Methanol as C_1 Source: Redox Coupling of Nitrobenzenes and Alcohols for the Synthesis of Benzimidazoles

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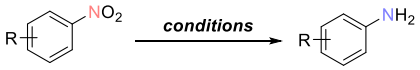
Supplementary Information

Table of Contents

2. Summary of Traditional Methods for Nitrobenzene Reduction

Traditionally, nitrobenzenes were reduced to anilines using excess iron in the presence of acid. Typically, 5-10 equiv iron powder has to be used to obtain satisfied yields.

Table S1. Classical methods of reductive nitrobenzene to aniline



entry	conditions	Ref.
1	Fe (5 equiv), AcOH (175 equiv)	*Angew. Chem.* 2017, **129**, 5980–5983
2	Fe (6 equiv), NH_4Cl (10 equiv)	*ACS Catal*. 2020, **10**, 13641–13649
3	Fe (5 equiv), NH_4Cl (4 equiv)	*J. Am. Chem. Soc*. 2020, **142**, 4456−4463
4	Fe (10 equiv), HCl (conc., 2 drops)	*Angew. Chem. Int. Ed*. 2012, **51**, 771 –774
5	Fe (5.5 equiv), HCl (0.6M aq., 1.3 equiv)	*Org. Lett*. 2021, **23**, 4034−4039

3. Experimental Procedures and Characterization Data

3.1. General Information

Glassware was dried in an oven overnight before use. Thin layer chromatography was carried out on SIL G/UV254 silica-aluminum plates and plates were visualized using ultra-violet light (254 nm) and $KMnO_4$ solution. NMR data was collected at 300 or 500 MHz. Data was manipulated directly from the spectrometer or *via* a networked PC with appropriate software. All samples were analyzed in $CDCl_3$ unless otherwise stated. Reference values for residual solvent were taken as δ = 7.27 ($CDCl_3$) for ^1H NMR; δ = 77.1 ($CDCl_3$) for $^{13}C\{^1H\}$ NMR. Multiplicities for coupled signals were designated using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, quin = quintet, br = broad signal, and are given in Hz.

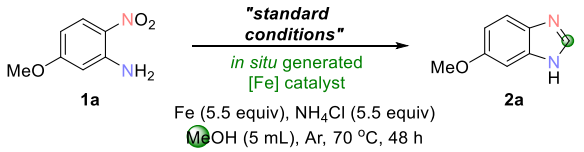
All compounds used in this study have been described in the literature or are commercially available. All solvents and reagents were used as supplied. 2-nitroaniline were purchased from commercial suppliers or prepared by standard method. [1]

3.2 Optimization Studies of the Synthesis of Benzimidazoles

Optimization studies of the synthesis of benzimidazoles (Table S2). To a Schlenk tube was added 5-methoxy-2-nitroaniline (50.4 mg, 0.300 mmol, 1.00 equiv), iron powder (50.3 - 92.2 mg, 0.900 - 1.65 mmol, 3.00 - 5.50 equiv) and NH_4Cl (32.1 - 88.3 mg, 0.600 - 1.65 mmol, 2.00 - 5.50 equiv), followed by MeOH (5.0 mL). The resulted mixture was stirred vigorously under Ar at 70 °C for 48 h. Then the reaction was quenched by an aqueous solution of $NaHCO_3$ (5.0 mL, saturated), diluted with EtOAc

(10 mL) and brine (5.0 mL). The mixture was filtered through thin Kieselguhr to remove insoluble materials. The organic layer of the filtrate was separated and the aqueous layer was extracted with EtOAc (2 × 10 mL). The organic layer was combined, dried over Na_2SO_4, filtered and concentrated to give the pure product. Then the sample was analyzed by ^1H NMR ($CDCl_3$, 500 MHz) to obtain the yield using internal standard (1,1,2,2-tetrachloroethane).

Table S2. Further Optimization Studies of the Synthesis of Benzimidazoles [a]



entry	variation from the "standard conditions"	yield (%)[a]
1	none	95
2	Fe (4 equiv), NH_4Cl (5.5 equiv)	50
2	Fe (4 equiv), NH_4Cl (4 equiv)	46
3	Fe (3 equiv), NH_4Cl (3 equiv)	15
4	Fe (5.5 equiv), NH_4Cl (4 equiv)	93
5	Fe (5.5 equiv), NH_4Cl (3 equiv)	90
6	Fe (5.5 equiv), NH_4Cl (2 equiv)	63

[a] Determined by ^1H NMR.

3.3 Synthesis of Benzimidazole

General Procedure:

To a Schlenk tube was added 2-nitroaniline (0.300 mmol, 1.00 equiv), iron powder (92.2 mg, 1.65 mmol, 5.50 equiv) and NH_4Cl (88.3 mg, 1.65 mmol, 5.50 equiv), followed by ROH (5.0 mL). The resulted mixture was stirred vigorously under Ar at 70 ℃ for 48 h. Then the reaction was quenched by an aqueous solution of $NaHCO_3$ (5.0 mL, saturated), diluted with EtOAc (10 mL) and brine (5.0 mL). The mixture was filtered through thin Kieselguhr to remove insoluble materials. The organic layer of the filtrate was separated and the aqueous layer was extracted with EtOAc (2 × 10 mL). The organic layer was combined, dried over Na_2SO_4, filtered and concentrated to give the pure product.

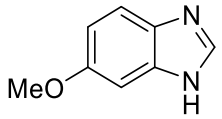
Note:

1. After 24 h, a solution of NH_4Cl (0.200 mmol) in MeOH (1.3 mL) was added to the reaction mixture, if significant amount of the solvent was evaporated.

2. For compounds soluble in water, the aqueous layer should be extracted by organic solvent multiple times to achieve good yield.

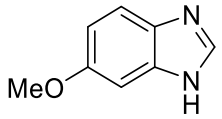
3. If any by-product was formed, the crude products need to be purified by flash chromatography (silica, EtOAc).

6-Methoxy-1*H*-benzo[*d*]imidazole 2a [2] (Scheme 2)



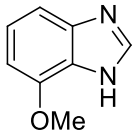
According to the general procedure, the reaction of 5-methoxy-2-nitroaniline (50.4 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2a** (44.0 mg, >98%) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.94 (br, 1H), 8.08 (s, 1H), 7.56 (d, J = 8.8 Hz, 1H), 7.11 (d, J = 2.0 Hz, 1H), 6.94 (dd, J = 8.8, 2.0 Hz, 1H), 3.82 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 156.8, 140.4, 137.6, 132.9, 116.5, 112.8, 97.6, 55.9.

6-Methoxy-1*H*-benzo[*d*]imidazole 2a [2] (Scheme 2)



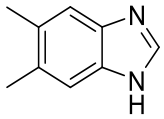
According to the general procedure, the reaction of 5-methoxy-2-nitroaniline (252 mg, 1.50 mmol), iron powder (460 mg, 8.25 mmol) and NH_4Cl (441 mg, 8.25 mmol) in MeOH (25 mL) afforded **2a** (200 mg, 90%) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.94 (br, 1H), 8.08 (s, 1H), 7.56 (d, J = 8.8 Hz, 1H), 7.11 (d, J = 2.0 Hz, 1H), 6.94 (dd, J = 8.8, 2.0 Hz, 1H), 3.82 (s, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 156.8, 140.4, 137.6, 132.9, 116.5, 112.8, 97.6, 55.9.

7-Methoxy-1*H*-benzo[*d*]imidazole 2b [3] (Scheme 2).



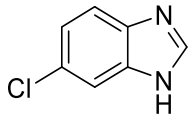
According to the general procedure, the reaction of 2-methoxy-6-nitroaniline (50.4 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2b** (42.7 mg, 96%) as a white solid. ^1H NMR (300 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.28 (d, J = 8.1 Hz, 1H), 7.20 (dd, J = 8.1, 7.7 Hz, 1H), 6.73 (d, J = 7.7 Hz, 1H), 3.99 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 149.6, 140.2, 138.6, 129.4, 123.3, 107.7, 102.9, 55.6.

5,6-Dimethyl-1*H*-benzo[*d*]imidazole 2c [4] (Scheme 2).



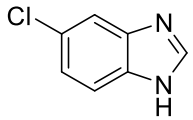
According to the general procedure, the reaction of 4,5-dimethyl-2-nitroaniline (49.9 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2c** (43.4 mg, >98%) as a yellow solid. ^{1}H NMR (300 MHz, DMSO-d_6) δ 8.05 (s, 1H), 7.35 (s, 2H), 2.30 (s, 6H); ^{13}C{^{1}H} NMR (75 MHz, DMSO-d_6) δ 141.2, 130.5, 115.5, 20.1.

6-Chloro-1*H*-benzo[*d*]imidazole 2d [4] (Scheme 2).



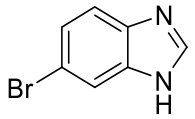
According to the general procedure, the reaction of 5-chloro-2-nitroaniline (51.8 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL), after chromatography (silica, EtOAc), afforded **2d** (37.1 mg, 81%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (s, 1H), 7.66 (d, J = 1.8 Hz, 1H), 7.59 (d, J = 8.6 Hz, 1H), 7.28 (dd, J = 8.6, 1.8 Hz, 1H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 141.6, 138.4, 136.4, 128.8, 123.7, 116.5, 115.5.

5-Chloro-1*H*-benzo[*d*]imidazole 2e [4] (Scheme 2).



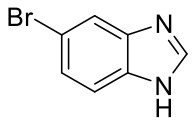
According to the general procedure, the reaction of 4-chloro-2-nitroaniline (51.8 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL), after chromatography (silica, EtOAc), afforded **2e** (37.8 mg, 83%) as a white solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (s, 1H), 7.66 (d, J = 1.6 Hz, 1H), 7.59 (d, J = 8.6 Hz, 1H), 7.28 (dd, J = 8.6, 1.6 Hz, 1H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 141.6, 138.3, 136.4, 128.8, 123.7, 116.5, 115.5.

6-Bromo-1*H*-benzo[*d*]imidazole 2f [5] (Scheme 2).



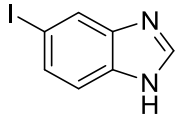
According to the general procedure, the reaction of 5-bromo-2-nitroaniline (65.1 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL), after chromatography (silica, EtOAc), afforded **2f** (48.2 mg, 82%) as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.11 (s, 1H), 7.83 (d, J = 1.6 Hz, 1H), 7.54 (d, J = 8.6 Hz, 1H), 7.42 (dd, J = 8.6, 1.6 Hz, 1H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 141.4, 138.9, 136.6, 126.4, 118.6, 116.9, 116.3.

5-Bromo-1*H*-benzo[*d*]imidazole 2g [5] (Scheme 2).



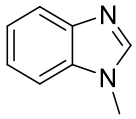
According to the general procedure, the reaction of 4-bromo-2-nitroaniline (65.1 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL), after chromatography (silica, EtOAc), afforded **2g** (47.3 mg, 80%) yield as a white solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.14 (s, 1H), 7.83 (d, J = 1.7 Hz, 1H), 7.54 (d, J = 8.6 Hz, 1H), 7.41 (dd, J = 8.6, 1.7 Hz, 1H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 141.6, 139.0, 136.7, 126.3, 118.5, 116.8, 116.2.

5-Iodo-1*H*-benzo[*d*]imidazole 2h [2] (Scheme 2).



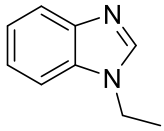
According to the general procedure, the reaction of 4-iodo-2-nitroaniline (79.2 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL), after chromatography (silica, EtOAc), afforded **2h** (56.6 mg, 77%) yield as a pale-yellow solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.08 (s, 1H), 8.03 (d, J = 1.5 Hz, 1H), 7.58(dd, J = 8.5, 1.5 Hz, 1H), 7.43 (d, J = 8.5 Hz, 1H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 141.2, 139.6, 137.3, 131.9, 124.6, 117.3, 86.4.

1-Methyl-1*H*-benzo[*d*]imidazole 2i [6] (Scheme 2).



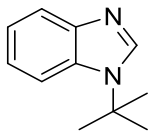
According to the general procedure, the reaction of *N*-methyl-2-nitroaniline (45.6 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2i** (33.7 mg, 85%) as a white solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.86 (s, 1H), 7.81 (m, 1H), 7.40 (m, 1H), 7.36 – 7.28 (m, 2H), 3.84 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 143.7, 143.6, 134.6, 123.0, 122.2, 120.3, 109.4, 31.1.

1-Ethyl-1*H*-benzo[*d*]imidazole 2j [2] (Scheme 2).



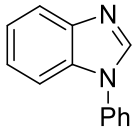
According to the general procedure, the reaction of *N*-ethyl-2-nitroaniline (49.9 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2j** (36.4 mg, 83%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.90 (s, 1H), 7.81 (m, 1H), 7.40 (m, 1H), 7.31 – 7.26 (m, 2H), 4.21 (q, J = 7.3 Hz, 2H), 1.52 (t, J = 7.3 Hz, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 144.0, 142.3, 133.7, 122. 8, 122.0, 120.4, 109.6, 39.8, 15.2.

1-(*tert*-Butyl)-1*H*-benzo[*d*]imidazole 2k [7] (Scheme 2).



According to the general procedure, the reaction of *N*-(*tert*-butyl)-2-nitroaniline (58.3 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2k** (51.7 mg, >98%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.84 (m, 1H), 7.64 (m, 1H), 7.31-7.22 (m, 2H), 1.75 (s, 9H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 144.8, 140.7, 132.8, 122.4, 121.9, 120.5, 113.2, 56.3, 29.4.

1-Phenyl-1*H*-benzo[*d*]imidazole 2l [8] (Scheme 2).

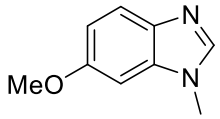


According to the general procedure, the reaction of 2-nitro-*N*-phenylaniline (64.3 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2l** (53.0 mg, 91%) as a brown solid. ^1H NMR (500 MHz, $CDCl_3$) δ 8.14 (s, 1H), 7.89 (m, 1H), 7.59 – 7.45 (m, 6H), 7.38 – 7.30 (m, 2H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 143.9, 142.3, 136.3, 133.7, 130.1, 128.1, 124.1, 123.8, 122.9, 120.5, 110.5.

1-Benzyl-1*H*-benzo[*d*]imidazole 2m [9] (Scheme 2).

According to the general procedure, the reaction of *N*-benzyl-2-nitroaniline (68.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2m** (56.2 mg, 90%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.91 (s, 1H), 7.82 (d, J = 8.1 Hz, 1H), 7.36 – 7.20 (m, 6H), 7.18 – 7.09 (m, 2H), 5.29 (s, 2H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 144.0, 143.2, 135.5, 134.0, 129.0, 128.2, 127.1, 123.1, 122.3, 120.4, 110.0, 48.8.

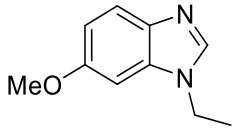
6-Methoxy-1-methyl-1*H*-benzo[*d*]imidazole 2n [10] (Scheme 2).



According to the general procedure, the reaction of 5-methoxy-*N*-methyl-2-nitroaniline (54.6 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2n** (47.7 mg, 98%) as a yellow solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.73 (s, 1H), 7.66 (d, J = 8.8 Hz, 1H), 6.91 (dd, J = 8.8, 2.4 Hz, 1H), 6.78 (d, J = 2.4 Hz, 1H), 3.85 (s, 3H), 3.73 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 156.8, 142.7, 138.1, 135.1, 120.5,

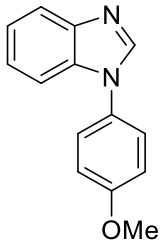
111.4, 92.7, 55.8, 30.8.

1-Ethyl-6-methoxy-1*H*-benzo[*d*]imidazole 2o [11] (Scheme 2).



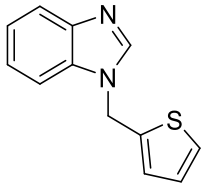
According to the general procedure, the reaction of *N*-ethyl-5-methoxy-2-nitroaniline (58.9 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2o** (44.9 mg, 85%) as a yellow solid. ^1H NMR (500 MHz, $CDCl_3$) δ 7.82 (s, 1H), 7.67 (d, *J* = 8.8 Hz, 1H), 6.91 (dd, *J* = 8.8, 2.3 Hz, 1H), 6.82 (d, *J* = 2.3 Hz, 1H), 4.15 (q, *J* = 7.3 Hz, 2H), 3.86 (s, 3H), 1.50 (t, *J* = 7.3 Hz, 3H); $^{13}C\{^1H\}$ NMR (126 MHz, $CDCl_3$) δ 156.7, 141.5, 138.2, 134.2, 120.7, 111.4, 93.1, 55.9, 39.8, 15.1.

1-(4-Methoxyphenyl)-1*H*-benzo[*d*]imidazole 2p [12] (Scheme 2).



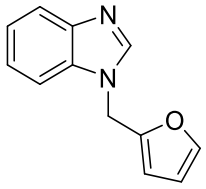
According to the general procedure, the reaction of *N*-(4-methoxyphenyl)-2-nitroaniline (73.3 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2p** (57.2 mg, 85%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 8.05 (s, 1H), 7.87 (m, 1H), 7.47-7.36 (m 3H), 7.35 – 7.26 (m, 2H), 7.06 (m, 2H), 3.88 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 159.4, 143.8, 142.6, 134.3, 129.2, 125.7, 123.5, 122.6, 120.5, 115.2, 110.4, 55.6.

1-(Thiophen-2-ylmethyl)-1*H*-benzo[*d*]imidazole 2q [13] (Scheme 2).



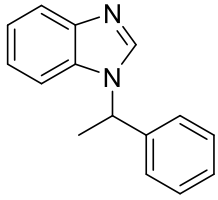
According to the general procedure, the reaction of 2-nitro-*N*-(thiophen-2-ylmethyl)aniline (70.3 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2q** (63.6 mg, >98%) as a brown oil. ^1H NMR (300 MHz, $CDCl_3$) δ 7.92 (s, 1H), 7.81 (m, 1H), 7.38 (m, 1H), 7.31-7.24 (m, 2H), 7.22 (m, 1H), 6.97 (m, 1H), 6.93 (m, 1H), 5.44 (s, 2H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 143.9, 142.6, 137. 8, 133.6, 127.2, 126.8, 126.1, 123.1, 122.4, 120.4, 109.8, 43.6.

1-(Furan-2-ylmethyl)-1*H*-benzo[*d*]imidazole 2r [14] (Scheme 2).



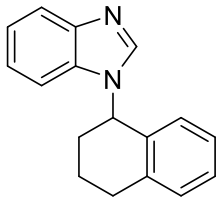
According to the general procedure, the reaction of *N*-(furan-2-ylmethyl)-2-nitroaniline (65.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2r** (53.5 mg, 90%) as a brown oil. ^1H NMR (300 MHz, $CDCl_3$) δ 7.93 (s, 1H), 7.80 (m, 1H), 7.43 (m, 1H), 7.35 (m, 1H), 7.32 – 7.25 (m, 2H), 6.35-6.29 (m 2H), 5.26 (s, 2H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 148.5, 143.7, 143.2, 142.8, 133. 7, 123.2, 122.4, 120.4, 110.7, 109.8, 109.2, 41.8.

1-(1-Phenylethyl)-1*H*-benzo[*d*]imidazole 2s [9] (Scheme 2).



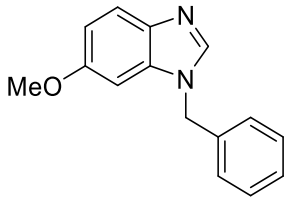
According to the general procedure, the reaction of 2-nitro-*N*-(1-phenylethyl) aniline (72.7 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2s** (60.0 mg, 90%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 8.07 (s, 1H), 7.81 (d, J = 7.9 Hz, 1H), 7.36 – 7.12 (m, 8H), 5.58 (q, J = 7.1 Hz, 1H), 1.96 (d, J = 7.1 Hz, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 144.1, 141. 0, 140.7, 133.7, 129.0, 128.1, 126.0, 122.8, 122.2, 120.4, 110.6, 55.2, 21.5.

1-(1,2,3,4-Tetrahydronaphthalen-1-yl)-1*H*-benzo[*d*]imidazole 2t [9] (Scheme 2).



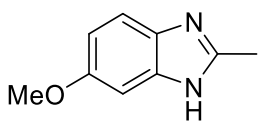
According to the general procedure, the reaction of *N*-(2-nitrophenyl)-1,2,3,4-tetrahydronaphthalen-1-amine (80.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2t** (68.6 mg, 92%) as a brown solid. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75 (m, 1H), 7.60 (s, 1H), 7.26 – 7.08 (m, 5H), 7.02 (m, 1H), 6.83 (d, *J* = 7.8 Hz, 1H), 5.59 (t, *J* = 6.1 Hz, 1H), 2.92 (m, 1H), 2.82 (m, 1H), 2.26 – 2.13 (m, 2H), 1.88 – 1.63 (m, 2H); ^{13}C{^{1}H} NMR (126 MHz, $CDCl_3$) δ 143.8, 142.9, 137.9, 133.4, 133.2, 129.6, 128.8, 128.4, 126.8, 122.9, 122.3, 120.4, 110.5, 54.7, 30.2, 29.0, 20.0.

1-Benzyl-6-methoxy-1*H*-benzo[*d*]imidazole 2u [15] (Scheme 2).



According to the general procedure, the reaction of *N*-benzyl-5-methoxy-2-nitroaniline (77.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2u** (69.3 mg, 97%) as a white solid. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 (s, 1H), 7.69 (d, *J* = 8.8 Hz, 1H), 7.37-7.24 (m, 3H), 7.19-7.12 (m, 2H), 6.90 (dd, *J* = 8.8, 2.2 Hz, 1H), 6.70 (d, *J* = 2.2 Hz, 1H), 5.26 (s, 2H), 3.77 (s, 3H); ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$) δ 156.8, 142.5, 138.4, 135.5, 134.6, 129.0, 128.2, 127.0, 120.8, 111.5, 93.6, 55.8, 48.7.

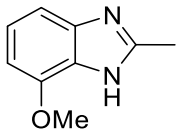
6-Methoxy-2-methyl-1*H*-benzo[*d*]imidazole 2v [16] (Scheme 2)



According to the general procedure, the reaction of 5-methoxy-2-nitroaniline (50.4

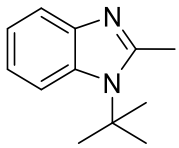
mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2v** (42.3 mg, 87%) as a pale-yellow solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.7 Hz, 1H), 7.01 (d, *J* = 2.4 Hz, 1H), 6.85 (dd, *J* = 8.7, 2.4 Hz, 1H), 3.79 (s, 3H), 2.60 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 156.4, 150.9, 138.5, 133.1, 115.2, 111.7, 97.6, 55.9, 14.8.

7-Methoxy-2-methyl-1*H*-benzo[*d*]imidazole 2w [17] (Scheme 2)



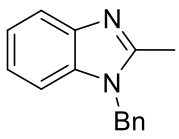
According to the general procedure, the reaction of 2-methoxy-6-nitroaniline (50.4 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2w** (41.4 mg, 85%) as a pale-yellow solid. ^1H NMR (300 MHz, $CDCl_3$) δ 9.07 (br, 1H), 7.37 – 7.29 (m, 2H), 6.65 (dd, *J* = 6.9, 1.9 Hz, 1H), 3.89 (s, 3H), 2.61 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 150.5, 148.8, 139.2, 129.7, 122.6, 106.9, 102.6, 55.5, 14.7.

1-(*tert*-Butyl)-2-methyl-1*H*-benzo[*d*]imidazole 2x [18] (Scheme 2)



According to the general procedure, the reaction of *N*-(*tert*-butyl)-2-nitroaniline (58.3 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2x** (55.9 mg, >98%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.70 – 7.58 (m, 2H), 7.22 – 7.09 (m, 2H), 2.79 (s, 3H), 1.82 (s, 9H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 151.5, 143.0, 135.4, 121.5, 121.3, 119.2, 114.1, 58.6, 30.9, 20.2.

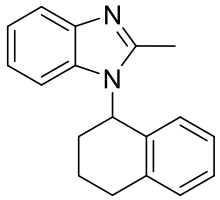
1-Benzyl-2-methyl-1*H*-benzo[*d*]imidazole 2y [19] (Scheme 2)



According to the general procedure, the reaction of *N*-benzyl-2-nitroaniline (68.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2y** (56.7 mg, 85%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.72 (m, 1H), 7.33 – 7.16 (m, 6H), 7.06 – 6.99 (m, 2H), 5.27 (s, 2H), 2.54 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 151.9, 142.6, 135.9, 135.5, 129.0, 127.9, 126.2, 122.3, 122.0, 119.1, 109.4, 47.1, 14.0.

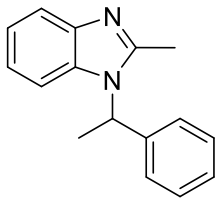
2-Methyl-1-(1,2,3,4-tetrahydronaphthalen-1-yl)-1*H*-benzo[*d*]imidazole 2z

(Scheme 2)



According to the general procedure, the reaction of *N*-(2-nitrophenyl)-1,2,3,4-tetrahydronaphthalen-1-amine (80.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2z** (74.8 mg, 95%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.69 (d, J = 8.0 Hz, 1H), 7.25 – 7.12 (m, 3H), 7.06 – 6.96 (m, 2H), 6.83 – 6.64 (m, 2H), 5.67 (m, 1H), 3.12 – 2.89 (m, 2H), 2.60 (s, 3H), 2.38 – 2.09 (m, 3H), 1.96 (m, 1H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 151.8, 142.8, 137.4, 134.1, 133.8, 129.4, 127.7, 127.2, 126.7, 121.8, 121.7, 119.1, 111.3, 55.0, 29.9, 29.5, 22.3, 14.8; HRMS (FTMS-ESI) m/z: $[M + H]^+$ calc for $C_{18}H_{19}N_2$ 263.1543, found 263.1538.

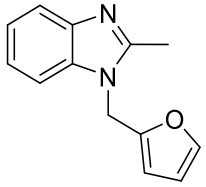
2-Methyl-1-(1-phenylethyl)-1*H*-benzo[*d*]imidazole 2aa [20] (Scheme 2)



According to the general procedure, the reaction of 2-nitro-*N*-(1-phenylethyl) aniline (72.7 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2aa** (62.4 mg, 88%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.70 (d, J = 8.0 Hz, 1H), 7.35 – 7.25 (m, 3H), 7.20 – 7.14 (m, 3H), 7.09 – 7.01 (m, 2H), 5.74 (q, J = 7.2 Hz, 1H), 2.57 (s, 3H), 1.95 (d, J = 7.2 Hz,

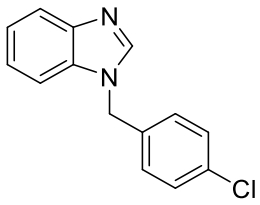
3H); $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$) δ 151.5, 142.9, 139.5, 134.1, 128.8, 127.8, 126.2, 121.9, 121.7, 119.1, 111.1, 53.4, 18.7, 14.9.

1-(Furan-2-ylmethyl)-2-methyl-1*H*-benzo[*d*]imidazole 2ab [21] (Scheme 2)



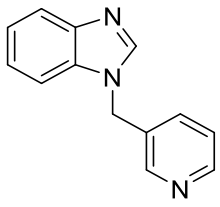
According to the general procedure, the reaction of *N*-(furan-2-ylmethyl)-2-nitroaniline (65.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2ab** (57.3 mg, 90%) as a brown oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 (m, 1H), 7.37 – 7.29 (m, 2H), 7.26 – 7.16 (m, 2H), 6.27 (m, 1H), 6.21 (m, 1H), 5.16 (s, 2H), 2.65 (s, 3H); $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$) δ 151.5, 149.0, 142.9, 142.5, 135.0, 122.2, 122.0, 119.0, 110.5, 109.2, 108.3, 40.5, 13.9.

1-(4-Chlorobenzyl)-1*H*-benzo[*d*]imidazole 2ac [9] (Scheme 2).



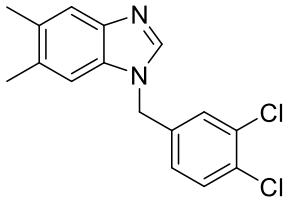
According to the general procedure, the reaction of *N*-(4-chlorobenzyl)-2-nitroaniline (78.8 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2ac** (55.3 mg, 76%) as a brown oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94 (s, 1H), 7.82 (m, 1H), 7.32-7.21 (m 5H), 7.08 (d, J = 8.4 Hz, 2H), 5.29 (s, 2H); $^{13}C\{^{1}H\}$ NMR (75 MHz, $CDCl_3$) δ 143.9, 143.1, 134.2, 134.0, 133.7, 129.2, 128.4, 123.3, 122.5, 120.5, 109.9, 48.2.

1-(Pyridin-3-ylmethyl)-1*H*-benzo[*d*]imidazole 2ad [22] (Scheme 2).



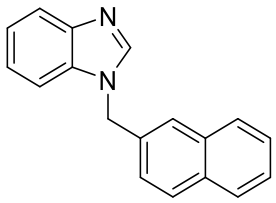
According to the general procedure, the reaction of 2-nitro-*N*-(pyridin-3-ylmethyl) aniline (68.8 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2ad** (62.1 mg, >98%) as a pale-yellow solid. ^1H NMR (300 MHz, $CDCl_3$) δ 8.63 – 8.52 (m, 2H), 7.97 (s, 1H), 7.83 (m, 1H), 7.40 (m, 1H), 7.33 – 7.20 (m, 4H), 5.36 (s, 2H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 149.8, 148.5, 143.9, 142.9, 134.7, 133.6, 131.2, 123.9, 123.4, 122.6, 120.6, 109.8, 46.3.

1-(3,4-Dichlorobenzyl)-5,6-dimethyl-1*H*-benzo[*d*]imidazole 2ae [23] (Scheme 2).



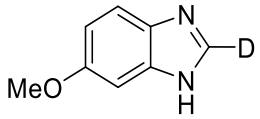
According to the general procedure, the reaction of *N*-(3,4-dichlorobenzyl)-4,5-dimethyl-2-nitroaniline (97.6 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2ae** (82.4 mg, 90%) as a brown solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.87 (s, 1H), 7.60 (s, 1H), 7.38 (d, J = 8.3 Hz, 1H), 7.25 (d, J = 1.7 Hz, 1H), 7.04 – 6.91 (m, 2H), 5.26 (s, 2H), 2.36 (s, 3H), 2.33 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 136.1, 133.3, 132.8, 132.5, 131.6, 131.1, 128.8, 126.1, 120.7, 110.0, 29.8, 20.6, 20.3.

1-(Naphthalen-2-ylmethyl)-1*H*-benzo[*d*]imidazole 2af [24] (Scheme 2).



According to the general procedure, the reaction of *N*-(naphthalen-2-ylmethyl)-2-nitroaniline (83.5 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOH (5.0 mL) afforded **2af** (62.0 mg, 80%) as a pale-yellow solid. ^1H NMR (300 MHz, $CDCl_3$) δ 7.93 – 7.76 (m, 5H), 7.55 – 7.47 (m, 2H), 7.38 – 7.22 (m, 4H), 7.02 (d, J = 7.1 Hz, 1H), 5.69 (s, 2H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 143.9, 143.3, 134.2, 133.8, 130.8, 130. 5, 129.2, 129.1, 127.1, 126.3, 125.7, 125.5, 123.2, 122.4, 122.3, 120.5, 110.0, 46.6.

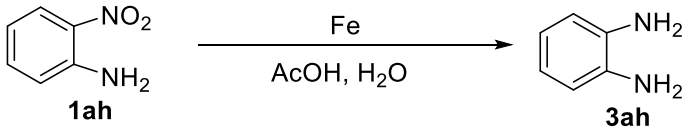
6-Methoxy-1*H*-benzo[d]imidazole-2-*d* 2ai [2] (Scheme 2)



According to the general procedure, the reaction of 5-methoxy-2-nitroaniline (50.4 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in MeOD-d_4 (5.0 mL) afforded **2ai** (42.1 mg, 94%) as a white solid. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.55 (d, J = 8.8 Hz, 1H), 7.10 (d, J = 2.3 Hz, 1H), 6.94 (dd, J = 8.8, 2.3 Hz, 1H), 3.83 (s, 3H); ^{13}C{^{1}H} NMR (75 MHz, $CDCl_3$) δ 156.8, 140.4 (m), 137.8, 133.0, 116.6, 112.8, 97.8, 55.9.

3.4. Synthesis of Antifungals-Chlormidazole

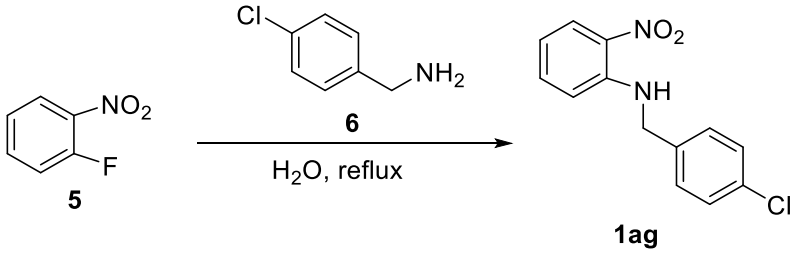
Classical synthetic route



To a solution of **1ah** (41.4 mg, 0.300 mmol) in AcOH (3 mL) and deionized water (0.30 mL) was added iron powder (83.8 mg, 1.50 mmol) in one portion under argon atmosphere. Then the resulting mixture was vigorously stirred at room temperature for ca. 11 h. The mixture was poured into a saturated K_2CO_3 aqueous solution slowly. Upon completion, the mixture was separated, and the aqueous layer was extracted with EtOAc. The combined organic layer was dried over anhydrous Na_2SO_4, filtered and concentrated to give the pure product. Then the sample was analyzed by ^{1}H NMR ($CDCl_3$, 500 MHz) to obtain the yield (88%) using internal standard (1,1,2,2-tetrachloroethane).

This work: a greener synthetic route

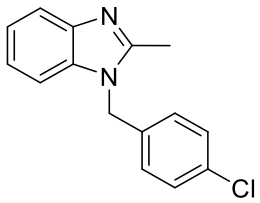
***N*-(4-chlorobenzyl)-2-nitroaniline 1ag** [1] (Scheme 2)



The mixture of 1-fluoro-2-nitrobenzene (141 mg, 1.00 mmol, 1.00 equiv) and (4-chlorophenyl)methanamine (142 mg, 1.00 mmol, 1.00 equiv.) in water (2.0 mL)

was stirred magnetically at 100 °C (oil-bath) for 2.5 h (TLC). The reaction mixture was cooled to room temperature and treated with $NaHCO_3$ (170 mg) and extracted with EtOAc (2 × 10 mL). The organic layer was combined, dried over Na_2SO_4, filtered and concentrated to give the pure product **1ag** (246 mg, 94%) as an orange solid.

1-(4-Chlorobenzyl)-2-methyl-1*H*-benzo[*d*]imidazole 2ag [25] (Scheme 2)



According to the general procedure, the reaction of *N*-(4-chlorobenzyl)-2-nitroaniline **1ag** (78.8 mg, 0.300 mmol), iron powder (92.2 mg, 1.65 mmol) and NH_4Cl (88.3 mg, 1.65 mmol) in EtOH (5.0 mL) afforded **2ag** (73.2 mg, 96%) as a brown solid. ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.72 (d, J = 7.0 Hz, 1H), 7.29 – 7.15 (m, 5H), 6.96 (m, 2H), 5.24 (s, 2H), 2.53 (s, 3H); $^{13}C\{^1H\}$ NMR (75 MHz, $CDCl_3$) δ 151.7, 142.6, 135.3, 134.4, 133.8, 129.2, 127.6, 122.5, 122.2, 119.2, 109.2, 46.5, 13.9.

4. References

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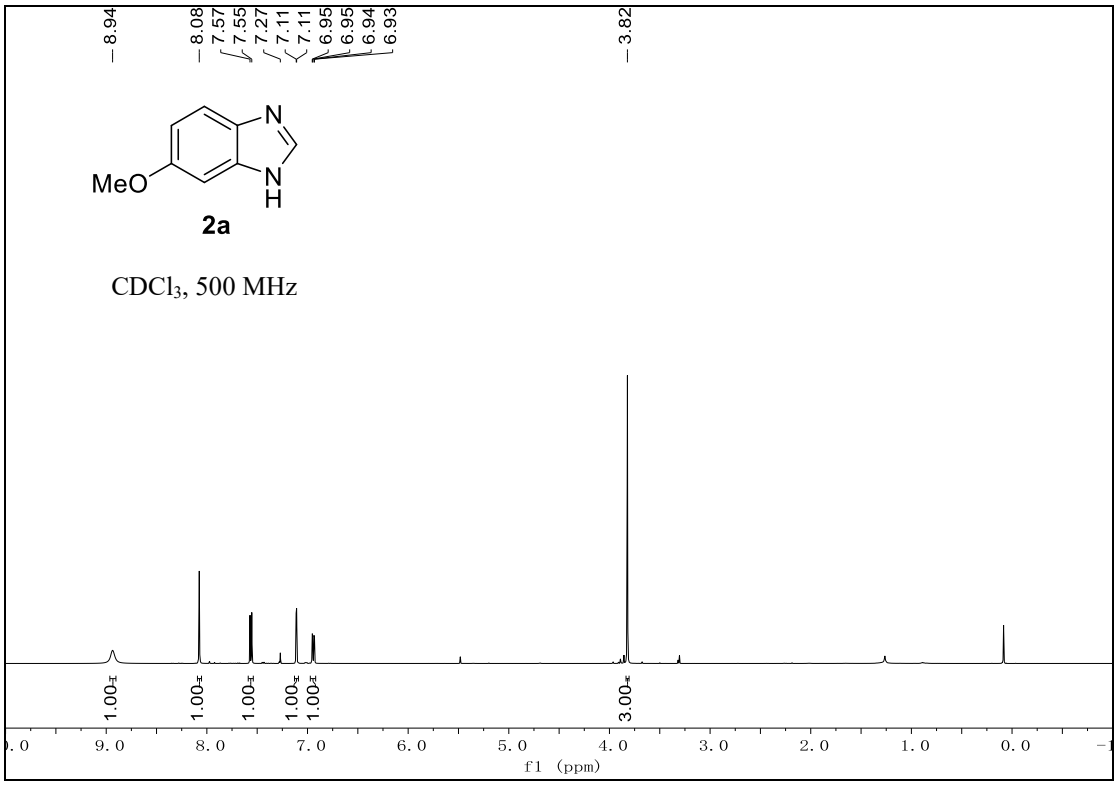
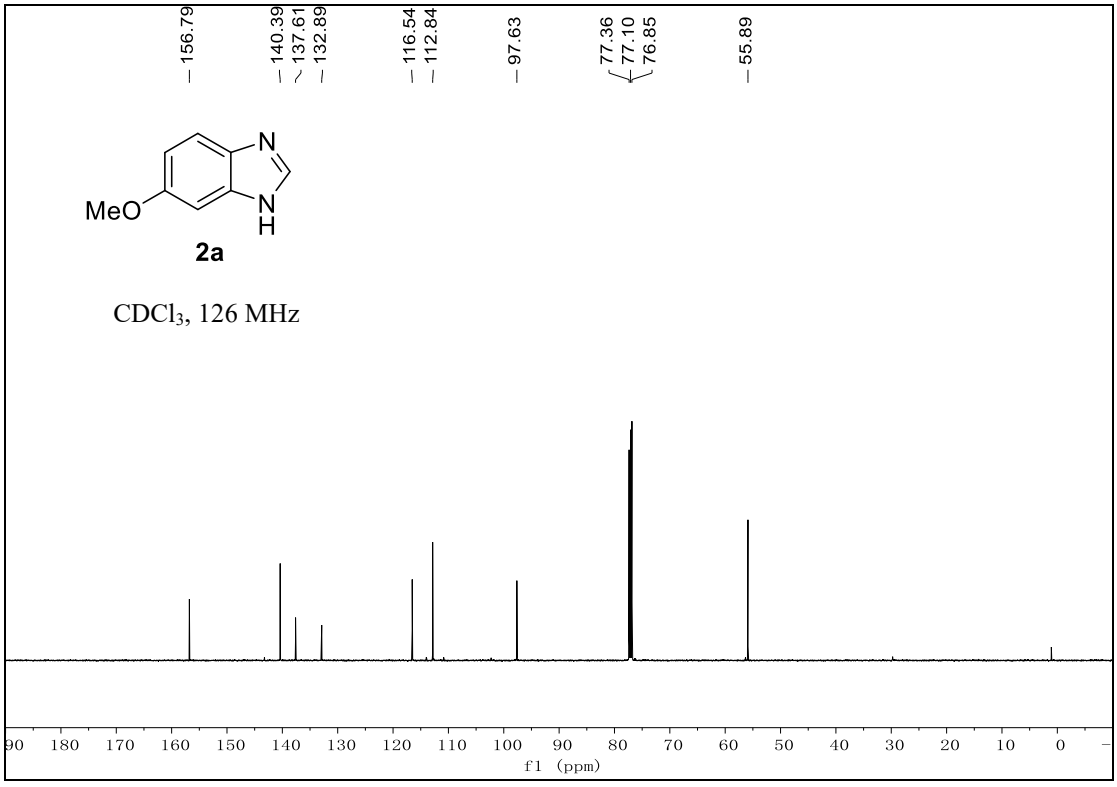
5. ^{1}H and $^{13}C\{^{1}H\}$ NMR Spectra of Products



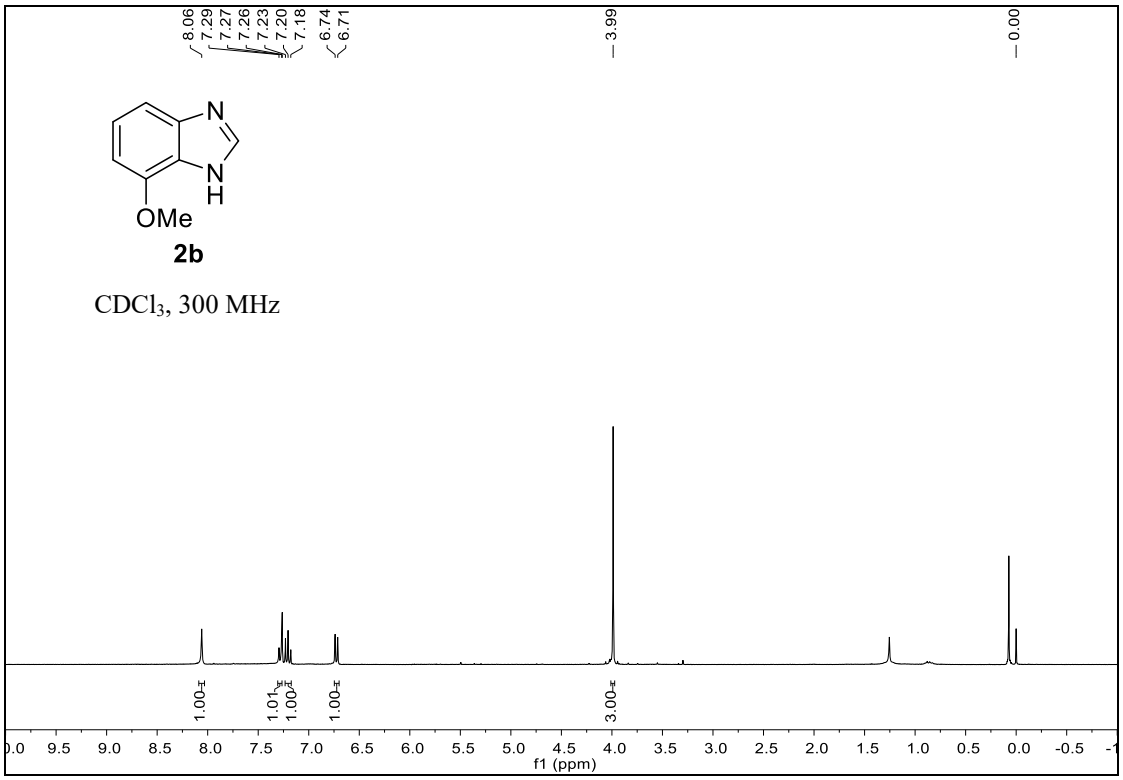
2a

$CDCl_3$, 500 MHz



2a

$CDCl_3$, 126 MHz



2b

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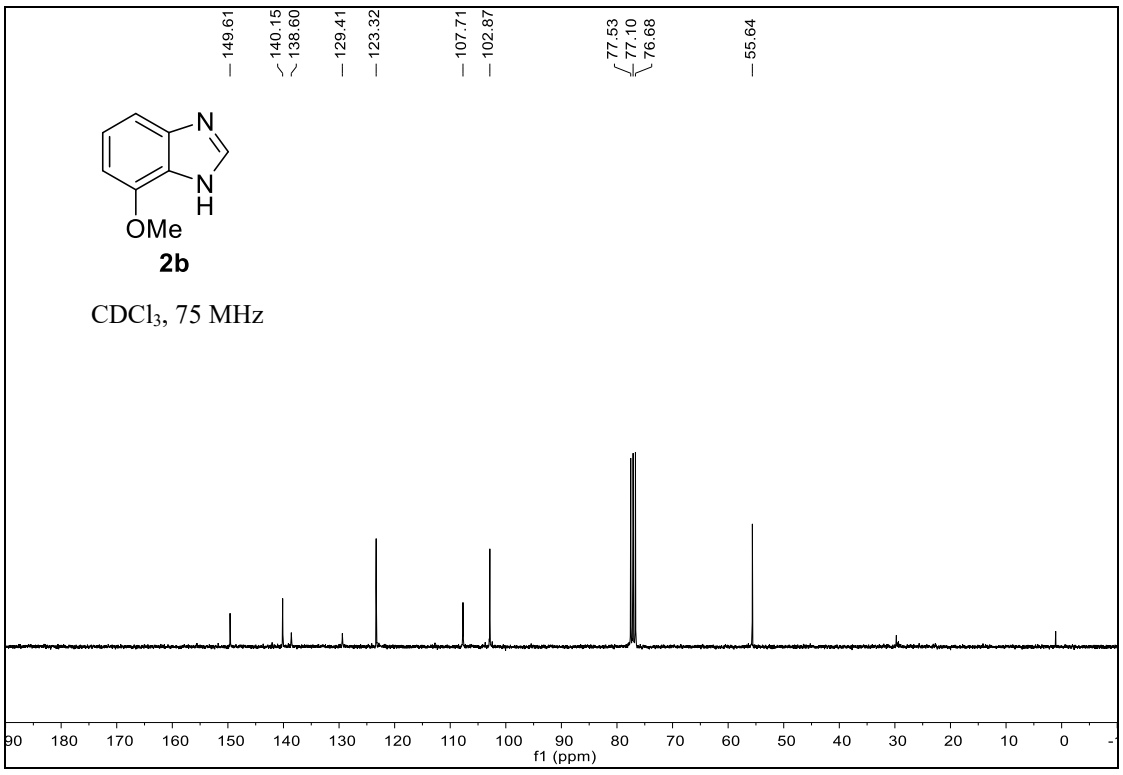
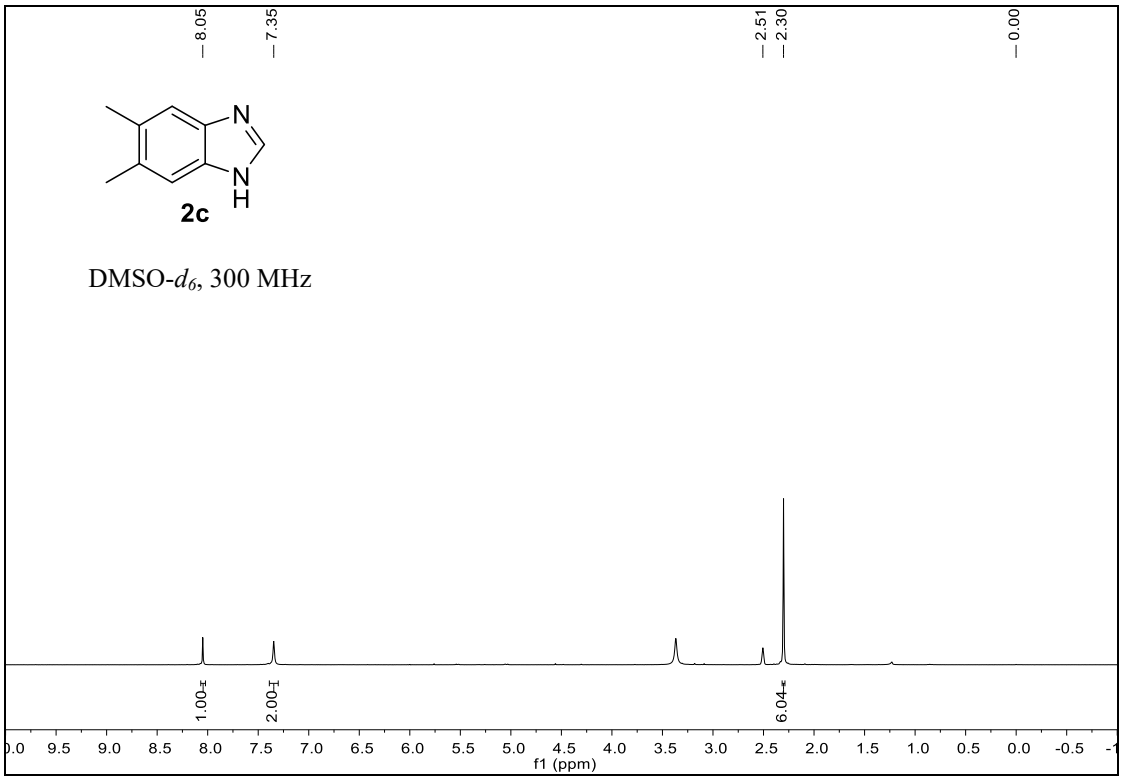


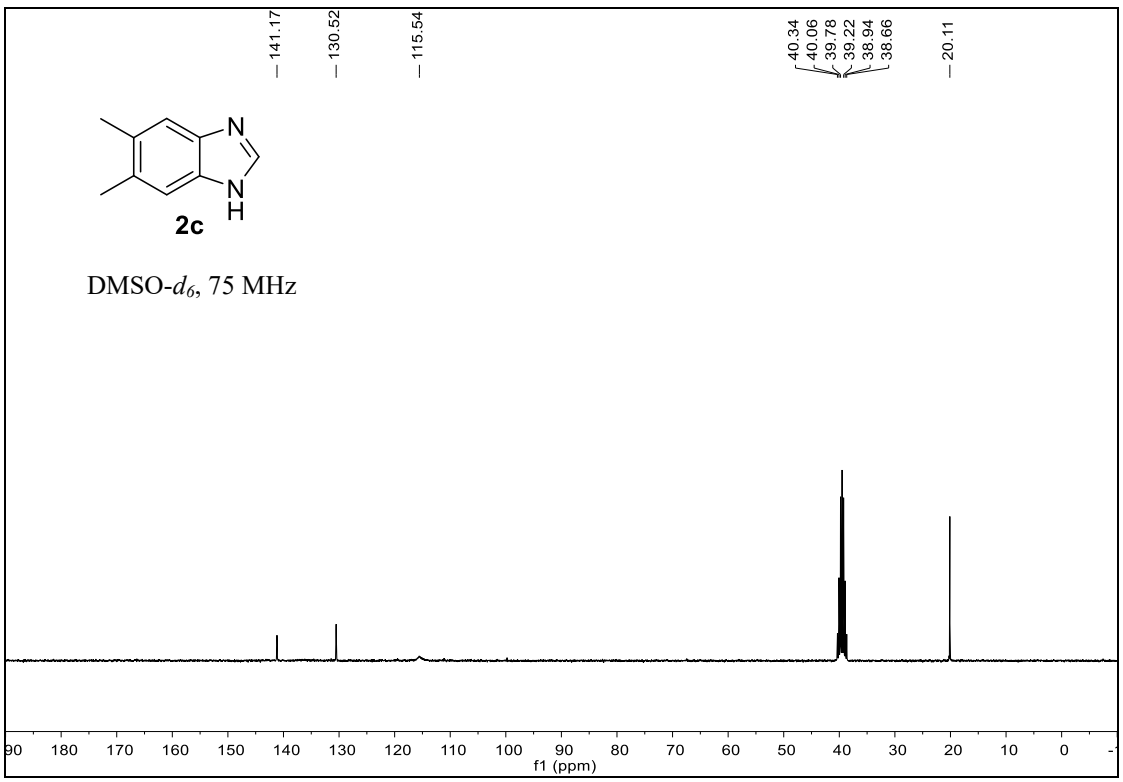
2b

$CDCl_3$, 75 MHz



2c

DMSO-d_6, 300 MHz



2c

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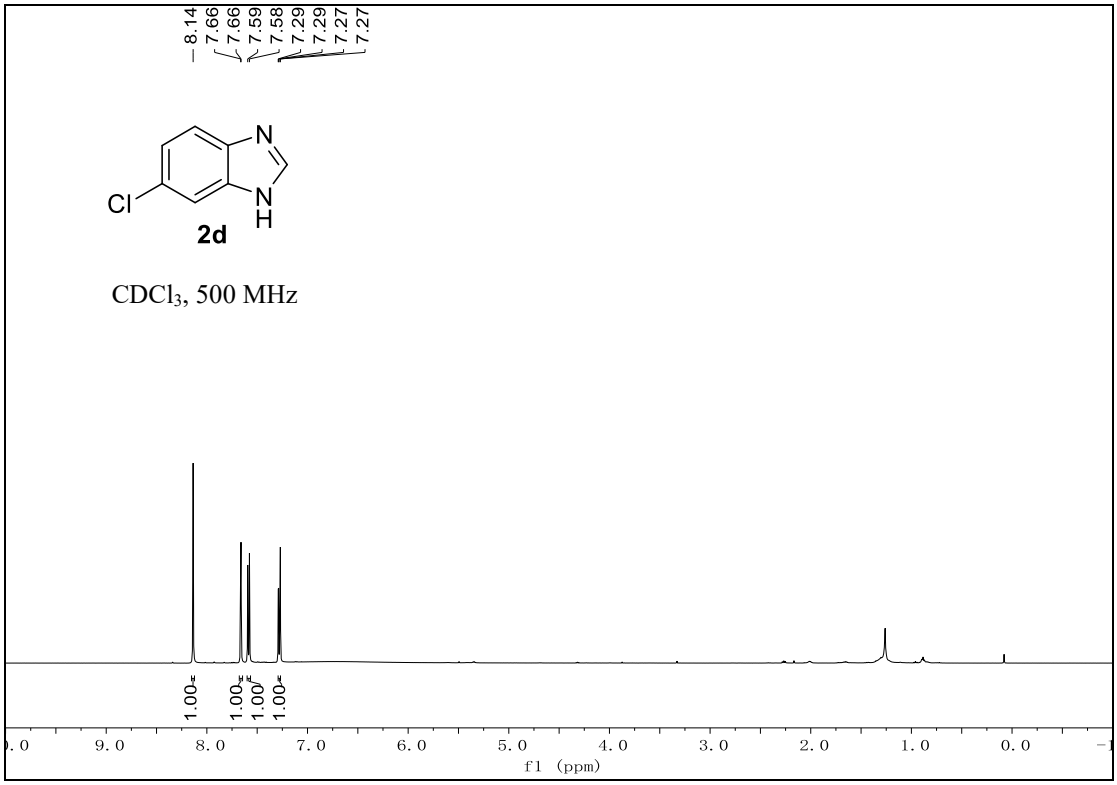

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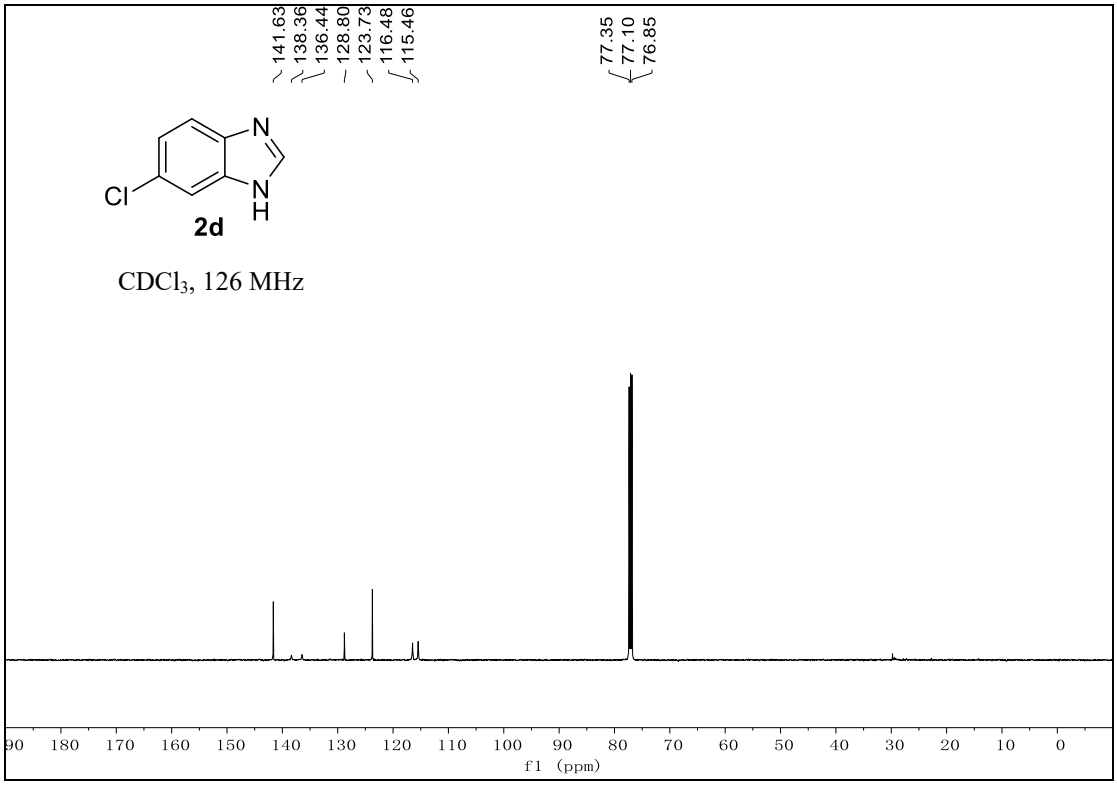

