Supporting information.

C-N bond formation between alcohols and amines using an iron catalyst

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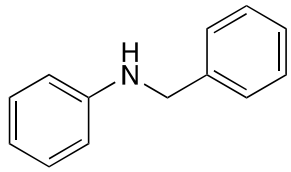
General Procedure for the alkylation of amines with alcohols.

Aniline (0.069 mL, 0.76 mmol), benzyl alcohol (0.157 mL, 1.52 mmol), trimethylamine *N*-oxide dihydrate (5.7mg, 0.076 mmol), **1** (40 mg, 0.076 mmol) were placed in a pressure tube which was flushed with nitrogen. Degassed toluene or xylene (0.40 mL) was added and the pressure tube was sealed and heated at 110 ^{o}C (in toluene) or 110 ^{o}C (in xylene) for the time indicated. Once the reaction was complete an additional excess of trimethylamine *N*-oxide dihydrate was added and reacted for a further 0.5 hours after which time the mixture was filtered through celite using 100% EtOAc and the solvent was removed under reduced pressure. Purification is as described below for each product.

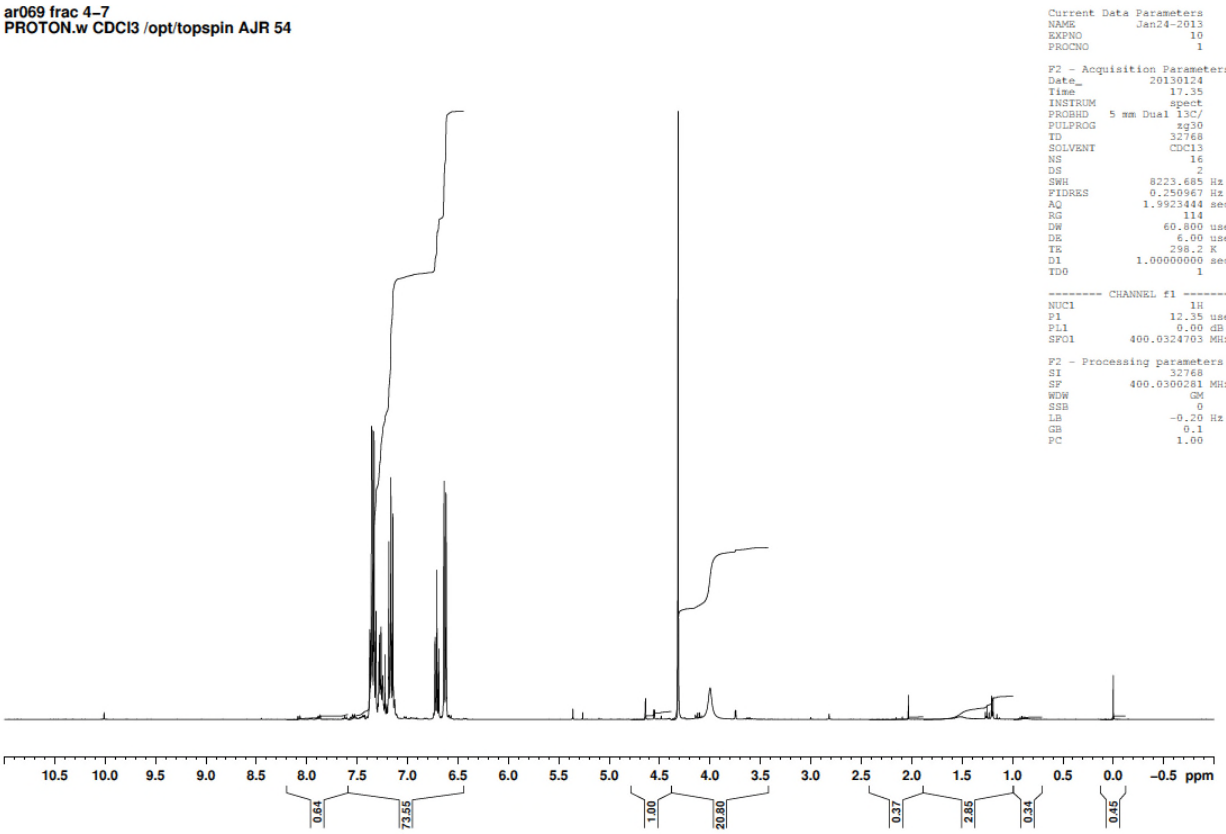
N-Benzylaniline 6.



(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.[1] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give the product as a pale yellow oil (133.7 mg, 0.731 mmol, 95 %). δ_H (400 MHz, $CDCl_3$) 7.30-7.40 (4H, m, Ar*H*), 7.24-7.29 (1H, m, Ar*H*), 7.12-7.20 (2H, m, Ar*H*), 6.68-6.74 (1H, m, Ar*H*), 6.61-6.65 (2H, m, Ar*H*), 4.32 (2H, s, NHCH_2), 4.00 (1H, s, N*H*); δ_C (100 MHz, $CDCl_3$) 148.20 (C), 139.48 (C), 129.30 (CH), 128.67 (CH), 127.55 (CH), 127.27 (CH), 117.60 (CH), 112.49 (CH), 48.36 (CH_2); *m/z* (ESMS+) $[M+H]^+$ 184.1. $C_{13}H_{14}N^+$. Conversion was determined by chiral GC analysis: Chrompac cyclodextrin-β-236M-19, 50 m x 0.25 mm x 0.25 μM, T = 140 ^{o}C, 10 min, 5 ^{o}C /min, P = 15 psi H_2, det = FID 220 ^{o}C, inj = 220 ^{o}C, aniline 5.8 min, benzyl alcohol 7.9 min, imine 31.2 min, amine 39.9 min.

ar069 frac 4–7
PROTON.w CDCl3 /opt/topspin AJR 54



ar069 frac 4–7
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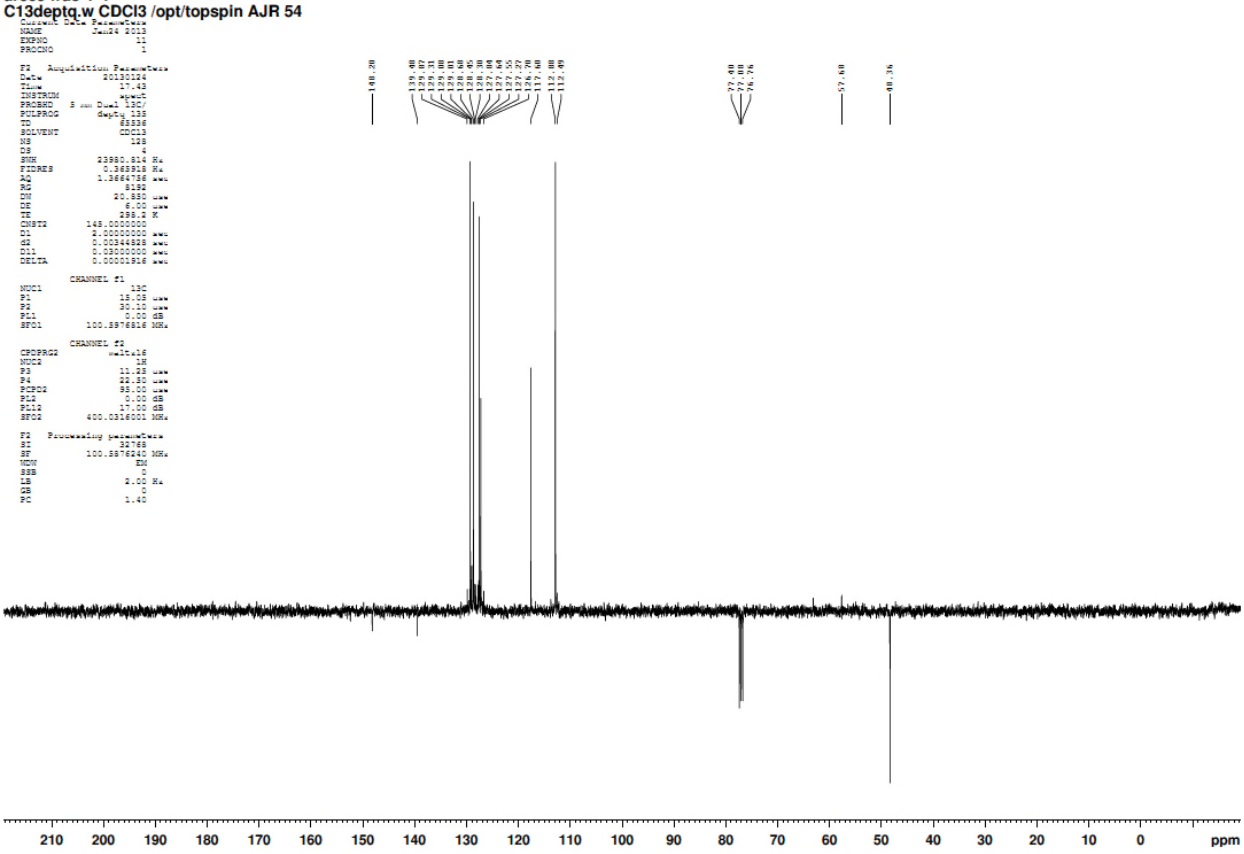
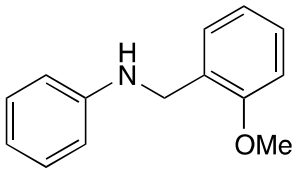
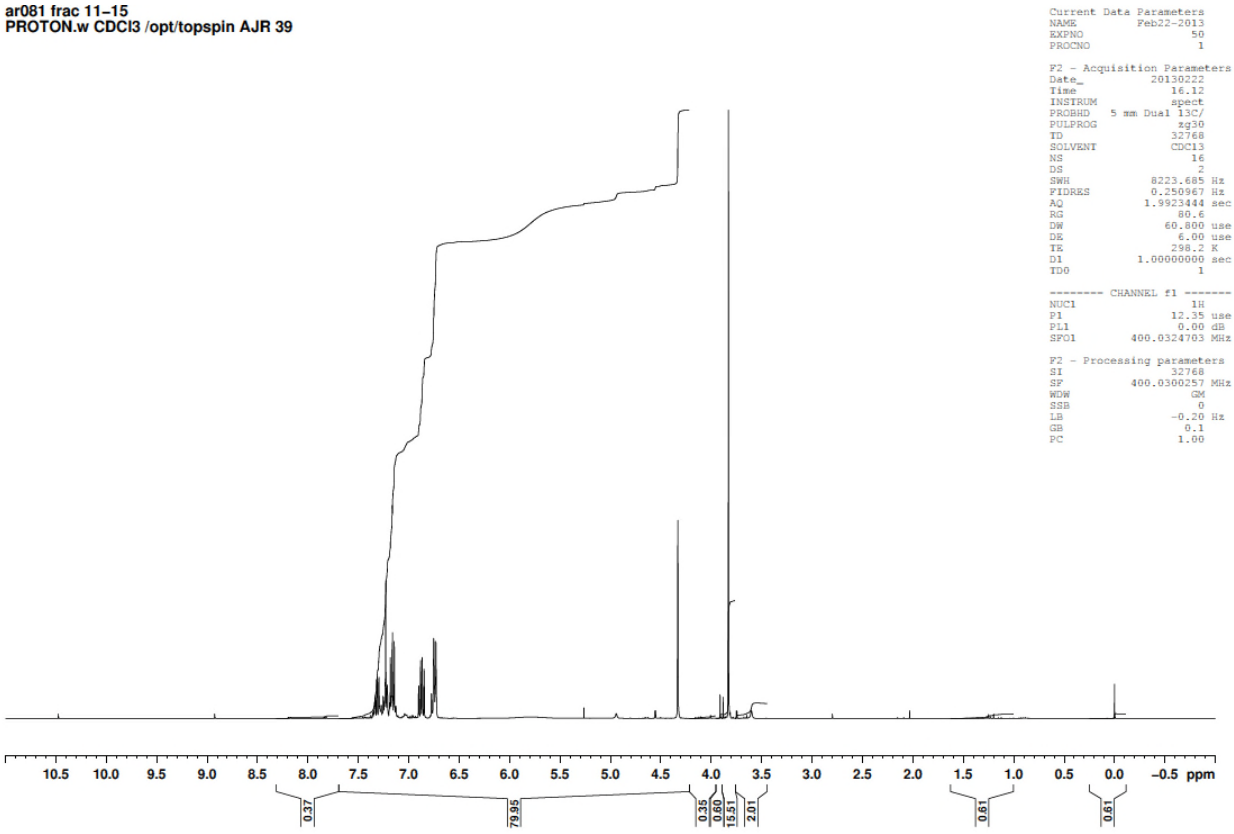


