Aminoborohydrides. 7. A General Synthesis of Alkyl-Substituted Borohydrides from the Corresponding Organoborane by Means of Lithium Hydride Transfer from Lithium Aminoborohydride

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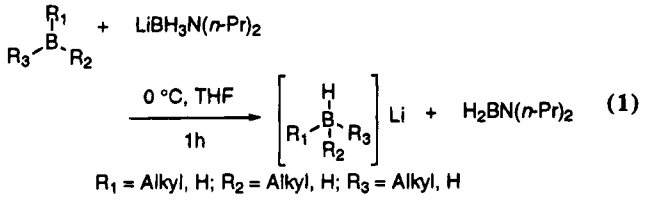
Received August 11, 1994®

Summary: A new general method for the synthesis of alkyl-substituted borohydrides from the corresponding organoborane is presented based on the transfer of lithium hydride from lithium aminoborohydrides.

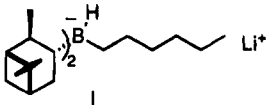
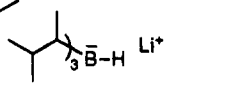
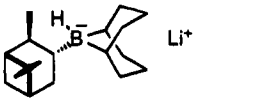
Trialkylborohydrides are a class of powerful and selective reducing agents and are attractive synthetic reagents.[1] Consequently, synthesis of trialkylborohydrides have received much attention.[2] The most direct synthesis of trialkylborohydrides is the addition of the corresponding trialkylborane to an alkali metal hydride.[3] Unfortunately in the case of many sterically hindered alkylboranes, such as trisiamylborane,[4] direct addition of lithium hydride is not feasible. This has led to the development of a number of reactive lithium hydride equivalents. For example, *tert*-butyllithium has been a popular lithium hydride equivalent.[5] Alternatively, lithium trialkylborohydrides may be synthesized by addition of lithium aluminum hydride (LAH) to the corresponding trialkylborane in the presence of triethylenediamine (TED).[6]

We recently reported the synthesis, characterization, and general properties of a class of reducing agents, lithium aminoborohydrides ($LiABH_3$).[7] We envisioned these $LiABH_3$ reagents to be an ether soluble lithium hydride source that would readily add to alkylboranes. In this communication, we wish to report the use of $LiABH_3$ reagents as ether soluble lithium hydride equivalents. $LiABH_3$ reagents readily add lithium hydride to borane, monoalkylboranes, dialkylboranes, and hindered trialkylboranes such as trisiamylborane to form the corresponding lithium trialkylborohydride (eq 1).



In order to test the generality of this metal hydride transfer reaction (exchange reaction), three hindered trialkylboranes were selected: diisopinocampheylhexylborane, trisiamylborane, and *B*-isopinocampheyl-9-borabicyclo(3.3.1)nonane (*B*-Ipc-9-BBN). Lithium hydride does not readily add to these trialkylboranes to form the corresponding borohydride. However, reaction of each of these trialkylboranes with lithium (di-*n*-propylamino)borohydride in THF afforded the corresponding lithium trialkylborohydrides. The results are summarized in Table 1.[8]

Table 1. Reactions of Lithium (Di-*n*-propylamino)borohydride with Trialkylboranes To Yield the Corresponding Trialkylborohydrides[a,b]

trialkylborohydride	^{11}BNMR Data
	d, δ = -5.9 ppm, J = 75 Hz
	d, δ = -12.7 ppm, J = 78 Hz [c] d, δ = -14.0 ppm, J = 78 Hz [c]
	d, δ = -6.6 ppm, J = 75 Hz

[a] Reactions performed in THF at 0 °C. [b] ^{11}B-NMR chemical shifts are relative to $Et_2O{:}BF_3$ (δ 0). [c] Predominant diastereomeric pair of borohydrides.

The exchange of lithium hydride from $LiABH_3$ to the trialkylboranes indicates that the aminoboranes are less Lewis acidic than these trialkylboranes. Normally, exchange reactions involving alkali metal hydrides and organoboranes give broad undefined peaks in their ^{11}B-NMR spectrum when there is incomplete hydride exchange.[9] However, the ^{11}B-NMR spectrum of each of the borohydrides tested in our study showed sharp splitting patterns indicating that the exchange of lithium hydride was complete.

Upon transferring lithium hydride, the lithium aminoborohydride is converted to an aminoborane which remains in the reaction mixture (eq 1). Since aminoboranes are innocuous and poor reducing agents, this byproduct does not represent a problem.[10] Furthermore, the presence of the aminoborane in the final product does not influence the reactivity pattern of the lithium alkylborohydride. An example of a trialkylborohydride with a well-characterized reactivity pattern is lithium tri-

® Abstract published in *Advance ACS Abstracts,* November 1, 1994.

