OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY

Trends and Patterns

2815/01

Wednesday **25 JANUARY 2006** 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 blue or black ink, in the spaces provided on the question paper.
- Pencil may be used for diagrams and graphs **only**.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do not write in the bar code. Do not write in the grey area between the pages.
- **DO NOT** WRITE IN THE AREA **OUTSIDE** THE BOX BORDERING EACH PAGE. ANY WRITING IN THIS AREA WILL NOT BE MARKED.

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	9	
2	8	
3	7	
4	8	
5	13	
TOTAL	45	

This question paper consists of 8 printed pages.

313139501

[Turn over

3 The compound $FeSO_4.7H_2O$ can be used to kill moss in grass. Iron(II) ions in a solution of $FeSO_4.7H_2O$ are slowly oxidised to form iron(III) ions.

(a) Describe a test to show the presence of iron(III) ions in a solution of $FeSO_4.7H_2O$.

.....

.....[1]

(b) The percentage purity of an impure sample of $FeSO_4.7H_2O$ can be determined by titration against potassium dichromate(VI), $K_2Cr_2O_7$, under acid conditions, using a suitable indicator.

During the titration, $Fe^{2+}(aq)$ ions are oxidised to $Fe^{3+}(aq)$ ions.

- Stage 1 – A sample of known mass of the impure $FeSO_4.7H_2O$ is added to a conical flask.
- Stage 2 – The sample is dissolved in an excess of dilute sulphuric acid.
- Stage 3 - The contents of the flask are titrated against $K_2Cr_2O_7(aq)$.

(i) The reduction half equation for acidified dichromate(VI) ions, $Cr_2O_7^{2-}$, is as follows.

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Construct the balanced equation for the redox reaction between $Fe^{2+}(aq)$, $Cr_2O_7^{2-}(aq)$ and $H^+(aq)$.

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.....[2]

(ii) In Stage 1, a student uses a 0.655 g sample of impure $FeSO_4.7H_2O$.

In Stage 3, the student uses 19.6 cm^3 of 0.0180 mol dm^{-3} $Cr_2O_7^{2-}$ to reach the end-point.

One mole of $Cr_2O_7^{2-}$ reacts with 6 moles of Fe^{2+}.

Calculate the percentage purity of the impure sample of $FeSO_4.7H_2O$.

percentage purity ..... [4]

[Total: 7]

4 Dilute aqueous copper(II) sulphate contains $[Cu(H_2O)_6]^{2+}$ ions.

(a) Concentrated hydrochloric acid is added drop by drop to a small volume of dilute aqueous copper(II) sulphate. The equation for the reaction taking place is as follows.

$$[Cu(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \longrightarrow [CuCl_4]^{2-}(aq) + 6H_2O(l)$$

(i) Describe the observations that would be made during the addition of the concentrated hydrochloric acid.

.....[1]

(ii) Describe the bonding within the complex ion, $[CuCl_4]^{2-}$.

.....

.....

.....[2]

(b) Concentrated aqueous ammonia is added drop by drop to aqueous copper(II) sulphate until present in excess. Two reactions take place, one after the other, to produce the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$.

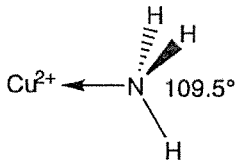
Describe the observations that would be made during the addition of concentrated aqueous ammonia.

.....

.....

.....[2]

(c) Ammonia is a simple molecule. The H—N—H bond angle in an isolated ammonia molecule is 107°.
The diagram shows part of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ion and the H—N—H bond angle in the ammonia ligand.



Explain why the H—N—H bond angle in the ammonia ligand is 109.5° rather than 107°.

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.....[3]

[Total: 8]

For Examiner's Use

Answer **all** the questions.

1 Cobalt readily forms complex ions in which the cobalt has an oxidation state of +2.

(a) One complex ion of cobalt is the hexaaquocobalt(II) ion $[Co(H_2O)_6]^{2+}$.

(i) What is the co-ordination number of Co^{2+} in this complex ion?

..... [1]

(ii) Water is acting as a ligand. Explain the meaning of the term *ligand*.

.....

.....

..... [2]

(b) $[Co(H_2O)_6]^{2+}$ readily undergoes the following reaction.

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

(i) What is the shape of each complex in this reaction?

$[Co(H_2O)_6]^{2+}$ shape .....

