Please write clearly in block capitals.

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

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________

A-level CHEMISTRY

Unit 5 Energetics, Redox and Inorganic Chemistry

Wednesday 22 June 2016 Morning Time allowed: 1 hour 45 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this 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 100.
- You are expected to use a calculator, where appropriate.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 75 minutes on **Section A** and about 30 minutes on **Section B**.

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WMP/Jun16/E5

CHEM5

Section A

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

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

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

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

[1 mark]

____

1 (a) (ii) Identify element **X**.

[1 mark]

____

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

[1 mark]

____

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

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

[1 mark]

____

1 (b) (ii) Identify element **Y**.

[1 mark]

____

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

[1 mark]

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

[1 mark]

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

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

[1 mark]

1 (c) (ii) Write the formula of this amphoteric oxide.

[1 mark]

1 (c) (iii) State the meaning of the term amphoteric.

[1 mark]

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

[2 marks]

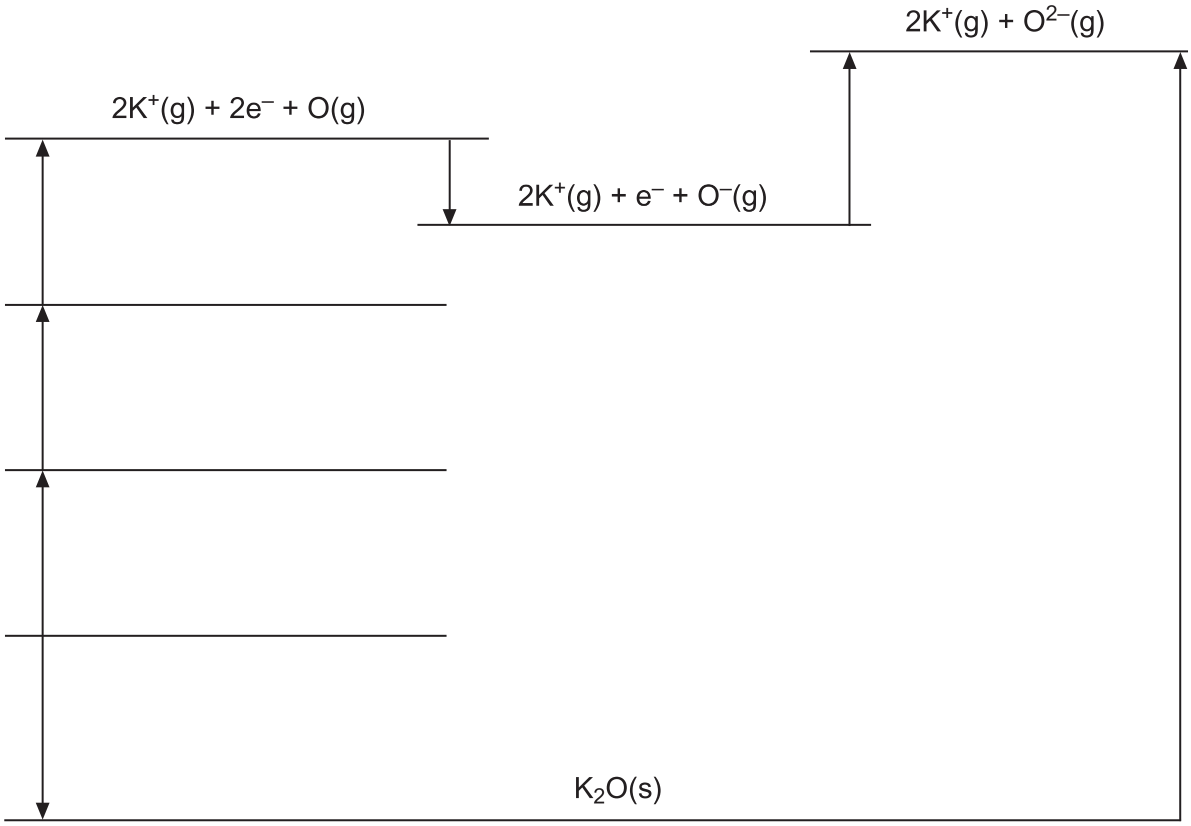
12

2 (a) **Figure 1** is a Born–Haber cycle for potassium oxide, K_2O. **Figure 1** is not to scale and not fully labelled.

