

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.2.4 PERIOD 3 ELEMENTS AND THEIR OXIDES

SCORE

/220

PERCENTAGE

%

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Q1.

Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

- (a) State the meaning of the term strong acid.

(1)

- (b) In an experiment, 10.35 cm³ of 0.100 mol dm⁻³ hydrochloric acid are added to 25.0 cm³ of 0.150 mol dm⁻³ barium hydroxide solution.

Calculate the pH of the solution that forms at 30 °C

$$K_w = 1.47 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6} \text{ at } 30^\circ \text{C}$$

Give your answer to 2 decimal places.

pH _____

(6)

- (c) The pH of water at 30 °C is 6.92

Give the reason why water is neutral at this temperature.

(1)

- (d) Identify the oxide that could react with water to form a solution with pH = 2

Tick (✓) **one** box.

Al₂O₃

☐

Na₂O

☐

SiO₂

☐

SO₂



(1)

- (e) Give the expression for the acid dissociation constant (K_a) for ethanoic acid (CH₃COOH).

K_a

(1)

- (f) A buffer solution contains 0.025 mol of sodium ethanoate dissolved in 500 cm³ of 0.0700 mol dm⁻³ ethanoic acid at 25 °C

A sample of 5.00 cm³ of 2.00 mol dm⁻³ hydrochloric acid is added to this buffer solution.

Calculate the pH of the solution formed.

For ethanoic acid, $K_a = 1.76 \times 10^{-5}$ mol dm⁻³ at 25 °C

pH _____

(5)

(Total 15 marks)

Q2.

- (a) When anhydrous aluminium chloride reacts with water, solution **Y** is formed that contains a complex aluminium ion, **Z**, and chloride ions.

Give an equation for this reaction.

(1)

- (b) Give an equation to show how the complex ion **Z** can act as a Brønsted–Lowry acid with water.

(1)

- (c) Describe **two** observations you would make when an excess of sodium carbonate solution is added to solution **Y**.

Give an equation for the reaction. In your equation, include the formula of each complex aluminium species.

Observation 1 _____

Observation 2 _____

Equation _____

(3)

- (d) Aqueous potassium hydroxide is added, until in excess, to solution Y.

Describe **two** observations you would make.

For each observation give an equation for the reaction that occurs.

In your equations, include the formula of each complex aluminium species.

Observation 1 _____

Equation 1 _____

Observation 2 _____

Equation 2 _____

(4)

(Total 9 marks)

Q3.

The elements sodium to sulfur in Period 3 all react with oxygen to form oxides.

- (a) Give an equation and **two** observations made for the reaction that occurs when sodium is heated in oxygen.

Equation _____

Observation 1 _____

Observation 2 _____

(2)

- (b) Give an equation and **one** observation made for the reaction that occurs when phosphorus is heated in oxygen.

Equation _____

Observation _____

(2)

- (c) The melting points of the highest oxides of the elements sodium to sulfur are shown in the table.

	Highest oxide of					
	sodium	magnesium	aluminium	silicon	phosphorus	sulfur
Melting point / K	1548	3125	2345	1883	573	290

Explain the increase in melting point from sodium oxide to magnesium oxide.

(2)

- (d) Explain why the melting point of the oxide of silicon is much higher than that of the highest oxide of phosphorus.

(3)

- (e) A sample of the highest oxide of phosphorus was prepared in a laboratory.

Describe a method for determining the melting point of the sample.
State how the result obtained could be used to evaluate its purity.

(3)
(Total 12 marks)

Q4.

Which element forms an ionic oxide that reacts with strong alkalis?

- A** Aluminium ☐
- B** Magnesium ☐
- C** Sodium ☐
- D** Sulfur ☐

(Total 1 mark)

Q5.

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

- (a) Write an equation for the reaction of phosphorus with an excess of oxygen.

(1)

- (b) Describe a test you could carry out in a test tube to distinguish between sodium oxide and the product of the reaction in part (a)

(3)

- (c) State the type of crystal structure shown in silicon dioxide and in sulfur trioxide.

Silicon dioxide _____

Sulfur trioxide _____

(2)

- (d) Explain why silicon dioxide has a higher melting point than sulfur trioxide.

(4)

- (e) Write an equation for the reaction of sulfur trioxide with potassium hydroxide solution.

(1)

- (f) Write an equation for the reaction of an excess of magnesium oxide with phosphoric acid.

(1)

- (g) Draw the displayed formula of the undissociated acid formed when sulfur dioxide reacts with water.

(1)

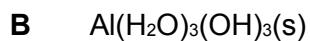
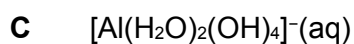
(Total 13 marks)

Q6.

Which is the formula of the main aluminium-containing species present when aluminium oxide is added to an excess of water?

A $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$



☐☐☐

(Total 1 mark)

Q7.

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

(2)

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

(2)

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

(2)

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

Q8.

This question is about the elements in Period 3 from sodium to phosphorus (Na to P) and their oxides.

- (a) Element **X** forms an oxide that has a low melting point. This oxide dissolves in water to form an acidic solution.

- (i) Deduce the type of bonding in this oxide of **X**.

_____ (1)

- (ii) Identify element **X**.

_____ (1)

- (iii) Write an equation for the reaction between this oxide of **X** and water.

_____ (1)

- (b) Element **Y** reacts vigorously with water. An oxide of **Y** dissolves in water to form a solution with a pH of 14.

- (i) Deduce the type of bonding in this oxide of **Y**.

_____ (1)

- (ii) Identify element **Y**.

_____ (1)

- (iii) Write an equation for the reaction of element **Y** with water.

_____ (1)

- (iv) Write an equation for the reaction of this oxide of **Y** with hydrochloric acid.

_____ (1)

- (c) Element **Z** forms an amphoteric oxide that has a very high melting point.

- (i) Deduce the type of bonding in this oxide of **Z**.

_____ (1)

(ii) Write the formula of this amphoteric oxide.

_____ (1)

(iii) State the meaning of the term amphoteric.

_____ (1)

(iv) Write two equations to show the amphoteric nature of the oxide of **Z**.

_____ (2)

(Total 12 marks)

Q9.

- (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 _____

_____ (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 _____

_____ (3)

(Total 6 marks)

Q10.

- (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.

(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.

(2)

(Total 10 marks)

Q11.

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 _____

Equation _____

(3)

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

(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 _____

(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)

Q12.

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.

(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 _____

(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)

Q13.

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

	Na ₂ O	SiO ₂	SO ₂	SO ₃
Melting point / K	1548	1883	200	290

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

(2)

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

(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)

Q14.

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.

(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.

(1)

(Total 9 marks)

Q15.

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

	Na_2O	P_4O_{10}	SO_2
T_m/K	1548	573	200

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

(i) sodium oxide has a high melting point

(2)

(ii) sulfur dioxide has a low melting point.

(2)

(b) Explain why the melting point of P_4O_{10} is higher than the melting point of SO_2

(2)

(c) Write equations for the reactions of Na_2O and P_4O_{10} with water. In each case give the approximate pH of the resulting solution.

Equation for Na_2O _____

pH _____

Equation for P_4O_{10} _____

pH _____

(4)

(d) Write an equation for the acid–base reaction that occurs when Na_2O reacts with P_4O_{10} in the absence of water.

(1)

(Total 11 marks)

Q16.

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 _____

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.

(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)

Q17.

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 ₂ O	SiO ₂	P ₄ O ₁₀
<i>T_m</i> /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.

Na₂O

SiO₂

(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.

(2)

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

(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)

Q18.

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)

Q19.

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

(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.

(6)

- (c) A chemical company has a waste tank of volume 25 000 dm³. The tank is full of phosphoric acid (H₃PO₄) solution formed by adding some unwanted phosphorus(V) oxide to water in the tank.

A 25.0 cm³ sample of this solution required 21.2 cm³ of 0.500 mol dm⁻³ 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.

(5)
(Total 15 marks)

Q20.

- (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)

Q21.

Consider the following oxides.

Na_2O , MgO , Al_2O_3 , SiO_2 , P_4O_{10} , SO_3

- (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) MgO and HNO_3

(ii) SiO_2 and NaOH

(iii) Na_2O and H_3PO_4

(3)

- (c) Explain, in terms of their type of structure and bonding, why P_4O_{10} can be vaporised by gentle heat but SiO_2 cannot.

(4)

(Total 9 marks)

Mark schemes

Q1.

- (a) completely dissociates/ionises (to form H^+ ions) 1
- (b) **M1** moles $\text{HCl} = 1.035 \times 10^{-3}$ and moles $\text{Ba(OH)}_2 = 3.75 \times 10^{-3}$
If M1 incorrect, lose M1 and M6 1
- M2** moles $\text{OH}^- = 2 \times (3.75 \times 10^{-3} = 7.50 \times 10^{-3})$
If M2 not $\times 2$, lose M2 and M6 1
- M3** XS n $\text{OH}^- = 7.50 \times 10^{-3} - 1.035 \times 10^{-3} = 6.465 \times 10^{-3}$ mol in 35.35 cm^3
If no subtraction for M3, lose M3 and M6 1
- M4** $[\text{OH}] = 6.465 \times 10^{-3} / 35.35 \times 10^{-3} = 0.182885 \text{ mol dm}^{-3}$
 $= \text{M3} / 35.35 \times 10^{-3}$
If M4 not $/ 35.35 \times 10^{-3}$, lose M4 and M6
However, if divided by 35.35 only lose M4 and allow M6 (ecf = 10.09) 1
- M5** $[\text{H}^+] = K_w / [\text{OH}^-] = 1.47 \times 10^{-14} / 0.182885 = 8.0378 \times 10^{-14} \text{ mol dm}^{-3}$
 $= 1.47 \times 10^{-14} / \text{M4}$
If incorrect rearrangement or wrong equation, lose M5 and M6
If $K_w = 1.00 \times 10^{-14}$ used only lose M5 and allow M6 (ecf = 13.26) 1
- M6** pH = 13.09 to 13.10
Must be 2dp 1
- Alternative MS to get M2:
- Starting amounts are 1.035×10^{-3} mol HCl and 3.75×10^{-3} mol Ba(OH)_2 M1
- So the HCl will react with 5.175×10^{-4} mol of the Ba(OH)_2 leaving an excess of 3.2325×10^{-3} mol of Ba(OH)_2 (as alternative M2)
- So n $\text{OH}^- = 2 \times 3.2325 \times 10^{-3} = 6.465 \times 10^{-3}$ mol M3
Credit other methods eg limiting reagent method since HCl limiting reagent
- (c) $[\text{H}^+] = [\text{OH}^-]$ 1
- (d) SO_2 1

- (e) $K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$ 1
- (f) **M1** moles HCl added = 0.01 mol and moles CH₃COOH = 0.035 mol 1
- M2** moles CH₃COO⁻ = 0.025 – 0.01 (= 0.015)
M2 mol CH₃COO⁻ = 0.025 - M1(HCl) 1
- M3** moles CH₃COOH = 0.035 + 0.01 (= 0.045)
M3 mol CH₃COOH = M1(CH₃COOH) + M1(HCl) 1
- M4** $[\text{H}^+] = 1.76 \times 10^{-5} \times \frac{\text{M3 (I/V)}}{\text{M2 (I/V)}} (= 5.28 \times 10^{-5})$
M4 is conditional on an attempt at an addition/subtraction in M2 OR M3 1
- M5** pH = 4.28
M5 must be 2dp
If used 0.07 mol for CH₃COOH can score M2, M3 and M4 (pH = 4.03) 1
- [15]**

Q2.

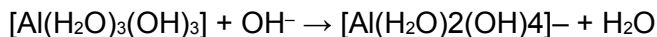
- (a) $\text{AlCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{Cl}^-$
Allow
 $\text{AlCl}_3 + 6\text{H}_2\text{O} \rightarrow \text{Al}(\text{H}_2\text{O})_5(\text{OH})_2^+ + \text{H}^+ + 3\text{Cl}^-$
Or equation to form Al(H₂O)₄(OH)₂⁺ 1
- (b) $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + \text{H}_2\text{O} \rightarrow [\text{Al}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{H}_3\text{O}^+$
allow equations to form [Al(H₂O)₄(OH)₂]⁺ 1
- (c) white ppt/solid
M1 and M2 in either order 1
- effervescence/bubbles/fizzing 1
- $2[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2[\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{CO}_2 + 3\text{H}_2\text{O}$
accept multiples
only allow spectator ions in a balanced equation 1
- (d) White ppt/solid 1
- $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow [\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{H}_2\text{O}$

only allow spectator ions in a balanced equation

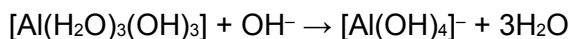
1

Colourless solution forms / ppt or solid dissolves

1



OR



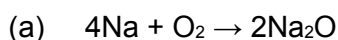
only allow 6 or 4 co-ordination

Allow $[\text{Al}(\text{OH})_6]^{3-}$ in a balanced equation

1

[9]

Q3.



Ignore state symbols

Allow multiples and fractions

Allow $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2$

1

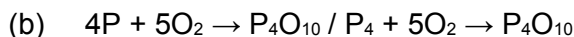
Yellow/orange flame/light AND white solid/powder/smoke/fumes/ash

Allow yellow solid

Do not allow ppt. Apply list principle

Ignore formulae in observations

1



Ignore state symbols

Do not allow equations with P_2O_5

Allow $4\text{P} + 3\text{O}_2 \rightarrow \text{P}_4\text{O}_6$ / $\text{P}_4 + 3\text{O}_2 \rightarrow \text{P}_4\text{O}_6$

1

white flame/light OR white fumes/smoke/solid/powder/ash

Do not allow ppt. Apply list principle

1

- (c) Greater/increased charge/charge density on magnesium ion/ Mg^{2+} (specific mention of ion(s) can be scored from M2)

Allow magnesium ion is smaller (than sodium ion);

Ignore atomic radius

If mention of molecules, intermolecular forces, metallic bonding then CE=0

1

Stronger attraction for anions/oxide ion / stronger attraction between oppositely charged ions/ stronger attraction between Mg^{2+} and O^{2-} / stronger ionic bonding

Ignore references to covalent character

Mark independently

1

- (d) (SiO_2) giant covalent / macromolecular

Do not allow M1 and M2 if it is clear that the candidate is referring to the structure of the elements rather than the oxides. M3 could score from correct comparison of giant covalent to simple molecular
Allow giant molecule

1

(P₄O₁₀) (simple) molecular
Not simple covalent

1

(Covalent) bonds (throughout structure) of SiO₂ much stronger than the forces between molecules/intermolecular forces in P₄O₁₀

Reference to 'between molecules' in M3 would also get M2

Allow van der Waals' forces between molecules

M3 dependent on correct M1 and M2

1

- (e) **M1** Sample in suitable melting point apparatus (e.g. capillary in oil bath/Thiele tube / melting point apparatus)
Do not allow water bath

1

M2 Heat slowly/gradually/gently (to establish melting point range)

1

M3 Lower melting point / (broad) range of melting point indicates presence of impurities

OR melting point agrees with/close to data book value / melts sharply/over narrow range / melting point exactly 573K indicates purity

1

[12]

Q4.

A

[1]

Q5.

- (a) $P_4 + 5 O_2 \rightarrow P_4O_{10}$

allow $4 P + 5 O_2 \rightarrow P_4O_{10}$

allow multiples

ignore state symbols

1

- (b) React with water / add water / solution (of substances in question)
If no M1 then CE = 0/3

1

Add litmus paper / universal indicator / measure pH (with pH meter)

Allow other reagents in solution, e.g. sodium carbonate solution, that give a positive result

Allow other indicators with appropriate colour changes

M3 is dependent on M2

Litmus: blue with sodium oxide (solution) **and** red with phosphorus oxide (solution) OR

If blue litmus added phosphorus oxide solution goes red OR

If red litmus added sodium (hydr)oxide goes blue

Universal Indicator: blue/ purple with sodium oxide (solution) **and** red with phosphorus oxide (solution)

pH meter or Universal Indicator: sodium (hydr)oxide (solution) has a higher pH (than phosphorus oxide (solution)) or vv

sodium (hydr)oxide pH (12 to 14) **and** phosphorus oxide (solution) pH (-1 to 2)

For pH meter or Universal Indicator: allow sodium (hydr)oxide (solution) has a higher pH and phosphorus oxide (solution) has lower pH.

1

- (c) For silicon dioxide - giant covalent (molecule)/ macromolecular

1

For sulfur trioxide - molecular / (simple) molecule

1

Do not allow simple covalent

- (d) Covalent bonds (between atoms) in SiO₂

1

Van der Waals between molecules / intermolecular forces in SO₃

1

Covalent bonds are stronger than van der Waals forces

1

(Covalent bonds) take more energy to be overcome/broken or (Van der Waals) take less energy to be overcome/broken

1

If covalent bonds between molecules of SiO₂ lose M1 only

If hydrogen bonds in SO₃ lose M2 only

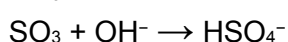
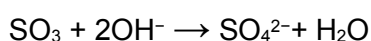
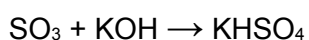
If metallic or ionic max score = 1 (either M1 or M2)

If IMF in SiO₂ then max 1 (M2 only)

Allow dipole-dipole forces between molecules

For M3 and M4 comparison is required/implied

- (e) $\text{SO}_3 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + \text{H}_2\text{O}$



Allow multiples

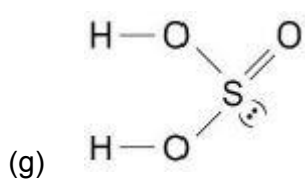
Ignore state symbols

1

- (f) $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$

Allow multiples
Ignore state symbols

1



Ignore lone pairs

1

[13]

Q6.

D

[1]

Q7.

- (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) S₈ molecules are bigger than P₄ molecules

Allow sulfur molecules have bigger surface area and sulfur molecules have bigger M_r

1

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

1

- (c) Sodium oxide contains O²⁻ ions

1

These O²⁻ ions react with water forming OH⁻ ions



1

- (d) $\text{P}_4\text{O}_{10} + 12\text{OH}^- \longrightarrow 4\text{PO}_4^{3-} + 6\text{H}_2\text{O}$

1

[7]

Q8.

- (a) (i) Covalent

Ignore simple / molecular

Do not allow macromolecular/giant covalent/dative/dipole-dipole/Hydrogen bonds

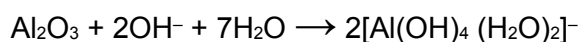
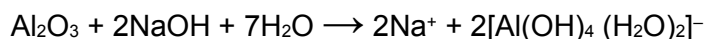
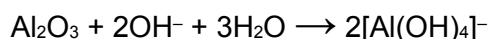
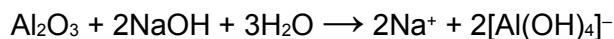
Ignore VdW

1

- (ii) P / phosphorus / P₄ 1
- (iii) $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
Mark independently of (a)(ii)
Accept multiples/fractions
Ignore state symbols
Allow ions on the RHS ($\rightarrow 12H^+ + 4PO_4^{3-}$)
Allow correct equations from P₄O₆, P₂O₃ and P₂O₅
 $P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$
 $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$
 $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$ 1
- (b) (i) Ionic
Ignore giant / lattice 1
- (ii) Na / Sodium 1
- (iii) $2Na + 2H_2O \rightarrow 2Na^+ + 2OH^- + H_2$
Allow equation to form 2NaOH
Accept multiples/fractions
Ignore state symbols 1
- (iv) $Na_2O + 2HCl \rightarrow 2NaCl + H_2O$
Accept multiples/fractions
Ignore state symbols
Allow ions, but do not allow H⁺ only for the acid 1
- (c) (i) Ionic
Allow ionic and covalent / ionic with covalent character 1
- (ii) Al₂O₃
Ignore state symbols 1
- (iii) Reacts with acids and bases
Allow reacts with acids and alkalis / acts as both an acid and a base / shows acidic and basic properties 1
- (iv) $Al_2O_3 + 6HCl \rightarrow 2Al^{3+} + 6Cl^- + 3H_2O$
 $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$
Allow equation to form 2AlCl₃ (but not Al₂Cl₆)

Allow equations with other acids

1



Allow equations to form $2\text{Na}[\text{Al}(\text{OH})_4]$ or $2\text{Na}[\text{Al}(\text{OH})_4(\text{H}_2\text{O})_2]$

Allow equations with other alkalis

Allow correct equations which form $[\text{Al}(\text{OH})_6]^{3-}$

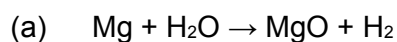
Allow equations to form $[\text{Al}(\text{OH})_x(\text{H}_2\text{O})_{6-x}]^{3-x}$ etc

Ignore state symbols

1

[12]

Q9.



ignore state symbols

1

White solid / powder / ash / smoke

ignore precipitate

ignore fumes

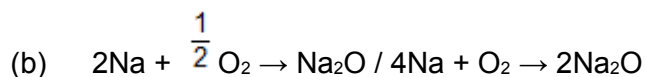
1

(Bright) white light / flame

allow glow

penalise effervescence under list principle

1



Allow multiples, ignore state symbols

Allow $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2$

1

white / yellow solid / ash / smoke

ignore precipitate

ignore fumes

1

orange / yellow flame

1

[6]

Q10.

(a) (i) 1500

1

(ii) Ionic lattice / giant ionic

Mention of vdW / covalent bonding / molecules / atoms /

metal etc. $CE = 0$

1

Strong attraction between oppositely charged ions / Na^+ and O^{2-}
OR

lots of energy required to separate / overcome attraction between
oppositely charged ions / Na^+ and O^{2-}

Do not allow incorrect formulae for ions.

1

(iii) 200 (K)

Allow range 10–273 (K)

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

Allow correct answers in $^{\circ}\text{C}$ but units must be given.

1

SO_2 smaller (molecule) (than P_4O_{10}) (or converse)

*also SO_2 has lower M_r / less surface area / less polarisable /
fewer electrons*

penalise SO_3 and P_2O_5 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) $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$ / $\text{H}^+ + \text{HSO}_3^-$ / $2\text{H}^+ + \text{SO}_3^{2-}$

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^-

1

$\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$

*Allow $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$ or equation with any suitable
base*

M2 can score M1 even if equation unbalanced or incorrect

1

[10]

Q11.

