# Topic Exploration Pack

# The Chemistry of Group 2

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## Instructions and answers for teachers

These instructions cover the student activity section which can be found on [page 10](#_Student_Activity). This Topic Exploration Pack supports OCR AS and A Level Chemistry B (Salters).

**When distributing the activity section to the students either as a printed copy or as a Word file you will need to remove the teacher instructions section.**

### Learning outcomes

### EL(d) balanced full and ionic chemical equations, including state symbols

### EL(o) the relationship between the position of an element in the s- or p-block of the periodic table and the charge on its ion

### EL(p) a description and comparison of the following properties of the elements and compounds of Mg, Ca, Sr and Ba in Group 2: reactions of the elements with water and oxygen, thermal stability of the carbonates, solubilities of hydroxides and carbonates

### EL(q) the term ionisation enthalpy; explanation of trends in first ionisation enthalpies for Periods 2 and 3 and groups and the resulting difference

### EL(r) charge density of an ion and its relation to the thermal stability of the Group 2 carbonates

### EL(u) the basic nature of the oxides and hydroxides of Group 2 (Mg–Ba)

### Introduction

**Preparation**

Before learners attempt this section, it is worth checking that they have a solid understanding of some of the concepts that will help them predict and rationalise the reactions learnt in this section. Learners should be confident with previous sections relating to periodicity. For example, learners need to understand patterns relating to atomic radius and how it changes both across a period and down a group. Learners should also be familiar with the charges on common ions, such as carbonates (CO32–) and hydroxides (OH–).

**Practical**

When carrying out a practical with a class, make sure time is taken to ensure that learners make the correct observations. Make sure common misconceptions are cleared up when discussing what is seen in a practical. For example, make sure learners do not mix up concepts of colourless and clear solutions. Also make sure that when writing down observations of effervescence learners do not write down the gas that evolves, even if they know it, as this is bad practice. Depending on class sizes and availability of equipment, it is worth having small groups, or even have learners work individually to ensure they are aware of the reagents that are being used.

**Thermal stability**

Ensure you provide a clear explanation for the thermal stability of Group 2 carbonates. A common misconception is that decrease in polarisation of the carbonate ion due to decreased charge density results in thermal stability decreasing down the group, rather than the reverse. This misconception is due to learners associating the higher charge density in the metal ion with a stronger attraction between the ion and the carbonate, and so requiring more energy to break apart. Some learners may find the actual explanation initially counterintuitive. When explaining the logic behind thermal stability, explain how the greater charge density distorts the carbonate ion, lowering the energy of decomposition. Make sure the reasons are explained clearly, in that higher polarisation results in a greater chance of the carbonate breaking down to form carbon dioxide.

**Reactions of Group 2 metals with water and oxygen**

It is important that learners know these reactions, though the practical can be potentially dangerous. As such, they are good material for teacher-led demonstrations.

The reaction of magnesium with steam can be found here:

<http://www.rsc.org/learn-chemistry/resource/res00000728/the-reaction-of-magnesium-with-steam?cmpid=CMP00000806>

The reaction for many elements (including those from Group 2) with oxygen can be found here:

<http://www.rsc.org/learn-chemistry/resource/res00000705/reacting-elements-with-oxygen?cmpid=CMP00000783>

After observing the reactions, the equations can be written down and discussed. For reference, the equations and reactivity can be found here:

<http://www.chemguide.co.uk/inorganic/group2/reacth2o.html>

As you progress down Group 2, the reactivity increases. This is due to a decrease in ionisation enthalpy as you progress down the group. As it requires less energy to form the ions, the reactivity increases.

|  |  |
| --- | --- |
| **Group 2 element** | **Reactivity with water  (at room temperature)** |
| Be | no reaction |
| Mg | very slow |
| Ca | steady |
| Sr | fairly quick |
| Ba | rapid |

The general equation for the reaction of Group 2 metals with water is:

M(s) + 2H2O(l) → M(OH)2(aq) + H2(g)

### Suggested activities

### Activity 1: Reactions and properties of Group 2 elements

This practical activity demonstrates the (in)solubility of Group 2 hydroxides and carbonates, as well as the trend in alkalinity of Group 2 hydroxide solutions.

This activity is microscale, and so can be done with limited space and reagents. It should take approximately 45 minutes.