2 (a) (i) Complete **Figure 1** by writing the formulae, including state symbols, of the appropriate species on each of the three blank lines.

[3 marks]

Figure 1



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2 (a) (ii) **Table 1** shows some enthalpy data.

Table 1

Enthalpy change	$\Delta H^{\ominus}$ / kJ mol^{-1}
Enthalpy of atomisation of potassium	+90
First ionisation enthalpy of potassium	+418
Enthalpy of atomisation of oxygen	+248
First electron affinity of oxygen	–142
Second electron affinity of oxygen	+844
Enthalpy of formation of potassium oxide	–362

Use the data in **Table 1** to calculate the enthalpy of lattice dissociation of potassium oxide, K_2O

[3 marks]

2 (b) Explain why the enthalpy of lattice dissociation of potassium oxide is less endothermic than that of sodium oxide.

[2 marks]

8

3 This question is about magnesium chloride.

3 (a) Write the equation, including state symbols, for the process corresponding to the enthalpy of solution of magnesium chloride.

[1 mark]

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3 (b) Use these data to calculate the standard enthalpy of solution of magnesium chloride.

Enthalpy of lattice dissociation of $MgCl_2$	= +2493 kJ mol^{-1}
Enthalpy of hydration of magnesium ions	= –1920 kJ mol^{-1}
Enthalpy of hydration of chloride ions	= –364 kJ mol^{-1}

[2 marks]

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3 (c) Solubility is the measure of how much of a substance can be dissolved in water to make a saturated solution. A salt solution is saturated when an undissolved solid is in equilibrium with its aqueous ions.

Use your answer to part **(b)** to deduce how the solubility of $MgCl_2$ changes as the temperature is increased.
Explain your answer.

[3 marks]

6

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4 **Table 2** shows some standard electrode potential data.

Table 2

Electrode half-reaction	$E^{\ominus}$**/ V**
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$	+1.23
$Au^+(aq) + e^- \rightarrow Au(s)$	+1.68
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82

4 (a) (i) Identify the weakest oxidising agent in **Table 2**.

[1 mark]

____

4 (a) (ii) Give the conditions under which the electrode potential of the Zn^{2+}/Zn electrode is –0.76 V.

[2 marks]

____

____

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4 (b) Two half-cells, involving species in **Table 2**, are connected together to give a cell with an e.m.f. = +0.48 V.

Use data from **Table 2** to deduce the conventional representation of this cell.
Write the half-equation for the reaction that occurs at the negative electrode.

[3 marks]

Conventional representation ____

____

Half-equation ____

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4 (c) Use data from **Table 2** to identify a cobalt species that can react with water.

Write an equation for the redox reaction that occurs and identify the oxidation product in the reaction.

[3 marks]

Cobalt species ______________________________

Equation ______________________________

____

____

Oxidation product ______________________________

4 (d) Use data from **Table 2** to explain why gold jewellery is unreactive in moist air.

[2 marks]

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11

Turn over for the next question

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5 A representation of a hydrogen–oxygen fuel cell that operates in alkaline conditions is

$$Pt|H_2|H_2O||O_2|OH^-|Pt$$

5 (a) (i) Write a half-equation for the reaction that occurs at each electrode.
Use the half-equations to deduce an overall equation for the cell.

[3 marks]

Half-equation at positive electrode ____

Half-equation at negative electrode ____

Overall equation ____

5 (a) (ii) State and explain the effect, if any, of increasing the pressure of oxygen on the e.m.f of this cell.

