

Aluminum

Discovered: H.C. Oersted in 1825

Name: From *alum*, used by ancient Greeks and Romans as an astringent and as a mordant in dyeing. Sir Humphrey Davy proposed the name aluminum, but changed it to aluminium to have it conform to the spelling of other metals. This spelling was used in the U.S. until 1925 when the ACS went back to the original spelling. The rest of the world uses the “-ium” ending.

Occurrence: It is the most common metallic element in the Earth's crust and occurs in many different forms in nature some of which are: bauxite, cryolite (Na_3AlF_6), micas, feldspars, vermiculite, diaspore (AlO_2H), gibbsite ($\text{Al}(\text{OH})_3$), garnet ($\text{Ca}_3\text{Al}_2(\text{SiO}_4)_3$), beryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$), turquoise ($\text{Al}_2(\text{OH})_3\text{PO}_4\text{H}_2\text{O}/\text{Cu}$), corundum ($\alpha\text{-Al}_2\text{O}_3$), other Al_2O_3 with impurities are ruby (Cr(III)), topaz (Fe(III)), sapphire, and oriental emerald.

Bauxite deposits are common. Large reserves are found in Australia, Africa, Brazil, Central America, Guinea, and Jamaica.

Isolation: Bauxite ($\text{AlO}_2\text{H}\cdot n\text{H}_2\text{O}$) is dissolved in molten NaOH (1200 °C) and is precipitated with CO_2 , then dissolved in cryolite at 950 °C and electrolyzed (Bayer process).

Cost of 1 gram, 1 mole: \$0.36, \$9.83

Natural Isotopes: ^{27}Al (100%)

Physical and Chemical Properties:	Relatively low melting point
	High electrical conductivity
	Soft
	Low density
	Silvery white in color
	Non-magnetic
	Corrosion resistant

Highly malleable and ductile

Reactions: $2\text{Al} + 6\text{HCl} \xrightarrow{\Delta} 2\text{AlCl}_3 + 3\text{H}_2$
 $2\text{Al}(\text{OH})_3 \xrightarrow{\Delta} \text{Al}_2\text{O}_3 + 3\text{H}_2\text{O}$

Uses: Alloys for building construction, transportation, containers and packaging, electrical power lines, cookware, etc.

$\text{Al}_8\text{Zr}(\text{OH})_{13}\text{Cl}_3\cdot x\text{H}_2\text{O}$ •glycine is the active ingredient in some antiperspirants

Al_2O_3 is a major component of Portland cement

Beryllium

Discovered: By L.-N. Vauguelin in 1798 as the oxide, isolated in 1828 by F. Wohler and A.-B. Bussy independently.

Name: From *beryl*, the mineral it was originally isolated from ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$). Beryl is derived from the Greek word *beryllous*, which is the precious stone form of beryl. It is also called *glucinium*, from the Greek work *glykys*, for "sweet." (Beryllium compounds tend to have a sweet taste. See note at the bottom of the page.)

Occurrence: It is relatively non-abundant in the Earth's crust, concentrated in pegmatite rocks (last part of granite to crystallize). Aquamarine and emerald are precious forms of beryl. Largest deposits are in South America and South Africa.

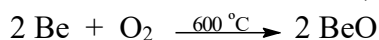
Isolation: $\text{beryl} + \text{Na}_2\text{SiF}_6 \xrightarrow{700^\circ\text{C}} \text{BeF}_2$
 $\text{BeF}_2 + \text{Mg} \xrightarrow{1300^\circ\text{C}} \text{Be} + \text{MgF}_2$

Cost for 1 gram, 1 mole: \$12.30, \$88.45

Natural Isotopes: ^9Be (100%)

Physical and Chemical Properties: High melting point
Grayish white in color
Soft
Very low density for a metal
Relatively non-reactive (e.g. polished Be remains shiny indefinitely)
Chemically different from other Alkaline Earth metals (e.g. rarely forms ionic compounds; cold, concentrated HNO_3 deactivates beryllium)

Reactions: With only one or two exceptions, the compounds of beryllium are always covalent.



Uses: Alloy with copper used in aircraft engines, electronics, and spacecraft
Alloy with nickel used in high temperature springs and spark-proof equipment
Moderator in nuclear reactors
Windows on X-ray tubes

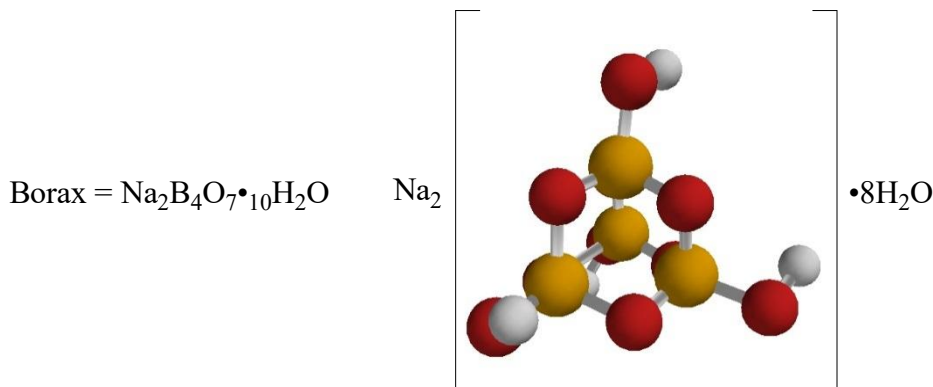
Note: Beryllium is very toxic. For example, BeCl_2 is about 6 times more poisonous than NaCN by weight. Also, the effects may be permanent or may occur years later. For example, skin burns may remain open indefinitely. This is truly nasty stuff. Its toxicity may arise from replacing Mg in some enzymes.

Boron

Discovered: Sir Humphrey Davy, J.L. Gay-Lussac, and L.J. Thenard in 1808

Name: *Borax* + Carbon (source + chemical similarity)

Occurrence: Although boron is a rare element, in nature it is concentrated in the mineral borax (also called tincal). Large deposits of borax are found in southern California and Turkey.



Isolation: i) $\text{B}_2\text{O}_3 + 3 \text{Mg} \longrightarrow 2 \text{B} + 3 \text{MgO}$ (95-98% pure).
ii) Electrolytic reduction of fused borates.
iii) Reduction of volatile boron compounds by H_2 . (Yields high purity boron: 99.9%)
iv) Thermal decomposition of BX_3 and B_nH_m .

Cost for 1 gram, 1 mole: \$42.60, \$460

Natural Isotopes: ^{10}B (19.6%) ^{11}B (80.4%)

Physical and Chemical Properties: Very hard
Low density
High melting point
Very low electrical conductivity at room temperature (but good at high temperature)
Chemically inert at room temperature (except with F_2)

Reactions: $2 \text{NaBH}_4 + 2 \text{HCl} \longrightarrow 2 \text{NaCl} + 2 \text{H}_2 + \text{B}_2\text{H}_6$ (diborane)
 $\text{BCl}_3 + 3 \text{H}_2\text{O} \longrightarrow 3 \text{HCl} + \text{B}(\text{OH})_3$ (boric acid)
 $\text{BCl}_3 + \text{NH}_3 \xrightarrow{\Delta} (\text{BN})_x$ (artificial diamond)

Uses: Pyrotechnic flares (green color)
Rocket ignitors
Neutron capture in nuclear reactors (^{10}B)
Antiseptic and fire retardant (boric acid)
Cleansing flux (borax)
Borosilicate glass (Pyrex and Kimax, 30-35%)
Artificial diamonds (BN, boron nitride, 9.3 on Moh's hardness scale)
Reinforcing materials (boron fiber composites)

Helium

Discovered: In 1868 Pierre Janssen found a new line in the solar spectrum during a solar eclipse. J.N. Lockyer and E. Frankland suggested that it arose from a new element and named it helium. Sir William Ramsey first isolated helium in 1895 from a uranium containing mineral, cleveite. Helium has the distinction of being the only element not discovered on Earth.

Name: From the Greek word *helios* (or *ilios*) meaning "the sun" because of the location of its discovery.

