



Cite this: *Chem. Commun.*, 2015, 51, 3239

Received 5th November 2014,
Accepted 9th January 2015

DOI: 10.1039/c4cc08846h

www.rsc.org/chemcomm

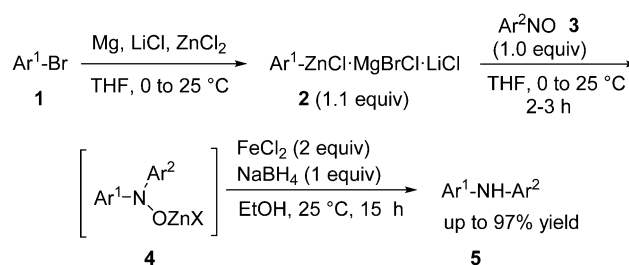
Synthesis of polyfunctional secondary amines by the addition of functionalized zinc reagents to nitrosoarenes†

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Addition of functionalized aryl, heteroaryl or adamantyl zinc reagents to various nitroso-arenes in the presence of magnesium salts and LiCl in THF produces after a reductive work-up with FeCl₂ and NaBH₄ in ethanol the corresponding polyfunctional secondary amines in high yields.

The preparation of arylamines is an important synthetic goal since these compounds often have useful properties for pharmaceuticals or material science applications.¹ Transition metal catalyzed aminations have been well studied,² but the use of expensive and toxic metallic catalysts reduces somewhat the utility of such synthetic methods. Another approach has been the use of electrophilic nitrogen reagents and their reactions with non-expensive and low toxic main-group organometallics.³ A few years ago, we have reported that functionalized arylmagnesium reagents add to nitroso-arenes⁴ and nitro-arenes.⁵ Although satisfactory yields were obtained, the high reactivity of the carbon–magnesium bond reduces the functional group tolerance. Furthermore, nitroso-arenes have proven to be versatile reagents for performing nitroso aldol and related reactions.⁶

Herein, we wish to report a mild synthesis of diaryl or heteroaryl-(aryl)amines as well as functionalized highly sterically hindered adamantyl(aryl)amines. Thus, the treatment of an arylzinc derivative **2**, prepared either by the direct insertion of Mg in the presence of LiCl and ZnCl₂ (ref. 7) or by a I/Mg-exchange with iPrMgCl·LiCl⁸ followed by transmetalation with ZnCl₂, with various nitroso-arenes of type **3**⁹ affords an intermediate zincated hydroxylamine derivative **4** which after reductive work-up with FeCl₂ and NaBH₄ in ethanol (25 °C, 15 h) produce the corresponding secondary amines of type **5** in excellent yields (Scheme 1). A range of functional groups have been tolerated in the starting arylzinc reagent as shown in Table 1.



Scheme 1 Synthesis of polyfunctional secondary amines of type **5** via the addition of functionalized zinc reagents of type **2** to various nitroso compounds of type **3**.

Thus, PhZnCl (1.1 equiv.) prepared by the direct insertion of Mg in the presence of LiCl and ZnCl₂ reacts with nitrosobenzene **3a** (1.0 equiv.) at 25 °C within 2–3 h and produces after reductive work-up with FeCl₂ (2.0 equiv.) and NaBH₄ (1.0 equiv.) in ethanol (25 °C, 15 h) the corresponding diphenylamine **5a** in 85% yield (Table 1, entry 1).^{10a} The presence of both Mg salts and LiCl were found to be essential for achieving a high yield. A variety of arylzinc reagents prepared similarly were used in the addition to **3a**. Both electron withdrawing and donating groups can be attached at the aryl ring (Table 1, entries 2–8).^{10b–g} Arylzinc reagent **2c** has been prepared *via* an I/Mg-exchange,⁸ its reaction with nitrosobenzene (**3a**) furnishes the corresponding secondary amine **5c** in 76% yield (Table 1, entry 3). Although sensitive functional groups like a formyl or an acetyl group are not tolerated, the corresponding bromoacetal (**1i**) or bromoketal (**1j**) are readily converted to the zinc reagents (**2i** and **2j**) by the insertion of Mg in the presence of LiCl and ZnCl₂.⁷ The addition of nitrosobenzene (**3a**) provides after removal of the ethylene glycol protecting group (CF₃CO₂H in CH₂Cl₂ at 25 °C for 5–8 h) the secondary amines (**5i** and **5j**) in 64–75% yield (Table 1, entries 9 and 10).

