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Aqueous-Mediated *N*-Alkylation of Amines

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Direct *N*-alkylation of primary amines to secondary/tertiary amines and of secondary amines to tertiary amines has been achieved in excellent yields by employing alkyl, benzylic and allylic halides in the presence of $NaHCO_3$ in an aqueous medium at an elevated temperature. Amines of different stereoelectronic nature react with ease with different halides. The selective formation of secondary amines and the formation of three different substituted tertiary amines are some of the interesting features of this methodology. Reaction in an aqueous medium, operationally convenient conditions, excellent yields and innocuous byproducts, and the absence of transition-metal catalysts, expensive bases, solid supports and the formation of undesired quaternary ammonium salts makes this method a green chemical process.

Introduction

A lot of attention is currently being focused upon the replacement of volatile organic solvents by environmentally less hazardous ones or by water. Nature's own solvent, water, is ideally suited for this purpose owing to its nontoxic character. Its abundance on this planet makes water the cheapest and most readily accessible alternative. The increased focus on water as a reaction medium in synthetic organic chemistry during the past two decades has resulted in a large number of reactions that can now be performed successfully in an aqueous medium.[1] In addition to acting as a solvent, water has special characteristics, such as hydrophobic association, high internal solvent pressure, cohesive energy density, high solvent polarity and hydrogen-bonding ability. An important part of our efforts towards an environmentally friendly green chemistry is aimed at reducing the use of organic solvents.[2]

Amines in general and tertiary amines in particular are one of the most common structural features of naturally occurring biologically active compounds and are widely used throughout the chemical industry as basic intermediates or additives for the preparation of fine chemicals, dyes, fluorescence probes, pharmaceuticals, agrochemicals and catalysts for polymerisation.[3] The formation of secondary and tertiary amino functionalities is a crucial step in the construction of polyamines on solid-phase supports and in the solid-phase organic synthesis of small molecules.[4] Many unnatural homochiral aminophenol compounds have been reported to be excellent ligands in metal-ion-catalysed reactions in asymmetric synthesis, particularly those having a structure based on the *N*-methyl-*N*-alkyl-Betti base.[5]

One of the most frequently used procedures for the preparation of tertiary amines is the *N*-alkylation of primary and secondary amines with alkyl halides in the presence of a base such as KOH or *t*BuOK,[6] potassium,[7] sodium amide,[8] CsOH,[9] thallium(I) ethoxide,[10] CsF/Celite[11] and Hünig's base.[12] Other methods for *N*-alkylation include the displacement of methanesulfonates, *p*-toluenesulfonates or *p*-nitrobenzenesulfonates by amines on solid supports.[13] Tertiary amines on solid supports have also been synthesised by a variety of other protocols.[14] Some other methods, such as a Mannich-type reaction,[15] reductive and catalytic amination,[16] metal-initiated amination of alkenes, alkynes and aryl halides,[17] deamination of quaternary hydrazinium halides[18] and reduction of *N*-tosylamidines,[19] have been devised for this purpose. Unsymmetrical tertiary amines have been obtained in a single step through the $CuCl/B(OMe)_3$-catalysed reaction of primary amines, alkyl halides and α-chlorine-substituted allylsilanes.[20] Synthesis of tertiary amines using a palladium-catalysed nucleophilic substitution of benzylic esters and secondary amines has been reported.[21] Recently, *N*-alkylation of amines using alkyl halides in an aqueous basic (NaOH) medium under microwave irradiation was also found to be quite satisfactory.[22]

The direct *N*-alkylation of primary and secondary amines often results in the formation of quaternary ammonium salts owing to the enhanced nucleophilicity of the tertiary amines. The formation of a mixture of the desired tertiary amine and a quaternary ammonium salt along with the presence of starting amines makes the purification pro-

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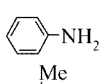
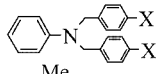
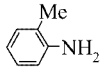
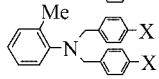
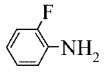
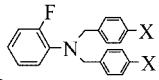
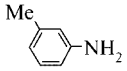
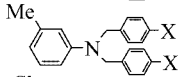
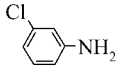
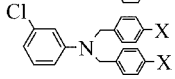
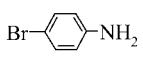
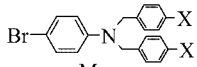
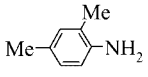
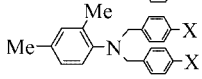
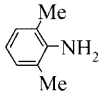
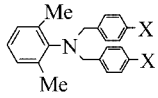
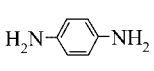
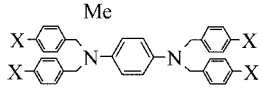
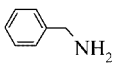
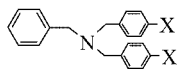
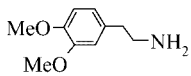
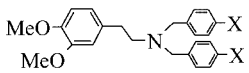
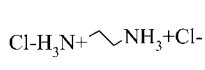
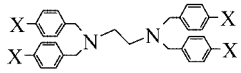
cedure tedious and the method more expensive. Solid-supported methods, although useful, are not practical for large-scale reactions because the process is a multistep procedure and involves the use of an expensive polymer like REM. Many of the reductive methods use strong reducing agents or dangerous hydrogen gas and are not always desirable. The use of excess reagents is particularly undesirable from an environmental point of view and from an economic standpoint in the case of costly or commercially unavailable reagents, as is the case with many methods. The use of expensive and strong nucleophilic bases during the process results in significant hydrolysis of the halides. Although the recently reported microwave-mediated method is quite useful, it requires the use of specialised microwave equipment and hence is not suitable for large-scale reactions.[22] Thus there is a need for a simple, efficient and environmentally benign methodology for the preparation of secondary and tertiary amines.

Results and Discussion

The efficient dissolution of amines in an aqueous medium[2a] and their subsequent acylation prompted us to perform alkylation reactions in aqueous media. Initially aniline was used as a model substrate to test the alkylation procedure. Various conditions were sampled, but a 1:2.2:2.2 ratio of substrate/benzylic halide/$NaHCO_3$ gave the best result. In a typical reaction, aniline (5 mmol) was suspended in water (20 mL). To this was added SDS (20 mg) followed by $NaHCO_3$ (11 mmol) and benzyl bromide (11 mmol). Complete conversion was observed after heating the reaction mixture at 80 °C for 1 h. The reaction mixture was cooled and the product filtered and recrystallised from a mixture of ethyl acetate and hexane to yield the pure product in nearly quantitative yield. Interestingly, side-products such as benzyl alcohol were not observed during the reaction. This reaction can be performed at room temperature,

Table 1. Aqueous *N*-alkylation of amines using $NaHCO_3$ and benzyl bromide/*p*-nitrobenzyl bromide.[a]

Entry	Substrate	Product[b]	X = H / Yield (%)[c]		X = NO_2 / Yield (%)[c]	
1			**1a**	94	**1b**	96
2			**2a**	95	**2b**	93
3			**3a**	91	**3b**	93
4			**4a**	96	**4b**	97
5			**5a**	93	**5b**	97
6			**6a**	96	**6b**	94
7			**7a**	91	**7b**	96
8			**8a**	89	**8b**	94
9			**9a**	92[d]	**9b**	92[d]
10			**10a**	95	**10b**	91
11			**11a**	93	**11b**	90
12			**12a**	89[e]	**12b**	93[e]

[a] All reactions were carried out on 5-mmol scale at 80 °C for 1 h. [b] Confirmed by IR, ^1H and ^{13}C NMR spectroscopy. [c] Isolated yield. [d] Benzylic halide (22 mmol) and $NaHCO_3$ (22 mmol) were used. [e] Benzylic halide (22 mmol) and $NaHCO_3$ (32 mmol) were used.

but the reaction rate is slow and it requires a longer reaction time (8–10 h). Some of the existing aqueous alkylation procedures are not successful because of the rapid hydrolysis of the alkyl/benzylic halides under strongly basic conditions (CsOH, NaOH, K_2CO_3 KOH, etc.). The use of a mild inorganic base such as $NaHCO_3$ circumvented this problem and excellent yields were obtained, as shown in Table 1. The synthetic protocol includes a two-step alkylation of a primary amine with an alkyl halide and occurs via an intermediate secondary amine. This novel procedure is illustrated through the examples **1**–**8** shown in Table 1. Amines of various stereoelectronic nature react efficiently with two different benzyl halides, that is, benzyl bromide and *p*-nitrobenzyl bromide. This observation is consistent with the acylation of amines; various cyclic and acyclic anhydrides were found to react with equal ease with amines of different stereoelectronic nature.[2a,2b] Aromatic diamine 1,4-phenylenediamine (**9**) gave a tetraalkylated product in excellent yield with 2 equivalents of benzylic halide (4.4 equiv.) and $NaHCO_3$ (4.4 equiv.).

Compound **9a** was crystallized from a mixture of ethyl acetate/hexane (1:1) and a single-crystal XRD was recorded. The asymmetric unit contains one half of the molecule and the ORTEP diagram is shown in Figure 1. It is a propeller-shaped molecule (Figure 1, b) with opposite phenyl groups oriented parallel to each other.

The synthetic methodology was also successfully applied to benzylic amine **10** and aliphatic amines **11** and **12**. All gave the corresponding alkylated products in excellent yields. To our delight, aliphatic diamine dihydrochloride **12** was also tetraalkylated in excellent yield with twice the amount of alkyl halide (4.4 equiv.) and 6.4 equiv. of $NaHCO_3$. The additional amount of $NaHCO_3$ was essential to generate the free diamine from the dihydrochloride salt **12**.

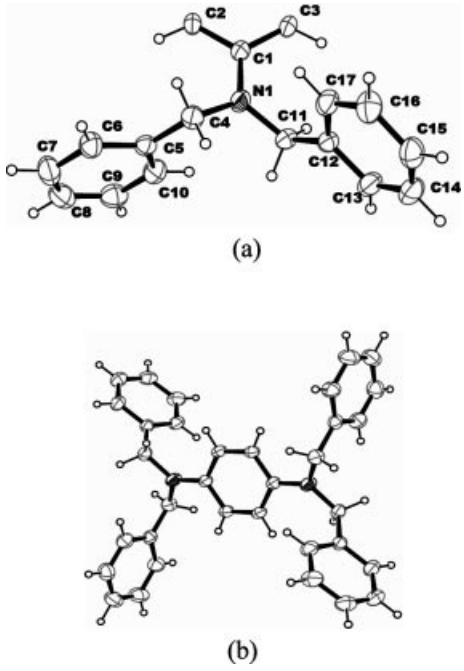
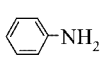
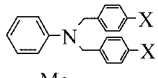
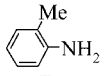
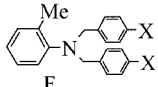
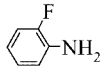
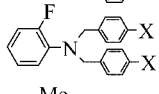
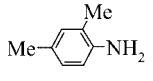
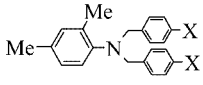
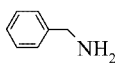
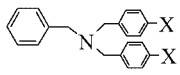
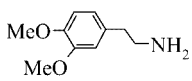
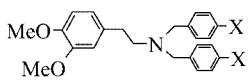


Figure 1. (a) ORTEP plot with the atom numbering of asymmetric unit **9a**; (b) ORTEP plot of **9a**.

When benzyl and *p*-nitrobenzyl bromide were replaced with benzyl chloride and *p*-nitrobenzyl chloride the reaction worked with almost equal efficiency. Thus the generality of the method has been proved using a variety of amines, as shown in Table 2.

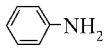
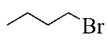
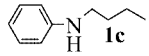
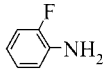
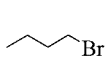
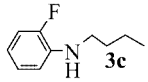
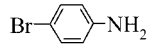
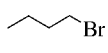
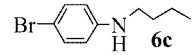
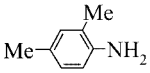
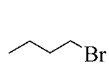
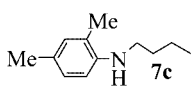
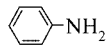
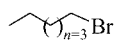
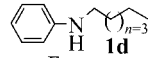
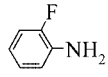
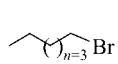
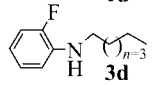
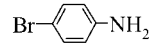
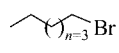
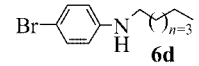
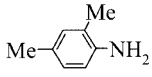
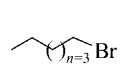
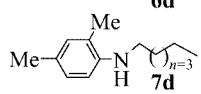
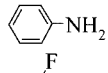
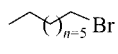
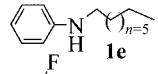
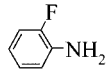
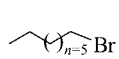
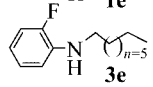
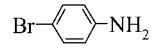
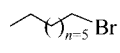
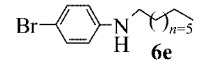
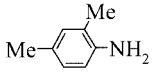
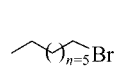
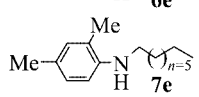
Having successfully applied this protocol to benzylic systems, we extended the methodology to aliphatic halides. Thus, when aniline (5 mmol) in water (20 mL) containing SDS (20 mg) was treated with $NaHCO_3$ (11 mmol) and bu-

Table 2. Aqueous *N*-alkylation of amines using $NaHCO_3$ and benzyl bromide/*p*-nitrobenzyl chloride.[a]

Entry	Substrate	Product[b]	X = H / Yield (%)[c]		X = NO_2 / Yield (%)[c]	
1			**1a**	94	**1b**	96
2			**2a**	95	**2b**	93
3			**3a**	91	**3b**	93
7			**7a**	91	**7b**	96
10			**10a**	95	**10b**	91
11			**11a**	93	**11b**	90

[a] All reactions were carried out on 5-mmol scale at 80 °C for 1.5 h. [b] Confirmed by IR, ^1H and ^{13}C NMR spectroscopy. [c] Isolated yield.

Table 3. Aqueous *N*-alkylation of amines using $NaHCO_3$ and aliphatic bromides.[a]

Entry	Substrate	Halide	Product[b]	Time / h	Yield[c](%)
1			 **1c**	6	65
3			 **3c**	9	78
6			 **6c**	7	70
7			 **7c**	5	67
1			 **1d**	7	74
3			 **3d**	10	75
6			 **6d**	8	82
7			 **7d**	6	80
1			 **1e**	9	78
3			 **3e**	12	80
6			 **6e**	9	84
7			 **7e**	7	85

[a] All reactions were carried out on 2-mmol scale at 80 °C. [b] Confirmed by IR, ^1H and ^{13}C NMR spectroscopy. [c] Isolated yield.

tyl bromide (11 mmol) and heated at 80 °C, the products obtained were a mixture of tertiary and secondary amines in a ratio of 3:2. The product ratio remained nearly unaltered even after refluxing the reaction for 12 h. Thus we focused our attention on controlling the reaction at the secondary amine rather than the tertiary amine stage. Thus, when aniline (5 mmol) was treated with butyl bromide (6 mmol) and $NaHCO_3$ (6 mmol) under the above reaction conditions the reaction stops at the secondary amine stage giving good yields of secondary amines, as shown in Table 3 (**1c**, **3c**, **6c**, **7c**), and yielding less than 10% of the tertiary amines. When similar reactions were performed using hexyl or octyl bromide, the corresponding secondary amines **1d**, **3d**, **6d**, **7d** and **1e**, **3e**, **6e**, **7e** were also obtained in good yields, as shown in Table 3. In these cases less than 5% of tertiary amines were formed. Note here that the reactions with alkyl bromides took longer (Table 3) than the reactions with benzylic halide (Table 1 and Table 2).

