A

AQA

Surname ______________________

Other Names ______________________

Centre Number ______________________

Candidate Number ______________________

Candidate Signature ______________________

A-LEVEL
CHEMISTRY
Paper 1 Inorganic and Physical Chemistry
7405/1

Tuesday 5 June 2018 Afternoon

Time allowed: 2 hours

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

For this paper you must have:

- **the Periodic Table/Data Booklet, provided as an insert (enclosed)**
- **a ruler with millimetre measurements**
- **a scientific calculator, which you are expected to use where appropriate.**

INSTRUCTIONS

- **Use black ink or black ball-point pen.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do NOT write on blank pages.**
- **All working must be shown.**
- **Do all rough work in this book. Cross through any work you do not want to be marked.**

INFORMATION

- **The marks for questions are shown in brackets.**
- **The maximum mark for this paper is 105.**

DO NOT TURN OVER UNTIL TOLD TO DO SO

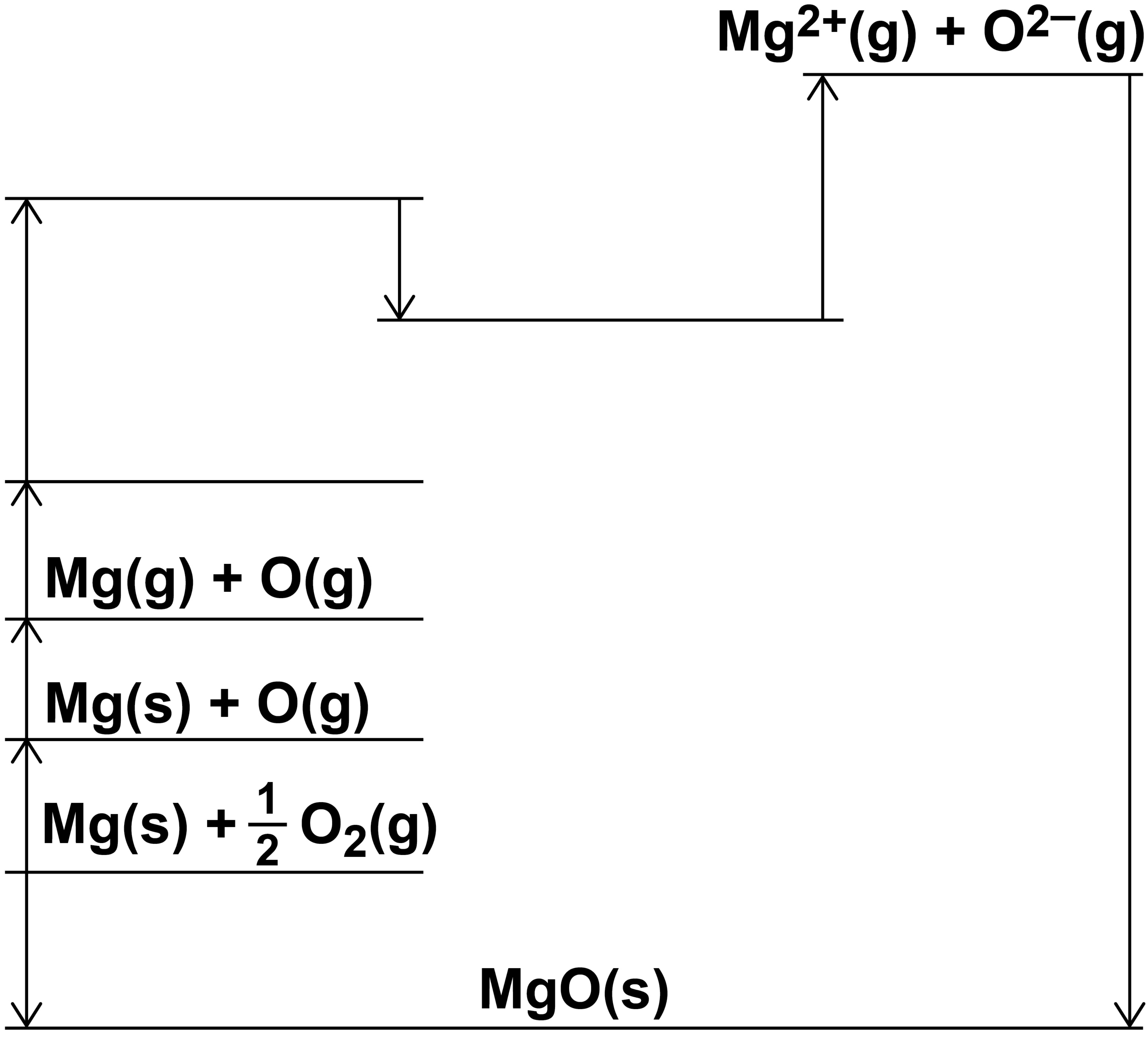
Answer ALL questions in the spaces provided.

