Centre Number						Candidate Number				
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Other Names										
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For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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6	
7	
8	
TOTAL	

General Certificate of Education
Advanced Level Examination
January 2012

Chemistry CHEM5

Unit 5 Energetics, Redox and Inorganic Chemistry

Wednesday 1 February 2012 9.00 am to 10.45 am

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

Time allowed
- 1 hour 45 minutes

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.
- The Periodic Table/Data Sheet is provided as an insert.
- 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 accurate scientific terminology.

Advice
- You are advised to spend about 70 minutes on **Section A** and about 35 minutes on **Section B**.

Section A

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

1 This question is about magnesium oxide. Use data from the table below, where appropriate, to answer the following questions.

	$\Delta H^\ominus$/ kJ mol^{-1}
First electron affinity of oxygen (formation of O^-(g) from O(g))	–142
Second electron affinity of oxygen (formation of O^{2-}(g) from O^-(g))	+844
Atomisation enthalpy of oxygen	+248

1 (a) Define the term *enthalpy of lattice dissociation.*

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(3 marks)

1 (b) In terms of the forces acting on particles, suggest **one** reason why the first electron affinity of oxygen is an exothermic process.

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(1 mark)

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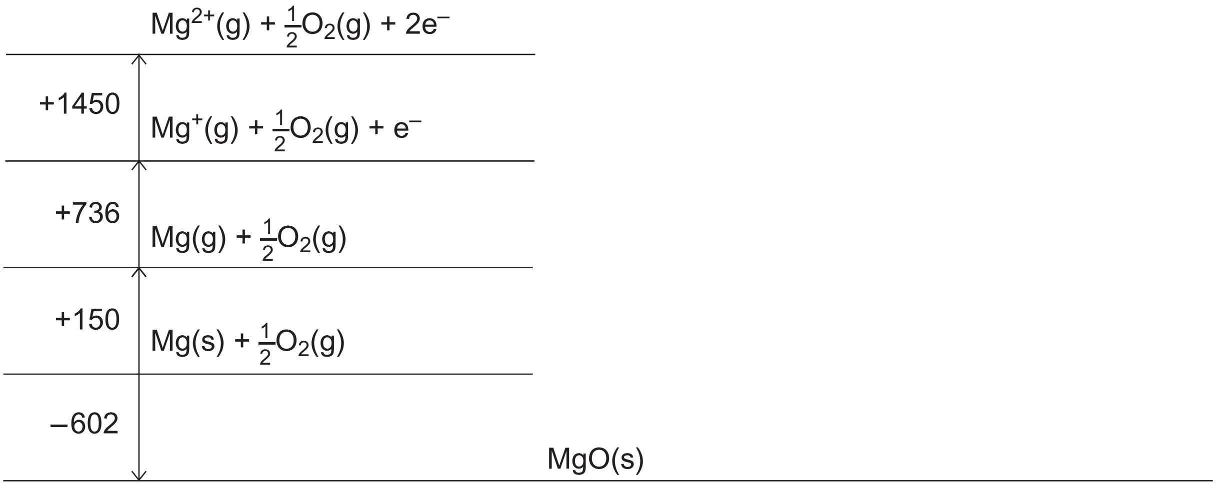
1 (c) Complete the Born–Haber cycle for magnesium oxide by drawing the missing energy levels, symbols and arrows.
The standard enthalpy change values are given in kJ mol^{-1}.



(4 marks)

1 (d) Use your Born–Haber cycle from part **(c)** to calculate a value for the enthalpy of lattice dissociation for magnesium oxide.

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(2 marks)

Question 1 continues on the next page

Turn over ▶

Do not write outside the box

1 (e) The standard free-energy change for the formation of magnesium oxide from magnesium and oxygen, $\Delta G_f^\ominus = -570\ \text{kJ mol}^{-1}$.
Suggest **one** reason why a sample of magnesium appears to be stable in air at room temperature, despite this negative value for $\Delta G_f^\ominus$.

