290
7.265
6.977
6.968
6.964
6.956
6.921
6.115
0.000
OH
S
N
1t
1H NMR
(400 MHz, CDCl3)
1.00 0.99 0.98 1.96 1.96 1.00
Chemical Shift (ppm)

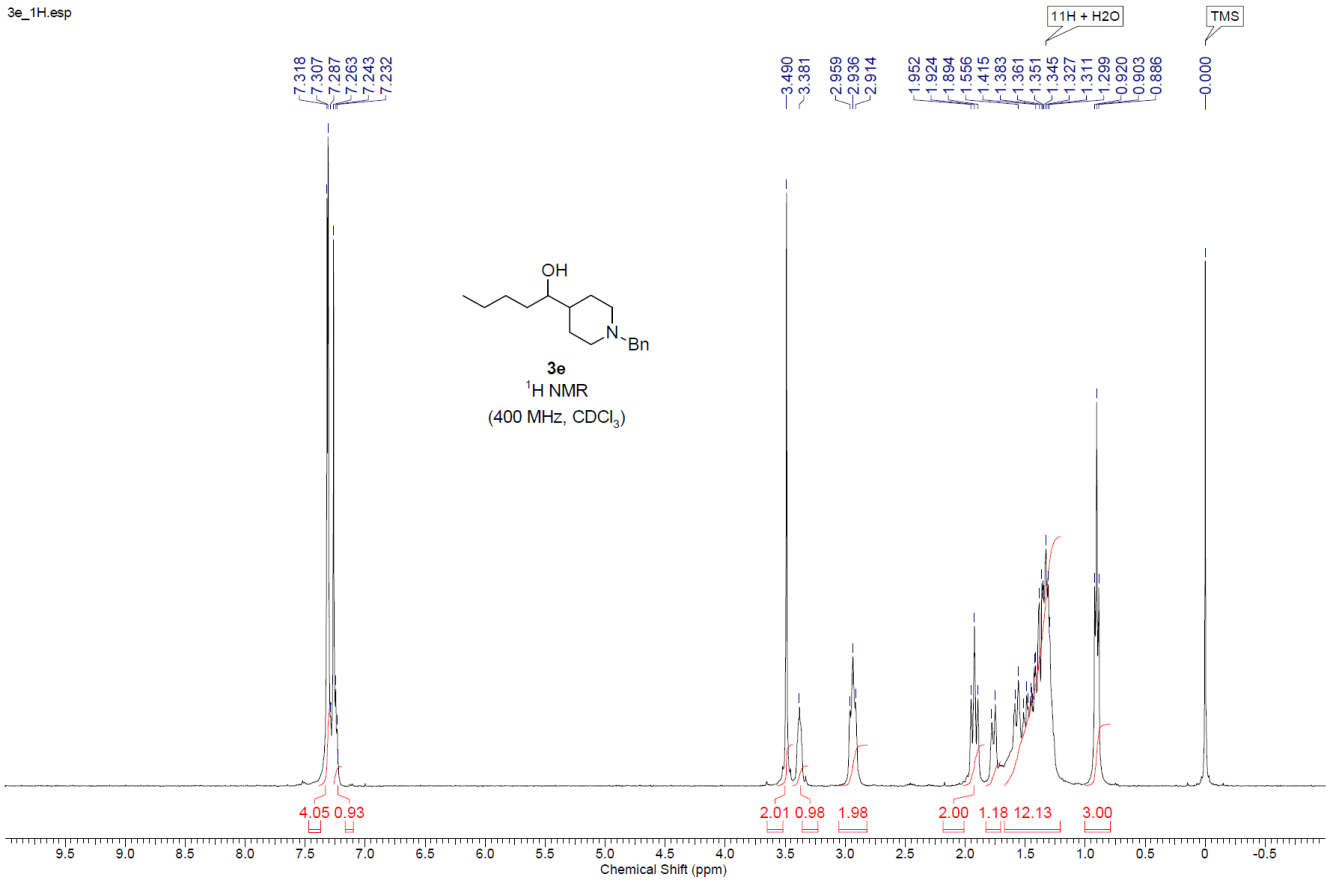

1t_13C.esp
CHLOROFORM-d
148.345
147.818
147.595
139.591
134.538
126.740
125.577
124.868
123.583
77.321
77.000
76.687
69.664
OH
S
N
1t
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

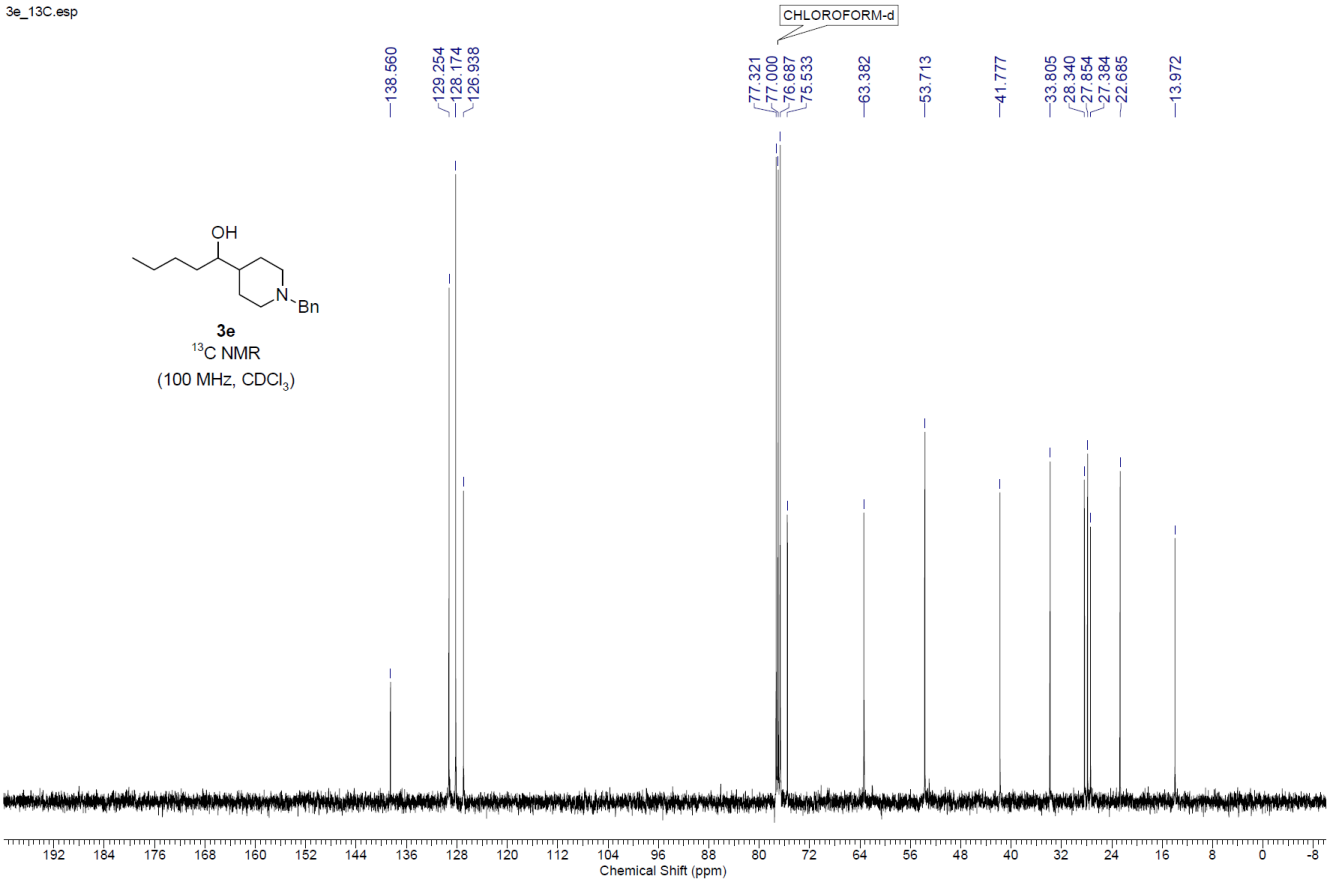

1u_1H.esp
TMS
8.681
8.675
8.493
8.489
8.482
8.477
7.728
7.631
7.628
7.320
7.298
7.264
7.208
7.203
7.186
7.182
7.082
7.075
6.478
6.471
6.003
3.790
0.000
OH
N
N
Me
1u
1H NMR
(400 MHz, CDCl3)
0.99 0.99 1.04 1.01 1.11 1.10 1.04 1.00 1.02 1.07
3.16
Chemical Shift (ppm)

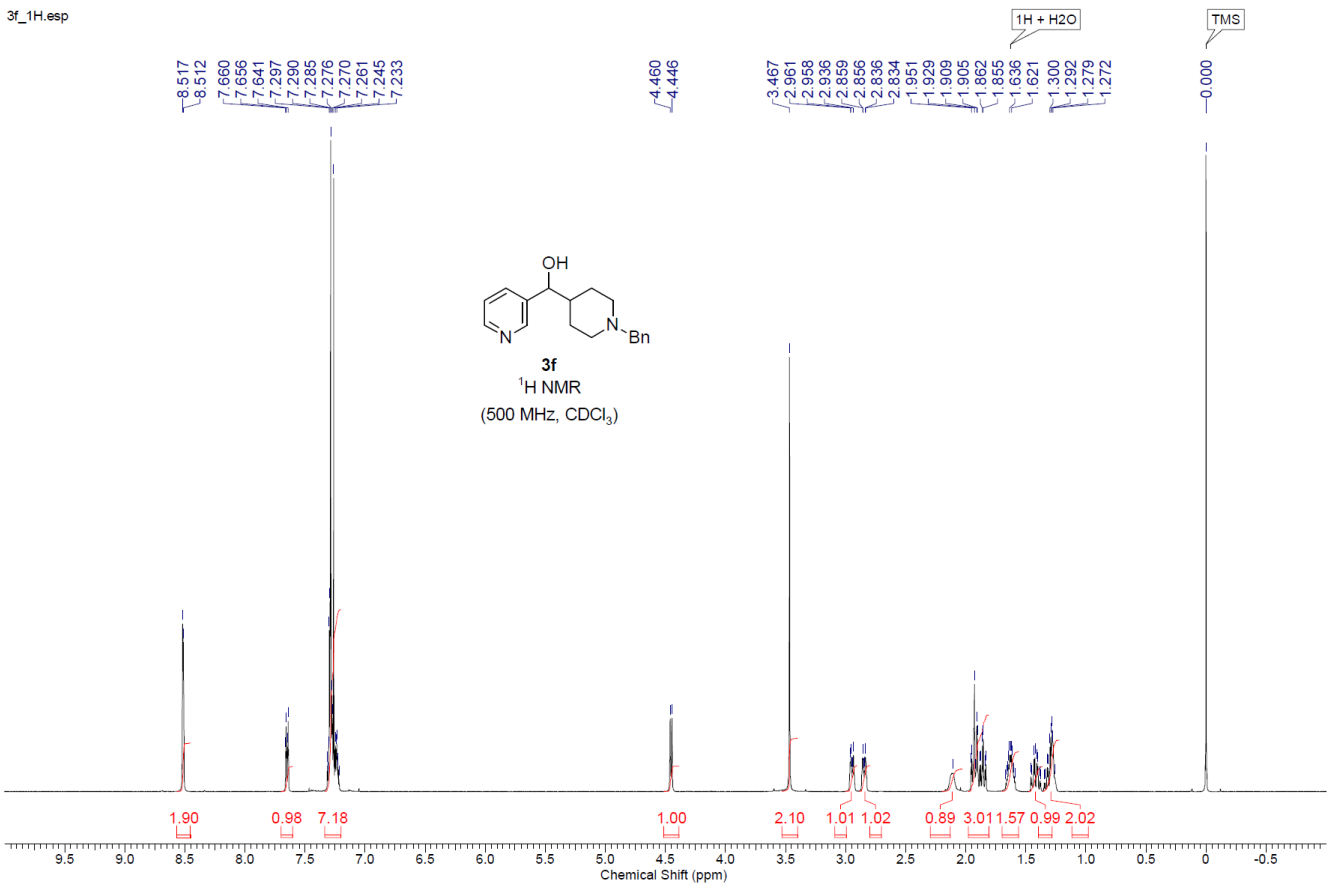

1u_13C.esp
CHLOROFORM-d
148.230
140.127
136.401
134.513
134.175
129.608
128.446
123.245
120.565
119.214
109.643
101.194
77.321
77.000
76.679
74.626
32.816
OH
N
N
Me
1u
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

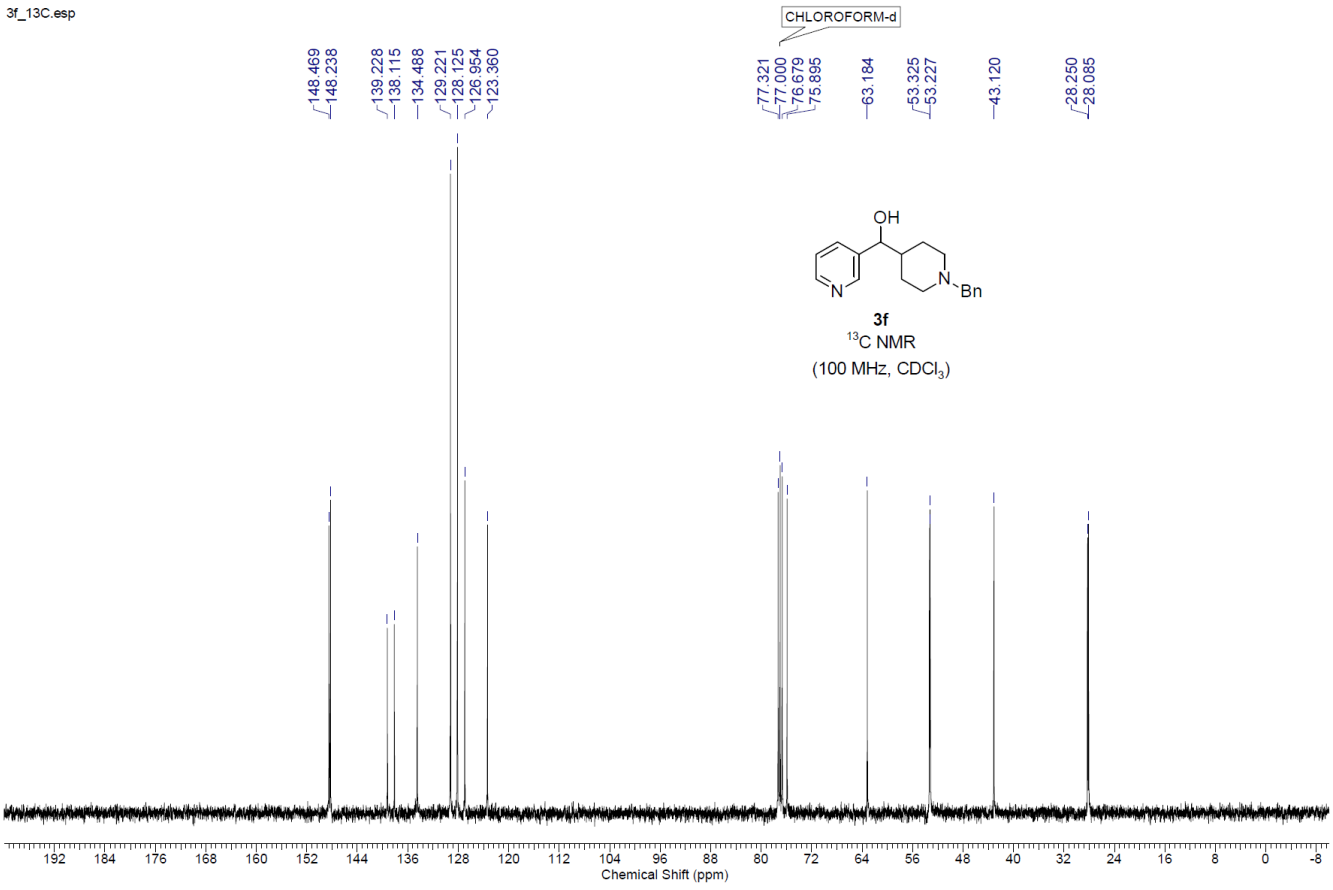

3a_1H (v2).esp
1H + H2O
TMS
7.333
7.319
7.300
7.297
7.293
7.284
7.267
7.259
7.209
4.386
4.370
3.462
2.961
2.955
2.940
2.929
2.923
2.831
2.809
1.952
1.931
1.926
1.908
1.868
1.861
1.845
1.839
1.436
1.273
1.265
1.250
1.243
0.000
OH
N
Bn
3a
1H NMR
(500 MHz, CDCl3)
11.43
1.00
2.10
1.02
1.01
4.11
1.79
1.04
2.16
Chemical Shift (ppm)

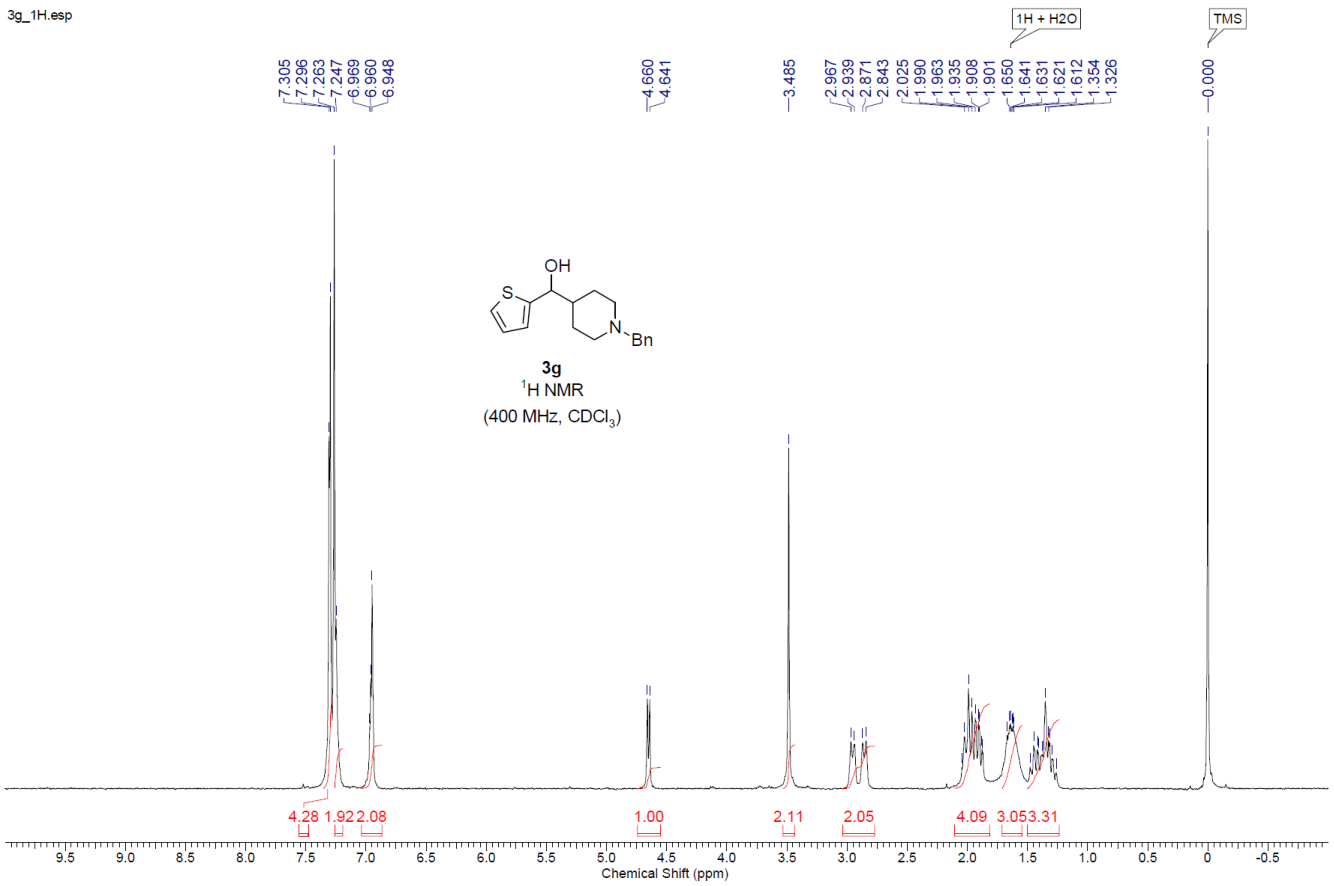

3a_13C.esp
CHLOROFORM-d
143.523
138.214
129.287
128.240
128.108
127.523
126.913
126.665
78.706
77.321
77.000
76.687
63.259
53.424
43.096
28.497
28.266
OH
N
Bn
3a
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

