Group 2

Alkaline Earth Metals

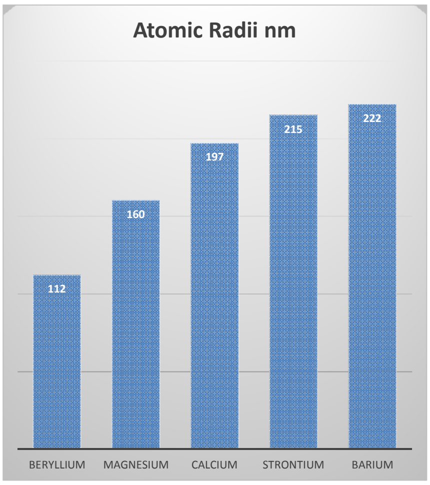
N Goalby
Chemrevise.org

Trends in Atomic Radius

Atomic radius increases down the Group.

As one goes down the group the atoms have more shells of electrons making the atom bigger

Beryllium has a particularly small atom compared with the rest of the Group.



CORE

Explaining the increase in atomic radius

Generally, the radius of an atom is governed by the number of shells of electrons around the nucleus and the pull of the outer electrons feel from the nucleus.

Comparing beryllium and magnesium:

Be	$1s^2 2s^2$
Mg	$1s^2 2s^2 2p^6 3s^2$

The more shells of electrons there are, the more space they will take up - electrons repel each other. That means that the atoms get bigger down the Group

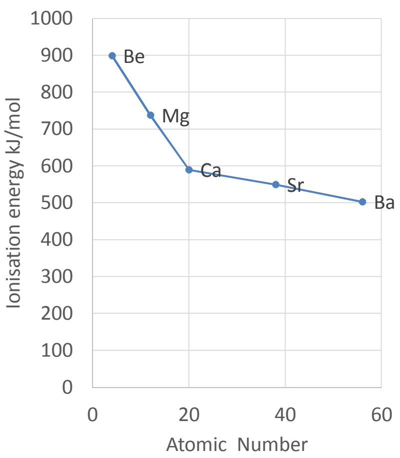
CORE

Trends in First Ionisation Energy

First ionisation energy is the energy needed to remove an electron from one mole of gaseous atoms to make one mole of singly charged gaseous ions

$X (g) \rightarrow X^+ (g) + e^-$

First ionisation energy falls as you go down the group.



CORE

Explaining the decrease in first ionisation energy

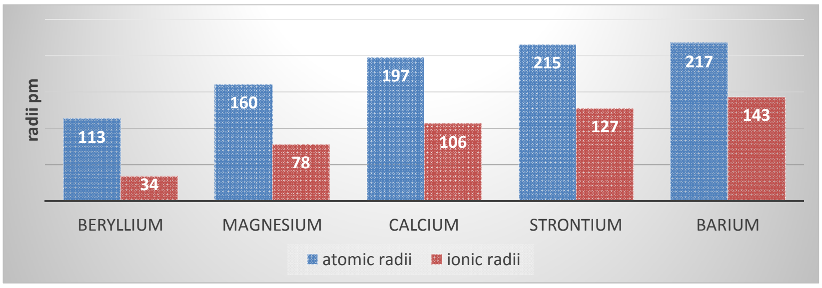
Ionisation energy is governed by
- the charge on the nucleus,
- the amount of shielding by the inner electrons,
- the distance between the outer electrons and the nucleus.