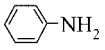
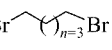
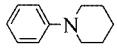
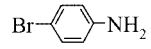
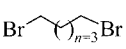
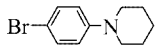
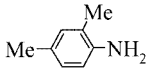
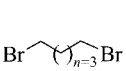
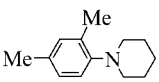
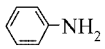
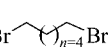
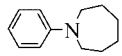
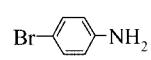
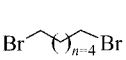
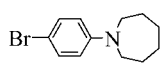
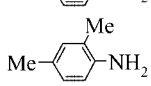
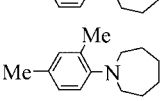
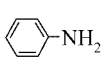
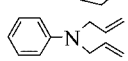
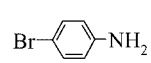
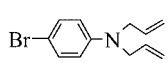
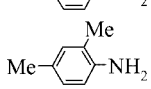
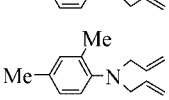
The general nature of the reaction is illustrated through the intramolecular double-alkylation of primary amines with dihalides such as 1,5-dibromopentane and 1,6-dibromohexane giving the corresponding cyclic amines **1f**, **6f**, **7f** and **1g**, **6g**, **7g**, respectively, providing a potentially useful approach to the assembly of cyclic amines in a single step (Table 4). Allyl bromide also reacted successfully with various amines giving good yields of diallylated tertiary amines **1h**, **6h**, **7h**, as shown in Table 4.

As suggested earlier and proved by isolating some of the secondary amines, the synthetic approach involves a two-step alkylation of the primary amine with alkyl halide via an intermediate secondary amine. To further prove this we treated some of the secondary amines with benzyl or allyl bromide to obtain good yields of mixed tertiary amines (Table 5).

Conclusions

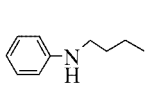
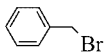
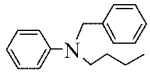
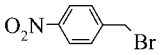
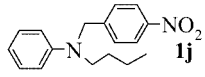
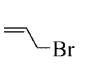
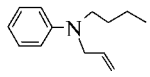
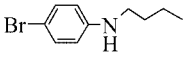
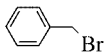
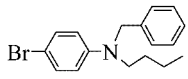
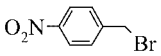
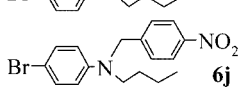
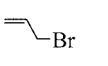
In conclusion, we have demonstrated an efficient and economic process for the synthesis of secondary and tertiary amines by direct *N*-alkylation of primary or secondary amines with various benzylic halides in an aqueous medium in the presence of sodium dodecyl sulfate and $NaHCO_3$. Some of the advantages of this process include mild reaction conditions, higher product yields, scalability, the absence of quaternary ammonium salt formation and opera-

Table 4. Aqueous *N*-alkylation of amines using $NaHCO_3$ and 1,5-dibromopentane, 1,6-dibromohexane or allyl bromide.[a]

Entry	Amine	Alkyl / Allyl halides	Product[b]		Time / h	Yield[c](%)
1				**1f**	4	59[d]
6				**6f**	6	66[d]
7				**7f**	4	71[d]
1				**1g**	4	64[d]
6				**6g**	6	62[d]
7				**7g**	5	67[d]
1				**1h**	5	84[e]
6				**6h**	7	82[e]
7				**7h**	5	89[e]

[a] All reactions were carried out on 2-mmol scale at 80 °C. [b] Confirmed by IR, ^1H and ^{13}C NMR spectroscopy and GC-MS. [c] Isolated yield. [d] Dibromides (2.4 mmol) and $NaHCO_3$ (4.8 mmol) were used. [e] Allylic bromide (6 mmol) and $NaHCO_3$ (6 mmol) were used.

Table 5. Aqueous *N*-alkylation of secondary amines using $NaHCO_3$ and benzyl or allylic bromides.[a]

Entry	Substrate	Alkyl / Allyl halides	Product[b]		Time / h	Yield[c](%)
1c				**1i**	1	93
				**1j**	1	95
				**1k**	4	90
6c				**6i**	1	92
				**6j**	1	95
				**6k**	5	87
13				**13i**	1	93
				13j	1	92

[a] All reactions were carried out on 2-mmol scale at 80 °C for 1 h. [b] Confirmed by IR, ^1H and ^{13}C NMR spectroscopy and GC-MS. [c] Isolated yield. [d] Allylic bromide (4 mmol) and $NaHCO_3$ (4 mmol) were used.

tionally convenient conditions. The selective formation of secondary amines and mixed tertiary amines will find useful applications in organic synthesis. Although procedures exist for the alkylation of amines, the simplicity and low cost of our procedure allow it to compete as a better practical alternative to the existing methods.

Experimental Section

General Remarks: All reagents were commercial grade and purified according to the established procedures. Reactions were monitored by TLC on silica gel 60 F_{254} (0.25 mm). NMR spectra were recorded in $CDCl_3$ or [D_6]DMSO with tetramethylsilane as the internal standard for ^1H NMR (400 MHz) or $CDCl_3$ or [D_6]DMSO solvent as the internal standard for ^{13}C NMR (100 MHz). IR spectra were recorded in KBr on a Nicolet Impact 410 spectrometer. GC-MS were recorded using a capillary column (30 × 0.25 mm, 0.25 mμ) in EI mode.

General Procedure for the Alkylation of Primary Amines to Tertiary Amines with Benzyl Halides: Aniline (5 mmol), sodium hydrogencarbonate (11 mmol), sodium dodecyl sulfate (ca. 20 mg) were taken up in water (20 mL) and heated at 80 °C for 5 min. The benzylic halide (11 mmol) was added to the reaction mixture and heated for a period of 1 h. The reaction mixture was cooled and the alkylated product filtered and dried. The crude reaction mixture was recrystallised from a mixture of ethyl acetate and hexane to yield the product. The product was identified by NMR, IR and GC-MS analysis.

General Procedure for the Alkylation of Primary Amines to Secondary Amines with Alkyl Halides: Aniline (5 mmol), sodium hydrogencarbonate (6 mmol) and sodium dodecyl sulfate (ca. 20 mg) were taken up in water (20 mL) and heated at 80 °C for 5 min. Alkyl halide (6 mmol) was added to the reaction mixture and heated for a further period time as mentioned in Table 3 against each substrate. The reaction mixture was cooled and the alkylated product extracted with ethyl acetate. The crude reaction mixture was purified by passing it through a short column of silica gel and eluting with a mixture of ethyl acetate and hexane to yield the pure product. The product was identified by NMR, IR and GC-MS analysis.

General Procedure for the Alkylation of Amines with Alkyl Dihalides: Similar to the procedure for the alkylation of amines with alkyl halides, except 2.4 mmol of the dibromoalkane and 4.8 mmol of $NaHCO_3$ were used per 2 mmol of the primary amine.

General Procedure for the Alkylation of Amines with Allyl Bromide: Similar to the procedure for the alkylation of amines with alkyl halide, except 6 mmol of the allyl bromide and 6 mmol of $NaHCO_3$ were used per 2 mmol of the primary amine.

Characterisation of Compounds: Compounds **1a**,[22a] **9a**,[23a] **10a**,[22a] **1c**, **3c** and **6c**,[17b] **7c**,[23b] **1d**,[23c] **6d**,[23d] **1f** and **6f**,[22] **7f**,[23e] **1g**,[22a] **6g**,[22b,22c] **7g**,[23e] **1h**[23e] and **13i**,[22a] are known compounds. The new compounds were fully characterised.

Dibenzyl(*o*-tolyl)amine (2a): Yield: 1.360 g (95%). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.43 (s, 3 H), 4.05 (s, 4 H), 6.90–7.24 (m, 14 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 18.6, 57.0, 122.4, 123.3, 125.9, 126.7, 127.9, 128.5, 130.9, 133.7, 138.4, 149.7 ppm. IR (KBr): $\tilde{\nu}$ = 3063, 3027, 2925, 2822, 1593, 1496, 1450, 1368, 1214, 1107, 1035, 948, 758, 743, 702 cm^{-1}. $C_{21}H_{21}N$ (287.41): calcd. C 87.76, H 7.36, N 4.87; found C 87.47, H 7.42, N 5.01.

