Aluminium oxide

From Wikipedia, the free encyclopedia
(Redirected from Aluminum Oxide)

Aluminium oxide is an amphoteric oxide with the chemical formula Al_2O_3. It is commonly referred to as **alumina** (α-alumina), or corundum in its crystalline form, as well as many other names, reflecting its widespread occurrence in nature and industry. Its most significant use is in the production of aluminium metal, although it is also used as an abrasive owing to its hardness and as a refractory material owing to its high melting point.[5] There is also a cubic γ-alumina with important technical applications.

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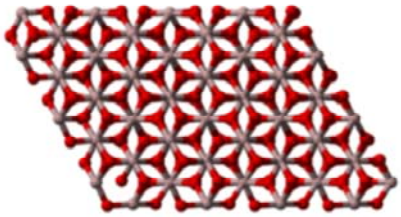
Natural occurrence

Corundum is the most common naturally occurring crystalline form of aluminium oxide. Rubies and sapphires are gem-quality forms of corundum, which owe their characteristic colors to trace impurities. Rubies are given their characteristic deep red color and their laser qualities by traces of chromium. Sapphires come in different colors given by various other impurities, such as iron and titanium.

Properties

Aluminium oxide is an electrical insulator but has a relatively high thermal conductivity (30 $Wm^{-1}K^{-1}$[1]) for a ceramic material. In its

Aluminium oxide	
	
	
Identifiers	
CAS number	1344-28-1 ✓
PubChem	9989226
ChemSpider	8164808 ✓
UNII	LMI26O6933 ✓
RTECS number	BD120000
ATC code	D10AX04 (http://www.whocc.no/atc_ddd_index/?code=D10AX04)
Jmol-3D images	Image 1 (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BAl%2B3%5D.%5BAl%2B3%5D.%5BO-2%5D.%5BO-2%5D.%5BO-2%5D) Image 2 (http://chemapps.stolaf.edu/jmol/jmol.php?model=%5BO-2%5D.%5BO-2%5D.%5BO-2%5D.%5BAl%2B3%5D.%5BAl%2B3%5D)
SMILES	
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Properties	
Molecular formula	Al_2O_3
Molar mass	101.96 g mol^{-1}
Appearance	white solid


Aluminium oxide in its powdered form.

most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools.[5]

Aluminium oxide is responsible for the resistance of metallic aluminium to weathering. Metallic aluminium is very reactive with atmospheric oxygen, and a thin passivation layer of alumina (4 nm thickness) forms in about 100 picoseconds on any exposed aluminium surface.[6] This layer protects the metal from further oxidation. The thickness and properties of this oxide layer can be enhanced using a process called anodising. A number of alloys, such as aluminium bronzes, exploit this property by including a proportion of aluminium in the alloy to enhance corrosion resistance. The alumina generated by anodising is typically amorphous, but discharge assisted oxidation processes such as plasma electrolytic oxidation result in a significant proportion of crystalline alumina in the coating, enhancing its hardness.

Aluminium oxide is completely insoluble in water. However it is an amphoteric substance, meaning it can react with both acids and bases, such as hydrochloric acid and sodium hydroxide.

$$Al_2O_3 + 6\ HCl \rightarrow 2\ AlCl_3 + 3\ H_2O$$
$$Al_2O_3 + 6\ NaOH + 3\ H_2O \rightarrow 2\ Na_3Al(OH)_6$$

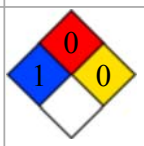
Aluminium oxide was taken off the United States Environmental Protection Agency's chemicals lists in 1988. Aluminium oxide is on EPA's Toxics Release Inventory list if it is a fibrous form.[7]

Structure


Corundum from Brazil, size about 2x3 cm.

The most common form of crystalline alumina is known as corundum. The oxygen ions nearly form a hexagonal close-packed structure with aluminium ions filling two-thirds of the octahedral interstices. Each Al^{3+} center is octahedral. In terms of its crystallography, corundum adopts a trigonal Bravais lattice with a space group of R-3c (number 167 in the International Tables). The primitive cell contains two formula units of aluminium oxide.

Alumina also exists in other phases, namely γ-, δ-, η-, θ-, and χ-aluminas.[8] Each has a unique crystal structure and properties. The so-called β-alumina proved to be $NaAl_{11}O_{17}$.[9]

Odor	odorless
Density	3.95–4.1 g/cm^3
Melting point	2072 °C [2]
Boiling point	2977 °C [3]
Solubility in water	insoluble
Solubility	insoluble in diethyl ether practically insoluble in ethanol
Thermal conductivity	30 W·m^{-1}·K^{-1}[1]
Refractive index (n_D)	n_ω=1.768–1.772 n_ε=1.760–1.763 Birefringence 0.008
Structure	
Crystal structure	Trigonal, hR30, space group = R$\bar{3}$c, No. 167
Coordination geometry	octahedral
Thermochemistry	
Std enthalpy of formation $\Delta_f H^\circ_{298}$	−1675.7 kJ·mol^{-1}[4]
Standard molar entropy S°_{298}	50.92 J·mol^{-1}·K^{-1}[4]
Hazards	
MSDS	External MSDS
EU classification	Not listed.
NFPA 704	
Flash point	non-flammable
Related compounds	
Other anions	aluminium hydroxide
Other cations	boron trioxide gallium oxide indium oxide thallium oxide
Supplementary data page	
Structure and properties	n, ε_r, etc.
Thermodynamic data	Phase behaviour Solid, liquid, gas

