OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY 2815/01

Trends and Patterns

Tuesday **29 JUNE 2004** Morning 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	11	
2	14	
3	7	
4	13	
TOTAL	45	

This question paper consists of 10 printed pages and 2 blank pages.

Registered Charity Number: 1066969
[Turn over

2 Aqueous iron(III) chloride contains the complex ion, $[Fe(H_2O)_6]^{3+}$.

(a) Draw the shape of the complex ion $[Fe(H_2O)_6]^{3+}$. Label the bond angles on your diagram.

[2]

(b) Explain how the water molecules are bonded to the metal ion in $[Fe(H_2O)_6]^{3+}$.

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.....[2]

(c) Aqueous iron(III) chloride, $FeCl_3$, reacts with aqueous ammonium thiocyanate, NH_4SCN, to give a blood-red solution.
A ligand substitution reaction occurs to form a complex with the formula $[Fe(SCN)_x(H_2O)_y]^{2+}$.

The formula of this complex ion can be determined using colorimetry.

- A student makes up six different mixtures of 0.0500 mol dm^{-3} $FeCl_3$(aq) and 0.100 mol dm^{-3} NH_4SCN(aq).
- The student places each mixture into a colorimeter and measures the absorbance of each mixture.

The table below shows the absorbance of each mixture.

mixture	one	two	three	four	five	six
volume of 0.0500 mol dm^{-3} $FeCl_3$(aq) / cm^3	4.0	8.0	12.0	16.0	18.0	19.0
volume of 0.100 mol dm^{-3} NH_4SCN(aq) / cm^3	16.0	12.0	8.0	4.0	2.0	1.0
absorbance	0.23	0.46	0.68	0.46	0.23	0.11

(d) Another complex of iron is used as an anti-caking agent in table salt. Analysis of a sample of this complex shows that it contains 547 mg of potassium, 195 mg of iron, 252 mg of carbon and 294 mg of nitrogen.

(i) Calculate the empirical formula of the complex.

answer .....[2]

(ii) The complex is a potassium salt. The complex anion present has an octahedral shape and has iron in the +2 oxidation state. Suggest a possible formula for the complex ion.

.....[1]

[Total: 14]

3 Sunglasses can be made from photochromic glass. Photochromic glass contains small amounts of silver chloride, AgC*l*, and copper(I) chloride, CuC*l*.

When bright light strikes photochromic glass, silver chloride decomposes to make silver atoms and chlorine atoms. This makes the glass darken. The chlorine atoms immediately react with copper(I) chloride to make copper(II) chloride.

When the exposure to bright light ends, silver atoms reduce copper(II) chloride back into copper(I) chloride and the glass lightens.

(a) Suggest which substance is formed to give the glass its dark colour.

.....[1]

(b) A sample of photochromic glass containing 0.0287 g of AgC*l* is placed in bright sunlight. Calculate the maximum mass, in g, of chlorine atoms that can be formed.

answer .....g [1]

(c) (i) Construct the equation for the reaction between silver and copper(II) chloride.

.....[1]

(ii) Use oxidation states to explain why this reaction involves both oxidation **and** reduction.

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.....[2]

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

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

(ii) Use the electronic configuration to explain why copper is a transition element.

.....

.....[1]

[Total: 7]

For Examiner's Use

4 In this question, one mark is available for the quality of written communication.

Lattice enthalpy is used to compare the strengths of ionic bonds.

- Define the term *lattice enthalpy*.
- Describe and explain the effect of ionic charge and ionic radius on the magnitude of a lattice enthalpy.
- Explain the trend in thermal decomposition of the carbonates of Group 2 elements.

[12]

QWC = [1]

TOT = [13]

