

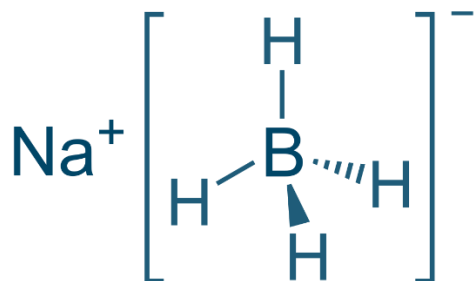
Reactions of Synthetic Importance

Metal Hydride Reduction (NaBH_4 and LiAlH_4)

- Metal hydrides like **sodium borohydride (NaBH_4)** and lithium aluminium hydride (LiAlH_4) are used to reduce carbonyl compounds (aldehydes, ketones, esters, carboxylic acids, etc.) to alcohols.

Sodium Borohydride (NaBH_4)

- Structure:** $\text{Na}^+[\text{BH}_4]^-$ (a tetrahedral borohydride ion)



- Solubility & Stability:** Stable in water and alcohol; can be used in aqueous or alcoholic solutions.

Reactivity:

- **Reduces:** Aldehydes and ketones easily.
- **Does not reduce:** Esters, acids, amides (generally unreactive unless in harsh conditions).

Mechanism:

- The hydride ion (H^-) from NaBH_4 attacks the electrophilic carbonyl carbon.
- This forms a tetrahedral alkoxide intermediate.
- Protonation of the alkoxide by solvent gives the **alcohol**.

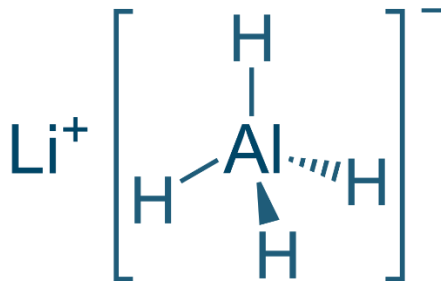
Example:

- R-CHO (aldehyde) + $\text{NaBH}_4 \rightarrow \text{R-CH}_2\text{OH}$ (primary alcohol)
- R-CO-R' (ketone) + $\text{NaBH}_4 \rightarrow \text{R-CHOH-R'}$ (secondary alcohol)



Lithium Aluminium Hydride (LiAlH_4)

- Structure:** $\text{Li}^+[\text{AlH}_4]^-$



- **Solubility:** Reacts violently with water and alcohol — must be used in dry ethers like diethyl ether or THF.

Reactivity:

- **Reduces:** Aldehydes, ketones, esters, acids, amides, nitriles.
- **Very strong reducing agent.**

Mechanism (for ester reduction):

1. LiAlH_4 donates a hydride to the carbonyl carbon.
2. Tetrahedral intermediate collapses, ejecting the alkoxide leaving group.
3. Another hydride adds to the aldehyde intermediate.
4. Protonation gives a **primary alcohol**.

Example:



- $\text{R-COOH} + \text{LiAlH}_4 \rightarrow \text{R-CH}_2\text{OH}$ (primary alcohol)
- $\text{R-COOR}' + \text{LiAlH}_4 \rightarrow \text{R-CH}_2\text{OH} + \text{R}'\text{OH}$
- $\text{R-CONH}_2 + \text{LiAlH}_4 \rightarrow \text{R-CH}_2\text{NH}_2$ (primary amine)

Clemmensen Reduction

- **Type:** Metal-acid reduction

Purpose:

- Reduces aldehydes and ketones to alkanes.
- Used especially for carbonyl groups adjacent to aromatic rings (aryl ketones).

Reagents:

- Zinc amalgam (Zn(Hg))
- Concentrated hydrochloric acid (HCl)
- Reaction is acidic

Mechanism (Simplified Concept):

1. Coordination to Zinc:

- The carbonyl oxygen coordinates to the **Zn surface**, making the C=O bond more electrophilic.

2. Single Electron Transfer (SET):

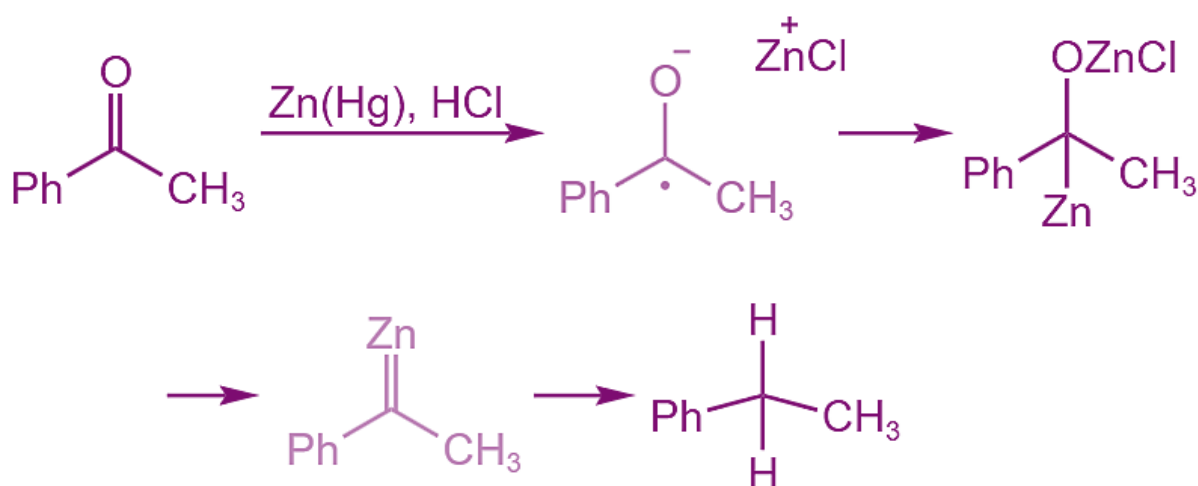
- Zn donates an electron to the carbonyl carbon → forms radical anion.

3. Protonation:

- Proton from acid (HCl) stabilizes the intermediate.

4. Further Reduction and Protonation:

- Repeated electron transfer and protonation convert the **C=O group to -CH₂-**.



- **Best used** for aromatic ketones where acid-sensitive groups are absent.

Conditions:

- Harshly acidic, so acid-sensitive compounds may degrade.

Example:

- $\text{Ar-CO-R} \rightarrow \text{Ar-CH}_2\text{-R}$ (using Zn(Hg) / conc. HCl)

Birch Reduction

Purpose:

- Reduces aromatic rings (like benzene) to non-conjugated cyclohexadienes.
- Partial reduction – breaks aromaticity but doesn't fully saturate the ring.

Reagents:

- Alkali metal (Na, Li, or K) in liquid ammonia (NH_3)



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