Supporting Information For:

An Umpolung Strategy for the Synthesis of β-Aminoketones via Copper-Catalyzed Electrophilic Amination of Cyclopropanols

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Part 1. Experimental procedures and spectra data

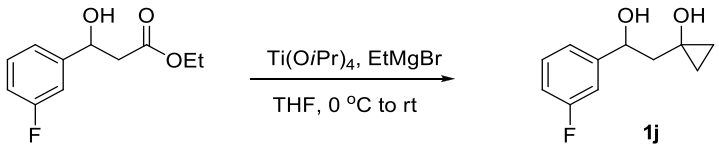
I. General Methods

General Methods: NMR spectra were recorded on Bruker spectrometers (^{1}H at 400 MHz, 500 MHz, 800 MHz and ^{13}C at 100 MHz, 125 MHz, 200 MHz). Chemical shifts (δ) were given in ppm with reference to solvent signals [^{1}H NMR: $CHCl_3$ (7.26); ^{13}C NMR: $CDCl_3$ (77.2), C_6D_6 (128.02), CD_3OD (49.0)]. Column chromatography was performed on silica gel. All reactions sensitive to air or moisture were conducted under argon atmosphere in dry and freshly distilled solvents under anhydrous conditions, unless otherwise noted. Anhydrous THF and toluene were distilled over sodium benzophenone ketyl under Argon. Anhydrous CH_2Cl_2 was distilled over calcium hydride under Argon. All other solvents and reagents were used as obtained from commercial sources without further purification.

II. Synthesis of Cyclopropanol Substrates

Starting materials **1a**[1], **1b**[2], **1c**[3], **1d**[4], **1e**[1], **1f**[5], **1g**[6], **1h**[7], **1i**[8], **1s**[6] are prepared according to the previously reported procedures[1].

Preparation of 1j:

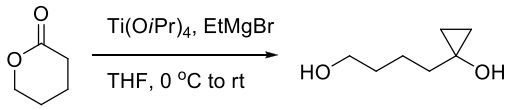


To a stirred solution of ethyl 3-(3-fluorophenyl)-3-hydroxypropanoate (2.38 g, 11.2 mmol) and Ti(O*i*Pr)$_4$ (3.34 g, 11.8 mmol) in dry THF (66 mL), a 3 M solution of EtMgBr (17.9 mL, 53.8 mmol) in Et_2O was added dropwise at 0 ˚C over 2 h under argon atmosphere. The reaction mixture was allowed to warm to room temperature and stirred for an additional 2 h before the addition of water (100 ml). The aqueous layer was extracted with dichloromethane. The organic layer was washed with brine,

dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 2/1) to give **1j** (0.68 g, 31%) as a clear, colorless oil.

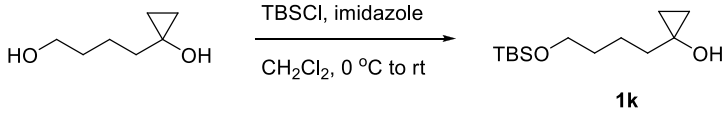
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.30 – 7.25 (m, 1H), 7.08 – 7.05 (m, 2H), 6.95 – 6.92 (m, 1H), 5.05 – 5.03 (m, 1H), 3.91 (br s, 2H), 2.27– 2.17 (m, 1H), 1.53 – 1.49 (m, 1H), 0.78 – 0.74 (m, 2H), 0.44 – 0.41 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ163.0 (d, $J_{C\text{-}F}$ = 245.7 Hz), 147.0 (d, $J_{C\text{-}F}$ = 6.5 Hz), 130.0 (d, $J_{C\text{-}F}$ = 8.1 Hz), 121.3, 114.4 (d, $J_{C\text{-}F}$ = 21.2 Hz), 112.7 (d, $J_{C\text{-}F}$ = 21.9 Hz), 74.0, 55.7, 46.3, 14.1, 12.5; ^{19}F NMR (470 MHz, $CDCl_3$) δ -112.9; IR (cm^{-1}) (neat): ν = 3334, 1615, 1591, 1247, 1133, 1060, 1012, 923, 874; MS (EI): m/z 196.

Preparation of 1-(4-hydroxybutyl)cyclopropanol:



To a stirred solution of δ-valerolactone (4.29 g, 42.68 mmol) and $Ti(O\textit{i}Pr)_4$ (12.18 g, 42.86 mmol) in dry THF (120 mL), the 3 M solution of EtMgBr (30 mL, 90 mmol) in Et_2O was added dropwise at 0 ˚C over 2 h under argon atmosphere. The reaction mixture was allowed to warm to room temperature and stirred for an additional 2 h before the addition of a saturated aqueous solution of NH_4Cl (50 mL). The aqueous layer was extracted with ethyl acetate and the combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 2/1) to give 1-(4-hydroxybutyl)cyclopropanol (2.55 g, 46%) as a clear, colorless oil.

Preparation of 1k:



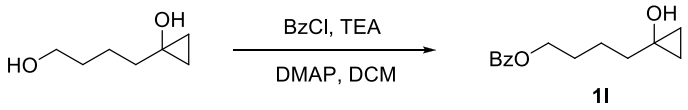
1k

To a stirred solution of 1-(4-hydroxybutyl)cyclopropanol (2.55 g, 19.6 mmol) and imidazole (2.67 g,

39.2 mmol) in CH_2Cl_2 (145 mL) was added *tert*-butyldimethylsilyl chloride (2.95 g, 19.6 mmol) in portions at 0 ^oC. The reaction mixture was allowed to warm to room temperature and stirred for an additional 12 h before the addition of water (100 mL). The aqueous layer was extracted with dichloromethane. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 10 /1) to give **1k** (3.32 g, 69%) as a clear, colorless oil.

^1H NMR (500 MHz, $CDCl_3$) δ 3.64 (t, *J* = 6.0 Hz, 2H), 1.97 (br s, 1H), 1.60 –1.57 (m, 6H), 0.90 (s, 9H), 0.73 (t, *J* = 5.7 Hz, 2H), 0.44 (t, *J* = 5.7Hz, 2H), 0.05 (s, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 63.3, 55.9, 38.1, 32.7, 26.1, 22.3, 18.5, 13.7, -5.1; IR(neat): *v* = 3354, 2929, 2587, 1712, 1472, 1462, 1388, 1361, 1253, 1099, 1006, 957, 938 cm^{-1}; MS (ESI): m/z 245.2 $[M+H]^+$.

Preparation of 1l:



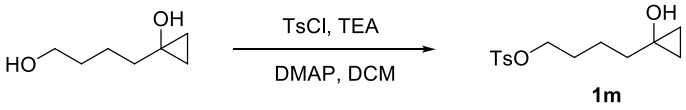
1l

To a solution of 1-(4-hydroxybutyl)cyclopropanol (100 mg, 0.77 mmol) in DCM (1 mL), triethylamine (116 mg, 1.15 mmol), 4-(dimethylamino)pyridine (1.7 mg, 0.014 mmol), and benzoyl chloride (140 mg, 1.0 mmol) were added at 0 ˚C. The reaction mixture was stirred for 20 h at room temperature. After being quenched with a saturated solution of ammonia chloride (2 mL), the aqueous layer was extracted with ethyl acetate (3 × 10 mL), and the combined organic layer was concentrated *in vacuo*. The crude residue was purified by flash column chromatography (hexane/ethyl acetate = 20/1) on silica gel to afford desired product **1l** (100 mg, 55%) as a colorless oil.

^1H NMR (400 MHz, $CDCl_3$) δ 8.05 (d, *J* = 7.7 Hz, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 4.35 (t, *J* = 6.5 Hz, 2H), 1.85 – 1.75 (m, 2H), 1.76 – 1.54 (m, 5H), 0.81 – 0.71 (m, 2H), 0.50 – 0.45 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.8, 133.0, 130.6, 129.7, 128.5, 65.1, 55.8, 38.1, 28.9,

22.6, 13.8; IR (neat): v = 3415, 2942, 2159, 2031, 1715, 1451, 1274, 1116 cm^{-1}; MS (ESI): m/z 235.2, $[M+H]^+$.

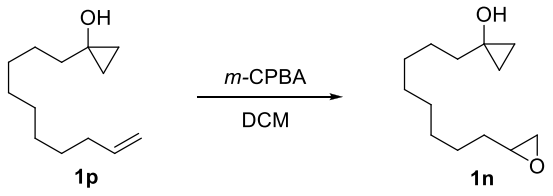
Preparation of 1m:



To a solution of 1-(4-hydroxybutyl)cyclopropanol (92 mg, 0.7 mmol) in DCM (1.5 mL), triethylamine (0.2 mL, 1.4 mmol), *p*-toluenesulfonyl chloride (135 mg, 0.7 mmol), and 4-(dimethylamino)pyridine (1.7 mg, 0.014 mmol) were added at 0 ˚C. The reaction mixture was further stirred for 24 h. After being quenched with saturated aqueous ammonium chloride (5 mL), the aqueous phase was extracted with ethyl acetate (3 × 10 mL), and the combined organic extracts were dried over sodium sulfate, and concentrated *in vacuo*. The residue was purified by flash column chromatography (hexane/ethyl acetate = 15/1 to 4/1) on silica gel to give product **1m** (68 mg, 34%) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96 – 7.78 (m, 2H), 7.35 – 7.33 (m, 2H), 4.04 (t, J = 6.4 Hz, 2H), 2.45 (s, 3H), 1.80 (br s, 1H), 1.75 – 1.66 (m, 2H), 1.59 – 1.46 (m, 4H), 0.73 – 0.70 (m, 2H), 0.40 – 0.38 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 144.8, 133.3, 130.0, 128.0, 70.7, 55.5, 37.7, 28.9, 22.0, 21.8, 13.7; IR (neat): v = 3287, 2935, 1710, 1610, 1455, 1170, 1103, 925 cm^{-1}; MS (ESI): m/z 285.2 $[M+H]^+$.

Preparation of 1n:

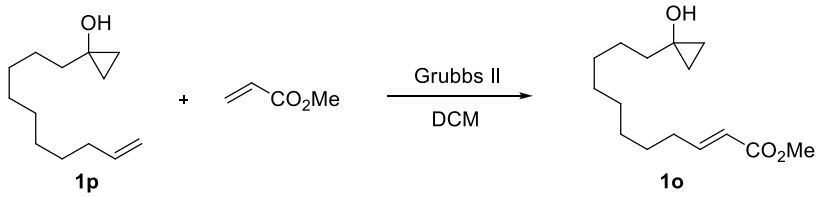


To a stirred solution of substrate **1p** (196 mg, 1.0 mmol) in DCM (2 mL), sodium acetate (820 mg, 10 mmol) and 3-chloroperbenzoic acid (340 mg, 2.0 mmol) were added in one portion. The reaction mixture was further stirred for 72 h. After being quenched with saturated aqueous ammonium chloride

(5 mL), the aqueous phase was extracted with ethyl acetate (3 × 10 mL), and the combined organic extracts were dried over sodium sulfate, and concentrated *in vacuo*. The residue was purified by flash column chromatography (hexane/ethyl acetate = 15/1) on silica gel to give product **1n** (143 mg, 67%) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 2.90 (td, *J* = 5.9, 2.9 Hz, 1H), 2.76 – 2.72 (m, 1H), 2.45 (dd, *J* = 5.2, 2.9 Hz, 1H), 1.90 (s, 1H), 1.57 – 1.39 (m, 8H), 1.39 – 1.18 (m, 8H), 0.75 – 0.68 (m, 2H), 0.45 – 0.40 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 55.9, 52.6, 47.3, 38.4, 32.6, 29.7, 29.7, 29.6, 29.5, 26.1, 26.0, 13.6; IR (neat): *v* = 3310, 3215, 2910, 2845, 1485, 1440, 1310, 1265, 1010, 960, 920, 840 cm^{-1}; MS (ESI): m/z 213.2 $[M+H]^+$.

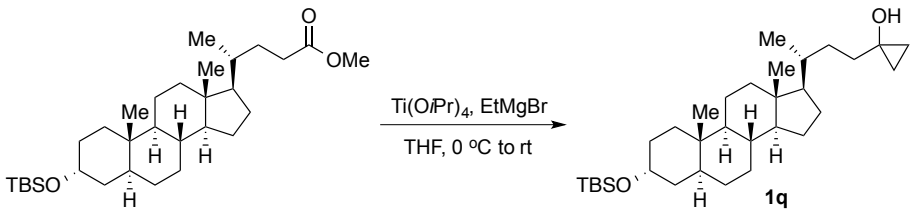
Preparation of 1o:



To a solution of substrate **1p** (103 mg, 0.5 mmol) in DCM (2 mL), methyl acrylate (140 mg, 1.5 mmol) and Grubbs II catalyst (18 mg, 0.025 mmol) was added at room temperature. After being stirred for 5 h, the reaction mixture was concentrated *in vacuo* and the crude product was purified by flash column chromatography (hexane/ethyl acetate = 20/1) on silica gel to give product **5o** (88 mg, 69%) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 6.97 (dt, *J* = 15.7, 7.0 Hz, 1H), 5.81 (dt, *J* = 15.7, 1.6 Hz, 1H), 3.72 (s, 3H), 2.19 (qd, *J* = 7.1, 1.6 Hz, 2H), 1.80 (s, 1H), 1.58 – 1.41 (m, 6H), 1.35 – 1.25 (m, 8H), 0.78 – 0.68 (m, 2H), 0.51 – 0.37 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.4, 150.0, 121.0, 56.0, 51.5, 38.4, 32.3, 29.7, 29.7, 29.4, 29.2, 28.1, 26.0, 13.7; IR (neat): *v* = 3340, 3235, 2915, 2820, 1720, 1660, 1420, 1310, 1285, 1200, 1170, 1002, 910 cm^{-1}; MS (ESI): m/z 255.1 $[M+H]^+$.

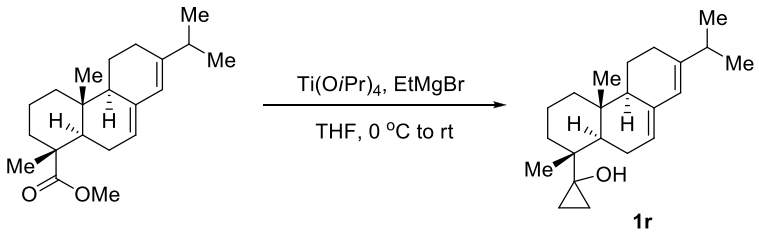
Preparation of 1q:



To a stirred solution of substrate ester (1.08 g, 2.0 mmol) and Ti(O*i*Pr)$_4$ (0.86 g, 3.0 mmol) in dry THF (40 mL), a 3 M solution of EtMgBr (2 mL, 6.0 mmol) in Et_2O was added dropwise at 0 ˚C over 2 h under argon atmosphere. The reaction mixture was allowed to warm to room temperature and stirred for an additional 2 h before the addition of water (100 mL). The aqueous layer was extracted with dichloromethane. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 10:1) to give **1q** (0.45 g, 44%) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ 3.60 – 3.56 (m, 1H), 1.80 – 0.89 (m, 44H), 0.72 (s, 2H), 0.63 (s, 3H), 0.42 (s, 2H), 0.05 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 73.0, 56.6, 56.3, 56.2, 42.8, 42.5, 40.4, 40.3, 37.1, 36.0, 35.7, 34.8, 34.7, 32.0, 31.2, 28.4, 27.5, 26.6, 26.1, 25.9, 25.8, 24.4, 23.6, 23.5, 21.0, 18.9, 18.5, 13.8, 13.5, 12.2, -3.4, -4.4; IR (neat): ν = 3317, 2928, 1251, 1094, 1080, 835 cm^{-1}; MS (ESI): m/z 503.8 $[M+H]^+$.

Preparation of 1r:



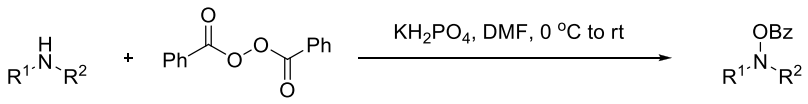
To a stirred solution of substrate ester (1.58 g, 5.0 mmol) and Ti(O*i*Pr)$_4$ (1.99 g, 7.0 mmol) in dry THF (60 mL), a 3 M solution of EtMgBr (5 mL, 15.0 mmol) in Et_2O was added dropwise at 0 ˚C over 2 h

under argon atmosphere. The reaction mixture was allowed to warm to room temperature and stirred for an additional 2 h before the addition of water (100 mL). The aqueous layer was extracted with dichloromethane. The organic layer was washed with brine, dried over Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified by flash chromatography (hexane/ethyl acetate = 10:1) to give **1r** (0.73 g, 47%) as a white solid.

47% yield; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.77 (s, 1H), 5.42 (s, 1H), 2.32 – 1.30 (m, 13H), 1.06 – 0.61 (m, 15H), 0.52 – 0.38 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.3, 135.6, 122.6, 121.5, 60.8, 51.4, 43.9, 38.9, 38.8, 35.3, 35.0, 34.9, 27.7, 24.7, 22.9, 21.6, 21.0, 18.7, 15.9, 14.2, 13.0, 8.00; IR (neat): ν = 3376, 2929, 1696, 1459, 1383, 1013 cm^{-1}; MS (ESI): m/z 353.5 $[M+K]^+$.

III. Synthesis of *O*-Benzoyl Hydroxylamines

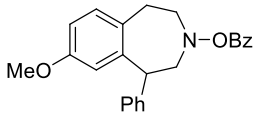
Known starting materials **2a**[9], **2b**[9], **2c**[9], **2d**[10], **2e**[9], **2i**[9], **2o**[11], are prepared according to the previously reported procedure [10]. The others are prepared with the same procedure as well.



General Procedure: Under argon atmosphere and 0 °C, to a 50 mL flask equipped with a stir bar and a rubber septum was charged with benzoyl peroxide (70% purity, 1 equiv), dipotassium hydrogen phosphate (2 equiv), and *N,N*-dimethylformamide. Amine starting material (1 equiv) was added dropwise. After stirring for 3 h, the reaction was quenched with water (10 mL) and extracted with ether (4 × 30 mL). The combined organic extract was washed with brine, dried over anhydrous $MgSO_4$, filtered and concentrated under vacuum. The residue was purified by column chromatography on silica gel to give desired product *O*-benzoyl hydroxylamine.

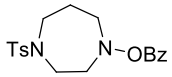
2f

45 mg, 70% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 7.6 Hz, 2H), 7.55 – 7.40 (m, 3H), 3.97 – 3.96 (m, 2H), 3.81 – 3.77 (m, 2H), 2.19 – 2.06 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.9, 133.1, 129.4, 129.1, 128.5, 60.0, 14.6; IR (neat): *v* = 1726, 1262, 1086, 1066, 1024 cm^{-1}; MS (ESI): m/z 178.3 $[M+H]^+$.



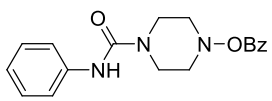
2g

1.03 g, 74% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 4.8 Hz, 2H), 7.58 – 7.11 (m, 9H), 6.71 – 6.69 (m, 1H), 6.29 (br s, 1H), 4.62 (br s, 1H), 3.85 – 3.69 (m, 5H), 3.34 (s, 2H), 2.85 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 158.3, 145.2, 141.8, 133.2, 132.6, 130.6, 129.5, 128.8, 128.6, 128.5, 126.8, 115.5, 110.7, 58.4, 55.2, 46.3, 46.1, 31.5; IR (neat): *v* = 1734, 1494, 1243, 1087, 1066, 1023 cm^{-1}; MS (ESI): m/z 374.5 $[M+H]^+$.



2h

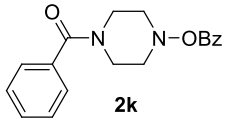
1.44 g, 77% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 7.5 Hz, 2H), 7.67 (d, *J* = 8.0 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.41 (t, *J* = 7.6 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 3.50 – 3.39 (m, 8H), 2.41 (br s, 3H), 2.02 – 2.00 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.5, 143.5, 135.9, 133.3, 129.9, 129.4, 129.1, 128.5, 127.0, 59.9, 56.9, 46.7, 44.1, 23.7, 21.6; IR (neat): *v* = 1737, 1333, 1246, 1155, 1083, 1061 cm^{-1}; MS (ESI): m/z 375.5 $[M+H]^+$.



2j

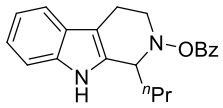
1.06 g, 76% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.0 Hz, 2H), 7.60 – 7.24 (m,

7H), 7.08 – 7.01 (m, 2H), 4.01 (br s, 2H), 3.40 – 3.34 (m, 4H), 2.94 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.7, 155.1, 139.0, 133.4, 129.5, 128.9, 128.6, 123.4, 120.6, 55.7, 42.5; IR (neat): ν = 3329, 1736, 1641, 1535, 1444, 1244, 1018 cm^{-1}; MS (ESI): m/z 326.4 $[M+H]^+$.



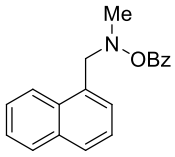
2k

452 mg, 76% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, J = 7.4 Hz, 2H), 7.57 – 7.41 (m, 8H), 4.58 (br s, 1H), 3.79 (br s, 1H), 3.48 (br s, 4H), 2.96 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.4, 164.5, 135.1, 133.4, 130.1, 129.5, 128.9, 128.7, 128.5, 127.1, 56.1, 45.8, 40.5; IR (neat): ν = 1737, 1633, 1428, 1281, 1245, 1017 cm^{-1}; MS (ESI): m/z 333.4 $[M+Na]^+$.



2m

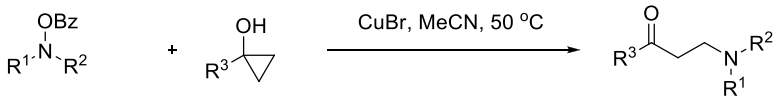
165 mg, 12% yield, yellow solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 – 7.96 (m, 3H), 7.55 – 7.15 (m, 7H), 4.45 (br s, 1H), 3.63 (br s, 2H), 2.99 (br s, 2H), 1.90 – 1.89 (m, 2H), 1.71 – 1.70 (m, 3H), 0.98 (t, J = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.3, 136.1, 133.2, 129.6, 129.4, 128.5, 127.0, 121.8, 119.6, 118.3, 111.0, 107.6, 66.0, 62.1, 19.6, 18.4, 15.4, 14.4; IR (neat): ν = 3362, 1723, 1451, 1256, 1084, 1023 cm^{-1}; MS (ESI): m/z 375.5 $[M+H]^+$.



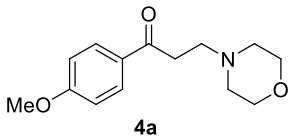
2n

654 mg, 74% yield, white solid; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.63 (d, J = 8.4 Hz, 1H), 8.00 – 7.81 (m, 4H), 7.66 – 7.40 (m, 7H), 4.62 (br s, 2H), 2.92 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.1, 133.9, 133.1, 132.5, 131.7, 129.5, 129.0, 128.5, 128.2, 126.7, 126.0, 125.2, 124.9, 63.4, 45.9; IR (neat): ν = 1732, 1450, 1246, 1091, 1059, 1024 cm^{-1}; MS (ESI): m/z 314.4 $[M+Na]^+$.

4. Genaral procedure for amination of cyclopropanols

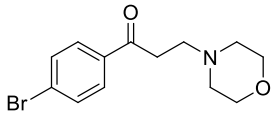


Under argon atmosphere, a mixture of cyclopropanols (0.15 mmol), *O*-benzoyl hydroxylamine (0.1 mmol), CuBr (1.4 mg, 0.01 mmol) and 1 mL MeCN was stirred at 50 °C for 10-12 h. The saturated sodium carbonate was added and the mixture was stirred for 15-30 min. The organic layer was separated and extracted with EtOAc three times, and the combined organic extracts were washed with aq. NaCl three times and dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by column chromatography on silica gel to give the desired product.



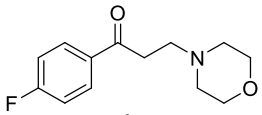
4a

24.4 mg, 98% yield (0.5 gram, 97% yield), yellow solid, known compound[12]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.9 Hz, 2H), 6.93 (d, *J* = 8.9 Hz, 2H), 3.86 (s, 3H), 3.71 (t, *J* = 4.5 Hz, 4H), 3.13 (t, *J* = 7.4 Hz, 2H), 2.82 (t, *J* = 7.4 Hz, 2H), 2.51 (t, *J* = 4.5 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.6, 163.7, 130.5, 130.1, 113.2, 67.1, 55.6, 53.9, 53.8, 35.7.



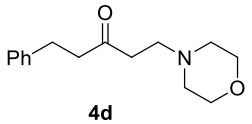
4b

29.6 mg, 99% yield, yellow solid, known compound[13]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, *J* = 8.6 Hz, 2H), 7.59 (d, *J* = 8.6 Hz, 2H), 3.69 (t, *J* = 4.6 Hz, 4H), 3.13 (t, *J* = 7.3 Hz, 2H), 2.80 (t, *J* = 7.3 Hz, 2H), 2.48 (t, *J* = 4.6 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.0, 135.7, 132.1, 129.7, 128.4, 67.0, 53.8, 53.6, 36.1.



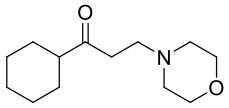
4c

22.5 mg, 95% yield, yellow solid, known compound[13]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 – 7.94 (m, 2H), 7.11 (t, *J* = 8.6 Hz, 2H), 3.68 (t, *J* = 4.6 Hz, 4H), 3.13 (t, *J* = 7.3 Hz, 2H), 2.80 (t, *J* = 7.3 Hz, 2H), 2.48 (t, *J* = 4.6 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.41, 165.8 (d, J_{C-F} = 254.5 Hz), 133.4, 130.7 (d, J_{C-F} = 9.2 Hz), 115.8 (d, J_{C-F} = 21.9 Hz), 67.0, 53.8, 53.6, 36.0; ^{19}F NMR (376 MHz, $CDCl_3$) δ -106.67.



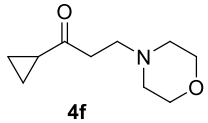
4d

24.5 mg, 99% yield, yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 – 7.17 (m, 5H), 3.70 – 3.65 (m, 4H), 2.90 (t, *J* = 7.5 Hz, 2H), 2.76 (t, *J* = 7.6 Hz, 2H), 2.65 – 2.55 (m, 4H), 2.40 (t, *J* = 4.6 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 208.9, 141.1, 128.6, 128.4, 126.2, 67.0, 53.7, 53.2, 44.6, 40.4, 29.7; IR (neat): *v* =2808, 1711, 1454, 1117, 865 cm^{-1}; MS (ESI): m/z 248.3 $[M+H]^+$.



4e

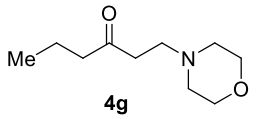
22.0 mg, 98% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.77 (t, *J* = 4.6 Hz, 4H), 2.62 (br s, 4H), 2.43 – 2.32 (m, 5H), 1.83 – 1.64 (m, 5H), 1.36 – 1.59 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 212.9, 67.0, 53.8, 53.2, 51.2, 38.0, 28.5, 25.9, 25.8; IR (neat): *v* = 2929, 2853, 1706, 1449, 1136, 1118 cm^{-1}; MS (ESI): m/z 226.3 $[M+H]^+$.



4f

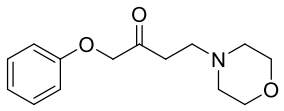
12.8 mg, 70% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.68 (t, *J* = 4.6 Hz, 4H), 2.73 – 2.66 (m, 4H), 2.44 (t, *J* = 4.6 Hz, 4H), 1.92 (tt, *J* = 7.9, 4.5 Hz, 1H), 1.01 (dt, *J* = 11.8, 3.8 Hz, 2H), 0.86 (dt,

J = 11.7, 3.7 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.7, 67.1, 53.7, 53.3, 40.8, 20.8, 10.9; IR (neat): ν = 1696, 1384, 1118, 1085, 1002, 864 cm^{-1}; MS (ESI): m/z 184.3 $[M+H]^+$.



