Beryllium is an element found in nature and is combined with other elements in minerals, including beryl and chrysoberyl. In its purest form, beryllium is a steel-gray and lightweight alkaline earth metal.

**Introduction**

Due to its physical properties, beryllium is useful as a hardening agent in alloys, making aerospace material, and used as a filter for radiation. Beryllium is not used for commercial use due to the harmful effects when it is inhaled through dust particles, causing berylliosis (a corrosive disease typically in the lungs). Beryllium is a rare element on Earth and in the universe and is not found to be necessary or helpful for plants or animals.

General Properties of Beryllium

<table>
<thead>
<tr>
<th><strong>Symbol</strong></th>
<th>Be</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color</strong></td>
<td>Steel Gray</td>
</tr>
<tr>
<td><strong>Atomic Number</strong></td>
<td>4</td>
</tr>
<tr>
<td><strong>Category</strong></td>
<td>Alkali Earth Metal</td>
</tr>
<tr>
<td><strong>Atomic Weight</strong></td>
<td>9.012182</td>
</tr>
<tr>
<td><strong>Group/Period</strong></td>
<td>2/2</td>
</tr>
<tr>
<td><strong>Electron Configuration</strong></td>
<td>1s² 2s²</td>
</tr>
<tr>
<td><strong>Valence Electrons</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Phase (room temperature)</strong></td>
<td>Solid</td>
</tr>
<tr>
<td><strong>Melting Point</strong></td>
<td>1560 K, 1287°C</td>
</tr>
<tr>
<td><strong>Boiling Point</strong></td>
<td>2742 K, 2469 °C</td>
</tr>
<tr>
<td>** Atomic Radius**</td>
<td>105 pm</td>
</tr>
</tbody>
</table>

**History**

In 1798, N.L. Vauquelin discovered the element in beryl and emerald. Beryllium was first isolated in 1828 by Wöhler. It is used in specialty alloys such as spring metal in which it increases toughness. It was once known as glucinium because of the sweet taste of its compounds (which, alas, are toxic). During World War I, larger amounts of beryllium were made, but it was not until the early 1930s when mass quantities of beryllium were made. During World War II, the Brush Beryllium Company was popular as the demand for beryllium copper alloys and fluorescent material in lamps grew.

**Characteristics**
Physical

Despite how light it is for a metal, beryllium has a very high melting point. It also has a high modulus of elasticity that is 50% greater than steel, along with a low density giving it a fast sound conduction speed. At STP, beryllium resists oxidation and resists corrosion in the air.

Isotopes

Although beryllium has many isotopes, only $^9\text{Be}$ is stable, classifying it as a monoisotopic element. $^{10}\text{Be}$ is produced in the atmosphere when cosmic ray spallation of oxygen and nitrogen occurs. $^{10}\text{Be}$ resides on top of soil, and has a long half-life which allows it to survive a long time before turning into $^{10}\text{B}$. This makes $^{10}\text{Be}$ useful for examining soil and solar activity because solar activity is inversely correlated with $^{10}\text{Be}$ production. Besides $^{10}\text{Be}$, many of beryllium’s isotopes, especially $^{13}\text{Be}$, have very short half-lives.

Chemical

Beryllium is a steel-gray metal that tarnishes slowly in the air due to oxide forming around it. This thin layer of oxide allows beryllium to scratch glass. Common compounds containing beryllium are emerald and aquamarine. Due to its light, stiff, and stable structure, beryllium alloys are being used in industrial work more and more.

Like all elements in the 2nd group on the periodic table, beryllium has +2 oxidation state. With a small atomic radius, Be$^{2+}$ has high polarization characteristics allowing it to form many covalent bonds. Beryllium forms an oxide layer making it not react with air or water even in extreme heat. However, when it is ignited, beryllium burns brightly making beryllium oxide and beryllium nitride. Beryllium dissolves easily in non-oxidizing acids, such as HCl, with the exception of nitric because it forms the oxide making it very similar to aluminum metal.

