

**1**

- (a) Write an equation for the reaction that occurs when magnesium is heated in steam. Describe what you would observe when this reaction occurs.

Equation .....

Observations .....

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**(3)**

- (b) Write an equation for the reaction that occurs when sodium is heated in oxygen. Describe what you would observe when this reaction occurs.

Equation .....

Observations .....

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**(3)**

**(Total 6 marks)**

**2**

- (a) The table below contains data that show a trend in the melting points of some oxides of the Period 3 elements.

Oxide	Sodium oxide	Magnesium oxide	Aluminium oxide	Silicon(IV) oxide	Phosphorus(V) oxide	Sulfur(IV) oxide
Melting point / K		3125	2345	1883	573	

- (i) Use data from the table above to predict an approximate melting point for sodium oxide.

Tick (✓) **one** box.

250 K

500 K

1500 K

3500 K

**(1)**

- (ii) Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

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**(2)**

- (iii) Use data from the table above to predict a value for the melting point of sulfur(IV) oxide.

Suggest, in terms of structure and bonding, why the melting point of sulfur(IV) oxide is different from that of phosphorus(V) oxide.

Predicted melting point of sulfur(IV) oxide .....

Why the melting point is different from phosphorus(V) oxide .....

.....  
.....  
.....

**(3)**

(b) Write an equation for the reaction of sulfur(IV) oxide with water.

Suggest the pH value of the resulting solution.

Equation

.....

pH value .....

(2)

(c) Silicon(IV) oxide is insoluble in water.

Explain, using an equation, why silicon(IV) oxide is classified as an acidic oxide.

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(2)

(Total 10 marks)

3

(a) Explain why the atomic radii of the elements decrease across Period 3 from sodium to chlorine.

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(2)

(b) Explain why the melting point of sulfur ( $S_8$ ) is greater than that of phosphorus ( $P_4$ ).

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(2)

(c) Explain why sodium oxide forms an alkaline solution when it reacts with water.

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(2)

(d) Write an ionic equation for the reaction of phosphorus(V) oxide with an excess of sodium hydroxide solution.

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(1)

(Total 7 marks)

**4**

This question is about some Period 3 elements and their oxides.

(a) Describe what you would observe when, in the absence of air, magnesium is heated strongly with water vapour at temperatures above 373 K.  
Write an equation for the reaction that occurs.

Observations .....

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.....  
.....  
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Equation .....

(3)

(b) Explain why magnesium has a higher melting point than sodium.

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.....  
(Extra space) .....

(2)

(c) State the structure of, and bonding in, silicon dioxide.  
Other than a high melting point, give **two** physical properties of silicon dioxide that are characteristic of its structure and bonding.

Structure .....

Bonding.....

Physical property 1.....

Physical property 2.....

(4)

(d) Give the formula of the species in a sample of solid phosphorus(V) oxide.  
State the structure of, and describe fully the bonding in, this oxide.

Formula .....

Structure .....

Bonding.....

.....

.....

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(4)

(e) Sulfur(IV) oxide reacts with water to form a solution containing ions.

Write an equation for this reaction.

.....

(1)

- (f) Write an equation for the reaction between the acidic oxide, phosphorus(V) oxide, and the basic oxide, magnesium oxide.

.....

(1)  
(Total 15 marks)

**5**

Magnesium oxide, silicon dioxide and phosphorus(V) oxide are white solids but each oxide has a different type of structure and bonding.

- (a) State the type of bonding in magnesium oxide.  
Outline a simple experiment to demonstrate that magnesium oxide has this type of bonding.

Type of bonding .....

Experiment .....

.....  
.....  
.....  
.....  
.....

(3)

- (b) By reference to the structure of, and the bonding in, silicon dioxide, suggest why it is insoluble in water.

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(3)

- (c) State how the melting point of phosphorus(V) oxide compares with that of silicon dioxide. Explain your answer in terms of the structure of, and the bonding in, phosphorus(V) oxide.

Melting point in comparison to silicon dioxide .....

Explanation .....

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(3)

- (d) Magnesium oxide is classified as a basic oxide.

Write an equation for a reaction that shows magnesium oxide acting as a base with another reagent.

.....

(2)

- (e) Phosphorus(V) oxide is classified as an acidic oxide.

Write an equation for its reaction with sodium hydroxide.

.....

(1)

(Total 12 marks)

**6**

Some melting points of Period 3 oxides are given in this table.

	Na <sub>2</sub> O	SiO <sub>2</sub>	SO <sub>2</sub>	SO <sub>3</sub>
<b>Melting point / K</b>	1548	1883	200	290

- (a) Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

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.....

.....

.....

(2)

(b) Explain, in terms of structure and bonding, why sulfur trioxide has a higher melting point than sulfur dioxide.

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**(2)**

(c) Some Period 3 oxides have basic properties.

State the type of bonding in these basic oxides.

Explain why this type of bonding causes these oxides to have basic properties.

Type of bonding .....

Explanation .....

.....  
.....  
.....  
.....

**(3)**

(d) Sulfur dioxide reacts with water to form a weakly acidic solution.

(i) Ions are formed when sulfur dioxide reacts with water.  
Write an equation for this reaction.

.....

**(1)**

(ii) With reference to your equation from part (d)(i), suggest why sulfur dioxide forms a weakly acidic solution.

.....  
.....  
.....

**(1)**



(e) Suggest why silicon dioxide is described as an acidic oxide even though it is insoluble in water.

.....  
.....

(1)  
(Total 10 marks)

7

White phosphorus ( $P_4$ ) is a hazardous form of the element. It is stored under water.

(a) Suggest why white phosphorus is stored under water.

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.....  
.....

(1)

(b) Phosphorus(V) oxide is known as phosphorus pentoxide.  
Suggest why it is usually represented by  $P_4O_{10}$  rather than by  $P_2O_5$

.....  
.....  
.....

(1)

(c) Explain why phosphorus(V) oxide has a higher melting point than sulfur(VI) oxide.

.....  
.....  
.....  
.....  
.....

(2)

(d) Write an equation for the reaction of  $P_4O_{10}$  with water to form phosphoric(V) acid.  
Give the approximate pH of the final solution.

Equation .....

pH .....

(2)

(e) A waste-water tank was contaminated by  $P_4O_{10}$ . The resulting phosphoric(V) acid solution was neutralised using an excess of magnesium oxide. The mixture produced was then disposed of in a lake.

(i) Write an equation for the reaction between phosphoric(V) acid and magnesium oxide.

.....

**(1)**

(ii) Explain why an excess of magnesium oxide can be used for this neutralisation.

.....

.....

.....

**(1)**

(iii) Explain why the use of an excess of sodium hydroxide to neutralise the phosphoric(V) acid solution might lead to environmental problems in the lake.

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.....

.....

**(1)**

**(Total 9 marks)**

**8**

The data in the table below show the melting points of oxides of some Period 3 elements.

	Na <sub>2</sub> O	P <sub>4</sub> O <sub>10</sub>	SO <sub>2</sub>
T <sub>m</sub> /K	1548	573	200

(a) In terms of structure and bonding, explain why

(i) sodium oxide has a high melting point

.....  
.....  
.....  
(Extra space) .....  
.....

(2)

(ii) sulfur dioxide has a low melting point.

.....  
.....  
.....  
.....  
.....  
(Extra space) .....  
.....

(2)

(b) Explain why the melting point of P<sub>4</sub>O<sub>10</sub> is higher than the melting point of SO<sub>2</sub>

.....  
.....  
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.....  
(Extra space) .....  
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(2)

- (c) Write equations for the reactions of  $\text{Na}_2\text{O}$  and  $\text{P}_4\text{O}_{10}$  with water. In each case give the approximate pH of the resulting solution.

Equation for  $\text{Na}_2\text{O}$ .....

pH .....

Equation for  $\text{P}_4\text{O}_{10}$ .....

pH .....

.....

(4)

- (d) Write an equation for the acid–base reaction that occurs when  $\text{Na}_2\text{O}$  reacts with  $\text{P}_4\text{O}_{10}$  in the absence of water.

.....

(1)

(Total 11 marks)

9

This question is about the chemistry of the Period 3 elements and the trends in their properties.

- (a) (i) Describe what you would observe when magnesium burns in oxygen. Write an equation for the reaction that occurs. State the type of bonding in the oxide formed.

Observations .....

.....

.....

.....

Equation .....

Type of bonding .....

(4)

- (ii) Describe what you would observe when sulfur burns in oxygen. Write an equation for the reaction that occurs. State the type of bonding in the oxide formed.

Observations .....

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.....

.....

Equation .....

Type of bonding .....

**(4)**

- (b) State the type of bonding in sodium oxide. Explain why sodium oxide reacts to form an alkaline solution when added to water.

Type of bonding .....

Explanation.....

.....

.....

.....

**(3)**

- (c) Outline an experiment that could be used to show that aluminium oxide contains ions.

.....

.....

.....

*(Extra space)* .....

.....

**(2)**

- (d) Suggest one reason why a thin layer of aluminium oxide protects aluminium from corrosion in moist air.

.....

.....

**(1)**

(e) Write an ionic equation in each case to show how aluminium oxide reacts with the following

(i) hydrochloric acid

.....

(1)

(ii) aqueous sodium hydroxide.

.....

(1)

(Total 16 marks)

10

There is a link between the properties of the oxides of the Period 3 elements and their structure and bonding. The table below shows the melting points of the oxides of some Period 3 elements.

	Na <sub>2</sub> O	SiO <sub>2</sub>	P <sub>4</sub> O <sub>10</sub>
T <sub>m</sub> /K	1548	1883	573

(a) In terms of crystal structure and bonding, explain in each case why the melting points of sodium oxide and silicon dioxide are high.

Na<sub>2</sub>O .....

.....

.....

SiO<sub>2</sub> .....

.....

.....

(4)

(b) Predict whether the melting point of lithium oxide is higher than, the same as, or lower than the melting point of sodium oxide and explain your prediction.

Prediction .....

Explanation .....

.....

.....

(3)

(c) Phosphorus(V) oxide has a lower melting point than sodium oxide.

(i) State the structure of and bonding in phosphorus(V) oxide.

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.....  
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(2)

(ii) Explain why the melting point of phosphorus(V) oxide is low.

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(1)

(d) Separate samples of phosphorus(V) oxide and sodium oxide were reacted with water. In each case, predict the pH of the solution formed and write an equation for the reaction.

pH with  $P_4O_{10}$  .....

Equation .....

pH with  $Na_2O$ .....

Equation .....

(4)

(e) Write an equation for the reaction between  $Na_2O$  and  $P_4O_{10}$   
State the general type of reaction illustrated by this example.

Equation .....

Reaction type .....

(2)

(Total 16 marks)

11

Sodium, aluminium and silicon are solid elements with a silver colour. These elements react with oxygen to form oxides with high melting points. Aluminium is a reactive metal, but it resists corrosion in water because it has a surface coating of aluminium oxide.

(a) In terms of its structure and bonding, explain why silicon dioxide has a high melting point.

.....  
.....  
.....

(3)

(b) State the type of bonding in aluminium oxide.

.....

(1)

(c) Write an equation for the reaction of aluminium with oxygen.

.....

(1)

(d) Suggest **one** property of the aluminium oxide coating that causes aluminium to resist corrosion in water.

.....

(1)

(e) Sodium metal is **not** resistant to corrosion in water, despite having a surface coating of sodium oxide. Write an equation to show how sodium oxide reacts with water.

.....

(1)

(f) Aluminium oxide is amphoteric. It reacts with acids and alkalis.

(i) Write an equation for the reaction between aluminium oxide and hydrochloric acid.

.....

(1)

(ii) Write an equation for the reaction between aluminium oxide and an excess of aqueous sodium hydroxide.

.....

(1)

(g) Silicon dioxide does **not** react with hydrochloric acid but it does react with sodium hydroxide. State **one** property of silicon dioxide that can be deduced from this information and write an equation for its reaction with sodium hydroxide.

Property .....

Equation .....

(2)

(Total 11 marks)



12

(a) State and explain the trend in electronegativities across Period 3 from sodium to sulfur.

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(4)

(b) Explain why the oxides of the Period 3 elements sodium and phosphorus have different melting points. In your answer you should discuss the structure of and bonding in these oxides, and the link between electronegativity and the type of bonding.

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(6)

- (c) A chemical company has a waste tank of volume 25 000 dm<sup>3</sup>. The tank is full of phosphoric acid (H<sub>3</sub>PO<sub>4</sub>) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm<sup>3</sup> sample of this solution required 21.2 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> sodium hydroxide solution for complete reaction.

Calculate the mass, in kg, of phosphorus(V) oxide that must have been added to the water in the waste tank.

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**(5)**  
**(Total 15 marks)**

**13**

- (a) The melting points of some of the oxides formed by Period 3 elements are given in a random order below.

Oxide	A	B	C	D	E
$T_m/^\circ\text{C}$	2852	-73	1610	1275	300

- (i) Using the letters **A** to **E**, give **two** oxides which have simple molecular structures.

Explain your answer.

*Oxide 1* .....

*Oxide 2* .....

*Explanation* .....

.....

- (ii) Give a simple chemical test which could be used to show which of the oxides in the table is sodium oxide. State the observation you would make.

*Chemical test* .....

.....

*Observation* .....

**(6)**

- (b) The base calcium oxide can be used to remove sulfur dioxide from flue-gases produced when fossil fuels are burnt in coal-fired power stations. Calcium oxide is produced when calcium carbonate, is decomposed by heat.

- (i) Write an equation for the action of heat on calcium carbonate.

.....

- (ii) Identify the product formed when sulfur dioxide reacts with calcium oxide.

.....

- (iii) Despite the additional cost, operators of power stations are encouraged to remove the sulfur dioxide from flue-gases. Explain why this may not be environmentally beneficial.

.....

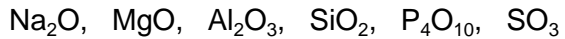
.....

**(4)**

**(Total 10 marks)**

**14**

Consider the following oxides.



(a) Identify one of the oxides from the above which

(i) can form a solution with a pH less than 3 .....

(ii) can form a solution with a pH greater than 12 .....

**(2)**

(b) Write an equation for the reaction between

(i)  $\text{MgO}$  and  $\text{HNO}_3$

.....

(ii)  $\text{SiO}_2$  and  $\text{NaOH}$

.....

(iii)  $\text{Na}_2\text{O}$  and  $\text{H}_3\text{PO}_4$

.....

**(3)**

(c) Explain, in terms of their type of structure and bonding, why  $\text{P}_4\text{O}_{10}$  can be vaporised by gentle heat but  $\text{SiO}_2$  cannot.

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.....

**(4)**

**(Total 9 marks)**

## Mark schemes

<b>1</b>	(a) $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$ <i>ignore state symbols</i>	1
	White solid / powder / ash / smoke <i>ignore precipitate</i> <i>ignore fumes</i>	1
	(Bright) <u>white</u> light / flame <i>allow glow</i> <i>penalise effervescence under list principle</i>	1
	(b) $2\text{Na} + \frac{1}{2}\text{O}_2 \rightarrow \text{Na}_2\text{O}$ / $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$ <i>Allow multiples, ignore state symbols</i> <i>Allow <math>2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2</math></i>	1
	white / yellow solid / ash / smoke <i>ignore precipitate</i> <i>ignore fumes</i>	1
	orange / yellow flame	1
		<b>[6]</b>
<b>2</b>	(a) (i) 1500	1
	(ii) Ionic lattice / giant ionic <i>Mention of vdW / covalent bonding / molecules / atoms / metal etc.</i> <i>CE = 0</i>	1
	Strong <u>attraction</u> between <u>oppositely charged ions</u> / $\text{Na}^+$ and $\text{O}^{2-}$ OR lots of energy required to separate / overcome attraction between oppositely charged ions / $\text{Na}^+$ and $\text{O}^{2-}$ <i>Do not allow incorrect formulae for ions.</i>	1

(iii) 200 (K)

*Allow range 10–273 (K)*

*CE = 0 if temperature >573 K, otherwise mark on*

*Allow correct answers in °C but units must be given.*

1

SO<sub>2</sub> smaller (molecule) (than P<sub>4</sub>O<sub>10</sub>) (or converse)

*also SO<sub>2</sub> has lower M<sub>r</sub> / less surface area / less polarisable / fewer electrons*

*penalise SO<sub>3</sub> and P<sub>2</sub>O<sub>5</sub> for M2 only*

1

vdW forces between molecules are weaker / require less energy to separate molecules

*ignore dipole–dipole*

*If covalent bonds broken lose M2 and M3 but can gain M1*

1

(b) SO<sub>2</sub> + H<sub>2</sub>O → H<sub>2</sub>SO<sub>3</sub> / H<sup>+</sup> + HSO<sub>3</sub><sup>-</sup> / 2H<sup>+</sup> + SO<sub>3</sub><sup>2-</sup>

*can be equilibrium sign instead of arrow*

1

1

*Allow values between 1–3*

*mark independently*

1

(c) Reacts with / neutralises bases / alkalis

*Allow any given base or alkali including OH<sup>-</sup>*

1

SiO<sub>2</sub> + 2NaOH → Na<sub>2</sub>SiO<sub>3</sub> + H<sub>2</sub>O

*Allow CaO + SiO<sub>2</sub> → CaSiO<sub>3</sub> or equation with any suitable base*

*M2 can score M1 even if equation unbalanced or incorrect*

1

[10]

3

(a) The number of protons increases (across the period) / nuclear charge increases

1

Therefore, the attraction between the nucleus and electrons increases

*Can only score M2 if M1 is correct*

1

(b) S<sub>8</sub> molecules are bigger than P<sub>4</sub> molecules

*Allow sulfur molecules have bigger surface area and sulfur molecules have bigger M<sub>r</sub>*

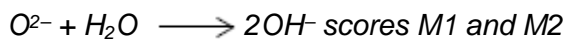
1

Therefore, van der Waals / dispersion / London forces between molecules are stronger in sulfur

1

(c) Sodium oxide contains  $O^{2-}$  ions 1

These  $O^{2-}$  ions react with water forming  $OH^-$  ions



1

(d)  $P_4O_{10} + 12OH^- \longrightarrow 4PO_4^{3-} + 6H_2O$  1

[7]

4

(a) White powder / solid / ash / smoke 1  
*Ignore ppt / fumes*

Bright / white light / flame 1  
*Allow glows white / glows bright*

$Mg + H_2O \rightarrow MgO + H_2$  1  
*Ignore state symbols*  
*Ignore reference to effervescence or gas produced*

(b)  $Mg^{2+}$  / magnesium ion has higher charge than  $Na^+$  1  
*Allow  $Mg^{2+}$  ions smaller / greater charge density than  $Na^+$  ions*  
*Allow Mg atoms smaller than Na (atoms)*  
*Allow magnesium has more delocalised electrons*  
*Must be a comparison*  
*Ignore reference to nuclear charge*

Attracts delocalised / free / sea of electrons more strongly / metal-metal bonding stronger / metallic bonding stronger 1  
*Wrong type of bonding (vdW, imf), mention of molecules CE = 0*

(c) **Structure:** Macromolecular / giant molecule / giant covalent 1  
*Mark independently*

**Bonding:** Covalent / giant covalent 1

**Physical Properties:**

Any **two** from: Hard/

Brittle / not malleable

Insoluble

Non conductor

*Ignore correct chemical properties*

*Ignore strong, high boiling point, rigid*

2

(d) **Formula:** P<sub>4</sub>O<sub>10</sub>

*Mention of ionic or metallic, can score M1 only*

1

**Structure:** Molecular

*If macromolecular, can score M1 & M3 only*

1

**Bonding:** Covalent / shared electron pair

1

van der Waals' / dipole–dipole forces between molecules

*Allow vdW, imf and dipole–dipole imf but do not allow imf alone*

1

(e) SO<sub>2</sub> + H<sub>2</sub>O → H<sup>+</sup> + HSO<sub>3</sub><sup>-</sup>

*Products must be ions*

*Allow SO<sub>2</sub> + H<sub>2</sub>O → 2H<sup>+</sup> + SO<sub>3</sub><sup>2-</sup>*

*Allow two equations showing intermediate formation of H<sub>2</sub>SO<sub>3</sub> that ends up as ions*

*Ignore state symbols*

*Allow multiples*

1

(f) P<sub>4</sub>O<sub>10</sub> + 6MgO → 2Mg<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>

OR P<sub>4</sub>O<sub>10</sub> + 6MgO → 6Mg<sup>2+</sup> + 4PO<sub>4</sub><sup>3-</sup>

OR P<sub>2</sub>O<sub>5</sub> + 3MgO → Mg<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub> etc

*Ignore state symbols*

*Allow multiples*

1

[15]

5

(a) MgO is ionic

*If not ionic, CE = 0*

1

Melt it

*If solution mentioned, cannot score M2 or M3*

1



(Molten oxide) conducts electricity

*Allow acts as an electrolyte.*

*Cannot score M3 unless M2 is correct.*

1

(b) Macromolecular

*CE = 0 if ionic, metallic or molecular.*

*Allow giant molecule.*

1

Covalent bonding

*Giant covalent scores M1 and M2*

1

Water cannot (supply enough energy to) break the covalent bonds / lattice

*Hydration enthalpy < bond enthalpy.*

1

(c) (Phosphorus pentoxide's melting point is) lower

If M1 is incorrect, can only score M2

1

Molecular with covalent bonding

*M2 can be awarded if molecular mentioned in M3*

1

Weak / easily broken / not much energy to break intermolecular forces

**OR** weak vdW / dipole-dipole forces of attraction between molecules

*Intermolecular / IMF means same as between molecules.*

1

(d) Reagent (water or acid)

*Can be awarded in the equation.*

1

Equation eg  $\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$

$\text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2$

*Equations can be ionic but must show all of the reagent eg  $\text{H}^+$  +  $\text{Cl}^-$*

*Simplified ionic equation without full reagent can score M2 only.*

*Allow  $6\text{MgO} + \text{P}_4\text{O}_{10} \rightarrow 2\text{Mg}_3(\text{PO}_4)_2$*

1

(e)  $\text{P}_4\text{O}_{10} + 12\text{NaOH} \rightarrow 4\text{Na}_3\text{PO}_4 + 6\text{H}_2\text{O}$

*Allow  $\text{P}_2\text{O}_5$  and acid salts.*

*Must be NaOH not just hydroxide ions.*

1

[12]

6

- (a)  $\text{Na}_2\text{O}$  is an ionic lattice / giant ionic / ionic crystal

*CE= 0 if molecules, atoms, metallic mentioned*

*Mention of electronegativity max 1 out of 2*

1

With strong forces of attraction between ions

*Allow strong ionic bonds / lots of energy to separate ions*

1

- (b)  $\text{SO}_3$  is a larger molecule than  $\text{SO}_2$

*Allow greater  $M_r$  / surface area*

1

So van der Waals' forces between molecules are stronger

*Any mention of ions, CE= 0*

1

- (c) Ionic

*Do not allow ionic with covalent character*

1

Contains  $\text{O}^{2-}$  ions / oxide ions

*Equations of the form  $\text{O}^{2-} + \text{H}^+ \rightarrow \text{OH}^-$  /  $\text{O}^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O}$  /  $\text{O}^{2-} +$*

*$\text{H}_2\text{O} \rightarrow 2\text{OH}^-$  score M2 and M3*

1

These /  $\text{O}^{2-}$  ions (accept protons to) form  $\text{OH}^-$  / hydroxide / water (must score M2 to gain M3)

1

- (d) (i)  $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HSO}_3^-$

*Allow  $2\text{H}^+ + \text{SO}_3^{2-}$  but no ions, no mark*

*Only score (d)(ii) if (d)(i) correct*

1

- (ii) Reaction is an equilibrium / reversible reaction displaced mainly to the left / partially ionised / dissociated

*Allow reaction does not go to completion*

1

- (e)  $\text{SiO}_2$  reacts with bases /  $\text{NaOH}$  /  $\text{CaO}$  /  $\text{CaCO}_3$

*Ignore incorrect formulae for silicate*

1

[10]

7

- (a) To prevent it coming into contact/reacting with oxygen/air

*Allow because it reacts with air/oxygen*

*And because with air/oxygen it forms an oxide. (Oxide, if identified, must be correct :-  $\text{P}_4\text{O}_{10}$ ,  $\text{P}_2\text{O}_5$ ,  $\text{P}_4\text{O}_6$ ,  $\text{P}_2\text{O}_6$ )*

1

- (b) One molecule contains 4P and 10O/the molecular formula is  $P_4O_{10}$   
*Allow exists as  $P_4O_{10}$*   
*Do not allow reference to combination of two  $P_2O_5$  molecules*  
*Ignore any reference to stability* 1
- (c)  $P_4O_{10}$  is a bigger molecule (than  $SO_3$ )/greater  $M_r$ /more electrons/ greater surface area  
*Penalise  $SO_2$  for one mark (max 1)*  
*CE = 0 if mention of hydrogen bonding/ionic/ giant molecule/breaking of covalent bonds* 1
- Van der Waals / vdW forces between molecules are stronger/require more energy to break  
*Do not allow just more vdW forces*  
*Ignore any reference to dipole-dipole forces* 1
- (d)  $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$   
*Allow correct ionic equations*  
*Ignore state symbols* 1
- pH must be in the range  $-1$  to  $+2$   
*Allow  $-1$  to  $+2$*   
*Mark independently* 1
- (e) (i)  $3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$   
OR  $MgO + 2H_3PO_4 \rightarrow Mg(H_2PO_4)_2 + H_2O$   
OR  $MgO + H_3PO_4 \rightarrow MgHPO_4 + H_2O$   
*Allow  $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$*   
*Allow magnesium phosphates shown as ions and ionic equations*  
*Ignore state symbols* 1
- (ii)  $MgO$  is sparingly soluble/insoluble/weakly alkaline  
*Excess/unreacted  $MgO$  can be filtered off/separated* 1
- (iii) An excess of  $NaOH$  would make the lake alkaline/toxic/kill wildlife  
*Allow pH increases* 1

[9]

8

- (a) (i) Ionic lattice / solid / giant ionic  
*CE = 0/2 if molecules / IMFs / atoms / metallic* 1
- Strong (electrostatic) forces/attraction between ions  
*Allow strong ionic bonds for M2 only*  
*Allow lot of energy to break ionic bonds* 1
- (ii) Molecular/molecules 1
- Weak dipole-dipole and/or van der Waals forces between molecules  
*QoL*  
*Type of force must be mentioned* 1
- (b)  $P_4O_{10}$  bigger molecule/has larger surface area than  $SO_2$   
*Allow  $M_r$  of  $P_4O_{10}$  greater than for  $SO_2$*   
*If  $P_4O_{10}$  macromolecule/ionic, CE = 0/2* 1
- van der Waals forces between molecules stronger  
*Allow stronger IMF* 1
- (c)  $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$   
*Allow 2NaOH* 1
- 14  
*Allow 12–14* 1
- $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$   
*Allow ions* 1
- 0  
*Allow -1 to +2* 1
- (d)  $6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$   
*Allow ionic*  
*Allow correct formula of product with atoms in any order* 1

[11]

9

(a) (i) white flame / white light

*Mark flame independent of other observations*

1

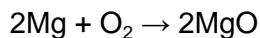
solid / powder / smoke / ash / white fumes

*penalise precipitate*

*penalise wrong colour*

*if more than one observation for M2 apply list principle. (If an observation is incorrect, the incorrect observation negates a correct one)*

1



*ignore state symbols*

*allow multiples*

1

ionic

*do not allow reference to covalent character*

1

(ii) blue flame

*do not allow any other colour*

*Mark flame independent of other observations*

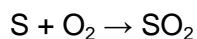
1

fumes or misty or pungent/choking/smelly gas

*do not allow incorrect smell (e.g. bad eggs)*

*apply list principle as in (a) (i)*

*do not allow just 'gas' or 'colourless gas'*



*ignore state symbols*

*allow multiples and S<sub>8</sub>*

1

covalent

*penalise giant covalent*

1

(b) ionic

*If covalent, can only score M3*

1

$O^{2-}$  / oxide ion reacts with water / accepts a proton

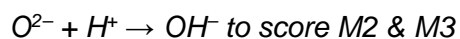
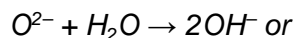
*M2 requires reference to  $O^{2-}$  / oxide ion*

1

forming  $OH^-$  ions/ NaOH / sodium hydroxide  
(can show in equation from  $Na_2O$  even if incorrect)

*allow*

1



*also allow equations with spectator  $Na^+$  ions on both sides.*

1

(c) (heat until) molten

*or dissolve in molten cryolite*

*do not allow solution in water*

1

conducts electricity / can be electrolysed / electrolyse and  
identify Al /  $O_2$  at an electrode

*M2 can only be gained if M1 scored*

1

(d) insoluble (in water)

*allow oxide impermeable to air / water*

*or oxide is unreactive / inert*

1

(e) (i)  $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

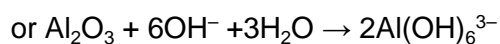
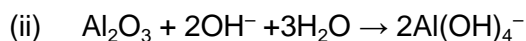
*allow  $O^{2-} + 2H^+ \rightarrow H_2O$*

*and formation of aquated  $Al^{3+}$  species*

*allow spectator  $Cl^-$  ions*

*penalise HCl (not ionic!)*

1



*allow formation of  $\text{Al}(\text{H}_2\text{O})_2(\text{OH})_4^-$*

*allow  $\text{Na}^+$  spectator ions*

*penalise  $\text{NaOH}$  (not ionic!)*

1

[16]

10

(a)  $\text{Na}_2\text{O}$  ionic

*mention of molecules/intermolecular forces/delocalised electrons,  
CE = 0*

1

Strong forces between ions/strong ionic bonding

*Allow lots of energy to break bonds provided M1 scored*

1

$\text{SiO}_2$  macromolecular

*Allow giant molecular/giant covalent.*

*If ions mentioned, CE = 0*

1

Strong covalent bonds (between atoms)

*Allow lots of energy to break covalent bonds*

*If breaking intermolecular forces are mentioned, CE = 0 for M4*

1

(b) Higher

1

$\text{Li}^+$  (or Li ion) smaller than  $\text{Na}^+$

*Must imply  $\text{Li}^+$  ion*

*Allow  $\text{Li}^+$  has higher charge/size ratio **not** charge/mass*

1

Attracts  $\text{O}^{2-}$  ion more strongly

*Allow stronger ionic bonding*

*Allow additional attraction due to polarisation in  $\text{Li}_2\text{O}$*

*M3 can only be scored if M2 gained*

1

- (c) (i) Molecular  
*Do not allow simple covalent BUT simple covalent molecule scores M1 and M2*  
 1
- Covalent bonds (between P and O)  
*Ignore reference to van der Waals' or dipole-dipole*  
 1
- (ii) Weak van der Waals' forces and/or dipole-dipole forces  
between molecules  
*Allow weak inter-molecular forces – can score “between” molecules in (c)(i)*  
*CE = 0 if ionic or macromolecular mentioned in (c)(i)*  
*Must state van der Waals' forces are weak OR low energy needed to break van der Waals' forces*  
 1
- (d) Allow –1 to +2  
 1
- $P_4O_{10} + 6H_2O \rightarrow 12H^+ + 4PO_4^{3-}$  (or  $4H_3PO_4$ )  
*Allow balanced equations to form  $HPO_4^{2-}$  or  $H_2PO_4^-$*   
*ignore state symbols*  
 1
- Allow 12 to 14  
 1
- $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$   
*Allow  $2Na^+ + O^{2-}$  on LHS,  $2NaOH$  on RHS, ignore s.s.*  
*Mark independently*  
 1
- (e)  $6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$   
 1
- Acid-base  
*Allow neutralisation, mark independently of M1*  
*Do not allow Acid + Base  $\rightarrow$  Salt + Water*  
 1

[16]



**11**(a) Macromolecular*Or giant molecule**Or giant covalent (also gains M2)**Do not allow giant atomic**Ionic/metallic CE=0 for all 3 marks*

1

Covalent bonding (between atoms)

*Do NOT allow if between molecules*

1

Many/strong bonds to be broken (or lots of energy required)

*Lose both bonding marks if contradiction e.g. mention of intermolecular forces**Note: 'covalent bonds between molecules' loses M2 but **not** M3*

1

(b)  $\text{Al}_2\text{O}_3$  ionic*Allow ionic + covalent/ionic with covalent character*

1

(c)  $2\text{Al} + 3/2\text{O}_2 \rightarrow \text{Al}_2\text{O}_3$ *Allow multiples**Ignore state symbols*

1

(d) Insoluble/impermeable/non-porous

*Or does not react/inert**Do not allow thick layer**Must imply property of  $\text{Al}_2\text{O}_3$  not Al*

1

(e)  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$ *Or  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$* 

1

(f) (i)  $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$ *Ionic equations with  $\text{Al}_2\text{O}_3$  possible**e.g.  $\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$* *Do not allow formation of  $\text{Al}_2\text{Cl}_6$* 

