Electronic Supplementary Material (ESI) for RSC Advances.


Supporting Information

# Green Approach for the Fabrication of a Ternary Nanocatalyst (Ag-ZnONPs@Cy) for Visible Light-induced Photocatalytic Reduction of Nitroarenes to Aminoarenes

Dana A. Kader [a,b,*]

[a]Department of Chemistry, College of Education, University of Sulaimani, Old Campus, 46001, Kurdistan Region, Iraq.
[b]Pharmacy Department, Komar University of Science and Technology, Sulaimani 46001, Kurdistan Region, Iraq

[*]**Corresponding author:** Dana A. Kader, Department of Chemistry, College of Education, University of Sulaimani, Old Campus, 46001, Kurdistan Region, Iraq. e-mail address: dana.kader@univsul.edu.iq

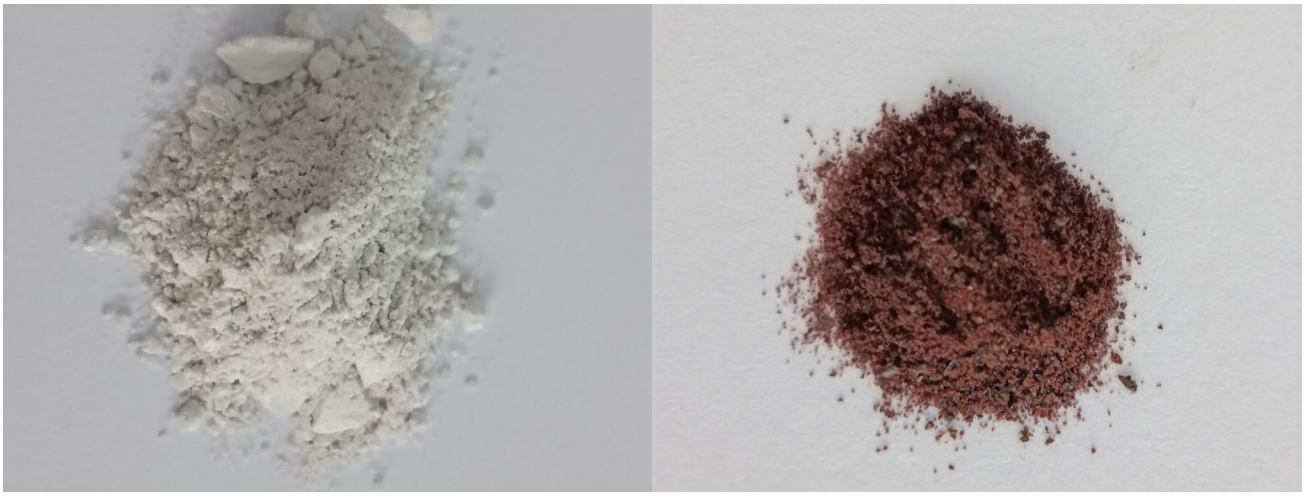
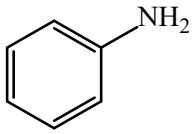


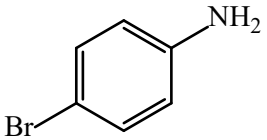
**Figure S1**: The powder form of Ag-ZnONPs (white) and Ag-ZnONPs@Cy (reddish-brown), respectively

# Analytical data, $^{1}$H-NMR and $^{13}$C-NMR spectra

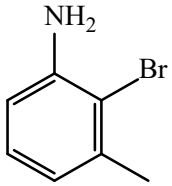
**Aniline (1b):** Pale Brown liquid (91 mg, 98%). $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.18 (t, *J*= 7.2 Hz, 2 H), 6.63 (t, *J*= 7.2 Hz, 1 H), 6.45 (d, *J*=7.4 Hz, 2H), 3.44 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 115.5, 118.3, 129.4, 146.4.



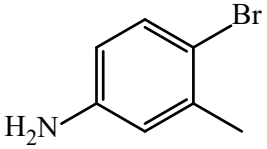

**4-bromoaniline (2b):** Brown solid (165 mg, 96%). Melting point = 57-60 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.22 (d, *J*=8.4 Hz, 2H), 6.54 (d, *J*=8.4 Hz, 2H), 3.66 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 110.5, 116.5, 132.3, 145.5.



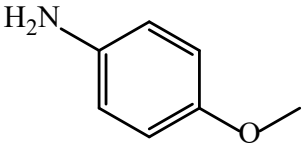

**2-Bromo-3-methylaniline (3b):** brownish-yellow liquid (165 mg, 89%). $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.04 (t, *J*=7.8 Hz, 1H), 6.51-6.64 (m, 2H), 4.43 (br s, *2*H), 2.52 (s, 3H), $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 23.9, 112.0, 113.4, 120.8, 127.6, 138.7, 144.5.



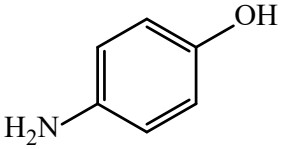

**4-bromo-3-methylaniline (4b):** brown solid (173 mg, 93%). %). Melting point = 79-81 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.19 (d, *J*=10Hz, 1H), 6.66 (s, 1H), 6.32 (d, *J*=10 Hz, 1H), 3.59 (s, 2H), 2.38 (s, $CH_3$, 3H).$^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 22.4, 112.2, 114,5, 117.4, 132,5, 138.1, 145.3.



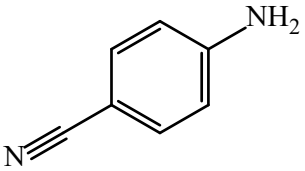

**4-Methoxyaniline (5b):** Grey solid (117 mg, 95%). Melting point = 57-59 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 6.73 (d, *J*=8.8 Hz, 2H), 6.62 (d, *J*=8.8 Hz, 2H), 3.85 (s, 3H), 3.34 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 56.3, 114.4, 116.5, 138.6, 152.1.



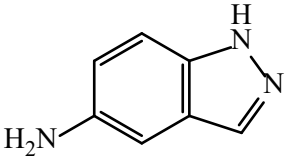

**4-aminophenol (6b):** grey solid (99 mg, 91%). Melting point = 183-188 °C. $^{1}$H NMR (400 MHz, DMSO-$d_6$) δ (ppm) 9.10 (br s, 1H), 6.41-6.53 (m, 4H), 4.29 (br s, 2H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ (ppm) 115.3, 116.1, 141.1, 148.0.



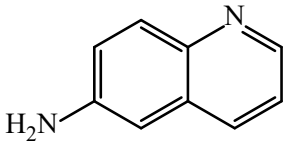
**4-aminobenzonitrile (7b):** white solid (114 mg, 97%). Melting point = 80-84 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.49 (d, *J*=8.8 Hz, 2H), 6.57 (d, *J*=8.8 Hz, 2H), 4.67 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 100.1, 114.5, 120.3, 133.4, 150.4.



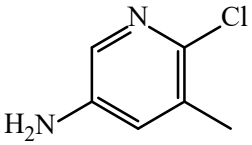
**1H-indazol-5-amine (8b):** brown solid (120 mg, 90%). Melting point = 131-132 °C. $^{1}$H NMR (400 MHz, DMSO-$d_6$) δ (ppm) 12.53 (br s, 1H), 7.57 (s, 1H), 7.15 (d, *J*=8.6,1H), 6.68-6.81 (m, 2H), 5.04 (br s, 2H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ (ppm) 99.3, 110.9, 111.6, 117.7, 123.9, 131.6, 142.7.



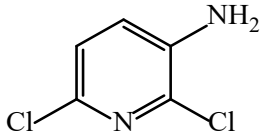
**Quinolin-6-amine (9b):** brown solid (141 mg, 98%). Melting point = 115-117 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 8.59 (dd, *J*=4, 1.4 Hz, 1H), 7.85-7.97 (m, 2H), 7.27 (dd, *J*=8, 4.1 Hz, 1H), 7.21 (dd, *J*=8.8, 2.4 Hz, 1H), 6.90 (d, 2.4 Hz, 1H), 3.88 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 107.5, 121.5, 122.5, 129.9, 130.9, 133.7, 143.4, 144.5, 147.0.



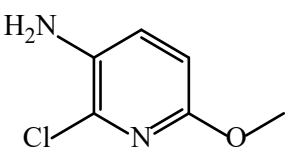
**6-Chloro-5-methylpyridin-3-amine (10b):** brown solid (133 mg, 94%). Melting point = 90-94 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.58 (d, *J*=8.2 Hz, 1H), 6.84 (d, *J*=2,8 Hz, 1H), 3.79 (br s, 2H), 2.38 (s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 19.1, 123.5, 125.5, 135.4, 137.6, 138.9.



**2,6-Dichloropyridin-3-amine (11b):** brown solid (134 mg, 82%). Melting point = 119-122 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.13 (d, *J*=8.4 Hz, 1H), 7.02 (d, *J*=8.4 Hz, 1H), 4.17 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 123.7, 125.2, 134.5, 138.2, 139.0.



**12. 2-Chloro-6-methoxypyridin-3-amine (12b):** brown solid (135 mg, 85%). Melting point = 44-47 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ (ppm) 7.06 (d, *J*=8.2 Hz, 1H), 6.46 (d, *J*=8.2 Hz, 1H), 3.82 (s, 3H) 3.52 (br s, 2H). $^{13}$C NMR (100 MHz, $CDCl_3$) δ (ppm) 54.4, 110.7, 128.8, 132.8, 133.8, 156.0.



## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 1b

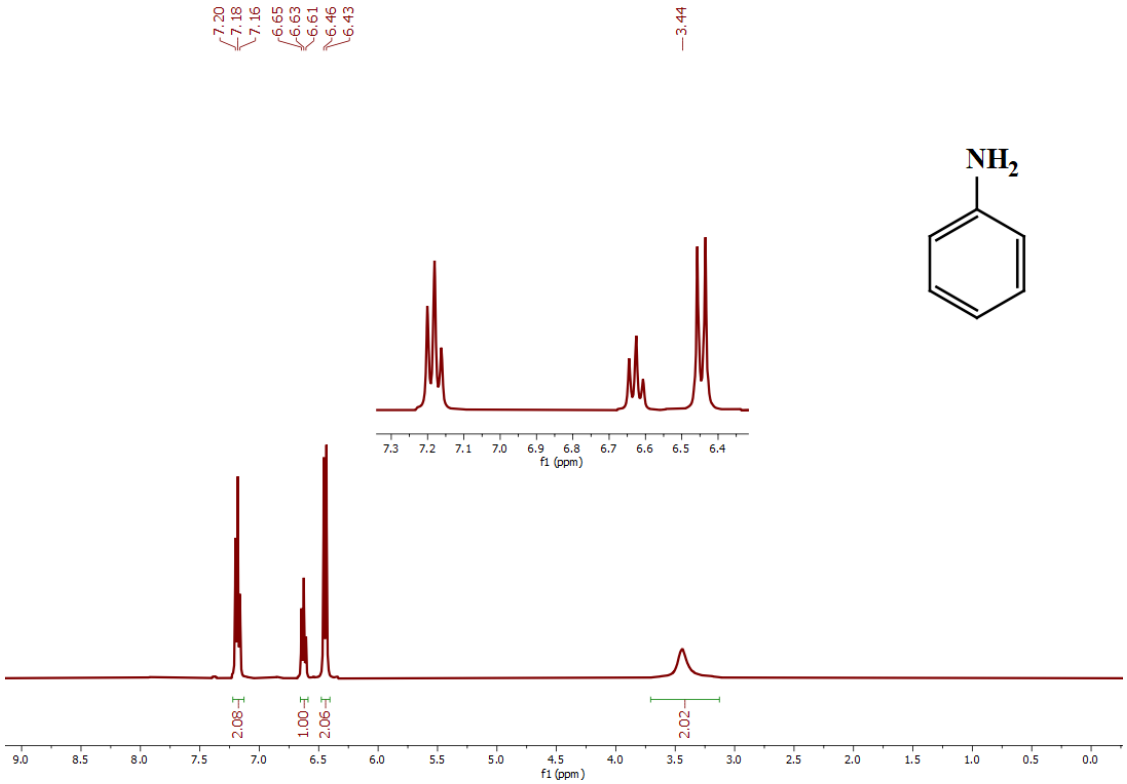



**Figure S2**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of Aniline (**1b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 1b

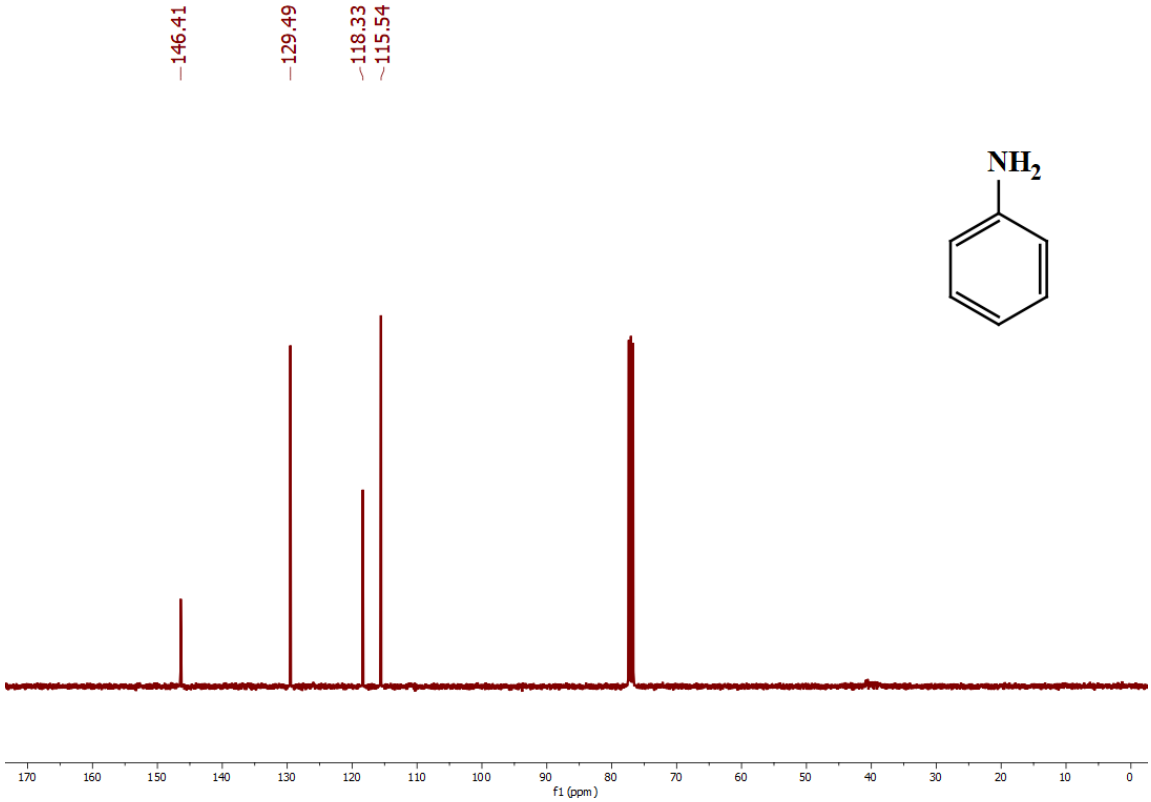



**Figure S3**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of Aniline (**1b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 2b

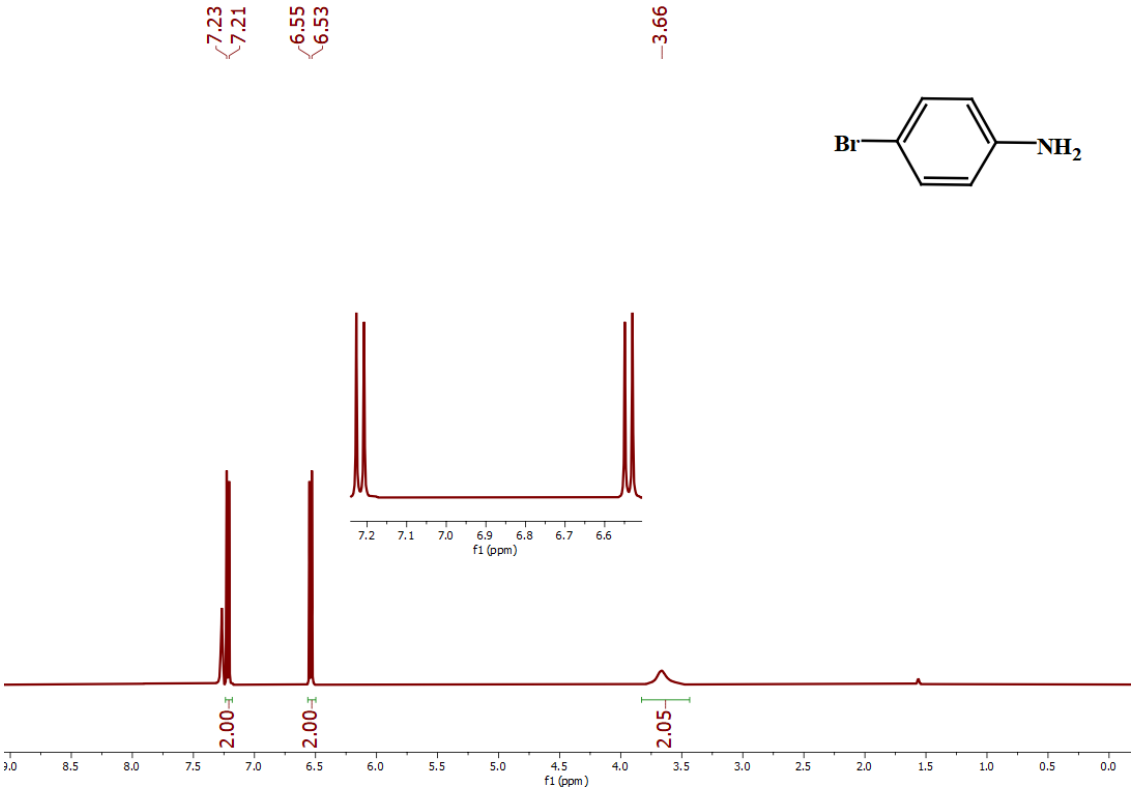



**Figure S4**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 4-bromoaniline (**2b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 2b

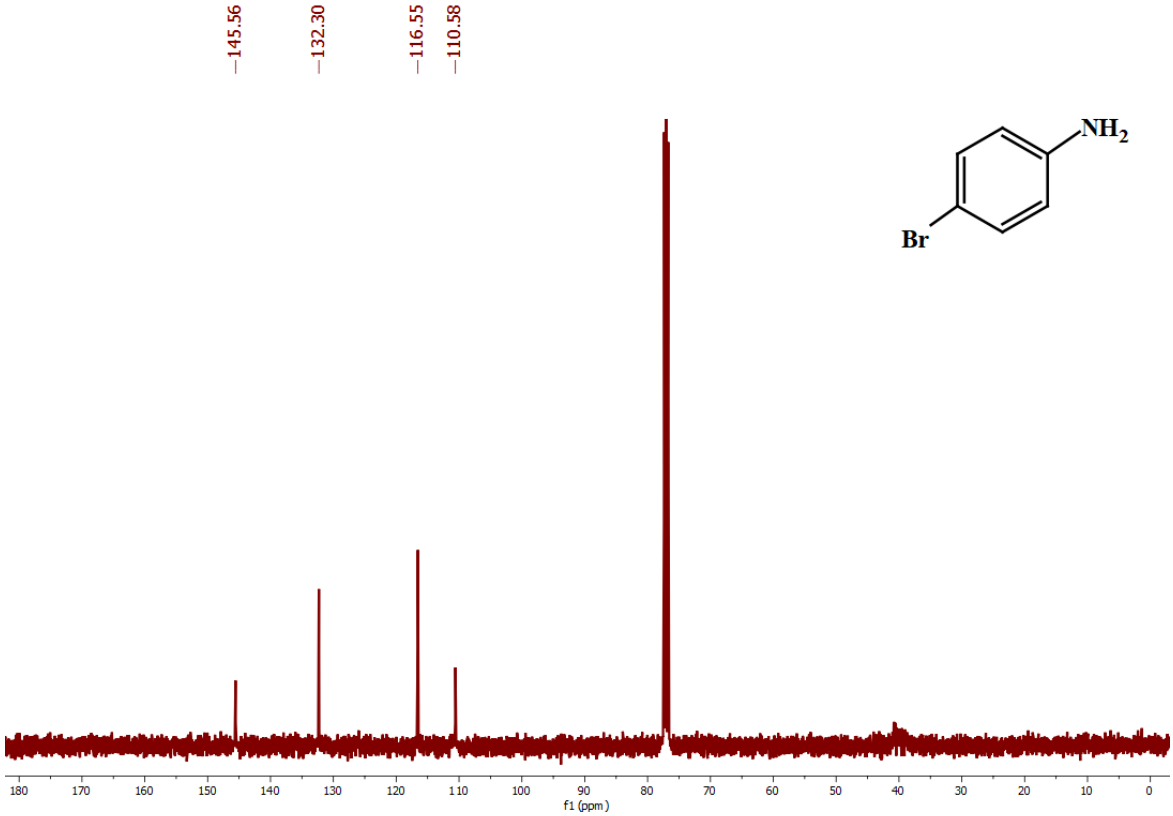



**Figure S5**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 4-bromoaniline (**2b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 3b

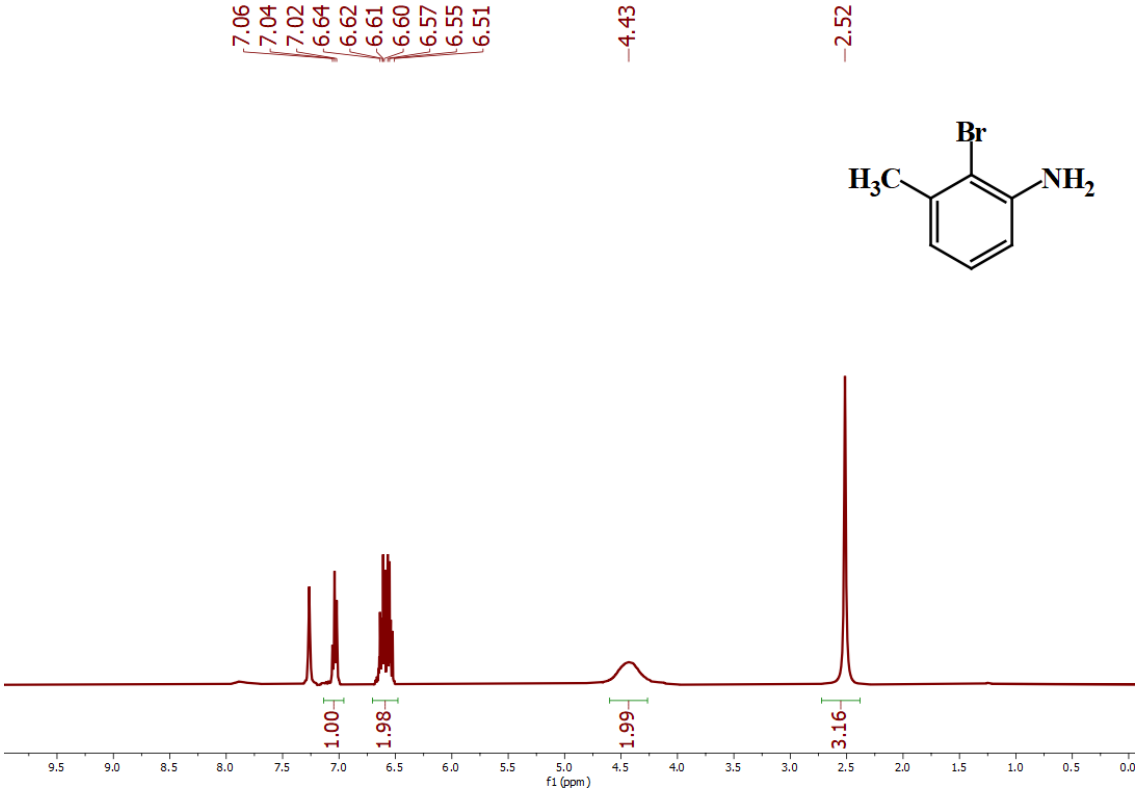



**Figure S6**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 2-Bromo-3-methylaniline (**3b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 3b

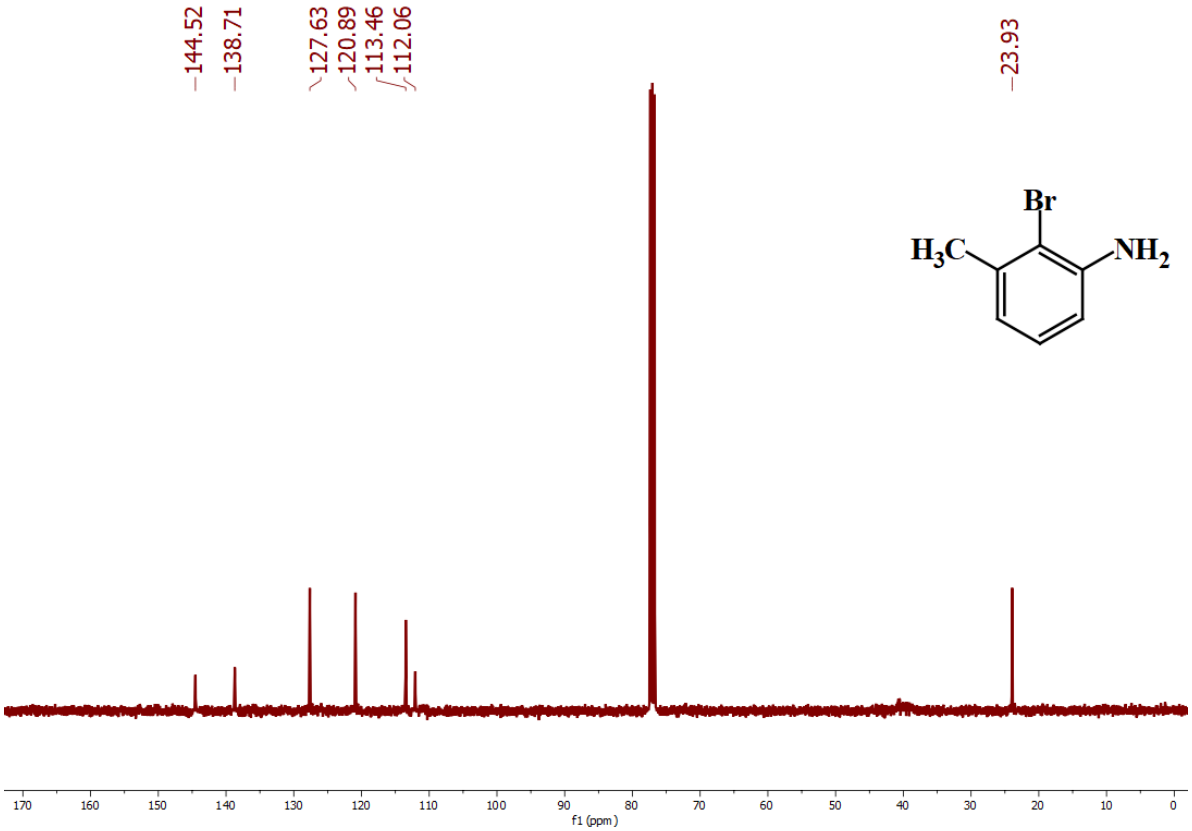



**Figure S7**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 2-Bromo-3-methylaniline (**3b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 4b