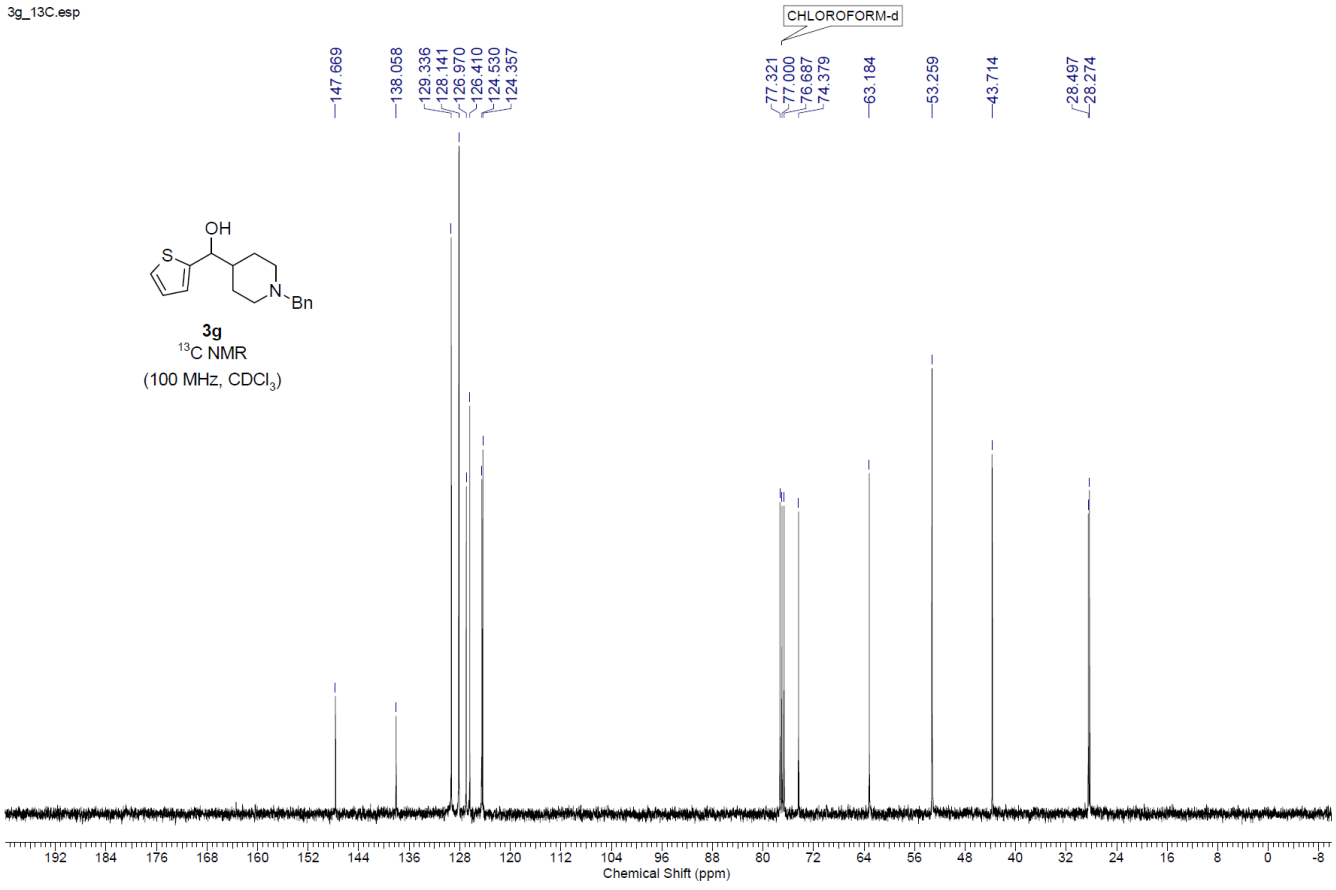

3e_1H.esp
11H + H2O
TMS
7.318
7.307
7.287
7.263
7.243
7.232
3.490
3.381
2.959
2.936
2.914
1.952
1.924
1.894
1.556
1.415
1.383
1.361
1.351
1.345
1.327
1.311
1.299
0.920
0.903
0.886
0.000
OH
N
Bn
3e
1H NMR
(400 MHz, CDCl3)
4.05 0.93
2.01 0.98 1.98
2.00 1.18 12.13 3.00
Chemical Shift (ppm)

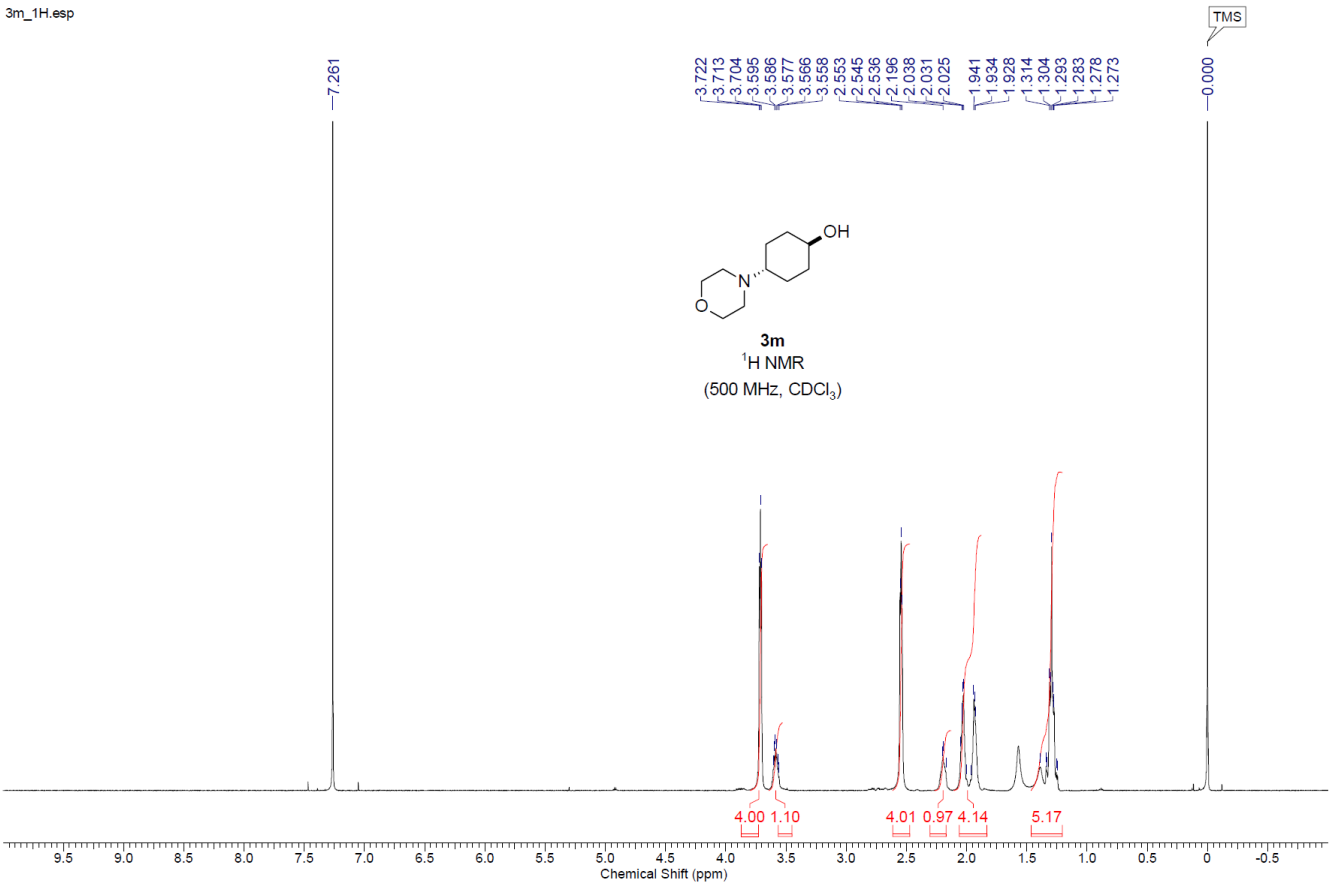

3e_13C.esp
CHLOROFORM-d
138.560
129.254
128.174
126.938
77.321
77.000
76.687
75.533
63.382
53.713
41.777
33.805
28.340
27.854
27.384
22.685
13.972
OH
N
Bn
3e
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