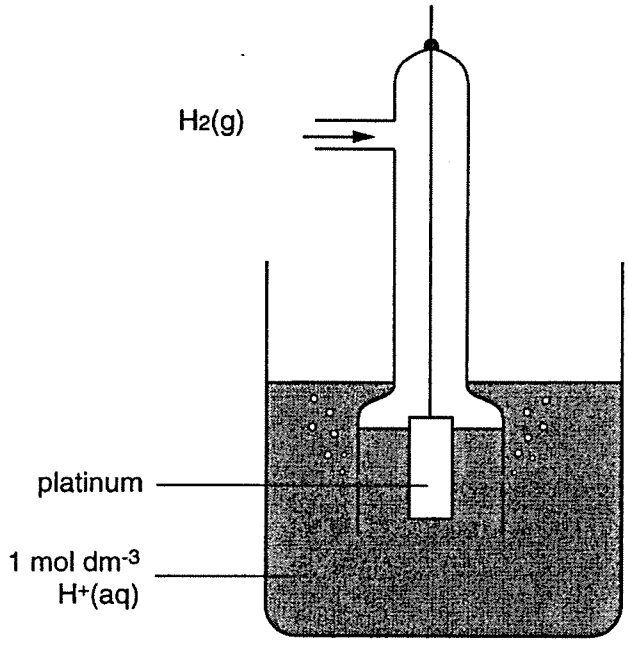
Answer **all** the questions.

1 Common chromium-containing ions include dichromate(VI), $Cr_2O_7^{2-}$, and chromium(III), Cr^{3+}. Dichromate(VI) can be converted to chromium(III) in a redox reaction.

(a) State the colour change that takes place in this conversion.

Colour change from ..... to ..... [2]

(b) **(i)** Complete the diagram below of a cell to measure an electrode potential for the $Cr_2O_7^{2-}/Cr^{3+}$ system. Label the diagram.



[4]

(ii) What conditions are needed to measure the **standard** electrode potential of the $Cr_2O_7^{2-}/Cr^{3+}$ system?

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.....[3]

(c) The half-equations for the reactions involved in the cell are shown below.

$$H^+ + e^- \rightleftharpoons \tfrac{1}{2}H_2 \qquad E^\ominus = 0.00V$$

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O \qquad E^\ominus = +1.33V$$

Use these data to derive the equation for the overall reaction that occurs in the cell.

[2]

(d) The concentration of $Cr_2O_7^{2-}$ ions is increased and all other concentrations are kept constant. The cell potential increases.

Suggest why the cell potential increases in terms of the equilibria involved.

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.....[2]

[Total: 13]

3 This question is concerned with complexes formed by transition metals.

(a) For each of the following complexes, state the co-ordination number and the oxidation state of the metal present.

formula	co-ordination number	oxidation state
$[Ni(H_2O)_6]^{2+}$	.....	.....
$CuCl_2^-$	.....	.....

[4]

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

Transition metal complexes can show *cis-trans* and optical isomerism.

Discuss what is meant by *cis-trans* and optical isomerism in transition metal complexes.

For each type of isomerism give **one** example and labelled diagrams.

For Examiner's Use

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.....[9]

Quality of Written Communication [1]

[Total: 14]

Turn over for question 4

4 The equations below show some reactions of transition metal ions.

$$Zn^{2+} + 2OH^- \longrightarrow Zn(OH)_2$$

$$CoCl_4^{2-} + 6NH_3 \rightleftharpoons [Co(NH_3)_6]^{2+} + 4Cl^-$$

$$2CrO_4^{2-} + 2H^+ \rightleftharpoons Cr_2O_7^{2-} + H_2O$$

$$2Cu^+ \longrightarrow Cu^{2+} + Cu$$

(a) Use **one** of these equations to describe what is meant by a redox reaction.

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.....[3]

(b) Use **one** of these equations to explain what is meant by a ligand exchange reaction.

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.....[3]

[Total: 6]

END OF QUESTION PAPER

Answer **all** the questions.

1 In an experiment, maltose, $C_{12}H_{22}O_{11}$, was hydrolysed to form glucose, $C_6H_{12}O_6$. The hydrochloric acid behaves as a catalyst for this reaction.

$$\underset{\textbf{maltose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{H^+ \text{ catalyst}} 2\underset{\textbf{glucose}}{C_6H_{12}O_6(aq)}$$

This reaction was carried out several times using different concentrations of maltose and of hydrochloric acid. The initial rate of each experimental run was calculated and the results are shown below. In each case, initial concentrations are shown.

experiment	$[C_{12}H_{22}O_{11}(aq)]$ /mol dm^{-3}	$[HCl(aq)]$ /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1	0.10	0.10	0.024
2	0.20	0.10	0.048
3	0.10	0.15	0.036

(a) (i) Suggest what is meant by the *initial* rate of reaction.

.....

.....[1]

(ii) The initial rates measured in each experimental run are for the rate of **disappearance** of maltose.

