AQA A Level Chemistry

Your notes

Properties of Period 3 Elements & their Oxides

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Na & Mg with water

Sodium & Magnesium

- Both sodium, Na, and magnesium, Mg, are metals and are found in Group 1 and Group 2 of the periodic table respectively
- Both have high melting points, but magnesium has a higher melting point than sodium
  - This is because of the 2+ charge of magnesium, meaning that it is has a higher charge density
- Both are silvery metals
  - Sodium is quite a soft, silvery metal which tarnishes quickly in air
  - Magnesium is harder than sodium and you will often see it as magnesium ribbon

Reactions with water

- Despite their similarities, sodium and magnesium will react with water quite differently:
- Sodium with cold water:

$$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$$

  - This is a very vigorous, exothermic reaction
  - The sodium floats on the surface of the water fizzing rapidly and melting as a result of the heat produced during the reaction
  - The colourless sodium hydroxide formed will have a pH of around 13–14, so a very alkaline solution is formed
  - The oxidation state of the sodium changes from 0 in its elemental state, to +1 in the sodium hydroxide
- Magnesium with cold water:

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

  - This is an extremely slow reaction - only a very small number of bubbles will form on the magnesium ribbon
  - The magnesium hydroxide formed will have a pH of around 10 - it is less alkaline than sodium hydroxide because magnesium hydroxide is only **partially soluble**
  - This is the key component in 'milk of magnesia'
  - The oxidation state of the magnesium changes from 0 in the elemental state, to +2 in the magnesium hydroxide
- Heated magnesium with steam:

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

- This reaction is much faster than with cold water
- The magnesium burns with a bright, white flame
- The products of this reaction are different - magnesium oxide is produced instead of magnesium hydroxide
- The oxidation state of the magnesium changes from 0 in its elemental state, to +2 in the magnesium oxide

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Reaction with Oxygen

Oxide Formation

- The period 3 elements, excluding chlorine and argon, combine with oxygen to form oxides
- The oxide formed will contain the elements in their highest oxidation state
- The following equations show these reactions:

$$4Na\,(s) + O_2\,(g) \rightarrow 2Na_2O\,(s)$$

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

$$4Al\,(s) + 3O_2\,(g) \rightarrow 2Al_2O_3\,(s)$$

$$Si\,(s) + O_2\,(g) \rightarrow SiO_2\,(s)$$

$$4P\,(s) + 5O_2\,(g) \rightarrow P_4O_{10}\,(s)$$

$$S\,(s) + O_2\,(g) \rightarrow SO_2\,(g)$$

Reaction of Period 3 elements with oxygen table

	Chemical Equation	Reaction Conditions	Reaction	Flame	Product
Na	$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$	Heated	Vigorously	Bright yellow flame	White solid
Mg	$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$	Heated	Vigorously	Bright white flame	White solid
Al	$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$	Powdered Al	Fast	Bright white flame	White powder
Si	$Si(s) + O_2(g) \rightarrow SiO_2(s)$	Powdered Si Heat strongly	Slowly	Bright white sparkles	White powder
P	$4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$	Heated	Vigorously	Yellow or white flame	White clouds
S	$S(s) + O_2(g) \rightarrow SO_2(g)$	Powdered S is heated	Gently	Blue flame	Toxic fumes

- Sulfur can actually form two oxides - SO_2 and SO_3
  - For SO_3 to form, a catalyst must be used and the reaction must take place at a very high temperature
  - The equation for this reaction is:

$$2S\,(s) + 3O_2\,(g) \rightarrow 2SO_3\,(g)$$

- The oxides formed from these reactions have different physical properties, depending on the type of structure and bonding
- Sodium oxide, magnesium oxide and aluminium oxide are all ionic oxides
    - Sodium, magnesium and aluminium are all metals and oxygen is a non-metal
- Silicon oxide has a giant covalent structure, like diamond
- Phosphorus oxide and sulfur dioxide are simple covalent molecules