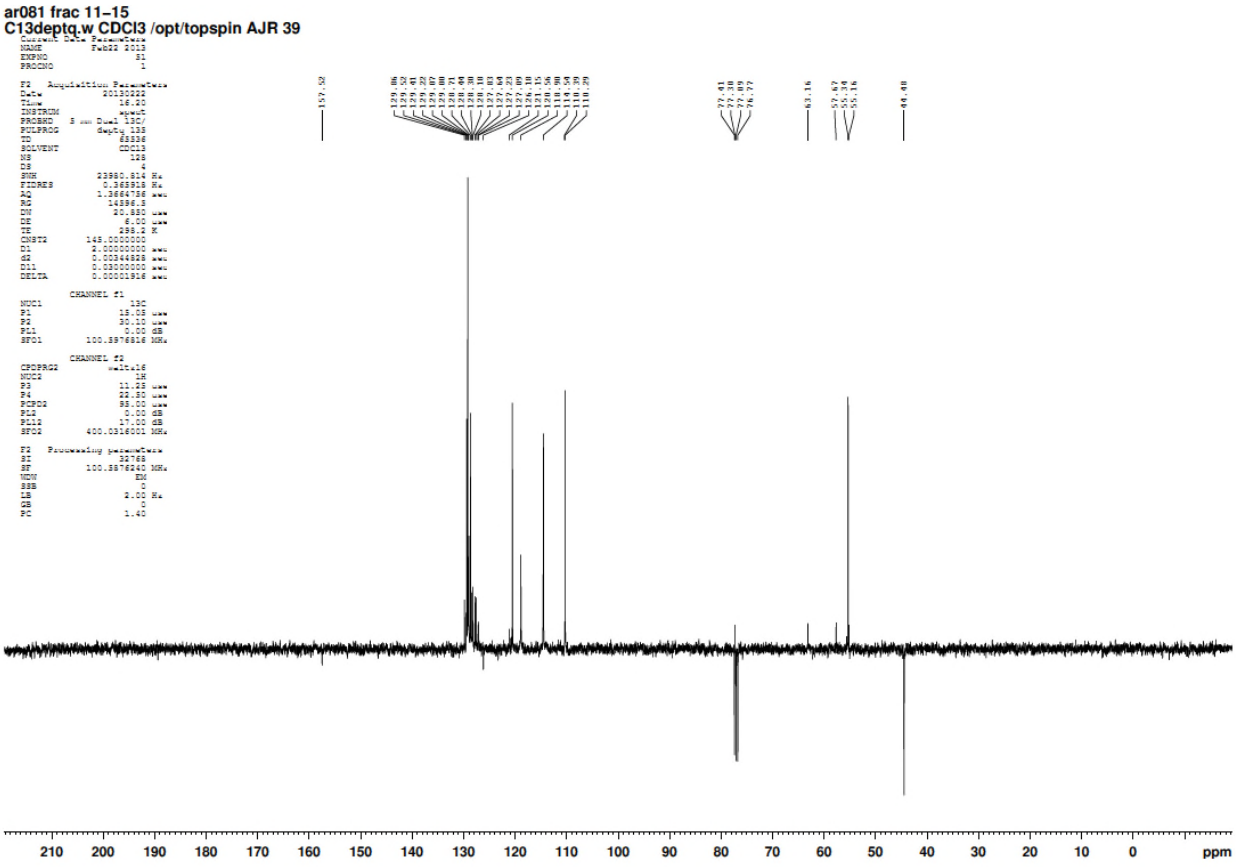
***N*-(2-Methoxybenzyl)aniline 9.**



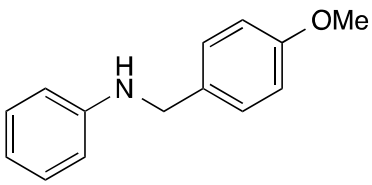
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.[2] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give a pale yellow oil (136.6 mg, 0.641 mmol, 84 %). δ_H (400 MHz, $CDCl_3$) 7.27-7.36 (2H, m, Ar*H*), 7.12-7.20 (2H, m, Ar*H*), 6.84-6.91 (2H, m, Ar*H*), 6.71-6.78 (3H, m, Ar*H*), 5.35-6.17 (1H, br s, N*H*), 4.33 (2H, s, NHCH_2), 3.83 (3H, s, OCH_3); δ_C (100 MHz, $CDCl_3$) 157.52 (C), 146.61 (C), 129.40 (CH), 129.22 (CH), 128.69 (CH), 126.18 (C), 120.55 (CH), 118.89 (CH), 114.53 (CH), 110.28 (CH), 55.35 (CH_3), 44.48 (CH_2); *m/z* (ESMS+) $[M+H]^+$ 214.1. $C_{14}H_{16}NO^+$.



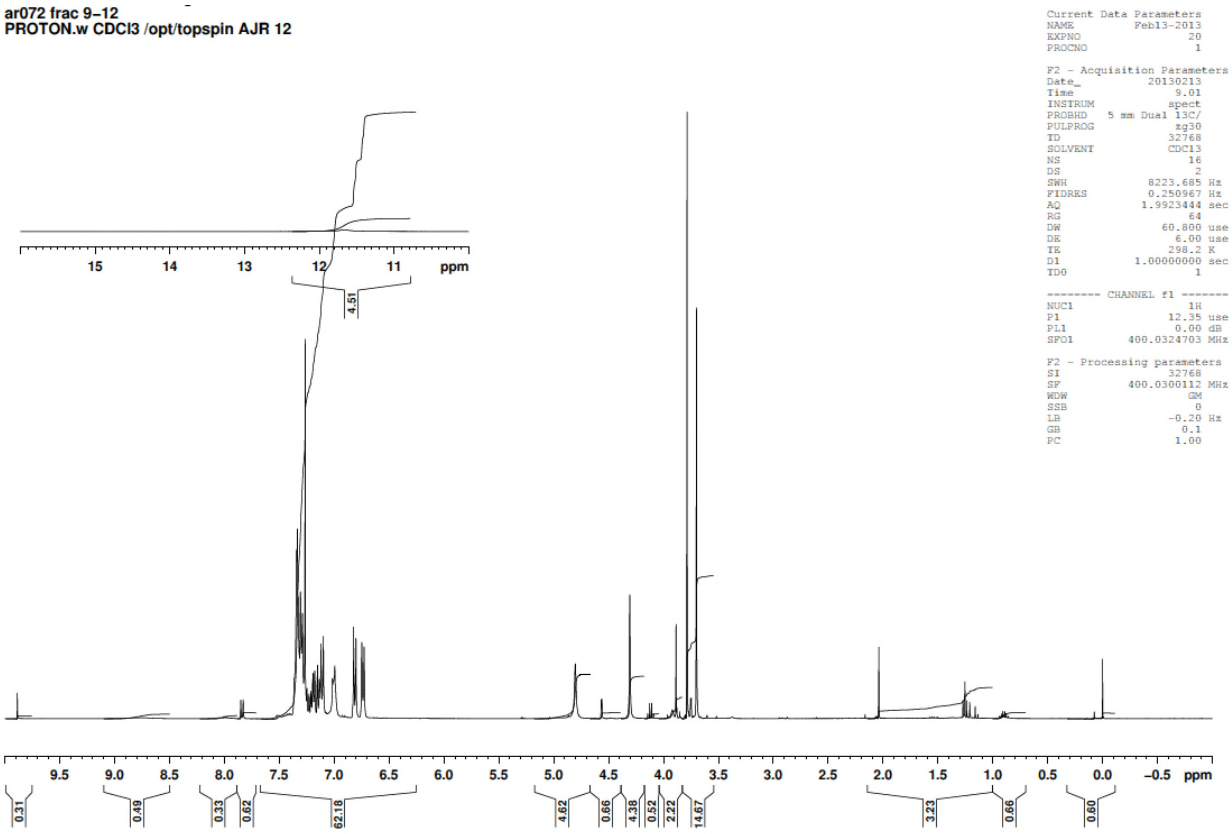


***N*-(4-Methoxybenzyl)aniline 10.**

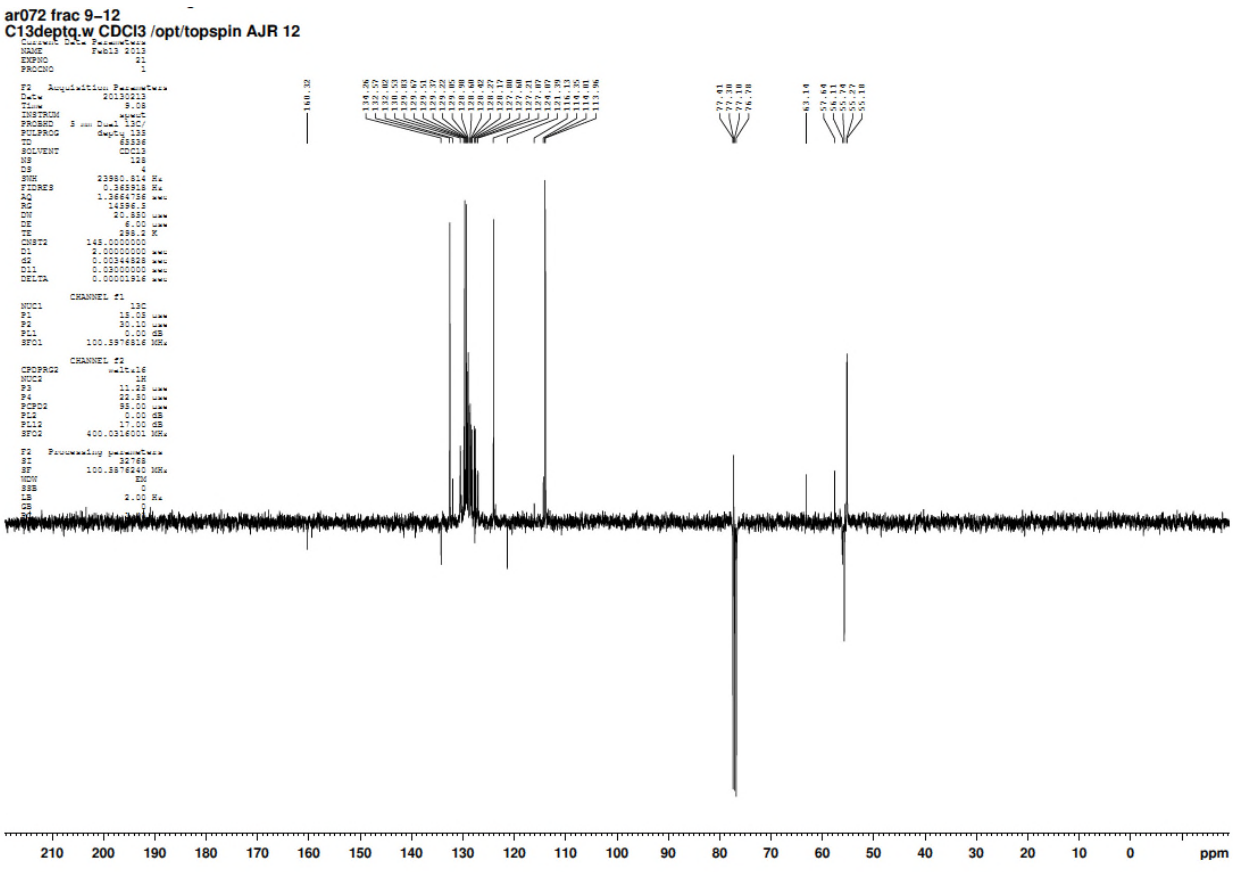


(Toluene, 110 °C, 48h)

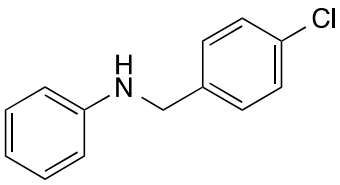
This compound has been reported and fully characterized.[1] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. Ether to give the product as a brown oil (103.5 mg, 0.486 mmol, 64 %). After purification there was still presence of starting material but the characteristic peaks could be identified from 1H NMR. δ_H (400 MHz, $CDCl_3$) 7.16-7.23 (2H, m, Ar*H*), 7.08-7.15 (3H, m, Ar*H*), 6.79-6.84 (2H, m, Ar*H*), 6.70-6.77 (2H, m, Ar*H*), 4.27-4.33 (1H, br s, N*H*), 3.78 (3H, s, OCH_3), 3.70 (2H, s, NHCH_2); *m/z* (ESMS+) $[M+H]^+$ 214.1. $C_{13}H_{13}ClN^+$.



