AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

Candidate signature _____

A-level
CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 5 June 2018 Afternoon Time allowed: 2 hours

Materials

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.
- Fill in the boxes at the top of the page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or 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.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	

Answer **all** questions in the spaces provided.

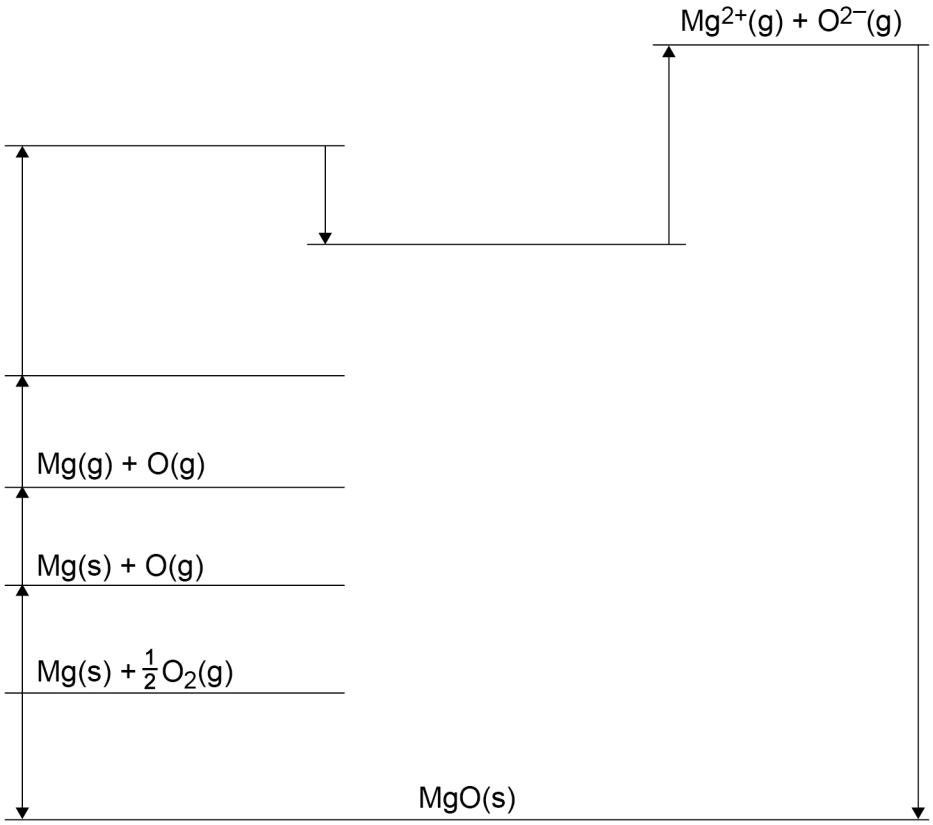
0 1 This question is about lattice enthalpies.

0 1 . 1 **Figure 1** 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



0 1 . 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

Turn over for the next question

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

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 _____

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 _____

_____

_____

_____

_____

9

Turn over ►

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

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905 \text{ kJ mol}^{-1}$$

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 (ΔG), 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]

ΔG _____ 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 ΔG for the reaction.

[2 marks]

_____

_____

_____

_____

_____

Question 3 continues on the next page

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]

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]

Question 4 continues on the next page

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 _____

_____

_____

_____

_____

0 4 . 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]

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

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 _____

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]

0 5 . 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 ☐

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

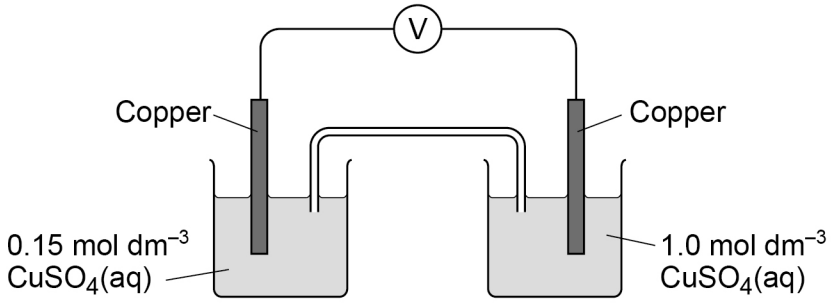
[5 marks]

pH _____

15

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]

0 6 . 2 The standard electrode potential for the Cu^{2+}/Cu electrode is

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \qquad E^{\ominus} = +0.34\ V$$

Calculate the electrode potential of the left-hand electrode in **Figure 2**.

[1 mark]

Electrode potential _____ V

0 6 . 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]

0 6 . 4 Give the conventional representation for the cell in **Figure 2**.
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** 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

6

Turn over for the next question

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]

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

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

_____

9

Turn over for the next question

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]

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

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}

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 for the next question

0 9 This question is about vanadium compounds and ions.

0 9 . 1 Use data from **Table 4** 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.

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

[2 marks]

Reagent _____

Explanation _____

_____

_____

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

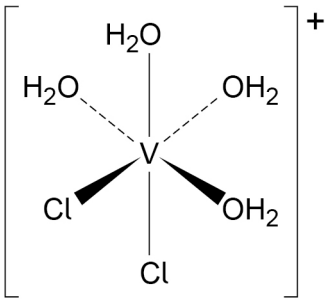
[1 mark]

_____

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

Draw the structure of the other isomer and state the type of isomerism.

[2 marks]



Type of isomerism _____

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

1 0 . 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 _____

7

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED