Reductive *N*-Monoalkylation of Primary Aromatic Amines

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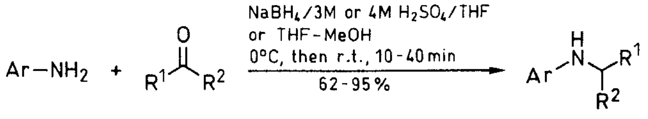
Received 3 June 1992

Primary aromatic amines **1** with a variety of ring substituents are easily converted to their *N*-monoalkyl derivatives **3** by a simple variation of the sodium borohydride/sulfuric acid/carbonyl compound procedure previously described for their *N*-permethylations. The procedure is suitable for the α-monodeuterium labelling of the new *N*-substituent.



1a-i **2a-f** **3aa-if**

1	Ar
a	Ph
b	2-MeC$_6$H$_4$
c	4-MeC$_6$H$_4$
d	2,6-(*i*-Pr)$_2$C$_6$H$_3$
e	2-MeO$_2$CC$_6$H$_4$
f	4-MeOCC$_6$H$_4$
g	2-NO$_2$C$_6$H$_4$
h	3-NO$_2$C$_6$H$_4$
i	4-NO$_2$C$_6$H$_4$

2	R^1	R^2
a	Me	Me
b	H	(*E*)-CH=CHMe
c	H	Ph
d	H	Me
e	H	Et
f	H	Pr

3	Ar	R^1	R^2
aa	Ph	Me	Me
ab	Ph	H	(*E*)-CH=CHMe
bb	2-MeC$_6$H$_4$	H	(*E*)-CH=CHMe
cc	4-MeC$_6$H$_4$	H	Ph
cd	4-MeC$_6$H$_4$	H	Me
dc	2,6-(*i*-Pr)$_2$C$_6$H$_3$	H	Ph
eb	2-MeO$_2$CC$_6$H$_4$	H	(*E*)-CH=CHMe
fb	4-MeOCC$_6$H$_4$	H	(*E*)-CH=CHMe
gd	2-NO$_2$C$_6$H$_4$	H	Me
gb	2-NO$_2$C$_6$H$_4$	H	(*E*)-CH=CHMe
ge	2-NO$_2$C$_6$H$_4$	H	Et
hd	3-NO$_2$C$_6$H$_4$	H	Me
he	3-NO$_2$C$_6$H$_4$	H	Et
ia	4-NO$_2$C$_6$H$_4$	Me	Me
ib	4-NO$_2$C$_6$H$_4$	H	(*E*)-CH=CHMe
id	4-NO$_2$C$_6$H$_4$	H	Me
ie	4-NO$_2$C$_6$H$_4$	H	Et
if	4-NO$_2$C$_6$H$_4$	H	Pr

Two classical synthetic challenges in amine chemistry, which may be reduced to a single problem, are the *N*-monosubstitution of primary amines and the preparation of tertiary amines from secondary (*N*-alkylation) and primary (*N*,*N*-peralkylation) amines, without *N*-alkylation proceeding beyond the desired stage.

We have applied our aqueous formaldehyde/sulfuric acid/sodium borohydride procedure to a large number of aliphatic and aromatic primary and secondary amines to obtain *N*-permethylated amines.[1-2] By this method even the desired mono, di or per α-deuterated substituent could be obtained by using the suitable deuterated reagents.[2] A special case of *N*,*N*-dialkylation was performed by using glutaraldehyde to obtain *N*-arylpiperidines with a wide array of phenyl substituents.[3] The procedure was also adapted to produce a number of *N*,*N*-peralkylations other than methylations.[4]

We wish to report now some variations of our procedure which enabled us to synthesize various ring substituted *N*-alkylanilines **3** from the corresponding anilines **1** in good to excellent yields (Table).

A solution of aqueous sulfuric acid and the carbonyl compound in tetrahydrofuran was slowly added to a solution of the amine in tetrahydrofuran at ca. 0°C followed by pelletized sodium borohydride (portionwise) at the same temperature. The essential procedural variations are the following:

A. – when amines not bearing electron-withdrawing (EW) substituents were used in combination with aliphatic carbonyl compounds, 4 N sulfuric acid (0.3 mol) and sodium borohydride (1 mol) were employed (Method A);

B.– when amines with EW-substituents were used in connection with aliphatic carbonyl compounds the required amounts of 3 N sulfuric acid was found to be in the neighborhood of 3 moles and that of sodium borohydride 2.5 moles (Method B); and

C. – when amines with and without EW-substituents were used in connection with aromatic and α,β-unsaturated aldehydes, less acid and reducing agent (1 and 2 mol respectively) than the previous procedure are enough; but methanol (1 mL/mmol of amine) was found to be beneficial to the reaction, perhaps because it solubilizes the intermediate solid observed in the mixture to be treated with sodium borohydride (Method C).

