# Metal Extraction

Metals from their ores

- A rock from which a metal can be extracted from is called an ore

Metal extraction and the reactivity series

- The way we extract metal from its ore depends on its position in the reactivity series
- Carbon is used to reduce metal oxides of metals below it in the reactivity series
- Carbon monoxide is also a good reductant
- Metals above carbon in the reactivity series cannot be extracted from their oxides by heating with carbon. This is because the metal bonds to oxygen too strongly and the carbon is not strong enough to remove it
- Metals more reactive than carbon are extracted by electrolysis
- Electrolysis is used to extract metals such as aluminium, calcium and magnesium
- It is possible to use electrolysis to extract metals less reactive than carbon. This is not done because much more energy is needed to carry out electrolysis compared with extraction using carbon
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Extraction of zinc

- The raw materials used in the extraction if zinc are: zinc blende (zinc sulphide [ZnS]), coke (carbon) and air

The process of extraction is as follows:

1. The ore is first crushed and treated to remove waster rock and impurities
2. The zinc blende is then roasted (Strongly heated) in air to form zinc oxide:
    i. $2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$
3. The zinc oxide is then heated with coke (carbon) in the blast furnace
4. A blast of air is blown into the bottom of the furnace. The excess carbon reacts with oxygen in the air to form carbon monoxide:
    ii. $2C(s) + O_2(g) \rightarrow 2CO(g)$
5. Higher up in the blast furnace carbon monoxide reduced zinc oxide to zinc::
    iii. $ZnO(s) + CO(g) \rightarrow Zn(g) + CO_2\,(g)$
6. The carbon dioxide formed can react with more carbon to reform more carbon monoxide:
    iv. $CO_2(g) + C(s) \rightarrow 2CO(g)$
7. Some zinc oxide may also react directly with the carbon:
    v. $ZnO(s) + C(s) \rightarrow Zn(g) + CO(g)$
8. The zinc vapour is carried up through the furnace by the stream of carbon monoxide and carbon dioxide
9. The vapour condenses in trays at the top of the furnace together with lead which is extracted at the same time
10. The zinc is then purified by distillation

- This method only produces only about 20% of the world's zinc. Electrolysis of zinc sulphate is now preferred because it produces much purer zinc

Extracting Iron

- The main ore of iron, haematite, usually contains 60% of iron. Haematite is largely iron (III) oxide. We extract iron by the reduction of iron (III) oxide with carbon
- The raw materials for making iron are haematite, coke, limestone and air.

The chemical reaction is the blast furnace

1. At the bottom of the furnace the coke burns in the not air blast to form carbon dioxide. This reaction is exothermic. The heat released helps heat the furnace.
$$C(s) + O_2(g) \to CO_2(g)$$

2. The carbon dioxide reacts with the coke to form carbon monoxide:
$$CO_2(g) + C(s) \to 2CO(g)$$
3. The carbon monoxide reduces the iron (III) oxide to iron:
$$Fe_2O_3(s) + 3C(g) \to 2Fe(l) + 3CO_2(g)$$
4. Most of the iron is produced this way. The iron flows to the bottom of the furnace and is removed as a liquid. It flows into moulds and is left to solidify
5. In the hotter parts of the furnace carbon reduces iron (III) oxide directly
$$Fe_2O_3(s) + 3C(g) \to 2Fe(l) + 3CO_2(g)$$

- The hot waste gases exiting from the top of the furnace are used to heat the air going into the furnace thus reducing energy costs

Why we add limestone to the blast furnace

- Haematite contains sand [silicon (IV) oxide] as a major impurity. The limestone (calcium carbonate) helps remove most of the impurities in the following way:

6. The heat from the blast furnace decomposes the limestone:
$$CaCO_3(s) \to CaO(s) + CO_2(g)$$
7. The calcium oxide reacts with silicon (IV) oxide to form slag in the form of calcium silicate:
$$CaO(s) + SiO_2(l) \to CaSiO_3(l)$$

- The liquid slag runs down and forms a layer on top of the liquid iron because it has a lower density than iron. The slag is run off. The solid slag is used as a building material, particularly in road building

Iron to Steel

- The iron produced in the blast furnace us only about 95% pure
- The impurities are mainly carbon but also include sulfur, silicon and phosphorus
- The impurities make the iron brittle
- If all impurities are removed, the iron becomes very soft. IN this condition, it is easily shaped but is too soft for many uses
- Pure iron also rusts very easily
- To make iron strong only some of the impurities are removed to produce various types of steel. Steel is an alloy of iron and or carbon with other metals

Steel making

- Steel is made using a basic oxygen converter
- The converter is tipped to one side and molten iron and scrap iron are poured in
- The convertor is put back into a vertical position. A water cooled tube called an oxygen lance is lowered into the convertor

- Oxygen and powdered calcium oxide are blown onto the surface of the molten iron through the lance
- The oxygen oxidises carbon, sulfur, silicon and phosphorus to their oxides.
- The carbon dioxide and sulfur dioxide escape from the convertor because they are gases
- These reactions are exothermic. The heat released in these oxidation reactions keep iron molten.
- Silicon and phosphorus oxides are solids. They are acidic oxides. So these react with the powdered calcium oxide which is basic and slag is formed
- The slag floats on the surface of the molten iron and is removed
- The amount of carbon in steel is controlled by the amount of oxygen blown into the impure iron. The longer the oxygen blast, the more carbon is removed
- After the required amount of carbon has been removed, other elements such as chromium and nickel are added to make particular types of steel.

Steel alloys

- Mild steel is low carbon steel. It is soft, malleable and ductile. It is used to make car bodies and parts of machinery. It is also used for buildings and general building purposes
- High carbon steel is used for hammers and chisels
- Low alloy steels contain other metals such as chromium, magnesium and titanium. They are hard and do not stretch much. Nickel steels are used for bridges where strength is needed for bicycle chains. Tungsten steel is used for high speed tools because it does not change shape at high temperatures
- Stainless steel are high metal alloys. They are very strong and resist corrosion, so they are used in the construction of pipes and towers in chemical factories. Stainless steel is also used to make cutlery. Surgical instruments are made from stainless steel.

Other alloys

- Aluminium is used for making aircraft bodies because it is lightweight and has a low density. Some food containers and cooking foil are made from aluminium. This is because there is an unreactive oxide layer that does not flake off, the oxide does not react with the acids that are present in many foods.
- Zinc is used to galvanise iron or mild steel to prevent rusting, Galvanised steel is used for roofing because it is weather resistant.
- Copper is used for electrical wiring and because of its high conductivity, it is also malleable and ductile. It is also used for the base of saucepans because of its high heat conductivity
- Brass is stronger than copper and it does corrode. It is malleable, and an attractive colour. It is used to make musical instruments, door handles, ornaments and screws.