OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY 2815/01

Trends and Patterns

Friday **23 JANUARY 2004** Afternoon 1 hour

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry
Scientific calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- You may use the *Data Sheet for Chemistry*.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu	Max.	Mark
1	15	
2	7	
3	9	
4	14	
TOTAL	45	

This question paper consists of 11 printed pages and 1 blank page.

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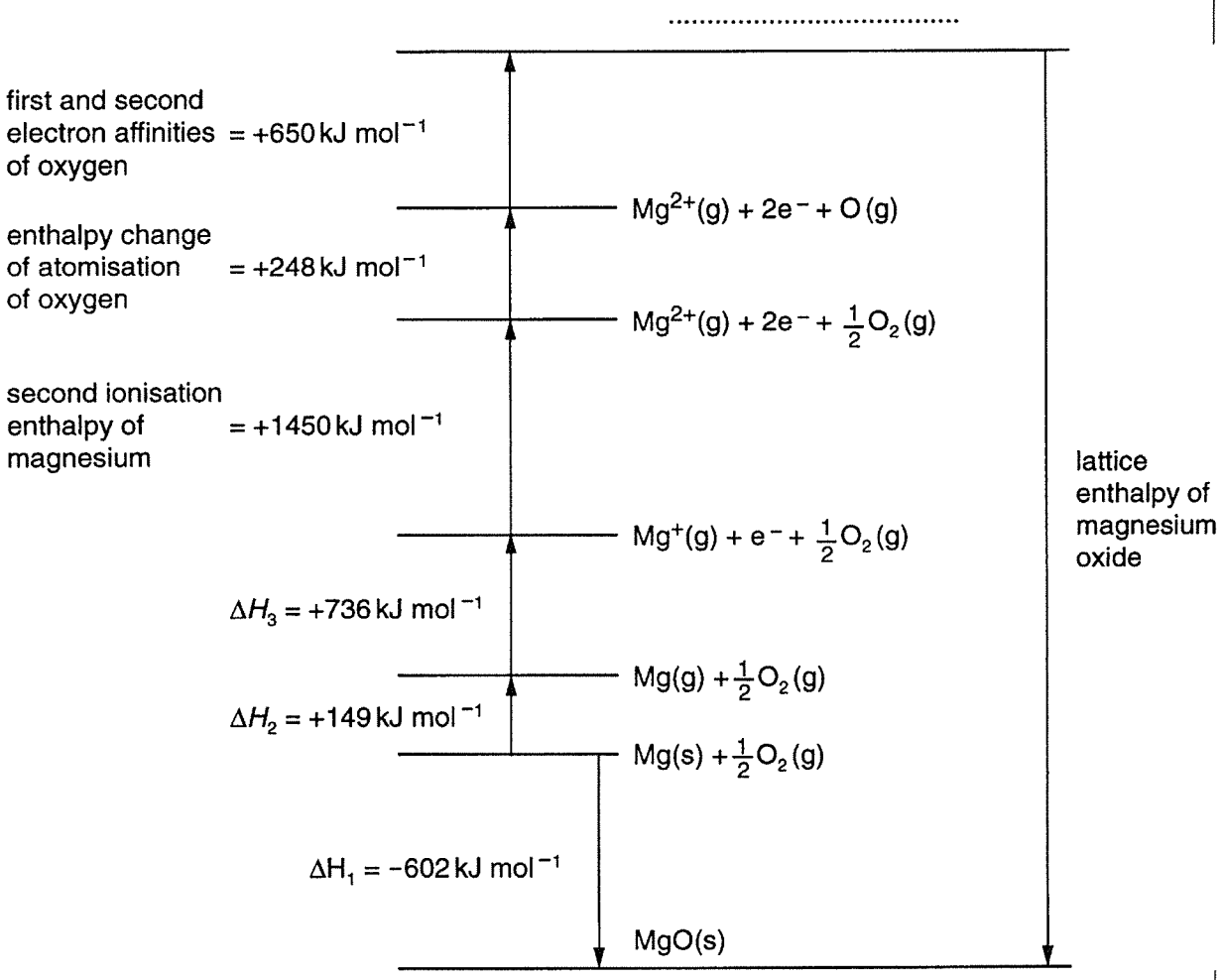
[Turn over

For Examiner's Use

Answer **all** the questions.

1 The Born-Haber cycle below can be used to calculate the lattice enthalpy for magnesium oxide.



(a) (i) Write down the name for each of the following enthalpy changes.

ΔH_1 .....

ΔH_2 .....

ΔH_3 .....[3]

(ii) Write down the missing formulae on the dotted line at the **top** of the Born-Haber cycle. Include state symbols. [1]

(iii) The equations representing the first and second electron affinities for oxygen are shown below.

$$O(g) + e^- \longrightarrow O^-(g) \qquad \Delta H = -141\ kJ\ mol^{-1}$$
$$O^-(g) + e^- \longrightarrow O^{2-}(g) \qquad \Delta H = +791\ kJ\ mol^{-1}$$

Suggest why the enthalpy change for the second of these processes is positive.

.....

.....[1]

(b) (i) Use the Born-Haber cycle to calculate the lattice enthalpy of magnesium oxide.

answer ..... kJ mol^{-1} [2]

(ii) Describe how, and explain why, the lattice enthalpy of magnesium oxide differs from that of barium oxide.

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.....[3]

(c) Give **one** reason why magnesium oxide is a good material to make the lining of a furnace.

.....[1]

[Turn over

2 Copper is a typical transition element.

- It forms coloured compounds.
- It forms complex ions.
- It has more than one oxidation state in its compounds.

(a) State **one** other typical property of a transition element.

.....[1]

(b) Dilute aqueous copper(II) sulphate is a blue solution containing $[Cu(H_2O)_6]^{2+}$ ions. A ligand substitution involving $[Cu(H_2O)_6]^{2+}$ is shown below.

$$\underset{\text{blue solution}}{[Cu(H_2O)_6]^{2+}} \xrightarrow{\text{reagent X}} \underset{\text{yellow solution}}{[CuCl_4]^{2-}}$$

(i) Suggest a shape for the $[CuCl_4]^{2-}$ ion. Include the bond angles in your diagram.

[2]

(ii) State the **formula** of the ligand in $[CuCl_4]^{2-}$.

.....[1]

(iii) State the name or formula of reagent **X**.

.....[1]

(iv) Explain, with the aid of a balanced equation, what is meant by the term *ligand substitution*.

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.....[2]

[Total: 7]

3 Aqueous hydrogen peroxide, H_2O_2, is used to sterilise contact lenses.
H_2O_2 decomposes to make oxygen and water as shown in the equation.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$$

(a) Decomposition of hydrogen peroxide is a redox reaction.
Use oxidation numbers to show that oxidation and reduction take place.

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.....[2]

(b) The concentration of an aqueous solution of hydrogen peroxide can be determined by titration. Aqueous potassium manganate(VII), $KMnO_4$, is titrated against a solution of hydrogen peroxide in the presence of acid.

The half-equation for the oxidation of H_2O_2 is as follows.

$$H_2O_2(aq) \longrightarrow O_2(g) + 2H^+(aq) + 2e^-$$

The half-equation for the reduction of acidified MnO_4^- is as follows.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \longrightarrow Mn^{2+}(aq) + 4H_2O(l)$$

(i) Construct the equation for the reaction between H_2O_2, MnO_4^- ions and H^+ ions.

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.....[2]

(ii) A student takes a 25.0 cm^3 sample of aqueous hydrogen peroxide and places this into a conical flask and then adds sulphuric acid to acidify the hydrogen peroxide.

The student titrates this sample of acidified hydrogen peroxide against a solution containing 0.0200 mol dm^{-3} $MnO_4^-(aq)$ ions. For complete reaction with the acidified hydrogen peroxide, the student uses 17.5 cm^3 of this solution containing $MnO_4^-(aq)$ ions.

Calculate the concentration, in mol dm^{-3}, of the aqueous hydrogen peroxide.

2 mol MnO_4^- reacts with 5 mol H_2O_2.

concentration ..... mol dm^{-3} [3]

(c) Acidified hydrogen peroxide oxidises $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$.

Describe a simple chemical test to show the presence of $Fe^{3+}(aq)$.

name of reagent used .....

observation .....

.....[2]

[Total: 9]

2 A cell can be constructed between a Ni^{2+}/Ni half-cell and an I_2/I^- half-cell.

(a) Draw a labelled diagram of this cell operating under standard conditions.

[5]

(b) The standard electrode potentials for the half-cells in this cell are given below.

Ni^{2+}/Ni $\quad E^{\ominus} = -0.25\,V$

I_2/I^- $\quad E^{\ominus} = +0.54\,V$

(i) What is the standard cell potential of this cell?

..... V [1]

(ii) Write equations for the reactions that occur in each half-cell.

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.....[2]

(iii) Write the overall equation for the reaction that occurs in the cell.

.....[1]

(iv) State, and explain, the direction of flow of electrons in the external circuit.

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.....[1]

[Total: 10]

For Examiner's Use

4 Titanium(IV) oxide, TiO_2, can be used as a white pigment in horseradish sauce. However, many compounds of transition elements are coloured.

(a) Complete the electronic structures of a

Ti atom $1s^2 2s^2 2p^6$ .....

Ti^{4+} ion $1s^2 2s^2 2p^6$ ..... [2]

(b) In this question, one mark is available for the quality of written communication.

Explain why compounds of transition elements are usually coloured.

Explain why titanium(IV) oxide is **not** coloured.

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.....[6]

Quality of Written Communication [1]

[Total: 9]

5 Chrome alum is used in dyeing and in tanning leather.

(a) On heating chrome alum gently, it loses its water of crystallisation. The equation for this is given below.

$$KCr(SO_4)_2.xH_2O \longrightarrow KCr(SO_4)_2 + xH_2O$$

chrome alum

It was found that when 1.73 g of chrome alum was heated, 0.75 g of water was lost.

Show that the value of x in the formula $KCr(SO_4)_2.xH_2O$ is 12.

[3]

(b) Chrome alum contains the complex ion $[Cr(H_2O)_6]^{3+}$.

(i) Draw a diagram of this complex ion showing its shape and bond angle clearly.

[2]

(ii) What name is given to this shape of complex ion?

.....[1]

(c) Another complex ion of chromium contains one chromium(III) ion, four molecules of water and two chloride ions. This complex shows *cis-trans* isomerism.

(i) Write the formula of this complex ion.

.....[1]

(ii) Draw labelled diagrams to show the *cis* and *trans* isomers of this complex ion.

[3]

[Total: 10]

END OF QUESTION PAPER

Answer **all** the questions.

1 The formation of ethyl ethanoate and water from ethanoic acid and ethanol is a reversible reaction which can be allowed to reach equilibrium. The equilibrium is shown below.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(a) Write the expression for K_c for this equilibrium system.

[2]

(b) A student mixed together 6.0 mol ethanoic acid and 12.5 mol ethanol. A small amount of hydrochloric acid was also added to catalyse the reaction. He left the mixture for two days to reach equilibrium in a water bath at constant temperature, after which time 1.0 mol ethanoic acid remained.

(i) Complete the table below to show the equilibrium composition of the equilibrium mixture.

component	CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O
initial amount / mol	6.0	12.5	0.0	0.0
equilibrium amount / mol				

[2]

(ii) Calculate K_c to two significant figures. State the units, if any. The total volume of the equilibrium mixture is 1.0 dm^3.

K_c = ... units ..... [2]

(c) The student was concerned that the mixture may **not** have reached equilibrium. What could he do to be sure that equilibrium had been reached?

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.....[2]

(d) The student added more ethanol to the mixture.

(i) State, giving a reason, what would happen to the composition of the equilibrium mixture.

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.....[2]

(ii) What happens to the value of K_c?

.....[1]

(e) The student added more of the acid catalyst to the mixture.
State, giving a reason, what would happen to the composition of the equilibrium mixture.

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.....[2]

(f) The student repeated the experiment at a higher temperature and found that the value of K_c decreased.

(i) State, giving a reason, what would happen to the composition of the equilibrium mixture.

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.....[2]

(ii) What additional information does this information tell you about the reaction?

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.....[1]

[Total: 16]

2 Hydrogen peroxide, H_2O_2, is a colourless liquid, widely used as an oxidising agent, antiseptic, and bleach for hair and cloth.

Hydrogen peroxide reacts with iodide ions, I^-, in the presence of acid, $H^+(aq)$, forming iodine, I_2.

(a) Suggest a balanced equation for the overall reaction between $H_2O_2(aq)$, $I^-(aq)$ and $H^+(aq)$ to form aqueous iodine.