[2 marks]

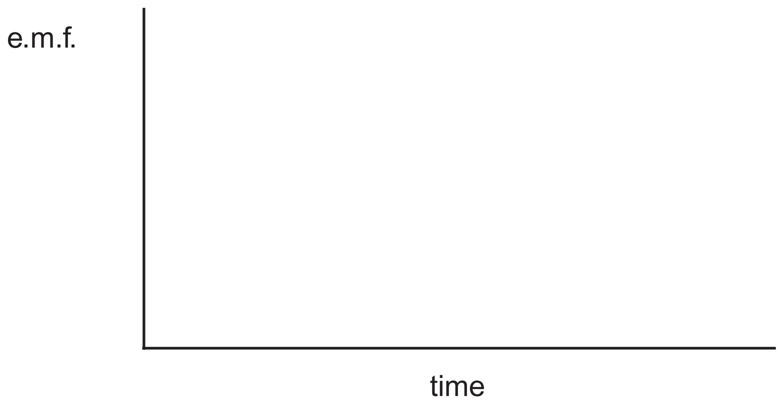
Effect on e.m.f. ____

Explanation ____

____

5 (b) Complete the diagram to show how the e.m.f. of a hydrogen–oxygen fuel cell changes with time.

[1 mark]



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5 (c) (i) Suggest the effect, if any, on the e.m.f. of this cell if the surface area of each platinum electrode is increased.

[1 mark]

5 (c) (ii) State the main environmental advantage of using a hydrogen–oxygen fuel cell to power a car.

[1 mark]

5 (d) Suggest why the use of a hydrogen–oxygen fuel cell might not be carbon-neutral.

[1 mark]

9

Turn over for the next question

6 In the Contact Process sulfur dioxide reacts with oxygen to form sulfur trioxide as shown in the equation.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Table 3 shows some thermodynamic data.

Table 3

	$\Delta H_f^\ominus$ /kJ mol^{-1}	$S^\ominus$/J K^{-1} mol^{-1}
SO_2(g)	–297	248
O_2(g)	0	205
SO_3(g)	–395	256

6 (a) Use data from **Table 3** to calculate the standard enthalpy change for this reaction.

[2 marks]

6 (b) Use data from **Table 3** to calculate the standard entropy change for this reaction.

[2 marks]

6 (c) State what the sign of the entropy change in your answer to part **(b)** indicates about the product of this reaction relative to the reactants.

[1 mark]

6 (d) Use your answers to parts **(a)** and **(b)** to calculate a value for the free–energy change for this reaction at 50 °C.

(If you were unable to calculate ΔH in part **(a)** assume a value of –250 kJ mol^{-1}
If you were unable to calculate ΔS in part **(b)** assume a value of –250 J K^{-1} mol^{-1}
These are not the correct values.)

[3 marks]

6 (e) Use your answer to part **(d)** to explain whether the reaction is feasible at 50 °C

[1 mark]

6 (f) Vanadium(V) oxide acts as a heterogeneous catalyst in the Contact Process.

6 (f) (i) State what is meant by the term heterogeneous.

[1 mark]

6 (f) (ii) Write **two** equations that show how this catalyst is involved in the Contact Process.

[2 marks]

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6 (f) (iii) Suggest why the vanadium(V) oxide is used in small pellet form rather than as large lumps.

[1 mark]

____

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6 (f) (iv) State why the reactants should be purified before they come into contact with the vanadium(V) oxide.

