FACTFILE:
GCE CHEMISTRY

2.11 GROUP II ELEMENTS AND THEIR COMPOUNDS

Rewarding Learning

Learning Outcomes

Students should be able to:

2.11.1 explain why these are regarded as s-block elements;

2.11.2 recall and explain the trends within the Group, limited to electronic configuration, atomic radius and first ionisation energy;

2.11.3 investigate and describe the reactions of the elements with oxygen, water and dilute acids;

2.11.4 describe the basic nature of the oxides and their reactions with water and dilute acids;

2.11.5 recall the use of magnesium oxide in indigestion remedies and the use of calcium carbonate in toothpaste;

2.11.6 state the trends in thermal stability of the carbonates and hydroxides and explain with reference to the charges and sizes of the cations;

2.11.7 recall the use of calcium carbonate to make calcium oxide (quick lime) and calcium hydroxide (slaked lime) and their use in producing cement and concrete;

2.11.8 recall the solubility trends of the sulfates and hydroxides; and

2.11.9 demonstrate understanding of how solubility curves are drawn from experimental data.

Group II elements

The alkaline earth metals, beryllium, magnesium, calcium, strontium and barium are found in Group II of the Periodic Table and are a group of reactive metals. They are known as s-block elements.

An s-block element is one which has an atom with the highest energy/outer electron in an s-subshell (orbital).

They are not found in nature in their elemental state but as compounds in minerals or rocks.

(Barite, mineral containing Barium)

The chemistry of the Group II elements is dominated by their ability to lose two electrons to form cations with a charge of 2+. The reactivity of the elements increases down the Group as it becomes easier to lose two electrons as the group is descended. The Group II elements react with oxygen, water and acids.

Trends within the Group

1. Atomic radius
The atomic radius increases down Group II as there are more filled energy levels between the nucleus and the electrons in the highest occupied energy level. The outer electrons are thus more shielded and further from the nucleus, leading to an increase in the atomic radius down the group.

2. Ionisation energy
The first ionisation energy decreases down the group. As the group is descended the distance between the nucleus and the outer electrons increases. There is an accompanying increase in shielding as the group is descended as there are more filled energy levels between the nucleus and the outer electrons. Therefore less energy is required to remove an electron as the group is descended.

Reaction with oxygen

The metals burn in oxygen to form a simple metal oxide. For example,

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

- Magnesium burns with an bright white flame to form a white solid
- Calcium burns with a brick red flame to form a white solid.
- Strontium burns with a red flame.
- Barium burns with a green flame.

Metal oxides are bases and react with water to form alkaline solutions, for example:

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

Calcium hydroxide solution is better known as limewater.

Group II metal oxides also react with acids in a **neutralisation** reaction, for example:

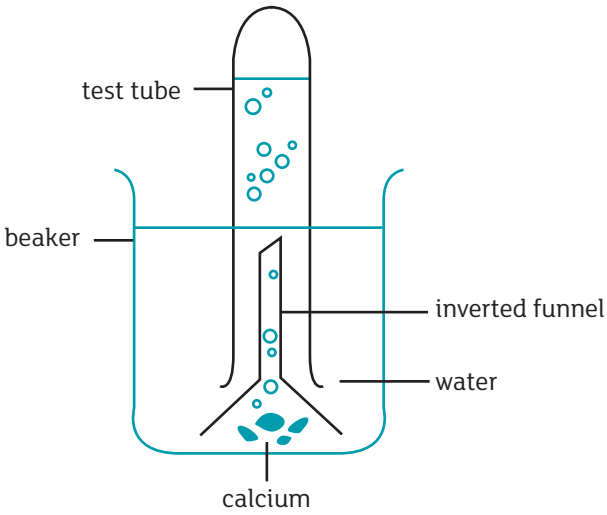
$MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$

Reaction with water

Beryllium does not react with water and magnesium only reacts very slightly if left for a prolonged period of time. Calcium, strontium & barium react with water with increasing vigour to give the corresponding metal hydroxide and hydrogen, for example:

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

Magnesium reacts with water and produces a few bubbles over a long period of time and the metal dulls. Calcium reacts with water and there is fizzing, the mixture warms up, the metal rises and falls and disappears. A white solid is produced.

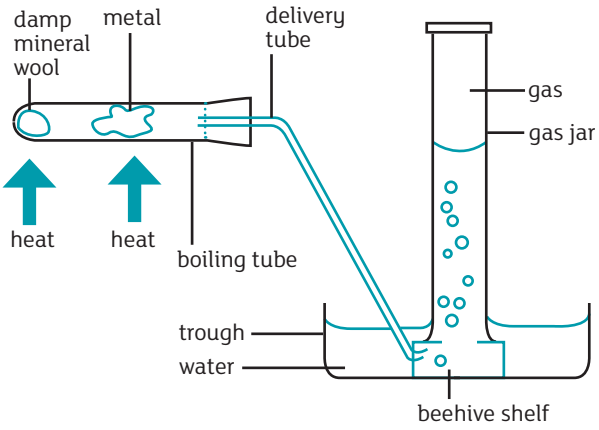


The white solid produced when calcium reacts with water is calcium hydroxide which is only slightly soluble in water. The solubility of the hydroxides increases down the group.

