

Centre Number						Candidate Number				
Surname										
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Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
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**.



J A N 1 2 C H E M 5 0 1

WMP/Jan12/CHEM5

CHEM5

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.

	$\Delta H^\ominus/\text{kJ mol}^{-1}$
First electron affinity of oxygen (formation of $\text{O}^-(\text{g})$ from $\text{O}(\text{g})$)	-142
Second electron affinity of oxygen (formation of $\text{O}^{2-}(\text{g})$ from $\text{O}^-(\text{g})$)	+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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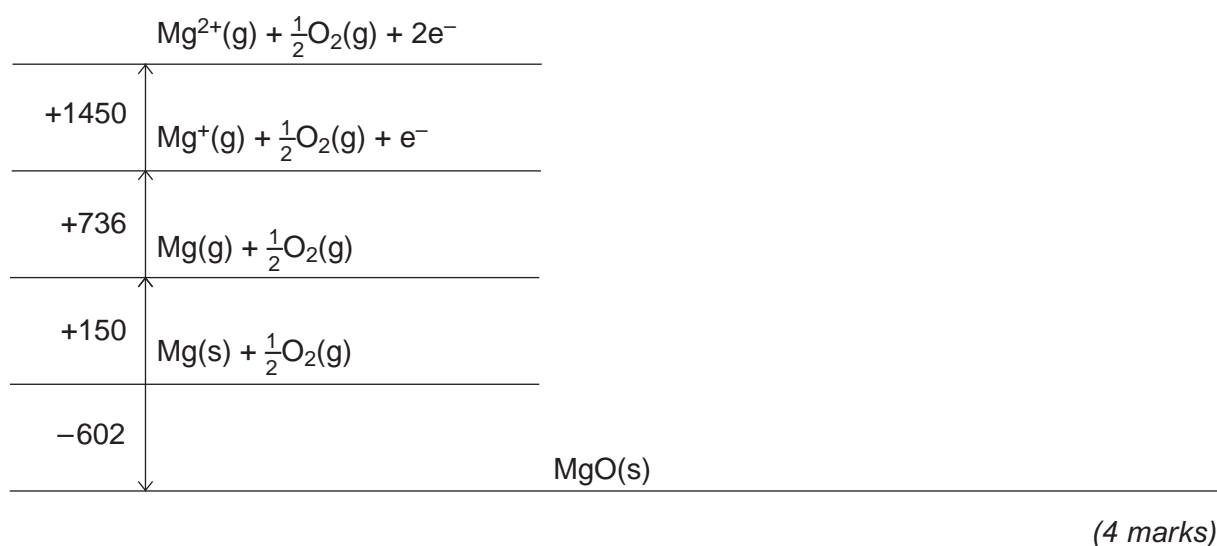
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- 1 (c)** Complete the Born–Haber cycle for magnesium oxide by drawing the missing energy levels, symbols and arrows.
The standard enthalpy change values are given in kJ mol^{-1} .



- 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 ►



- 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 ΔG_f^\ominus .

.....
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(1 mark)
(Extra space)

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

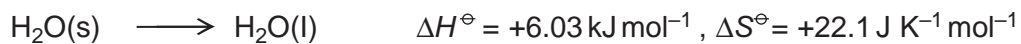
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(3 marks)
(Extra space)

- 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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.....
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(2 marks)



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



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

.....

 (1 mark)

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

.....

 (2 marks)

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

.....

 (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.

.....

 (1 mark)

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

.....

 (2 marks)

9

Turn over ►



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

	Na ₂ O	P ₄ O 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

.....

(2 marks)

(Extra space)

.....

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

.....

(2 marks)

(Extra space)

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- 3 (b)** Explain why the melting point of P₄O₁₀ is higher than the melting point of SO₂

.....