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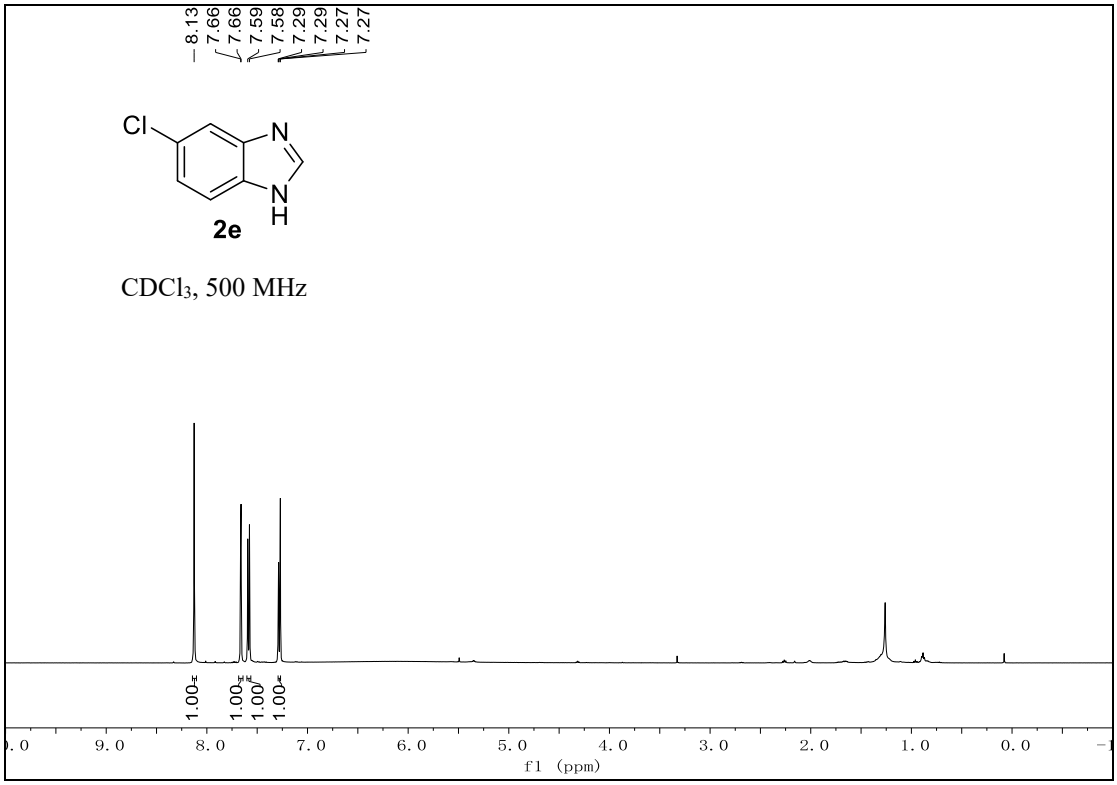
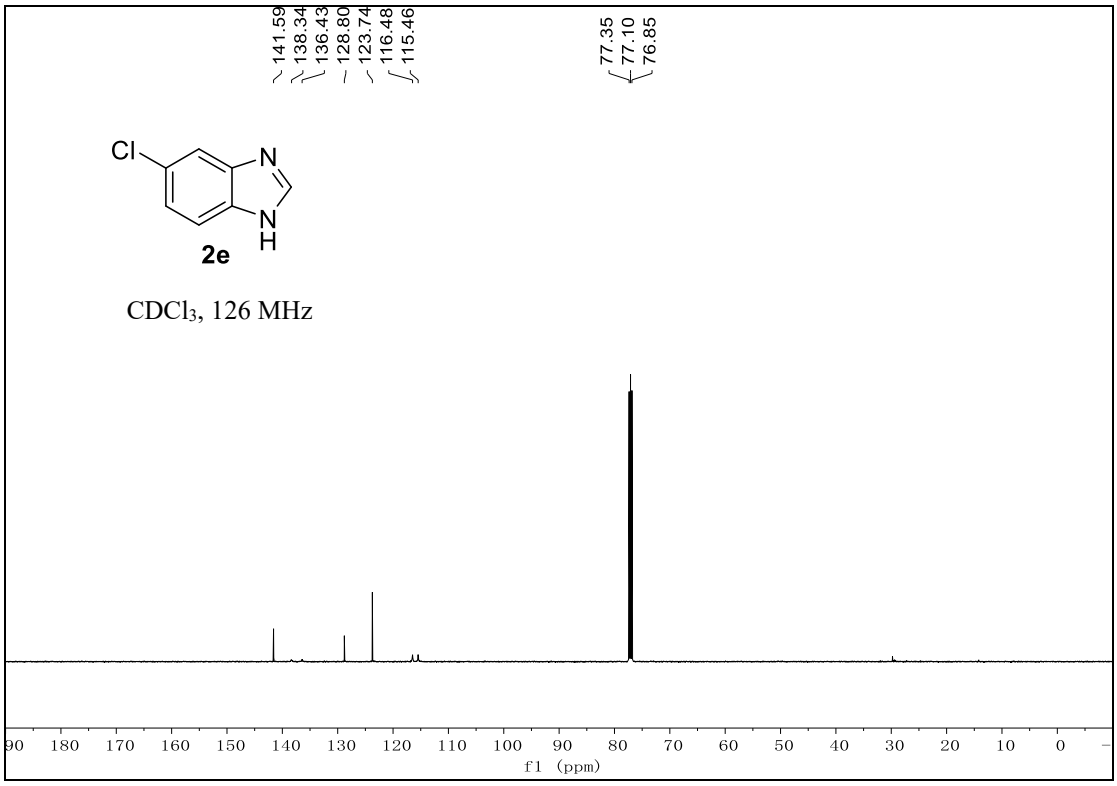
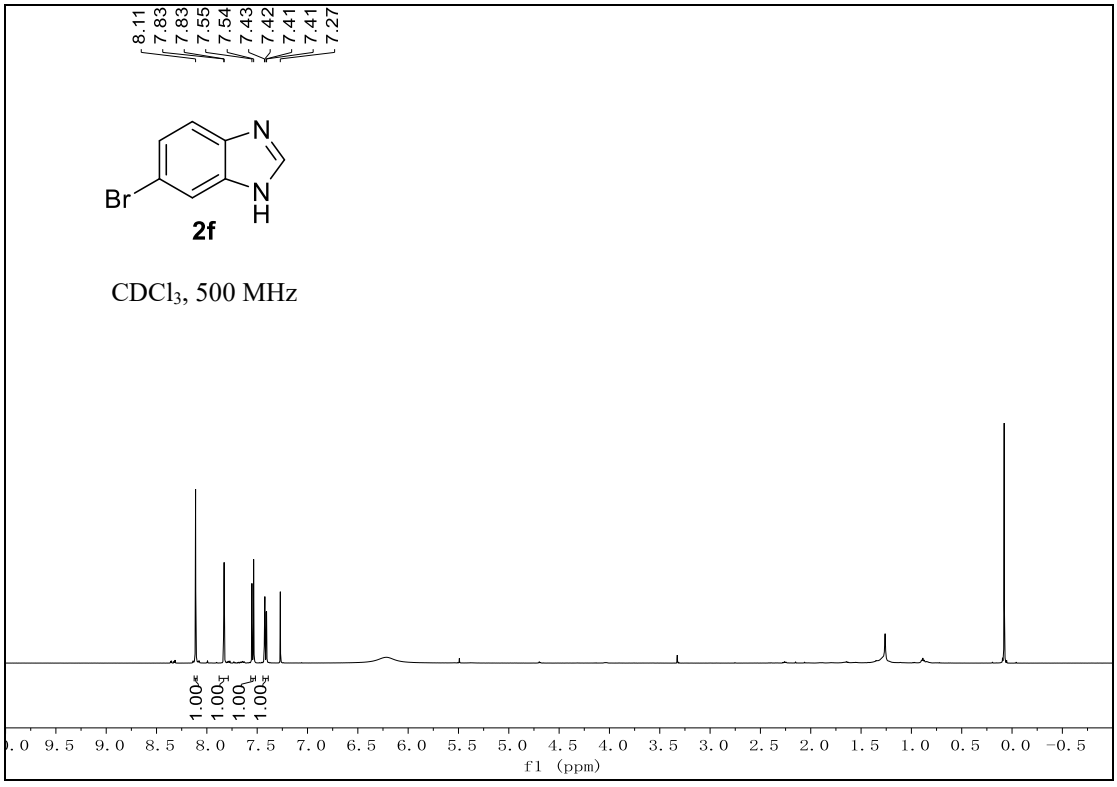
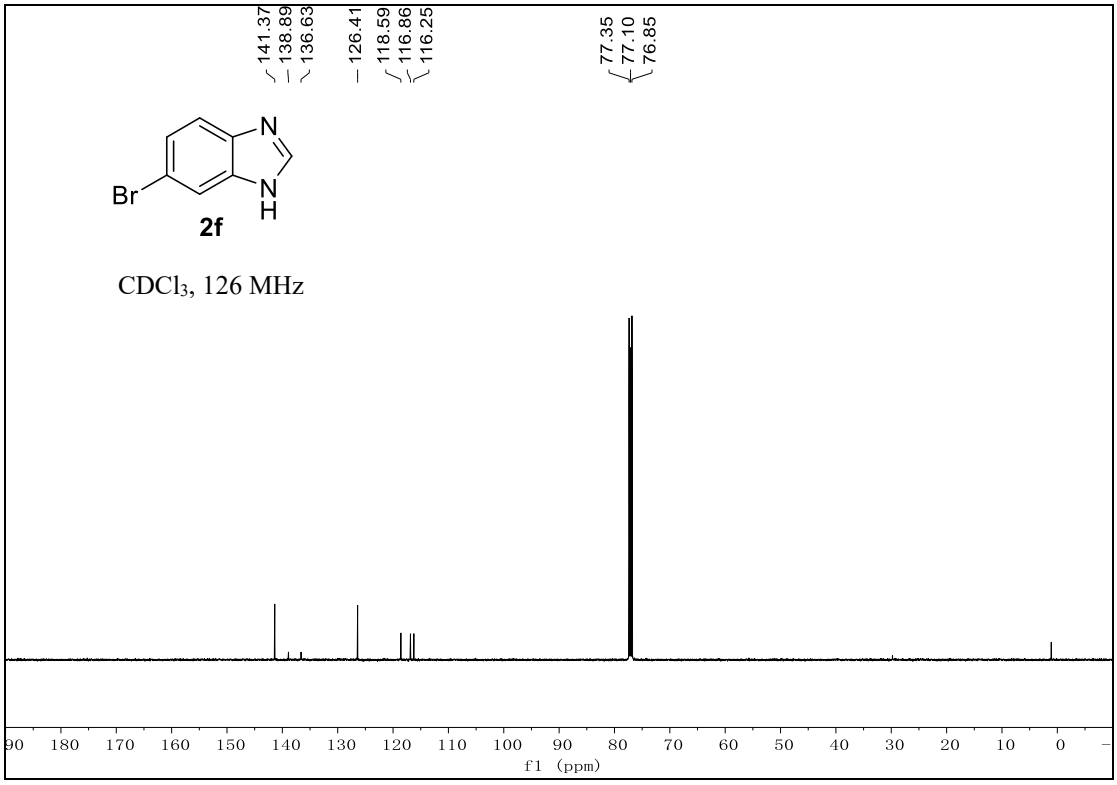
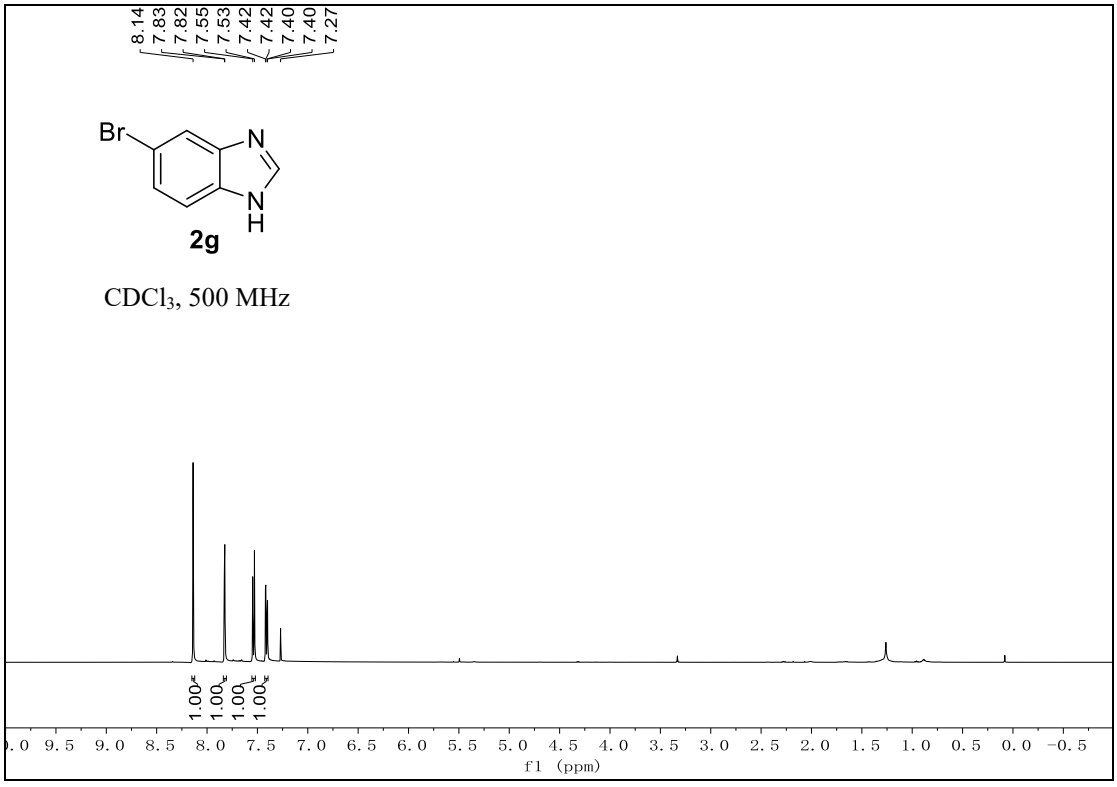

8.13
7.66
7.66
7.59
7.58
7.29
7.29
7.27
7.27
Cl
N
N
H
2e
CDCl3, 500 MHz
1.00
1.00
1.00
1.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


141.59
138.34
136.43
128.80
123.74
116.48
115.46
77.35
77.10
76.85
Cl
N
N
H
2e
CDCl3, 126 MHz
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.11
7.83
7.83
7.55
7.54
7.43
7.42
7.41
7.41
7.27
N
N
H
Br
2f
CDCl3, 500 MHz
1.00
1.00
1.00
1.00
f1 (ppm)


141.37
138.89
136.63
126.41
118.59
116.86
116.25
77.35
77.10
76.85
N
N
H
Br
2f
CDCl3, 126 MHz
f1 (ppm)



2g

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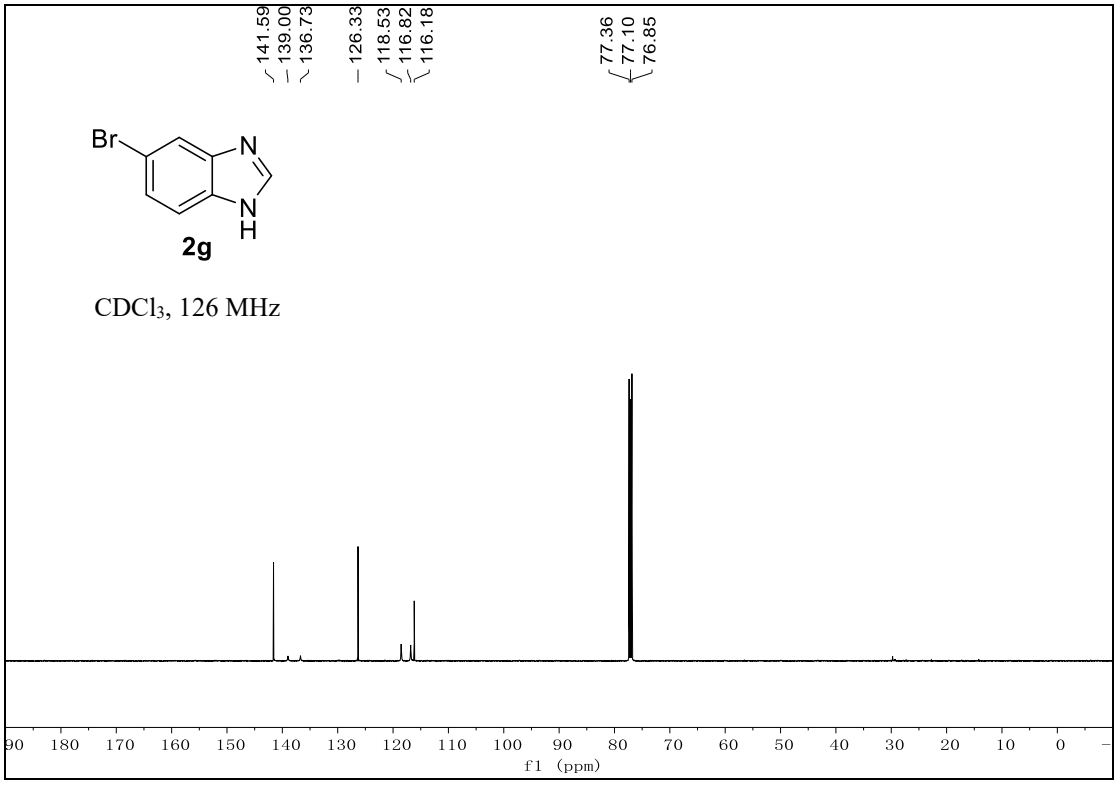
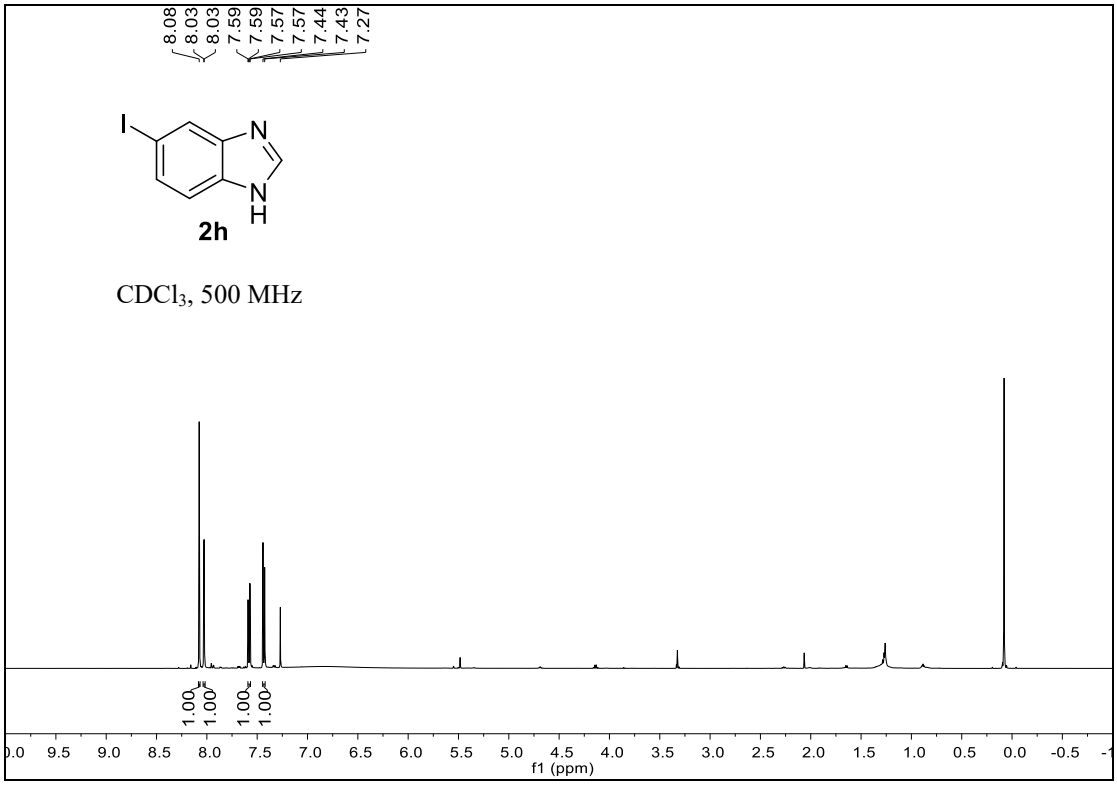
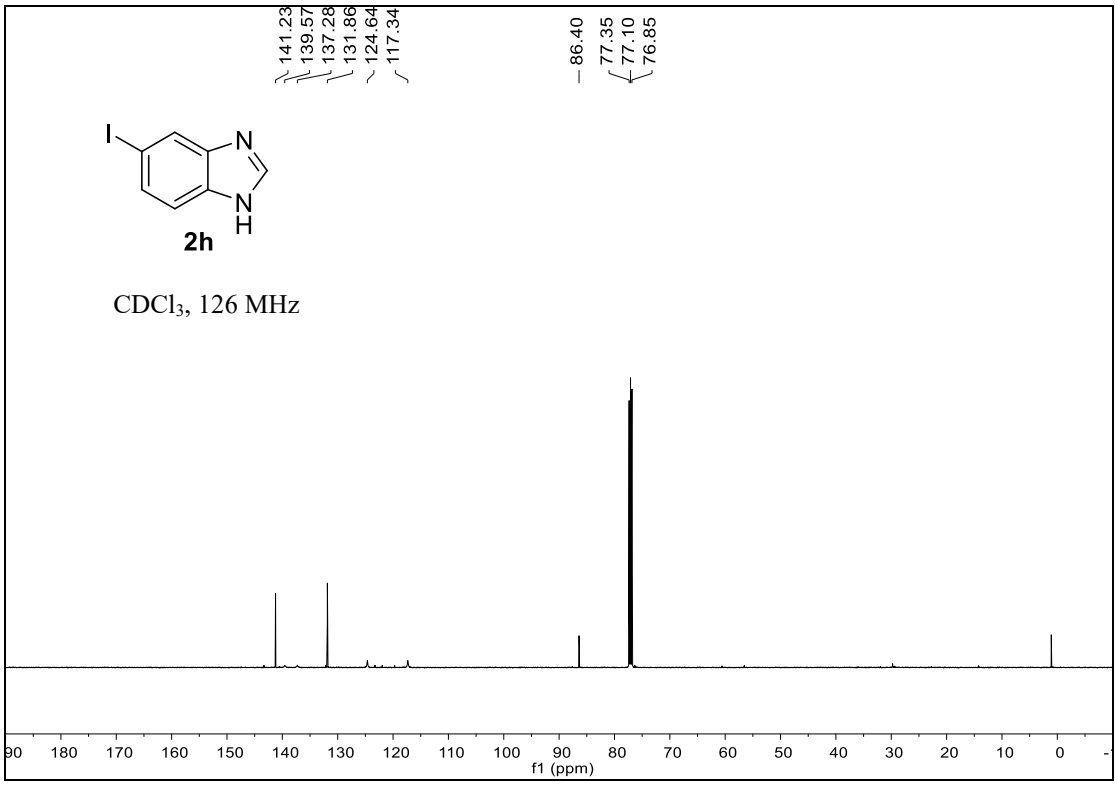
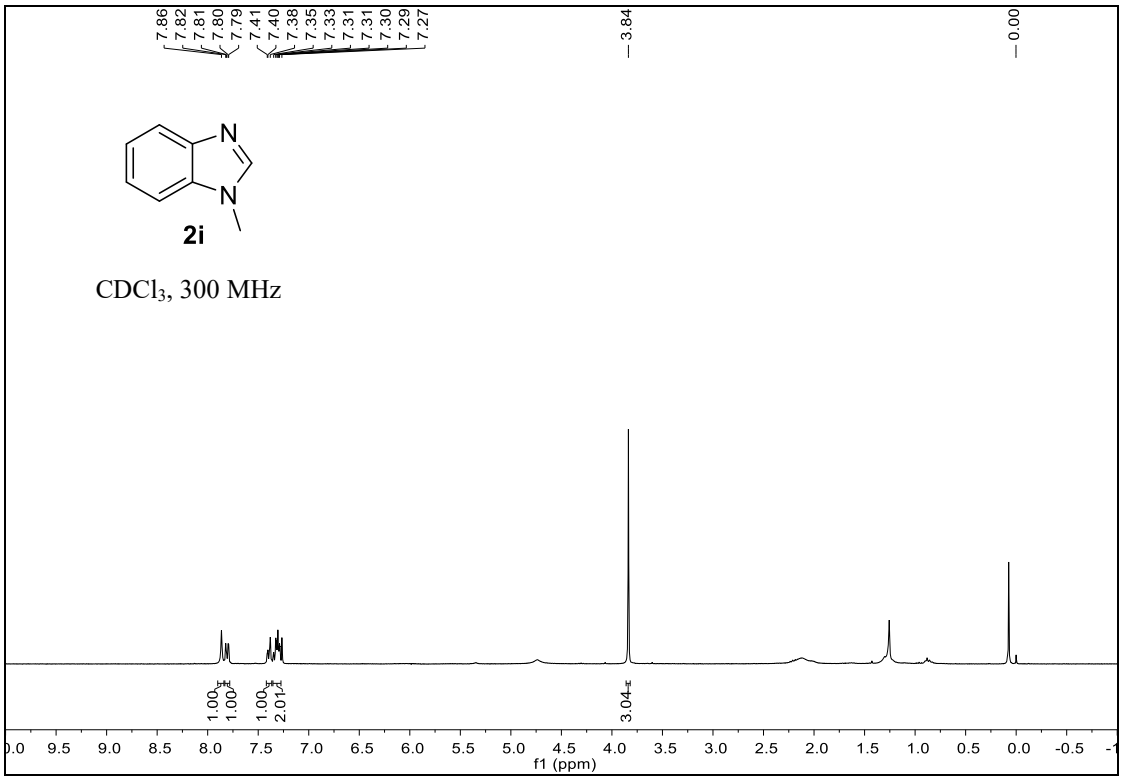


2g

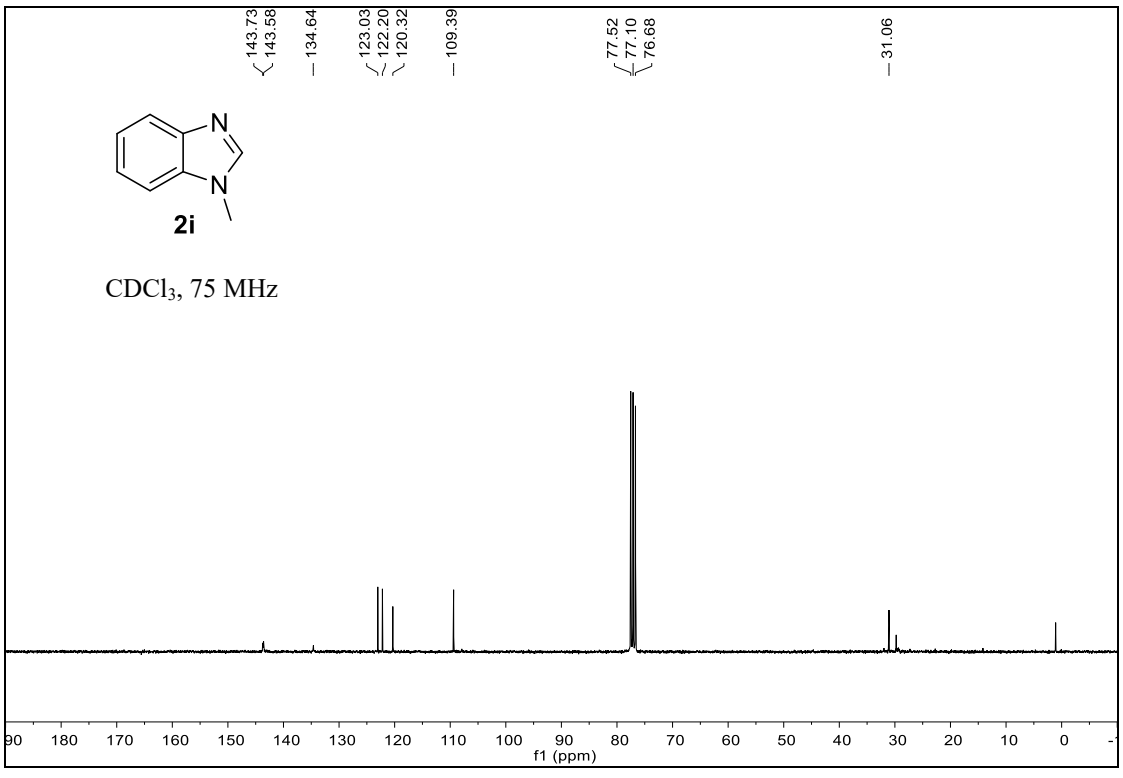
$CDCl_3$, 126 MHz


8.08
8.03
8.03
7.59
7.59
7.57
7.57
7.44
7.43
7.27
I
N
N
H
2h
CDCl3, 500 MHz
1.00
1.00
1.00
1.00
f1 (ppm)

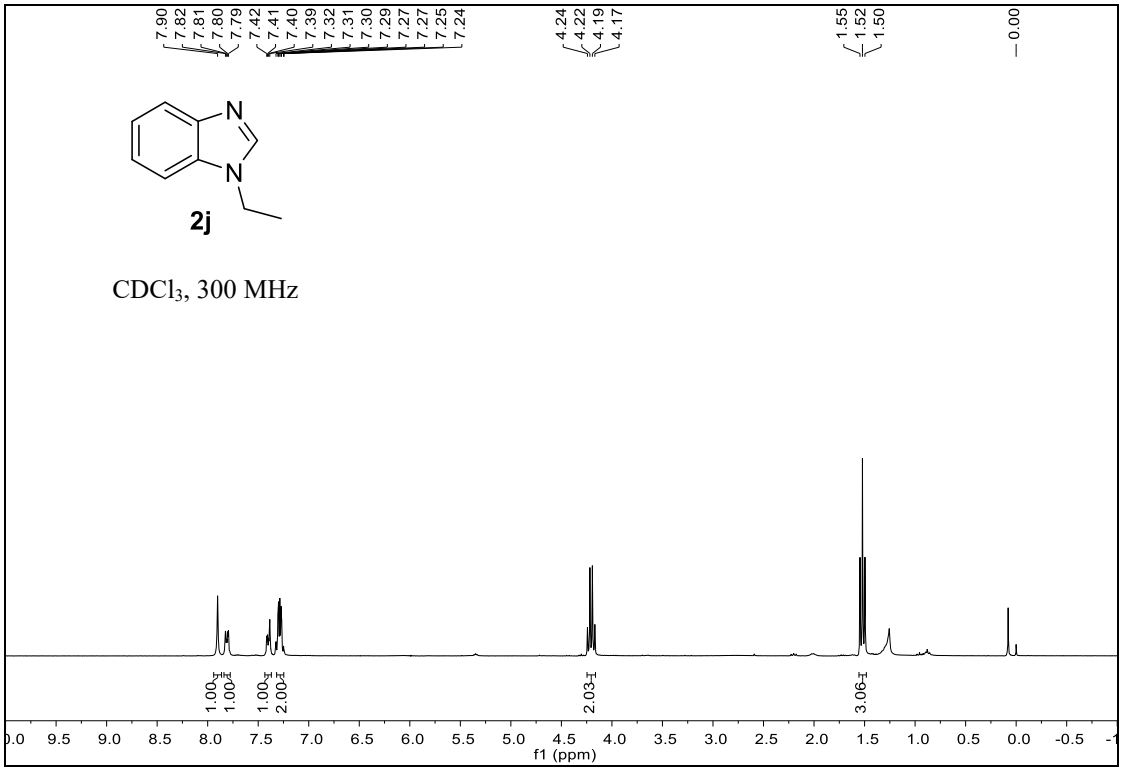

141.23
139.57
137.28
131.86
124.64
117.34
86.40
77.35
77.10
76.85
I
N
N
H
2h
CDCl3, 126 MHz
f1 (ppm)



$CDCl_3$, 300 MHz



$CDCl_3$, 75 MHz



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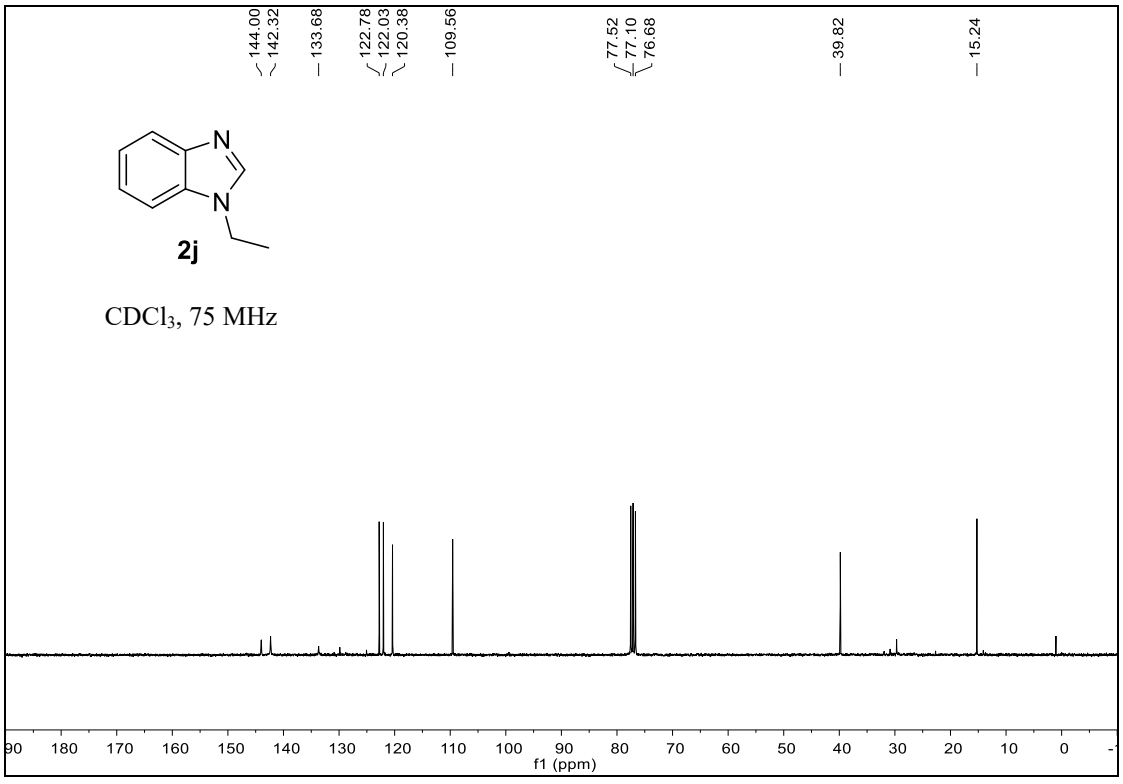

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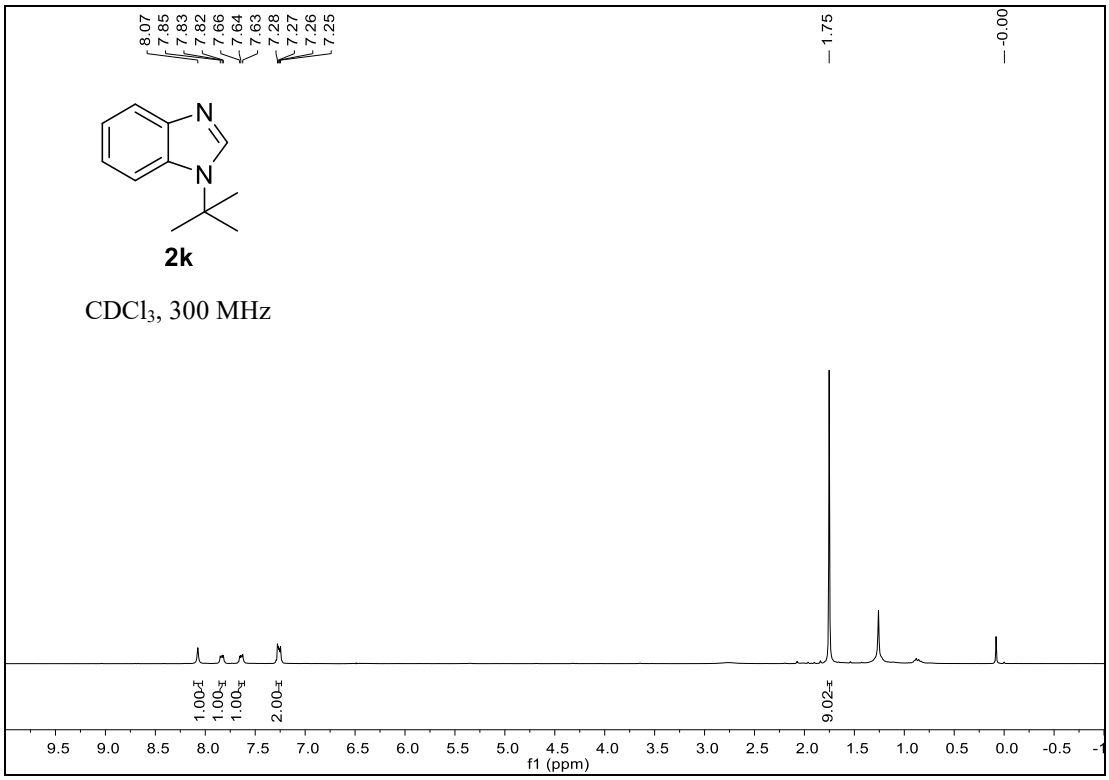

2k

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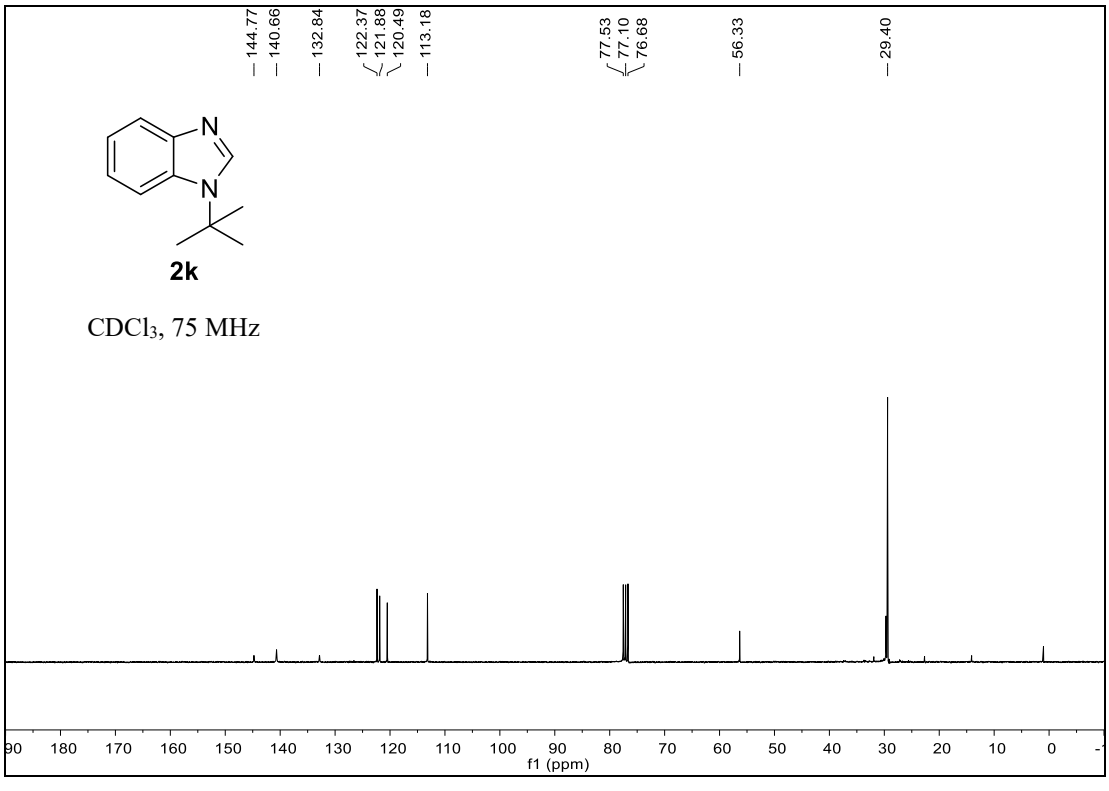
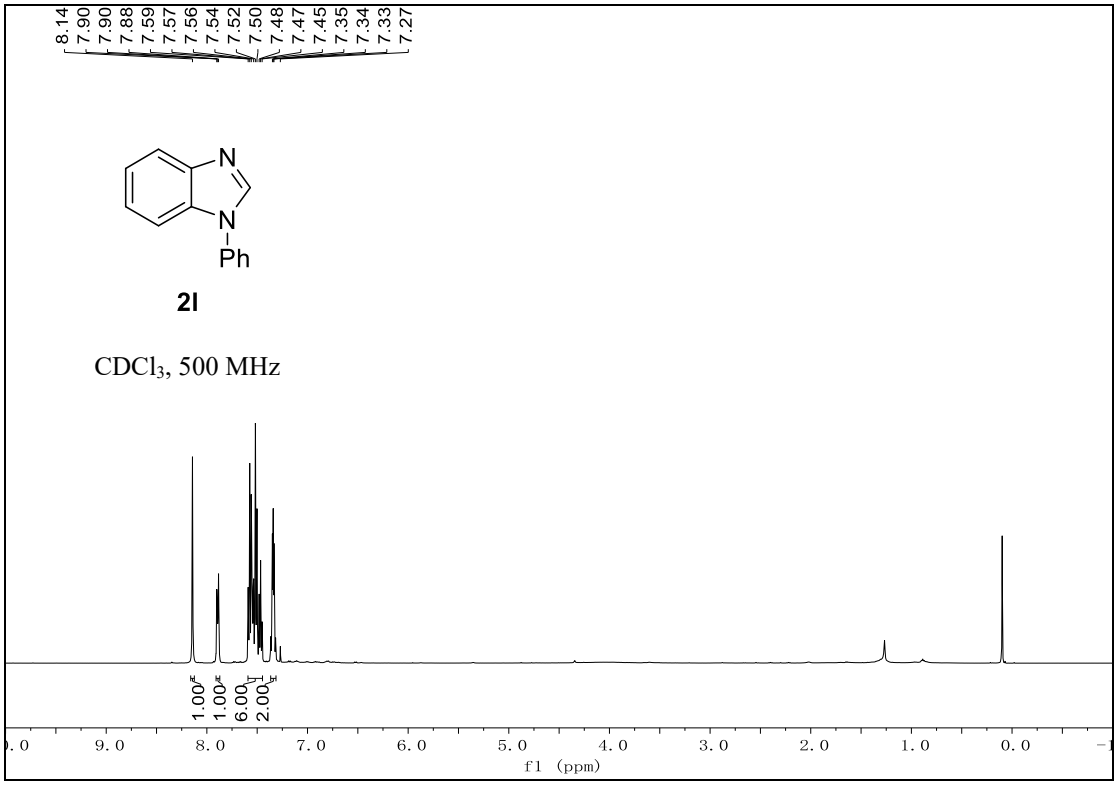


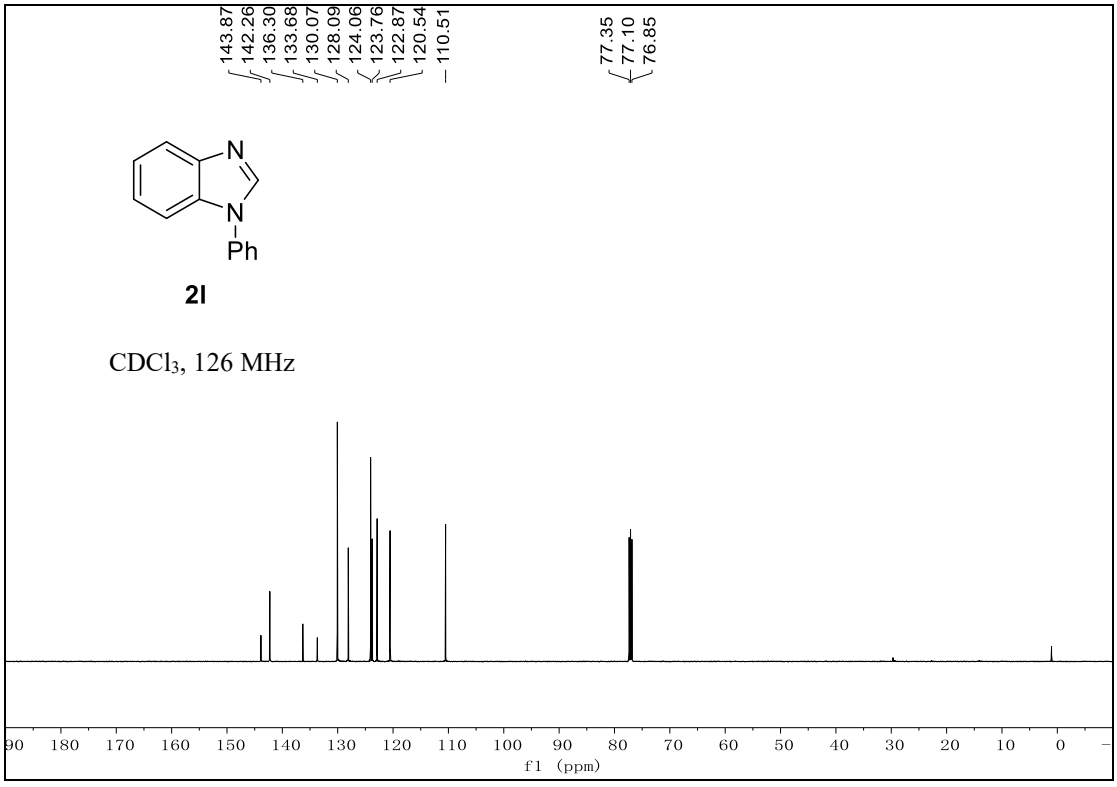
2k

$CDCl_3$, 75 MHz



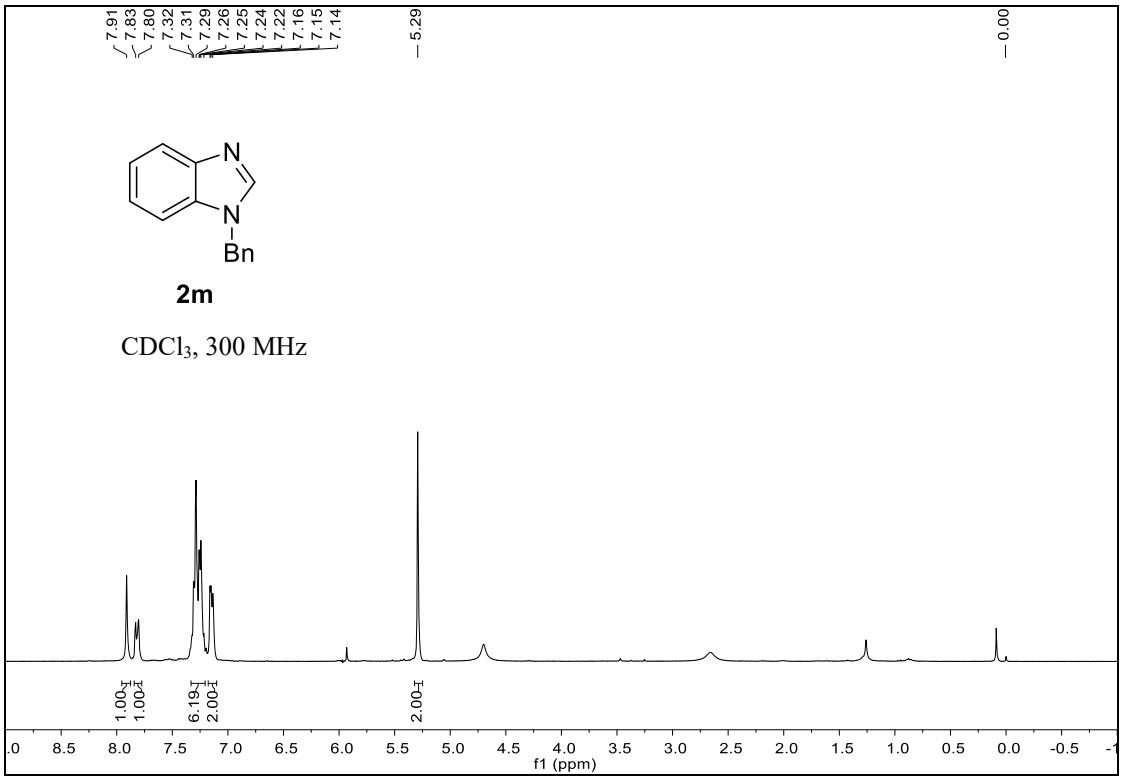
2l

$CDCl_3$, 500 MHz



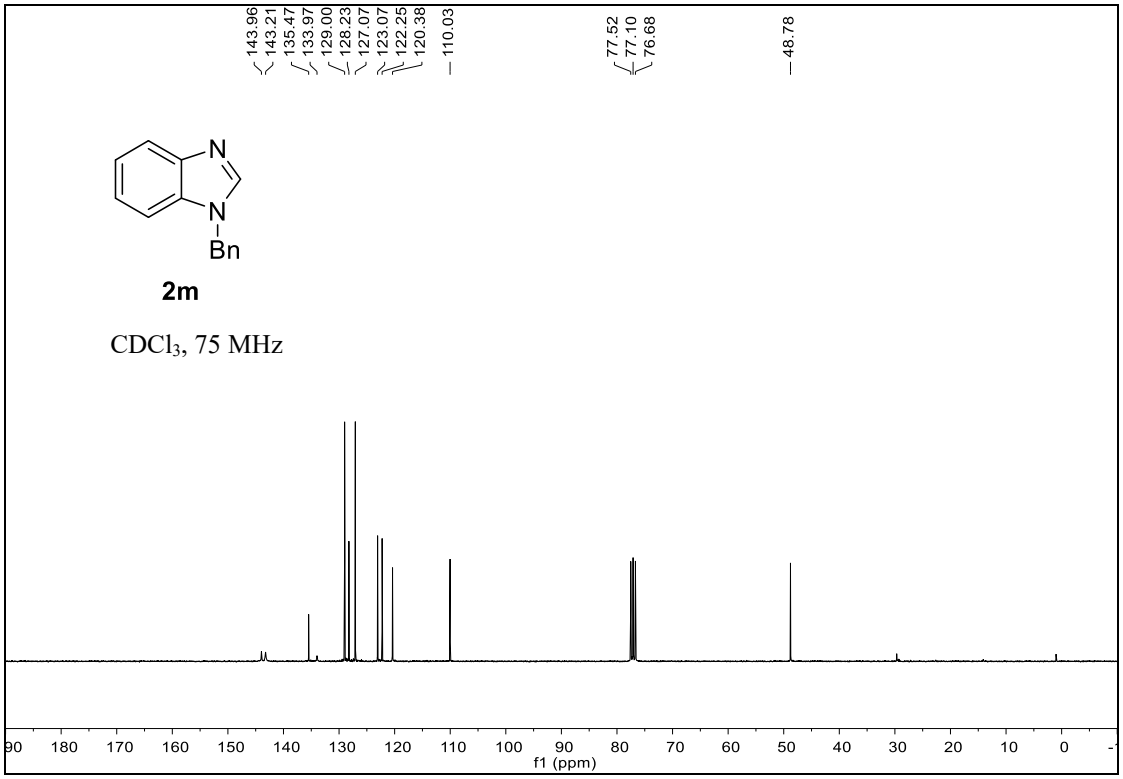
2l

$CDCl_3$, 126 MHz



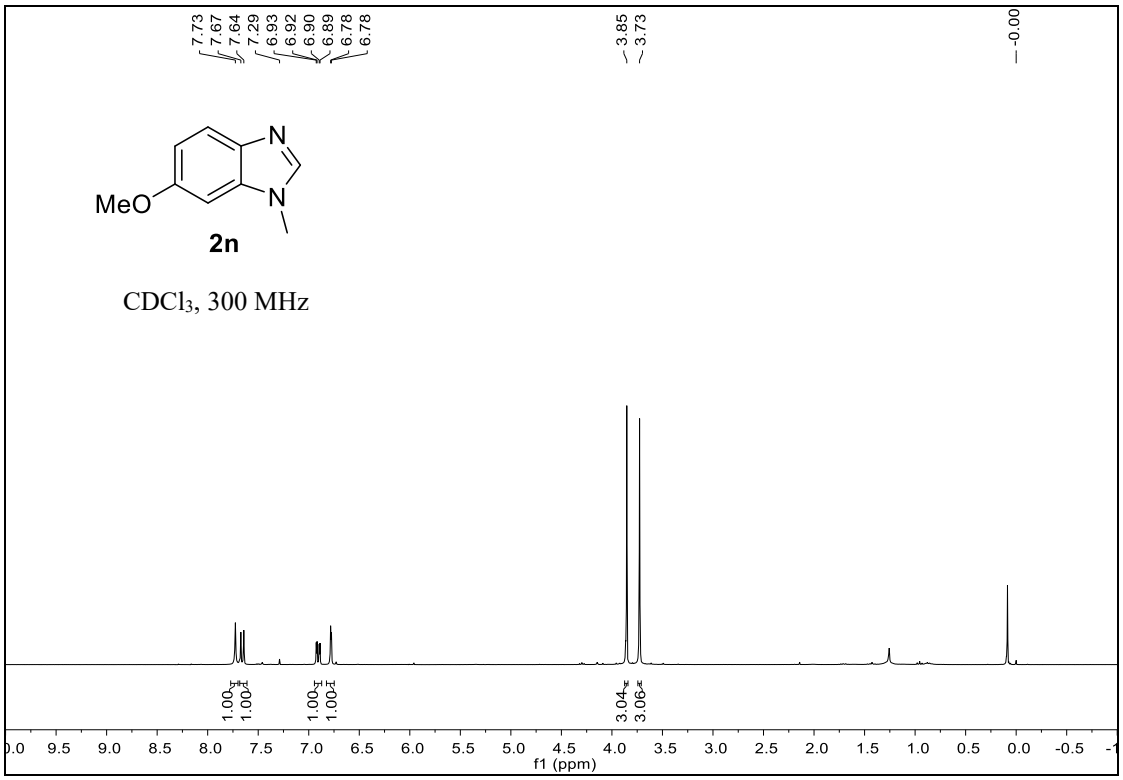
2m

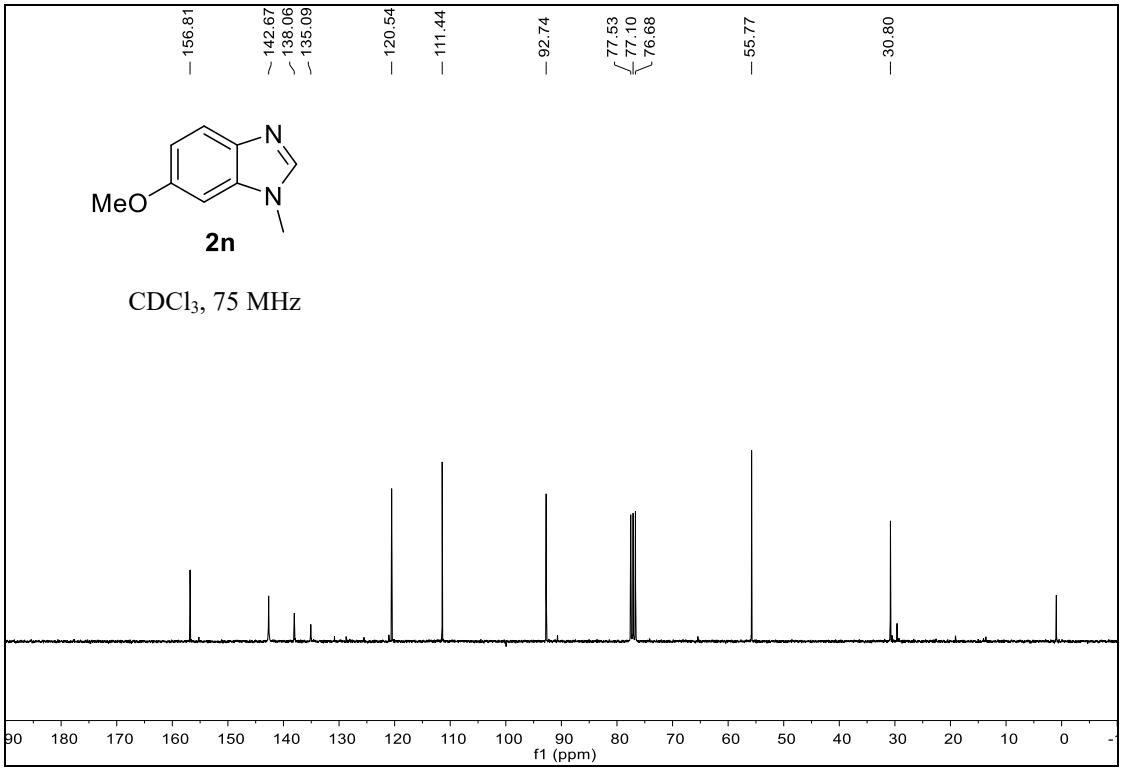
$CDCl_3$, 300 MHz

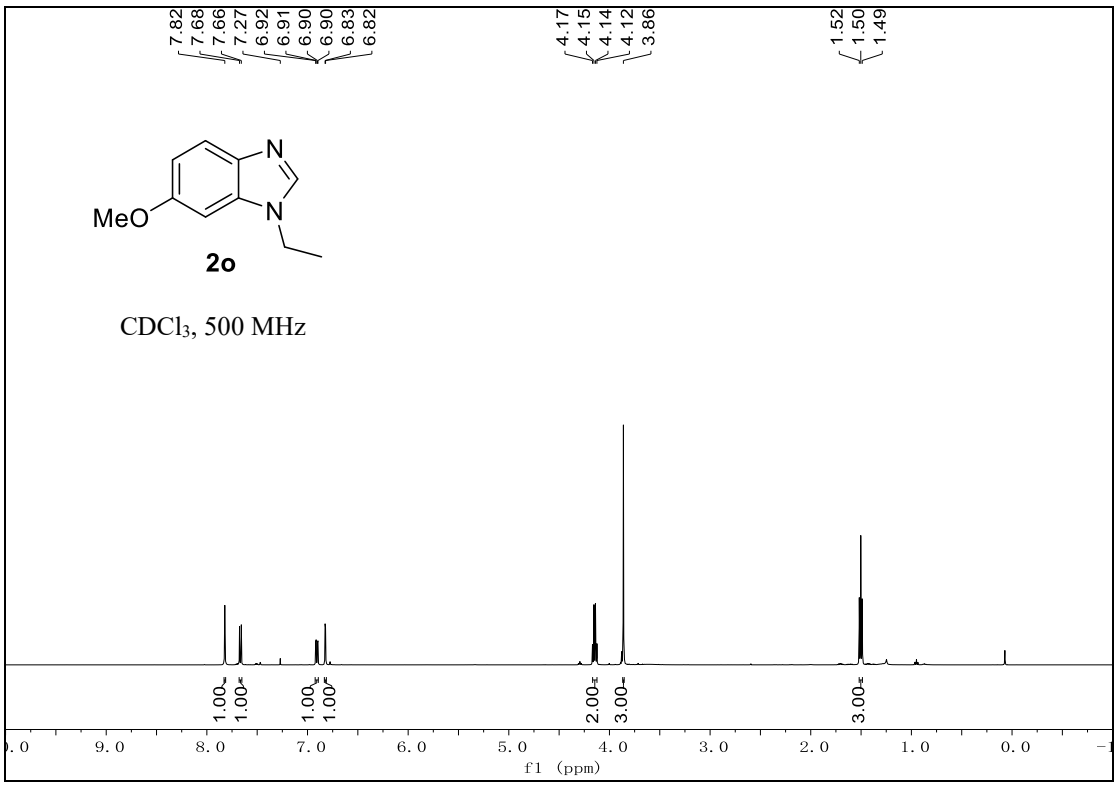


2m

$CDCl_3$, 75 MHz

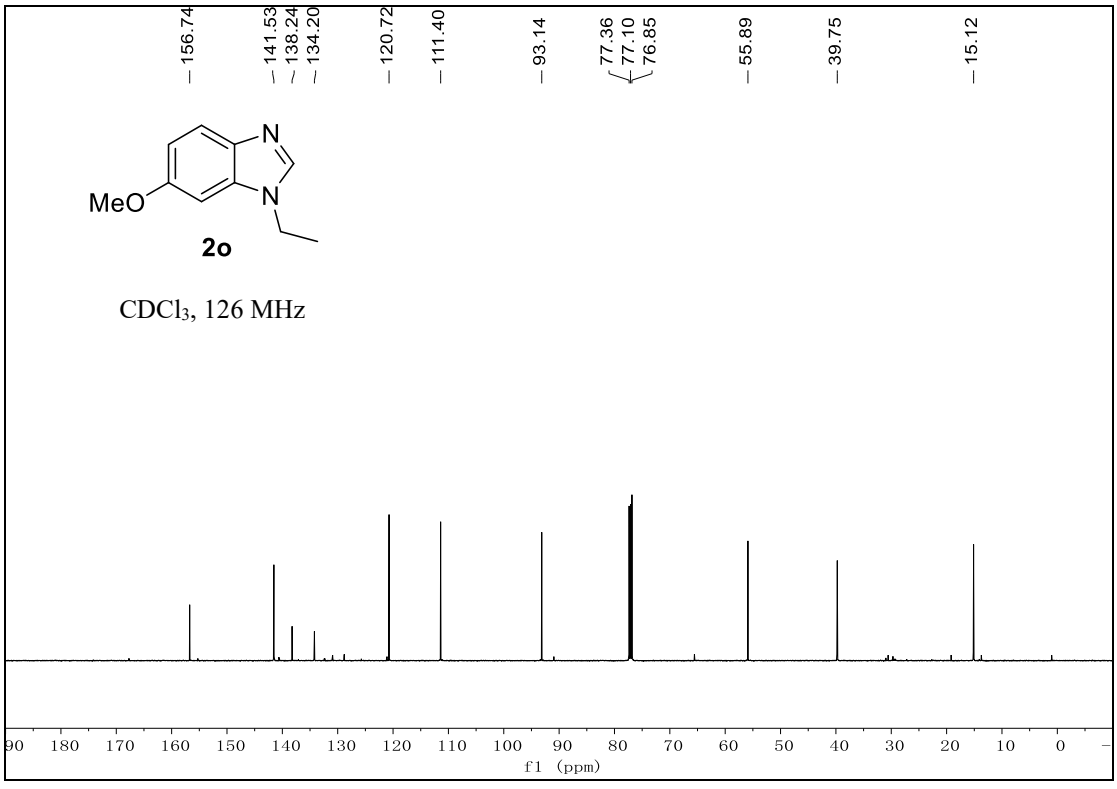

7.73
7.67
7.64
7.29
6.93
6.92
6.90
6.89
6.78
6.78
3.85
3.73
-0.00
MeO
N
N
2n
CDCl3, 300 MHz
1.00
1.00
1.00
1.00
3.04
3.06
f1 (ppm)


