MEGA LECTURE · A LEVEL CHEMISTRY

Chapter 8: Group 2, the Alkaline Earth Metals

OCR A Level Chemistry A (H432) — Structured Practice Worksheet

SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
3.1.2 Group 2: reactivity, reactions with water/oxygen/ acid, solubility trends, uses	85	1 hour 45 minutes

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Instructions to candidates

- Answer **all** questions in the spaces provided.
- Group 2 elements: beryllium, magnesium, calcium, strontium, barium.
- Marks are shown in brackets [ ] at the end of each part.

Question 1 — Reactivity trend down Group 2 3.1.2

a. Describe the general trend in reactivity of the Group 2 metals going down the group. **[2]**

b. Explain this trend in reactivity in terms of atomic radius, shielding and ionisation energy. **[4]**

c. Write the electron configuration of a calcium atom and of a Ca^{2+} ion. **[2]**

Question 1 total: 8 marks

Question 2 — Reactions with water 3.1.2

a. Write the equation, with state symbols, for the reaction of magnesium with cold water. **[2]**

b. State the observation for the reaction of magnesium with cold water. **[1]**

c. Write the equation, with state symbols, for the reaction of calcium with cold water. **[2]**

d. State three observations for the reaction of calcium with cold water. **[3]**

e. Predict and explain how the rate of reaction with cold water changes going down the group from magnesium to barium. **[3]**

f. Write the equation for the reaction of magnesium with steam, and name the products. **[2]**

Question 2 total: 13 marks

Question 3 — Reactions with oxygen and dilute acid 3.1.2

a. Write the equation for the combustion of magnesium in oxygen. **[2]**

b. State the observation when magnesium burns in air. **[1]**

c. Write the equation, with state symbols, for the reaction of magnesium with dilute hydrochloric acid. **[2]**

d. Write the ionic equation for the reaction of any Group 2 metal with dilute acid. **[2]**

e. Explain why the reaction of a Group 2 metal with dilute acid is faster than its reaction with water. **[2]**

Question 3 total: 9 marks

Question 4 — Oxides and hydroxides: basicity 3.1.2

a. Write the equation for the reaction of magnesium oxide with water, and state the approximate pH of the resulting mixture. **[2]**

b. Write the equation for the reaction of calcium oxide with water. **[2]**

c. Explain why the resulting solution is more strongly alkaline for calcium oxide than for magnesium oxide, in terms of solubility of the hydroxide formed. **[3]**

d. Write the equation for the reaction of magnesium oxide with dilute hydrochloric acid. **[2]**

e. State the use of magnesium hydroxide and calcium hydroxide as bases in agriculture and medicine, giving one example of each. **[2]**

Question 4 total: 11 marks

Question 5 — Solubility trends 3.1.2

a. Describe the trend in solubility of the Group 2 hydroxides going down the group. **[2]**

b. Describe the trend in solubility of the Group 2 sulfates going down the group. **[2]**

c. Explain why magnesium hydroxide is used as an antacid ("milk of magnesia") despite being only sparingly soluble in water. **[3]**

d. Barium sulfate is used in "barium meals" for X-ray imaging of the digestive system, even though barium ions are toxic. Explain why this is safe. **[2]**

Question 5 total: 9 marks

Question 6 — Testing for sulfate ions

3.1.2 / PAG

A student is asked to test an unknown solution for the presence of sulfate ions.

a. Describe the test, including the reagents added and the observation for a positive result. **[3]**

b. Write the ionic equation, with state symbols, for the reaction that occurs in a positive test. **[2]**

c. Explain why dilute hydrochloric acid is added to the solution before the test. **[2]**

d. The student uses barium nitrate instead of barium chloride. Explain why this is a valid alternative, but explain one advantage of using barium chloride. **[2]**

Question 6 total: 9 marks

Question 7 — Thermal stability of carbonates and nitrates

3.1.2

a. Write the equation for the thermal decomposition of magnesium carbonate. **[2]**

b. **[3]**

Describe and explain the trend in thermal stability of the Group 2 carbonates going down the group.

c. Explain the trend in (b) in terms of the polarising power (charge density) of the Group 2 cation and its effect on the carbonate ion. **[4]**

d. Write the equation for the thermal decomposition of magnesium nitrate, $Mg(NO_3)_2$. **[2]**

