Q1.

This question is about Period 3 elements and their oxides.

(a) Give an equation for the reaction between phosphorus and an excess of oxygen.

_____

(1)

(b) Give an equation for the reaction between sulfur dioxide and water.

_____

(1)

(c) Give the displayed formula for the anion formed when sulfur trioxide reacts with water.

(1)

(d) Give an equation for the reaction of magnesium with steam.

State one observation made.

Equation

_____

Observation _____

_____

(2)

(e) Give an equation to show how an excess of magnesium oxide reacts with phosphoric acid (H_3PO_4).

_____

(1)

(Total 6 marks)

Q2.

This question is about Period 3 elements and their compounds.

(a) Which is **not** a correct statement about magnesium hydroxide?

Tick (✓) **one** box.

It is used to neutralise stomach acid ☐

It forms a solution with pH = 14 at 25 °C ☐

It has the empirical formula H_2MgO_2 ☐

(1)

(b) Give an equation for the reaction of aluminium oxide with sulfuric acid.

_____

(1)

(c) Identify a reagent or test that could be used to distinguish between aqueous solutions of sulfur dioxide and sulfur trioxide with the same concentrations.

State the observation in each case.

Reagent or test _____

Observation with sulfur dioxide solution _____

_____

Observation with sulfur trioxide solution _____

_____

(3)

(d) The mass spectrum of the element phosphorus has a peak at $\frac{m}{z} = 124$

Give the formula of the species responsible for this peak.

_____

(2)

(e) Give an equation for the reaction of phosphorus(V) oxide with sodium hydroxide solution.

_____

(1)

(f) Draw the displayed formula of the molecule formed when phosphorus(V) oxide reacts with water.

(1)

(g) The table below shows the melting points of three substances.

Substance	Melting point / K
sodium chloride	1074
chlorine	172
hydrogen chloride	158

Explain why the melting points of these substances are different.

You should refer to the structure of and bonding in each substance.

(6)

(Total 15 marks)

Q3.

This question is about elements in Period 3 and their compounds.

(a) When a piece of sodium is added to 200 cm^3 of water in a large beaker a vigorous reaction occurs. The temperature of the water increases by 25 ^oC

Give an equation, including state symbols, for the reaction of sodium with water.

Suggest why it is dangerous to react a similar piece of sodium with 10 cm^3 of water in a boiling tube.

Equation

_____

Why it is dangerous _____

_____

(2)

(b) Give an equation for the reaction of phosphorus(V) oxide with water.

Suggest a pH for the solution formed.

Equation

_____

pH _____

(2)

(c) Explain, in terms of crystal structure and bonding, why silicon(IV) oxide has a higher melting point than phosphorus(V) oxide.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) An element in Period 3 forms an oxide that is insoluble in water.
This oxide reacts with sulfuric acid and with aqueous potassium hydroxide.

Give the formula for this oxide.

Give an equation for the reaction of this oxide with sulfuric acid.

Formula _____

Equation

_____

(2)

(e) Give the formula of a hydroxide of an element in Period 3 used in medicine.

_____

(1)

(f) Identify the element in Period 3, from sodium to chlorine, that has the largest atomic radius.

_____

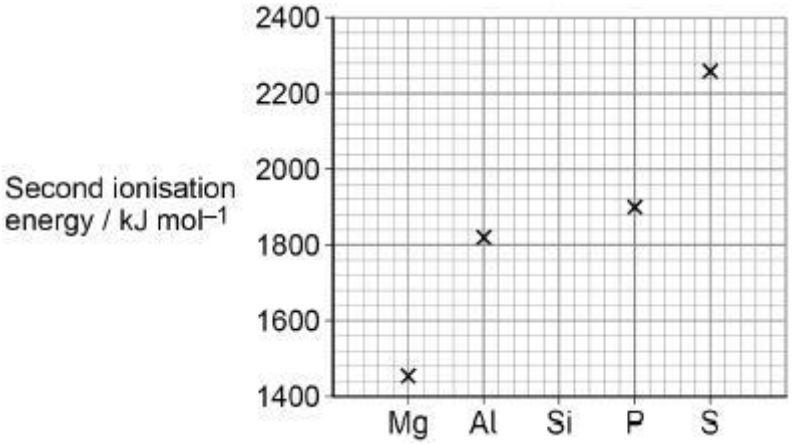
(1)

(Total 12 marks)

Q4.

This question is about Period 3 elements.

The graph shows the **second** ionisation energies of some elements in Period 3.



(a) Draw a cross (x) on the graph above to show the **second** ionisation energy of silicon.