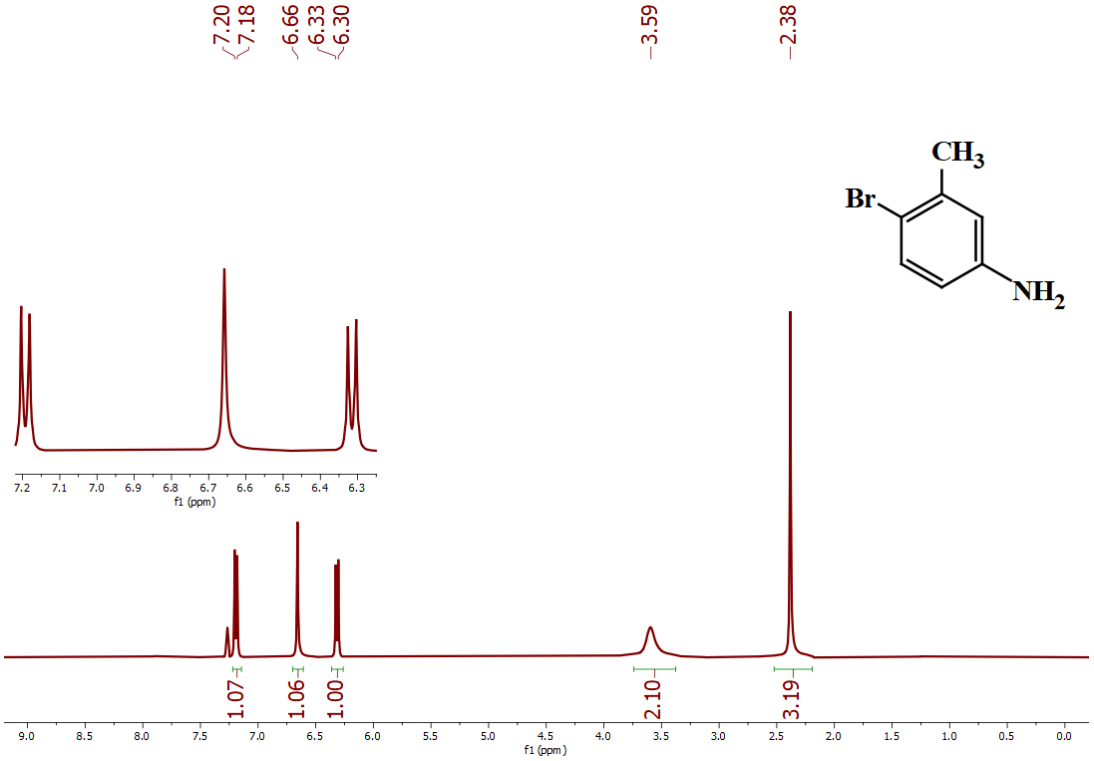



**Figure S8**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 4-bromo-3-methylaniline **(4b)**.

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 4b

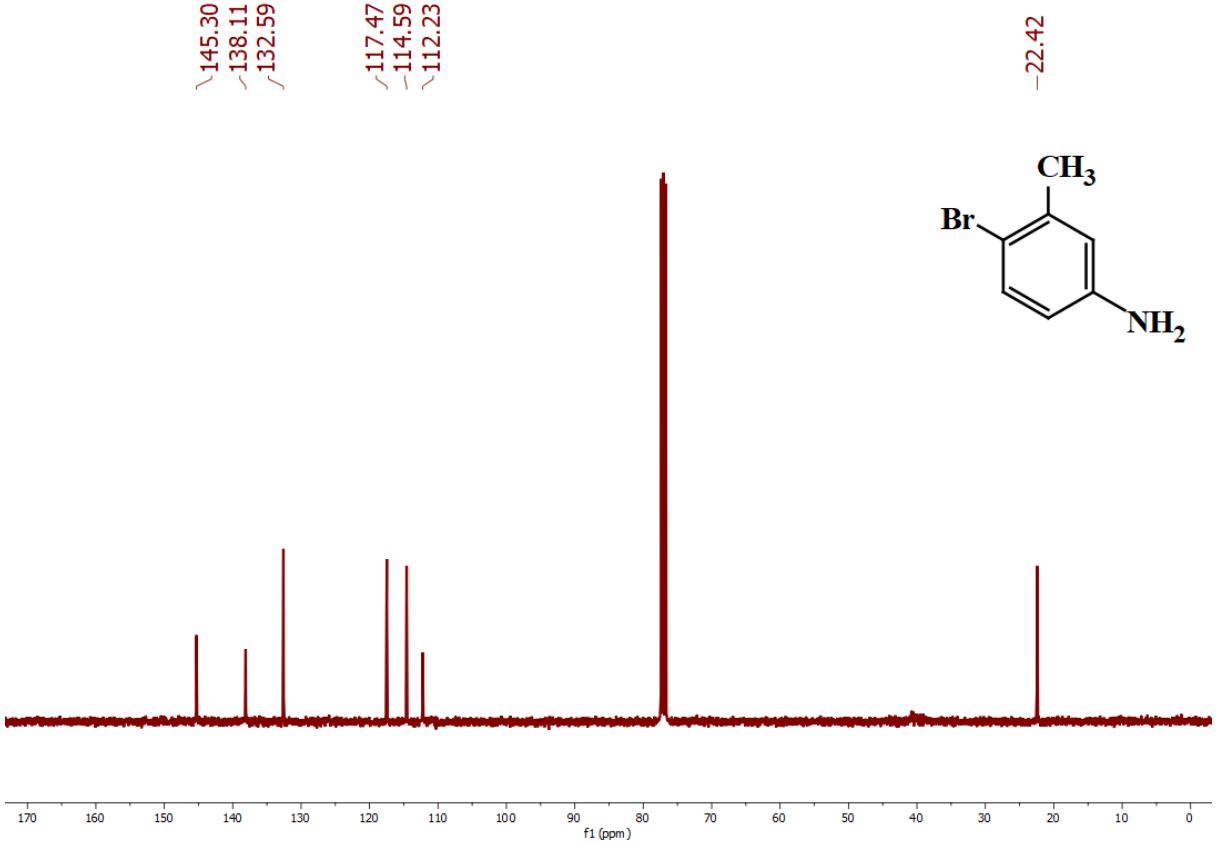



**Figure S9**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 4-bromo-3-methylaniline **(4b)**.

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 5b

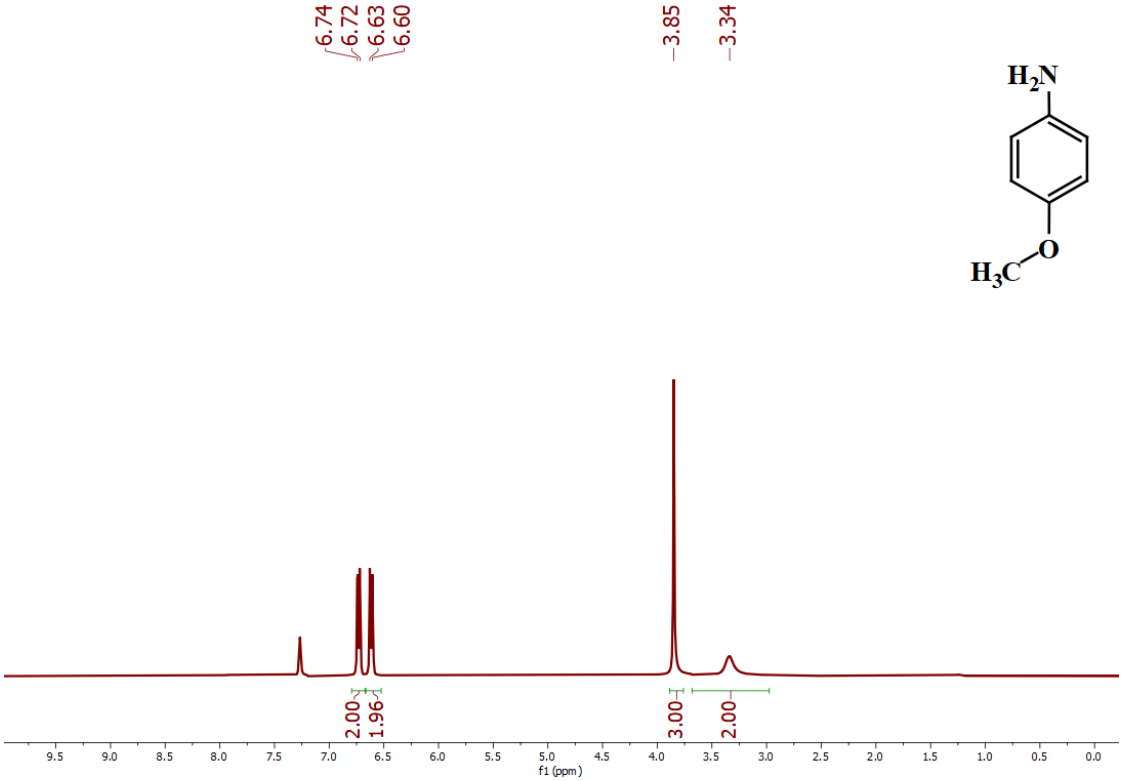



**Figure S10**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 4-Methoxyaniline **(5b)**.

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 5b

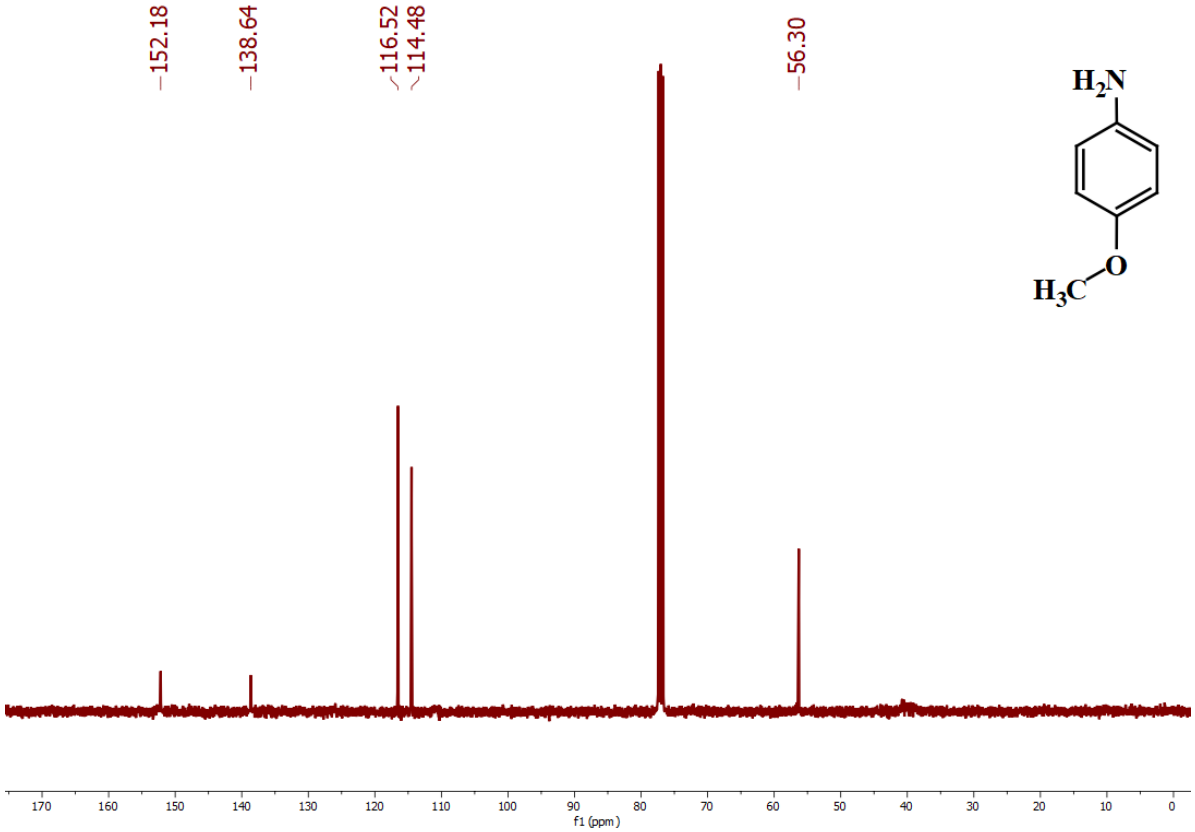



**Figure S11**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 4-Methoxyaniline **(5b)**.

## $^{1}$H NMR (400 MHz, DMSO-$d_6$) spectrum of 6b

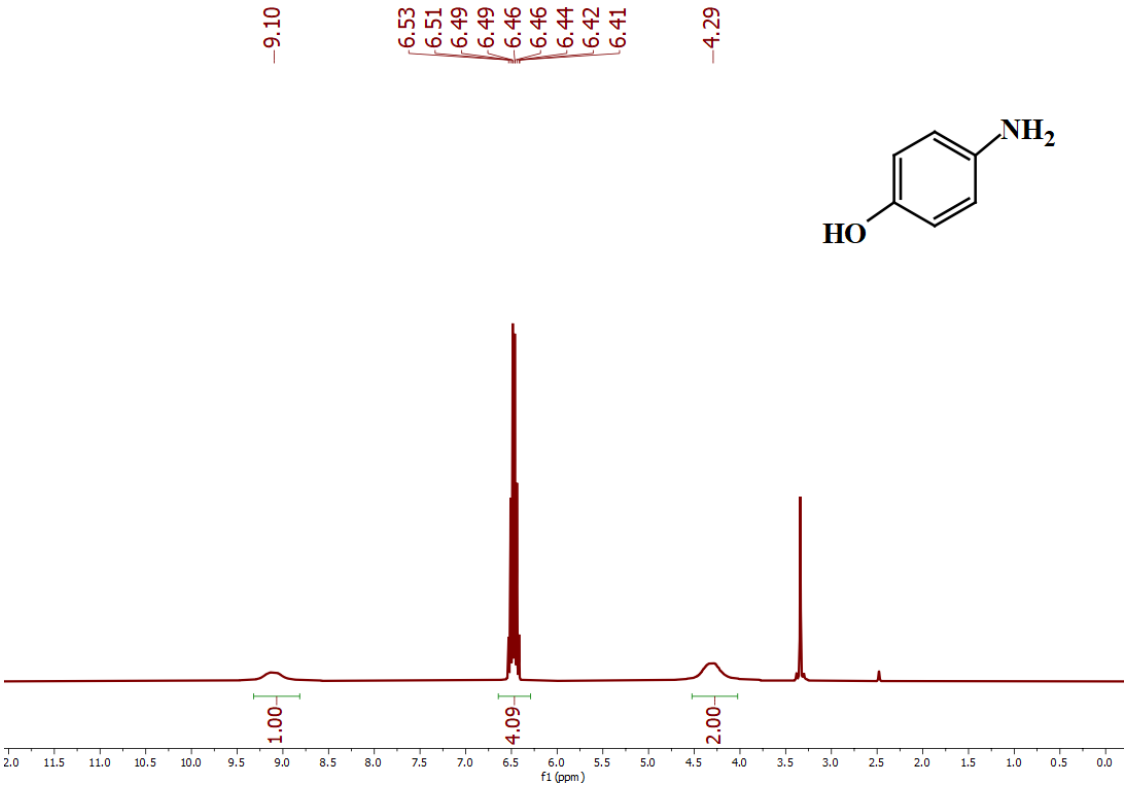



**Figure S12**: $^{1}$H NMR (400 MHz, DMSO-$d_6$) Spectrum of 4-aminophenol **(6b)**.

## $^{13}$C NMR (100 MHz, DMSO-$d_6$) spectrum of 6b

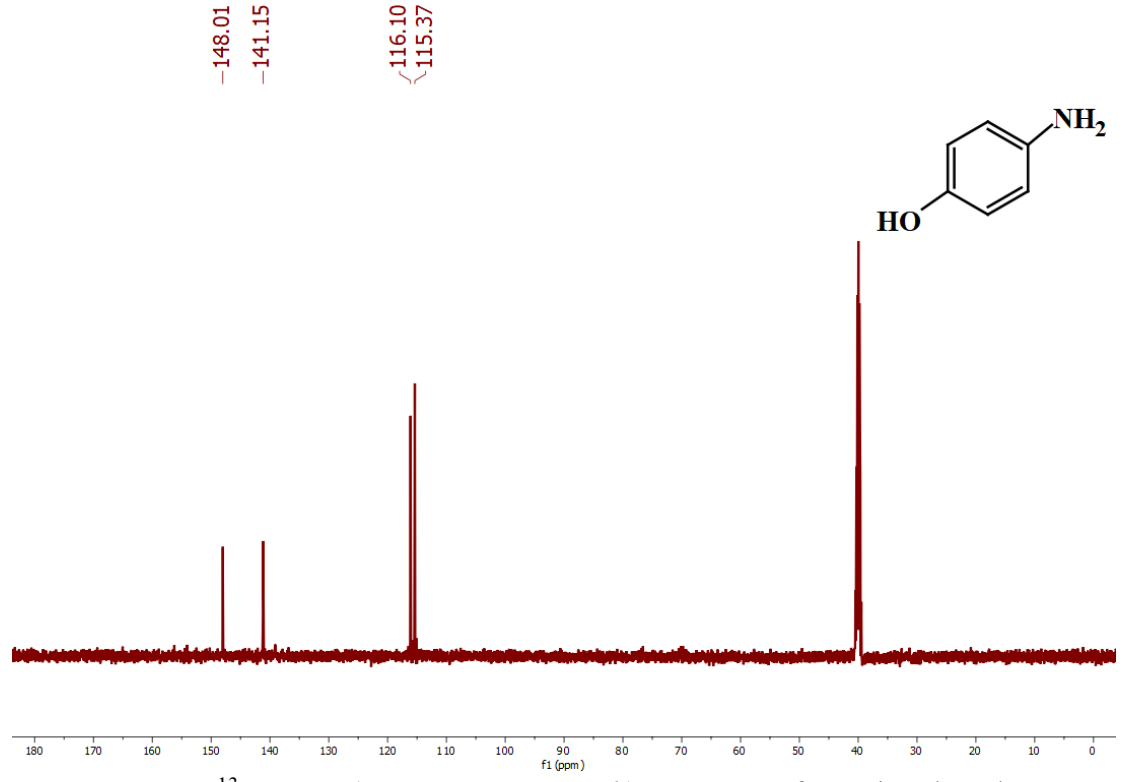



**Figure S13**: $^{13}$C NMR (100 MHz, DMSO-$d_6$) Spectrum of 4-aminophenol **(6b)**.

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 7b

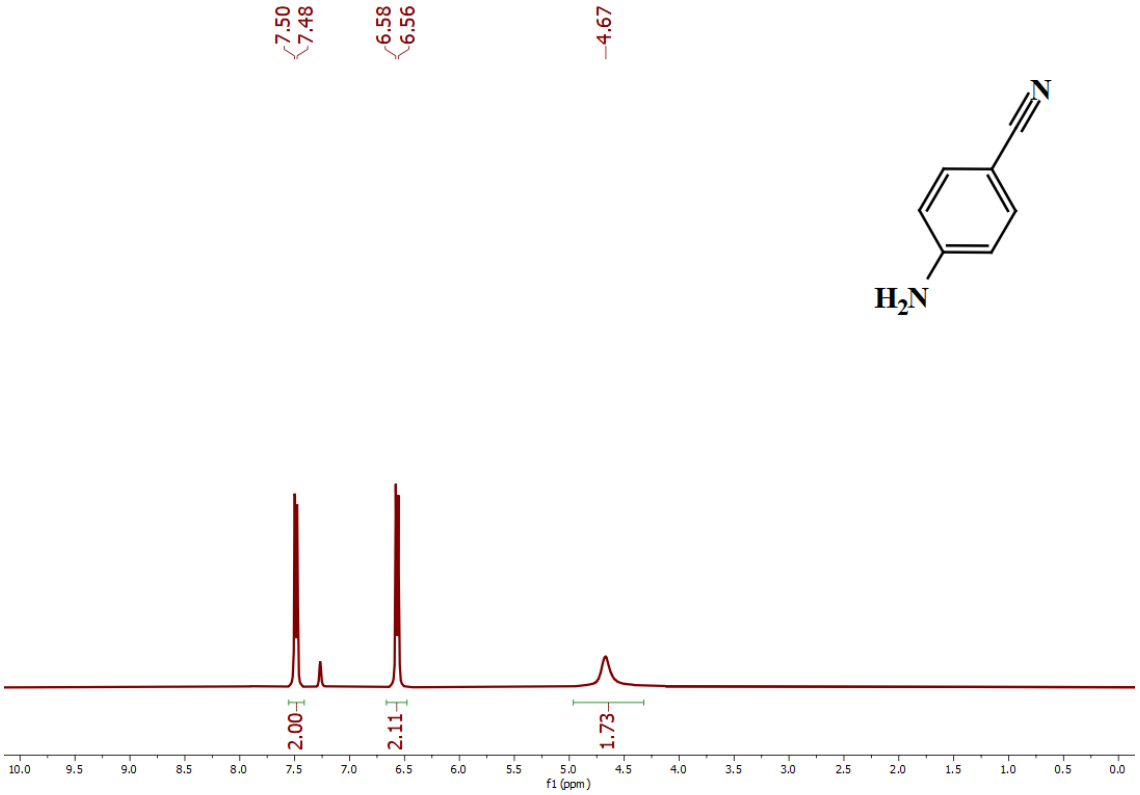



**Figure S14**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 4-aminobenzonitrile (**7b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 7b