Make sure that you allow groups to feed back their findings, checking whether these findings are the same as for other groups. Where findings differ, there is opportunity for discussion regarding accuracy of observation and interpretation. The patterns of solubility of Group 2 hydroxides and carbonates should be explained if learners are unsure. Make sure attention is also given to the resultant pH of the solutions, and the pattern between the solubility of the solution (and so availability of hydroxide ions) and the pH.

**Practical requirements**

Chemicals

* 0.5 mol dm–3 solutions of Mg(NO3)2 (WARNING; causes skin and eye irritation), Ca(NO3)2 and Sr(NO3)2 (both DANGER; causes serious eye damage), Ba(NO3)­2
* 1 mol dm–3 NaOH(aq) (DANGER; causes severe skin burns and eye damage)
* 0.5 mol dm–3 Na2CO3(aq)
* Universal Indicator

The volumes required are not large – just a few drops of each solution per test.

Apparatus and equipment

* dropping pipettes OR solutions provided in dropper bottles
* the worksheet can be used as a testing surface if covered with a plastic sheet; alternatively, a white tile can be used
* if preferred, the tests can be carried out in test tubes.

Health and safety

* Health and safety should always be considered by a centre before undertaking any practical work. A full risk assessment of any activity should always be undertaken.
* It is advisable to check the CLEAPSS website (<http://science.cleapss.org.uk/>) in advance of undertaking the practical tasks.
* Learners should wear eye protection throughout.
* Learners should take care to avoid skin contact with the hydroxide suspensions / solutions formed. Solutions should be treated as irritant; solid hydroxides as corrosive.

Learners should find the following observations:

|  |  |  |
| --- | --- | --- |
|  | **1 mol dm–3 NaOH** | **0.5 mol dm–3 Na2CO3** |
| **0.5 mol dm–3 Mg(NO3)2** | white precipitate  pH = slightly alkaline | white precipitate  pH = neutral |
| **0.5 mol dm–3 Ca(NO3)2** | white precipitate  pH = slightly alkaline | white precipitate  pH = neutral |
| **0.5 mol dm–3 Sr(NO3)2** | some white precipitate  pH = more strongly alkaline | white precipitate  pH = neutral |
| **0.5 mol dm–3 Ba(NO3)2** | thin white precipitate may be seen  pH = more strongly alkaline | white precipitate  pH = neutral |

### Activity 2 – Thermal stability of Group 2 carbonates

This is a guided task that allows learners to work through the explanation of the trend in thermal stability. In order for them to be able to access this task, they need to be familiar with the trends in atomic radius down a group and across a period. They also need to be aware of the definition of ionisation enthalpy.

The final question links the idea of thermal stability with that of enthalpy change of reaction. Enthalpy changes are covered in detail in *Developing fuels*. If teaching EL alongside DF, this question can be used to link concepts from the two storylines. If teaching DF after EL, this question could be saved until teaching DF, where it can offer an opportunity to revisit the concepts of thermal stability.

**Answers**

1. Describe and explain the trend of atomic radius as you progress across a period, from left to right.

The atomic radius decreases across a period. As the number of protons / nuclear charge increases, the electrons in the outer shell are more strongly attracted and therefore drawn closer to the nucleus.

2. Describe the trend of atomic radius as you progress down Group 2.

The atomic radius increases due to the increased number of occupied shells.

3. What is the charge of an ion from Group 2?

2+

4. As you progress down Group 2, as mentioned in Section 1, the atomic size ***increases***. Even though the charge on all Group 2 ions is the same, the *charge density* ***decreases*** as you progress down the group.  
Ions with a ***greater*** charge density distort the carbonate ion more. This increase in distortion ***increases*** the chance of the carbonate decomposing and forming carbon dioxide. This results in a ***lower*** temperature being required to decompose the compound.  
Magnesium carbonate has ***lower*** thermal stability than barium carbonate.

5. Consider the decomposition of Group 2 carbonates:

XCO3 → XO + CO2

Use your understanding of the thermal stability of Group 2 carbonates to estimate the enthalpy changes of decomposition for CaCO3 and SrCO3. Use the data in the table below.

|  |  |
| --- | --- |
| **Group 2 carbonate** | **Enthalpy change of decomposition / kJ mol–1** |
| MgCO3 | 117 kJ mol–1 |
| CaCO3 | CaCO3; actual value 178 kJ mol–1, 145–200 kJ mol–1 is a reasonable estimate |
| SrCO3 | SrCO3; actual value 235 kJ mol–1, 200–260 kJ mol–1 is a reasonable estimate |
| BaCO3 | 267 kJ mol–1 |

### Activity 3 – The reactions of Group 2 elements

This activity covers questions related to the work covered so far, and has links to areas that will help learners read further if they are not sure about an area.