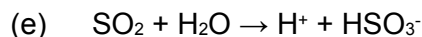
(a) White powder / solid / ash / smoke

Ignore ppt / fumes

1

Bright / white light / flame

	Allow glows white / glows bright	1
	Mg + H ₂ O → MgO + H ₂ Ignore state symbols Ignore reference to effervescence or gas produced	1
(b)	Mg ²⁺ / magnesium ion has higher charge than Na ⁺ 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	1
	Attracts <u>delocalised / free / sea of</u> electrons more strongly / metal–metal bonding stronger / metallic bonding stronger Wrong type of bonding (vdW, imf), mention of molecules CE = 0	1
(c)	Structure: Macromolecular / giant molecule / giant covalent Mark independently	1
	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 ₄ O ₁₀ 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 <u>between molecules</u> Allow vdW, imf and dipole–dipole imf but do not allow imf alone	1



Products must be ions

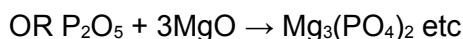
Allow $\text{SO}_2 + \text{H}_2\text{O} \rightarrow 2\text{H}^+ + \text{SO}_3^{2-}$

Allow two equations showing intermediate formation of H_2SO_3 that ends up as ions

Ignore state symbols

Allow multiples

1



Ignore state symbols

Allow multiples

1

[15]

Q12.

(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.

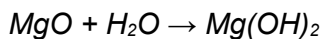
1

- (d) Reagent (water or acid)

Can be awarded in the equation.

1

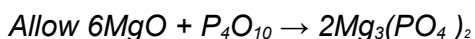
Equation eg $\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$



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



Simplified ionic equation without full reagent can score M2 only.



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 P_2O_5 and acid salts.

Must be NaOH not just hydroxide ions.

1

[12]

Q13.

- (a) Na_2O 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) SO_3 is a larger molecule than 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 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 / O^{2-} ions (accept protons to) form 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) SiO_2 reacts with bases / NaOH / CaO / CaCO_3
Ignore incorrect formulae for silicate 1
- [10]**

Q14.

- (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 :- P_4O_{10} , P_2O_5 , P_4O_6 , P_2O_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

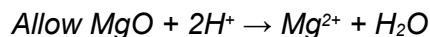
Do not allow just more vdW forces
Ignore any reference to dipole-dipole forces

- (d) $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
Allow correct ionic equations
Ignore state symbols 1

pH must be in the range -1 to +2

Allow -1 to +2
Mark independently

- (e) (i) $3\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}_3(\text{PO}_4)_2 + 3\text{H}_2\text{O}$
 OR $\text{MgO} + 2\text{H}_3\text{PO}_4 \rightarrow \text{Mg}(\text{H}_2\text{PO}_4)_2 + \text{H}_2\text{O}$
 OR $\text{MgO} + \text{H}_3\text{PO}_4 \rightarrow \text{MgHPO}_4 + \text{H}_2\text{O}$



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]

Q15.

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

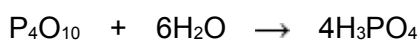
Allow 2NaOH

1

14

Allow 12–14

1



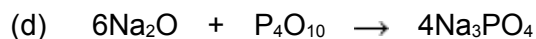
Allow ions

1

0

Allow -1 to +2

1



Allow ionic

Allow correct formula of product with atoms in any order

1

[11]

Q16.

- (a) (i) white flame / white light

Mark flame independent of other observations

1

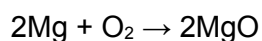
solid / powder / smoke / ash / white fumes

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

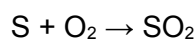
1

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_8

1

covalent

penalise giant covalent

1

- (b) ionic

If covalent, can only score M3

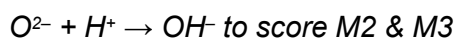
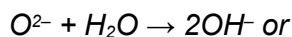
1

O²⁻ / oxide ion reacts with water / accepts a proton
M2 requires reference to O²⁻ / oxide ion

1

forming OH⁻ ions/ NaOH / sodium hydroxide
(can show in equation from Na₂O 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 / O₂ 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) Al₂O₃ + 6H⁺ → 2Al³⁺ + 3H₂O

allow O²⁻ + 2H⁺ → H₂O

and formation of aquated Al³⁺ species

allow spectator Cl⁻ ions

penalise HCl (not ionic!)

1

(ii) Al₂O₃ + 2OH⁻ + 3H₂O → 2Al(OH)₄⁻

or Al₂O₃ + 6OH⁻ + 3H₂O → 2Al(OH)₆³⁻

allow formation of Al(H₂O)₂(OH)₄⁻

allow Na⁺ spectator ions

penalise NaOH (not ionic!)

1

[16]

Q17.

(a) Na₂O ionic

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

1

Strong forces between ions/strong ionic bonding

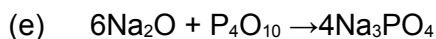
Allow lots of energy to break bonds provided M1 scored