0 1 This question is about lattice enthalpies.

0 1 . 1 FIGURE 1, on the opposite page, shows a Born–Haber cycle for the formation of magnesium oxide.

Complete FIGURE 1 by writing the missing symbols on the appropriate energy levels.
[3 marks]

FIGURE 1



01.2 TABLE 1 contains some thermodynamic data.

TABLE 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation for magnesium oxide	–602
Enthalpy of atomisation for magnesium	+150
First ionisation energy for magnesium	+736
Second ionisation energy for magnesium	+1450
Bond dissociation enthalpy for oxygen	+496
First electron affinity for oxygen	–142
Second electron affinity for oxygen	+844

Calculate a value for the enthalpy of lattice formation for magnesium oxide. [3 marks]

Enthalpy of lattice formation

_________________________ kJ mol^{-1}

6

0 2 **Nitrogen and hydrogen were mixed in a 1:3 mole ratio and left to reach equilibrium in a flask at a temperature of 550 K. The equation for the reaction between nitrogen and hydrogen is shown.**

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

0 2 . 1 **When equilibrium was reached, the total pressure in the flask was 150 kPa and the mole fraction of $NH_3(g)$ in the mixture was 0.80**

Calculate the partial pressure of each gas in this equilibrium mixture. [3 marks]

Partial pressure of nitrogen

________________ **kPa**

Partial pressure of hydrogen

________________ **kPa**

Partial pressure of ammonia

________________ **kPa**

[Turn over]

0 2 . 2 Give an expression for the equilibrium constant (K_p) for this reaction. [1 mark]

K_p

0 2 . 3 In a different equilibrium mixture, under different conditions, the partial pressures of the gases are shown in TABLE 2.

TABLE 2

GAS	Partial pressure / kPa
N_2	1.20×10^2
H_2	1.50×10^2
NH_3	1.10×10^3

Calculate the value of the equilibrium constant (K_p) for this reaction and give its units.
[2 marks]

K_p ____________ **Units** ____________

[Turn over]

0 2 . 4 **The enthalpy change for the reaction is –92 kJ mol^{-1}**

State the effect, if any, of an increase in temperature on the value of K_p for this reaction.
Justify your answer. [3 marks]

Effect on K_p

___

Justification

[Turn over]

9

0 3 The equation for the reaction between ammonia and oxygen is shown.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

$\Delta H = -905$ kJ mol^{-1}

Some standard entropies are given in TABLE 3.

TABLE 3

GAS	$S^\ominus$ / J K^{-1} mol^{-1}
$NH_3(g)$	193
$O_2(g)$	205
$NO(g)$	211
$H_2O(g)$	189

0 3 . 1 **Calculate the entropy change for the reaction between ammonia and oxygen. [2 marks]**

Entropy change

____________________ J K^{-1} mol^{-1}

0 3 . 2 **Calculate a value for the Gibbs free-energy change (Δ*G*), in kJ mol^{-1}, for the reaction between ammonia and oxygen at 600 °C**

(If you were unable to obtain an answer to Question 03.1, you should assume that the entropy change is 211 J K^{-1} mol^{-1}. This is NOT the correct answer.)
[2 marks]

Δ*G* ____________________ kJ mol^{-1}

0 3 . 3 **The reaction between ammonia and oxygen was carried out at a higher temperature.**

Explain how this change affects the value of Δ*G* for the reaction.
[2 marks]

[Turn over]

0 3 . 4 **Platinum acts as a heterogeneous catalyst in the reaction between ammonia and oxygen. It provides an alternative reaction route with a lower activation energy.**

Describe the stages of this alternative route. [3 marks]

0 3 . 5 **Deduce the change in oxidation state of nitrogen, when NH_3 is oxidised to NO [1 mark]**

[Turn over]

0 3 . 6 **When ammonia reacts with oxygen, nitrous oxide (N_2O) can be produced instead of NO**

Give an equation for this reaction.
[1 mark]

