Mercury(II) Oxide/Tetrafluoroboric Acid; A Convenient Reagent for the Hydroxy(alkoxy)-phenylamination of Alkenes

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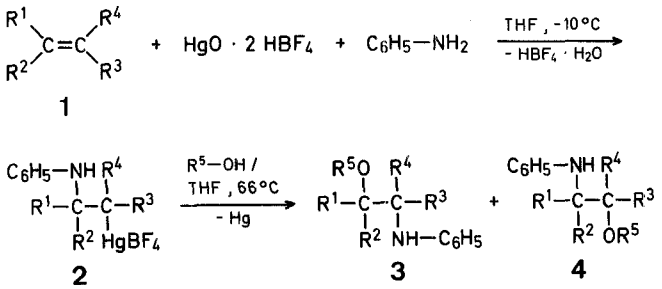
In a recent communication[1], we reported the synthesis of vicinal aromatic diamines by reacting alkenes **1** with amines and mercury(II) oxide/tetrafluoroboric acid. The key step of the process appears to be the nucleophilic cleavage of the Hg—C bond of an intermediate aminoalkylmercury(II) tetrafluoroborate **2**. We have found now that aminomercurials **2** are stable species in tetrahydrofuran solution at $-10\,^{\circ}C$ when the aminomercuration process is carried out at this temperature using the stoichiometric amounts of aromatic amine and mercury(II) oxide/tetrafluoroboric acid mixture (Scheme **A**).

Subsequent reaction of the tetrahydrofuran solution of **2** with water or alcohols leads to the corresponding 1,2-hydroxy(alkoxy)-phenylaminated products **3** and **4** and mercury(0) in good yields (Scheme **A**, Table 1). However, the presence of aliphatic amines in the reaction media inhibits the reduction of the mercurial under these conditions.



Scheme **A**

The ratio of the products **3**:**4** depends on the substitution pattern at the C—C double bond; in the case of terminal alkenes **1**

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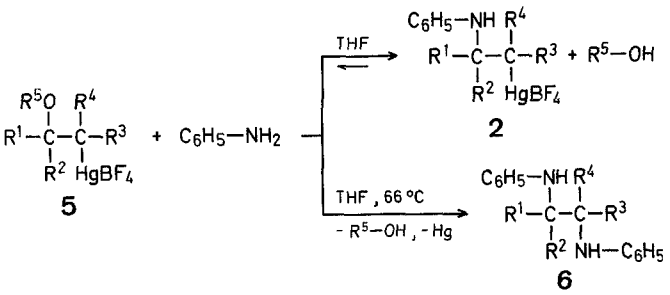
($R^3 = R^4 = H$) the rearranged isomer **3** is the major product (see Table 1). Reactions with cyclic alkenes show that this oxyamination process is *trans*-stereospecific.

The oxyamination of alkenes **1** cannot be achieved by reversing the order of addition of the nucleophiles, namely first obtaining the corresponding oxymercury(II) tetrafluoroborate **5** and then removing the mercury by reaction with an aromatic amine. In contrast, this sequence of reactions results in the formation of the vicinal diamines **6**. Since the oxymercuration is a reversible process, it can be assumed that, in the presence of aniline, the oxymercurials **5** are transformed into the aminomercurials **2** and then the mercury is replaced by the strongest nucleophile present in the reaction medium, i.e. the aromatic amine (Scheme **B**).



