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

Wednesday 27 January 2010
Morning

Duration: 1 hour

OCE/19256

2815 01

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.

Examiner's Use Only:			
1			
2			
3			
4			
Total			

DC (SC/SW) 19256/4

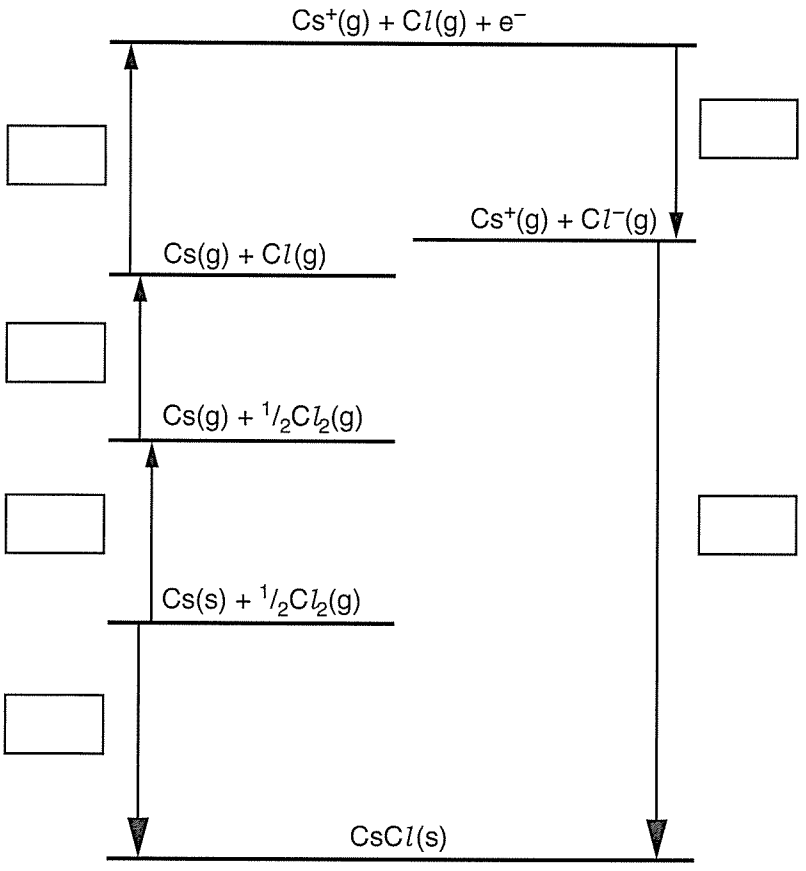
Answer **all** the questions.

1 The lattice enthalpy of caesium chloride, CsC*l*, can be calculated using a Born–Haber cycle.

The table below shows the enthalpy changes and corresponding data for this cycle.

enthalpy change	label	energy/kJ mol^{-1}
lattice enthalpy of caesium chloride	**A**	?
1st electron affinity of chlorine	**B**	–349
1st ionisation energy of caesium	**C**	+376
atomisation of chlorine	**D**	+122
formation of caesium chloride	**E**	–443
atomisation of caesium	**F**	+76

(a) On the cycle below, put the letter for each enthalpy change in the appropriate box.



[3]

(b) Use the Born–Haber cycle to calculate the lattice enthalpy of caesium chloride.

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

(c) State and explain the relative sizes of the lattice enthalpies in sodium chloride and caesium chloride.

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

[Total: 8]

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 below.

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

(a) Decomposition of hydrogen peroxide is a redox reaction.

Using oxidation numbers, 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.

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

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.

.....

.....

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

(ii) A student followed the procedure below:

- Pipette 25.0 cm^3 of aqueous hydrogen peroxide into a conical flask;
- Add sulphuric acid to acidify the hydrogen peroxide;
- Titrate this sample against a solution containing 0.0150 mol dm^{-3} MnO_4^-(aq) ions.

23.35 cm^3 of the solution containing MnO_4^-(aq) ions is required.

2 mol MnO_4^- reacts with 5 mol H_2O_2.

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

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]

4 Copper is an example of a transition element.

(a) Complete the electronic configuration for a copper(II) ion, Cu^{2+}, and use it to explain why copper is a transition element.

Cu^{2+}: $1s^2 2s^2 2p^6$ .....

explanation .....

.....

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

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

Transition elements form complex ions.

- Explain what is meant by the terms *complex ion* and *ligand.*
- Using complex ions of copper, give two examples of ligand substitution reactions that are accompanied by a colour change. Include equations in your answer.
- Describe, using suitable examples and 3-D diagrams, two different shapes of complex ions.

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.... [12]

Quality of Written Communication **[1]**

[Total: 15]

END OF QUESTION PAPER

Answer **all** the questions.

1 Transition metal compounds commonly undergo ligand substitution reactions.

(a) What is meant by the term *ligand substitution*?

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

(b) The following equilibrium is readily established.

$$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$$

In the boxes below, draw the 3-D shape of each complex ion.