____

11

0 4 **This question is about s-block metals.**

0 4 . 1 **Give the full electron configuration for the calcium ion, Ca^{2+} [1 mark]**

0 4 . 2 **Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium. [2 marks]**

0 4 . 3 **Identify the s-block metal that has the highest first ionisation energy. [1 mark]**

____

0 4 . 4 **Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water. [1 mark]**

____

[Turn over]

0 4 . 5 **A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.**
The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.
Show by calculation which reagent is in excess.
Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.
[3 marks]

Ionic equation ____________________

Reagent in excess

Total volume of other reagent

[Turn over]

04.6 A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{87}Sr and ^{88}Sr
In this sample, the ratio of abundances of the isotopes ^{86}Sr:^{87}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.
Calculate the percentage abundance of the ^{88}Sr isotope in this sample. [4 marks]

Why isotopes of strontium have identical chemical properties

____

____

____

____

Percentage abundance of ^{88}Sr

______________ %

0 4 . 7 A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight. [1 mark]

___

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[Turn over]

0 4 . 8 **A $^{137}Ba^{+}$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J**
This ion takes 2.71×10^{-5} s to reach the detector.

$$KE = \frac{1}{2} mv^2$$

where m = mass (kg) and
v = speed ($m\ s^{-1}$)

The Avogadro constant,
$L = 6.022 \times 10^{23}\ mol^{-1}$

Calculate the length of the flight tube in metres.
Give your answer to the appropriate number of significant figures. [5 marks]

Length of flight tube

______________ m

[Turn over]

18

0 5 Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

0 5 . 1 State the meaning of the term strong acid. [1 mark]

0 5 . 2 In an experiment, 10.35 cm^3 of 0.100 mol dm^{-3} hydrochloric acid are added to 25.0 cm^3 of 0.150 mol dm^{-3} barium hydroxide solution.

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

K_W = 1.47 x 10^{-14} mol^2 dm^{-6} at 30 °C

Give your answer to 2 decimal places. [6 marks]

pH ______________________________

[Turn over]

0 5 . 3 The pH of water at 30 °C is 6.92

Give the reason why water is neutral at this temperature.
[1 mark]

05.4 **Identify the oxide that could react with water to form a solution with pH = 2**

Tick (✓) ONE box. [1 mark]

☐ Al_2O_3

☐ Na_2O

☐ SiO_2

☐ SO_2

[Turn over]

0 5 . 5 **Give the expression for the acid dissociation constant (K_a) for ethanoic acid (CH_3COOH).**
[1 mark]

K_a

0 5 . 6 **A buffer solution contains 0.025 mol of sodium ethanoate dissolved in 500 cm^3 of 0.0700 mol dm^{-3} ethanoic acid at 25 °C**
A sample of 5.00 cm^3 of 2.00 mol dm^{-3} hydrochloric acid is added to this buffer solution.

Calculate the pH of the solution formed.

