Aminoborohydrides. 12. Novel Tandem S_NAr Amination−Reduction Reactions of 2-Halobenzonitriles with Lithium *N,N*-Dialkylaminoborohydrides

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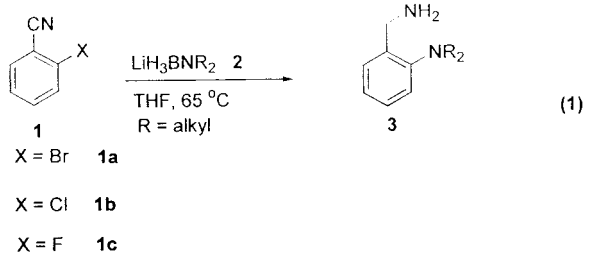
A novel tandem amination−reduction reaction has been developed in which 2-(*N,N*-dialkylamino)-benzylamines are generated from 2-halobenzonitriles and lithium *N,N*-dialkylaminoborohydride (LAB) reagents. These reactions are believed to occur through a tandem S_NAr amination−reduction mechanism wherein the LAB reagent promotes halide displacement by the *N,N*-dialkylamino group, and the nitrile is subsequently reduced. This one-pot procedure is complimentary to existing synthetic methods and is an attractive synthetic tool for the nucleophilic aromatic substitution of halobenzenes with less nucleophilic amines. The (*N,N*-dialkylamino)benzylamine products of this reaction are easily isolated after a simple aqueous workup procedure in very good to excellent yields.

Introduction

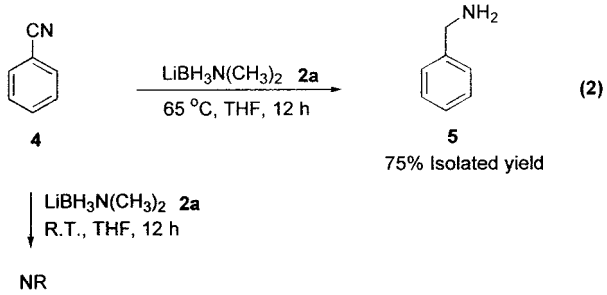
Tandem reactions are a unique class of reactions in organic chemistry in which two or more chemical transformations are carried out in one synthetic step. A new addition to this class of reactions has been discovered that is complementary to existing synthetic methods.[1] In particular, lithium aminoborohydride (LAB) reagents (**2**) have been found to promote a unique tandem S_NAr amination−nitrile reduction reaction with 2-halobenzonitriles (**1**) to produce 2-(*N,N*-dialkylamino)benzylamine (**3**) products in very good to excellent yields after a simple aqueous workup procedure (eq 1).



(1)

Nucleophilic aromatic substitution (S_NAr) reactions of amines with halobenzenes containing strong electron-withdrawing groups, such as nitrohalobenzenes, are well-known.[1] Halobenzonitriles do not generally undergo S_NAr reactions with amines due to lack of activating strength of the nitrile group.[1] A unique and synthetically useful exception to this generality has been found in the reaction of various LAB reagents with halobenzonitriles. Notably, the lithium *N,N*-dialkylaminoborohydride reagent apparently activates the halobenzonitrile toward nucleophilic attack by the amine contained within the reagent.

Lithium aminoborohydrides are a new class of powerful and chemoselective reducing agents which are easy to prepare and handle and can be stored under nitrogen in an ampule for prolonged periods of time without undergoing decomposition.[2] While investigating their reduction capabilities, it was found that LABs reduce aromatic nitriles, but the reduction requires extended refluxing in THF.[2] For example, lithium dimethylaminoborohydride (**2a**) reduces benzonitrile (**4**) to benzylamine (**5**) in 75% isolated yield after refluxing for 12 h in THF. Recovery of starting material is observed if the reaction is carried out at room temperature (eq 2).



(2)

Transfer of the aminoborohydride group from lithium aminoborohydrides to alkyl halides has also been observed, producing the corresponding amine−borane complex.[3] For instance, 4-cyanobenzyl bromide (**6**) is con-

‡ The Dow Chemical Company.

(1) (a) March, J. *Advanced Organic Chemistry*, 4th ed.; Wiley and Sons: New York, 1989; pp 641−653. (b) Miller, J. *Aromatic Nucleophilic Substitution*; Elsevier Publishing Co.: New York, 1968.

(2) Collins, C. J.; Fisher, G. B.; Reem, A.; Goralski, C. T.; Singaram, B. *Tetrahedron Lett.* **1997**, *38*, 529.