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(7) Fisher, G. B.; Harrison, J.; Fuller, J. C.; Goralski, C. T.; Singaram, B. *Tetrahedron Lett.* **1992**, *33*, 4533.

(8) The following procedure is representative: The trisiamylborane was prepared *in-situ* as a 1 M solution in THF (10 mmol) and cooled to 0 °C. A 1 M solution of lithium (di-*n*-propylamino)borohydride ($LiABH_3$) (10 mmol) was then added dropwise to the alkylborane over 15 min. The solution was then stirred for 45 min. and examined by ^{11}B-NMR. The solvent was removed under reduced pressure (1 Torr). Pentane (15 mL) was added followed by TMEDA (10 mmol). The mixture was stirred for 10 min and then the pentane layer was removed by decantation to afford lithium trisiamylborohydride:TMEDA adduct as a viscous liquid.

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(10) Fisher, G. B.; Juarez-Brambila, J. J.; Goralski, C. T.; Wipke, W. T.; Singaram, B. *J. Am. Chem. Soc.* **1993**, *115*, 440.

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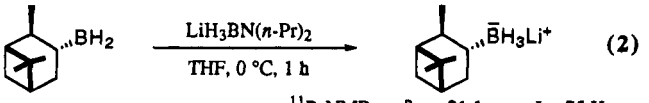
siamylborohydride. This trialkylborohydride is known to react with 4-*tert*-butylcyclohexanone to yield the corresponding *cis* alcohol.[11] Lithium trisiamylborohydride produced by the exchange reaction also reduces 4-*tert*-butylcyclohexanone to give only the *cis* alcohol.

However, it would still be desirable to remove the aminoborane from the product mixture. Consequently, we explored the possibility of isolating the pure alkylborohydrides by complexation with tetramethylethylenediamine (TMEDA).[12] We then sought to use this method to remove the byproduct, aminoborane, which is soluble in pentane. After some optimization, we determined that this may be done by removing the solvent under reduced pressure (1 Torr) followed by addition of pentane and TMEDA (1 equiv). The trisiamylborohydride:TMEDA complex is imiscible under these conditions, separates out as a thick liquid, and is freed of aminoborane by decanting the supernatant solution. The trisiamylborohydride: TMEDA complex produced in this manner shows the same pattern of reactivity as trisiamylborohydride produced by means of *tert*-butyllithium.

We then sought to determine the scope of this reaction. Further studies of the exchange reaction show that $LiABH_3$ transfers lithium hydride to dialkylboranes as well as trialkylboranes. These results are summarized in Table 2.

In addition to forming di- and trialkylborohydrides, we also tested the exchange reaction on monoisopinocampheylborane, a monoalkylborane. The exchange reaction afforded the corresponding monoalkylborohydride (eq 2).

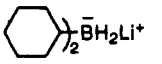
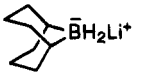
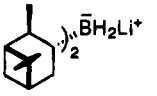
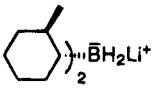
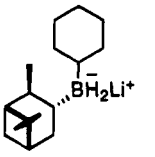


(2)

^{11}B-NMR q, δ = - 21.1 ppm, J = 75 Hz

The exchange reaction also works with borane to yield lithium borohydride. The aminoborane which is produced during the exchange reaction is much less Lewis acidic than borane or alkylboranes. Consequently, the exchange reaction is the result of the thermodynamically favorable exchange of lithium hydride.

Table 2. Reaction of Lithium (Di-*n*-propylamino)borohydride with Dialkylboranes To Yield the Corresponding Borohydrides[a,b]

dialkylborohydride	^{11} BNMR Data
	t, δ = -12.2 ppm, J = 69 Hz
	t, δ = -16.6 ppm, J = 72 Hz
	t, δ = -5.8 ppm, J = 67 Hz
	t, δ = -12.5 ppm, J = 70 Hz [c,d]
	t, δ = -5.3 ppm, J = 66 Hz

[a] Reactions were performed in THF at 0 °C. [b] ^{11}B-NMR chemical shifts relative to $Et_2O:BF_3$ (δ 0). [c] The borane was used as a slurry in THF. [d] The mixture was stirred at 25 °C for 3 h.

In summary, the exchange reaction allows for the single pot synthesis of borohydride from the corresponding borane. The general nature of the exchange reaction, and the mild reaction conditions, makes the exchange reaction attractive for the synthesis of a variety of borohydrides without substrate specific conditions. Extending the utility of this mild procedure is the subject of ongoing investigations.

Acknowledgment. The authors would like to thank the Callery Chemical Co. for providing boranes and amineboranes.

Supplementary Material Available: Experimental procedures and spectral data for all the prepared compounds (24 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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