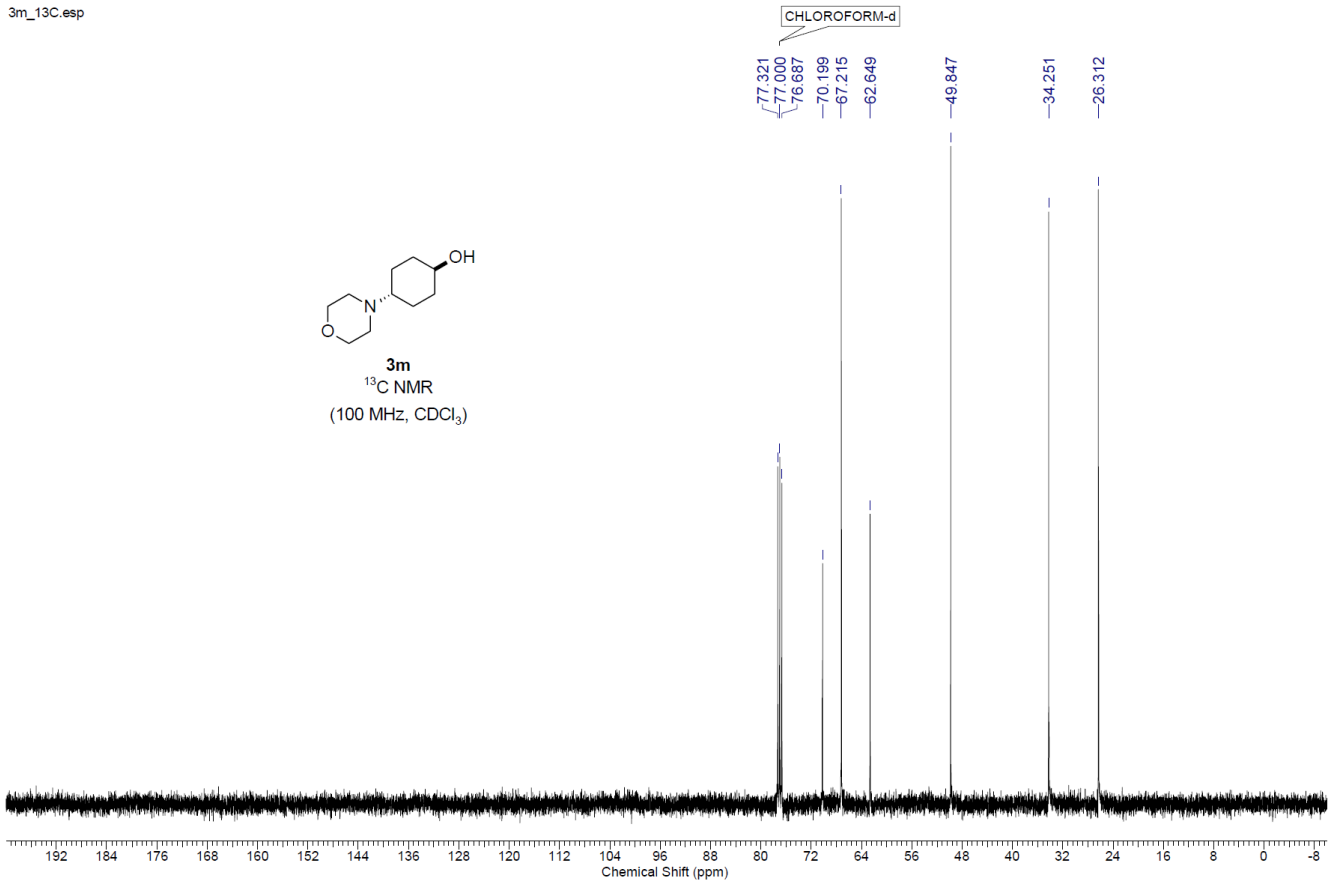

3f_1H.esp
1H + H2O
TMS
8.517
8.512
7.660
7.656
7.641
7.297
7.290
7.285
7.276
7.270
7.261
7.245
7.233
4.460
4.446
3.467
2.961
2.958
2.936
2.859
2.856
2.836
2.834
1.951
1.929
1.909
1.905
1.862
1.855
1.636
1.621
1.300
1.292
1.279
1.272
0.000
OH
N
N
Bn
3f
1H NMR
(500 MHz, CDCl3)
1.90
0.98
7.18
1.00
2.10
1.01
1.02
0.89
3.01
1.57
0.99
2.02
Chemical Shift (ppm)

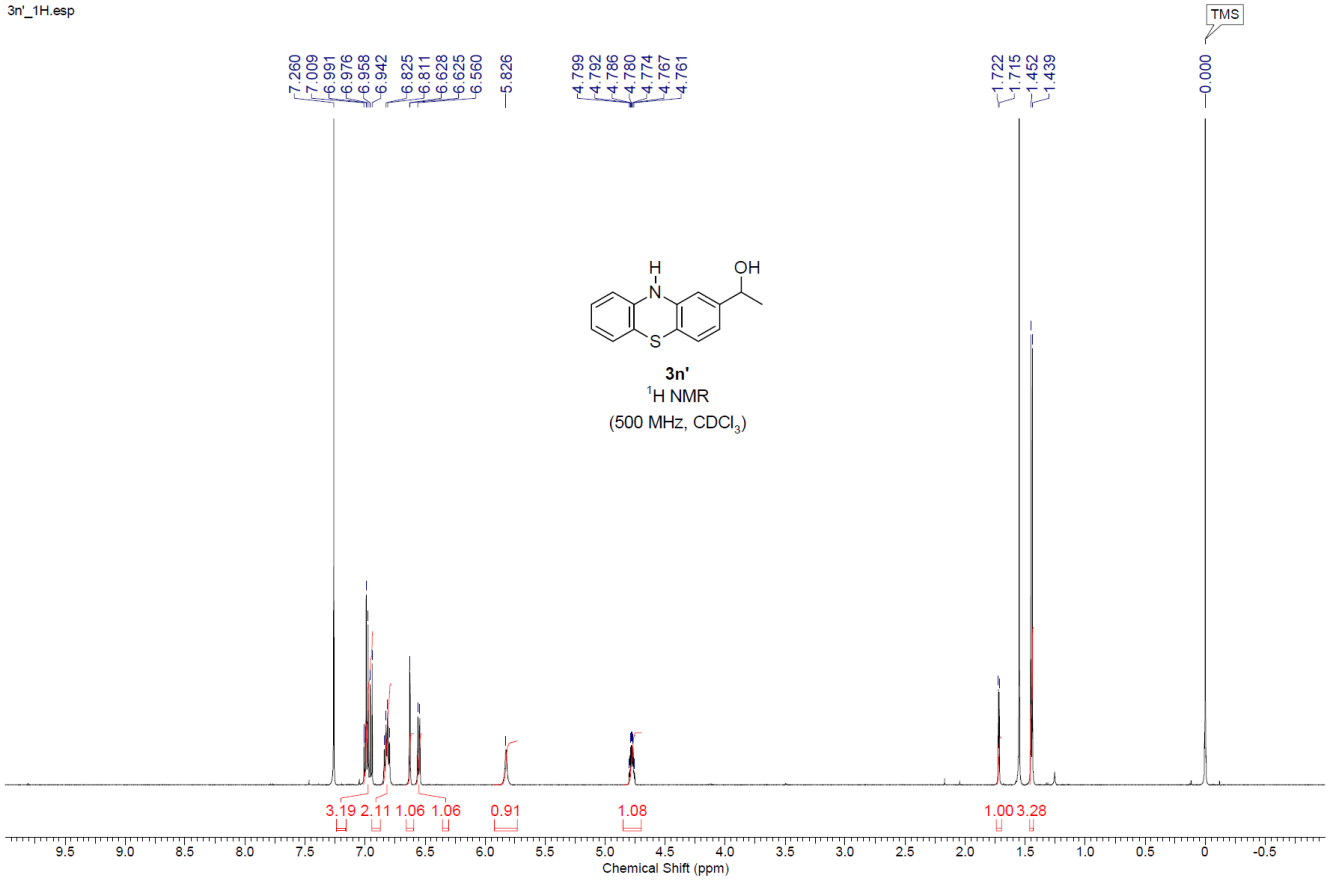

3f_13C.esp
CHLOROFORM-d
148.469
148.238
139.228
138.115
134.488
129.221
128.125
126.954
123.360
77.321
77.000
76.679
75.895
63.184
53.325
53.227
43.120
28.250
28.085
OH
N
N
Bn
3f
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