(3) Collins, C. J.; Lanz, M.; Goralski, C. T.; Singaram, B. *J. Org. Chem.* **1999**, *64*, 2574.

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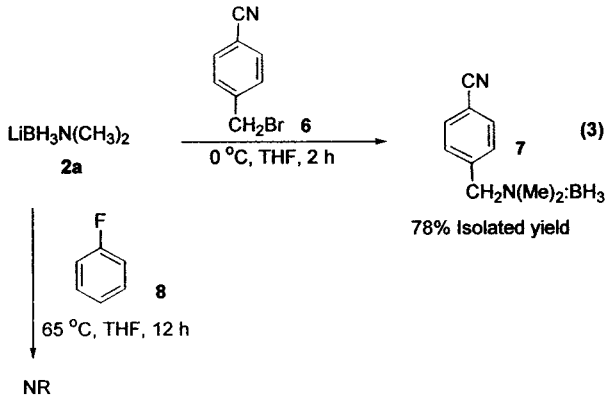
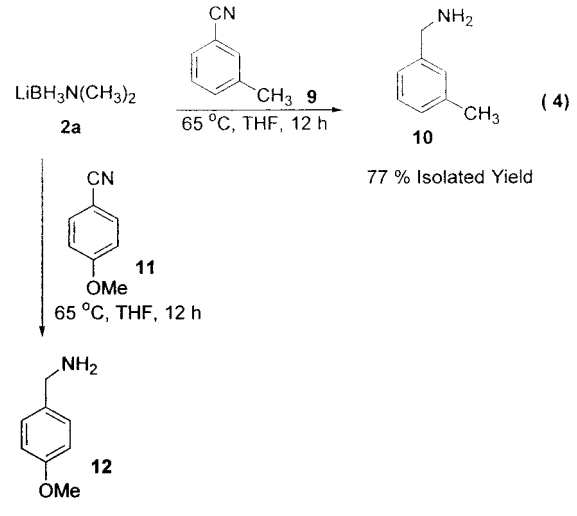
verted to the 4-cyanobenzylamine borane complex (**7**) in 78% isolated yield when treated with LAB **2a** (eq 3).



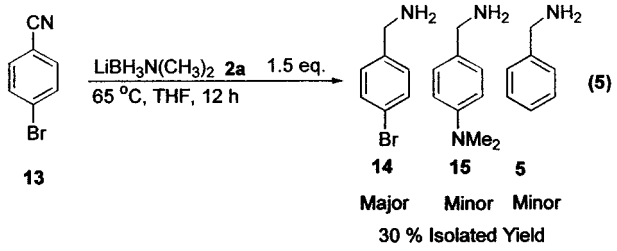
Additionally, LAB reagents had not been found to react with aryl halides, such as bromobenzene, chlorobenzene, or fluorobenzene (**8**). However, aryl halides containing a cyano group behaved differently with LAB reagents and gave a uniquely novel reaction. In this paper the results of this new reaction between LAB reagents and 2-halobenzonitriles is disclosed.

Results and Discussion

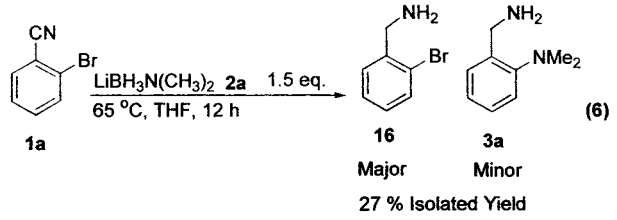
Initially, our interests were in the reduction of substituted benzonitriles with LAB reagents. Benzonitriles containing electron-donating substituents gave benzylamine products in very good yields after refluxing in THF (65 °C) with 1.5 equiv of lithium dimethylaminoborohydride (**2a**) for 12 h. For instance, reduction of 3-methylbenzonitrile (**9**) and 4-methoxybenzonitrile (**11**) gave 3-methylbenzylamine (**10**) and 4-methoxybenzylamine (**12**) in 77% and 80% yield, respectively (eq 4).



However, when reduction of benzonitriles containing electron-withdrawing groups such as halogens were attempted in the same reaction, instead of obtaining just halobenzylamines as the simple reduction product, (*N*,*N*-dialkylamino)benzylamines were also detected in the product mixture by ^{1}H NMR analysis. When 4-bromobenzonitrile (**13**) was treated with 1.5 equiv of LAB reagent, rather than recovering the simple nitrile reduction product in good yield as expected, a mixture of products was obtained in low yield (eq 5).

