# Electrophilic amination of organozinc reagents with acetone *O*-(2,4,6-trimethylphenylsulfonyl)oxime and *O*-methylhydroxylamine

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Reaction of diorganozincs and triorganozincates with acetone *O*-(2,4,6-trimethylphenylsulfonyl)oxime or *O*-methylhydroxylamine in the presence of CuCN provides a new one-flask method for electrophilic amination of organozinc reagents. Considering the lithium- or magnesium-to-zinc transmetallation, this method also extends the scope of electrophilic amination of organolithiums and Grignard reagents.

# Introduction

The importance of amines and the commonplace use of organometallic reagents in organic synthesis has created the need for 'NH<sub>2</sub><sup>+</sup>'-containing reagents capable of C–N connection. There are detailed reviews on the amination of carbanions.<sup>1</sup> In addition, a number of new reagents have been recently developed, among them N,O-bis(trimethylsilyl)-hydroxylamine,<sup>2</sup> LiN(OTs)CO<sub>2</sub>Bu<sup>t</sup> (LiBTOC),<sup>3</sup> N-protected oxaziridines,<sup>4</sup> 1-chloro-1-nitrosocyclohexane,<sup>5</sup> acetone O-(2,4,6-trimethylphenylsulfonyl)oxime,<sup>6</sup> 4,4'-bis(trifluorometh-yl)benzophenone O-methyloxime<sup>7</sup> and bis(2,2,2-trichloroethyl) azodicarboxylate.<sup>8</sup>

Efficient methods are known for electrophilic amination of organolithiums,<sup>1a,3a-d,4,5,9</sup> Grignard reagents,<sup>1a,6,7,9</sup> organocoppers<sup>1a,2,3,8-10</sup> and organoboranes.<sup>11</sup> However, to date, there have been only some unsuccessful attempts on the amination of ordinary organozinc reagents<sup>1a,3e,8,9,12,13</sup> and a few successful amination examples for zinc enolates.<sup>3a,5,14</sup> Recently, two papers have appeared on the amination of organozinc reagents. In the first,<sup>15</sup> zinc cyanocuprates react with lithium amides and the formed zinc amidocyanocuprates, upon oxidation, decompose to provide amines. In the second,<sup>16</sup> the addition of organozinc halides to di-*tert*-butyl azodicarboxylate (DBAD) is described to give hydrazino derivatives, which give amines after the removal of *tert*-butoxycarbonyl groups and then reductive cleavage of the N–N bond.

The importance of organozinc reagents<sup>17–20</sup> due to their high reactivity, easy preparation by Li- and Mg-to-Zn transmetallation, and the use of electrophilic functional group-containing reagents prompted us to investigate the electrophilic amination of organozinc reagents. Since the major drawback related to the use of organozinc reagents is the use of active zinc, the work to be discussed here involves preparation of organozincs by transmetallation, except for some functional groupcontaining organozincs which are prepared by metallation of organic halides. In our study, the reagents of choice for amination of organozincs are acetone O-(2,4,6-trimethylphenyl sulfonyl)oxime and O-methylhydroxylamine (Scheme 1). Acetone O-(2,4,6-trimethylphenylsulfonyl)oxime 7 has been developed in our laboratories for amination of Grignard reagents<sup>6</sup> and reacts by displacement of the mesitylsulfonyloxy group giving an imine, which upon hydrolysis provides amines. O-Methylhydroxylamine and its methyllithium complex have long been used successfully for amination of organolithiums,<sup>9,21</sup> Grignard reagents<sup>9,21-23</sup> and organocoppers<sup>9</sup> and once unsuccessfully for organozincs.<sup>9</sup> Compound 7 can be more easily prepared and conveniently stored than can 8.