13C NMR could be added:

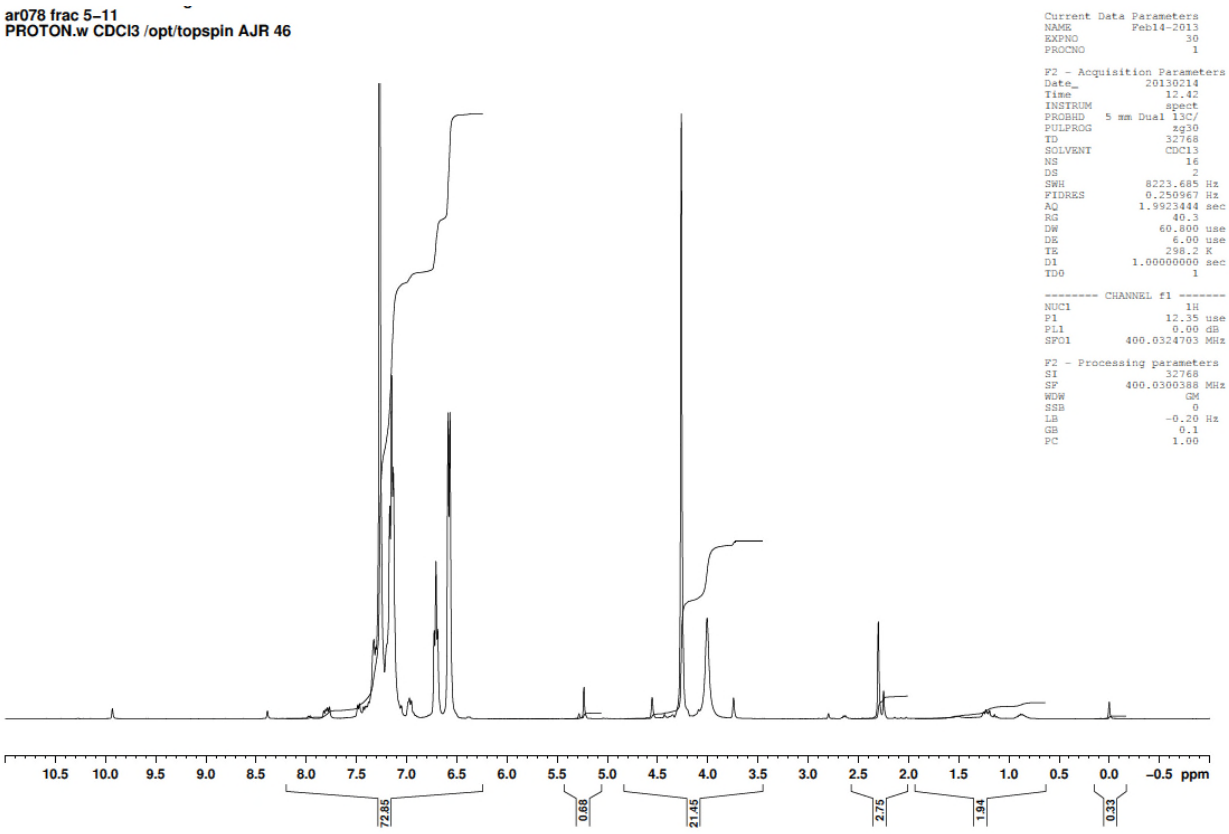


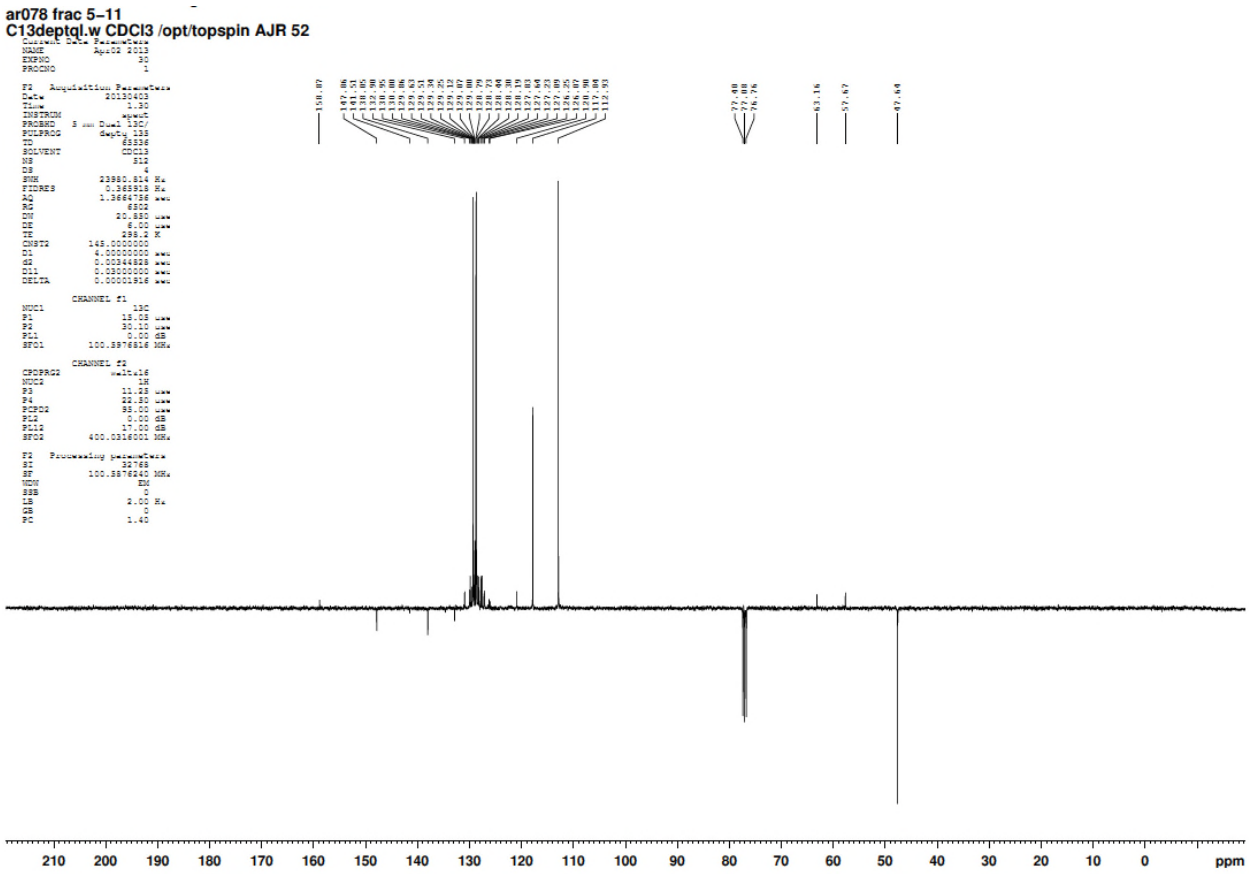
***N*-(4-Chlorobenzyl)aniline, 11.**



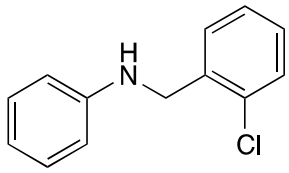
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.[1] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. Ether to give the product as a pale yellow oil (100.0 mg, 0.461 mmol, 60 %). δ_H (400 MHz, $CDCl_3$) 7.22-7.36 (4H, m, Ar*H*), 7.09-7.19 (2H, m, Ar*H*), 6.67-6.75 (1H, m, Ar*H*), 6.53-6.61 (2H, m, Ar*H*), 4.26 (2H, s, NHCH_2), 4.01 (1H, br s, N*H*); δ_C (100 MHz, $CDCl_3$) 147.86 (C), 138.05 (C), 132.90 (C), 129.34 (CH), 128.79 (CH), 128.73 (CH), 117.84 (CH), 112.93 (CH), 47.64 (CH_2); *m/z* (ESMS+) $[M+H]^+$ 218.1. $C_{13}H_{13}ClN^+$.