Again, some links are made to enthalpy content from *Developing fuels*. How and when these questions are best discussed will depend on the teaching sequence followed.

**Answers**

1. Describe, and explain, the pattern of charge density of Group 2 ions as you progress down the group.

As you progress down Group 2, the charge density decreases. This is because the charge remains constant at 2+, but the atomic radius (and therefore size of the atom) increases.

2. Explain how the thermal stability of Group 2 carbonates changes as you progress down the group.

As the charge density of the metal ions decreases, there is less distorting effect on the carbonate ions. This decrease in distortion means more energy is required to break the bonds within the carbonate ion to form carbon dioxide. This results in an increase in thermal stability as you go down Group 2.

3. Magnesium hydroxide is used as a laxative (to treat constipation) and antacid. It has two characteristics that make it suitable for this role:

• it is able neutralise stomach acid

• it passes through the body quickly without being absorbed, making it non-toxic.

Use your knowledge of Group 2 hydroxides to explain why magnesium hydroxide has these characteristics.

Magnesium hydroxide is a base, so it reacts with acid and neutralises it. It is not absorbed by the body because it is barely soluble in water. Any unreacted magnesium hydroxide remains as a solid and passes through the stomach and colon.

4 a) Calcium carbonate is heated to produce quicklime, which can be used to produce mortar. When it is produced, gas is released. Give the equation for the reaction that happens.

CaCO3 → CaO + CO2

b) The following two reactions were carried out, and the enthalpy changes determined.

CaCO3(s) + 2HC*l*(aq) → CaC*l*2(aq) + H2O(l) + CO2(g) Δr*H* = –17.14 kJ mol–1

CaO(s) + 2HC*l*(aq) → CaC*l*2(aq) + H2O(l) Δr*H* = –79.13 kJ mol–1

Use these data to calculate an enthalpy change for the decomposition of CaCO3. You will find it helpful to construct a Hess cycle.

Using a Hess cycle gives the calculation

Δ*H* = –17.14 – (–79.13) = +61.99 kJ mol–1

5. Describe and explain the differences between the reaction of magnesium with water at room temperature and with steam. Compare this to the reactivity of other Group 2 metals with water.

Magnesium reacts very slowly with water, and so there may not be any observation (at the most some bubbles may form on the surface of the magnesium). In steam magnesium reacts quickly, burning with a bright white flame. Magnesium has a relatively high ionisation enthalpy compared to metals further down the group, and therefore only reacts readily at higher temperature. Other Group 2 metals are progressively more reactive as you go down the group. The production of hydrogen is clearly visible in the reaction with water, and a white precipitate (of the hydroxide) forms.

6. Give an example equation for the reaction of a Group 2 metal with oxygen where a simple oxide is formed.

e.g. 2Ba + O2 → 2BaO

7. Give an example equation for the reaction of a Group 2 metal with an acid. Explain how you would be able to identify the gas formed.

e.g. 2Ca + 2HC*l* → CaC*l*2 + H2

The gas released in the reaction can be collected in a test tube. When ignited with a lit splint it will burn with a squeaky pop.

8. Give an example equation for the reaction of a Group 2 oxide with hydrochloric acid.

e.g. MgO + 2HC*l* → MgC*l*2 + H2O

9. Give an example equation for the reaction of a Group 2 hydroxide with hydrochloric acid.

e.g. Sr(OH)2 + 2HC*l* → SrC*l*2 + 2H2O

### Test yourself questions

**Answers**

1. Describe what you would observe if you add magnesium nitrate to the following solutions:

white precipitate

1. sodium carbonate: ­­­

white precipitate

1. sodium hydroxide:

2. Describe the difference between the reactions of magnesium with water and with steam.

There is no (observable) reaction, or only very slow reaction with water. With steam there is a vigorous exothermic reaction.

3. One Group 2 metal has a first ionisation enthalpy of +555 kJ mol–1, and another a first ionisation enthalpy of +740 kJ mol–1. Use this information to predict which of these metals would react more readily with water.

The metal with the lower ionisation enthalpy (+555 kJ mol–1) will react more readily, as it is more easily oxidised.