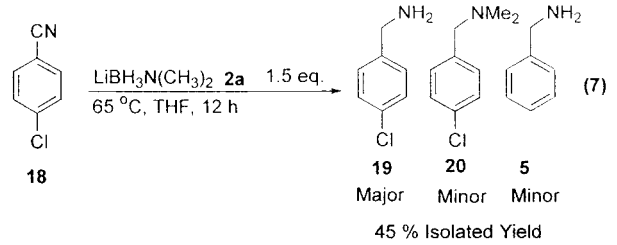


The major product of this mixture was 4-bromobenzylamine (**14**), the expected reduction product. However, minor products were both 4-(*N*,*N*-dimethylamino)benzylamine (**15**) and the dehalogenated product, benzylamine (**5**). A similar result was observed when the *o*-bromobenzonitrile was used in this reaction. When 2-bromobenzonitrile (**1a**) was treated with **2a**, a mixture of products was again obtained in low yield (eq 6).

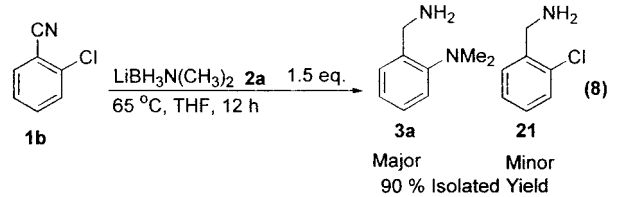


The simple reduction product (**16**) was the major product, and 2-(*N*,*N*-dimethylamino)benzylamine (**3a**) was observed as a minor product. The expected result of isolating bromobenzylamine as the sole product of these reactions, arising from nitrile reduction, was not achieved. The results obtained seemed uncharacteristic and called for further investigation.

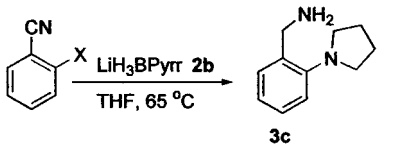
When 4-chlorobenzonitrile (**18**) was treated with 1.5 equiv of LAB reagent **2a**, as with the bromo-substituted counterpart, a mixture of products was obtained (eq 7).



The expected reduction product (**19**) was obtained as the major component, and 4-chloro-*N*,*N*-dimethylbenzylamine (**20**) and benzylamine (**5**) were obtained as minor products. Similar results were expected when 2-chlorobenzonitrile (**1b**) was refluxed with 1.5 equiv of lithium *N*,*N*-dimethylaminoborohydride (**2a**). However, unlike the reaction of 2-bromobenzonitrile (**1a**), when 2-chlorobenzonitrile (**1b**) was used as the substrate, 2-(*N*,*N*-dimethylamino)benzylamine (**3a**) was recovered as the major product in good yield (eq 8).



Scheme 1

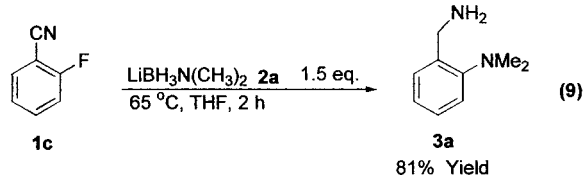


X = Br **1a** 10 % GC yield

X = Cl **1b** 70 % GC yield

X = F **1c** 100 % GC yield

This result indicated that a novel reaction was taking place. In particular, a one-pot tandem reaction seemed to occur, wherein amination at the carbon bearing the halogen was accompanied by reduction of the nitrile. Furthermore, it was found that **2a** similarly reacts with 2-fluorobenzonitrile (**1c**) to give exclusively the *tandem amination−reduction* reaction product, 2-(*N*,*N*-dimethylamino)benzylamine (**3a**) (eq 9).



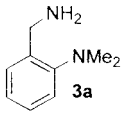
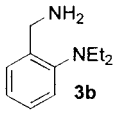
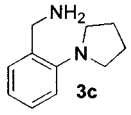
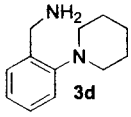
(9)

In addition, rather than requiring extended reaction times at reflux temperature, this reaction was complete in 2 h. This reaction was termed the tandem amination−reduction reaction.

The results obtained for the tandem reactions of *ortho* bromo-, chloro-, and fluorobenzonitriles, summarized in Scheme 1 for lithium pyrrolidinoborohydride, led toward a proposed mechanism to explain the results. It is well-known that in nucleophilic aromatic substitution reactions, the leaving group order of reactivity is F > Cl ≫ Br. The product ratios for bromo-, chloro- and fluorobenzonitrile are in good agreement with the involvement of a S_NAr mechanism, as fluoride is a better leaving group than chloride and bromide in the S_NAr reaction. In contrast, the leaving group order of reactivity is I > Br > Cl >F for the benzyne mechanism[4] and $S_{RN}1$ mechanism.[5] In addition, *cine* substitution would be expected for a benzyne mechanism.

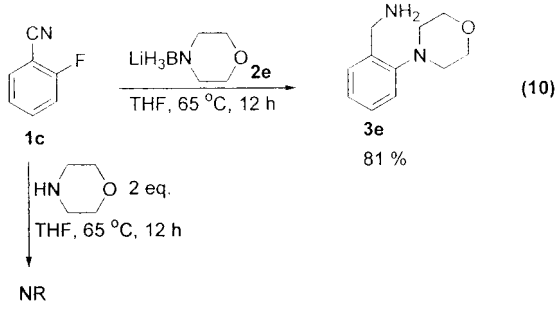
Encouraged by the initial results, the generality of this reaction was investigated with the use of various lithium *N*,*N*-dialkylaminoborohydrides with fluorobenzonitriles, since the fluoride ion is a much better leaving group than chloride or bromide in nucleophilic aromatic substitution reactions.[6] Through this screening a particularly appealing aspect of the LAB-induced tandem amination−reduction reaction of halobenzonitriles is illustrated. In particular, LAB reagents containing a less nucleophilic amine were able to undergo amine substitution as well as reduction of the nitrile. In contrast, the free amine failed to induce amine substitution. In this case, the nitrile moiety does not activate the aromatic ring for nucleophilic attack by the free amine, and the starting material is recovered unchanged. For example, lithium morpholinoborohydride (**2e**) reacts with 2-fluorobenzonitrile **1c** via the tandem amination−reduction reaction

Table 1. Tandem S_NAr Amination−Reduction Products from the Reaction of 2-Fluorobenzonitrile with Various Lithium Aminoborohydrides

entry	LiH_3BNR_2	product[a, b]	yield (%)[c]
1	LiH_3BNMe_2 **2a**	 **3a**	81
2	LiH_3BNEt_2 **2b**	 **3b**	70
3	LiH_3BN **2c**	 **3c**	84
4	LiH_3BN **2d**	 **3d**	94
5	LiH_3BN O **2e**	 **3e**	81
6	LiH_3BN **2f**	 **3f**	75

[a] All reactions were carried out on a 10 mmol scale with 1.5 equiv of LiH_3BNR_2 for 2 h at 65 °C in THF, unless otherwise noted. [b] All products characterized by ^1H and ^{13}C NMR spectroscopy. [c] Crude, isolated yields.

pathway to provide 2-(4-morpholino)benzylamine (**3e**) in 81% yield. In comparison, free morpholine does not give any S_NAr reaction with the same substrate under reflux conditions, and the starting material is recovered unchanged (eq 10).



(10)

The reaction of 2-fluorobenzonitrile (**1c**) with various lithium *N*,*N*-dialkylaminoborohydrides is fairly general and gives the corresponding 2-(*N*,*N*-dialkylamino)benzylamines in very good yield (Table 1).

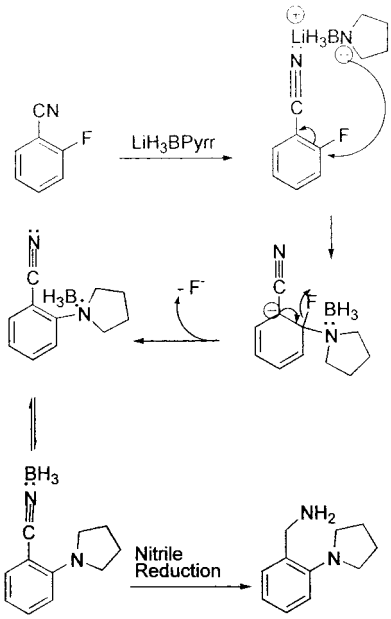
Thus, a wide variety of amines, from the very nucleophilic, such as pyrrolidine, to the less nucleophilic, such as morpholine, are able to undergo substitution with 2-fluorobenzonitriles via LAB reagents. However, aminoborohydrides containing a sterically demanding amine,

(4) March, J. *Advanced Organic Chemistry*; 4th ed.; John Wiley and Sons: New York, 1992; p 646.

(5) Kim, J. K.; Bunnett, J. *J. Am. Chem. Soc.* **1970**, *92*, 7463.

(6) Vlaov, V. M. *J. Fluorine Chem.* **1993**, 193.

Scheme 2



such as lithium diisopropylaminoborohydride, gives primarily reduction of the nitrile moiety in 2-fluorobenzonitrile.

The one-pot tandem amination−reduction reactions of various LAB reagents are complementary to existing synthetic methods. A similar transformation could be carried out in two steps by palladium-catalyzed amination[7] of 2-chloro- or 2-bromobenzonitrile followed by reduction of the nitrile with lithium aluminum hydride[8] or borane.[9] However, lithium *N*,*N*-dialkylaminoborohydrides offer the convenience of a one-pot procedure, as well as the ability to induce substitution of less nucleophilic amines.

The proposed mechanism for these tandem reactions is depicted in Scheme 2.[10]

Initial coordination of the lithium ion to the nitrogen lone pair on the nitrile activates the aromatic ring for nucleophilic attack. The *N*,*N*-dialkylaminoborane moiety attacks the carbon containing the halide on the benzene ring, forming a Meisenhiemer complex. The fluoride ion then leaves to give a 2-(*N*,*N*-dialkylamino)benzonitrile−borane. The borane moiety of the 2-(*N*,*N*-dialkylamino)-benzonitrile−borane is quite labile and dissociates from the amine. The short reaction times for these reactions imply the presence of a Lewis acidic reducing agent, such as borane, which tend to rapidly reduce nitriles when compared to nucleophilic hydride reagents. ^{11}B NMR displayed a quartet at δ −1.1 ppm, attributable to a borane−THF complex. The availability of free borane was investigated by the addition of 1-hexene to the reaction flask. However, ^{11}B NMR analysis did not detect the expected trihexylborane. Rapid association of the borane with the lone pair of electrons of the nitrile and subsequent reduction is thus suspected.

It was speculated that if the lithium ion of the LAB reagent was indeed promoting the S_NAr reaction, then the simple addition of a lithium salt to a refluxing mixture of 2-fluorobenzonitrile and a less nucleophilic amine could promote amination in a similar manner. However, only a trace amount of the aminated product was observed with the addition of LiCl to a refluxing mixture of 2-fluorobenzonitrile and piperidine. Though the addition of a lithium salt was not sufficient to promote a S_NAr reaction, the corresponding LAB reagent, lithium piperidinoborohydride, provided 81% of the tandem amination−reduction reaction product **3e**.

Conclusions

In summary, a novel tandem amination−reduction reaction of 2-halobenzonitriles with lithium *N*,*N*-dialklaminoborohydride reagents has been discovered. LAB reagents react with 2-halobenzonitriles via a unique tandem reaction mechanism, promoting nucleophilic aromatic substitution on substrates that are otherwise unreactive toward amine substitution. The reaction of 2-bromobenzonitrile (**1a**) with various LAB reagents gives primarily the reduction product, 2-bromobenzylamine (**16**), while the reaction of 2-chlorobenzonitrile (**1b**) with various LAB reagents gives primarily the tandem reaction product, 2-(*N*,*N*-dialkylamino)benzylamine **2**. Last, when 2-fluorobenzonitrile is treated with LAB reagent, the tandem reaction product is exclusively obtained. The S_NAr tandem amination−reduction reaction of 2-halobenzonitriles with lithium aminoborohydrides is a one-pot procedure and an attractive synthetic tool for the aromatic substitution of less nucleophilic amines.

Experimental Section

General Methods. All reactions were performed in oven-dried, nitrogen-cooled apparatus. All air- and moisture-sensitive compounds were introduced via syringes or cannula through a rubber septum. THF was distilled from sodium−benzophenone. NMR spectra were recorded in $CDCl_3$. Chemical shifts are reported relative to TMS ($\delta = 0$) for ^{1}H NMR and are referred to the $CDCl_3$ resonance ($\delta = 77$) for ^{13}C NMR spectra. Boron NMR samples were run neat and referenced to BF_3:OEt_2 ($\delta = 0$) for ^{11}B NMR spectra. Mass spectra were obtained on a mass spectrometer in TIS (turbo ion spray) mode. The 2-bromobenzonitrile, 2-chlorobenzonitrile, and 2-fluorobenzonitrile were purchased from the Acros chemical company and used without further purification. The 4-methoxybenzonitrile, 3-methylbenzonitrile, benzonitrile, and 4-cyanobenzyl bromide were purchased from Aldrich Chemical Co. and were used without further purification. The *N*,*N*-dimethylamine−borane was donated from the Callery Chemical Company.