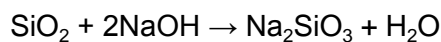
1

(ii)  $\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$ *Other equations with  $\text{Al}_2\text{O}_3$  are possible e.g.* *$\text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{OH})_4]^-$*  *$\text{Al}_2\text{O}_3 + 2\text{OH}^- + 7\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{H}_2\text{O})_2(\text{OH})_4]^-$* 

1

(g) SiO<sub>2</sub> acidic/Lewis acid/electron pair acceptor

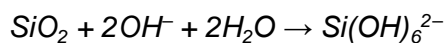
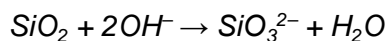
1



*Allow SiO<sub>2</sub> **not** amphoteric*

*Do NOT allow BL acid*

*Other equations with SiO<sub>2</sub> are possible e.g.*



1

[11]

12

(a) Electronegativity increases

1

Proton number increases (increase in nuclear charge)

1

Same number of electron shells/levels

*Or same radius or Shielding of outer electrons remains the same*

1

Attraction of bond pair to nucleus increases

*Allow 'electrons in bond' instead of 'bond pair'*

1

(b) Big difference in electronegativity leads to ionic bonding, smaller covalent

*Lose a mark if formula incorrect*

1

Sodium oxide ionic lattice

1

Strong forces of attraction between ions

1

P<sub>4</sub>O<sub>10</sub> covalent molecular

*Must have covalent and molecular (or molecules)*

1

Weak (intermolecular) forces between molecules

*Or weak vdW, or weak dipole–dipole between molecules*

1

melting point Na<sub>2</sub>O greater than for P<sub>4</sub>O<sub>10</sub>

*Or argument relating mpt to strength of forces*

1

(c)	Moles NaOH = $0.0212 \times 0.5 = 0.0106$ <i>M1 moles of NaOH correct</i>	1
	Moles of $H_3PO_4 = 1/3$ moles of NaOH (= 0.00353) <i>M2 is for 1/3</i>	1
	Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$ <i>M3 is for factor of 1,000,000</i>	1
	Moles of $P_4O_{10} = 3.53 \times 10^3/4$ <i>M4 is for factor of 1/4 (or 1/2 if <math>P_2O_5</math>)</i>	1
	Mass of $P_4O_{10} = 3.53 \times 10^3/4 \times 284 = 0.251 \times 10^6$ g = 251 kg <i>(Or if <math>P_2O_5</math> <math>3.53 \times 10^3/2 \times 142</math>)</i> <i>M5 is for multiplying moles by <math>M_r</math> with correct units</i> <i>allow conseq on incorrect M4</i> <i>(allow 250-252)</i>	1

[15]

13

(a)	(i)	Oxide 1	B	1
		Oxide 2	E	1
		Explanation	Low melting point or weak van der Waals' forces between molecules	1
	(ii)	Chemical test	Add water or flame test	1
		Test	pH or flame colour	1
		Observation	pH = 13/14 or colour yellow	1

- (b) (i) Equation  $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}$  1
- (ii) Product  $\text{CaSO}_3$  1
- (iii) Disposal of large quantities of  $\text{CaSO}_3$  (allow  $\text{CaSO}_4$ ) 1
- Produces  $\text{CO}_2$  or uses up  $\text{CaCO}_3$  1
- [10]**

**14**

- (a) (i) *can form a solution with pH less than 3:  $\text{P}_4\text{O}_{10}$  or  $\text{SO}_3$  (1)*
- (ii) *can form a solution with with a pH greater than 12:  $\text{Na}_2\text{O}$  (1)*
- penalise any wrong answer to zero 2
- (b) (i)  $\text{MgO} + 2\text{HNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{H}_2\text{O}$  or an ionic equation (1)  
 i.e.  $\text{MgO} + 2\text{H}^+ \rightarrow \text{Mg}^{2+} + \text{H}_2\text{O}$   
*not  $\text{O}^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O}$*
- (ii)  $2\text{NaOH} + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$  or ionic equation (1)  
 i.e.  $\text{SiO}_2 + 2\text{OH}^- \rightarrow \text{SiO}_3^{2-} + \text{H}_2\text{O}$
- (iii)  $3\text{Na}_2\text{O} + 2\text{H}_3\text{PO}_4 \rightarrow 2\text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O}$  etc or ionic equation (1)  
*i.e.  $\text{Na}_2\text{O} + 2\text{H}^+ \rightarrow 2\text{Na}^+ + \text{H}_2\text{O}$*  3
- (c)  $\text{P}_4\text{O}_{10}$  is a molecular (structure) or simple covalent (1)  
 Weak intermolecular forces or van der Waals forces (between molecules) (1)  
 $\text{SiO}_2$  is a macromolecule / giant covalent / giant molecule (1)  
*Not giant lattice*
- (Strong) covalent bonds (between atoms) must be broken (1) 4

**[9]**