# 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](#_Learner_activity). This Topic Exploration Pack supports OCR AS and A Level Chemistry A.

**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

### 3.1.2(a) the outer shell s2 electron configuration and the loss of these electrons in redox reactions to form 2+ ions

3.1.2(b) the relative reactivities of the Group2 elements Mg → Ba shown by their redox reactions with:

1. oxygen
2. water
3. dilute acids

3.1.2(c) the trend in reactivity in terms of the first and second ionisation energies of Group 2 elements down the group

3.1.2(d) the action of water on Group 2 oxides and the approximate pH of any resulting solutions, including the trend of increasing alkalinity

3.1.2(e) uses of some Group 2 compounds as bases, including equations, for example (but not limited to):

1. Ca(OH)2 in agriculture to neutralise acid soils
2. Mg(OH)2 and CaCO3 as ‘antacids’ in treating indigestion.

### 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 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.

**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 energy 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. This can be a useful way of leading into the reactions of Group 2 oxides with water, and the resulting trend in pH which is dependent on solubility of the hydroxide product. Separating investigating the trend in solubility from the oxide/water reaction will help learners to initially get the separate ideas clear in their minds, before the understanding is combined.

This activity could be followed up or replaced with an activity involving adding Group 2 oxides to water, recording observations and constructing the equations for the reactions.

This activity is microscale, and so can be done with limited space and reagents. It should take approximately 30 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 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)
* 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 Mg(NO3)2** | white precipitatepH = slightly alkaline |
| **0.5 mol dm–3 Ca(NO3)2** | white precipitatepH = slightly alkaline |
| **0.5 mol dm–3 Sr(NO3)2** | some white precipitatepH = more strongly alkaline |
| **0.5 mol dm–3 Ba(NO3)2** | thin white precipitate may be seen pH = more strongly alkaline  |

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

This question worksheet can be used to consolidate and develop understanding while teaching this topic. The first section begins with a recap of understanding about atomic structure and ionisation energy, which is likely to have been taught earlier in the course. The questions then extend to develop an understanding of the trend in reactivity of Group 2 elements. The second section focuses on reviewing the reactions of Group 2 elements and oxides, and makes some links with the content on acids in Section 2.1.4 of the specification.

**Answers**

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

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

2. Describe and explain the trend in first ionisation energy as you progress down Group 2.

The first ionisation energy becomes smaller. The increase in nuclear charge is outweighed by the increase in atomic radius (therefore the greater distance between the electron and the nucleus) and the greater shielding of the nuclear charge by the inner shells of electrons. Therefore, the attraction between the nucleus and the outer electrons is overall smaller, the further you go down the group. Therefore, there is less energy required to remove the electron from the neutral atom.

3. What is the charge on an ion formed from a Group 2 element?

2+

4. (a) Write the equation for the **second** ionisation energy of calcium.

Ca+(g) → Ca2+(g) + e–

 (b) What do you think the trend in **second** ionisation energy is as you progress down Group 2? Explain your answer.

The second ionisation energy becomes smaller as you go down the group, for the same reasons as given above for the first ionisation energy.

5. What can you conclude about the trend in reactivity of the Group 2 elements as you progress down the group? Explain your answer.

Reactivity is related to the ease with which the electrons can be removed from the atoms. Therefore the Group 2 elements will be more reactive the further you go down the group.

6. (a) Describe and explain the differences between reacting magnesium with water and with steam. What would you observe?

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.

(b) Compare your answer to (a) to the reactivity of other Group 2 metals with water.

The Group 2 metals further down the group are more reactive. They react readily with water, showing effervescence as hydrogen is released.

7. Write the equation for the reaction between a Group 2 metal and oxygen, where a simple oxide is formed.

E.g. 2Mg + O2 → 2MgO

8. Write the equation for the reaction between a Group 2 metal and an acid.

E.g. Ca + 2HC*l* → CaC*l*2 + H2

9. (a) Write the equation for the reaction between a Group 2 metal oxide and water.

E.g. SrO + H2O → Sr(OH)2

 (b) Write the equation for the reaction between a Group 2 metal oxide and hydrochloric acid.

E.g. BaO + 2HC*l* → BaC*l*2 + H2O

N.B. Learners may have covered this earlier in the course in the introduction to acid–base chemistry in Module 2. If they do not remember the equation, encourage them to recognise that this is a neutralisation reaction, therefore the products will be water and a salt.

10. Magnesium hydroxide, Mg(OH)2, is commonly used as an antacid. It is able to neutralise stomach acid, and to pass through the body quickly without being absorbed, making it non-toxic. Using your knowledge about the solubility of Group 2 hydroxides and the pH of their solutions, explain why magnesium hydroxide is suitable for this purpose.

Magnesium hydroxide is a base, and therefore reacts with stomach acid to neutralise it. As it is barely soluble, any magnesium hydroxide that does not react with the stomach acid will pass through the body without being absorbed.

### Activity 3 – Extended reactions of Group 2

This is an extension activity involving discussion of the general nature of bonding. GCSE and A Level specifications tend to leave learners with a two-sided view of bonding (ionic vs covalent). This is far from the truth. This activity gives learners the opportunity to study the wider range of bonding behaviour in Group 2.

The activity begins with a discussion paper on some of the intermediate bonding shown by Group 2 metals in their compounds. Group discussion may help learners to fully understand this information, and further research is to be encouraged. As extension material this activity takes students away from the specification somewhat, but this is good practice for considering new information as is often given in extension questions in examinations.

After considering the information and further research learners should complete the question sheet. The material covered here confirms the constant oxidation number of Group 2 metals, looks at ionic and covalent bonding, and introduces the idea that ionic and covalent bonding represent extreme ends of a spectrum. The questions also extend into organic chemistry and synthesis.

**Answers**

1. (a) In water, magnesium ions form bonds with water molecules to form an octahedral complex. What kind of bond is formed?

dative covalent bond

 (b) Suggest a structure for the complex.



If students have not yet covered any transition metal chemistry, students might be encouraged to think of the shape of molecules with six electron pairs around the central atom (e.g. SF6).

2. What characteristics of the magnesium ion cause the distortion of the water molecules in this complex.

The small radius / size of the ion combined with the 2+ charge.

3. What type of bond exists between Mg and C in a Grignard reagent?

covalent

Note that the bond is extremely polar.

4 Why would a calcium-based Grignard reagent be more reactive?

Calcium ions are larger than magnesium ions, and calcium has lower electronegativity than magnesium. So, calcium has lower ability to attract electrons, and the Ca–C bond would be more polar than the Mg–C bond. A calcium-based reagent would therefore be more reactive.

5. Suggest what product forms if a Grignard reactant is reacted with the following compounds.

(a) Water.

An organic molecule, i.e. if the Grignard reagent has an alkyl tail the product will be an alkane.

(b) Carbon dioxide.

A carboxylic acid.

### Chemistry in the cupboard – Calgon

This handout produced by the Royal Society of Chemistry offers further context to the study of Group 2 chemistry, also linking in with acid–base chemistry and other topics. This resource could be used later in the teaching programme to support learners in being able to bring together understanding of different areas of the specification.

<http://www.rsc.org/learn-chemistry/resource/res00000006/calgon?cmpid=CMP00000008>

### Test yourself questions

This worksheet contains questions that can be used to review learning at the end of teaching this topic.

**Answers**

1. Describe what you would observe if you add magnesium nitrate to a solution of sodium hydroxide.

A white precipitate forms.

2. Give a use for the following compounds.

(a) Magnesium hydroxide.

antacid

(b) Calcium hydroxide.

neutralising acidic soils and lakes

3. Describe the difference between the reaction of magnesium with water at room temperature and with steam.

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.

4. Element **X** is a Group 2 metal with a first ionisation energy of 549 kJ mol–1. Element **Y** is a Group 2 metal with a first ionisation energy of 738 kJ mol–1.Which element will react more readily with water? Explain your answer.

Element **X** will react more readily. As the ionisation energy is lower, the element is more easily oxidised.

5. Group 2 oxides react with water. Explain the trend in pH of the resulting solutions as you go down the group.

As you go down Group 2, the pH of the solutions increases. This is due to the increased solubility of the hydroxide product, and therefore greater concentration of OH– ions.

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

Ca(OH)2 + 2HNO3 → Ca(NO3)2 + 2H2O

7. Give an equation for the reaction of magnesium oxide with 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.

The table on the next page shows you which reactions to carry out. Each Group 2 nitrate will be reacted with solutions containing hydroxide 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 Mg(NO3)2** | Observation diagram**Observations:** **pH =**  |
| **0.5 mol dm–3 Ca(NO3)2** | Observation diagram**Observations:** **pH =**  |
| **0.5 mol dm–3 Sr(NO3)2** | Observation diagram**Observations:** **pH =**  |
| **0.5 mol dm–3 Ba(NO3)2** | 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 of work done previously in the course. This knowledge 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 down Group 2.

2. Describe and explain the trend in first ionisation energy as you progress down Group 2.

3. What is the charge on an ion formed from a Group 2 element?

4. (a) Write the equation for the **second** ionisation energy of calcium.

 (b) What do you think the trend in **second** ionisation energy is as you progress down Group 2? Explain your answer.

5. What can you conclude about the trend in reactivity of the Group 2 elements as you progress down the group? Explain your answer.

**Section 2 – The reactions of Group 2 elements**

In this section you will think about the reactions of Group 2 elements, and link this with prior knowledge about acid–base reactions.

6. (a) Describe and explain the differences between reacting magnesium with water and with steam. What would you observe?