Dibenzyl(2-fluorophenyl)amine (3a): Yield: 1.330 g (91%). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.31 (s, 2 H), 4.35 (s, 2 H), 6.52–7.37 (m, 14 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 48.2, 56.0, 112.5, 112.6, 114.5, 114.7, 116.4, 116.6, 117.0, 117.1, 121.6, 124.3, 124.4, 124.8, 124.9, 127.3, 127.5, 127.6, 128.4, 128.5, 128.9, 139.1, 151.2, 152.6, 154.2, 157.4 ppm. IR (KBr): $\tilde{\nu}$ = 3124, 3083, 3048, 2935, 2853, 1624, 1521, 1455, 1342, 1250, 1189, 1117, 856, 750 cm^{-1}. $C_{20}H_{18}FN$ (291.37): calcd. C 82.45, H 6.23, N 4.81; found C 81.95, H 6.53, N 5.06.

Dibenzyl(*m*-tolyl)amine (4a): Yield: 1.377 g (96%). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.22 (s, 3 H), 4.60 (s, 4 H), 6.56 (m, 2 H), 7.02 (t, J = 7.8 Hz, 1 H), 7.26 (m, 11 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 22.0, 54.0, 109.6, 112.9, 117.6, 126.5, 126.7, 128.4, 128.9, 138.5, 138.7 ppm. IR (KBr): $\tilde{\nu}$ = 3032, 2904, 2858, 1603, 1501, 1450, 1342, 1265, 1189, 1071, 958, 846, 738, 692 cm^{-1}. MS (EI): m/z = 287 $[M]^+$.$C_{21}H_{21}N$ (287.42): calcd. C 87.76, H 7.36, N 4.87; found C 88.16, H 7.28, N 4.76.

Dibenzyl(*m*-chlorophenyl)amine (5a): Yield: 1.430 g (93%). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.60 (s, 4 H), 6. 62 (m, 3 H), 7.03 (m, 1 H), 7.26 (m, 10 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.1, 110.5, 112.1, 116.6, 126.4, 126.9, 128.6, 129.9, 137.6, 150.1 ppm. IR (KBr): $\tilde{\nu}$ = 3053, 2909, 2863, 1588, 1496, 1450, 1358, 1312, 1230, 1158, 1096, 958, 835, 743, 692 cm^{-1}. MS (EI): m/z = 307 $[M]^+$. $C_{20}H_{18}ClN$ (307.83): calcd. C 78.04, H 5.89, N 4.55; found C 78.21, H 5.75, N 5.01.

Dibenzyl(4-bromophenyl)amine (6a): Yield: 1.684 g (96%). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.60 (s, 4 H), 6.56 (d, J = 9.2 Hz, 2 H), 7.28 (m, 12 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.5, 108.6, 114.1, 126.4, 126.9, 128.6, 131.7, 137.8, 147.8 ppm. IR (KBr): $\tilde{\nu}$ = 3068, 3022, 2899, 2858, 1588, 1496, 1440, 1347, 1245, 1189, 1076, 963, 799, 723, 680 cm^{-1}. $C_{20}H_{18}BrN$ (352.28): calcd. C 68.19, H 5.15, N 3.98; found C 67.89, H 5.27, N 4.05.

Dibenzyl(2,4-dimethylphenyl)amine (7a): Yield: 1.370 g (91%). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.23 (s, 3 H), 2.39 (s, 3 H), 4.02 (s, 4 H), 6.85 (s, 2 H), 6.97 (s, 1 H), 7.22 (m, 10 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 19.6, 52.8, 128.1, 128.6, 129.1, 129.5, 129.6, 130.5, 131.7, 133.2 ppm. IR (KBr): $\tilde{\nu}$ = 3068, 2955, 2919, 1620, 1588, 1496, 1460, 1370, 1230, 1102, 963, 850, 700 cm^{-1}. MS (EI): m/z = 301 $[M]^+$. $C_{22}H_{23}N_3$ (301.44): calcd. C 87.66, H 7.69, N 4.65; found C 87.44, H 7.82, N 4.74.

Dibenzyl(2,6-dimethylphenyl)amine (8a): Yield: 1.339 g (89%). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.39 (s, 6 H), 4.73 (s, 4 H), 6.99 (d, J = 7.6 Hz, 3 H), 7.21 (m, 10 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 20.0, 53.3, 128.6, 129.3, 129.5, 129.9, 130.0, 131.2, 132.1, 133.6 ppm. IR (KBr): $\tilde{\nu}$ = 2930, 2858, 1619, 1517, 1342, 1209, 1112, 1015, 866, 702 cm^{-1}. MS (EI): m/z = 301 $[M]^+$. $C_{22}H_{23}N_3$ (301.44): calcd. C 87.66, H 7.69, N 4.65; found C 88.11, H 7.57, N 4.42.

***N*,*N*,*N*′,*N*′,-Tetrabenzylbenzene-1,4-diamine (9a):** Yield: 2.152 g (92%). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.48 (br. s, 8 H), 6.27 (br. s, 4 H), 7.22 (m, 20 H) ppm ^{13}C NMR (100 MHz, $CDCl_3$): δ = 55.2, 114.9, 126.5, 126.9, 128.3, 139.3, 141.7 ppm. IR (KBr): $\tilde{\nu}$ = 3027, 2899, 2843, 1603, 1521, 1440, 1363, 1219, 1168, 1071, 1030, 953, 805, 738, 697, 625 cm^{-1}. $C_{34}H_{32}N_2$ (468.65): calcd. C 87.14, H 6.88, N 5.98; found C 86.75, H 6.97, N 6.18.

Dibenzyl[2-(3,4-dimethoxyphenyl)ethyl]amine (11a): Yield: 1.678 g (93%). ^1H NMR (400 MHz, $CDCl_3$): δ = 2.72 (m, 4 H), 3.63 (s, 4 H), 3.76 (s, 3 H), 3.84 (s, 3 H), 6.54 (d, J = 1.6 Hz, 1 H), 6.59 (dd, J_1 = 2 Hz, J_2 = 8 Hz, 1 H), 7.25 (d, J = 8.4 Hz, 1 H), 7.27 (m, 10 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 33.2, 55.2, 55.8, 56.0, 58.3, 111.1, 112.1, 120.6, 126.7, 128.0, 128.6 ppm. IR (KBr): $\tilde{\nu}$ = 3068, 2935, 2827, 2786, 1593, 1516, 1460, 1414, 1265, 1235, 1137, 1030, 805, 748, 702, 641 cm^{-1}. $C_{24}H_{27}NO_2$ (361.49): calcd. C 79.74, H 7.53, N 3.87; found C 79.05, H 7.73, N 4.17.

***N*,*N*,*N*′,*N*′,-Tetrbenzylethane-1,2-diamine (12a):** Yield: 1.869 g (89%). ^1H NMR (400 MHz, [D_6]DMSO): δ = 2.59 (s, 4 H), 3.49 (s, 8 H), 7.22 (m, 20 H) ppm. ^{13}C NMR (100 MHz, [D_6]DMSO): δ = 51.1, 58.6, 126.6, 127.9, 128.5, 139.5 ppm. IR (KBr): $\tilde{\nu}$ = 3068, 3024, 2948, 2800, 1599, 1492, 1451, 1372, 1320, 1242, 1124, 1089,

1067, 1028, 977, 913, 743, 695 cm^{-1} $C_{30}H_{32}N_2$ (420.60): calcd. C 85.67, H 7.67, N 6.66; found C 86.07, H 7.87, N 6.56.

Bis(4-nitrobenzyl)phenylamine (1b): Yield: 1.740 g (96%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.73 (s, 4 H), 6.65 (d, J = 8 Hz, 2 H), 6.77 (m, 1 H), 7.18 (m, 2 H), 7.39 (d, J = 8.4 Hz, 4 H), 8.16 (d, J = 8 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.5, 112.7, 118.2, 123.8, 126.9, 127.2, 129.4, 145.8, 147.0 ppm. IR (KBr): $\tilde{\nu}$ = 3042, 2853, 1609, 1527, 1342, 1214, 1102, 856, 692 cm^{-1}. $C_{20}H_{17}N_3O_4$ (363.38): calcd. C 66.11, H 4.72, N 11.56; found C 65.91, H 4.92, N 11.86.