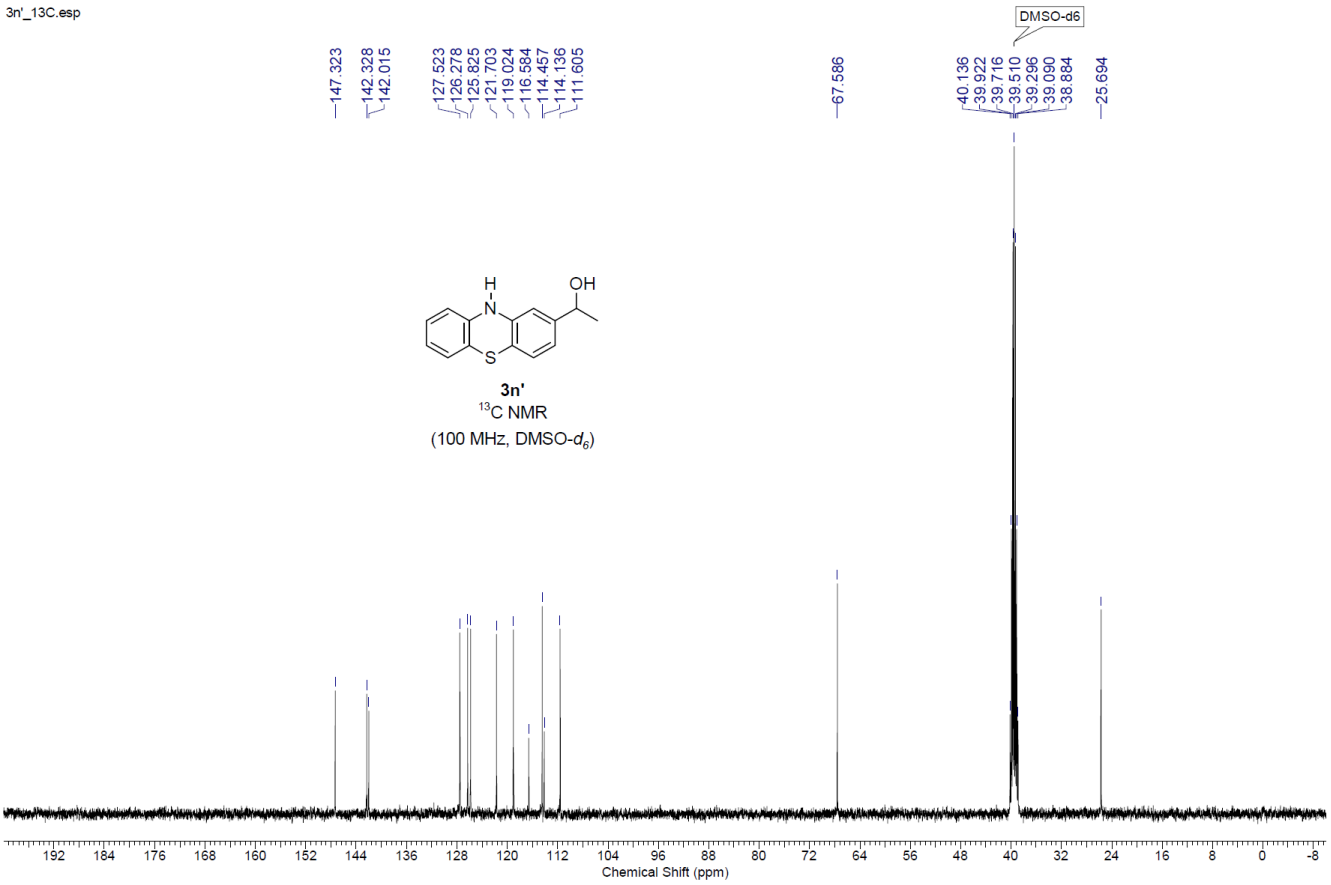

3g_1H.esp
1H + H2O
TMS
7.305
7.296
7.263
7.247
6.969
6.960
6.948
4.660
4.641
3.485
2.967
2.939
2.871
2.843
2.025
1.990
1.963
1.935
1.908
1.901
1.650
1.641
1.631
1.621
1.612
1.354
1.326
0.000
OH
S
N
Bn
3g
1H NMR
(400 MHz, CDCl3)
4.28
1.92
2.08
1.00
2.11
2.05
4.09
3.05
3.31
Chemical Shift (ppm)

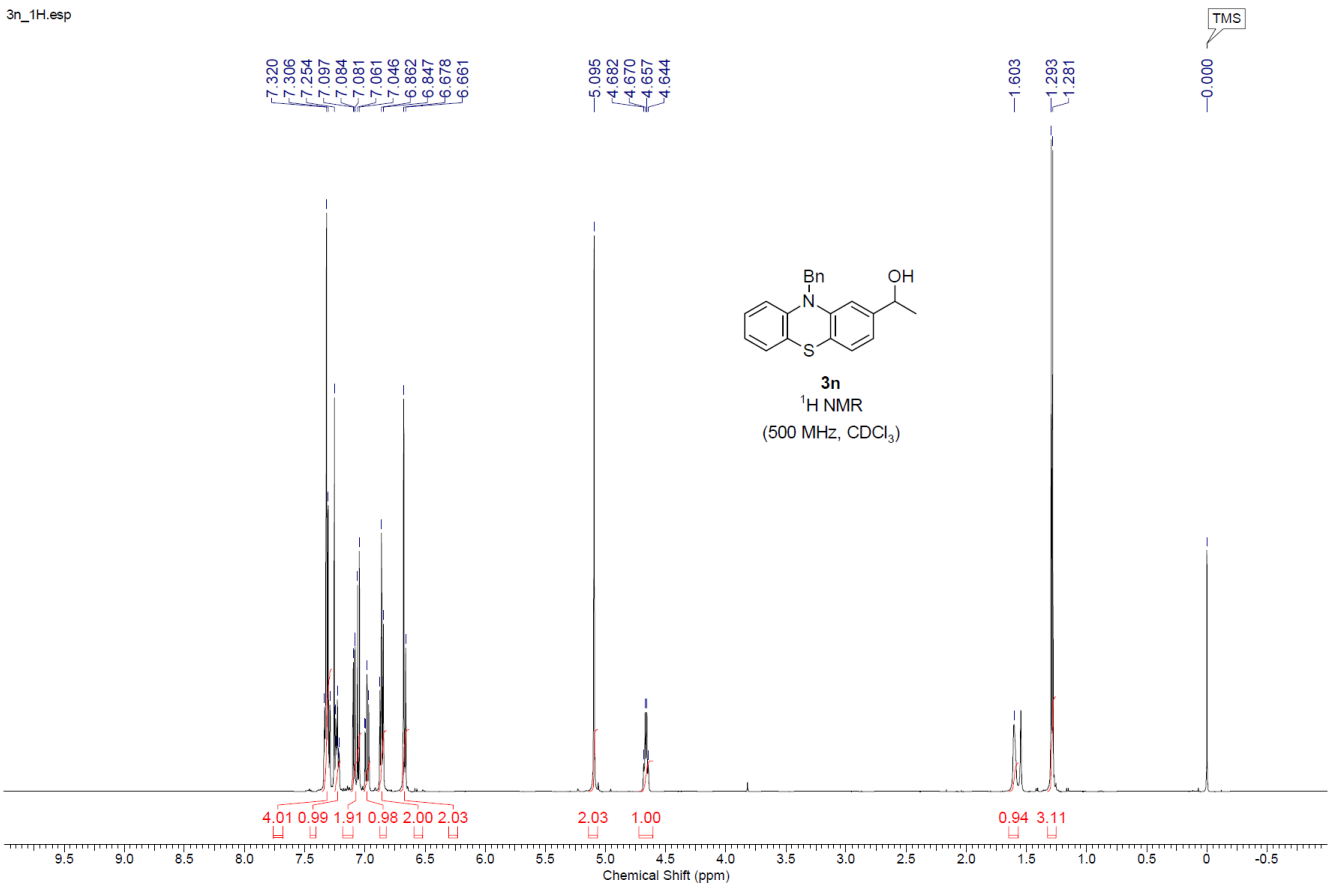

3g_13C.esp
CHLOROFORM-d
147.669
138.058
129.336
128.141
126.970
126.410
124.530
124.357
77.321
77.000
76.687
74.379
63.184
53.259
43.714
28.497
28.274
OH
S
N
Bn
3g
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

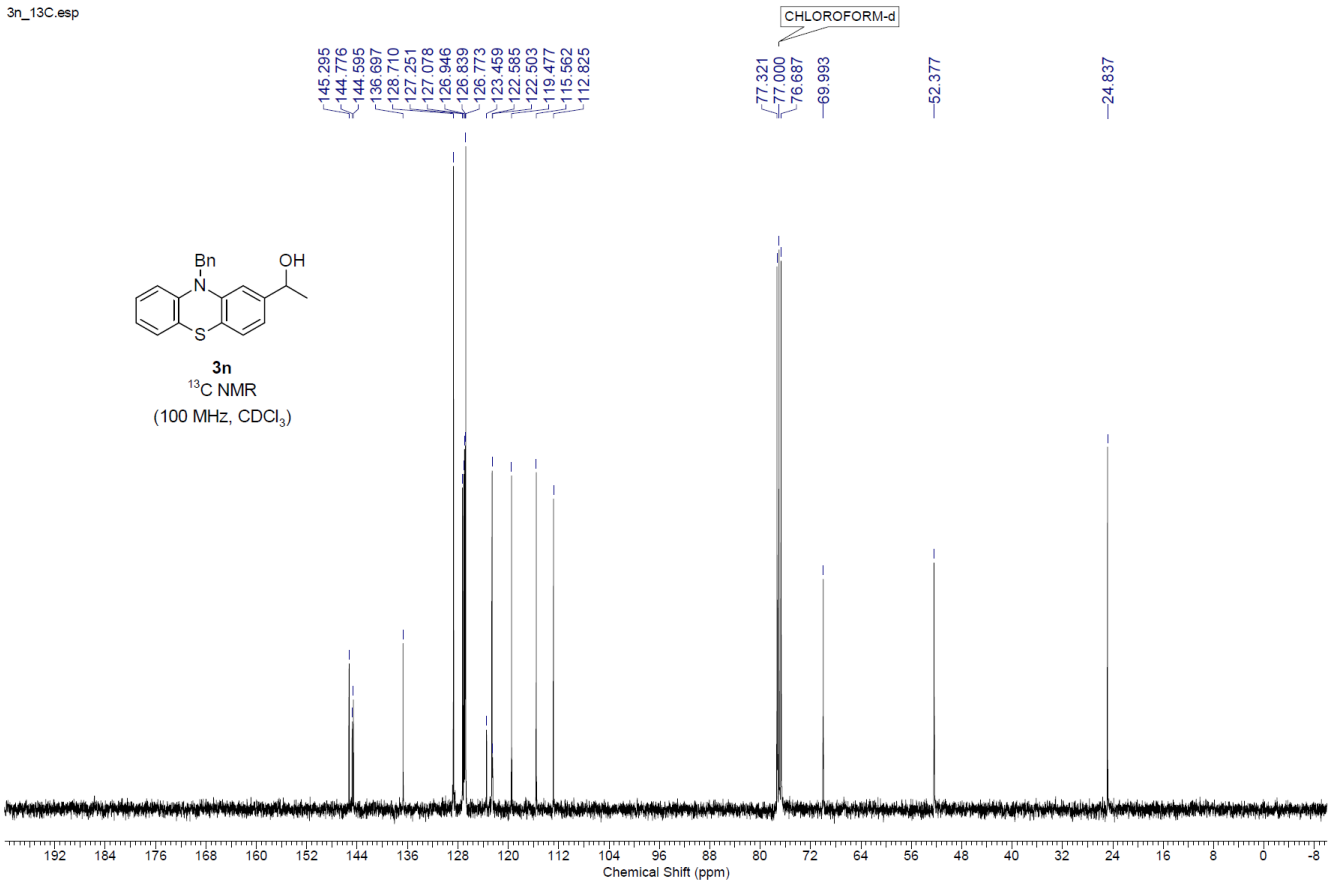

3m_1H.esp
TMS
7.261
3.722
3.713
3.704
3.595
3.586
3.577
3.566
3.558
2.553
2.545
2.536
2.196
2.038
2.031
2.025
1.941
1.934
1.928
1.314
1.304
1.293
1.283
1.278
1.273
0.000
OH
N
O
3m
1H NMR
(500 MHz, CDCl3)
4.00 1.10 4.01 0.97 4.14 5.17
Chemical Shift (ppm)