(1)

(b) Identify the element in Period 3, from sodium to argon, that has the highest **second** ionisation energy.

Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of this element is measured.

If you were unable to identify the element you may use the symbol **Q** in your equation.

Element _____

Equation

_____

(2)

(c) Explain why the atomic radius decreases across Period 3, from sodium to chlorine.

_____

_____

_____

_____

(2)

(d) Identify the element in Period 3, from sodium to chlorine, that has the highest electronegativity.

_____

(1)

(e) Phosphorus burns in air to form phosphorus(V) oxide.
Give an equation for this reaction.

_____

(1)

(Total 7 marks)

Q5.

This question is about oxides.

(a) Sodium oxide forms a solution with a higher pH than magnesium oxide when equal amounts, in moles, of each oxide are added separately to equal volumes of water.

State why both oxides form alkaline solutions.

Suggest why sodium oxide forms a solution with a higher pH than the solution formed from magnesium oxide.

_____

_____

_____

_____

_____

(2)

(b) Give an equation for the reaction between phosphorus(V) oxide and water.

_____

(1)

(c) In the Contact process, sulfur(IV) oxide is converted into sulfur(VI) oxide using vanadium(V) oxide as a catalyst.

Give **two** equations to show how the vanadium(V) oxide acts as a catalyst in this process.

Equation 1 _____

Equation 2 _____

(2)

(Total 5 marks)

Q6.

Sodium thiosulfate reacts with dilute hydrochloric acid as shown.

$$Na_2S_2O_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + SO_2\ (g) + S(s) + H_2O(l)$$

(a) Give the simplest ionic equation for this reaction.

_____

(1)

(b) The gas SO_2 is a pollutant.

State the property of SO_2 that causes pollution when it enters rivers.

Give an equation to show the reaction of SO_2 with water.

Property _____

Equation _____

(2)

(c) Draw a diagram to show the shape of a molecule of H_2O
Include any lone pairs of electrons.

State the H-O-H bond angle.

Explain this shape and bond angle.

Diagram

Bond angle _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) The initial rate of the reaction between sodium thiosulfate and hydrochloric acid can be monitored by measuring the time taken for a fixed amount of sulfur to be produced.

Describe an experiment to investigate the effect of temperature on the initial rate of this reaction.

Include

- a brief outline of your method
- how you will measure the time taken for a fixed amount of sulfur to be formed
- how you will present your results in graphical form
- a sketch of the graph that you would expect.

(6)

(Total 13 marks)

Q7.

This question is about sulfuric acid and its salts.

(a) Draw the displayed formula of a molecule of H_2SO_4

(1)

(b) In aqueous solution, sulfuric acid acts as a strong acid. The H_2SO_4 dissociates to form HSO_4^- ions and H^+ ions.

The HSO_4^- ions act as a weak acid and dissociate to form SO_4^{2-} ions and H^+ ions.

Give an equation to show each stage in the dissociation of sulfuric acid in aqueous solution.

Include appropriate arrows in your equations.

Equation 1 _____

Equation 2 _____

(2)

(c) A student is required to make 250 cm^3 of an aqueous solution that contains an accurately measured mass of sodium hydrogensulfate ($NaHSO_4$).

Describe the method that the student should use to make this solution.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) A solution that contains 605 mg of $NaHSO_4$ in 100 cm^3 of solution has a pH of 1.72

Calculate the value of K_a for the hydrogensulfate ion (HSO_4^-) that is behaving as a weak acid.
Give your answer to three significant figures.

State the units of K_a

K _____ Units _____

(6)

(e) Some sodium sulfate is dissolved in a sample of the solution from part **(d)**.

Explain why this increases the pH of the solution.

_____

_____

_____

_____

_____

_____

(2)

(Total 15 marks)

Mark schemes

Q1.

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

Allow 4 P + 5 O_2 → P_4O_{10}

1

(b) $SO_2 + H_2O \rightarrow H_2SO_3$

Or

$SO_2 + H_2O \rightarrow 2\ H^+ + SO_3^{2-}$

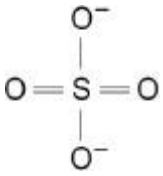
Or

$SO_2 + H_2O \rightarrow H^+ + HSO_3^-$

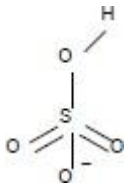
Do not accept H_2SO_4

1

(c)



Allow



1

(d) **M1** $Mg + H_2O \rightarrow MgO + H_2$

M2 White solid/white powder

OR (Bright) white light/white flame

Do not accept white ppt

Do not accept effervescence

2

(e) $3\ MgO + 2\ H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3\ H_2O$

Allow

$3\ MgO + 2\ H_3PO_4 \rightarrow 3\ Mg^{2+} + 2\ PO_4^{3-} + 3\ H_2O$

1

[6]

Q2.

