

# Aminosilylation of arynes with aminosilanes: synthesis of 2-silylaniline derivatives†

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The nitrogen–silicon  $\sigma$ -bond of aminosilanes added across the triple bond of arynes to give varied 2-silylaniline derivatives straightforwardly.

Much attention has been focused on the addition reactions of an element–element  $\sigma$ -bond across the carbon–carbon triple bond of arynes as potent synthetic approaches to diverse polysubstituted arenes, which are otherwise difficult to prepare.<sup>1</sup> In particular, the reactions using metallic reagents would be much more attractive from the synthetic standpoint, because the resulting carbon–metal bond can be applied to further carbon–carbon bond formation and/or introduction of a functional group. In this context, we have recently developed the addition of a carbon–tin,<sup>2</sup> silicon–silicon<sup>3</sup> or tin–tin<sup>4</sup>  $\sigma$ -bond to arynes using a palladium catalyst. Furthermore, we have also disclosed a different type of the addition, in which the nucleophilic attack of stannyl sulfides (sulfur–tin  $\sigma$ -bond)<sup>5</sup> or ureas (nitrogen–carbonyl  $\sigma$ -bond)<sup>6</sup> to arynes is a key step, and demonstrated that the use of element–element  $\sigma$ -bond compounds bearing appropriate nucleophilic and electrophilic sites is essential for the reactions to proceed smoothly. Herein we report on the addition of a nitrogen–silicon  $\sigma$ -bond of aminosilanes to arynes (aminosilylation), which provides a variety of 2-silylaniline derivatives in one step (eqn. 1).

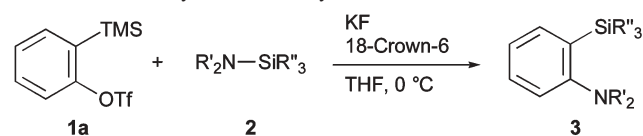


We first examined the reaction of *in situ*-generated benzyne (from **1a** and KF–18-crown-6)<sup>7</sup> with (diethylamino)dimethylphenylsilane (**2a**) in THF at 0 °C, and observed that benzyne was inserted into the nitrogen–silicon bond of **2a** to afford *N,N*-diethyl-2-(dimethylphenylsilyl)aniline (**3aa**) in 65% yield (Table 1, entry 1). Aminosilanes containing a dimethylamino (**2b**), dibutylamino (**2c**) or bis(2-methoxyethyl)amino (**2d**) moiety also reacted with benzyne (entries 2–4), and (diethylamino)benzyltrimethylsilane (**2e**) or (diethylamino)triethylsilane (**2f**) furnished the corresponding products (**3ae** or **3af**) in moderate yields (entries 5 and 6). It should be noted that the vinyl (**2g**) or 3-chloropropyl (**2h**) group on the silicon atom did not interfere with the course of the aminosilylation, leading to the formation of products (**3ag** or **3ah**) with these reactive functional groups remaining intact (entries 7 and 8). Furthermore, cyclic amine-derived aminosilanes could participate in the reaction as well, which resulted in the

† Electronic supplementary information (ESI) available: Experimental procedures and characterization of the products. See <http://www.rsc.org/suppdata/cc/b5/b505615b/>

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Table 1 Aminosilylation of benzyne<sup>a</sup>