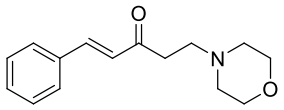
4g

14.1 mg, 76% yield, colorless oil, known compound[14]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.68 (t, J = 4.6 Hz, 4H), 2.66 – 2.56 (m, 4H), 2.43 – 2.38 (m, 6H), 1.60 (dt, J = 14.7, 7.4 Hz, 2H), 0.90 (t, J = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 210.0, 67.0, 53.7, 53.3, 45.1, 40.1, 17.3, 13.9.



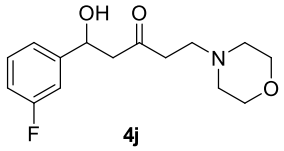
4h

18.1 mg, 73% yield, yellow oil, known compound[15]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (t, J = 7.9 Hz, 2H), 7.08 – 6.83 (m, 3H), 4.59 (s, 2H), 3.77 – 3.59 (m, 4H), 2.86 – 2.66 (m, 4H), 2.45 (br s, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 207.0, 157.9, 152.3, 129.8, 121.9, 114.6, 73.1, 67.0, 53.7, 53.1, 36.7.



4i

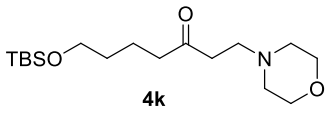
22.7 mg, 93% yield, colorless oil, known compound[16]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 – 7.53 (m, 3H), 7.41 – 7.39 (m, 3H), 6.75 (d, J = 16.3 Hz, 1H), 3.17 (t, J = 4.6 Hz, 4H), 2.88 (t, J = 6.7 Hz, 2H), 2.78 (t, J = 7.0 Hz, 2H), 2.50 (t, J = 4.3 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.0, 143.0, 134.5, 130.7, 129.1, 128.4, 126.2, 67.0, 53.7, 53.6, 38.2.



4j

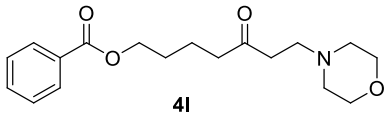
20.7 mg, 74% yield, yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31 – 7.26 (m, 1H), 7.12 – 7.01 (m, 2H), 6.96 – 6.93 (m, 1H), 5.19 – 5.16 (m, 1H), 3.71 – 3.64 (m, 5H), 2.93 – 2.45 (m, 10H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 209.9, 163.1 (d, J_{C-F} = 245.9 Hz), 146.0 (d, J_{C-F} = 6.7 Hz), 130.1 (d, J_{C-F} = 8.1 Hz),

121.3, 114.5 (d, J_{C-F} = 21.1 Hz), 112.7 (d, J_{C-F} = 22.1 Hz), 69.8, 66.7, 53.5, 53.3, 51.6, 41.1; IR (neat): ν = 3400, 1711, 1590, 1449, 1116, 865; MS (ESI): m/z 282.3 $[M+H]^+$.



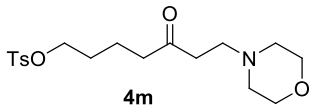
4k

32.2 mg, 98% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.69 – 3.57 (m, 6H), 2.62 – 2.57 (m, 4H), 2.43 – 2.32 (m, 6H), 1.63 – 1.59 (m, 2H), 1.50 – 1.46 (m, 2H), 0.86 (s, 9H), 0.02 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.9, 67.0, 62.9, 53.7, 53.3, 42.9, 40.1, 32.3, 26.1, 20.3, 18.4, -5.2; IR (neat): ν = 2855, 1713, 1255, 1118, 1099, 835 cm^{-1}; MS (ESI): m/z 330.5 $[M+H]^+$.



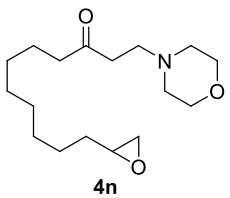
4l

30.4 mg, 95% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, J = 7.3 Hz, 2H), 7.59 – 7.41 (m, 3H), 4.32 (t, J = 6.0 Hz, 2H), 3.67 (t, J = 4.2 Hz, 4H), 2.64 – 2.41 (m, 10H), 1.76 (br s, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.3, 166.7, 133.0, 130.4, 129.6, 128.4, 67.0, 64.6, 53.7, 53.3, 42.4, 40.2, 28.3, 20.2; IR (neat): ν = 1714, 1451, 1314, 1273, 1117, 1070 cm^{-1}; MS (ESI): m/z 320.4 $[M+H]^+$.



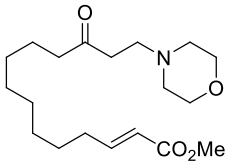
4m

29.5 mg, 80% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 – 7.75 (m, 2H), 7.34 – 7.32 (m, 2H), 4.00 (t, J = 6.0 Hz, 2H), 3.67 – 3.65 (m, 4H), 2.66 – 2.50 (m, 4H), 2.44 – 2.40 (m, 9H), 1.68 – 1.55 (m, 4H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 209.0, 144.9, 133.1, 130.0, 128.0, 70.2, 67.0, 53.6, 53.2, 41.9, 40.2, 28.3, 21.8, 19.6; IR (neat): ν = 1711, 1356, 1188, 1175, 1116, 932; MS (ESI): m/z 370.3 $[M+H]^+$.



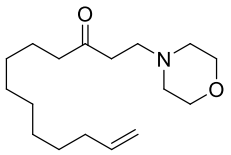
4n

21.5 mg, 72% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.68 – 3.66 (m, 4H), 2.90 – 2.86 (m, 1H), 2.73 – 2.72 (m, 1H), 2.65 – 2.56 (m, 4H), 2.45 – 2.39 (m, 7H), 1.58 – 1.24 (m, 14H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 210.1, 67.0, 53.7, 53.3, 52.5, 47.2, 43.2, 40.1, 32.6, 29.5, 29.4, 29.3, 26.1, 23.8; IR (neat): v = 2926, 2853, 1711, 1458, 1118, 915, 860; MS (ESI): m/z 298.4 $[M+H]^+$.



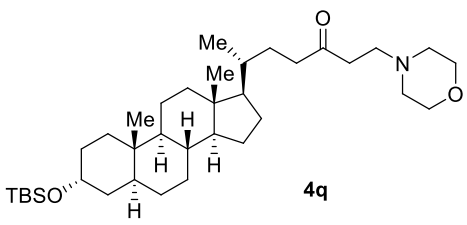
4o

27.0 mg, 79% yield, colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 6.94 (dt, J = 15.6, 7.0 Hz, 1H), 5.79 (dt, J = 15.6, 1.4 Hz, 1H), 3.70 (s, 3H), 3.69 – 3.61 (m, 4H), 2.66 – 2.54 (m, 4H), 2.42 – 2.38 (m, 6H), 2.19 – 2.14 (m, 2H), 1.57 – 1.39 (m, 4H), 1.26 (br s, 8H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 210.0, 167.3, 149.8, 120.9, 67.0, 53.7, 53.3, 51.5, 43.2, 40.1, 32.3, 29.4, 29.3, 29.3, 29.1, 28.1, 23.8; IR (neat): v = 2928, 2854, 1711, 1272,1197, 1175, 1118; MS (ESI): m/z 340.3 $[M+H]^+$.



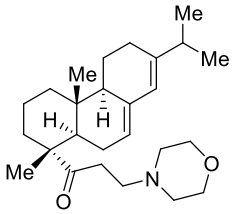
4p

28.0 mg, 99% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.79 (ddt, J = 16.9, 10.2, 6.7 Hz, 1H), 4.94 (ddd, J = 13.6, 11.1, 1.4 Hz, 2H), 3.67 (t, J = 4.6 Hz, 4H), 2.65 – 2.55 (m, 4H), 2.42 – 2.38 (m, 6H), 2.01 (dd, J = 14.2, 6.8 Hz, 2H), 1.59 – 1.53 (m, 2H), 1.37 – 1.33 (m, 2H), 1.26 (br s, 8H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 210.1, 139.3, 114.3, 67.0, 53.7, 53.3, 43.2, 40.1, 33.9, 29.4, 29.4, 29.3, 29.2, 29.0, 23.8; IR (neat): v = 2924, 2853, 1713, 1457, 1118, 911 cm^{-1}; MS (ESI): m/z 282.4 $[M+H]^+$.



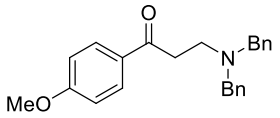
4q

44.4 mg, 76% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.68 (t, *J* = 4.3 Hz, 4H), 3.55 – 3.54 (m, 1H), 2.63 – 2.32 (m, 9H), 1.93 – 1.02 (m, 26H), 0.88 (br s, 16H), 0.61 (s, 3H), 0.04 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 210.6, 72.9, 67.0, 56.5, 56.1, 53.7, 53.4, 42.9, 42.4, 40.3, 40.1, 37.1, 36.0, 35.7, 35.4, 34.7, 31.2, 29.9, 28.4, 27.4, 26.5, 26.1, 24.3, 23.5, 20.9, 18.6, 18.5, 12.2, -4.5; IR (neat): *v* = 2927, 2855, 1714, 1118, 1094, 1079, 869, 835 cm^{-1}; MS (ESI): m/z 588.8 $[M+H]^+$.



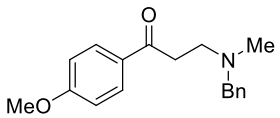
4r

31.1mg, 78% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.75 (s, 1H), 5.32 (s, 1H), 3.67 (t, *J* = 4.3 Hz, 4H), 2.67 – 2.55 (m, 4H), 2.42 (br s, 4H), 2.23 – 2.19 (m, 1H), 2.08 – 1.79 (m, 7H), 1.60 (br s, 4H), 1.24 – 1.11 (m, 6H), 1.01 (d, *J* = 2.9 Hz, 3H), 0.99 (d, *J* = 2.9 Hz, 3H), 0.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 214.8, 145.5, 135.7, 122.5, 120.6, 67.1, 54.1, 53.9, 52.0, 51.3, 44.1, 38.5, 36.3, 35.0, 34.6, 34.3, 27.6, 25.7, 22.7, 21.5, 21.0, 18.2, 16.6, 14.2; IR (neat): *v* = 2929, 1698, 1456, 1118, 872 cm^{-1}; MS (ESI): m/z 400.6 $[M+H]^+$.



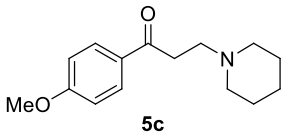
5a

26.1 mg, 73% yield, colorless oil, known compound[17]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.7 Hz, 2H), 7.36 – 7.23 (m, 10H), 6.87 (d, *J* = 8.7 Hz, 2H), 3.86 (s, 3H), 3.64 (s, 4H), 3.09 (t, *J* = 7.3 Hz, 2H), 2.93 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.4, 163.5, 139.6, 130.5, 130.2, 128.9, 128.3, 127.0, 113.8, 58.6, 55.6, 49.6, 36.8.



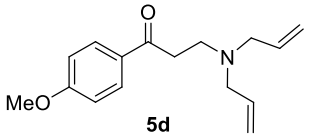
5b

24.5 mg, 87% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.5 Hz, 2H), 7.30 – 7.24 (m, 5H), 6.92 (d, *J* = 8.4 Hz, 2H), 3.86 (s, 3H), 3.56 (s, 2H), 3.14 (t, *J* = 7.3 Hz, 2H), 2.88 (t, *J* = 7.3 Hz, 2H), 2.27 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.1, 163.6, 138.8, 130.5, 130.2, 129.2, 128.4, 127.2, 113.8, 62.5, 55.6, 52.8, 42.3, 36.6; IR (neat): *v* = 1674, 1599, 1258, 1169, 1028, 839 cm^{-1}; MS (ESI): m/z 284.4 $[M+H]^+$.



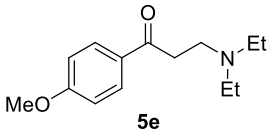
5c

22.2 mg, 90% yield, white solid, known compound[18]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.7 Hz, 2H), 6.90 (d, *J* = 8.7 Hz, 2H), 3.84 (s, 3H), 3.20 (t, *J* = 7.4 Hz, 2H), 2.85 (t, *J* = 7.4 Hz, 2H), 2.52 (br s, 4H), 1.63 (t, *J* = 4.6 Hz, 4H), 1.44 (br s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.5, 163.6, 130.4, 129.9, 113.8, 55.5, 54.6, 53.9, 35.6, 25.6, 24.0.



5d

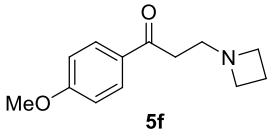
21.1 mg, 81% yield, yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.3 Hz, 2H), 6.92 (d, *J* = 8.3 Hz, 2H), 5.88 – 5.82 (m, 2H), 5.24 – 5.12 (m, 4H), 3.85 (s, 3H), 3.15 – 3.07 (m, 6H), 2.91 (t, *J* = 7.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.2, 163.6, 135.7, 130.5, 130.3, 117.8, 113.8, 57.2, 55.6, 48.9, 36.4; IR (neat): *v* = 1673, 1599, 1255, 1169, 1030, 919 cm^{-1}; MS (ESI): m/z 260.5 $[M+H]^+$.



5e

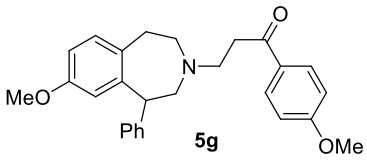
12.5 mg, 58% yield, colorless oil, known compound[19]; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.6 Hz, 2H), 6.94 (d, *J* = 8.5 Hz, 2H), 3.87 (s, 3H), 3.62 (t, *J* = 7.0 Hz, 2H), 3.42 (t, *J* = 7.1 Hz, 2H), 3.12

(q, J = 7.0 Hz, 4H), 1.38 (t, J = 7.2 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ194.9, 164.4, 130.8, 128.9, 114.2, 55.7, 47.6, 47.0, 33.4, 8.8.



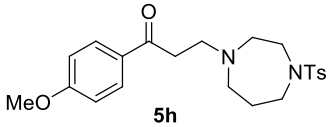
5f

16.3 mg, 74% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, J = 8.7 Hz, 2H), 6.92 (d, J = 8.6 Hz, 2H), 3.85 (s, 3H), 3.35 (t, J = 6.9 Hz, 4H), 3.00 (t, J = 7.2 Hz, 2H), 2.91 (t, J = 7.2 Hz, 2H), 2.15 – 2.11 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.2, 163.7, 130.5, 130.0, 113.9, 55.6, 55.2, 54.2, 36.2, 29.8, 17.5; IR (neat): v = 1673, 1600, 1257, 1222, 1170, 1028 cm^{-1}; MS (ESI): m/z 220.4 $[M+H]^+$.



5g

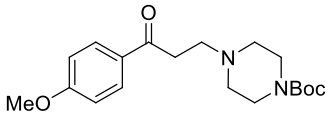
32.5 mg, 78% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, J = 8.7 Hz, 2H), 7.36 – 7.32 (m, 5H), 7.06 (d, J = 8.2 Hz, 1H), 6.91 (d, J = 8.7 Hz, 2H), 6.65 (dd, J = 8.1, 2.1 Hz, 1H), 6.26 (s, 1H), 4.31 (d, J = 8.1 Hz, 1H), 3.86 (s, 3H), 3.65 (s, 3H), 3.21 – 2.96 (m, 8H), 2.82 – 2.77 (m, 1H), 2.56 (t, J = 10.7 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.2, 163.6, 158.1, 146.0, 143.1, 133.7, 130.5, 130.2, 128.6, 128.6, 126.5, 115.3, 113.8, 110.4, 60.8, 55.6, 55.6, 55.1, 54.5, 50.2, 35.9, 35.7; IR (neat): v = 1674, 1599, 1485, 1258, 1169, 1030 cm^{-1}; MS (ESI): m/z 416.6 $[M+H]^+$.



5h

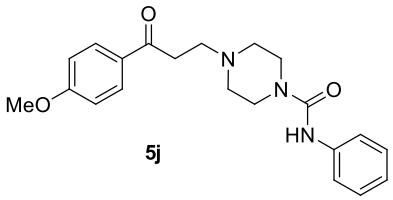
36.6 mg, 88% yield, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, J = 8.8 Hz, 2H), 7.65 (d, J = 8.1 Hz, 2H), 7.27 (d, J = 8.1 Hz, 2H), 6.91 (d, J = 8.8 Hz, 2H), 3.85 (s, 3H), 3.34 – 3.30 (m, 4H), 3.06 – 2.91 (m, 4H), 2.75 – 2.70 (m, 4H), 2.40 (s, 3H), 1.83 – 1.77 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ

197.9, 163.6, 143.2, 136.3, 130.4, 130.1, 129.8, 127.1, 113.9, 56.2, 55.6, 54.1, 52.9, 48.5, 47.2, 36.3, 28.0, 21.6; IR (neat): ν = 1671, 1598, 1330, 1256, 1157, 1090, 1027 cm^{-1}; MS (ESI): m/z 417.5 $[M+H]^+$.



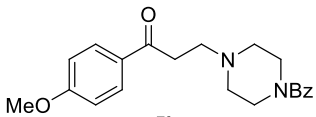
5i

32.4 mg, 93% yield, white solid, known compound[17]; ^1H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, J = 8.7 Hz, 2H), 6.91 (d, J = 8.7 Hz, 2H), 3.85 (s, 3H), 3.41 (br s, 4H), 3.11 (t, J = 7.2 Hz, 2H), 2.81 (t, J = 7.2 Hz, 2H), 2.43 (br s, 4H), 1.43 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.6, 163.6, 154.8, 130.4, 130.1, 113.9, 79.7, 55.6, 53.5, 53.1, 35.9, 28.5.



5j

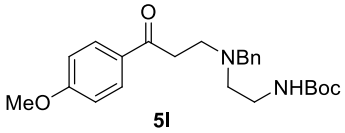
32.0 mg, 87% yield, colorless oil; ^1H NMR (400 MHz, $CDCl_3$) δ 7.90 (d, J = 8.7 Hz, 2H), 7.32 – 7.20 (m, 4H), 6.97 (t, J = 7.3 Hz, 1H), 6.90 (d, J = 8.7 Hz, 2H), 6.67 (s, 1H), 3.83 (s, 3H), 3.45 (br s, 4H), 3.09 (t, J = 7.2 Hz, 2H), 2.80 (t, J = 7.2 Hz, 2H), 2.46 (br s, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.6, 163.7, 155.2, 139.2, 130.4, 130.0, 128.9, 123.1, 120.2, 113.9, 55.6, 53.3, 52.9, 44.1, 35.8; IR (neat): ν = 3326, 1639, 1597, 1511, 1442, 1240, 1169 cm^{-1}; MS (ESI): m/z 368.5 $[M+H]^+$.



5k

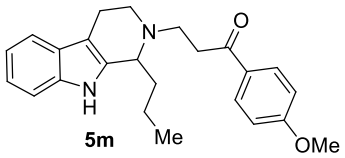
32.9 mg, 93% yield, colorless oil; ^1H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, J = 8.8 Hz, 2H), 7.38 (br s, 5H), 6.92 (d, J = 8.8 Hz, 2H), 3.84 (s, 3H), 3.78 (s, 2H), 3.41 (s, 2H), 3.12 (t, J = 7.2 Hz, 2H), 2.84 (t, J = 7.2 Hz, 2H), 2.50 (d, J = 53.7 Hz, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.4, 170.4, 163.7, 135.9,

130.4, 130.0, 129.8, 128.5, 127.1, 113.9, 55.6, 53.3, 47.8, 42.2, 35.8; IR (neat): v = 1672, 1628, 1598, 1258, 1170, 1019 cm^{-1}; MS (ESI): m/z 353.5 $[M+H]^+$.



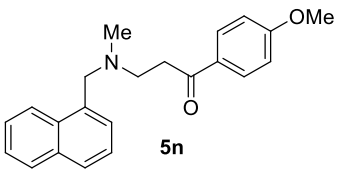
5l

18.1 mg, 44% yield, colorless oil; ^1H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, J = 8.9 Hz, 2H), 7.31 – 7.26 (m, 5H), 6.95 (d, J = 8.9 Hz, 2H), 5.02 (br s, 1H), 3.91 (s, 3H), 3.67 (s, 2H), 3.24 (t, J = 5.6 Hz, 2H), 3.12 (t, J = 6.9 Hz, 2H), 2.99 (t, J = 7.0 Hz, 2H), 2.63 (t, J = 5.8 Hz, 2H), 1.48 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 163.6, 156.2, 139.1, 130.5, 130.2, 128.9, 128.4, 127.2, 113.9, 79.0, 58.8, 55.6, 53.4, 49.5, 38.2, 36.3, 28.6; IR (neat): v = 3376, 1709, 1674, 1599, 1510, 1256, 1170 cm^{-1}; MS (ESI): m/z 413.6 $[M+H]^+$.



5m

22.2 mg, 60% yield, yellow oil; ^1H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, J = 8.6 Hz, 2H), 7.83 (s, 1H), 7.48 (d, J = 7.5 Hz, 1H), 7.30 – 7.26 (m, 1H), 7.15 – 7.07 (m, 2H), 6.94 (d, J = 8.6 Hz, 2H), 3.87 (s, 3H), 3.67 (t, J = 6.0 Hz, 1H), 3.25 – 2.84 (m, 7H), 2.61 – 2.57 (m, 1H), 1.77 – 1.70 (m, 2H), 1.44 – 1.41 (m, 2H), 0.91 (t, J = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.4, 163.6, 135.9, 135.6, 130.5, 130.3, 127.4, 121.4, 119.3, 118.1, 113.8, 110.7, 108.1, 57.8, 55.6, 48.9, 45.4, 37.6, 36.6, 19.6, 18.4, 14.4; IR (neat): v = 3353, 1665, 1598, 1453, 1255, 1166, 1027 cm^{-1}; MS (ESI): m/z 377.5 $[M+H]^+$.

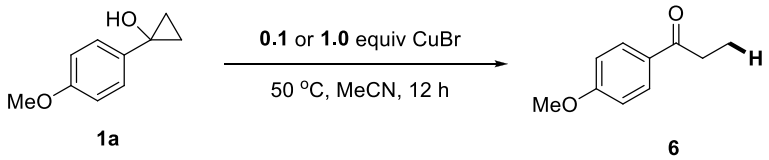


5n

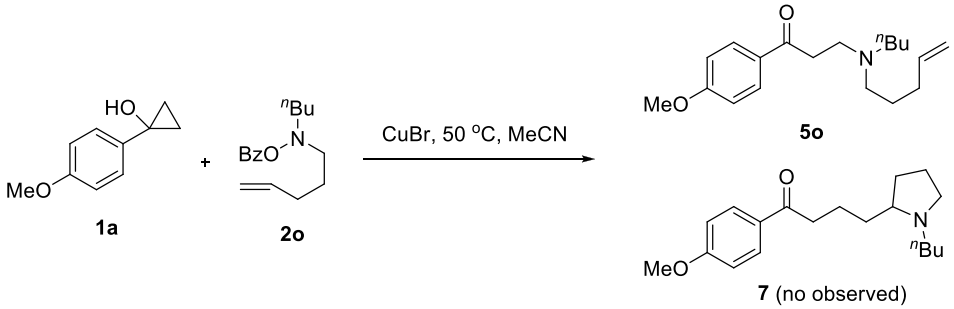
15.0 mg, 45% yield, colorless oil; ^1H NMR (400 MHz, $CDCl_3$) δ 8.29 – 8.27 (m, 1H), 7.92 – 7.79 (m, 4H), 7.51 – 7.40 (m, 4H), 6.91 (d, J = 8.6 Hz, 2H), 3.99 (s, 2H), 3.90 (s, 3H), 3.19 (t, J = 7.2 Hz, 2H),

3.01 (t, J = 7.2 Hz, 2H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 163.5, 134.8, 134.0, 132.6, 130.4, 130.2, 128.5, 128.1, 127.5, 125.9, 125.7, 125.2, 124.8, 113.8, 61.1, 55.6, 53.4, 42.4, 36.7; IR (neat): ν = 1674, 1599, 1462, 1259, 1170, 1030 cm^{-1}; MS (ESI): m/z 334.5 $[M+H]^+$.

V. Preliminary Mechanistic Study



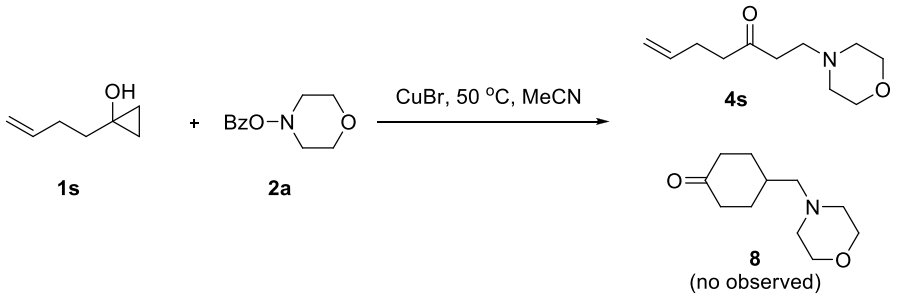
Under argon atmosphere, a mixture of **1a** (16.4 mg, 0.10 mmol) and CuBr (0.1 or 1.0 equiv) in 1 mL MeCN was stirred at 50 °C for 12 h. The ratio of the **1a** and **6** was detected by the crude ^{1}H NMR.



Under argon atmosphere, a mixture of **1a** (24.0 mg, 0.15 mmol), **2o** (26.1 mg, 0.1 mmol), and CuBr (1.4 mg, 0.01 mmol) in 1 mL MeCN was stirred at 50 °C for 10 h. A saturated aqueous sodium carbonate solution was added. The mixture was stirred for 15 min, then extracted with EtOAc. The combined organic extracts were washed with brine, dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by column chromatography on silica gel to give desire product **5o** (19.9 mg, 69% yield, yellow oil).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, J = 8.7 Hz, 2H), 6.91 (d, J = 8.7 Hz, 2H), 5.86 – 5.70 (m, 1H), 5.01 – 4.92 (m, 2H), 3.84 (s, 3H), 3.09 (t, J = 7.6 Hz, 2H), 2.92 (t, J = 7.6 Hz, 2H), 2.50 – 2.48 (m, 3H), 2.03 (dd, J = 13.9, 6.8 Hz, 2H), 1.59 – 1.52 (m, 2H), 1.43 (dt, J = 14.8, 7.2 Hz, 2H), 1.32 – 1.21 (m,

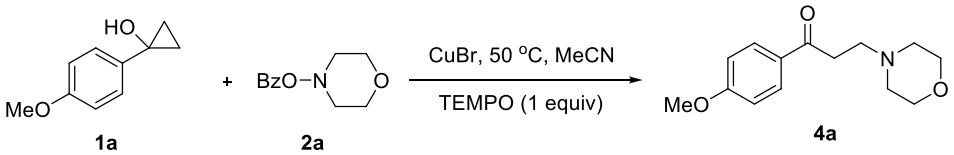
2H), 0.89 (t, J = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 163.6, 138.5, 130.4, 130.2, 114.8, 113.8, 55.5, 53.8, 53.5, 49.4, 35.9, 31.6, 29.0, 26.1, 20.7, 14.1; IR (neat): v = 1674, 1599, 1576, 1257, 1169, 1030 cm^{-1}; MS (ESI): m/z 304.6 $[M+H]^+$.



1s 2a

Under argon atmosphere, a mixture of **1s** (33.6 mg, 0.3 mmol), **2a** (41.4 mg, 0.2 mmol), and CuBr (2.9 mg, 0.02 mmol) in 1 mL MeCN was stirred at 50 °C for 10 h. A saturated aqueous sodium carbonate solution was added and the mixture was stirred for 15 min. The mixture was stirred for 15 min, then extracted with EtOAc. The combined organic extracts were washed with brine, dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by column chromatography on silica gel to give desire product **4s** (30.1 mg, 76% yield, yellow oil).