Spectral data	UV, IR, NMR, MS
✓ (verify) (what is: ✓/✗?) Except where noted otherwise, data are given for materials in their standard state (at 25 °C, 100 kPa)	
Infobox references	

Production

Aluminium hydroxide minerals are the main component of bauxite, the principal ore of aluminium. A mixture of the minerals comprise bauxite ore, including gibbsite ($Al(OH)_3$), boehmite (γ-$AlO(OH)$), and diaspore (α-$AlO(OH)$), along with impurities of iron oxides and hydroxides, quartz and clay minerals.[10] Bauxites are found in laterites. Bauxite is purified by the Bayer process:

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

Except for SiO_2, the other components of bauxite do not dissolve in base. Upon filtering the basic mixture, Fe_2O_3 is removed. When the Bayer liquor is cooled, $Al(OH)_3$ precipitates, leaving the silicates in solution. The solid is then calcined (heated strongly) to give aluminium oxide:[5]

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

The product alumina tends to be multi-phase, i.e., consisting of several phases of alumina rather than solely corundum.[8] The production process can therefore be optimized to produce a tailored product. The type of phases present affects, for example, the solubility and pore structure of the alumina product which, in turn, affects the cost of aluminium production and pollution control.[8]

Known as alundum (in fused form) or **aloxite**[11] in the mining, ceramic, and materials science communities, alumina finds wide use. Annual world production of alumina is approximately 45 million tonnes, over 90% of which is used in the manufacture of aluminium metal.[5] The major uses of specialty aluminium oxides are in refractories, ceramics, and polishing and abrasive applications. Large tonnages are also used in the manufacture of zeolites, coating titania pigments, and as a fire retardant/smoke suppressant.

Applications

The great majority of alumina is consumed for the production of aluminium, usually by the Hall process.

As a filler

Being fairly chemically inert and white, alumina is a favored filler for plastics. Alumina is a common ingredient in sunscreen and is sometimes present in cosmetics such as blush, lipstick, and nail polish.

As a catalyst and catalyst support

Alumina catalyses a variety of reactions that are useful industrially. In its largest scale application, alumina is the catalyst in the Claus process for converting hydrogen sulfide waste gases into elemental sulfur in refineries. It is also useful for dehydration of alcohols to alkenes.

Alumina serves as a catalyst support for many industrial catalysts, such as those used in hydrodesulfurization and some Ziegler-Natta polymerizations. Zeolites are produced from alumina.

Gas purification and related absorption applications

Alumina is widely used to remove water from gas streams. Other major applications are described below.[12]

As an abrasive

Aluminium oxide is used for its hardness and strength. It is widely used as an abrasive, including as a much less expensive substitute for industrial diamond. Many types of sandpaper use aluminium oxide crystals. In addition, its low heat retention and low specific heat make it widely used in grinding operations, particularly cutoff tools. As the powdery

abrasive mineral aloxite, it is a major component, along with silica, of the cue tip "chalk" used in billiards. Aluminium oxide powder is used in some CD/DVD polishing and scratch-repair kits. Its polishing qualities are also behind its use in toothpaste. Alumina can be grown as a coating on aluminium by anodising or by plasma electrolytic oxidation (see the "Properties" above). Both its strength and abrasive characteristics originate from the high hardness (9 on the Mohs scale of mineral hardness) of aluminium oxide.

As an effect pigment

Aluminium oxide flakes are base material for effect pigments. These pigments are widely used for decorative applications e.g. in the automotive or cosmetic industry. See main article *Alumina effect pigment*.

Alumina output in 2005

As a fiber for composite materials

Alumina has been used in a few experimental and commercial fiber materials for high-performance applications (e.g., Fiber FP, Nextel 610, Nextel 720).[13]

Niche applications and research themes

In lighting, transparent alumina is used in some sodium vapor lamps.[14] Aluminium oxide is also used in preparation of coating suspensions in compact fluorescent lamps.

In chemistry laboratories, alumina is a medium for chromatography, available in basic (pH 9.5), acidic (pH 4.5 when in water) and neutral formulations.

Health and medical applications include it as a material in hip replacements.[5]

As well, it is used as a dosimeter for radiation protection and therapy applications for its optically stimulated luminescence properties.

Aluminium oxide is an electrical insulator used as a substrate (Silicon_on_sapphire) for integrated circuits but also as quantum tunneling barrier films for the fabrication of superconducting devices such as single electron transistors and superconducting quantum interference (SQUID) devices.

Insulation for high-temperature furnaces is often manufactured from aluminium oxide. Sometimes the insulation has varying percentages of silica depending on the temperature rating of the material. The insulation can be made in blanket, board, brick and loose fiber forms for various application requirements.

Small pieces of alumina are often used as boiling chips in chemistry.

It is also used to make spark plug insulators.

Using a plasma spray process and mixed with titania, it is coated onto the braking surface of some aluminium bicycle rims to provide abrasion and wear resistance.[*citation needed*]

See also

- Charged Aerosol Release Experiment (CARE)
- Corundum
- List of alumina refineries
- Micro-Pulling-Down
- Ruby
- Sapphire
- Transparent alumina

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