2.4 Period 3

Period 3

Na	Mg	Al	Si	P	S	Cl	Ar

Periodicity:

> ***Periodicity:***
> ***The repeating trends in physical and chemical properties of elements as you go across the Periodic Table***

- Periods often show gradual changes in properties.
- In A2, we need a bit more detail about the reactions with water, with oxygen and the reaction of the oxides with water and acids or bases:

1) Reactions of Na and Mg with water:

- They react with water to give the hydroxide and hydrogen gas:

Metal	**+**	**Water**	**→**	**Metal hydroxide**	**+**	**Hydrogen**
$2Na_{(s)}$ 0	+	$2H_2O_{(l)}$	→	$2NaOH_{(aq)}$ +1 *Strong alkali*	+	$H_{2(g)}$
$Mg_{(s)}$ 0	+	$2H_2O_{(l)}$	→	$Mg(OH)_{2(aq)}$ +2 *Weak alkali*	+	$H_{2(g)}$

- Remember that the group 2 hydroxides increase in solubility as you go down the group:

$Mg(OH)_2$	↓	Least soluble		$MgSO_4$	↑	Most soluble
$Ca(OH)_2$				$CaSO_4$		
$Sr(OH)_2$				$SrSO_4$		
$Ba(OH)_2$		Most soluble		$BaSO_4$		Least soluble

- Mg reacts with **steam** slightly differently:

$Mg_{(s)}$ 0	+	$H_2O_{(g)}$	→	$MgO_{(s)}$ +2	+	$H_{2(g)}$

2) Reactions with oxygen:

$2Na_{(s)}$	+	$\frac{1}{2}O_{2(g)}$	→	$Na_2O_{(s)}$	Vigorous	Yellow flame / white solid
0				+1		
$Mg_{(s)}$	+	$\frac{1}{2}O_{2(g)}$	→	$MgO_{(s)}$	Vigorous	White flame / white solid
0				+2		
$2Al_{(s)}$	+	$1\frac{1}{2}O_{2(g)}$	→	$Al_2O_{3(s)}$	Slow	
0				+3		
$Si_{(s)}$	+	$O_{2(g)}$	→	$SiO_{2(s)}$	Slow	
0				+4		
$P_{4(s)}$	+	$5O_{2(g)}$	→	$P_4O_{10(s)}$	Spontaneously	White flame
0				+5		
$S_{(s)}$	+	$O_{2(g)}$	→	$SO_{2(g)}$	Steady	Blue flame / pungent smell
0				+4		

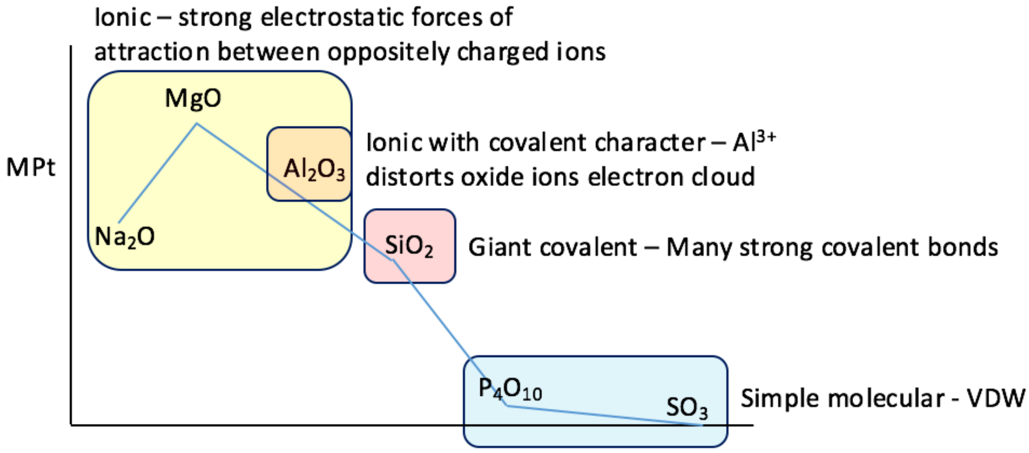
- SO_2 can form SO_3 in the presence of **V_2O_5 catalyst** and excess oxygen:

$S_{(s)}$	+	$O_{2(g)}$	→	$SO_{3(g)}$
0				+6

- The colours of the flames can be used to distinguish between these oxides.

3) Reactions of the oxides with water:

- The oxides react differently with water due to their structure and bonding and the effect this has on the melting points of the oxides:



➢ **Ionic oxides of metals form alkaline solutions, $OH^-_{(aq)}$**

$Na_2O_{(s)}$	+	$H_2O_{(l)}$	→	$2NaOH_{(aq)}$	Soluble	pH 12 - 14
$MgO_{(s)}$	+	$H_2O_{(l)}$	→	$Mg(OH)_{2(aq)}$	Sparingly Soluble	pH 9 - 10

- **Covalent oxides of non - metals form acidic solutions, $H^+_{(aq)}$**

$P_4O_{10(s)} + 6H_2O_{(l)} \rightarrow 4H_3PO_{4(aq)}$ Phosphoric (IV) acid

$H_3PO_{4(aq)} \rightarrow 3H^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$ Sulphuric (IV) acid

$H_2SO_{3(aq)} \rightarrow 2H^+_{(aq)} + SO_3^{2-}{}_{(aq)}$

$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$ Sulphuric (VI) acid

$H_2SO_{4(aq)} \rightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

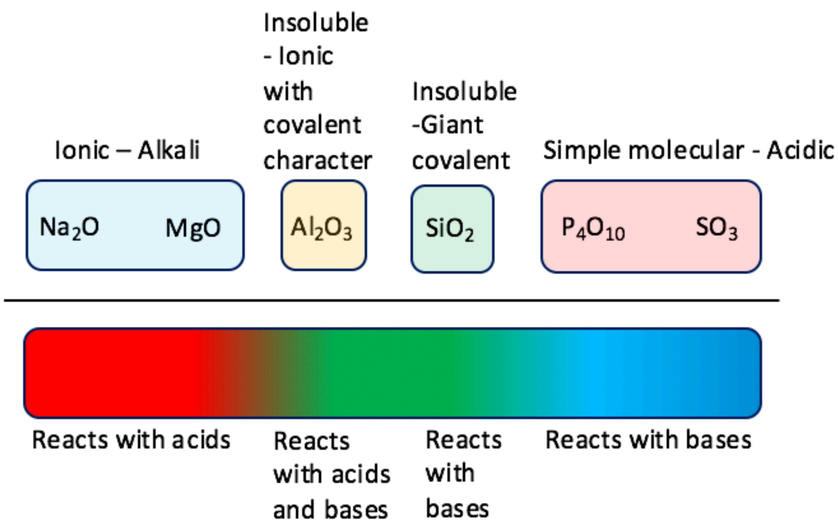
$Al_2O_{3(s)}$ Is insoluble in water
Partially ionic / partially covalent so will react with acids and bases - Amphoteric

$SiO_{2(s)}$ Is insoluble in water
Will react with bases, therefore classed as acidic.

Amphoteric

Amphoteric:
A substance that has both acidic and basic properties

Summary of the oxides with water:



4) Reactions of the oxides with acids / bases:

Acid + Base → Salt + Water

- Alkaline oxides:

$Na_2O_{(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(l)}$

$MgO_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2O_{(l)}$

$Al_2O_{3(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)}$ *Amphoteric

*Tip:

- Think of the oxides reacting with the water / aq to form the hydroxides.
- The hydroxides then react with the acids forming salt and water.

- Acidic oxides:

$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \rightarrow 2NaAl(OH)_{4(aq)}$ *Amphoteric

$SiO_{2(s)} + 2NaOH_{(aq)} \rightarrow Na_2SiO_{3(aq)} + H_2O_{(l)}$

$P_4O_{10(s)} + 12NaOH_{(aq)} \rightarrow 4Na_3PO_{4(aq)} + 6H_2O_{(l)}$

$SO_{2(g)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{3(aq)} + H_2O_{(l)}$

$SO_{3(g)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + H_2O_{(l)}$

*Tip:

- Think of the oxides reacting with the water / aq to form the acids.
- The acids then react with the metal hydroxides forming salt and water.

