10 Group 2

For AS Level you should know about the chemistry of two groups in the Periodic Table – Groups 2 and 17. In addition you need to have studied the elements nitrogen and sulfur.

Group 2 is revisited in Chapter 27 for A Level.

Physical properties of the Group 2 elements

Some of the most useful physical properties of the Group 2 metals are shown in Table 10.1.

Table 10.1

Element	Atomic radius/nm	1st ionisation energy/kJ mol^{-1}	Electronegativity	Melting point/ °C
Beryllium	0.111	900	1.57	1278
Magnesium	0.160	738	1.31	649
Calcium	0.197	590	1.00	839
Strontium	0.215	550	0.95	769
Barium	0.217	503	0.89	729

STUDY TIP

Remember that **ionisation energy** is governed by:

- the charge on the nucleus
- the amount of screening by the inner electrons
- the distance between the outer electrons and the nucleus

- The first three physical properties show steady trends – increasing upwards in atomic radius and downwards in **first ionisation energy** and electronegativity. The decrease in melting point would fit this pattern if it were not for the anomalous low value for magnesium.
- You can explain the change in atomic radius in terms of the additional shell of electrons added for each period and the reduced effective nuclear charge as more electron shells are added.
- As Group 2 is descended, the increase in charge of the nucleus is offset by the number of inner electrons. However, the distance of the outer electrons from the nucleus increases and the first ionisation energy decreases down the group.
- The **electronegativity** of the atoms decreases down the group. As the size of the atoms increases, any bonding pair of electrons is further from the nucleus, which means it is less strongly held and the electronegativity decreases. The effect of this is to increase the ionic (electrovalent) character of any compounds as the group is descended.

STUDY TIP

Remember that **electronegativity** is the ability of an atom to attract a pair of bonding electrons.

NOW TEST YOURSELF

1 As Group 2 is descended the nuclear charge increases, but the electronegativity decreases. Explain this behaviour.

Reactions of the Group 2 elements with oxygen, water and dilute acids

The only reactions you need to remember for the Group 2 elements are their reactions with oxygen, water, and dilute hydrochloric and sulfuric acids.

These are summarised in Table 10.2.

Table 10.2

Element	Reaction with oxygen	Reaction with water	Reaction with dilute acids
Beryllium	Reluctant to burn, white flame	No reaction	Reacts rapidly
Magnesium	Burns easily with a bright white flame	Reacts vigorously with steam but only slowly with water	Reacts vigorously
Calcium	Difficult to ignite, flame tinged red	Reacts moderately forming the hydroxide	Reacts vigorously
Strontium	Difficult to ignite, flame tinged red	Reacts rapidly forming the hydroxide	Reacts violently
Barium	Difficult to ignite, flame tinged green	Reacts vigorously forming the hydroxide	Reacts violently

The general equation for the reaction with oxygen is:

$$2X(s) + O_2(g) \rightarrow 2XO(g)$$

where X is any metal in the group.

Both strontium and barium can also form a peroxide as well as the oxide:

$$Y(s) + O_2(g) \rightarrow YO_2(g)$$

where Y is strontium or barium.

The general equation for the reaction with water is:

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

The exception to this is magnesium, which forms the oxide when reacted with steam.

The general equation for the reaction with dilute acids is:

$$X(s) + 2H_3O^+(aq) \rightarrow X^{2+}(aq) + H_2(g) + 2H_2O(l)$$

Behaviour of Group 2 oxides, hydroxides and carbonates with water and dilute acids

Beryllium oxide is amphoteric, but all the other oxides are sparingly soluble in water, producing solutions of increasing base strength:

$$XO(s) + H_2O(l) \rightarrow X(OH)_2(aq)$$

The hydroxides increase in solubility down the group, due to the decrease in lattice dissociation enthalpy, which outweighs the change in the enthalpy of hydration of the metal ion (see Chapter 23).

The carbonates decrease in solubility down the group, due to the decrease in the enthalpy of hydration of the metal ion.

The compounds react with dilute hydrochloric and sulfuric acids depending on the solubility of the salts they produce. Only the magnesium compounds react appreciably with sulfuric acid because the other sulfates are sparingly soluble.

NOW TEST YOURSELF

2 Look at the reactions of strontium in Table 10.2.

The reactions with water and dilute acids indicate that this is a reactive metal. Suggest why the metal is difficult to ignite when it is heated in oxygen.

Thermal decomposition of Group 2 nitrates and carbonates

The changes in thermal stability stem from the ability of a cation to polarise the anion. This is more pronounced at the top of the group, where the cations are smaller and have a high charge density. This applies to both the nitrate and carbonate, where polarisation results in the formation of the oxide:

$$2X(NO_3)_2(s) \rightarrow 2XO(s) + 4NO_2(g) + O_2(g)$$

$$XCO_3(s) \rightarrow XO(s) + CO_2(g)$$

where X is any metal in the group.

You can examine this trend by comparing the decomposition temperatures of the carbonates (Table 10.3).

Table 10.3

Element	Decomposition temperature of the carbonate/K
Beryllium	Unstable at 298
Magnesium	700
Calcium	1200
Strontium	1580
Barium	1660

NOW TEST YOURSELF

3 Why are the nitrates of Group 2 elements less stable at the top of the group than at the bottom?

Solubility of Group 2 sulfates and hydroxides

- The **solubility** of the sulfates of Group 2 elements decreases down the group. This is due to a combination of the relative sizes of the enthalpy change of hydration of the cations and the lattice energy of the sulfate concerned (see Chapter 23).
- As the cations get bigger, the energy released when the ions bond to water molecules (the enthalpy change of hydration) falls. Larger ions are not as strongly attracted to the water molecules.
- As you go down a group, the energy needed to break up the lattice decreases as the positive ions get bigger. The bigger the ions, the more distance there is between them, and the weaker are the forces holding them together.
- Because both energy changes decrease, it is a question of which is the more significant. For large ions, such as SO_4^{2-}, it is the enthalpy change of hydration factor that dominates.
- Conversely the hydroxides of Group 2 elements become *more* soluble descending the group, but there is not a simple explanation for this.

STUDY TIP

Remember that the **solubility** of the sulfates of Group 2 decreases down the group.

REVISION ACTIVITY

a Suggest how the chemical properties of the Group 2 elements compare with those of Group 1.

b Suggest a reason for this.

END OF CHAPTER CHECK

By now you should be able to:

- describe and write equations for the reactions of the Group 2 elements with oxygen, water and dilute hydrochloric acid
- describe and write equations for the reactions of Group 2 oxides, hydroxides and carbonates with water and dilute hydrochloric and sulfuric acids

- describe and write equations for the thermal decomposition of Group 2 nitrates and carbonates, including the trend in thermal stabilities
- state the variation in the solubilities of Group 2 hydroxides and sulfates