Despite the fearsome names, the structures of the two reducing agents are very simple. In each case, there are four hydrogens ("tetrahydrido") around either aluminium or boron in a negative ion (shown by the "ate" ending). The "(III)" shows the oxidation state of the aluminium or boron, and is often left out because these elements only ever show the +3 oxidation state in their compounds.

The formulae of the two compounds are \(\text{LiAlH}_4\) and \(\text{NaBH}_4\). Their structures are:

\[
\text{Li}^+ \left[ \begin{array}{c} \text{H} \\ \text{H} \\ \text{H} \\ \text{H} \\ \text{Al} \end{array} \right]^- \quad \text{Na}^+ \left[ \begin{array}{c} \text{H} \\ \text{H} \\ \text{B} \\ \text{H} \end{array} \right]^- 
\]

- **lithium tetrahydridoaluminate**
- **sodium tetrahydridoborate**

In each of the negative ions, one of the bonds is a co-ordinate covalent (dative covalent) bond using the lone pair on a hydride ion (H-) to form a bond with an empty orbital on the aluminium or boron.

**The reduction of an aldehyde**

You get exactly the same organic product whether you use lithium tetrahydridoaluminate or sodium tetrahydridoborate. For example, with ethanal you get ethanol:

\[
\text{CH}_3\text{C}=\text{O} + 2\text{[H]} \rightarrow \text{CH}_3\text{CH}_2\text{OH}
\]

Notice that this is a simplified equation where [H] means "hydrogen from a reducing agent". In general terms, reduction of an aldehyde leads to a primary alcohol.

**The reduction of a Ketone**

Again the product is the same whichever of the two reducing agents you use. For example, with propanone you get propan-2-ol:

\[
\text{CH}_3\text{C}==\text{O} + 2\text{[H]} \rightarrow \text{CH}_3\text{CH}(\text{CH}_3)\text{OH}
\]

Reduction of a ketone leads to a secondary alcohol.

**Using lithium tetrahydridoaluminate (lithium aluminium hydride)**

Lithium tetrahydridoaluminate is much more reactive than sodium tetrahydridoborate. It reacts violently with water and alcohols, and so any reaction must exclude these common solvents. The reactions are usually carried out in solution in a
carefully dried ether such as ethoxyethane (diethyl ether). The reaction happens at room temperature, and takes place in two separate stages.

In the first stage, a salt is formed containing a complex aluminium ion. The following equations show what happens if you start with a general aldehyde or ketone. R and R' can be any combination of hydrogen or alkyl groups.

\[
4 \text{R}^\cdot\text{C}^\cdot\text{R}' + \text{Li}^+\text{Al}^{4-} \rightarrow \left(\begin{array}{c} \text{R} \\ \text{R}' \cdot \text{C} \cdot \text{O} \end{array}\right)\text{Al}^+\text{Li}^+
\]

The product is then treated with a dilute acid (such as dilute sulfuric acid or dilute hydrochloric acid) to release the alcohol from the complex ion.

\[
\left(\begin{array}{c} \text{R} \\ \text{R}' \cdot \text{C} \cdot \text{O} \end{array}\right)\text{Al}^+ + \text{H}^+ + \text{Cl}^- \rightarrow 4 \text{R}' \cdot \text{C} \cdot \text{H} + \text{Al}^{3+}\text{[aq]}
\]

The alcohol formed can be recovered from the mixture by fractional distillation.

**Using sodium tetrahydridoborate (sodium borohydride)**

Sodium tetrahydridoborate is a more gentle (and therefore safer) reagent than lithium tetrahydridoaluminate. It can be used in solution in alcohols or even solution in water - provided the solution is alkaline. Solid sodium tetrahydridoborate is added to a solution of the aldehyde or ketone in an alcohol such as methanol, ethanol or propan-2-ol. Depending on which recipe you read, it is either heated under reflux or left for some time around room temperature. This almost certainly varies depending on the nature of the aldehyde or ketone.

At the end of this time, a complex similar to the previous one is formed.

\[
4 \text{R}^\cdot\text{C}^\cdot\text{R}' + \text{Na}^+\text{BH}_4^- \rightarrow \left(\begin{array}{c} \text{R} \\ \text{R}' \cdot \text{C} \cdot \text{O} \end{array}\right)\text{B}^-\text{Na}^+
\]

In the second stage of the reaction, water is added and the mixture is boiled to release the alcohol from the complex.

\[
\left(\begin{array}{c} \text{R} \\ \text{R}' \cdot \text{C} \cdot \text{O} \end{array}\right)_{4} + 3\text{H}_2\text{O} \rightarrow 4 \text{R}' \cdot \text{C} \cdot \text{H} + \text{NaH}_2\text{BO}_3
\]

Again, the alcohol formed can be recovered from the mixture by fractional distillation.
Contributors

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