156.81
142.67
138.06
135.09
120.54
111.44
92.74
77.53
77.10
76.68
55.77
30.80
MeO
N
N
2n
CDCl3, 75 MHz
f1 (ppm)



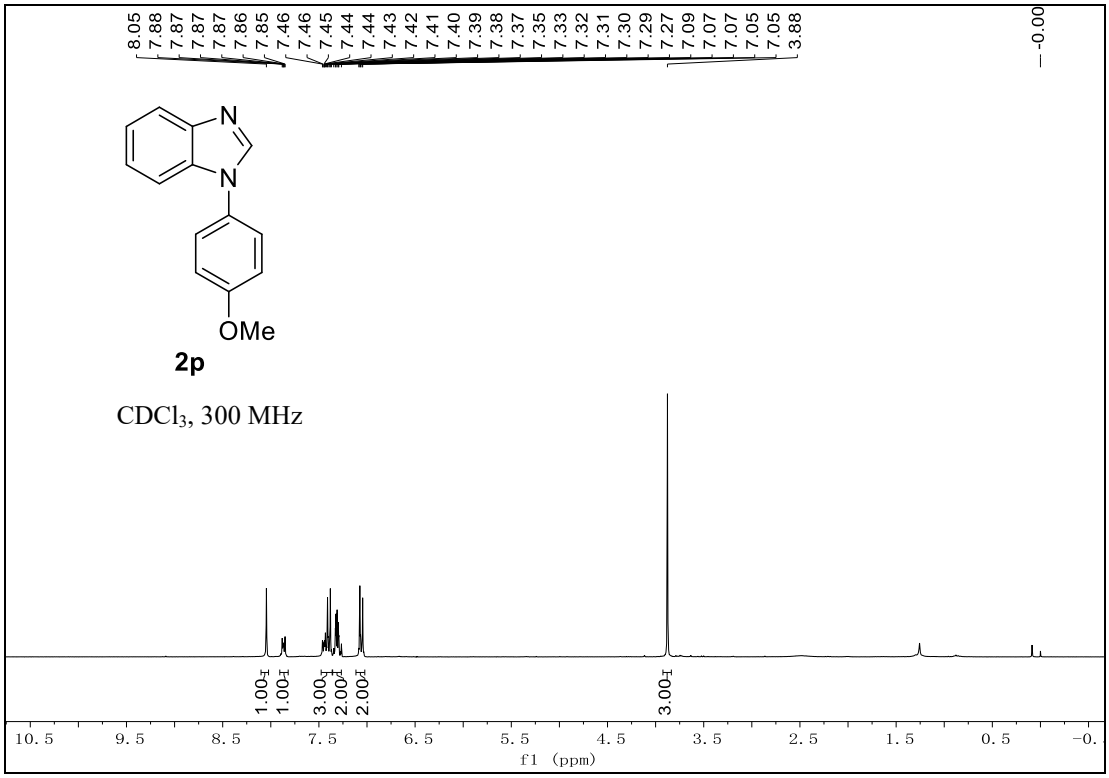
2o

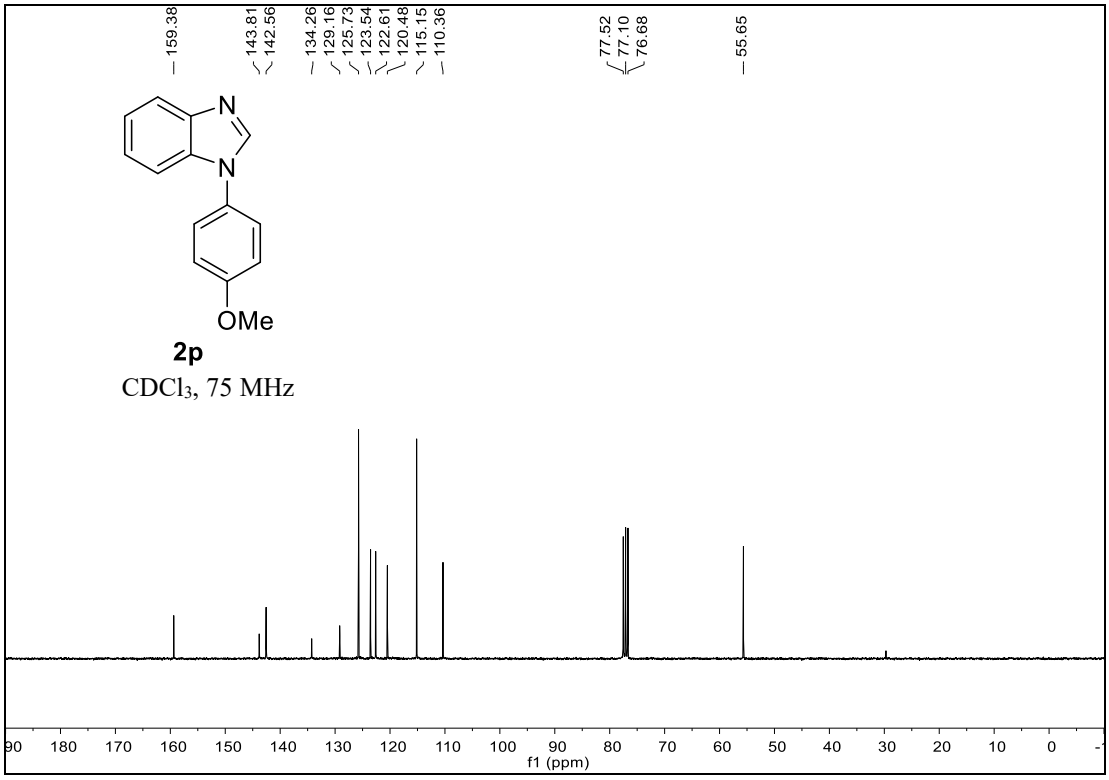
$CDCl_3$, 500 MHz



2o

$CDCl_3$, 126 MHz


8.05
7.88
7.87
7.87
7.87
7.86
7.85
7.46
7.46
7.45
7.44
7.44
7.43
7.42
7.41
7.40
7.39
7.38
7.37
7.35
7.33
7.32
7.31
7.30
7.29
7.27
7.09
7.07
7.07
7.05
7.05
3.88
-0.00
N
N
OMe
2p
CDCl3, 300 MHz
1.00
1.00
3.00
2.00
2.00
3.00
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
f1 (ppm)


159.38
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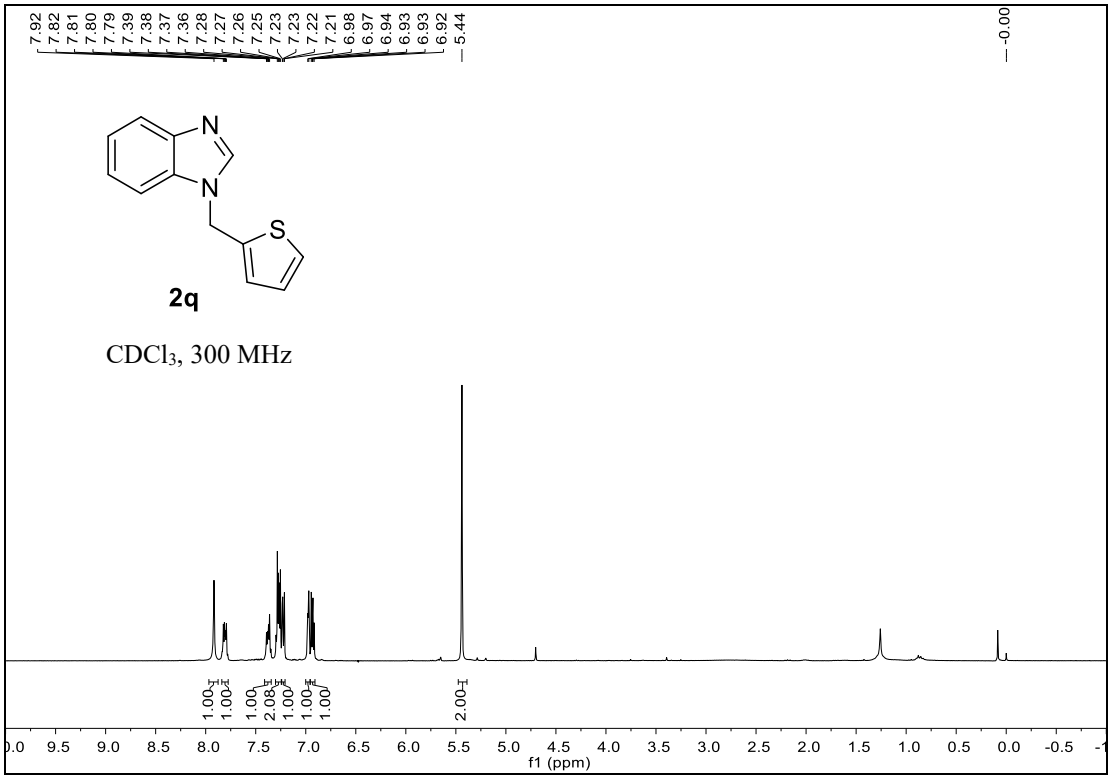
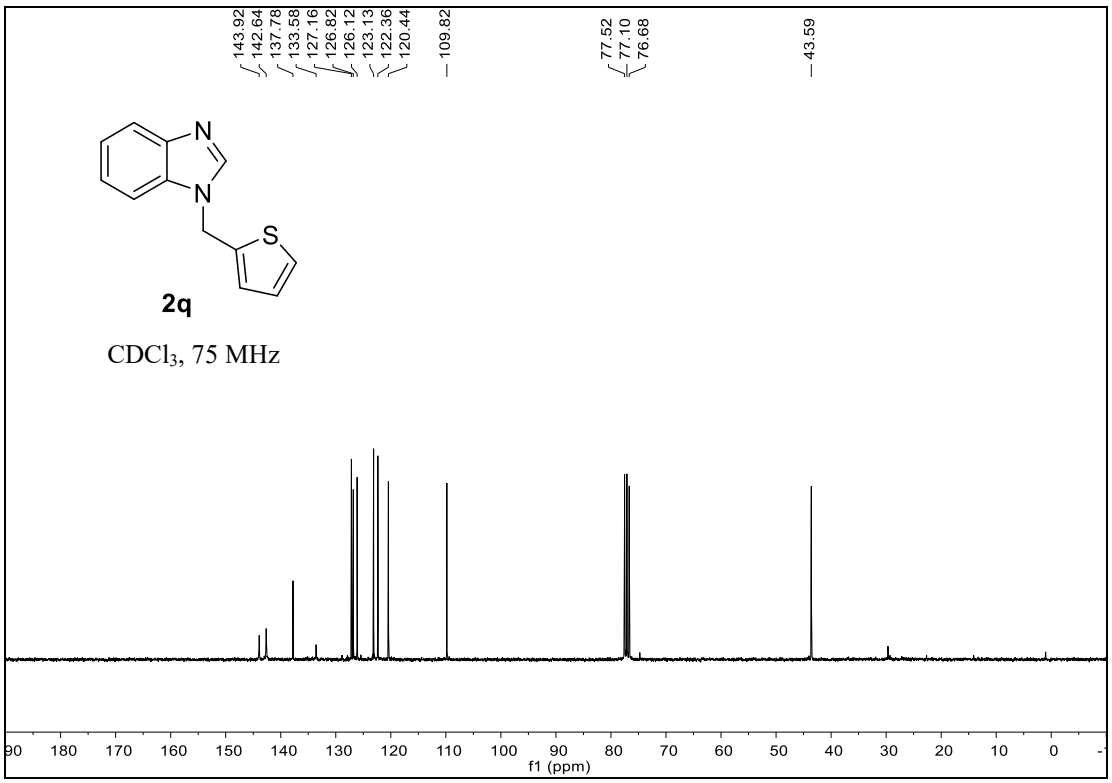
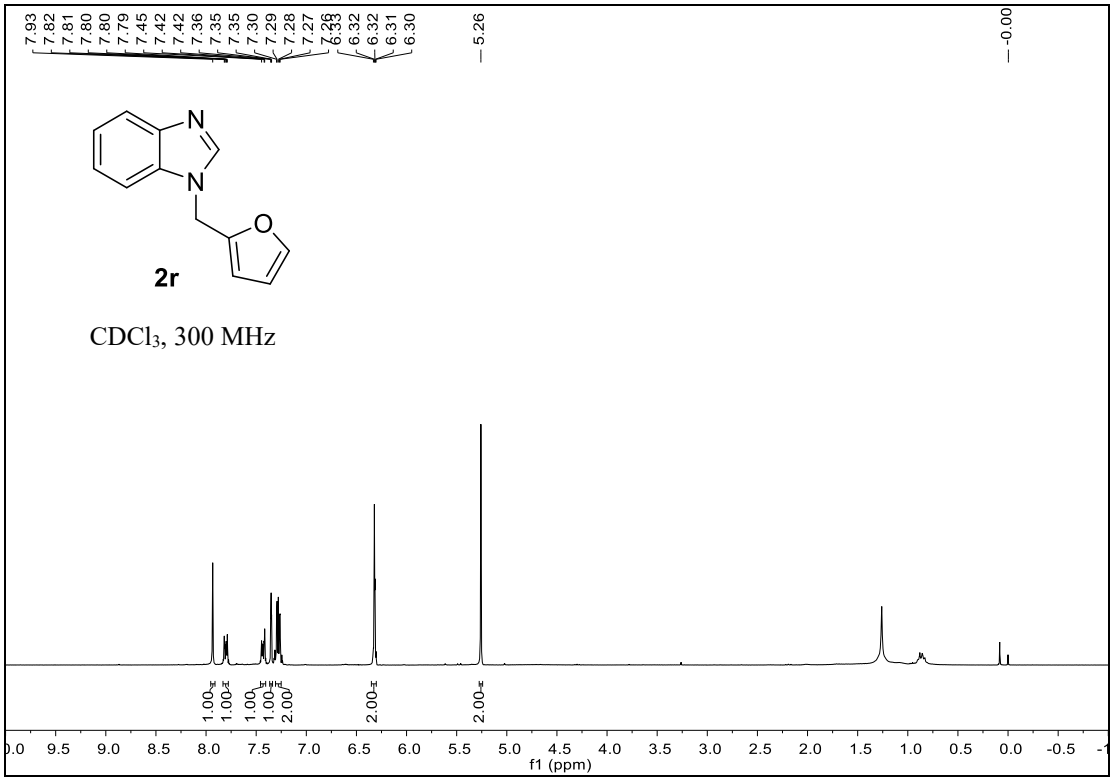
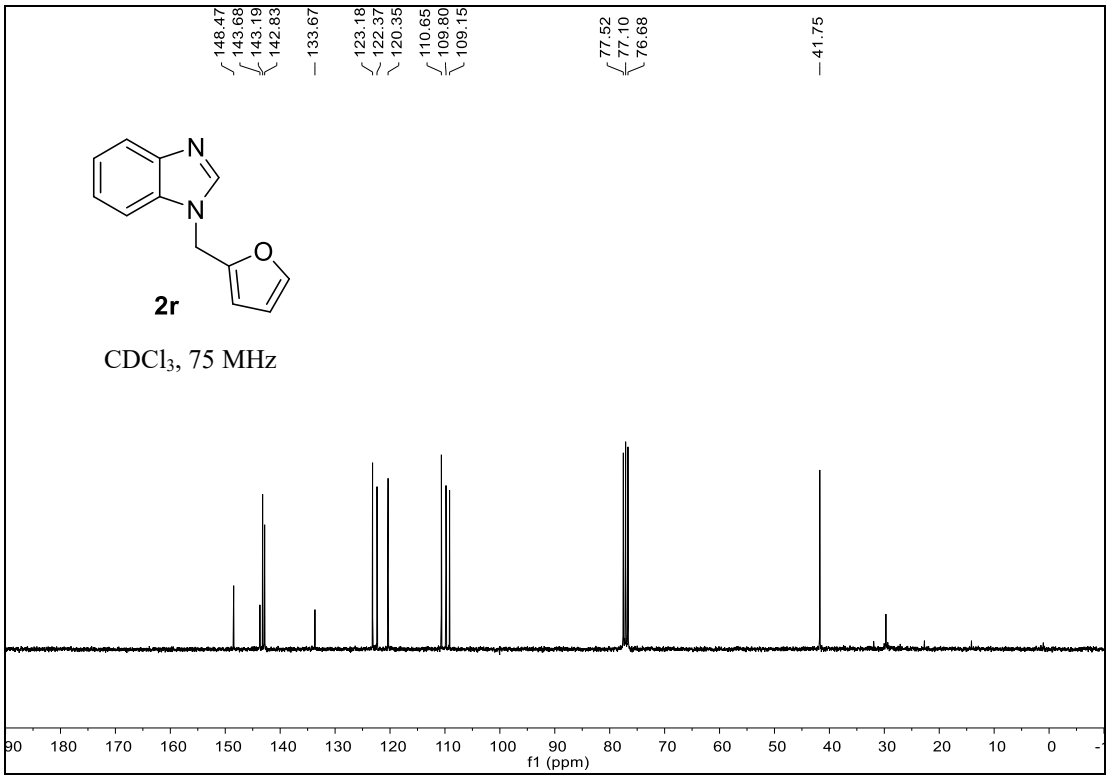
142.56
134.26
129.16
125.73
123.54
122.61
120.48
115.15
110.36
77.52
77.10
76.68
55.65
N
N
OMe
2p
CDCl3, 75 MHz
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.92
7.82
7.81
7.80
7.79
7.39
7.38
7.37
7.36
7.28
7.27
7.26
7.25
7.23
7.23
7.22
7.21
6.98
6.97
6.94
6.93
6.93
6.92
5.44
-0.00
N
N
S
2q
CDCl3, 300 MHz
1.00
1.00
2.08
1.00
1.00
1.00
2.00
f1 (ppm)

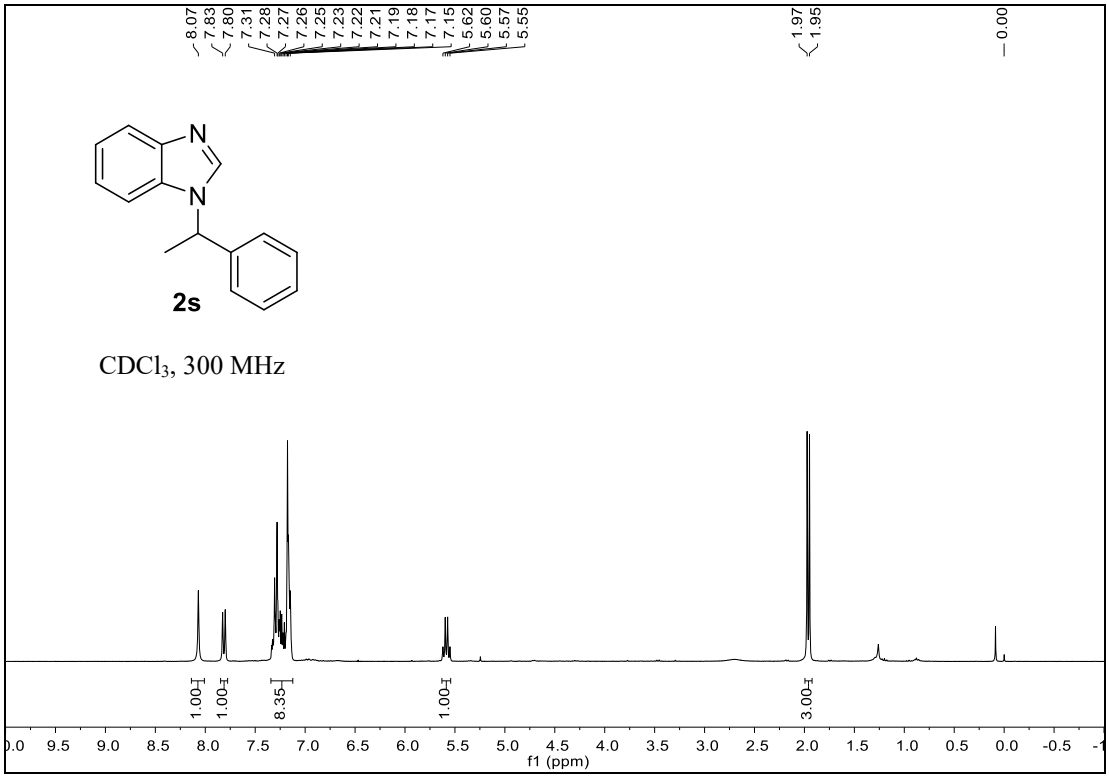

143.92
142.64
137.78
133.58
127.16
126.82
126.12
123.13
122.36
120.44
109.82
77.52
77.10
76.68
43.59
N
N
S
2q
CDCl3, 75 MHz
f1 (ppm)

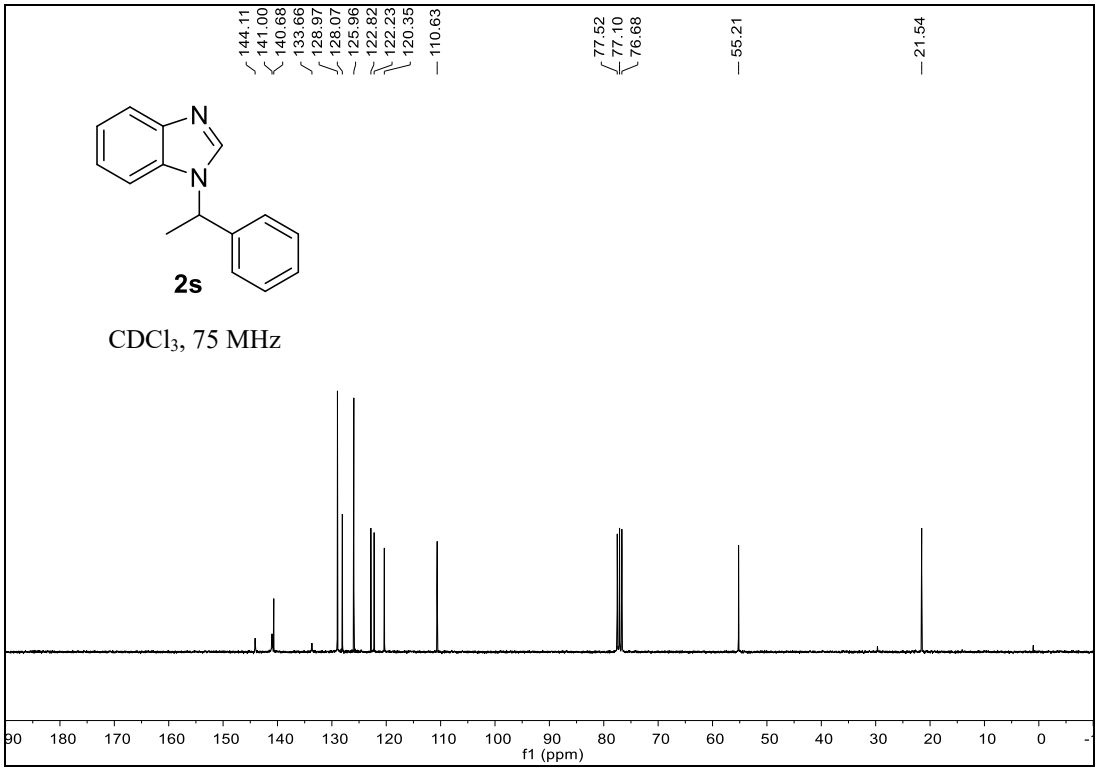


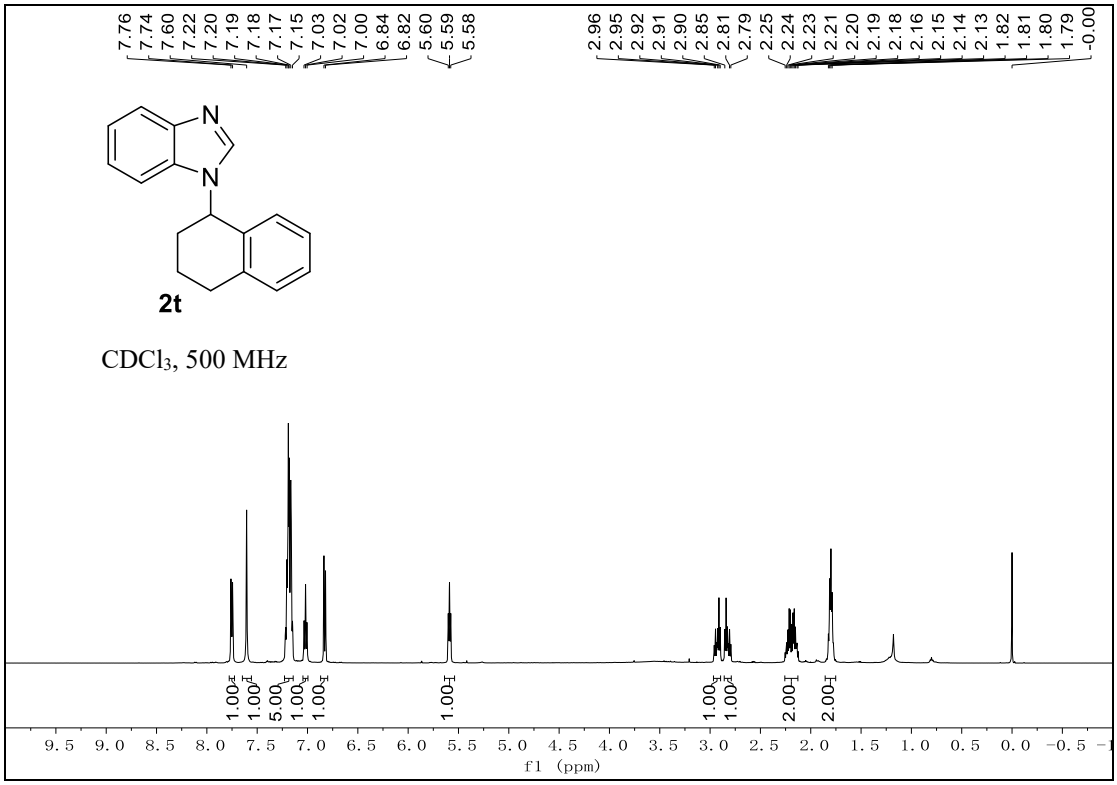
$CDCl_3$, 300 MHz



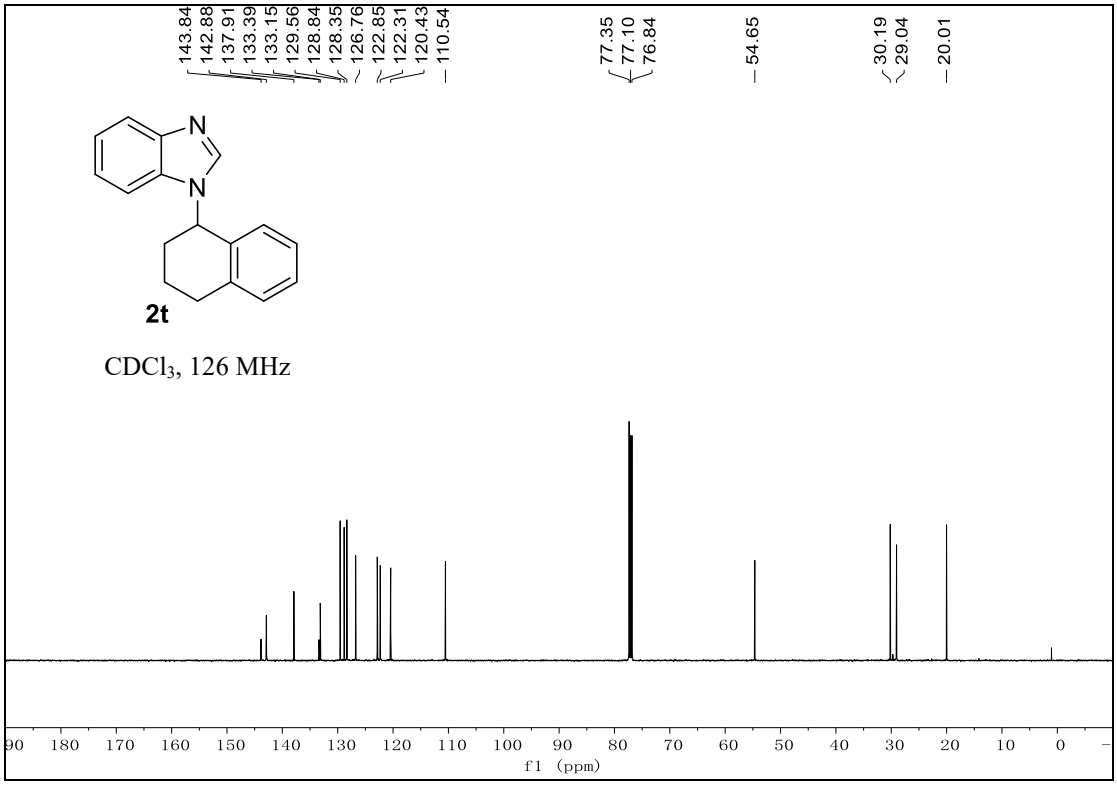
$CDCl_3$, 75 MHz


8.07
7.83
7.80
7.31
7.28
7.27
7.26
7.25
7.23
7.22
7.21
7.19
7.18
7.17
7.15
5.62
5.60
5.57
5.55
1.97
1.95
0.00
N
N
2s
CDCl3, 300 MHz
1.00
1.00
8.35
1.00
3.00
f1 (ppm)