4. State and explain which Group 2 ion has the highest charge density.

The Be2+ ion has the highest charge density, because it is the smallest Group 2 ion (because it has the fewest number of occupied shells).

5. Give an equation, including state symbols, for the decomposition of magnesium carbonate.

MgCO3(s) → MgO(s) + CO2(g)

6. Describe and explain the trend in thermal stability for Group 2 carbonates.

The thermal stability increases as you go down Group 2. This is because the Group 2 ion has lower charge density, and thus distorts the carbonate ion less. The less distorted the carbonate ion is, the more stable it is, and so a higher temperature is required to decompose the carbonate.

7. A scientist reacts samples of MgO, CaO and SrO and BaO with water. Describe and explain the trend in the pH of the resulting solutions.

The reaction of the oxides with water produces hydroxides. The resulting solutions are therefore alkaline. Going from Mg down the group to Ba the alkalinity of the solutions increases (pH goes up), because the solubility of the hydroxides increases and therefore there is a higher concentration of OH– ions in solution.

8. Give an equation for the reaction of calcium hydroxide with nitric acid.

Ca(OH)2 + 2HNO3 → Ca(NO3)2 + 2H2O

9. Give an equation for the reaction between magnesium oxide and sulfuric acid.

MgO + H2SO4 → MgSO4 + H2O

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# Topic Exploration Pack

# The Chemistry of Group 2

## Learner activity

### Learner Activity 1 Reactions and properties of Group 2 elements

In this activity you will examine reactions of Group 2 nitrate solutions with hydroxide and carbonate.

The table on the next page shows you which reactions to carry out. Each Group 2 nitrate will be reacted with solutions containing hydroxide and carbonate ions. Use the table to record your results.

Your teacher will tell you whether you will carry out the reactions on a flat surface or in test tubes. If doing the reactions on a surface use one drop of each reagent. If doing the reactions in a test tube use 5 drops of each reagent.

When recording your results, consider the following:

* Has any precipitate been formed? (This indicates how soluble the compound formed   
  may be.)
* Has there been any effervescence?
* Has there been a colour change? If a precipitate has been formed, what is the colour of the precipitate compared to that of the solution?
* If there is no chemical reaction, write 'no reaction' in the box.
* After each reaction, use a little Universal Indicator to check the pH of the solution, and include it in your observations.

Health and safety

* Wear eye protection.
* Mg(NO3)2 solution causes skin and eye irritation; Ca(NO3)2 and Sr(NO3)2 solutions cause serious eye damage.
* 1 mol dm–3 NaOH(aq) cases severe skin burns and eye damage.
* Take care to avoid skin contact with the products of the reactions. Group 2 hydroxide solutions should be treated as irritant, solid hydroxides as corrosive.

|  |  |  |
| --- | --- | --- |
|  | **1 mol dm–3 NaOH** | **0.5 mol dm–3 Na2CO3** |
| **0.5 mol dm–3 Mg(NO3)2** | Observation diagram  **Observations:**  **pH =** | Observation diagram  **Observations:**  **pH =** |
| **0.5 mol dm–3 Ca(NO3)2** | Observation diagram  **Observations:**  **pH =** | Observation diagram  **Observations:**  **pH =** |
| **0.5 mol dm–3 Sr(NO3)2** | Observation diagram  **Observations:**  **pH =** | Observation diagram  **Observations:**  **pH =** |
| **0.5 mol dm–3 Ba(NO3)2** | Observation diagram  **Observations:**  **pH =** | Observation diagram  **Observations:**  **pH =** |

### Learner Activity 2 The thermal stability of Group 2 carbonates

This worksheet requires knowledge from previous sections on atomic radii and electronegativity to work best. If you are unfamiliar with these sections, ask your teacher to help.

**Section 1 – Atomic structures recap**

This section is a recap over previous work done in the course. Knowledge of this section will help you understand patterns that arise in the properties of Group 2 elements and compounds.

1. Describe and explain the trend of atomic radius as you progress across a period, from left   
to right.

2. Describe the trend of atomic radius as you progress down Group 2.

3. What is the charge of an ion from Group 2?

**Section 2 – Thermal stability of Group 2 carbonates**

Group 2 carbonates differ in their properties depending on the Group 2 ion involved.

4. Complete the following sentences.

As you progress down Group 2, as mentioned in Section 1, the atomic size \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ . Even though the charge on all Group 2 ions is the same, the charge density \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as you progress down the group.

