

Aluminium

Aluminium or **aluminum** is a silvery white and ductile member of the boron group of chemical elements. It has the symbol **Al**; its atomic number is 13. It is not soluble in water under normal circumstances. Aluminium is the most abundant metal in the Earth's crust, and the third most abundant element overall, after oxygen and silicon. It makes up about 8% by weight of the Earth's solid surface. Aluminium is too reactive chemically to occur in nature as the free metal. Instead, it is found combined in over 270 different minerals.^[1] The chief source of aluminium is bauxite ore.

Aluminium is remarkable for its ability to resist corrosion (due to the phenomenon of passivation) and its light weight. Structural components made from aluminium and its alloys are vital to the aerospace industry and very important in other areas of transportation and building. Its reactive nature makes it useful as a catalyst or additive in chemical mixtures, including being used in ammonium nitrate explosives to enhance blast power.

Characteristics

Aluminium is a soft, lightweight, malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. Aluminium is nontoxic, nonmagnetic, and nonsparking. It is also insoluble in alcohol, though it can be soluble in water in certain forms. The yield strength of pure aluminium is 7–11 MPa, while aluminium alloys have yield strengths ranging from 200 MPa to 600 MPa.^[2] Aluminium has about one-third the density and stiffness of steel. It is ductile, and easily machined, cast, and extruded.

Corrosion resistance is excellent due to a thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest aluminium alloys are less corrosion resistant due to galvanic reactions with alloyed copper.^[2]

Aluminium atoms are arranged in an face-centered cubic (FCC) structure. Aluminium has a high stacking-fault energy of approximately 200 mJ/m².^[3]

Aluminium is one of the few metals that retain full silvery reflectance in finely powdered form, making it an important component of silver paints. Aluminium mirror finish has the highest reflectance of any metal in the 200–400 nm (UV) and the 3000–10000 nm (far IR) regions, while in the 400–700 nm visible range it is slightly outdone by tin and silver and in the 700–3000 (near IR) by silver, gold, and copper.^[citation needed]

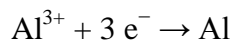
Aluminium is a good thermal and electrical conductor, by weight better than copper. Aluminium is capable of being a superconductor, with a superconducting critical temperature of 1.2 kelvins and a critical magnetic field of about 100 gauss.^[4]

Production and refinement

Although aluminium is the most abundant metallic element in the Earth's crust (believed to be 7.5 to 8.1 percent), it is rare in its free form, occurring in oxygen-deficient environments such as volcanic mud, and it was once considered a precious metal more valuable than gold. Napoleon III, emperor of France, is reputed to have given a banquet where the most honoured guests were given aluminium utensils, while the other guests had to make do with gold.^{[7][8]} The Washington Monument was completed, with the 100 ounce (2.8 kg) aluminium capstone being put in place on December 6, 1884, in an elaborate dedication ceremony. It was the largest single piece of aluminium cast at the time. At that time, aluminium was more expensive than silver, gold, or platinum. Aluminium has been produced in commercial quantities for just over 100 years.

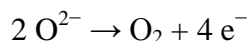
Aluminium is a strongly reactive metal that forms a high-energy chemical bond with oxygen. Compared to most other metals, it is difficult to extract from ore, such as bauxite, due to the energy required to reduce aluminium oxide (Al_2O_3). For example, direct reduction with carbon, as is used to produce iron, is not chemically possible, since aluminium is a stronger reducing agent than carbon. Aluminium oxide has a melting point of about 2,000 °C. Therefore, it must be extracted by electrolysis. In this process, the aluminium oxide is dissolved in molten cryolite and then reduced to the pure metal. The operational temperature of the reduction cells is around 950 to 980 °C. Cryolite is found as a mineral in Greenland, but in industrial use it has been replaced by a synthetic substance. Cryolite is a chemical compound of aluminium, sodium, and calcium fluorides: (Na_3AlF_6). The aluminium oxide (a white powder) is obtained by refining bauxite in the Bayer process of Karl Bayer. (Previously, the Deville process was the predominant refining technology.)

The electrolytic process replaced the Wöhler process, which involved the reduction of anhydrous aluminium chloride with potassium. Both of the electrodes used in the electrolysis of aluminium oxide are carbon. Once the ore is in the molten state, its ions are free to move around. The reaction at the cathode (negative electrode) is

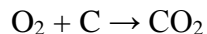


Here the aluminium ion is being reduced (electrons are added). The aluminium metal then sinks to the bottom and is tapped off.