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(1 mark)

(Extra space) ....

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1 (f) Use the value of $\Delta G_f^\ominus$ given in part **(e)** and the value of $\Delta H_f^\ominus$ from part **(c)** to calculate a value for the entropy change $\Delta S^\ominus$ when one mole of magnesium oxide is formed from magnesium and oxygen at 298 K. Give the units of $\Delta S^\ominus$.

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(3 marks)

(Extra space) ....

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1 (g) In terms of the reactants and products and their physical states, account for the sign of the entropy change that you calculated in part **(f)**.

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(2 marks)

16

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2 Consider the following process that represents the melting of ice.

$$H_2O(s) \longrightarrow H_2O(l) \qquad \Delta H^\ominus = +6.03\,kJ\,mol^{-1}\,,\ \Delta S^\ominus = +22.1\,J\,K^{-1}\,mol^{-1}$$

2 (a) State the meaning of the symbol $^\ominus$ in $\Delta H^\ominus$.

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(1 mark)

2 (b) Use your knowledge of bonding to explain why $\Delta H^\ominus$ is positive for this process.

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(2 marks)

2 (c) Calculate the temperature at which $\Delta G^\ominus = 0$ for this process. Show your working.

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(3 marks)

2 (d) The freezing of water is an exothermic process. Give **one** reason why the temperature of a sample of water can stay at a constant value of 0 °C when it freezes.

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(1 mark)

2 (e) Pure ice can look pale blue when illuminated by white light. Suggest an explanation for this observation.

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(2 marks)

9

Turn over ▶

3 The data in the table below show the melting points of oxides of some Period 3 elements.

	Na_2O	P_4O_{10}	SO_2
T_m / K	1548	573	200

3 (a) In terms of structure and bonding, explain why

3 (a) (i) sodium oxide has a high melting point

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(2 marks)

(Extra space) ....

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3 (a) (ii) sulfur dioxide has a low melting point.

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(2 marks)

(Extra space) ....

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3 (b) Explain why the melting point of P_4O_{10} is higher than the melting point of SO_2

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(2 marks)

(Extra space) ....

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Do not write outside the box

3 (c) Write equations for the reactions of Na_2O and P_4O_{10} with water. In each case give the approximate pH of the resulting solution.

Equation for Na_2O ....

pH ....

Equation for P_4O_{10} ....

pH ....

(4 marks)

3 (d) Write an equation for the acid–base reaction that occurs when Na_2O reacts with P_4O_{10} in the absence of water.

....

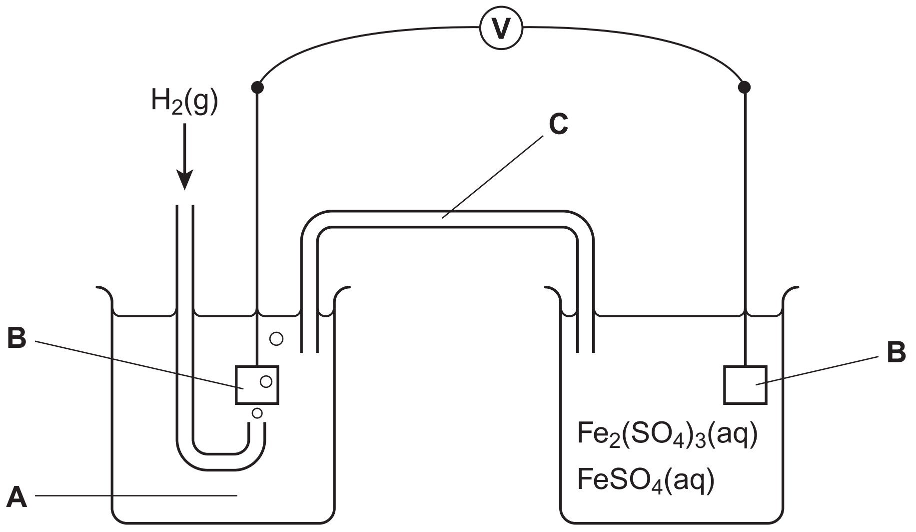
(1 mark)

11

Turn over for the next question

Do not write outside the box

4 The diagram below shows a cell that can be used to measure the standard electrode potential for the half-reaction $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$. In this cell, the electrode on the right-hand side is positive.



