Beryllium

From Wikipedia, the free encyclopedia

Beryllium is a chemical element with symbol **Be** and atomic number 4. It is a relatively rare element in the universe, usually occurring as a product of the spallation of larger atomic nuclei that have collided with cosmic rays. Within the cores of stars beryllium is depleted as it is fused and creates larger elements. It is a divalent element which occurs naturally only in combination with other elements in minerals. Notable gemstones which contain beryllium include beryl (aquamarine, emerald) and chrysoberyl. As a free element it is a steel-gray, strong, lightweight and brittle alkaline earth metal.

Beryllium improves many physical properties when added as an alloying element to aluminium, copper (notably the alloy beryllium copper), iron and nickel.[4] Beryllium does not form oxides until it reaches very high temperatures. Tools made of beryllium copper alloys are strong and hard and do not create sparks when they strike a steel surface. In structural applications, the combination of high flexural rigidity, thermal stability, thermal conductivity and low density (1.85 times that of water) make beryllium metal a desirable aerospace material for aircraft components, missiles, spacecraft, and satellites.[4] Because of its low density and atomic mass, beryllium is relatively transparent to X-rays and other forms of ionizing radiation; therefore, it is the most common window material for X-ray equipment and components of particle physics experiments.[4] The high thermal conductivities of beryllium and beryllium oxide have led to their use in thermal management applications.

The commercial use of beryllium requires the use of appropriate dust control equipment and industrial controls at all times because of the toxicity of inhaled beryllium-containing dusts that can cause a chronic life-threatening allergic disease in some people called berylliosis.[5]

Beryllium, $_4$Be

General properties	
Name, symbol	beryllium, Be
Pronunciation	/bəˈrɪliəm/ *bə-RIL-ee-əm*
Appearance	white-gray metallic
Beryllium in the periodic table	
Atomic number (Z)	4
Group, block	group 2 (alkaline earth metals), s-block
Period	period 2
Element category	alkaline earth metal
Standard atomic weight (±) (A_r)	9.0121831(5)[1]
Electron configuration	[He] $2s^2$
per shell	2, 2
Physical properties	

Characteristics

Physical properties

Beryllium is a steel gray and hard metal that is brittle at room temperature and has a close-packed hexagonal crystal structure.[4] It has exceptional stiffness (Young's modulus 287 GPa) and a reasonably high melting point. The modulus of elasticity of beryllium is approximately 50% greater than that of steel. The combination of this modulus and a relatively low density results in an unusually fast sound conduction speed in beryllium – about 12.9 km/s at ambient conditions. Other significant properties are high specific heat (1925 $J \cdot kg^{-1} \cdot K^{-1}$) and thermal conductivity (216 $W \cdot m^{-1} \cdot K^{-1}$), which make beryllium the metal with the best heat dissipation characteristics per unit weight. In combination with the relatively low coefficient of linear thermal expansion ($11.4 \times 10^{-6}\ K^{-1}$), these characteristics result in a unique stability under conditions of thermal loading.[6]

Nuclear properties

Naturally occurring beryllium, save for slight contamination by cosmogenic radioisotopes, is essentially pure beryllium-9, which has a nuclear spin of $\frac{3}{2}$. Beryllium has a large scattering cross section for high-energy neutrons, about 6 barns for energies above approximately 10 keV. Therefore, it works as a neutron reflector and neutron moderator, effectively slowing the neutrons to the thermal energy range of below 0.03 eV, where the total cross section is at least an order of magnitude lower – exact value strongly depends on the purity and size of the crystallites in the material.

The single primordial beryllium isotope ^{9}Be also undergoes a (n,2n) neutron reaction with neutron energies over about 1.9 MeV, to produce ^{8}Be, which almost immediately breaks into two alpha particles. Thus, for high-energy neutrons, beryllium is a neutron multiplier, releasing more neutrons than it absorbs. This nuclear reaction is:[7]

$$^{9}_{4}Be + n \rightarrow 2(^{4}_{2}He) + 2n$$

Neutrons are liberated when beryllium nuclei are struck by energetic alpha particles[6] producing the nuclear reaction

Phase	solid
Melting point	1560 K (1287 °C, 2349 °F)
Boiling point	2742 K (2469 °C, 4476 °F)
Density near r.t.	1.85 g/cm^3
when liquid, at m.p.	1.690 g/cm^3
Critical point	5205 K, MPa *(extrapolated)*
Heat of fusion	12.2 kJ/mol
Heat of vaporization	292 kJ/mol
Molar heat capacity	16.443 J/(mol·K)

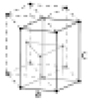
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1462	1608	1791	2023	2327	2742

Atomic properties

Oxidation states	**+2**, +1[2] (an amphoteric oxide)
Electronegativity	Pauling scale: 1.57
Ionization energies	1st: 899.5 kJ/mol 2nd: 1757.1 kJ/mol 3rd: 14,848.7 kJ/mol (more)
Atomic radius	empirical: 112 pm
Covalent radius	96±3 pm
Van der Waals radius	153 pm

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound	12,890 m/s (at r.t.)[3]

$$^{9}_{4}Be + ^{4}_{2}He \rightarrow ^{12}_{6}C + n$$, where $^{4}_{2}He$ is an alpha particle and $^{12}_{6}C$ is a carbon-12 nucleus.[7]

Beryllium also releases neutrons under bombardment by gamma rays. Thus, natural beryllium bombarded either by alphas or gammas from a suitable radioisotope is a key component of most radioisotope-powered nuclear reaction neutron sources for the laboratory production of free neutrons.

Small amounts of tritium are liberated when $^{9}_{4}Be$ nuclei absorb low energy neutrons in the three-step nuclear reaction

$$^{9}_{4}Be + n \rightarrow ^{4}_{2}He + ^{6}_{2}He, \quad ^{6}_{2}He \rightarrow ^{6}_{3}Li + \beta^{-}, \quad ^{6}_{3}Li + n \rightarrow ^{4}_{2}He + ^{3}_{1}H$$

Note that $^{6}_{2}He$ has a half life of only 0.8 seconds, β^{-} is an electron, and $^{6}_{3}Li$ has a high neutron absorption cross-section. Tritium is a radioisotope of concern in nuclear reactor waste streams.[8]

As a metal, beryllium is transparent to most wavelengths of X-rays and gamma rays, making it useful for the output windows of X-ray tubes and other such apparatus.

thin rod	
Thermal expansion	11.3 µm/(m·K) (at 25 °C)
Thermal conductivity	200 W/(m·K)
Electrical resistivity	36 nΩ·m (at 20 °C)
Magnetic ordering	diamagnetic
Young's modulus	287 GPa
Shear modulus	132 GPa
Bulk modulus	130 GPa
Poisson ratio	0.032
Mohs hardness	5.5
Vickers hardness	1670 MPa
Brinell hardness	590–1320 MPa
CAS Number	7440-41-7
	History
Discovery	Louis Nicolas Vauquelin (1797)
First isolation	Friedrich Wöhler & Antoine Bussy (1828)

Most stable isotopes of beryllium

iso	NA	half-life	DM	DE (MeV)	DP
^{7}**Be**	trace	53.12 d	ε	0.862	^{7}Li
			γ	0.477	–
^{9}**Be**	100%	is stable with 5 neutrons			
^{10}**Be**	trace	1.36×10^{6} y	β^{-}	0.556	^{10}B

Isotopes and nucleosynthesis

Both stable and unstable isotopes of beryllium are created in stars, but the radioisotopes do not last long. It is believed that most of the stable beryllium in the universe was originally created in the interstellar medium when cosmic rays induced fission in heavier elements found in interstellar gas and dust.[9] Primordial beryllium contains only one stable isotope, ^{9}Be, and therefore beryllium is a monoisotopic element.

Radioactive cosmogenic ^{10}Be is produced in the atmosphere of the Earth by the cosmic ray spallation of oxygen.[10] ^{10}Be accumulates at the soil surface, where its relatively long half-life (1.36 million years) permits a long residence time before decaying to boron-10. Thus, ^{10}Be and its daughter products are used to examine natural soil erosion, soil formation and the development of lateritic soils, and as a proxy for measurement of the variations in solar activity and the age of ice cores.[11] The production of ^{10}Be is inversely proportional to solar activity, because increased solar wind during periods of high solar activity decreases the flux of galactic cosmic rays that reach the Earth.[10] Nuclear explosions also form ^{10}Be by the reaction of fast neutrons with ^{13}C in the carbon dioxide in air. This is one of the indicators of past activity at nuclear weapon test sites.[12] The isotope ^{7}Be (half-life 53 days) is also cosmogenic, and shows an atmospheric abundance linked to sunspots, much like ^{10}Be.

^{8}Be has a very short half-life of about 7×10^{-17} s that contributes to its significant cosmological role, as elements heavier than beryllium could not have been produced by nuclear fusion in the Big Bang.[13] This is due to the lack of sufficient time during the Big Bang's nucleosynthesis phase to produce carbon by the fusion of ^{4}He nuclei and the very low concentrations of available beryllium-8. The British astronomer Sir Fred Hoyle first showed that the energy levels of ^{8}Be and ^{12}C allow carbon production by the so-called triple-alpha process in helium-fueled stars where more nucleosynthesis time is available. This process allows carbon to be produced in stars, but not in the Big Bang. Star-created carbon (the basis of carbon-based life) is thus a component in the elements in the gas and dust ejected by AGB stars and supernovae (see also Big Bang nucleosynthesis), as well as the creation of all other elements with atomic numbers larger than that of carbon.[14]

The 2s electrons of beryllium may contribute to chemical bonding. Therefore, when ^{7}Be decays by L-electron capture, it does so by taking electrons from its atomic orbitals that may be participating in bonding. This makes its decay rate dependent to a measurable degree upon its chemical surroundings – a rare occurrence in nuclear decay.[15]

The shortest-lived known isotope of beryllium is ^{13}Be which decays through neutron emission. It has a half-life of 2.7×10^{-21} s. ^{6}Be is also very short-lived with a half-life of 5.0×10^{-21} s.[16] The exotic isotopes ^{11}Be and ^{14}Be are known to exhibit a nuclear halo.[17] This phenomenon can be understood as the nuclei of ^{11}Be and ^{14}Be have, respectively, 1 and 4 neutrons orbiting substantially outside the classical Fermi 'waterdrop' model of the nucleus.

Occurrence

The Sun has a concentration of 0.1 parts per billion (ppb) of beryllium.[18] Beryllium has a concentration of 2 to 6 parts per million (ppm) in the Earth's crust.[19] It is most concentrated in the soils, 6 ppm.[20] Trace amounts of ^{9}Be are found in the Earth's atmosphere.[20] The concentration of beryllium in sea water is 0.2–0.6 parts per trillion.[20][21] In stream water, however, beryllium is more abundant with a concentration of 0.1 ppb.[22]

Beryllium ore with 1US¢ coin for scale

Beryllium is found in over 100 minerals,[23] but most are uncommon to rare. The more common beryllium containing minerals include: bertrandite ($Be_4Si_2O_7(OH)_2$), beryl ($Al_2Be_3Si_6O_{18}$), chrysoberyl (Al_2BeO_4) and phenakite (Be_2SiO_4). Precious forms of beryl are aquamarine, red beryl and emerald.[6][24][25] The green color in gem-quality forms of beryl comes from varying amounts of chromium (about 2% for emerald).[26]

The two main ores of beryllium, beryl and bertrandite, are found in Argentina, Brazil, India, Madagascar, Russia and the United States.[26] Total world reserves of beryllium ore are greater than 400,000 tonnes.[26]

Source

- Beryllium (https://en.wikipedia.org/wiki/Beryllium)