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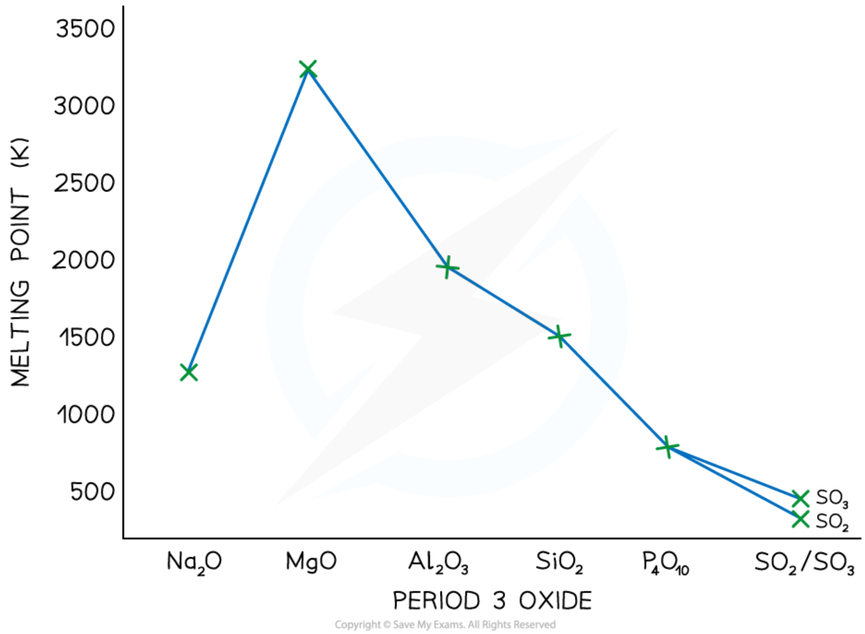
Melting Point Trend

- The melting points of the oxides vary significantly across Period 3 and show a clear trend
- Melting point is a clear indication of the forces of attraction which exist between ions, atoms or molecules



A graph to show the melting points of the Period 3 Oxides

Ionic Oxides

- The graph starts off showing the melting points of the ionic oxides
  - Sodium oxide
  - Magnesium oxide
  - Aluminium oxide
- These are ionic oxides because the bonding exists between metals and non metals
- They have giant lattice structures and thus, high melting points

Giant Covalent Oxides

- The graph then shows a giant covalent oxide
  - Silicon dioxide

- This is covalent because both silicon and oxygen are non metals
- The millions of covalent bonds within this giant structure are extremely strong, and thus it has a high melting point
- Giant covalent structures can also be called macromolecules or giant molecules

Simple Covalent Oxides

- The graph then shows a significant drop in melting point, as we reach the simple covalent oxide molecules
  - Phosphorus(V) oxide
  - Sulfur dioxide
  - Sulfur trioxide
- These are small molecules with only weak intermolecular forces of attraction between them
- Sulfur dioxide and sulfur trioxide are both gases at room temperature, because both their melting point and boiling point are so low
  - Sulfur trioxide, SO_3, has a slightly higher melting point than sulfur dioxide, SO_2, because of the increase in intermolecular forces between the slightly larger SO_3 molecules

Summary Table of the Physical Properties of the Period 3 Oxides

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Element	Na	Mg	Al	Si	P	S	S
Formula of oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	SO_3
State at 25 °C	solid	solid	solid	solid	solid	gas	liquid
Melting point / K	1 548 (sublimes)	3 125	2 345	1 883	853 > 1 atm	200	290
Electrical conductivity when molten	good	good	good	none	none	none	none
Structure	giant ionic	giant ionic	giant ionic	giant molecule	simple molecule	simple molecule	simple molecule
Adding water	reacts and forms hydroxide ions in solution	slightly soluble, dissolved oxide forms a few hydroxide ions in solution	insoluble but amphoteric	insoluble but acidic	acidic; reacts and gives H^+ ions in solution	acidic; reacts and forms weak acid H_2SO_3 with a few H^+ ions in solution	acidic; reacts and forms strong acid H_2SO_4 with H^+ ions in solution
Typical pH of aqueous solution of oxide	13	8	7, i.e. does not dissolve	7, i.e. does not dissolve	2	3	1
Covalent character	INCREASES →						
Ionic character	DECREASES →						

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Examiner Tips and Tricks

Make sure that you can state and explain the link between the physical properties of the Period 3 Oxides and their structure and bonding!

Oxides Reacting with Water

Structure, bonding & electronegativity of the Period 3 elements table

Period 3 element	Na	Mg	Al	Si	P	S
Period 3 oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2 SO_3
Relative melting point	High	High	Very high	Very high	Low	Low
Chemical bonding	Ionic	Ionic	Ionic (with a degree of covalent)	Covalent	Covalent	Covalent
Structure	Giant ionic	Giant ionic	Giant ionic	Giant covalent	Simple molecular	Simple molecular
Element	Na	Mg	Al	Si	P	S
Electronegativity	0.9	1.2	1.5	1.8	2.1	2.5