4 (a) Identify solution **A** and give its concentration. State the other essential conditions for the operation of the standard electrode that forms the left-hand side of the cell.

Solution **A** ....

Conditions ....

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(3 marks)

4 (b) Identify the material from which electrodes **B** are made. Give **two** reasons why this material is suitable for its purpose.

Material ....

Reason 1 ....

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Reason 2 ....

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(3 marks)

Do not write outside the box

4 (c) Identify a solution that could be used in **C** to complete the circuit. Give **two** reasons why this solution is suitable for its purpose.

Solution ....

Reason 1 ....

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Reason 2 ....

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(3 marks)

4 (d) Write the conventional representation for this cell.

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(1 mark)

4 (e) The voltmeter **V** shown in the diagram of the cell was replaced by an ammeter.

4 (e) (i) Write an equation for the overall cell reaction that would occur.

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(1 mark)

4 (e) (ii) Explain why the ammeter reading would fall to zero after a time.

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(1 mark)

12

Do not write outside the box

5 Some electrode potentials are shown in the table below. These values are **not** listed in numerical order.

Electrode half-equation	$E^\ominus$/ V
$Cl_2(aq) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$2HOCl(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(aq) + 2H_2O(l)$	+1.64
$H_2O_2(aq) + 2H^+(aq) + 2e^- \longrightarrow 2H_2O(l)$	+1.77
$O_2(g) + 2H^+(aq) + 2e^- \longrightarrow H_2O_2(aq)$	+0.68
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$	+1.23

5 (a) Identify the most powerful reducing agent from all the species in the table.

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(1 mark)

5 (b) Use data from the table to explain why chlorine should undergo a redox reaction with water. Write an equation for this reaction.

Explanation ....

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Equation ....

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(2 marks)

5 (c) Suggest **one** reason why the redox reaction between chlorine and water does **not** normally occur in the absence of light.

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(1 mark)

5 (d) Use the appropriate half-equation from the table to explain in terms of oxidation states what happens to hydrogen peroxide when it is reduced.

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(2 marks)

Do not write outside the box

5 (e) Use data from the table to explain why one molecule of hydrogen peroxide can oxidise another molecule of hydrogen peroxide. Write an equation for the redox reaction that occurs.

Explanation ....

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Equation ....

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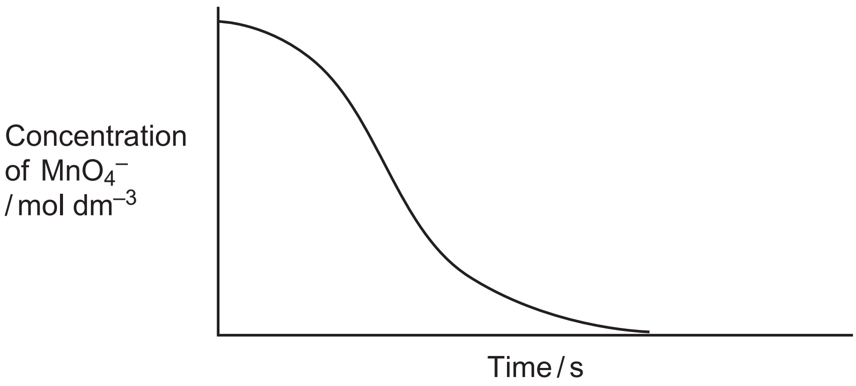
(2 marks)

8

Turn over for the next question

6 An acidified solution of potassium manganate(VII) was reacted with a sample of sodium ethanedioate at a constant temperature of 60 °C. The concentration of the manganate(VII) ions in the reaction mixture was determined at different times using a spectrometer to measure the light absorbed.

