Reduction of Carbonyls to Alcohols

\[
\text{R-C-R'}(\text{H}) \xrightarrow{\text{Reduction}} \xrightarrow{\text{Oxidation}} \text{R-C-R'}(\text{H}) \quad \text{gains H atoms!}
\]

Examples

\(\Delta\) Hydrogenation of C=O

- Similar to hydrogenation of alkenes
- Rxn. is Exothermic but very slow...
- Catalyst used: Pt, Ni, Pd, Ru

\[
a \rightarrow \text{R-C-H} \xrightarrow{\text{H}_2 \text{Catalyst}} \text{R-C-H} \quad \text{1º-Alcohol}
\]

\[
b \rightarrow \text{R-C-R'} \xrightarrow{\text{H}_2 \text{Catalyst}} \text{R-C-R'} \quad \text{2º-Alcohol}
\]
Metal hydrides as reducing agents

- Two common reagents are:
  \[ \text{Li}^+ \left[ \begin{array}{c} \text{H} \\ \text{H} \end{array} \right] \quad \text{Na}^+ \left[ \begin{array}{c} \text{H} \\ \text{H} \end{array} \right] \]
  Lithium aluminum hydride
  Sodium Borohydride
  Sodium tetrahydroborate

- Both B-H and Al-H bonds are polarized.
  \[ \begin{array}{cc} \text{H} & \text{H} \\ \text{H} & \text{H} \end{array} \]
  B: 1.8; Al: 1.6; C: 2.5; H: 2.2
  Both Al and B less electronegative than C!

- H more electronegative than B and Al!
  - H in both the B-H and Al-H bonds bears the (-)ve Charge
  - Serves as source of H:^{\ominus}
GENERAL MECHANISM

i) In the reduction the H bonded to the C, comes from BH₄⁻ or AlH₄⁻.

ii) The H on the oxygen comes from Solvent (H₂O or alcohol)

alkoxyborate

Tetraalkoxyborate
Mechanism Continued...

Each $\text{BH}_4^-$ can reduce up to 4 carbonyls.

Similar mechanism with $\text{Li}\overset{+}{}\text{AlH}_4^-$. 

Careful when handling $\text{LiAlH}_4$!

$\text{LiAlH}_4 + 4\text{H}_2\text{O} \rightarrow \text{LiOH} + \text{Al(OH)}_3 + 4\text{H}_2$

Explosive in $\text{H}_2\text{O}!$ **Use solvents such as diethyl ether.**
Lab 10: Reduction of Camphor to Isoborneol using NaBH₄

Isoborneol → trialkoxyborate

3 more hydrolysis steps

\[
\begin{align*}
\text{[CH}_3\text{CH}_3\text{CH}_3\text{CH}_3\text{OH]} & + \text{[HO-B=OH]} \\
\end{align*}
\]