(2 marks)

(Extra space)

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- 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)

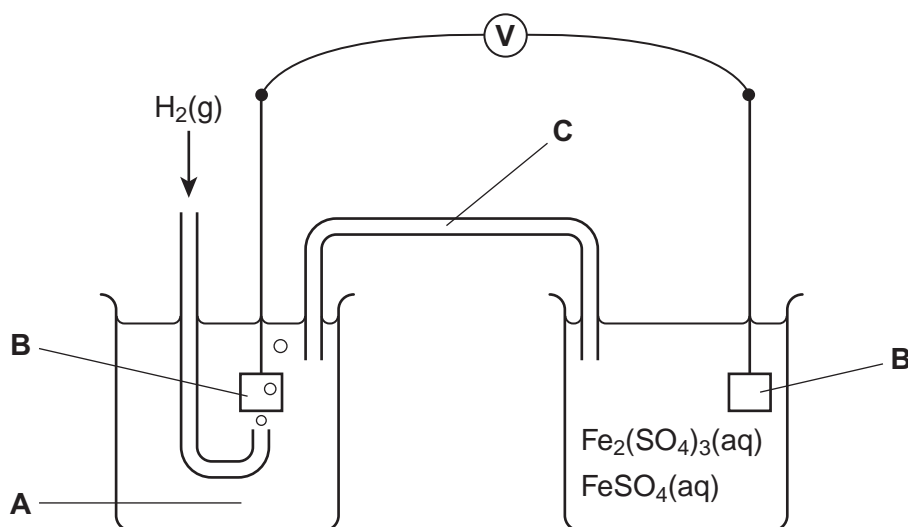
11

Turn over for the next question

Turn over ►



- 4 The diagram below shows a cell that can be used to measure the standard electrode potential for the half-reaction $\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \longrightarrow \text{Fe}^{2+}(\text{aq})$. 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

.....

.....

(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

.....

Reason 2

.....

(3 marks)



- 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

.....

Reason 2

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(3 marks)

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

.....

(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

Turn over ►



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

Electrode half-equation	E^\ominus / V
$\text{Cl}_2(\text{aq}) + 2\text{e}^- \longrightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$2\text{HOCl}(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cl}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+1.64
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$	+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)



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

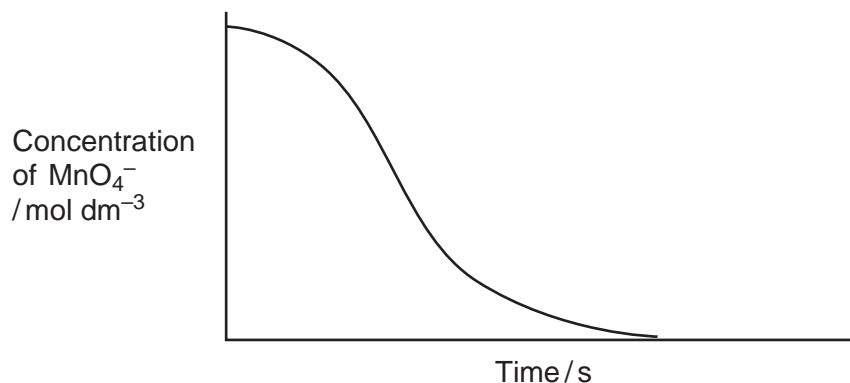
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- 6** An acidified solution of potassium manganate(VII) was reacted with a sample of sodium ethanedioate at a constant temperature of 60 °C. The concentration of the manganate(VII) ions in the reaction mixture was determined at different times using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



- 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

Turn over ►



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)



7 (c) It is possible for Group 2 metal ions to form complexes. For example, the $[\text{Ca}(\text{H}_2\text{O})_6]^{2+}$ 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 $0.0532 \text{ mol dm}^{-3}$ 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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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 ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) and ammonia in which ammonia acts as a Brønsted–Lowry base. State what you would observe.

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(2 marks)

(Extra space)

8 (c) Write an equation for a different reaction between aqueous copper(II) ions ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) 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)

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