For experiment 1, deduce the initial rate of **appearance** of glucose, in mol dm^{-3} s^{-1}.

.....mol dm^{-3} s^{-1} [1]

(b) (i) For each reactant, deduce the order of reaction. Show your reasoning.

$C_{12}H_{22}O_{11}(aq)$ .....

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$HCl(aq)$ .....

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.....[4]

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

.....[1]

(iii) Deduce the rate equation for this reaction.

.....[2]

(c) The experiment was repeated at a higher temperature.

State whether the rate constant would increase, decrease or stay the same.

.....[1]

(d) Experiment 1 was repeated and the concentration of maltose was measured continuously until the reaction was complete.

The half-life of this reaction with respect to maltose was measured as 3 seconds.

(i) What is meant by the *half-life* of a reaction?

.....

.....[1]

(ii) Determine the concentrations of maltose and hydrochloric acid in experiment 1 after 3 seconds. In each case, explain how you have arrived at your answer.

$[C_{12}H_{22}O_{11}(aq)]$ .....

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[HCl(aq)] .....

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.....[3]

[Total: 14]

2 **Equilibrium 1**, shown below, exists between $N_2(g)$, $O_2(g)$ and NO(g).

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \textbf{equilibrium 1}$$

The equilibrium constant K_c for this reaction is 4.8×10^{-31} at 25 °C.

(a) **(i)** Write the expression for the equilibrium constant, K_c, for **equilibrium 1**.

[2]

(ii) What does the value of K_c tell you about the equilibrium position in **equilibrium 1** at 25 °C? Explain your reasoning.

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.....[1]

(iii) An equilibrium mixture of these three gases had the following equilibrium concentrations: 1.1 mol dm^{-3} $N_2(g)$ and 4.0×10^{-16} mol dm^{-3} NO(g).

Calculate the equilibrium concentration of $O_2(g)$.

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

(b) In a car, nitrogen and oxygen gases in the air are drawn into the engine. The high temperature inside a working car engine increases the value of K_c for **equilibrium 1**.

(i) Deduce the sign of the enthalpy change for the forward reaction in **equilibrium 1**. Explain your reasoning.

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.....[2]

(ii) Compare the proportion of NO gas inside a working car engine to that at 25 °C. Explain your answer.

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.....[2]

(iii) In the absence of a catalytic converter, the NO gas emerges from a car exhaust and then reacts with oxygen in the air. The oxidation number of the nitrogen increases to +4.

Suggest an equation for this reaction

.....[2]

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

In industry, NO(g) is used in the manufacture of nitric acid. The production of NO(g) involves the oxidation of ammonia.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -900\,kJ\,mol^{-1}$$

The actual industrial conditions used are a temperature of about 1000 °C, a pressure of 10 atmospheres and a platinum-rhodium catalyst.

Giving reasons,

- predict the conditions required for an optimum equilibrium yield,
- suggest reasons why the actual conditions used may be different from the optimum equilibrium conditions.

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.....[7]

Quality of Written Communication [1]

[Total: 20]

3 A student carried out some practical work on acids and alkalis.

(a) He measured the pH of aqueous solutions of two acids. His results are shown in Table 3.1 below.

acid	concentration/mol dm^{-3}	pH
HBr	0.0100	2.0
CH_3COOH	0.0100	3.4

Table 3.1

(i) Define pH.

.....[1]

(ii) Compare the concentrations and pH values of the two acids in **Table 3.1**.

Explain what this tells you about the relative strengths of the two acids.

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.....[2]

(iii) The student mixed together 10 cm^3 of 0.0100 mol dm^{-3} HBr with 90 cm^3 of water.

Determine the pH of the diluted acid. Show your working.

[2]

(b) The constant K_w has a value of 1.0×10^{-14} mol^2 dm^{-6}.

(i) Define K_w by completing the expression below.

K_w = ...[1]

(ii) Calculate the pH of 0.020 mol dm^{-3} KOH(aq). Show your working.

[2]

(c) The student pipetted 20.0 cm^3 of 0.0100 mol dm^{-3} $CH_3COOH(aq)$ into a conical flask.