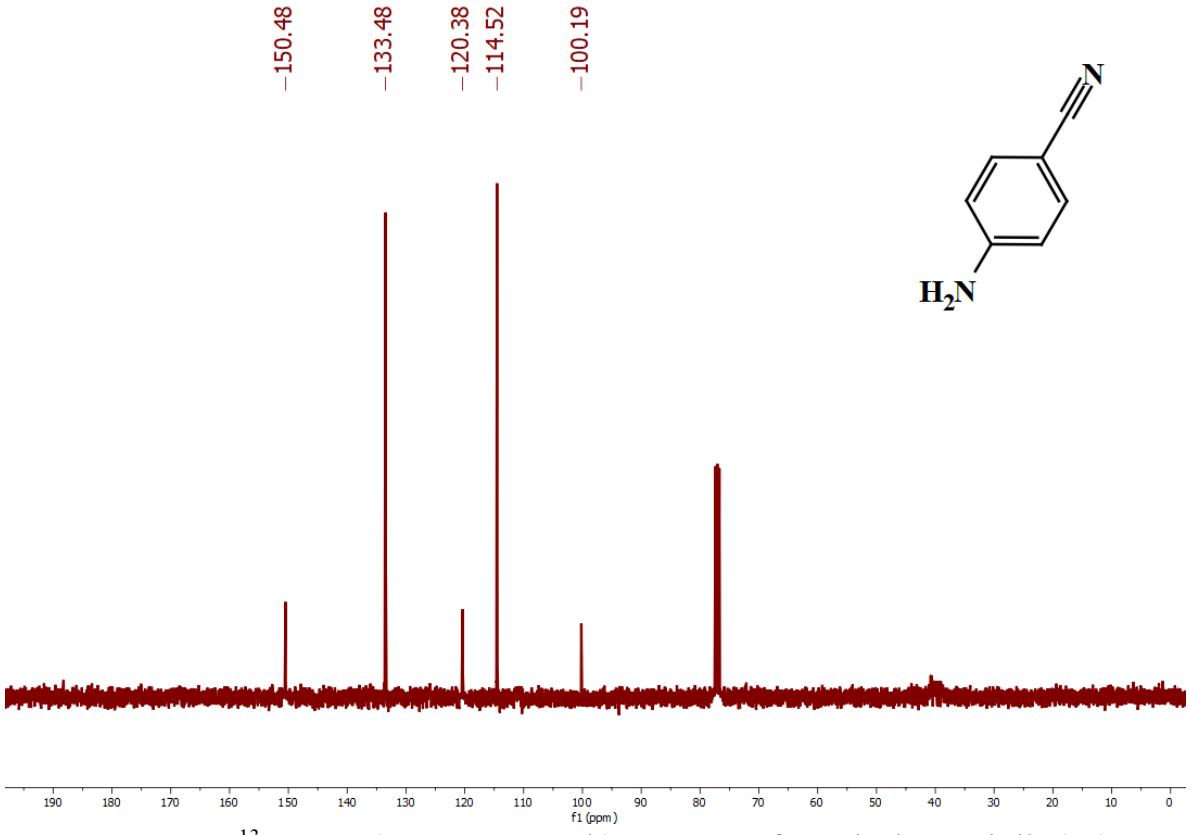



**Figure S15**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 4-aminobenzonitrile (**7b**).

## $^{1}$H NMR (400 MHz, DMSO-$d_6$) spectrum of 8b

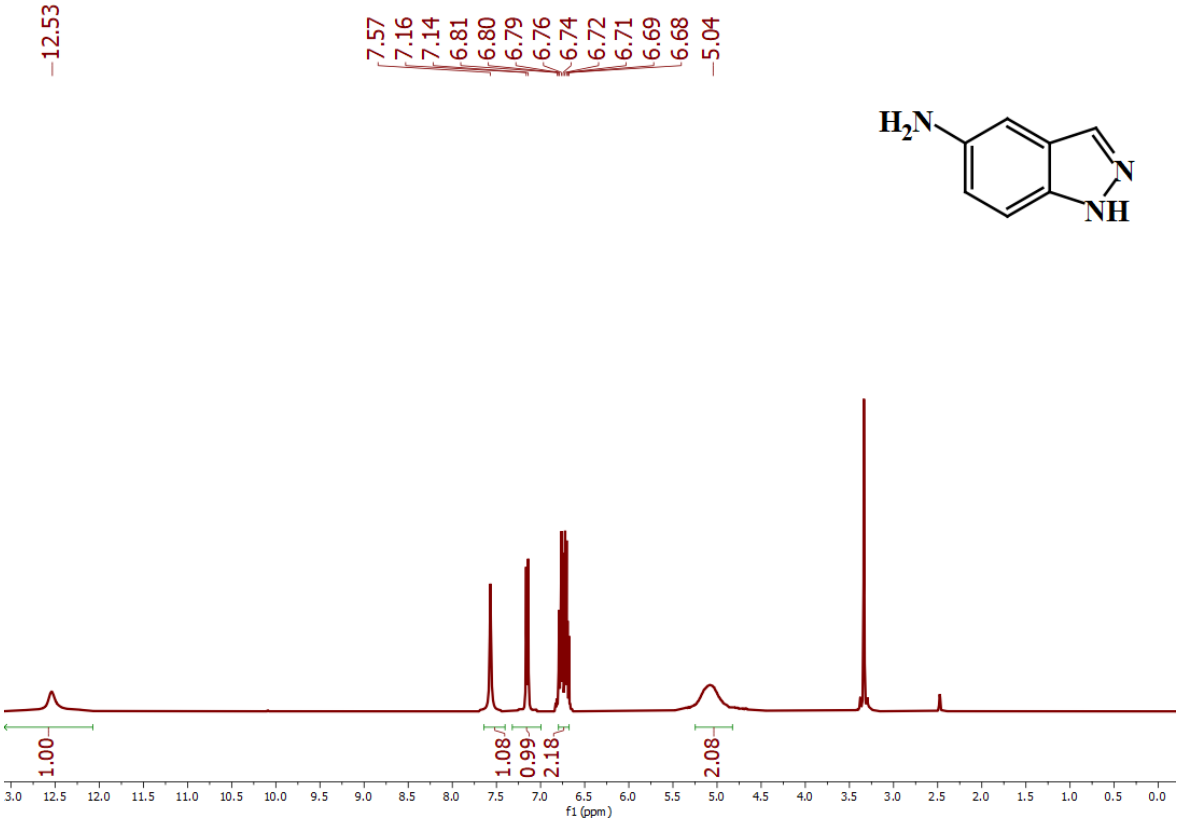



**Figure S16**: $^{1}$H NMR (400 MHz, DMSO-$d_6$) Spectrum of 1H-indazol-5-amine (**8b**).

## $^{13}$C NMR (100 MHz, DMSO-$d_6$) spectrum of 8b

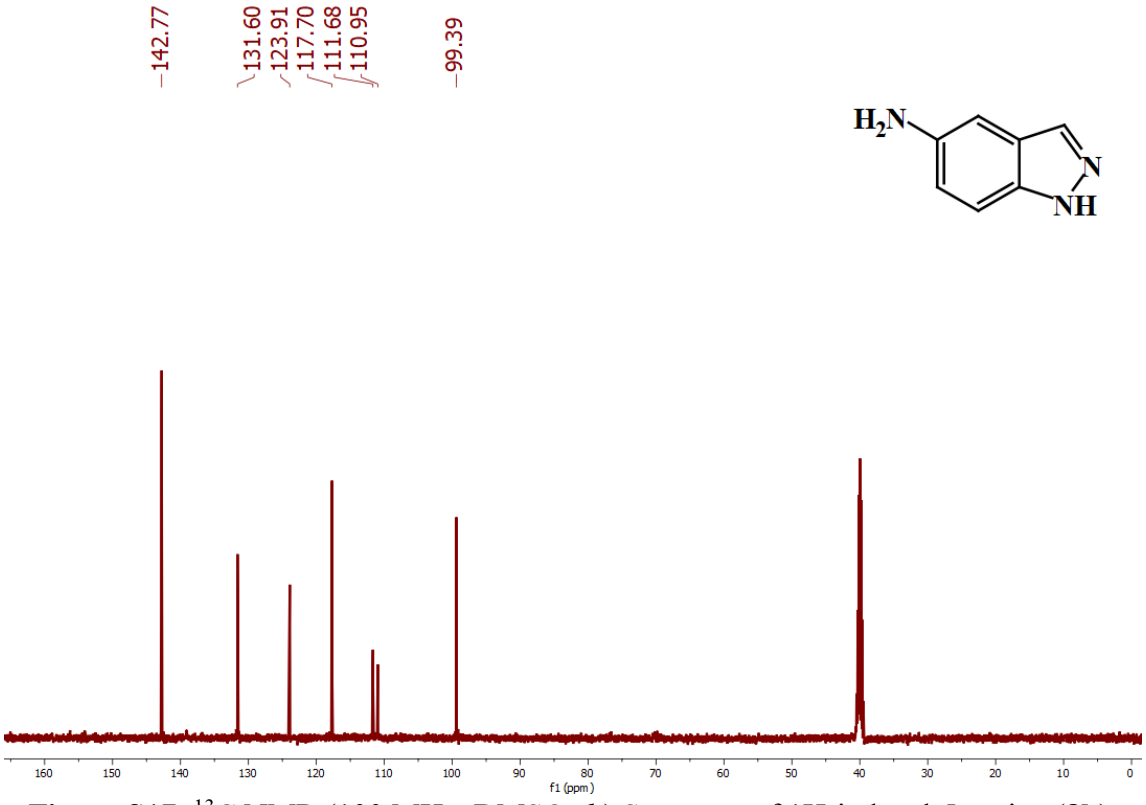



**Figure S17**: $^{13}$C NMR (100 MHz, DMSO-$d_6$) Spectrum of 1H-indazol-5-amine (**8b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 9b

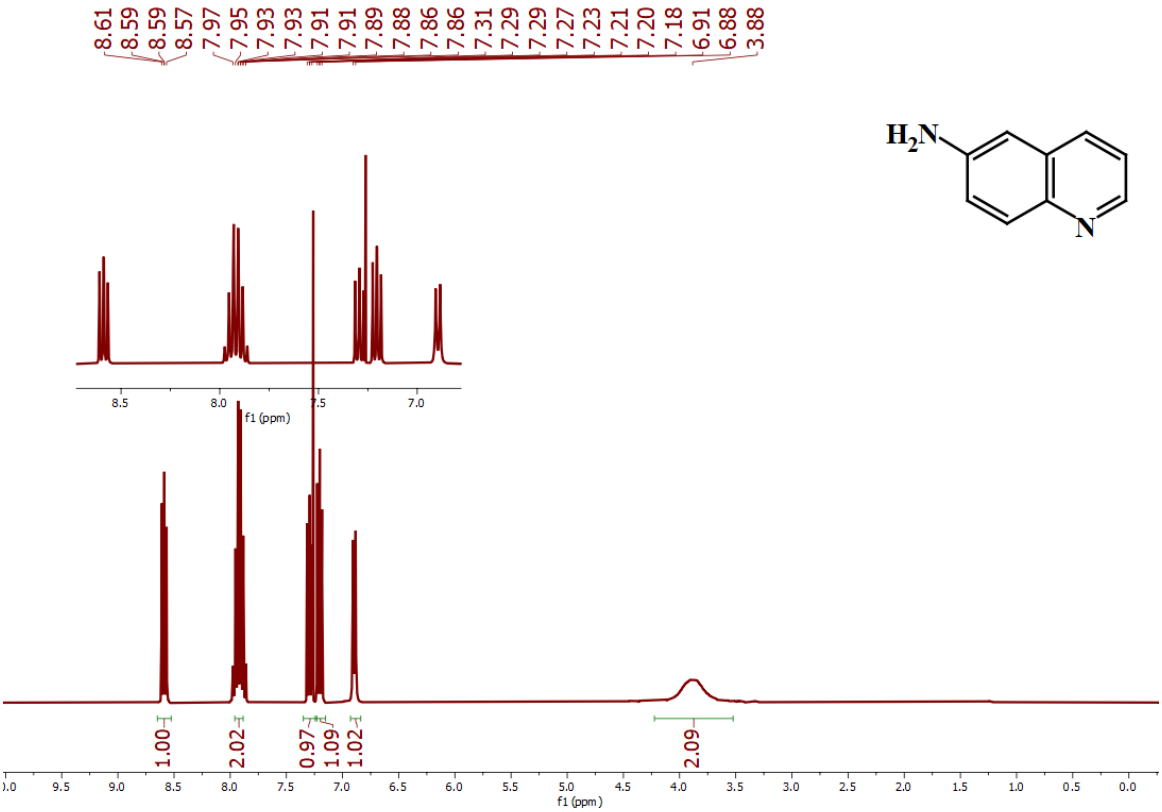



**Figure S18**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of Quinolin-6-amine (**9b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 9b

