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THE PRODUCTION OF ALUMINIUM

Aluminium is a light, conductive, corrosion resistant metal with a strong affinity for oxygen. This combination of properties have made it a widely used material, with applications in the aerospace, architectural construction and marine industries, as well as many domestic uses. It is only over the last century, however, that it has been possible to economically refine aluminium, due to the enormous amount of energy needed to electrolyse its oxide.

Aluminium occurs naturally as the mineral bauxite (primarily a mixture of $Al_2O_3 \cdot 3H_2O$, Fe_2O_3 and SiO_2), and is purified in the following process.

Step 1 - Purification of raw materials
Bauxite is mined at Weipa, in Queensland, then crushed and washed to remove water soluble impurities. The remaining material is dissoved in NaOH and heated. where Al_2O_3 is selectively dissolved by the reaction

$$Al_2O_3 + 6NaOH + 3H_2O \rightarrow 2Na_3Al(OH)_6$$

Some crystalline forms of SiO_2 can also dissolve by the reaction

$$SiO_2 + 4NaOH \rightarrow Na_4SiO_4 + 2H_2O$$

These two new species are soluble, but Fe_2O_3 is a basic oxide and hence it is insoluble in this solution and can be filtered out. Over time the $Na_3Al(OH)_6$ decomposes to $Al(OH)_3$ (an insoluble species), which is also filtered out.

$$Na_3Al(OH)_6 + 2H_2O \rightarrow 3NaOH + Al(OH)_3 \cdot 3H_2O$$

This is then decomposed by heating to tempertures above 1000 °C to give alumina, Al_2O_3.

$$2Al(OH)_3 \cdot 3H_2O \rightarrow Al_2O_3 + 9H_2O$$

Step 2 - Reduction of the alumina
The resultant alumina (Al_2O_3) is dissolved in molten cryolite (Na_3AlF_6), forming an ionic and electrically conductive solution. This is decomposed by electrolysis, using a consumable carbon anode with two concurrent reactions proceding according to the following equations:

$$Al_2O_3 + 3C \rightarrow 2Al + 3CO$$

$$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$$

The aluminium produced is subsequently alloyed depending on the required end-product. Alloying reagents include Cu, Mg and Si and these are added in a metal treatment furnace because of the importance of precise composition control in order to impart the desired properties.

INTRODUCTION

The first aluminium to be produced commercially in New Zealand was at the New Zealand Aluminium Smelters Ltd. plant at Tiwai Point, Southland, in April 1971. The N.Z.A.S. plant is 79% owned by Comalco New Zealand Ltd. and 21% by Sumitomo Chemicals Ltd. It extracts aluminium from alumina imported from the Queensland Alumina Ltd. (Q.A.L.) refinery in Gladstone, Queensland. This is the largest alumina refinery in the world, processing the extensive ore-body in the Weipa region. Electrical energy from Lake Manapouri, Fiordland, New Zealand, is also used. Each year over 300 000 tonnes of metal

3rd

are produced and the value of the exported metal accounts for about one sixth of the annual value of manufactured goods exported from New Zealand.

Aluminium is found in many rock minerals, usually combined with silicon and oxygen in compounds called alumino silicates. Under certain types of tropical soil weathering these alumino-silicate compounds are separated into layers of hydrated iron oxide, hydrated alumina and silica. When such deposits are rich in alumina, they comprise the mineral bauxite. The Weipa deposits are 45-55% alumina as $Al_2O_3{\cdot}3H_2O$, with the remainder being water, iron oxide, silica and titania (TiO_2).

This plant produces about 4 million tonnes of pure alumina per year, which is shipped to smelters around the world.

Properties
Aluminium is a lightweight, durable metal. It is silvery in appearance when freshly cut, is a good conductor of heat and electricity and is easily shaped by moulding and extruding. Aluminium has two main advantages when compared with other metals. Firstly, it has a low density, about one third that of iron and copper. Secondly, although it reacts rapidly with the oxygen in air, it forms a thin tough and impervious oxide layer which resists further oxidation. This removes the need for suface protection coatings such as those required with other metals, in particular with iron.