Beryllium combines with many non-metals to form binary compounds, such as beryllium oxide (BeO). BeO is a white solid that has a high melting point, making it useful in engines, radio equipment, and semiconductor devices.

Occurrence and Production

Beryllium is in approximately 100 of the 4000 known minerals, such as bertrandite, beryl, chrysoberyl, and phenakite. Beryllium is also present in precious gems such as aquamarine, bixbite, and emerald. Of the many beryllium minerals, only two are of commercial importance in the preparation of beryllium metal and its compounds. Bertrandite ($\text{Be}_4\text{Si}_2\text{O}_7(\text{OH})_2$) contains less than 1% Be and is the main beryllium mineral mined in the U.S., while beryl ($\text{Be}_3\text{Al}_2(\text{SiO}_3)_6$) is mined in other countries and contains approximately 4% Be. In the U.S., beryllium is mainly mined at Gold Hill and Spor Mountain in Utah, and in Alaska on the Seward Peninsula.

Beryllium metal began commercial production in 1957, but did not live up to its expectation of expanding the industry. Beryllium is made by reducing beryllium fluoride with magnesium metal in the following equation:

\[
\text{BeF}_2 + \text{Mg} \rightarrow \text{MgF}_2 + \text{Be}
\]
Emerald is less common than diamond and more expensive than gold. Columbia produces the most emerald in the world, where the Muzo mine and eastern emerald belt are located.

Applications

Despite having problems of beryllium being brittle, pricey, and poisonous, it still has many valuable purposes. Its lightweight, non-magnetic properties, and reluctance to spark is great for non-sparking tools. Beryllium is great for making aircraft and space ships due to its low density, high heat capacity, and high modulus of elasticity.

With a simple nuclei of just 4 protons and 5 neutrons, beryllium is great for tubes as it allows all radiation to pass through easily. On the contrary, beryllium atoms reflect neutrons making it great for reflectors, moderators, and control rods in research reactors. Beryllium oxide is a great electric insulator and heat conductor. It is transparent to microwaves making it useful in microwave communications systems. Beryllium oxide is also used in computers, lasers, and automotive ignition systems.

Toxicity

Beryllium is very toxic to people. The severity of toxicity depends upon how it enters the body, how long it remains in the body, how much enters the body, and how many times it enters the body. Inside the body, beryllium binds to phosphate-containing systems causing damage to one's health. Due to only small amounts of beryllium in the natural environment, there is no biological system creating a protection against this element, despite it being used more in today's industry.

If one is exposed to high levels of beryllium for an extended period of time, chronic beryllium disease (CBD) may develop. CBD symptoms include fatigue, weakness, difficulty in breathing, and chronic coughing. CBD develops when the body senses beryllium particles entering the body, which is typically inhaled into the lungs. The immune system responds by sending white blood cells to the organ, which later prevents the organ from performing its job efficiently.

References

3. Harber, Philip; Siddharth Bansal; and John Balmes. Environmental Health Perspectives, Vol. 117, No. 6 (Jun., 2009), pp. 970-974

Problems

1. What is the common chemical equation for making beryllium?
2. How many stable isotopes does beryllium have and what are they?
3. Why is beryllium able to scratch through glass?
4. Why is beryllium harmful to one's body? What disease can it lead to?
5. Name 2 industrial/commercial uses for beryllium?
Answers (Highlight over the section)

1. \[BeF_2 + Mg \rightarrow MgF_2 + Be\]

2. Be is the only stable beryllium isotope, making it a monoisotopic element.

3. Beryllium is able to scratch glass because a thin layer of oxide forms around beryllium when it is exposed to the air.

4. Beryllium is harmful to the body because it bonds to phosphate-containing systems and interferes with the organs job working productively. This can lead to illnesses such as chronic beryllium disease (CBD).

5. Beryllium is used in X-rays to allow radiation to enter and block other rays and for building aircraft and space parts due to its high heat capacity and light weight.

Contributors

• Jean Kim (UC Davis)