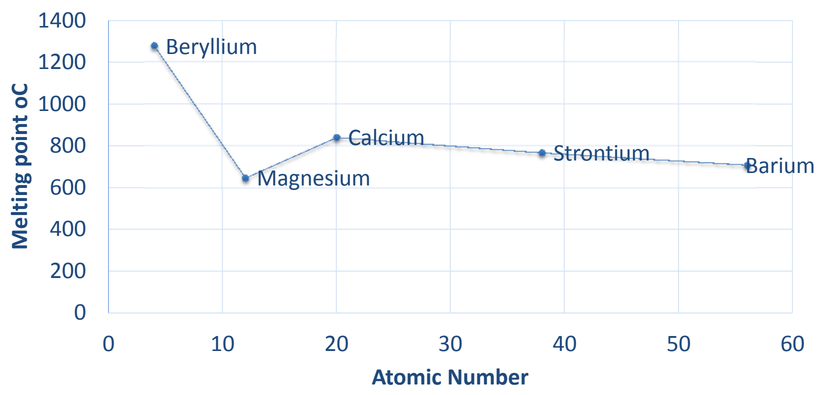
- Each successive element down the group has more (inner) electrons and one more shell than the previous element.
- The outermost electrons are therefore held more weakly because they are successively further from the nucleus
- In addition, the outer shell electrons become more shielded from the attraction of the nucleus by the repulsive force of inner shell electrons

CORE

Ionic Radii

The ionic radius of a group 2 metal will be smaller than the corresponding atomic radius, because it has lost one shell of electrons and the remaining protons hold onto the remaining electrons more strongly and pulls them in more tightly.





Down the group the melting **points decrease**. The **metallic bonding** weakens as the **atomic size increases**. The distance between the positive ions and delocalized electrons increases. Therefore the attractive forces between the **positive ions** and the **delocalized electrons** weaken.

CORE

Typical reactions of group 2

1 Reaction with air

They all react with air to form oxides (sometimes they burn with a flame)

Mg burns with a bright white flame

$2\ Mg + O_2 \rightarrow 2\ MgO$

MgO is a white solid with a high melting point due to its ionic bonding

Cleaning Mg Ribbon

- Mg will also react slowly with oxygen without a flame.
- Mg ribbon will often have a thin layer of magnesium oxide on it formed by reaction with oxygen

$2Mg + O_2 \rightarrow 2MgO$

- This needs to be cleaned off by emery paper before doing reactions with Mg ribbon
- If testing for reaction rates with Mg and acid, an un-cleaned Mg ribbon would give a false result because both the Mg and MgO would react but at different rates.

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

Reaction with water

Reactivity increases down the group

Beryllium has no reaction with water or steam.

Reaction of magnesium with steam

Magnesium burns in steam to produce magnesium oxide and hydrogen.

$$Mg_{(s)} + H_2O_{(g)} \rightarrow MgO_{(s)} + H_{2\,(g)}$$

The Mg would burn with a bright white flame

CORE

Reacting magnesium with cold water

Mg will also react with warm water, giving a different **magnesium hydroxide** product

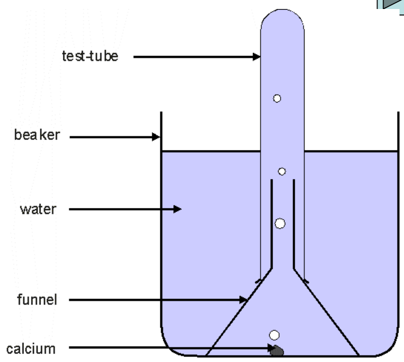
$Mg + 2\ H_2O \rightarrow \mathbf{Mg(OH)_2} + H_2$

This is a much slower reaction than the reaction with steam and there is no flame

The magnesium needs to be clean and only has a very slight reaction with cold water. The reaction soon stops because the magnesium hydroxide formed is almost insoluble in water and forms a barrier on the magnesium preventing further reaction.

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

The other group 2 metals react with cold water with increasing vigour to form hydroxides Strontium and barium have reactivities similar to lithium in Group 1.



All the rest of the group react to give the same products

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

The hydroxides produced make the water alkaline.

One would observe fizzing, the metal dissolving, the solution heating up and with calcium a white precipitate appearing

CORE

Summary of the trend in reactivity

The Group 2 metals become more reactive towards water as you go down the Group.

Explaining the trend in reactivity

The reactions become easier as the energy needed to form positive ions falls. This is mainly due to a decrease in ionisation energy as you go down the group. This leads to lower activation energies, and therefore faster reactions.

EXTRA

Solubility of Hydroxides

Group II hydroxides become more soluble down the group.