$[CoCl_4]^{2-}$ shape ..... [1]

(ii) What colour change would occur on going from left to right in this reaction?

from ..... to ..... [1]

(iii) What type of reaction is taking place when $[Co(H_2O)_6]^{2+}$ reacts with Cl^-?

..... [1]

(c) Co^{2+} forms the complex $[Co(NH_3)_4Cl_2]$. This complex exists as two stereoisomers.

(i) Draw diagrams to show the two isomeric forms of this complex.

[2]

(ii) What type of stereoisomerism is shown by this complex?

..... [1]

(d) Cobalt also forms a complex with the formula $[Co(H_2NCH_2CH_2NH_2)_2Cl_2]$. This complex shows the same kind of isomerism as $[Co(NH_3)_4Cl_2]$ but it also shows a different type of stereoisomerism.

Draw diagrams to show the two isomers of this different type of stereoisomerism.

[2]

[Total: 11]

For Examiner's Use

3 Chromium metal and its compounds have a number of important uses.

(a) State one use of chromium and explain why chromium is suitable for this purpose.

.....

.....

..... [1]

(b) CrO_4^{2-} ions and $Cr_2O_7^{2-}$ ions are both oxidising agents. They exist in the following equilibrium.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

(i) Show that this equilibrium does **not** represent a redox reaction.

.....

.....

..... [1]

(ii) What colour change occurs in the forward reaction?

from ..... to ..... [1]

(iii) What reagent would you add to reverse this colour change?

..... [1]

(c) $Cr_2O_7^{2-}$ ions oxidise I^- ions to I_2 under acid conditions according to the following equation.

$$Cr_2O_7^{2-}(aq) + 6I^-(aq) + 14H^+(aq) \rightleftharpoons 2Cr^{3+}(aq) + 3I_2(aq) + 7H_2O(l)$$

(i) If you carried out this reaction, how could you see that iodine is formed?

.....

..... [1]

For Examiner's Use

(ii) How could you use the formation of I_2 in this reaction to determine the concentration of a solution of $Cr_2O_7^{2-}$ ions?

In your answer

- state the method you would use
- state the reagents used
- show how you would use your results.

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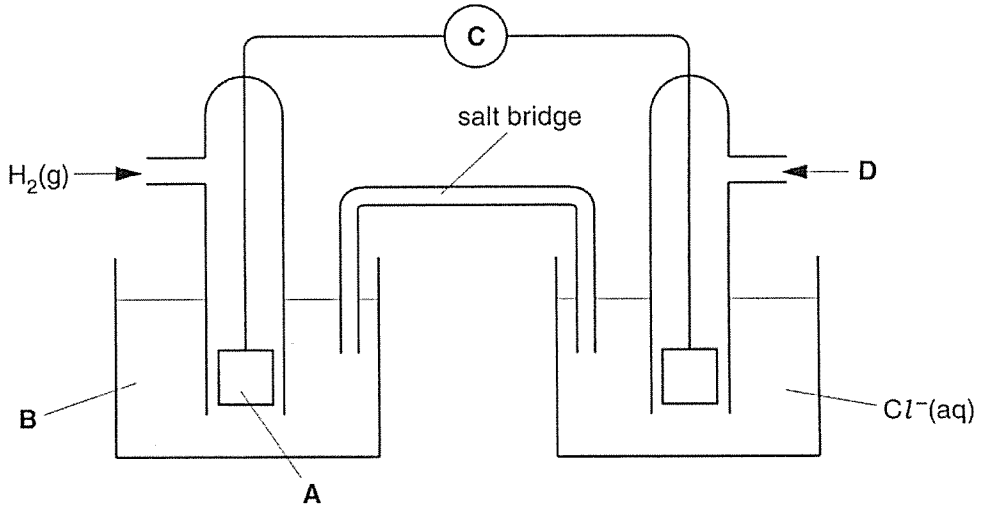
..... [4]

[Total: 9]

4 The standard electrode potential of the $\frac{1}{2}Cl_2/Cl^-$ half-cell may be measured using the following apparatus.



(a) Suggest suitable labels for **A**, **B**, **C** and **D**.

A .....

B .....

C .....

D ..... [2]

(b) The half cell reactions involved are shown below.

$$\frac{1}{2}Cl_2 + e^- \rightleftharpoons Cl^- \qquad E^\ominus = +1.36\,V$$

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

(i) Use an arrow to show the direction of flow of electrons in the diagram of the apparatus. Explain your answer.

