THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE
CHEMISTRY
Trends and Patterns

2815/01

Candidates answer on the question paper
A calculator may be used for this paper

OCR Supplied Materials:
- *Data Sheet for Chemistry* (Inserted)

Other Materials Required:
- Scientific calculator

Friday 23 January 2009
Morning

Duration: 1 hour

C U P / T 7 6 2 0 3

2 8 1 5 0 1

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **45**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- This document consists of **12** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	10	
2	12	
3	6	
4	17	
TOTAL	45	

Answer **all** the questions.

1 Copper is a transition element. It forms compounds in which the oxidation number of copper is +1 or +2.

(a) Complete the electronic configuration of the copper(II) ion, Cu^{2+}.

$1s^2\ 2s^2\ 2p^6$..... **[1]**

(b) Transition elements form coloured complex ions. Choose an example of a coloured complex ion in which copper has the +2 oxidation state.

(i) Write the formula of your chosen coloured copper(II) complex ion.

..... **[1]**

(ii) What is the colour of your chosen complex ion?

..... **[1]**

(iii) Name and describe the bonding between the ligand and the metal ion within your chosen complex ion.

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..... **[2]**

(c) Aqueous sodium hydroxide is added to aqueous copper(II) sulphate.

(i) Describe what you would see.

..... **[1]**

(ii) Write an ionic equation for the reaction taking place.

..... **[1]**

3 This question is about redox reactions of some compounds of transition elements.

(a) Chromium(III) ions can be oxidised by hydrogen peroxide under alkaline conditions.

The relevant half-equations are as follows.

$$H_2O_2(aq) + 2e^- \longrightarrow 2\ OH^-(aq)$$

$$Cr^{3+}(aq) + 8\ OH^-(aq) \longrightarrow CrO_4^{2-}(aq) + 4H_2O(l) + 3e^-$$

Construct the equation for the oxidation of Cr^{3+} by H_2O_2 under alkaline conditions.

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..... **[2]**

(b) In this question, one mark is available for the quality of your spelling, punctuation and grammar.

Lattice enthalpy is a measure of ionic bond strength.

- Distinguish, with the aid of equations, between the terms *lattice enthalpy* of sodium oxide and *enthalpy change of formation* of sodium oxide, Na_2O.

- Draw a labelled Born-Haber cycle. Include the names of all relevant enthalpy changes.

  Describe how the lattice enthalpy of sodium oxide can be calculated.

- Arrange the following compounds in order of their lattice enthalpies with the most exothermic first. Explain your answer.

  magnesium oxide **potassium bromide** **sodium chloride**

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[12]

Quality of Written Communication [1]

[Total: 17]

END OF QUESTION PAPER

Answer **all** the questions.

1 A student wanted to measure the standard electrode potential of:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$$

(a) (i) What is the oxidation number of Cr in the $Cr_2O_7^{2-}$ ion?

..... **[1]**

(ii) Draw a labelled diagram of the apparatus he could use. State the conditions required.

[5]

(b) The standard electrode potential of the $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ half-cell is +1.33 V.

The solution in the student's half-cell contained 1 mol dm^{-3} Cr^{3+} and H^+ but less than 1 mol dm^{-3} $Cr_2O_7^{2-}$.

Would the student's measured value be higher, lower or the same as the standard electrode potential?

Explain your answer.

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..... **[2]**

[Total: 8]

2 The following standard electrode potential data refers to different reactions involving cobalt complexes in the +2 and +3 oxidation states.

$$[Co(H_2O)_6]^{3+} + e^- \rightleftharpoons [Co(H_2O)_6]^{2+} \qquad E^{\ominus} = +1.81\,V$$

$$[Co(NH_3)_6]^{3+} + e^- \rightleftharpoons [Co(NH_3)_6]^{2+} \qquad E^{\ominus} = +0.11\,V$$

(a) Which cobalt complex is the strongest oxidising agent? Explain your answer.

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..... **[3]**

(b) What is the colour of $[Co(H_2O)_6]^{2+}$?