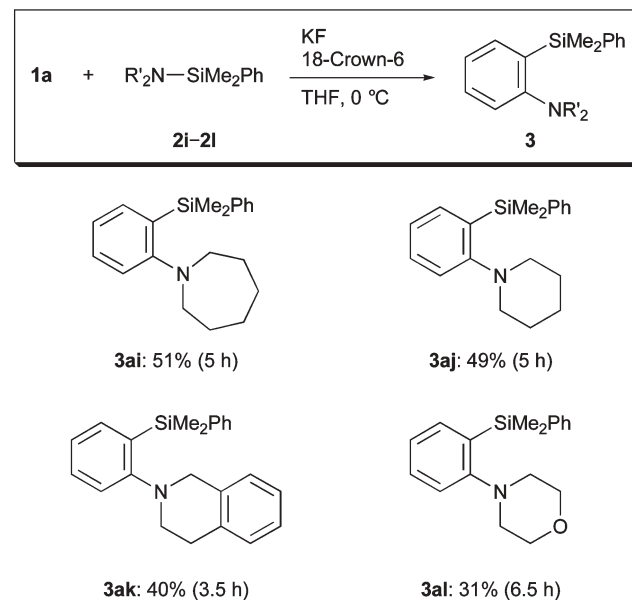


Entry	R' <sub>2</sub> N	SiR'' <sub>3</sub>	2	Time/h	Yield (%)	3
1	Et <sub>2</sub> N	SiMe <sub>2</sub> Ph	<b>2a</b>	1.5	65	<b>3aa</b>
2	Me <sub>2</sub> N	SiMe <sub>2</sub> Ph	<b>2b</b>	5	54	<b>3ab</b>
3	Bu <sub>2</sub> N	SiMe <sub>2</sub> Ph	<b>2c</b>	5	42	<b>3ac</b>
4	(MeOCH <sub>2</sub> CH <sub>2</sub> ) <sub>2</sub> N	SiMe <sub>2</sub> Ph	<b>2d</b>	10	33	<b>3ad</b>
5	Et <sub>2</sub> N	SiMe <sub>2</sub> Bn	<b>2e</b>	5	49	<b>3ae</b>
6	Et <sub>2</sub> N	SiEt <sub>3</sub>	<b>2f</b>	6	43	<b>3af</b>
7	Et <sub>2</sub> N	SiMe <sub>2</sub> (vinyl)	<b>2g</b>	3	52	<b>3ag</b>
8	Et <sub>2</sub> N	SiMe <sub>2</sub> [(CH <sub>2</sub> ) <sub>2</sub> CH <sub>2</sub> Cl]	<b>2h</b>	4	40	<b>3ah</b>

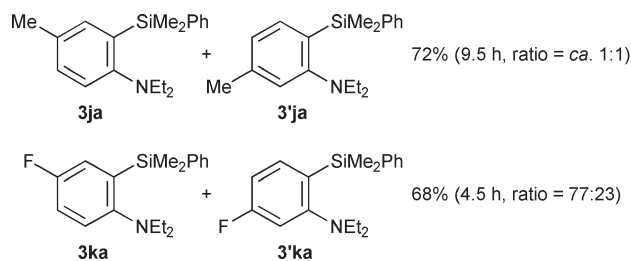
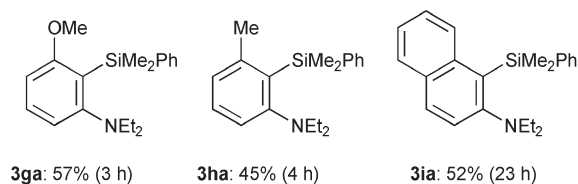
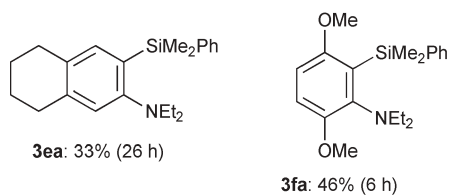
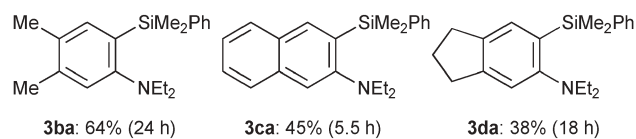
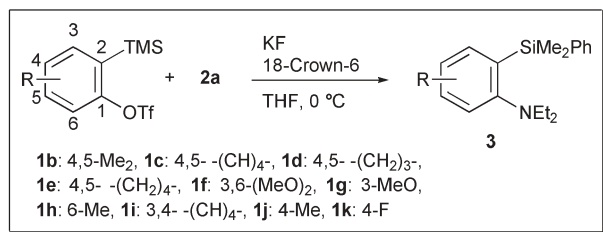
<sup>a</sup> The reaction was carried out in THF (1 mL) at 0 °C using **1a** (0.30 mmol), **2** (0.20 mmol), KF (0.60 mmol) and 18-crown-6 (0.60 mmol). <sup>b</sup> Isolated yield based on the aminosilane.

introduction of a 1-azepinyl (**3ai**), piperidino (**3aj**), 2-isoquinolinyl (**3ak**) or morpholino (**3al**) moiety into the aromatic skeleton (Scheme 1).