Scheme **B**

The method described in this paper allows the direct, one-pot hydroxy(alkoxy)-phenylamination of alkenes with good yields and its advantages are that it does not require the tedious prepa-

Table 1. Hydroxy(alkoxy)-phenylamination of Alkenes **1**

Alkene **1** R^1	R^2	R^3	R^4	R^5 in R^5—OH	Product	Yield [%]	Ratio[a] of **3**:**4**	m.p. [°C] or b.p. [°C]/torr	Molecular formula or Lit. m.p. or b.p./torr
H	H	H	H	H	**3a**	60	—	166°/0.01	286°/760[6]
H	—$(CH_2)_3$—		H	H	**3b**	79	—	57–59°	175°/16[5]
H	—$(CH_2)_4$—		H	H	**3c**	80	—	59–61°	58°[5]
CH_3	H	H	H	H	**3d**	67	16:3	78–82°/0.001	$C_9H_{13}NO$ (151.2)[b]
					4d	—	—	—	80–83°/0.001[3]
C_6H_5	H	H	H	H	**3e**	65	26:4	oil	$C_{14}H_{15}NO$ (213.3)[b]
					4e	—	—	—	oil[3]
H	—$(CH_2)_4$—		H	CH_3	**3f**	71	—	72–75°/0.01	$C_{13}H_{19}NO$ (205.3)[b]
CH_3	H	H	H	CH_3	**3g**	54	26:6	68–70°/0.01	$C_{10}H_{15}NO$ (165.2)[b]
					4g	—	—	—	$C_{10}H_{15}NO$ (165.2)
n-C_5H_{11}	H	H	H	CH_3	**3h**	73	16:7	70–73°/0.01	$C_{14}H_{23}NO$ (221.3)
					4h	—	—	—	$C_{14}H_{23}NO$ (221.3)[b]

[a] Estimated from the ^{13}C-N.M.R. spectra of the crude reaction products.
[b] Satisfactory microanalyses obtained: C ±0.05, H ±0.07, N ±0.06.

Table 2. Spectra Data for Compounds **3** and **4**

Product	I.R. (nujol) [cm^{-1}]			^{1}H-N.M.R. ($CDCl_3$/TMS, 80 MHz)	^{13}C-N.M.R. ($CDCl_3$/TMS, 20 MHz) [ppm][a]		
	$\nu_{NH,OH}$	ν_{C-O}	ν_{arom}	δ [ppm]	$\delta_{C-N,\ C_6H_5}$	$\delta_{C\ OR^5}$	δ_{OCH_3}
3a	3400	—	3600, 1600, 1500, 760, 700	2.95 (t, 2H, J=6 Hz); 3.50 (t, 2H, J=6 Hz); 4.00 (br. s, 2H); 6.3–7.2 (m, 5 H_{arom})	45.3	60.1	—
3b	3360	—	3020, 1600, 1500, 760, 700	2.0–2.4 (m, 6H); 3.10 (br. s, 2H); 3.4 (m, 1H); 3.9 (m, 1H); 6.4–7.3 (m, 5 H_{arom})	62.1	78.0	—
3c	3360	—	3020, 1610, 1500, 760, 700	0.7–2.3 (m, 8H); 3.10 (br. s, 2H); 3.2 (m, 2H); 6.5–7.4 (m, 5 H_{arom})	59.2	73.4	—
3d	3360	—	3010, 1600, 1500, 750, 700	1.15 (d, 3H, J=6 Hz); 2.9 (m, 8H); 3.35 (br. s, 2H); 3.0 (m, 2H); 6.4–7.3 (m, 5 H_{arom})	50.2	64.8	—
4d	3360	—	3010, 1600, 1500, 760, 700	1.00 (d, 3H, J=6 Hz); 3.2–3.6 (m, 3H); 3.80 (br. s, 2H); 6.3–7.2 (m, 5 H_{arom})	49.1	64.4	—
3e	3360	—	3010, 1600, 1500, 760, 700	3.3 (m, 2H); 4.60 (br. s, 2H); 5.0 (m, 1H); 6.5–7.8 (m, 10 H_{arom})	46.8	76.8	—
4e	3400	—	3070, 1600, 1500, 760, 700	3.6–4.0 (m, 4H); 4.5 (m, 1H); 6.4–7.5 (m, 10 H_{arom})	50.6	73.2	—
3f	3360	1100	3010, 1600, 1500, 750, 700	0.9–2.3 (m, 8H); 3.2 (m, 2H); 3.35 (s, 3H); 3.75 (br. s, 1H); 6.5–7.4 (m, 5 H_{arom})	56.2	81.8	55.7
3g	3380	1100	3010, 1600, 1500, 750, 700	1.15 (d, 3H, J=6 Hz); 3.1–3.7 (m, 4H); 3.30 (s, 3H); 6.3–7.4 (m, 5 H_{arom})	48.9	75.2	55.7
4g	3380	1100	3010, 1600, 1500, 750, 700	1.00 (d, 3H, J=6 Hz); 3.1–3.7 (m, 4H); 3.25 (s, 3H); 6.3–7.4 (m, 5 H_{arom})	48.3	76.1	60.2
3h	3360	1100	3010, 1600, 1500, 750, 700	0.6–2.9 (m, 11H); 3.1 (m, 2H); 3.2 (m, 1H); 3.30 (s, 3H); 3.55 (br. s, 1H); 6.4–7.3 (m, 5 H_{arom})	46.5	79.4	56.2
4h	3360	1100	3010, 1600, 1500, 750, 700	0.6–2.9 (m, 11H); 3.2 (m, 2H); 3.20 (s, 3H); 3.3 (m, 1H); 3.55 (br. s, 1H); 6.4–7.3 (m, 5 H_{arom})	53.0	74.3	58.5