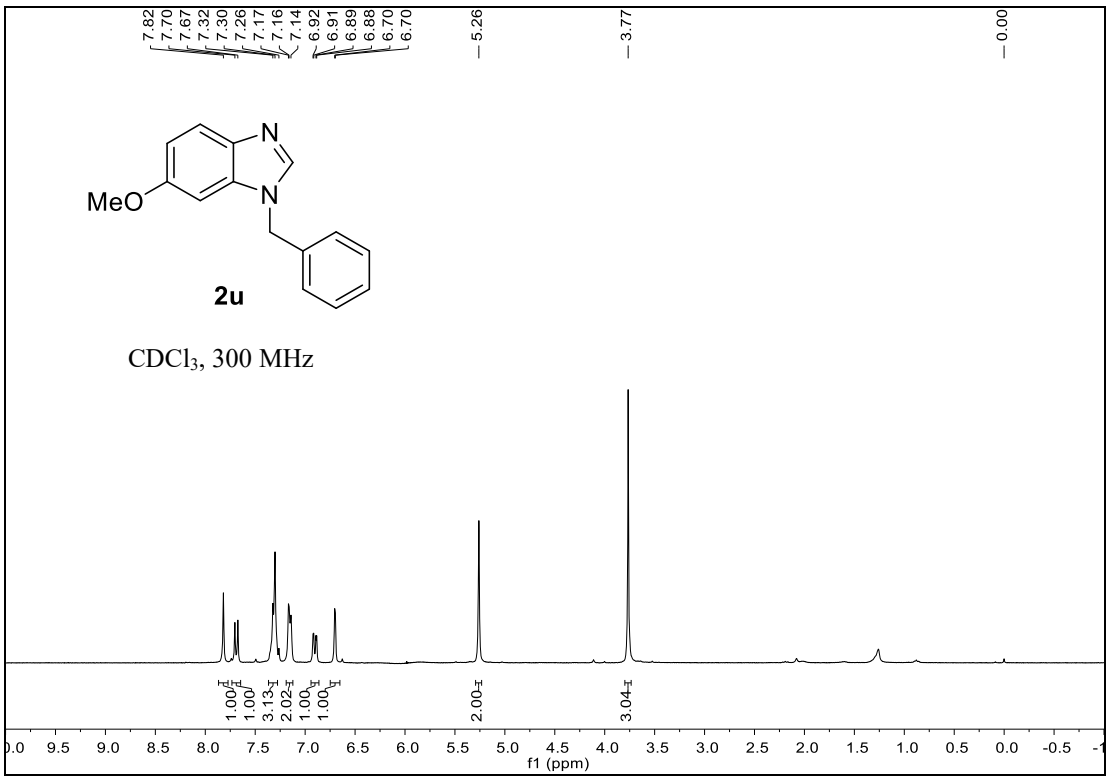

144.11
141.00
140.68
133.66
128.97
128.07
125.96
122.82
122.23
120.35
110.63
77.52
77.10
76.68
55.21
21.54
N
N
2s
CDCl3, 75 MHz
f1 (ppm)

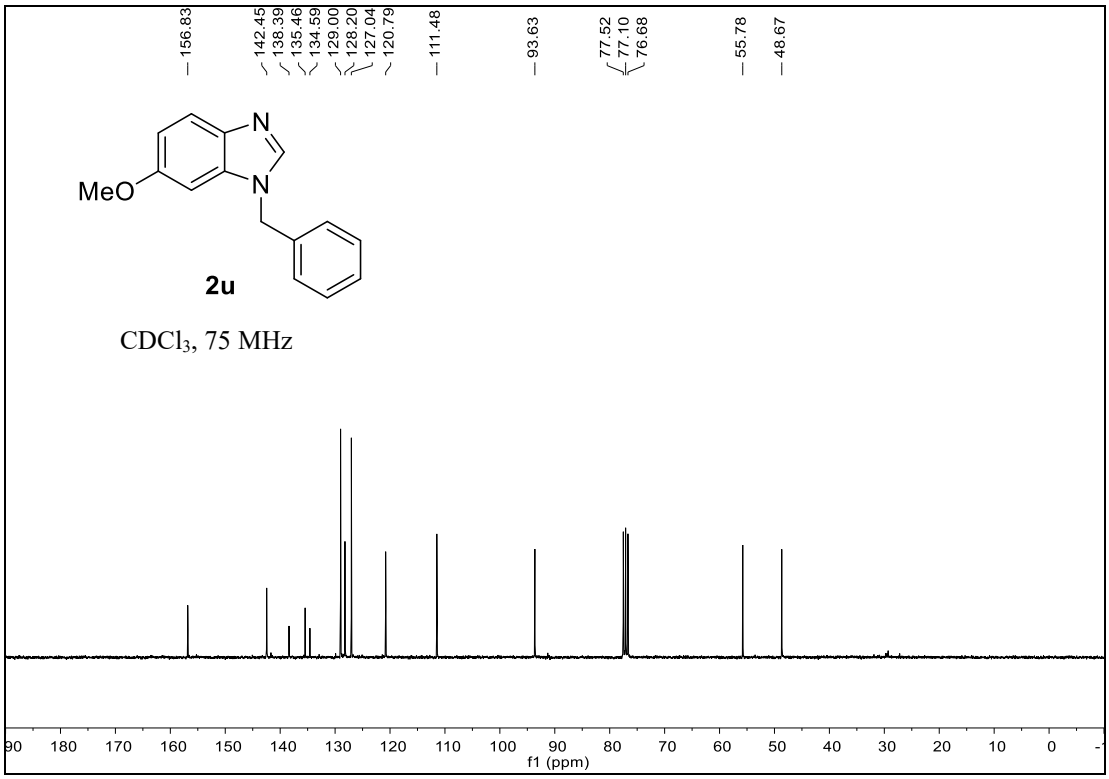


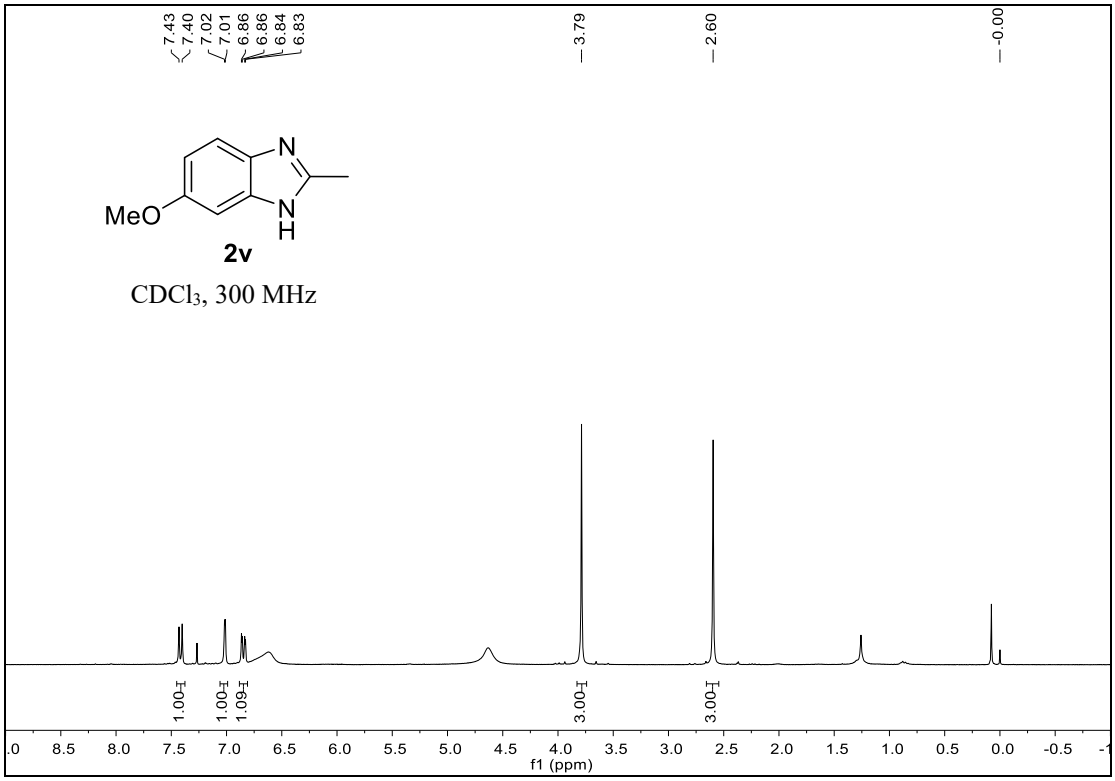
$CDCl_3$, 500 MHz



$CDCl_3$, 126 MHz

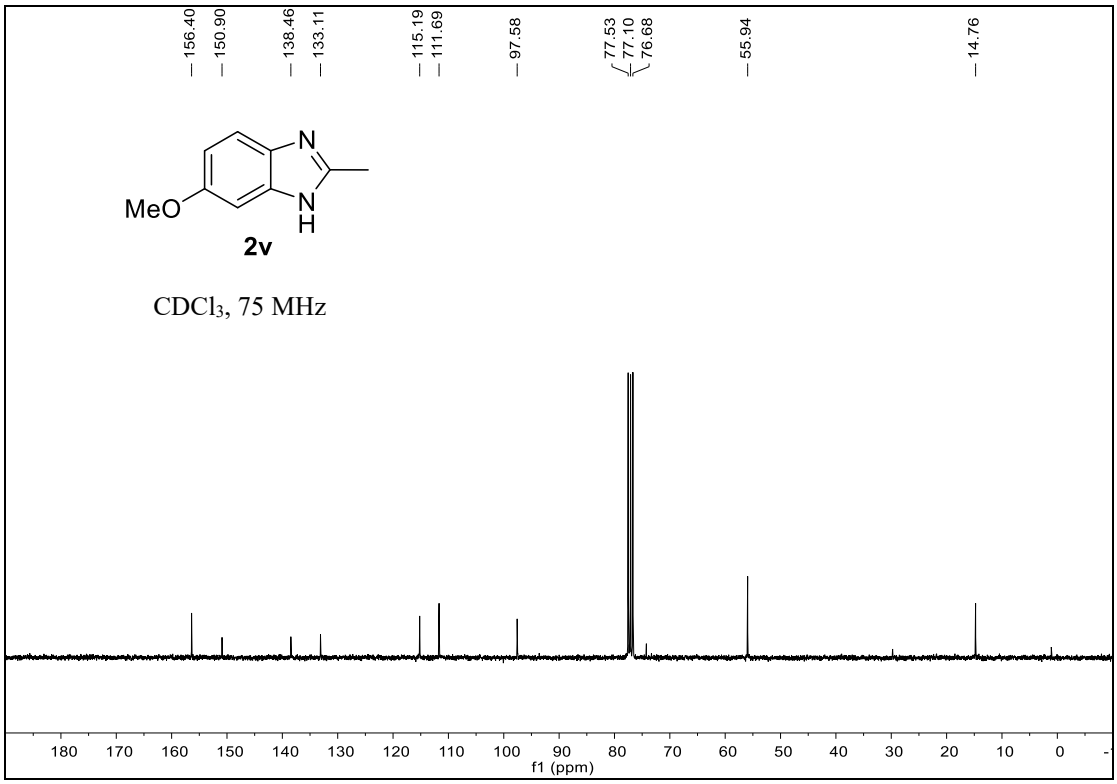

7.82
7.70
7.67
7.32
7.30
7.26
7.17
7.16
7.14
6.92
6.91
6.89
6.88
6.70
6.70
5.26
3.77
0.00
N
N
MeO
2u
CDCl3, 300 MHz
1.00
1.00
3.13
2.02
1.00
1.00
2.00
3.04
f1 (ppm)


156.83
142.45
138.39
135.46
134.59
129.00
128.20
127.04
120.79
111.48
93.63
77.52
77.10
76.68
55.78
48.67
N
N
MeO
2u
CDCl3, 75 MHz
f1 (ppm)



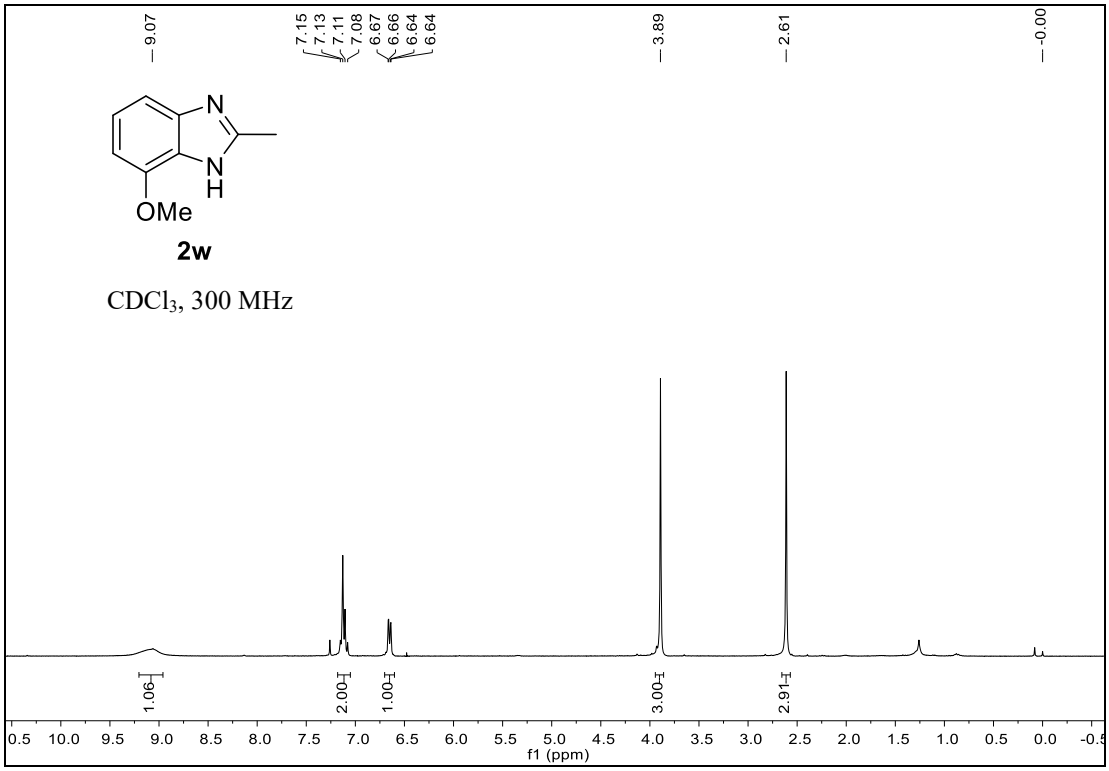
2v

$CDCl_3$, 300 MHz



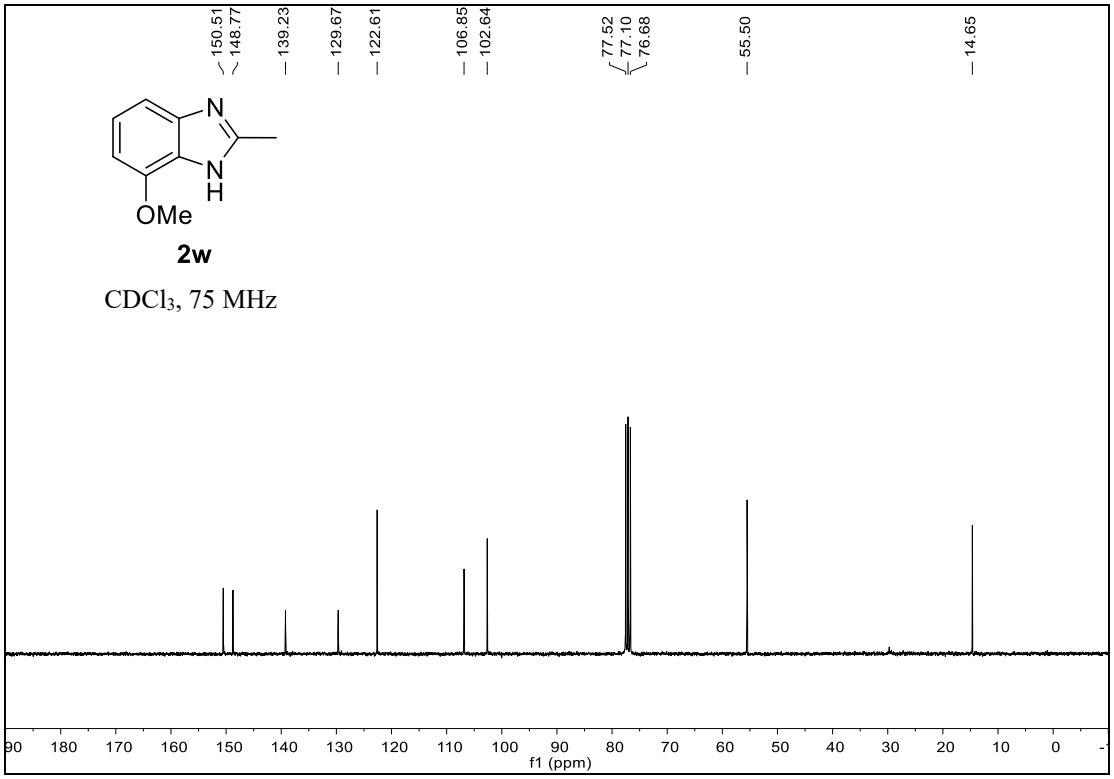
2v

$CDCl_3$, 75 MHz



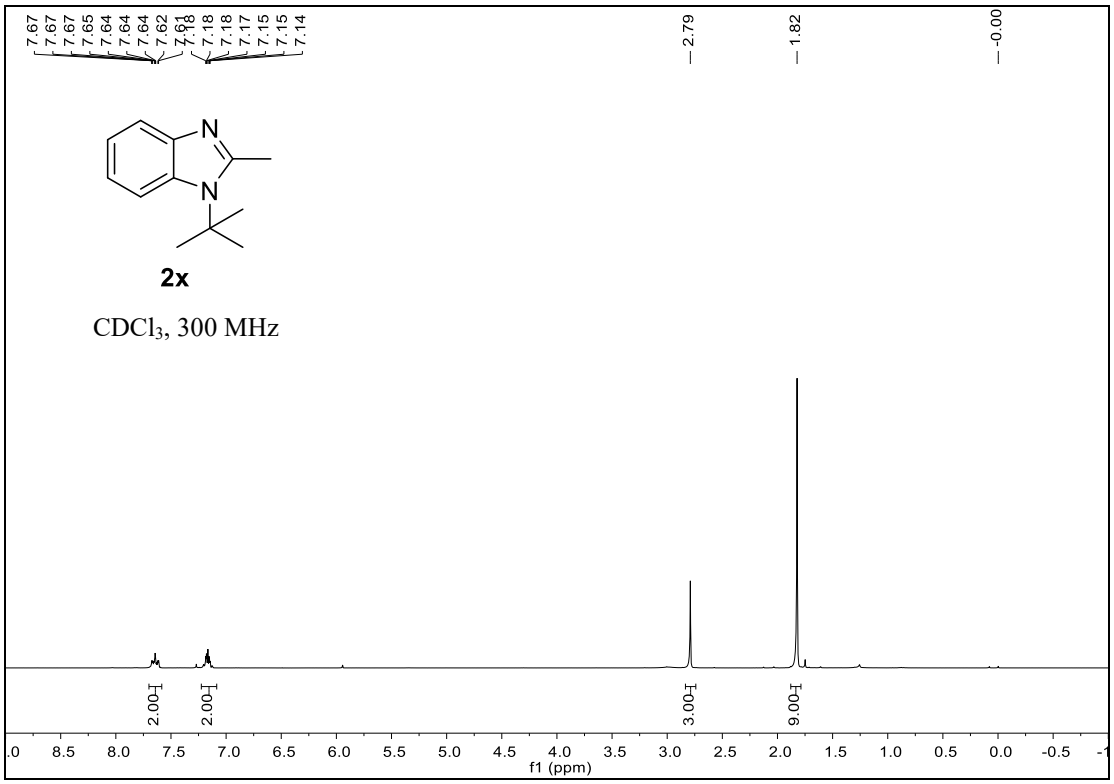
2w

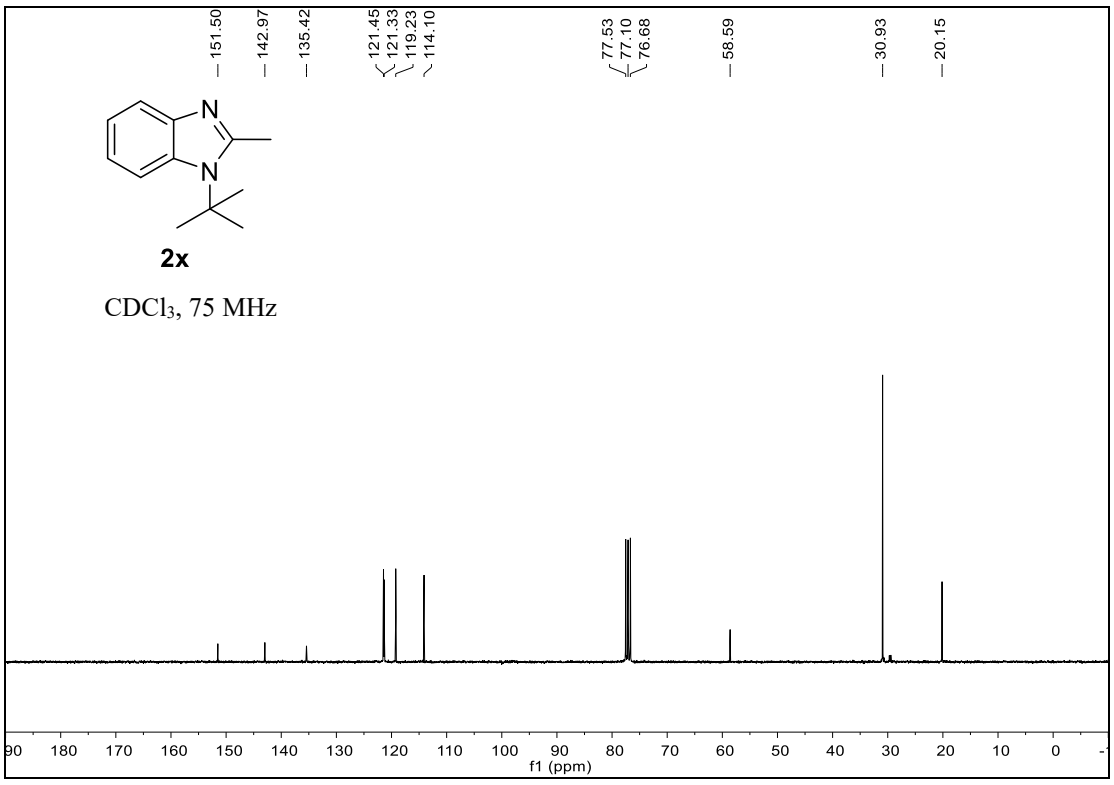
$CDCl_3$, 300 MHz

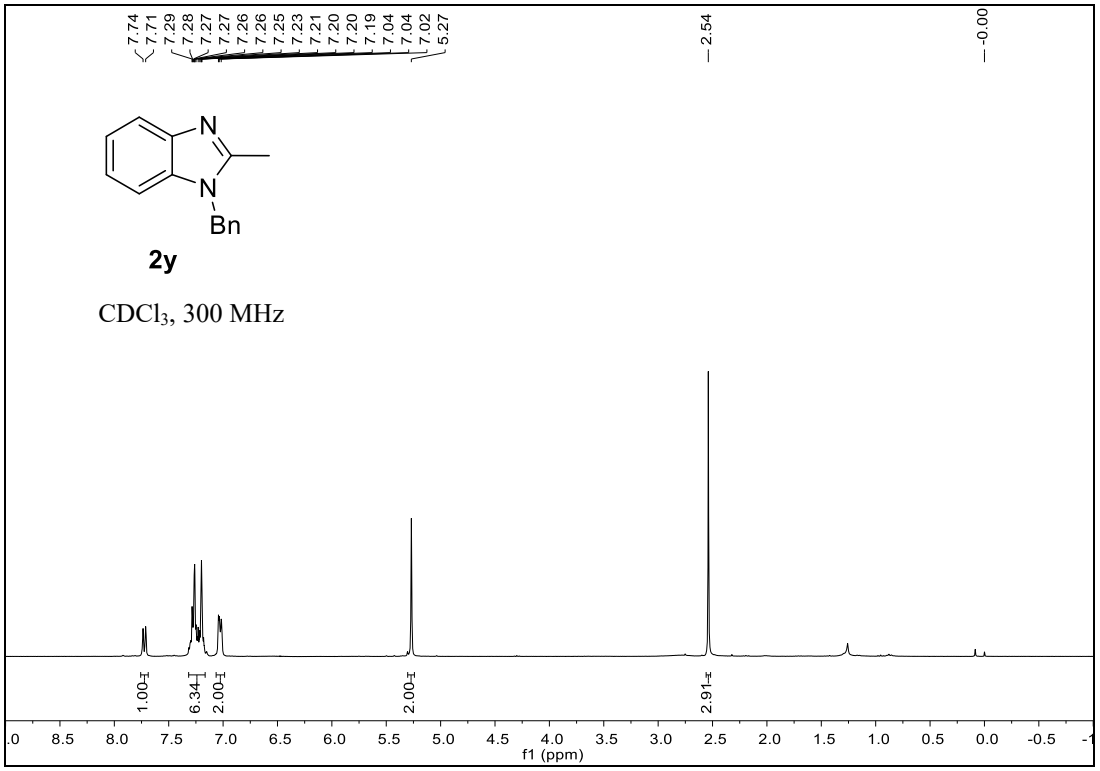


2w

$CDCl_3$, 75 MHz

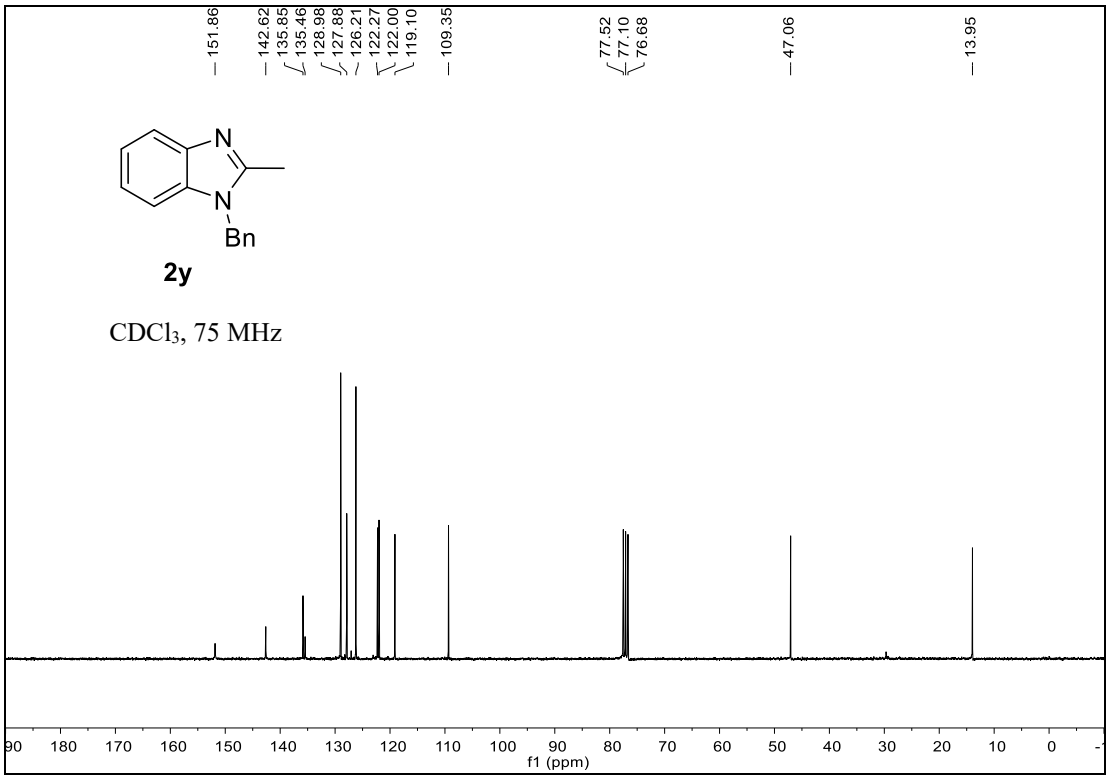

7.67
7.67
7.67
7.65
7.64
7.64
7.64
7.62
7.61
7.18
7.18
7.17
7.15
7.15
7.14
2.79
1.82
0.00
N
N
2x
CDCl3, 300 MHz
2.00
2.00
3.00
9.00
f1 (ppm)