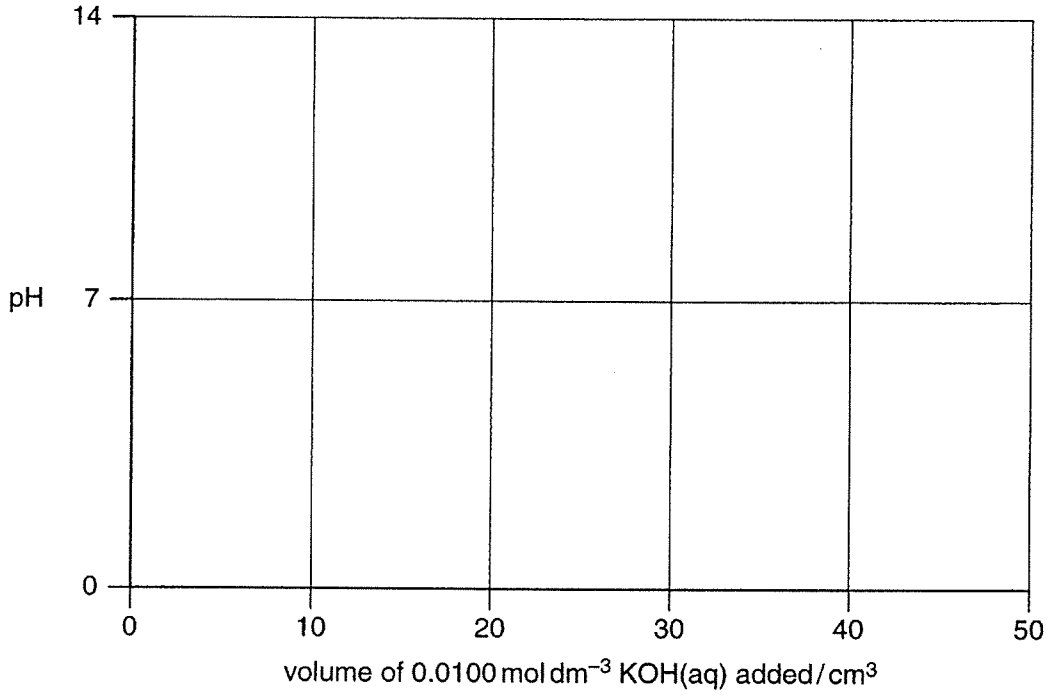
He then slowly added an **excess** of 0.0100 mol dm^{-3} $KOH(aq)$ from a burette. In total, 50.00 cm^3 of the alkali were added.

The pH of the resulting solution was measured throughout the experiment with a pH meter.

The equation for the reaction is shown below.

$$CH_3COOH(aq) + KOH(aq) \longrightarrow CH_3COOK(aq) + H_2O(l)$$

(i) Sketch the pH curve for this titration on the grid below.



[3]

(ii) This titration could be carried out using an indicator. The pH ranges for the pH changes of four indicators are shown below.

indicator	pH range
clayton yellow	12.2 – 13.2
thymol blue	8.0 – 9.6
brilliant yellow	6.6 – 7.8
resazurin	3.8 – 6.4

Explain which of the four indicators is most suitable for this titration.

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.....[2]

[Total: 13]

(b) In solution, phosphoric acid can donate its three protons in turn.

$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$ $\quad K_a = 7.5 \times 10^{-3}\,mol\,dm^{-3}$

$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$ $\quad K_a = 6.2 \times 10^{-8}\,mol\,dm^{-3}$

$HPO_4^{2-}(aq) \rightleftharpoons H^+(aq) + PO_4^{3-}(aq)$ $\quad K_a = 1.7 \times 10^{-12}\,mol\,dm^{-3}$

(i) Compare the relative acidic strengths of H_3PO_4, $H_2PO_4^-$ and HPO_4^{2-}. Explain how you arrived at your answer.

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.....[1]

(ii) Salts of phosphoric acid can be formed by replacing one, two or three protons from H_3PO_4.

For example, **two** protons from $\mathbf{H_3}PO_4$ can be replaced to form $Na_2\mathbf{H}PO_4$.

$$H_3PO_4(aq) + 2NaOH(aq) \longrightarrow Na_2HPO_4(aq) + 2H_2O(l)$$

Calculate the volumes of $0.500\,mol\,dm^{-3}$ $H_3PO_4(aq)$ and $0.500\,mol\,dm^{-3}$ NaOH(aq) that you would need to prepare 4.26 g of the salt Na_2HPO_4.

[5]

[Total: 13]

END OF QUESTION PAPER