Elements Handbook

Group 2A: Alkaline Earth Metals

Physical Properties

- Alkaline earth metals are relatively soft, but harder than alkali metals.
- Alkaline earth metals have a gray white luster when freshly cut. When exposed to air, they quickly form a tough, thin oxide coating.
- Densities, melting points, and boiling points tend to be higher than for the alkali metal in the same period.
- Strong, lightweight magnesium alloys are used in cameras, lawnmowers, aircraft, and automobiles.

Sources

- Alkaline earth metals are not found in nature in the elemental state.
- Many mountain ranges contain alkaline earth carbonates—limestone (CaCO₃) and dolomite (CaCO₃·MgCO₃).
- Oyster shells containing CaCO₃ are used to extract magnesium. The chlorine gas produced as a by-product is fed back into the process.
- Barium is made by reduction of its oxide with aluminum at high temperature.
  
  3BaO(s) + 2Al(s) → 3Ba(l) + Al₂O₃(s)
- Salts of highly radioactive radium are a by-product of uranium refining.

Production of Magnesium

CaCO₃

Heat

CaO + CO₂

MgCl₂

+ H₂O

Driers

MgCl₂ (aq) + H₂O (l) → MgCl₂ (s) + H₂O

MgCl₂ (s) + H₂O (l) → MgCl₂ (aq)

CaO

HCl(g)

MgCl₂ (aq) + 2HCl(g) → MgCl₂ (s) + H₂O (l)

MgCl₂ (s) + 2HCl(g) → MgCl₂ (aq)

Electrolysis

Mg + Cl₂(g)

MgCl₂ (aq) → Mg (l) + Cl₂(g)

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Atomic Properties

- Alkaline earth metals have an electron configuration that ends in \( ns^2 \).
- The alkaline earth metals are strong reducing agents, losing 2 electrons and forming ions with a 2+ charge.
- Because radium is luminous, it was once used to make the hands and numbers on watches glow in the dark.
- The ratio of \(^{87}\text{Sr} \) to \(^{86}\text{Sr} \) varies with location. This data can be used to solve problems, such as the source of materials.

Important Compounds and Reactions

- Alkaline earth metals are less reactive than alkali metals.
- Alkaline earth metals react with halogens to form ionic halides. Example:
  \[
  \text{Mg}(s) + \text{Br}_2(l) \rightarrow \text{MgBr}_2(s)
  \]
- All Group 2A metals (except Be) react with water to form an alkaline solution. Example:
  \[
  \text{Sr}(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Sr(OH)}_2(aq) + \text{H}_2(g)
  \]
- Alkaline earth metals react with oxygen to form binary oxides. Example:
  \[
  2\text{Ca}(s) + \text{O}_2(g) \rightarrow 2\text{CaO(s)}
  \]
  \[
  \Delta H = -635.1 \text{ kJ/mol}
  \]
- Heating limestone produces lime, \( \text{CaO} \).
  \[
  \text{CaCO}_3(s) \rightarrow \text{CaO(s)} + \text{CO}_2(g)
  \]
  \[
  \Delta H = 176 \text{ kJ/mol}
  \]
- Slaked lime, \( \text{Ca(OH)}_2 \), reacts with carbon dioxide to form limestone.
  \[
  \text{Ca(OH)}_2(s) + \text{CO}_2(g) \rightarrow \text{CaCO}_3(s) + \text{H}_2\text{O(g)}
  \]
- Barium peroxide is used as a dry powdered bleach. It reacts with water to form the bleaching agent, hydrogen peroxide.
  \[
  \text{BaO}_2(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}_2(aq) + \text{Ba(OH)}_2(aq)
  \]
- Gypsum, calcium sulfate dihydrate, \( \text{CaSO}_4\cdot2\text{H}_2\text{O} \), is used to make plasterboard.
- Calcium phosphate, \( \text{Ca}_3(\text{PO}_4)_2 \), is the major component of bone and teeth.

\[\text{Slaked lime is an ingredient in plaster, cement, and the mortar used in this stone wall.}\]
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**Mg Chlorophyll**

A plant that is deprived of magnesium will turn yellow and eventually die. The yellow color is a sign that the plant is not producing enough of the green pigment chlorophyll, which is found in structures called chloroplasts. There are about half a million chloroplasts in one square millimeter of leaf surface. In chloroplasts, light energy is changed to chemical energy. Chlorophyll molecules absorb wavelengths of blue light and red light, and reflect green light. There is a magnesium ion at the center of each chlorophyll molecule. It is embedded like a jewel in a crown-like ring. The magnesium ion forms a bond with each nitrogen atom.