Solubility is the maximum mass of solute that can dissolve in 100 g of solvent at a stated temperature.

Magnesium, calcium, strontium and barium all react with steam to produce the corresponding metal oxide and hydrogen:

$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$



Reaction with acid

Group II metals react even more vigorously with acids than with water forming the metal salt and hydrogen. Again reactivity increases down the Group as the outer shell electrons are lost more readily.

When Group II metals react with hydrochloric acid, the observations are that the metal disappears, there is fizzing and the mixture warms up.
With sulfuric acid the observation are the same except for with calcium where there is fizzing initially but this stops (due to the formation of insoluble calcium sulfate).

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

The sulfates decrease in solubility down the Group.

Thermal decomposition

The Group II carbonates undergo thermal decomposition, requiring higher temperatures as the Group is descended:

$BeCO_3 \rightarrow BeO + CO_2$ (at 100 °C)
$MgCO_3 \rightarrow MgO + CO_2$ (at 540 °C)
$CaCO_3 \rightarrow CaO + CO_2$ (at 900 °C)
$SrCO_3 \rightarrow SrO + CO_2$ (at 1290 °C)
$BaCO_3 \rightarrow BaO + CO_2$ (at 1360 °C)

The increased thermal stability can be explained with reference to the cation. As the Group is descended, the metal cation increases in size and has less of a polarising effect on the carbonate ion. This makes it more difficult for the carbonate to be decomposed.

The Group II hydroxides also form the corresponding oxide via thermal decomposition, for example:

$Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(l)$

The trend can be explained in a similar manner for that of the Group II carbonates.

Uses

1. Calcium carbonate is used to make calcium oxide (quicklime) and is also used in toothpaste.
2. Calcium hydroxide (slaked lime) is used to make cement and concrete. It is made by the thermal decomposition of calcium carbonate followed by the reaction of the quicklime with water.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

3. Magnesium oxide is a base used in indigestion remedies.

Credits

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Revision Questions

1 Which one of the following lists both sets of compounds in order of increasing solubility (least soluble first, most soluble last)?

	Sulphates	Hydroxides
A	$MgSO_4$, $CaSO_4$, $SrSO_4$, $BaSO_4$	$Ba(OH)_2$, $Sr(OH)_2$, $Ca(OH)_2$, $Mg(OH)_2$
B	$MgSO_4$, $CaSO_4$, $SrSO_4$, $BaSO_4$	$Mg(OH)_2$, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$
C	$BaSO_4$, $SrSO_4$, $CaSO_4$, $MgSO_4$	$Mg(OH)_2$, $Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$
D	$MgSO_4$, $SrSO_4$, $CaSO_4$, $BaSO_4$	$Ba(OH)_2$, $Sr(OH)_2$, $Ca(OH)_2$, $Mg(OH)_2$

[1]

2 The world production of calcium oxide is currently 280 million tonnes annually. It is used extensively in steel making and the construction industries. The production of calcium oxide involves heating limestone (calcium carbonate) in a kiln at a temperature of 1200 °C.

$$CaCO_3 \rightarrow CaO + CO_2$$

The heat needed to sustain the reaction is provided by the combustion of fossil fuels.

(a) Compare the thermal stability of calcium carbonate with the other Group II metal carbonates.

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..... [2]

(b) Explain how the thermal stability of a group II carbonate is related to the charge and size of the cation.

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..... [2]

(c) Explain how manufacture of calcium oxide contributes to global warming.

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..... [2]

(d) The calcium oxide produced is basic and reacts with water and dilute acids.

(i) Write the equation for the reaction of calcium oxide with hydrochloric acid.

..... [2]

(ii) Write the equation for the reaction of calcium oxide with water to form calcium hydroxide.

..... [1]

(e) A saturated solution of calcium hydroxide is known as limewater. Describe how you would prepare limewater and use it to test for carbon dioxide, stating the result of a positive test.

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..... [4]

(f) Write the equation for the reaction of aqueous calcium hydroxide with carbon dioxide including state symbols.

..... [2]

3 Magnesium, calcium and barium are found in Group II of the Periodic Table.

(a) Explain why the Group II elements are regarded as s-block elements.

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..... [1]

(b) (i) Write an equation, including state symbols, for the first ionisation energy of magnesium.

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(ii) State and explain the change in the value of the first ionisation energy from magnesium to barium.

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..... [3]

(c) Calcium hydroxide can be decomposed by heating.

(i) Write an equation for the decomposition of calcium hydroxide.

..... [1]

(ii) Compare and explain the thermal stability of magnesium hydroxide with barium hydroxide.

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..... [3]