OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

**CHEMISTRY** **2815/01**

Trends and Patterns

Tuesday **25 JANUARY 2005** 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 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** | **10** | |
| **2** | **15** | |
| **3** | **7** | |
| **4** | **13** | |
| **TOTAL** | **45** | |

**This question paper consists of 8 printed pages.**

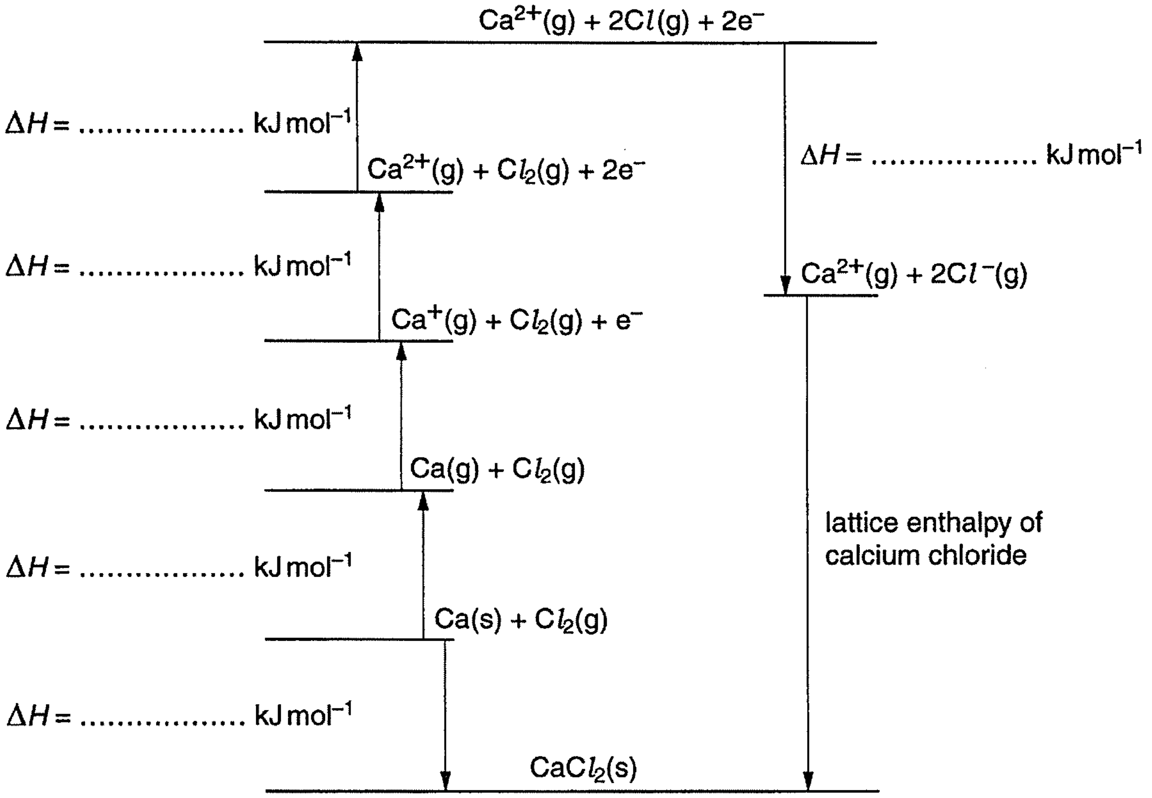
For Examiner's Use

Answer **all** the questions.

1 The table below shows the enthalpy changes needed to calculate the lattice enthalpy of calcium chloride, $CaCl_2$.

| process | enthalpy change / kJ mol$^{-1}$ |
|---|---|
| first ionisation energy of calcium | +590 |
| second ionisation energy of calcium | +1150 |
| electron affinity of chlorine | −348 |
| enthalpy change of formation for calcium chloride | −796 |
| enthalpy change of atomisation for calcium | +178 |
| enthalpy change of atomisation for chlorine | +122 |

**(a)** The Born-Haber cycle below can be used to calculate the lattice enthalpy for calcium chloride.



For Examiner's Use

(i) Use the table of enthalpy changes to complete the Born-Haber cycle by putting in the correct numerical values on the appropriate dotted line. [3]

(ii) Use the Born-Haber cycle to calculate the lattice enthalpy of calcium chloride.

answer .......................... $kJ\,mol^{-1}$ [2]

(iii) Describe how, and explain why, the lattice enthalpy of magnesium fluoride differs from that of calcium chloride.