- The oxides of **Na and Mg** which show purely **ionic bonding** produce **alkaline** solutions with water as their **oxide** ions (O^{2-}) become **hydroxide** ions (OH^-):

$$O^{2-}\ (aq) + H_2O\ (l) \rightarrow 2OH^-\ (aq)$$

- The oxides of **P and S** which show purely **covalent bonding** produce **acidic** solutions with water because when these oxides react with water, they form an acid which donates **H^+** ions to water
  - Eg. SO_3 reacts with water as follows:

$$SO_3\ (g) + H_2O\ (l) \rightarrow H_2SO_4\ (aq)$$

- The H_2SO_4 is an acid which will donate a H^+ to water:

$$H_2SO_4\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + HSO_4^-\ (aq)$$

- **Al** and **Si** are insoluble and when they react with **hot, concentrated alkaline solution** they act as a base and form a salt
  - This behaviour is very typical of a **covalently bonded oxide**
- **Al** can also react with **acidic solutions** to form a salt and water
  - This behaviour is very typical of an **ionic bonded metal oxide**

- This behaviour of **Al** proves that the chemical bonding in aluminium oxide is not purely **ionic** nor **covalent: therefore it exhibits amphoteric character**

Reaction of Period 3 oxides with water table

Oxide	Chemical equation	pH	Comments
Na_2O	Na_2O (s) + H_2O (l) → 2NaOH (aq)	14 (strongly alkaline)	-
MgO	MgO (s) + H_2O (l) → $Mg(OH)_2$ (aq)	10 (weakly alkaline)	-
Al_2O_3	No reaction	-	Al_2O_3 is insoluble in water
SiO_2	No reaction	-	SiO_2 is insoluble in water
P_4O_{10}	P_4O_{10} (s) + 6H_2O (l) → 4H_3PO_4 (aq)	2 (strongly acidic)	Vigorous / violent reaction
SO_2 **SO_3**	SO_2 (g) + H_2O (l) → H_2SO_3 (aq) SO_3 (g) + H_2O (l) → H_2SO_4 (aq)	1 (strongly acidic)	-

Behaviour of the Period 3 Oxides with Water

- Metal oxides (to the left of the periodic table):
  - Sodium oxide, Na_2O, and magnesium oxide, MgO, are made up of ions
  - They contain an oxide ion, O^{2-}, which is a strong base and will readily produce hydroxide ions through reaction with water
  - This is why the solutions formed are strongly alkaline
  - Sodium oxide forms a more alkaline solution than magnesium oxide because it is far more soluble in water
- Oxides in the middle of the periodic table
  - Although ionic, aluminium oxide does not react with water because the oxide ions are held too strongly in the ionic lattice
  - This means the ions cannot be separated
  - Silicon dioxide is a giant covalent molecule - it is the main component of sand
  - It has millions of strong covalent bonds, so it does not react with water
- Non-metal oxides (to the right of the periodic table):
  - Oxides of phosphorus and sulfur are simple covalent molecules

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- They will react with water to produce acidic solutions

Examiner Tips and Tricks

Key thing to remember: The metal oxides form alkaline solutions in water, the oxides in the middle do not react and the non-metal oxides form acidic solutions.

Acid-Base Reactions of the Oxides

Acid/base Nature of the Period 3 Oxides

- Aluminium oxide is **amphoteric** which means that it can act both as a base (and react with an acid such as HC*l*) and an acid (and react with a base such as NaOH)

Period 3 oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2 SO_3
Acid / base nature	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic

Reactions of the Period 3 oxides with acid/base table

Period 3 oxide	Chemical equation	Comments
Na_2O	Na_2O (s) + 2HCl (aq) → 2NaCl (aq) + H_2O (l)	-
MgO	MgO (s) + 2HCl (aq) → $MgCl_2$ (aq) + H_2O (l)	Used in indigestion remedies by neutralising the excess acid in the stomach
Al_2O_3	Al_2O_3 (s) + $3H_2SO_4$ (aq) → $Al_2(SO_4)_3$ (aq) + $3H_2O$ (l)	Reacts with acid to form a salt and water
	Al_2O_3 (s) + 2NaOH (aq) + $3H_2O$ (l) → $2NaAl(OH)_4$ (aq)	Reacts with hot, concentrated alkali to form a salt
SiO_2	SiO_2 (s) + 2NaOH (aq) → Na_2SiO_3 (aq) + H_2O (l)	Reacts with hot, concentrated alkali to form a salt and water
P_4O_{10}	P_4O_{10} (s) + 12NaOH → $4Na_3PO_4$ + $6H_2O$ (l)	-

SO_2 **SO_3**	SO_2 (g) + 2NaOH (aq) → Na_2SO_3 (aq) + H_2O (l) SO_3 (g) + 2NaOH (aq) → Na_2SO_4 (aq) + H_2O (l)	-

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Examiner Tips and Tricks

It is crucial that you learn these reactions - make sure that you know the state symbols, the products formed and the full balanced equations!