$[Co(H_2O)_6]^{2+}$	$[CoCl_4]^{2-}$

[2]

(c) Cobalt also forms complex ions with an oxidation state of +3. The following standard electrode potentials refer to cobalt(III) complexes.

$[Co(H_2O)_6]^{3+} + e^- \rightleftharpoons [Co(H_2O)_6]^{2+}$ $\quad E^{\ominus} = +1.82\,V$

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

(i) Which of the four complexes above is the strongest reducing agent?

Explain your answer.

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

(ii) Suggest why the cobalt(III) oxidation state is more stable in ammonia than in water.

.....

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

(d) Vanadium has several oxidation states in its aqueous ions.

Complete the table below.

	$VO_2^+(aq)$	$VO^{2+}(aq)$	$V^{3+}(aq)$	$V^{2+}(aq)$
oxidation state of vanadium			+3	+2
colour	yellow		green	

[4]

[Total: 12]

2 A sample of impure copper was analysed to find its percentage by mass of copper.

A solution was prepared by dissolving a sample of 8.95 g of the impure metal in dilute nitric acid to give 250 cm^3 of solution. The impurities did not dissolve and were filtered from the solution.

The copper was all converted into Cu^{2+}.

An excess of potassium iodide, KI(aq), was added to 25.0 cm^3 of this solution. Iodine formed:

$$2Cu^{2+}(aq) + 4I^-(aq) \longrightarrow 2CuI(s) + I_2(aq)$$

The iodine produced was titrated with 0.500 mol dm^{-3} sodium thiosulphate.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

Starch was added near the end-point to make the colour change easier to observe.

The average titre obtained was 23.50 cm^3 of the thiosulphate solution.

(a) (i) State the oxidation number of sulphur in $S_2O_3^{2-}$.

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

(ii) Calculate the amount, in moles, of $S_2O_3^{2-}$ ions in the average titre.

answer = ...mol **[1]**

(iii) Calculate the percentage, by mass, of copper present in the sample of the impure copper.

Give your answer to **three** significant figures.

answer = ... % **[5]**

3 **(a)** The standard electrode potentials for two redox systems are shown below.

$Br_2(aq) + 2e^- \rightleftharpoons 2Br^-(aq)$ $\quad E^\ominus = +1.09\,V$

$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$ $\quad E^\ominus = -0.28\,V$

(i) Draw a labelled diagram of the standard cell formed using half-cells based on the two redox systems above.

[5]

(ii) Calculate the standard cell potential, $E^\ominus$, for this cell.

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

(iii) Write an equation for the overall cell reaction.

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

(iv) Identify the redox system in which reduction occurs. Explain your answer.

redox system .....

explanation .....

.....

.....

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

(b) An environmental chemist investigated the chloride ion concentration in a sample of water. She decided to convert the chloride ions into chlorine.

The standard electrode potentials of three redox systems are given below.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \qquad E^\ominus = +1.52V$$

$$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq) \qquad E^\ominus = +1.36V$$

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

Suggest with reasons, whether acidified manganate(VII) and/or acidified dichromate(VI) would be suitable to convert chloride ions into chlorine.

suitable reagent(s) .....

reason .....

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

[Total: 11]

4 In this question, one mark is available for the quality of spelling, punctuation and grammar.

This question relates to the chemistry of chromium.

4.000 g of hydrated chromium(III) chloride, $CrCl_3.xH_2O$, is reacted to remove **all** of its water of crystallisation.

After removal of the water of crystallisation, the residue weighed 2.380 g.

An aqueous solution of $CrCl_3.xH_2O$ contains the complex ion $[Cr(H_2O)_4Cl_2]^+$ which shows stereoisomerism.

When an aqueous solution of chromium(III) chloride is reacted with aqueous sodium hydroxide, followed by hydrogen peroxide, a solution containing chromate(VI) ions is formed.

- Calculate the value of ***x*** in the formula $CrCl_3.xH_2O$.
- Using 3-D diagrams, describe the stereoisomerism in $[Cr(H_2O)_4Cl_2]^+$.
- Outline how chromate(VI) ions can be converted into dichromate(VI) ions. Using a balanced equation, show the equilibrium that exists between chromate(VI) and dichromate(VI) ions in aqueous solution. State clearly any observations associated with this equilibrium.

[9]

Answer **all** the questions.

1 In the UK, almost all sulphuric acid, H_2SO_4, is manufactured by the Contact process.

One stage in the Contact process involves the reaction between sulphur dioxide and oxygen.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The table below shows values of K_p for this equilibrium at different temperatures.

temperature / °C	K_p / kPa^{-1}
25	4.0×10^{22}
200	2.5×10^{8}
800	1.3×10^{-3}

(a) (i) Write the expression for the equilibrium constant, K_p, for this equilibrium.

[1]

(ii) What does this value of K_p suggest about the position of equilibrium at 25 °C and the relative equilibrium proportions of the reactants and products?