The new results confirmed the previously observed selectivity of the reduction and the practical non-influence of the nature, size and location of most ring substituents,[2-3] as well as the advantages of the one-pot simple synthesis utilizing relatively unexpensive reagents with the inherent possibility of introducing an α-deutero atom (Table **3fb**-D). These findings provide the way to use carbonyl compounds of widely different nature bypassing difficult, cumbersome and sometimes troublesome preliminary preparation of imines. Enolizable and polymer formation prone carbonyl compounds are perfectly suitable in our synthetic procedure: thus, we were able to achieve *N*-isopropylation using acetone as well as *N*-(*n*-alkylations) using linear aliphatic aldehydes, and introduce unsaturated substituents like the useful benzyl group and β,γ-unsaturated alkyl groups. In many of the instances given here, our method actually qualifies as the most

Table. *N*-Alkylarylamines **3** Prepared

Product	Yield[a] (%)	mp[b] (°C) or bp[b] (°C)/kPa	Molecular Formula or Lit. mp (°C) or bp (°C)/kPa	IR (KBr or neat) ν (cm^{-1})	^{1}H NMR (CDCl$_3$/TMS) δ, *J* (Hz)	MS (70 eV) *m/z* (%)
3aa	95	80/1.33	198–206/101,[19] 201.5–203.0/101,[20] 83–84/1.33,[21] 105–106/3.59[22]	3360, 2940, 2905, 1598, 1500, 1424, 1380, 1361, 1312, 1253, 1175, 1148, 745, 690	1.16 (d, 6H, *J* = 6.29), 3.34 (s, 1H), 3.58 (sept, 1H, *J* = 6.29), 6.50–6.69 (m, 3H), 7.07–7.19 (m, 2H)	135 (M^+, 51), 120 (100), 103 (9), 93 (19), 91 (12), 77 (33), 65 (19), 51 (20)
3ab	62	96/0.60	89–90/0.4,[23] 96/0.3,[24] 131–138/2.8[25]	–[26]	–[26]	–[26]
3bb	76	103/1.50	89–90/0.27[27]	3380, 2980, 2880, 2820, 1604, 1572, 1505, 1440, 1312, 1252, 1128, 1048, 960, 742	1.66–1.75 (m, 3H), 2.21 (s, 3H), 3.37 (s, 1H), 3.63–3.73 (m, 2H), 5.45–5.80 (m, 2H), 6.53–6.68 (m, 2H), 7.00–7.17 (m, 2H)	161 (M^+, 100), 146 (54), 130 (21), 120 (44), 118 (52), 107 (61), 106 (84), 91 (39), 77 (30), 55 (67)
3cc	92	130/0.06	181/1.33,[28] 154–157/0.66,[29] 130/0.03[30]	–[30]	–[30]	197 (M^+, 58), 196 (22), 120 (17), 91 (100), 77 (9), 65 (17)
3cd	72	96/1.36	91–92/0.93,[31] 95–98/1.33,[19] 76/0.4[32]	3360, 2950, 2900, 2845, 1612, 1512, 1480, 1446, 1315, 1300, 1250, 1179, 1143, 800	1.18 (t, 3H, *J* = 7.12), 2.22 (s, 3H), 3.07 (q, 2H, *J* = 7.12), 3.28 (s, 1H), 6.49 (d, 2H, *J* = 8.47), 6.92–7.00 (m, 2H)	135 (M^+, 52), 120 (100), 106 (5), 91 (28), 77 (18), 65 (17), 51 (9)
3dc	78	mp 39 178/0.35	167/0.1[33]	3340, 3000, 2930, 2840, 1490, 1450, 1380, 1360, 1250, 1190, 1100, 1050, 795, 765, 725, 695	1.24 (d, 12H, *J* = 6.87), 3.08 (s, 1H), 3.31 (sept, 2H, *J* = 6.87), 4.03 (s, 2H), 7.07–7.13 (m, 3H), 7.23–7.43 (m, 5H)	267 (M^+, 23), 176 (100), 160 (14), 146 (14), 134 (18), 117 (14), 106 (16), 91 (84), 77 (13)
3eb	78[c]	106/0.15	$C_{12}H_{15}NO_2$ (173.3)	3322, 2982, 2920, 2820, 1680, 1600, 1575, 1505, 1432, 1320, 1250, 1225, 1160, 1095, 960, 745, 700	1.65–1.72 (m, 3H), 3.69–3.78 (m, 2H), 3.81 (s, 3H), 5.47–5.81 (m, 2H), 6.50–6.68 (m, 2H), 7.24–7.37 (m, 1H), 7.77 (s, 1H), 7.84–7.92 (m, 1H)	205 (M^+, 85), 190 (51), 172 (100), 158 (83), 132 (65), 130 (56), 119 (74), 92 (38), 77 (66), 55 (62)
3fb	75[c]	112	$C_{11}H_{15}NO$ (177.3)	3280, 2800, 1642, 1580, 1420, 1350, 1335, 1275, 1170, 1120, 968, 951, 818, 570	1.65–1.75 (m, 3H), 2.50 (s, 3H), 3.70–3.77 (m, 2H), 4.37 (s, 1H), 5.45–5.83 (m, 2H), 6.55 (d, 2H, *J* = 8.94), 7.81 (d, 2H, *J* = 8.94)	189 (M^+, 59), 174 (72), 148 (12), 130 (14), 120 (70), 105 (5), 92 (18), 55 (100), 43 (71)
3fb-D	77[c]	111	$C_{11}H_{14}DNO$ (178.3)	3280, 1645, 1580, 1420, 1353, 1340, 1275, 1170, 1123, 972, 948, 820, 570	1.65–1.75 (m, 3H), 2.50 (s, 3H), 3.67–3.76 (m, 1H), 4.55 (s, 1H), 5.45–5.80 (m, 2H), 6.55 (d, 2H, *J* = 8.92), 7.80 (d, 2H, *J* = 8.92)	190 (M^+, 54), 175 (67), 149 (13), 131 (11), 120 (87), 106 (11), 92 (25), 56 (100), 43 (80)
3gd	77[c]	93/1.80	red oil[12]	3340, 2950, 2840, 1612, 1567, 1503, 1414, 1348, 1257, 1228, 1160, 1070, 1038, 738	1.36 (t, 3H, *J* = 7.19), 3.26–3.41 (m, 2H), 6.57–6.67 (m, 1H), 6.80–6.87 (m, 1H), 7.38–7.47 (m, 1H), 8.10–8.18 (m, 1H)	166 (M^+, 61), 151 (66), 118 (35), 106 (100), 105 (67), 93 (68), 91 (63), 77 (63), 65 (71), 51 (52)
3gb	89[c]	103/1.20	$C_9H_{11}NO_2$ (165.2)	3350, 2880, 2820, 1612, 1565, 1501, 1435, 1412, 1345, 1260, 1230, 1148, 1032, 960, 736	1.69–1.75 (m, 3H), 3.81–3.90 (m, 2H), 5.47–5.85 (m, 2H), 6.57–6.67 (m, 1H), 6.77–6.85 (m, 1H), 7.35–7.44 (m, 1H), 8.07 (s, 1H), 8.08–8.12 (m, 1H)	192 (M^+, 26), 157 (12), 145 (21), 130 (29), 118 (9), 105 (14), 92 (27), 77 (21), 69 (45), 55 (100)
3ge	75	100/1.70	170–172/1.6[34]	3370, 2940, 2910, 2850, 1615, 1568, 1505, 1413, 1351, 1260, 1227, 1155, 1034, 862, 738	1.04 (t, 3H, *J* = 7.33), 1.65–1.85 (m, 2H), 3.20–3.33 (m, 2H), 6.55–6.64 (m, 1H), 6.79–6.86 (m, 1H), 7.36–7.46 (m, 1H), 8.06 (s, 1H), 8.08–8.15 (m, 1H)	180 (M^+, 24), 151 (100), 121 (9), 106 (17), 105 (21), 104 (24), 93 (44), 92 (9), 77 (33)
3hd	80	61	59–60[35]	3350, 2940, 2840, 1615, 1525, 1470, 1330, 1260, 1148, 1090, 988, 842, 817, 728, 660	1.29 (t, 3H, *J* = 7.14), 3.21 (q, 2H, *J* = 7.14), 4.01 (s, 1H), 6.82–6.89 (m, 1H), 7.26 (t, 1H, *J* = 8.27), 7.38 (t, 1H, *J* = 2.30), 7.47–7.53 (m, 1H)	166 (M^+, 32), 151 (100), 119 (6), 105 (43), 92 (11), 91 (9), 77 (8), 65 (24), 51 (7)
3he	81	58	39–41[36]	3360, 2940, 2900, 2840, 1612, 1516, 1468, 1340, 1324, 1248, 1095, 842, 816, 785, 730, 663	1.01 (t, 3H, *J* = 7.32), 1.57–1.75 (ses, 2H), 3.11 (t, 2H, *J* = 7.02), 4.06 (s, 1H), 6.82–6.90 (m, 1H), 7.24 (t, 1H, *J* = 8.09), 7.36 (t, 1H, *J* = 2.30), 7.43–7.51 (m, 1H)	180 (M^+, 16), 151 (100), 105 (56), 104 (16), 92 (9), 76 (11), 65 (14)
3ia	90	84	81–82,[5] 82–84,[6] 82–84[8]	3320, 2940, 2880, 1600, 1525, 1492, 1470, 1320, 1290, 1270, 1180, 1100, 828, 752, 694	1.15 (d, 6H, *J* = 6.35), 3.72 (sept, 1H, *J* = 6.35), 4.72 (s, 1H), 6.51 (d, 2H, *J* = 9.28), 8.06 (d, 2H, *J* = 9.28)	180 (M^+, 23), 165 (100), 133 (5), 119 (65), 92 (11), 76 (8), 65 (17)

Table. (continued)

Product	Yield[a] (%)	mp[b] (°C) or bp[b] (°C)/kPa	Molecular Formula[c] or Lit. mp (°C) or bp (°C)/kPa	IR (KBr or neat) ν (cm^{-1})	^{1}H NMR (CDCl$_3$/TMS) δ, J (Hz)	MS (70 eV) m/z (%)
3ib	78[c]	61	$C_{10}H_{12}N_2O_2$ (192.2)	3360, 1590, 1492, 1452, 1315, 1287, 1178, 1102, 1054, 960, 824, 745	1.65–1.77 (m, 3H), 3.74–3.82 (m, 2H), 4.89 (s, 1H), 5.44–5.83 (m, 2H), 6.53 (d, 2H, J = 9.28), 8.05 (d, 2H, J = 9.28)	192 (M$^+$, 32), 177 (37), 164 (5), 151 (9), 138 (23), 130 (22), 105 (12), 92 (9), 76 (10), 55 (100)
3id	85	97	94–96,[8] 95,[11] 95,[37] 96,[38] 96–97[39]	3320, 2940, 1595, 1520, 1480, 1452, 1318, 1290, 1268, 1180, 1150, 1105, 832, 750	1.30 (t, 3H, J = 7.14), 3.26 (q, 2H, J = 7.15), 4.62 (s, 1H), 6.52 (d, 2H, J = 9.25), 8.07 (d, 2H, J = 9.25)	166 (M$^+$, 48), 151 (100), 119 (12), 105 (84), 92 (13), 91 (11), 76 (15), 65 (24)
3ie	85	69	70[40]	3310, 2940, 2900, 1600, 1530, 1452, 1312, 1283, 1260, 1180, 1140, 1100, 832, 747, 652	1.01 (t, 3H, J = 7.35), 1.58–1.77 (ses, 2H), 3.18 (t, 2H, J = 7.05), 4.72 (s, 1H), 6.52 (d, 2H, J = 9.24), 8.07 (d, 2H, J = 9.24)	180 (M$^+$, 18), 151 (100), 135 (2), 105 (54), 92 (4), 76 (7), 65 (5)
3if	87	58	55–57,[8] 54,[11] 56,[15] 54[37]	3310, 2920, 2840, 1600, 1535, 1468, 1318, 1285, 1183, 1136, 1104, 832, 750, 652	0.96 (t, 3H, J = 7.19), 1.35–1.56 (m, 2H), 1.57–1.74 (m, 2H), 3.20 (t, 2H, J = 7.02), 4.72 (s, 1H), 6.52 (d, 2H, J = 9.30), 8.07 (d, 2H, J = 9.30)[8, 15]	194 (M$^+$, 17), 151 (100), 105 (56), 104 (10), 92 (4), 76 (8), 65 (6)

[a] Yield of isolated pure product.

[b] Melting and boiling points are not corrected.

[c] Satisfactory microanalyses obtained: C, H, N ± 0.20.

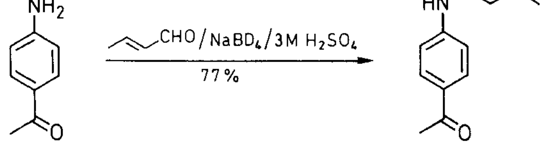
practical and least expensive in order to produce the desired products among those published so far (see for example **3id**[5-10] and **3if**[8,10-16]).

N-Alkylation via preliminary formation of separate *N*-alkylidenebenzeneamine was in at least one case shown to be impossible by the usual procedure, since the mixture 4-acetylbenzeneamine (**1f**) and (*E*)-2-butenal gave only an intractable polymeric material. We observed partial reduction of the side chain double bond only for the system (*E*)-2-butenal/2,6-diisopropylbenzeneamine (**1d**), whereas the analogous system with benzeneamine did not show any side reaction of this type. This is believed to be due to the relative inaccessibility of the N–C double bond of the intermediate imine (or iminium ion) formed to the hydride donor.

N-Benzylation of 2,6-diisopropylbenzeneamine (**1d**) yielded the corresponding *N*-benzyl-2,6-diisopropylbenzeneamine (**3dc**) (80%), whereas the alternate two-step process required a 6 hours reaction between benzaldehyde and **1d** at reflux temperature in toluene in the presence of *p*-toluensulfonic acid (20% mol equiv, the reaction without acid catalysis was extremely slow). Eventually, the separated imine (79%) was then converted to **3dc** in 100% yield by treatment with sodium borohydride (1 mol) in acetic acid.

N,*N*-Dialkylation was observed to be a minor process (less than 15%) only with the systems requiring the Method A. Optimization of the conditions was not performed on single systems, but was partly attempted in the instance of ethanal/4-methylbenzeneamine, the results obtained being simply transferred to the other cases.

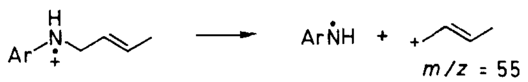
The reaction mechanism[1-2] allows for the potential introduction of a deuterium atom in the α position of the entering *N*-substituent when sodium tetradeuteridoborate is used, as it was shown in some *N*-permethylations,[2] where the reaction product faithfully reflected the isotopic composition of the hydride reagent. The same pattern was, as expected, confirmed for the present *N*-monoalkylation, in the particularly interesting instance of a *N*-butenylation of the amine **1f** exhibiting a reduction sensitive, electron-withdrawing substituent.



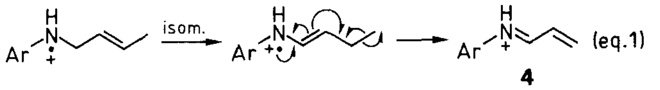
1f **3fb**-D(*R*,*S*)

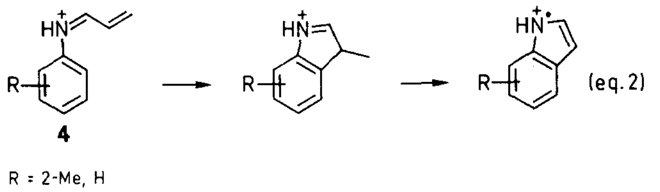
As in the previously described[1-2] reductive *N*-alkylation experiments, the new procedural variations to obtain selective *N*-monoalkylation were also found to be applicable to aromatic amines with all types of ring substituents used in the study. It is also noteworthy that reduction of neither the double bond of (*E*)-2-butenal nor the double bond of the product amines **3ab**, **3bb**, **3eb**, **3fb**, **3gb** and **3ib** occurred. The reaction conditions did not affect the original *E*/*Z* isomeric ratio fo the reactant (*E*)-2-butenal either.

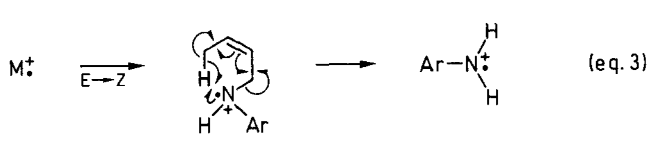
A few passing remarks about some features of the electron impact fragmentations observed for the *N*-(2-butenyl)amines obtained in this work seem to be of interest. Positioning a double bond in the *n*-C_4 chain was expected to cause a large change in the mass spectra of *N*-alkyl derivatives. In fact, whereas, e.g. the 70 eV mass spectrum of **3if** is made up of practically two ions only (M$^+$ − Pr and M$^+$ − Pr − NO$_2$), the corresponding unsaturated amine **3ib** exhibited a quite complex mass spectral behaviour, dominated by the base peak for the *N*-alkenyl group (m/z = 55).

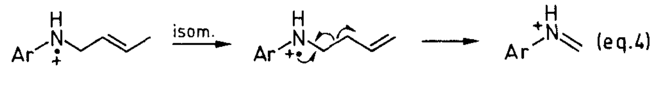


This was, indeed, one of the common features involving this side chain, the others being the expulsion of a methyl radical (eq. 1), the sequential expulsion of a second methyl group from the secondary ion **4** derived from **3ab** and **3bb** (eq. 2), the elimination of the side chain (C_4H_6), but for an hydrogen atom in a rearrangement-cleavage process (eq. 3), and the expulsion of a propenyl group following isomerization (eq. 4).









An ion at M^+−43 was also frequently observed, but could not be rationalized at the present time. The hydrogen mobility in the side chain observed in the *N*-(2-butenyl) derivatives may be both a dynamic process ensuing in the parent ion and one catalyzed by the ion source wall, as hinted by some H/D exchange observed for **3fb**-D where, contrary to any reasonable rationale, the ratio M—1/M is larger than for **3fb**. The formation of other fragmentations was in line with what could be expected for the type of substituent present in the aromatic ring and the known behaviour of intermediate fragment ions.

All the aromatic amines **1** and the carbonyl compounds **2** used in this work, $NaBH_4$ pellets (8 mm diameter) and $NaBD_4$ powder (pelletized with an IR die), were purchased from Aldrich Chimica S.r.l., Milano, Italy. All solvents used were laboratory grade and were used as such. Al_2O_3 (neutral) was purchased from BDH Italia S.r.l., Milano, Italy.

GC analyses were performed with a fused silica capillary column (30 m long, 0.32 i.d., Supelchem^R SE-54, film thickness 0.25 μm) assembled on a Perkin-Elmer Sigma 10 gas chromatograph, using the ion source of the mass spectrometer as a detector. MS in the electron impact positive ions mode were obtained with a Finnigan 1020 mass spectrometer equipped with a conventional source operating at 70 eV, a quadrupole filter and detector of ions, data system and library. IR spectra were recorded on a JASCO IR Spectrophotometer DS-702G. ^1H NMR spectra were obtained on a Bruker AC-200 spectrometer.

4-Methyl-*N*-ethylbenzeneamine (3cd); Typical Procedure:

Method A: A solution of aq 4 M H_2SO_4 (2.1 mL, 8.4 mmol) and ethanal (1.67 mL, 29.90 mmol) in THF (80 mL) was slowly added to an open flask containing a solution of 4-methylbenzeneamine (**1a**; 3.00 g, 28.03 mmol) in THF (30 mL) followed by the portionwise addition of $NaBH_4$ pellets, (to a total of approximately 0.70 g, 18.4 mmol) under vigorous magnetic stirring at 0 °C (± 5 °C). The mixture was stirred for an additional 40 min at r.t., diluted with H_2O (30 mL), made strongly alkaline with NaOH pellets (cooling) and extracted with *t*-BuOMe (4 x 40 mL). The combined organic phases were washed with brine, dried (Na_2SO_4) and the solvent removed by distillation. Pure **3cd** (yield: 72 %) was obtained by column chromatography on neutral Al_2O_3 (hexane/CH_2Cl_2, gradient from 100–0 % to 20–80 %); yield: 2.72 g (72 %) (Table).

