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 13 June 2017 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 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	
11	
TOTAL	

Answer **all** questions in the spaces provided

0 1 This question is about silver iodide.

0 1 . 1 Define the term enthalpy of lattice formation.

[2 marks]

0 1 . 2 Some enthalpy change data are shown in **Table 1**.

Table 1

	Enthalpy change / kJ mol^{-1}
$AgI(s) \rightarrow Ag^+(aq) + I^-(aq)$	+112
$Ag^+(g) \rightarrow Ag^+(aq)$	–464
$I^-(g) \rightarrow I^-(aq)$	–293

Use the data in **Table 1** to calculate the enthalpy of lattice formation of silver iodide.

[2 marks]

Enthalpy of lattice formation _____ kJ mol^{-1}

0 1 . 3 A calculation of the enthalpy of lattice formation of silver iodide based on a perfect ionic model gives a smaller numerical value than the value calculated in Question **1.2**

Explain this difference.

[2 marks]

0 1 . 4 Identify a reagent that could be used to indicate the presence of iodide ions in an aqueous solution and describe the observation made.

[2 marks]

Reagent _____

Observation _____

_____

8

Turn over for the next question

0 2 This question is about acidic solutions.

0 2 . 1 The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C

A buffer solution with a pH of 3.87 was prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoate ions was 0.136 mol dm^{-3}

Calculate the concentration of the ethanoic acid in the buffer solution.
Give your answer to three significant figures.

[3 marks]

Concentration of acid _____ mol dm^{-3}

0 2 . 2 In a different buffer solution, the concentration of ethanoic acid was 0.260 mol dm^{-3} and the concentration of ethanoate ions was 0.121 mol dm^{-3}

A 7.00×10^{-3} mol sample of sodium hydroxide was added to 500 cm^3 of this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added. Give your answer to two decimal places.

[6 marks]

pH of buffer solution _____

9

0 3 The ionic product of water, $K_w = 2.93 \times 10^{-15}$ mol^2 dm^{-6} at 10 °C

0 3 . 1 Which is the correct expression for K_w?
Tick (✓) **one** box.

[1 mark]

A $K_w = \dfrac{[H_2O]}{[H^+][OH^-]}$ ☐

B $K_w = [H^+][H_2O]$ ☐

C $K_w = [H^+][OH^-]$ ☐

D $K_w = \dfrac{[H^+][OH^-]}{[H_2O]}$ ☐

0 3 . 2 Calculate the pH of pure water at 10 °C
Give your answer to two decimal places.

[2 marks]

pH of water _____

0 3 . 3 Suggest why this pure water at 10 °C is **not** alkaline.

[1 mark]

_____

_____

_____

0 3 . 4 Calculate the pH of a 0.0131 mol dm^{-3} solution of calcium hydroxide at 10 °C
Give your answer to two decimal places.

[3 marks]

pH of solution _____

0 3 . 5 The 0.0131 mol dm^{-3} calcium hydroxide solution at 10 °C was a saturated solution.

A student added 0.0131 mol of magnesium hydroxide to 1.00 dm^3 of water at 10 °C and stirred the mixture until no more solid dissolved.

Predict whether the pH of the magnesium hydroxide solution formed at 10 °C is larger than, smaller than or the same as the pH of the calcium hydroxide solution at 10 °C

Explain your answer.

[2 marks]

pH of magnesium hydroxide compared to calcium hydroxide

_____

Explanation _____

_____

_____

9

0 4 A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in **Table 2**.

Table 2

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

0 4 . 1 Calculate the relative atomic mass of titanium in this sample.
Give your answer to one decimal place.

[2 marks]

Relative atomic mass of titanium in this sample _____

0 4 . 2 Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

[2 marks]

Equation _____

m/z value _____

0 4 . 3 Calculate the mass, in kg, of one atom of ^{49}Ti

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

[1 mark]

Mass _____ kg

0 4 . 4 In a TOF mass spectrometer the time of flight, *t,* of an ion is shown by the equation

$$t = d\sqrt{\frac{m}{2E}}$$

In this equation *d* is the length of the flight tube, *m* is the mass, in kg, of an ion and *E* is the kinetic energy of the ions.

In this spectrometer, the kinetic energy of an ion in the flight tube is 1.013×10^{-13} J

The time of flight of a $^{49}Ti^{+}$ ion is 9.816×10^{-7} s

Calculate the time of flight of the $^{47}Ti^{+}$ ion.
Give your answer to the appropriate number of significant figures.

[3 marks]

Time of flight _____ s

8

0 5 Titanium(IV) chloride can be made from titanium(IV) oxide as shown in the equation.