 $\begin{array}{c} \begin{array}{c} CH_{3} \\ RM + (CH_{3})_{2} C=NOSO_{2} \xrightarrow{CH_{3}} -CH_{3} \xrightarrow{} [(CH_{3})_{2}C=NR] \xrightarrow{H_{2}O} RNH_{2} \\ \hline 1-6 & & & & \\ 1-6 & & & & & \\ 1-6 & & & & & \\ RM + CH_{3}ONH_{2} \xrightarrow{} RNH_{2} \\ 1-5 & 8 & & & & \\ 1-5 & 8 & & & & \\ 1-5 & & & & & \\ M: ZnX, & \frac{1}{2} Zn, & \frac{1}{3} ZnM', & \frac{1}{2} CuZnX, & Cu(CN)ZnX \\ (M':Li \text{ or } MgBr), & & & (X:CI, Br) \\ 1 & 2 & 3 & 4 & 5 \end{array}$ 

Scheme 1 Amination of organozinc species 1–6 with acetone *O*-(2,4,6-trimethylphenylsulfonyl)oxime 7 and *O*-methylhydroxylamine 8.

We have reported in an earlier paper<sup>24</sup> a simple and mild method for electrophilic amination of diarylzincs and triarylzincates with 7 and 8. In this paper, we explore the use of this method.

# **Results and discussion**

At the initial stage of this investigation, we focused on the amination of phenylzinc species with 7 and 8 for determining the optimal reaction conditions. Phenylzinc chloride 1a, diphenylzinc 2a and lithium (or bromomagnesium) triphenylzincate 3a were prepared by transmetallation of the corresponding phenyllithium or phenylmagnesium bromide with ZnCl<sub>2</sub>; chlorozinc diphenylcuprate 4a and chlorozinc phenylcyanocuprate 5a were prepared by transmetallation of *in situ* prepared lithium diphenylcuprate and lithium phenylcyanocuprate, respectively, with ZnCl<sub>2</sub>.<sup>19</sup> Amination yields of phenylzinc reagents 1a–6a with 7 and 8 are given in Table 1.

We observed that the reaction of phenylzinc chloride 1a, diphenylzinc 2a, and triphenylzincate 3a with 7 takes place only in the presence of CuCN, except a low-yield reaction of 3a with 8 (entry 7).

The reaction conditions were optimized by adding 1 mol equiv. of aminating reagent 7 or 8 to 1.5 mol equiv. of phenylzinc reagents 1a, 2a and phenyl zincate 3a or 2 mol equiv. of zinc phenylcuprates 4a, 5a in diethyl ether or in diethyl ether–THF at room temperature, resulting in almost complete consumption of 7 or 8 within 3 h. Experiments indicated that the yield is strongly dependent on the type of phenylzinc species and on the amount of CuCN. The highest yield in the amination with 7 is obtained by treating triphenylzincate 3a in the presence of 20 mol% CuCN (entry 9); however phenylzinc chloride 1a and diphenylzinc 2a are also effective in CuCNmediated amination (entries 3 and 6). Carrying out the

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Table 1 Reactions of phenylzinc reagents 1a-6a with aminating reagents 7 and  $8^{a}$ 

|                  | 1a-6a                                 | 2. Hydrolysis  | 9  |                     |
|------------------|---------------------------------------|----------------|--|---------------------|
| Entry            | PhM <sup>b</sup>                      | CuCN<br>(mol%) | Yield of PhNH <sub>2</sub> <sup>c</sup><br>Aminating reagent |                     |
|                  |                                       |                |  |                     |
|                  |                                       |                | 1  | PhZnCl 1a           |
| 2                | PhZnCl 1a                             | 10             | $25(25^{d})$   |                     |
| 2<br>3<br>4<br>5 | PhZnCl 1a                             | 20             | 58   | 7                   |
| 4                | PhZnCl 1a                             | 20             | 48 <sup>e</sup>  |                     |
| 5                | $Ph_2Zn 2a$                           |                | 0  |                     |
| 6                | $Ph_2Zn 2a$                           | 20             | 44   | $82(82^{f})$        |
| 7                | Ph₃ZnLi <b>3a</b>                     |                | 0  | 33                  |
| 8                | Ph <sub>3</sub> ZnLi <b>3a</b>        | 10             | 52   |                     |
| 9                | Ph <sub>3</sub> ZnLi <b>3a</b>        | 20             | 70   | $95(89,^{g}95^{f})$ |
| 10               | Ph <sub>2</sub> CuZnCl 4a             |                | 49   | $50(50^{f})$        |
| 11               | PhCu(CN)ZnCl 5a                       |                | 56   | $42(38^{f})$        |
| 12               | PhZnCl 1a                             | 20             | $65(49^{f})$   |                     |
| 13               | Ph <sub>2</sub> Zn <b>2a</b>          | 20             | $68(51^{f})$   |                     |
| 14               | Ph₃ZnMgBr <b>3a</b>                   | 20             | $85(76^{f})$   |                     |
| 15               | Ph₃ZnLi <b>3a</b> <sup><i>h</i></sup> | 20             | $79(70^{f})$   |                     |
| 16               | Me <sub>2</sub> PhZnLi 6a             | 20             | 59   |                     |

<sup>*a*</sup> Reactions were carried out on 1.5 or 3.0 mmol aminating reagent 7 or 8. PhM: 7 = 1.5 and PhM: 8 = 2 for 1a, 2a and 3a; PhM: 7 (or 8) = 2 for 4a and 5a. <sup>*b*</sup> Phenylzinc reagents in entries 1–10, 15 and 16 were prepared by Li-to-Zn transmetallation and in entries 11–14 by Mg-to-Zn transmetallation. <sup>*c*</sup> Yield determined as average of two or more runs by GC using internal standard technique and based on 7 or 8. <sup>*d*</sup> Yield of aniline purified by column chromatography. <sup>*c*</sup> PhZnC1: 7 = 4. <sup>*f*</sup> Yield of aniline isolated as benzanilide. <sup>*g*</sup> Yield of aniline purified by distillation. <sup>*h*</sup> 20 mol% MgCl<sub>2</sub> was added.

amination of phenylzinc chloride with a 4:1 molar ratio of **1a:7** did not give a comparable yield with **3a**. The use of dimethylphenylzincate **6a** instead of triphenylzincate was not found to be more successful for amination. These observations seem identical with the fact that tetracoordinated zincates prepared *in situ* from trioganozincates and anion species such as CN have higher reactivity compared with the conventional triorganozincates.<sup>25</sup>

As seen, higher yields are obtained in the amination of Grignard reagent-derived organozincs rather than lithium reagent-derived organozincs (entries 3 and 12; 6 and 13; 9 and 14), supporting the role of MgCl<sub>2</sub> as a Lewis acid in electrophilic amination of carbanions with synthetic equivalents of the NH<sub>2</sub><sup>+</sup> synthon.<sup>6,26</sup> In fact, CuCN-catalyzed amination of lithium triphenylzincate with 7 led to a higher yield in the presence of MgCl<sub>2</sub> (20 mol%) (entries 9 and 15). Amination of stoichiometric zinc diphenylcuprate **4a** and zinc phenylcyanocuprate **5a** did not give higher yields than amination of CuCN-mediated zincates **3c** and even phenylzinc chloride **1a**.

Applying the same procedure to the amination of phenylzinc reagents with  $\mathbf{8}$ , diphenylzinc  $\mathbf{2a}$  afforded a surprisingly higher yield compared with the amination with  $\mathbf{7}$  (entry 6) while amination of phenylzinc chloride  $\mathbf{1a}$  did not take place. Lithium triphenylzincate  $\mathbf{3a}$  was aminated almost in quantitative yield (entry 9).

In an effort to determine the most effective phenylmetal in the amination with 7 and 8, we examined the relevant literature data and we also carried out amination of phenyl-lithium and -copper reagents with 7 in addition to our amination studies of phenyl Grignard reagents with 7 (Table 2). For comparison, only lithium phenylcyanocuprate (entry 8) gives a yield comparable with that of the lithium triphenylzincate/CuCN system, but not as high as the yield of bromomagnesium triphenylTable 2 Amination reactions of phenylmetals with 7 and 8

| PhM + 7  or  8      | 1. THF, rt, 3 h | → PhNH <sub>2</sub> |
|---------------------|-----------------|---------------------|
| $r_{\rm HW} + 7010$ | 2. Hydrolysis   | PIINE <sub>2</sub>  |
|                     |                 | 0                   |

|       |                              | $\frac{\text{Yield of PhNH}_2}{\text{Aminating reagent}}$ |                                |
|-------|------------------------------|---|--------------------------------|
|       |                              |   |                                |
| Entry | М                            | 7 <i>ª</i>  | <b>8</b> <sup><i>b,c</i></sup> |
| 1     | Li                           | 6 <sup><i>d</i></sup>                                     | 91                             |
| 2     | Li/'CuI'                     | 22 <i>°</i>   |                                |
| 3     | Li/'CuI'                     | 46 <sup>e</sup>   |                                |
| 4     | MgBr                         | 58 <sup>d</sup>   | 37                             |
| 5     | MgBr/'CuI'                   | 59 <sup><i>d</i>,<i>f</i></sup>                           |                                |
| 6     | Cu                           | 56 <sup>e</sup>   |                                |
| 7     | 1/2 CuLi                     | 43 <sup>e</sup>   | 83                             |
| 8     | Cu(CN)Li                     | 76 <sup>e</sup>   |                                |
| 9     | 1/3 CuLi <sub>2</sub>        | 39 <i>°</i>   |                                |
| 10    | $1/2 Cu(CN)Li_2$             | 35°   |                                |
| 11    | ZnCl/'CuCN'                  | $58^{g}(65^{h})$  | 7 ª                            |
| 12    | 1/2 Zn/'CuCN'                | $44^{g}(68^{h})$  | 82                             |
| 13    | 1/3 ZnM/CuCN' (M = Li, MgBr) | $70^{g}(85^{h})$  | 95 <sup>g</sup>                |
| 14    | 1/2 CuZnCl                   | 49 <sup>g</sup>   |                                |
| 15    | Cu(CN)ZnCl                   | 56 <sup>g</sup>   |                                |

<sup>*a*</sup> GC yield. <sup>*b*</sup> Aminating reagent is **8**–methyllithium complex (refs. 9 and 22). <sup>*c*</sup> Yield of benzanilide. <sup>*d*</sup> Ref. 6a. <sup>*e*</sup> Amination of phenylithium (2 mol equiv.), phenylcopper (2 mol equiv.), lower- and higher-order homocuprates (2 mol equiv.) and lower- and higher-order cyano-cuprates (1 mol equiv.) with **7** (1 mol equiv.) was carried out in diethyl ether at room temperature similar to amination of organozinc reagents as explained in the Experimental section. <sup>*f*</sup> Ref. 6a. The reaction time decreases in CuI-mediated reaction. <sup>*s*</sup> Organozinc reagent was prepared by Li-to-Zn metallation (Table 1, entries 3, 6, 9). <sup>*h*</sup> Organozinc reagent was prepared by Mg-to-Zn metallation (Table 1, entries 12–14).

zincate/CuCN (entry 13). Phenylmagnesium bromide/CuI (entry 5) is not as effective as bromomagnesium triphenylzincate/CuCN (entry 13). Concerning the available data for the amination with **8**, the most effective phenylmetals are phenyllithium (entry 1) and lithium triphenylzincate/CuCN (entry 13). Lithium diphenylcuprate and diphenylzinc/CuCN can also be aminated in comparable high yields (entries 7 and 12, respectively). From these results, it appears that transmetallation of organolithiums to triorganozincates instead of organocyanocuprates seems to provide an alternative method in the amination with **7**. However, transmetallation of Grignard reagents to organozincates rather than organocuprates seems to be the method of choice in the amination with either **7** or **8**.

Having established a viable route to aminate organozincs with acetone O-(2,4,6-trimethylphenylsulfonyl)oxime 7 and with *O*-methylhydroxylamine **8**; the scope and generality of the amination protocol was examined for a series of organozincs (Table 3). In amination with 7, yields of monoorganozincs 1 were tabulated in addition to diorganozines 2 and triorganozincates 3 since 1 and 2 are expected to give comparable yields with 3; however, in amination with 8, yields of only 2 and 3 were reported, except for **1a** and **1e**. These data show that amination proceeds with medium yields for aryl, alkyl, cycloalkyl and benzyl zinc reagents. However, to some degree, there are differences between the effectiveness of organozincs and aminating reagents. For example, amination of p-ethoxycarbonylphenylzinc bromide 1e with 8 resulted in a very low yield (entry 13); and n-hexylzinc reagents 1f, 2f, 3f could not be aminated with 7 (entries 14-16). The mildness of the conditions involved allow a certain tolerance for electron-rich functional groups on arylzincs; however, attempts to aminate functional-groupcontaining alkylzincs, for example, 4-chlorobutylzinc reagents failed and products possibly formed after amination of organozinc species were not identified.

Table 3 CuCN-mediated amination of organozinc reagents with aminating reagents 7 and 8

$$\operatorname{RM}^{a,b} + 7 \text{ or } 8 \xrightarrow{1. \operatorname{CuCN}(20 \text{ mol}\%), \text{ THF, rt, 3 h}}_{2. \text{ Hydrolysis, rt, 3-4 h}} \operatorname{RNH}_{2}$$

$$1-3 \qquad 9$$

M = ZnCl (or ZnBr), 1/2 Zn, 1/3 ZnMgBr  $1 \qquad 2 \qquad 3$ 

|        | RM  | Yield of RNH <sub>2</sub> <sup>c</sup> |                 |
|--------|---|--|-----------------|
|        |   | Aminating reagent                      |                 |
| Entry  |   | 7                                      | 8               |
| 1      | C <sub>6</sub> H <sub>5</sub> ZnCl 1a   | 40                                     | 7 <sup>d</sup>  |
| 2      | $(C_6H_5)_2$ Zn 2a  | 51                                     | 82 <sup>d</sup> |
| 2<br>3 | $(C_6H_5)_3$ ZnMgBr <b>3a</b>   | 76                                     | 95 <sup>d</sup> |
| 4<br>5 | p-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> ZnCl 1b                                       | 49                                     |                 |
|        | $(p-\mathrm{CH}_{3}\mathrm{C}_{6}\mathrm{H}_{4})_{2}\mathrm{Zn}\ \mathbf{2b}$                 | 45                                     | 62              |
| 6      | (p-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub> ) <sub>3</sub> ZnMgBr <b>3b</b>              | 55                                     | 70              |
| 7      | p-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> ZnCl 1c                                      | 54                                     |                 |
| 8      | $(p-CH_3OC_6H_4)_2Zn \ 2c$  | 51                                     | 65              |
| 9      | $(p-CH_3OC_6H_4)_3ZnMgBr 3c$  | 61                                     | 63              |
| 10     | <i>p</i> -BrC <sub>6</sub> H <sub>4</sub> ZnCl 1d   | 33                                     |                 |
| 11     | $(p-BrC_6H_4)_2Zn \ 2d$   | 42                                     | 40              |
| 12     | $(p-BrC_6H_4)_3ZnMgBr 3d$   | 52                                     | 50              |
| 13     | <i>p</i> -C <sub>2</sub> H <sub>5</sub> O <sub>2</sub> CC <sub>6</sub> H <sub>4</sub> ZnBr 1e | 51                                     | 12              |
| 14     | n-C <sub>6</sub> H <sub>13</sub> ZnCl 1f  | 0                                      |                 |
| 15     | $(n-C_6H_{13})_2$ Zn <b>2f</b>  |  | 35              |
| 16     | $(n-C_6H_{13})_3$ ZnMgBr <b>3f</b>  | 0                                      | 50              |
| 17     | c-C <sub>6</sub> H <sub>11</sub> ZnCl <b>1g</b>   | 12                                     |                 |
| 18     | $(c-C_6H_{11})_2Zn \ 2g$  | 10                                     | 28              |
| 19     | (c-C <sub>6</sub> H <sub>11</sub> ) <sub>3</sub> ZnMgBr <b>3g</b>                             | 42                                     | 38              |
| 20     | C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> ZnCl 1h   | 20                                     |                 |
| 21     | $(C_6H_5CH_2)_3Zn 2h$   | 56                                     | 50              |
| 22     | $(C_6H_5CH_2)_3ZnMgBr$ 3h   | 62                                     | 61              |