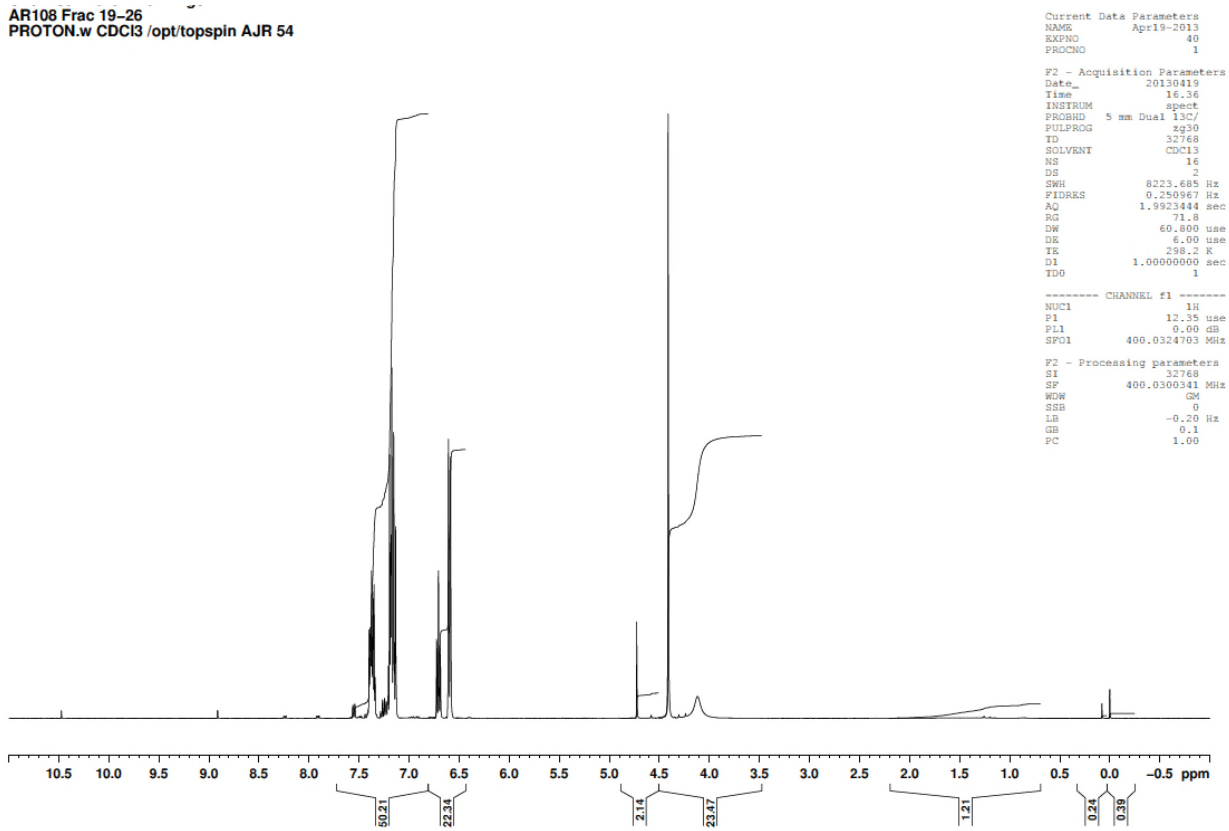


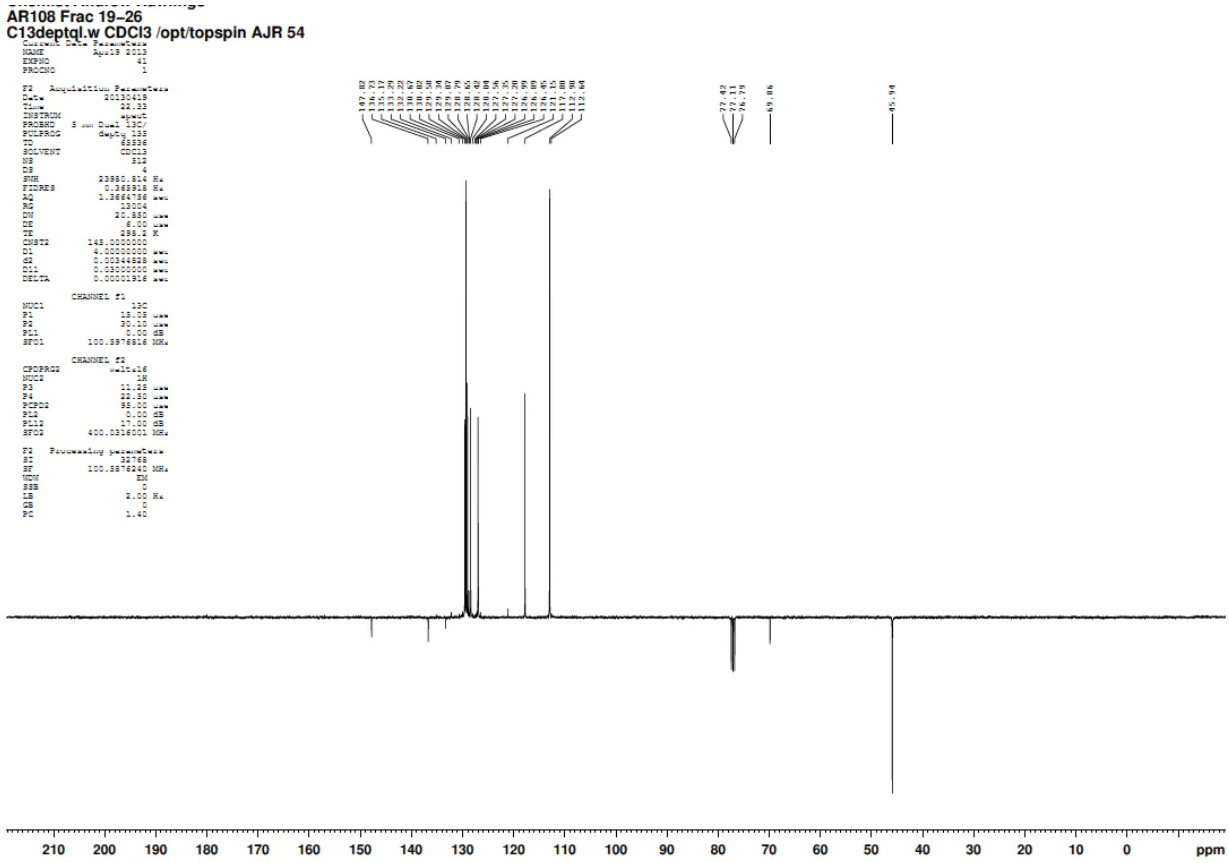
***N*-(2-Chlorobenzyl)aniline 12.**



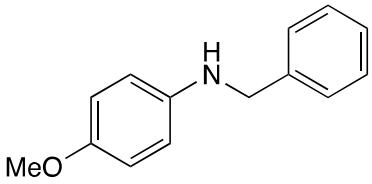
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised [2] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give the product as a light brown oil (93.0 mg, 0.429 mmol, 56 %). δ_H (400 MHz, $CDCl_3$) 7.34-7.42 (2H, m, Ar*H*), 7.11-7.20 (4H, m, Ar*H*), 6.68-6.73 (1H, m, Ar*H*), 6.57-6.62 (2H, m, Ar*H*), 4.41 (2H, s, NHCH_2), 4.12 (1H, br s, N*H*); δ_C (100 MHz, $CDCl_3$) 147.81 (C), 136.72 (C), 133.28 (C), 129.57 (CH), 129.33 (CH), 129.06 (CH), 128.41 (CH), 126.97 (CH), 117.79 (CH), 112.97 (CH), 45.94 (CH_2); *m/z* (ESMS+) $[M+H]^+$ 218.1. $C_{13}H_{13}ClN^+$.



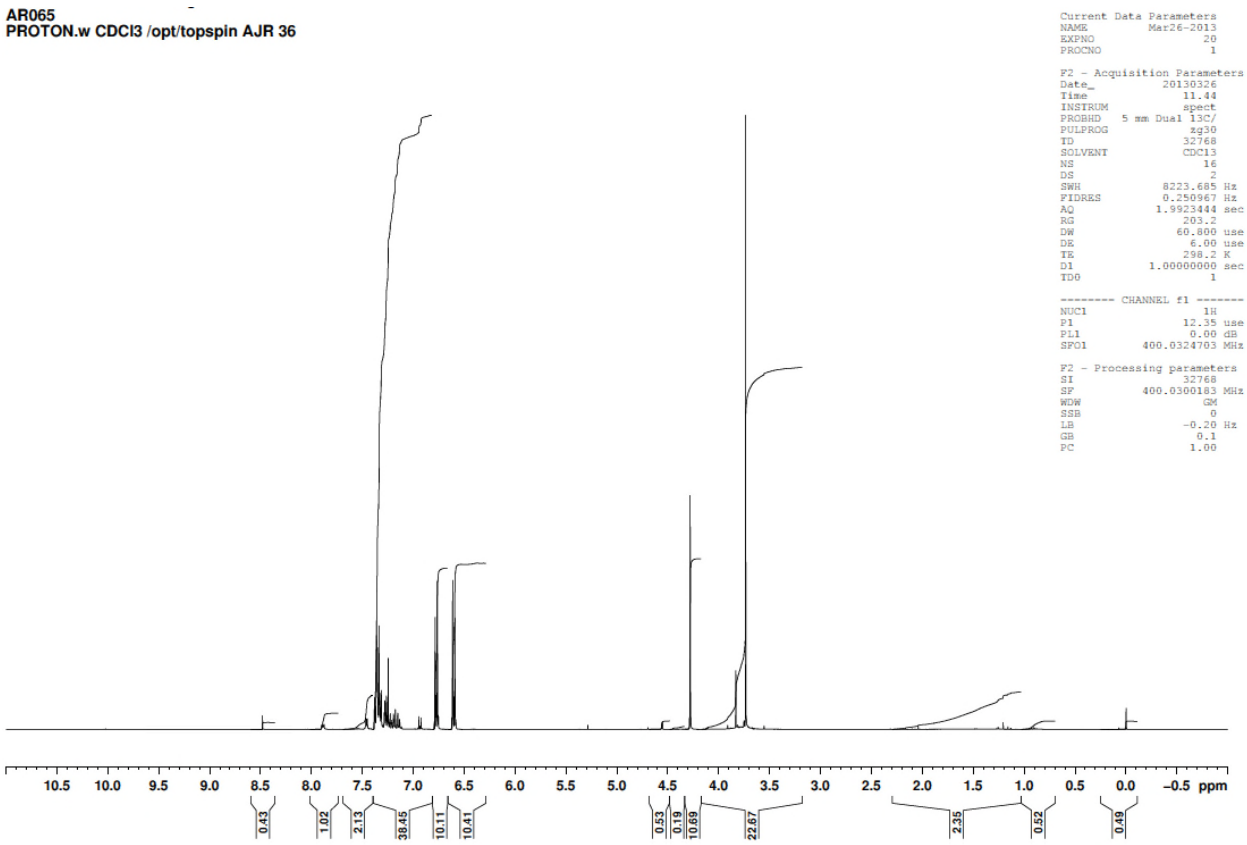


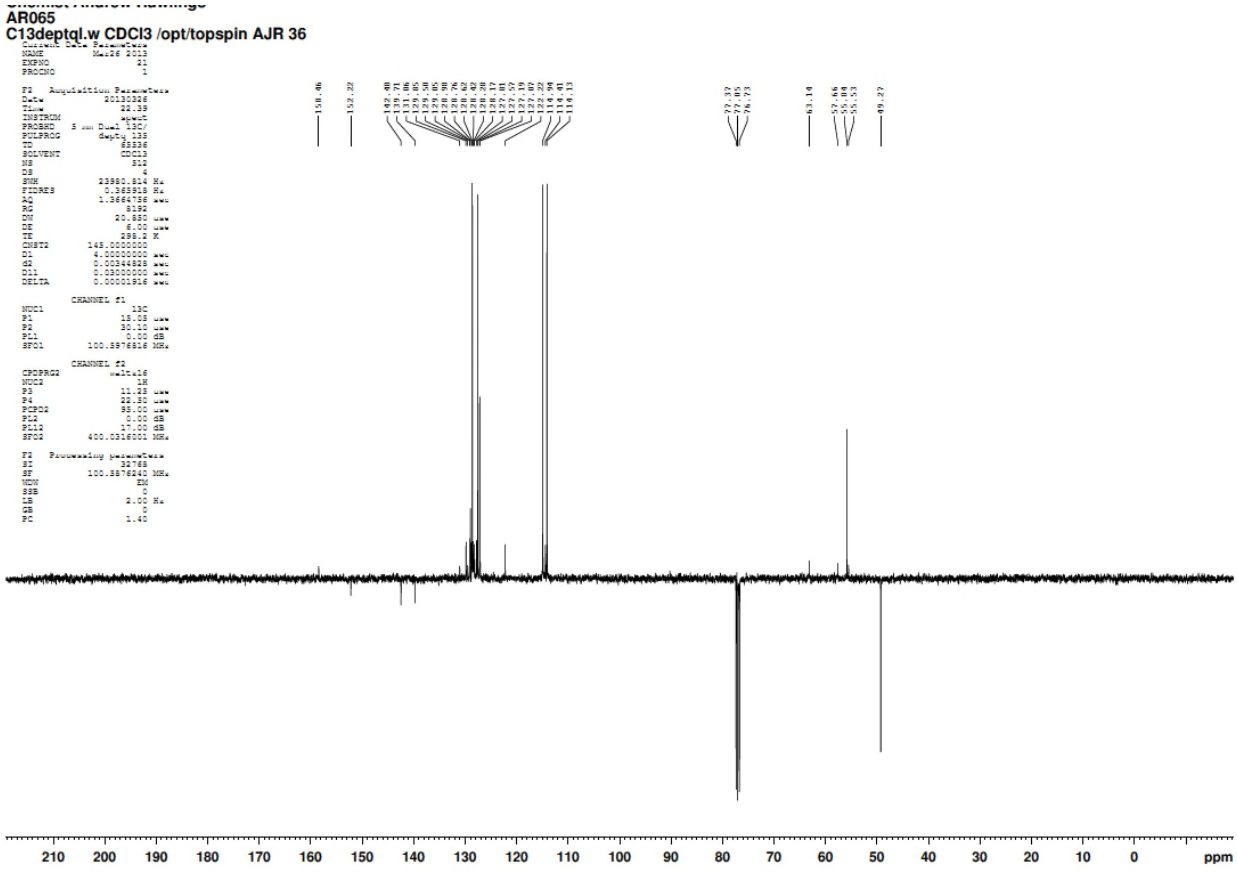
***N*-Benzyl-4-methoxyaniline 13.**



(Toluene, 110 °C, 48h)

This compound has been reported and fully characterized.[3] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give the product as a brown oil (140.6 mg, 0.660 mmol, 87 %). δ_H (400 MHz, $CDCl_3$) 7.31-7.39 (3H, m, Ar*H*), 7.11-7.29 (1H, m, Ar*H*), 6.75-6.80 (2H, m, Ar*H*), 6.57-6.63 (2H, m, Ar*H*), 4.28 (2H, s, NHCH_2), 3.74 (3H, s, OCH_3); δ_C (100 MHz, $CDCl_3$) 152.22 (C), 142.48 (C), 139.71 (C), 128.62 (CH), 127.57 (CH), 127.19 (CH), 114.94 (CH), 114.13 (CH), 55.84 (CH_3), 49.27 (CH_2); *m/z* (ESMS+)$[M+H]^+$ 214.1. $C_{14}H_{16}NO^+$.

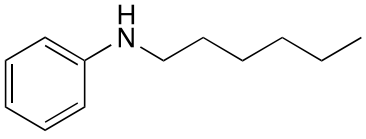




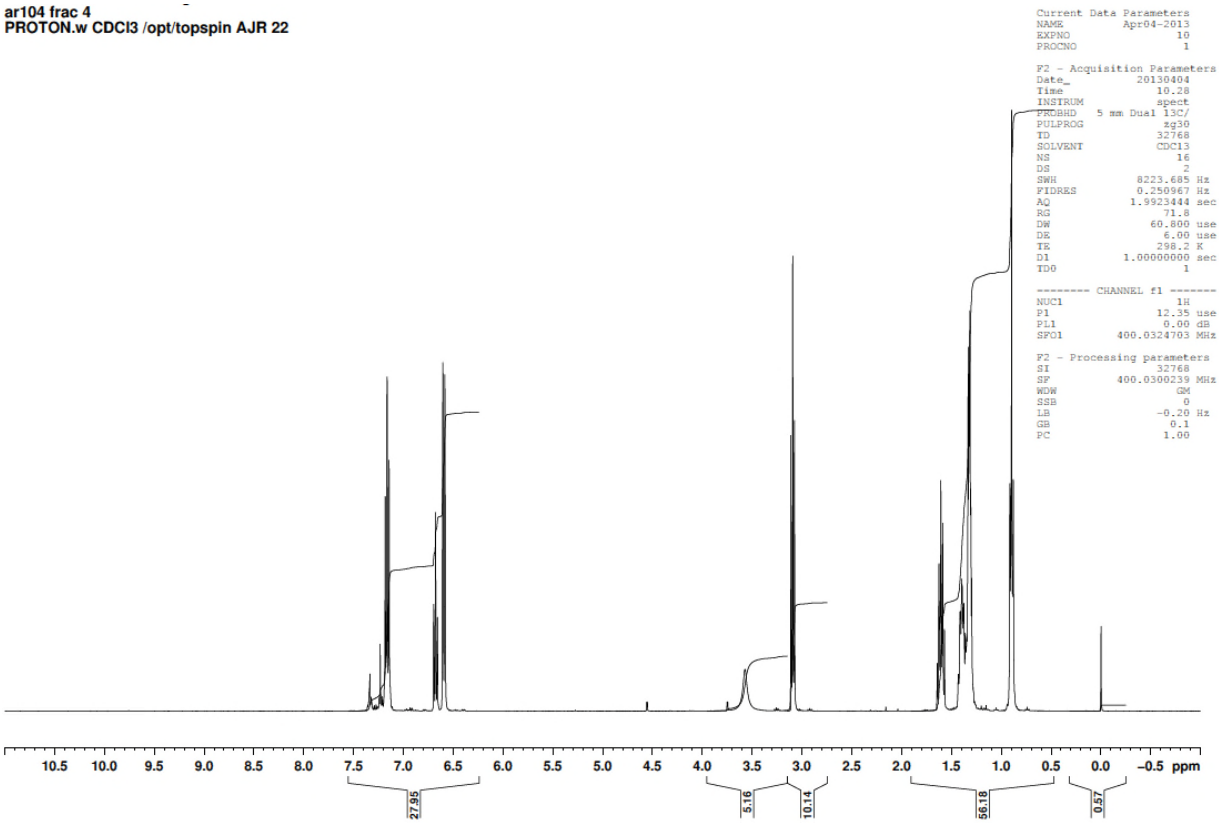
_N_-Hexylaniline 14 and di(n-hexyldiamine) 15.

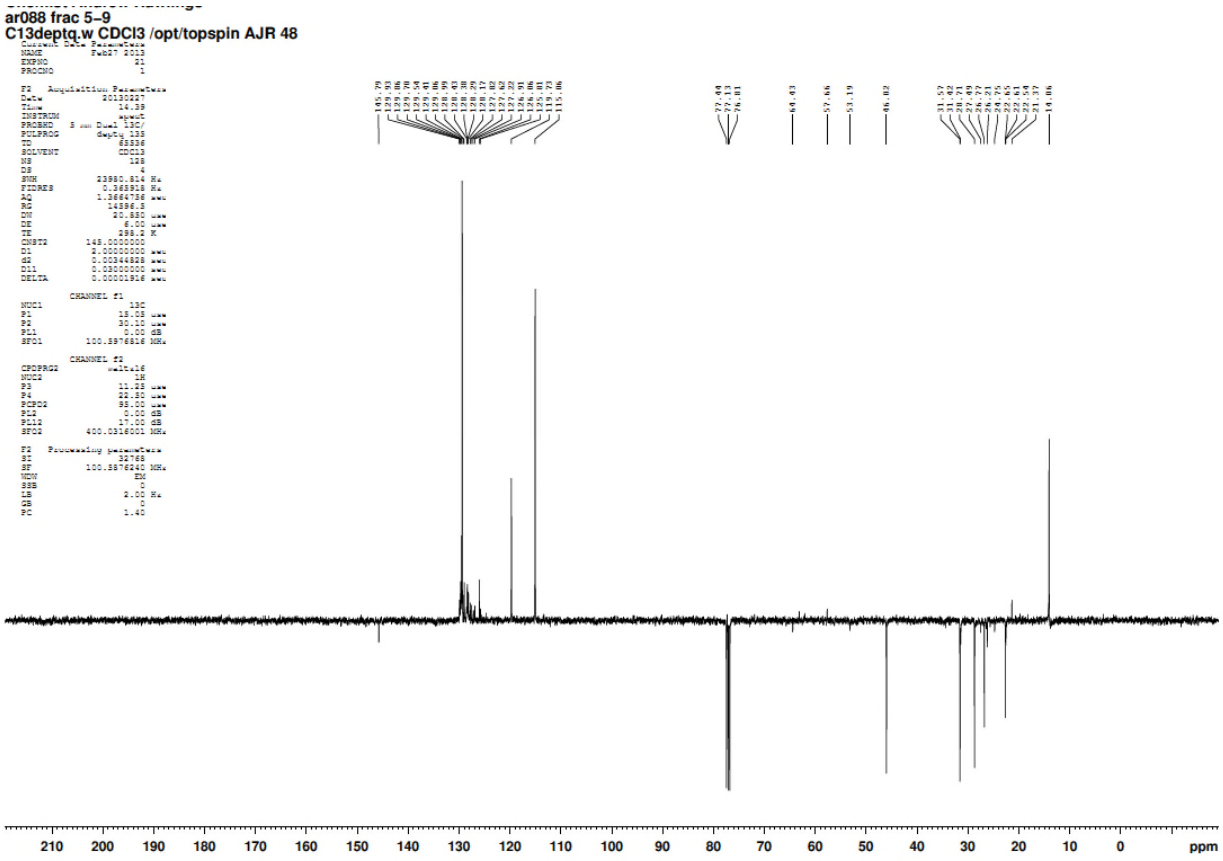
(Xylene, 140 ^{o}C):

Experi-ment	Mol% catalyst	Time/ h	Eq amine	Eq. Alcohol	Monoalkyl-ated **14**	Dialkylated **15**	Comments
088	10	24	1	2	51%	Not deter-mined	Isolated yield.
100	10	24	1	3	72%	13%	Isolated yield.
104	10	24	1	1.1	67%	0%	Isolated yield, no dialk seen.
105	10	48	1	3	96	4	Ratio in crude 1H NMR only.
134	20	24	1	3	87.5%	12.5%	Ratio in crude 1H NMR only.
138	20	48	1	3	72%	28%	Ratio in crude 1H NMR only.

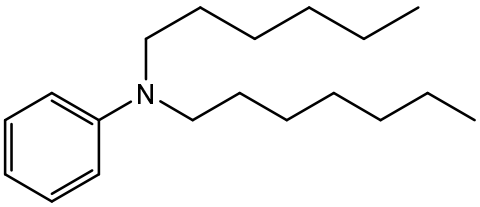


This compound has been reported and fully characterised.[4] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give the product as a pale yellow oil (110.0 mg, 0.623 mmol, 82 %). δ_H (400 MHz, $CDCl_3$) 7.13-7.19 (2H, m, Ar*H*), 6.65-6.70 (1H, m, Ar*H*), 6.56-6.61 (2H, m, Ar*H*), 3.57 (1H, br s, N*H*), 3.09 (2H, t, *J* 8.0 NHCH_2), 1.61 (2H, quin, *J* 8.0 NHCH$_2$CH_2), 1.26-1.44 (6H, m, hex), 0.85-0.94 (3H, m, CH$_2$CH_3); δ_C (100 MHz, $CDCl_3$) 148.58 (C), 129.24 (CH), 117.08 (CH), 112.71 (CH), 44.04 (CH_2), 31.69 (CH_2), 29.59 (CH_2), 26.90 (CH_2), 22.67 (CH_2), 14.08 (CH_3); *m/z* (ESMS+) $[M+H]^+$ 178.1. $C_{12}H_{19}N^+$.