3-Nitro-*N*-propylbenzeneamine (3he); Typical Procedure:

Method B: A solution of aq 3 M H_2SO_4 (22 mL, 66 mmol) and propanal (1.67 mL, 23.2 mmol) in THF (40 mL) was slowly added to an open flask containing a solution of 3-nitrobenzeneamine (**1h**; 3.00 g, 21.74 mmol) in THF (150 mL) and followed by the portionwise addition of $NaBH_4$ pellets (to a total of approximately 1.45 g, 55 mmol) under vigorous magnetic stirring at 0–5 °C. The reaction mixture was worked up as given in Method A to afford pure **3he**; yield: 3.17 g (81 %).

4-Acetyl-*N*-(*E*-2-butenyl)benzeneamine (3fb); Typical Procedure:

Method C: A solution fo aqueous 3 M H_2SO_4 (4.3 mL, 12.90 mmol) and (*E*)-2-butenal[17] (1.41 mL, 17 mmol) in THF (15 mL) was slowly added to an open vessel containing a solution of 4-acetylbenzeneamine (**1f**; 2.00 g, 14.81 mmol) in THF (75 mL) and MeOH (25 mL) at 0 °C (± 5 °C). After 5 min $NaBH_4$ pellets (1.00 g, 26.43 mmol) were added to the vigorously stirred mixture at the same temperature. The mixture was stirred for an additional 10 min at r.t., diluted with H_2O (30 mL) and worked up as given in Method A to give pure **3fb**; yield: 2.10 g (75 %).

(*R*,*S*)-4-Acetyl-*N*-[(*E*)-2-(1-deuterio)butenyl]benzeneamine (3fb-D):

The procedure employed for the preparation of **3fb** was followed using $NaBD_4$. The amine **3fb**-D was obtained in 77 % yield, as a solid after purification by column chromatography. ^1H NMR analysis showed 98 ± 1 % monodeuterium incorporation reflecting the composition of geometric isomers very closely (± 1 %) to that of (*E*)-2-butenal used.

***N*-Benzyl-2,6-diisopropylbenzeneamine (3dc):**

N-Benzylidene-2′,6′-diisopropylbenzeneamine: A solution of 2,6-diisopropylbenzeneamine (**1d**; 4.70 g, 26.55 mmol), benzaldehyde (3.38 g, 31.90 mmol) and TsOH · H_2O (1.00 g, 5.31 mmol) in toluene (50 mL) was refluxed for 6 h in a Dean-Stark apparatus. The solvent was distilled and the residue dissolved in *t*-BuOMe (80 mL). This solution was washed with 0.2 M NaOH (40 mL) and water (40 mL) and dried (Na_2SO_4). After evaporation of the solvent the crude imine was distilled; yield: 5.52 g (78 %); bp 142 °C/0.70 kPa; mp 56 °C (Lit.[18] mp 55–56 °C).

MS (EI): m/z = 265 (M^+, 54), 250 (60), 208 (100), 193 (32), 188 (21), 146 (65), 132 (30), 115 (32), 103 (23), 91 (93), 77 (47), 65 (20).

IR (KBr): ν = 3030, 3000, 2920, 2840, 1635, 1575, 1450, 1380, 1358, 1321, 1305, 1290, 1250, 1172, 1100, 931, 870, 792, 750, 689 cm^{-1}.

^1H NMR ($CDCl_3$/TMS): δ = 1.17 (d, 12 H, J = 6.88 Hz), 2.99 (sept, 2 H, J = 6.88 Hz), 7.05–7.18 (m, 3 H), 7.43–7.54 (m, 3 H), 7.85–7.97 (m, 2 H), 8.19 (s, 1 H).

N-Benzyl-2,6-diisopropylbenzeneamine (**3dc**): $NaBH_4$ pellets (0.15 g, 3.95 mmol) were added portionwise to a stirred solution of *N*-benzylidene-2′,6′-diisopropylbenzeneamine (1.00 g, 3.77 mmol) in AcOH (3 mL) at 0 °C and the stirring was continued at r.t. for 10 min. The mixture was made alkaline with 5 M NaOH (15 mL), extracted with *t*-BuOMe (25 mL) and the organic phase was washed with water (10 mL) and dried (Na_2SO_4). The solvent was evaporated and the crude product was distilled; yield: 1.00 g (98 %); bp 178 °C/0.35 kPa..

This work was supported in part by grants to AGG (CNR 86.01649, MPI 1987–1990 40 % and 60 %) and to GV (MPI 1987 60 % and 1990–1991 40 %). The authors are grateful to Mr. P. Padovani for expert instrumental maintenance.

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