Bis(4-nitrobenzyl)-*o*-tolylamine (2b): Yield: 1.753 g (93%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.42 (s, 3 H), 4.16 (s, 4 H), 6.92 (m, 1 H), 7.02 (m, 2 H), 7.20 (m, 1 H), 7.38 (d, J = 8.8 Hz, 4 H), 8.12 (d, J = 8.4 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 18.6, 57.1, 122.1, 123.5, 124.6, 126.4, 129.0, 131.5, 145.3 ppm. IR (KBr): $\tilde{\nu}$ = 3048, 2889, 2592, 1614, 1547, 1496, 1143, 1086, 1015, 810, 610 cm^{-1}. $C_{21}H_{19}N_3O_4$ (377.40): calcd. C 66.83, H 5.07, N 11.13; found C 67.13, H 5.07, N 11.24.

(2-Fluorophenyl)bis(4-nitrobenzyl)amine (3b): Yield: 1.772 g (93%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.48 (s, 4 H), 6.47 (t, J = 8.0 Hz, 1 H), 6.62 (m, 1 H), 6.95 (m, 2 H), 7.50 (d, J = 7.6 Hz, 4 H), 8.16 (d, J = 7.6 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 47.2, 111.7, 112.2, 114.4, 114.6, 117.5, 117.5, 123.3, 123.8, 124.5, 127.1, 127.5, 146.7, 150.2, 152.5 ppm. IR (KBr): $\tilde{\nu}$ = 2899, 2832, 1614, 1516, 1347, 1230, 1117, 958, 856, 758, 687 cm^{-1}.$C_{20}H_{16}FN_3O_4$ (381.37): calcd. C 62.99, H 4.23, N 11.02; found C 63.27, H 4.43, N 11.22.

Bis(4-nitrobenzyl)-*m*-tolylamine (4b): Yield: 1.828 g (97%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.24 (s, 3 H), 4.70 (s, 4 H), 6.47 (m, 1 H), 6.61 (d, J = 7.2 Hz, 1 H), 7.07 (t, J = 8 Hz, 2 H), 7.39 (d, J = 8.4 Hz, 4 H), 8.16 (d, J = 8.8 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 21.9, 54.4, 110.0, 113.4, 119.3, 123.9, 127.3, 129.3, 139.4, 145.9, 147.1, 147.8 ppm. IR (KBr): $\tilde{\nu}$ = 3048, 2914, 1598, 1516, 1424, 1347, 1255, 1199, 1107, 953, 846, 748, 687 cm^{-1}. MS (EI): m/z = 378 [M + H]$^+$. $C_{21}H_{19}N_3O_4$ (377.40): calcd. C 66.83, H 5.07, N 11.13; found C 67.13, H 5.27, N 11.33.

(3-Chlorophenyl)bis(4-nitrobenzyl)amine (5b): Yield: 1.925 g (97%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.71 (s, 4 H), 6.51 (m, 1 H), 6.62 (m, 1 H), 6.75 (d, J = 8.8 Hz, 1 H), 7.08 (t, J = 8 Hz, 1 H), 7.37 (d, J = 8.4 Hz, 4 H), 8.18 (d, J = 8.4 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.3, 110.8, 111.0, 112.6, 118.3, 124.1, 127.2, 130.4, 144.9, 147.3 ppm. IR (KBr): $\tilde{\nu}$ = 3068, 2919, 2843, 1593, 1511, 1424, 1337, 1225, 1102, 948, 851, 733, 677 cm^{-1}. MS (EI): m/z = m/z = 397 [M]$^+$. $C_{20}H_{16}ClN_3O_4$ (397.82): calcd. C 60.38, H 4.05, N 10.56; found C 59.97, H 4.25, N 10.49.

(4-Bromophenyl)bis(4-nitrobenzyl)amine (6b): Yield: 2.077 g (94%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.70 (s, 4 H), 6.51 (d, J = 8.8 Hz, 2 H), 7.25 (d, J = 8.8 Hz, 2 H), 7.36 (d, J = 8.4 Hz, 4 H), 8.18 (d, J = 8.4 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 54.6, 114.1, 124.1, 127.2, 132.2, 145.0 ppm. IR (KBr): $\tilde{\nu}$ = 3083, 2914, 2843, 1598, 1506, 1342, 1214, 1112, 943, 825, 738, 687, 595 cm^{-1}. MS (EI): m/z = 442 [M]$^+$. $C_{20}H_{16}BrN_3O_4$ (442.27): calcd. C 54.32, H 3.65, N 9.50; found C 54.19, H 3.85, N 9.55.

(2,4-Dimethylphenyl)bis(4-nitrobenzyl)amine (7b): Yield: 1.876 g (96%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.23 (s, 3 H), 2.36 (s, 3 H), 4.12 (s, 4 H), 6.81 (m, 1 H), 6.98 (s, 1 H), 7.23 (s, 1 H), 7.39 (d, J = 8.4 Hz, 4 H), 8.11 (d, J = 8.4 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 18.4, 20.8, 57.4, 109.7, 121.9, 123.4, 126.9, 129.1, 132.1, 145.5 ppm. IR (KBr): $\tilde{\nu}$ = 3112, 2930, 2845, 1714, 1600, 1523, 1346, 1200, 1104, 860, 816, 736, 690 cm^{-1}. MS (EI): m/z = 391 [M]$^+$. $C_{22}H_{21}N_3O_4$ (391.43): calcd. C 67.51, H 5.41, N 10.74; found C 67.77, H 5.41, N 10.67.

(2,6-Dimethylphenyl)bis(4-nitrobenzyl)amine (8b): Yield: 1.838 g (94%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.18 (s, 6 H), 4.21 (s, 4 H), 6.98 (s, 3 H), 7.33 (d, J = 8.4 Hz, 4 H), 8.12 (d, J = 8.4 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 20.0, 56.6, 123.4, 125.6, 129.5, 136.4, 146.1 ppm. IR (KBr): $\tilde{\nu}$ = 2930, 2838, 1598, 1516, 1470, 1434, 1342, 1194, 1096, 1025, 927, 861, 784, 697 cm^{-1}. MS (EI): m/z = 414 [M + Na]$^+$. $C_{22}H_{21}N_3O_4$ (391.43): C 67.51, H 5.41, N 10.74; found C 67.97, H 5.52, N 10.90.

***N,N,N′,N′*-Tetrakis(4-nitrobenzyl)benzene-1,4-diamine (9b):** Yield: 2.980 g (92%). ^{1}H NMR (400 MHz, [D$_6$]DMSO): δ = 4.28 (br. s, 4 H), 4.63 (br. s, 4 H), 6.45 (m, 4 H), 7.50 (m, 8 H),8.14 (d, J = 8.4 Hz, 8 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO): δ = 55.9, 124.1, 124.6, 128.6, 128.8, 129.3, 147.0, 148.6 ppm. IR (KBr): $\tilde{\nu}$ = 3119, 3073, 2940, 2853, 1603, 1527, 1352, 1281, 1235, 1107, 856, 820, 748 cm^{-1}. $C_{34}H_{28}N_6O_8$ (648.64): calcd. C 62.96, H 4.35, N 12.96; found C 63.21, H 4.55, N 13.16.

Benzylbis(4-nitrobenzyl)amine (10b): Yield: 1.715 g (91%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.58 (s, 2 H), 3.65 (s, 4 H), 7.30 (m, 5 H), 7.54 (d, J = 8 Hz, 4 H), 8.18 (d, J = 8 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 57.6, 58.4, 123.5, 127.4, 128.4, 128.5, 129.0, 137.8, 146.6, 147.0 ppm. IR (KBr): $\tilde{\nu}$ = 3076, 2795, 1599, 1515, 1448, 1344, 1255, 1107, 986, 850, 738, 694 cm^{-1}. MS (EI): m/z = 378 [M + H]$^+$. $C_{21}H_{19}N_3O_4$ (377.40): calcd. C 66.83, H 5.07, N 11.13; found C 66.91, H 5.32, N 11.31.