Question 7 total: 11 marks

Question 8 — Flame tests and identification

3.1.2 / PAG

a. State the flame test colour for calcium, strontium and barium compounds, and describe how a flame test is carried out. **[4]**

b. Explain, in terms of electron transitions, why metal ions produce a characteristic flame colour. **[3]**

c. A student is given an unknown white solid and told it is either magnesium carbonate or calcium carbonate. Describe a test, other than a flame test, that could distinguish between them, including the reagent and expected observations. **[3]**

Question 8 total: 10 marks

Question 9 — Extended response

Synoptic

Magnesium hydroxide and magnesium sulfate are both compounds of magnesium, yet magnesium hydroxide is used as an antacid while magnesium sulfate solution is used as a laxative, and both rely on their different solubility behaviour. Explain, using the solubility trends of Group 2 hydroxides and sulfates, why these two compounds have such different levels of solubility in water despite both containing the same Mg^{2+} cation. **[5]**

This question is marked using a level of response.

Question 9 total: 5 marks

PAPER TOTAL: 85 MARKS

MARK SCHEME — Chapter 8: Group 2, the Alkaline Earth Metals

Award marks independently unless stated.

Q1 (a) [2]

- Reactivity increases going down Group 2. (2, or 1 for a vague/partial statement)

Q1 (b) [4]

- Atomic radius increases down the group (extra electron shells). (1)
- Shielding increases down the group. (1)
- Both effects outweigh the increasing nuclear charge, so the two outer electrons are more easily lost. (1)
- Lower ionisation energy down the group means the metal reacts (loses electrons) more readily/reacts faster. (1)

Q1 (c) [2]

- Ca: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$. (1)
- Ca^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6$. (1)

Q2 (a) [2]

- $Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2(g)$ (1 species, 1 balancing/states)
- *Accept $Mg(OH)_2(s)$ as magnesium hydroxide is only sparingly soluble.*

Q2 (b) [1]

- Very slow reaction; few/slow bubbles of gas seen (reaction is very slow at room temperature). (1)

Q2 (c) [2]

- $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$ (1 species, 1 balancing/states)

Q2 (d) [3]

- Effervescence (bubbles of gas). (1)
- The metal moves around in the water / dissolves. (1)
- The solution turns cloudy/milky as calcium hydroxide (limewater) forms. (1)

Q2 (e) [3]

- Rate of reaction with cold water increases going down the group (from very slow with Mg to vigorous with Ba). (1)
- This follows the increasing reactivity trend down the group. (1)
- Explanation: lower ionisation energy down the group (larger radius, more shielding) means electrons are lost more readily, so reaction is faster. (1)

Q2 (f) [2]

- $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$ (1)
- Products: magnesium oxide and hydrogen. (1)

Q3 (a) [2]

- $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ (1 species, 1 balancing)

Q3 (b) [1]

- Bright/brilliant white flame/light, leaving a white solid/ash. (1)

Q3 (c) [2]

- $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ (1 species, 1 balancing/states)

Q3 (d) [2]

- $M(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$ (1 species/charges, 1 state symbols)

Q3 (e) [2]

- Dilute acid has a much higher concentration of H^+ ions available to react than water (which only slightly self-ionises). (1)
- Higher concentration of the reacting species (H^+) increases the frequency of successful collisions, increasing the rate. (1)

Q4 (a) [2]

- $MgO + H_2O \rightarrow Mg(OH)_2$ (1)
- Weakly alkaline, pH around 9–10 (magnesium hydroxide is only sparingly soluble). (1)

Q4 (b) [2]

- $CaO + H_2O \rightarrow Ca(OH)_2$ (1 species, 1 balancing)

Q4 (c) [3]

- $Ca(OH)_2$ is more soluble in water than $Mg(OH)_2$. (1)
- A higher concentration of OH^- ions is released into solution. (1)
- Higher $[OH^-]$ gives a higher pH, so the calcium oxide solution is more strongly alkaline. (1)

Q4 (d) [2]

- $MgO + 2HCl \rightarrow MgCl_2 + H_2O$ (1 species, 1 balancing)

Q4 (e) [2]

- Calcium hydroxide (slaked lime) is used to neutralise acidic soils in agriculture. (1)
- Magnesium hydroxide is used as an antacid to neutralise excess stomach acid ("milk of magnesia"). (1)

Q5 (a) [2]

- Solubility of the hydroxides increases going down the group. (2, or 1 for partial)

Q5 (b) [2]

- Solubility of the sulfates decreases going down the group. (2, or 1 for partial)

Q5 (c) [3]

- Although only sparingly soluble, enough $Mg(OH)_2$ dissolves to provide OH^- ions to neutralise excess stomach (hydrochloric) acid. (1)
- Its low solubility means the concentration of OH^- released is limited/controlled. (1)
- This makes it gentle/safe to use, avoiding a dangerously alkaline solution forming in the stomach. (1)

Q5 (d) [2]

- Barium sulfate is (essentially) insoluble in water. (1)
- So it passes through the digestive system without releasing (dissolving into) toxic Ba^{2+} ions into the bloodstream. (1)

Q6 (a) [3]

- Add dilute hydrochloric acid, then add aqueous barium chloride (or barium nitrate) solution. (2)
- Positive result: a white precipitate forms. (1)

Q6 (b) [2]

- $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ (1 species, 1 state symbols)

Q6 (c) [2]

- The acid removes/reacts with other ions (e.g. carbonate or sulfite) that could also form a white precipitate with barium ions. (1)
- This prevents a false positive result. (1)

Q6 (d) [2]

- Both barium chloride and barium nitrate provide the Ba^{2+} ion needed for the test; both their anions (Cl^-, NO_3^-) do not interfere by forming a precipitate. (1)
- Advantage of barium chloride: it is cheaper / more commonly available (either valid comparative advantage accepted). (1)

Q7 (a) [2]

- $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$ (1 species, 1 balancing/states)

Q7 (b) [3]

- Thermal stability of the carbonates increases going down the group. (1)
- Group 2 carbonates need a higher temperature to decompose as you go down the group. (1)
- Correct direction linked to the group trend (Mg least stable, Ba most stable). (1)

Q7 (c) [4]

- Smaller Group 2 cations (e.g. Mg^{2+}) have a higher charge density (charge/radius ratio). (1)
- These cations more strongly polarise/distort the electron cloud of the neighbouring carbonate ion. (1)
- This weakens a C–O bond within the carbonate ion, making it easier to decompose to the oxide and CO_2. (1)
- Down the group, cation radius increases, charge density and polarising power decrease, so the carbonate ion is less distorted and more thermally stable. (1)

Q7 (d) [2]

- $2Mg(NO_3)_2(s) \rightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$ (1 species, 1 balancing)

Q8 (a) [4]

- Calcium: brick-red / orange-red. (1)
- Strontium: crimson/red. (1)
- Barium: pale/apple green. (1)
- Procedure: dip a clean nichrome/platinum wire (moistened, dipped in the solid or solution) into a blue Bunsen flame and observe the flame colour. (1)

Q8 (b) [3]

- Heat energy from the flame excites electrons to a higher energy level. (1)
- Electrons are unstable at the higher level and fall back down to a lower energy level. (1)
- Energy is released as a photon of visible light with a frequency (and hence colour) characteristic of that metal's energy level spacing. (1)

Q8 (c) [3]

- Heat a sample of each solid strongly and test any gas produced with limewater (or observe general thermal decomposition). (1)
- Alternative valid answer: dissolve in water and add dilute sulfuric acid — $MgSO_4$ is soluble (no visible change), $CaSO_4$ is only sparingly soluble and may form a faint white precipitate. (1)
- Correct link between the observation and correctly identifying which carbonate is which. (1)

Q9 [5] — Level of response

- **Level 3 (4–5):** Correctly applies both solubility trends (hydroxide increases, sulfate decreases down the group) to explain why $Mg(OH)_2$ is only sparingly soluble while $MgSO_4$ is soluble, in a clear, logical answer.
- **Level 2 (2–3):** Identifies at least one correct trend and applies it partially to magnesium's position in the group.
- **Level 1 (1):** Vague or generic statement about solubility with little reference to Group 2 trends.

Indicative content: *Group 2 hydroxide solubility increases down the group — magnesium, near the top, therefore forms a hydroxide that is only sparingly soluble, releasing OH^- slowly and safely to neutralise excess stomach acid as an antacid. Group 2 sulfate solubility decreases down the group — magnesium, again near the top, forms a sulfate that is relatively soluble, so magnesium sulfate solution contains a high concentration of ions that draws water into the gut by osmosis, producing a laxative effect. The opposite solubility trends of the two anions (OH^- vs SO_4^{2-}) mean the same cation (Mg^{2+}) can form both a poorly soluble and a soluble compound.*

END OF MARK SCHEME · 85 marks