.....

..... [2]

(ii) The values of $E^\ominus$ are measured under standard conditions. What are the standard conditions?

.....

.....

..... [2]

(c) The half cell reaction for ClO_3^-/ $\frac{1}{2}Cl_2$ is shown below.

$$ClO_3^- + 6H^+ + 5e^- \rightleftharpoons \tfrac{1}{2}Cl_2 + 3H_2O \qquad E^{\ominus} = +1.47\,V$$

What does this tell you about the oxidising ability of ClO_3^- compared with Cl_2?

Explain your answer.

.....

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..... [2]

[Total: 8]

For Examiner's Use

Answer **all** the questions.

1 Methanoic acid, HCOOH, is a weak organic acid which occurs naturally in ants and stinging nettles.

(a) Use an equation for the dissociation of methanoic acid to show what is meant by a *weak acid*.

.....

.....[1]

(b) A 1.50×10^{-2} mol dm^{-3} solution of HCOOH has $[H^+] = 1.55 \times 10^{-3}$ mol dm^{-3}.

(i) Calculate the pH of this solution and give one reason why the pH scale is a more convenient measurement for measuring acid concentrations than $[H^+]$.

.....

.....

.....[2]

(ii) Write the expression for K_a for methanoic acid.

[1]

(iii) Calculate the values of K_a and pK_a for methanoic acid.

[3]

(iv) Estimate the percentage of HCOOH molecules that have dissociated in this aqueous solution of methanoic acid.

[1]

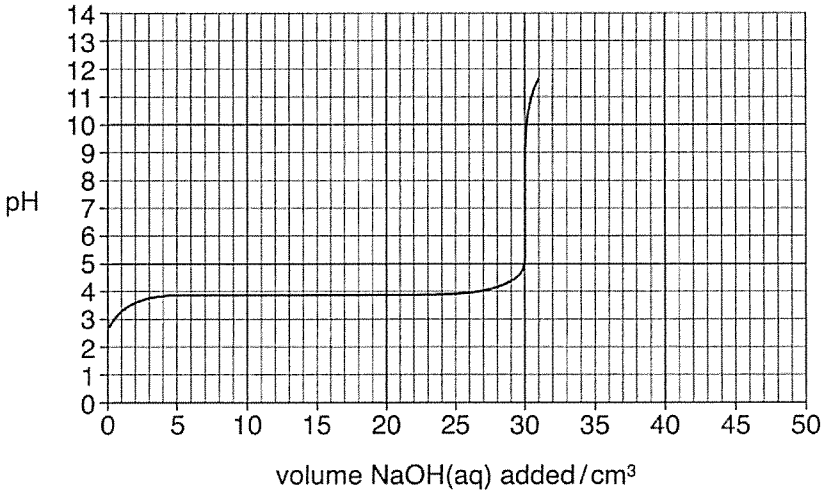
[Turn over

(c) A student titrated the 1.50×10^{-2} mol dm^{-3} methanoic acid with aqueous sodium hydroxide.
A 25.00 cm^3 sample of the HCOOH(aq) was placed in a conical flask and the NaOH(aq) was added from a burette until the pH no longer changed.

(i) Write a balanced equation for the reaction between HCOOH(aq) and NaOH(aq).

.....[1]

(ii) Part of the pH curve for this titration is shown below.



Calculate the concentration, in mol dm^{-3}, of the aqueous sodium hydroxide.

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

(iii) Calculate the pH of the aqueous sodium hydroxide.
$K_w = 1.00 \times 10^{-14}$ mol dm^{-3}

pH = ...[2]

(iv) The pH ranges in which colour changes for three acid-base indicators are shown below.

indicator	pH range
metacresol purple	7.4 – 9.0
2,4,6-trinitrotoluene	11.5 –13.0
ethyl orange	3.4 – 4.8

Explain which of the three indicators is suitable for this titration.

.....

.....

.....[2]

[Total: 16]

[Turn over

2 The preparation of hydrogen iodide, HI(g), from hydrogen and iodine gases is a reversible reaction which reaches equilibrium at constant temperature.

