Alkaline Earth Metals

Be
Mg
Ca
Sr
Ba

Alkaline Earth Group

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• Group IIA shows the same general trends of increasing atomic and ionic sizes and decreasing ionization energies from top to bottom as does Group IA.
General properties

• Except for Be, the metals have similar properties.
  – They readily react to produce cations with +2 charge,
  – They are good reducing agents.
General properties

• Except for Be, the metals have similar properties
  – As the cation size increases, the interionic attractions (anion-cation interaction) that hold the crystalline solid together decrease in strength and the solubilities of the compounds in water increases
General properties

• The hydroxides and oxides are strong bases but they are not very soluble.

• The solubilities of the metal hydroxides of Group IIA in water increase from top to bottom.
• Be is more like Al than other alkali earth metals – diagonal relationship.
Almost alkaline earth metals are hydrated
Ion density $\gg\gg \rightarrow \Sigma$ hydrated water molecule $\gg\gg$

The salt of alkaline earth slightly soluble
Monovalent salt $\rightarrow$ soluble
Divalent salt $\rightarrow$ slightly soluble
Reactions Of The Alkaline Earth Metals

- Reactions with water is more vigorous toward the bottom of the family.

\[ \text{M(s)} + 2 \text{H}_2\text{O (ℓ)} \rightarrow \text{M(OH)}_2(aq) + \text{H}_2(g) \]

\[ \text{M} = \text{Ca, Sr, Ba} \]
Mg does react with steam, but MgO is formed rather than Mg(OH)$_2$.

$$\text{Mg(s) + 2 H}_2\text{O(g) → MgO(s) + H}_2\text{(g)}$$
Reactions Of The Alkaline Earth Metals

• All alkali earth metals react with dilute acids to displace hydrogen.

\[ M(s) + 2 \ H^+(aq) \rightarrow M^{2+}(aq) + H_2(g) \]
Reactions Of The Alkaline Earth Metals

The following reactions occur with Mg, Ca, Sr, Ba, NOT with Be.

1. \[ M(s) + X_2(g) \rightarrow MX_2(s) \]
   \[ X_2 = F_2, Cl_2, Br_2, I_2 \]

2. \[ M(s) + O_2(g) \rightarrow 2MO(s) \]

3. \[ M(s) + N_2(g) \rightarrow M_3N_2(s) \]
Physical properties

• Have higher melting points, are harder and are denser than potassium and sodium

• When put in flame:
  – Mg : white
  – Ca : dark red
  – Sr : crinsom
  – Ba : light green
Beryllium

Sources:

• beryl mineral \((\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18} / \text{Be}_3\text{Al}_2(\text{SiO}_3)_6)\)

• bertrandite \([4\text{BeO}.2\text{SiO}_2.\text{H}_2\text{O}]\)
  Light green-bluish from beryl → aquamarine
  Deep green → emerald → ~ 2% Cr(III)
Beryllium

Production:

1. Extraction from its ore (complex procedure)

Beryl ore are heated by hexafluorosilicate (Na$_2$SiF$_6$) at 700$^\circ$C → beryllium fluoride / beryllium chloride → electrolyzed in molten NaCl

BeCl$_2$ (in molten NaCl) → Be(s) + Cl$_2$(g)
Beryllium

Production:

2. Reduction of beryllium fluoride by magnesium (T\(\approx\) 1300\(^\circ\)C)

\[
\text{BeF}_2(s) + \text{Mg}(\ell) \rightarrow \text{MgF}_2(s) + \text{Be}(s)
\]
Beryllium

1-st & 2-nd ionization energy of Be>other alkaline earth metals?

What is the coordination number of Be$^{2+}$?

Geometri shape of BeH$_2$, BeCl$_2$ BeBr$_2$?
Beryllium

• Beryllium oxide & beryllium halides → covalent properties,
  \[ \text{[Be(H}_2\text{O)}_4\text{]}^{2+}, \text{[BeF}_4\text{]}^{2-}, \text{[BeCl}_4\text{]}^{2-} \]
• Beryllium amphoteric

\[
\text{H}_2\text{O(ℓ) + BeO(s) + 2 H}_3\text{O}^+(aq) \rightarrow [\text{Be(H}_2\text{O)}_4\text{]}^{2+}(aq)
\]

\[
\text{H}_2\text{O(ℓ) + BeO(s) + 2OH}^-(aq) \rightarrow [\text{Be(OH)}_4\text{]}^{2-}(aq)
\]
Beryllium

- Uses
- Spacecraft
- Aircraft
- Missiles
- X-rays
Magnesium

Sources:
- carnalite \((\text{MgCl}_2.\text{KCl}.6\text{H}_2\text{O})\) & dolomite \((\text{MgCO}_3.\text{CaCO}_3)\)
  - Carnalite compiler ratio: \(\text{Cl}^-:\text{Mg}^{2+}:\text{K}^+:\text{H}_2\text{O} = 3 : 1 : 1 : 6\) \(\rightarrow\) \(\text{KMgCl}_3.6\text{H}_2\text{O}\)
- brine (no 3. after \(\text{Na}^+\) & \(\text{Cl}^-\))
Magnesium

Production:
- Dow process
- Calcinations of dolomite → calcinated dolomite (MgO.CaO) → reacted by ferrosilicon alloy

\[
2[\text{MgO.CaO}] (s) + \text{FeSi}(s) \\
\rightarrow 2 \text{Mg}(\ell) + \text{Ca}_2\text{SiO}_4(s) + \text{Fe} (s)
\]

Magnesium is distilled from the mixture.
Magnesium

Uses

• Used on pyrotechnic, light on photographic
• Because of its weight just 1/3 of aluminum`s, magnesium is used in aircraft making, missile construction
Magnesium

• Alloy of Magnesium – Aluminum:
  95% Mg – 5% Al
  strength >>> weight<<< (strength/weight ratio>>>)
  5% Mg – 95% Al
  increase mechanical property & corrosion resistance
Uses

• Because of its reactivity >>>
  – sacrificial anode
  – cathode corrosion protection

• Reducing agent on the production of titanium, uranium, beryllium
Magnesium

Uses

• Magnesia milk (suspension solution of pure Mg(OH)$_2$ → antacid (neutralized stomach acid))

• Used on the production of organomagnesium compounds (Grignard reagent)
Fire by burning magnesium

Magnesium oxidized slowly at room temperature, violence at heating

\[ 2 \text{Mg} (s) + \text{O}_2 (g) \rightarrow \text{MgO} (s) \]
Fire by burning magnesium

Burned magnesium metal can not be extinguished by conventional extinguisher.

Why?

What should we do?
Fire by burning magnesium

Conventional extinguisher $\rightarrow$ $\text{CO}_2$ and $\text{H}_2\text{O}$

$2 \text{ Mg}(s) + \text{ CO}_2(g) \rightarrow 2 \text{ MgO}(s) + \text{ C}(s)$

Fire is getting more violent
Fire by burning magnesium

**Extinguish method**:  
- Graphite → react with burned magnesium → magnesium carbide  
  \[
  \text{Mg}(s) + \text{C}(s) \rightarrow \text{MgC}_2(s)
  \]  
  \(\text{MgC}_2\) cover burned metal surface effectively & prevent further burning reaction
Fire by burning magnesium

Extinguish method:

• NaCl melt on the burning temperature of magnesium → inert layer → cover burned metal surface prevent further contact with O₂, H₂O, and CO₂
Calcium

Uses

• Builds Strong bones and teeth

• Used in Milk

• Used to make plaster
Strontium

Uses

• Flares

• To create a crimson color
Barium

Uses

• Medical Applications

• Glass making

• Rat poison

• Making Rubber
Uses

- Treating Cancer
Alkaline earth oxide

Be, Mg, Ca, Sr + O_2 → normal oxide
Ba + O_2 → peroxide

MgO:
• melting point >>> (2825°C) → raw material of furnace lining
• good thermal conductor, but not for electric
Alkaline earth oxide

CaO:
- used on steel industry
- with water forms \( \text{Ca(OH)}_2 \rightarrow \text{neutralized} \) soil acidity \( \rightarrow \) too base

\[
\text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca(OH)}_2(aq)
\]

\[
\text{Ca(OH)}_2(aq) + \text{H}_3\text{O}^+(aq)
\rightarrow \text{Ca}^{2+}(aq) + 3\text{H}_2\text{O}(l)
\]

\[
\text{CaCO}_3(s) + \text{H}_3\text{O}^+(aq)
\rightarrow \text{Ca}^{2+}(aq) + \text{CO}_2(g) + 3\text{H}_2\text{O}(l)
\]
Alkaline earth oxide

1. Calcium carbonate (CaCO$_3$)
The formation of lime cave, stalagmite dan stalagmite

Reactions:

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

\[
\text{Ca(HCO}_3)_2(aq) \rightarrow \text{CaCO}_3(s) + \text{CO}_2(g) + \text{H}_2\text{O}(ℓ)
\]
1. Calcium carbonate (antacid) reacts with stomach acid → $\text{CO}_2 \ (g) + \text{Ca}^{2+} (aq)$

$\text{Ca}^{2+} \rightarrow \text{efek sembelit}$ (in contrast to $\text{Mg}^{2+} \rightarrow \text{memperlancar}$)
Alkaline earth oxide

2. Magnesium sulfate (MgSO$_4$.7H$_2$O)
Other name: Epsom salt
Uses: laxative effect / memperlancar
3. Calcium sulfate (CaSO$_4$·2H$_2$O)

Other name: gypsum

Uses: inflammable room separator
Alkaline earth oxide

3. Calcium sulfate (CaSO₄·2H₂O)

\[
\text{CaSO}_4\cdot2\text{H}_2\text{O} \xrightarrow{100^\circ C} \text{CaSO}_4\cdot\frac{1}{2}\text{H}_2\text{O}(s) + \frac{3}{2}\text{H}_2\text{O}(l)
\]
\[\Delta H = +446 \text{ kJ/mol}\]
(hemidrate, paris plaster)

\[
\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(g)
\]
\[\Delta H = +44 \text{ kJ/mol}\]
Important Reactions of Ca Compounds

Calcination: \( \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \)
quicklime or lime

Hydration: \( \text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca(OH)}_2(s) \)
slaked lime

Carbonation: \( \text{Ca(OH)}_2 + \text{CO}_2(g) \rightarrow \text{CaCO}_3(s) + \text{H}_2\text{O}(l) \)

• The three steps are combined and used to prepare chemically pure \( \text{CaCO}_3(s) \) from limestone.
The Group IIA Metals
And Living Matter

- Persons of average size have approximately 25 g of magnesium in their bodies.
- The recommended daily intake of magnesium for adults is 350 mg.
- Calcium is essential to all living matter. The human body typically contains from 1 to 1.5 kg of calcium – bones and teeth.
The Group IIA Metals And Living Matter

- Strontium is not essential to living matter, but it is of interest because of its chemical similarity to calcium.
- Barium also has no known function in organisms; in fact the $\text{Ba}^{2+}$ ion is toxic.
Diagonal Relationships: The Special Case Of Beryllium

In some of its properties, beryllium and its compounds resemble aluminium and its compounds.

1. Both Be and Al react with air to form oxide layer that protect the layer below from further contact with air.
Diagonal Relationships: The Special Case Of Beryllium

In some of its properties, beryllium and its compounds resemble aluminium and its compounds.

2. Both Be and Al are amphoteric. Berilat and aluminat anions are formed from the reaction of Be and Al with concentrated hydroxide.
In some of its properties, beryllium and its compounds resemble aluminium and its compounds.

3. The two carbide of Be and Al (Be$_2$C and Al$_4$C$_3$) react with water to form metane. While dicarbide(-2) of other alkaline earth react with water to form ethyne.

$$\text{Be}_2\text{C(s) + 4H}_2\text{O(ℓ) → 2Be(OH)\text{\textsubscript{2}}(s) + CH}_4\text{(g)}$$

$$\text{Al}_4\text{C}_3\text{(s) + 12H}_2\text{O(ℓ) → 4Al(OH)\text{\textsubscript{3}}(s) + 3CH}_4\text{(g)}}$$