OCR
RECOGNISING ACHIEVEMENT

**ADVANCED GCE**

# CHEMISTRY

Trends and Patterns

**THURSDAY 25 JANUARY 2007**

**2815/01**

Afternoon

Time: 1 hour

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

Candidate Name

Centre Number

Candidate Number

**INSTRUCTIONS TO CANDIDATES**

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams 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 outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

**INFORMATION FOR CANDIDATES**

- The number of marks for each question 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.
- 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 | 7 | |
| 2 | 6 | |
| 3 | 20 | |
| 4 | 12 | |
| TOTAL | 45 | |

This document consists of **12** printed pages and a *Data Sheet for Chemistry*.

Answer **all** the questions.

**1** This question is about oxides of elements in Period 3.

| chemical formula | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_4O_{10}$ | $SO_3$ |
|---|---|---|---|---|---|---|
| structure | giant | giant | giant | giant | simple | simple |
| bonding | ionic | ionic | intermediate | covalent | covalent | covalent |

**(a)** Explain the trend in chemical formula shown in the table.

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..... [1]

**(b)** Solid magnesium oxide is an electrical insulator. Explain this property in terms of structure and bonding.

.....

..... [1]

**(c)** Solid aluminium oxide is amphoteric. This means it reacts with acids and bases.

**(i)** Write an equation to show the reaction between aluminium oxide and hot dilute hydrochloric acid.

..... [1]

**(ii)** Aluminium oxide reacts with hot aqueous sodium hydroxide. Balance this equation for the reaction shown below.

$$Al_2O_3 \quad + \quad H_2O \quad + \quad NaOH \quad \rightarrow \quad Na_3Al(OH)_6$$ [1]

**(d)** Silicon(IV) oxide, $SiO_2$, has a high melting point. Explain this property in terms of structure and bonding.

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..... [2]

**(e)** Use the information in the table to help you predict the action of water on $P_4O_{10}$.

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..... [1]

[Total: 7]

**2** Mercury thermometers are not used in some laboratories because of the danger of mercury vapour. This vapour is very easily absorbed through the lungs into the blood.

In the blood, mercury reacts with hydrogen peroxide to form mercury(II) oxide.

$$Hg + H_2O_2 \rightarrow HgO + H_2O$$

The mercury(II) oxide formed accumulates within organs in the body.

**(a)** Use oxidation numbers to show that the reaction between mercury and hydrogen peroxide is an example of both oxidation and reduction.

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..... [2]

**(b)** Mercury forms two ions, $Hg_2^{2+}$ and $Hg^{2+}$. The table shows the electronic configuration of mercury in these ions.

| ion | electronic configuration |
|---|---|
| $Hg_2^{2+}$ | $[Xe]4f^{14}5d^{10}6s^1$ |
| $Hg^{2+}$ | $[Xe]4f^{14}5d^{10}$ |

Use the electronic configurations to explain why mercury is **not** a transition element.

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..... [1]

**(c)** Hydrogen peroxide has the following displayed formula.

H—O—O—H

**(i)** Draw a *'dot-and-cross'* diagram for a molecule of $H_2O_2$ showing only the outer shell electrons.

[1]

**(ii)** Use the *'dot-and-cross'* diagram to predict the H—O—O bond angle in hydrogen peroxide. Explain your answer.

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..... [2]

[Total: 6]

3 A 167 mg sample of iron reacts with a stream of dry chlorine to form 487 mg of solid **X**. The molar mass of solid **X** was determined to be 324.6 g mol$^{-1}$.

**(a)** Calculate the molecular formula of **X**.

molecular formula of **X** is ..... [3]

**(b)** Two properties of solid **X** are shown below.

- It melts when heated gently.
- It reacts with water to form a solution that is highly acidic.

What do these properties suggest about the structure and bonding in solid **X**?

Explain your answer.

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..... [2]

**(c)** A sample of iron is heated with a stream of dry hydrogen chloride. A different chloride of iron is formed that contains the $Fe^{2+}$ ion. This chloride dissolves in water to form a pale green solution that contains the hexaaquairon(II) complex ion.

**(i)** Complete the electronic configuration of $Fe^{2+}$.

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

**(ii)** Draw the shape of the hexaaquairon(II) complex ion. Include the bond angles on your diagram.

[2]

**(iii)** Aqueous sodium hydroxide is added to a solution containing $Fe^{2+}(aq)$.

State what you would observe.

.....

Write an ionic equation, with state symbols, for the reaction.

..... [2]

**(d)** Aqueous hexaaquairon(III) ions react with aqueous thiocyanate ions in a ligand substitution reaction to give a complex ion with the formula $[Fe(H_2O)_5(SCN)]^{2+}$.

**(i)** Write an equation for this ligand substitution reaction.

..... [1]

**(ii)** You are provided with

- 0.100 mol $dm^{-3}$ aqueous iron(III) chloride,
- 0.0500 mol $dm^{-3}$ aqueous potassium thiocyanate.

Describe how you would use colorimetry to confirm the formula of the complex ion $[Fe(H_2O)_5(SCN)]^{2+}$.

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..... [5]

**(e)** The percentage purity of a sample of manganese(IV) oxide, $MnO_2$, can be determined by its reaction with acidified iron(II) ions.

- Stage 1 – A sample of known mass of the impure $MnO_2$ is added to a conical flask.
- Stage 2 – The sample is reacted with a known excess amount of $Fe^{2+}$ acidified with dilute sulphuric acid.
- Stage 3 – The contents of the flask are heated gently.
- Stage 4 – The cooled contents of the flask are titrated with aqueous potassium manganate(VII) in acidic conditions to find the amount of unreacted $Fe^{2+}$.

**(i)** The reduction half-equation for manganese(IV) oxide in the presence of dilute acid is shown below.

$$MnO_2(s) + 4H^+(aq) + 2e^- \rightarrow Mn^{2+}(aq) + 2H_2O(l)$$

Construct the balanced equation for the redox reaction between $Fe^{2+}(aq)$, $MnO_2(s)$ and $H^+(aq)$.

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..... [1]

**(ii)** In Stage 1 and Stage 2 a student uses a 0.504 g sample of impure $MnO_2$ and 100 $cm^3$ of 0.200 mol $dm^{-3}$ $Fe^{2+}$.

In Stage 4 the student determines that the amount of unreacted $Fe^{2+}$ is 0.0123 mol.

1 mol of $MnO_2$ reacts with 2 mol of $Fe^{2+}$.

Calculate the percentage purity of the impure sample of $MnO_2$.

percentage purity = ..... % [3]

[Total: 20]

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

The lattice enthalpy of magnesium chloride, $MgCl_2$, can be determined using a Born-Haber cycle and the following enthalpy changes.

| name of process | enthalpy change / kJ mol$^{-1}$ |
|---|---|
| enthalpy change of formation of $MgCl_2(s)$ | −641 |
| enthalpy change of atomisation of magnesium | +148 |
| first ionisation energy of magnesium | +738 |
| second ionisation energy of magnesium | +1451 |
| enthalpy change of atomisation of chlorine | +123 |
| electron affinity of chlorine | −349 |

- Define, using an equation with $MgCl_2$ as an example, what is meant by the term *lattice enthalpy*.
- Construct a Born-Haber cycle for $MgCl_2$, including state symbols, and calculate the lattice enthalpy of $MgCl_2$.
- Explain why the lattice enthalpy of NaBr is much less exothermic than that of $MgCl_2$.

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..... [11]

Quality of Written Communication [1]

[Total: 12]

**END OF QUESTION PAPER**

**PLEASE DO NOT WRITE ON THIS PAGE**