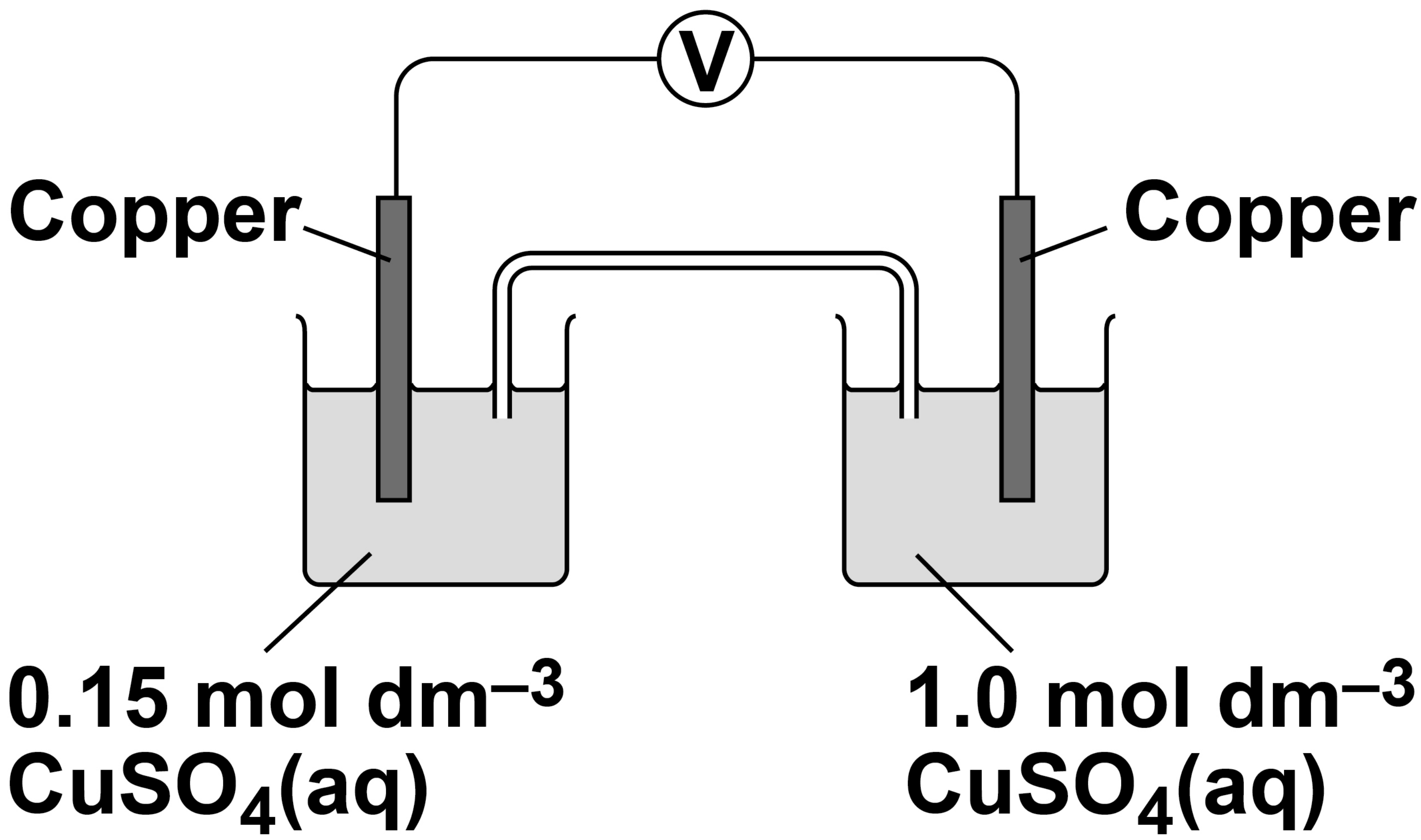
For ethanoic acid,
K_a = 1.76 × 10^{-5} mol dm^{-3} at 25 °C

[5 marks]

pH ______________________________

0 6 A student set up the cell shown in FIGURE 2.

FIGURE 2



The student recorded an initial voltage of +0.16 V at 25 °C

0 6 . 1 **Explain how the salt bridge provides an electrical connection between the two solutions.**
[1 mark]

[Turn over]

06.2 **The standard electrode potential for the Cu^{2+}/Cu electrode is**

$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$

$E^{\ominus}$ = + 0.34 V

Calculate the electrode potential of the left-hand electrode in FIGURE 2, on page 38. [1 mark]

Electrode potential ____________ V

06.3 Both electrodes contain a strip of copper metal in a solution of aqueous Cu^{2+} ions.

State why the left-hand electrode does NOT have an electrode potential of +0.34 V [1 mark]

06.4 Give the conventional representation for the cell in FIGURE 2 on page 38.
Include all state symbols. [1 mark]

0 6 . 5 **When the voltmeter is replaced by a bulb, the EMF of the cell in FIGURE 2, on page 38, decreases over time to 0 V**

Suggest how the concentration of copper(II) ions in the left-hand electrode changes when the bulb is alight.

Give ONE reason why the EMF of the cell decreases to 0 V [2 marks]

Change in concentration of copper(II) ions in the left-hand electrode

___

___

___

Reason why the EMF decreases to 0 V

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____

____

____

____

____

6

[Turn over]

0 7 . 1 **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 mark]

0 7 . 2 **Give an equation to show how the complex ion Z can act as a Brønsted–Lowry acid with water.**
[1 mark]

____

[Turn over]

0 7 . 3 **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. [3 marks]

Observation 1

___

___

___

Observation 2

___

___

___

Equation

____

[Turn over]

0 7 . 4 **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. [4 marks]

Observation 1

___

___

___

Equation 1

Observation 2

Equation 2

[Turn over]

9

0 8 This question is about sodium and some of its compounds.

0 8 . 1 Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide. [6 marks]

[Turn over]

[Turn over]

[Turn over]

0 8 . 2 When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.

Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[6 marks]

Equation

____

Volume

____________________________ cm^3

[Turn over]

0 8 . 3 **Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in Question 08.2. [1 mark]**

Concentration

_________________________ mol dm^{-3}

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[Turn over]

0 8 . 4 Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion. Include any lone pairs of electrons that influence the shape.

Predict the bond angle. Justify your prediction. [4 marks]

Shape

Bond angle ______________

Justification

____

____

____

____

____

____

____

17

[Turn over]

0 9 This question is about vanadium compounds and ions.

0 9 . 1 Use data from TABLE 4, on the opposite page, to identify the species that can be used to reduce VO_2^+ ions to VO^{2+} in aqueous solution and no further.

Explain your answer. [2 marks]

Reagent ____________________________________

Explanation ____________________________________

____

____

____

TABLE 4

Electrode half-equation	$E^{\ominus}$ / V
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76

[Turn over]

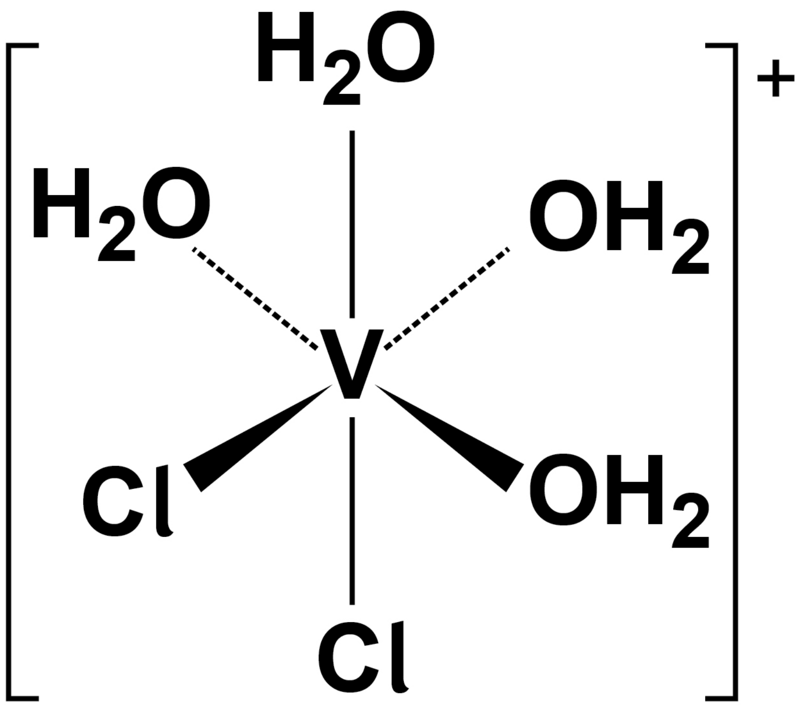
0 9 . 2 Give the oxidation state of vanadium in $[VO(H_2O)_5]^{2+}$
[1 mark]

____

____

0 9 . 3 The $[V(H_2O)_4Cl_2]^+$ ion exists as two isomers. One isomer is shown opposite.

Draw the structure of the other isomer and state the type of isomerism. [2 marks]



Type of isomerism

____

____

[Turn over]

0 9 . 4 **Heating NH_4VO_3 produces vanadium(V) oxide, water and one other product.**

Give an equation for the reaction.
[1 mark]

____

0 9 . 5 **Vanadium(V) oxide is the catalyst used in the manufacture of sulfur trioxide.**

Give TWO equations to show how the catalyst is used and regenerated. [1 mark]

____

____

7

[Turn over]

10.1 A student added 627 mg of hydrated sodium carbonate ($Na_2CO_3.xH_2O$) to 200 cm^3 of 0.250 mol dm^{-3} hydrochloric acid in a beaker and stirred the mixture. After the reaction was complete, the resulting solution was transferred to a volumetric flask, made up to 250 cm^3 with deionised water and mixed thoroughly.

Several 25.0 cm^3 portions of the resulting solution were titrated with 0.150 mol dm^{-3} aqueous sodium hydroxide. The mean titre was 26.60 cm^3 of aqueous sodium hydroxide.

Calculate the value of x in $Na_2CO_3.xH_2O$

Show your working.

Give your answer as an integer.

[7 marks]

Value of x ______________________________

END OF QUESTIONS

7

There are no questions printed on this page

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
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7	
8	
9	
10	
TOTAL	

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