^{1}H NMR (400 MHz, $CDCl_3$) δ 5.82 – 5.74 (m, 1H), 5.02 – 4.93 (m, 2H), 3.65 (t, J = 4.3 Hz, 4H), 2.64 – 2.27 (m, 12H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.0, 137.1, 115.3, 67.0, 53.6, 53.2, 42.1, 40.2, 27.7; IR (neat): v = 1710, 1335, 1116, 913, 868 cm^{-1}; MS (ESI): m/z 198.4 $[M+H]^+$.



1a 2a

Under argon atmosphere, a mixture of **1a** (24.0 mg, 0.15 mmol), **2a** (20.7 mg, 0.1 mmol), TEMPO (15.6 mg, 0.1 mmol), and CuBr (1.4 mg, 0.01 mmol) in 1 mL MeCN was stirred at 50 °C for 10 h.. A saturated aqueous sodium carbonate solution was added and the mixture was stirred for 15 min. The mixture was stirred for 15 min, then extracted with EtOAc. The combined organic extracts were

washed with brine, dried over $MgSO_4$ and concentrated in vacuo. The residue was purified by column chromatography on silica gel to give desire product **4a** (23.8 mg, 96% yield).

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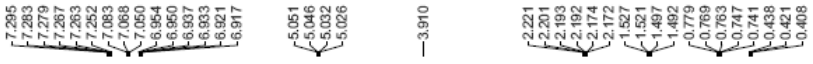
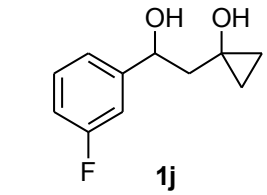
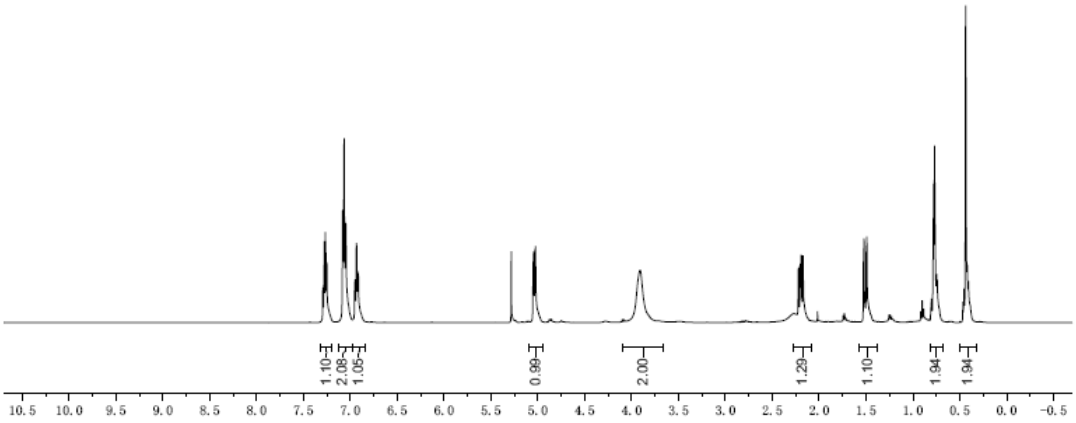
Part 2. ^{1}H and ^{13}C NMR Spectra for New Compounds

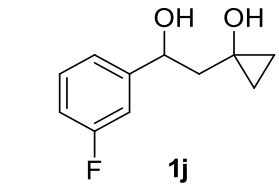




1j

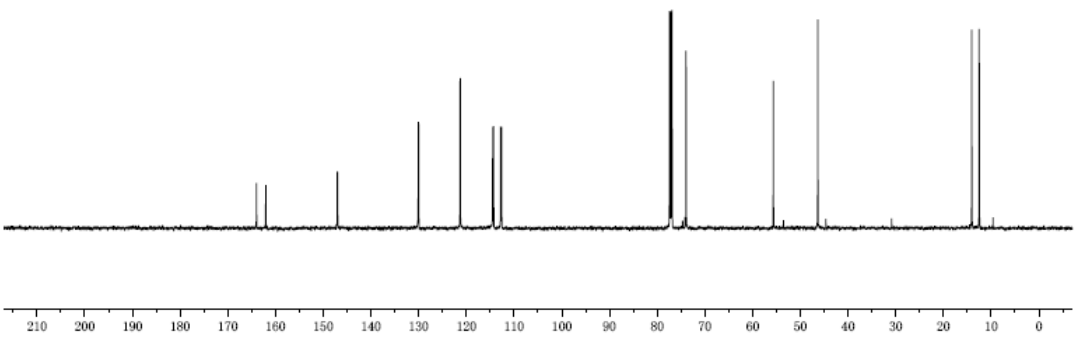
^{1}H NMR (400 MHz, $CDCl_3$)

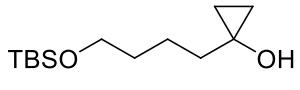




1j

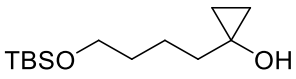
^{13}C NMR (100 MHz, $CDCl_3$)





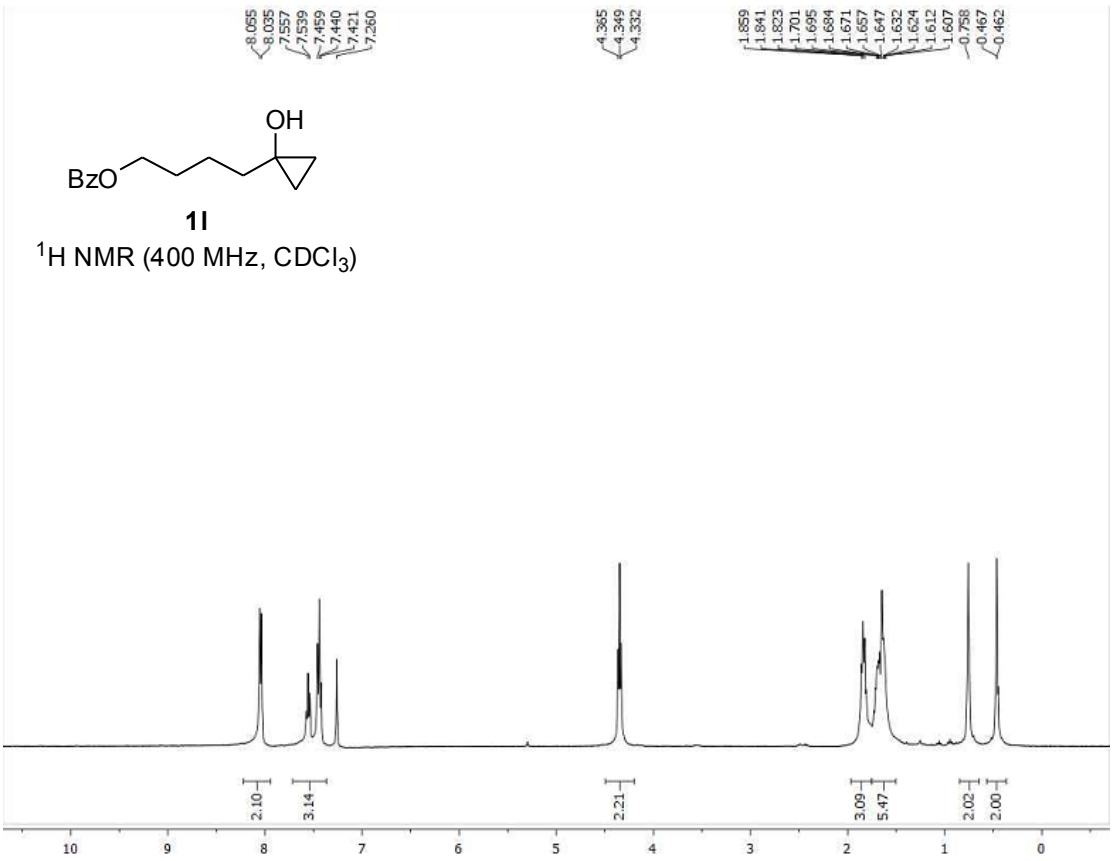
1k

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



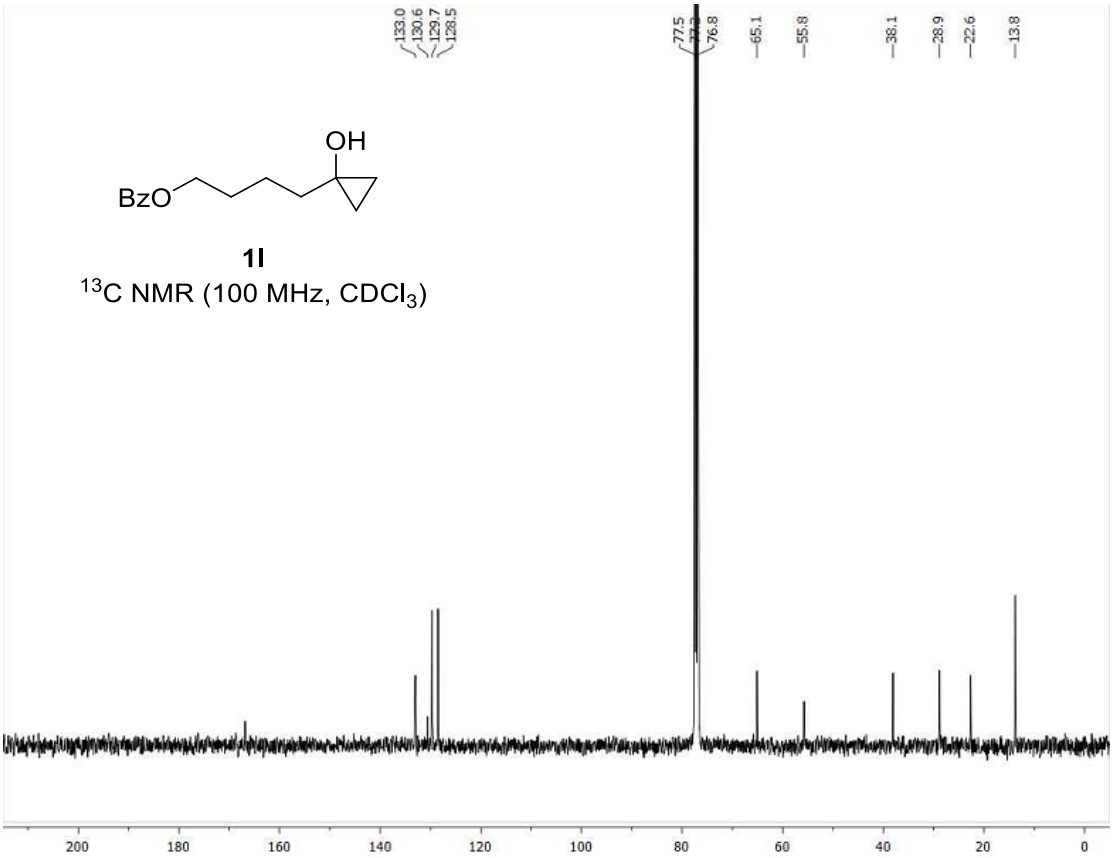
1k

^{13}C NMR (125 MHz, $CDCl_3$)



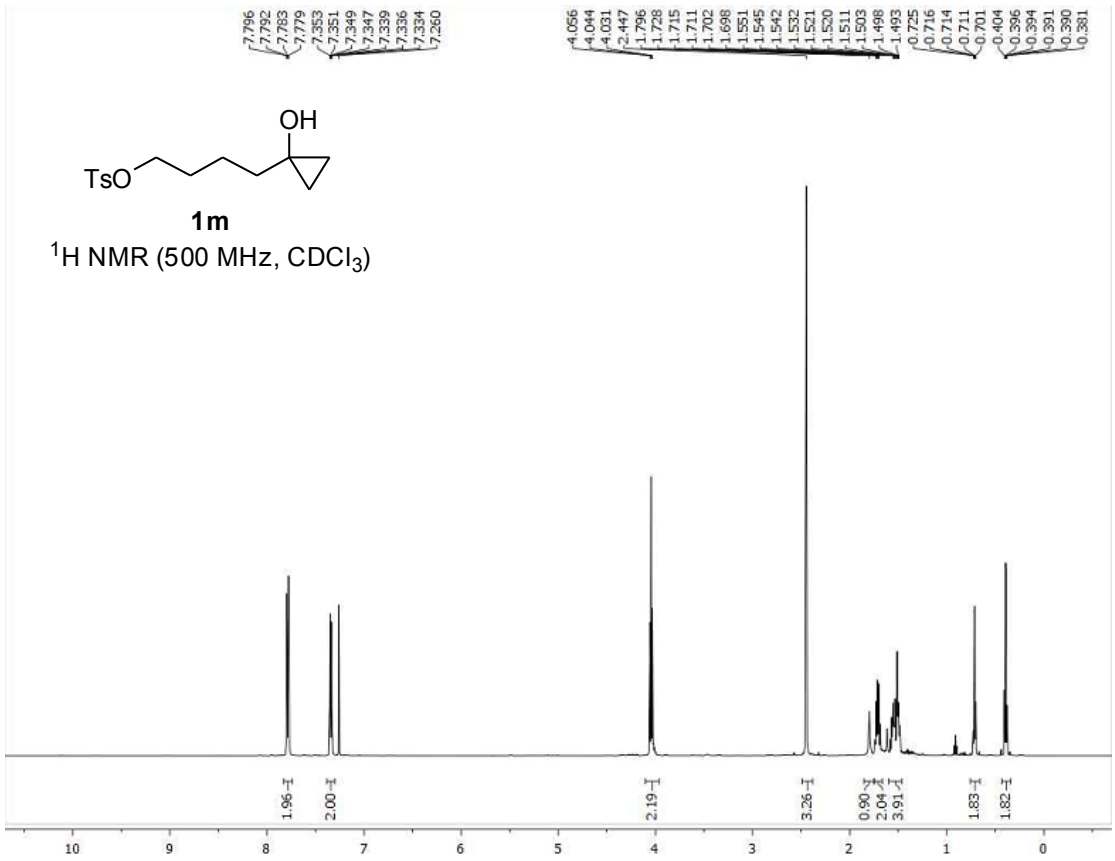
1l

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



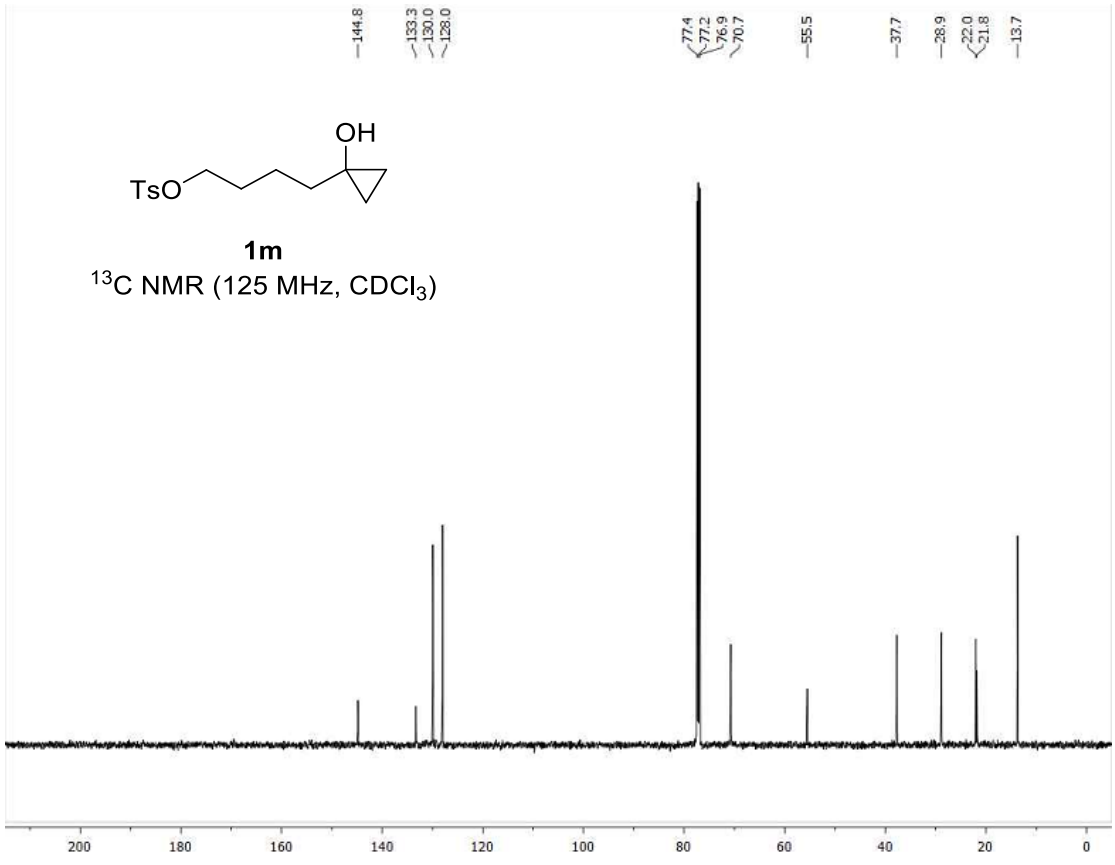
1l

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



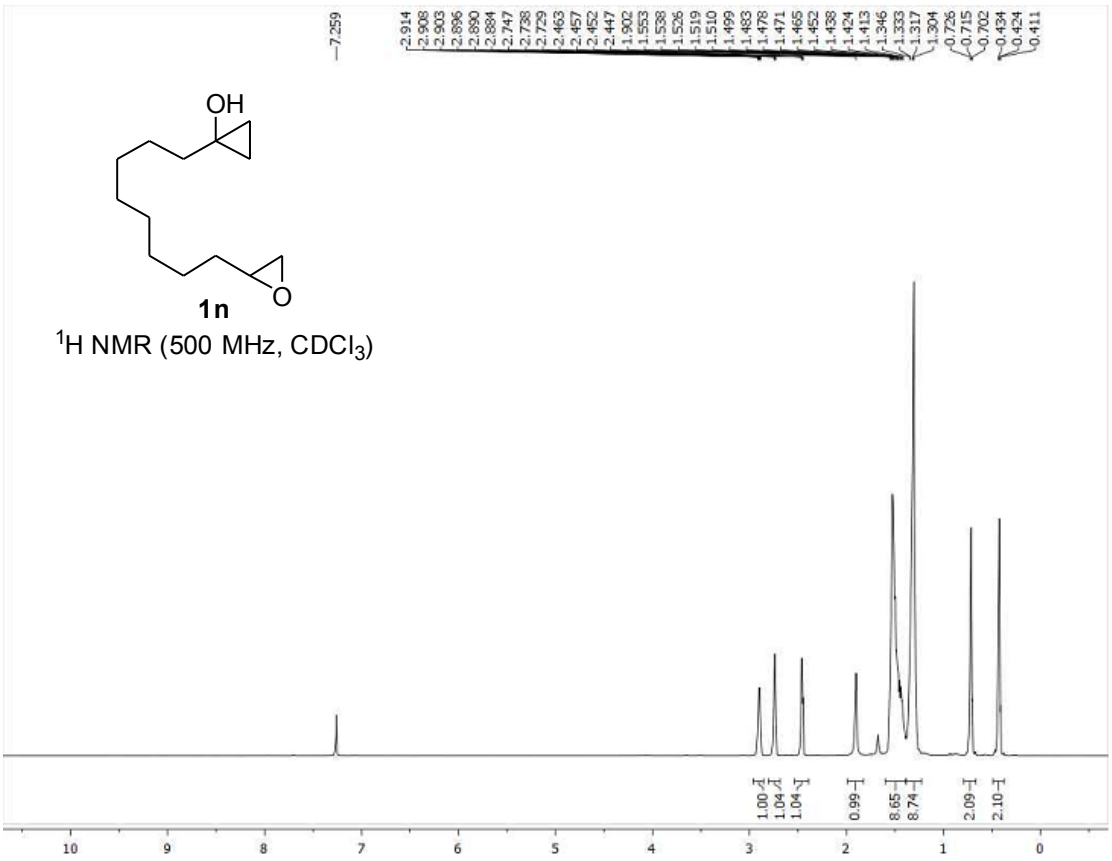
1m

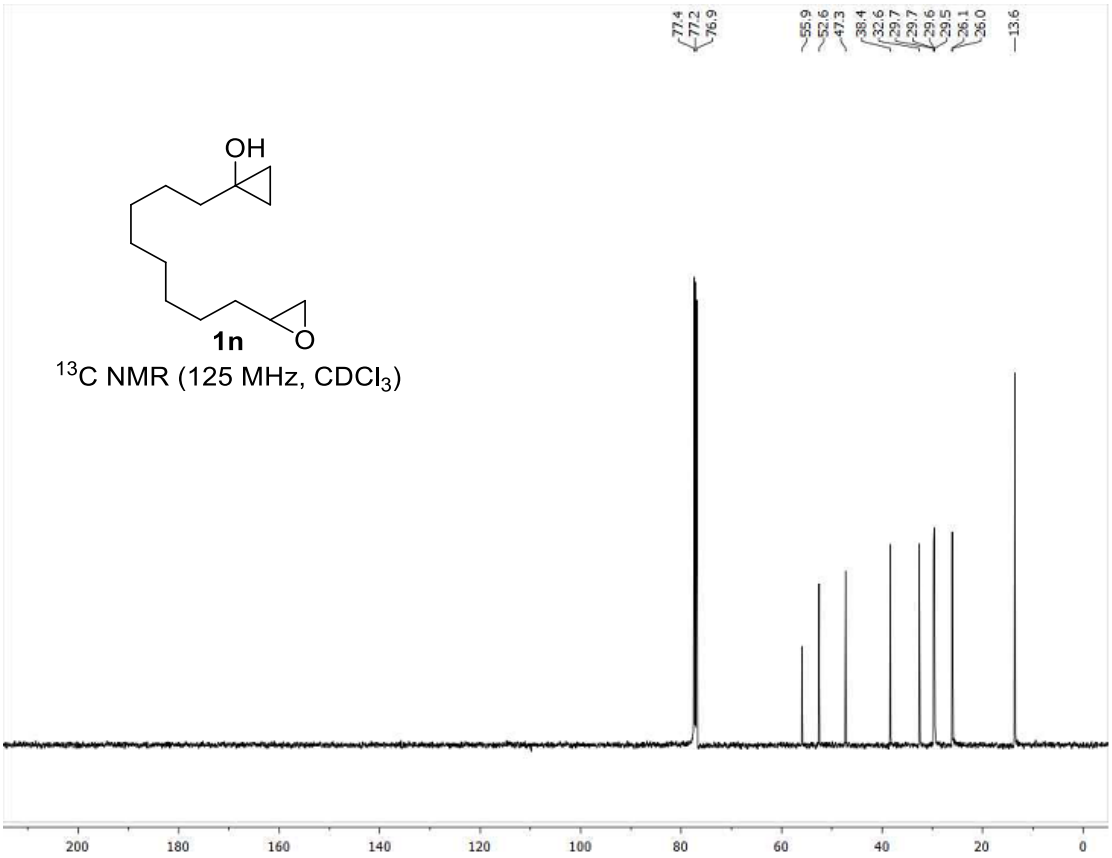
^{1}H NMR (500 MHz, $CDCl_3$)

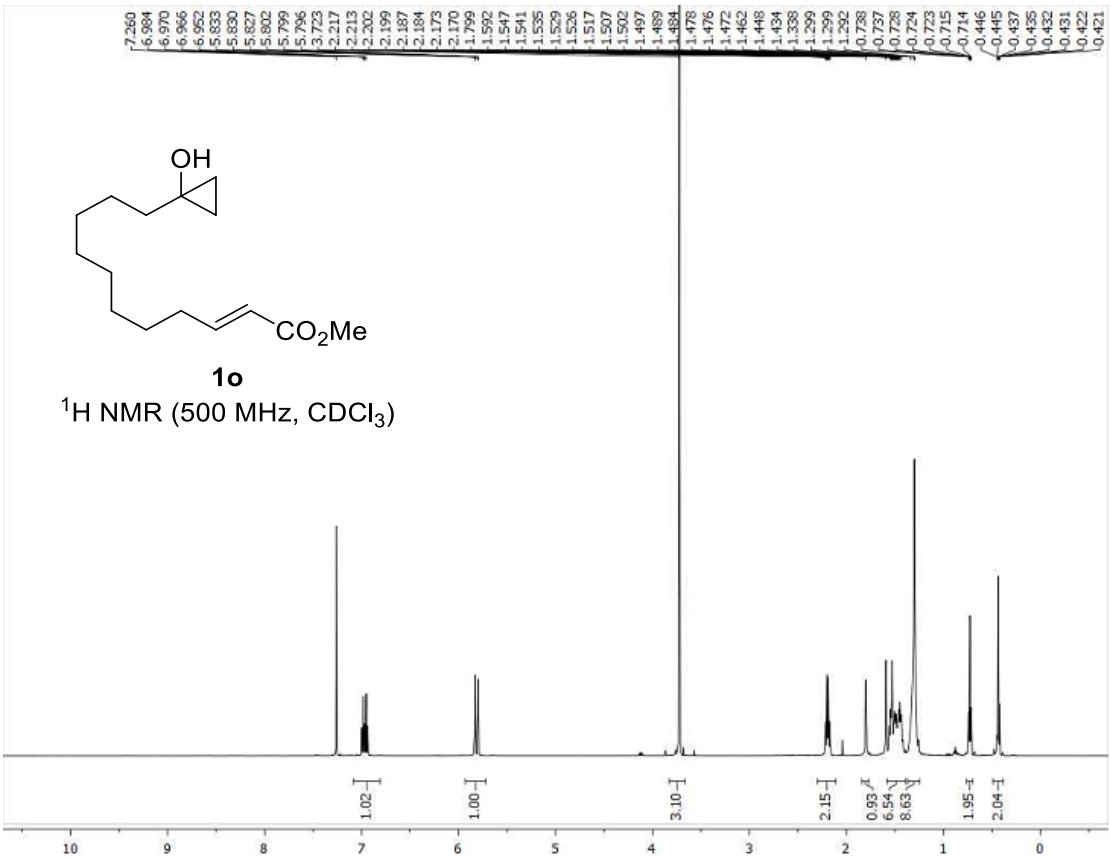


1m

^{13}C NMR (125 MHz, $CDCl_3$)

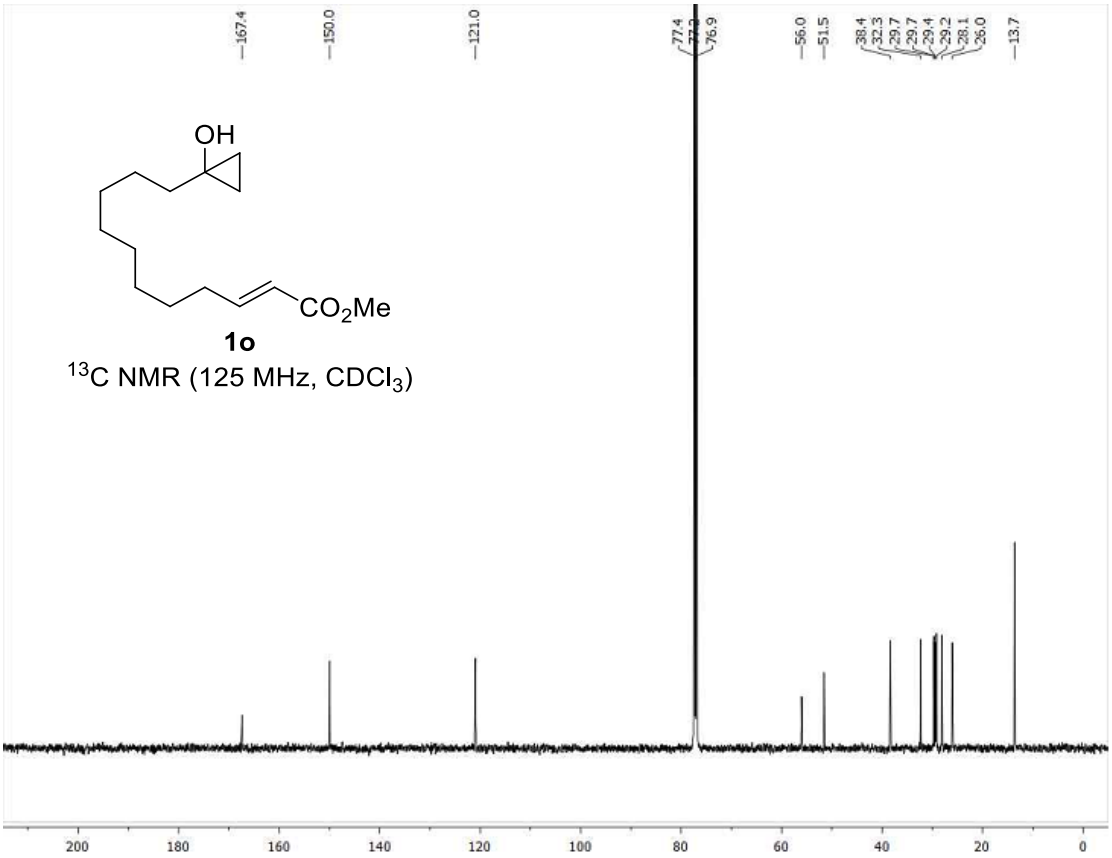

OH
O
1n
^{1}H NMR (500 MHz, CDCl$_3$)


OH
O
1n
^{13}C NMR (125 MHz, CDCl$_3$)



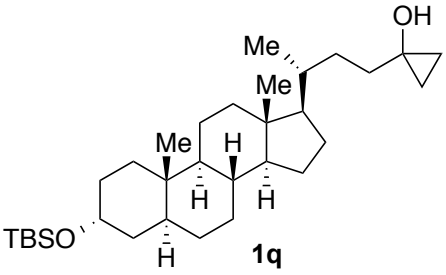
1o

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



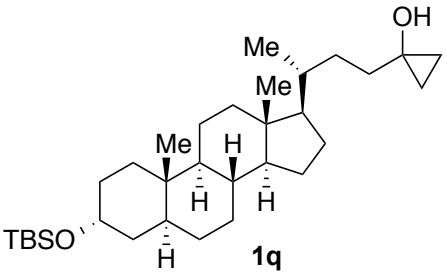
1o

^{13}C NMR (125 MHz, $CDCl_3$)



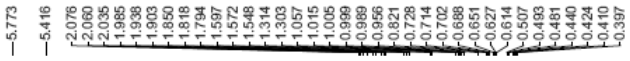
1q

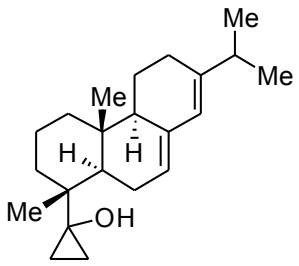
^{1}H NMR (400 MHz, $CDCl_3$)



1q

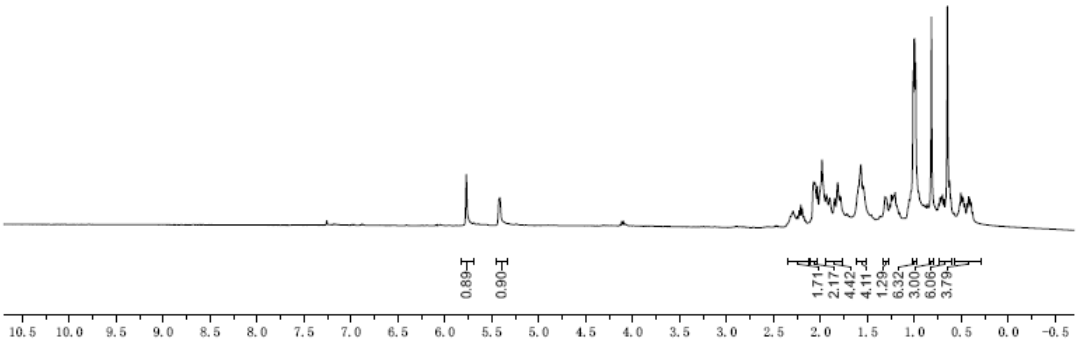
^{13}C NMR (400 MHz, $CDCl_3$)

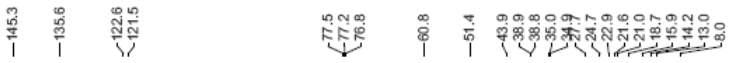


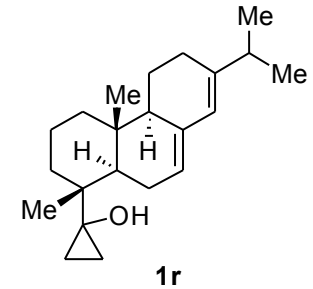


1r

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

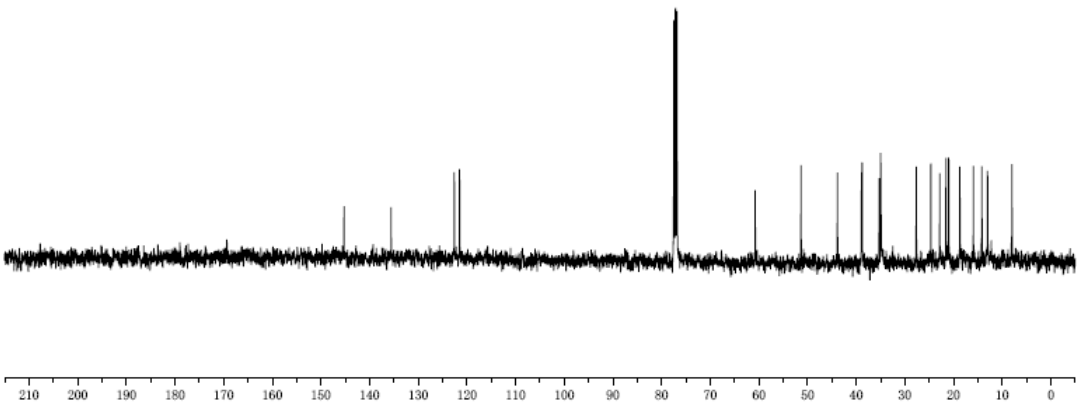






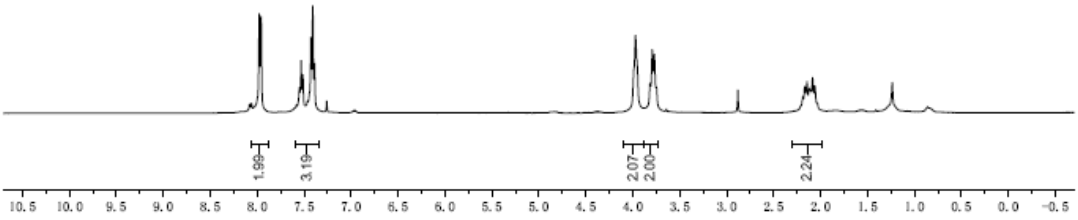
1r

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



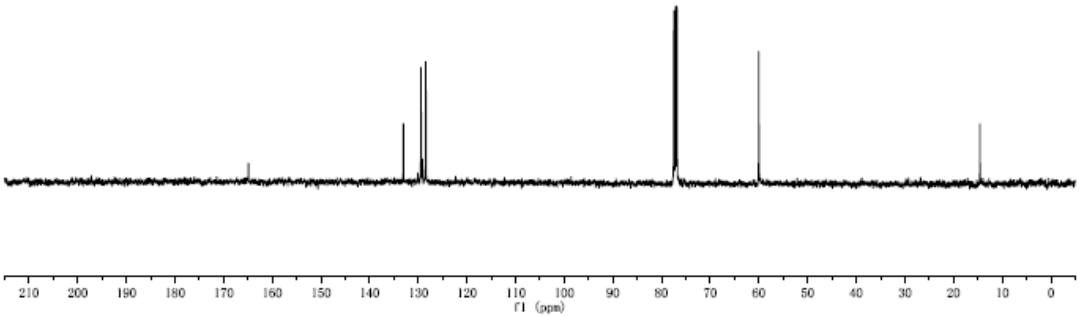
2f

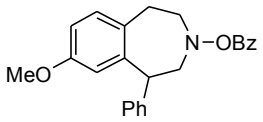
^{1}H NMR (400 MHz, $CDCl_3$)



2f

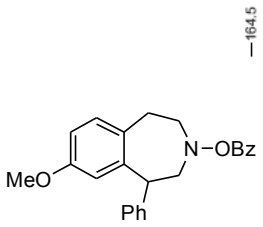
^{13}C NMR (100 MHz, $CDCl_3$)





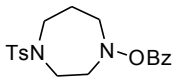
2g

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



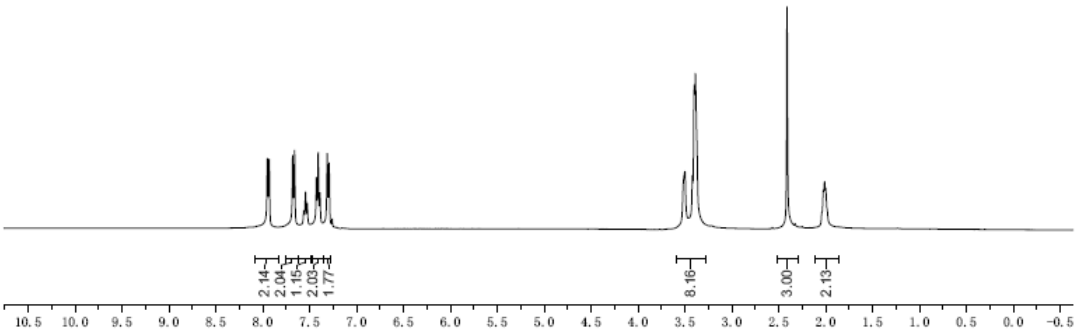
2g

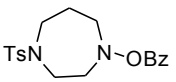
^{13}C NMR (100 MHz, $CDCl_3$)



2h

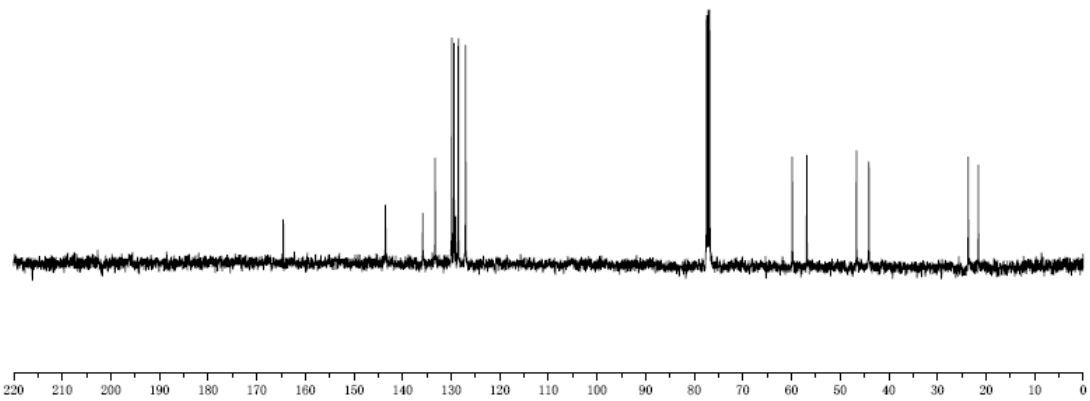
^{1}H NMR (400 MHz, $CDCl_3$)

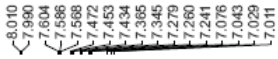


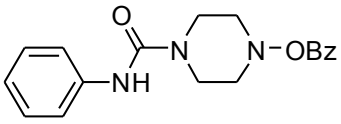


2h

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

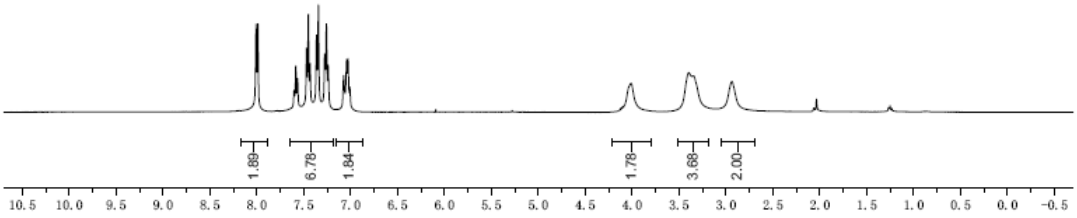


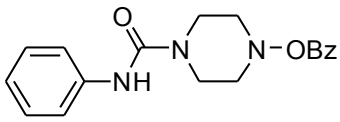




2j

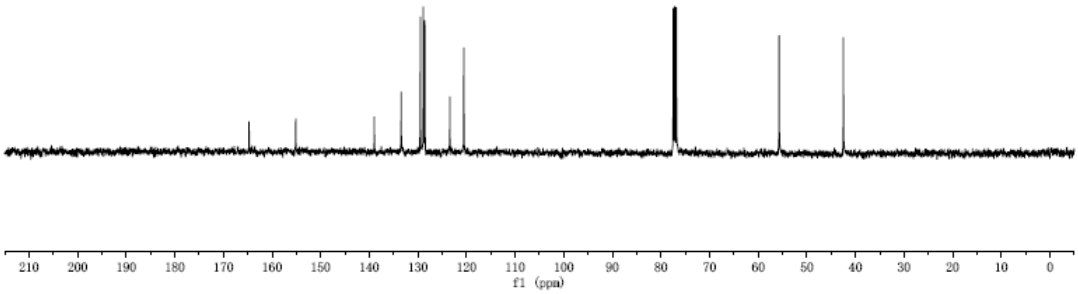
^{1}H NMR (400 MHz, $CDCl_3$)

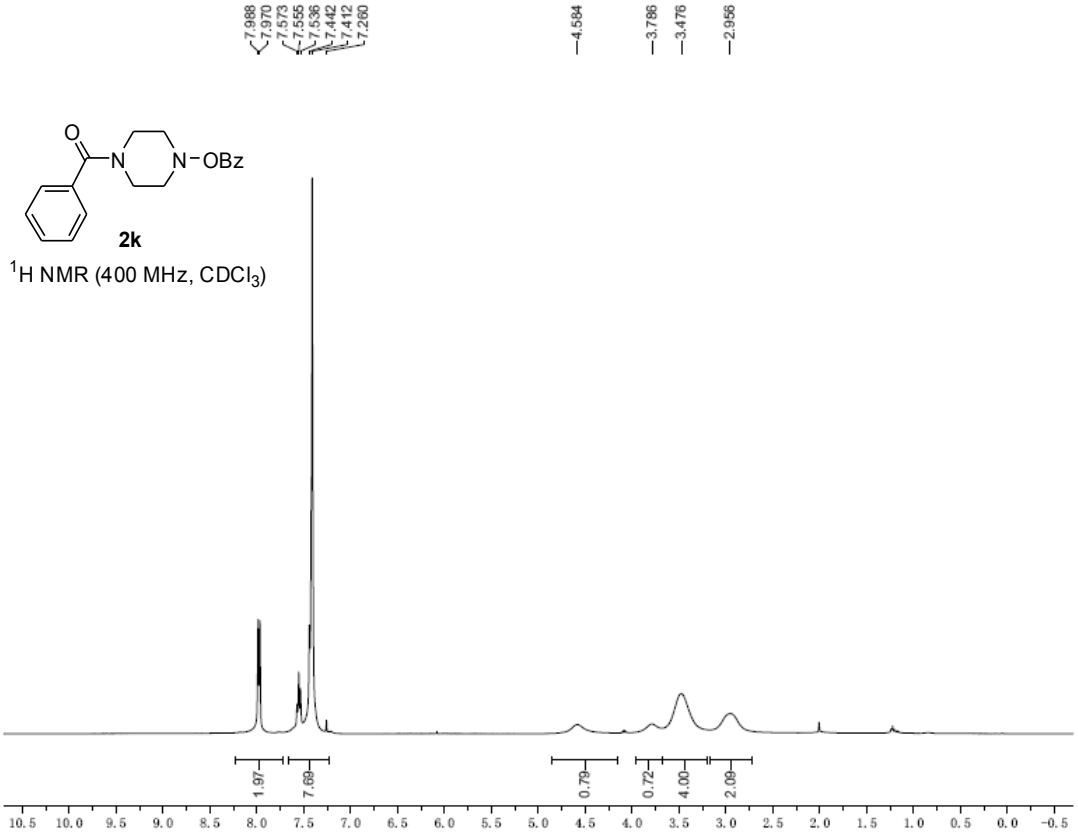




2j

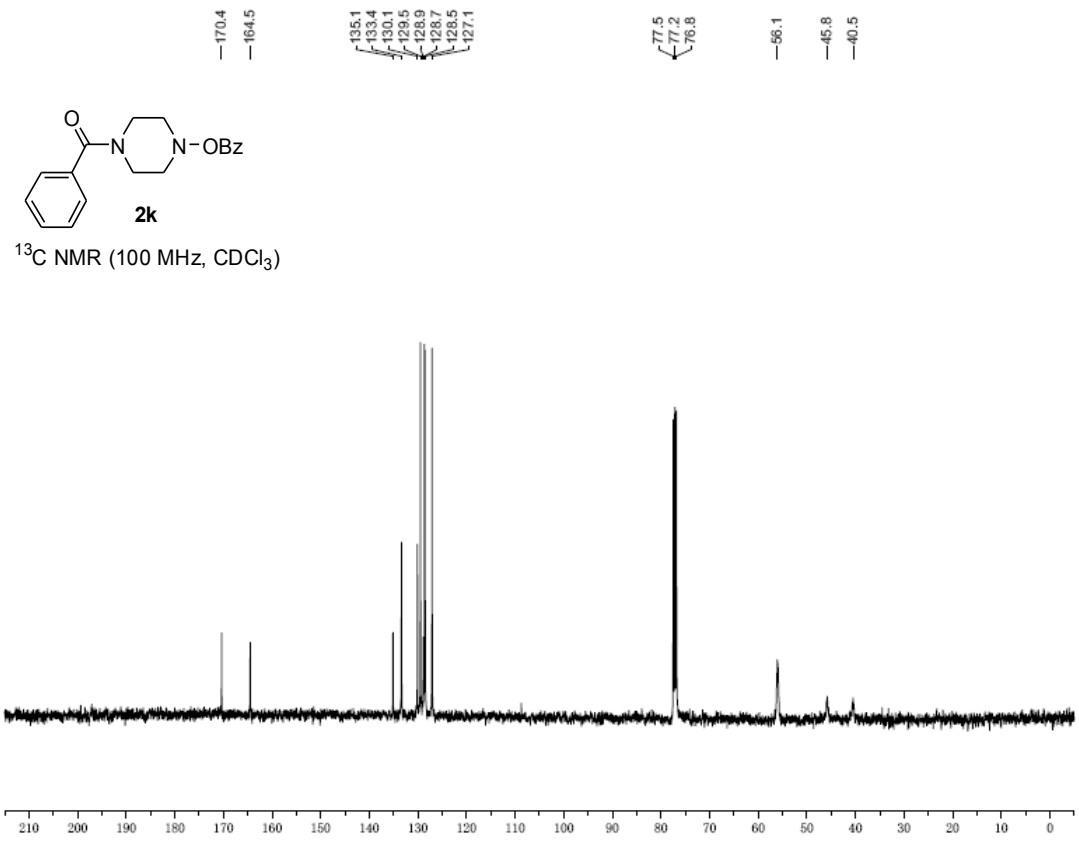
^{13}C NMR (100 MHz, $CDCl_3$)





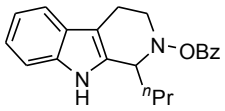
2k

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



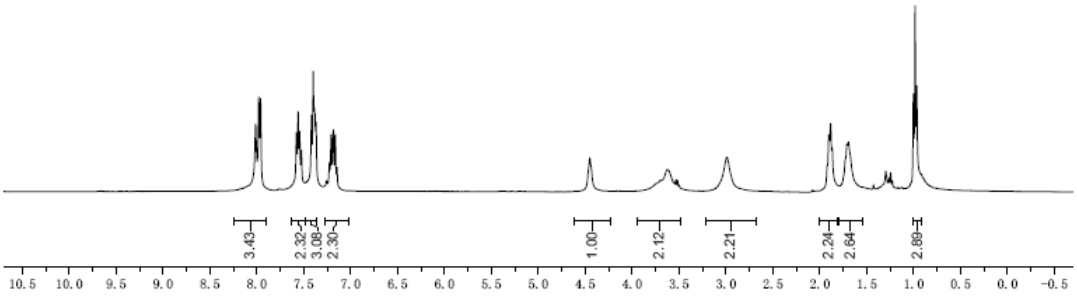
2k

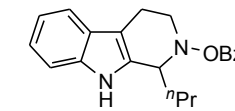
^{13}C NMR (100 MHz, $CDCl_3$)



2m

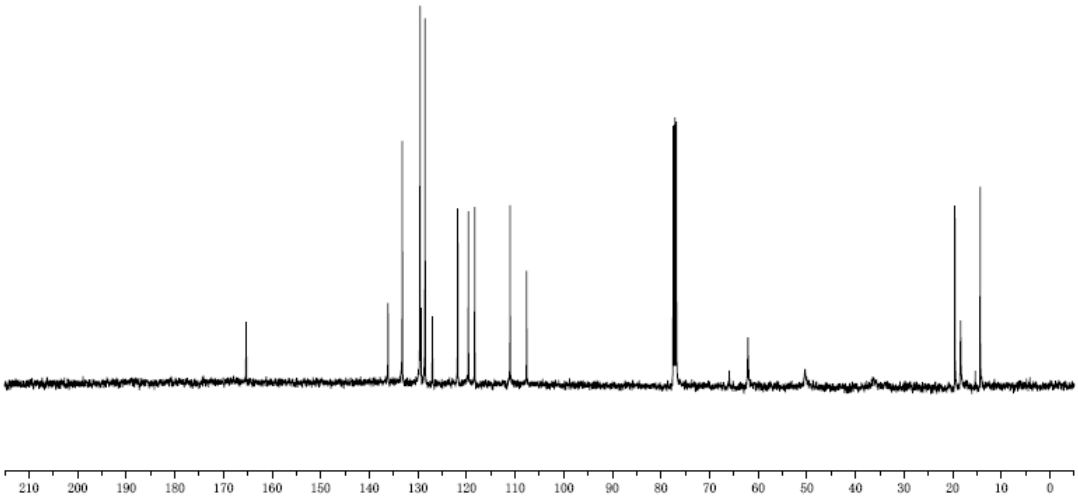
^{1}H NMR (400 MHz, $CDCl_3$)

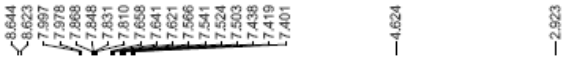


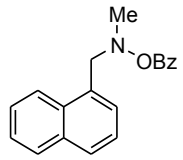


2m

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

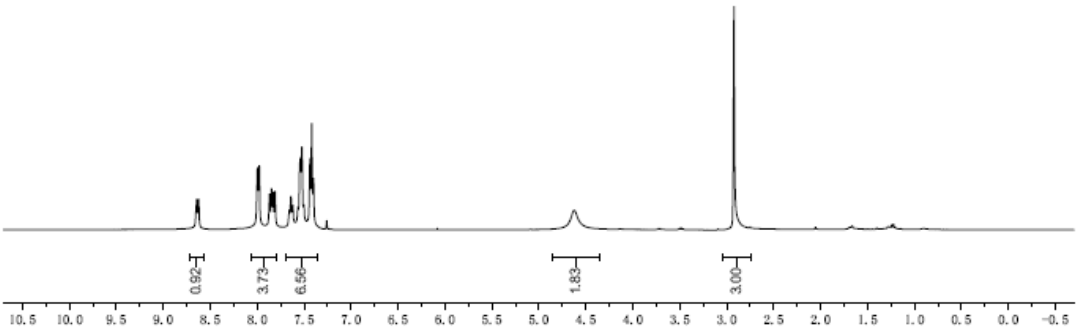


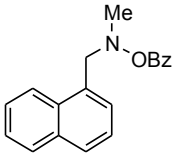




2n

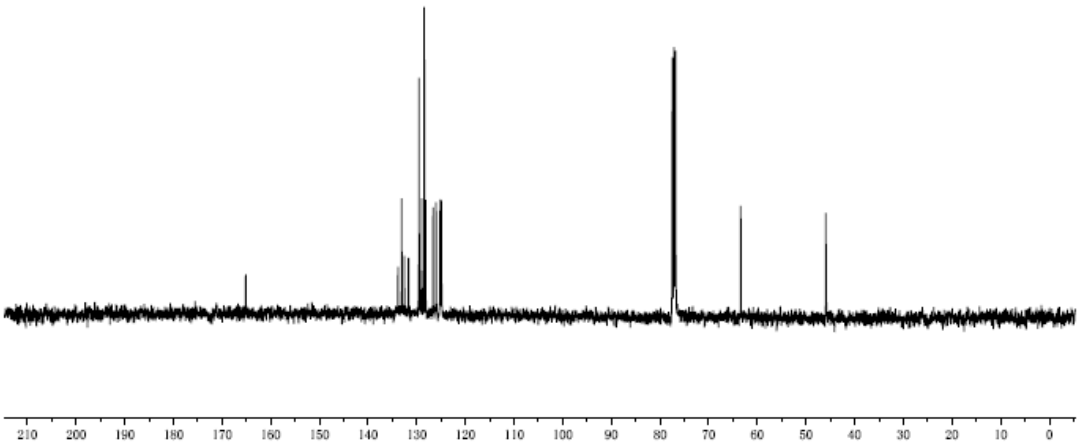
^{1}H NMR (400 MHz, $CDCl_3$)

