OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY 2815/01

Trends and Patterns

Tuesday **25 JUNE 2002** 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 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		
Question Number	Mark	Mark
1	11	
2	5	
3	13	
4	5	
5	11	
TOTAL	45	

This question paper consists of 8 printed pages.

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[Turn over

For Examiner's Use

Answer **all** questions.

1 **(a)** **(i)** Explain what is meant by the term *transition element.*

.....

.....[1]

(ii) Complete the electronic configuration of the vanadium atom.

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

(b) Aqueous transition metal ions can react with aqueous hydroxide ions.

(i) Complete the table below.

metal ion	**formula** and **state symbol** of the product of the reaction with $OH^-(aq)$	colour of product
$Fe^{2+}(aq)$		
$Fe^{3+}(aq)$		

[5]

(ii) Aqueous ammonia reacts with water in the following way.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

When aqueous ammonia is added dropwise to aqueous copper(II) ions, a very pale blue precipitate is observed which disappears in excess ammonia to give a deep blue solution.

Write equations to show the formation from aqueous copper(II) ions of

the pale blue precipitate,

.....

the deep blue solution.

.....[4]

[Total : 11]

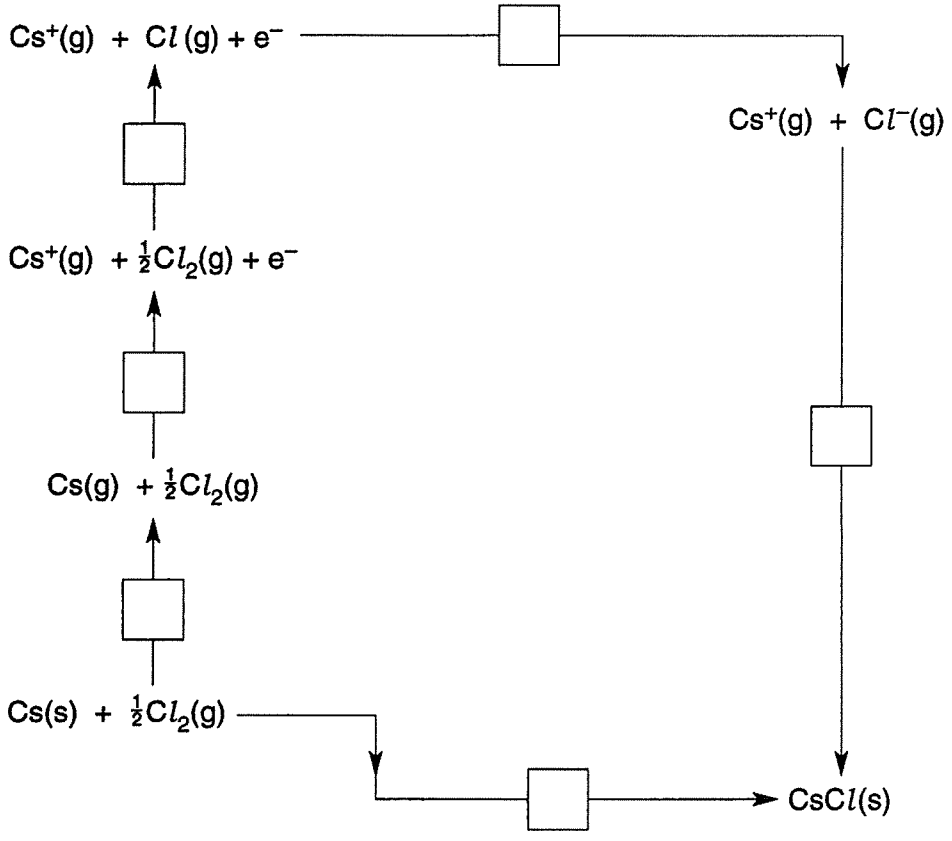
For Examiner's Use

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

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



[3]

(b) Calculate the lattice enthalpy of caesium chloride.

Answer .....kJ mol^{-1} [2]

(c) The lattice enthalpy of sodium chloride is **more exothermic** than the lattice enthalpy of caesium chloride.

State and explain the relative strengths of the ionic bonding in sodium chloride and caesium chloride.

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.....

.....[3]

(d) What would you expect to observe when solid caesium chloride is added to water?

.....

.....

.....[2]

(e) Describe how you would distinguish between aqueous caesium chloride and aqueous caesium iodide using a simple laboratory test. State the observations you would make.

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.....[3]

[Total : 13]

4 The manganate(VII) ion, MnO_4^-, is a strong oxidising agent frequently used in laboratory analysis. It reacts with the ethanedioate ion, $C_2O_4^{2-}$, in hot acidic solution to form CO_2 and Mn^{2+} ions.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$
$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$$

(a) Construct the full ionic equation for this reaction.

[2]

(b) Calculate the volume of 0.0200 mol dm^{-3} potassium manganate(VII) required to react with 25.0 cm^3 of 0.0400 mol dm^{-3} sodium ethanedioate.

[3]

[Total : 5]

For Examiner's Use

Answer **all** questions.

