

Extracting metals

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ORES

- Most metal compounds in ores are found as oxides or sulphides, but the sulphides are usually converted to oxides before extraction.
 - The most important ore of zinc consists mostly of zinc sulphide
 - To form the metal oxide roast the sulphide ore with oxygen
- $$2 \text{ZnS} + 3 \text{O}_2 \rightarrow 2 \text{ZnO} + 2\text{SO}_2$$

Roasting of sulphide ores to give oxides leads to SO_2 pollution, leading to acid rain. However, if the SO_2 is absorbed by water it can be used to make Sulphuric acid

Different methods for Extracting metals

- The extraction of metals involves **reduction**, usually of metal oxides.

This reduction of the metal compound is usually done in one of three main ways:

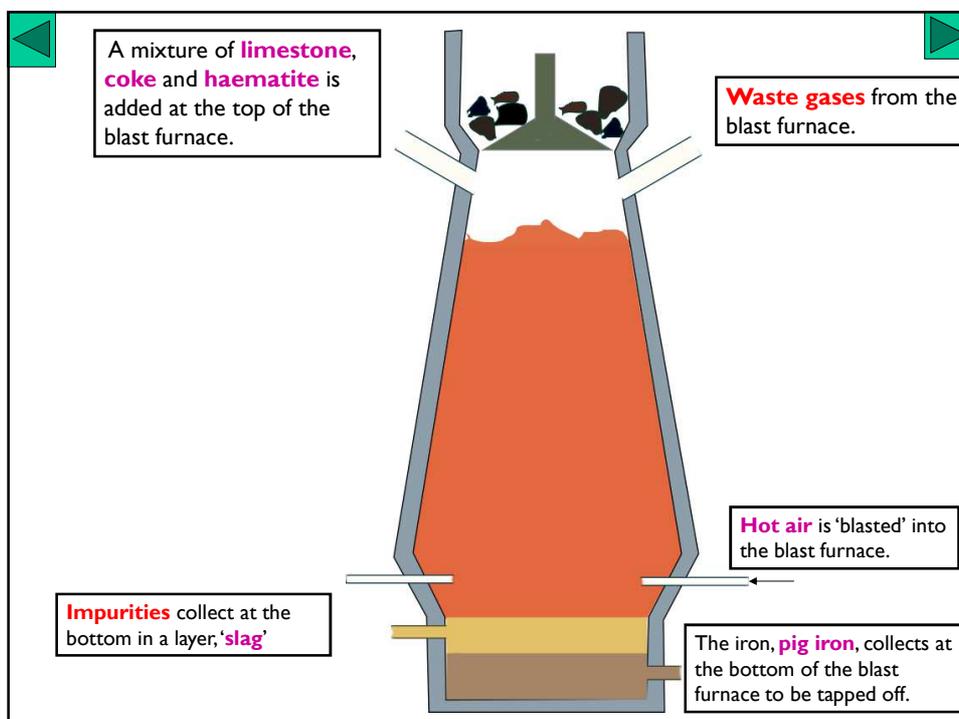
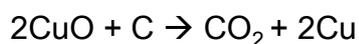
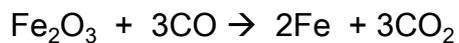
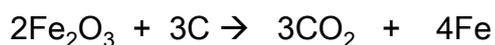
1. by heating with carbon (in the form of coke)
2. by electrolysis
3. by heating with a more reactive metal (active metal)
4. by reacting with hydrogen

Which method is used depends on:

- **the energy requirements**
extraction uses large amounts of energy (electricity and / or heat)
- **the cost of the reductant**
carbon (in the form of coke), which is cheap, is widely used, but sometimes more reactive metals are required which are very costly
- **the metal purity required**
the higher the required purity, the greater the cost in obtaining that purity

1. Extraction using carbon or Carbon monoxide

Carbon and carbon monoxide are cheap and effective reducing agents that are used in the extraction of iron, manganese and copper

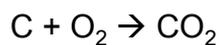


Blast Furnace Reactions

A series of reactions take place

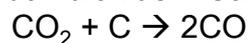
1) Coke (carbon) reacts with oxygen

Carbon + Oxygen → Carbon dioxide



The reaction is highly exothermic and produces the heat for most of the blast furnace

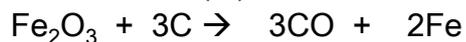
2) Carbon dioxide + Carbon → carbon monoxide



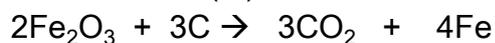
This produces carbon monoxide which is the main reducing agent.