At the anode (positive electrode), oxygen is formed:

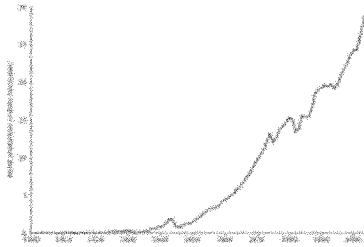


This carbon anode is then oxidized by the oxygen, releasing carbon dioxide.



The anodes in a reduction cell must therefore be replaced regularly, since they are consumed in the process.

Unlike the anodes, the cathodes are not oxidized because there is no oxygen present, as the carbon cathodes are protected by the liquid aluminium inside the cells. Nevertheless, cathodes do erode, mainly due to electrochemical processes. After five to ten years, depending on the current used in the electrolysis, a cell has to be rebuilt because of cathode wear.



World production trend of aluminium

Aluminium electrolysis with the Hall-Héroult process consumes a lot of energy, but alternative processes were always found to be less viable economically and/or ecologically. The worldwide average specific energy consumption is approximately 15 ± 0.5 kilowatt-hours per kilogram of aluminium produced (52 to 56 MJ/kg). The most modern smelters achieve approximately $12.8 \text{ kW}\cdot\text{h}/\text{kg}$ (46.1 MJ/kg). (Compare this to the heat of reaction, 31 MJ/kg, and the Gibbs free energy of reaction, 29 MJ/kg.) Reduction line currents for older technologies are typically 100 to 200 kA; state-of-the-art smelters^[9] operate at about 350 kA. Trials have been reported with 500 kA cells.

Recovery of the metal via recycling has become an important facet of the aluminium industry. Recycling involves melting the scrap, a process that requires only five percent of the energy used to produce aluminium from ore. However, a significant part (up to 15% of input material) is lost as dross (ash-like oxide).^[10] Recycling was a low-profile activity until the late 1960s, when the growing use of aluminium beverage cans brought it to the public consciousness.

Electric power represents about 20% to 40% of the cost of producing aluminium, depending on the location of the smelter. Smelters tend to be situated where electric power is both plentiful and inexpensive, such as South Africa, the South Island of New Zealand, Australia, the People's Republic of China, the Middle East, Russia, Quebec and British Columbia in Canada, and Iceland.



Aluminium output in 2005

In 2005, the People's Republic of China was the top producer of aluminium with almost one-fifth world share, followed by Russia, Canada, and USA, reports the British Geological Survey.

Over the last 50 years, Australia has become a major producer of bauxite ore and a major producer and exporter of alumina.^[11] Australia produced 62 million tonnes of bauxite in 2005. The Australian deposits have some refining problems, some being high in silica but have the advantage of being shallow and relatively easy to mine.^[12]

General use



A piece of aluminium metal.

Aluminium is the most widely used non-ferrous metal.^[14] Global production of aluminium in 2005 was 31.9 million tonnes. It exceeded that of any other metal except iron (837.5 million tonnes).^[15] Relatively pure aluminium is encountered only when corrosion resistance and/or workability is more important than strength or hardness. A thin layer of aluminium can be deposited onto a flat surface by physical vapor deposition or (very infrequently) chemical vapor deposition or other chemical means to form optical coatings and mirrors. When so deposited, a fresh, pure aluminium film serves as a good reflector (approximately 92%) of visible light and an excellent reflector (as much as 98%) of medium and far infrared.

Pure aluminium has a low tensile strength, but when combined with thermo-mechanical processing, aluminium alloys display a marked improvement in mechanical properties, especially when tempered. Aluminium alloys form vital components of aircraft and rockets as a result of their high strength-to-weight ratio. Aluminium readily forms alloys with many elements such as copper, zinc, magnesium, manganese and silicon (e.g., duralumin). Today, almost all bulk metal materials that are referred to loosely as "aluminium," are actually alloys. For example, the common aluminium foils are alloys of 92% to 99% aluminium.^[16]

Some of the many uses for aluminium metal are in:



household aluminium foil

- Transportation (automobiles, aircraft, trucks, railway cars, marine vessels, bicycles etc.)
- Packaging (cans, foil, etc.)
- Water treatment
- Treatment against fish parasites such as *Gyrodactylus salaris*.
- Construction (windows, doors, siding, building wire, etc.)
- Cooking utensils
- Electrical transmission lines for power distribution
- MKM steel and Alnico magnets
- Super purity aluminium (SPA, 99.980% to 99.999% Al), used in electronics and CDs.
- Heat sinks for electronic appliances such as transistors and CPUs.
- Powdered aluminium is used in paint, and in pyrotechnics such as solid rocket fuels and thermite.
- In the blades of prop swords and knives used in stage combat.
- Aluminium is widely used in watch production as it provides durability and resists tarnishing and corrosion.^[17]