[1 mark]

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14

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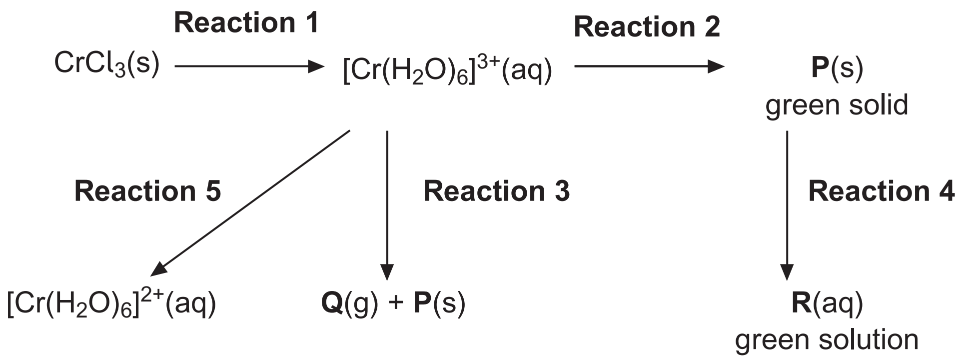
7 The following scheme shows some reactions of chromium compounds.



7 (a) Write an equation for **Reaction 1**.

[1 mark]

___

7 (b) For **Reaction 2,** identify the complex **P**, state a reagent and write an equation.

[3 marks]

Identity of **P** ___

Reagent ___

Equation ___

___

7 (c) For **Reaction 3**, identify **Q**, state a reagent and write an equation.

[3 marks]

Identity of **Q** ___

Reagent ___

Equation ___

___

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7 (d) For **Reaction 4**, identify the complex **R**, state a reagent and write an equation for the formation of **R** from **P**.

[3 marks]

Identity of **R** ____________________________________

Reagent ____________________________________

Equation ____________________________________

____

7 (e) For **Reaction 5** suggest the reagents and state the colour of $[Cr(H_2O)_6]^{2+}(aq)$.

[2 marks]

Reagents ____________________________________

Colour ____________________________________

12

Turn over for the next question

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Section B

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

8 This question is about cobalt chemistry.

8 (a) Give the electron configuration of the Co atom and of the Co^{2+} ion.

State three characteristic features of the chemistry of cobalt and its compounds.

[5 marks]

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8 (b) Ethane-1,2-diamine can act as a bidentate ligand. When $[Co(H_2O)_6]^{2+}$(aq) ions are treated with an excess of ethane-1,2-diamine, the water ligands are replaced.

Explain what is meant by the term bidentate ligand.

Explain, with the aid of an equation, the thermodynamic reasons why this reaction occurs.

Draw a diagram to show the structure of the complex ion formed.

[7 marks]

12

Turn over ▶

9 A student weighed out a 2.29 g sample of impure $K_3[Fe(C_2O_4)_3].3H_2O$ and dissolved it in water.
This solution was added to a 250 cm^3 volumetric flask and made up to 250 cm^3 with distilled water.
A 25.0 cm^3 portion was pipetted into a conical flask and an excess of acid was added.
The mixture was heated to 60 ºC and titrated with 0.0200 mol dm^{-3} $KMnO_4$ solution.
26.40 cm^3 of $KMnO_4$ solution were needed for a complete reaction.

In this titration only the $C_2O_4^{2-}$ ions react with the $KMnO_4$ solution.

9 (a) The reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions is autocatalysed.

Explain what is meant by the term autocatalysed and identify the catalyst in the reaction.

[2 marks]

9 (b) Select from the list the most suitable substance used to acidify the solution in the conical flask.
Put a tick (✓) in the correct box.

[1 mark]

$H_2C_2O_4$ ☐

H_2SO_4 ☐

HCl ☐

HNO_3 ☐

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9 (c) The reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions is very slow at first.
Explain why the reaction is initially slow.

[3 marks]

9 (d) Write an equation for the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions in acidic solution.
Calculate the percentage purity of the original sample of $K_3[Fe(C_2O_4)_3].3H_2O$
Give your answer to 3 significant figures.

[7 marks]

Turn over ▶

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9 (e) A solution of $KMnO_4$ has an unknown concentration.

Describe briefly how colorimetry can be used to determine the concentration of this solution.

[3 marks]

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END OF QUESTIONS

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