The aminosilylation of substituted arynes was next investigated. As depicted in Scheme 2, 4,5-dimethylbenzyne (from **1b**) or 2,3-naphthalene (from **1c**) underwent the addition of **2a** efficiently, giving **3ba** or **3ca** in 64% or 45% yield, whereas the yields of the



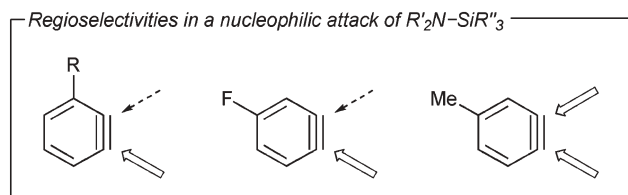
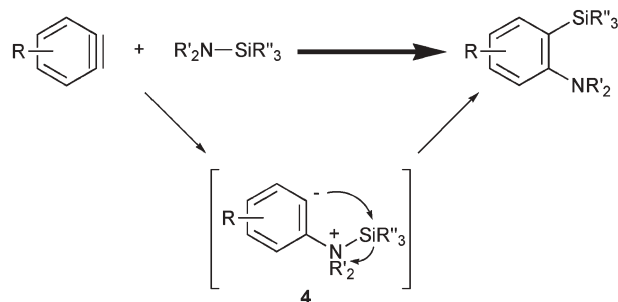
Scheme 1 Aminosilylation with cyclic amine-derived aminosilanes.



**Scheme 2** Aminosilylation of substituted arynes.

reaction using a cyclopentene- or cyclohexene-condensed aryne (from **1d** or **1e**, respectively) were somewhat low. Besides 4,5-disubstituted arynes, sterically congested 3,6-dimethoxybenzynes (from **1f**) or 3-substituted arynes (from **1g–1i**) also reacted with **2a** to offer the corresponding products (**3fa–3ia**). The regioselectivities of the reaction with these 3-substituted arynes were perfect, and thus, the diethylamino group was introduced into the *m*-position of the substituent. In sharp contrast, 4-methylbenzynes (from **1j**) gave almost equal amounts of regioisomeric products (**3ja** and **3'ja**), which implies that the present reaction indeed proceeds through an aryne intermediate. Although the steric surroundings of 4-fluorobenzynes (from **1k**) should be analogous to those of 4-methylbenzynes, its reaction with **2a** provided **3ka** preferentially.<sup>8</sup>

The nucleophilic attack of a nitrogen atom of an aminosilane to an aryne would be an initiation step of the aminosilylation as described in Scheme 3.<sup>9,10</sup> The resulting zwitterion (**4**) subsequently

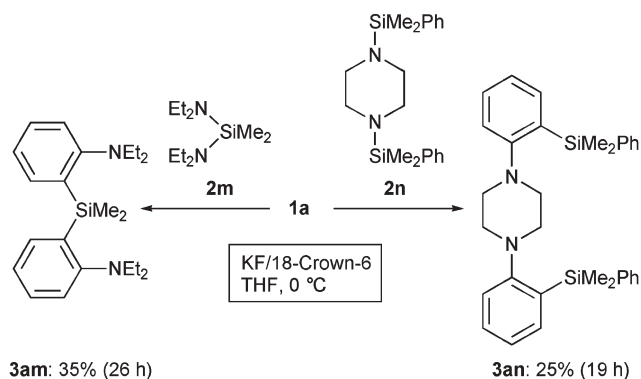


**Scheme 3** A reaction pathway of the aminosilylation.

undergoes an intramolecular nucleophilic substitution at the silyl moiety to provide the product. The exclusive formation of **3ga–3ia** in the reaction using 3-substituted arynes can be rationally explained by unfavorable steric repulsion between the substituent in the arynes and an incoming aminosilane, which prevents the nitrogen atom approaching the *ortho* position of the arynes. Owing to the strong electron-withdrawing effect of the fluoro substituent, the developing negative charge at the *meta* position (*vs. para*) would be stabilized to a greater extent in the transition state by the addition of an aminosilane to 4-fluorobenzynes, which leads to the predominant formation of **3ka**.<sup>11</sup> In contrast, steric and electronic effects around the triple bond would be negligible in the reaction of 4-methylbenzynes, and equal addition of an aminosilane to both ends of the triple bond occurs.<sup>12,13</sup>

Finally, utility of the aminosilylation has been demonstrated by application to aminosilanes bearing two reaction sites (**2m** or **2n**). Thus, benzynes were inserted into each of the nitrogen–silicon bonds to afford bis(2-aminophenyl)silane **3am** or *N,N'*-bis(2-silylphenyl)-piperazine **3an** in 35% or 25% yield, respectively (Scheme 4).

In conclusion, we have disclosed that arynes are readily inserted into the nitrogen–silicon  $\sigma$ -bond of aminosilanes to produce diverse 2-silylaniline derivatives, which are hardly accessible by conventional methods. Further studies on addition reactions of element–element  $\sigma$ -bonds to arynes are in progress.



**Scheme 4** Aminosilylation with aminosilanes bearing two reaction sites.

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