(a) forms a solution with pH = 14 at 25°C

auto

1

(b) $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

allow multiples

ignore state symbols

1

(c) universal indicator

1

SO_2(aq) orange-red

1

SO_3(aq) red

1

allow correct comparison of acidic colours (red, orange, yellow)

or
pH meter
SO_2(aq) pH 2-3
SO_3(aq) pH 0-1

allow correct comparison of acidic pH ignoring values

or

any named metal carbonate (**or** formula) **or** Mg **or** Ca **or** Zn
SO_2(aq) slower effervescence
SO_3(aq) faster effervescence

if reagent is incomplete lose M1 and mark on

allow observation
allow correct comparison

allow named oxidising agent
*eg (acidified) $KMnO_4$ **or** (acidified) $K_2Cr_2O_7$*
SO_2(aq) correct colour acidified change
*SO_3(aq) no visible change **or** NVC*

allow (acidified) barium chloride solution
***or** allow (acidified) barium chloride solution*
*SO_2(aq) no visible change **or** NVC*
SO_3(aq) white precipitate

(d) $^{31}P_4^+$

Allow P_4^+ = 1 mark

Allow ^{31}P = 1 mark

2

(e) $P_4O_{10} + 12\ NaOH \rightarrow 4\ Na_3PO_4 + 6\ H_2O$

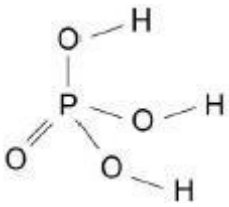
allow formation of acid salts

$P_4O_{10} + 4\ NaOH + 2\ H_2O \rightarrow 4\ NaH_2PO_4$

$P_4O_{10} + 8\ NaOH \rightarrow 4\ Na_2HPO_4 + 2\ H_2O$

1

(f)



must show all bonds

1

(g) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3 **5-6 marks**	All stages are covered and the description of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and stage 3.
Level 2 **3-4 marks**	All stages are covered but the description of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3.
Level 1 **1-2 marks**	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements and these are presented in a logical order.
0 marks	Insufficient correct chemistry to gain a mark.

indicative chemistry content

contradictions negate statements

Stage 1 **structure**

1a NaCl ionic lattice **or** giant ionic

1b Cl_2 **and** HCl molecular (covalent)
or
Cl_2 **and** HCl (simple) molecules

Stage 2 **forces responsible for melting point**

2a NaCl attractions between + and – ions

2b Cl_2 vdw forces

2c HCl dipole dipole forces

Stage 3 **comparison of melting point**

3a ionic bonds stronger than IMF

3b chlorine/Cl_2 is a bigger (molecule) than HCl
or
chlorine/Cl_2 has more electrons than HCl

3c more/stronger forces between molecules in Cl_2 than those in HCl
or
more/stronger IMF in Cl_2 than those in HCl
or
vdw between molecules in Cl_2 > dipole dipole between molecules in HCl

[15]

Q3.

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

Allow ionic equations

Allow multiples

1

Temperature will go up more **or** reactants can shoot out of the tube

Allow the mixture could explode or glass could shatter or hydrogen could ignite/is flammable

Ignore reaction is exothermic/vigorous

1

(b) $P_4O_{10} + 6\ H_2O \rightarrow 4\ H_3PO_4$

Allow ionic equations

1

Allow –1 to + 1

Do not allow equations from P_2O_5

1

(c) M1 SiO_2 is macromolecular / giant covalent / giant molecule

Do not allow giant, giant atomic or giant ionic

1

M2 Strong covalent bonds (between atoms) or covalent bonds need a lot of energy to be broken/overcome

1

M3 P_4O_{10} is molecular or simple covalent molecule

1

M4 Weak van der Waals forces between molecules or van der Waals forces between molecules break easily

1

(d) Al_2O_3

1

$Al_2O_3 + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\ H_2O$
or $Al_2O_3 + 6\ H^+ \rightarrow 2\ Al^{3+} + 3\ H_2O$

1

(e) $Mg(OH)_2$

1

(f) Na / sodium

1

[12]

Q4.