There are five principal characteristic properties of aluminium. Comparative figures for Al, Cu and Fe are given for the first three in **Table 1**.

Table 1 - Comparisons of some of the characteristic properties of aluminium

Property	**Property/Units**	**Al**	**Cu**	**Fe**
Lightness	Density/g cm^{-3}	2.70	8.96	7.87
Electrical conductivity	International annealed copper standard	49.6	103.6*	17.8
Thermal conductivity	J $cm^{-1}s^{-1}K^{-1}$†	2.47	3.94	0.84

* w/w aluminium is a better conductor of electricity than copper.
† i.e. the heat conducted per second through a 1 cm cube of metal when the temperature difference betwen two faces is 1°C

In addition, aluminium has a high corrosion resistance because of the tough oxide film always present on the surface of aluminium in the presence of air, water vapour, etc., and it has a strong affinity for oxygen.

Usage
These properties lead to a variety of specialised uses.

Lightness. Use in aerospace and transport industries, as its lightness enables a greater volume of metal to be used, thus giving greater rigidity. Also used in pistons, connecting rods, etc. to give better balance, reduced friction and lower bearing loads, meaning that less energy is required to overcome inertia.

Electrical conductivity. Used extensively for electrical conductors, especially in overhead cables. However this requires a high purity grade (in excess of 99.93%).

Thermal conductivity. Extensive usage in heat exchangers, cooking utensils, pistons, etc.

Corrosion resistance. This is made use of in chemical plant, food industry packaging, building and marine applications. Aluminium paint is widely used. The oxide film can be thickened by anodising, and the film can be dyed in a wide range of colours. This is done by making the article the anode of a direct current electrolysis cell using an electrolyte solution of approximately 15% sulfuric acid.

$$2Al + 3H_2O \rightarrow Al_2O_3 + 6H^+ + 6e^-$$

Affinity for oxygen. This allows it to be used in explosives, as a deoxidant in steels, in thermic reactions for welding and for the manufacture of hardener alloys such as ferro-titanium. In these applications a finely powdered form (and hence a high surface area to weight ratio) is used. This property also makes possible the thermite reaction, which produces molten iron.

The thermite reaction is used by the N.Z. Railways to weld sections of rail together on the track. A mould is clamped around the ends of the two pieces of rail to be joined and any gaps sealed with sand. A previously prepared mixture of iron oxide and powdered aluminium is placed in a crucible and ignited. Ignition powders such as a mixture of barium peroxide and aluminium powder can be used, but ignition tape is more convenient. The heat from the ignition mixture starts the thermite reaction.

ignition reaction: $2Al + 3BaO_2 \rightarrow Al_2O_3 + 3BaO + \text{heat}$

thermite reaction: $2Al + Fe_2O_3 \rightarrow Al_2O_3 + 2Fe + \text{heat}$

The heat of this reaction is such that temperatures of up to 3000°C are reached and the iron formed is molten. The iron is run from the crucible into the gap between the rails which has been heated just previously with an oxy-acetylene torch. As the join cools, the mould is broken away and the excess metal trimmed off with a cold chisel and sledge hammer. The final smoothing is done with a portable grinding machine that is guided by the rail. However today nowdays direct Thermite welding is more common, powdered FeO and Al being placed between the two pieces to be jointed.

THE BAUXITE PURIFICATION PROCESS

To produce metal of high quality it is essential to start with alumina of high purity and to strictly control the reduction process. The process consists of two parts:

1. Chemical purification of raw materials to form a high purity alumina.
2. Reduction of alumina.

The major raw materials used in the manufacture of aluminium are shown in **Table 2**. Other raw materials include oil for manufacture of electrode blocks and the metals for alloying with pure aluminium.