2-[(3,4-Dimethoxyphenyl)ethyl]bis(4-nitrobenzyl)amine (11b): Yield: 2.029 g (90%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.72 (m, 2 H), 3.71 (s, 2 H), 3.71 (s, 4 H), 3.78 (s, 3 H), 3.86 (s, 3 H), 6.57 (m, 2 H), 6.74 (m, 1 H), 7.41 (d, J = 6.8 Hz, 4 H), 8.10 (d, J = 6.8 Hz, 4 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 33.4, 55.6, 55.8, 56.0, 57.8, 111.3, 112.1, 120.5, 123.4, 128.9, 132.2, 146.8, 147.0, 147.5, 148.7 ppm. IR (KBr): $\tilde{\nu}$ = 2940, 2832, 1603, 1516, 1460, 1337, 1245, 1143, 1102, 1020, 846, 738 cm^{-1}. MS (EI): m/z = 474 [M + Na]$^+$. $C_{24}H_{25}N_3O_6$ (451.48): calcd. C 63.85, H 5.58, N 9.31; found C 63.85, H 5.78, N 9.51.

***N,N,N′,N′*-Tetrakis(4-nitrobenzyl)ethane-1,2-diamine (12b):** Yield: 2.790 g (93%). ^{1}H NMR (400 MHz, [D$_6$]DMSO): δ = 3.41 (s, 4 H), 3.61 (s, 8 H), 7.48 (d, J = 8.4 Hz, 8 H), 8.06 (d, J = 8.4 Hz, 8 H) ppm. ^{13}C NMR (100 MHz, [D$_6$]DMSO): δ = 52.1, 58.4, 123.9, 130.1, 148.1 ppm. $C_{30}H_{28}N_6O_8$ (600.59): calcd. C 60.00, H 4.70, N 13.99; found C 59.65, H 4.51, N 14.10.

(2-Fluorophenyl)hexylamine (3d): Yield: 0.293 g (75%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.89 (t, J = 7.2 Hz, 3 H), 1.25–1.47 (br. s, 6 H), 1.62 (m, 2 H), 3.12 (t, J = 7.2 Hz, 2 H), 3.84 (br. s, 1 H), 6.54 (m, 1 H), 6.69 (m, 1 H), 6.92 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 22.8, 27.3, 29.6, 32.0, 43.8, 112.2, 112.3, 114.3, 114.6, 116.3, 116.4, 124.8, 137.1, 137.2, 150.5, 150.8 ppm. IR (KBr): $\tilde{\nu}$ = 3414, 3020, 2956, 2929, 2853, 1615, 1523, 1336, 1189, 1097, 912, 743 cm^{-1}. $C_{12}H_{18}FN$ (195.28): calcd. C 73.81, H 9.29, N 7.17; found C 74.11, H 9.49, N 7.09.

(2,4-Dimethylphenyl)hexylamine (7d): Yield: 0.328 g (80%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, J = 7.6 Hz, 3 H), 1.27–1.40 (br. s, 6 H), 1.63 (m, 2 H), 2.08 (s, 3 H), 2.21 (s, 3 H), 3.09 (t, J = 7.2 Hz, 2 H), 6.49 (d, J = 8.0 Hz, 1 H), 6.84 (s, 1 H), 6.88 (d, J = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.5, 17.7, 20.6, 23.0, 27.5, 29.6, 29.7, 29.9, 32.1, 44.5, 109.9, 121.9, 125.7, 127.3, 130.9, 144.1 ppm. IR (KBr): $\tilde{\nu}$ = 3423, 2923, 2857, 1615, 1514, 1465, 1374, 1308, 1267, 1146, 803, 743 cm^{-1}. $C_{14}H_{23}N$ (205.35): calcd. C 81.89, H 11.29, N 6.82; found C 82.09, H 11.53, N 6.92.

(2-Fluorophenyl)octylamine (3e): Yield: 0.357 g (80%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.88 (t, J = 7.2 Hz, 3 H), 1.27–1.49 (br. s, 10 H), 1.66 (m, 2 H), 3.12 (t, J = 7.2 Hz, 2 H), 3.89 (br. s, 1 H), 6.58 (m, 1 H), 6.67 (m, 1 H), 6.97 (m, 1 H) ppm.^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.3, 22.8, 27.3, 29.4, 29.6, 29.7, 32.0, 43.8, 112.1, 112.2, 114.4, 114.5, 116.3, 116.4, 124.7, 124.8, 137.1, 137.2, 150.5, 152.8 ppm. IR (KBr): $\tilde{\nu}$ = 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1}. $C_{14}H_{22}FN$ (223.34): calcd. C 75.19, H 9.93, N 6.27; found C 74.97, H 9.89, N 6.27.

(4-Bromophenyl)octylamine (6e): Yield: 0.477 g (84%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.89 (t, J = 6.8 Hz, 3 H), 1.26–1.37 (br. s, 10 H), 1.56 (m, 2 H), 3.04 (t, J = 7.2 Hz, 2 H), 3.59 (br. s, 1 H), 6.44 (d, J = 8.8 Hz, 2 H), 7.22 (d, J = 8.8 Hz, 2 H) ppm.^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 22.8, 26.3, 29.4, 29.5, 29.7, 29.9, 31.8, 44.2, 108.6, 114.3, 132.0, 147.6 ppm. IR (KBr): $\tilde{\nu}$ = 3445, 3020, 2950, 2929, 2858, 1621, 1524, 1340, 1257, 1189, 1102, 1031, 913, 743 cm^{-1}. $C_{14}H_{22}BrN$ (284.24): calcd. C 59.16, H 7.80, N 4.93; found C 59.86, H 7.50, N 5.23.

(2,4-Dimethylphenyl)octylamine(7e): Yield: 0.396 g (85%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.96 (t, J = 7.2 Hz, 3 H), 1.37–1.49 (br. s, 10 H), 1.68 (m, 2 H), 2.16 (s, 3 H), 2.28 (s, 3 H), 3.16 (t, J = 7.2 Hz, 2 H), 6.58 (d, J = 8.0 Hz, 1 H), 6.91 (s, 1 H), 6.97 (d, J = 8.0 Hz, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.4, 17.7, 20.6, 22.9, 27.2, 29.9, 31.9, 44.5, 110.0, 121.9, 125.8, 127.4, 130.9, 144.2 ppm. IR (KBr): $\tilde{\nu}$ = 3423, 2923, 2857, 1615, 1514, 1465, 1308, 1267, 1146, 803, 751 cm^{-1}. $C_{16}H_{27}N$ (233.40): calcd. C 82.34, H 11.66, N 6.00; found C 82.54, H 11.46, N 6.07.

Diallyl(4-bromophenyl)amine(6h): Yield: 0.413 g (82%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 3.85 (m, 4 H), 5.11 (m, 4 H), 5.77 (m, 2 H), 6.51 (d, J = 7.6 Hz, 2 H), 7.20 (d, J = 9.2 Hz, 2 H) ppm.^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.1, 108.2, 114.1, 116.3, 131.8, 133.6, 147.7 ppm. IR (KBr): $\tilde{\nu}$ = 3081, 2981, 2929, 2862, 1592, 1498, 1388, 1233, 1180, 992, 920, 806, 750 cm^{-1}. $C_{12}H_{14}BrN$ (252.16): calcd. C 57.16, H 5.60, N 5.55; found C 57.36, H 5.40, N 5.44.

Diallyl(2,4-dimethylphenyl)amine(7h): Yield: 0.357 g (89%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.27 (s, 3 H), 2.29 (s, 3 H), 3.54 (d, J = 6 Hz, 4 H), 5.10 (m, 4 H), 5.77 (m, 2 H), 6.92 (s, 1 H), 7.00 (s, 1 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 18.5, 21.1, 56.2, 116.9, 121.9, 126.5, 131.8, 132.5, 133.8, 135.5, 147.3 ppm. IR (KBr): $\tilde{\nu}$ = 3071, 3000, 2923, 2851, 2813, 1503, 1418, 1264, 1212, 1111, 990, 913, 812, 749 cm^{-1}. $C_{14}H_{19}N$ (201.31): calcd. C 83.53, H 9.51, N 6.96; found C 83.68, H 9.49, N 7.03.

