Summary and Notes for Exam Preparation: Group 2 Elements

1. Physical Properties of Group 2 Elements

Key Elements

- Beryllium (Be)
- Magnesium (Mg)
- Calcium (Ca)
- Strontium (Sr)
- Barium (Ba)
- Radium (Ra)

Trends in Physical Properties

a) Atomic and Ionic Size

- Trend: Increases down the group.
- Explanation: As the atomic number increases, more electron shells are added, leading to a larger atomic and ionic size.
- Example:
  - Be^{2+} (31 pm)
  - Mg^{2+} (65 pm)
  - Ca^{2+} (99 pm)
  - Sr^{2+} (113 pm)
  - Ba^{2+} (135 pm)

b) Melting and Boiling Points

- Trend: Generally decrease down the group.
- Values:
  - Beryllium: mp 1278°C, bp 2970°C
  - Magnesium: mp 649°C, bp 1090°C
  - Calcium: mp 842°C, bp 1484°C
- Explanation: Despite increasing atomic size, the metallic bonding becomes weaker due to increasing atomic radius and decreasing charge density, which lowers the melting and boiling points.

c) First and Second Ionization Energies

- Trend: Decrease down the group.
- Explanation:
  - Outer electrons are further from the nucleus.
  - Increased shielding from inner electrons.
  - Weaker nuclear attraction makes it easier to remove the outer electrons.
- Example Values (First Ionization Energy, kJ/mol):

- Beryllium: 899
- Magnesium: 738
- Calcium: 590

d) Density

- Trend: Generally increases down the group.
- Exception: Beryllium has an unusually high density due to its small atomic size and tightly packed crystal lattice.

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2. Reactions of Group 2 Elements

A. General Reactivity Trend

- Trend: Reactivity increases down the group.
- Reason:
  - Larger atoms make it easier to lose electrons.
  - Lower ionization energies down the group.
  - Increased reactivity with water and oxygen.

B. Reaction with Oxygen

General Equation: $2M(s) + O_2(g) \rightarrow 2MO(s)$ [where M = Group 2 metal]

Specific Examples:

1. **Magnesium**:
   - $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
   - Bright white flame
   - Forms white powder
   - **Practical Note**: Used in fireworks
2. **Calcium**:
   - $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$
   - Less vigorous than Mg
   - Forms white calcium oxide (quicklime)
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C. Reaction with Water

- Trend: Reactivity increases down the group.
  - Beryllium: No reaction.
  - Magnesium: Reacts slowly with steam.
  - Calcium, Strontium, Barium: React vigorously with cold water.
- Equations and Observations:

Magnesium with Steam:

- $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$
- Requires heating
- White oxide coating forms

Calcium with Cold Water:

- $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$
- Vigorous reaction
- Solution turns milky
- **Test**: Limewater formed ($Ca(OH)_2$)
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3. Reactions of Group 2 Carbonates

A. With Water

- Generally insoluble in water.
- Solubility increases down the group.
- Example: $BaCO_3$ is more soluble than $MgCO_3$.

B. With Dilute Acids

- General Equation:
- $MCO_3(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + CO_2(g) + H_2O(l)$
- Example (with HCl):
- $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$
- Test for CO_2: Turns limewater milky $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

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4. Thermal Decomposition

A. Carbonates

General Equation:

$MCO_3(s) \rightarrow MO(s) + CO_2(g)$

Stability Trend:

Stability increases down the group

Decomposition Temperatures:

- $MgCO_3$: ~350°C
- $CaCO_3$: ~900°C
- $BaCO_3$: ~1300°C

B. Nitrates

- General Equation:
- $2M(NO_3)_2(s) \rightarrow 2MO(s) + 4NO_2(g) + O_2(g)$
- Observations:
- Brown gas (NO_2) evolved.
- White solid residue (metal oxide).

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5. Uses of Group 2 Compounds

A. Magnesium Compounds

- MgO:
  - Refractory lining in furnaces.
  - Antacid medication.
- $MgCO_3$:
  - Gymnastics chalk.
  - Toothpaste additive.

B. Calcium Compounds

- CaO (Quicklime):
  - Making cement.
  - Neutralizing acidic soils.
- $Ca(OH)_2$ (Slaked Lime):
  - Making mortar.
  - Water treatment.
- $CaCO_3$:
  - Building material.
  - Antacid tablets.

C. Barium Compounds

- $BaSO_4$:
  - X-ray contrast medium.
  - Paint pigment.

Exam Tips and Common Questions

1. Trend Questions

- Always link to atomic/ionic size and charge density.
- Remember: Reactivity increases down the group.
- Explain trends using electronic configuration.

2. Practical Questions

- Know the test for CO_2 (limewater).
- Recognize observations (colors, gas evolution).
- Understand flame colors:
    - Calcium: Brick red.
    - Strontium: Crimson red.
    - Barium: Apple green.

3. Calculation Tips

- Know how to calculate:
    - Empirical formulae.
    - Percentage yield.
    - Atom economy.
- Practice with past paper questions involving these compounds.

Sample Exam Question

Q: Explain why magnesium reacts with steam but not cold water, while calcium reacts with cold water.

Model Answer:

- Magnesium has a higher ionization energy than calcium.
- Mg^{2+} has a higher charge density than Ca^{2+}.
- More energy (steam) is needed to overcome the activation energy for magnesium.
- Calcium's larger atomic size and lower ionization energy make it more reactive.
- Ca^{2+} has a lower charge density, making it easier to form hydroxide.

Remember: Always use correct chemical terminology and include balanced equations where relevant.