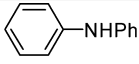

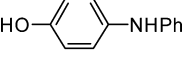

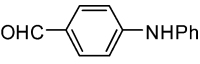
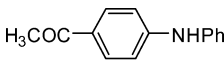
This addition reaction can be extended to various nitroso-arenes (commercially available) or prepared according to the method of Bäckvall.¹¹ Again, electron-donating or accepting substituents are tolerated in the arylnitroso reagents of type **3** furnishing the

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† Electronic supplementary information (ESI) available: Detailed experimental procedures and spectroscopic data for all compounds. See DOI: 10.1039/c4cc08846h



Table 1 Synthesis of diarylamines of type **5** via the reaction of functionalized arylzinc reagents **2a–j** with nitrosobenzene **3a**

Entry	Zn-reagent	Product, yield ^{a,b} (%)
1	2a , PhZnCl	 5a : 85
2	2b , FG = CF ₃	 5b : 69
3	2c , FG = CO ₂ Et ^c	5c : 76
4	2d , FG = <i>t</i> Bu	5d : 96
5	2e , FG = SCH ₃	5e : 70
6	2f , FG = OCH ₃	5f : 78
7	2g , FG = OTMS	 5g : 89 ^d
8	2h	 5h : 72
9	2i ^e	 5i : 64 ^f
10	2j ^e	 5j : 75 ^f

^a General reaction conditions: arylzinc reagent (1.1 equiv.), nitroso electrophile (1.0 equiv.), NaBH₄ (1.0 equiv.), FeCl₂ (2.0 equiv.). ^b Yield of analytically pure isolated product as determined by ¹H-NMR analysis. ^c Prepared by I/Mg-exchange with *i*PrMgCl·LiCl.^{8 d} The TMS-group was cleaved during workup and column chromatography purification. ^e The arylzinc reagents (**2i** and **2j**) were prepared from the corresponding bromides (see ESI). ^f Obtained after removal of the ethylene glycol group with CF₃CO₂H in CH₂Cl₂ (see ESI).

corresponding diarylamines **5k–r** in 77–97% yield (Table 2, entries 1–8).^{5a,10h–k} Noteworthy, a heterocyclic zinc reagent (**2m**) has also been used as well as a nitrosopyridine (**3g**)¹² leading to heteroaryl(aryl)-amines **5s–y** in 55–96% yield (Table 2, entries 9–15). Moreover, tertiary alkylzinc reagents such as *t*-BuZnCl (**6a**) and adamantylzinc chloride (**6b**)¹³ add to various nitroso-arenes under similar reaction conditions producing otherwise difficult to prepare tertiaryalkyl(aryl)amines **7a–d** in 50–89% yield (Table 3, entries 1–4).¹⁴

In summary, we have shown that aryl, heteroaryl or adamantyl zinc reagents add to various nitroso-arenes in the presence of Mg-salts and LiCl. Both Mg and Li salts are necessary to achieve high yields for the synthesis of the corresponding functionalized secondary amines. Further extensions of this work are currently underway in our laboratories.

The research leading to these results has received funding from the European Research Council under the European Community's Seventh Framework Programme (FP7/2007–2014) ERC grant agreement no. 227763. We thank the Fonds der Chemischen Industrie for financial support. We also thank Heraeus Holding GmbH (Hanau), Rockwood Lithium (Frankfurt), and BASF SE (Ludwigshafen) for the generous gift of chemicals.