Chlorophyll is typical of a family of compounds called porphyrins, which contain a central metal ion. In heme, the ion is Fe^{2+}. There are four heme molecules in hemoglobin, which transports oxygen in the blood.

**Sr Ba Fireworks**

Producing an aerial fireworks display requires skill and knowledge of chemistry. Shells are stored in steel pipes anchored in sand. A typical shell contains two charges, one to launch the shell and one to cause the shell to burst. When the lifting charge explodes, the shell is blown out of the pipe and the fuse attached to the bursting charge ignites. The shell travels for a few seconds before it bursts.

The explosions that launch the shells and cause them to burst are exothermic redox reactions. The reducing agent, or fuel, may be aluminum, magnesium, or sulfur. The oxidizing agent may be a nitrate, a chlorate, or a perchlorate, such as potassium perchlorate (KClO₄).

When a shell bursts, it releases tiny pellets called “stars,” which produce the colors. Only a few elements are needed to produce these colors. Two are alkaline earth metals, strontium for bright red and barium for light green. These same colors are produced when strontium and barium compounds are heated in a flame. Flame tests can identify elements because an element emits characteristic wavelengths of light when its atoms absorb heat and then return to the ground state.
**Limestone Caves**

The chemical reactions that form a limestone cave are simple. Carbon dioxide in the air dissolves in rain to form weak carbonic acid, $\text{H}_2\text{CO}_3$. As rain passes through soil, it dissolves carbon dioxide produced by decaying plants and becomes even more acidic. The rainwater seeps into limestone, $\text{CaCO}_3$, beneath the soil. The $\text{CaCO}_3$ dissolves in the carbonic acid, forming a solution of calcium hydrogen carbonate, $\text{Ca(HCO}_3\text{)}_2$.

$$\text{CaCO}_3(s) + \text{H}_2\text{CO}_3(aq) \rightarrow \text{Ca}^{2+}(aq) + 2\text{HCO}_3^-(aq)$$

Over millions of years, as more and more limestone dissolves, a cave forms and slowly grows in size. Once the cave stops growing, another process may occur. Calcium hydrogen carbonate solution drips through the cave’s roof. Carbon dioxide is released from solution, leaving behind a tiny deposit of solid calcium carbonate.

$$\text{Ca}^{2+}(aq) + 2\text{HCO}_3^-(aq) \rightarrow \text{CaCO}_3(s) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$$

The deposit slowly grows into a stalactite, which hangs from the ceiling like an icicle. Drops of solution that fall from the ceiling form stalagmites on the cave floor. Calcium carbonate is white. So any color in the deposits is due to traces of metal ions, such as copper (blue-green) and iron (red-brown). The growth rate of the formations depends mainly on the volume of water that drips through the roof and the concentration of calcium bicarbonate in the water. In many caves, the rate of growth is measured in centimeters per hundreds or thousands of years. ■

**Building Strong Bones**

As a young adult, you can have a major effect on the health of your bones later in life. You acquire 90% of the bone tissue in your skeleton before age 18 as females and age 20 as males. Physical activity and the amount of calcium in your diet affect the buildup of bone mass.

To maintain a constant level of calcium in your blood, your body may release calcium from bone tissue. If enough calcium is lost from bones, they become brittle and tend to break easily. This condition, known as osteoporosis, is most common in older people. However, it can occur in young and middle-aged adults.

The recommended daily intake of calcium from age 9 to age 18 is 1.3 grams per day. This is the amount in a liter of milk.

Calcium-fortified foods, such as orange juice, are a good choice for those who cannot tolerate the lactose in milk. Vitamin D in orange juice helps you absorb calcium. ■

**Did You Know...**

Calcium oxide (lime) emits a bright white light when it is heated. Before electric lights, theaters used lime to focus light on a single actor. So the expression in the limelight describes a person in a prominent position.

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