Occurrence: It is the second most abundant element in the universe, but one of the rarest naturally occurring elements on earth. Its only source here is radioactive decay (α -particle emission). Earth's gravity is too weak to retain helium so once it breaks into the atmosphere it escapes into space.

Isolation: Distilled from natural gas (up to 7% concentration). Most helium is produced in the U.S., with other plants in Poland, India, and the former USSR.

Cost of 1 gram, 1 mole: \$0.18, \$0.71

Natural Isotopes: ^3He (trace) ^4He (100%)

Physical Properties: Only known substance that cannot be solidified at atmospheric pressure (even at 0 K,* it can be solidified at higher pressure)

Only known substance without a triple point.

Has 2 liquid forms. The high temperature form ($T > 2.2 \text{ K}$) behaves as a normal liquid. Below 2.2 K HeII exists. Under vacuum, HeII evaporates but does not bubble. Forms films only a few hundred atoms thick over all edges in contact with the liquid. The liquid will crawl up vessel walls and out of the container to coat the entire inside of the apparatus. This liquid does not appear to be subject to friction and has zero viscosity and entropy.

Diffuses through many common substances such as glass and rubber making long-term storage difficult.

Colorless, odorless gas

Uses: Provides an inert atmosphere

Refrigerant or cryogenics (33%)

Flow gas in gas chromatography

Coolant in some nuclear reactors

Substitute for N_2 in synthetic breathing gas for deep-sea diving (reduces chances of developing the bends because of low solubility in the blood)

Filling balloons

*The zero-point energy (the energy the molecule possesses at 0 K) is large enough to overcome the intermolecular forces that are necessary for a solid to form.

Hydrogen

Discovered: Paracelsus first characterized it in the late 15th century from the reaction between iron and sulfuric acid. Its discovery is credited to Henry Cavendish in 1766, although it had been isolated as early as 1671 by Robert Boyle.

Name: From the Greek *hydro* and *genes* meaning "water producer" by Antoine Lavoisier.

Occurrence: It is the most abundant element in the universe and is very abundant on Earth (found in water and organic matter).

Isolation:
$$\text{C}_3\text{H}_8(\text{g}) + 3 \text{H}_2\text{O}(\text{g}) \xrightarrow{\Delta} 3 \text{CO}(\text{g}) + 7 \text{H}_2(\text{g})$$
$$\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \xrightarrow{\Delta} \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$$
$$\text{H}_2\text{O}(\text{g}) + \text{C}(\text{s}) \xrightarrow{\Delta} \text{CO}(\text{g}) + \text{H}_2(\text{g})$$

Cost of 1 gram, 1 mole: \$07.5, \$0.15

Natural Isotopes: ^1H (99.98%) ^2H (0.02%) ^3H (trace)

Physical and Colorless, odorless gas

Chemical Flammable

Properties: Low solubility in most liquid solvents

Lightest of all gases

Becomes metallic(!) at high pressure (> 2 megabars)

Uses: Ammonia synthesis (Haber process)

Hydrogenation of fats and oils

Production of HCl

Methanol synthesis

Welding

Filling balloons

Fuel cells will probably constitute a major use in the future

Lithium

Discovered: J.A. Arfvedson in 1817

Name: From the Greek *lithos* meaning "stone." This name was chosen to contrast with sodium and potassium which were originally isolated from plant matter. *Note:* Implicit in Arfvedson's choice of name was the observation of the chemical similarity between Li and Na, K. This was 50 years before the periodic table was proposed!

Occurrence: It is relatively non-abundant. The most important mineral is spodumene ($\text{LiAlSi}_2\text{O}_6$) with large deposits in the U.S., Canada, Brazil, Argentina, the former USSR, Spain, and Congo.

Isolation:
$$\text{LiAlSi}_2\text{O}_6 \xrightarrow{1100^\circ\text{C}} \xrightarrow[250^\circ\text{C}]{\text{H}_2\text{SO}_4} \text{Li}_2\text{SO}_4 \xrightarrow{\text{Na}_2\text{CO}_3} \text{Li}_2\text{CO}_3 \xrightarrow{\text{HCl}} 2 \text{LiCl}$$

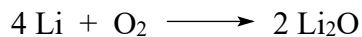
LiCl(55%)/KCl(45%) electrolysis at 450 °C produces Li metal

Cost for 1 gram, 1 mole: \$0.95, \$6.65

Natural Isotopes: ^6Li (7.4%) ^7Li (92.6%)

Physical and Chemical Properties: Soft (although hardest of the alkali metals)
Gray in color
Very low density ($\sim 0.5 \text{ g/cm}^3$)
Burns crimson in flame
Very electropositive
Soluble in mercury (amalgam) and liquid ammonia
Reacts directly with most other elements (including N_2 !)
Highest elemental oxidation potential

Reactions: The only alkali metal that reacts with O_2 to give the oxide:



The only alkali metal that reacts with N_2 :



Uses: Anode in light weight and long life batteries such as the ones in cell phones and electric cars

Lithium stearate thickens oil into grease (major use)

Alloy with Al used in aircraft construction

Lithium oxide is a component of oven glassware

LiOH used for CO_2 absorption in submarines/space craft

Li_2CO_3 is a treatment (Lithobid[®] or Eskalith[®]) for bipolar disorder (manic depression)

LiClO is a bleach for commercial laundries and sanitizing swimming pools

LiCl and LiBr are used as desiccants in air conditioners

Magnesium

Discovered: It was first recognized as an element by Scottish chemist Joseph Black in 1755. Sir Humphrey Davy isolated it in 1808. Compounds were known since ancient times.

Name: From the Magnesia district of Thessaly (region of eastern Greece) in which magnesian stone (talc) was found.

Occurrence: Common element, usually found as carbonates, sulfates, and silicates because all are water insoluble, minerals: dolomite ($\text{MgCa}(\text{CO}_3)_2$), magnesite (MgCO_3), olivine ($(\text{MgFe})_2\text{SiO}_4$), soapstone (talc, $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$), asbestos ($\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$), and micas. Minerals are widespread.

Isolation: a) Electrolysis of MgCl_2 at 750°C



Cost for 1 gram, 1 mole: \$0.43, \$10.35

Natural Isotopes: ^{24}Mg (79.0%) ^{25}Mg (10.0%) ^{26}Mg (11.0%)

Physical and Chemical Properties:

- Low density
- Grayish white in color
- Very electropositive
- Soft
- Oxidation resistant
- Large oxidation potential
- Burns with a bright flame
- Anomalously low melting point

Reactions: $\text{Mg} + \text{N}_2 \xrightarrow{\Delta} \text{Mg}_3\text{N}_2$ Mg actually "burns" in an atmosphere of pure nitrogen.
Only Li and Mg react directly with N_2

$2 \text{Mg} + \text{O}_2 \xrightarrow{\Delta} 2 \text{MgO}$ This is the reaction that occurs in a photographic flash bulb.

$\text{MgCl}_2 + 2 \text{NaOH} \xrightarrow{\text{H}_2\text{O}} \text{Mg}(\text{OH})_2 + 2 \text{NaCl}$ (Milk of Magnesia)

Chlorophyll is a magnesium containing compound.

Uses: Construction alloys (light weight useful)
Incendiary bombs
Antacid ($\text{Mg}(\text{OH})_2$, Milk of Magnesia)
Cathartic (MgSO_4 , Epsom salts (named after a town in England))
Grignard reagent

Neon

Discovered: W. Ramsey and M.W. Travers in 1898 isolated neon by the low temperature distillation of air. It was identified by spectroscopic analysis of the sample.

Name: From the Greek meaning "new."

Occurrence: Relatively rare. Majority of it is found in the atmosphere (*ca.* 1 part in 65,000), but small samples are occluded in igneous rocks. Abundant in the universe.

Isolation: From the fractional distillation of air.

Natural Isotopes: ^{20}Ne (91%) ^{21}Ne (0.26%) ^{22}Ne (9%)

Cost for 1 gram, 1 mole: \$0.68, \$13.75

Physical and Glows red-orange in a vacuum discharge tube.