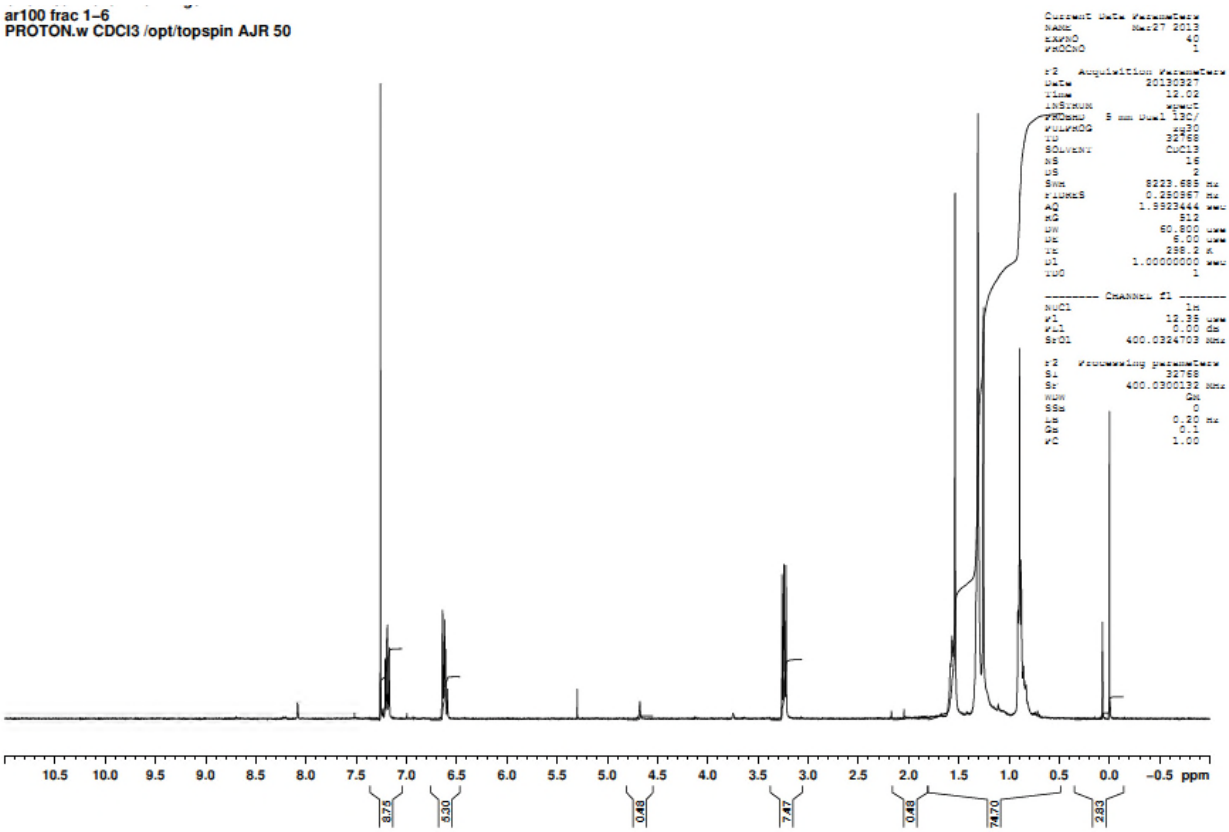




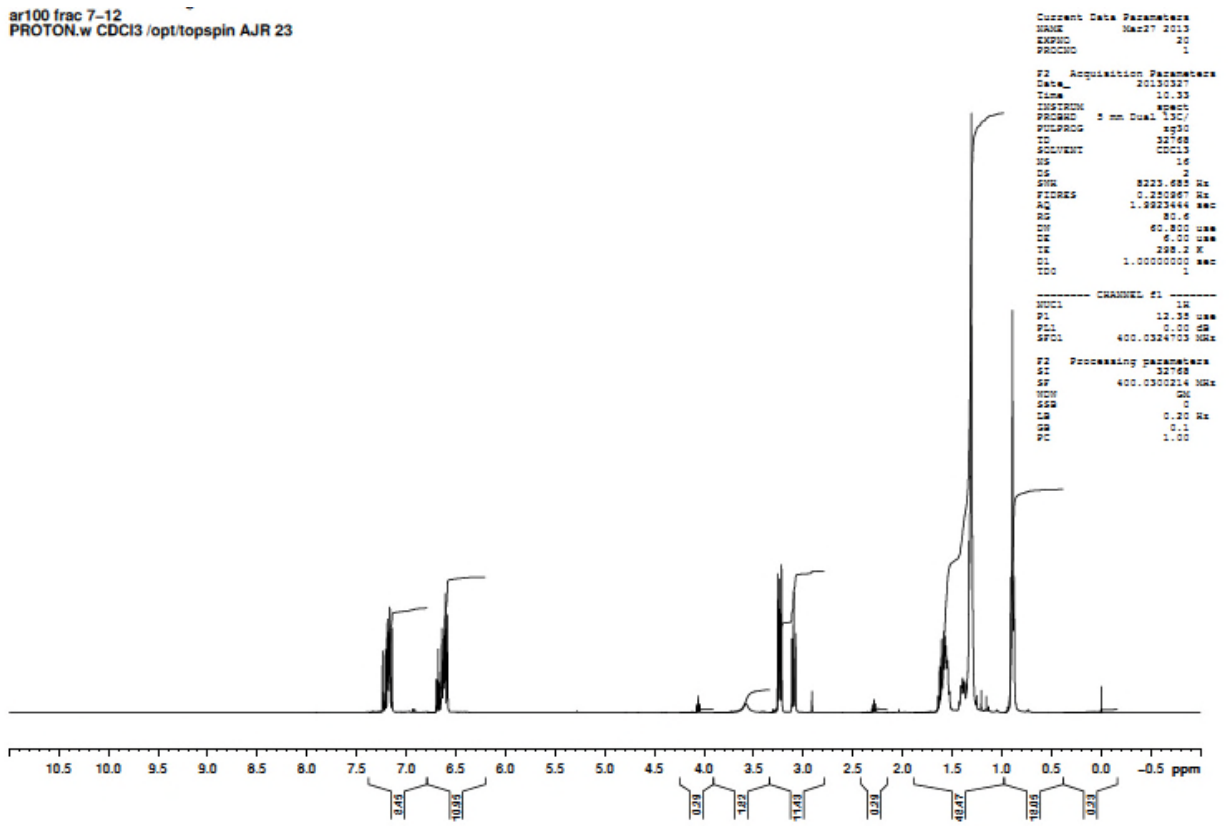
The dialkylation product **15** was formed in low conversion as a mixture with**14** however sufficient could be isolated to characterize the product by 1H NMR[5]:



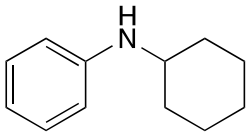
δ_H (400 MHz, $CDCl_3$) 7.25-7.15 (2H,M,Ar*H*), 6.65-6.55 (3H, m, Ar*H*), 3.22 (4H, t, *J* = 6.5, 2 x NCH_2), 1.60-1.50 (4H, m, 2 x CH_2), 1.30-1.20 (12H, m, 6 x CH_2), 0.85 (6H, t, *J* = 6.5, 2 x CH_3).



Fraction containing 16% mono and 11% dialkylated:

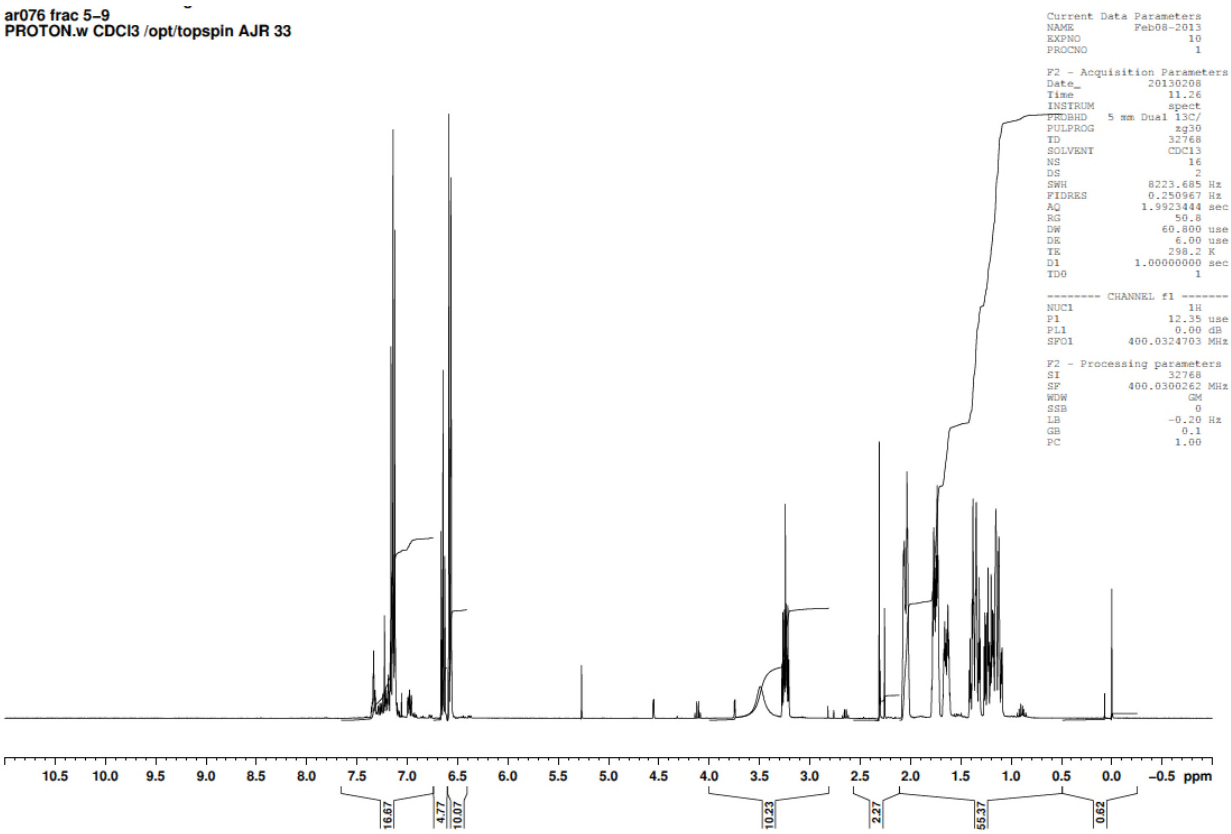


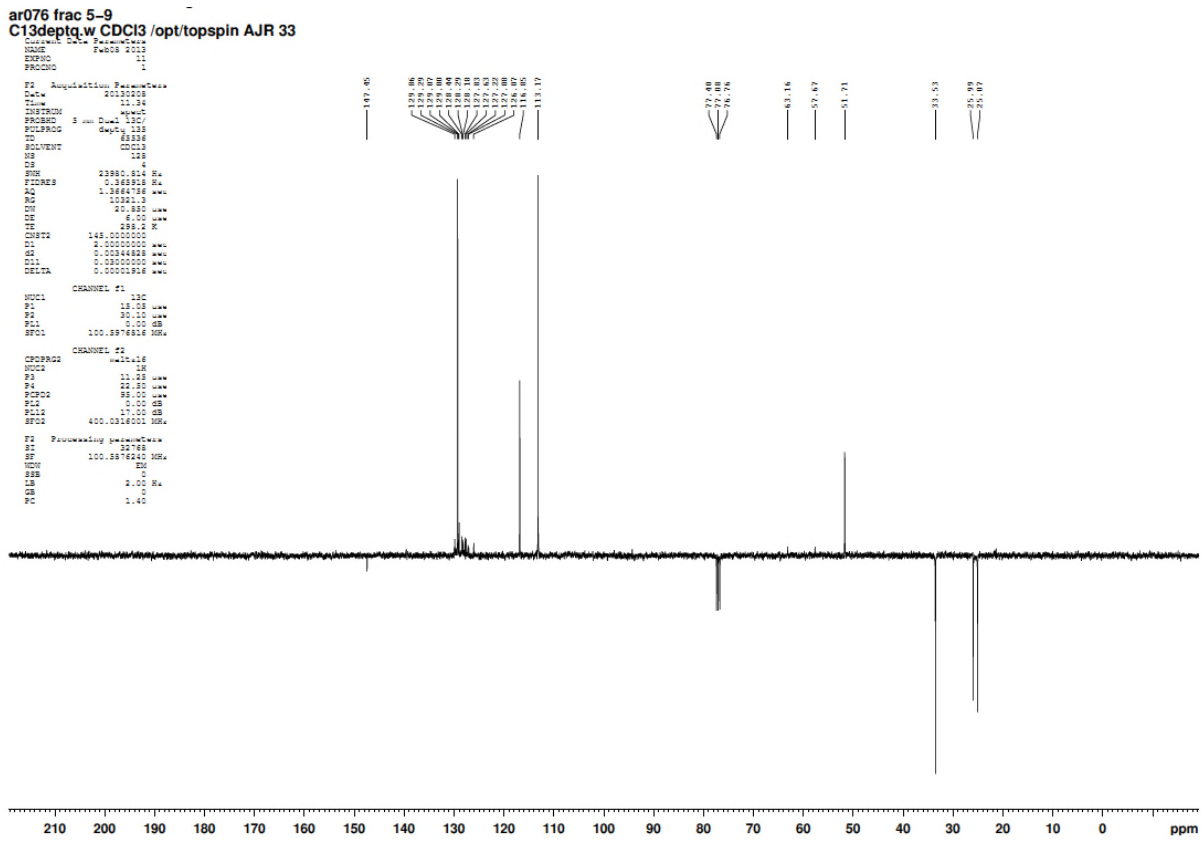
***N*-Cyclohexylaniline 16.**



(Xylene, 140 °C, 24h)

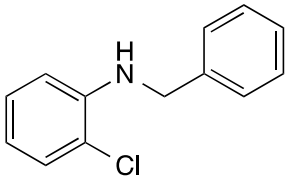
This compound has been reported and fully characterised.[1] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. Ether to give the product as a pale yellow oil (102.8 mg, 0.587 mmol, 77 %). δ_H (400 MHz, $CDCl_3$) 7.11-7.18 (2H, m, Ar*H*), 6.62-6.67 (1H, m, Ar*H*), 6.55-6.60 (2H, m, Ar*H*), 3.49 (1H, br s, N*H*), 3.20-3.28 (1H, m, NHC*H*CH_2), 2.01-2.09 (2H, m, *c*-Hex), 1.70-1.80 (2H, m, *c*-Hex), 1.60-1.69 (1H, m, *c*-Hex), 1.29-1.43 (2H, m, *c*-Hex), 1.08-1.28 (3H, m, *c*-Hex); δ_C (100 MHz, $CDCl_3$) 147.43 (C), 129.28 (CH), 116.84 (CH), 113.16 (CH), 51.71 (CH), 33.54 (CH_2), 25.98 (CH_2), 25.07 (CH_2); *m/z* (ESMS+) $[M+H]^+$ 176.1. $C_{12}H_{18}N^+$.