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(b) Explain why the first ionisation energy of calcium is less positive than the second ionisation energy.

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[Total: 10]

For Examiner's Use

**2** A moss killer contains iron(II) sulphate.

Some of the iron(II) sulphate gets oxidised to form iron(III) sulphate. During the oxidation iron(II) ions, $Fe^{2+}$, react with oxygen, $O_2$, and hydrogen ions to make water and iron(III) ions, $Fe^{3+}$.

**(a)** Complete the electronic configuration for $Fe^{3+}$ and use it to explain why iron is a transition element.

$Fe^{3+}$: $1s^22s^22p^6$ ..........................................................................................

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**(b)** State **two** typical properties of **compounds** of a transition element.

1 ..........................................................................................

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

**(c)** Describe how aqueous sodium hydroxide can be used to distinguish between aqueous iron(II) sulphate and aqueous iron(III) sulphate.

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**(d)** Construct the equation for the oxidation of acidified iron(II) ions by oxygen.

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For Examiner's Use

**(e)** The percentage by mass of iron in a sample of moss killer can be determined by titration against acidified potassium manganate(VII).

- Stage 1 – A sample of moss killer is dissolved in excess sulphuric acid.
- Stage 2 – Copper turnings are added to the acidified sample of moss killer and the mixture is boiled carefully for five minutes. Copper reduces any iron(III) ions in the sample to give iron(II) ions.
- Stage 3 – The reaction mixture is filtered into a conical flask to remove excess copper.
- Stage 4 – The contents of the flask are titrated against aqueous potassium manganate(VII).

**(i)** Suggest why it is important to remove all the copper in stage 3 before titrating in stage 4.

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**(ii)** The ionic equation for the redox reaction between acidified $MnO_4^-$ and $Fe^{2+}$ is given below.

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \longrightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$$

Explain, in terms of electron transfer, why this reaction involves both oxidation and reduction.

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**(iii)** A student analyses a 0.675 g sample of moss killer using the method described.

In stage 4, the student uses 22.5 $cm^3$ of 0.0200 mol $dm^{-3}$ $MnO_4^-$ to reach the end-point.

Calculate the percentage by mass of iron in the moss killer.

percentage .................................. [4]

[Total: 15]

For Examiner's Use

**3** Aqueous copper(II) sulphate contains $[Cu(H_2O)_6]^{2+}$ ions. Aqueous ammonia is added drop by drop to a small volume of aqueous copper(II) sulphate. Two reactions take place, one after the other, as shown in the equations.

$$[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s) + 6H_2O(l)$$

$$Cu(OH)_2(s) + 2H_2O(l) + 4NH_3(aq) \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 2OH^-(aq)$$

**(a)** Describe the observations that would be made as ammonia is added drop by drop until it is in an excess.

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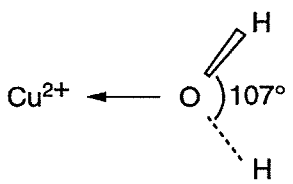
**(b)** Draw the shape for the $[Cu(H_2O)_6]^{2+}$ ion. Include the bond angles in your diagram.

[2]

**(c)** Water is a simple molecule. The H—O—H bond angle in an isolated water molecule is 104.5°.

The diagram shows part of the $[Cu(H_2O)_6]^{2+}$ ion and the H—O—H bond angle in the water ligand.




Explain why the H—O—H bond angle in the water ligand is 107° rather than 104.5°.

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[Total: 7]

For Examiner's Use

Answer **all** the questions.

1 Vanadium is a hard corrosion-resistant metal which forms compounds with a number of different oxidation states.

(a) State a common use for vanadium or one of its compounds.

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(b) The standard electrode potential of the $V^{2+}/V$ redox system is –1.20 V.

Draw a labelled diagram to show how you would measure the standard electrode potential of the $V^{2+}/V$ system.

[5]

(c) The most common oxidation states of vanadium are shown in the table below.

| | $V^{2+}$ | $VO_2^+$ | $VO^{2+}$ | $V^{3+}$ |
|---|---|---|---|---|
| oxidation number of vanadium | +2 | | | +3 |
| colour | lilac | yellow | X | |

(i) Complete the table by filling in the empty spaces. [4]

For Examiner's Use

**(ii)** Each oxidation state may be observed by carrying out the successive reduction of ammonium vanadate(V) using zinc in an acidic solution.

The final step converts $V^{3+}(aq)$ into $V^{2+}(aq)$.

Use the following standard electrode potentials to explain why the reduction process stops at the ion $V^{2+}$.

$$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s) \qquad E^\ominus = -0.76\,V$$

$$V^{2+}(aq) + 2e^- \rightleftharpoons V(s) \qquad E^\ominus = -1.20\,V$$

$$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq) \qquad E^\ominus = -0.26\,V$$

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[Total: 12]

For Examiner's Use

2 Transition metals readily form complex ions when they are combined with a suitable ligand.

(a) What is meant by the following terms?

(i) *complex ion*

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(ii) *ligand*

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(b) A common ligand which combines with a number of transition metal ions is ethane-1,2-diamine, $H_2NCH_2CH_2NH_2$. This is a bidentate ligand.

Explain the meaning of the term *bidentate*.

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**(c)** The complex $[CoCl_2(H_2NCH_2CH_2NH_2)_2]$ is a neutral molecule. It shows two types of stereoisomerism. Use this molecule to explain what you understand by the term *stereoisomerism*. Your answer should include diagrams to show clearly the structures of the different isomers in both types of stereoisomerism.

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[Total: 11]

For Examiner's Use

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

Complexes containing $Cu^{2+}$ are coloured, whereas complexes of $Cu^{+}$ are not coloured. Explain why.

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Quality of Written Communication [1]



[Turn over

For Examiner's Use

4 Potassium dichromate(VI) can be used in a number of redox reactions. The standard electrode potentials for two half reactions are given below.

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

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

**(a)** Acidified potassium dichromate(VI) is added to aqueous potassium iodide to give aqueous iodine.

**(i)** Construct an ionic equation to show the reaction taking place when acidified potassium dichromate(VI) is added to aqueous potassium iodide.

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**(ii)** An excess of aqueous sodium thiosulphate was then added. Describe and explain what you would see.

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**(b)** Potassium dichromate(VI) also takes part in the following reaction.

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

**(i)** Show that chromium is **not** taking part in a redox reaction.

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**(ii)** Describe the colour change for the forward reaction.

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

**(iii)** Suggest a reagent that would convert $CrO_4^{2-}$ back to $Cr_2O_7^{2-}$.

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[Total: 9]

**END OF QUESTION PAPER**

**2** One cause of low-level smog is the reaction of ozone, $O_3$, with ethene. The smog contains methanal, $CH_2O(g)$, and the equation for its production is shown below.

$$O_3(g) + C_2H_4(g) \longrightarrow 2CH_2O(g) + \tfrac{1}{2}O_2(g)$$ **equation 2.1**

**(a)** The rate of the reaction doubles when the initial concentration of either $O_3(g)$ or $C_2H_4(g)$ is doubled.

**(i)** What is the order of reaction with respect to

$O_3$............................

$C_2H_4$?...................... [1]

**(ii)** What is the overall order of the reaction? ..........................................................[1]

**(iii)** Write the rate equation for this reaction.

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**(b)** For an initial concentration of ozone of $0.50 \times 10^{-7}$ mol dm$^{-3}$ and one of ethene of $1.0 \times 10^{-8}$ mol dm$^{-3}$, the initial rate of methanal formation was $1.0 \times 10^{-12}$ mol dm$^{-3}$ s$^{-1}$.

**(i)** How could the **initial** rate of methanal formation be measured from a concentration/time graph?

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**(ii)** Calculate the value of the rate constant and state the units.

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

**(iii)** The initial rate of methanal formation is different from that of oxygen formation in equation **2.1**.

Explain why.

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For Examiner's Use

**(iv)** The experiment was repeated but at a higher temperature. What would be the effect of this change on the rate and the rate constant of the reaction?

