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Aluminium

Aluminium is a shiny silvery metal, which is extracted from its ore by electrolysis. Further addition of other metallic elements results in an alloy, which can be cast into various shapes using moulds.

GCSE key words
Aluminium manufacture and uses
Electrolysis
Metals and structure

Anglesey Aluminium extracts 142 000 tonnes of aluminium a year.

Steel melts at 1535 °C – without cryolite the steel container would melt!

Cryolite is sodium aluminium fluoride, Na_3AlF_6.

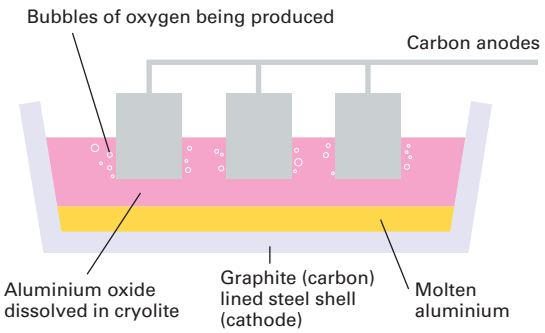
Electrolysis uses a current of about 125 000 amps and 4 volts.

Aluminium ore (bauxite) is dug up in many parts of the world. Britain gets a lot of its supply from Jamaica. This ore is impure. The impurities are mainly from oxides of iron. The ore is carried by ship to treatment works, such as Auchinish in Ireland, where the impurities are removed. The pure oxide (alumina) is then shipped to aluminium smelting works (e.g. Anglesey Aluminium) where the process of electrolysis is used in order to separate the aluminium and the oxygen from the alumina.

Extraction

Aluminium oxide melts at 2015 °C. It takes a lot of energy to get it to this temperature, so the oxide is dissolved in cryolite to reduce the melting point. Carbon electrodes are dipped into a bath of molten alumina and cryolite. A high current and low voltage are used to electrolyse the mixture (Figure 1). Aluminium is formed at the cathode and oxygen at the anode (Box 1).

Figure 1 *Extraction of aluminium from alumina*



The oxygen corrodes the carbon anodes and they break down forming carbon dioxide, so the anodes have to be replaced fairly often. The carbon dioxide produced is passed through a filter to remove any oxide dust particles and then released to the atmosphere. The high current which is used during the electrolysis process causes an increase in temperature and the mixture bubbles at about 1000 °C.

One electrolysis cell makes about 5 tonnes of aluminium a day. At Anglesey Aluminium there are 135 cells in each of four different cell rooms. The aluminium produced is then cast into ingots or rods and sold to manufacturers who turn it into all sorts of different items made from aluminium and its alloys.

Aluminium is a relatively expensive metal since electricity is used in its manufacture, and electricity is costly, but aluminium has many useful properties (see Table 1).

Box 1 Electrode reactions in the manufacture of aluminium

At the cathode (negative electrode):

$$Al^{3+} + 3e^- \longrightarrow Al$$

At the anode (positive electrode):

$$2O^{2-} \longrightarrow O_2 + 4e^-$$

Aluminium ingots ready to be melted and cast

Objects made by casting

Table 1 *Properties and uses of aluminium*

Property	Example of use
Lightweight	Aeroplanes, boats and bicycles
Conducts electricity well	High-voltage power cables
Malleable	Boats, cooking foil
Doesn't corrode easily	Window frames

Casting

Aluminium can be used with other metals to form a range of alloys. These alloys are cast into a variety of useful and decorative objects which might be difficult to make by other means.

The White Eagle Foundry at Hurstpierpoint in Sussex casts aluminium into a range of products. In this foundry, ingots of aluminium (often containing other metals such as magnesium, iron, manganese, nickel, titanium and chromium) are melted using natural gas in refractory-lined ovens. Strontium, a group 2 metal, is often added in small amounts in order to cause small crystal grains to form when the metal solidifies. These small grains make the final product stronger.

Some hydrogen is absorbed into the molten metal as bubbles. This is because the molten aluminium reacts with moisture in the air. If the bubbles were left, they would cause a weakness in the final product. They are removed by blowing nitrogen gas through the mixture. Nitrogen absorbs the hydrogen and both gases are removed from the furnace. Aluminium oxide is also formed and floats to the surface. It is scraped off along with other impurities. If the impurities were left they would form impure lumps within the body of the cast object.

Preparing to blow nitrogen through the molten aluminium to remove traces of hydrogen dissolved in the metal

Stirring the furnace to ensure that the mixture is the same all the way through

Patterns and moulds

To make a casting mould a 'pattern' has to be made. This is an exact three-dimensional model of the object to be cast. It is made from wood, rubber or resin. The pattern is placed into a mould and sand is packed around it.

Several different types of sand are used. One commonly-used sand is Mansfield sand (also known as Greensand). This occurs naturally and was first discovered by the Romans. It is silica sand with 12–14% clay mixed in, which is bonded by water. It can be recycled by replacing the water lost as steam when the molten metal is poured into the mould. Other sands may have various resins and a catalyst added to them. The catalyst causes the resins in the sand to harden and so adopt the shape of the pattern.

An alloy is a substance made by mixing a metal with one or more other metals or non-metals. Alloys generally have different properties from their constituent elements.

• Can you write the equation for the reaction of aluminium with water to produce hydrogen? (Answer on page 18.)

Checking the mixture after the nitrogen blow

Right: *Pouring molten aluminium into a mould*

The finished object — ready to have excess metal trimmed off and then cleaned up

Right: *Shrinkage occurs as the aluminium cools in the mould*

Silica gel is a covalently bound network structure containing silicon and oxygen atoms.

The mould is made in two halves so that it can be separated and the pattern removed. This leaves a mould with the imprint of the object to be cast in it.

Channels are cut so that molten aluminium can be poured into the mould and to allow trapped air to escape. A reservoir is added so that when the molten metal contracts as it cools the mould can be topped up with molten metal (Box 2).

Aluminium shrinks by 6–7 % as it turns from liquid into a solid and then by a further 1.3% as the solid metal cools to room temperature. Patterns are therefore made larger by 1.3% to take into account any shrinkage. Often a ceramic filter is used in the mould to trap any remaining impurities and to stop them becoming part of the object being cast. Impurities weaken the structure.

• Find out more about the White Eagle Foundry on its website (www.wef.co.uk).

Box 2 Runners and risers

Channels which are added to allow metals to enter the mould are called **runners**. Extra shapes which may be added to feed the molten metal as it contracts are called **risers**.

Equation for reaction of aluminium with water:

$$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$$

Finishing the casting

Sometimes hollow objects may have to be cast, or shapes that cannot be cast from a single mould. If this is the case cores are used. These are special patterns which are made from a mixture of sand and silica gel. In order to get the silica gel to harden, carbon dioxide gas is blown over the pattern as it reacts with the silica gel.

Once the mould has been filled with molten aluminium alloy, it is allowed to cool. The sand is then knocked away from the cast object — this is usually with a sledge hammer! Any extraneous pieces of aluminium are sawn off — this is known as fettling — and the object is polished or treated prior to its use. Waste aluminium which has been cut off is returned to the melting furnace ready to be reused. The sand is crushed and screened to ensure that all the particles are of the correct size before being reused — this can be repeated many times before the sand finally becomes unworkable.

Finally

The casting process is labour intensive and so the objects produced are relatively expensive. This method is usually used when just a small number of items are made, or when items have a particularly complex shape. Countries such as China, where labour is cheaper, are now starting to compete for trade, with the inevitable closure of a number of foundries in the UK.

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