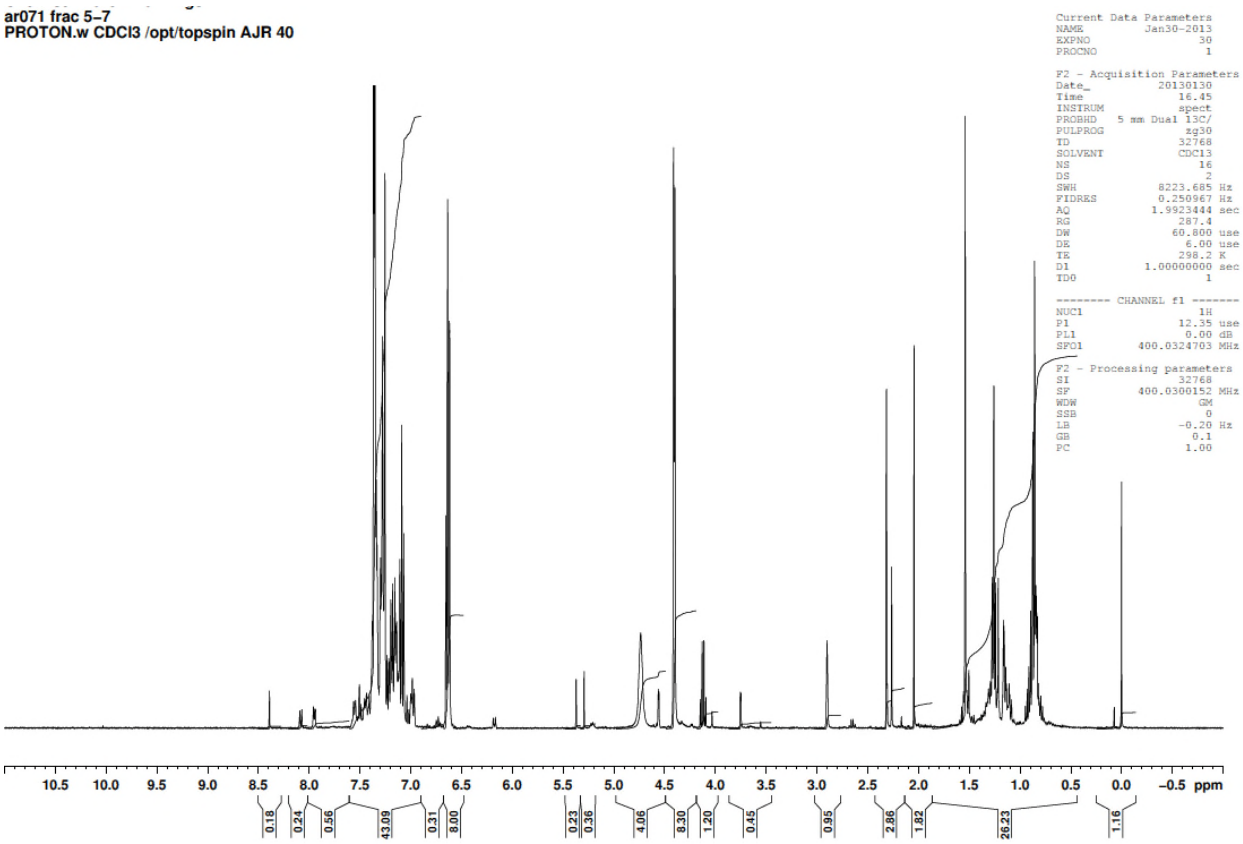
Examples which worked poorly:

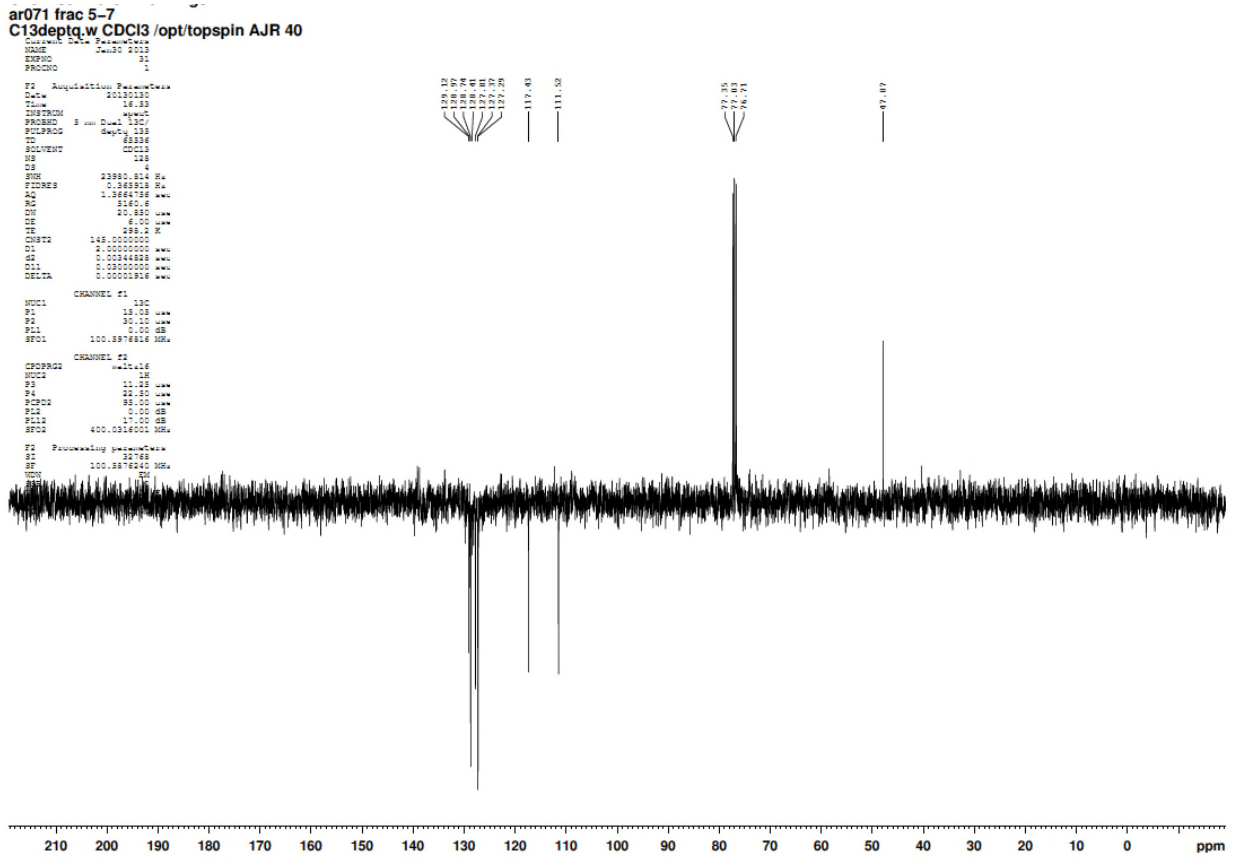
***N*-Benzyl-2-chloroaniline.**



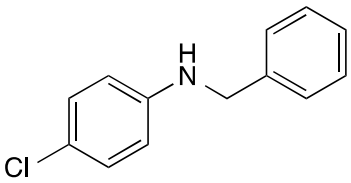
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.2 The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. ether to give the product as a brown oil (6.60 mg, 0.03 mmol, 4 %). *After purification there was still presence of starting material but most of the characteristic peaks could be identified from 1H NMR*. δ_H (400 MHz, $CDCl_3$) 7.32-7.39 (4H, m, Ar*H*), 7.24-7.31 (2H, m, Ar*H*), 7.06-7.12 (1H, m, Ar*H*), 6.60-6.67 (2H, m, Ar*H*), 4.67-4.81 (1H, br s, N*H*), 4.38-4.43 (2H, s, NHCH_2); *m/z* (ESMS+) $[M+H]^+$ 218.1. $C_{13}H_{13}ClN^+$.