$TiO_2(s) + 2C(s) + 2Cl_2(g) \rightarrow 2CO(g) + TiCl_4(l)$ $\Delta H^{\ominus} = -60.0$ kJ mol^{-1}

0 5 . 1 Some entropy data are shown in **Table 3**.

Table 3

Substance	$TiO_2(s)$	$C(s)$	$Cl_2(g)$	$CO(g)$	$TiCl_4(l)$
$S^{\ominus}$ / J K^{-1} mol^{-1}	50.2	5.70	223	198	253

Use the equation and the data in **Table 3** to calculate the Gibbs free-energy change for this reaction at 989 °C
Give your answer to the appropriate number of significant figures.

Use your answer to explain whether this reaction is feasible.

[6 marks]

Gibbs free-energy change _____ kJ mol^{-1}

Explanation _____

_____

6

Turn over for the next question

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0 6 This question is about some Period 3 elements and their oxides.

0 6 . 1 Write an equation for the reaction of phosphorus with an excess of oxygen.

[1 mark]

0 6 . 2 Describe a test you could carry out in a test tube to distinguish between sodium oxide and the product of the reaction in Question **6.1**

[3 marks]

0 6 . 3 State the type of crystal structure shown in silicon dioxide and in sulfur trioxide.

[2 marks]

Silicon dioxide _____

Sulfur trioxide _____

0 6 . 4 Explain why silicon dioxide has a higher melting point than sulfur trioxide.

[4 marks]

0 6 . 5 Write an equation for the reaction of sulfur trioxide with potassium hydroxide solution.

[1 mark]

0 6 . 6 Write an equation for the reaction of an excess of magnesium oxide with phosphoric acid.

[1 mark]

0 6 . 7 Draw the displayed formula of the undissociated acid formed when sulfur dioxide reacts with water.

[1 mark]

13

Turn over for the next question

0 7 Solution **A** contains the compound $[Cu(H_2O)_6]Cl_2$

0 7 . 1 State the type of bonding between the oxygen and hydrogen in this compound.

[1 mark]

0 7 . 2 State why the chloride ions in this compound are **not** considered to be ligands.

[1 mark]

0 7 . 3 An excess of ammonia was added to a sample of solution **A** to form solution **B**.

Write an ionic equation for the reaction that occurs when solution **A** is converted into solution **B** and state the colour of solution **B**.

[2 marks]

Equation

Colour

0 7 . 4 Aqueous sodium carbonate was added to another sample of solution **A** to form a blue-green solid **C**.

Identify the blue-green solid **C**.

[1 mark]

0 7 . 5 Reagent **D** was added to another sample of solution **A** to form a yellow-green solution.

Identify reagent **D** and write an ionic equation for the reaction that occurs when the yellow-green solution is formed from solution **A**.

[2 marks]

Identity of reagent **D**

Equation

0 7 . 6 Explain why colorimetry cannot be used to determine the concentration of solutions containing $[CuCl_2]^-$
In your answer refer to the electron configuration of the metal ion.

[2 marks]

9

Turn over for the next question

0 8 This question is about ion testing.

0 8 . 1 Describe how a student could distinguish between aqueous solutions of potassium nitrate, KNO_3, and potassium sulfate, K_2SO_4, using **one** simple test-tube reaction.

[3 marks]

Reagent _____

Observation with $KNO_3(aq)$ _____

_____

Observation with $K_2SO_4(aq)$ _____

_____

0 8 . 2 Describe how a student could distinguish between aqueous solutions of magnesium chloride, $MgCl_2$, and aluminium chloride, $AlCl_3$, using **one** simple test-tube reaction.

[3 marks]

Reagent _____

Observation with $MgCl_2(aq)$ _____

_____

Observation with $AlCl_3(aq)$ _____

_____

6

0 9 There are several stages in the industrial production of methanol from methane.

0 9 . 1 The first stage involves a gaseous equilibrium between the reactants (methane and steam), and some gaseous products. **Figures 1** and **2** show the percentage conversion of methane into the gaseous products under different conditions at equilibrium.