General Procedure for the Preparation of LAB Reagent 1 M Solution in THF. The following procedure for the preparation of LiH_3Bpyrr (**2c**) is representative. A dry 125-mL serum vial equipped with a magnetic stirring bar and fitted with a rubber septum was charged with pyrrolidine (7.11 g, 100 mmol) and anhydrous THF (43 mL) via syringe. At 0 °C,

(7) (a) Driver, M. S.; Hartwig, J. F. *J. Am. Chem. Soc.* **1996**, *118*, 7217.

(8) Brown, H. C.; Weissman, J.; Yoon, N. M. *J. Am. Chem. Soc.* **1966**, *58*, 1458.

(9) Brown, H. C.; Subba Rao, B. C. *J. Am. Chem. Soc.* **1960**, *82*, 681.

(10) Lithium aminoborohydrides can act as hydride or nitrogen transfer agents. This *proposed* mechanism is based on the dual properties of LABs, both of which are moderated by boron. X-ray crystal data obtained by Heinrich Noth (*Chem. Ber.* **1996**, *129*, 451−458) confirms that LABs are a mixed aggregate, with Li situated between boron and nitrogen. The amino group is thus a strong base, as it initiates Li−N bonding. However, the addition of Li salts to the reaction of a free amine did not enhance the S_NAr reaction with halobenzonitrile, indicating that the LAB reagent does not behave as a lithium amide. A referee suggested as a possible mechanism the transfer of the B−N bond via intermolecular transfer analogous to a tetravalent "ate" complex. However, this type of transfer would only be possible if boron was on the migrating terminus. It is thus suggested that the amine of the LAB reagent acts as the nucleophile attacking the carbon bearing the leaving group.

borane−dimethyl sulfide (10 mL, 10 M, 100 mmol) was added dropwise via syringe. After stirring at 0 °C for 1 h, an aliquot was taken and analyzed by ^{11}B NMR spectroscopy. ^{11}B NMR analysis (80.25 MHz, THF) showed the solution to be pyrrolidine−borane $\delta = -18.0$ ppm (q, $J = 96$ Hz). If commercial amine−borane is used, the previous step is modified so as to dissolve the complex in the appropriate volume of dry THF. At 0 °C, *n*-butyllithium in hexanes (40 mL, 2.5 M, 100 mmol) was added dropwise via syringe. After stirring at 0 °C for 1 h, an aliquot was taken and analyzed by ^{11}B NMR spectroscopy. ^{11}B NMR analysis (80.25 MHz, THF) showed the solution to be lithium pyrrolidinoborohydride (**2c**) $\delta = -20.6$ ppm (q, $J =$ 85 Hz). LAB reagents may be transferred to an oven-dried, nitrogen-cooled ampule via a cannula and stored under nitrogen for up to six months without undergoing decomposition.

General Procedure for the Tandem Amination−Reduction Reaction of Halobenzonitriles. The following procedure for the reduction of 2-fluorobenzonitrile (**1c**) with LiH_3Bpyrr (**2c**) is representative. A dry 50-mL round-bottom flask equipped with a magnetic stirring bar was sealed with a rubber septum and was charged with 2-fluorobenzonitrile (10 mmol, 1.21 g). At 0 °C, 1 M lithium pyrrolidinoborohydride (15 mmol) was added dropwise via syringe. The flask was fitted with a water-cooled reflux condenser and the reaction mixture heated to reflux under nitrogen. After 2 h, the reaction was cooled under N_2 gas. At 0 °C, the reaction was quenched by the slow addition of 25 mL of 3 M HCl [*Caution: Hydrogen evolution!*]. The aqueous fraction was extracted with diethyl ether (4 × 20 mL). Solid sodium hydroxide was added to the aqueous fraction until strongly basic to litmus. The aqueous layer was extracted with diethyl ether/THF 1:1 (4 × 20 mL). The combined ethereal fractions were dried over $MgSO_4$ and filtered. The solvents were removed in vacuo (25 °C, 1 Torr) to yield 2-(1-pyrrolidino)benzylamine (**3c**) as a light yellow oil (1.48 g, 84%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.87−1.97 (m, 4H), 2.29 (s, 2H), 3.18−3.21 (t, $J = 7$ Hz, 4H), 3.92 (s, 2H), 6.92−6.95 (t, $J = 8$ Hz, 1H), 6.98−6.99 (d, $J = 8$ Hz, 1H), 7.17−7.20 (td, $J = 1$ Hz, $J = 8$ Hz, 1H), 7.26−7.28 (dd, $J = 1$ Hz, $J = 8$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 25.06, 29.81, 54.38, 117.21. 121.30, 127.88, 129.54, 130.68, 148.66; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 177.1386, found 177.1363.

2-(*N*,*N*-Dimethylamino)benzylamine (3a). Reaction of 2-fluorobenzonitrile (**1c**) (0.606 g, 5 mmol) and lithium dimethylaminoborohydride (7.5 mmol, 7.5 mL, 1 M) produced **3a** as a light yellow oil (0.61 g, 81%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.71 (s, 6H), 3.93 (s, 2H), 7.05−7.08 (td, $J = 1$ Hz, $J = 7$ Hz, 3H), 7.12−7.14 (d, $J = 8$ Hz, 1H), 7.21−7.25 (td, $J = 2$ Hz, $J = 8$ Hz, 1H), 7.31−7.32 (d, $J = 8$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 43.45, 45.10, 119.57, 123.65, 127.63, 128.66, 138.07, 152.47; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 151.1230, found 151.1182.

2-(*N*,*N*-Diethylamino)benzylamine (3b). Reaction of 2-fluorobenzonitrile (**1c**), (1.21 g, 10 mmol) and lithium diethylaminoborohydride (15 mmol, 15 mL, 1 M) produced **3b** as a light yellow oil (1.24 g, 70%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 0.98−1.02 (td, $J = 2$ Hz, $J = 8$ Hz, 6H), 1.76 (bs, 2H), 2.95−3.00 (qd, $J = 2$ Hz, $J = 8$ Hz, 4H), 3.88 (s, 2H), 7.05−7.09 (tt, $J = 1$ Hz, $J = 7$ Hz, 1H), 7.13−7.15 (d, $J = 8$ Hz, 1H), 7.19−7.22 (tt, $J = 2$ Hz, $J = 8$ Hz, 1H), 7.27−7.29 (d, $J = 8$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 12.84, 43.74, 48.35, 122.93, 124.30, 140.83, 149.59; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 179.1519, found 179.1543.

2-(1-Piperidino)benzylamine (3d). Reaction of 2-fluorobenzonitrile (**1c**), (0.606 g, 5 mmol) and lithium piperidinoborohydride (7.5 mmol, 7.5 mL, 1 M) produced **3d** as a light yellow oil (0.89 g, 94%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.57−1.60 (quint. $J = 6$ Hz, 4H), 2.85−2.87 (t, $J = 5$ Hz, 4H), 3.90 (s, 2H), 7.04−7.07 (t, $J = 7$ Hz, 1H), 7.10−7.12 (d, $J = 8$ Hz, 1H), 7.20−7.23 (t, $J = 8$ Hz, 1H), 7.27−7.29 (d, $J = 8$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 24.40, 26.90, 43.61, 54.40, 120.41, 123.90, 127.68, 128.55, 138.81, 152.69; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 191.1543, found 191.1526.

2-(4-Morpholino)benzylamine (3e). Reaction of 2-fluorobenzonitrile (**1c**), (0.606 g, 5 mmol) and lithium morpholinoborohydride (7.5 mmol, 15 mL, 0.5 M) produced **3e** as a light yellow oil (0.77 g, 81%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.92−2.94 (t, $J = 5$ Hz, 4H), 3.84−3.86 (t, $J = 5$ Hz, 4H), 3.91 (s, 2H), 7.10−7.14 (m, 2H), 7.24−7.27 (m, $J = 2$ Hz, $J = 9$ Hz, 1H), 7.31−7.32 (d, $J = 7$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 43.09, 53.26, 67.20, 120.33, 124.63, 127.89, 128.78, 138.78, 138.63, 150.98; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 193.1335, found 193.1345.

2-(1-Hexamethyleneimino)benzylamine (3f). Reaction of 2-fluorobenzonitrile (**1c**), (1.21 g, 10 mmol) and lithium homopiperidinoborohydride (15 mmol, 15 mL, 1 M) produced **3f** as a light yellow oil (1.53 g, 75%); ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.69 (bs, 4H), 3.03−3.06 (t, $J = 6$ Hz, 4H), 3.86 (s, 2H), 6.98−7.01 (t, $J = 8$ Hz, 1H), 7.10−7.11 (d, $J = 8$ Hz, 1H), 7.15−7.18 (t, $J = 8$ Hz, 1H), 7.21−7.22 (d, $J = 8$ Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 27.16, 29.85, 44.22, 57.26, 122.28, 123.69, 127.80, 128.56, 138.78, 154.85; HRMS (70 eV) *m*/*z* ($M^+ + 1$), calcd 205.1699, found 205.1699.