<sup>*a*</sup> Organozinc reagents **1**, **2** and **3** were prepared by transmetallation of corresponding Grignard reagents in THF (1, 2 and 3 mol equiv., respectively) with anhydrous ZnCl<sub>2</sub> (1 mol equiv.) in THF. Organozinc reagent **1e** was prepared by metallation of the corresponding aryl bromide with active Zn in diethyl ether. <sup>*b*</sup> Reactions were carried out on 1.5 or 3.0 mmol aminating reagent, **7** or **8**, which was added to a mixture of RM and CuCN in THF (RM:**7** = 1.5 and RM:**8** = 2.0). <sup>*c*</sup> Yield of amine isolated as *N*-benzoyl derivative. <sup>*d*</sup> Organozinc reagents **1**, **2** and **3** were prepared by transmetallation of phenyllithium in Et<sub>2</sub>O (1, 2 and 3 mol equiv., respectively) with anhydrous ZnCl<sub>2</sub> (1 mol equiv.) in THF.

### Conclusions

In summary, we have shown that one-flask and medium-yield amination of aryl, functionalized aryl, alkyl and benzyl zinc reagents with acetone O-(2,4,6-trimethylphenylsulfonyl)oxime or with O-methylhydroxylamine is possible in the presence of CuCN. This amination protocol also provides an alternative method for electrophilic amination of organolithiums and Grignard reagents, which can be easily transmetallated to organozincs. Efforts to broaden the scope of our new amination procedure and to develop other one-flask amination methods for organozincs are currently in progress.

### **Experimental**

### **General conditions**

All reactions were carried out under a positive pressure of dry nitrogen in oven-dried glassware.<sup>27</sup> Reagents and solvents were handled by using standard syringe–septum cap techniques. Reactions were monitored by gas chromatography analysis of reaction aliquots using a Perkin-Elmer F-11 gas chromatograph equipped with an SE-30 column. Analytical TLC analysis was done on Merck silica gel plates. Chromatography was performed on silica gel-60 using light petroleum (distillation range 40–60 °C)–diethyl ether mixtures as eluent. IR

spectra were recorded on a Unicam Mattson 1000 FT-IR spectrometer as a KBr pellet, and wavenumbers of only the strongest/structurally more important peaks are reported in cm<sup>-1</sup>. <sup>1</sup>H NMR spectra were obtained in CDCl<sub>3</sub> at 400 MHz using a Bruker-GmbH DPX instrument. Chemical shifts are reported in  $\delta$ (ppm)-values relative to Me<sub>4</sub>Si and, for peak multiplicities, the following abbreviations are used: s, singlet; d, doublet; t, triplet; q, quartet; br s, broad singlet; m, multiplet.

Diethyl ether and THF were distilled from sodium and benzophenone ketyl under dry nitrogen. Magnesium turnings for Grignard reactions (Fischer), lithium dispersion in mineral oil (BDH), and zinc dust (Merck) were used without purification. Zinc chloride (Aldrich) was dried under reduced pressure (2 mmHg) at 100 °C for 2 h and dissolved in THF before use. Magnesium chloride (BDH) was dried under nitrogen before use. Copper(I) iodide (Fischer)<sup>28</sup> and copper(I) cyanide (Aldrich)<sup>29</sup> were purified according to the published procedures, dried at 60–90 °C under reduced pressure (1 mmHg) for 4 h and kept under dry nitrogen. Phenyllithium and benzylmagnesium bromide were prepared in diethyl ether, and other Grignard reagents were prepared in THF by conventional standard methods found elsewhere. The concentration of phenyllithium and Grignard reagents was found prior to use by titration with sec-butyl alcohol using o-phenanthroline as an indicator.30

Phenylcopper PhCu, lithium diphenylcuprate Ph<sub>2</sub>CuLi, and dilithium triphenylcuprate Ph<sub>3</sub>CuLi<sub>2</sub> were prepared by addition of 1, 2 and 3 mol equiv. of phenyllithium, respectively, to a suspension of 1 mol equiv. of CuI in diethyl ether at 0 °C.<sup>31</sup> Lithium phenylcyanocuprate PhCu(CN)Li and dilithium diphenylcyanocuprate Ph<sub>2</sub>Cu(CN)Li<sub>2</sub> were prepared by addition of 1 and 2 mol equiv. of phenyllithium, respectively, to a suspension of 1 mol equiv. of CuCN in THF at  $0 \degree C.^{2,31}$ Chlorozinc diphenylcuprate, Ph<sub>2</sub>CuZnCl<sup>32</sup> and chlorozinc phenylcyanocuprate PhCu(CN)ZnCl<sup>15</sup> were prepared by addition of *in situ* prepared 1 mol equiv. of lithium cuprates to a 0.45 M solution of 1 mol equiv. of ZnCl<sub>2</sub> in THF at 0 °C. Carrying out the transmetallation reactions at -78 °C did not produce any change in the reactivities of phenylcopper, phenyllithium cuprates and phenylzinc cuprates in amination reactions. Diorganozinc R<sub>2</sub>Zn, organozinc chloride RZnCl, and lithium triorganozincate (or bromomagnesium triorganozincate) reagents  $R_3ZnM$  (M = Li or MgBr) were prepared by addition of 2, 1 or 3 mol equiv. of organolithium or Grignard reagent, respectively, to a 0.45 M solution of 1 mol equiv. of ZnCl<sub>2</sub> in THF at 0 °C.<sup>19</sup> In transmetallation reactions, stirring was continued (ca. 15-30 min) at 0 °C until the reaction mixtures became clear. p-(Ethoxycarbonyl)phenylzinc bromide 1e was prepared from the corresponding aryl bromide by using active zinc in THF.19

Acetone O-(2,4,6-trimethylphenylsulfonyl)oxime  $7^{33}$  and O-methylhydroxylamine  $8^{34}$  were prepared and purified according to the published procedures.

### Amination of organozinc reagents

Typical procedure for the CuCN-mediated amination of monoand di-organozinc and triorganozincate reagents 1-3 with acetone *O*-(2,4,6-trimethylphenylsulfonyl)oxime 7 or *O*-methylhydroxylamine 8 is given below.

Under nitrogen atmosphere and at room temperature, to a THF solution of an organozinc reagent (4.5 mmol) was added CuCN (0.614 g, 0.90 mmol). (If the organozinc reagent was prepared *in situ* by transmetallation of an organolithium or Grignard reagent at 0 °C, the temperature was allowed to rise to room temperature before the addition of CuCN.) After stirring of the mixture for 15 min, a solution of 7 (0.765 g, 3.00 mmol) in THF (6 cm<sup>3</sup>) or **8** (0.047 g, 2.25 mmol) in THF (4 cm<sup>3</sup>) was added and stirring was continued for 3 h. For hydrolytic

work-up after amination with 7, the mixture was stirred at room temperature with 12 M HCl (10 cm<sup>3</sup>) for 2 h. The aqueous phase was washed with diethyl ether, made basic with conc. NaOH and the free amine was extracted with diethyl ether  $(4 \times 30 \text{ cm}^3)$ . The organic layer was dried over Na<sub>2</sub>SO<sub>4</sub>. The crude material obtained after evaporation of solvent in vacuo was purified by distillation or flash chromatography on silica gel with diethyl ether-light petroleum (5:4) to give pure amine 9 whose GC and spectral data matched those of authentic material. After amination with 8, hydrolysis of the mixture was carried out with saturated aq. NH<sub>4</sub>Cl-NH<sub>3</sub> (5:1) (10 cm<sup>3</sup>). The aqueous phase was extracted with diethyl ether and the crude material was purified with column chromatography to give the amine as above. For convenience in isolation, the product amines were converted to their N-benzoyl derivatives by reaction with benzoyl chloride in the presence of NaOH.<sup>35</sup> Crude derivatives were recrystallized from ethanol or ethanol-water as white solids whose mp<sup>36</sup> matched that of previously synthesized material.

*N*-Phenylbenzamide **9a**: mp 162–164 °C (lit.,<sup>22,36</sup> 160 °C); δ<sub>H</sub><sup>22,37</sup> 7.88–7.92 (2H, m, NArH), 7.65–7.69 (2H, m, COArH), 7.48-7.62 (3H, m, NArH), 7.16-7.43 (3H, m, COArH); v<sub>max</sub>/cm<sup>-1</sup> 3345, 1655, 1599, 1531, 1439, 1250, 1070, 755, 715, 698

*N-p*-Tolylbenzamide **9b**: mp 158 °C (lit.,  ${}^{22,36}$  158 °C);  $\delta_{\rm H}{}^{22,37}$ 7.85-7.92 (2H, m, NArH), 7.52-7.58 (2H, m, COArH), 7.44-7.50 (3H, m, COArH), 7.15-7.20 (2H, m, NArH), 2.30 (s, ArCH<sub>3</sub>); v<sub>max</sub>/cm<sup>-1</sup> 3308, 1647, 1599, 1531, 1404, 1265, 1024, 813, 697.

