OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE
CHEMISTRY
Trends and Patterns
THURSDAY 19 JUNE 2008

2815/01

Morning
Time: 1 hour

Additional materials: Scientific calculator
Data Sheet for Chemistry (Inserted)

CUP/T45712

Candidate Forename | Candidate Surname

Centre Number | Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or 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.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	13	
2	8	
3	13	
4	11	
TOTAL	45	

This document consists of **10** printed pages, **2** blank pages and a *Data Sheet for Chemistry*.

2 This question is about molybdenum and iron.

Molybdenum steel is extremely hard.
Molybdenum is made by heating molybdenum(VI) oxide, MoO_3, with aluminium powder.

(a) Construct an equation to show the reduction of molybdenum(VI) oxide to molybdenum metal by aluminium.

..... [1]

(b) Molybdenum has the electronic configuration $[Kr]4d^5 5s^1$ where [Kr] represents the electronic configuration for krypton.

Complete the electronic configuration for Mo^{3+} and use it to explain why molybdenum is a transition element.

[Kr] .....

explanation ..... [1]

(c) Molybdenum(IV) oxide, MoO_2, can be oxidised by dichromate(VI) ions, $Cr_2O_7^{2-}$, under acidic conditions.

The relevant half-equations are as follows.

$$MoO_2(s) + 2H_2O(l) \rightarrow MoO_4^{2-}(aq) + 4H^+(aq) + 2e^-$$

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

Construct the equation for the oxidation of MoO_2 by $Cr_2O_7^{2-}$ ions under acidic conditions.

.....

.....

..... [2]

(d) Iron can form the ferrate(VI) ion, FeO_4^{2-}.

(i) What is the formula for potassium ferrate(VI)?

..... [1]

(ii) Aqueous ferrate(VI) ions can be made by the oxidation of iron(III) oxide by chlorine in alkaline conditions.

$$Fe_2O_3 + 3Cl_2 + 10\,OH^- \longrightarrow 2FeO_4^{2-} + 6Cl^- + 5H_2O$$

A 1.00 g sample of Fe_2O_3 is added to 10.0 cm^3 of 4.00 mol dm^{-3} KOH.

Which reagent, Fe_2O_3 or KOH, is in excess? Explain your answer.

[3]

[Total: 8]

3 This question is about oxides and chlorides.

(a) Complete the following table about some of the enthalpy changes needed to determine the lattice enthalpy of calcium oxide.

Include the state symbols in equations for any process.

enthalpy change	process
enthalpy change of formation of calcium oxide	$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$
second ionisation energy of calcium	
	$\frac{1}{2}O_2(g) \rightarrow O(g)$
	$O^-(g) + e^- \rightarrow O^{2-}(g)$
enthalpy change of atomisation of calcium	

[4]

(b) Explain, in terms of structure and bonding, why aluminium oxide has a much higher melting point than aluminium chloride.

.....

.....

.....

..... [3]

(c) Compare the action of water on aluminium oxide with that of water on aluminium chloride.

Include experimental observations where relevant.

.....

.....

.....

..... [3]

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

Transition elements form complex ions that have characteristic colours.

Describe, using complex ions containing **copper**,

- the bonding within a complex ion
- the shape of a complex ion clearly indicating relevant bond angles
- ligand substitution illustrating any reaction with an equation
- the colours of two different complex ions.

Answer **all** the questions.

1 This question is about complex ions of cobalt.

(a) The equilibrium below exists between two complex ions of cobalt(II).

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

(i) What colour change occurs during the reaction from left to right?

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

(ii) What is the shape of the $[CoCl_4]^{2-}$ ion?

..... [1]

(iii) What type of reaction is this?

..... [1]

(b) Cobalt(III) forms a complex ion of formula $[Co(en)_3]^{3+}$ where 'en' is ethane-1,2-diamine, $H_2NCH_2CH_2NH_2$.

Draw a displayed formula for ethane-1,2-diamine, showing clearly any lone pairs of electrons.

[1]

(c) The $[Co(en)_3]^{3+}$ ion shows a type of stereoisomerism.

(i) What type of stereoisomerism does it show?

..... [1]

(ii) Draw 3D diagrams to show the two stereoisomers of $[Co(en)_3]^{3+}$.

You may use 'en' to represent the ethane-1,2-diamine ligand.

[2]

[Total: 7]

2 The standard electrode potential of $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ is +0.77 V.

(a) Define the standard electrode potential of $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$.

In your answer, include the conditions that apply when measuring the standard electrode potential.

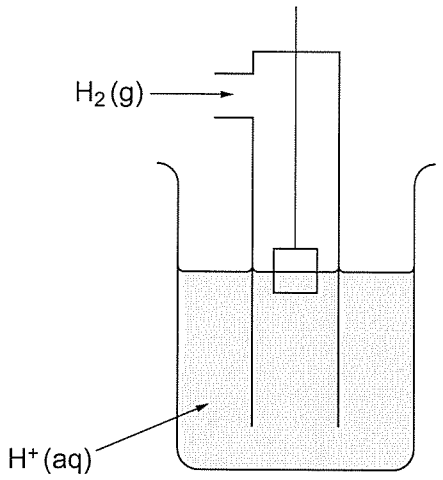
.....

.....

.....

..... [3]

(b) Complete the diagram below of apparatus that would be used to measure the standard electrode potential of $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$.



[3]

(c) A standard cell is set up using the following redox equilibria.

$$Fe^{3+} + e^- \rightleftharpoons Fe^{2+} \qquad E^{\ominus} = +0.77\ V$$

$$I_2 + 2e^- \rightleftharpoons 2I^- \qquad E^{\ominus} = +0.54\ V$$

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

standard cell potential of cell = ... V [1]

(ii) The cell is used to provide a current.

Construct an equation for the overall cell reaction that takes place.

[1]

[Total: 8]

4 Copper ions can exist in two different oxidation states, Cu^+ and Cu^{2+}.

Some standard electrode potentials involving copper and its ions are given below.

	$E^{\ominus}$ / V
$Cu^+ + e^- \rightleftharpoons Cu$	+0.52
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0.15

(a) Use these data to show that the reaction below is likely to occur.

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

.....

.....

.....

..... [2]

(b) The reaction in **(a)** is an example of *disproportionation*.

Explain the meaning of this term.

.....

.....

..... [2]

(c) Suggest a condition under which copper(I) compounds are likely to be stable.

.....

..... [1]

[Total: 5]

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

Copper is an element which finds many uses in alloys such as brass and bronze.

(a) Name the other element that is mixed with copper to form brass.

..... [1]

(b) The percentage of copper in brass can be estimated by titration.

The brass is completely reacted with concentrated nitric acid. The solution is then neutralised and an excess of KI(aq) is added. This mixture is then titrated with $Na_2S_2O_3(aq)$.

Describe how you would carry out this titration.

Your answer should:

- describe what you would see during the titration
- consider the indicator used and the end point of the titration
- include relevant equations.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [8]

Quality of Written Communication [1]

(c) In an experiment to determine the percentage of copper in a sample of brass, 6.00 g of brass was reacted completely with nitric acid. The resulting solution was neutralised and made up to 500 cm^3 in a volumetric flask.

Excess KI(aq) was added to 25.0 cm^3 of this solution. The iodine formed required 18.90 cm^3 of 0.200 mol dm^{-3} $Na_2S_2O_3(aq)$ for complete reaction.

One mole of $S_2O_3^{2-}$ is equivalent to one mole of Cu^{2+}.

Determine the percentage of copper, by mass, in the sample of brass.

[5]

[Total: 15]

END OF QUESTION PAPER

Answer **all** the questions.

1 The hydrolysis of ethyl ethanoate is a reversible reaction. The equation for the equilibrium is shown below.

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

A student mixed together 8.0 mol ethyl ethanoate and 5.0 mol water. He also added a small amount of hydrochloric acid to catalyse the reaction.

The student left the mixture until it had reached equilibrium at constant temperature. He found that 2.0 mol of ethanoic acid had formed.

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

[1]

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

component	$CH_3COOC_2H_5$	H_2O	CH_3COOH	C_2H_5OH
initial amount / mol	8.0	5.0	0.0	0.0
equilibrium amount / mol			2.0	

[2]

(ii) The mole fraction of CH_3COOH can be found from the composition of the equilibrium mixture.

Explain what is meant by the term *mole fraction* and calculate the mole fraction of CH_3COOH in the equilibrium mixture.

mole fraction .....

.....

mole fraction of CH_3COOH

[2]

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

K_c = ... units ..... [3]

(c) The student left the mixture at a higher temperature until a new equilibrium had been reached. He again measured the equilibrium amount of ethanoic acid and found that it had increased.

What conclusions can be drawn about the reaction and its equilibrium constant?

.....

.....

.....

.....

.....

.....

.....[3]

[Total: 11]

2 Hydrogen peroxide, H_2O_2, is a strong oxidising agent that has bleaching properties.

(a) Hydrogen peroxide oxidises iodide ions, $I^-(aq)$, in the presence of acid, $H^+(aq)$.

The rate equation for this reaction is shown below.

$$\text{rate} = k[H_2O_2(aq)][I^-(aq)]$$

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

Some of the experimental results are shown in the table below.

experiment	$[H_2O_2(aq)]$ / mol dm^{-3}	$[I^-(aq)]$ / mol dm^{-3}	$[H^+(aq)]$ / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
1	0.020	0.010	0.0050	2.30×10^{-6}
2	0.040	0.010	0.0050	
3	0.020	0.010	0.0025	
4	0.100	0.005	0.0100	

(i) Deduce the initial rates for experiments 2, 3 and 4. Complete the table.

[3]

(ii) Use the results of experiment 1 to calculate the rate constant k for this reaction. State the units for k.

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

(iii) The overall equation for this reaction is shown below.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \longrightarrow I_2(aq) + 2H_2O(l)$$

The rate equation is: rate = $k[H_2O_2(aq)][I^-(aq)]$.

Explain what the overall equation and the rate equation tell us about the reaction.

.....

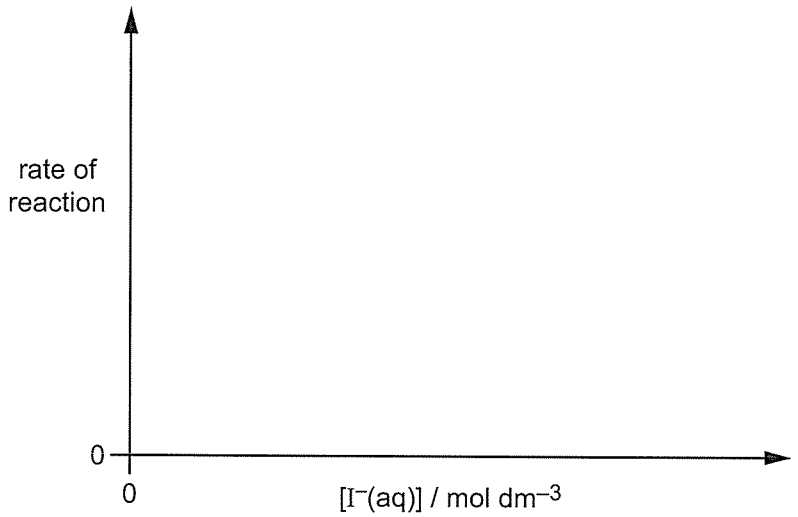
.....

.....

.....

.....[3]

(b) Using the axes below, sketch a graph to show how the rate of this reaction changes with increasing $I^-(aq)$ concentration.



[1]

(c) Hydrogen peroxide is used in the preparation of 'carbamide peroxide', widely used by dentists as a 2.30 mol dm^{-3} solution for teeth-whitening.

Carbamide peroxide has the following percentage composition by mass.

H, 6.38%; O, 51.06%; N, 29.79%; C, 12.77%.

The empirical formula of carbamide peroxide is the same as its molecular formula.

Calculate the mass of carbamide peroxide that is required to prepare 150 cm^3 of a teeth-whitening solution for use by dentists.

[5]

[Total: 15]

3 Potassium hydroxide, KOH, is a strong alkali and vitamin C is a weak Brønsted-Lowry acid.

(a) What is meant by a *weak Brønsted-Lowry acid*?

.....

.....

.....

.....[2]

(b) An aqueous solution of KOH had a pH of 12.72 at 25 °C.

$$K_w = 1.00 \times 10^{-14}\,mol^2\,dm^{-6} \text{ at } 25\,°C.$$

(i) What is the expression for K_w?

.....[1]

(ii) Calculate the concentration, in mol dm^{-3}, of this solution of KOH.

[2]

(c) Vitamin C, $C_6H_8O_6$, has a K_a value of 6.76×10^{-5} mol dm^{-3}.

The equilibrium for the dissociation of vitamin C in water is shown below.

$$C_6H_8O_6(aq) \rightleftharpoons H^+(aq) + C_6H_7O_6^-(aq)$$

0.500 g of vitamin C was dissolved in water to form a solution with a volume of 125 cm^3.

Calculate the pH of the solution formed.

[6]

[Total: 11]

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

A buffer solution can be prepared by mixing together a weak acid with a salt of the weak acid.

The pK_a values of some weak acids are shown below.

weak acid	pK_a
chloroethanoic acid	2.9
methanoic acid	3.8
ethanoic acid	4.8
carbonic acid	6.4
boric acid	9.2

- Explain what is meant by the term *buffer solution*.
- Explain, with equations, how a buffer solution works.
- Choose from the table above the most appropriate weak acid that could be used to prepare a buffer solution with a pH in the range of 3.5–4.5. Explain how you made your choice and suggest a salt that could be added to this weak acid to prepare the buffer solution.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

[8]