Chemical Low melting and boiling points.

Properties: Inert, but very limited evidence suggests that it may form a compound with F.

Uses: Advertising signs (largest use)

Refrigerant

Lasers

Sodium

Discovered: Sir Humphrey Davy in 1807

Name: From the source element soda (Na_2CO_3), which is found in high content in a plant called *Suwwad* (Arabic). The symbol Na (from *Natrium*) comes from *Neter* (Hebrew) and *Nitrum* (Latin), which were ancient names for basic substances. They became *natron* in 15th century Europe.

Occurrence: Widespread and plentiful in nature, most common form is NaCl (Utah, Dead Sea, oceans, etc.), also trona (Na_2CO_3), salt peter (NaNO_3), mirabilite (Na_2SO_4), borax.

Isolation: Electrolysis of NaCl/CaCl₂ (2:3) at 580 °C.

Cost of 1 gram, 1 mole: \$0.52, \$11.96

Natural Isotopes: ²³Na (100%)

Physical and Chemical Properties: Grayish white in color
Soft
Burns orange in flame
Large oxidation potential
Very electropositive
Soluble in mercury
Reacts directly with most elements
Solutions in liquid NH₃ conduct electricity (Probably by $\text{Na}^+ + (\text{NH}_3)_x\text{e}^-$. Dilute solutions are blue and concentrated solns are gold in color.)

Reactions: $2 \text{Na} + \text{O}_2 \longrightarrow \text{Na}_2\text{O}_2$
 $2 \text{NaOH} + \text{CO}_2 \longrightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$ (Soda ash)
 $\text{NaOH} + \text{xs CO}_2 \longrightarrow \text{NaHCO}_3$ (Baking Soda)
 $4 \text{Na/Pb} + 4 \text{C}_2\text{H}_5\text{Cl} \longrightarrow \text{Pb}(\text{C}_2\text{H}_5)_4 + 4 \text{NaCl} + 3 \text{Pb}$

Uses: Production of $\text{Pb}(\text{C}_2\text{H}_5)_4$ (anti-knock gasoline additive still used in other countries)
Heat exchange liquid in fast breeder reactors
NaOCl is used as a bleach.
NaHCO₃ is used as baking soda, an antacid, in fire extinguishers, as a cleaning agent, and as toothpaste.
NaNO₃ is used in fertilizer.

Note: One of the primary uses of salt in the diet is in the production of HCl for your stomach. The need for salt was known to the ancients. Roman soldiers were issued salt during campaigns, which is from where the word salary is derived.

Xenon

Discovered: W. Ramsey and M.W. Travers in 1898 by the fractional distillation of air.

Name: From the Greek *xenos* meaning "strange(r)."

Occurrence: It is 50 parts per billion in the atmosphere.

Isolation: From fractional distillation of the air.

Cost of 1 gram, 1 mole: \$4.95, \$650

Natural Isotopes: ^{124}Xe (0.1%) ^{126}Xe (0.1%) ^{128}Xe (1.9%) ^{129}Xe (26.4%) ^{130}Xe (4.1%)
 ^{131}Xe (21.2%) ^{132}Xe (26.9%) ^{134}Xe (10.4%) ^{136}Xe (8.9%)

Physical and Chemical Properties: Glows blue in an electric discharge
Inert under normal conditions
Colorless, odorless, and tasteless gases

Reactions: $\text{Xe} + \text{F}_2 \xrightarrow{\Delta} \text{XeF}_x$ (X = 2, 4, or 6)
 $\text{XeF}_6 + \text{SiO}_2 \longrightarrow \text{XeOF}_4 + \text{XeO}_2\text{F}_2 + \text{XeO}_3$
 $2 \text{XeF}_2 + 2 \text{H}_2\text{O} \longrightarrow 2 \text{Xe} + 4 \text{HF} + \text{O}_2$

Uses: Manufacture of electron tubes, stroboscopic lamps, bactericidal lamps, and used to excite ruby lasers for generating coherent light
Bubble chambers and probes in the atomic energy field
Automobile and truck headlights
Nuclear reaction moderator