.....[2]

(b) Three experiments were carried out using different initial concentrations of $H_2O_2(aq)$, $I^-(aq)$ and $H^+(aq)$. The initial rate of formation of I_2 was measured for each experiment.

The experimental results are shown below.

experiment	$[H_2O_2(aq)]$ /mol dm^{-3}	$[I^-(aq)]$ /mol dm^{-3}	$[H^+(aq)]$ /mol dm^{-3}	rate /mol dm^{-3} s^{-1}
1	0.010	0.010	0.005	1.15×10^{-6}
2	0.010	0.020	0.005	4.60×10^{-6}
3	0.010	0.020	0.010	4.60×10^{-6}

(i) Showing all your reasoning, determine the reaction orders for I^- and for H^+.

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.....[4]

(ii) This reaction is first order with respect to H_2O_2.
Use this information and your answers to **(i)** to complete the rate equation for this reaction.

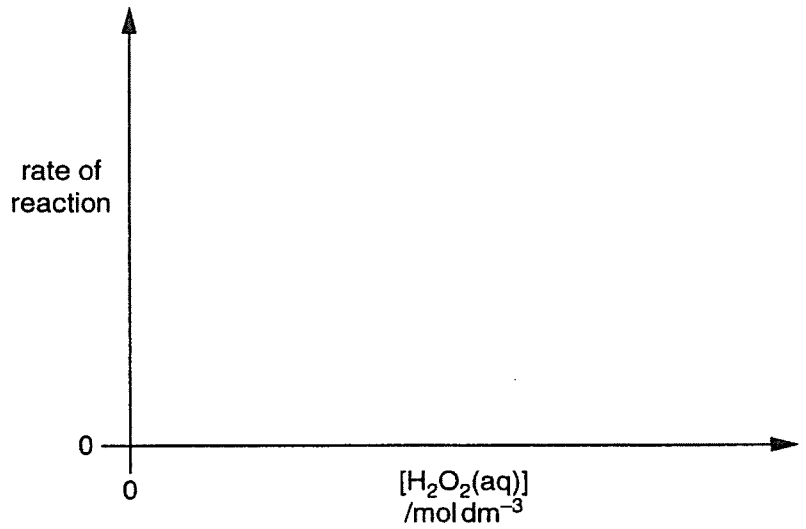
rate = ...[2]

(iii) Calculate the rate constant *k* for this reaction. State the units for *k*.

rate constant, *k* ..... units ..... [3]

(c) This reaction was shown to be first order with respect to H_2O_2 by plotting a rate-concentration graph.

Using the axes below, sketch a graph to show how the rate of this reaction changes with increasing H_2O_2 concentration.



[2]

(d) Hydrogen peroxide readily decomposes to give water and oxygen.

Hydrogen peroxide is sold by volume strength. For example, 20-volume H_2O_2 yields 20 volumes of oxygen gas for each volume of aqueous H_2O_2 solution.

(i) Construct an equation for the decomposition of hydrogen peroxide.

.....[1]

(ii) Determine the concentration, in mol dm^{-3}, of 20-volume hydrogen peroxide.

Show all your working clearly.

answer ..... mol dm^{-3} [3]

[Total: 17]

3 Carbonic acid, H_2CO_3, is a weak Bronsted-Lowry acid formed when carbon dioxide dissolves in water. Blood contains several buffer solutions and healthy blood is buffered to a pH of 7.40. The most important buffer solution in blood is a mixture of carbonic acid and hydrogencarbonate ions, HCO_3^-.

The equilibrium in the carbonic acid / hydrogencarbonate buffer system is shown below.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad K_a = 4.17 \times 10^{-7}\,\text{mol dm}^{-3}$$

(a) Carbonic acid is a weak Bronsted-Lowry acid.

What is meant by the following terms?

(i) A *Bronsted-Lowry acid.*

.....

..... [1]

(ii) A *weak* acid.

.....

..... [1]

(iii) pH.

..... [1]

(iv) A *buffer solution.*

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..... [1]

(b) In this question, one mark is available for the quality of written communication.

Explain how the carbonic acid / hydrogencarbonate buffer works. Use equations to help your answer.

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.....[4]

Quality of Written Communication [1]

(c) Calculate the ratio $\frac{[HCO_3^-(aq)]}{[H_2CO_3(aq)]}$ in healthy blood with a pH of 7.40.

[4]

[Total: 13]