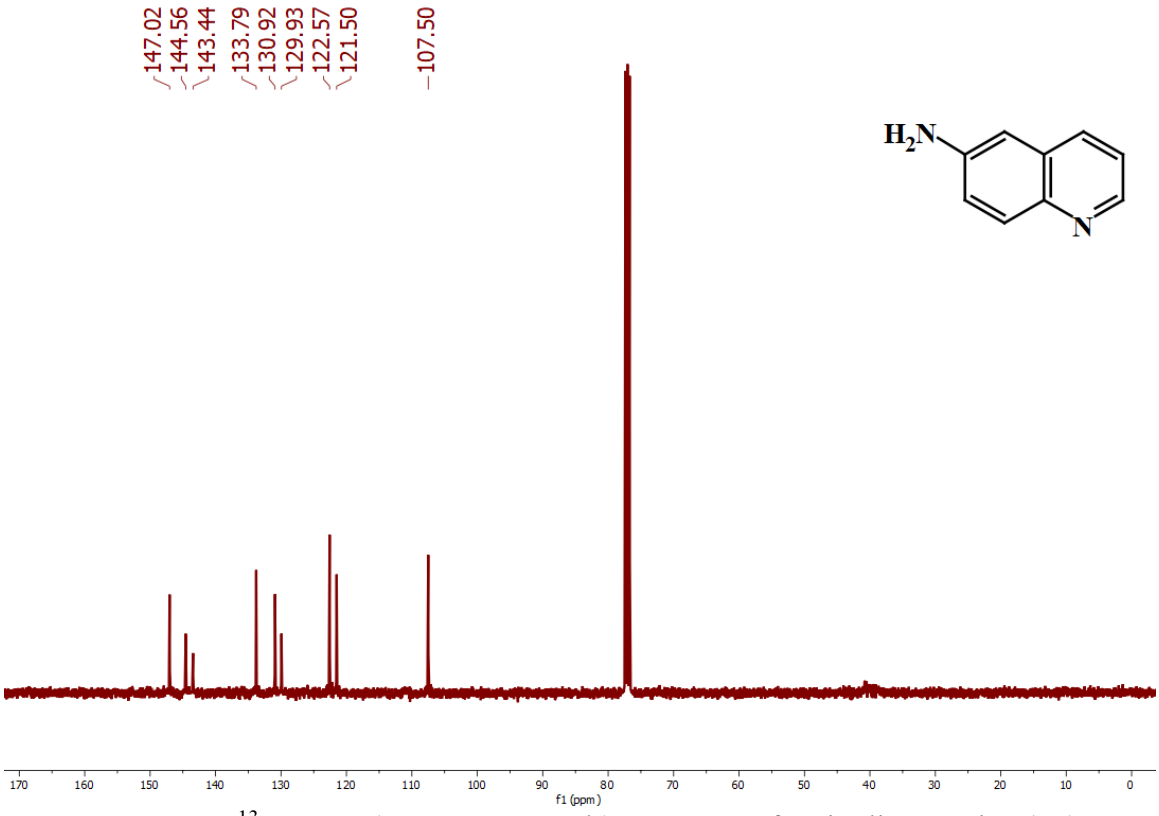



**Figure S19**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of Quinolin-6-amine (**9b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 10b