3-Methylbenzylamine (10).[11] A 100 mL, round-bottom flask equipped with a magnetic stirring bar and fitted with a rubber septa was charged with lithium dimethylaminoborohydride (30 mmol, 30 mL, 1 M) and cooled under nitrogen to 0 °C. At °C, *m*-tolunitrile (0.58 g, 5 mmol) was added via syringe. The reaction was heated to reflux (65 °C) under nitrogen and quickly became blood red in color. After 12 h, TLC analysis indicated the absence of starting material. The reaction mixture was then cooled under nitrogen to 0 °C. At °C, deionized water (4 mL) and then 12 M HCl (10 mL, 120 mmol) were added [*Caution: Hydrogen evolution!*]. The aqueous layer was extracted with 2 × 50 mL portions of diethyl ether/THF. At 0 °C, the aqueous layer was made strongly basic to litmus (pH = 12 with solid NaOH. The aqueous layer was extracted with 2 × 50 mL portions of diethyl ether/THF. The organic layers were combined, dried over anhydrous $MgSO_4$, and filtered. The solvent was removed under vacuum (35 °C, 30 Torr and then 25 °C, 1 Torr). The 3-methylbenzylamine product was obtained as (1.87 g, 77% yield) a light yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.62 (brd. S, 2H), 2.37 (s, 3H), 3.84 (s, 2H), 7.07−7.27 (mult., 4H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 21.42, 46.58, 1247.14, 127.54, 127.90, 128.50, 138.18, 143.45.

4-Methoxybenzylamine (11).[12] 80% yield; ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.43 (s, 2H), 3.78 (s, 5H), 6.68 (d, 2H), 7.22 (d, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 45.98, 55.32, 114.0, 128.26, 135.74, 158.60.

Attempted Borane Scavenging Using 1-Hexene. A dry 100-mL round-bottom flask equipped with a magnetic stirring bar was sealed with a rubber septum and was charged with 2-fluorobenzonitrile (5 mmol, 0.545 mL) and 1-hexene (22.5 mmol, 5.66 mL). At 0 °C, lithium dimethylaminoborohydride (7.5 mmol, 7.5 mL, 1 M) was added dropwise via syringe. The flask was fitted with a water-cooled reflux condenser, and the reaction mixture heated to reflux under nitrogen. After 2 h, the reaction was monitored by ^{11}B NMR, and no peaks indicating an alkylborane were present. A TLC analysis at this time showed no indication of starting material. The reaction was cooled under N_2 gas. At 0 °C, the reaction was quenched by the slow addition of 25 mL of 3 M HCl [*Caution: Hydrogen evolution!*]. The aqueous fraction was extracted with diethyl ether (4 × 20 mL). Solid sodium hydroxide was added to the aqueous fraction until strongly basic to litmus. The aqueous layer was extracted with diethyl ether/THF 1:1 (4 × 20 mL). The combined ethereal fractions were dried over $MgSO_4$ and filtered. The solvents were removed in vacuo (25 °C, 1 Torr) to yield 2-(*N*,*N*-dimethylamino)benzylamine **3c** as a light yellow oil in 71% yield.

Attempted Activation of 2-Fluorobenzonitrile with LiCl. A dry 100-mL, round-bottom flask equipped with a sidearm and a magnetic stirring bar was charged with LiCl (15 mmol, 0.63 g) and sealed with a rubber septum. Dry THF (7.5 mL), 2-fluorobenzonitrile (10 mmol, 1.09 mL), and piperdine (15 mmol, 1.49 mL) were introduced to the flask via the

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sidearm, and the flask was fitted with a nitrogen-filled reflux condenser. The reaction mixture was heated to reflux under nitrogen. The reaction was monitored by TLC analysis at 2 h, 4 h, 6 h, and 24 h. After 24 h at reflux temperature (65 °C), a TLC analysis showed the strong presence of starting material, with a faint indication of another compound. At this time, the reaction was cooled under N_2 gas, and at 0 °C, the reaction was quenched by the slow addition of 25 mL of 3 M HCl [*Caution: Hydrogen evolution!*]. The aqueous fraction was extracted with diethyl ether (4 × 20 mL). Solid sodium hydroxide was added to the aqueous fraction until strongly basic to litmus. The aqueous layer was extracted with diethyl ether/THF 1:1 (4 × 20 mL). The combined ethereal fractions were dried over $MgSO_4$ and filtered. The solvents were removed in vacuo (25 °C, 1 Torr) to yield only a trace amount of 2-(1-piperidino)benzylamine. The starting material was recovered unchanged in the neutral ether fraction.

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Supporting Information Available: Proton and carbon spectra and HRMS data for representative compounds. This material is free of charge via the Internet at http://pubs.acs.org.

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