*Tip:

- You would be expected to balance these with any acid or base
- It is worth learning the unusual compounds formed and balancing accordingly ie $NaAl(OH)_4$ and Na_2SiO_3.

Questions:

1 Write a balanced chemical equation when magnesium reacts with water.

2 Write a balanced chemical reaction when magnesium reacts with steam.
What would you observe during this reaction?

3 What observations would there be when sulphur is burnt in oxygen?
Write a balanced chemical equation.

4 The melting point of phosphorus (V) oxide is 573K. Predict with a reason the melting point of sulphur (IV) oxide.

5 Predict the pH and write a chemical reaction when sulphur (IV) oxide is added to water

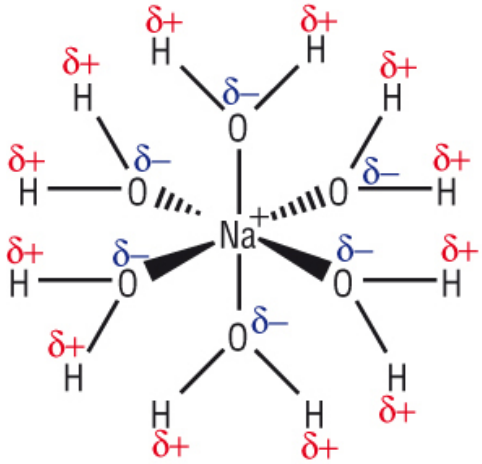
6 Samples of sodium oxide and magnesium oxide are added to water, predict their relative pH's and give a reason for your answer

7 Aluminium oxide is described as **amphoteric**. What does this mean and write balanced chemical equations to show its amphoteric nature.

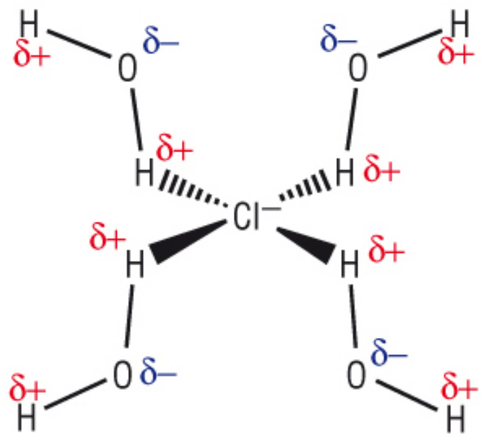
8 Silicon dioxide is a macromolecule and does not dissolve in water. It still described as an acidic oxide. Explain with an equation why it is described as acidic.

The acidic nature of aluminium
Recap:

- When ionic compounds dissolve in water, the ions become surrounded by water molecules.



$Na^+_{(aq)}$

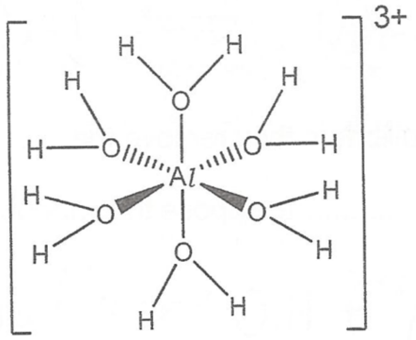


$Cl^-_{(aq)}$

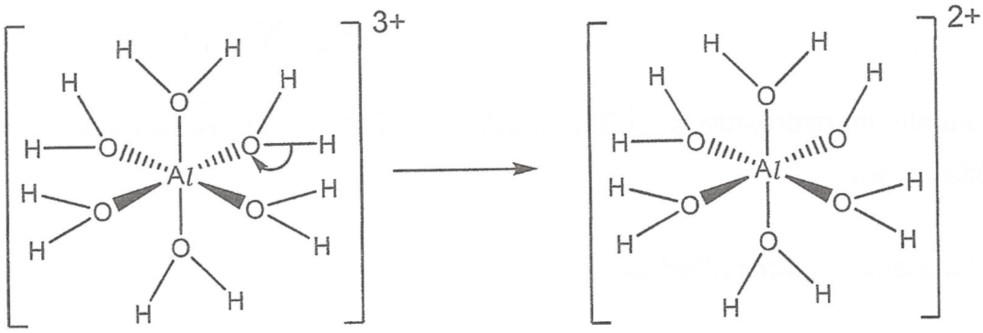
- Central metals with a 2+ or 3+ charge, the resulting solution can be acidic in nature.