Table 2 Synthesis of polyfunctional secondary amines of type **5** by the addition of aryl and heteroaryl zinc reagents **2a–m** to various nitroso compounds **3a–g**

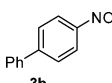
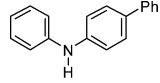

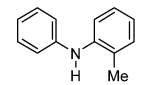
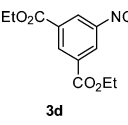
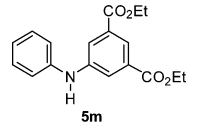
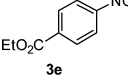
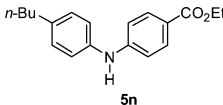
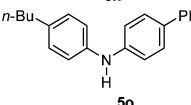
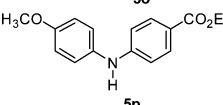
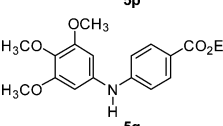
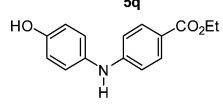
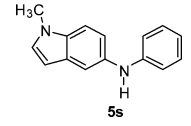
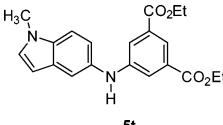
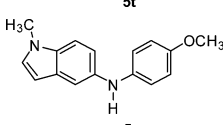
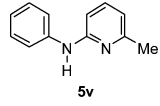
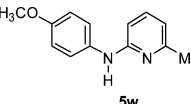
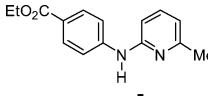
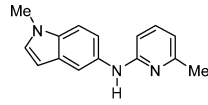
Ar ¹ -ZnX + Ar ² -NO		1. THF, 0 to 25 °C, 2-3 h 2. FeCl ₂ (2 equiv) NaBH ₄ (1 equiv) EtOH, 25 °C, 15 h		Ar ¹ -NH-Ar ²
Entry	Zn-reagent (Ar ¹)	Electrophile (Ar ²)	Product	Yield ^{a,b} (%)
1	2a			79
2	2a			77
3	2a			83
4	2k			97
5	2k	3b		90
6	2f	3e		81
7	2l	3e		97
8	2g	3e		97 ^c
9	2m	3a		63
10	2m	3d		55
11	2m	3f		60
12	2a	3g		67
13	2f	3g		96

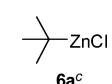
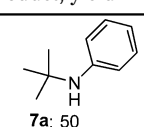
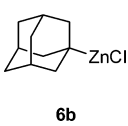
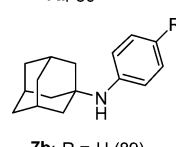
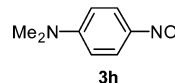


Table 2 (continued)

Ar ¹ -ZnX + Ar ² -NO		1. THF, 0 to 25 °C, 2-3 h 2. FeCl ₂ (2 equiv) NaBH ₄ (1 equiv) EtOH, 25 °C, 15 h		Ar ¹ -NH-Ar ²
Entry	Zn-reagent (Ar ¹)	Electrophile (Ar ²)	Product	Yield ^{a,b} (%)
14	2c ^d	3g		83
15	2m	3g		70

^a General reaction conditions: arylzinc reagent (1.1 equiv.), nitroso electrophile (1.0 equiv.), NaBH₄ (1.0 equiv.), FeCl₂ (2.0 equiv.). ^b Yield of analytically pure isolated product as determined by ¹H-NMR analysis. ^c The TMS-group was cleaved during the workup and column chromatography purification. ^d Prepared by I/Mg-exchange with iPrMgCl·LiCl.⁸

Table 3 Synthesis of tertiaryalkyl(aryl)amines **7a–d** by the addition of tertiary alkylzinc reagents **6a** and **6b** to nitroso compounds **3a**, **3f** and **3h**

Entry	Zn-reagent	Electrophile	Product, yield ^{a,b} (%)
1		3a	
2		3a	
3	6b		7c: R = NMe ₂ (71)
4	6b	3f	7d: R = OMe (56)

^a General reaction conditions: alkylzinc reagent (1.1 equiv.), nitroso electrophile (1.0 equiv.), NaBH₄ (1.0 equiv.), FeCl₂ (2.0 equiv.). ^b Yield of analytically pure isolated product as determined by ¹H-NMR analysis. ^c Prepared by transmetalation of commercially available *t*-BuMgCl with ZnCl₂.

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