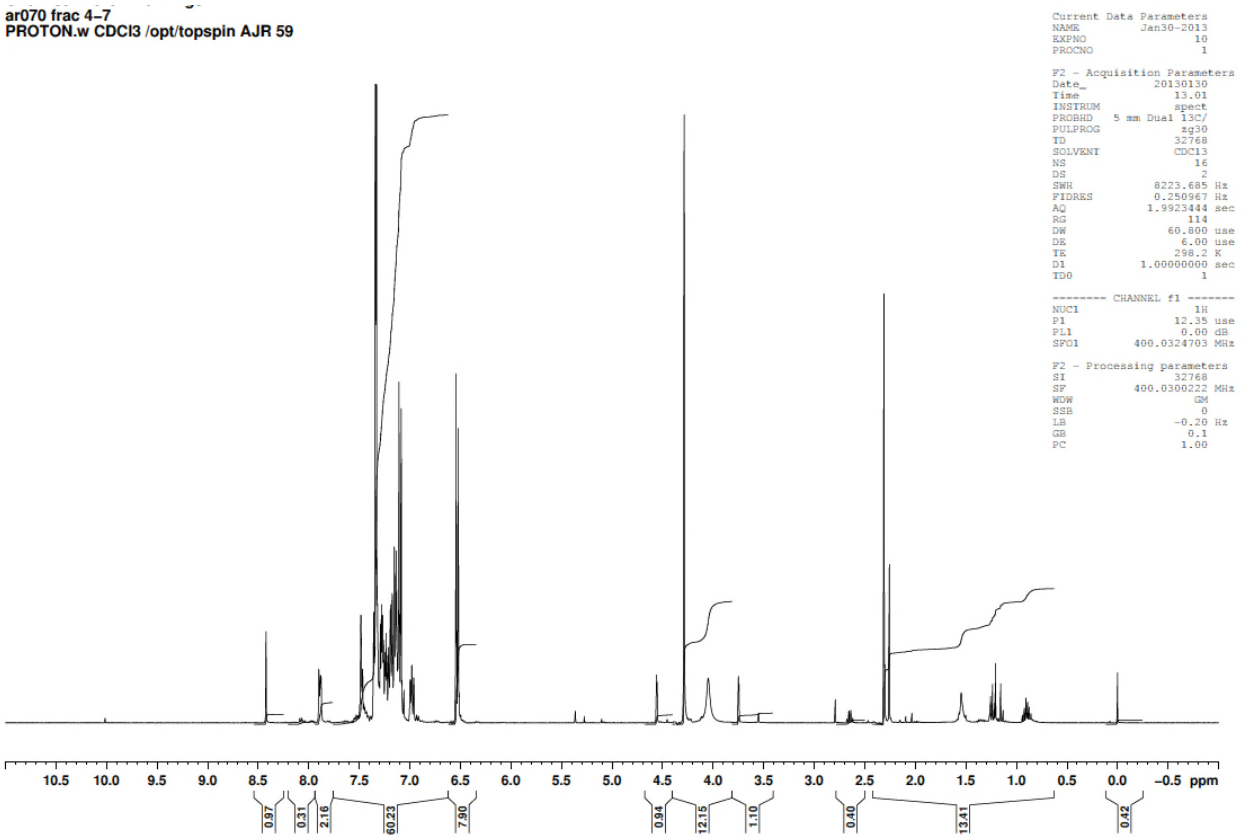


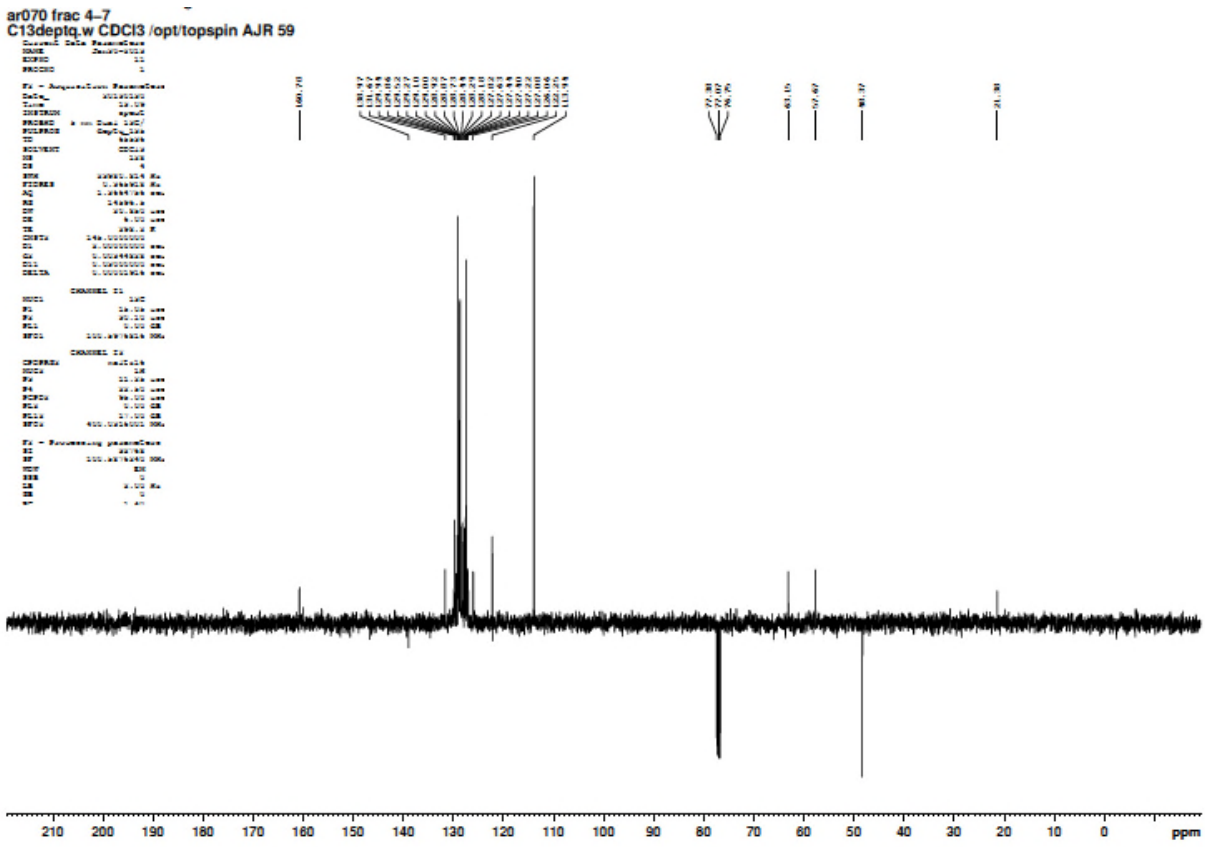
_N_-Benzyl-3-chloroaniline.



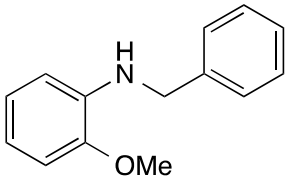
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.[1] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. Ether to give the product as a brown oil (57.7 mg, 0.266 mmol, 35 %). *After purification there was still presence of starting material but most of the characteristic peaks could be identified from 1H NMR*. δ_H (400 MHz, $CDCl_3$) 7.07-7.12 (2H, m, Ar*H*), 6.50-6.56 (2H, m, Ar*H*), 4.29 ((2H, s, NHCH_2), 3.96-4.14 (1H, br s, N*H*); *m/z* (ESMS+) $[M+H]^+$ 218.1. $C_{13}H_{13}ClN^+$.





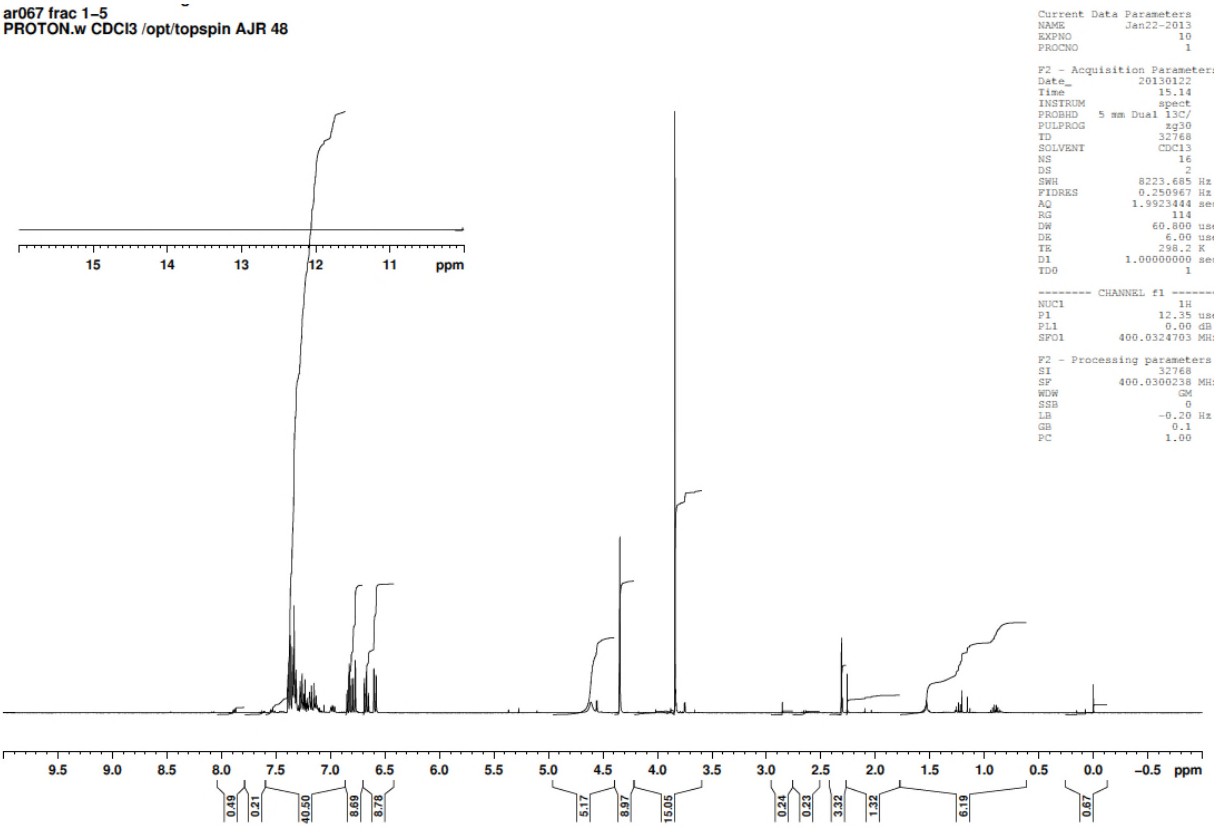
Benzyl(2-methoxyphenyl)amine.



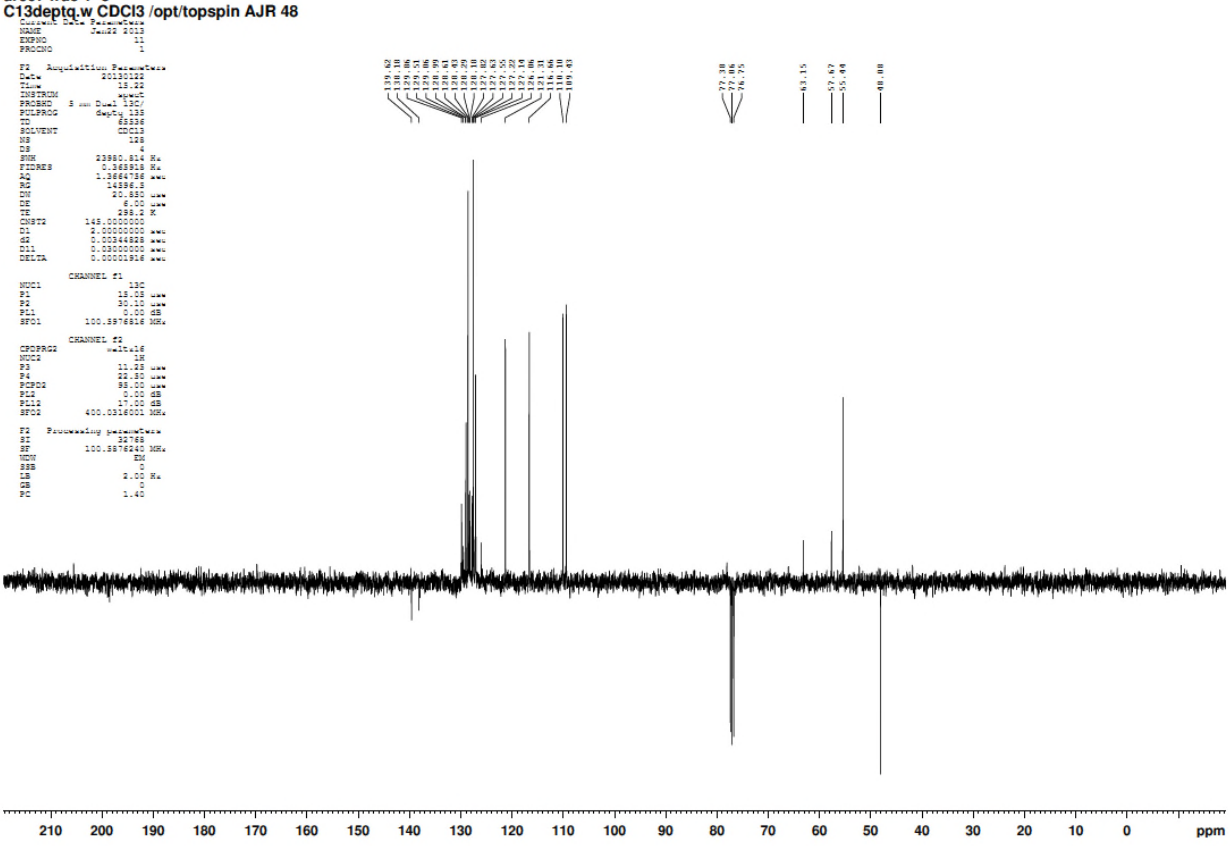
(Toluene, 110 °C, 48h)

This compound has been reported and fully characterised.[3] The compound was purified by column chromatography on silica with a gradient elution 0-20% EtOAc in pet. Ether to give the product as a pale brown oil (37.3 mg, 0.175 mmol, 23 %). *After purification there was still presence of starting material but most of the characteristic peaks could be identified from 1H NMR*. δ_H (400 MHz, $CDCl_3$) 6.64-6.70 (1H, m, Ar*H*), 6.57-6.61 (1H, m, Ar*H*), 4.57-4.69 (1H, br s, N*H*), 4.35 (2H, s, $NHCH_2$), 3.84 (3H, s, OCH_3); *m/z* (ESMS+) $[M+H]^+$ 214.1. $C_{14}H_{16}NO^+$.

ar067 frac 1–5
PROTON.w CDCl3 /opt/topspin AJR 48



ar067 frac 1–5
C13deptq.w CDCl3 /opt/topspin AJR 48



References

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