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

(b) Predict how the equilibrium position of this equilibrium is affected by the following changes.

Explain your answers.

(i) The temperature is increased whilst keeping the pressure constant.

effect on equilibrium position .....

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

effect on partial pressure of $SO_3(g)$ .....

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

(ii) The pressure is increased whilst keeping the temperature constant.

effect on equilibrium position .....

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

effect on partial pressure of $SO_3(g)$ .....

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

(c) An equilibrium is set up for the SO_2, O_2, SO_3 system at 400 °C.

At this temperature,

- the equilibrium partial pressure of SO_2 is 25 kPa;
- the equilibrium partial pressure of O_2 is 125 kPa;
- $K_p = 3.0 \times 10^2$ kPa^{-1}.

Calculate the equilibrium partial pressure of SO_3 at 400 °C.

Hence determine the molar percentage of SO_3 in the equilibrium mixture at 400 °C.

answer = ... % **[3]**

(d) In the UK, almost all the sulphuric acid manufactured uses sulphur as a starting material for SO_2 production. In some countries, metal ores such as zinc sulphide, ZnS, are used instead of sulphur to form SO_2 by heating in air.

(i) Construct a balanced equation to show the reaction that takes place when zinc sulphide is heated in air.

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

(ii) Suggest why countries may find it more economic to manufacture sulphuric acid from zinc sulphide instead of from sulphur.

.....

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

[Total: 13]

2 Solutions of hydrogen peroxide, H_2O_2, are colourless and widely used as oxidising agents, antiseptic and bleaches 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	0.050	0.010	0.005	5.75×10^{-6}
2	0.050	0.020	0.005	1.15×10^{-5}
3	0.050	0.040	0.010	2.30×10^{-5}

(i) Showing all your reasoning, determine the orders of reaction for I^- and 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 write the rate equation for this reaction.

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

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

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

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

Hydrogen peroxide is sold by volume strength. For example, 40 volume hydrogen peroxide is used to bleach hair, fur and bones.

40 volume H_2O_2 produces 40 volumes of oxygen gas, measured at room temperature and pressure, r.t.p., 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 40 volume hydrogen peroxide.

1 mol of $O_2(g)$ occupies 24.0 dm^3 at r.t.p.

Show all your working clearly.

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

[Total: 14]

3 This question looks at several acids.

(a) Hydroiodic acid, HI(aq), is a strong acid that is an aqueous solution of hydrogen iodide gas. In the laboratory, hydroiodic acid is prepared by the method below.

A mixture of iodine and water is put into a flask. The mixture is stirred and hydrogen sulphide gas, $H_2S(g)$, is bubbled through the mixture for several hours. The mixture becomes yellow as sulphur separates out.

The sulphur is filtered off and the solution is purified by fractional distillation.

A 225 cm^3 sample of hydroiodic acid is collected containing 47.2 g of HI.

(i) Construct a balanced equation, with state symbols, for the preparation of hydroiodic acid from iodine and hydrogen sulphide.

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

(ii) Calculate the pH of the hydroiodic acid sample that is collected.

pH = ... **[2]**

(b) Ethanoic acid, CH_3COOH, is a weak acid with a K_a value of 1.70×10^{-5} mol dm^{-3}.

(i) Write an equation for the dissociation of ethanoic acid.

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

(ii) The concentration of ethanoic acid in a solution **X** was 2.74×10^{-3} mol dm^{-3}.

Calculate the pH of solution **X**.

pH = ... **[3]**

(iii) When ethanoic acid is mixed with hydroiodic acid, an acid–base reaction takes place.

Complete the acid–base equilibrium that is set up and identify the acid–base pairs.

- label **one** conjugate acid–base pair as **acid 1** and **base 1**,
- label the other conjugate acid–base pair as **acid 2** and **base 2**.

..... + ... ⇌ ..... + ...

.... **[2]**

(c) Methanoic acid, HCOOH, is an ant's main defence mechanism, squirted at potential intruders and injected in 'ant bites'.

(i) The recommended treatment for an ant bite is 'bicarbonate of soda', which contains $NaHCO_3$.

Suggest, with an equation, how $NaHCO_3$ helps to relieve the effect of an ant bite.

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

(ii) Wasp stings are treated with vinegar. What does this suggest about the nature of the active ingredient in a wasp sting? Explain your answer.

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

(iii) Methanoic acid can be used in buffer solutions.

Calculate the pH of a buffer solution containing equal volumes of 0.75 mol dm^{-3} methanoic acid and 1.92 mol dm^{-3} sodium methanoate.

For HCOOH, $K_a = 1.60 \times 10^{-4}$ mol dm^{-3}.

pH = ... **[2]**

[Total: 16]

4

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

This question considers different graphs used in chemistry.

- Explain how the shapes of rate–concentration graphs can be used to deduce the orders with respect to reactants.
- Explain how acid–base titration pH curves can be used to suggest suitable indicators for titrations of strong and weak acids with strong bases.

In your answer, include sketch graphs with labelled axes.

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