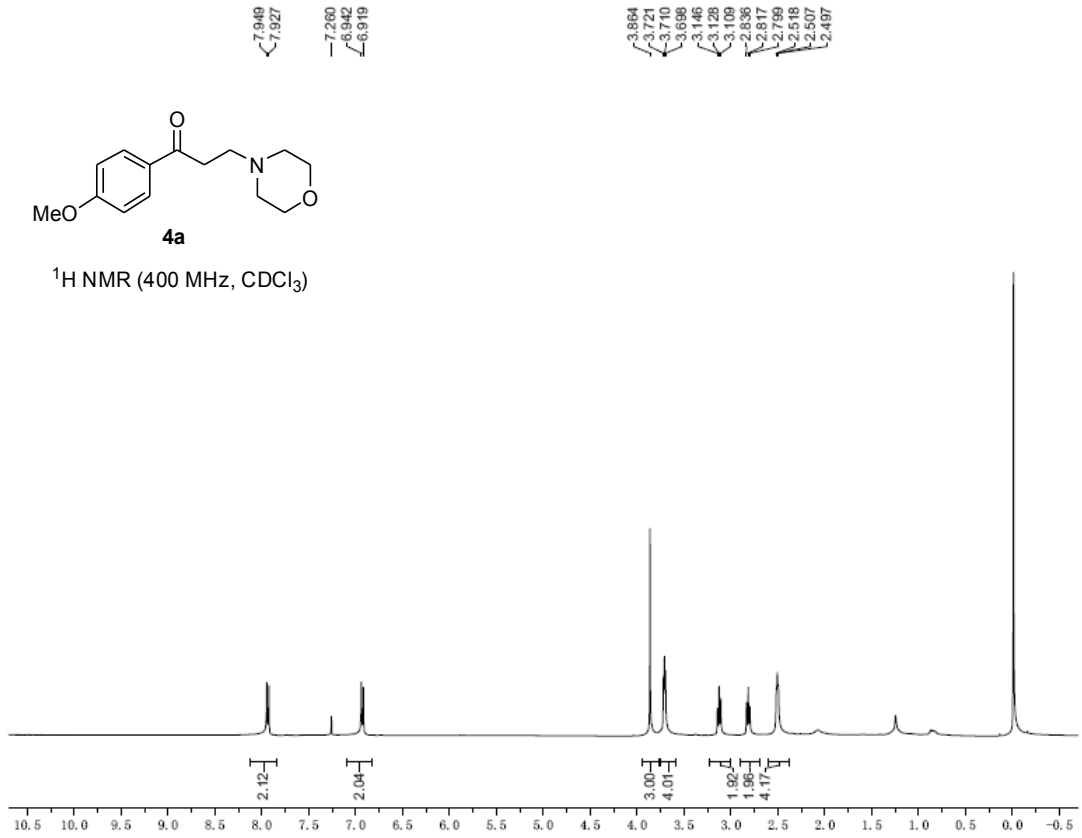




2n

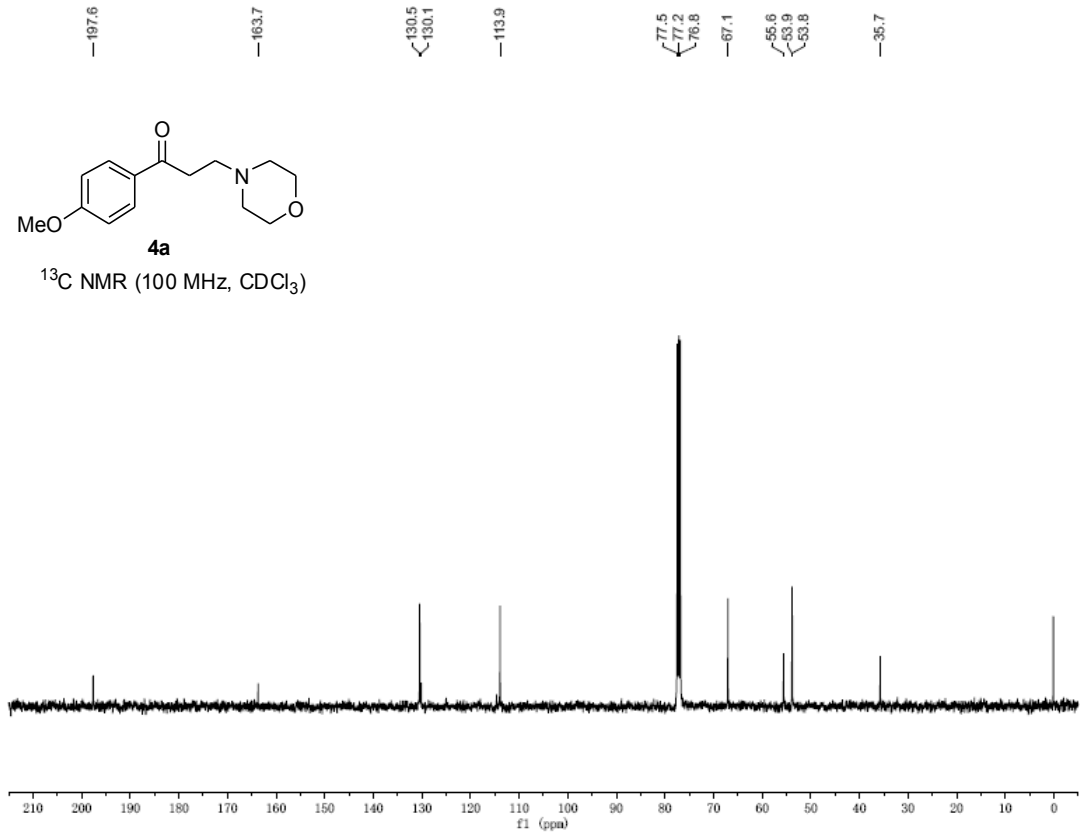
^{13}C NMR (100 MHz, $CDCl_3$)





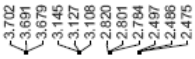
4a

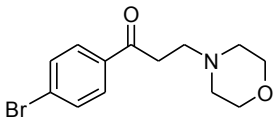
^{1}H NMR (400 MHz, $CDCl_3$)



4a

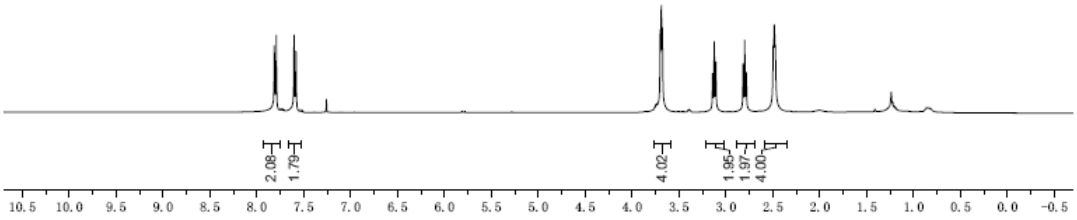
^{13}C NMR (100 MHz, $CDCl_3$)

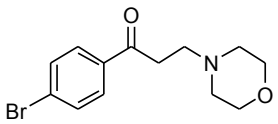




4b

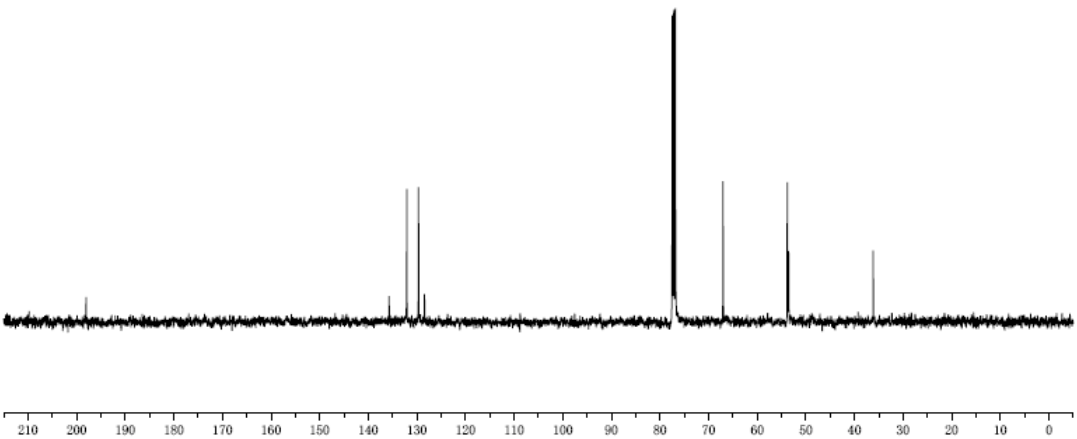
^{1}H NMR (400 MHz, $CDCl_3$)

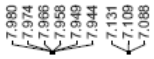


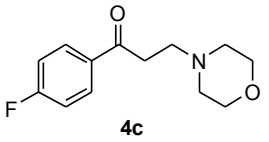


4b

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

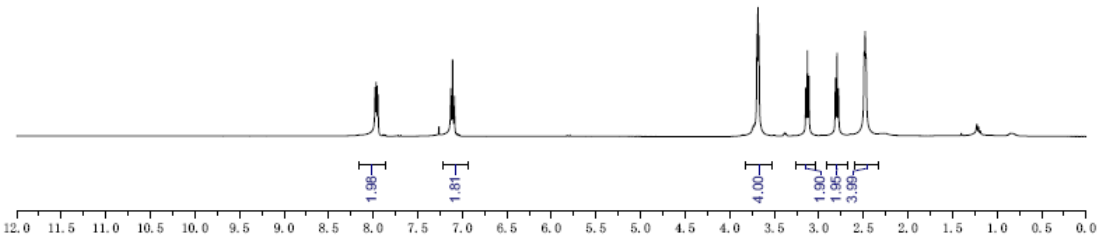


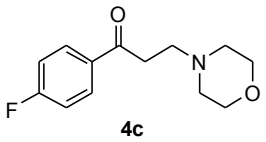




4c

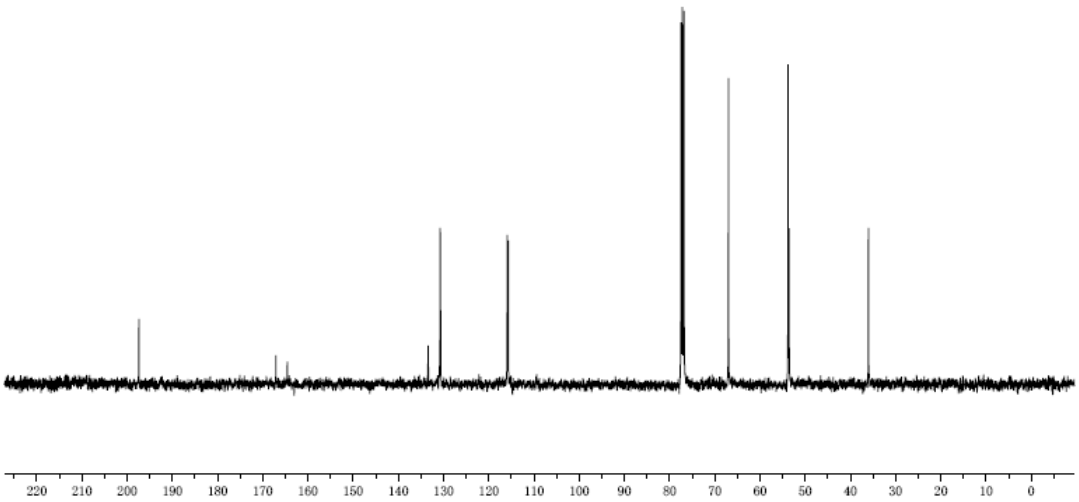
^{1}H NMR (400 MHz, $CDCl_3$)

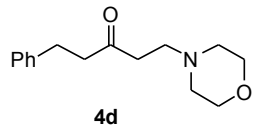




4c

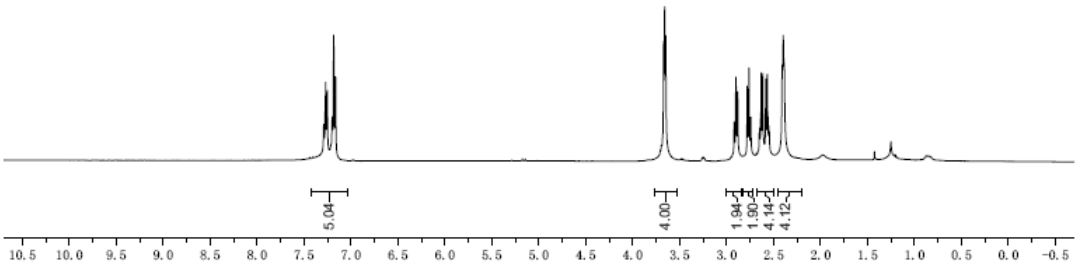
^{13}C NMR (100 MHz, $CDCl_3$)

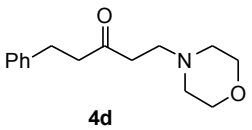




4d

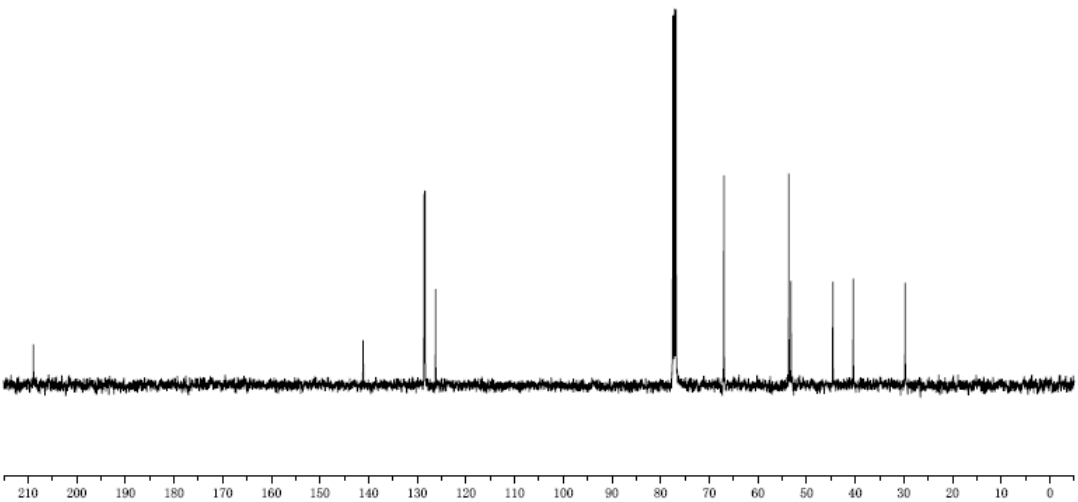
^{1}H NMR (400 MHz, $CDCl_3$)

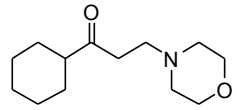




4d

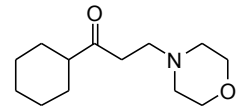
^{13}C NMR (100 MHz, $CDCl_3$)





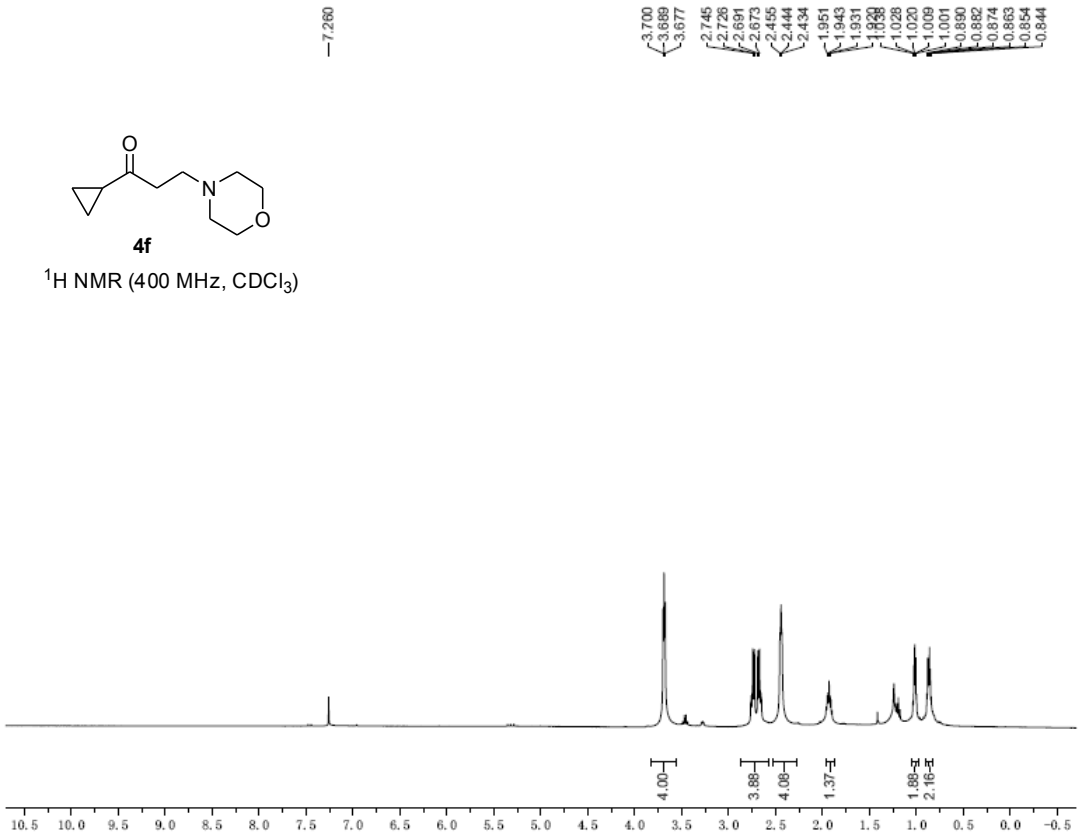
4e

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



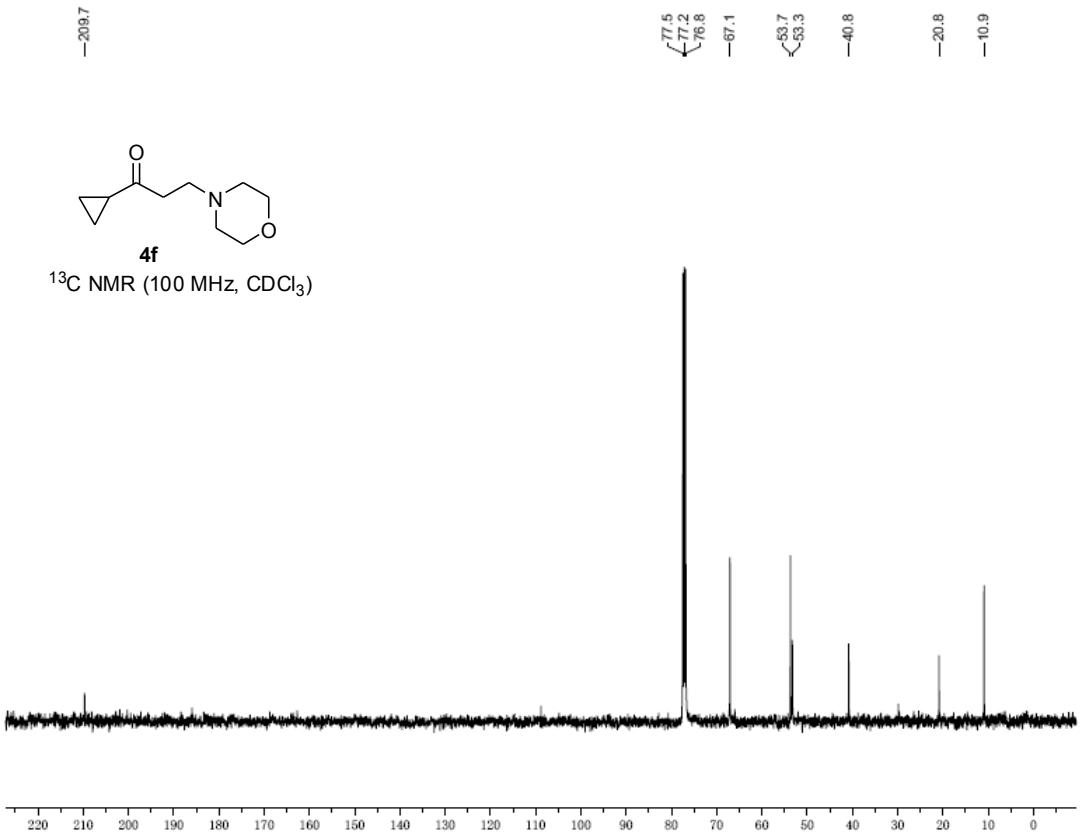
4e

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



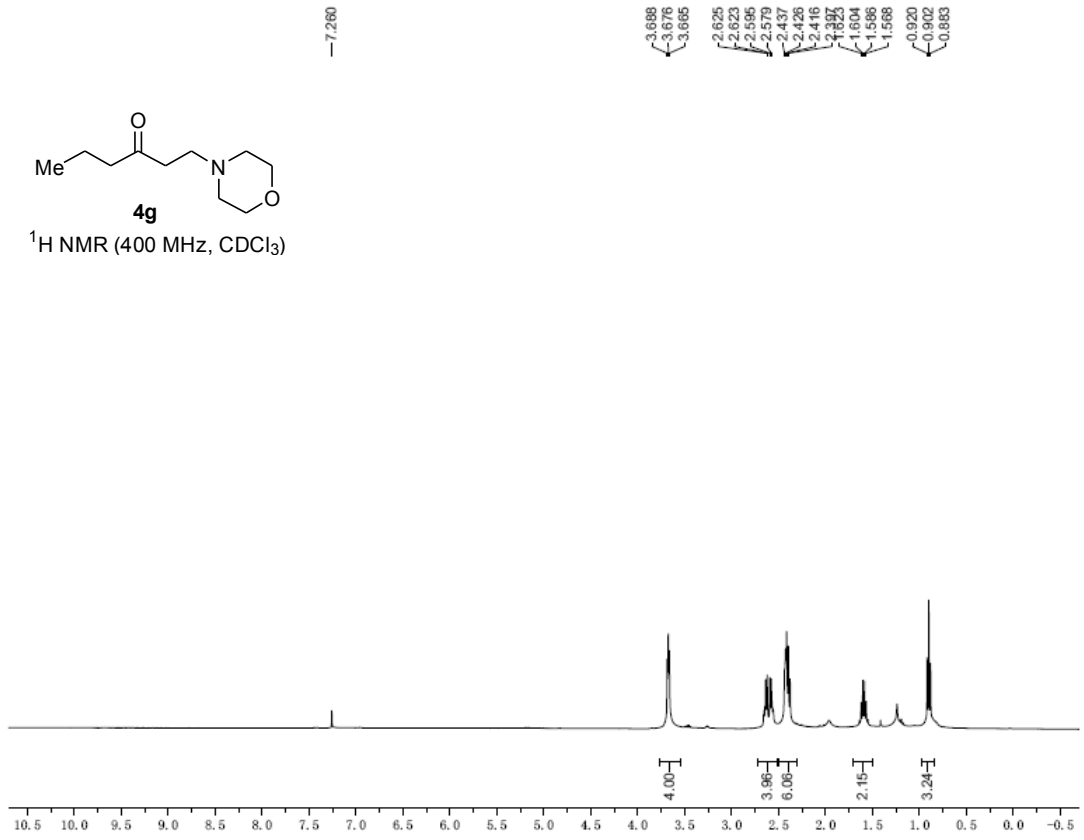
4f

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



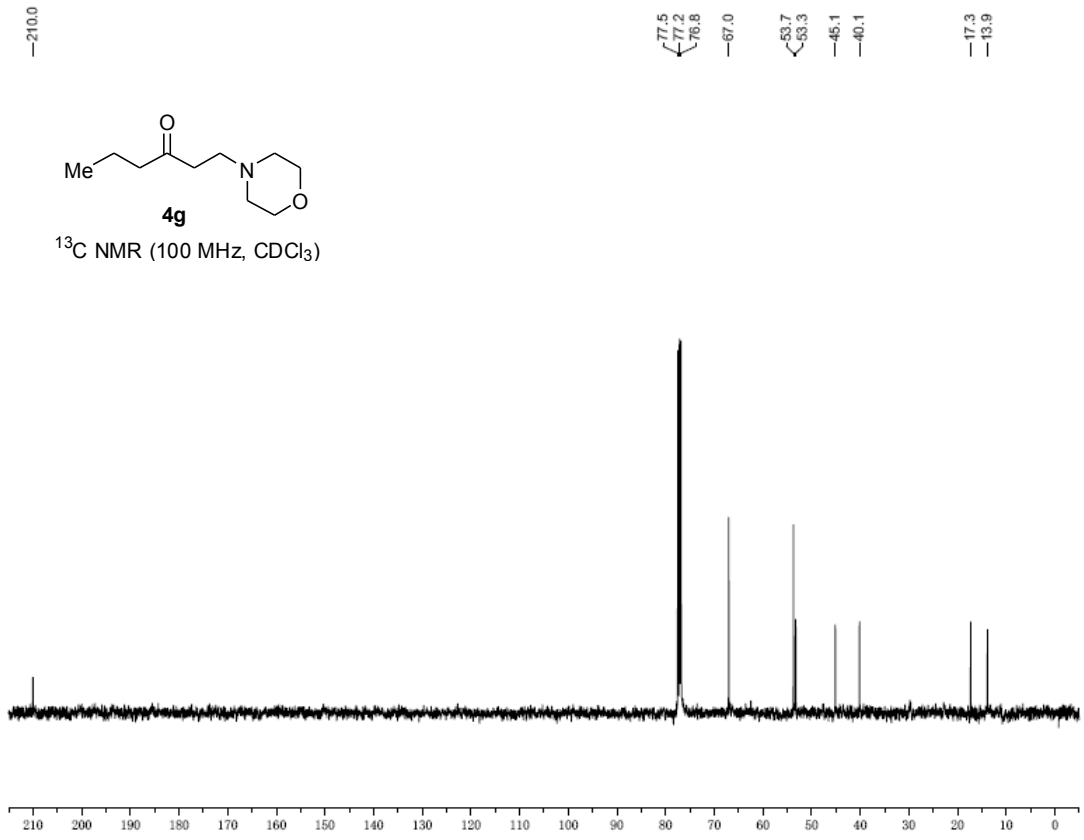
4f

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



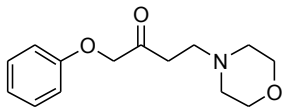
4g

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



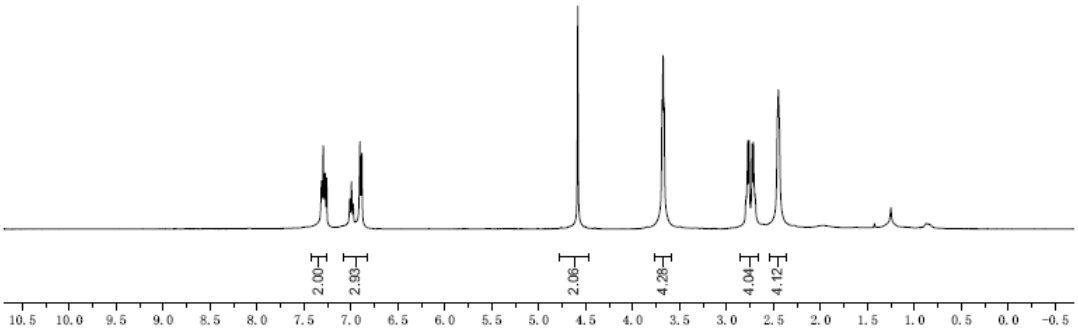
4g

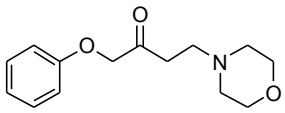
^{13}C NMR (100 MHz, $CDCl_3$)



4h

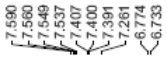
^{1}H NMR (400 MHz, $CDCl_3$)

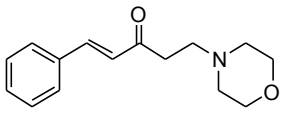




4h

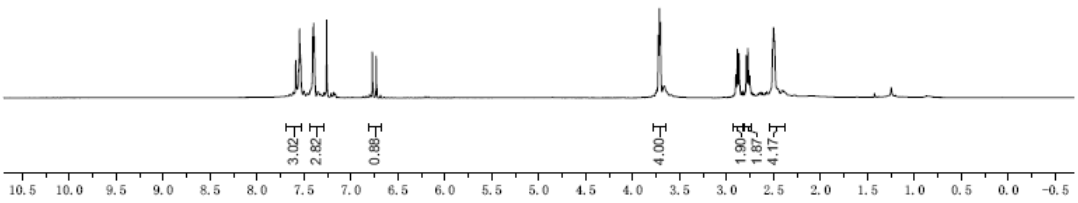
^{13}C NMR (100 MHz, $CDCl_3$)

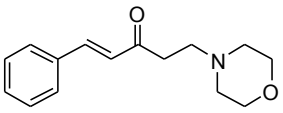




4i

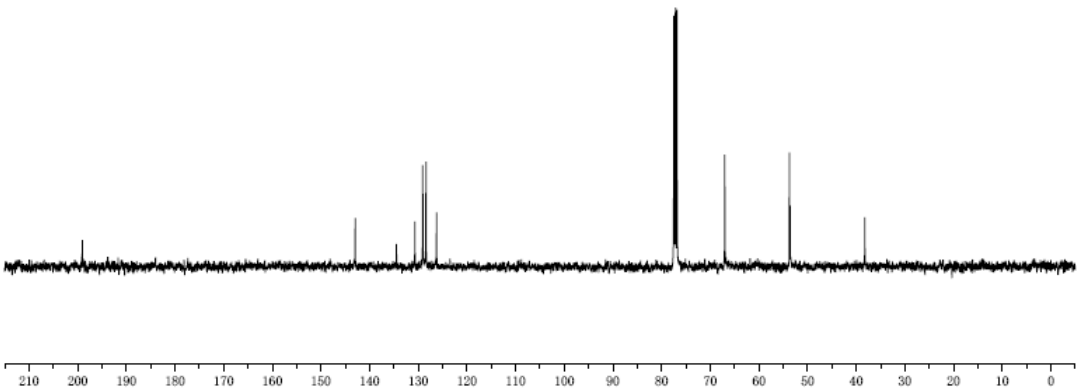
^{1}H NMR (400 MHz, $CDCl_3$)