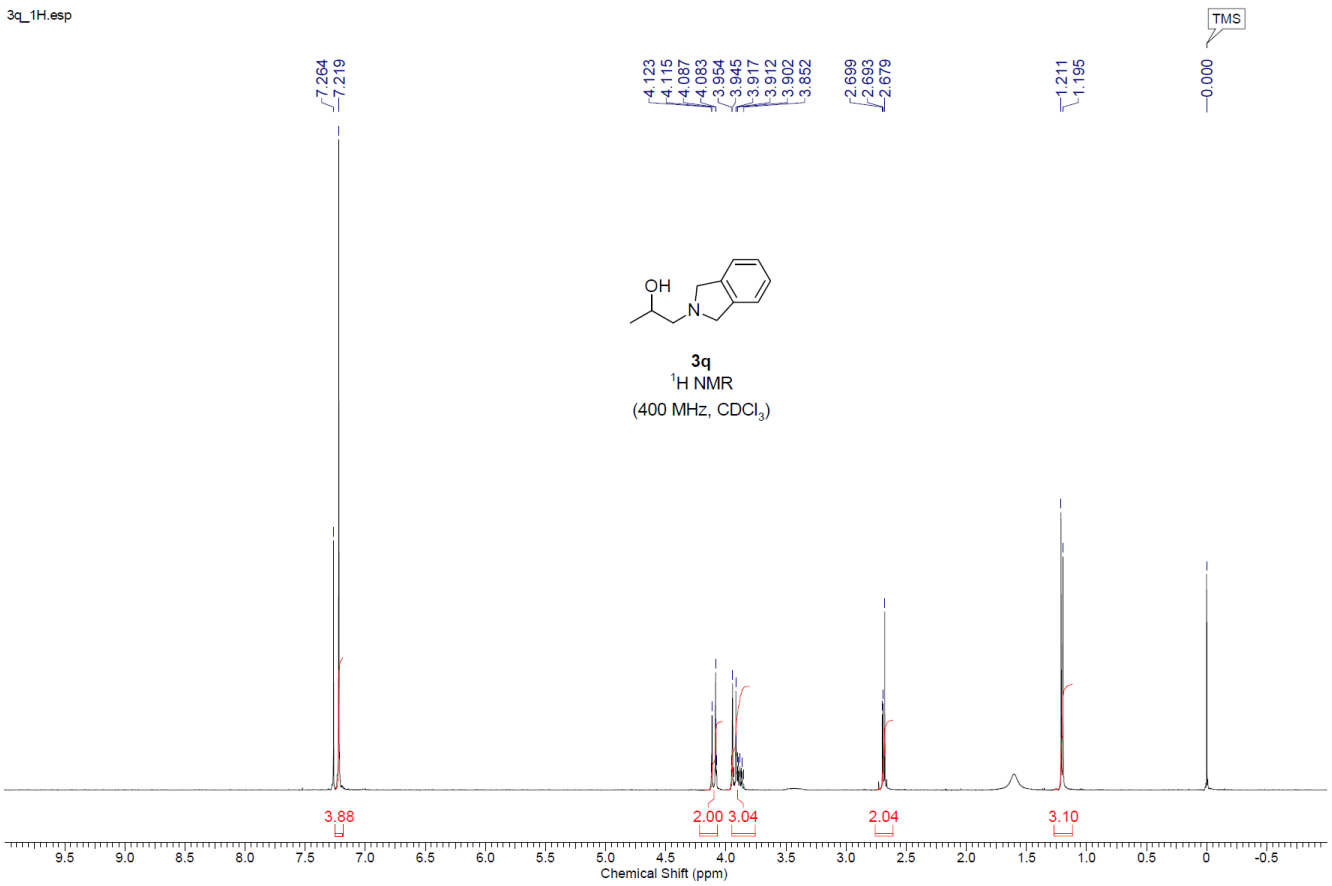

3m_13C.esp
CHLOROFORM-d
77.321
77.000
76.687
70.199
67.215
62.649
49.847
34.251
26.312
OH
N
O
3m
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

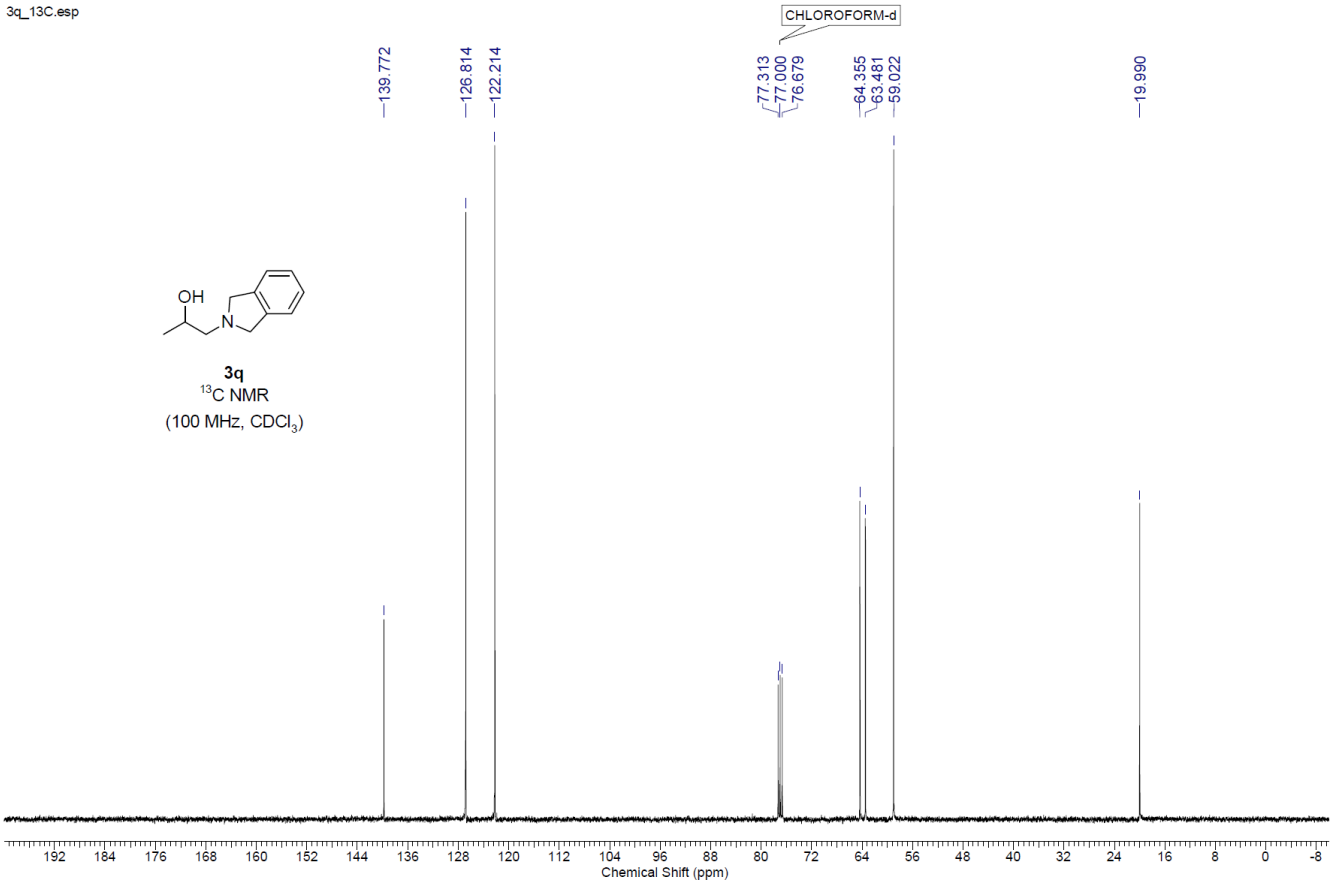

3n'_1H.esp
TMS
7.260
7.009
6.991
6.976
6.958
6.942
6.825
6.811
6.628
6.625
6.560
5.826
4.799
4.792
4.786
4.780
4.774
4.767
4.761
1.722
1.715
1.452
1.439
0.000
H
N
S
OH
3n'
1H NMR
(500 MHz, CDCl3)
3.19 2.11 1.06 1.06 0.91 1.08 1.00 3.28
Chemical Shift (ppm)