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

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

[1]

(b) A student mixed together 0.30 mol $H_2(g)$ with 0.20 mol $I_2(g)$ and the mixture was allowed to reach equilibrium. At equilibrium, 0.14 mol $H_2(g)$ was present.

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

component	$H_2(g)$	$I_2(g)$	HI(g)
initial amount / mol	0.30	0.20	0
equilibrium amount / mol			

[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]

For Examiner's Use

(d) The student repeated the experiment at a higher temperature and found that less HI was present at equilibrium.

Explain what additional information this tells you about the reaction.

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.....[2]

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

> A mixture of 480 g of iodine and 600 cm^3 of water was put into a flask. The mixture was stirred and hydrogen sulphide gas, $H_2S(g)$, was bubbled through for several hours.
>
> The mixture became yellow as sulphur separated out. The sulphur was filtered off and the solution was purified by fractional distillation. A fraction of HI(aq) was collected containing 440 g of HI in a total volume of 750 cm^3.

(i) Construct a balanced equation, with state symbols, for the preparation of hydroiodic acid.

.....[2]

(ii) Determine the percentage yield of hydroiodic acid.

[3]

(iii) Calculate the pH of the hydroiodic acid fraction.

[2]

[Total: 17]

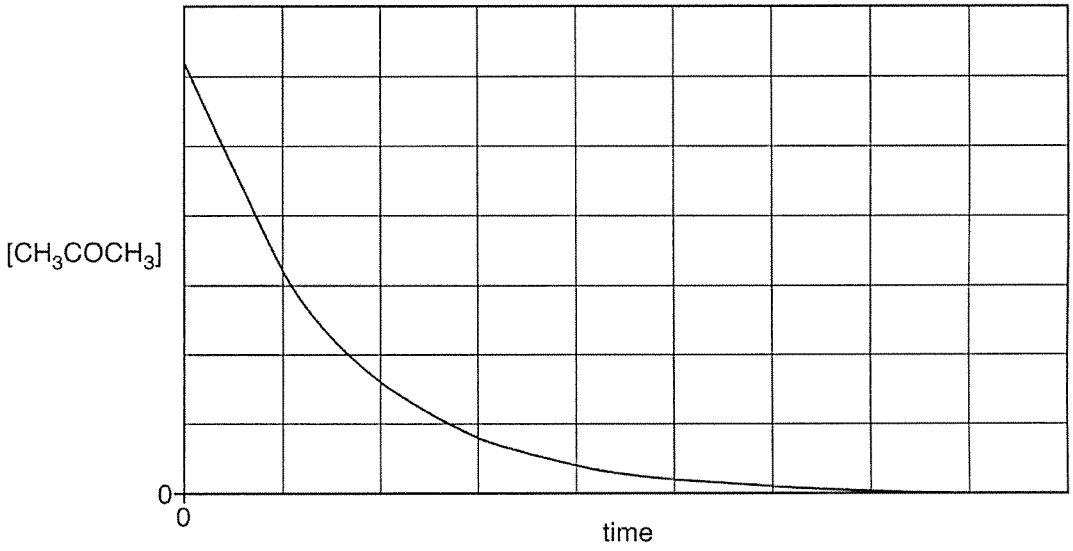
3 In this question, one mark is available for the quality of use and organisation of scientific terms.

Propanone reacts with iodine in the presence of dilute hydrochloric acid.

A student carried out an investigation into the kinetics of this reaction.

He measured how the concentration of propanone changes with time. He also investigated how different concentrations of iodine and hydrochloric acid affect the initial rate of the reaction.

The graph and results are shown below.



$[CH_3COCH_3]$ /mol dm^{-3}	$[I_2]$ /mol dm^{-3}	$[H^+]$ /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1.5×10^{-3}	0.0300	0.0200	2.1×10^{-9}
1.5×10^{-3}	0.0300	0.0400	4.2×10^{-9}
1.5×10^{-3}	0.0600	0.0400	4.2×10^{-9}

The overall equation for the reaction is given below.

$$CH_3COCH_3 + I_2 \longrightarrow CH_3COCH_2I + HI$$

This is a multi-step reaction.

- What conclusions can be drawn about the kinetics of this reaction from the student's investigation? Justify your reasoning.
- Calculate the rate constant for this reaction, including units.
- Suggest the equations for a possible two-step mechanism for this reaction. Label the rate-determining step and explain your reasoning.

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Quality of Written Communication [1]

[Total: 14]