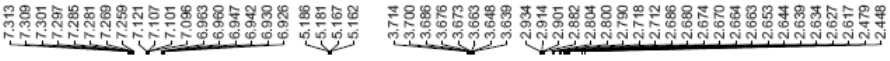


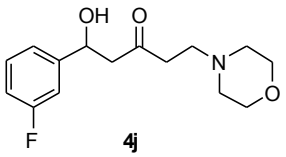


4i

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

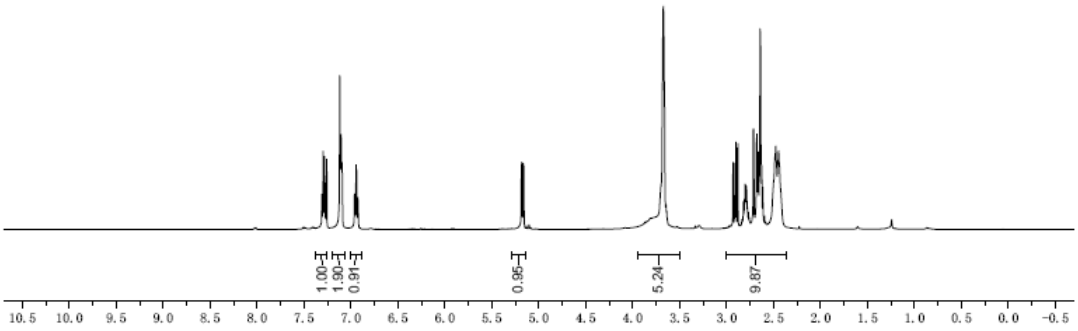






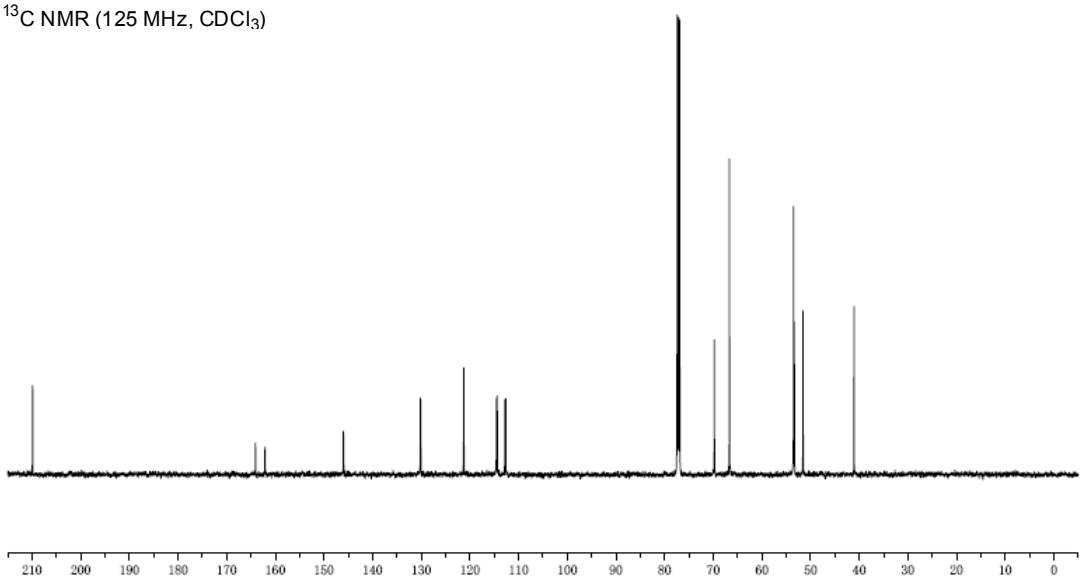
4j

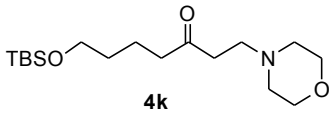
^{1}H NMR (500 MHz, $CDCl_3$)



4j

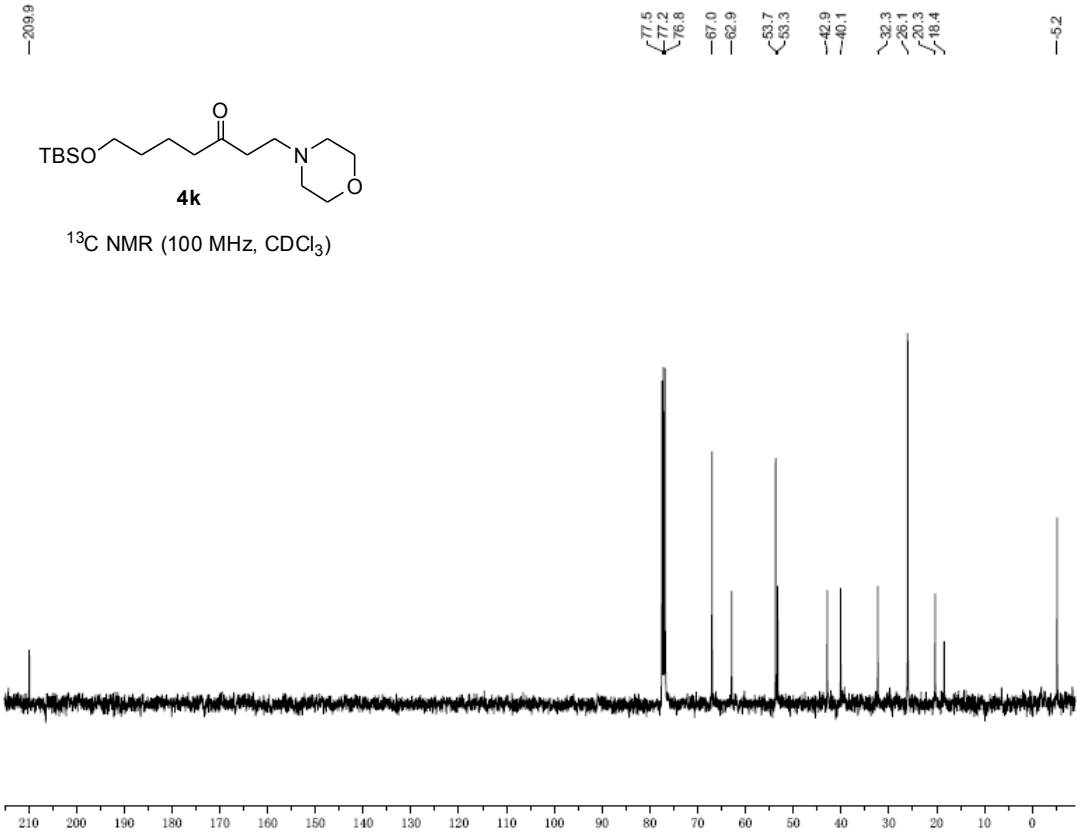
^{13}C NMR (125 MHz, $CDCl_3$)





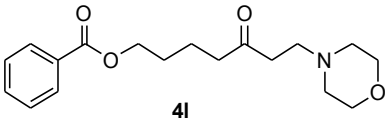
4k

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



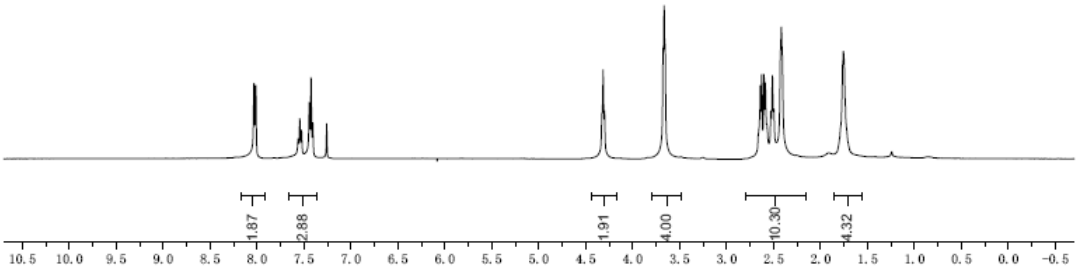
4k

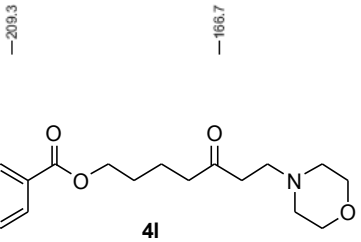
^{13}C NMR (100 MHz, $CDCl_3$)



4l

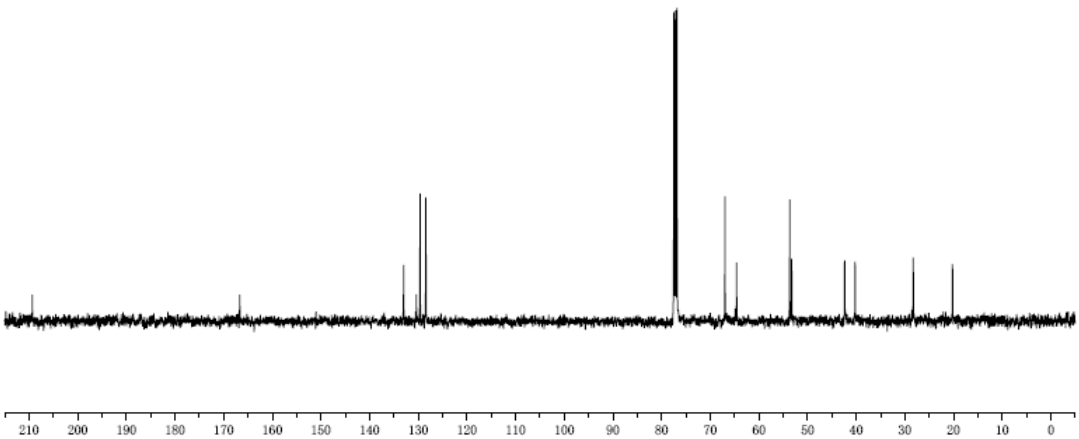
^{1}H NMR (400 MHz, $CDCl_3$)

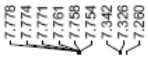


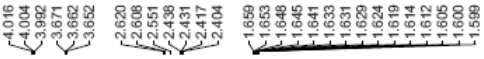


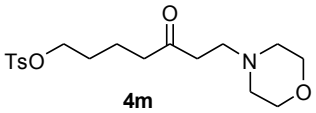
4l

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



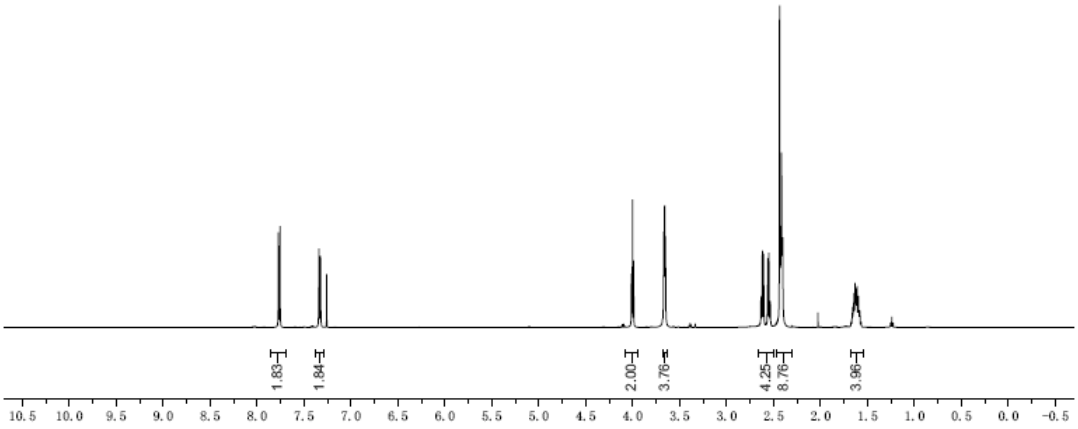


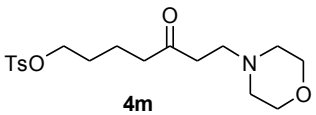




4m

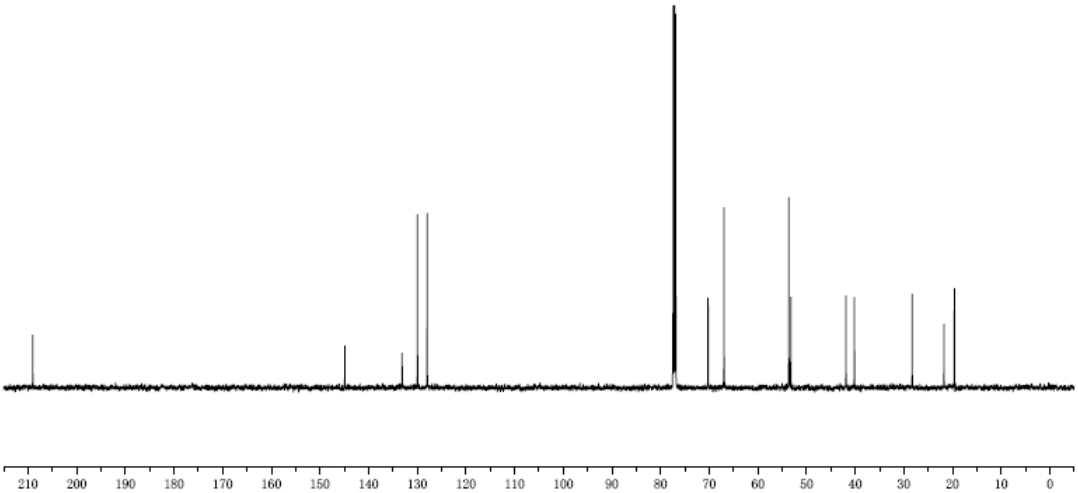
^{1}H NMR (500 MHz, $CDCl_3$)

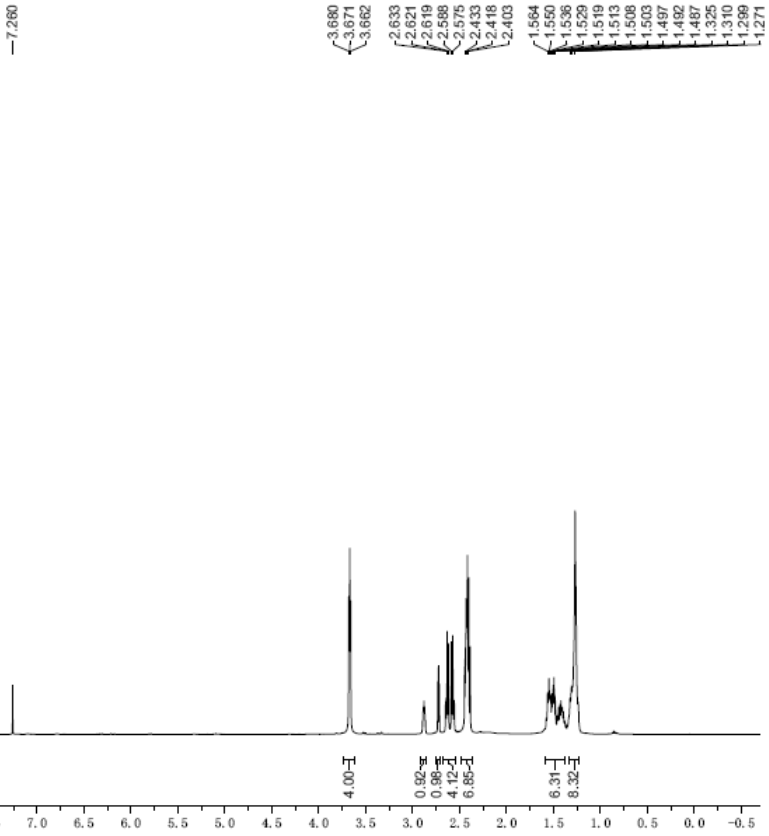




4m

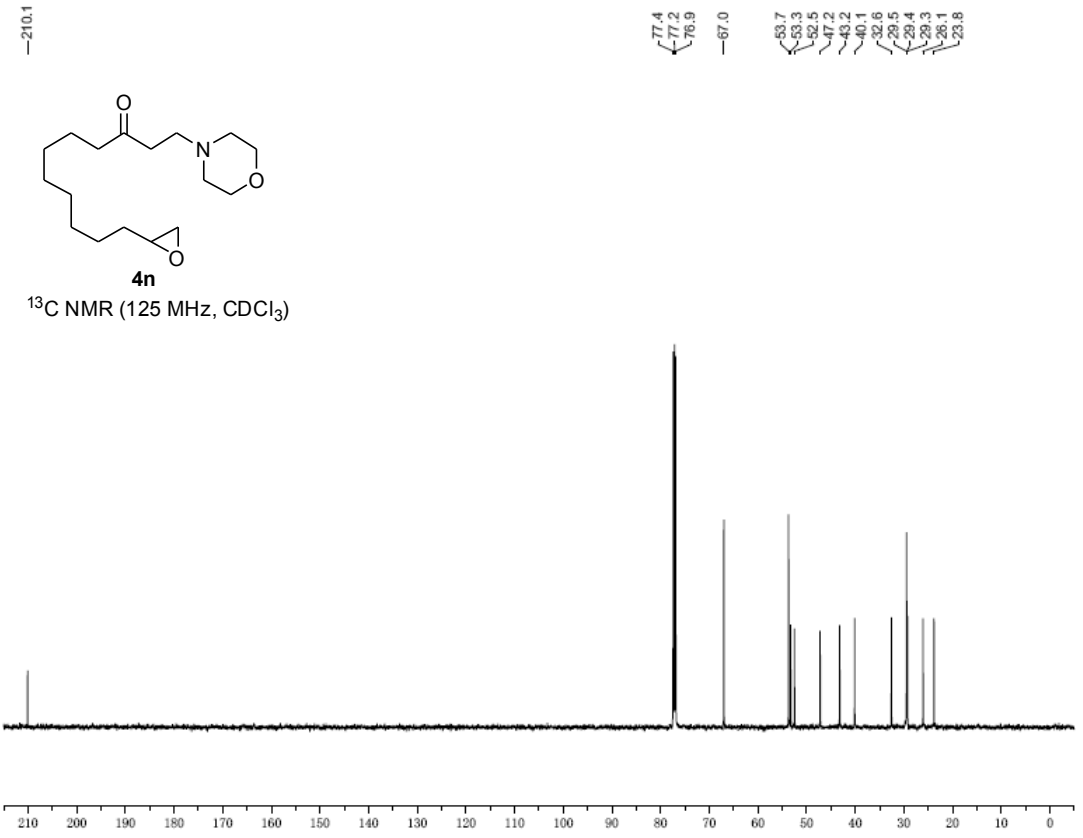
^{13}C NMR (125 MHz, $CDCl_3$)





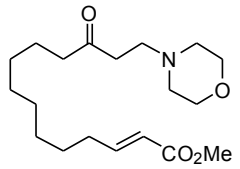
4n

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



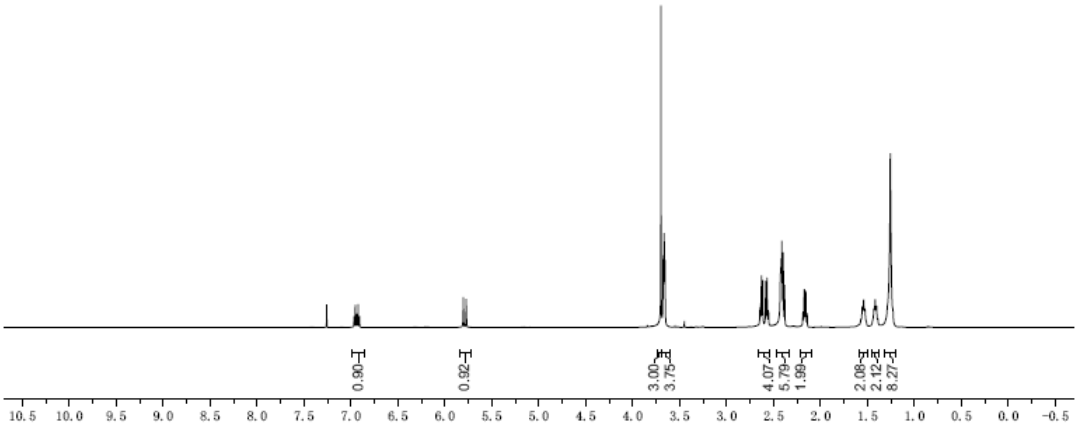
4n

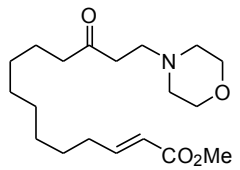
^{13}C NMR (125 MHz, $CDCl_3$)



4o

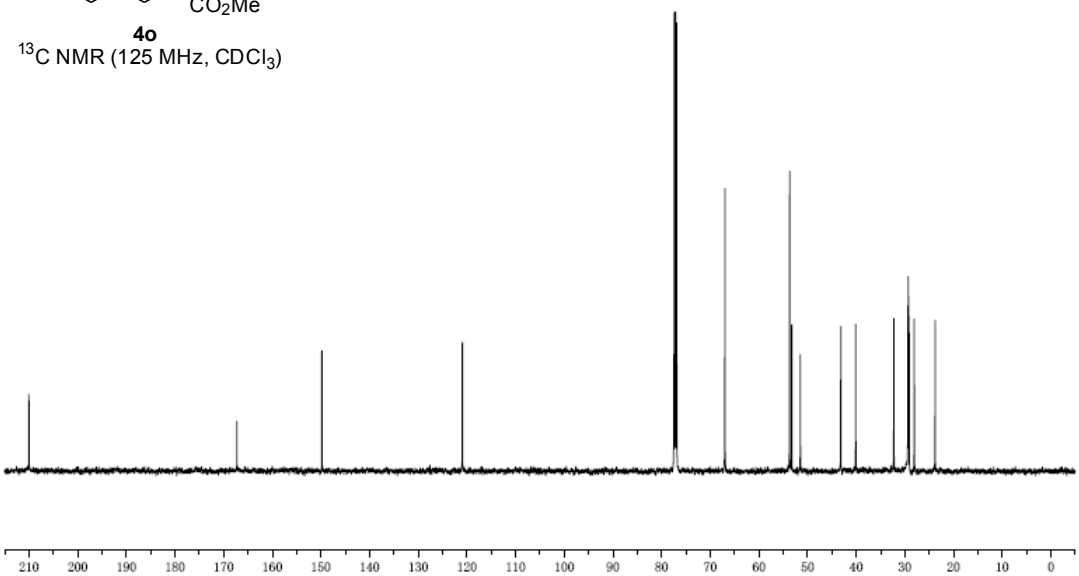
^{1}H NMR (500 MHz, $CDCl_3$)

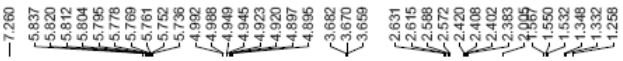


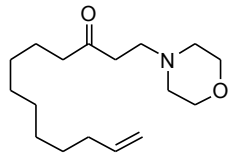


4o

^{13}C NMR (125 MHz, $CDCl_3$)

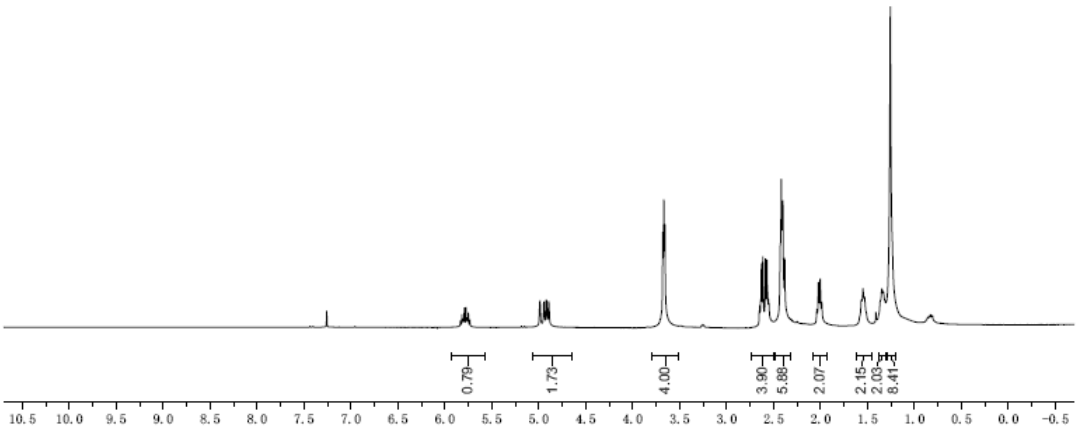


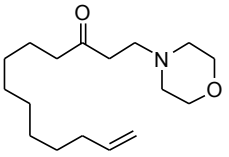




4p

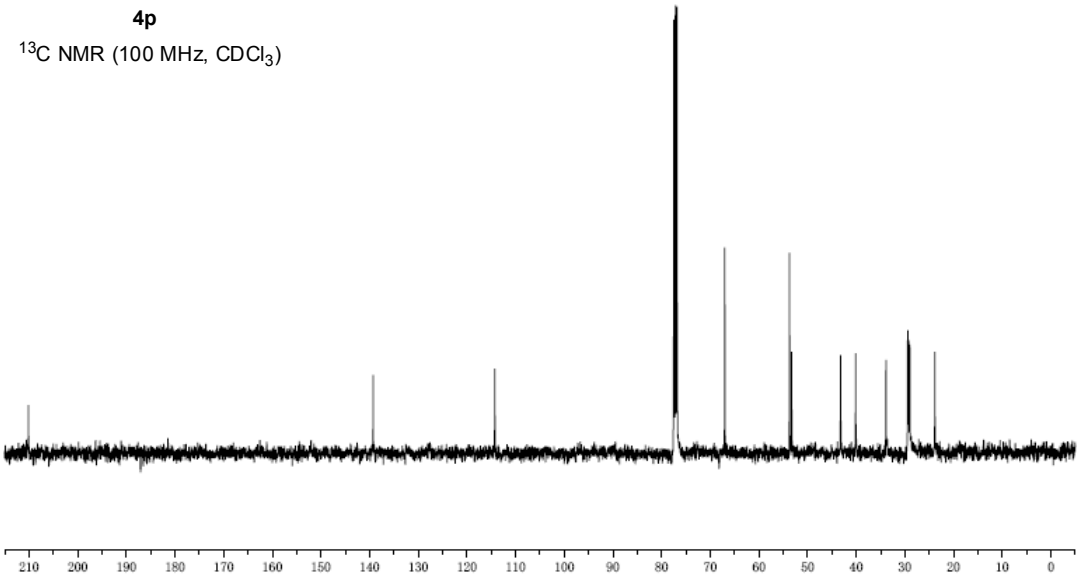
^{1}H NMR (400 MHz, $CDCl_3$)