(a) Cross at 1580

Allow a cross drawn for Si that is between the values for Mg and Al

1

(b) **M1** Na

1

M2 $Na^+(g) \rightarrow Na^{2+}(g) + e^-$

M2 *Allow* $Q^+(g) \rightarrow Q^{2+}(g) + e^-$

State symbols essential

Allow correct equation consequential on their element

1

(c) The number of protons increases OR nuclear charge increases

1

Shielding is similar/same OR electrons are added to the same shell

Allow same number of shells

1

(d) Chlorine/Cl

1

(e) $4P + 5O_2 \rightarrow P_4O_{10}$ OR $P_4 + 5O_2 \rightarrow P_4O_{10}$

Allow multiples

Ignore state symbols

Do not allow equations with P_2O_5

1

[7]

Q5.

(a) **M1** (oxide ions react with water to) form/produce hydroxide **ions**

M1 $O^{2-} + H_2O \rightarrow 2OH^-$

Ignore all non-ionic equations

1

M2 sodium hydroxide more soluble than magnesium hydroxide

M2 *ideas that more sodium hydroxide dissolves / dissociates*

Allow sodium oxide more soluble / dissociates more than magnesium oxide NOT 'molecules' or 'atoms'

1

(b) $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

Allow multiples and fractions
Allow ionic products
NOT P_2O_5

1

(c) **M1** $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$
Allow 1 mark if both equations correct, but in wrong order

1

M2 $V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$
ALLOW multiples

1

[5]

Q6.

(a) $S_2O_3^{2-} + 2\ H^+ \rightarrow SO_2 + S + H_2O$
Allow $S_2O_3^{2-} + 2H_3O+ \rightarrow SO_2 + S + 3H_2O$
Allow $½S_2O_3^{2-} + H^+ \rightarrow ½SO_2 + ½S + ½H_2O$
Allow $½S_2O_3^{2-} + H_3O + \rightarrow ½SO_2 + ½S + 1½H_2O$
Ignore state symbols
NOT multiples
NOT if any spectator ions included (unless crossed out)

1

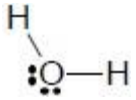
(b) **M1** acid(ic) / acidity / produces H^+
***M1** Allow low(ers) pH*
Ignore toxic / soluble
Ignore sulfurous / sulfuric / H_2SO_4
Ignore rain
Ignore proton donor (unless qualified, e.g. reacts with water to form a proton donor)
NOT any other named acid

1

M2 $SO_2 + H_2O \rightarrow H_2SO_3$ / $H^+ + HSO_3^-$
***M2** Allow $SO_2 + H_2O \rightarrow 2\ H^+ + SO_3^{2-}$*
Allow $SO_2 + 2\ H_2O \rightarrow H_3O^+ + HSO_3^-$
Allow $SO_2 + 3\ H_2O \rightarrow 2\ H_3O^+ + SO_3^{2-}$
Allow multiples
Ignore state symbols

1

(c) **M1**



***M1** bent shape and 2 lone pairs on O*
Allow any suitable representation of lone pairs (e.g.

dots, crosses, lobes with/without dots/crosses)

1

M2 104½°

***M2** Allow 104-105°*

1

M3 lone pairs repel more (strongly) than bond(ing) pairs

***M3** Allow non-bonding pair for lone pair*

Allow covalent bond for bond(ing) pair

Allow shared pair for bond(ing) pair

Allow OH bond for bond(ing) pair

Allow bond for bond(ing) pair

NOT OH or O-H without the word bond for bond(ing) pair

1

M4 so bond angle reduced from/less than 109½° / tetrahedral

M4** Allow bond angle reduced from 120° if bent with one lone pair in **M1

Allow reduced from 109°

*Allow reduced by 2.5° per lone pair or 5° if **M2** correct*

1

(d)

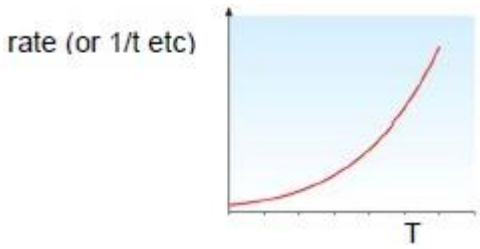
This question is marked using levels of response. Refer to the Mark Scheme Instructions for examiners for guidance on how to mark this question	
Level 3 **5-6 marks**	**All stages are covered and the explanation of each stage is correct and virtually complete.** (6 v 5) Answer is well structured, with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages covered and the explanations are generally correct and virtually complete** (4 v 3) Answer has some structure. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only minor errors in use of technical terms.
Level 1 **1-2 marks**	**Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete** (2 v 1) Answer includes statements which are presented in a logical order and/or linked.
0 marks	Insufficient correct Chemistry to warrant a mark

Indicative Chemistry content

Stage 1 Method
(1a) Idea of using disappearing cross or colorimetry
(1b) Puts acid or thiosulfate into container on/with cross or in colorimeter
(1c) Add second reactant and start timing

Stage 2 Measurements
(2a) Repeat at different temperatures (if number of temperatures stated, must be more than two)
(2b) Record time, t, for cross to disappear / defined reading on colorimeter
(2c) Idea of ensuring other variables (cross, volumes, concentrations) kept constant (apart from T)

Stage 3 Use of Results
(3a) 1/t (or 1000/time, etc) is a measure of rate
(3b) plot of rate (or 1/t etc) (y-axis) against T (x-axis) (can come from labelled axes on sketch) (IGNORE T against rate)
(3c) sketch of plot as shown (Allow 3c if axes not labelled but NOT if incorrectly labelled)

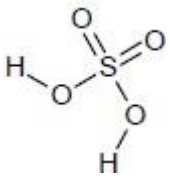


6

[13]

Q7.

(a)



Ignore shape / bond angles
Ignore lone pair(s) on O atoms
NOT lone pair(s) on S atom

1

(b) Equation 1: $H_2SO_4 \rightarrow HSO_4^- + H^+$ / $H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$

Equation 1: NOT $\rightleftharpoons$

1

Equation 2: $HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$ / $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$

Equation 2: NOT $\rightarrow$ *or* $\leftrightarrow$
Allow $\leftrightharpoons$ *or* $\rightleftarrows$ *or* $\leftrightarrows$

1

Ignore state symbols in both equations
Allow multiples in both equations

(c) **M1** weigh solid and transfer using a method that Allows exact mass to be known (there should be two weighings, one of which could be zeroing, and method could be by difference or with washings or directly weighed into container)

M1 *Ignore any mass quoted*

NOT if any other solid added

1

M2 <u>dissolve</u> in water in suitable container (NOT in 250 cm^3 of water)

M2 *NOT if any other solution added*

1

M3 transfer with washings into 250 cm^3 volumetric/graduated flask

M3 *Reference to 250 cm^3 can appear anywhere*

1

M4 make up to mark / 250 cm^3 AND THEN shake / invert / mix

M4 *Allow if conical flask used*

NOT if beaker used

1

Alternative method (M2-4)

M2 *in 250 cm^3 volumetric/graduated flask*

M3 *dissolve (NOT in 250 cm^3 of water)*

M4 *make up to mark / 250 cm^3 AND THEN shake/invert/mix*

(d) **M1** $[H^+] = 10^{-1.72}$ (= 0.0191 (mol dm^{-3}))

1

M2 amount $NaHSO_4$ = 0.605/120.1 (= 5.04×10^{-3} (mol))

1

M3 initial $[NaHSO_4] = [HSO_4^-]$ = **M2** x 10 (= 5.04×10^{-2} (mol dm^{-3}))

$$K_a = \frac{[H^+][SO_4^{2-}]}{[HSO_4^-]} \quad \text{or} \quad K_a = \frac{[H^+]^2}{[HSO_4^-]}$$

1

M4 $K_a = \dfrac{0.0191^2}{0.0504 - 0.0191}$

1

M5 K_a = 1.17×10^{-2} ($1.15 - 1.18 \times 10^{-2}$) must be 3sf

1

M6 mol dm^{-3}

1

*Correct answer scores **M1-5** (must be 3sf)*

***Alternative method** that does not subtract 0.0191:*

*7.21×10^{-3} ($7.15 - 7.26 \times 10^{-3}$) scores **M1-5***

(where **M4** $K_a = \dfrac{0.0191^2}{0.0504}$)

If not correct answer:

*For **M1-3**, if answer is shown, it must be correct (Ignore sf)*

*Allow ECF from **M1/2/3** to **M4**/5 (but not from **M3** to **M5***

*if omission of **M3** gives negative **M5**)*

*NOT ECF from incorrect K_a expression in **M4** to **M5***

M6** If not mol dm^{-3}, Allow ECF for units from incorrect K_a expression in **M4

*7.21×10^{-2} ($7.15 - 7.26 \times 10^{-2}$) gives **M1,2,4,5** (by alternative method omitting **M3**)*

(e) **M1** (HSO_4^- ⇌ SO_4^{2-} + H^+) equilibrium moves/shifts left (to counteract / remove increased [SO_4^{2-}])

***M1** Allow H^+ reacts with SO_4^{2-}/sulfate*

Ignore favours the reverse / left / backwards reaction

NOT base / A^- / sodium sulfate in place of SO_4^{2-}/sulfate

M2 so [H^+] decreases

1

***M2** Allow fewer H^+ (ions) or amount of H^+ lower or removes H^+*

M2** independent of **M1

1

[15]