 (b) Compare your answer to (a) to the reactivity of other Group 2 metals with water.

7. Write the equation for the reaction between a Group 2 metal and oxygen, where a simple oxide is formed.

8. Write the equation for the reaction between a Group 2 metal and an acid.

9. (a) Write the equation for the reaction between a Group 2 metal oxide and water.

 (b) Write the equation for the reaction between a Group 2 metal oxide and hydrochloric acid.

10. Magnesium hydroxide, Mg(OH)2, is commonly used as an antacid. It is able to neutralise stomach acid, and to pass through the body quickly without being absorbed, making it non-toxic. Using your knowledge about the solubility of Group 2 hydroxides and the pH of their solutions, explain why magnesium hydroxide is suitable for this purpose.

### Learner Activity 3 Extended reactions of Group 2

Read through the following information. Discuss the text with your classmates and extend your understanding with further research before tackling the question worksheet that follows.

You have probably learnt that metals form ionic compounds with non-metals, and that non-metals in combination form covalent bonds. One way to judge which type of bonding occurs is by looking at the difference in electronegativity between the two bonding elements. As a rule of thumb, a difference of 1.6 or more is likely to result in an ionic bond.

As ions become smaller and more charged they are less likely to easily lose electrons completely – they retain some attraction to the bonding pair. For this reason, the Group 2 metal beryllium has very different behaviour to the other members of the group. For example, the compound BeC*l*2 is covalent, rather than ionic. Magnesium is still small enough in diameter to mirror some of these differences. One example is the reaction of magnesium chloride with water.

The behaviour of Period 3 chlorides with water demonstrates the difference between ionic and covalent compounds. Ionic compounds simply dissolve in water, while covalent compounds hydrolyse, forming hydrochloric acid and hydrated forms of the other element. Aluminium chloride is distinctly covalent – it reacts with water as described above. Magnesium chloride is defined as an ionic compound (difference in electronegativity between Mg and C*l* is 1.85), but in water it produces a solution with a pH of around 6. So, it could be suggested that there is some covalent character in the bonds between magnesium and chlorine, despite the difference in their electronegativities.

The chemistry involved here revolves around the availability of the 3d orbital and the attractive power of the magnesium ion. The magnesium ion forms a dative covalently bonded octahedral complex with water:

 MgC*l*2 + 6H2O → [Mg(H2O)6]2+ + 2C*l*–

The magnesium ion attracts the electrons within the water molecules so strongly that the water molecules become distorted. A hydrogen ion may be lost:

 [Mg(H2O)6]2+  [Mg(H2O)5OH]1+ + H+

Sufficient H+ ions are released to lower the pH to a noticeable extent.

All the members of Group 2 are capable of forming organometallic compounds (compounds in which organic molecules are bonded to a metal atom or ion). The most famous organometallic reagent contains magnesium and is named after its discoverer, Victor Grignard. These compounds are so useful and the technique so refined that they are still used to manufacture new materials today.

A Grignard reagent is made by adding magnesium to a solution of an alkyl or aryl halide in ethoxyethane. This produces an alkyl or aryl magnesium halide – part salt, part organometallic, i.e. with magnesium bonded to carbon.

 CH3Br + Mg → CH3MgBr

 C6H5Br + Mg → C6H5MgBr

Grignard reagents act as powerful nucleophiles. The carbon in the C–Mg bond has a partial negative charge, and will react with electron-poor regions of species such as aldehydes and ketones. This allows the addition of a new carbon chain to a molecule, producing secondary and tertiary alcohols.

 CH3CH2CH2CHO + CH3CH2MgBr + H2O → CH3CH2CH2CH(OH)CH2CH3 + MgOHBr

This is one of the few reactions that can attach organic side chains to benzene without the need for a catalyst.

The ability to form such a stable reagent in the right conditions is testament to magnesium’s marginal covalent behaviour.

**Questions**

1. (a) In water, magnesium ions form bonds with water molecules to form an octahedral complex. What kind of bond is formed?

 (b) Suggest a structure for the complex.

2. What characteristics of the magnesium ion cause the distortion of the water molecules in this complex.

3. What type of bond exists between Mg and C in a Grignard reagent?

4. Why would a calcium-based Grignard reagent be more reactive?

5. Suggest what product forms if a Grignard reactant is reacted with the following compounds.

 (a) Water.

(b) Carbon dioxide.

### Test yourself questions

1. Describe what you would observe if you add magnesium nitrate to a solution of sodium hydroxide.

2. Give a use for the following compounds.

(a) Magnesium hydroxide.

(b) Calcium hydroxide.

3. Describe the difference between the reaction of magnesium with water at room temperature and with steam.

4. Element **X** is a Group 2 metal with a first ionisation energy of 549 kJ mol–1. Element **Y** is a Group 2 metal with a first ionisation energy of 738 kJ mol–1.Which element will react more readily with water? Explain your answer.

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