Supporting Information

Selective Hydrogenation of Nitriles to Primary Amines Catalyzed by a Cobalt Pincer Complex

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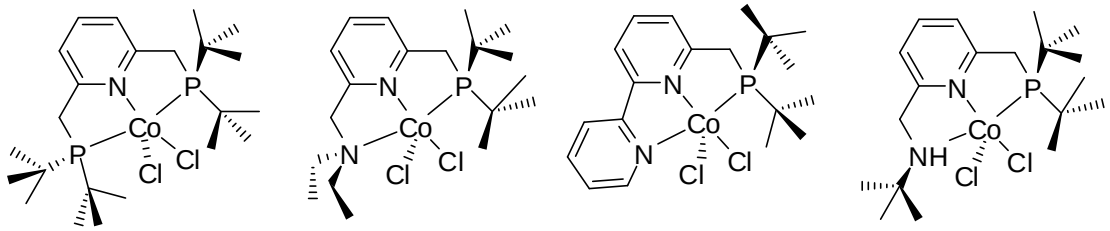
General Information:

All experiments with metal complexes and phosphine ligands were carried out under an atmosphere of purified nitrogen in a Vacuum Atmospheres glovebox equipped with a MO 40-2 inert gas purifier or using standard Schlenk techniques. All solvents were reagent grade or better. All non-deuterated solvents were refluxed over sodium/benzophenoneketyl and distilled under argon atmosphere. Deuterated solvents were used as received. All solvents were degassed with argon and kept in the glove box over 4Å molecular sieves. Most of the chemicals used in the catalytic reactions were purified according to standard procedures (vacuum distillation).[1] All ^{1}H NMR (300 MHz), ^{13}C NMR (75 MHz) spectra were recorded on a Bruker AMX-300 NMR spectrometer for a $CDCl_3$ solution and reported in ppm (δ). NMR spectroscopy abbreviations: br, broad; s, singlet; d, doublet; m, multiplet. GC–MS was carried out on HP 6890 (flame ionization detector and thermal conductivity detector) and HP 5973 (MS detector) instruments equipped with a 30 m column (Restek 5MS, 0.32 mm internal diameter) with a 5% phenylmethylsilicone coating (0.25 mm) and helium as carrier gas. GC analysis was carried out using a Carboxen 1000 column on a HP 690 series GC system or HP-5 cross- linked 5% phenylmethylsilicone column (30 m × 0.32 mm × 0.25 μm film thickness, FID) on a HP 6890 series GC system. All the catalytic products are commercially available and the spectra were in accordance with the available products.

Preparation of the cobalt complexes: The cobalt pincer complexes **1**, **2**, and **4** were prepared according to the procedure reported earlier by our group[2], while **3** was synthesized as reported by Huang et.al.[3]

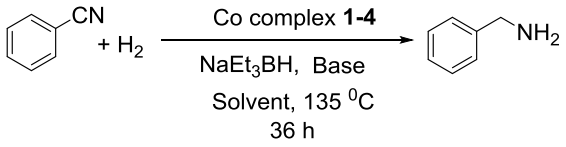


1 **2** **3** **4**

Experimental procedures:

General procedure for nitrile hydrogenation: 0.02 mmol of pre-catalyst **4** was dissolved in 1.5 mL THF and a solution of 0.02 mmol of $NaHBEt_3$ in 1 mL THF was added dropwise at room temperature. After stirring the reaction mixture for 45 min, the solvent was evaporated under vacuum. Then 4.4 mol% of base (with respect to pre-catalyst loading) and 1 mmol of nitrile were added to the residue and the mixture was dissolved in 2 mL of benzene and placed in a high pressure autoclave. The autoclave was purged three times with hydrogen, and then pressurised with 30 bar H_2 and heated at 135 ºC (bath temperature) with stirring for the specified time. The reaction mixture was then cooled down in an ice bath for 15 min before releasing H_2 pressure. Then 1mmol of an internal standard (toluene or dimethylformamide or pyridine) was added into the reaction mixture and a sample of this reaction mixture (50-100 µL) was dissolved in 0.6 mL of $CDCl_3$ and analyzed by ^1H NMR. The reaction products were also analyzed by GC-MS and GC analysis. Afterwards, the reaction mixture was filtered through Celite and washed with dichloromethane. The solvent was removed and the reaction mixture was purified by flash column chromatography using EtOAc/hexane solvent mixture, with 1% Et_3N.

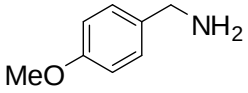
Table S1. Optimization of Reaction Conditions for Hydrogenation of Benzonitrile.[a]



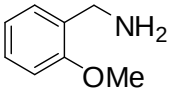
Entry	Co complex (mol%)	$NaEt_3BH$ (mol%)	Base (mol%)	$p(H_2)$ bar	Solvent	Conv. (%)[b]	Yield of benzylamine (%)[b]
1	**1** (4)	8	KO^{t}Bu (8.4)	50	benzene	54	41
2	**2** (4)	8	KO^{t}Bu (8.4)	50	benzene	89	84
3	**3** (4)	8	KO^{t}Bu (8.4)	50	benzene	83	65
4	**4** (4)	8	KO^{t}Bu (8.4)	50	benzene	96	96
5	**4** (4)	4	KO^{t}Bu (8.4)	50	benzene	97	97
6	**4** (3)	3	KO^{t}Bu (6.4)	50	benzene	88	86
7	**4** (2)	2	KO^{t}Bu (4.4)	50	benzene	85	85
8	**4** (1)	1	KO^{t}Bu (2.4)	50	benzene	72	69
9	**4** (2)	2	KO^{t}Bu (4.4)	50	toluene	89.5	80
10	**4** (2)	2	KO^{t}Bu (4.4)	50	THF	86	83
11	**4** (2)	2	KO^{t}Bu (4.4)	50	dioxane	87.5	86
12	**4** (2)	2	KH (4.4)	50	benzene	16.5	4
13	**4** (2)	2	NaOMe (4.4)	50	benzene	40.5	37
14	**4** (2)	2	KHMDS (4.4)	50	benzene	90	90
15	**4** (2)	2	NaOEt (4.4)	50	benzene	93.5	92
16	**4** (2)	2	NaOEt (4.4)	30	benzene	92	92
17	**4** (2)	2	NaOEt (4.4)	30	benzene	71	66[c]
18	**4** (2)	—	NaOEt (4.4)	30	benzene	88	66
19	**4** (2)	2	—	30	benzene	76	40
20	—	2	NaOEt (4.4)	30	benzene	—	—

[a] Reaction Conditions: benzonitrile (1 mmol), dry benzene (2 mL), performed in an autoclave at 135 ^{0}C (bath temperature); [b] Conversions and yields were determined by ^{1}H NMR spectroscopy with respect to toluene as an internal standard or by GC analysis; [c] reaction was carried out at 110 ^{0}C.

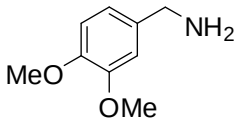
Spectroscopic characterization of the isolated primary amines:

(a) 

4-Methoxybenzylamine[4]: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.25 (d, J = 8.1 Hz, 2H), 6.89 (d, J = 8.4 Hz, 2H), 3.80 (br, 5H), 1.94 (br, 2H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 45.6, 55.1, 113.8, 128.2, 135.2, 158.4 ppm.

(b) 

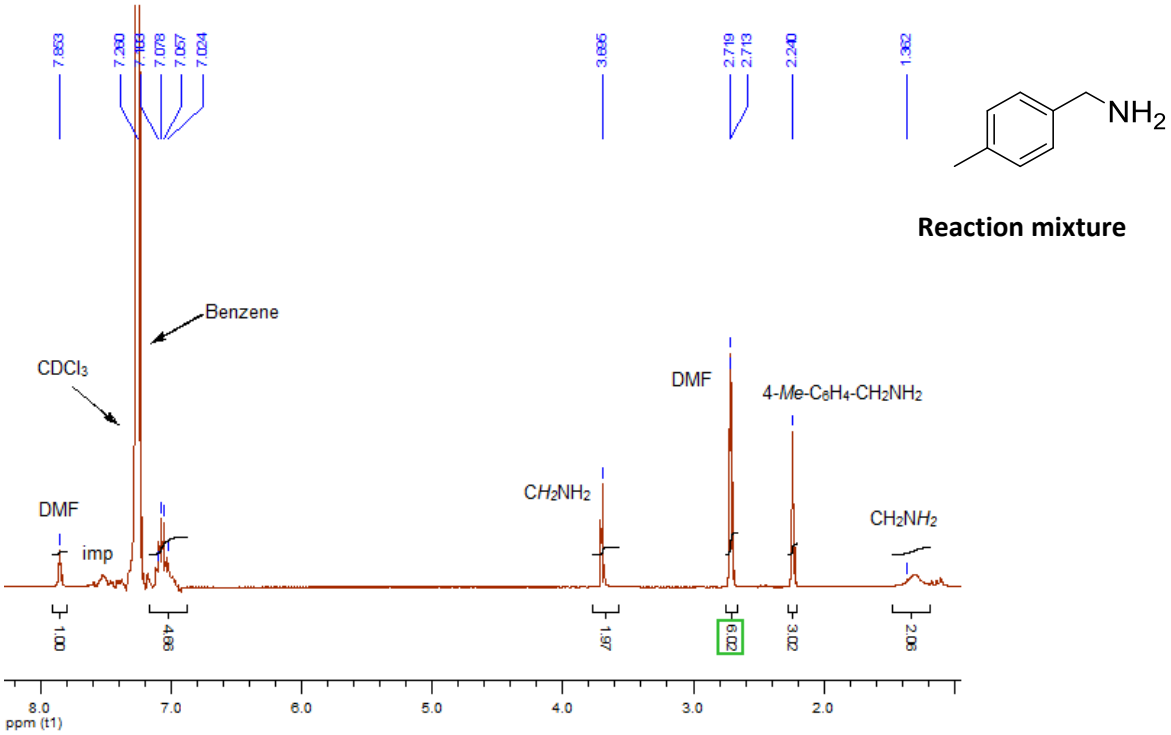
2-Methoxybenzylamine[5]: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.20-7.23 (m, 2H), 6.85-6.94 (m, 2H), 3.83-3.81 (br, 5H), 1.66 (br, 2H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 42.3, 54.9, 109.9, 120.3, 127.8, 128.2, 131.5, 157.2 ppm.