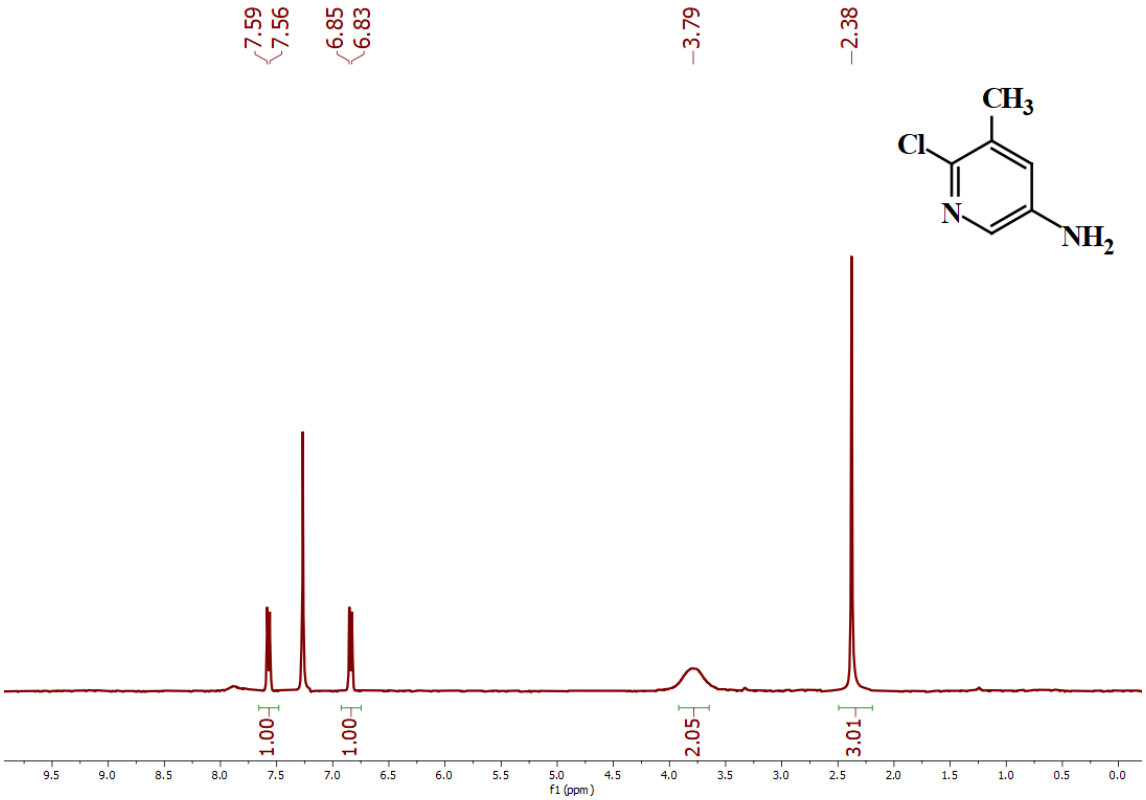



**Figure S20**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 6-Chloro-5-methylpyridin-3-amine (**10b**).

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 10b

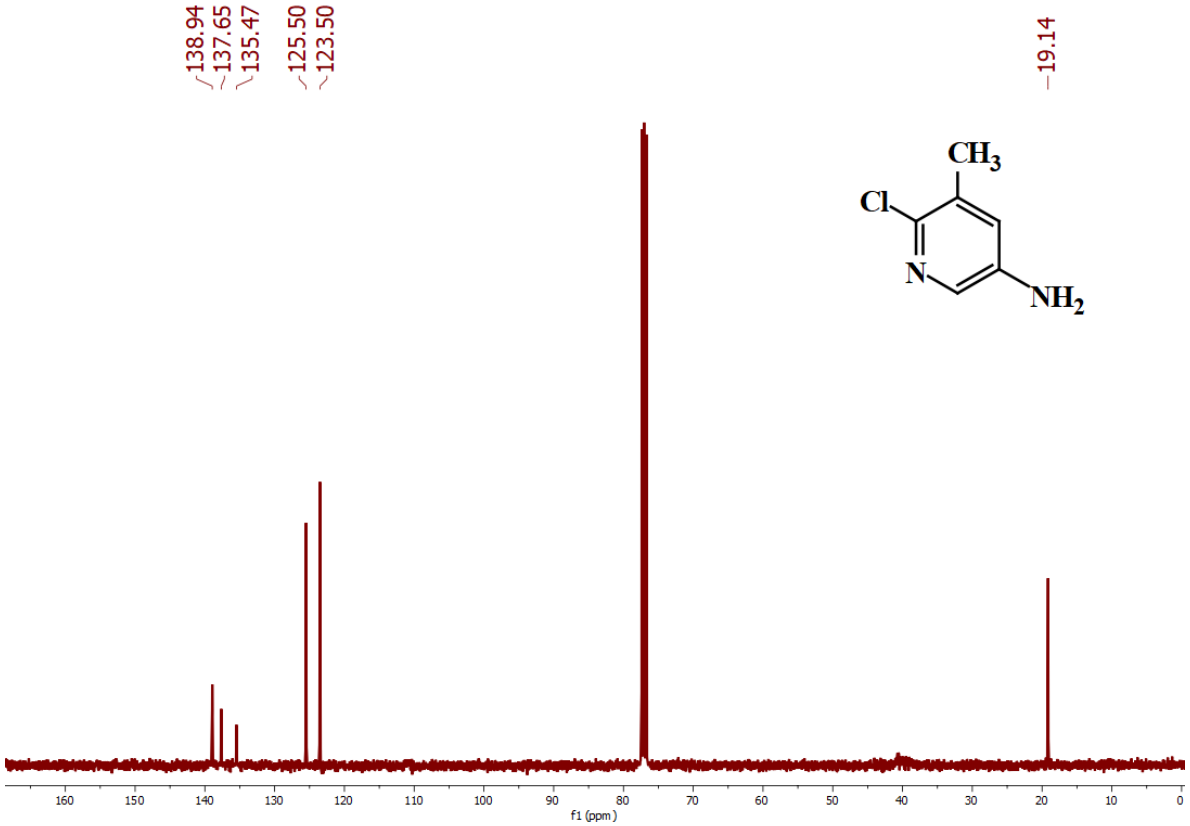



**Figure S21**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 6-Chloro-5-methylpyridin-3-amine (**10b**).

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 11b

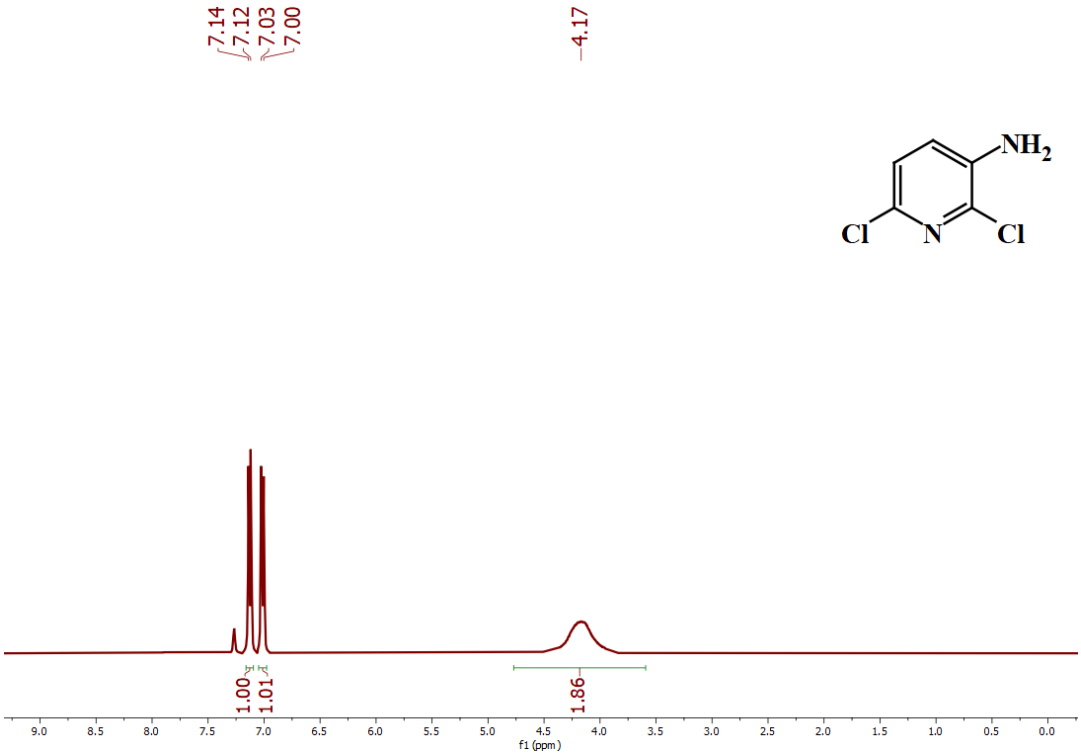



**Figure S22**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 2,6-Dichloropyridin-3-amine **(11b)**.

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 11b

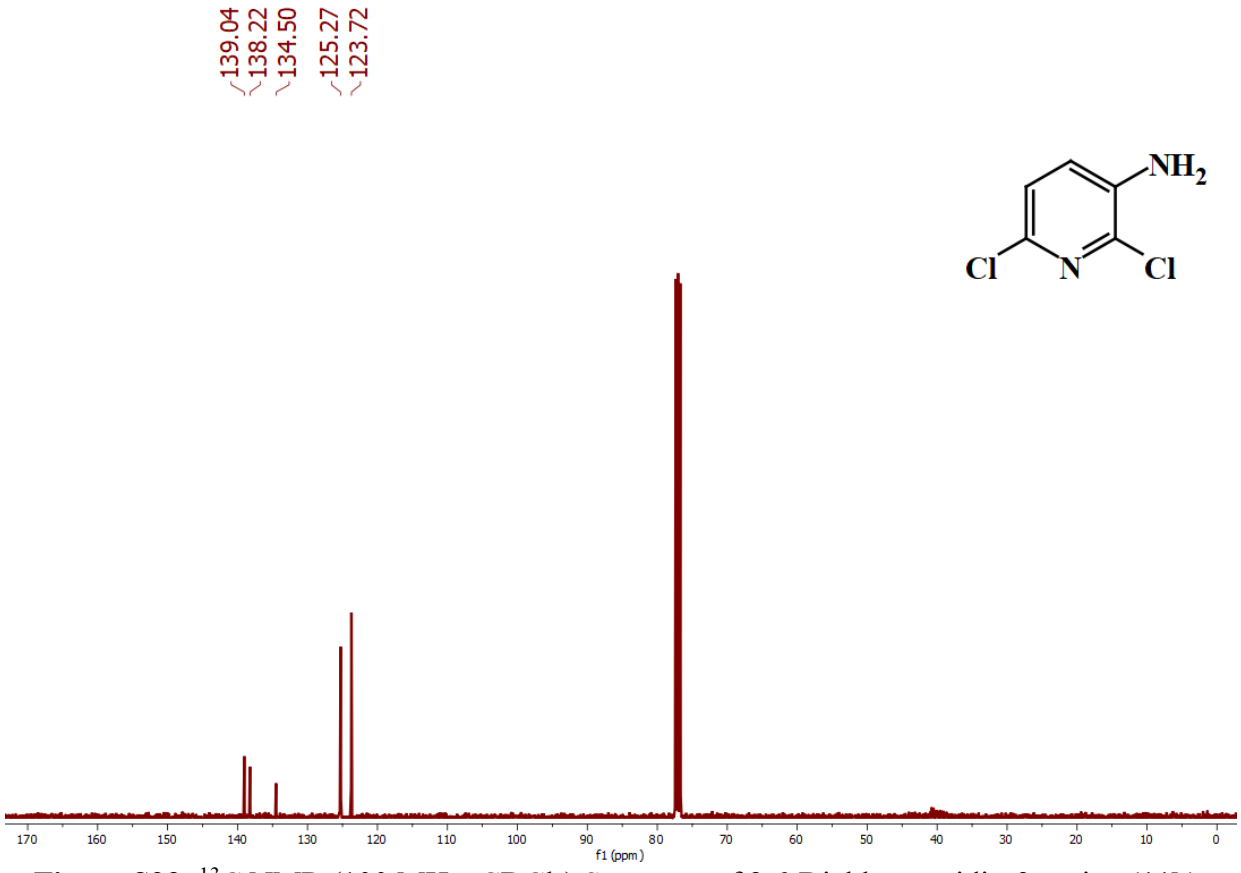



**Figure S23**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 2,6-Dichloropyridin-3-amine **(11b)**.

## $^{1}$H NMR (400 MHz, $CDCl_3$) spectrum of 12b

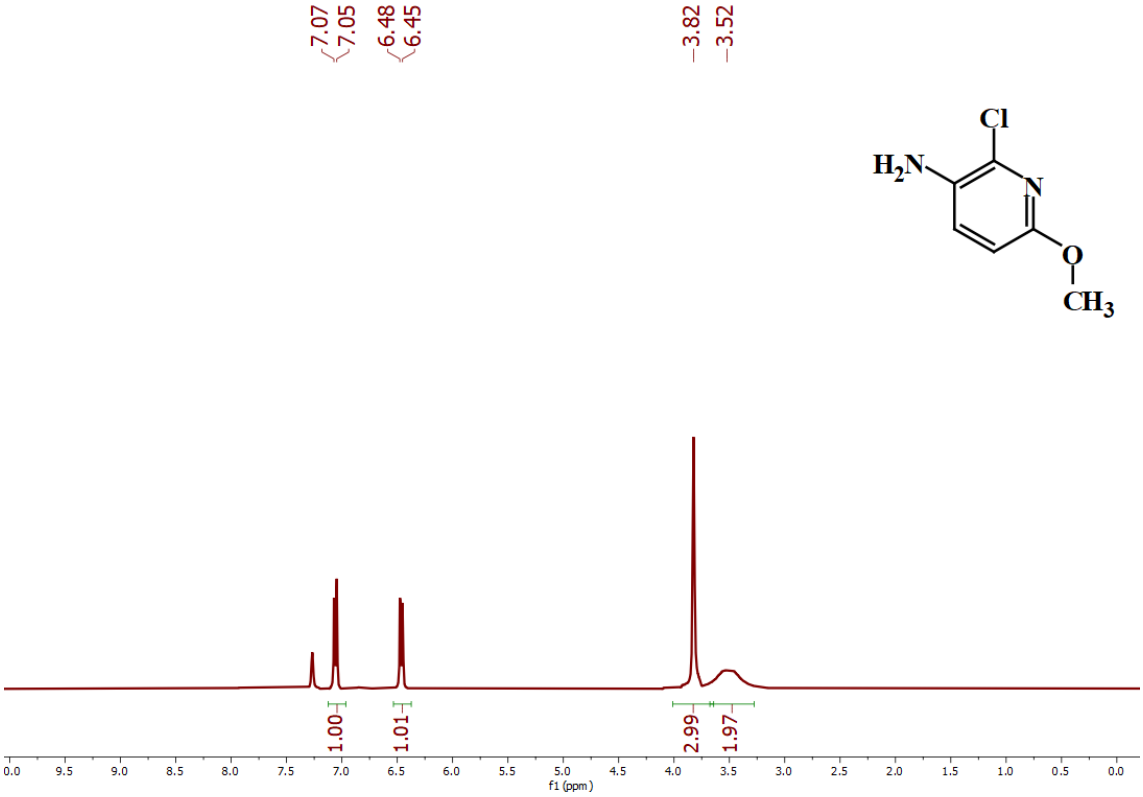



**Figure S24**: $^{1}$H NMR (400 MHz, $CDCl_3$) Spectrum of 2-Chloro-6-methoxypyridin-3-amine **(12b)**.

## $^{13}$C NMR (100 MHz, $CDCl_3$) spectrum of 12b

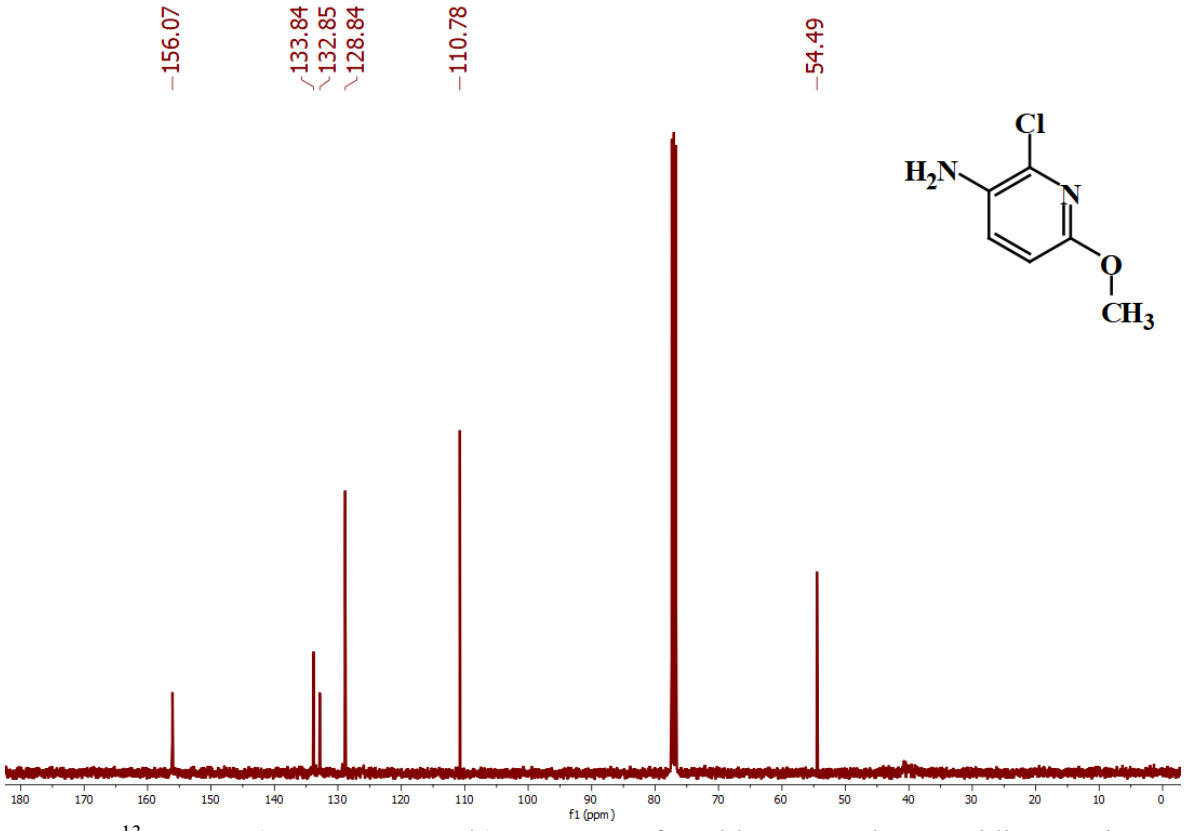



**Figure S25**: $^{13}$C NMR (100 MHz, $CDCl_3$) Spectrum of 2-Chloro-6-methoxypyridin-3-amine **(12b)**.