[a] Assignments made using off-resonance experiments.

ration of intermediate compounds[2,3] or the use of sophisticated reagents[4].

Mercury(II) oxide/tetrafluoroboric acid was prepared as reported[1]. Authentic samples of 2-(phenylamino)-propanol[3], *trans*-2-(phenylamino)-cyclohexanol[5], 2-phenyl-2-(phenylamino)-ethanol[3], and 1,2-bis[phenylamino]cyclohexane[1] were prepared for comparison according to the literature procedures.

2-(Phenylamino)-cyclohexanol; Typical Procedure:

Mercury(II) oxide/tetrafluoroboric acid (7.5 g, 20 mmol) is added to a solution of cyclohexene (1.6 g, 20 mmol) and aniline (1.8 g, 20 mmol) in tetrahydrofuran (40 ml) and the resultant mixture stirred at −10 °C for 5 min. Water (1 g, 55 mmol) is then added and the solution is heated under reflux for 6 h and then cooled. The mercury(0) precipitated is filtered off [yield: 3.8 g (95%)], the solution is treated with 3 normal potassium hydroxide solution (25 ml), and extracted with ether (3 × 20 ml). Solvents are removed under vacuum (10^{-2} torr) and the oily residue is purified by column chromatography (silica: toluene/hexane/diethylamine, 75:15:10) to give the product as an oil which is recrystallized from hot hexane; yield: 3.0 g (79%); m.p. 59–61 °C (Lit.[5], m.p. 58 °C).

$C_{12}H_{17}NO$	calc.	C 75.35	H 8.96	N 7.32
(191.3)	found	75.37	8.96	7.30

1,2-Bis[phenylamino]cyclohexane:

Mercury(II) oxide/tetrafluoroboric acid (7.5 g, 20 mmol) is added to a solution of cyclohexene (1.6 g, 20 mmol) and methanol (0.6 g, 20 mmol) in tetrahydrofuran (40 ml) and the resultant mixture stirred at −10 °C for 5 min. Aniline (3.6 g, 40 mmol) is then added and the solution is heated under reflux for 3 h and then cooled. The mercury(0) precipitated is filtered off [yield: 3.8 g (95%)], the solution is treated with 3 normal potassium hydroxide solution (25 ml), and extracted with ether (3 × 20 ml). Solvents and excess amine are removed under vacuum (10^{-2} torr) and the oily residue is purified by column chromatography (silica; toluene/hexane/diethylamine; 75:15:10) to give the product as an oil; yield: 3.6 g (68%).

$C_{18}H_{22}N_2$	calc.	C 81.15	H 8.33	N 10.52
(266.4)	found	81.19	8.31	10.49

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