

Introduction

Aluminum has many useful properties. It is the commonest metal in the rocks of the Earth's crust. About 8% of the crust is aluminium, not the metal itself but combined with other elements as natural minerals, such as **bauxite**.

MAIN PROPERTIES OF ALUMINIUM

1. An excellent conductor of heat and electricity.
2. Aluminium does not rust, it resists corrosion.
4. Low density compared with other common metals.
5. Good reflector of heat and light, it has a good metallic lustre (surface shine).
6. Nonmagnetic.
7. Can be alloyed to form stronger or harder alloys than pure aluminium.
8. Easily workable. It can be rolled into sheets, foil, and wire; cast or forged into useful shapes.

- **Aluminium ores** are

Bauxite $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ (Main)

Gibbsite $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

Diaspore $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$.

It contains impurities as well as aluminium oxide. The bauxite must be purified to give alumina (Al_2O_3).

- Aluminium is a very reactive metal, much more reactive than copper, iron or lead. Other metals have been extracted for thousands of years by heating them with carbon (smelting). Carbon is also needed to extract aluminium, but in a completely different way.
- **Ore dressing**—cleaning ore by means of separation of the metal containing mineral from the waste (gangue).

Bayer Process

- The bauxite ore is **crushed and ground** to produce slurry of coarse powder particles suspended in water.
- **Sodium hydroxide** (caustic soda) **NaOH** is added, and the slurry is heated with process steam to 160-180°C in a steel reactor or autoclave with pressure. The **aluminum-containing hydroxides** are dissolved during this **digestion** process, but other constituents of the bauxite remain solid.
- The digested bauxite suspension, which contains solids plus dissolved Al compounds, is referred to as **pregnant liquor**. It leaves the digester at about boiling temperature and passes through several stages of **filtration** referred to as clarification.
- **Precipitation** is conducted in large flat-bottomed tanks about 30 m high and 10-12 m in diameter with typically 10 to 14 in a series. Cooled supersaturated liquor enters the first tank, and particles of **aluminum hydroxide** begin to precipitate. Seeds (small particles of aluminum hydroxide) are added **to accelerate precipitation**.
- **Classification** in which the **aluminum hydroxide** particles are separated from the liquor by a combination of **cyclones and hydroclassifiers**. The coarser particles proceed to the **calciner**. The **finer particles are recycled as seeds**.
- **Calcination** is the final step of the Bayer process. The particles are dried and heated to **1100C** in either a **rotary kiln (a tubular-shaped furnace that rotates as the powder passes through)** or a fluidized bed (the kiln is stationary, but the powder is mixed by air bubbled through the powder bed).
- The aluminum hydroxide **Al(OH)₃** (is decomposed to form aluminum oxide (**Al₂O₃**) particles suitable for the **Hall-Heroult electrolytic smelting process**.



Choosing the method to extract a metal from its ore.

- Carbon can be used to extract metals lower in the series, ones which are less reactive than carbon. For example, iron from iron oxide (haematite) or tin from tin oxide (cassiterite).
- Carbon is less reactive than aluminium.** This is why we need a different method, **electrolysis**, to extract **aluminium** from its oxide (**bauxite**). The rule is: Carbon can displace less reactive metals from their ores.
- The carbon forms the anode block and the lining of the pot (the electrolytic cell), the cathode. As electricity flows between them the alumina splits into liquid aluminium metal and oxygen gas.

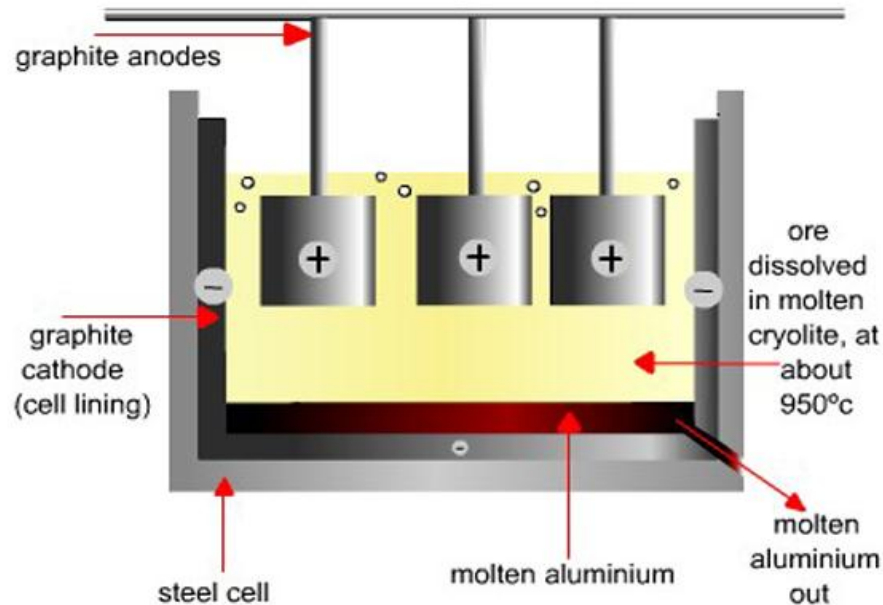
K	Potassium	↑ Most reactive	
Na	Sodium		
Ca	Calcium		
Mg	Magnesium		
Al	Aluminium		
C	Carbon		
Zn	Zinc		
Fe	Iron		
Sn	Tin		
Pb	Lead		
H	Hydrogen		
Cu	Copper		↓ Least reactive
Ag	Silver		
Au	Gold		
Pt	Platinum		
C	H	added for comparison	

Reactivity Series of Metals

Dissolved alumina → **aluminium metal** + oxygen gas

The key to this method of extracting aluminium (**Hall-Heroult process**) was to find a material which could dissolve the alumina. A natural ore called **cryolite** was used,

although the cryolite is prepared artificially now. Each pot can produce about one ton of aluminium each day. The hot liquid metal is removed regularly from the pot and cast into blocks or ingots.



In principle, aluminium could be produced by melting aluminium oxide (alumina) and passing an electric current through it. Unfortunately the oxide is a refractory material with an exceptionally high melting point of about **2000°C**. Refractories are used to line furnaces.

The function of cryolite is **to lower the melting point of aluminium oxide**. By dissolving the alumina in a second aluminium compound (cryolite, Na_3AlF_6) the extraction process can operate at a more economical temperature of **950C**. There is very little alumina in the melt, about 5% alumina and 95% cryolite. Fresh alumina is added regularly as the electrolysis proceeds.

When electric current passes between the anodes and the cathode through the cryolite, aluminum oxide decomposes to metallic aluminum deposited at the cathode and oxygen liberated at the anode.

The molten aluminum is periodically tapped from the furnace into a crucible and cast into ingots.

Electrode Reactions

The carbon cathode (negative electrode) is the lining of the pot.



The aluminium ions gain electrons from the cathode and become aluminium atoms.

The carbon anodes (positive electrodes) are made by baking a mixture of petroleum coke and pitch (مزيج القاروفحم الكوك النفطي). Carbon (graphite) is the only non-metal that is a good conductor of electricity.



The oxide ions lose electrons to the anode and become oxygen gas. There is a problem when hot carbon (the anode) comes into contact with oxygen. The anode burns away to form carbon monoxide and carbon dioxide gases. The anode is slowly lowered into the melt as the surface burns away.