1 Copper forms a number of complex ions.

(a) State the co-ordination number and oxidation state of copper in $[CuCl_4]^{2-}$.

co-ordination number .....[1]

oxidation state .....[1]

(b) Complete the following table.

	$[Cu(NH_3)_4(H_2O)_2]^{2+}$	$[Cu(H_2O)_6]^{2+}$	$[CuCl_4]^{2-}$
colour			
shape			

[6]

(c) One of these ions strongly absorbs light in the blue/violet region of the spectrum at wavelengths of 400–450 nm.

(i) Suggest the identity of this ion.

.....[1]

(ii) Explain how you made your choice.

.....

.....

.....[1]

(d) Outline how, starting with $[Cu(H_2O)_6]^{2+}$ in aqueous solution, you could make solutions containing:

(i) $[Cu(NH_3)_4(H_2O)_2]^{2+}$,

.....

(ii) $[CuCl_4]^{2-}$.

.....

[4]

[Total : 14]

2 **(a)** Complete the electronic configuration of a titanium atom.

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

(b) **(i)** Suggest the shape of the $[Ti(H_2O)_6]^{3+}$ ion.

.....[1]

(ii) Suggest a reason why solutions of $[Ti(H_2O)_6]^{3+}$ must be stored in a sealed container.

.....

.....[1]

(c) **(i)** Titanium(IV) oxide, TiO_2, is white whereas titanium(III) chloride, $TiCl_3$, is coloured. Suggest an explanation for this difference in colour.

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.....

.....

.....[3]

(ii) State **one** use of TiO_2.

.....[1]

[Total : 7]

For Examiner's Use

3 The following is an account of a laboratory experiment.

- A solution was prepared by dissolving some copper(II) sulphate to give 250 cm^3 of aqueous solution.
- 25.0 cm^3 of this solution was treated with an excess of aqueous potassium iodide, KI.

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

- The iodine produced was titrated with 0.100 mol dm^{-3} sodium thiosulphate.

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

- The average titre obtained was 22.0 cm^3 of the thiosulphate solution.

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

.....[1]

(b) Calculate the amount of $S_2O_3^{2-}$ ions in the titre.

Answer.....mol [1]

(c) Calculate the amount of I_2 produced.

Answer.....mol [1]

(d) Calculate the amount of Cu^{2+} ions in 25.0 cm^3 of solution.

Answer.....mol [1]

(e) Calculate the concentration of the aqueous copper(II) sulphate in mol dm^{-3}.

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

[Total : 5]

4 An electrochemical cell was set up based on the following electrode reactions.

$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$ $\quad E^{\ominus} = -0.40\,V$

$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s)$ $\quad E^{\ominus} = -0.74\,V$

(a) **(i)** Draw a diagram of this cell working under standard conditions.

[3]

(ii) Show on the diagram the direction of electron flow in the external circuit. [1]

(iii) Explain your answer to **(ii)**.

.....

.....

.....[2]

(b) Write a full ionic equation for the reaction taking place in this cell.

.....[1]

(c) **(i)** Calculate the standard cell potential of this cell.

[1]

(ii) When water is added to the chromium half cell, the cell potential changes. Suggest **one** reason for this observation.

.....[1]

[Total : 9]

For Examiner's Use

5 *(In this question, 1 mark is available for the quality of written communication.)*

Use suitable examples to illustrate two different types of isomerism in transition metal chemistry.

Outline how chromate(VI) ions and dichromate(VI) ions can be interconverted. How would you know that each change has taken place?

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.... ~~[9]~~ [5]

Quality of Written Communication [1]

[Total : 10]

For Examiner's Use

Answer **all** questions.

1 A chemist set up an equilibrium system between dinitrogen tetroxide, N_2O_4, and nitrogen dioxide, NO_2, at 25 °C.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

The equilibrium concentrations were: $N_2O_4(g)$, 0.0390 mol dm^{-3}; $NO_2(g)$, 0.0150 mol dm^{-3}.

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

[1]

(ii) Calculate K_c for this equilibrium. State the units.

[2]

(b) The standard enthalpy changes of formation of N_2O_4 and NO_2 are given below.

compound	$\Delta H_f^{\ominus}$/kJ mol^{-1}
N_2O_4	+9
NO_2	+33

Calculate the standard enthalpy change for the forward reaction in this equilibrium.

[2]

For Examiner's Use

(c) This equilibrium system was heated at constant pressure. How would you expect the relative proportions of N_2O_4 and NO_2 to change? Explain your answer.

change .....

explanation .....

.....

.....[3]

(d) NO_2 and N_2O_4 are both poisonous. After this investigation, the chemist needed to dispose of 0.00465 mol N_2O_4 safely. The chemist decided to do this by reacting the N_2O_4 with an alkali and chose aqueous sodium hydroxide.

$$N_2O_4(g) + 2NaOH(aq) \longrightarrow NaNO_3(aq) + NaNO_2(aq) + H_2O(l)$$

Calculate the minimum volume of 0.300 mol dm^{-3} NaOH(aq) required to dispose of this amount of N_2O_4.

[3]

[Total : 11]

[Turn over

For Examiner's Use

2 The reaction between hydrogen, H_2, and nitrogen monoxide, NO, has the following rate equation.

$$\text{rate} = k[H_2(g)][NO(g)]^2$$

(a) Using 6.0×10^{-3} mol dm^{-3} $H_2(g)$ and 3.0×10^{-3} mol dm^{-3} NO(g), the initial rate of this reaction was 4.5×10^{-3} mol dm^{-3} s^{-1}.

Calculate the rate constant, *k*, for this reaction and state its units.

[3]

(b) Predict what would happen to the reaction rate after the following changes in concentrations. Show your reasoning.

(i) The concentration of $H_2(g)$ is doubled.

effect on rate .....

reason .....

.....[2]

(ii) The concentration of NO(g) is halved.

effect on rate .....

reason .....

.....[2]

(iii) The concentrations of $H_2(g)$ and NO(g) are both tripled.

effect on rate .....[1]

For Examiner's Use

(c) The overall equation for the reaction between hydrogen and nitrogen monoxide is shown below.

$$2H_2(g) + 2NO(g) \longrightarrow N_2(g) + 2H_2O(l)$$

This reaction takes place by a two step mechanism with the rate-determining step taking place first.

(i) Explain the term *rate-determining step.*

.....

.....[1]

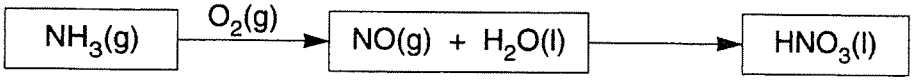
(ii) Suggest the two steps for this reaction and write their equations below. The equation for the rate-determining step (RDS) has been partly completed.

step 1 (RDS) ..... + 2..... $\longrightarrow$ ..... + $H_2O(l)$

step 2 ..... + ... $\longrightarrow N_2(g) + H_2O(l)$

[2]

(d) Each year in the UK, 700 000 tonnes of nitric acid, HNO_3, are manufactured for the production of fertilisers, dyes, explosives, etc. Nitrogen monoxide, NO, is prepared as an intermediate in the production of nitric acid from ammonia, NH_3.



(i) What is the oxidation state of nitrogen in the following?

NH_3 .....

NO .....

HNO_3 .....[3]

(ii) Construct a balanced equation for the formation of NO(g) from $NH_3(g)$.

.....[2]

(iii) Assuming that 1 mol NH_3 produces 1 mol HNO_3, calculate the mass of NH_3 that is required to meet the annual demand for HNO_3 in the UK.

[2]

[Total : 18]

[Turn over

3 Alpha hydroxy acids (AHAs) are monobasic organic acids, used in skin creams to combat the appearance of ageing. Approximately 1% solutions of AHAs remove wrinkles as the low pH aggravates the skin, causing it to swell. More concentrated solutions (approximately 12% or 1.5 mol dm^{-3}) are used to remove dead skin.

(a) An AHA was analysed and had the percentage composition by mass:

C, 40.0%; H, 6.7%; O, 53.3%. $M_r = 90$.

Calculate the molecular formula of this AHA.

[3]

(b) Calculate the pH of a 1.5 mol dm^{-3} solution of an AHA with an acid dissociation constant, K_a, of 1.2×10^{-5} mol dm^{-3}. Show your working.

[4]

(c) Beauty treatments often contain buffers. An example of a buffer is a mixture of ethanoic acid, CH_3COOH, and an ethanoate salt such as sodium ethanoate, CH_3COONa.

(i) Explain what is meant by a *buffer solution.*

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.....[1]

(ii) Write the chemical equation for the equilibrium in this buffer system.

.....[1]

(iii) Explain how this buffer solution works. Use equations where appropriate.

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.....[3]

(d) A buffer solution was prepared using equal concentrations of CH_3COOH and CH_3COONa.

What would be the effect on the pH of this buffer solution of adding some solid CH_3COONa? Explain your answer.

effect on pH .....

explanation .....

.....

.....[3]

[Total : 15]

4 In this question, you should use knowledge, principles and concepts from different areas of chemistry. *(In this question, 1 mark is available for the quality of written communication.)*

(a) The equation for the production of ammonia in the Haber process is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92\,kJ\,mol^{-1}$$

Explain why the conditions of temperature and pressure used in the Haber process (450 °C, 15 000 kPa) are a **compromise**.

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.....[7]

For Examiner's Use

(b) An *Alka-Seltzer* tablet contains about 0.5 g sodium hydrogencarbonate, $NaHCO_3$, and an excess of citric acid. When water is added to an *Alka-Seltzer* tablet, carbon dioxide gas is released.

The equation for the reaction that takes place is shown below. The formula of citric acid has been simplified as H_3A.

$$3NaHCO_3 + H_3A \longrightarrow Na_3A + 3CO_2 + 3H_2O$$

(i) Explain, using ionic equations, how the addition of water allows the release of carbon dioxide from an *Alka-Seltzer* tablet.

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.....[4]

(ii) Calculate the minimum mass of citric acid that needs to be in an *Alka-Seltzer* tablet to ensure that all the sodium hydrogencarbonate reacts. (M_r citric acid: 192)

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.....[5]

[Total : 16]