Ions with a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ charge density distort the carbonate ion more. This increase in distortion \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the chance of the carbonate decomposing and forming carbon dioxide. This results in a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ temperature being required to decompose the compound.

Magnesium carbonate has \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ thermal stability than barium carbonate.

5. Consider the decomposition of Group 2 carbonates:

XCO3 → XO + CO2

Use your understanding of the thermal stability of Group 2 carbonates to estimate the enthalpy changes of decomposition for CaCO3 and SrCO3. Use the data in the table below.

|  |  |
| --- | --- |
| **Group 2 carbonate** | **Enthalpy change of decomposition / kJ mol–1** |
| MgCO3 | 117 kJ mol–1 |
| CaCO3 |  |
| SrCO3 |  |
| BaCO3 | 267 kJ mol–1 |

### Learner Activity 3 The reactions of elements in Group 2

This worksheet is designed to help you consolidate some of the content related to Group 2 chemistry covered so far. If you are unsure about a section, included also are links where you can find out more information to help you revise.

1. Describe, and explain, the pattern of charge density of Group 2 ions as you progress down the group.

2. Explain how the thermal stability of Group 2 carbonates changes as you progress down the group.

**Unsure about these two questions?**

Look here for a complete explanation:

<http://www.chemguide.co.uk/inorganic/group2/thermstab.html#top>

Look here for a video explaining the process:

<https://www.youtube.com/watch?v=LSu9Ta2M7Uw>

3. Magnesium hydroxide is used as a laxative (to treat constipation) and antacid. It has two characteristics that make it suitable for this role:

• it is able neutralise stomach acid

• it passes through the body quickly without being absorbed, making it non-toxic.

Use your knowledge of Group 2 hydroxides to explain why magnesium hydroxide has these characteristics.

4 a) Calcium carbonate is heated to produce quicklime, which can be used to produce mortar. When it is produced, gas is released. Give the equation for the reaction that happens.

b) The following two reactions were carried out, and the enthalpy changes determined.

CaCO3(s) + 2HC*l*(aq) → CaC*l*2(aq) + H2O(l) + CO2(g) Δr*H* = –17.14 kJ mol–1

CaO(s) + 2HC*l*(aq) → CaC*l*2(aq) + H2O(l) Δr*H* = –79.13 kJ mol–1

Use these data to calculate an enthalpy change for the decomposition of CaCO3. You will find it helpful to construct a Hess cycle.

5. Describe and explain the differences between the reaction of magnesium with water at room temperature and with steam. Compare this to the reactivity of other Group 2 metals with water.

6. Give an example equation for the reaction of a Group 2 metal with oxygen where a simple oxide is formed.

7. Give an example equation for the reaction of a Group 2 metal with an acid. Explain how you would be able to identify the gas formed.

8. Give an example equation for the reaction of a Group 2 oxide with hydrochloric acid.

9. Give an example equation for the reaction of a Group 2 hydroxide with hydrochloric acid.

**Unsure about this section?**

Look here for an explanation of the solubility for Group 2 compounds:

[http://www.chemguide.co.uk/inorganic/group2/solubility.html#top](#top)

Look here for a description of Group 2 reactions:

<http://www.s-cool.co.uk/a-level/chemistry/group-ii-and-group-iv/revise-it/group-ii>

Look here for videos describing the reactions of Group 2 elements with water and steam:

Water: <https://www.youtube.com/watch?v=O6DaCYKh77E>

Steam: <https://www.youtube.com/watch?v=R-SdJihkoUg>

### Test yourself questions

1. Describe what you would observe if you add magnesium nitrate to the following solutions:

1. sodium carbonate: ­­­
2. sodium hydroxide:

2. Describe the difference between the reactions of magnesium with water and with steam.

3. One Group 2 metal has a first ionisation enthalpy of +555 kJ mol–1, and another a first ionisation enthalpy of +740 kJ mol–1. Use this information to predict which of these metals would react more readily with water.

4. State and explain which Group 2 ion has the highest charge density.

5. Give an equation, including state symbols, for the decomposition of magnesium carbonate.

6. Describe and explain the trend in thermal stability for Group 2 carbonates.

7. A scientist reacts samples of MgO, CaO and SrO and BaO with water. Describe and explain the trend in the pH of the resulting solutions.

8. Give an equation for the reaction of calcium hydroxide with nitric acid.

9. Give an equation for the reaction between magnesium oxide and sulfuric acid.