Complex ions:

- Consider the dissolved aluminium ion:

$Al^{3+}_{(aq)}$ →  → $[Al(H_2O)_6]^{3+}$

- It is surrounded by 6 water molecules and each water molecule forms a **co-ordinate bond** with the central metal ion.
- Al^{3+} is a **small highly charged ion**, Al^{3+} therefore has a **high charge density.**
- This **high charge density** will **polarise** the water molecule by attracting electrons from the oxygen.
- This effect is felt through the whole water molecule and weakens the O – H bond.
- The O – H bond breaks **releasing H^+ ions**, a **proton donor**, making **the complex ion acidic:**



\+ H^+

Reactions of the aluminium hexaaqua ion – hydrolysis / NaOH:

- Consider the dissolved aluminium ion in equilibria:

$$[Al(H_2O)_6]^{3+}{}_{(aq)} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}{}_{(aq)} + H^+{}_{(aq)}$$

- Adding OH^- reacts with H^+ from the equilibrium according to the following reaction:

$$OH^- + H^+ \rightarrow H_2O$$

- This shifts the equilibria to the right to oppose the change, it can be simplified to:

$$[Al(H_2O)_6]^{3+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}{}_{(aq)} + H_2O_{(l)}$$

- Once all the $[Al(H_2O)_6]^{3+}$ is used up, a second equilibria is set up as more OH^- is added:

$$[Al(H_2O)_5(OH)]^{2+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_4(OH)_2]^{+}{}_{(aq)} + H_2O_{(l)}$$

- Once all the $[Al(H_2O)_5(OH)]^{2+}$ is used up, a third equilibria is set up as more OH^- is added:

$$[Al(H_2O)_4(OH)_2]^{+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_3(OH)_3]_{(s)} + H_2O_{(l)}$$

White precipitate

- The product has neutral charge and therefore precipitates out of solution.

Simplifying to:

$$[Al(H_2O)_6]^{3+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}{}_{(aq)} + H_2O_{(l)}$$

$$[Al(H_2O)_5(OH)]^{2+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_4(OH)_2]^{+}{}_{(aq)} + H_2O_{(l)}$$

$$[Al(H_2O)_4(OH)_2]^{+}{}_{(aq)} + OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_3(OH)_3]_{(s)} + H_2O_{(l)}$$

White precipitate

- Adding more OH^- shifts the equilibrium to the right
- The product has neutral charge and therefore precipitates out of solution.

Simplifying further to:

$$[Al(H_2O)_6]^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightleftharpoons [Al(H_2O)_3(OH)_3]_{(s)} + 3H_2O_{(l)}$$

Precipitate

$$Al^{3+}{}_{(aq)} + 3OH^-{}_{(aq)} \rightleftharpoons Al(OH)_{3(s)}$$

White precipitate

- Use this simplified version unless you are told otherwise.

The amphoteric nature of aluminium hydroxide:

- Remember, aluminium hydroxide can be written as:

$$Al(OH)_3 \quad \text{or} \quad [Al(H_2O)_3(OH)_3]$$

- As it is amphoteric, it will react with an acid and a base:

With an acid:

$$\underset{\text{White precipitate}}{[Al(H_2O)_3(OH)_3]} + 3H^+ \rightarrow \underset{\text{colourless solution}}{[Al(H_2O)_6]}$$

Simplified to:

$$\underset{\text{White precipitate}}{Al(OH)_3} + 3H^+ \rightarrow \underset{\text{colourless solution}}{Al^{3+}} + 3H_2O$$

- White precipitate dissolves to give a clear colourless solution

With a base:

$$\underset{\text{White precipitate}}{[Al(H_2O)_3(OH)_3]} + OH^- \rightarrow \underset{\text{colourless solution}}{[Al(H_2O)_2(OH)_4]^-} + H_2O$$

Simplified to:

$$\underset{\text{White precipitate}}{Al(OH)_3} + OH^- \rightarrow \underset{\text{colourless solution}}{Al(OH)_4^-} + H_2O$$

- White precipitate dissolves to give a clear colourless solution