The following results were obtained.



6 (a) Write an equation for the reaction between manganate(VII) ions and ethanedioate ions in acidic solution.

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(2 marks)

(Extra space) ....

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6 (b) By considering the properties of the reactants and products, state why it is possible to use a spectrometer to measure the concentration of the manganate(VII) ions in this reaction mixture.

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(2 marks)

Do not write outside the box

6 (c) This reaction is autocatalysed. Give the meaning of the term *autocatalyst*.
Explain how the above curve indicates clearly that the reaction is autocatalysed.

Meaning of *autocatalyst* ....

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Explanation ....

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(3 marks)

6 (d) Identify the autocatalyst in this reaction.

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(1 mark)

6 (e) Write **two** equations to show how the autocatalyst is involved in this reaction.

Equation 1 ....

Equation 2 ....

(2 marks)

10

Turn over for the next question

Section B

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

7 Due to their electron arrangements, transition metals have characteristic properties including catalytic action and the formation of complexes with different shapes.

7 (a) Give **two other** characteristic properties of transition metals. For each property, illustrate your answer with a transition metal of your choice.

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(4 marks)

7 (b) Other than octahedral, there are several different shapes shown by transition metal complexes. Name **three** of these shapes and for each one give the formula of a complex with that shape.

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(6 marks)

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7 (c) It is possible for Group 2 metal ions to form complexes. For example, the $[Ca(H_2O)_6]^{2+}$ ion in hard water reacts with $EDTA^{4-}$ ions to form a complex ion in a similar manner to hydrated transition metal ions. This reaction can be used in a titration to measure the concentration of calcium ions in hard water.

7 (c) (i) Write an equation for the equilibrium that is established when hydrated calcium ions react with $EDTA^{4-}$ ions.

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(1 mark)

7 (c) (ii) Explain why the equilibrium in part **(c) (i)** is displaced almost completely to the right to form the EDTA complex.

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(3 marks)

7 (c) (iii) In a titration, 6.25 cm^3 of a 0.0532 mol dm^{-3} solution of EDTA reacted completely with the calcium ions in a 150 cm^3 sample of a saturated solution of calcium hydroxide. Calculate the mass of calcium hydroxide that was dissolved in 1.00 dm^3 of the calcium hydroxide solution.

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(3 marks)

(Extra space) ....

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17

Turn over ▶

Do not write outside the box

8 In its reactions with transition metal ions, ammonia can act as a Brønsted–Lowry base and as a Lewis base.

8 (a) Define the term *Lewis base*.

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(1 mark)

8 (b) Write an equation for a reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Brønsted–Lowry base. State what you would observe.

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(2 marks)

(Extra space) ....

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8 (c) Write an equation for a different reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Lewis base but **not** as a Brønsted–Lowry base. State what you would observe.

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(2 marks)

(Extra space) ....

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8 (d) An excess of dilute ammonia solution is added to an aqueous solution containing iron(II) ions in a test tube that is then left to stand for some time.
State and explain what you would observe.

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(4 marks)

(*Extra space*) ....

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8 (e) Diaminoethane ($H_2NCH_2CH_2NH_2$), like ammonia, can react as a base and as a ligand.

8 (e) (i) Write an equation for the reaction that occurs between an aqueous solution of aluminium chloride and an excess of aqueous diaminoethane.
Describe the appearance of the aluminium-containing reaction product.

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(3 marks)

(Extra space) ....

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Question 8 continues on the next page

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8 (e) (ii) Write an equation for the reaction that occurs between an aqueous solution of cobalt(II) sulfate and an excess of aqueous diaminoethane.
Draw a diagram to show the shape of and bonding in the complex product.
Write an equation for the reaction that would occur if the complex product of this reaction were allowed to stand in contact with oxygen gas.

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(5 marks)

17

END OF QUESTIONS

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