3) Several different reduction reactions occur that form the iron.

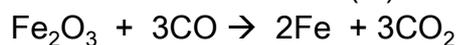
carbon + iron(III) oxide → carbon monoxide + iron



carbon + iron(III) oxide → carbon dioxide + iron



carbon monoxide + iron(III) oxide → carbon dioxide + iron



Reduction is losing oxygen. The iron is being reduced. The carbon and carbon monoxide are called reducing agents because they cause iron to reduce.

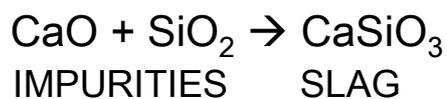
Removing impurities

4. The limestone is used to remove the impurities.

Calcium carbonate → Calcium oxide + Carbon dioxide



The CaO then reacts with impurities to form the slag



Slag can be sold to the construction industry for various uses such as Asphalt or concrete aggregate, Cement

Pollution due to iron extraction

Compounds formed during the extraction of iron in the blast furnace which lead to environmental pollution.

Compound: CO₂

Pollution caused: greenhouse gas or global warming

Compound: CO

Pollution caused: toxic atmosphere or greenhouse gas

Compound: SO₂

Pollution caused: acid rain

Compound: CaSiO₃

Pollution caused: slag heaps

Why not use carbon to extract...

Aluminium

Aluminium is more reactive than carbon. It can not be extracted by reduction with carbon; electrolysis is usually used,

Titanium and tungsten

These cannot be extracted with carbon because titanium carbide (TiC) is formed rather than titanium (similar reactions take place for vanadium, tungsten and molybdenum).

2. Electrolysis

- When a metal is more reactive than carbon (e.g. aluminium), it can not be extracted by reduction with carbon; electrolysis is usually used.
 - electrolysis is not used if the metal has to be very pure.
- The main cost in this process is the electricity – so a cheap supply is needed – plants are often built near hydroelectric power stations.

Extraction of Aluminium

The anode is made from **graphite**

Oxygen gas formed at the anode, reacts with the carbon to form CO_2 . The anode disintegrates and has to be replaced frequently.

The cathode is made from **graphite**

The electrolyte contains molten **aluminium oxide** dissolved in molten **cryolite**, at a temperature of **950°C**

The aluminium ions are **attracted to the cathode, gain three electrons** to form liquid aluminium.

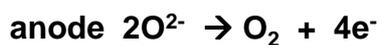
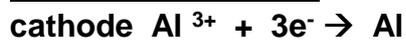
The key features of the manufacture of aluminium by electrolysis

- The raw materials for the extraction of aluminium are purified aluminium oxide (Al_2O_3) and cryolite (Na_3AlF_6).
- The aluminium oxide must be molten or dissolved to conduct electricity. (to enable the ions present in aluminium oxide to move and conduct electricity)
- It is dissolved in molten cryolite (this lowers the melting point of the aluminium oxide, increases conductivity and therefore reduces cost).
- Without using the cryolite, the aluminium oxide melts at too high a temperature which makes the process uneconomic.

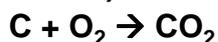
The electrode reactions in the manufacture of aluminium by electrolysis:

The electrodes are made of graphite.

Electrode Reactions



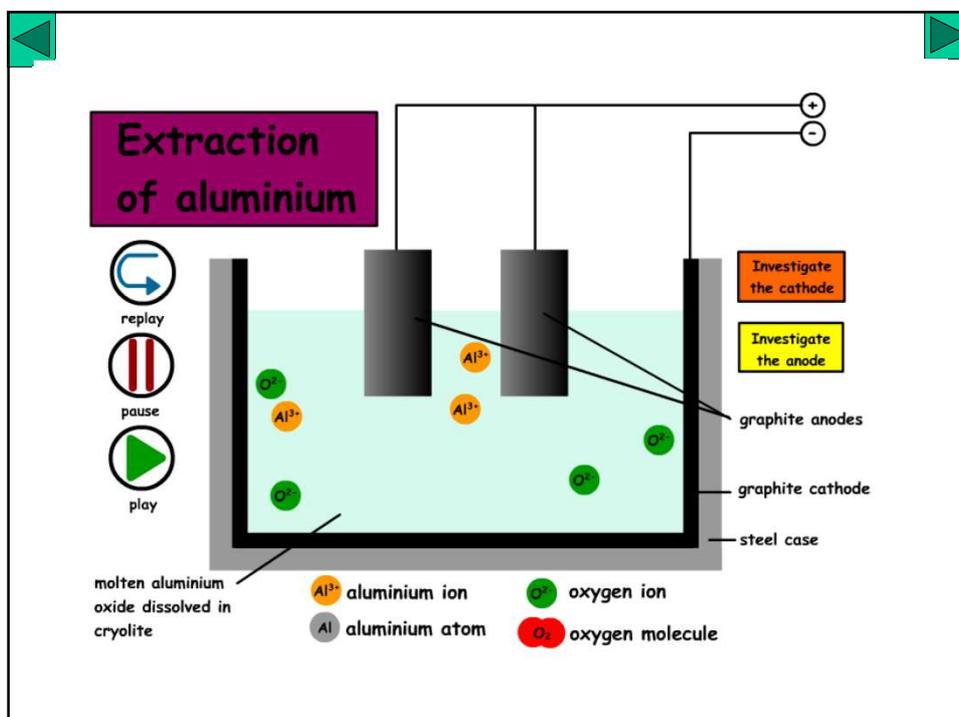
The oxygen gas formed at the anode then reacts with the graphite (carbon) anode and forms carbon dioxide



The anode therefore disintegrates and has to be replaced frequently.

The overall decomposition of aluminium oxide by electrolysis can be written as:

aluminium oxide \rightarrow aluminium + oxygen



3. Extracting Titanium with a more reactive metal

Titanium cannot be extracted with carbon because titanium carbide (TiC) is formed rather than titanium (similar reactions take place for vanadium, tungsten and molybdenum).

Titanium is a very useful metal as it abundant, has a low density and is corrosion resistant – it is used for making strong, light alloys for use in aircraft for example.

Titanium has to be very pure to have these useful properties and so electrolysis is not suitable. The metal is extracted by reaction with a more reactive metal (e.g. Mg, Na).

The main ore is rutile, containing TiO₂.

Extracting Titanium

TiO₂ (solid) is converted to TiCl₄ (liquid) at 900°C:



[Learn Equation](#)

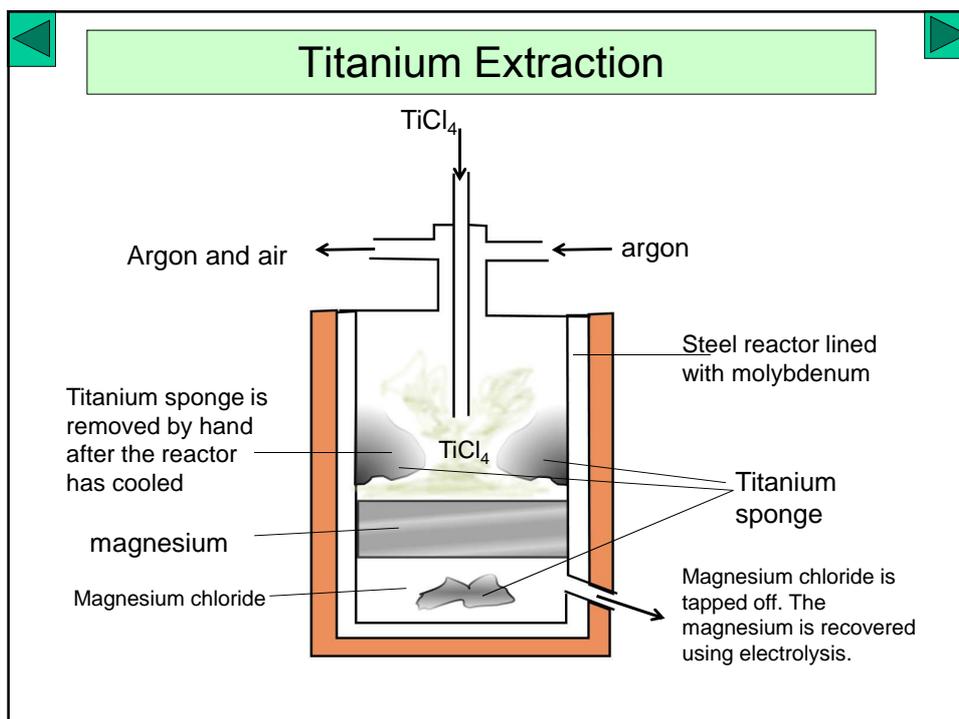
The TiCl₄ is purified by fractional distillation in an Ar atmosphere.

The Ti is extracted by reducing agent Mg or Na in an Ar atmosphere at 500°C:



[Learn Equation](#)

TiO₂ is converted to TiCl₄ as it can be purified by fractional distillation, TiCl₄ being molecular (liquid at room temperature) rather than ionic like TiO₂ (solid at room temperature).



Economics of extracting Titanium

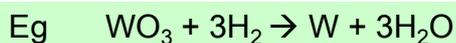
The titanium is expensive because

1. The expensive cost of the Na or Mg
2. This is a batch process which makes it expensive because the process is slower (having to fill up and empty reactors takes time) and requires more labour and the energy is lost when the reactor is cooled down after stopping
3. The process is also expensive due to the Ar, and the need to remove moisture (as TiCl_4 is susceptible to hydrolysis).

This all makes titanium expensive even though it is a relatively abundant metal. It is only therefore used to a limited amount even though it has useful properties

Extracting Tungsten using Hydrogen

Hydrogen can be used to reduce several metals from their oxide ores including Tungsten.



It might be used when carbon would form a carbide with the metal or when higher purity is required

Advantages of using hydrogen

no pollution (from CO, CO₂)
readily available from H₂O or CH₄

Will give higher purity than using Carbon

Disadvantages of using hydrogen

Hydrogen is an explosion hazard and is difficult to store

Recycling Iron

Method for recycling:

Iron scrap must be separated from other metals etc by using a magnet. It is then melted down (to convert it into steel)

And also used in BOS process

Reasons for recycling

- Use of scrap requires less energy than extraction because scrap has higher iron content than ore
- Scrap does not deplete native ore reserves
- Scrap removed from countryside
- Less CO₂ released into atmosphere (hence less greenhouse effect) compared with extraction

Recycling Aluminium

Electrolysis is expensive because it requires lots of electricity to extract Al from Al_2O_3

Recycling Al from scrap means only heat needed to melt metal so less energy is required

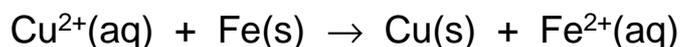
Pollution by is reduced as no need to dispose of Al scrap (e.g. by landfill)

Less damage is done to the environment as less extraction of Al_2O_3 means less holes from mining

Extracting copper with scrap iron

Copper can also be extracted by using the displacement reaction of scrap iron with an aqueous solution of copper. This solution can be made by reaction sulphuric acid with copper ores

The **more reactive iron** displaces the copper by **reducing the copper ions**.



Compared to the high temperature carbon reduction of copper oxide this

- uses less energy,
- can work with lower grade ores and so is more sustainable
- Would work with low quality scrap iron so saves this being wasted.