•$Ba(OH)_2$ is soluble

Barium hydroxide would easily dissolve in water. The hydroxide ions present would make the solution strongly alkaline

$$Ba(OH)_{2\,(S)} + aq \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$$

All Group II hydroxides when not soluble appear as white precipitates

CORE

Magnesium hydroxide

Magnesium hydroxide is classed as insoluble in water.

A suspension of magnesium hydroxide in water will appear slightly alkaline (pH 9) so some hydroxide ions must therefore have been produced by a very slight dissolving.

Magnesium hydroxide is used in medicine (in suspension as milk of magnesia) to neutralise excess acid in the stomach and to treat constipation.

$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

It is safe to use as it so weakly alkaline.

Calcium hydroxide

Calcium hydroxide is reasonably soluble in water. It is used in agriculture to neutralise acidic soils.

An aqueous solution of calcium hydroxide is called lime water and can be used a test for carbon dioxide. The limewater turns cloudy as white calcium carbonate is produced.

$Ca(OH)_{2\ (aq)} + CO_{2\ (g)} \rightarrow CaCO_{3\ (s)} + H_2O_{(l)}$

Solubility of Sulphates

Group II sulphates become less soluble down the group

Magnesium Sulphate is very soluble

Barium sulphate is very insoluble

$BaSO_4$ is used in medicine as a 'Barium meal' given to patients who need x-rays of their intestines. The Barium absorbs the x-rays and so the gut shows up on the x-ray image

Even though Barium compounds are toxic it is safe to use here because of its low solubility.

Reacting Barium with sulphuric acid

- If Barium metal is reacted with sulphuric acid it will only react slowly as the insoluble Barium sulphate produced will cover the surface of the metal and act as a barrier to further attack.
- $Ba + H_2SO_4 \rightarrow BaSO_4 + H_2$

The same effect will happen to a lesser extent with metals going up the group as the solubility decreases.

The same effect does not happen with other acids like hydrochloric or nitric as they form soluble group 2 salts.

Testing for presence of sulphate ion

The formation of insoluble Barium sulphate is used as a test for the presence of sulphate ions.

If acidified **Barium Chloride** is added to a solution that contains sulphate ions a **white precipitate** forms

$Ba^{2+}{}_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow BaSO_{4\,(s)}$

The acid is needed to react with carbonate impurities that are ofen found in salts which would form a white Barium carbonate precipitate and so give a false result

$2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$

Fizzing due to CO_2 would be observed if a carbonate was present

CORE

Exam question

(a) A small sample of barium metal was added to water in a flask. When the reaction had ceased, the contents of the flask were treated with a small amount of dilute aqueous sodium sulphate.

Describe all that you would observe and write equations, with state symbols, for the reactions that occur.

(8)

(b) Dilute sodium hydroxide solution was added dropwise until in excess to separate dilute aqueous solutions of magnesium chloride and barium chloride.

Describe what you would observe in each case and account for your observations.

Decomposition of Group 2 nitrates

The nitrates of group 2 all decompose in the same way, but become more difficult to decompose down the group.

$$2\ Mg(NO_3)_2\ (s) \rightarrow 2\ MgO\ (s) + 4\ NO_2\ (g) + O_2\ (g)$$

Remember NO_2 is a brown gas that turns damp blue litmus paper red.

If the nitrates are hydrated eg $Mg(NO_3)_2.5H_2O$ water vapour will be given off which will appear as steam or condensation on the test tube.

EXTRA

3 Action of water on oxides

The oxides dissolve in water to form alkaline solutions

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

The metal hydroxides produced are bases that will be neutralised by acid

$$Ca(OH)_2\ (aq) + HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l)$$

EXTRA

4 : Decomposition of group 2 carbonates

The carbonates decompose to give the metal oxide and CO_2 gas which turns lime water cloudy

The carbonates become more stable to heat as you go down the Group. This means they decompose more slowly down the group.

$$MgCO_3\ (s) \rightarrow MgO\ (s) + CO_2\ (g)$$

Lime water is a solution of $Ca(OH)_2$ on addition of CO_2 it goes cloudy.

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

The $CaCO_3$ is a white solid (cloudiness)

EXTRA