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**(c)** In the stratosphere, ozone forms when oxygen free radicals react with oxygen molecules.

$$O_2 + O \longrightarrow O_3$$

The oxygen free radicals are initially formed as diradicals when oxygen gas, $O_2$, is dissociated by strong ultraviolet radiation,

$$O_2(g) \longrightarrow 2O(g)$$

**(i)** Suggest why oxygen free radicals, O, are often called diradicals.

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**(ii)** Draw a '*dot-and-cross*' diagram of an ozone molecule. Show outer electrons only.

[2]

**(iii)** Chlorine free radicals formed from CFCs deplete the ozone layer in a chain reaction.

Typically, 1 g of chlorine free radicals destroys 150 kg of ozone during the atmospheric lifetime of the chlorine free radical (one to two years).

Calculate how many ozone molecules are destroyed in this chain reaction by a single chlorine free radical before the free radical is destroyed.

answer........................................[3]

[Total: 17]

For Examiner's Use

**3** Phenol, $C_6H_5OH$, is a powerful disinfectant and antiseptic. Phenol is a weak Brønsted-Lowry acid.

**(a)** What is meant by the following terms;

**(i)** a *Brønsted-Lowry* acid;

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**(ii)** a *weak* acid?

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**(b)** When phenol is mixed with aqueous sodium hydroxide, an acid-base reaction takes place.

$$C_6H_5OH(aq) \quad + \quad OH^-(aq) \quad \rightleftharpoons \quad C_6H_5O^-(aq) \quad + \quad H_2O(l)$$

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In the spaces above,

- 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)** A solution of phenol in water has a concentration of 38 g dm$^{-3}$.
The acid dissociation constant, $K_a$, of phenol is $1.3 \times 10^{-10}$ mol dm$^{-3}$.

**(i)** Write an expression for the acid dissociation constant, $K_a$, of phenol.

[1]

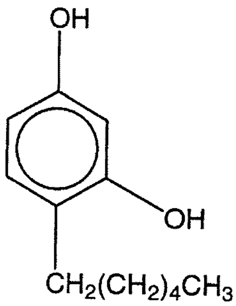
For Examiner's Use

**(ii)** Calculate the pH of this solution.

answer........................................[5]

**(d)** Hexylresorcinol is an antiseptic used in solutions for cleansing wounds and in mouthwashes and throat lozenges.

The structure of hexylresorcinol is shown below.




Identify a compound that could be added to hexylresorcinol to make a buffer solution. Explain your answer.

[2]

[Total: 12]



**[Turn over**

For Examiner's Use

4 Titration curves can be used to decide on a suitable indicator for a titration.

You are supplied with the following solutions.

- 0.100 mol dm$^{-3}$ NaOH(aq)
- 0.100 mol dm$^{-3}$ $CH_3COOH$(aq), which has a pH of 2.9

**(a)** 50.0 cm$^3$ of 0.100 mol dm$^{-3}$ NaOH(aq) is gradually added to 25.0 cm$^3$ of 0.100 mol dm$^{-3}$ $CH_3COOH$(aq).

Sketch the titration curve for this addition. Label the axes and mark approximate values, to show the variation of pH.

[6]

**(b)** Phenolphthalein is a suitable indicator for a titration between $CH_3COOH$(aq) and NaOH(aq) whereas methyl orange is **not** suitable.

Explain these two statements.

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For Examiner's Use

**(c)** The procedure in **(a)** was repeated with 25.0 $cm^3$ 0.050 mol $dm^{-3}$ $CH_3COOH(aq)$ instead of 0.100 mol $dm^{-3}$ $CH_3COOH(aq)$.

What differences would there be in the titration curve plotted?

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**(d)** Compound **B** is an organic base. A student analysed this base by the procedure below.

He first prepared a solution of **B** by dissolving 4.32 g of **B** in water and making the solution up to 250 $cm^3$. The student then carried out a titration in which 25.00 $cm^3$ of this solution of **B** were neutralised by exactly 23.20 $cm^3$ of 0.200 mol $dm^{-3}$ HC*l*.

1 mole of **B** reacts with 1 mole of HC*l*.

Use this information to calculate the molar mass of base **B** and suggest its identity.

[6]

[Total: 16]

**END OF QUESTION PAPER**