Benzyl(butyl)phenylamine (1i): Yield: 0.445 g (93%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.03 (t, J = 7.2 Hz, 3 H), 1.43 (m, 2 H), 1.73 (m, 2 H), 3.46 (t, J = 7.6 Hz, 2 H), 4.60 (s, 2 H), 6.72 (m, 3 H), 7.26 (m, 5 H), 7.35 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 20.5, 29.4, 51.2, 54.6, 112.2, 116.0, 126.6, 126.8, 128.7, 129.3, 139.3, 148.7 ppm. IR (KBr): $\tilde{\nu}$ = 3063, 3028, 2958, 2932, 2872, 1598, 1505, 1453, 1356, 1252, 1220, 1197, 988, 747, 693 cm^{-1}. $C_{17}H_{21}N$ (239.36): calcd. C 85.31, H 8.84, N 5.85; found C 85.42, H 8.63, N 5.95.

Benzyl(4-bromophenyl)butylamine (6i): Yield: 0.585 g (92%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.00 (t, J = 7.2 Hz, 3 H), 1.42 (m, 2 H), 1.68 (m, 2 H), 3.41 (t, J = 8.0 Hz, 2 H), 4.55 (s, 2 H), 6.56 (d, J = 8.4 Hz, 2 H), 7.26 (m, 5 H), 7.33 (d, J = 8.4 Hz, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 20.5, 29.4, 51.4, 54.7, 107.9, 113.9, 126.5, 127.0, 128.8, 131.9, 138.6, 147.7 ppm. IR (KBr): $\tilde{\nu}$ = 3060, 3027, 2961, 2923, 2868, 1593, 1497, 1451, 1363, 1220, 1193, 1130, 1075, 930, 801, 724, 696 cm^{-1}. $C_{17}H_{20}BrN$ (318.26): calcd. C 64.16, H 6.33, N 4.40; found C 64.36, H 6.39, N 4.37.

Butyl(4-nitrobenzyl)phenylamine(1j): Yield: 0.539 g (95%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.95 (t, J = 7.2 Hz, 3 H), 1.36 (m, 2 H), 1.62 (m, 2 H), 3.40 (t, J = 8.0 Hz, 2 H), 4.59 (s, 2 H), 6.59 (d, J = 8 Hz, 2 H), 6.67 (t, J = 7.2 Hz, 1 H), 7.15 (t, J = 7.2 Hz, 2 H), 7.35 (d, J = 8.4 Hz, 2 H), 8.12 (d, J = 8.4 Hz, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 20.5, 29.5, 51.7, 54.6, 112.5, 116.9, 124.0, 127.4, 129.5, 147.2, 147.6, 148.1 ppm. IR (KBr): $\tilde{\nu}$ = 3062, 3046, 2958, 2932, 2872, 1598, 1505, 1343, 1250, 1222, 1195, 1110, 932, 858, 806, 748, 735, 693 cm^{-1}. $C_{17}H_{20}N_2O_2$ (284.36): calcd. C 71.81, H 7.09, N 9.85; found C 72.06, H 7.24, N 9.75.

(4-Bromophenyl)butyl(4-nitrobenzyl)amine (6j): Yield: 0.689 g (95%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.94 (t, J = 7.2 Hz, 3 H), 1.35 (m, 2 H), 1.62 (m, 2 H), 3.89 (t, J = 7.6 Hz, 2 H), 4.58 (s, 2 H), 6.46 (d, J = 8.8 Hz, 2 H), 7.21 (d, J = 8.8 Hz, 2 H), 7.34 (d, J = 8.8 Hz, 2 H), 8.12 (d, J = 8.8 Hz, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.1, 20.4, 29.4, 51.8, 54.5, 108.7, 114.0, 124.0, 127.3, 132.1, 146.8, 147.0, 147.2 ppm. IR (KBr): $\tilde{\nu}$ = 3064, 3032, 2958, 2931, 2872, 1597, 1505, 1342, 1280, 1222, 1195, 1174, 1110, 932, 806, 734 cm^{-1}. $C_{17}H_{19}BrN_2O_2$ (363.26): calcd. C 56.21, H 5.27, N 7.71; found C 56.60, H 5.05, N 7.51.

Allyl(phenyl)butylamine (1k): Yield: 0.340 g (90%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.99 (t, J = 7.6 Hz, 3 H), 1.34 (m, 2 H), 1.55 (m, 2 H), 3.24 (m, 2 H), 3.88 (m, 2 H), 5.13 (m, 2 H), 5.82 (m, 1 H), 6.63 (m, 3 H), 7.18 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 20.5, 29.5, 50.7, 50.9, 53.3, 111.8, 112.1, 115.2, 115.8, 134.5, 148.3, 148.5 ppm. IR (KBr): $\tilde{\nu}$ = 3065, 3026, 2958, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 1187, 988, 917, 745, 691 cm^{-1}. $C_{13}H_{19}N$ (189.30): calcd. C 82.48, H 10.12, N 7.40; found C 82.39, H 10.06, N 7.46.

Allyl(4-bromophenyl)butylamine (6k): Yield: 0.466 g (87%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.93 (t, J = 7.2 Hz, 3 H), 1.32 (m, 2 H), 1.55 (m, 2 H), 3.24 (t, J = 7.6 Hz, 2 H), 3.86 (d, J = 4.4 Hz, 2 H), 5.11 (m, 2 H), 5.78 (m, 1 H), 6.48 (d, J = 8.8 Hz, 2 H), 7.22 (d, J = 8.8 Hz, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 14.2, 20.5, 29.5, 50.9, 53.4, 107.6, 113.7, 116.2, 131.9, 133.8, 147.5 ppm. IR (KBr): $\tilde{\nu}$ = 3065, 3046, 2968, 2833, 2873, 1598, 1505, 1364, 1287, 1120, 1187, 988, 917, 806 cm^{-1}. $C_{13}H_{18}BrN$ (268.20): calcd. C 58.22, H 6.76, N 5.22; found C 58.45, H 6.53, N 5.11.

4-(4-Nitrobenzyl)morpholine (13j): Yield: 0.408 g (92%). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 2.45 (m, 4 H), 3.58 (s, 2 H), 3.71 (m, 4 H), 7.51 (m, 2 H), 7.51 (m, 2 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 53.7, 62.6, 67.0, 123.6, 129.6, 146.1, 147.3 ppm. IR (KBr): $\tilde{\nu}$ = 3062, 3054, 2967, 2854, 2807, 1599, 1514, 1448, 1338, 1105, 1004, 858 cm^{-1}. $C_{11}H_{14}N_2O_3$ (222.25): calcd. C 59.45, H 6.35, N 12.60; found C 59.63, H 6.43, N 12.49.

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[1] a) R. Breslow, *Acc. Chem. Res.* **1991**, *24*, 159; b) W. A. Herrmann, C. W. Kohlpaintner, *Angew. Chem. Int. Ed. Engl.* **1993**, *32*, 1524; c) C.-J. Li, *Chem. Rev.* **1993**, *93*, 2023; d) U. M.

Lindström, *Chem. Rev.* **2002**, *102*, 2751; e) S. Kobayashi, K. Manabe, *Acc. Chem. Res.* **2002**, *35*, 209; f) K. Shu, M. Kei, *Acc. Chem. Res.* **2002**, *35*, 209; g) T. Okuhara, *Chem. Rev.* **2002**, *102*, 3641; h) A. N. Pae, Y. S. Cho, *Curr. Org. Chem.* **2002**, *6*, 715.

[2] a) S. Naik, G. Bhattacharjya, B. Talukdar, B. K. Patel, *Eur. J. Org. Chem.* **2004**, 1254; b) S. Naik, G. Bhattacharjya, V. Kavala, B. K. Patel, *ARKIVOC* **2004**, 55; c) V. Kavala, A. K. Samal, B. K. Patel, *ARKIVOC* **2005**, 20.

[3] a) A. Seayad, M. Ahmed, H. Klein, R. Jackstell, T. Gross, M. Beller, *Science* **2002**, *297*, 1676; b) S. Suwanprasop, T. Nhujak, S. Roengsumran, A. Petsom, *Ind. Eng. Chem. Res.* **2004**, *43*, 4973; c) S. R. Stauffer, J. F. Hartwig, *J. Am. Chem. Soc.* **2003**, *125*, 6977; d) J. S. Kim, O. J. Shon, J. A. Rim, S. K. Kim, J. Yoon, *J. Org. Chem.* **2002**, *67*, 2348; e) H.-J. Boehm, G. Klebe, *Angew. Chem. Int. Engl.* **1996**, *35*, 2588; f) M. Negwer, H. G. Scharnow, *Organic-Chemical Drugs and Their Synonyms*, 8th ed., Wiley Chichester, UK, **2001**; g) J. H. Montgomery, *Agrochemicals Desk Reference*, 2nd ed., Lewis, Chelsea, MI, **1997**; h) F. Kiuchi, S. Nishizawa, H. Kawanishi, S. Kinoshita, H. Ohshima, A. Uchitani, N. Sekino, M. Ishida, K. Kondo, Y. Tsuda, *Chem. Pharm. Bull. Jpn.* **1992**, *40*, 3234.

[4] L. A. Thompson, J. A. Ellman, *Chem. Rev.* **1996**, *96*, 555.

[5] Y. Dong, J. Sun, X. Wang, X. Xu, L. Cao, Y. Hu, *Tetrahedron: Asymmetry* **2004**, *15*, 1667.

[6] a) H. Heaney, S. V. Ley, *J. Chem. Soc., Perkin Trans. 1* **1973**, *5*, 499; b) E. Santaniello, C. Farachi, F. Ponti, *Synthesis* **1979**, 617; c) W. C. Guida, D. J. Mathra, *J. Org. Chem.* **1980**, *45*, 3172; d) K. Sukata, *Bull. Chem. Soc. Jpn.* **1983**, *56*, 280; e) Y. Kikugawa, *Synthesis* **1981**, 124.

[7] a) C. F. Hobbs, C. K. Mcmillin, E. P. Papadopoulos, C. A. Vanderwerf, *J. Am. Chem. Soc.* **1962**, *84*, 43; b) E. P. Papadopoulos, K. I. Y. Tabello, *J. Org. Chem.* **1968**, *33*, 1299.

[8] K. T. Potts, J. E. Saxton, *Org. Synth.* **1960**, *40*, 68.

[9] R. N. Salvatore, A. S. Nagle, K. W. Jung, *J. Org. Chem.* **2002**, *67*, 674.

[10] C. F. Candy, R. A. Jones, *J. Org. Chem.* **1971**, *36*, 3993.

[11] S. Hayat, A.-u. Rahman, M. I. Choudhary, K. M. Khan, W. Schumann, E. Bayer, *Tetrahedron* **2001**, *57*, 9951.

[12] J. L. Moore, S. M. Taylor, V. A. Soloshonok, *ARKIVOC* **2005**, 287.

[13] a) J. Renault, M. Lebranchu, A. Lecat, P. Uriac, *Tetrahedron Lett.* **2001**, *42*, 6655; b) E. K. Kick, J. A. Ellman, *J. Med. Chem.* **1995**, *38*, 1427; c) J. Zhou, A. Termin, M. Wayland, C. M. Tarby, *Tetrahedron Lett.* **1999**, *40*, 2729; d) C. E. Lee, E. K. Kick, J. A. Ellmann, *J. Am. Chem. Soc.* **1998**, *120*, 9735; e) C. A. Olsen, M. Witt, J. W. Joraszewski, H. Franzyk, *Org. Lett.* **2003**, *5*, 4183.

[14] a) F. Zaragoza, H. Stephensen, *J. Org. Chem.* **2001**, *66*, 2518; b) C. A. Olsen, M. Witt, J. W. Jaroszewski, H. Franzyk, *Org. Lett.* **2004**, *6*, 1935; c) A. A. Virgilio, S. C. Schürer, J. A. Ellman, *Tetrahedron Lett.* **1996**, *37*, 6961; d) T. Vojkovsky, A. Weichsel, M. Pátek, *J. Org. Chem.* **1998**, *63*, 3162; e) J. R. Morphy, Z. Rankovic, M. York, *Tetrahedron* **2003**, *59*, 2137; f) J. R. Morphy, Z. Rankovic, D. C. Rees, *Tetrahedron Lett.* **1996**, *37*, 3209; g) A. R. Brown, D. C. Rees, Z. Rankovic, J. R. Morphy, *J. Am. Chem. Soc.* **1997**, *119*, 3288; h) K. S. Cameron, J. R. Morphy, J. R. Rankovic, M. York, *J. Comb. Chem.* **2002**, *4*, 199; i) S. Löber, P. Gmeiner, *Tetrahedron* **2004**, *60*, 8699; j) Z. Flegelová, M. Pátek, *J. Org. Chem.* **1996**, *61*, 6735.

[15] a) J. P. Tremblay-Morin, S. Raeppel, F. Gaudett, *Tetrahedron Lett.* **2004**, *45*, 3471; b) M. Arend, B. Westermann, N. Risch, *Angew. Chem. Int. Ed.* **1998**, *37*, 1045; c) N. A. Petasis, I. Akritopoulou, *Tetrahedron Lett.* **1993**, *34*, 583; d) N. A. Petasis, A. Goodman, I. A. Zavialov, *Tetrahedron* **1997**, *53*, 16463; e) N. A. Petasis, I. A. Zavialov, *J. Am. Chem. Soc.* **1998**, *120*, 11798.

[16] a) S. Sato, T. Sakamoto, E. Miyazawa, Y. Kikugawa, *Tetrahedron* **2004**, *60*, 7899; b) A. F. Abdel-Magid, K. G. Carson, B. D. Harris, C. A. Maryanoff, R. D. Shah, *J. Org. Chem.* **1996**, *61*, 3849; c) R. Apodaca, W. Xiao, *Org. Lett.* **2001**, *3*, 1745; d) C. Botteghi, L. Cazzolato, M. Marchetti, S. Paganelli, *J. Org. Chem.* **1995**, *60*, 6612; e) H. Akamatsu, S. Kusumoto, K. Fukase, *Tetrahedron Lett.* **2002**, *43*, 8867; f) M. Gustafsson, R. Olsson, C.-M. Andersson, *Tetrahedron Lett.* **2001**, *42*, 133; g) H. Sajiki, T. Ikawa, K. Hirota, *Org. Lett.* **2004**, *6*, 4977; h) R. J. Mattson, K. M. Pham, D. J. Leuck, K. A. Cowen, *J. Org. Chem.* **1990**, *55*, 2552; i) D. M. Roundhill, *Chem. Rev.* **1992**, *92*, 1.

[17] a) T. E. Müller, M. Beller, *Chem. Rev.* **1998**, *98*, 675; b) K. Okano, H. Tokuyama, T. Fukuyama, *Org. Lett.* **2003**, *5*, 4987.

[18] R. F. Smith, K. J. Coffman, *Synth. Commun.* **1982**, *12*, 801.

[19] F. Clerici, M. A. Di, M. L. Gelmi, D. Pocar, *Synthesis* **1987**, 719.

[20] M. Kozuka, T. Tsuchida, M. Mitani, *Tetrahedron Lett.* **2005**, *46*, 4527.

[21] R. Kuwano, Y. Kondo, Y. Matsuyama, *J. Am. Chem. Soc.* **2003**, *125*, 12104.

[22] a) Y. Ju, R. S. Varma, *Green Chem.* **2004**, *6*, 219; b) Y. Ju, R. S. Varma, *Org. Lett.* **2005**, *7*, 2409; c) Y. Ju, R. S. Varma, *J. Org. Chem.* **2006**, *71*, 135.

[23] a) E. J. Grayson, B. J. Davis, *Org. Lett.* **2005**, *7*, 2361; b) B. C. Hamann, J. F. Hartwig, *J. Am. Chem. Soc.* **1998**, *120*, 7369; c) F. Y. Kwong, A. Klapars, S. L. Buchwald, *Org. Lett.* **2002**, *4*, 581; d) K. W. Anderson, M. Mendez-Perez, J. Priego, S. L. Buchwald, *J. Org. Chem.* **2003**, *68*, 9563; e) R. E. Walkup, S. Searles Jr, *Tetrahedron* **1985**, *41*, 101; f) S.-C. Yang, Y.-C. Hsu, K.-H. Gan, *Tetrahedron* **2006**, *62*, 3949.

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