N-(p-Methoxyphenyl)benzamide 9c: mp 154–157 °C (lit.,<sup>36</sup> 154 °C);  $\delta_{\rm H}$  7.85–7.90 (m, 2H, NArH), 7.78–7.82 (1H, br s, NH), 7.52–7.60 (2H, m, COArH), 7.45–7.52 (3H, m, COArH), 6.90–6.96 (m, 2H, NArH), 3.82 (s, OCH<sub>3</sub>);  $v_{max}/cm^{-1}$  3329, 2850, 1647, 1519, 1412, 1250, 1032, 820, 654.

*N*-(*p*-Bromophenyl)benzamide **9d**: mp 203 °C (lit., <sup>36</sup> 204 °C); δ<sub>H</sub> 7.86–7.90 (2H, m, NArH), 7.78–7.87 (1H, br s, NH), 7.58– 7.60 (2H, m, COArH), 7.48-7.55 (2H, m, COArH), 7.27-7.30 (2H, m, NArH); v<sub>max</sub>/cm<sup>-1</sup> 3332, 1647, 1578, 1522, 1491, 1385, 1250, 1070, 1005, 820, 715, 654, 508.

*N*-(*p*-Ethoxycarbonylphenyl)benzamide **9e**: mp 150 °C (lit., <sup>36</sup> 148 °C);δ<sub>H</sub> 7.96–8.07 (2H, m, NArH), 7.86–7.90 (2H, m, NArH), 7.30-7.60 (5H, m, COArH), 7.37 (2H, q, CO<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>), 1.39 (3H, t,  $CO_2CH_2CH_3$ );  $v_{max}/cm^{-1}$  3360, 1710, 1605, 1452, 1310, 1270, 1115, 712, 687, 650.

*N*-Hexylbenzamide **9f**: mp 40 °C (lit., <sup>36</sup> 40 °C);  $\delta_{\rm H}$  7.74–7.81 (2H, m, COArH), 7.36-7.48 (3H, m, COArH), 6.30-6.60 (1H, br s, NH), 3.38-3.45 (2H, m, NCH<sub>2</sub>), 1.55-1.65 (2H, m, NCH<sub>2</sub>CH<sub>2</sub>), 1.25-1.40 (6H, m, NCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>), 0.85-0.95 (3H, t,  $CH_2CH_3$ );  $v_{max}/cm^{-1}$  3341, 2925, 2855, 1631, 1570, 1530, 1485, 1275, 1155, 1070, 718, 687.

*N*-Cyclohexylbenzamide **9g**: mp 149 °C (lit.,  $^{36}$  149 °C); δ<sub>H</sub> 7.74–7.78 (2H, m, COArH), 7.38–7.50 (3H, m, COArH), 6.10-6.20 (1H, br s, NH), 3.84-4.05 (1H, br s, NCH), 1.72-2.10 (4H, m, 2-H and 6-H<sub>2</sub>), 1.28-1.50 (6H, m, 3-, 4- and 5-H<sub>2</sub>); v<sub>max</sub>/cm<sup>-1</sup> 3312, 2932, 2855, 1620, 1578, 1535, 1480, 1152, 1080, 690.

*N*-Benzylbenzamide **9h**: mp 106 °C (lit.,  ${}^{36}$  105 °C);  $\delta_{\rm H}{}^{37}$  7.76– 7.84 (2H, m, COArH), 7.40-7.55 (3H, m, COArH), 7.32-7.40 (5H, m, NCH<sub>2</sub>ArH), 6.50–6.52 (1H, br s, NH), 4.62–4.68 (2H, s, NCH<sub>2</sub>); v<sub>max</sub>/cm<sup>-1</sup> 3287, 1637, 1605, 1552, 1415, 1261, 1070, 980, 785, 697.

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