(c) 

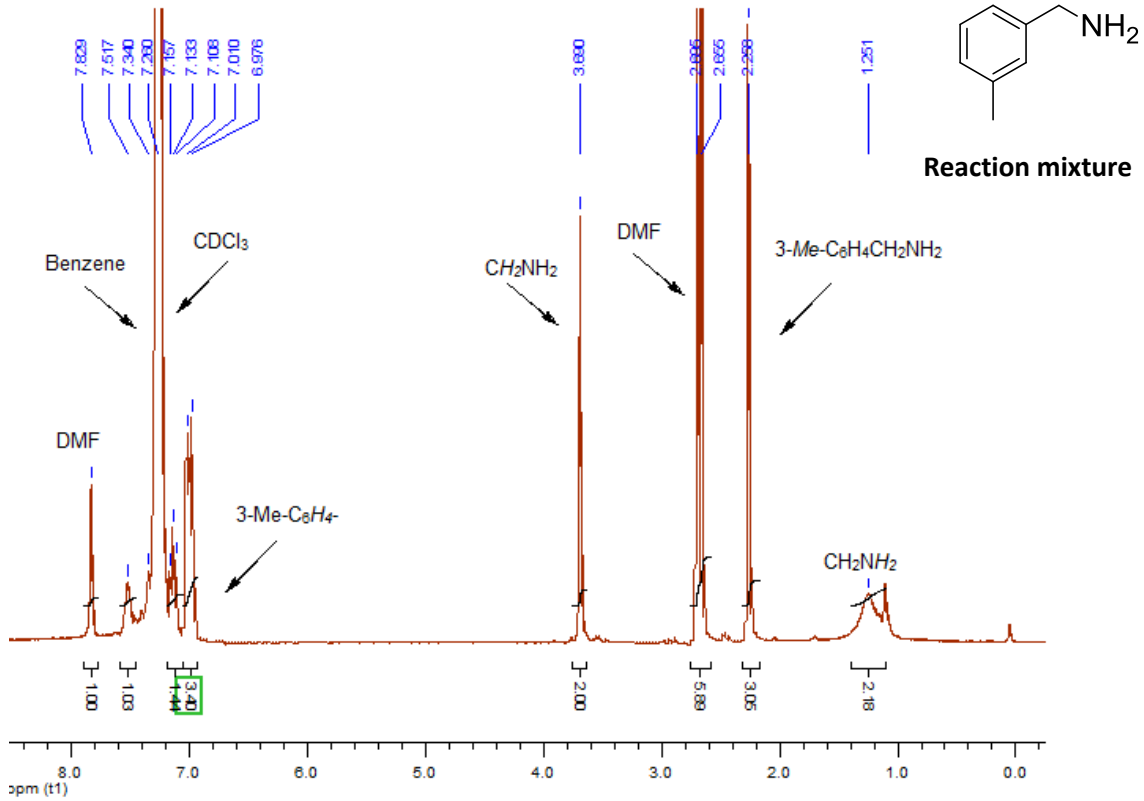
3,4-Dimethoxybenzylamine[6]: ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.26 (br, 1H), 7.21 (br, 2H), 4.18-4.27 (m, 8H), 2.49 (br, 2H) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 45.7, 55.5, 55.6, 110.2, 110.8, 118.8, 135.3, 147.5, 148.6 ppm.

NMR Spectra of the reaction mixture and the isolated products:

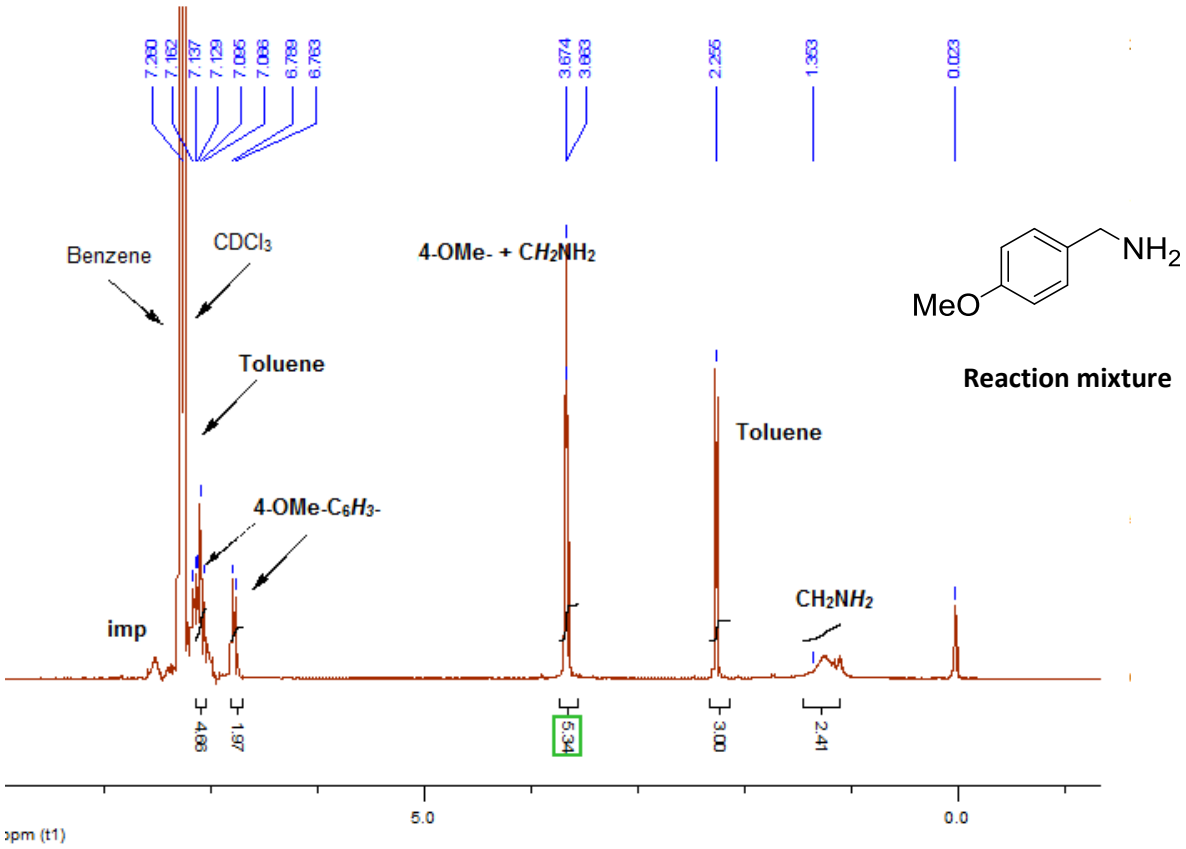
(a) ^{1}H NMR of the reaction mixture of 4-methylbenzylamine[7]:



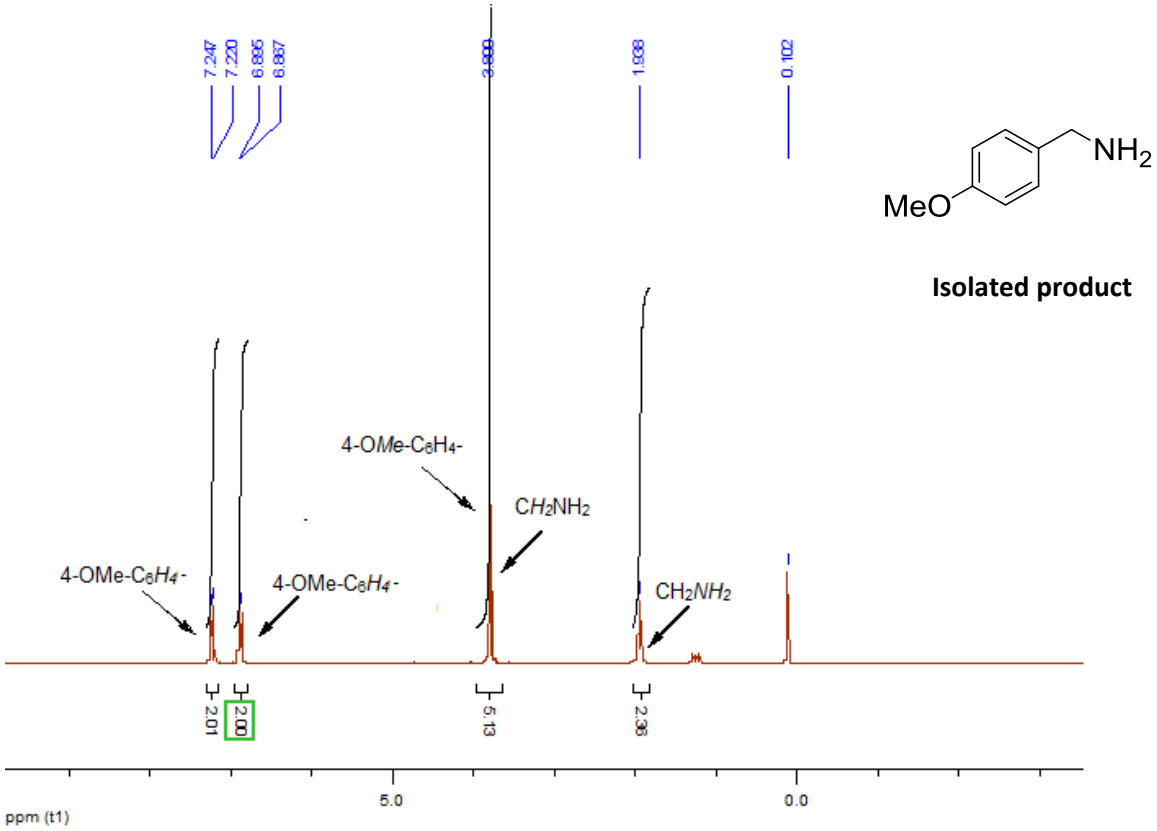
(b) ^{1}H NMR of the reaction mixture of 3-methylbenzylamine[7]:



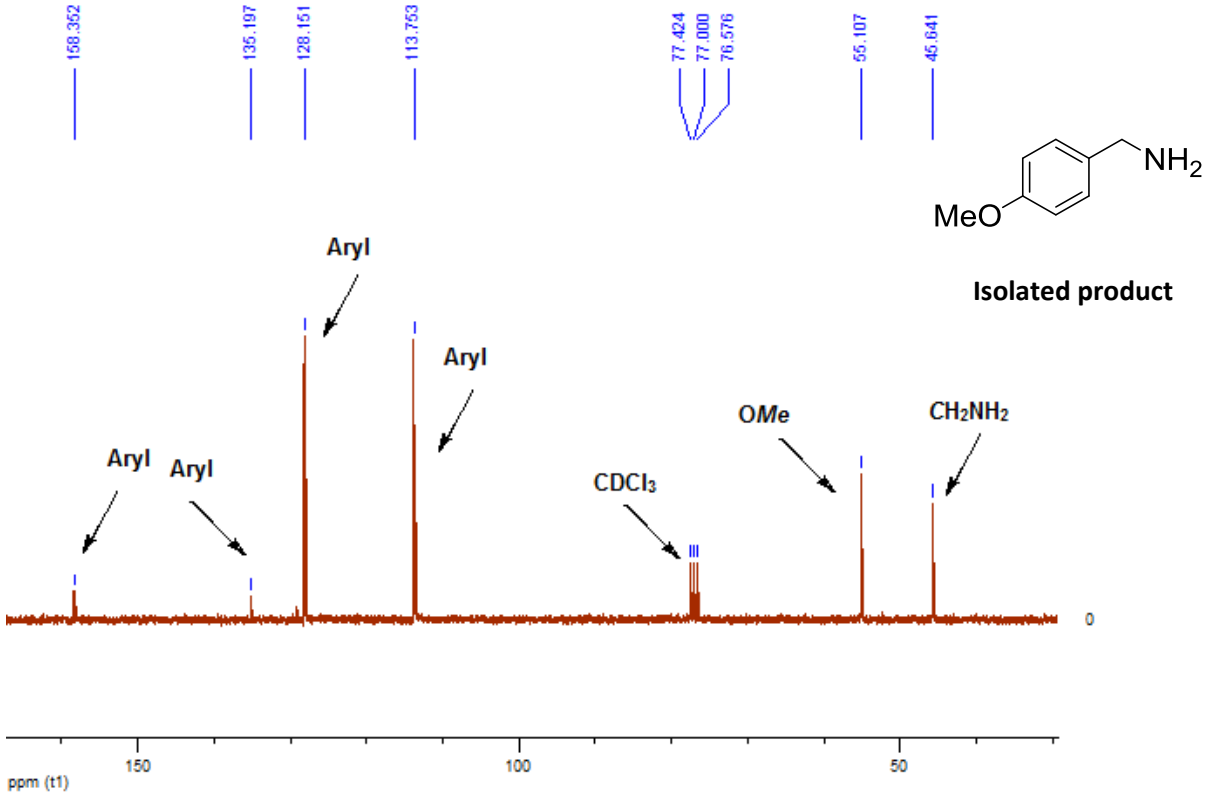
(c) ^{1}H NMR of the reaction mixture of 4-methoxybenzylamine[4]:



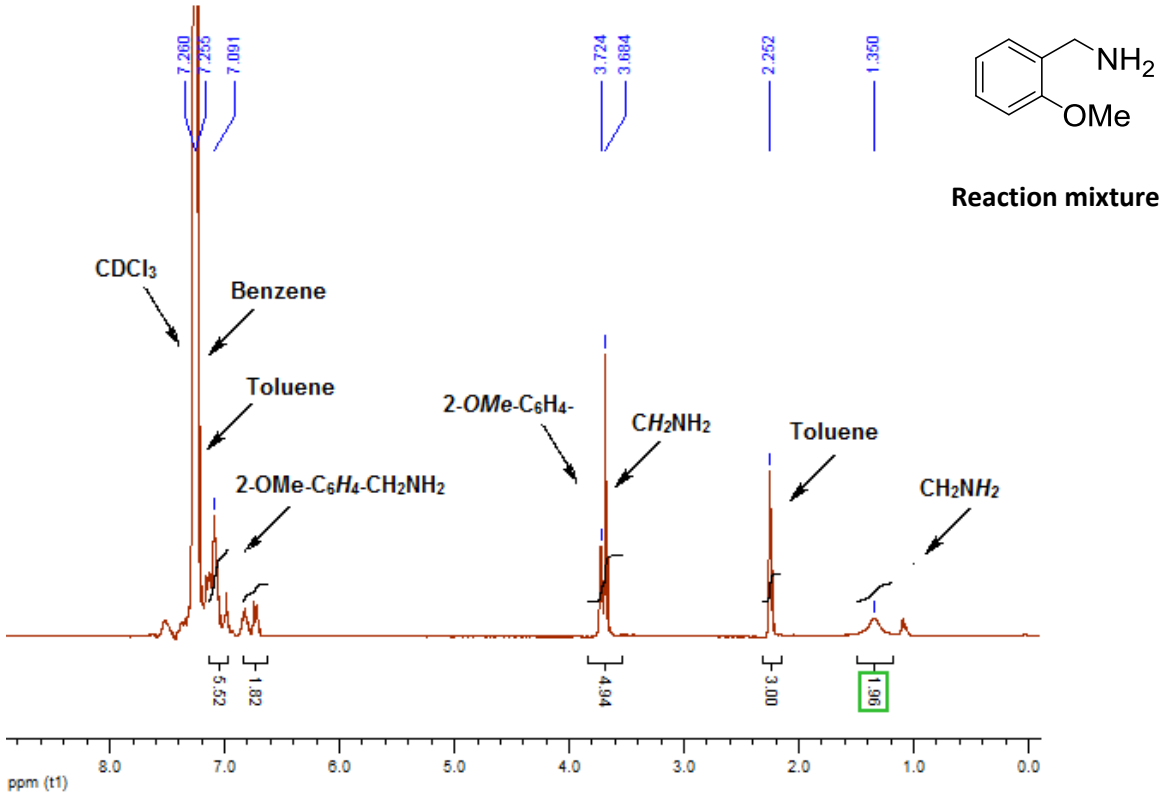
(d) ^{1}H NMR of the isolated product 4-methoxybenzylamine[4]:



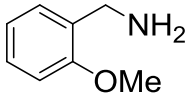
(e) ^{13}C NMR of the isolated product 4-methoxybenzylamine[4]:



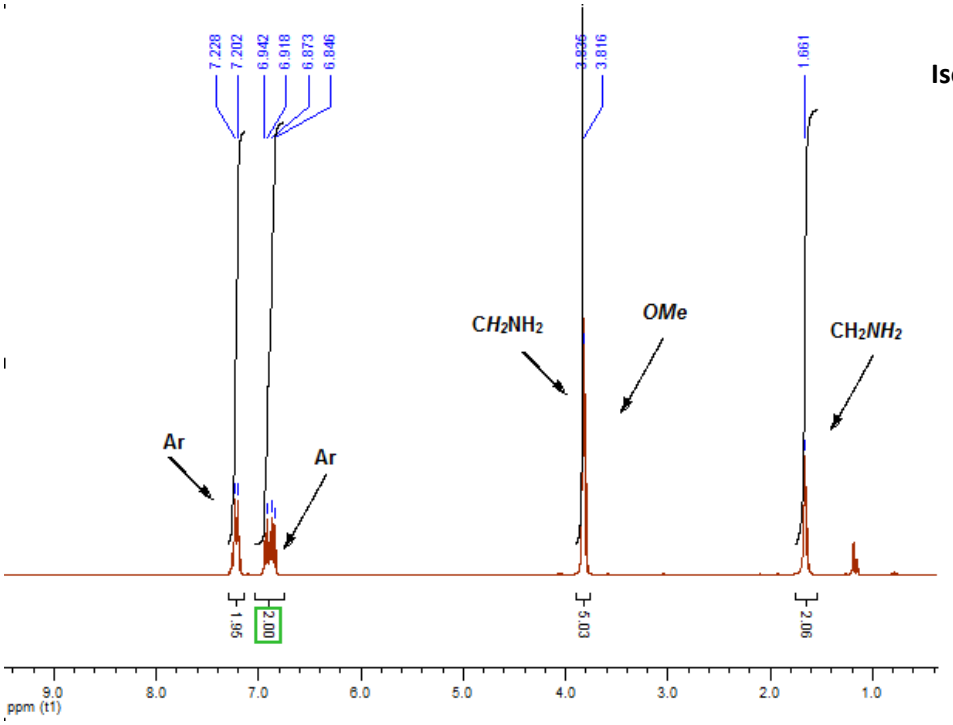
(f) ^{1}H NMR of the isolated product 2-methoxybenzylamine[5]:



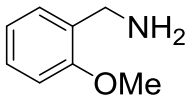
(g) ^{1}H NMR of the reaction mixture 2-methoxybenzylamine[5]:



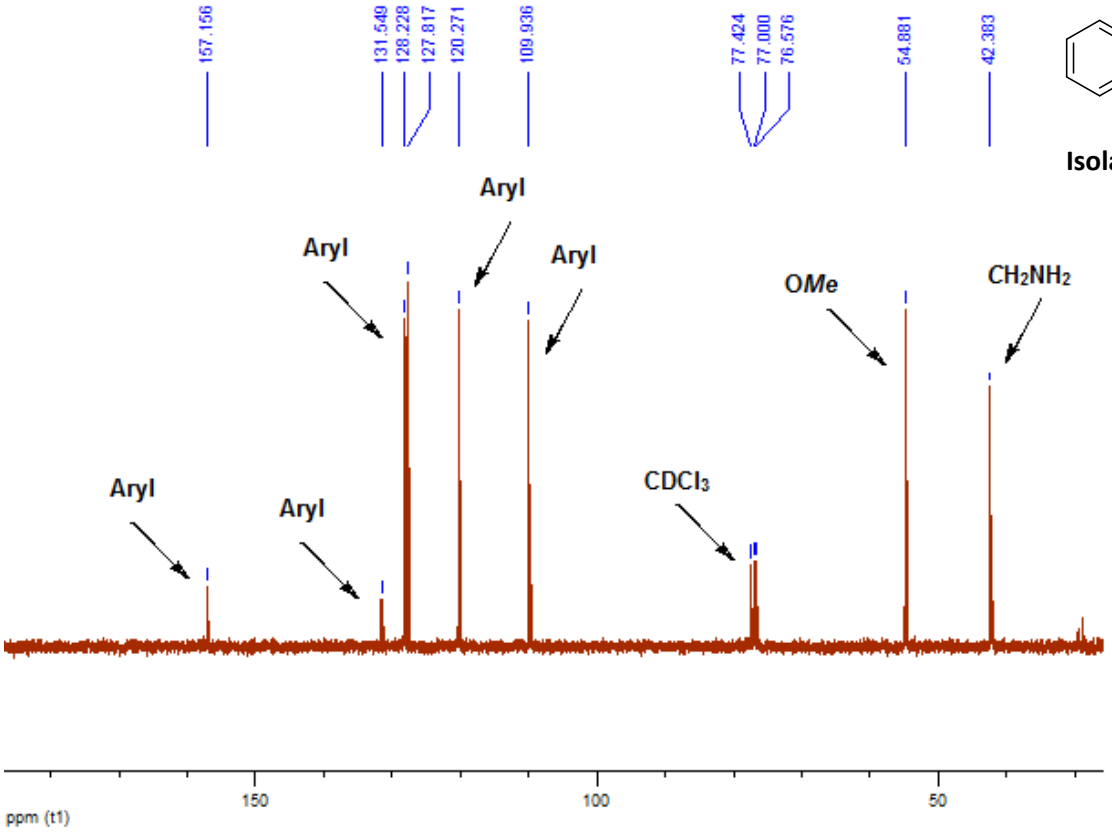
Isolated product



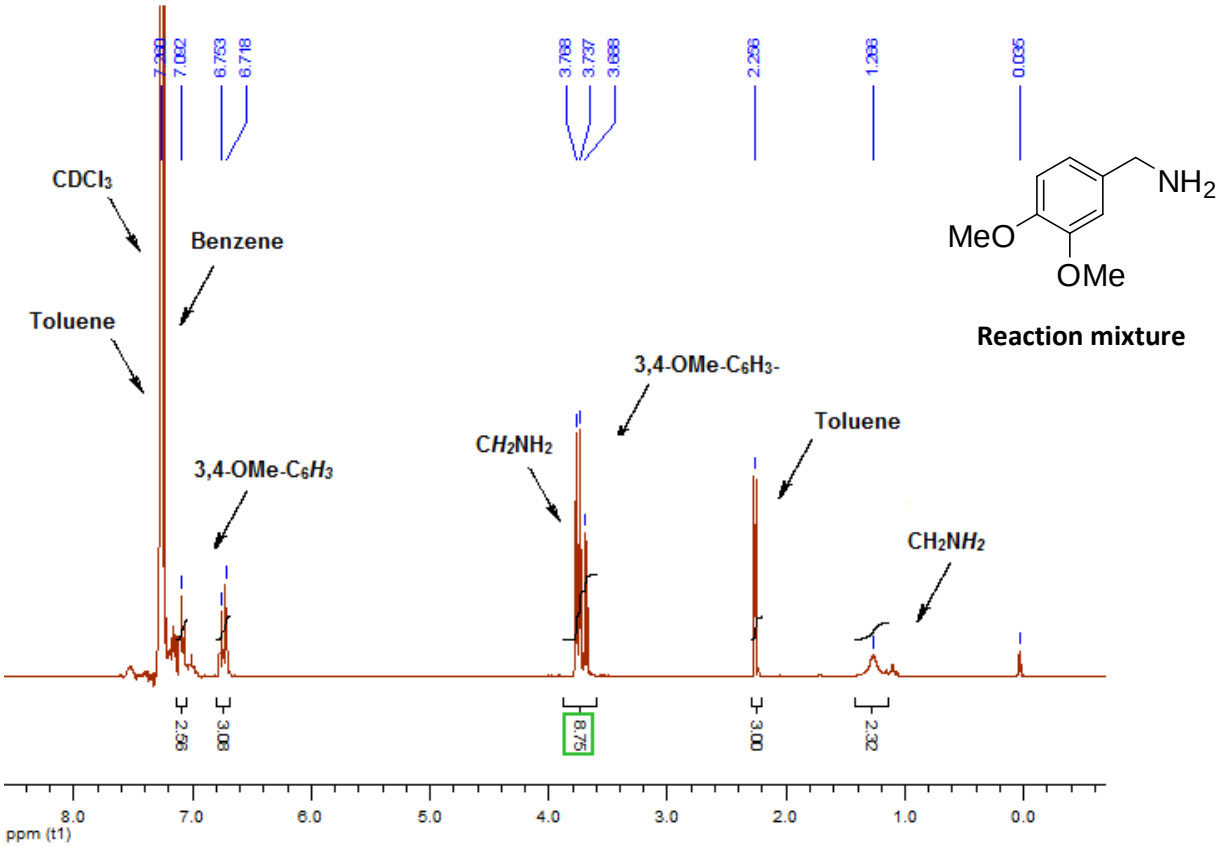
(h) ^{13}C NMR of the isolated product 2-methoxybenzylamine[5]:



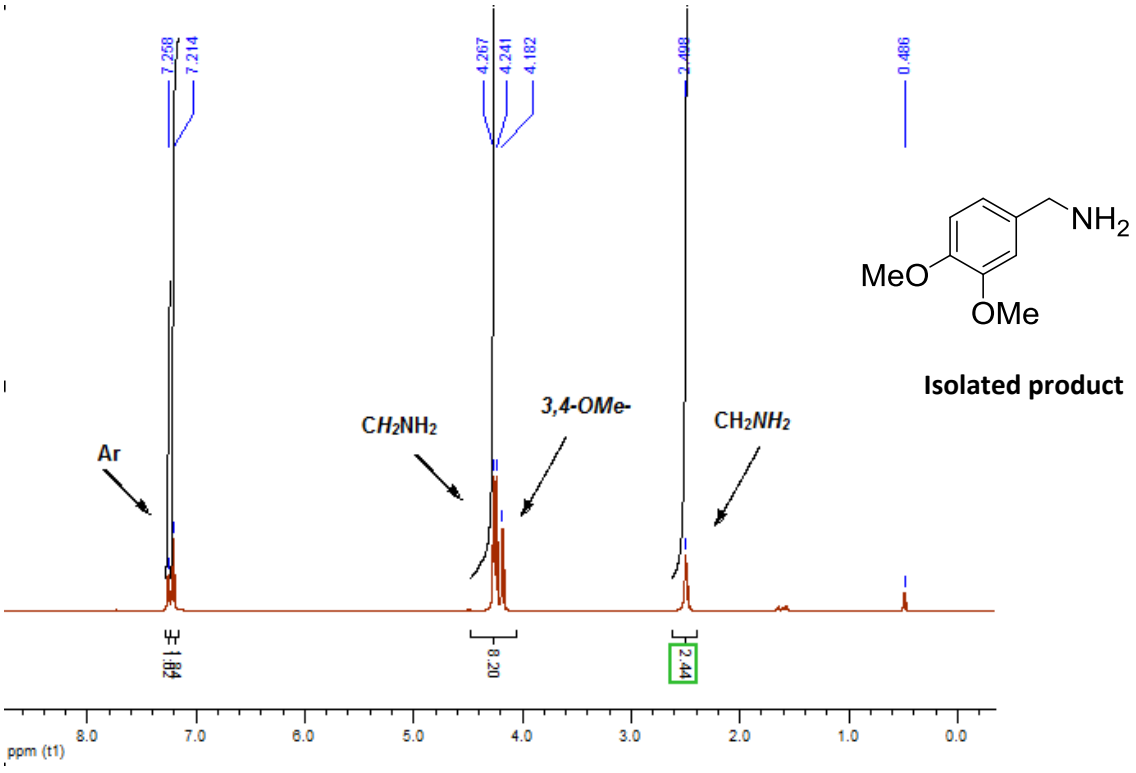
Isolated product



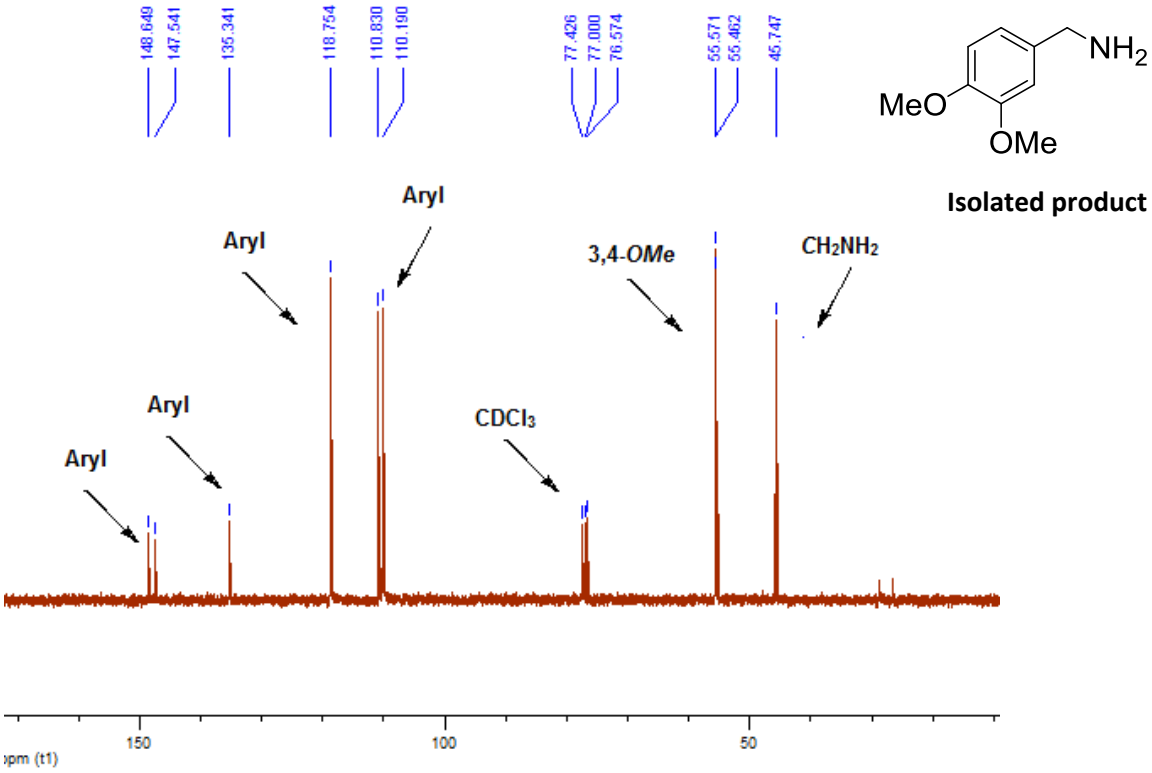
(i) ^{1}H NMR of the reaction mixture 3,4-dimethoxybenzylamine[6]:



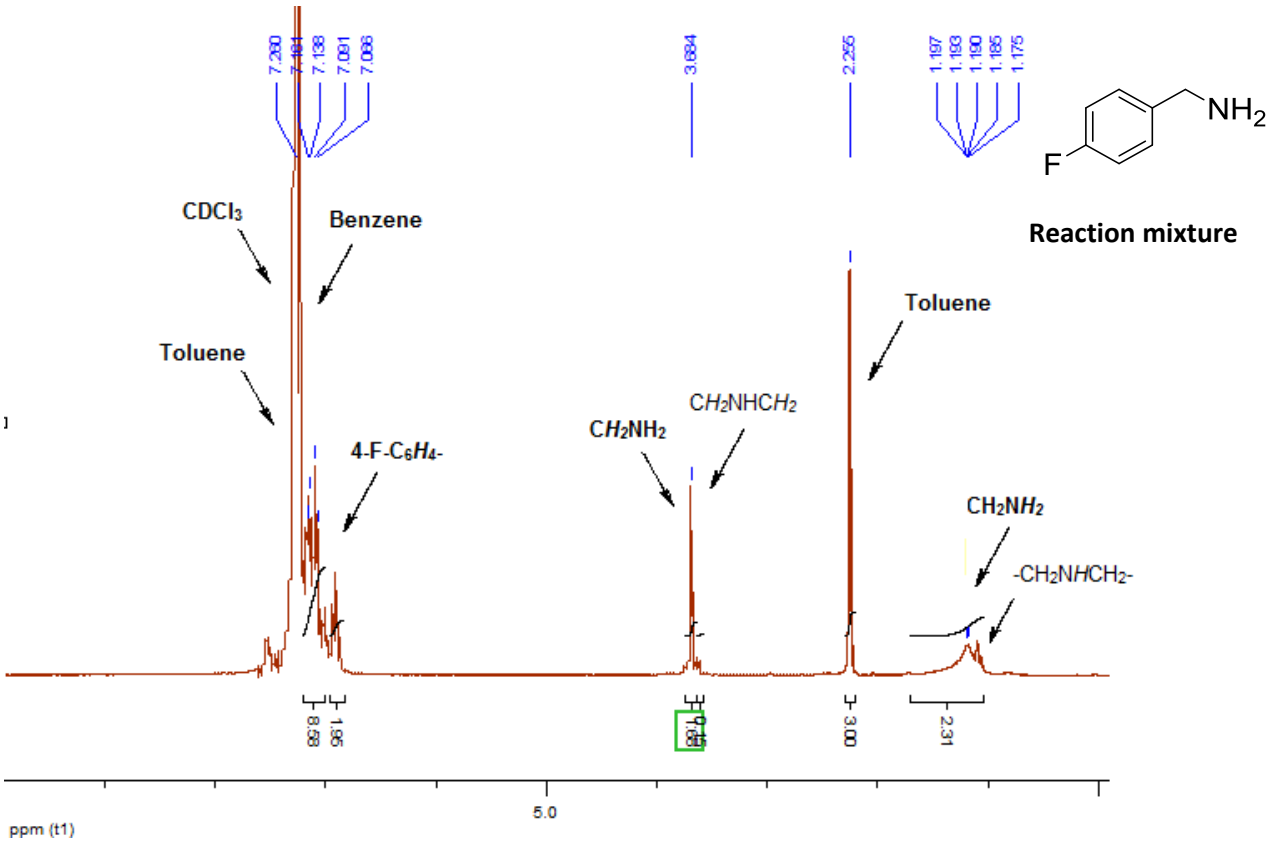
(j) ^{1}H NMR of isolated product 3,4-dimethoxybenzylamine[6]:



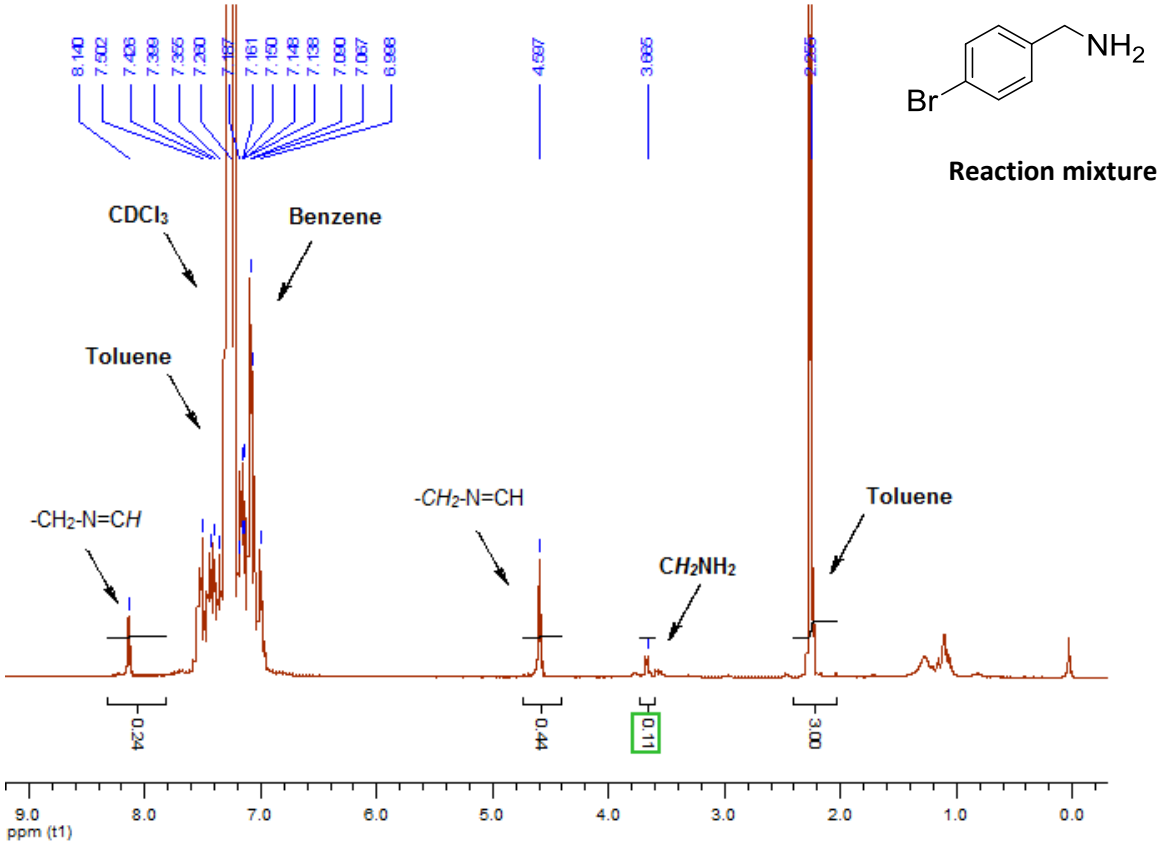
(k) ^{13}C NMR of the isolated product 3,4-dimethoxybenzylamine[6]:



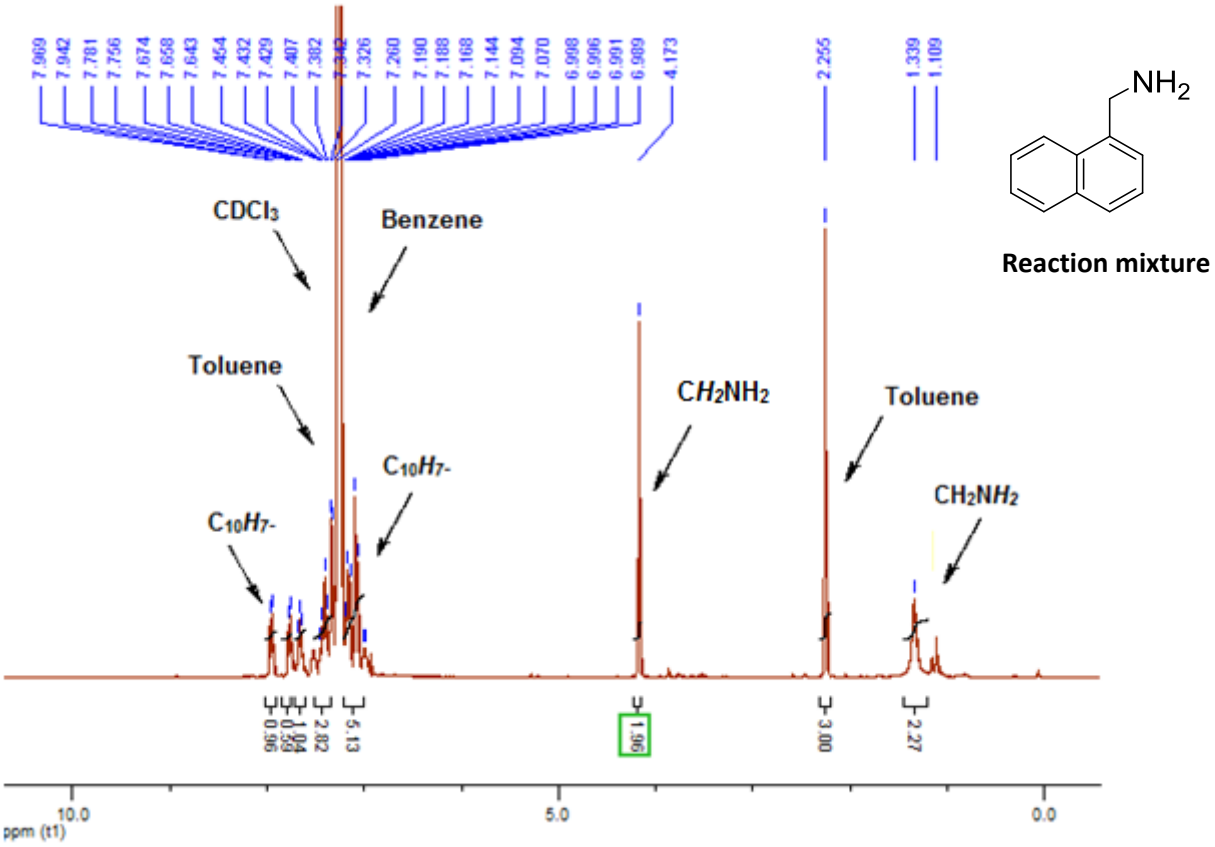
(l) ^{1}H NMR of the reaction mixture 4-fluorobenzylamine[8]:



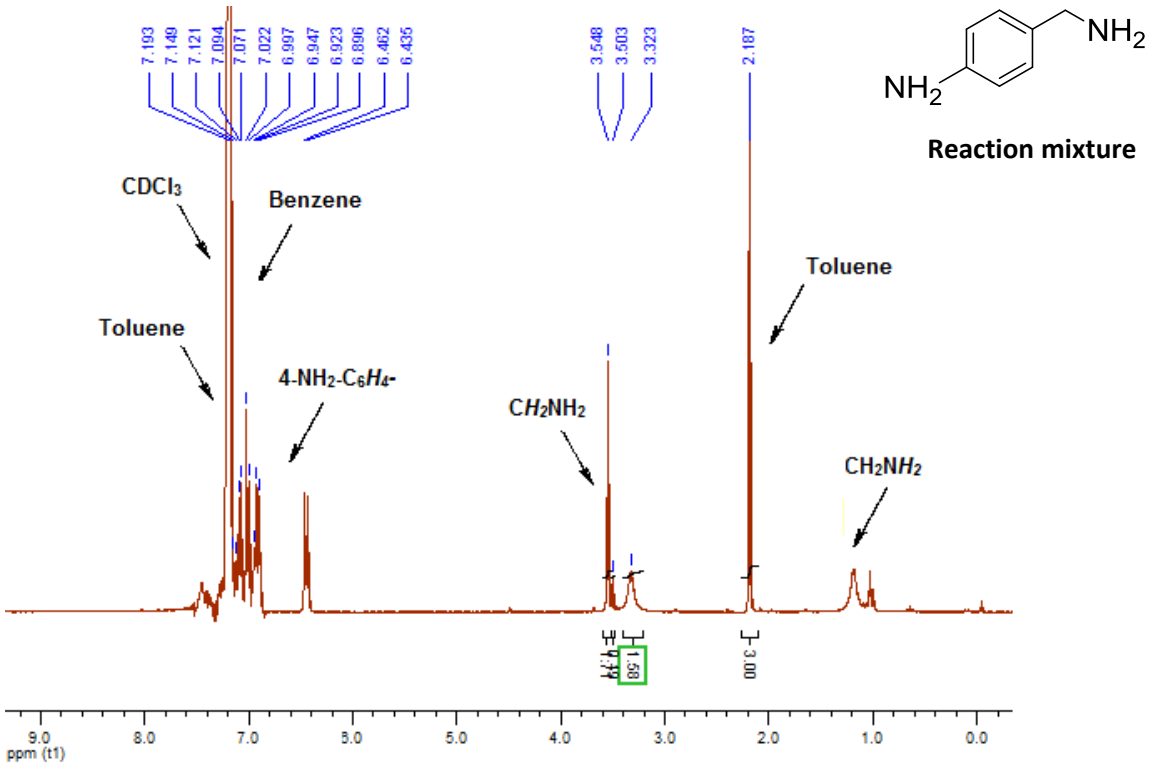
(m) ^{1}H NMR of the reaction mixture 4-bromobenzylamine[9]:



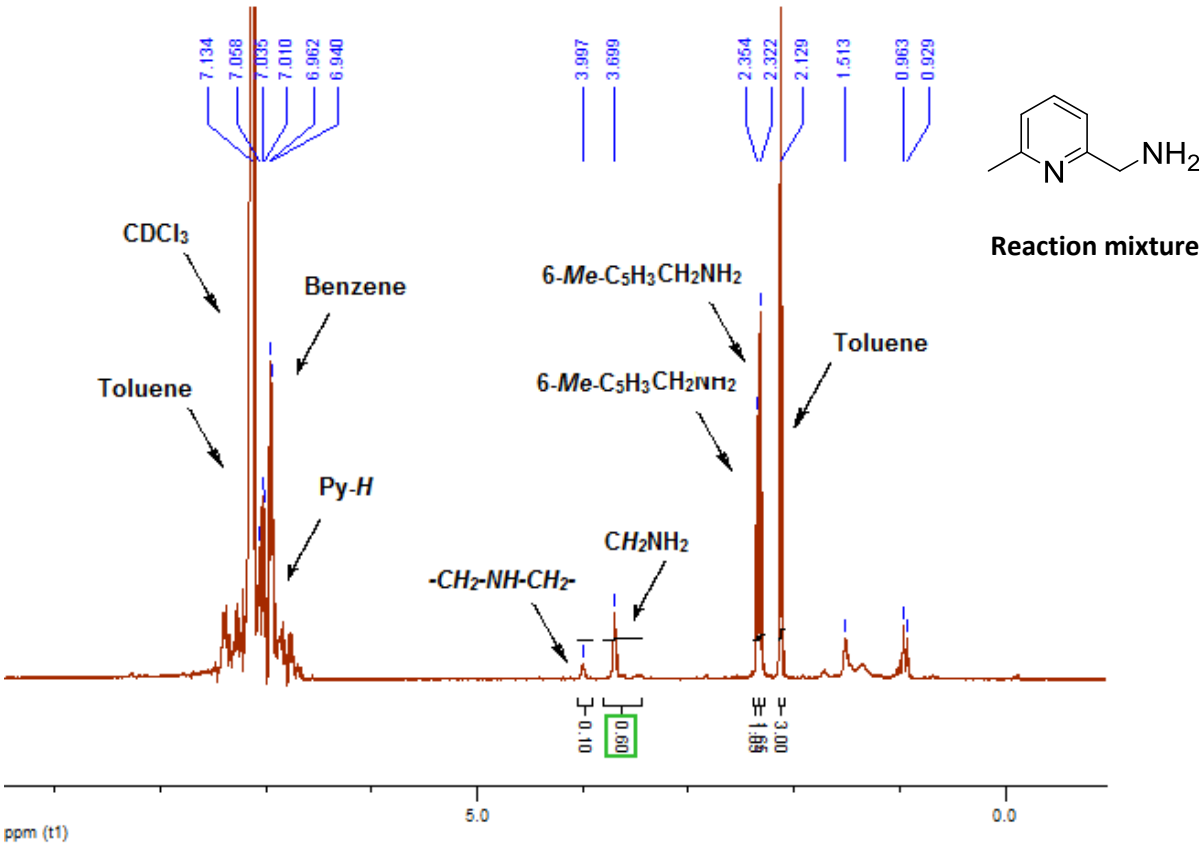
(n) ^{1}H NMR of the reaction mixture 1-napthylamine[10]:



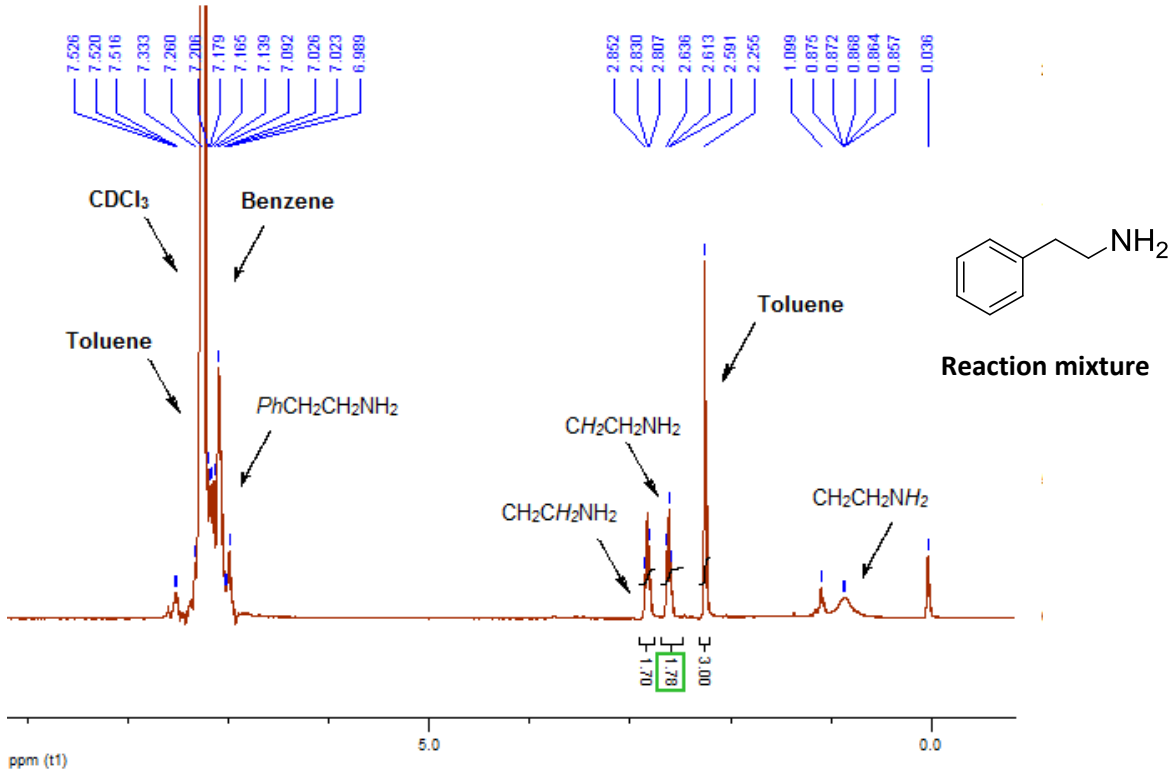
(o) ^{1}H NMR of the reaction mixture 4-aminobenzylamine[11]:



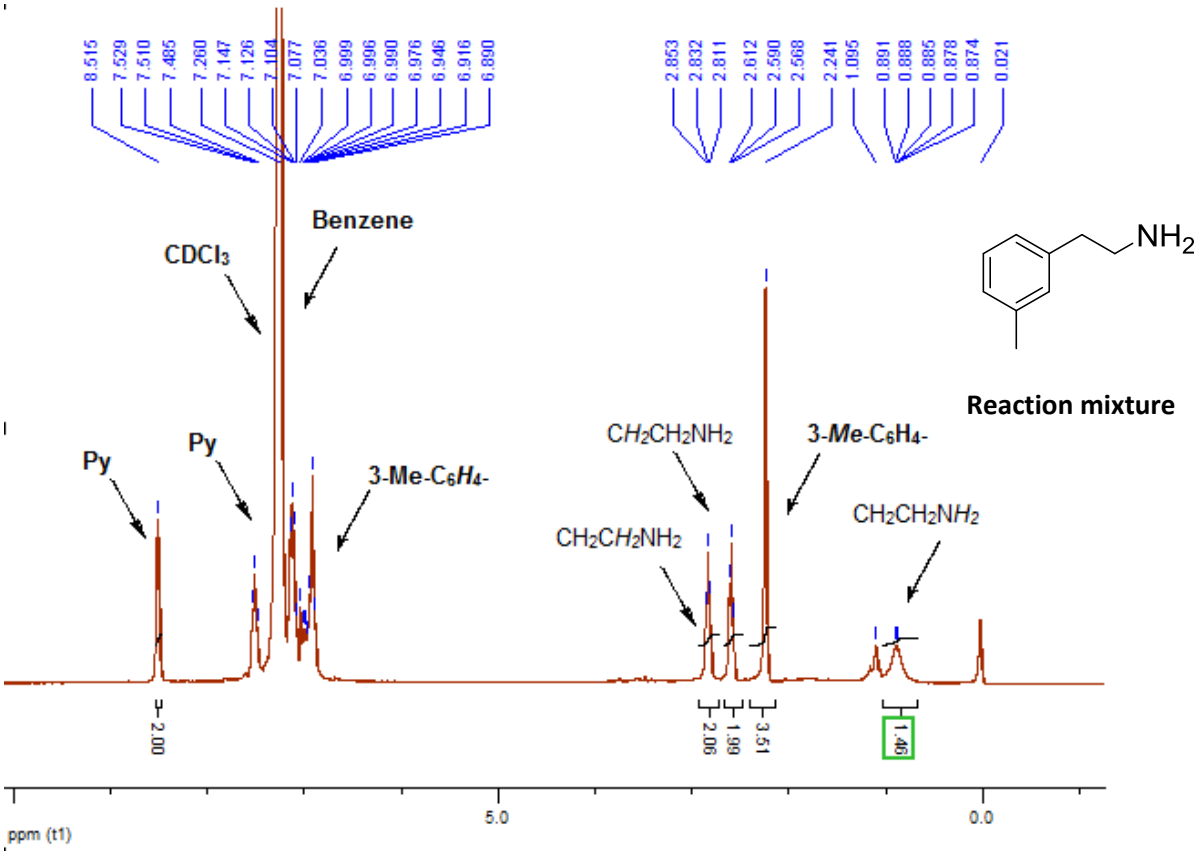
(p) ^{1}H NMR of the reaction mixture 2-aminomethyl-6-methyl-pyridine[12]:



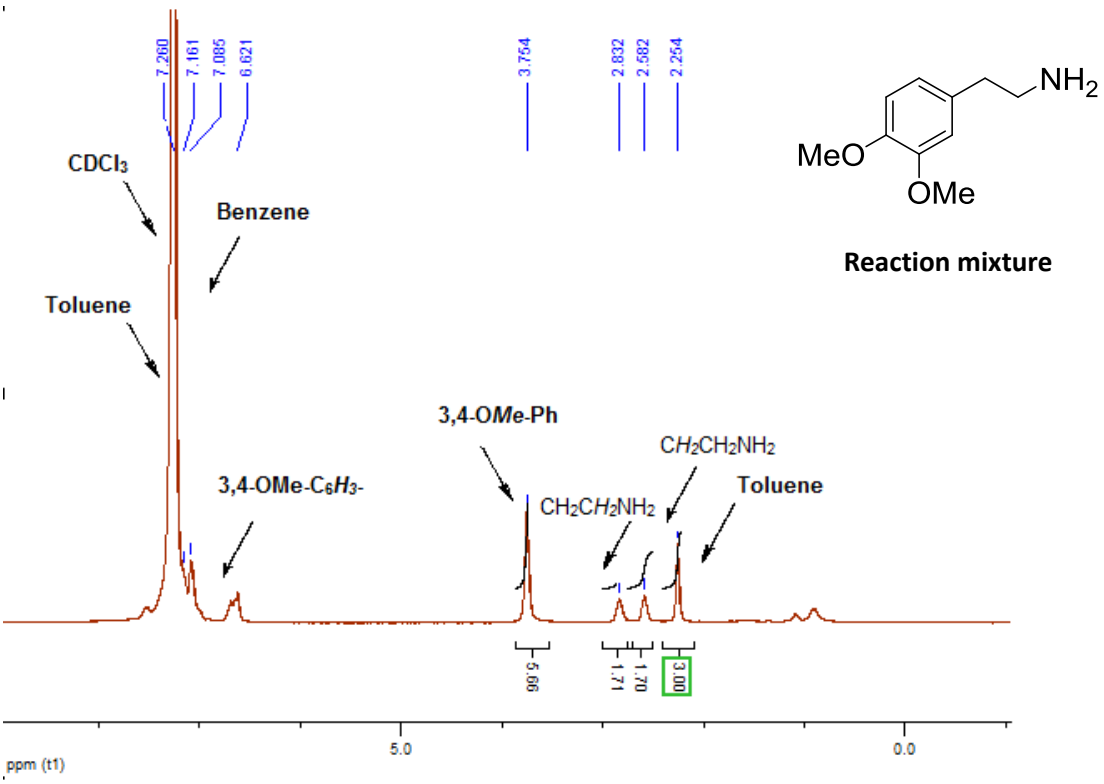
(q) ^{1}H NMR of the reaction mixture 2-phenethylamine [13]:



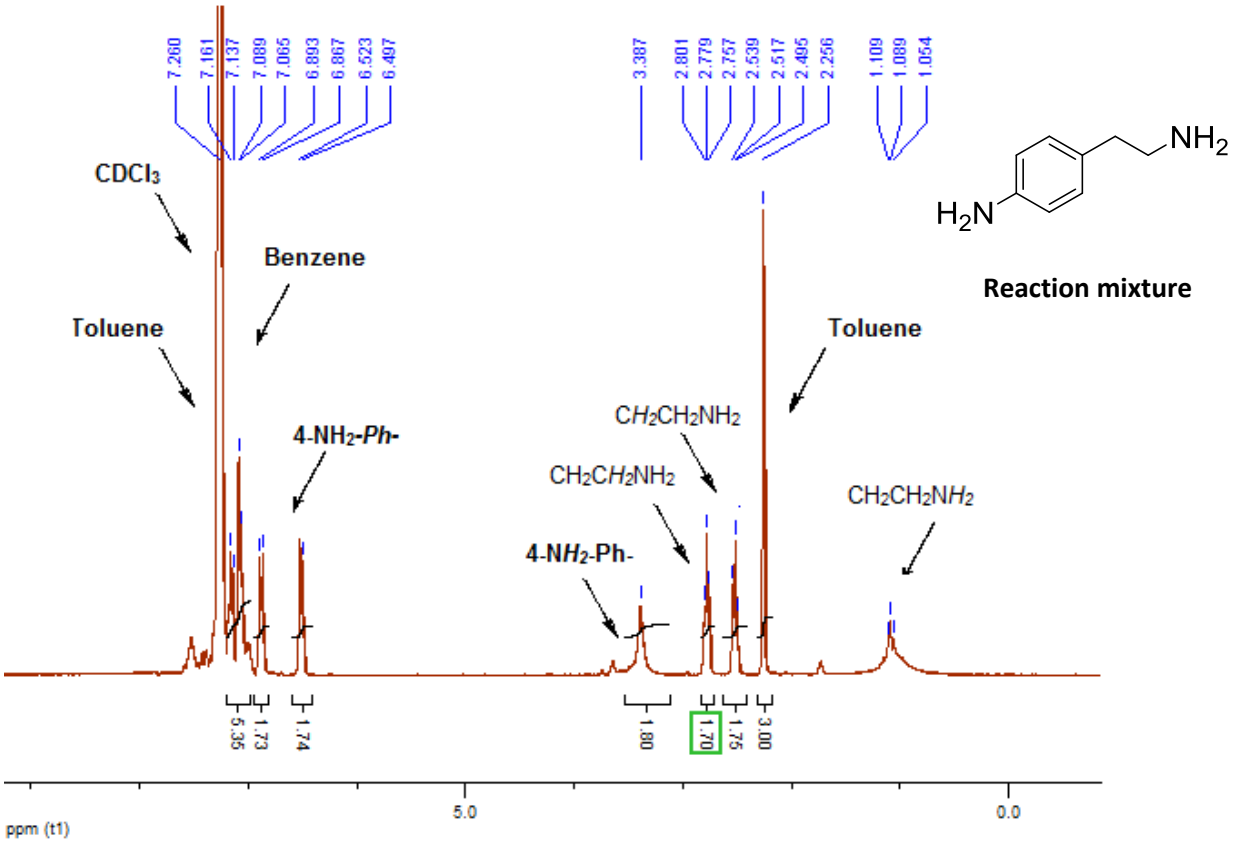
(r) ^{1}H NMR of the reaction mixture 3-methylphenethylamine[14]:



(s) ^{1}H NMR of the reaction mixture 3,4-Dimethoxyphenethylamine[15]:



(t) ^{1}H NMR of the reaction mixture 4-aminophenethylamine [16]:



References:

(1) Armarego, W. L. F.; Perrin, D. D. Purification of Laboratory Chemicals; 4th Edition; Butterworth-Heinemann: Oxford, **2000**.

(2) (a) Khaskin, E.; Posner, Y. D.; Weiner, L.; Leitus, G.; Milstein, D. *Chem commun.* **2013**, *49*, 2771; (b) Srimani, D.; Mukherjee, A.; Goldberg, A. F. G.; Leitus, G.; Diskin-Posner, Y.; Shimon, L. J. W.; Ben-David, Y.; Milstein, D. *Angew. Chem. Int. Ed.* **2015**, DOI: 10.1002/anie.201502418.

(3) Zhang, L.; Zuo, Z.; Leng, X.; Huang, Z. *Angew. Chem. Int. Ed*. **2014**, *53*, 2696.

(4) Gunanathan, C.; Milstein, D. *Angew. Chem. Int. Ed.* **2008**, *47*, 8661.

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(6)Lu, Z.; Williams, T. J. *Chem. Commun*. **2014**, *50*, 5391.

(7) Ayedi , M. A.; Bigot,Y. L.; Ammar, H.; Abid, S.; Gharbi, R. E.; Delmas, M. *Synth. Commun.* **2013**, *43*, 2127.

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(9) Commercially available from Acros Organics and the ^{1}H NMR spectrum is in accordance with it.

(10) van Kalkeren, A.; Bruins, J. J.; Rutjes, F. P. J. T.; van Delft, F. L. *Adv. Synth. Catal.* **2012**, *354*, 1417.

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(12) Commercially available and the ^{1}H NMR spectrum was in accordance with it.

(13) Gunanathan, C.; Milstein, D. *Angew. Chem. Int. Ed.* **2008**, *47*, 8661.

(14) Commercially available from Sigma-Aldrich and the ^{1}H NMR spectrum is in accordance with it.

(15) http://www.sigmaaldrich.com/spectra/fnmr/FNMR009969.PDF.

(16) http://www.sigmaaldrich.com/spectra/fnmr/FNMR000584.PDF.