1

SiO ₂ macromolecular	
<i>Allow giant molecular/giant covalent.</i>	
<i>If ions mentioned, CE = 0</i>	1
Strong <u>covalent bonds</u> (between atoms)	
<i>Allow lots of energy to break <u>covalent</u> bonds</i>	
<i>If breaking intermolecular forces are mentioned, CE = 0 for M4</i>	1
(b) Higher	1
Li ⁺ (or Li ion) smaller than Na ⁺	
<i>Must imply Li⁺ ion</i>	
<i>Allow Li⁺ has higher charge/size ratio not charge/mass</i>	1
Attracts O ²⁻ ion more strongly	
<i>Allow stronger ionic bonding</i>	
<i>Allow additional attraction due to polarisation in Li₂O</i>	
<i>M3 can only be scored if M2 gained</i>	1
(c) (i) Molecular	
<i>Do not allow simple covalent BUT simple covalent molecule scores M1 and M2</i>	1
Covalent bonds (between P and O)	
<i>Ignore reference to van der Waals' or dipole-dipole</i>	1
(ii) Weak van der Waals' forces and/or dipole-dipole forces <u>between molecules</u>	
<i>Allow weak <u>inter-molecular</u> forces – can score “between” molecules in (c)(i)</i>	
<i>CE = 0 if ionic or macromolecular mentioned in (c)(i)</i>	
<i>Must state van der Waals' forces are weak OR low energy needed to break van der Waals' forces</i>	1
(d) Allow –1 to +2	1
P ₄ O ₁₀ + 6H ₂ O → 12H ⁺ + 4PO ₄ ³⁻ (or 4H ₃ PO ₄)	
<i>Allow balanced equations to form HPO₄²⁻ or H₂PO₄⁻</i>	
<i>ignore state symbols</i>	1
Allow 12 to 14	1
Na ₂ O + H ₂ O → 2Na ⁺ + 2OH ⁻	
<i>Allow 2Na⁺ + O²⁻ on LHS, 2NaOH on RHS, ignore s.s.</i>	

Mark independently

1



1

Acid-base

Allow neutralisation, mark independently of M1

Do not allow Acid + Base $\rightarrow$ Salt + Water

1

[16]

Q18.

(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

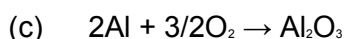
Note: 'covalent bonds between molecules' loses M2 but **not** M3

1

(b) Al_2O_3 ionic

Allow ionic + covalent/ionic with covalent character

1



Allow multiples

Ignore state symbols

1

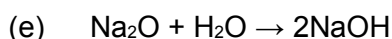
(d) Insoluble/impermeable/non-porous

Or does not react/inert

Do not allow thick layer

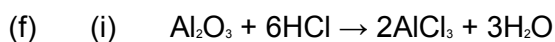
Must imply property of Al_2O_3 not Al

1



Or $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$

1

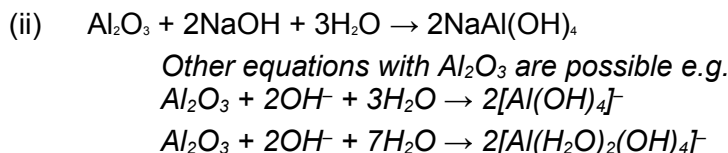


Ionic equations with Al_2O_3 possible

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 Al_2Cl_6

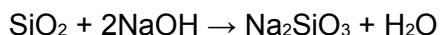
1



1

(g) SiO_2 acidic/Lewis acid/electron pair acceptor

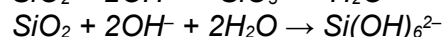
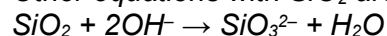
1



*Allow SiO_2 **not** amphoteric*

Do NOT allow BL acid

Other equations with SiO_2 are possible e.g.



1

[11]

Q19.

(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_4O_{10} 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_2O greater than for P_4O_{10}

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 $\text{H}_3\text{PO}_4 = 1/3$ 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 $\text{P}_4\text{O}_{10} = 3.53 \times 10^{3/4}$ <i>M4 is for factor of 1/4 (or 1/2 if P_2O_5)</i>	1
	Mass of $\text{P}_4\text{O}_{10} = 3.53 \times 10^{3/4} \times 284 = 0.251 \times 10^6 \text{ g}$ = 251 kg <i>(Or if P_2O_5 $3.53 \times 10^{3/2} \times 142$)</i> <i>M5 is for multiplying moles by M_r with correct units</i> <i>allow conseq on incorrect M4</i> <i>(allow 250-252)</i>	1

[15]

Q20.

(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	CaSO_3	1
	(iii)	Disposal of large quantities of CaSO_3	(allow CaSO_4)	1
		Produces CO_2 or uses up CaCO_3		1

[10]

Q21.

- (a) (i) *can form a solution with pH less than 3: P₄O₁₀ or SO₃ (1)*
(ii) *can form a solution with with a pH greater than 12: Na₂O (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) P₄O₁₀ is a molecular (structure) or simple covalent (1)
Weak intermolecular forces or van der Waals forces (between molecules) (1)
SiO₂ is a macromolecule / giant covalent / giant molecule (1)
Not giant lattice

(Strong) covalent bonds (between atoms) must be broken (1)

4

[9]

Examiner reports

Q1.

- (a) 86.2% of students gave the correct definition.
- (b) Most students calculated the amounts, in moles, of the reactants but often did not multiply the amount of barium hydroxide by two to give the amount of hydroxide ions. Some students did not convert the amount in moles to concentration and some did not quote their pH to two decimal places. This part of the question discriminated very well, with just over 20% of students scoring full marks.
- (c) 81.8% of students gave the correct reason here.
- (d) 78.5% correctly identified sulphur dioxide.
- (e) 91% of students could give the correct expression for K_a .
- (f) Most students could calculate the amount, in moles, of hydrochloric acid and of ethanoic acid, but many were unsure of how to use these numbers. Many students failed to recognise the need to increase the amount of acid and decrease the amount of salt due to the shift in the equilibrium when H^+ ions are added. Many added and subtracted the wrong way round or managed one process but not the other. Students could generally rearrange the K_a expression correctly; just over 40% of students scored full marks for this part of the question.

Q2.