151.50
142.97
135.42
121.45
121.33
119.23
114.10
77.53
77.10
76.68
58.59
30.93
20.15
N
N
2x
CDCl3, 75 MHz
f1 (ppm)



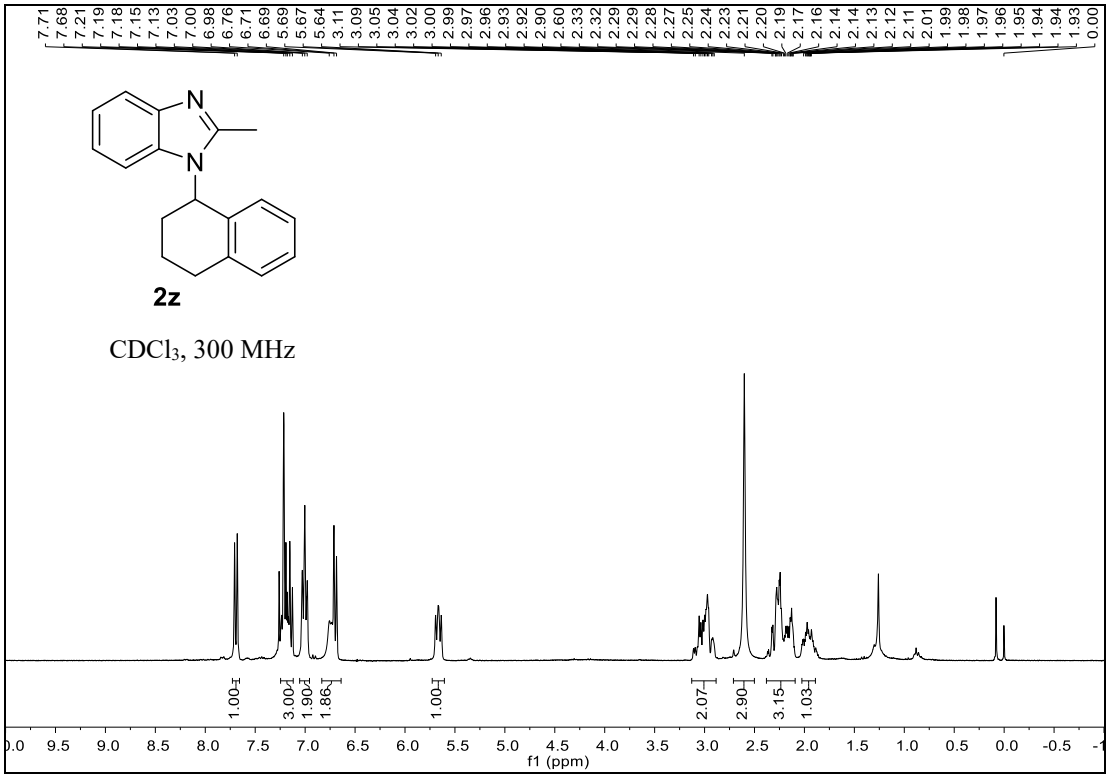
2y

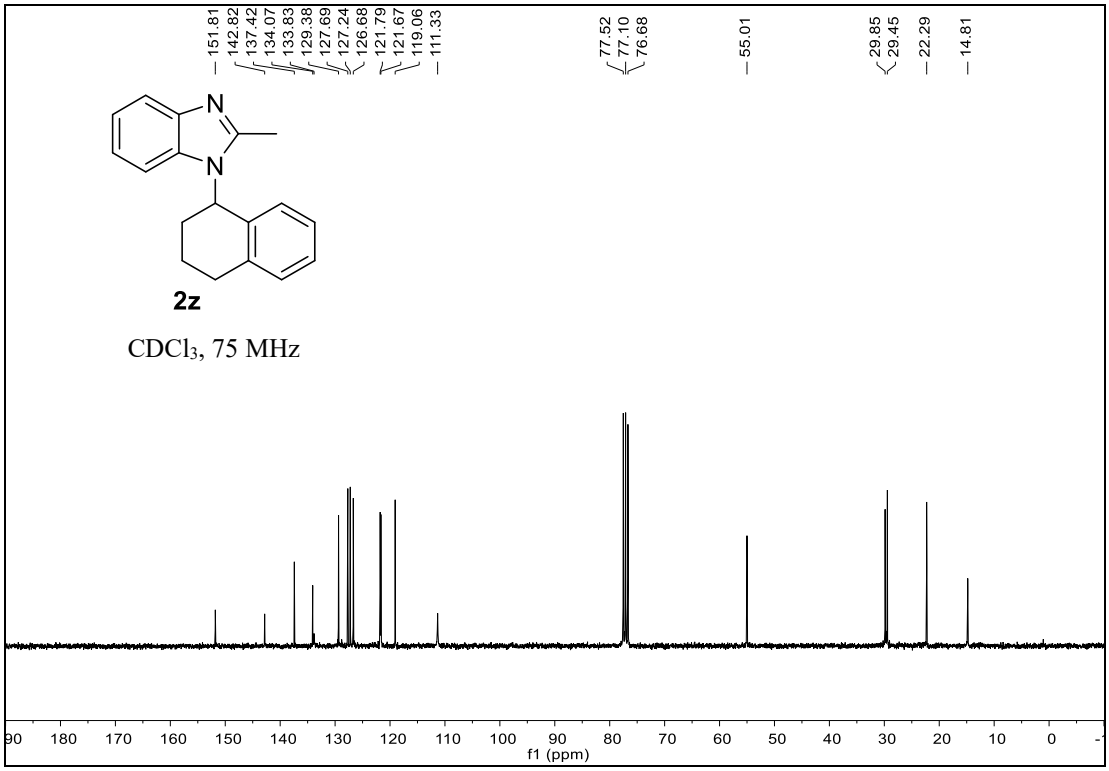
$CDCl_3$, 300 MHz

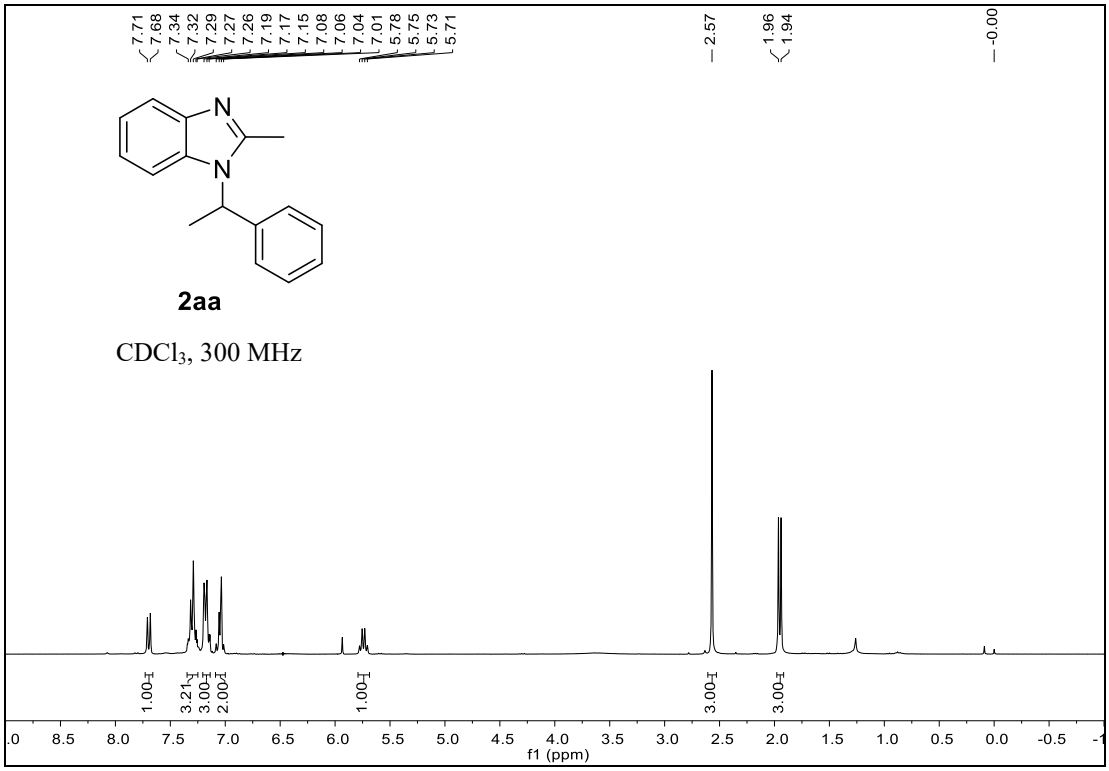


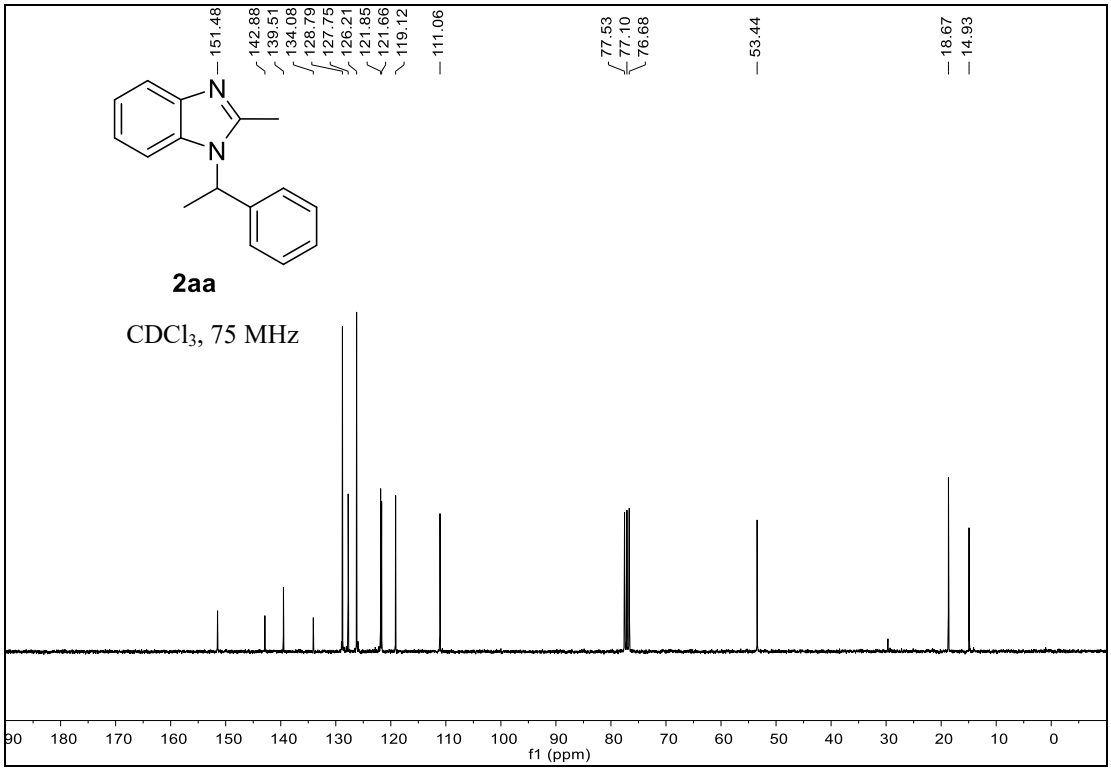
2y

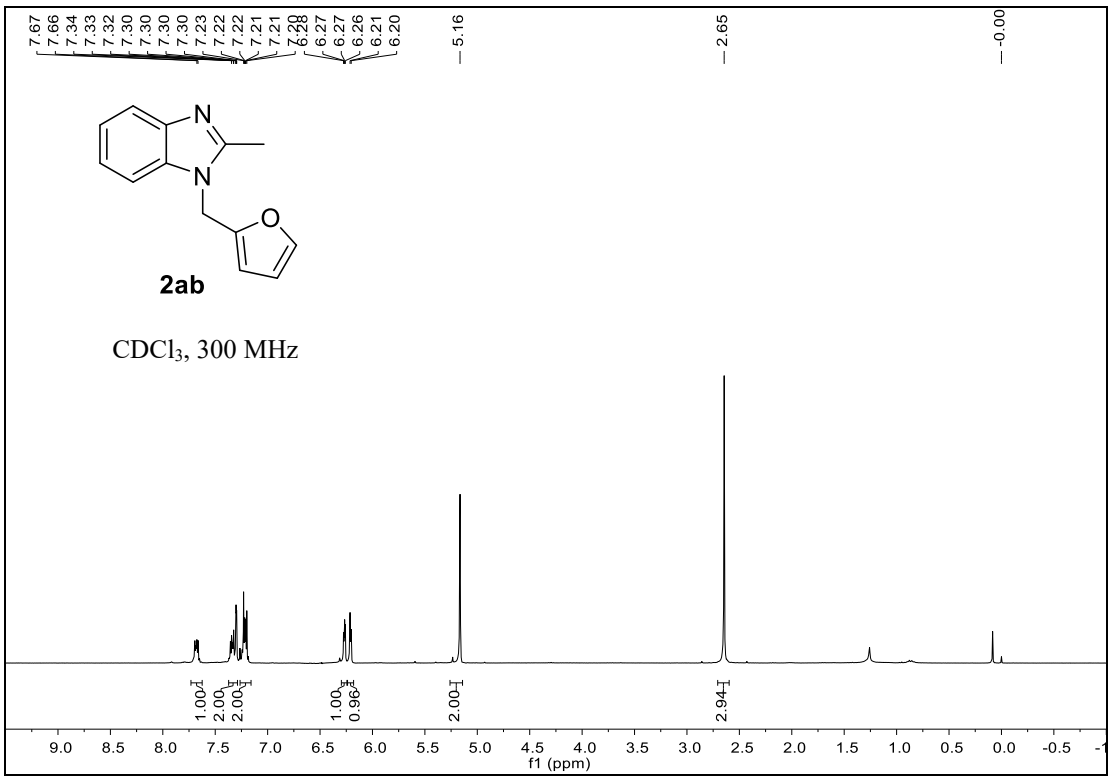
$CDCl_3$, 75 MHz

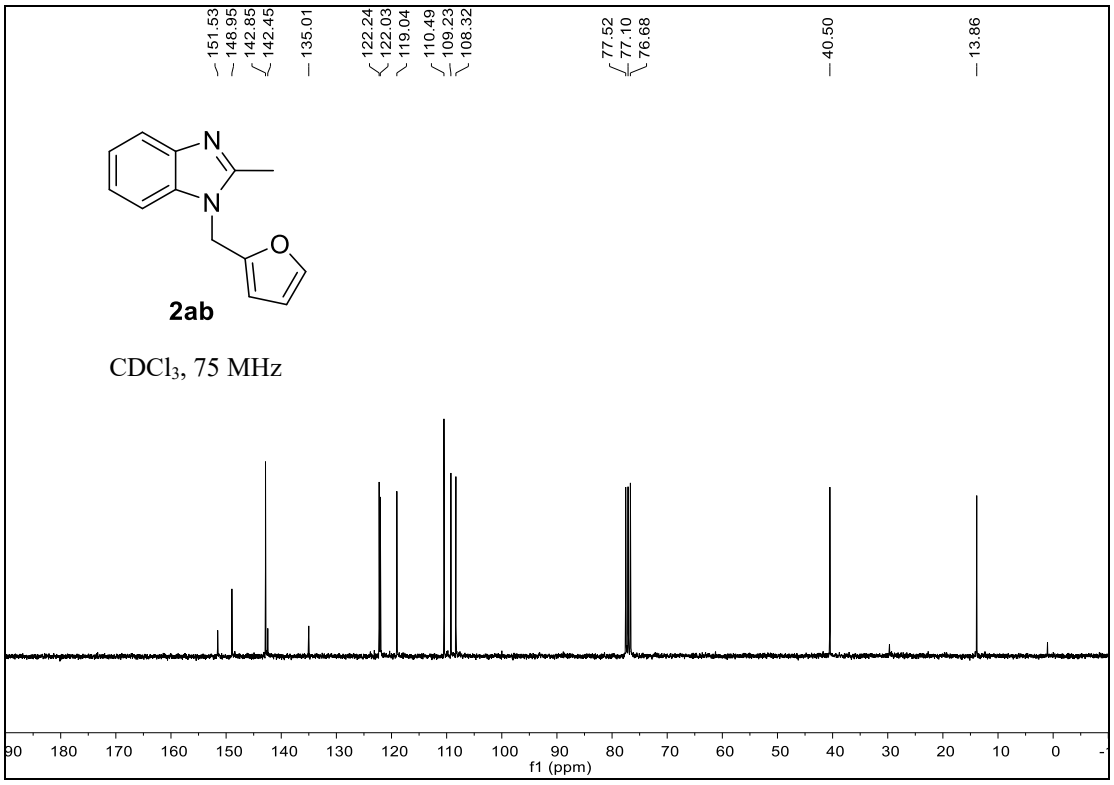

7.71 7.68 7.21 7.19 7.18 7.15 7.13 7.03 7.00 6.98 6.76 6.71 6.69 5.69 5.67 5.64 3.11 3.09 3.05 3.04 3.02 3.00 2.99 2.97 2.96 2.93 2.92 2.90 2.60 2.33 2.32 2.29 2.29 2.28 2.27 2.25 2.24 2.23 2.21 2.20 2.19 2.17 2.16 2.14 2.14 2.13 2.12 2.11 2.01 1.99 1.98 1.97 1.96 1.95 1.94 1.94 1.93 0.00
N
N
2z
CDCl3, 300 MHz
1.00 3.00 1.90 1.86 1.00 2.07 2.90 3.15 1.03
f1 (ppm)

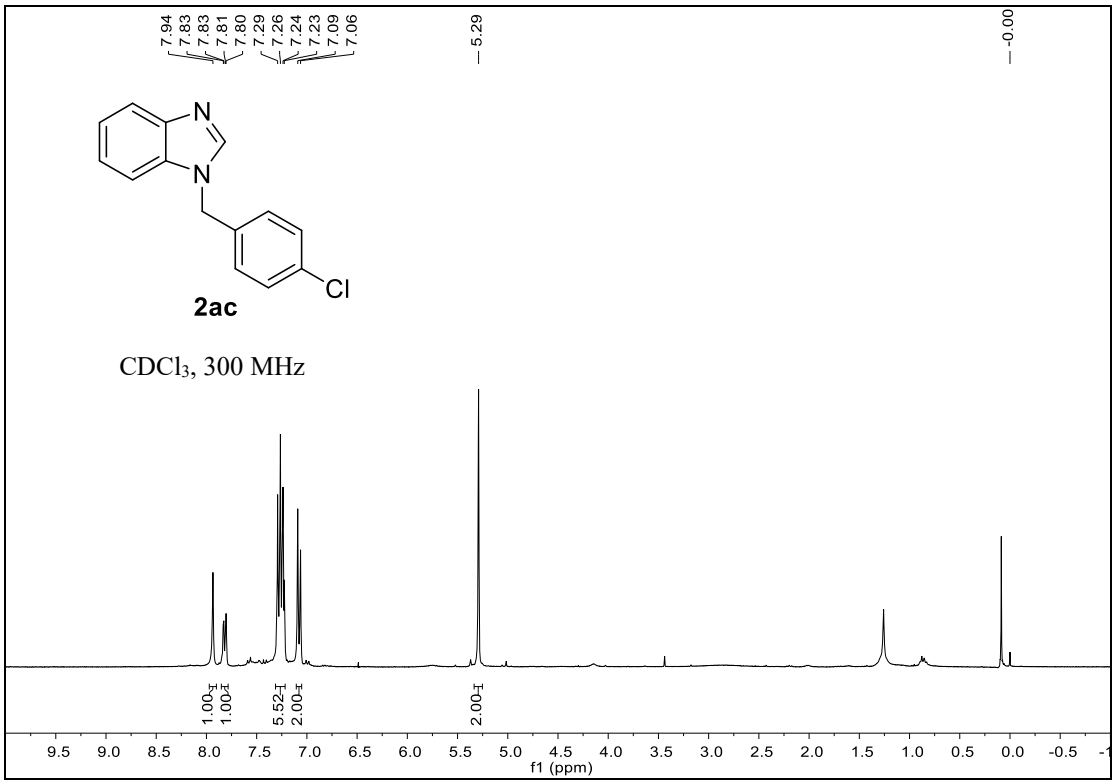

151.81 142.82 137.42 134.07 133.83 129.38 127.69 127.24 126.68 121.79 121.67 119.06 111.33
77.52 77.10 76.68
55.01
29.85 29.45 22.29 14.81
N
N
2z
CDCl3, 75 MHz
f1 (ppm)

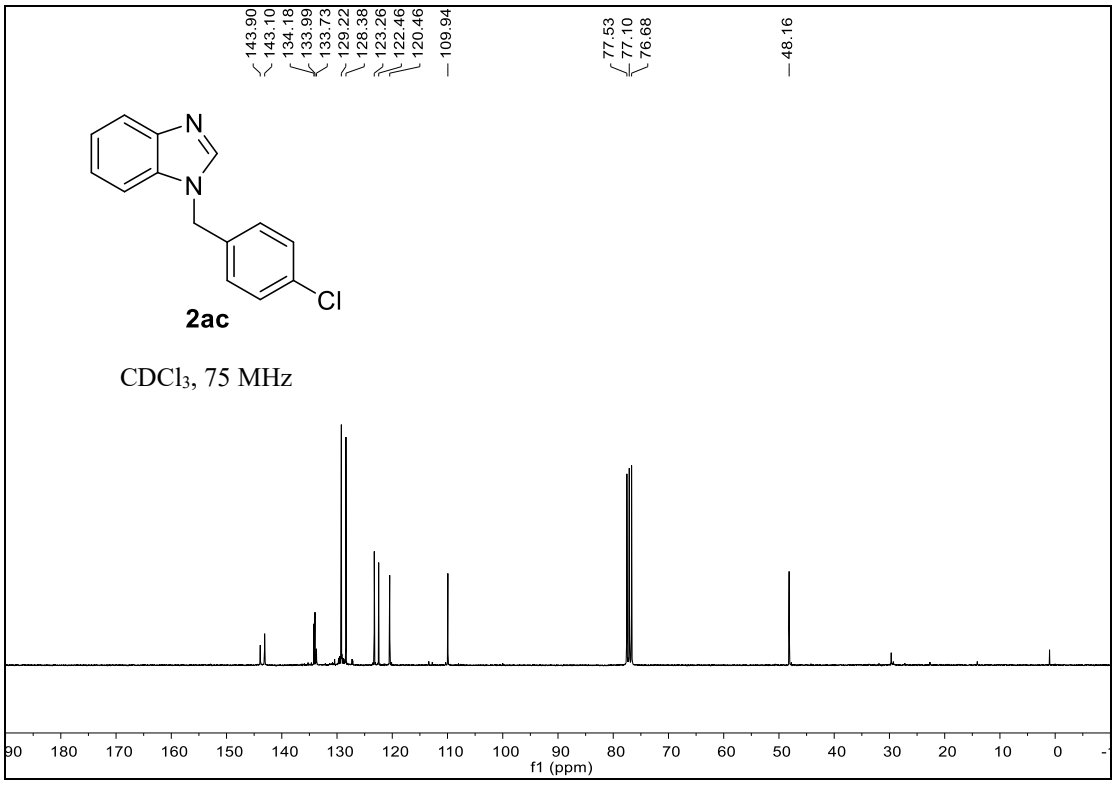

7.71
7.68
7.34
7.32
7.29
7.27
7.26
7.19
7.17
7.15
7.08
7.06
7.04
7.01
5.78
5.75
5.73
5.71
2.57
1.96
1.94
-0.00
N
N
2aa
CDCl3, 300 MHz
1.00
3.21
3.00
2.00
1.00
3.00
3.00
f1 (ppm)

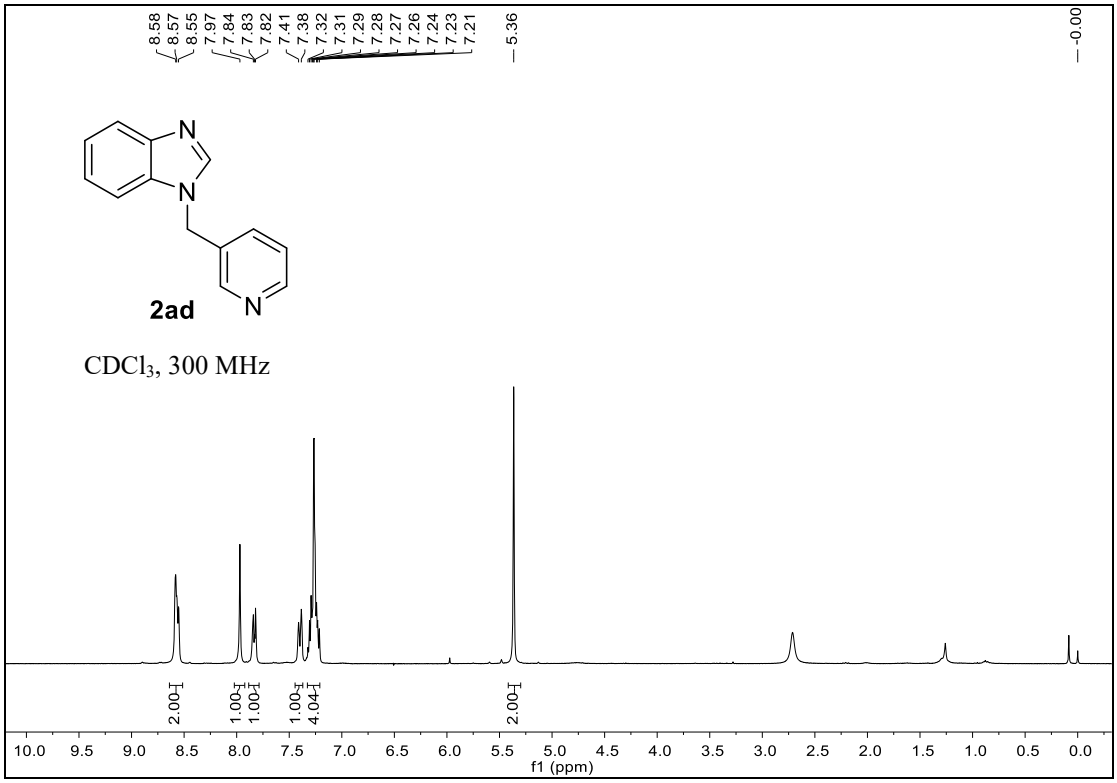

151.48
142.88
139.51
134.08
128.79
127.75
126.21
121.85
121.66
119.12
111.06
77.53
77.10
76.68
53.44
18.67
14.93
N
N
2aa
CDCl3, 75 MHz
f1 (ppm)

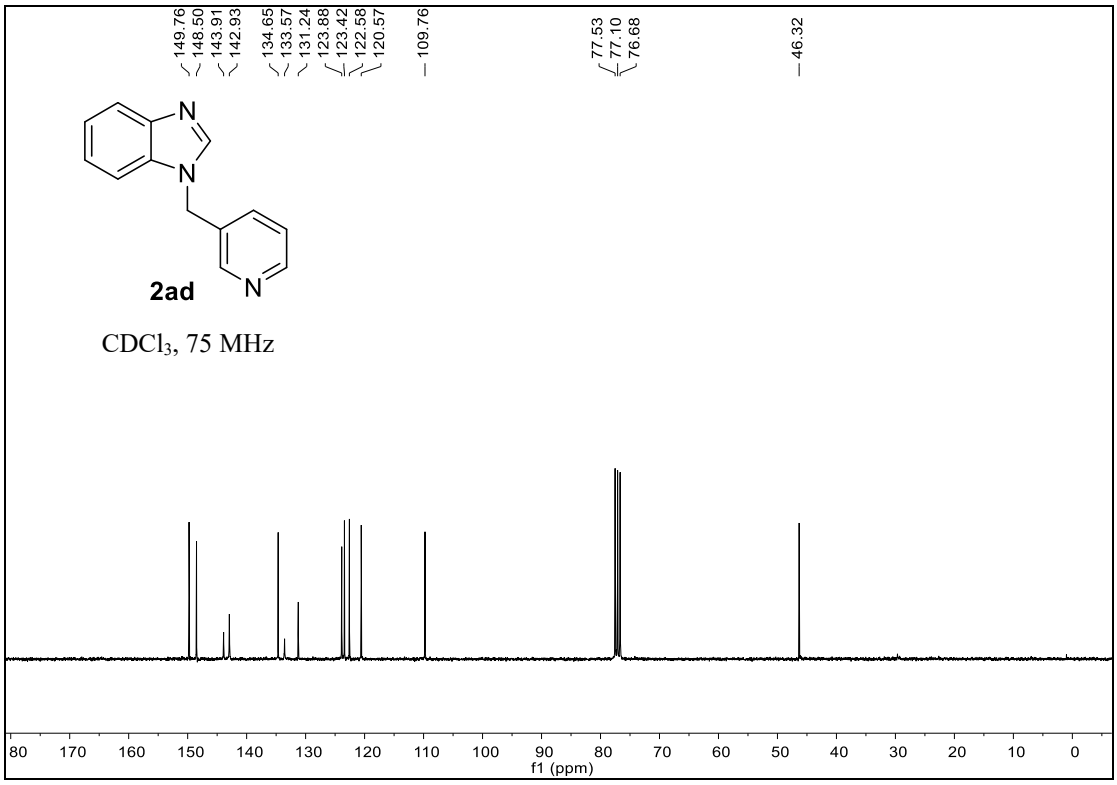

7.67
7.66
7.34
7.33
7.32
7.30
7.30
7.30
7.30
7.23
7.22
7.22
7.21
7.21
7.20
6.28
6.27
6.27
6.26
6.21
6.20
5.16
2.65
-0.00
N
N
O
2ab
CDCl3, 300 MHz
1.00
2.00
2.00
1.00
0.96
2.00
2.94
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