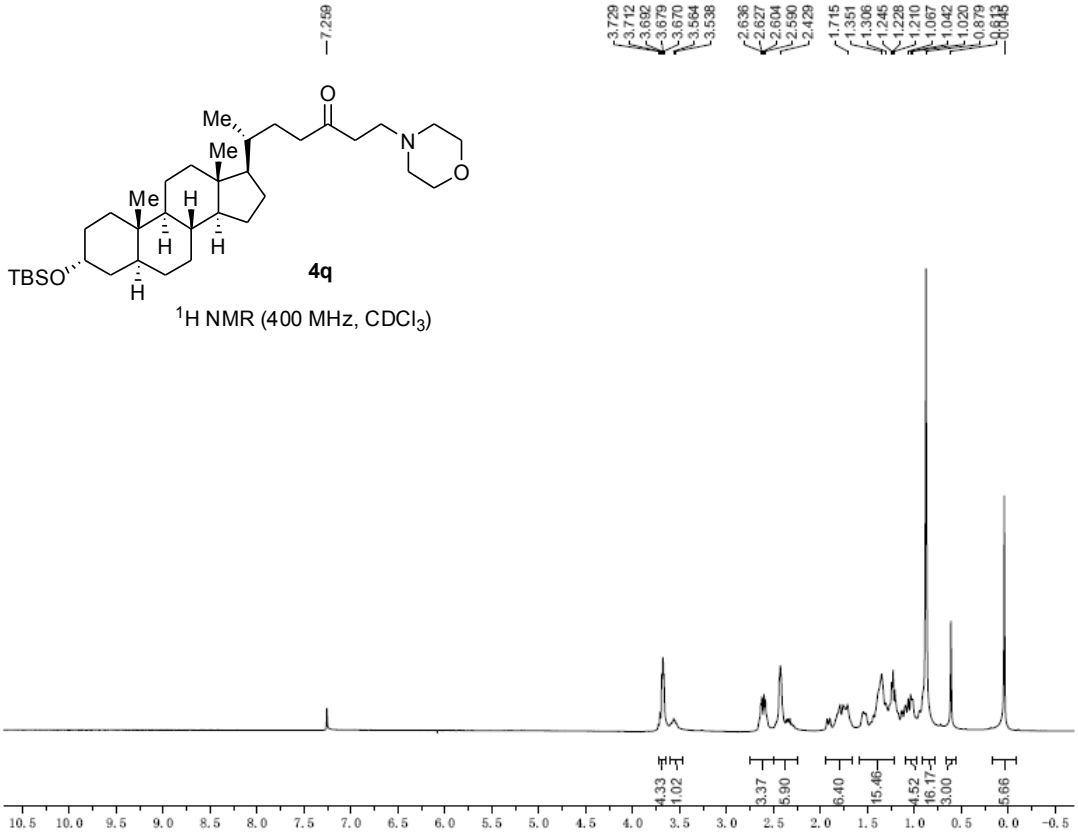




4p

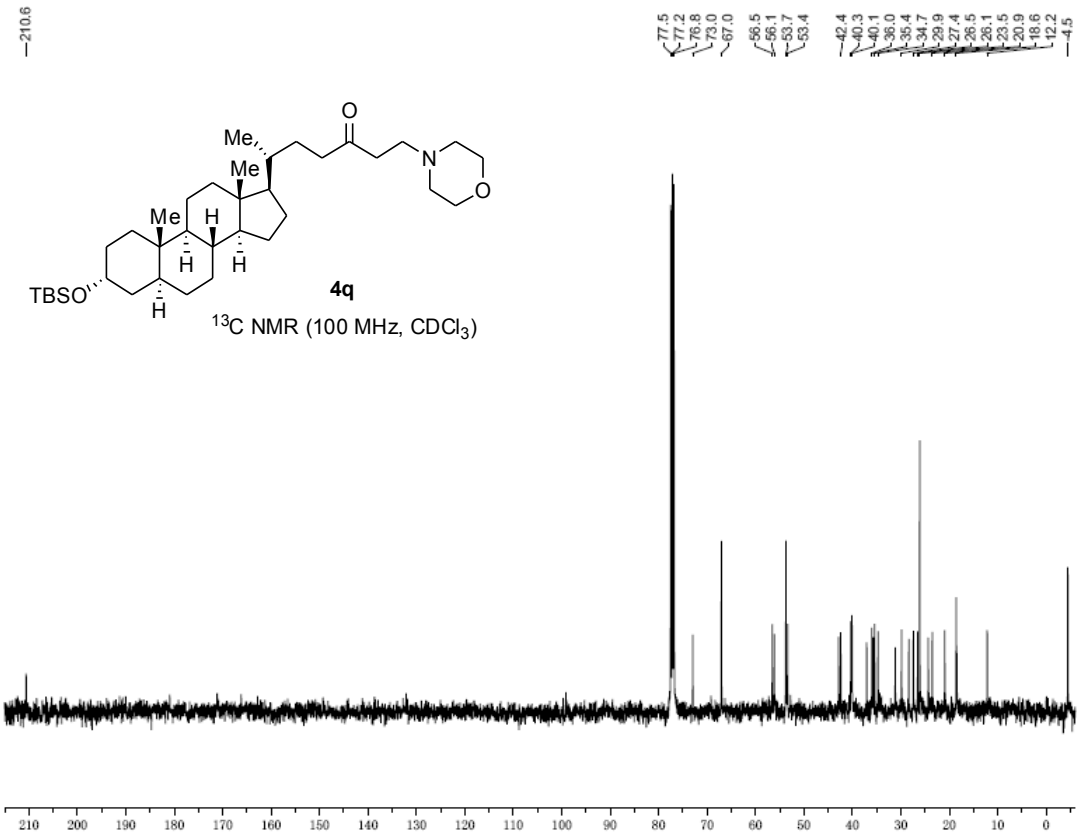
^{13}C NMR (100 MHz, $CDCl_3$)





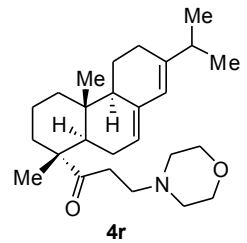
4q

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



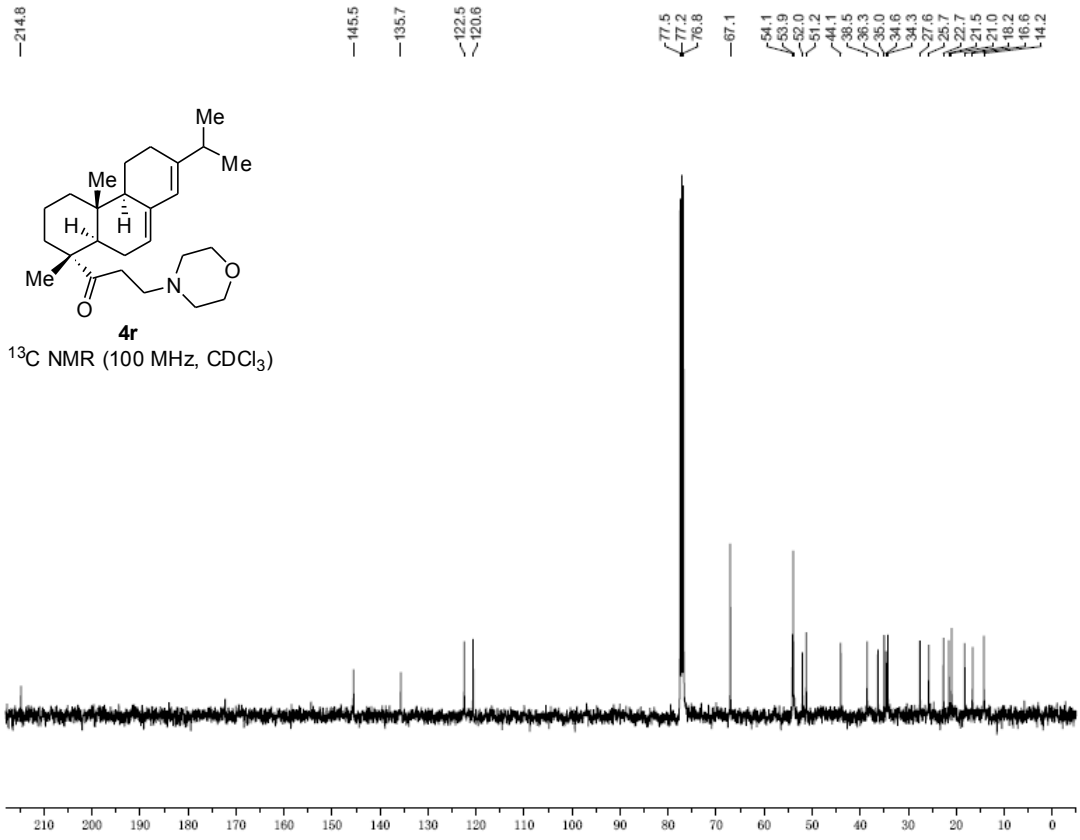
4q

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



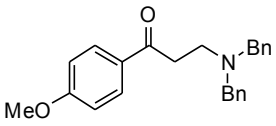
4r

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



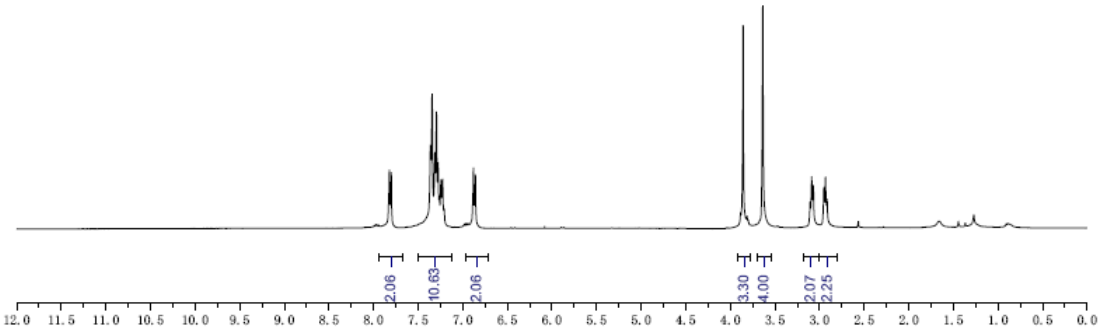
4r

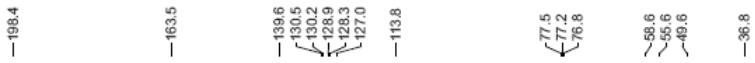
^{13}C NMR (100 MHz, $CDCl_3$)

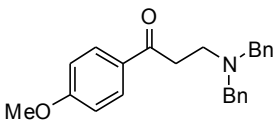


5a

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

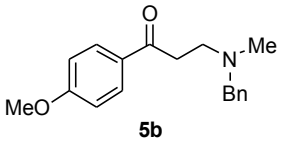






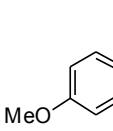
5a

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



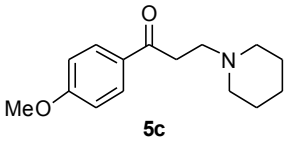
5b

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



5b

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

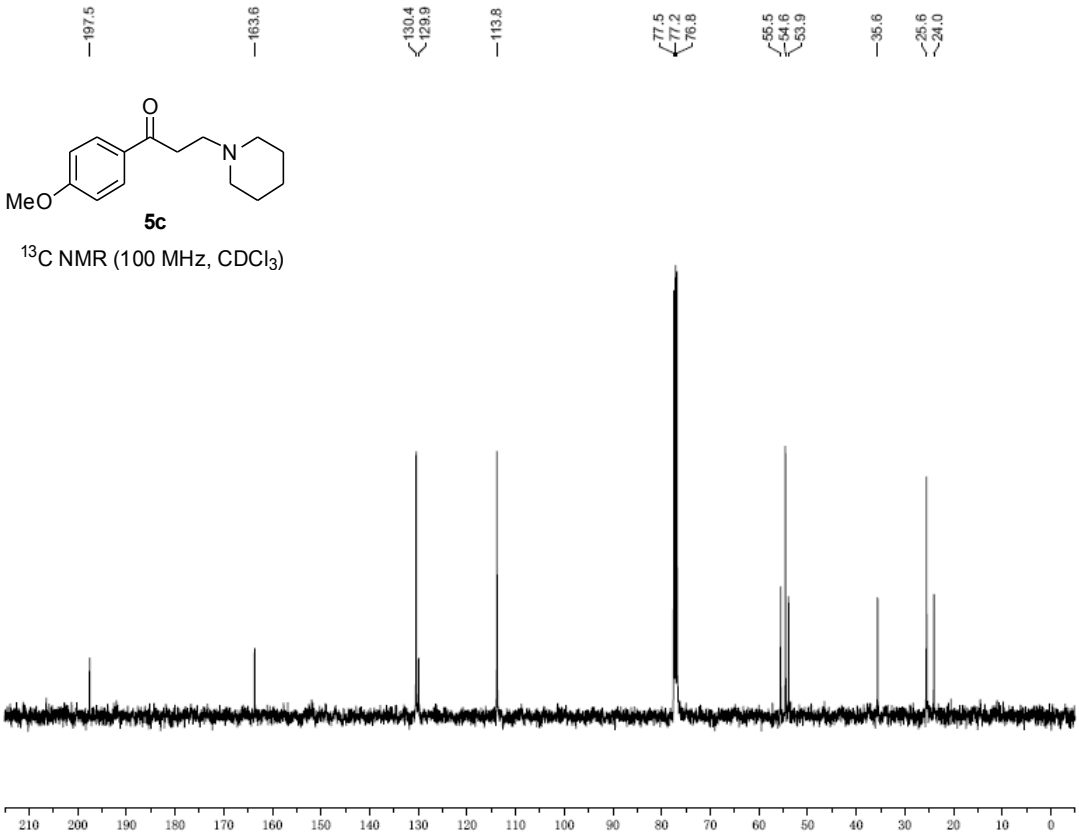


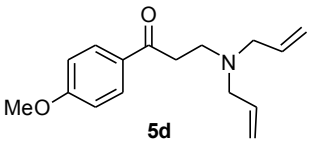
5c

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

5c

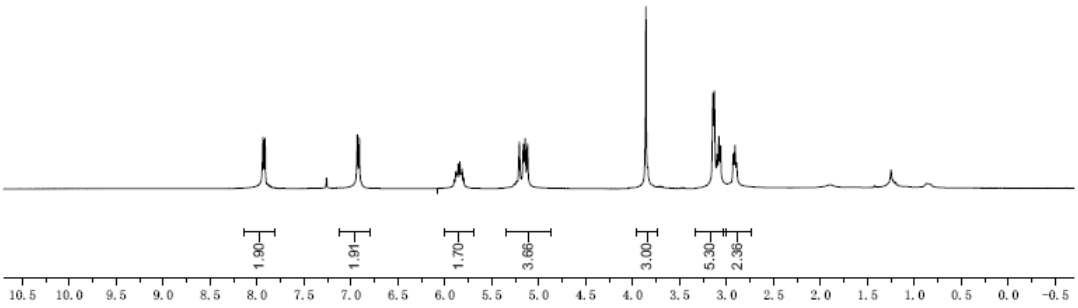
^{13}C NMR (100 MHz, $CDCl_3$)

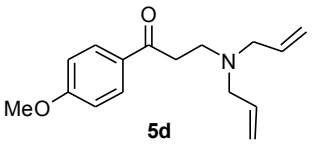




5d

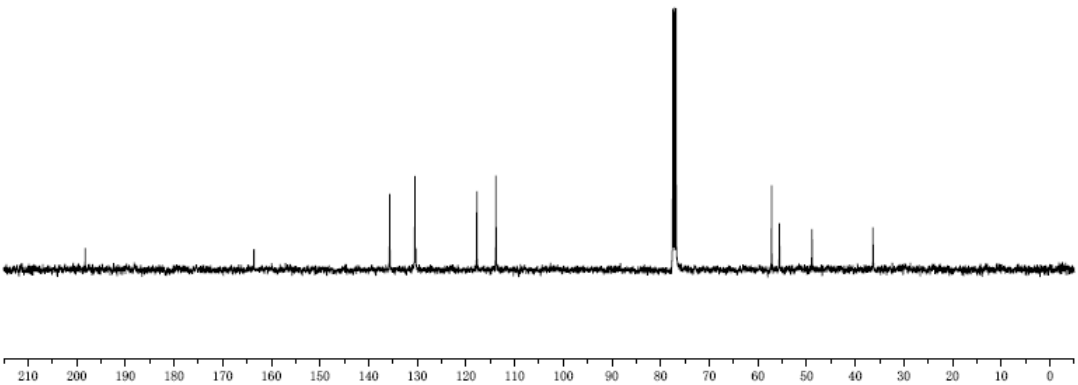
^{1}H NMR (400 MHz, $CDCl_3$)

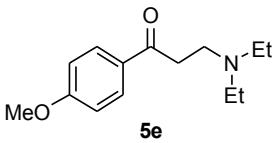




5d

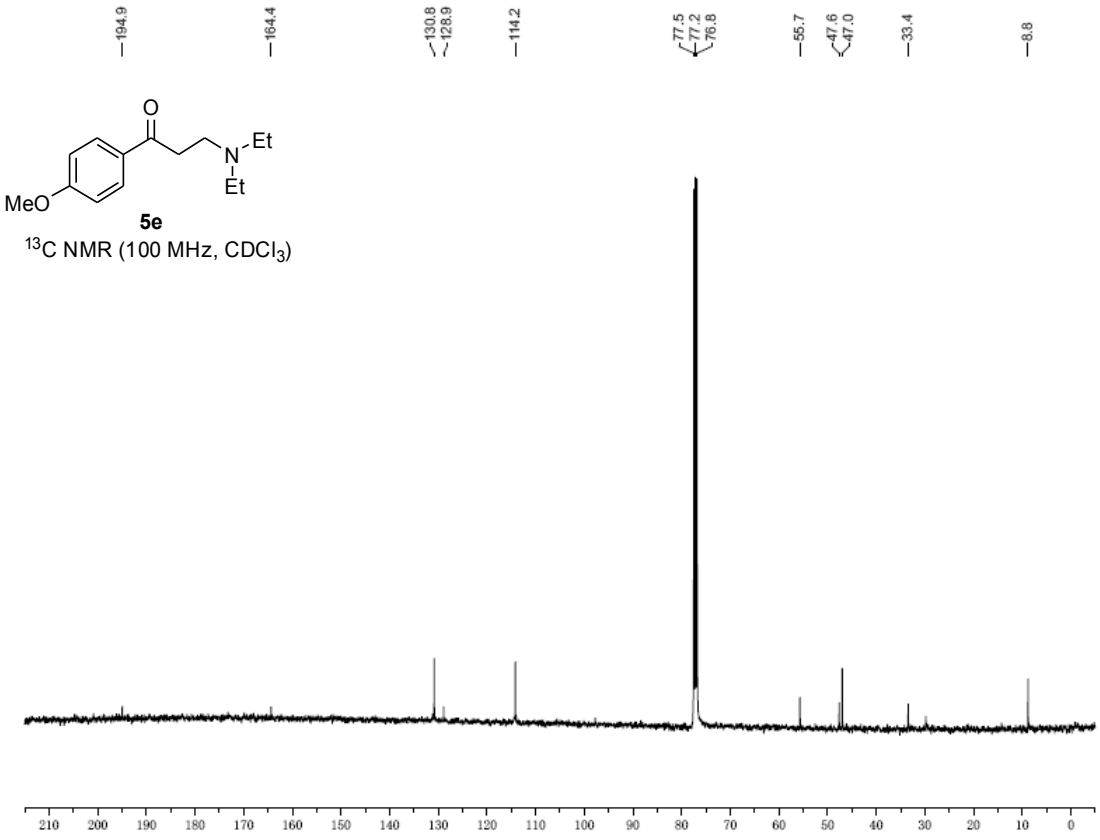
^{13}C NMR (100 MHz, $CDCl_3$)





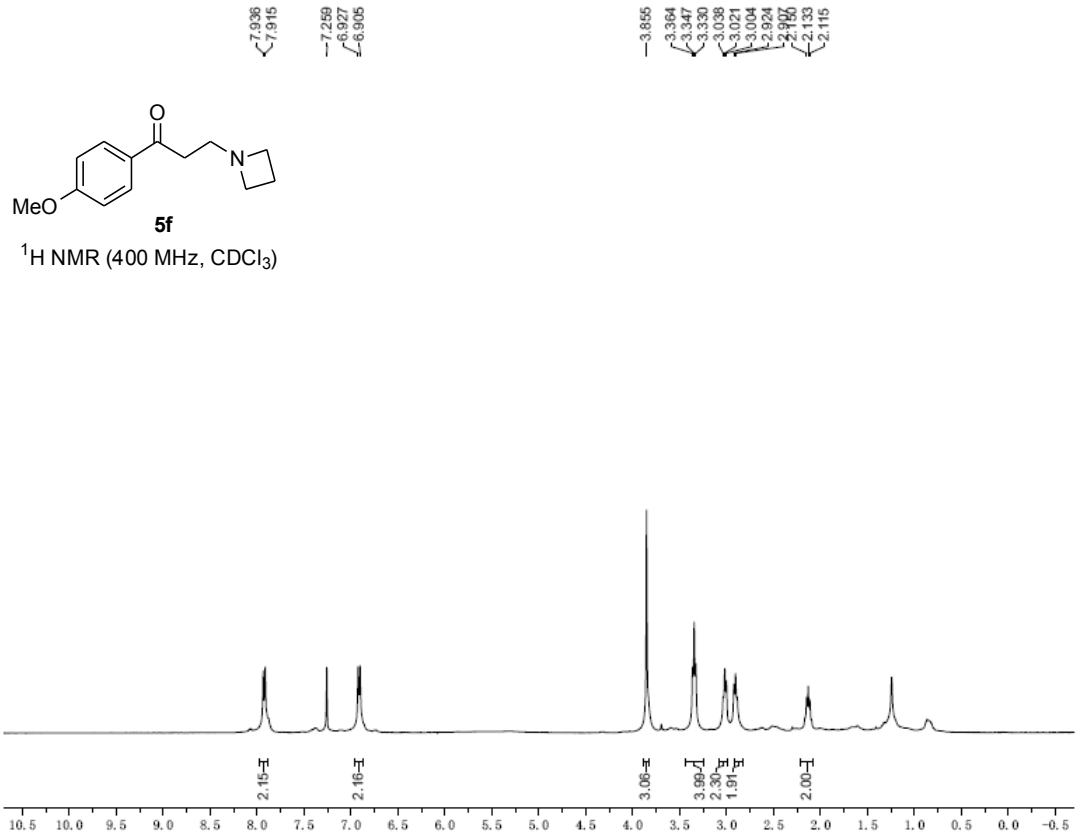
5e

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



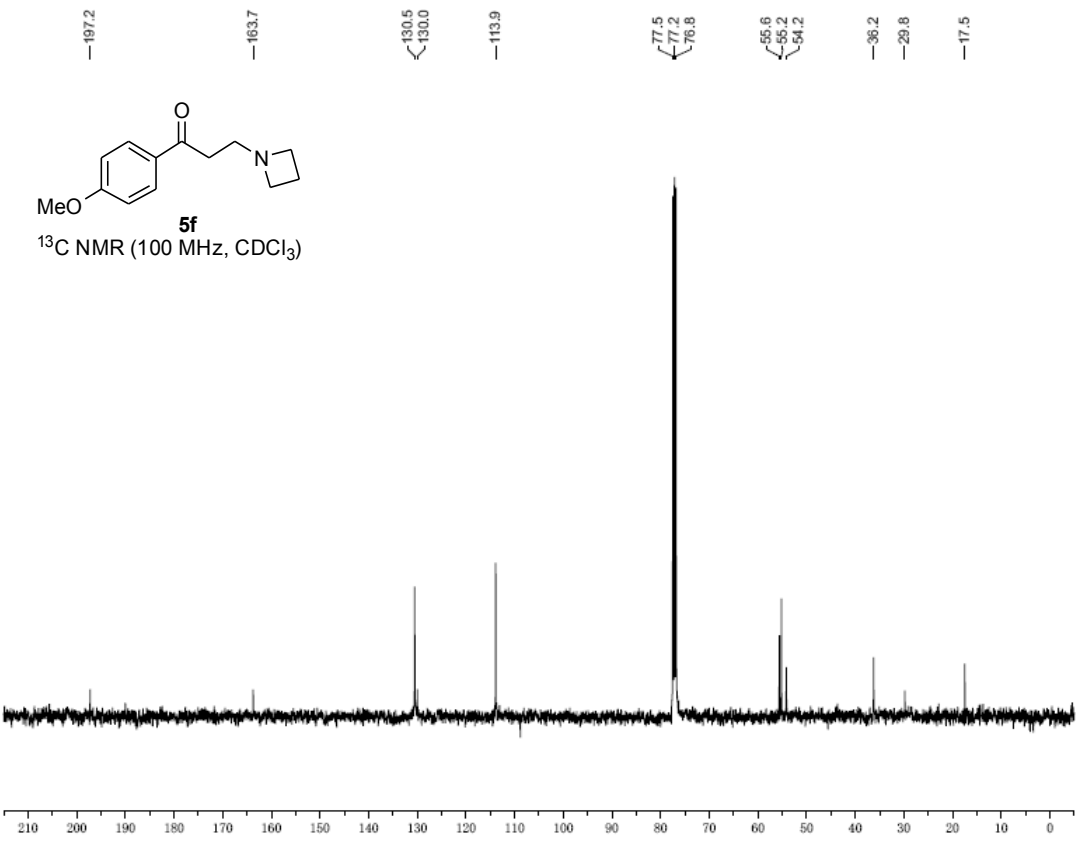
5e

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



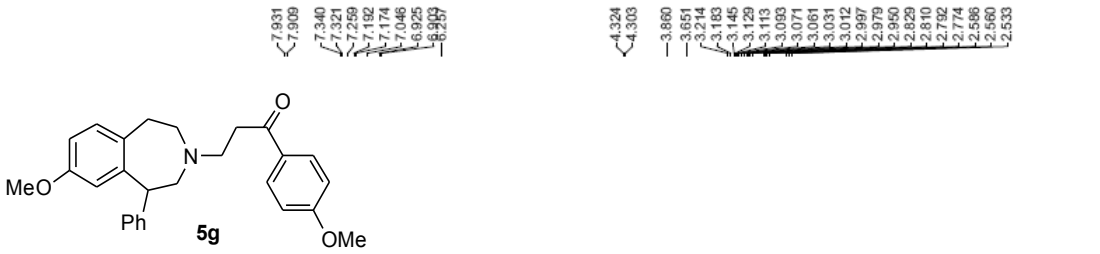
5f

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



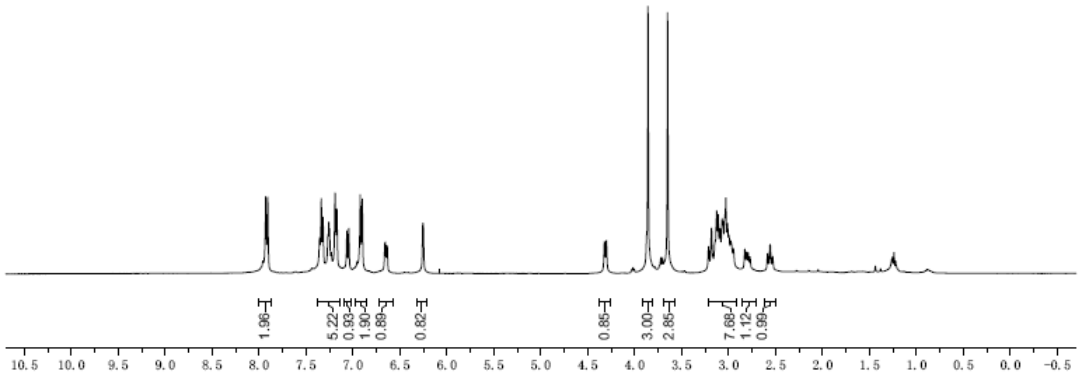
5f

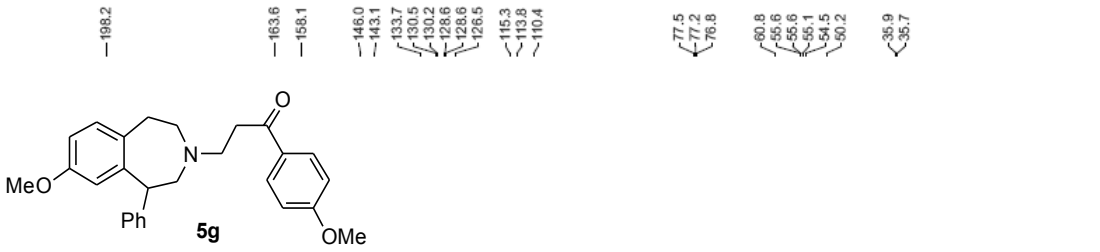
^{13}C NMR (100 MHz, $CDCl_3$)