Figure 1

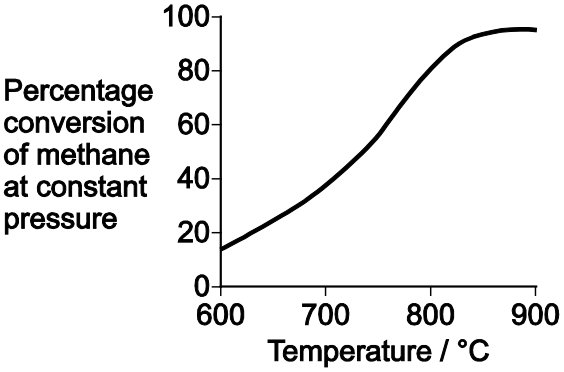
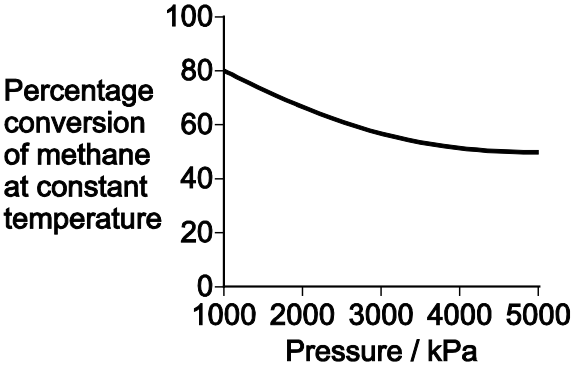


Figure 2



Deduce the optimum conditions for the industrial conversion of methane and steam into the gaseous products.

Explain your deductions.

[6 marks]

0 9 . 2 The equation shows the final stage in the production of methanol.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

20.1 mol of carbon monoxide and 24.2 mol of hydrogen were placed in a sealed container. An equilibrium was established at 600 K. The equilibrium mixture contained 2.16 mol of methanol.

Calculate the amount, in moles, of carbon monoxide and of hydrogen in the equilibrium mixture.

[2 marks]

Amount of carbon monoxide _____ mol

Amount of hydrogen _____ mol

Question 9 continues on the next page

0 9 . 3 A different mixture of carbon monoxide and hydrogen was allowed to reach equilibrium at 600 K

At equilibrium, the mixture contained 2.76 mol of carbon monoxide, 4.51 mol of hydrogen and 0.360 mol of methanol. The total pressure was 630 kPa

Calculate a value for the equilibrium constant, K_p, for this reaction at 600 K and state its units.

[6 marks]

Value of K_p _____ Units _____

14

1 0 **Table 4** shows some electrode half-equations and their standard electrode potentials.

Table 4

Electrode half-equation	$E^{\ominus}$ / V
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(aq) + 2H_2O(aq)$	+0.96
$Fe^{3+}(aq) + e^- \rightarrow Fe^{3+}(aq)$	+0.77
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow SO_2(g) + 2H_2O(aq)$	+0.17
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44

1 0 . 1 Deduce the oxidation state of nitrogen in NO_3^- and in NO

[2 marks]

Nitrogen in NO_3^- _____

Nitrogen in NO _____

1 0 . 2 State the weakest reducing agent in **Table 4**.

[1 mark]

_____

1 0 . 3 Write the conventional representation of the cell that has an EMF of +0.43 V

[2 marks]

_____

1 0 . 4 Use data from **Table 4** to identify an acid that will oxidise copper.

Explain your choice of acid.

Use these data to suggest a possible equation for the reaction.

Calculate the EMF of the cell that has the same overall reaction.

[4 marks]

9

1 1 This question is about compounds containing ethanedioate ions.

1 1 . 1 A white solid is a mixture of sodium ethanedioate ($Na_2C_2O_4$), ethanedioic acid dihydrate ($H_2C_2O_4.2H_2O$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 cm^3 of aqueous solution.

Two different titrations were carried out using this solution.

In the first titration 25.0 cm^3 of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 ^oC and then titrated with a 0.0200 mol dm^{-3} solution of potassium manganate(VII). When 26.50 cm^3 of potassium manganate(VII) had been added the solution changed colour.

The equation for this reaction is

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

In the second titration 25.0 cm^3 of the solution were titrated with a 0.100 mol dm^{-3} solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 cm^3 of sodium hydroxide solution.

The equation for this reaction is

$$H_2C_2O_4 + 2OH^- \rightarrow C_2O_4^{2-} + 2H_2O$$

Calculate the percentage by mass of sodium ethanedioate in the white solid.

Give your answer to the appropriate number of significant figures.
Show your working.

[8 marks]

Percentage by mass of sodium ethanedioate _____ %

1 1 . 2 Ethanedioate ions react with aqueous iron(III) ions in a ligand substitution reaction.

Write an equation for this reaction.

Suggest why the value of the enthalpy change for this reaction is close to zero.

[2 marks]

1 1 . 3 Draw the displayed formula of the iron complex produced in the reaction in Question **11.2**

Indicate the value of the O—Fe—O bond angle.

State the type of isomerism shown by the iron complex.

[3 marks]

Bond angle _____

Type of isomerism _____

1 1 . 4 Ethanedioate ions are poisonous because they react with iron ions in the body. Ethanedioate ions are present in foods such as broccoli and spinach.

Suggest one reason why people who eat these foods do not suffer from poisoning.

[1 mark]

END OF QUESTIONS

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