- (a) Just over half of the students (50.2%) could give the correct equation; common errors included giving chlorine as a product, incorrect balancing and sometimes an incorrect formula for aluminium chloride.
- (b) Only a small proportion of students (22.6%) could give a correct equation here; many did not include protonation of water, as implied in the question. A surprisingly high proportion of students (10.8%) failed even to attempt this question.
- (c) Here, students were more able to state observations than to write the equations. Some students stated that carbon dioxide was evolved, but this is not an observation – it is a deduction from the effervescence seen. Just over 25% of students scored all the marks in this part of the question.
- (d) Students were better able to state observations than write equations but only 35% of students scored all of the marks available. Again, just over 10% of students failed to attempt this part.

Q3.

- (a) This was expected to be a straightforward question on a familiar equation and set of observations. However, many students were unable to balance the equation, with $2Na + O_2 \rightarrow Na_2O$ seen frequently. Incorrect observations included numerous mentions of a 'red' flame and of the formation of a 'precipitate'. Only 23.6% of students scored both marks.
- (b) The need for only a single observation probably resulted in the higher marks here than in part (a) (39.4% fully correct). The formula of the oxide was usually correct, but incorrect reference to a 'precipitate' was again seen frequently.

- (c) This was another example where reading the question was key; many students incorrectly gave a comparison of sodium and magnesium (rather than their oxides), while others wasted time and space discussing the trend across the whole period. Any references to metallic bonding, or any suggestion of the presence of 'molecules', made it impossible to award credit in this question. 38.7% of students were able, however, to score both marks.
- (d) The confusion in students' minds between 'molecular' and 'giant' structures was evident in many of the answers to this question. Contradictions were frequently seen, such as "silicon dioxide has a macromolecular structure with strong covalent bonds between the molecules". An ideal answer would be structured with clear statements that silicon dioxide is giant covalent (or macromolecular) and phosphorous oxide is (simple) molecular, followed by the statement that the covalent bonds between the atoms in silicon dioxide are much stronger than the intermolecular forces in phosphorous oxide. Use of the word 'bonds' should be avoided when referring to intermolecular forces (apart from the specific case of hydrogen bonds, not relevant in the answer to this question).
- (e) This was answered quite well, although some answers were spoiled by reference to a water bath and many students failed to mention the need to heat slowly (near the melting point). More surprising at this level were those students who confused melting and boiling or who suggested dissolving the solid in water before starting to heat it.

Q4.

In a question where just under half of students arrived at the correct answer, D was the commonest incorrect response. This was presumably because sulfur forms an acidic oxide that reacts with alkali – but sulfur oxides are molecular, not ionic.

Q5.

- (a) Students generally scored the mark for the equation (78.8% correct), though some students used P_2 or gave P_2O_5 as the product and lost the mark.
- (b) Many students failed to realise that water was all that was required; those students who used water mostly went on to give a correct method for testing the solution.
- (c) Most students answered this well, but "simple covalent" was a common incorrect, incomplete answer for sulfur dioxide.
- (d) Most students understood that covalent bonds were broken for silicon dioxide and that intermolecular forces were overcome for sulfur trioxide. Some students lost marks because they thought intermolecular forces were also overcome in silicon dioxide. There were only a few examples where students got the type of bonding completely wrong.
- (e) Many students struggled with the equation here and gave the products as potassium oxide and sulfuric acid.
- (f) Many students found the formula of magnesium phosphate challenging and hence could not write a correct balanced equation. Often, students failed to pick up on the information that magnesium oxide was in excess and gave magnesium hydrogenphosphate as the product.
- (g) Many students found this question quite challenging; sulfuric(VI) acid was often thought to be the product. Very few students gave a correct fully displayed formula.

Q8.

This question was generally high scoring especially by the more able students. The types of bonding were generally well known. Common errors included sulfur in part (a), magnesium in part (b) and silicon in part (c) and therefore the equations could not gain credit. The correct equation between aluminium oxide and sodium hydroxide (or other alkalis) was not common in part (c) whilst the equation between aluminium oxide and an acid was better known.

Q9.

The quality of answers to inorganic questions of this type continues to be lower than hoped. The problem lies partly with a lack of knowledge and partly with imprecise language. In part (a) many equations were incorrect, showing formation of magnesium hydroxide rather than magnesium oxide. Students should know that precipitates and effervescence are only observed in reactions that take place in solution. In this question, magnesium oxide is formed as a solid, the hydrogen gas produced is invisible. In part (b) the equation was usually correct but the flame colour was not well known.

Q10.

In their answers to questions such as part (a)(ii) students should be encouraged to read the question carefully before answering. In this case the question asked students to explain the melting point in terms of structure **and** bonding. Parts (a)(iii) and (b) were answered well by most students. In part (c) a correct equation proved to be a challenge and it was surprising to note how often students attempted to balance an acid-base equation by producing hydrogen gas.

Q11.

Few students scored all three marks for part (a) and even the highest-scoring students often gave only one correct observation. Weaker students often suggested incorrectly that it would be possible to see a gas being evolved and also wrote an incorrect equation showing formation of magnesium hydroxide rather than the oxide. In part (b), metallic bonding was not explained well by most students, often being confused with ionic bonding or intermolecular forces. In part (c), very few students scored more than three marks, often being unable to give a correct second physical property of silicon dioxide. Incorrect answers usually involved misreading the question and giving 'high melting point' or suggesting a chemical property. The formula, structure and bonding for phosphorus(V) oxide were usually correct in part (d) but only the highest-scoring students gave correct equations in parts (e) and (f). In part (e), a very common error was to write an equation with sulfur trioxide rather than sulfur dioxide.

Q12.

This question was answered well and students of all abilities were able to score reasonable marks. In part (a), the most common error was to suggest that the conductivity of a solution could be tested. Apart from the problem that magnesium oxide is only sparingly soluble, A-level students should know that many covalent substances form ions in water so that testing the conductivity of a solution is not a good method for the identification of an ionic solid. In parts (b) and (c) only the higher-scoring students scored all marks. The marks for structure and bonding were usually gained but in part (b) a suggestion as to why water does not break down the structure was not given and in part (c) students often did not state clearly that the forces of attraction between molecules are weak.

Q13.

Answers to part (a) were usually correct. In part (b), weak students often confused intramolecular and intermolecular forces. In order to score both marks in a question like this, an answer must state that the stronger van der Waals' forces are between molecules. This was not often seen. In part (c), most students knew that basic oxides are usually ionic but only 18% of students could go on to explain fully how and why an oxide ion would act as a proton acceptor. Despite the statement in part (d)(i) that 'ions are formed', many students wrote an equation showing formation of the molecule H_2SO_3 . Such answers lost the mark for this part of the question and made it very difficult for a mark to be scored in part (d)(ii). Answers to part (e) were usually correct.

Q14.

Most students answered part (a) correctly by stating that phosphorus would be kept out of contact with air/oxygen or that phosphorus reacts with oxygen. In part (b), it was expected that students would understand that P_4O_{10} represents a single molecule with 4 atoms of phosphorus and ten of oxygen but this answer was seldom seen. A very common wrong answer was to suggest that the representation P_4O_{10} is used because it is more stable than P_2O_5 . Answers to part (c) were often good but common mistakes were to refer to SO_2 rather than SO_3 and to state that P_4O_{10} is macromolecular. A common omission was a failure to explain that van der Waals' forces are between molecules. Part (d) was answered well by most students. Part (e)(i) was answered correctly by good students but weaker students sometimes could not give a correct formula for a magnesium phosphate and sometimes used phosphorus(V) oxide instead of phosphoric(V) acid. In parts (e)(ii) and (iii), some students did not appreciate that the question referred to an excess of the reagent and confined their answers to the neutralisation reaction only. Many students did not appreciate or mention that magnesium oxide is sparingly soluble.

Q15.

Parts (a)(i) and (a)(ii) were answered correctly by most students. Part (b) proved to be more demanding and only the best students appreciated that the van der Waals' forces between molecules in P_4O_{10} are stronger than in SO_2 . Too many students thought incorrectly that P_4O_{10} was macromolecular or ionic. Part (c) was answered well and more than 80% of students scored at least three marks. As expected, part (d) was a little more demanding and only about 50% of students gained the mark.

Q16.

Period 3 chemistry always provides a challenge for candidates and this question was no exception to that rule. Part (a)(i) was well answered with almost 80% of candidates scoring at least 3 marks out of the four available. The observation that indicated the formation of magnesium oxide, a white solid, was most often omitted. Part (a)(ii) proved to be more difficult and although the blue flame observed when sulfur burns was quite well known, a positive observation for sulfur dioxide, such as a gas with a pungent odour, was not. In part (b) many candidates knew that sodium oxide is ionic and that it forms sodium hydroxide in water but they did not mention oxide ions and go on to explain why an oxide ion would form hydroxide ions in water. Answers to part (c) were very disappointing. Only about 18% of candidates suggested testing the conductivity of molten aluminium oxide. Most candidates suggested dissolving the oxide in water, even though, in part (d) they went on to state that aluminium oxide is insoluble in water. Answers to parts (e)(i) and (e)(ii) were only very occasionally correct. Many candidates appeared to be unfamiliar with the concept of an ionic equation and they often attempted to use HCl or NaOH. Perhaps, in future candidates could be encouraged to recognise that equations between aluminium oxide and H^+ or OH^- ions are easier to write than equations with HCl or NaOH.

Q17.

Part (a) was answered quite well, especially for Na_2O . For SiO_2 candidates too often spoiled their answers by referring to molecules and intermolecular forces or in some cases to ions. Quite often, such references appear to be careless use of contradictory terms rather than a completely false understanding of the structure and bonding. Answers to part (b) were very disappointing and the average score for this question was only one out of three. In the Specification, candidates are expected to understand that the melting point and lattice enthalpy of an ionic crystal depend on the size of the ions and on their charges. Answers to part (c)(i) were generally good but in part (c)(ii), candidates often failed to mention 'between molecules'. Part (d) produced the expected range of answers and a pleasing 60% of candidates scored full marks. As expected part (e) was much harder and only a very few candidates were able to write a correct equation.

Q18.

This question proved to be a little easier than question 1. Most candidates gave correct explanations in part (a) but weak candidates did not make a clear distinction between molecules and a macromolecule. Parts (b) and (c) were answered well but part (d) proved to be more testing and a significant number of candidates gave no answer. Most candidates answered part (e) correctly. As expected part (f)(i) was more challenging and in part (f)(ii), only the very best candidates could write a correct, balanced equation. It was pleasing to find that part (g) was usually correct.

Q19.

The first part of this question tested synoptic understanding of periodicity. The question discriminated well with good candidates gaining full marks. Weaker candidates often confused electronegativity with ionisation energy. Part (b) also produced a wide spread of marks. Many candidates did not include in their explanations, reasons for the strong forces between ions in sodium oxide and why the forces between molecules in phosphorus(V) oxide are relatively weak. Common errors amongst weak candidates were to mistake sodium oxide for an oxide of sulfur or to refer to the existence of molecules in sodium oxide. Part (c) demanded an appreciation that three moles of sodium hydroxide react with one mole of phosphoric acid and that one mole of phosphorus(V) oxide gives four moles of phosphoric acid. This, together with the dilution factor of one million, resulted in a wide but even spread of marks for the question with only 15% of candidates gaining all six marks.

Q21.

The acidity of Period 3 oxides was well known but a surprisingly large number of candidates were unable to write equations for their reactions as required in part (b). The structure and bonding in P_4O_{10} and SiO_2 were well known and most candidates were able to make the link to the volatility of the compound.