5g

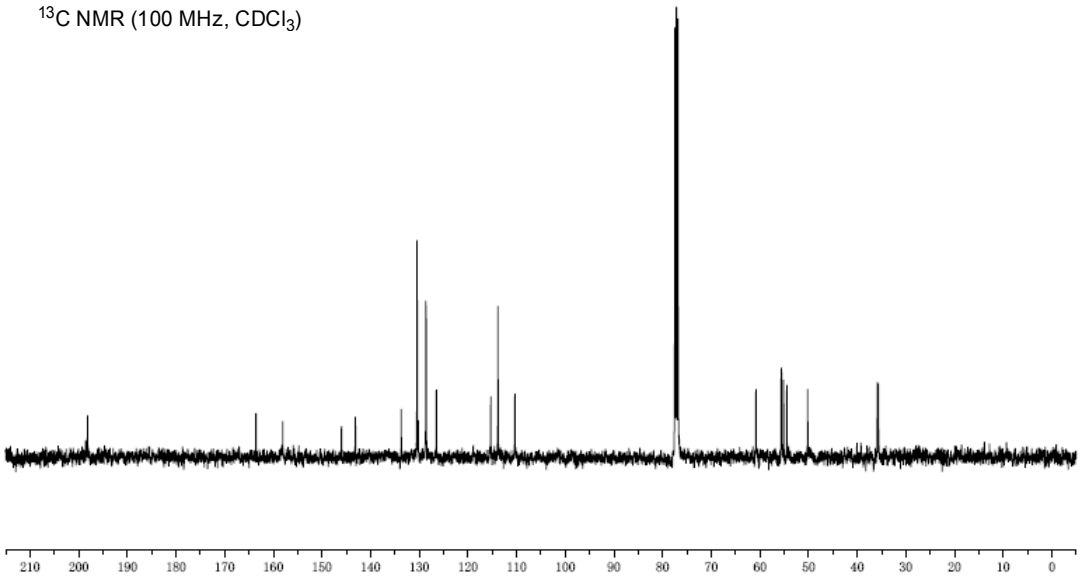
^{1}H NMR (400 MHz, $CDCl_3$)

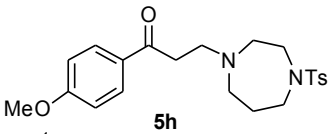




5g

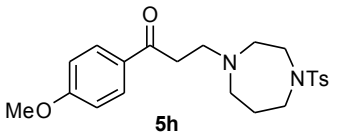
^{13}C NMR (100 MHz, $CDCl_3$)





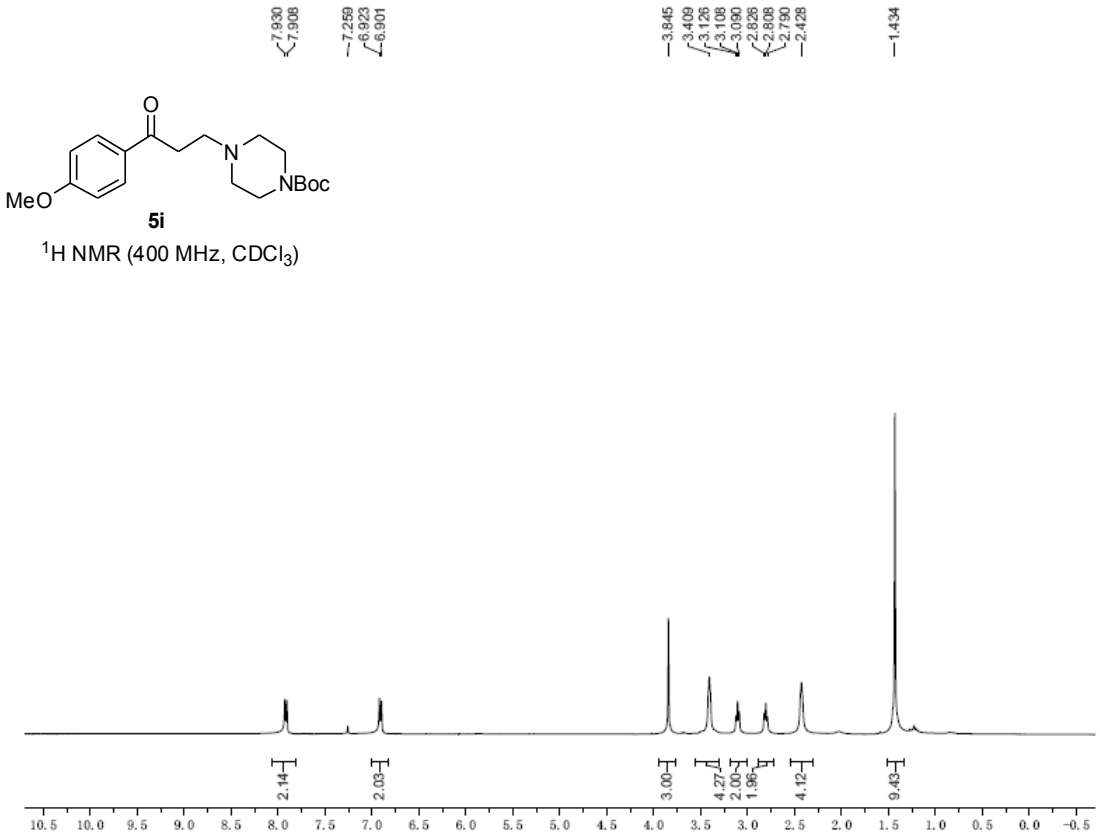
5h

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



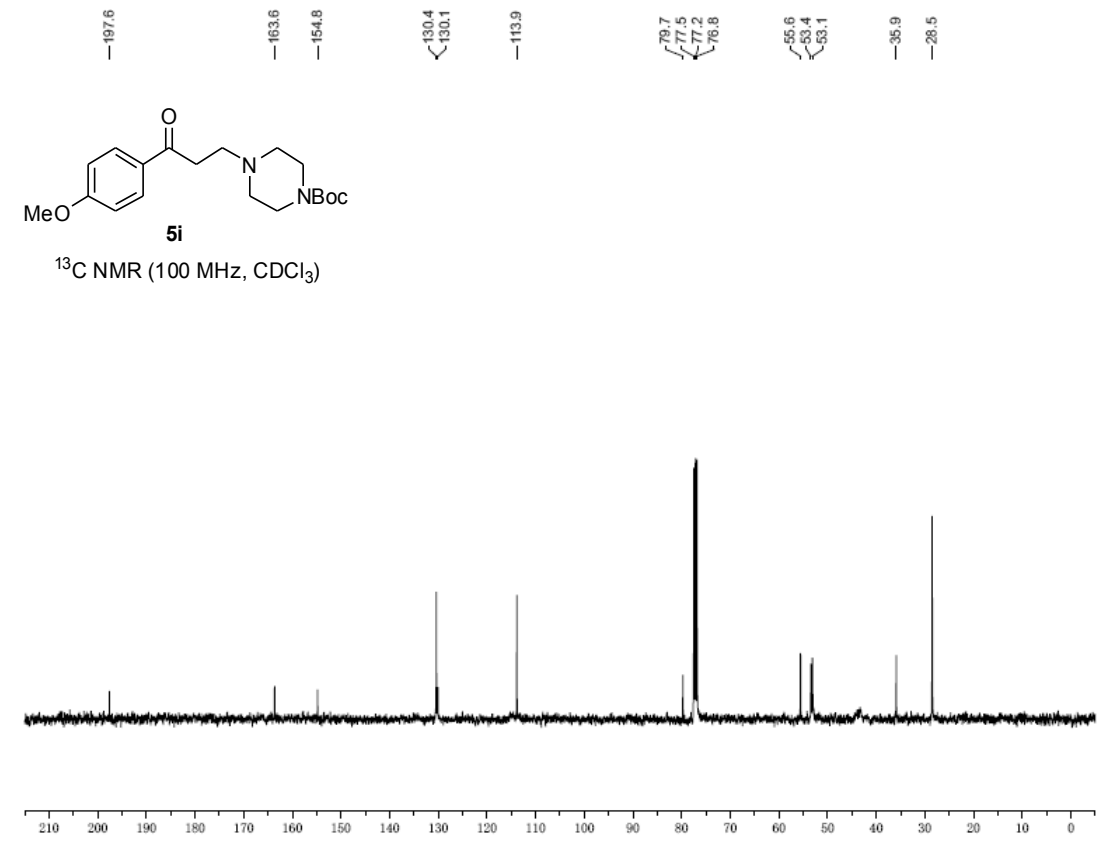
5h

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



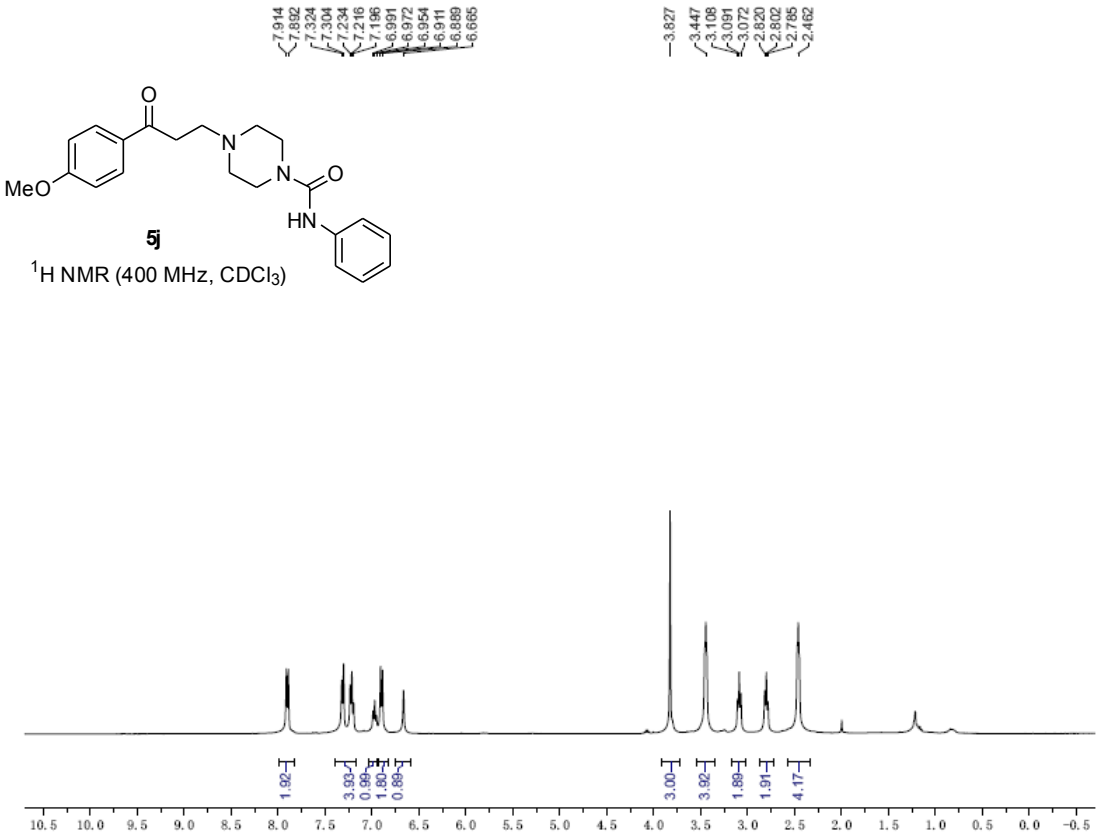
5i

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



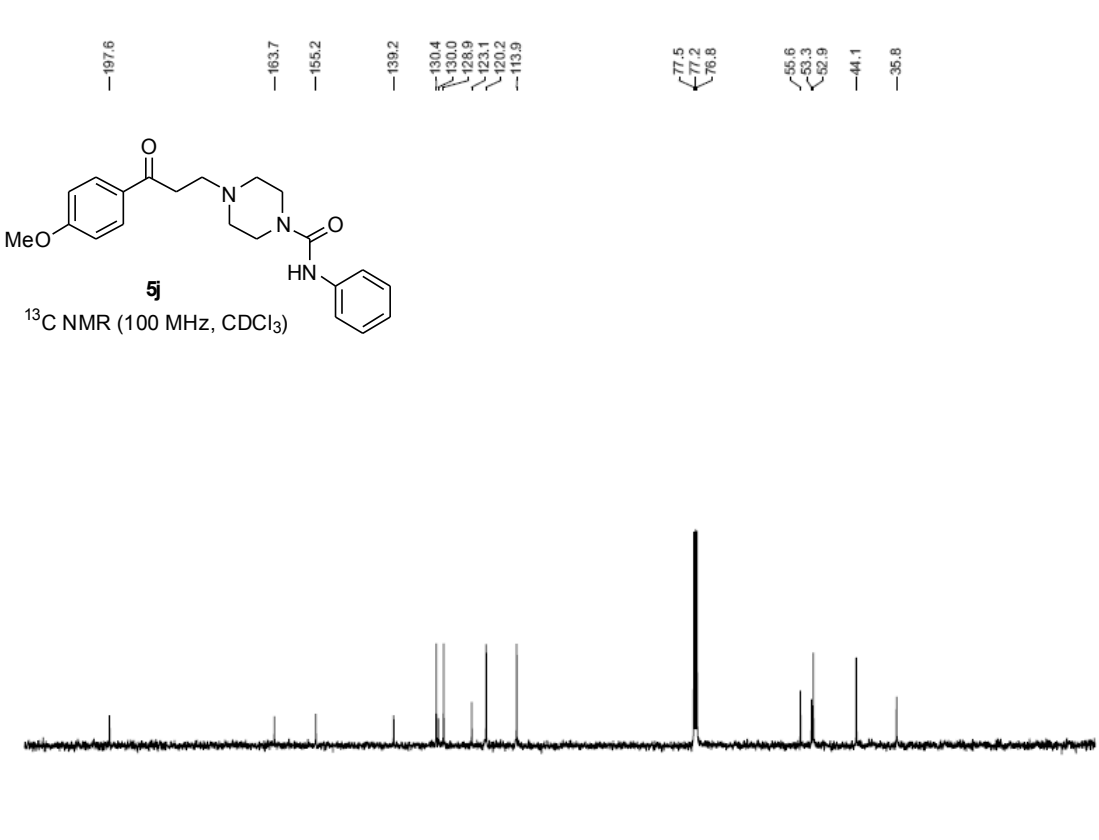
5i

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



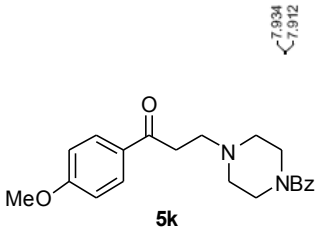
5j

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



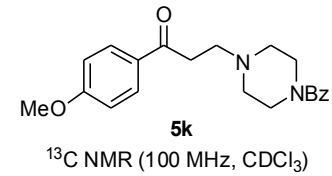
5j

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



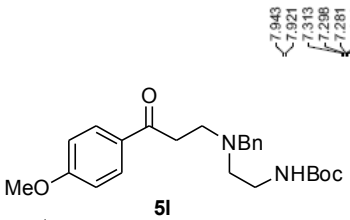
5k

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



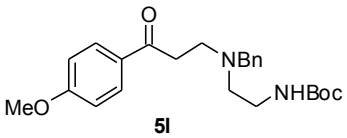
5k

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



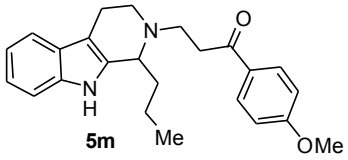
5l

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



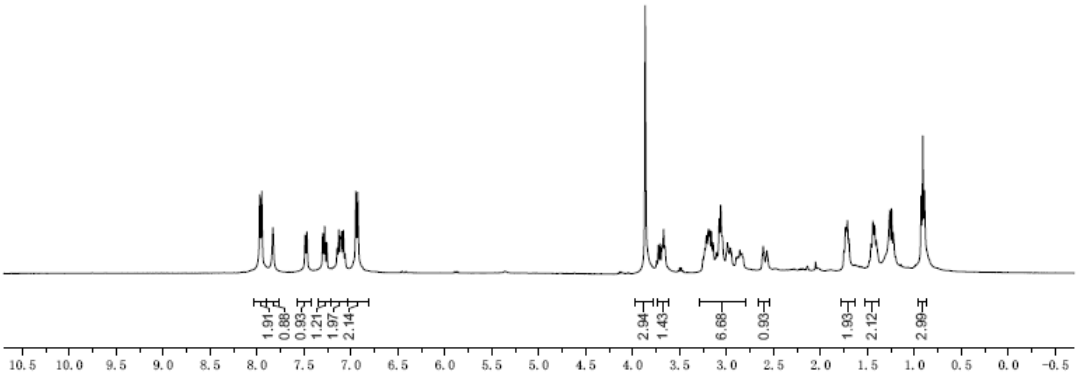
5l

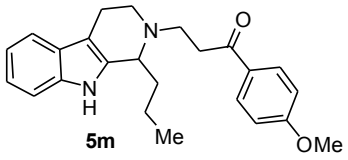
^{13}C NMR (100 MHz, $CDCl_3$)



5m

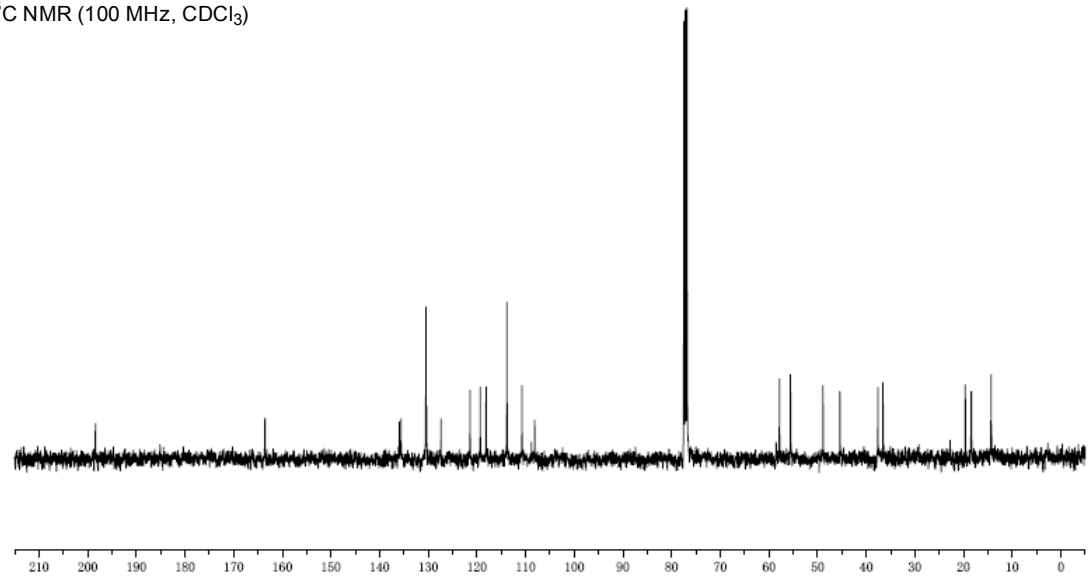
^{1}H NMR (400 MHz, $CDCl_3$)

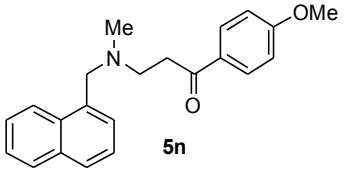




5m

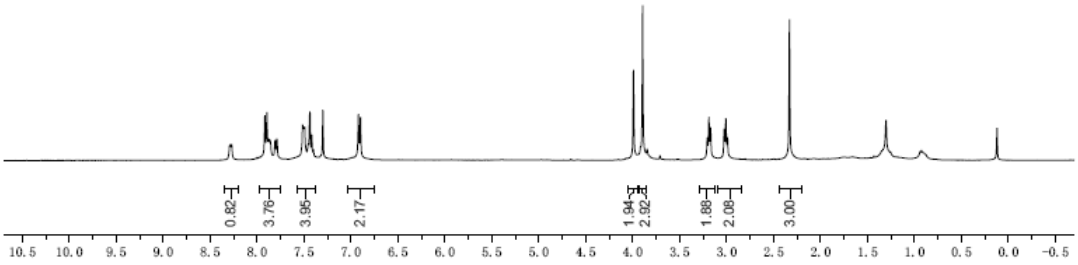
^{13}C NMR (100 MHz, $CDCl_3$)

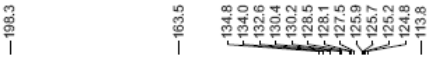


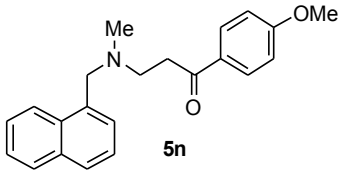


5n

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

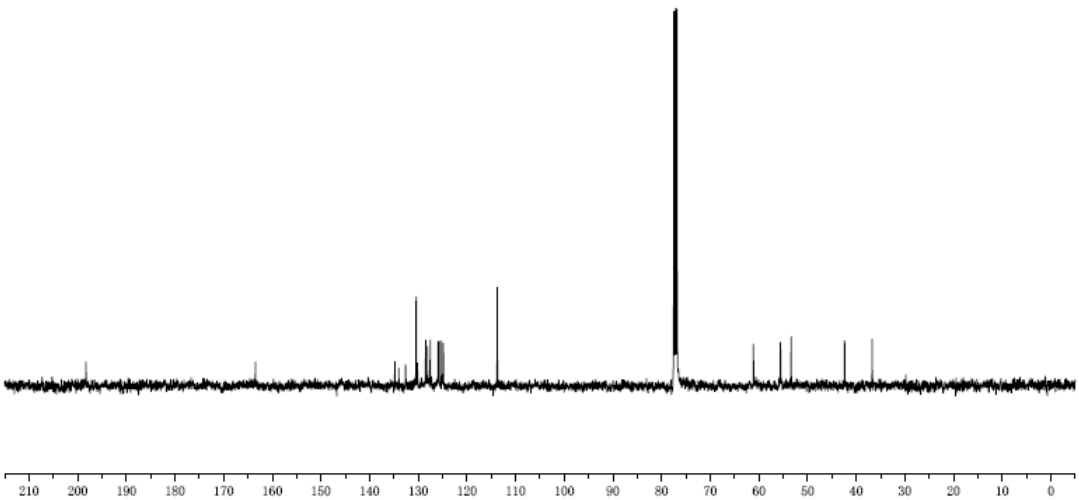


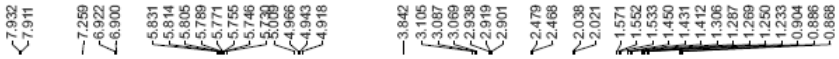


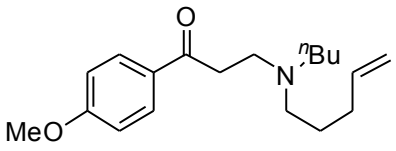


5n

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

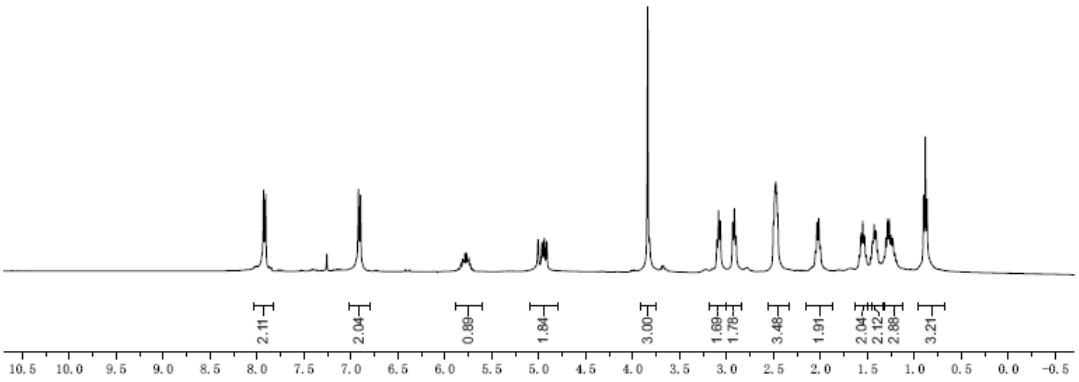


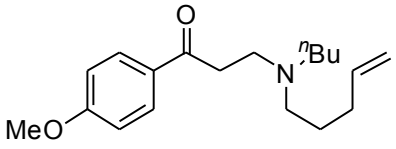




5o

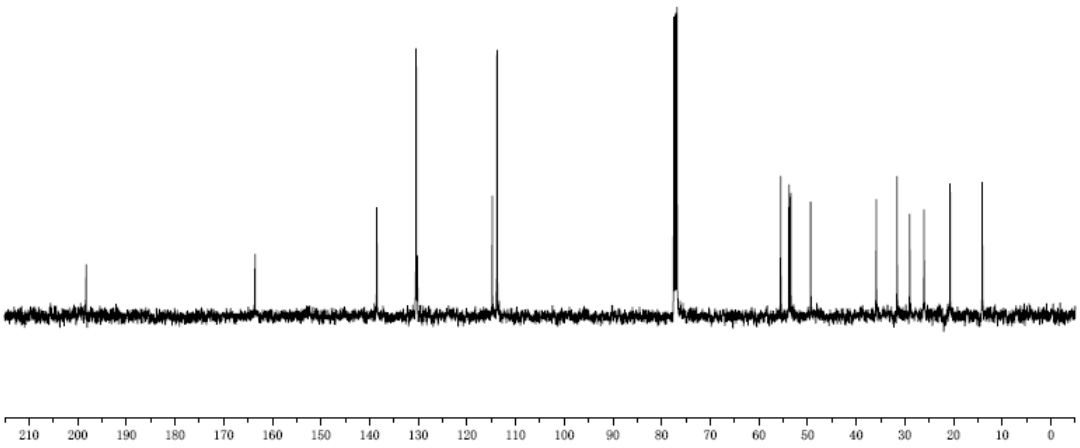
^{1}H NMR (400 MHz, $CDCl_3$)

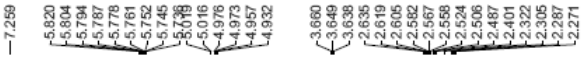


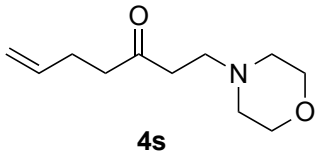


5o

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

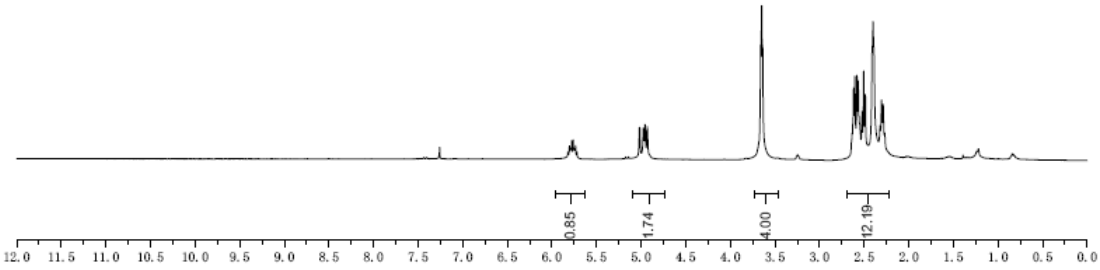


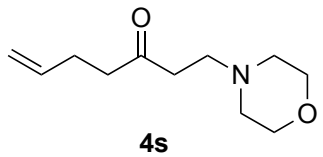




4s

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





4s

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