..... **[1]**

(c) $[Co(NH_3)_6]^{3+}$ ions may be reduced to $[Co(NH_3)_6]^{2+}$ by metallic iron, which is oxidised to Fe^{2+}.

$$Fe^{2+} + 2e^- \rightleftharpoons Fe \qquad E^{\ominus} = -0.44\,V$$

Write a balanced chemical equation for this reaction and show that the reaction is feasible.

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..... **[2]**

[Total: 6]

3

(d) Copper is widely used to make alloys such as brass. The % of copper in a sample of brass can be determined by titration.

- 1.65 g of brass were reacted with nitric acid and the resulting solution was neutralised and made up to 250 cm^3 in a standard flask;
- Excess KI was added to 25.0 cm^3 of this solution;
- The resulting solution required 19.80 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$ solution to react with the iodine produced.

The equations for the reactions involved are;

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

$$I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$$

Determine the % of copper in the sample of brass.

% copper in sample ..... % **[5]**

[Total: 14]

4 The complex ion, $[Co(NH_3)_4Cl_2]^+$ shows a form of stereoisomerism.

(a) What type of stereoisomerism does $[Co(NH_3)_4Cl_2]^+$ show?

..... **[1]**

(b) Draw 3-D diagrams to show the two isomers of $[Co(NH_3)_4Cl_2]^+$.

[2]

(c) The complex ion $[Co(en)_2Cl_2]^+$ shows a different type of stereoisomerism.

Name this type of stereoisomerism and draw 3-D diagrams of the two isomers.

name of type of stereoisomerism ..... **[1]**

[2]

[Total: 6]

5 In this question, one mark is available for the quality of use and organisation of scientific terms.

Transition metal complexes typically show four-fold and six-fold co-ordination.

Using suitable examples:

- State what is meant by co-ordination number;
- Discuss the possible shapes and bond angles of four and six co-ordinated complexes;
- Show how ligand exchange can result in a change in the co-ordination number, shape and charge of a complex ion.

Diagrams and equations should be used to illustrate your answer.

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[10]

Quality of Written Communication [1]

[Total: 11]

END OF QUESTION PAPER

Answer **all** the questions.

1 The decomposition of gaseous hydrogen iodide to form hydrogen and iodine gases is a reversible reaction.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

(a) Write the expression for K_c for an equilibrium mixture of these three gases.

[1]

(b) A student added 0.50 mol HI(g) to a 1.0 dm^3 container. The container was sealed and the contents were allowed to reach equilibrium at constant temperature.

The student then analysed the equilibrium mixture and found that 0.11 mol $I_2(g)$ was present.

(i) Complete the table below to show the amount of each gas in the equilibrium mixture.

gas	HI(g)	$H_2(g)$	$I_2(g)$
initial amount / mol	0.50	0.00	0.00
equilibrium amount / mol			0.11

[2]

(ii) Calculate K_c to an appropriate number of significant figures. State the units, if any.

K_c = ... units, if any ..... **[3]**

(c) The student compressed the equilibrium mixture so that its volume was reduced. The temperature was kept constant.

Comment on the value of K_c and the composition of the equilibrium mixture under these new conditions.

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..... **[2]**

(d) The student repeated the experiment at a higher temperature and found that more $I_2(g)$ was present at equilibrium.

Comment on the value of K_c and explain what additional information this tells you about the reaction.

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..... **[2]**

(e) Hydrogen iodide gas is mixed with chlorine gas.

Two reactions take place forming different compounds of iodine, **A** and **B**.

Compounds **A** and **B** each contain I and C*l* only.

- In the first reaction, compound **A** forms as a reddish brown liquid. Compound **A** contains 78.15% of I by mass.
- In the second reaction, compound **B** forms as yellow crystals. Compound **B** has a molar mass of 467 g mol^{-1}.

Deduce possible identities for **A** and **B** and write balanced equations for their formation.

A: .....

equation: .....

B: .....

equation: ..... **[5]**

[Total: 15]

2 The reaction between nitrogen monoxide, NO, and oxygen, O_2, has the following rate equation.

$$\text{rate} = k[NO(g)]^2[O_2(g)]$$

(a) What is the overall order of this reaction?

..... **[1]**

(b) The reaction rate is 6.90×10^{-7} mol dm^{-3} s^{-1} when

- the concentration of NO(g) is 2.80×10^{-4} mol dm^{-3}
- the concentration of $O_2(g)$ is 1.44×10^{-3} mol dm^{-3}.

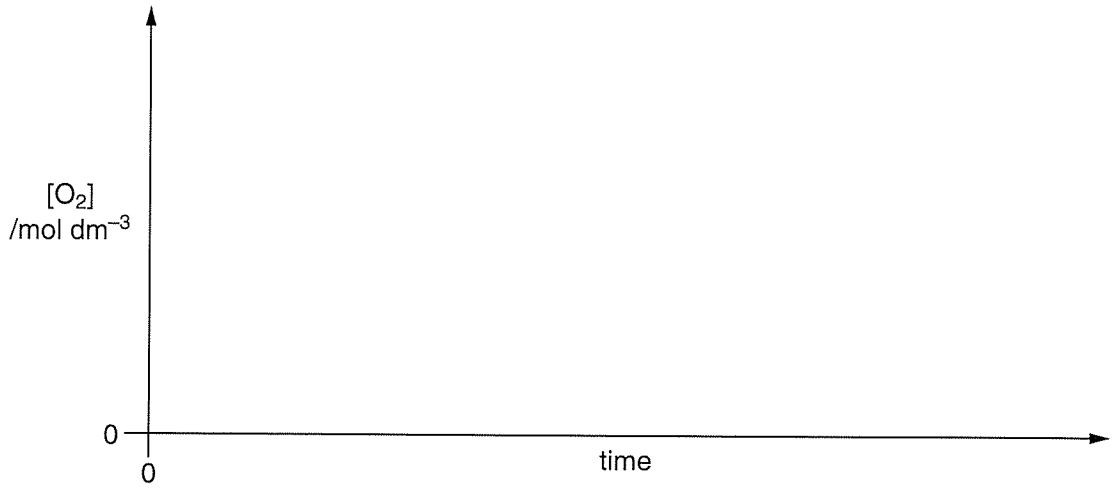
Calculate the rate constant, k, for this reaction. State the units.

Give your answer to an appropriate number of significant figures.

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

(c) The rate equation was determined experimentally.

(i) On the axes below, sketch a graph to show how the concentration of O_2 changes during the course of the reaction.



[1]

(ii) Explain how you would use the graph to determine the **initial** rate of the reaction.

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..... **[2]**

(iii) How could you use the graph to confirm that the reaction is first order with respect to O_2?

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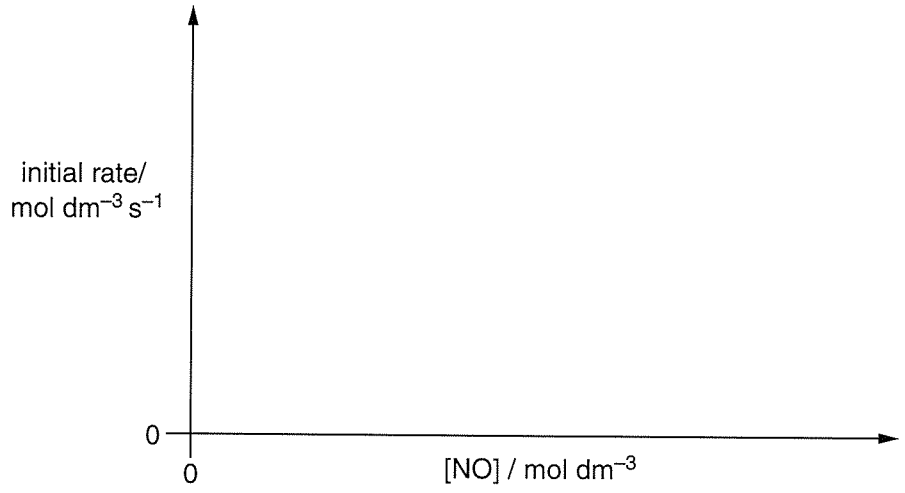
..... **[1]**

(d) The experiment was repeated using different initial concentrations of NO.

(i) Using the axes below, sketch a graph to show how the initial rate of the reaction would change with different initial concentrations of NO.



[1]

(ii) Predict, with a reason, what would happen to the rate when the initial concentration of NO(g) is tripled.

effect on rate: .....

reason: .....

..... **[2]**

(iii) Predict what would happen to the rate when the initial concentration of NO(g) is doubled **and** the initial concentration of O_2(g) is tripled.

effect on rate: ..... **[1]**

[Total: 12]

3 Sulphur dioxide is used as a wine preservative. Sulphur dioxide reacts with water forming sulphurous acid, H_2SO_3.

H_2SO_3 is a weak Brønsted–Lowry acid.

$$H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq) \qquad K_a = 1.50 \times 10^{-3}\ \text{mol dm}^{-3} \text{ at } 25\,^\circ\text{C}$$

(a) What is the value of pK_a for H_2SO_3 at 25 °C?

pK_a = ... **[1]**

(b) **(i)** Write an expression for K_a for the equilibrium above.

[1]

(ii) Use the expression for K_a from **(i)** to calculate the pH of a 0.0265 mol dm^{-3} aqueous solution of H_2SO_3 at 25 °C.

[3]

(iii) The measured pH of 0.0265 mol dm^{-3} sulphurous acid at 25 °C is slightly lower than the pH value calculated using the expression above.

Suggest a reason for this difference.

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..... **[1]**

(c) The constant K_w has a value of 1.00×10^{-14} mol^2 dm^{-6} at 25 °C.

(i) What name is commonly given to K_w?

..... **[1]**

(ii) Write the expression for K_w.

K_w = ... **[1]**

(d) In aqueous solution, potassium hydroxide acts as a strong alkali.

Calculate the pH of 0.0265 mol dm^{-3} KOH(aq) at 25 °C. Show your working.

[2]

(e) A student mixed 25.0 cm^3 0.0265 mol dm^{-3} H_2SO_3(aq) with 25.0 cm^3 0.0265 mol dm^{-3} KOH(aq).

- The student evaporated the water from the solution and obtained a solid **C**.

The student then mixed together 25.0 cm^3 0.0265 mol dm^{-3} H_2SO_3(aq) with 50.0 cm^3 0.0265 mol dm^{-3} KOH(aq).

- The student evaporated the water from the solution and obtained a solid **D**.

Deduce the formulae of compounds **C** and **D**.

Write equations for their formation from KOH(aq) and H_2SO_3(aq).

formula of compound **C**: .....

equation: .....

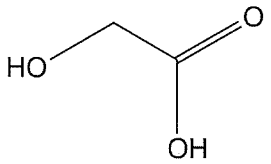
formula of compound **D**: .....

equation: ..... **[4]**

[Total: 14]

4 Alpha-hydroxy-acids (AHAs) are used in skin-care products. For effective treatment of the skin, it is important that the pH of cosmetics is closely controlled. Products are sold in a buffered form with different pH ranges for different uses.

Glycolic acid, shown below, is used as an AHA in many cosmetics.



glycolic acid

(a) Deduce the molecular formula of glycolic acid.

..... **[1]**

(b) Glycolic acid is manufactured in two stages.

- **Stage 1** Chloroethanoic acid, $ClCH_2COOH$, is reacted with aqueous sodium hydroxide.
- **Stage 2** The resulting solution is acidified.

Write equations for each stage in the manufacture of glycolic acid.

Stage 1:

Stage 2:

[3]

(c) In this question, one mark is available for the quality of use and organisation of scientific terms.

A glycolic acid skin-care product has a buffered pH of 4.4.
The buffer contains a solution of glycolic acid and its sodium salt, sodium glycolate.

- Explain what a buffer is and how **this** buffer system works. Include equations in your answer.
- Calculate the proportions of glycolic acid and sodium glycolate in this skin-care product.

Glycolic acid has a K_a value of 1.48×10^{-4} mol dm^{-3}.

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Quality of Written Communication [1]

TURN OVER FOR QUESTION 4(d)