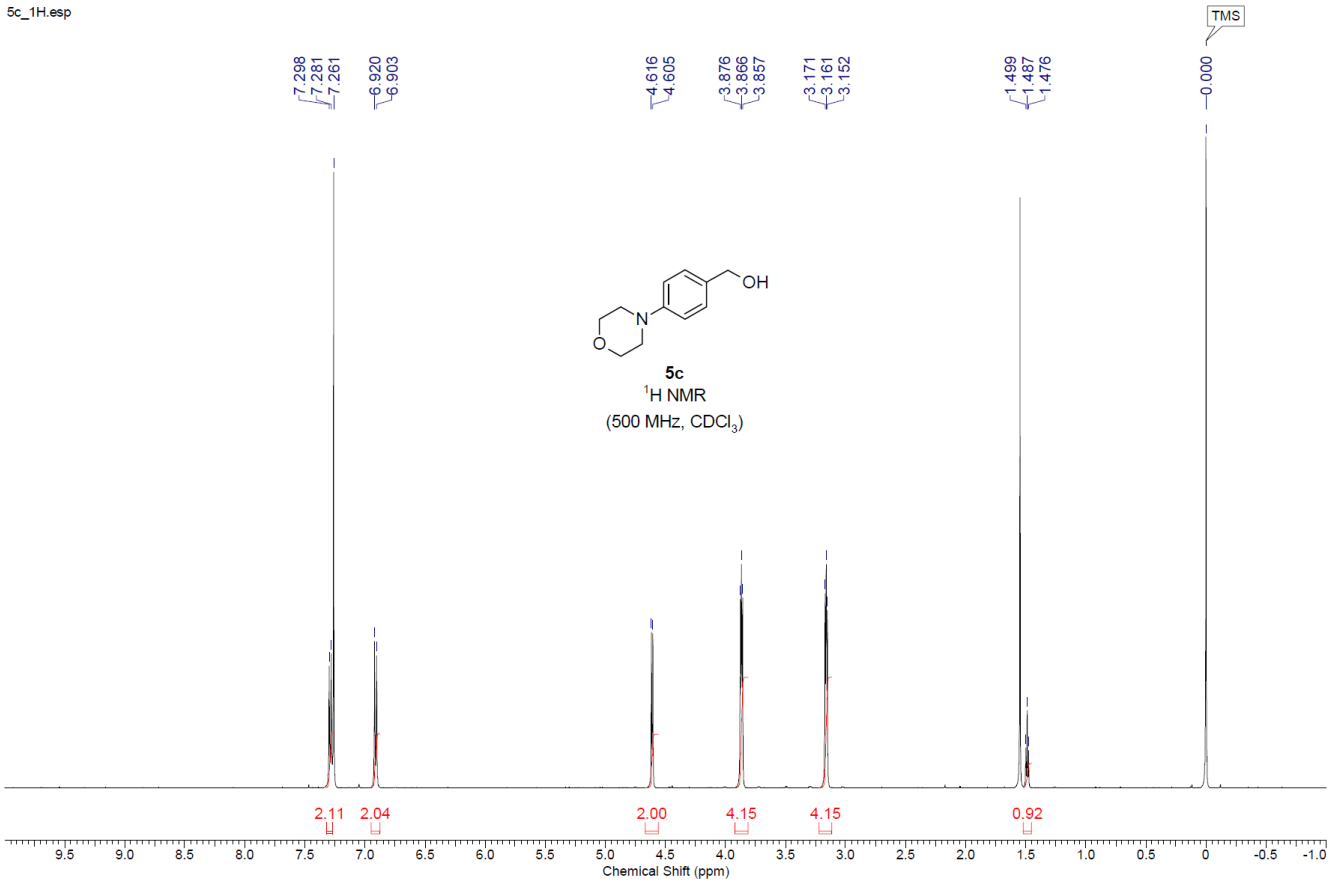

3n'_13C.esp
DMSO-d6
147.323
142.328
142.015
127.523
126.278
125.825
121.703
119.024
116.584
114.457
114.136
111.605
67.586
40.136
39.922
39.716
39.510
39.296
39.090
38.884
25.694
H
N
S
OH
3n'
13C NMR
(100 MHz, DMSO-d6)
Chemical Shift (ppm)

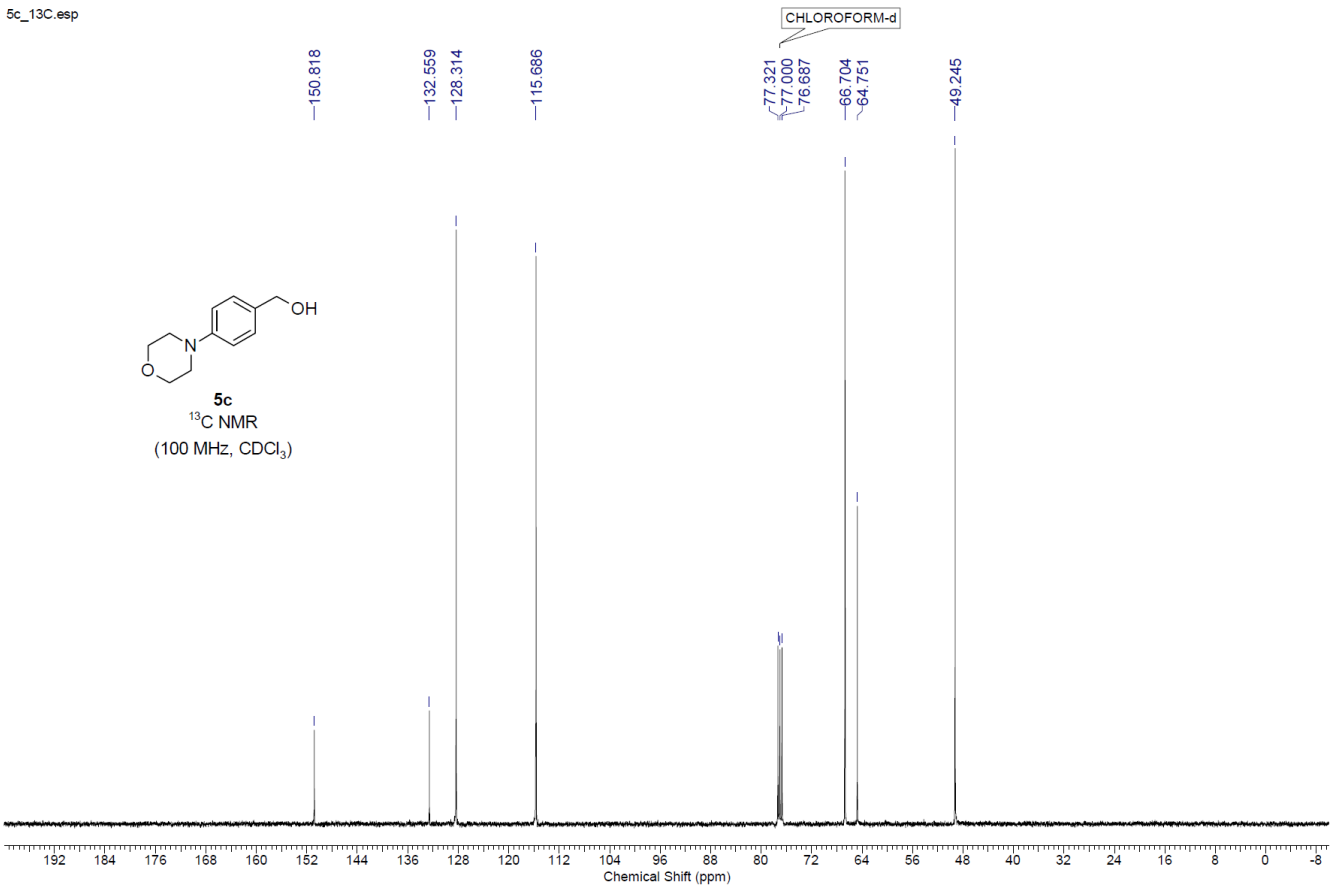

3n_1H.esp
TMS
7.320
7.306
7.254
7.097
7.084
7.081
7.061
7.046
6.862
6.847
6.678
6.661
5.095
4.682
4.670
4.657
4.644
1.603
1.293
1.281
0.000
Bn
OH
N
S
3n
1H NMR
(500 MHz, CDCl3)
4.01 0.99 1.91 0.98 2.00 2.03
2.03 1.00
0.94 3.11
Chemical Shift (ppm)

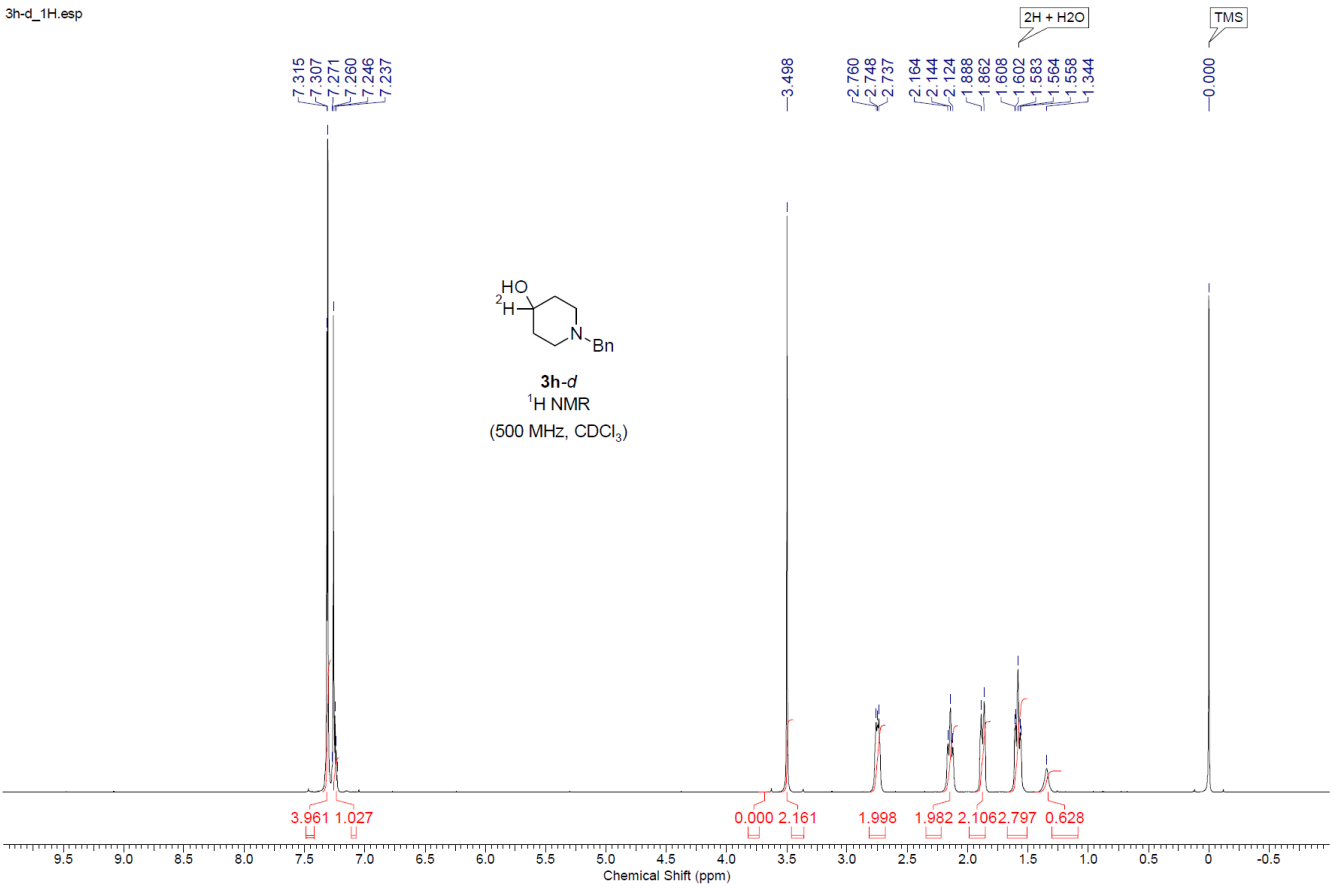

3n_13C.esp
CHLOROFORM-d
145.295
144.776
144.595
136.697
128.710
127.251
127.078
126.946
126.839
126.773
123.459
122.585
122.503
119.477
115.562
112.825
77.321
77.000
76.687
69.993
52.377
24.837
Bn
OH
N
S
3n
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)

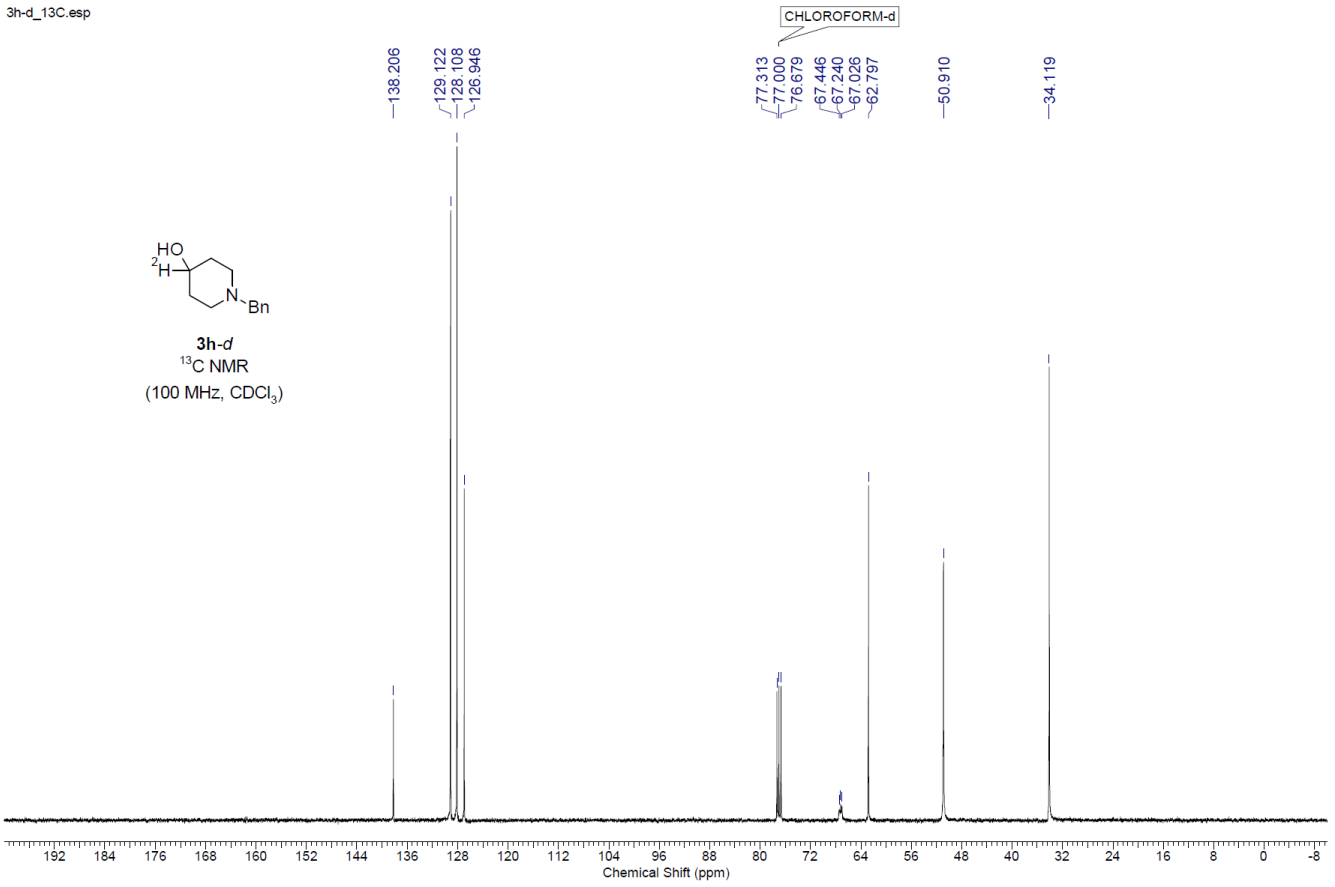

3q_1H.esp
TMS
7.264
7.219
4.123
4.115
4.087
4.083
3.954
3.945
3.917
3.912
3.902
3.852
2.699
2.693
2.679
1.211
1.195
0.000
OH
N
3q
1H NMR
(400 MHz, CDCl3)
3.88
2.00
3.04
2.04
3.10
Chemical Shift (ppm)

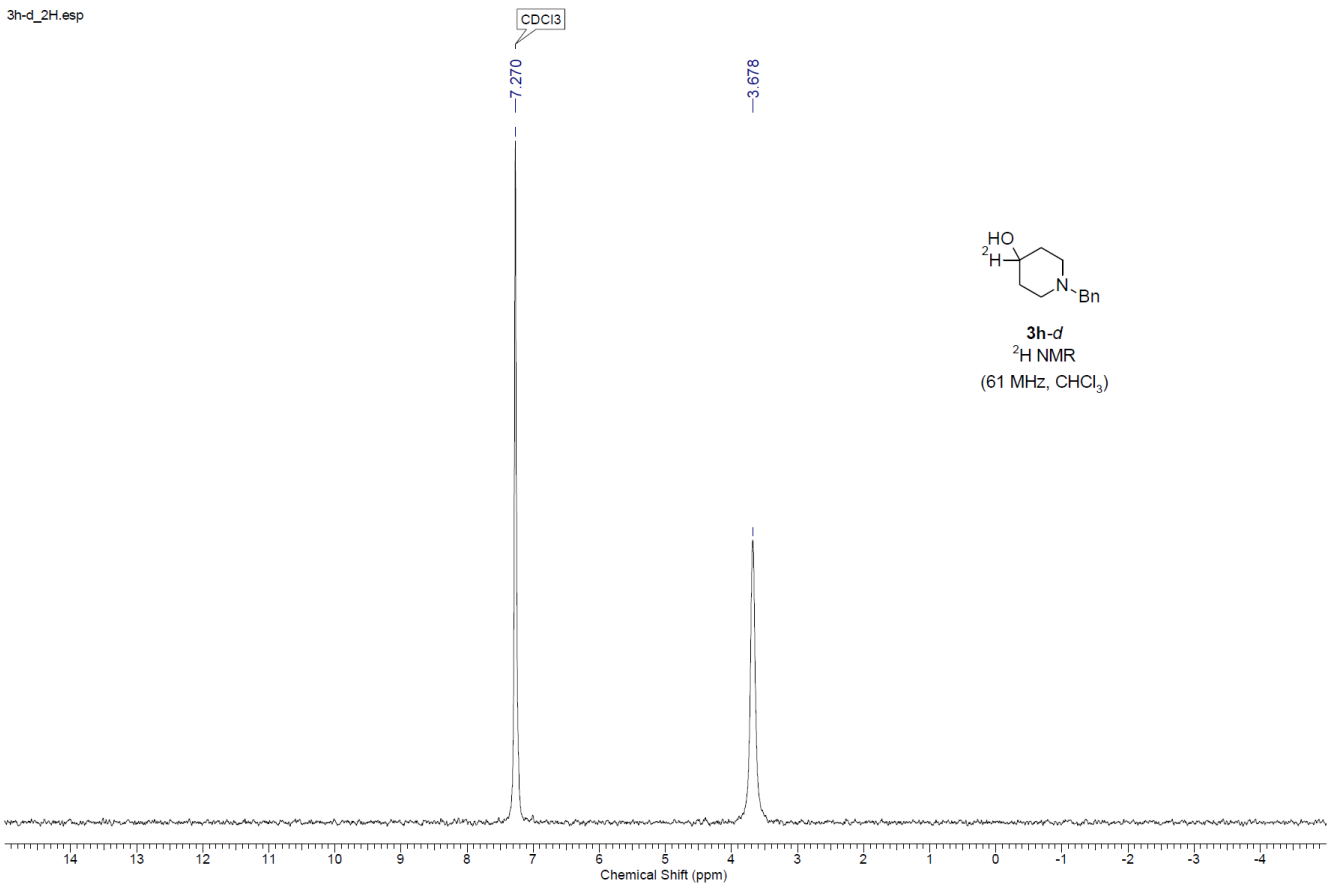

3q_13C.esp
CHLOROFORM-d
139.772
126.814
122.214
77.313
77.000
76.679
64.355
63.481
59.022
19.990
OH
N
3q
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


5c_1H.esp
TMS
7.298
7.281
7.261
6.920
6.903
4.616
4.605
3.876
3.866
3.857
3.171
3.161
3.152
1.499
1.487
1.476
0.000
OH
N
O
5c
1H NMR
(500 MHz, CDCl3)
2.11
2.04
2.00
4.15
4.15
0.92
Chemical Shift (ppm)


5c_13C.esp
CHLOROFORM-d
150.818
132.559
128.314
115.686
77.321
77.000
76.687
66.704
64.751
49.245
OH
N
O
5c
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


3h-d_1H.esp
2H + H2O
TMS
7.315
7.307
7.271
7.260
7.246
7.237
3.498
2.760
2.748
2.737
2.164
2.144
2.124
1.888
1.862
1.608
1.602
1.583
1.564
1.558
1.344
0.000
HO
2H
N
Bn
3h-d
1H NMR
(500 MHz, CDCl3)
3.961 1.027
0.000 2.161
1.998
1.982 2.106 2.797
0.628
Chemical Shift (ppm)


3h-d_13C.esp
CHLOROFORM-d
138.206
129.122
128.108
126.946
77.313
77.000
76.679
67.446
67.240
67.026
62.797
50.910
34.119
HO
2H
N
Bn
3h-d
13C NMR
(100 MHz, CDCl3)
Chemical Shift (ppm)


3h-d_2H.esp
CDCl3
7.270
3.678
HO
2H
N
Bn
3h-d
2H NMR
(61 MHz, CHCl3)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
Chemical Shift (ppm)