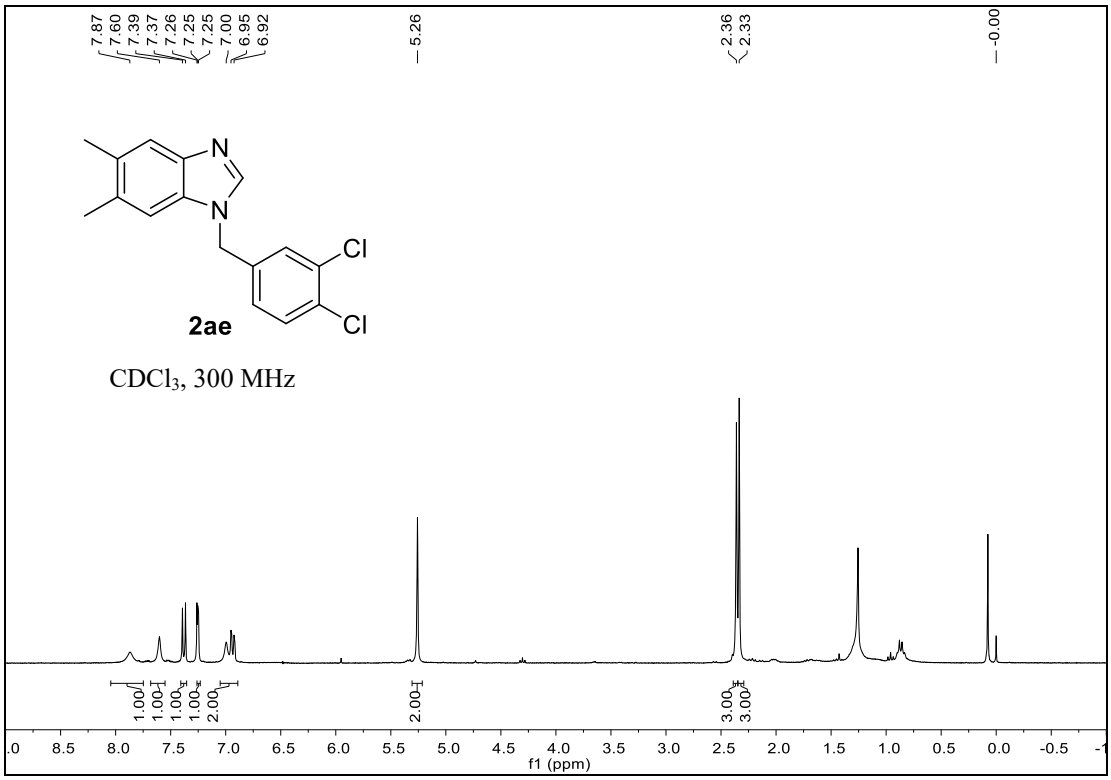

151.53
148.95
142.85
142.45
135.01
122.24
122.03
119.04
110.49
109.23
108.32
77.52
77.10
76.68
40.50
13.86
N
N
O
2ab
CDCl3, 75 MHz
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

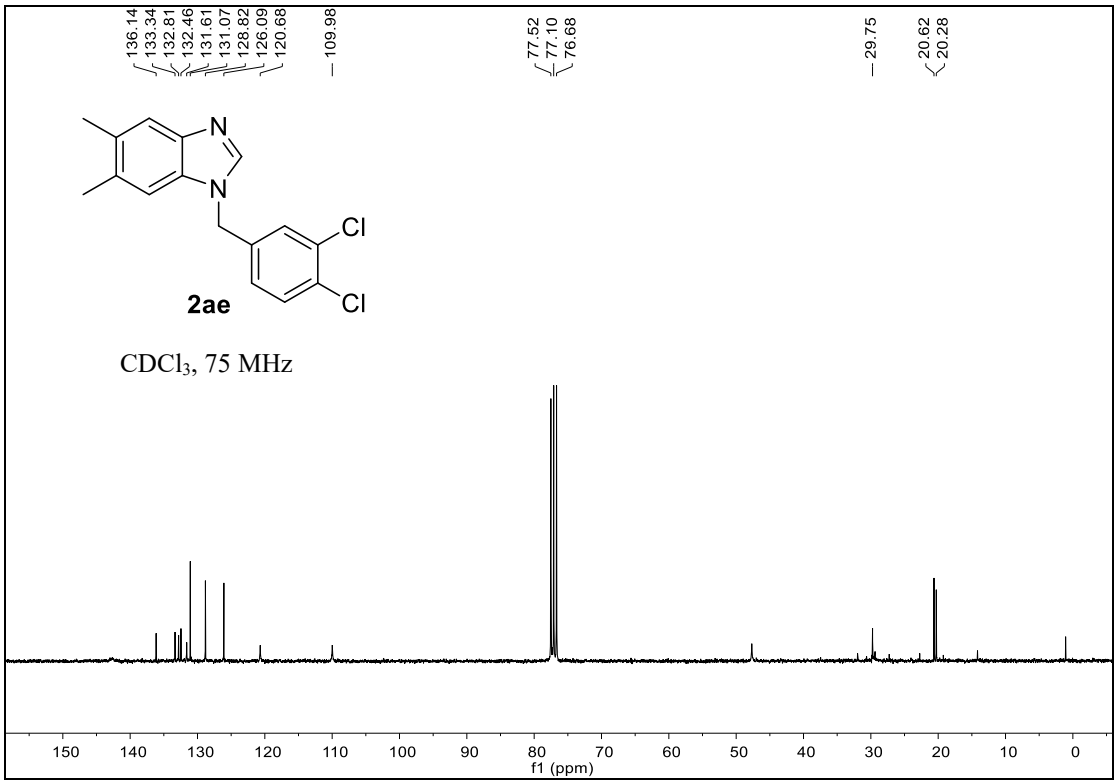

7.94
7.83
7.83
7.81
7.80
7.29
7.26
7.24
7.23
7.09
7.06
5.29
-0.00
N
N
Cl
2ac
CDCl3, 300 MHz
1.00
1.00
5.52
2.00
2.00
f1 (ppm)

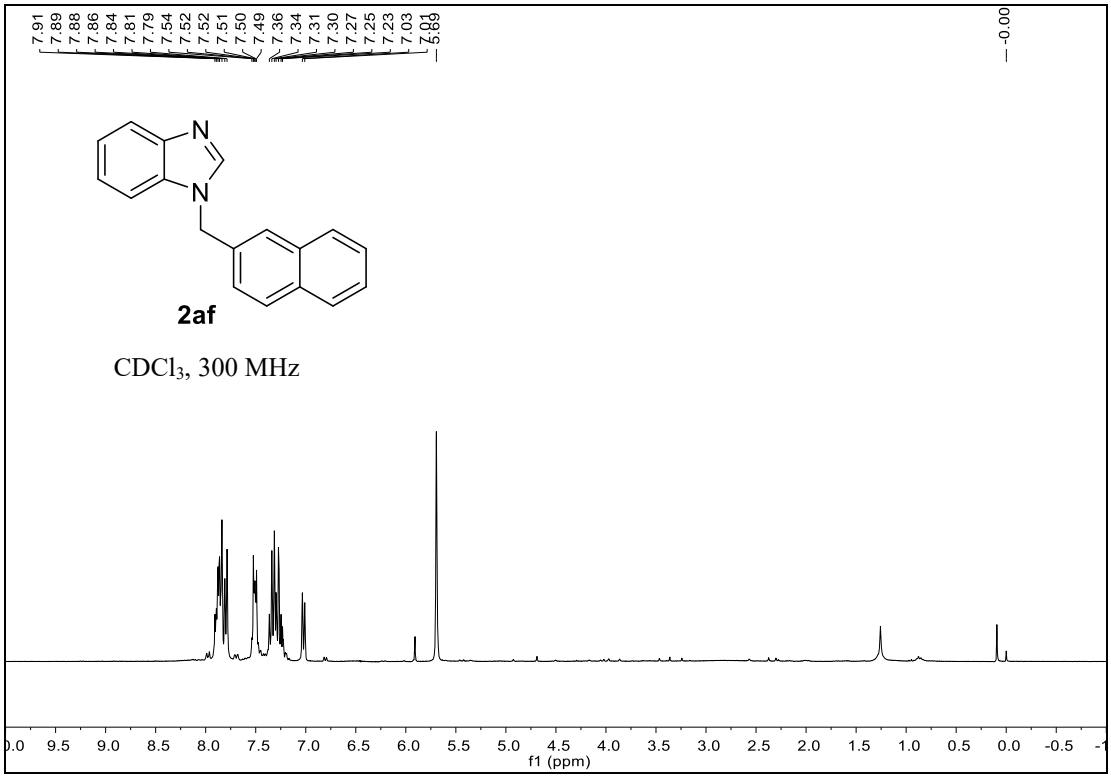

143.90
143.10
134.18
133.99
133.73
129.22
128.38
123.26
122.46
120.46
109.94
77.53
77.10
76.68
48.16
N
N
Cl
2ac
CDCl3, 75 MHz
f1 (ppm)


8.58
8.57
8.55
7.97
7.84
7.83
7.82
7.41
7.38
7.32
7.31
7.29
7.28
7.27
7.26
7.24
7.23
7.21
5.36
-0.00
N
N
N
2ad
CDCl3, 300 MHz
2.00
1.00
1.00
1.00
4.04
2.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

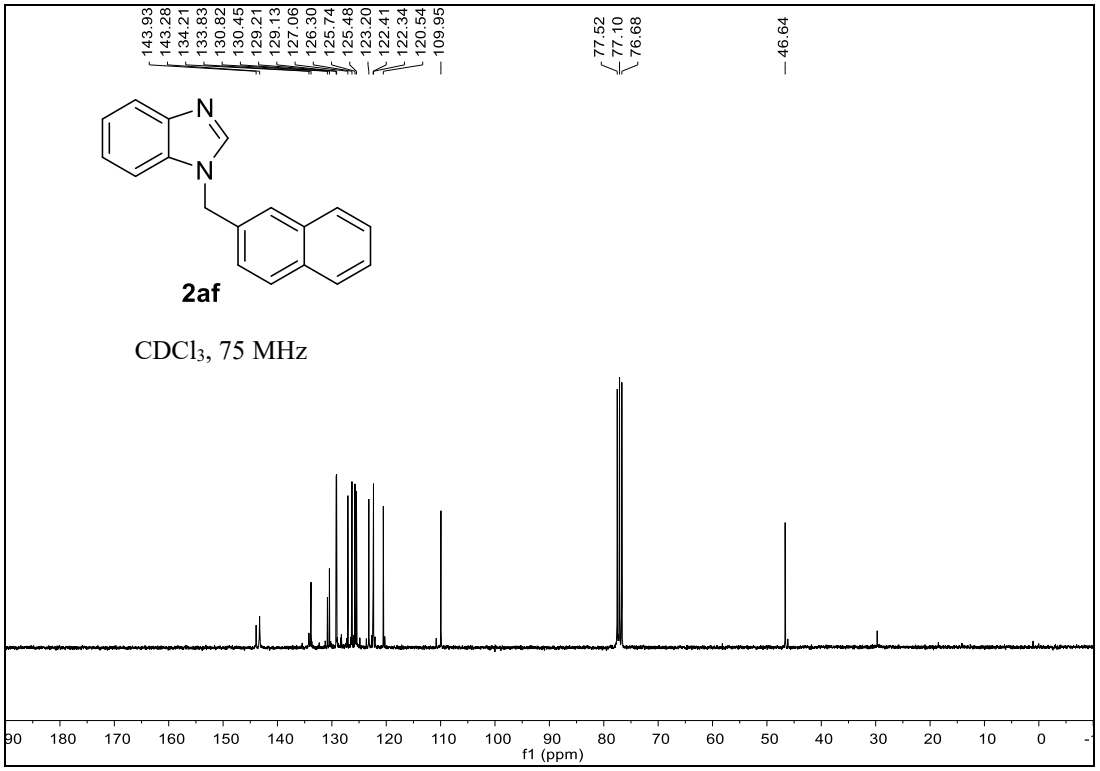

149.76
148.50
143.91
142.93
134.65
133.57
131.24
123.88
123.42
122.58
120.57
109.76
77.53
77.10
76.68
46.32
N
N
N
2ad
CDCl3, 75 MHz
80 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.87
7.60
7.39
7.37
7.26
7.25
7.25
7.00
6.95
6.92
5.26
2.36
2.33
-0.00
N
N
Cl
Cl
2ae
CDCl3, 300 MHz
1.00
1.00
1.00
1.00
2.00
2.00
3.00
3.00
f1 (ppm)

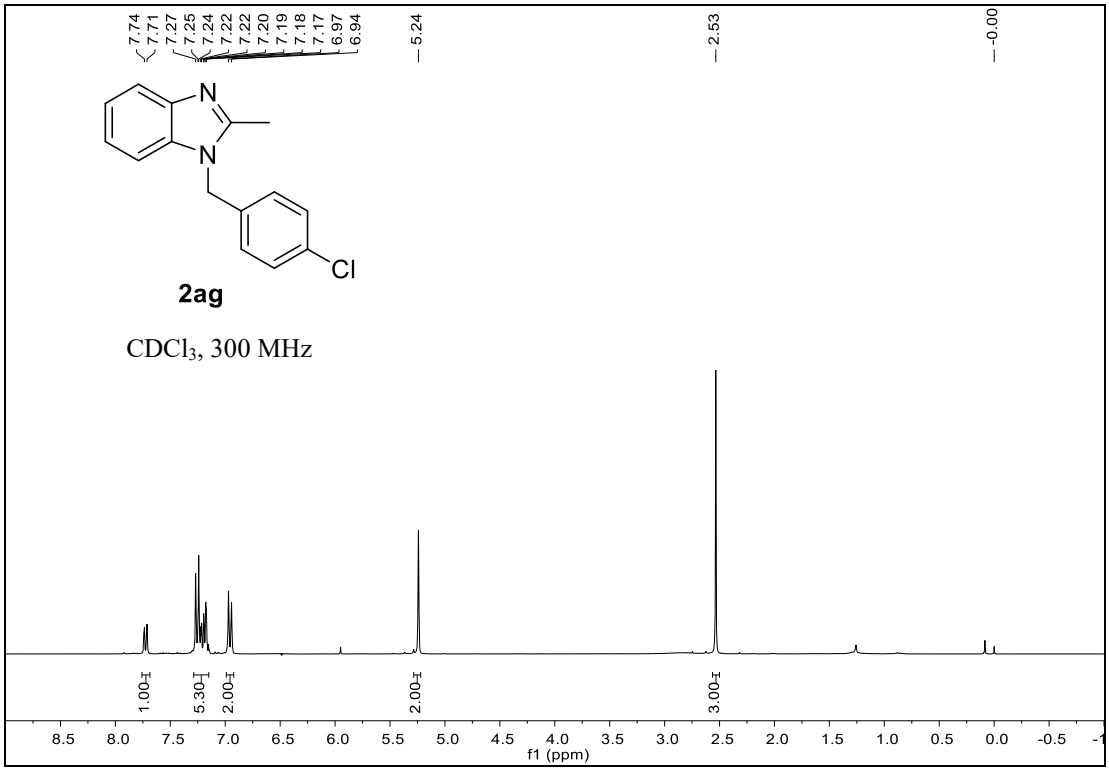

136.14
133.34
132.81
132.46
131.61
131.07
128.82
126.09
120.68
109.98
77.52
77.10
76.68
29.75
20.62
20.28
N
N
Cl
Cl
2ae
CDCl3, 75 MHz
f1 (ppm)



$CDCl_3$, 300 MHz

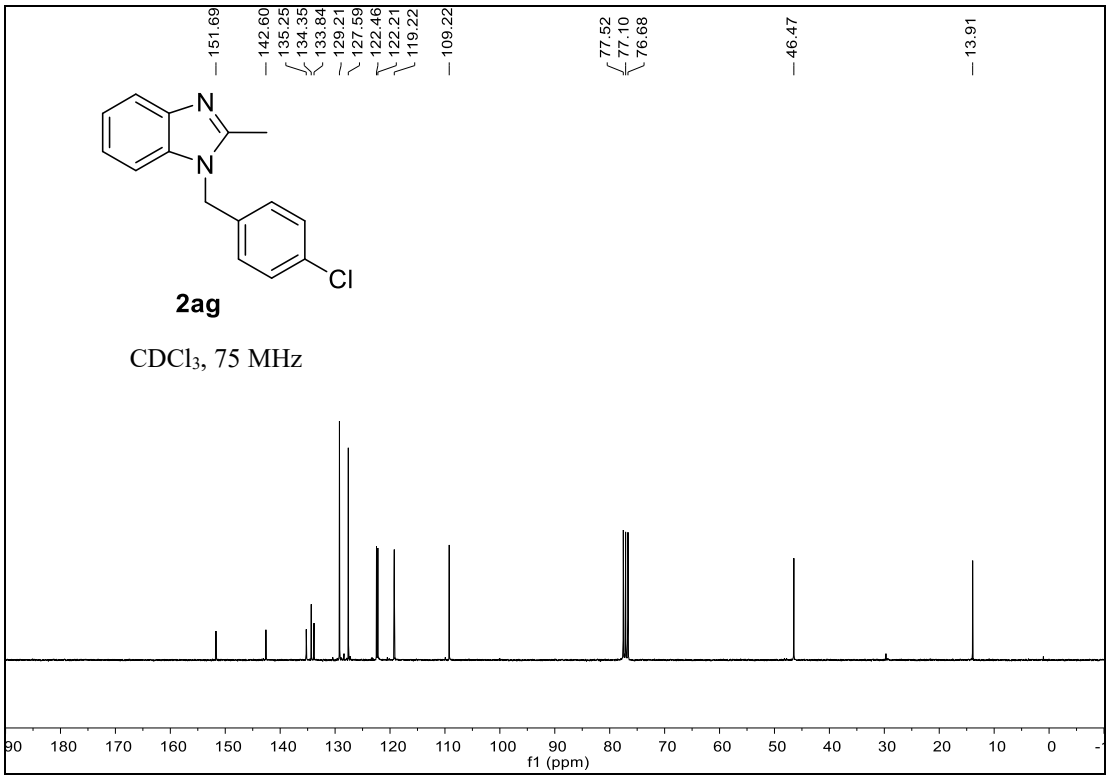


$CDCl_3$, 75 MHz



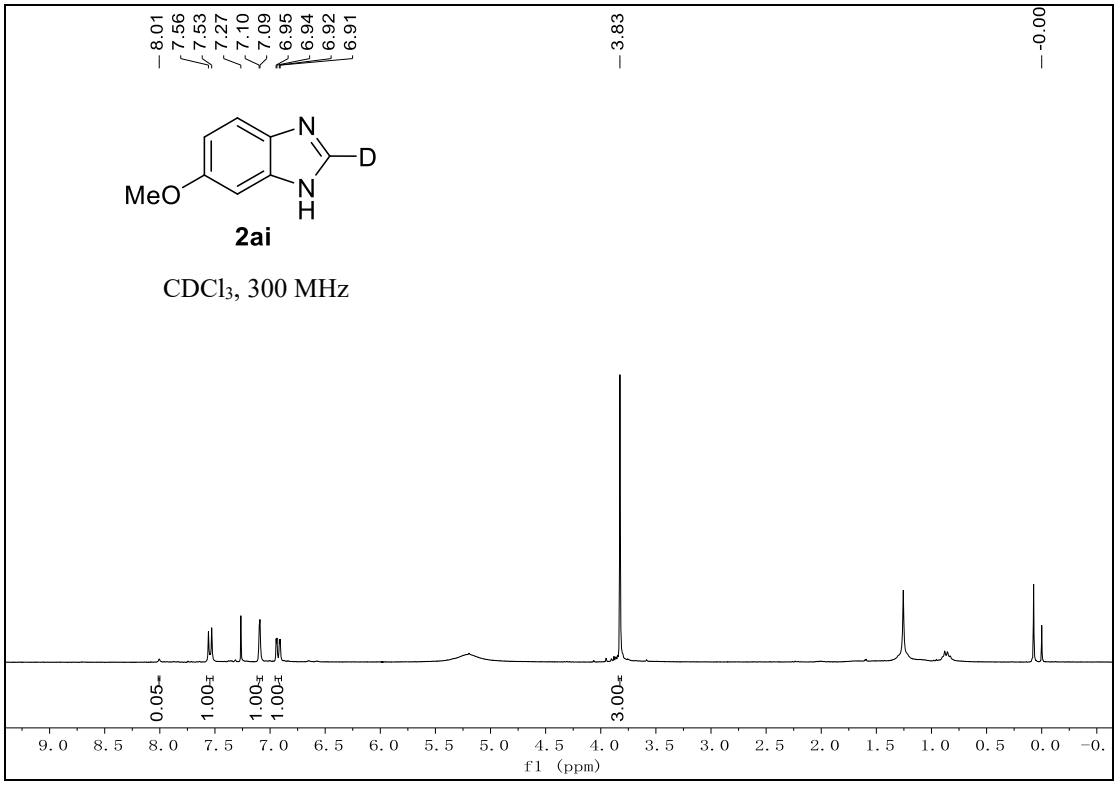
2ag

$CDCl_3$, 300 MHz



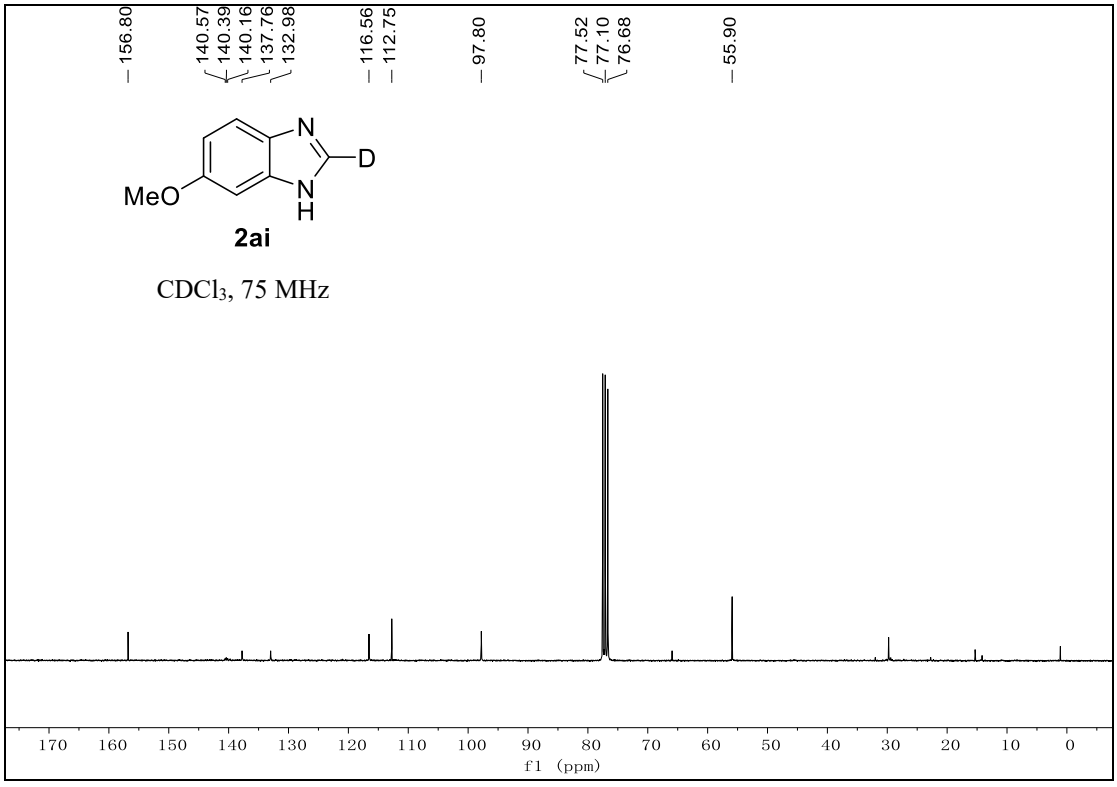
2ag

$CDCl_3$, 75 MHz



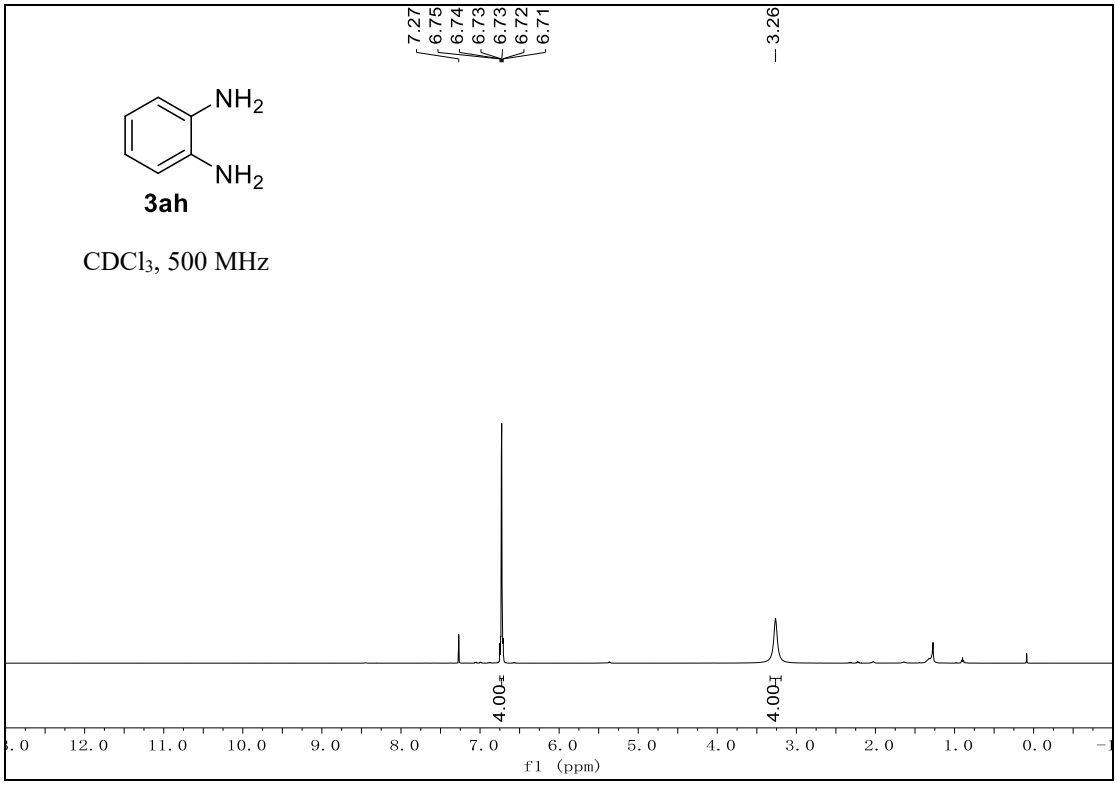
2ai

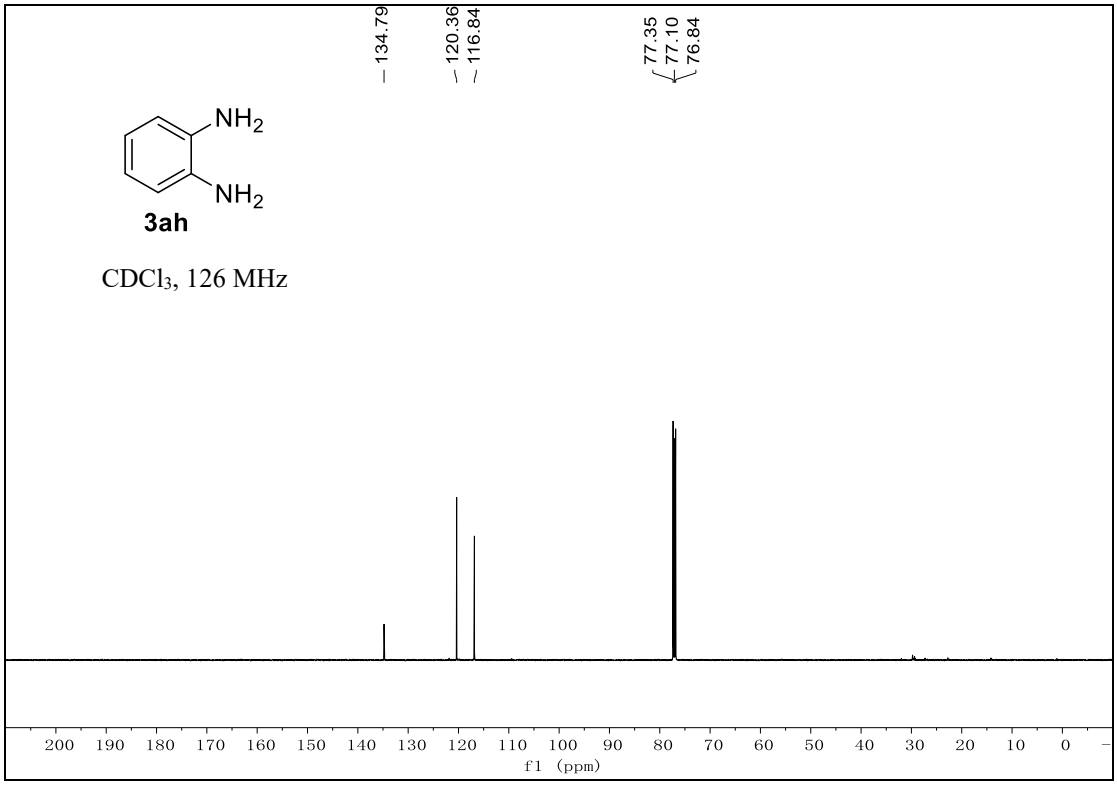
$CDCl_3$, 300 MHz



2ai

$CDCl_3$, 75 MHz


7.27
6.75
6.74
6.73
6.72
6.71
3.26
NH2
NH2
3ah
CDCl3, 500 MHz
4.00
4.00
f1 (ppm)


134.79
120.36
116.84
77.35
77.10
76.84
NH2
NH2
3ah
CDCl3, 126 MHz
f1 (ppm)