# Metal Production

The likelihood that an uncombined metal will occur naturally increases with lack of reactivity:

| Metals | Usual reduction method | Reactivity |
|---|---|---|
| Li | Electrolysis of a melt | Going from bottom to top, the metals: are more reactive, lose electrons more readily, form positive ions more readily, become stronger reducing agents<br><br>A metal 'high up' in the reactivity series:<br>· reacts vigorously and quickly with chemicals<br>· readily gives up electrons in reactions to form positive ions<br>· is corroded easily<br><br>A metal 'low down' in the reactivity series:<br>· does not react vigorously and quickly with chemicals<br>· does not readily give up electrons in reactions to form positive ions<br>· is not corroded easily |
| K | | |
| Ca | | |
| Na | | |
| Mg | | |
| Al | | |
| Zn | Smelting (chemical reduction) *or* Electrolysis of solution | |
| Fe | | |
| Sn | | |
| Pb | | |
| Cu | | |
| Hg | | |
| Ag | Found naturally in reduced form (uncombined) | |
| Au | | |

Where possible, reduction using electrolysis of an aqueous solution is preferable to electrolysis of a melt, since melting requires large amounts of energy (as well as the energy required for electrolysis), which increases cost of production.

The production of aluminium (and the metals more reactive than it) *requires* a molten non-aqueous electrolyte, since water is more easily reduced than aluminium ions ($H_2$ forms at the cathode).

Metals less active than aluminum can sometimes be produced without using electrolysis.

The oxide of a less active metal can be reduced by *smelting* (heating with carbon to produce the metal and carbon dioxide).

Examples:

reduction of iron $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

reduction of zinc $2ZnO + C \rightarrow 2Zn + CO_2$

This is only possible for metals that are more easily reduced (less reactive) than aluminium. Carbon is not a sufficiently strong reducing agent to reduce aluminium (or more reactive metals).

In general, these are the stages in the production of metals from their ores:

- concentration of the mineral
- conversion of the mineral into a compound suitable for reduction
- reduction
- refinement of the metal

In the production of some metals, not all stages are necessary:

- ores with low gangue (rock or mineral matter of no value mixed with the ore) content don't need concentration
- ores which are already in a reduction-suitable form do not require the conversion step
- metals found naturally in reduced form don't need reduction
- metals produced in purity during reduction don't need the refining step

## Example: Electrolytic production of zinc from its ore

| *Stage* | *Description* |
|---|---|
| concentration of the zinc mineral | Zinc ore (zinc sulfide and gangue) is crushed and ground to a fine powder.<br>This powder is mixed in a tank with water soluble 'collectors' (which attach to zinc sulfide but not to the gangue) and a frothing agent.<br>Air is blown into the slurry, forming bubbles which the collectors and therefore zinc sulfide rise to the surface with. This process is called *froth flotation*.<br>The zinc sulfide can then be skimmed off the surface (leaving gangue sludge on the bottom) |
| conversion of the zinc mineral into a form suitable for reduction | The concentrate is *roasted* (heated) in air to convert zinc sulfide to zinc oxide and sulfur dioxide:<br>$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$<br>Sulfuric acid is then reacted with the zinc oxide to make a solution of zinc sulfate. This process is called *leaching*.<br>$H_2SO_4 + ZnO \rightarrow ZnSO_4 + H_2O$<br>The zinc sulfate solution may contain other metal ions (impurities). Powdered zinc metal is added and will undergo single-displacement with the less reactive metal ions, removing them from solution. This process is solution *purification*.<br>Example: $Zn + Cd^{2+} \rightarrow Cd + Zn^{2+}$<br>Any metals ions present which are more reactive than zinc are not a problem as zinc will be preferentially reduced during electrolysis. |
| electrolytic reduction | The zinc sulfate solution $ZnSO_{4\,(aq)}$ is electrolysed.<br>Zinc metal forms at the cathode. |

This process can be summarised with a flowchart, as below: