[Template:About](/wiki/Template:About" \o "Template:About) [Template:Pp-move-indef](/wiki/Template:Pp-move-indef) [Template:Use dmy dates](/wiki/Template:Use_dmy_dates) [Template:Infobox aluminium](/wiki/Template:Infobox_aluminium) **Aluminium** (in [Commonwealth English](/wiki/English_in_the_Commonwealth_of_Nations)) or **aluminum** (in [American English](/wiki/American_English)) is a [chemical element](/wiki/Chemical_element) in the [boron group](/wiki/Boron_group) with symbol **Al** and [atomic number](/wiki/Atomic_number) 13. It is a silvery-white, soft, nonmagnetic, [ductile](/wiki/Ductility) [metal](/wiki/Metal). Aluminium is the third most [abundant element in the Earth's crust](/wiki/Abundance_of_elements_in_Earth's_crust) (after [oxygen](/wiki/Oxygen) and [silicon](/wiki/Silicon)) and its most abundant metal. Aluminium makes up about 8% of the crust by mass, though it is less common in the mantle below. Aluminium metal is so chemically reactive that [native specimens](/wiki/Native_metal) are rare and limited to extreme [reducing](/wiki/Redox) environments. Instead, it is found combined in over 270 different [minerals](/wiki/Mineral).[[1]](#cite_note-1) The chief [ore](/wiki/Ore) of aluminium is [bauxite](/wiki/Bauxite).

Aluminium is remarkable for the metal's low [density](/wiki/Density) and its ability to resist [corrosion](/wiki/Corrosion) through the phenomenon of [passivation](/wiki/Passivation_(chemistry)). Aluminium and its [alloys](/wiki/Aluminium_alloy) are vital to the [aerospace](/wiki/Aerospace) industry and important in [transportation](/wiki/Transport) and structures, such as building facades and window frames.[Template:Clarify](/wiki/Template:Clarify) The [oxides](/wiki/Oxides) and [sulfates](/wiki/Sulfates) are the most useful compounds of aluminium.[Template:Citation needed](/wiki/Template:Citation_needed)

Despite its prevalence in the environment, no known form of life uses aluminium [salts](/wiki/Salt_(chemistry)) [metabolically](/wiki/Metabolically), but aluminium is well tolerated by plants and animals.<ref name=Ullmann/> Because of their abundance, the potential for a biological role is of continuing interest and studies continue.

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## Characteristics[[edit](/index.php?title=(none)&action=edit&section=1)]

[thumb|"](/wiki/File:Luftaufnahmen_Nordseekueste_2012-05-by-RaBoe-478.jpg)[Bauxite tailings](/wiki/Bauxite_tailings)" storage facility in [Stade](/wiki/Stade), Germany. The aluminium industry generates about 70 million tons of this waste annually.

### Physical[[edit](/index.php?title=(none)&action=edit&section=2)]

Aluminium is a relatively soft, durable, lightweight, [ductile](/wiki/Ductility), and [malleable](/wiki/Malleable) [metal](/wiki/Metal) with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and does not easily ignite. A fresh film of aluminium serves as a good reflector (approximately 92%) of [visible light](/wiki/Visible_light) and an excellent reflector (as much as 98%) of medium and far [infrared](/wiki/Infrared) radiation. The [yield strength](/wiki/Yield_(engineering)) of pure aluminium is 7–11 [MPa](/wiki/Pascal_(unit)), while [aluminium alloys](/wiki/Aluminium_alloy) have yield strengths ranging from 200 MPa to 600 MPa.[[2]](#cite_note-2) Aluminium has about one-third the [density](/wiki/Density) and [stiffness](/wiki/Elastic_modulus) of [steel](/wiki/Steel). It is easily [machined](/wiki/Machining), [cast](/wiki/Casting_(metalworking)), [drawn](/wiki/Drawing_(metalworking)) and [extruded](/wiki/Extrusion).

Aluminium atoms are arranged in a [face-centered cubic](/wiki/Cubic_crystal_system) (fcc) structure. Aluminium has a [stacking-fault energy](/wiki/Stacking-fault_energy) of approximately 200 mJ/m2.[[3]](#cite_note-3) Aluminium is a good [thermal](/wiki/Heat_conduction) and [electrical conductor](/wiki/Electrical_conductor), having 59% the conductivity of copper, both thermal and electrical, while having only 30% of [copper's](/wiki/Copper) density. Aluminium is capable of [superconductivity](/wiki/Superconductor), with a superconducting critical temperature of 1.2 [kelvin](/wiki/Kelvin) and a critical magnetic field of about 100 [gauss](/wiki/Gauss_(unit)) (10 [milliteslas](/wiki/Millitesla)).[[4]](#cite_note-4)

### Chemical[[edit](/index.php?title=(none)&action=edit&section=3)]

[Corrosion](/wiki/Corrosion) resistance can be excellent because a thin surface layer of [aluminium oxide](/wiki/Aluminium_oxide) forms when the bare metal is exposed to air, effectively preventing further [oxidation](/wiki/Oxidation),[[5]](#cite_note-5) in a process termed [passivation](/wiki/Passivation_(chemistry)). The strongest aluminium alloys are less corrosion resistant due to [galvanic](/wiki/Galvanic_cell) reactions with alloyed [copper](/wiki/Copper).[[2]](#cite_note-2) This corrosion resistance is greatly reduced by aqueous salts, particularly in the presence of dissimilar metals.

In highly acidic solutions, aluminium reacts with water to form hydrogen, and in highly alkaline ones to form [aluminates](/wiki/Aluminates)— protective passivation under these conditions is negligible. Primarily because it is corroded by dissolved [chlorides](/wiki/Chlorides), such as common [sodium chloride](/wiki/Sodium_chloride), household plumbing is never made from aluminium.[[6]](#cite_note-6) However, because of its general resistance to corrosion, aluminium is one of the few metals that retains silvery reflectance in finely powdered form, making it an important component of [silver-colored](/wiki/Silver_(color)) paints. Aluminium mirror finish has the highest [reflectance](/wiki/Reflectance) of any metal in the 200–400 nm ([UV](/wiki/Ultraviolet)) and the 3,000–10,000 nm (far [IR](/wiki/Infrared)) regions; in the 400–700 nm visible range it is slightly outperformed by [tin](/wiki/Tin) and [silver](/wiki/Silver) and in the 700–3000 nm (near IR) by [silver](/wiki/Silver), [gold](/wiki/Gold), and [copper](/wiki/Copper).[[7]](#cite_note-7) Aluminium is [oxidized](/wiki/Oxidized) by [water](/wiki/Water) at temperatures below 280 °C to produce [hydrogen](/wiki/Hydrogen), [aluminium hydroxide](/wiki/Aluminium_hydroxide) and heat:

2 Al + 6 H2O → 2 Al(OH)3 + 3 H2

This conversion is of interest for the production of hydrogen. However, commercial application of this fact has challenges in circumventing the passivating oxide layer, which inhibits the reaction, and in storing the energy required to regenerate the aluminium metal.[[8]](#cite_note-8)

### Isotopes[[edit](/index.php?title=(none)&action=edit&section=4)]

[Template:Main](/wiki/Template:Main) Aluminium has many known [isotopes](/wiki/Isotope), with mass numbers range from 21 to 42; however, only 27Al ([stable](/wiki/Stable_isotope)) and 26Al ([radioactive](/wiki/Radioactive_decay), [t1⁄2](/wiki/Half-life) = 7.2×105 years) occur naturally. 27Al has a natural abundance above 99.9%. 26Al is produced from [argon](/wiki/Argon) in the [atmosphere](/wiki/Earth's_atmosphere) by [spallation](/wiki/Spallation) caused by [cosmic-ray](/wiki/Cosmic-ray) [protons](/wiki/Proton). Aluminium isotopes are useful in dating [marine](/wiki/Ocean) sediments, manganese nodules, glacial ice, [quartz](/wiki/Quartz) in [rock](/wiki/Rock_(geology)) exposures, and [meteorites](/wiki/Meteorite). The ratio of 26Al to 10[Be](/wiki/Beryllium) has been used to study transport, deposition, [sediment](/wiki/Sediment) storage, burial times, and erosion on 105 to 106 year time scales.[[9]](#cite_note-9) [Cosmogenic](/wiki/Cosmogenic) 26Al was first applied in studies of the Moon and meteorites. Meteoroid fragments, after departure from their parent bodies, are exposed to intense cosmic-ray bombardment during their travel through space, causing substantial 26Al production. After falling to Earth, atmospheric shielding drastically reduces 26Al production, and its decay can then be used to determine the meteorite's terrestrial age. Meteorite research has also shown that 26Al was relatively abundant at the time of formation of our planetary system. Most meteorite scientists believe that the energy released by the decay of 26Al was responsible for the melting and [differentiation](/wiki/Planetary_differentiation) of some [asteroids](/wiki/Asteroids) after their formation 4.55 billion years ago.[[10]](#cite_note-10)

### Natural occurrence[[edit](/index.php?title=(none)&action=edit&section=5)]

[Template:See also](/wiki/Template:See_also) Stable aluminium is created when [hydrogen](/wiki/Hydrogen) fuses with [magnesium](/wiki/Magnesium), either in large stars or in [supernovae](/wiki/Supernova).[[11]](#cite_note-11) It is estimated to be the 14th most common element in the Universe, by mass-fraction.[[12]](#cite_note-12) The Earth's crust has a greater abundance of aluminium than the rest of the planet, primarily in aluminium silicates. In the Earths [mantle](/wiki/Mantle_(geology)), which is only 2% aluminium by mass, these aluminium silicate minerals are largely replaced by [silica](/wiki/Silica) and magnesium oxides. Overall, the Earth is about 1.4% aluminium by mass (eighth in abundance by mass). Aluminium occurs in greater proportion in the Earth than in the Solar system and Universe because the more common elements (hydrogen, helium, neon, nitrogen, carbon as hydrocarbon) are volatile at Earth's proximity to the Sun and large quantities of those were lost.

Because of its strong affinity for oxygen, aluminium is almost never found in the elemental state; instead it is found in oxides or silicates. [Feldspars](/wiki/Feldspar), the most common group of minerals in the Earth's crust, are aluminosilicates. Native aluminium metal can only be found as a minor phase in low oxygen [fugacity](/wiki/Fugacity) environments, such as the interiors of certain volcanoes.[[13]](#cite_note-13) Native aluminium has been reported in [cold seeps](/wiki/Cold_seep) in the northeastern [continental slope](/wiki/Continental_slope) of the [South China Sea](/wiki/South_China_Sea). Chen *et al.* (2011)[[14]](#cite_note-14) propose the theory that these deposits resulted from [bacterial](/wiki/Bacteria) [reduction](/wiki/Redox) of tetrahydroxoaluminate Al(OH)4−.[[14]](#cite_note-14) Aluminium also occurs in the minerals [beryl](/wiki/Beryl), [cryolite](/wiki/Cryolite), [garnet](/wiki/Garnet), [spinel](/wiki/Spinel), and [turquoise](/wiki/Turquoise). Impurities in Al2O3, such as [chromium](/wiki/Chromium) and [iron](/wiki/Iron), yield the [gemstones](/wiki/Gemstone) [ruby](/wiki/Ruby) and [sapphire](/wiki/Sapphire), respectively.

Although aluminium is a common and widespread element, not all aluminium minerals are economically viable sources of the metal. Almost all metallic aluminium is produced from the [ore](/wiki/Ore) bauxite (AlO*x*(OH)3–2*x*). Bauxite occurs as a [weathering](/wiki/Weathering) product of low iron and silica bedrock in tropical climatic conditions.[[15]](#cite_note-15) Bauxite is mined from large deposits in Australia, Brazil, Guinea, and Jamaica; it is also mined from lesser deposits in China, India, Indonesia, Russia, and Suriname.

## Production and refinement[[edit](/index.php?title=(none)&action=edit&section=6)]

[Template:See also](/wiki/Template:See_also) [thumb||Bauxite, a major aluminium ore. The red-brown color is due to the presence of](/wiki/File:Bauxite_hérault.JPG) [iron](/wiki/Iron) minerals.

### Bayer process and Hall-Héroult processes[[edit](/index.php?title=(none)&action=edit&section=7)]

Bauxite is converted to aluminium oxide (Al2O3) by the [Bayer process](/wiki/Bayer_process).<ref name=Ullmann/> Relevant [chemical equations](/wiki/Chemical_equation) are:

Al2O3 + 2 NaOH → 2 NaAlO2 + H2O

2 H2O + NaAlO2 → Al(OH)3 + NaOH

The intermediate, sodium aluminate, with the simplified formula NaAlO2, is soluble in strongly alkaline water, and the other components of the ore are not. Depending on the quality of the bauxite ore, twice as much waste ("[Bauxite tailings](/wiki/Bauxite_tailings)") as alumina is generated.

The conversion of alumina to aluminium metal is achieved by the [Hall-Héroult process](/wiki/Hall-Héroult_process). In this energy-intensive process, a solution of alumina in a molten ([Template:Convert](/wiki/Template:Convert)) mixture of [cryolite](/wiki/Cryolite) (Na3AlF6) with [calcium fluoride](/wiki/Calcium_fluoride) is [electrolyzed](/wiki/Electrolysis) to produce metallic aluminium:

Al3+ + 3 e− → Al

The liquid aluminium metal sinks to the bottom of the solution and is tapped off, and usually cast into large blocks called [aluminium billets](/wiki/Bar_stock) for further processing. Oxygen is produced at the anode:

2 O2− + C → CO2 + 4 e−

The carbon anode is consumed by reaction with oxygen to form carbon dioxide gas, with a small quantity of [fluoride](/wiki/Fluoride) gases. In modern smelters, the gas is filtered through alumina to remove fluorine compounds and return aluminium fluoride to the [electrolytic](/wiki/Electrolytic) cells. The anode this reduction cell must be replaced regularly, since it is consumed in the process. The cathode is also eroded, mainly by electrochemical processes and liquid metal movement [induced](/wiki/Electromagnetic_induction) by intense electrolytic currents. After five to ten years, depending on the current used in the electrolysis, a cell must be rebuilt because of cathode wear.

[thumb|lang=en|World production trend of aluminium](/wiki/File:Aluminium_-_world_production_trend.svg)

Aluminium electrolysis with the [Hall-Héroult](/wiki/Hall-Héroult) process consumes a lot of energy. The worldwide average specific energy consumption is approximately 15±0.5 [kilowatt-hours](/wiki/Kilowatt-hour) per kilogram of aluminium produced (52 to 56 [MJ](/wiki/Megajoule)/kg). Some smelters achieve approximately 12.8 kW·h/kg (46.1 MJ/kg). (Compare this to the [heat of reaction](/wiki/Heat_of_reaction), 31 MJ/kg, and the [Gibbs free energy](/wiki/Gibbs_free_energy) of reaction, 29 MJ/kg.) Minimizing line currents for older technologies are typically 100 to 200 [kiloamperes](/wiki/Kiloampere); state-of-the-art smelters operate at about 350 kA. Trials have been reported with 500 kA cells.[Template:Citation needed](/wiki/Template:Citation_needed)

The Hall-Heroult process produces aluminium with a purity of above 99%. Further purification can be done by the [Hoopes process](/wiki/Hoopes_process). This process involves the electrolysis of molten aluminium with a sodium, barium and aluminium fluoride electrolyte. The resulting aluminium has a purity of 99.99%.<ref name=Ullmann> [Template:Cite book](/wiki/Template:Cite_book)</ref>[[16]](#cite_note-16) Electric power represents about 20% to 40% of the cost of producing aluminium, depending on the location of the smelter. Aluminium production consumes roughly 5% of electricity generated in the U.S.[[17]](#cite_note-17) Aluminium producers tend to locate smelters in places where electric power is both plentiful and inexpensive—such as the United Arab Emirates with its large natural gas supplies,[[18]](#cite_note-18) and Iceland[[19]](#cite_note-19) and Norway[[20]](#cite_note-20) with energy generated from [renewable sources](/wiki/Renewable_resource). The world's largest [smelters](/wiki/Smelting) of alumina are located in the People's Republic of China, Russia and the provinces of [Quebec](/wiki/Quebec) and [British Columbia](/wiki/British_Columbia) in Canada.[[17]](#cite_note-17)[[21]](#cite_note-21)[[22]](#cite_note-22) [thumb|Aluminium spot price 1987–2012](/wiki/File:Al-spotprice1987-2012.svg) In 2005, the People's Republic of China was the top producer of aluminium with almost a one-fifth world share, followed by Russia, Canada, and the US, reports the [British Geological Survey](/wiki/British_Geological_Survey).

Over the last 50 years, Australia has become the world's top producer of bauxite ore and a major producer and exporter of alumina (before being overtaken by China in 2007).[[21]](#cite_note-21)[[23]](#cite_note-23) Australia produced 77 million [tonnes](/wiki/Tonne) of bauxite in 2013.[[24]](#cite_note-24) The Australian deposits have some refining problems, some being high in silica, but have the advantage of being shallow and relatively easy to mine.[[25]](#cite_note-25)

### Aluminium chloride electrolysis process[[edit](/index.php?title=(none)&action=edit&section=8)]

The high energy consumption of [Hall-Héroult](/wiki/Hall-Héroult) process motivated the development of the electrolytic process based on [aluminium chloride](/wiki/Aluminium_chloride). The pilot plant with 6500 tons/year output was started in 1976 by [Alcoa](/wiki/Alcoa). The plant offered two advantages: (i) energy requirements were 40% less than plants using the Hall-Héroult process, and (ii) the more accessible [kaolinite](/wiki/Kaolinite) (instead of [bauxite](/wiki/Bauxite) and [cryolite](/wiki/Cryolite)) was used for feedstock. Nonetheless, the pilot plant was shut down. The reasons for failure were the cost of aluminium chloride, general technology maturity problems, and leakage of the trace amounts of extremely toxic [polychlorinated biphenyl](/wiki/Polychlorinated_biphenyl) compounds.[[26]](#cite_note-26) Aluminium chloride process can also be used for the co-production of [titanium](/wiki/Titanium), depending on titanium contents in [kaolinite](/wiki/Kaolinite).

### Aluminium carbothermic process[[edit](/index.php?title=(none)&action=edit&section=9)]

The non-electrolytic *aluminium carbothermic* process of aluminium production would theoretically be cheaper and consume less energy. However, it has been in the experimental phase for decades because the high operating temperature creates difficulties in material technology that have not yet been solved.[[27]](#cite_note-27) as is aluminium potassium sulfate ([Al(K)](SO4)2)·(H2O)12. The consumption of both alums is declining.

#### Chlorides[[edit](/index.php?title=(none)&action=edit&section=26)]

[Aluminium chloride](/wiki/Aluminium_chloride) (AlCl3) is used in [petroleum](/wiki/Petroleum) [refining](/wiki/Refining) and in the production of synthetic [rubber](/wiki/Rubber) and polymers. Although it has a similar name, [aluminium chlorohydrate](/wiki/Aluminium_chlorohydrate) has fewer and very different applications, particularly as a colloidal agent in water purification and an [antiperspirant](/wiki/Antiperspirant). It is an intermediate in the production of aluminium metal.

#### Niche compounds[[edit](/index.php?title=(none)&action=edit&section=27)]

[Template:Refimprove](/wiki/Template:Refimprove) Many aluminium compounds have niche applications:

* A[luminium acetate](/wiki/Aluminium_acetate) in solution is used as an [astringent](/wiki/Astringent).
* [aluminium borate](/wiki/Aluminium_borate) (Al2O3·B2O3) and [aluminium fluorosilicate](/wiki/Aluminium_fluorosilicate) (Al2(SiF6)3) are used in the production of [glass](/wiki/Glass), [ceramics](/wiki/Ceramic), synthetic [gemstones](/wiki/Gemstone).
* A[luminium phosphate](/wiki/Aluminium_phosphate) (AlPO4) used in the manufacture of glass, ceramic, [pulp](/wiki/Wood_pulp) and paper products, [cosmetics](/wiki/Cosmetics), paints, [varnishes](/wiki/Varnish), and in dental [cement](/wiki/Cement).
* [Aluminium hydroxide](/wiki/Aluminium_hydroxide) (Al(OH)3) is used as an [antacid](/wiki/Antacid), and mordant; it is used also in [water](/wiki/Water) purification, the manufacture of glass and ceramics, and in the [waterproofing](/wiki/Waterproofing) [fabrics](/wiki/Textile).
* [Lithium aluminium hydride](/wiki/Lithium_aluminium_hydride) is a powerful reducing agent used in [organic chemistry](/wiki/Organic_chemistry).
* [Organoaluminiums](/wiki/Organoaluminium_chemistry) are used as [Lewis acids](/wiki/Lewis_acid) and cocatalysts.
* M[ethylaluminoxane](/wiki/Methylaluminoxane) is a cocatalyst for [Ziegler-Natta](/wiki/Ziegler-Natta) [olefin](/wiki/Olefin) [polymerization](/wiki/Polymerization) to produce [vinyl polymers](/wiki/Vinyl_polymer) such as [polyethene](/wiki/Polyethene).
* Aqueous aluminium ions (such as aqueous aluminium sulfate) are used to treat against fish parasites such as [*Gyrodactylus salaris*](/wiki/Gyrodactylus_salaris).
* In many [vaccines](/wiki/Vaccine), certain aluminium salts serve as an immune [adjuvant](/wiki/Immunologic_adjuvant) (immune response booster) to allow the [protein](/wiki/Protein) in the vaccine to achieve sufficient potency as an immune stimulant.

### Aluminium alloys in structural applications[[edit](/index.php?title=(none)&action=edit&section=28)]

[Template:Main](/wiki/Template:Main) [thumb|](/wiki/File:Aluminium_foam.jpg)[Aluminium foam](/wiki/Aluminium_foam) [Template:Unreferenced section](/wiki/Template:Unreferenced_section) Aluminium alloys with a wide range of properties are used in engineering structures. Alloy systems are classified by a number system ([ANSI](/wiki/American_National_Standards_Institute)) or by names indicating their main alloying constituents ([DIN](/wiki/DIN) and [ISO](/wiki/International_Organization_of_Standardization)).

The strength and durability of aluminium alloys vary widely, not only as a result of the components of the specific alloy, but also as a result of heat treatments and manufacturing processes. A lack of knowledge of these aspects has from time to time led to improperly designed structures and gained aluminium a bad reputation.

One important structural limitation of aluminium alloys is their [fatigue](/wiki/Fatigue_(material)) strength. Unlike steels, aluminium alloys have no well-defined [fatigue limit](/wiki/Fatigue_limit), meaning that fatigue failure eventually occurs, under even very small cyclic loadings. Engineers must assess applications and design for a [fixed and finite life](/wiki/Fatigue_(material)#Design_against_fatigue) of the structure, rather than infinite life.

Another important property of aluminium alloys is sensitivity to heat. Workshop procedures are complicated by the fact that aluminium, unlike steel, melts without first glowing red. Manual [blow torch](/wiki/Blow_torch) operations require additional skill and experience. Aluminium alloys, like all structural alloys, are subject to internal stresses after heat operations such as welding and casting. The lower [melting point](/wiki/Melting_point)s of aluminium alloys make them more susceptible to distortions from thermally induced stress relief. Stress can be relieved and controlled during manufacturing by heat-treating the parts in an oven, followed by gradual cooling—in effect [annealing](/wiki/Annealing_(metallurgy)) the stresses.

The low melting point of aluminium alloys has not precluded use in rocketry, even in combustion chambers where gases can reach 3500 K. The [Agena](/wiki/RM-81_Agena) upper stage engine used regeneratively cooled aluminium in some parts of the nozzle, including the thermally critical throat region.

Another alloy of some value is [aluminium bronze](/wiki/Aluminium_bronze) (Cu-Al alloy).

## History[[edit](/index.php?title=(none)&action=edit&section=29)]

[thumb||The statue of the](/wiki/File:Eros-piccadilly-circus.jpg) [Anteros](/wiki/Anteros) in [Piccadilly Circus](/wiki/Piccadilly_Circus), London, was made in 1893 and is one of the first statues cast in aluminium.

Ancient [Greeks](/wiki/Ancient_Greece) and [Romans](/wiki/Ancient_Rome) used aluminium salts as dyeing mordants and as astringents for dressing wounds; [alum](/wiki/Alum) is still used as a [styptic](/wiki/Styptic). In 1782, [Guyton de Morveau](/wiki/Guyton_de_Morveau) suggested calling the "base" of (i.e., the metallic element in) alum *alumine.*[[51]](#cite_note-51) In 1808, [Humphry Davy](/wiki/Humphry_Davy) identified the existence of a metal base of alum, which he at first termed *alumium* and later *aluminum* (see [etymology section](/wiki/#Etymology), below).

The metal was first produced in 1825 in an impure form by Danish physicist and chemist [Hans Christian Ørsted](/wiki/Hans_Christian_Ørsted). He reacted [anhydrous](/wiki/Anhydrous) [aluminium chloride](/wiki/Aluminium_chloride) with [potassium](/wiki/Potassium) [amalgam](/wiki/Amalgam_(chemistry)), yielding a lump of metal looking similar to tin.[[52]](#cite_note-52)[[53]](#cite_note-53) [Friedrich Wöhler](/wiki/Friedrich_Wöhler) was aware of these experiments and cited them, but after repeating Ørsted's experiments, he concluded that this metal was pure potassium. He conducted a similar experiment in 1827 by mixing anhydrous aluminium chloride with potassium and produced aluminium.[[53]](#cite_note-53) Wöhler is therefore generally credited with isolating aluminium ([Latin](/wiki/Latin) *alumen*, alum). Further, [Pierre Berthier](/wiki/Pierre_Berthier) discovered aluminium in bauxite ore. [Henri Etienne Sainte-Claire Deville](/wiki/Henri_Etienne_Sainte-Claire_Deville) improved Wöhler's method in 1846. As described in his 1859 book, aluminium trichloride could be reduced by sodium, which was more convenient and less expensive than potassium, which Wöhler had used.[[54]](#cite_note-54)In the mid-1880s, aluminium metal was exceedingly difficult to produce, which made pure aluminium more valuable than gold.[[55]](#cite_note-55) So celebrated was the metal that bars of aluminium were exhibited at the [Exposition Universelle of 1855](/wiki/Exposition_Universelle_(1855)).[[56]](#cite_note-56) [Napoleon III of France](/wiki/Napoleon_III_of_France) is reputed to have held a banquet where the most honored guests were given aluminium utensils, while the others made do with gold.[[57]](#cite_note-57)[[58]](#cite_note-58) Aluminium was selected as the material to use for the [Template:Convert](/wiki/Template:Convert) capstone of the [Washington Monument](/wiki/Washington_Monument) in 1884, a time when one [ounce](/wiki/Ounce) (30 grams) cost the daily wage of a common worker on the project (in 1884 about $1 for 10 hours of labor; today, a construction worker in the US working on such a project might earn $25–$35 per hour and therefore around $300 in an equivalent single 10-hour day).<ref name=Binczewski1995> [Template:Cite journal](/wiki/Template:Cite_journal)</ref> The capstone, which was set in place on 6 December 1884 in an elaborate dedication ceremony, was the largest single piece of aluminium cast at the time.<ref name=Binczewski1995/>

The [Cowles companies](/wiki/Electric_Smelting_and_Aluminum_Company) supplied aluminium alloy in quantity in the United States and England using [smelters](/wiki/Smelting) like the furnace of [Carl Wilhelm Siemens](/wiki/Carl_Wilhelm_Siemens) by 1886.[[59]](#cite_note-59)[[60]](#cite_note-60)[[61]](#cite_note-61)

### Hall-Heroult process: availability of cheap aluminium metal[[edit](/index.php?title=(none)&action=edit&section=30)]

[Charles Martin Hall](/wiki/Charles_Martin_Hall) of [Ohio](/wiki/Ohio) in the U.S. and [Paul Héroult](/wiki/Paul_Héroult) of France independently developed the [Hall-Héroult electrolytic process](/wiki/Hall-Heroult_process) that facilitated large-scale production of metallic aluminium. This process remains in use today.[[62]](#cite_note-62) In 1888, with the financial backing of [Alfred E. Hunt](/wiki/Alfred_E._Hunt), the Pittsburgh Reduction Company started; today it is known as [Alcoa](/wiki/Alcoa). Héroult's process was in production by 1889 in Switzerland at Aluminium Industrie, now [Alcan](/wiki/Alcan), and at [British Aluminium](/wiki/British_Aluminium), now [Luxfer Group](/wiki/Luxfer_Group) and Alcoa, by 1896 in Scotland.[[63]](#cite_note-63) By 1895, the metal was being used as a building material as far away as [Sydney](/wiki/Sydney), Australia in the dome of the [Chief Secretary's Building](/wiki/Chief_Secretary's_Building).

With the explosive expansion of the airplane industry during World War I (1914–1917), major governments demanded large shipments of aluminium for light, strong airframes. They often subsidized factories and the necessary electrical supply systems.[[64]](#cite_note-64) Many navies have used an aluminium [superstructure](/wiki/Superstructure) for their vessels; the 1975 fire aboard [USS *Belknap*](/wiki/USS_Belknap_(CG-26)) that gutted her aluminium superstructure, as well as observation of battle damage to British ships during the [Falklands War](/wiki/Falklands_War), led to many navies switching to all [steel](/wiki/Steel) superstructures.

[Aluminium wire](/wiki/Aluminium_wire) was once widely used for [domestic electrical wiring](/wiki/Aluminum_wire#Problems_with_aluminum_wires) in the United States, and a number of fires resulted from [creep](/wiki/Creep_(deformation)) and corrosion-induced failures at junctions and [terminations](/wiki/Terminator_(electrical)); additional and preventable factors in the failures have been identified.[[65]](#cite_note-65)[[66]](#cite_note-66) Aluminium is still used in electrical services with specially designed wire termination hardware.

## Etymology[[edit](/index.php?title=(none)&action=edit&section=31)]

The various names all derive from its elemental presence in [alum](/wiki/Alum). The word comes into English from [Old French](/wiki/Old_French), from *alumen*, a [Latin](/wiki/Latin) word meaning "bitter salt".[[67]](#cite_note-67) Two variants of the name are in current use: *aluminium* ([Template:IPAc-en](/wiki/Template:IPAc-en)) and *aluminum* ([Template:IPAc-en](/wiki/Template:IPAc-en)). There is also an obsolete variant *alumium*. The [International Union of Pure and Applied Chemistry](/wiki/International_Union_of_Pure_and_Applied_Chemistry) (IUPAC) adopted *aluminium* as the standard international name for the element in 1990 but, three years later, recognized *aluminum* as an acceptable variant. The IUPAC periodic table now includes both spellings.[[68]](#cite_note-68) IUPAC internal publications use the two spelling with nearly equal frequency.[[69]](#cite_note-69)

### Different endings[[edit](/index.php?title=(none)&action=edit&section=32)]

Most countries use the ending "-ium" for "aluminium". In the United States and Canada, the ending "-um" predominates.<ref name=Greenwood1997/>[[70]](#cite_note-70) The [Canadian Oxford Dictionary](/wiki/Canadian_Oxford_Dictionary) prefers *aluminum*, whereas the Australian [Macquarie Dictionary](/wiki/Macquarie_Dictionary) prefers *aluminium*. In 1926, the [American Chemical Society](/wiki/American_Chemical_Society) officially decided to use *aluminum* in its publications; American dictionaries typically label the spelling *aluminium* as "chiefly British".[[71]](#cite_note-71)[[72]](#cite_note-72) The earliest citation given in the [Oxford English Dictionary](/wiki/Oxford_English_Dictionary) for any word used as a name for this element is *alumium*, which British chemist and inventor [Humphry Davy](/wiki/Humphry_Davy) employed in 1808 for the metal he was trying to isolate electrolytically from the mineral [*alumina*](/wiki/Alumina). The citation is from the journal *Philosophical Transactions of the Royal Society of London*: "Had I been so fortunate as to have obtained more certain evidences on this subject, and to have procured the metallic substances I was in search of, I should have proposed for them the names of silicium, alumium, zirconium, and glucium."[[73]](#cite_note-73)[[74]](#cite_note-74) Davy settled on *aluminum* by the time he published his 1812 book *Chemical Philosophy*: "This substance appears to contain a peculiar metal, but as yet Aluminum has not been obtained in a perfectly free state, though alloys of it with other metalline substances have been procured sufficiently distinct to indicate the probable nature of alumina."<ref name=Davy1812> [Template:Cite book](/wiki/Template:Cite_book)</ref> But the same year, an anonymous contributor to the [*Quarterly Review*](/wiki/Quarterly_Review)*,* a British political-literary journal, in a review of Davy's book, objected to *aluminum* and proposed the name *aluminium*, "for so we shall take the liberty of writing the word, in preference to aluminum, which has a less classical sound."[[75]](#cite_note-75) The *-ium* suffix followed the precedent set in other newly discovered elements of the time: potassium, sodium, magnesium, calcium, and [strontium](/wiki/Strontium) (all of which Davy isolated himself). Nevertheless, element names ending in *-um* were not unknown at the time; for example, [platinum](/wiki/Platinum) (known to Europeans since the 16th century), [molybdenum](/wiki/Molybdenum) (discovered in 1778), and [tantalum](/wiki/Tantalum) (discovered in 1802). The *-um* suffix is consistent with the universal spelling [alumina](/wiki/Alumina) for the [oxide](/wiki/Oxide) (as opposed to aluminia), as [lanthana](/wiki/Lanthana) is the oxide of [lanthanum](/wiki/Lanthanum), and [magnesia](/wiki/Magnesium_oxide), [ceria](/wiki/Ceria), and [thoria](/wiki/Thoria) are the oxides of [magnesium](/wiki/Magnesium), [cerium](/wiki/Cerium), and [thorium](/wiki/Thorium) respectively.[Template:Citation needed](/wiki/Template:Citation_needed)

The *aluminum* spelling is used in the [Webster's Dictionary](/wiki/Webster's_Dictionary) of 1828. In his advertising handbill for his new electrolytic method of producing the metal in 1892, [Charles Martin Hall](/wiki/Charles_Martin_Hall) used the *-um* spelling, despite his constant use of the *-ium* spelling in all the patents[[62]](#cite_note-62) he filed between 1886 and 1903. Hall's domination of production of the metal ensured that *aluminum* became the standard English spelling in North America.[Template:Citation needed](/wiki/Template:Citation_needed)

## Biology[[edit](/index.php?title=(none)&action=edit&section=33)]

[thumb|350px|Schematic of Al absorption by human skin.<ref name=health1>](/wiki/File:Al_absorption_by_skin.jpg)[Template:Cite journal](/wiki/Template:Cite_journal)</ref> [350px|thumb|There are five major Al forms absorbed by human body: the free solvated trivalent cation (Al3+(aq)); low-molecular-weight, neutral, soluble complexes (LMW-Al0(aq)); high-molecular-weight, neutral, soluble complexes (HMW-Al0(aq)); low-molecular-weight, charged, soluble complexes (LMW-Al(L)n+/−(aq)); nano and micro-particulates (Al(L)n(s)). They are transported across cell membranes or cell epi-/](/wiki/File:Al_transport_across_human_cells.jpg)[endothelia](/wiki/Endothelia) through five major routes: (1) [paracellular](/wiki/Paracellular); (2) [transcellular](/wiki/Transcellular); (3) [active transport](/wiki/Active_transport); (4) channels; (5) adsorptive or receptor-mediated [endocytosis](/wiki/Endocytosis).<ref name=health1/>

Despite its widespread occurrence in the Earth crust, aluminium has no known function in biology. Aluminium salts are remarkably nontoxic, [aluminium sulfate](/wiki/Aluminium_sulfate) having an [LD50](/wiki/Median_lethal_dose) of 6207 mg/kg (oral, mouse), which corresponds to 500 grams for an [Template:Convert](/wiki/Template:Convert) person.<ref name=Ullmann/> The extremely low acute toxicity notwithstanding, the health effects of aluminium are of interest in view of the widespread occurrence of the element in the environment and in commerce.

## Health concerns[[edit](/index.php?title=(none)&action=edit&section=34)]

In very high doses, aluminium is associated with altered function of the [blood–brain barrier](/wiki/Blood–brain_barrier).[[76]](#cite_note-76) A small percentage of people are [allergic](/wiki/Allergy) to aluminium and experience [contact dermatitis](/wiki/Contact_dermatitis), [digestive](/wiki/Digestion) disorders, [vomiting](/wiki/Vomiting) or other symptoms upon contact or ingestion of products containing aluminium, such as [antiperspirants](/wiki/Antiperspirant) and antacids. In those without allergies, aluminium is not as toxic as [heavy metals](/wiki/Heavy_metals), but there is evidence of some toxicity if it is consumed in amounts greater than 40 mg/day per kg of [body mass](/wiki/Body_weight).<ref name=Piero>[Template:Cite journal](/wiki/Template:Cite_journal)</ref> The use of aluminium [cookware](/wiki/Cookware) has not been shown to lead to aluminium toxicity in general, however excessive consumption of [antacids](/wiki/Antacid) containing aluminium compounds and excessive use of aluminium-containing antiperspirants provide more significant exposure levels. Studies have shown that consumption of acidic foods or liquids with aluminium significantly increases aluminium absorption,[[77]](#cite_note-77) and [maltol](/wiki/Maltol) has been shown to increase the accumulation of aluminium in nervous and osseous tissue.[[78]](#cite_note-78) Furthermore, aluminium increases [estrogen](/wiki/Estrogen)-related [gene expression](/wiki/Gene_expression) in human [breast cancer](/wiki/Breast_cancer) cells cultured in the laboratory.[[79]](#cite_note-79) The estrogen-like effects of these salts have led to their classification as a [metalloestrogen](/wiki/Metalloestrogen).

The effects of aluminium in antiperspirants have been examined over the course of decades with little evidence of skin irritation.<ref name=Ullmann/> Nonetheless, its occurrence in antiperspirants, [dyes](/wiki/Dyes) (such as aluminium [lake](/wiki/Lake_pigment)), and food additives has caused concern.[[80]](#cite_note-80) Although there is little evidence that normal exposure to aluminium presents a risk to healthy adults,[[81]](#cite_note-81) some studies point to risks associated with increased exposure to the metal.[[80]](#cite_note-80) Aluminium in food may be absorbed more than aluminium from water.[[82]](#cite_note-82) It is classified as a non-carcinogen by the [US Department of Health and Human Services](/wiki/US_Department_of_Health_and_Human_Services).[[83]](#cite_note-83) In case of suspected sudden intake of a large amount of aluminium, [deferoxamine mesylate](/wiki/Deferoxamine_mesylate) may be given to help eliminate it from the body by [chelation](/wiki/Chelation).[[84]](#cite_note-84)

### Occupational safety[[edit](/index.php?title=(none)&action=edit&section=35)]

Exposure to powdered aluminium or aluminium welding fumes can cause [pulmonary fibrosis](/wiki/Pulmonary_fibrosis). The United States [Occupational Safety and Health Administration](/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has set a [permissible exposure limit](/wiki/Permissible_exposure_limit) of 15 mg/m3 time weighted average (TWA) for total exposure and 5 mg/m3 TWA for respiratory exposure. The US [National Institute for Occupational Safety and Health](/wiki/National_Institute_for_Occupational_Safety_and_Health) (NIOSH) [recommended exposure limit](/wiki/Recommended_exposure_limit) is the same for respiratory exposure but is 10 mg/m3 for total exposure, and 5 mg/m3 for fumes and powder.

Fine aluminium powder can ignite or explode, posing another workplace hazard.[[85]](#cite_note-85)[[86]](#cite_note-86)

### Alzheimer's disease[[edit](/index.php?title=(none)&action=edit&section=36)]

Aluminium has controversially been implicated as a factor in [Alzheimer's disease](/wiki/Alzheimer's_disease).[[87]](#cite_note-87) According to the [Alzheimer's Society](/wiki/Alzheimer's_Society), the medical and scientific opinion is that studies have not convincingly demonstrated a causal relationship between aluminium and Alzheimer's disease.[[88]](#cite_note-88) Nevertheless, some studies, such as those on the [PAQUID cohort](/wiki/PAQUID_cohort),[[89]](#cite_note-89) cite aluminium exposure as a risk factor for Alzheimer's disease. Some [brain plaques](/wiki/Senile_plaques) have been found to contain increased levels of the metal.[[90]](#cite_note-90) Research in this area has been inconclusive; aluminium accumulation may be a consequence of the disease rather than a causal agent.[[91]](#cite_note-91)[[92]](#cite_note-92)

## Effect on plants[[edit](/index.php?title=(none)&action=edit&section=37)]

Aluminium is primary among the factors that reduce plant growth on acid soils. Although it is generally harmless to plant growth in pH-neutral soils, the concentration in acid soils of toxic Al3+ [cations](/wiki/Cation) increases and disturbs root growth and function.[[93]](#cite_note-93)[[94]](#cite_note-94)[[95]](#cite_note-95)[[96]](#cite_note-96) Most acid soils are saturated with aluminium rather than [hydrogen ions](/wiki/Hydrogen_ions). The acidity of the soil is therefore, a result of [hydrolysis](/wiki/Hydrolysis) of aluminium compounds.[[97]](#cite_note-97) The concept of "corrected lime potential"[[98]](#cite_note-98) is now used to define the degree of base saturation in [soil testing](/wiki/Soil_testing) to determine the "[lime](/wiki/Agricultural_lime) requirement"[[99]](#cite_note-99)[[100]](#cite_note-100) [Wheat](/wiki/Wheat) has [developed](/wiki/Adaptation) a [tolerance](/wiki/Adaptation) [to](/wiki/Adaptation) aluminium, releasing of [organic compounds](/wiki/Organic_compound) that bind to harmful aluminium [cations](/wiki/Cations). [Sorghum](/wiki/Sorghum) is believed to have the same tolerance mechanism. The first gene for aluminium tolerance has been identified in wheat. It was shown that sorghum's aluminium tolerance is controlled by a single gene, as for wheat.[[101]](#cite_note-101) This adaptation is not found in all plants.

## Biodegradation[[edit](/index.php?title=(none)&action=edit&section=38)]

A Spanish scientific report from 2001 claimed that the fungus [*Geotrichum candidum*](/wiki/Geotrichum_candidum) consumes the aluminium in [compact discs](/wiki/Compact_disc).[[102]](#cite_note-102)[[103]](#cite_note-103) Other reports all refer back to the 2001 Spanish report and there is no supporting original research. Better documented, the bacterium [*Pseudomonas aeruginosa*](/wiki/Pseudomonas_aeruginosa) and the fungus [*Cladosporium*](/wiki/Cladosporium) *resinae* are commonly detected in aircraft fuel tanks that use kerosene-based fuels (not AV gas), and laboratory cultures can degrade aluminium.[[104]](#cite_note-104) However, these life forms do not directly attack or consume the aluminium; rather, the metal is corroded by microbe waste products.[[105]](#cite_note-105)

## See also[[edit](/index.php?title=(none)&action=edit&section=39)]

[Template:Colbegin](/wiki/Template:Colbegin)

* [Aluminium granules](/wiki/Aluminium_granules)
* [*Aluminium: The Thirteenth Element*](/wiki/Aluminium:_The_Thirteenth_Element)
* [Aluminium–air battery](/wiki/Aluminium–air_battery)
* [Institute for the History of Aluminium](/wiki/Institute_for_the_History_of_Aluminium)
* [List of countries by aluminium production](/wiki/List_of_countries_by_aluminium_production)
* [Panel edge staining](/wiki/Panel_edge_staining)
* [Quantum clock](/wiki/Quantum_clock)
* [The Aluminum Association](/wiki/The_Aluminum_Association)

[Template:Colend](/wiki/Template:Colend) [Template:Subject bar](/wiki/Template:Subject_bar)

## References[[edit](/index.php?title=(none)&action=edit&section=40)]

[Template:Reflist](/wiki/Template:Reflist)

## Further reading[[edit](/index.php?title=(none)&action=edit&section=41)]

* Mimi Sheller, *Aluminum Dream: The Making of Light Modernity.* Cambridge, MA: Massachusetts Institute of Technology Press, 2014.

## External links[[edit](/index.php?title=(none)&action=edit&section=42)]

[Template:Commons category](/wiki/Template:Commons_category)

* [Aluminium](http://www.periodicvideos.com/videos/013.htm) at [*The Periodic Table of Videos*](/wiki/The_Periodic_Table_of_Videos) (University of Nottingham)
* [CDC – NIOSH Pocket Guide to Chemical Hazards – Aluminum](http://www.cdc.gov/niosh/npg/npgd0022.html)
* [Electrolytic production](http://electrochem.cwru.edu/encycl/art-a01-al-prod.htm)
* [World production of primary aluminium, by country](http://www.indexmundi.com/en/commodities/minerals/aluminum/aluminum_table12.html)
* [Price history of aluminum, according to the IMF](http://www.indexmundi.com/commodities/?commodity=aluminum&months=300)
* [History of Aluminium](http://www.world-aluminium.org/About+Aluminium/Story+of/In+history) – from the website of the International Aluminium Institute
* [Emedicine – Aluminium](http://www.emedicine.com/med/topic113.htm)
* [Template:Internet Archive short film](/wiki/Template:Internet_Archive_short_film)

[Template:Aluminium compounds](/wiki/Template:Aluminium_compounds) [Template:Compact periodic table](/wiki/Template:Compact_periodic_table)

[Template:Authority control](/wiki/Template:Authority_control)

[Category:Aluminium](/wiki/Category:Aluminium) [Aluminium](/wiki/Category:Rocket_fuels) [Category:Electrical conductors](/wiki/Category:Electrical_conductors) [Category:Pyrotechnic fuels](/wiki/Category:Pyrotechnic_fuels) [Category:Airship technology](/wiki/Category:Airship_technology) [Category:Chemical elements](/wiki/Category:Chemical_elements) [Category:Post-transition metals](/wiki/Category:Post-transition_metals) [Category:Reducing agents](/wiki/Category:Reducing_agents)