The use of lithium aluminum hydride (LiAlH₄) and sodium borohydride (NaBH₄) as reagents for the reduction of aldehydes and ketones to 1° and 2°-alcohols respectively has been noted. Of these, lithium aluminum hydride, often abbreviated LAH, is the most useful for reducing carboxylic acid derivatives. Thanks to its high reactivity, LAH easily reduces all classes of carboxylic acid derivatives, generally to the –1 oxidation state. Acids, esters, anhydrides and acyl chlorides are all reduced to 1°-alcohols, and this method is superior to catalytic reduction in most cases. Since acyl chlorides and anhydrides are expensive and time-consuming to prepare, acids and esters are the most commonly used reactants for this transformation. As in the reductions of aldehydes and ketones, the first step in each case is believed to be the irreversible addition of hydride to the electrophilic carbonyl carbon atom. Coordi

Amides are reduced to amines by treatment with LAH, and this has proven to be one of the most general methods for preparing all classes of amines (1°, 2° & 3°). Because the outcome of LAH reduction is so different for esters and amides, we must examine plausible reaction mechanisms for these reactions to discover a reason for this divergent behavior.
eject a metal oxide species (e.g. Al–O\(^{-}\)), and the resulting iminium double bond would then be reduced to an amine. This is the course followed by most amide reductions; but in the case of 1º-amides, the acidity of the nitrogen hydrogens coupled with the basicity of hydride enables a facile elimination of the oxygen (as an oxide moiety). The resulting nitrile intermediate is then reduced to a 1º-amine. Nitriles are in fact a major product when less than a full equivalency of LiAlH\(_4\) is used. A mechanism will be shown above by clicking on the diagram.

Lithium aluminum hydride reduces nitriles to 1º-amines, as shown in the following equation. An initial hydride addition to the electrophilic nitrile carbon atom generates the salt of an imine intermediate. This is followed by a second hydride transfer, and the resulting metal amine salt is hydrolyzed to a 1º-amine. This method provides a useful alternative to the catalytic reduction of nitriles, described above, when alkene or alkyne functions are present.

![Mechanism Diagram]

In contrast to the usefulness of lithium aluminum hydride in reducing various carboxylic acid derivatives, sodium borohydride is seldom chosen for this purpose. First, NaBH\(_4\) is often used in hydroxylic solvents (water and alcohols), and these would react with acyl chlorides and anhydrides. Furthermore, it is sparingly soluble in relatively nonpolar solvents, particularly at low temperatures. Second, NaBH\(_4\) is much less reactive than LAH, failing to reduce amides and acids (they form carboxylate salts) at all, and reducing esters very slowly.

Since relatively few methods exist for the reduction of carboxylic acid derivatives to aldehydes, it would be useful to modify the reactivity and solubility of LAH to permit partial reductions of this kind to be achieved. The most fruitful approach to this end has been to attach alkoxy or alkyl groups on the aluminum. This not only modifies the reactivity of the reagent as a hydride donor, but also increases its solubility in nonpolar solvents. Two such reagents will be mentioned here; the reactive hydride atom is colored blue.

**Lithium tri-tert-butoxyaluminohydride** (LtBAH), LiAl[OC(CH\(_3\))\(_3\)]\(_3\)H : Soluble in THF, diglyme & ether.

**Diisobutylaluminum hydride** (DIBAH), [(CH\(_3\))\(_2\)CHCH\(_2\)]\(_2\)AlH : Soluble in toluene, THF & ether.

Each of these reagents carries one equivalent of hydride. The first (LtBAH) is a complex metal hydride, but the second is simply an alkyl derivative of aluminum hydride. In practice, both reagents are used in equimolar amounts, and usually at temperatures well below 0 °C. The following examples illustrate how aldehydes may be prepared from carboxylic acid derivatives by careful application of these reagents. A temperature of -78 °C is easily maintained by using dry-ice as a coolant. The reduced intermediates that lead to aldehydes will be displayed on clicking the "Show Intermediates" button. With excess reagent at temperatures above 0 °C most carboxylic acid derivatives are reduced to alcohols or amines.
Contributors