OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

CHEMISTRY

Unifying Concepts

TUESDAY 23 JANUARY 2007

2816/01

Morning

Time: 1 hour 15 minutes

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	14	
2	14	
3	9	
4	7	
5	16	
TOTAL	60	

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

[Turn over

950401001

Answer **all** the questions.

1 Nitrogen monoxide reacts with hydrogen at 500 °C as in the equation below.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

A series of experiments was carried out to investigate the kinetics of this reaction. The results are shown in the table below.

experiment	[NO] /mol dm^{-3}	[H$_2$] /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1	0.10	0.20	2.6
2	0.10	0.50	6.5
3	0.30	0.50	58.5

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

(i) For each reactant, deduce the order of reaction. Show your reasoning.

....

....

....

....

....

....

....

....

....

....

....

.... [4]

Quality of Written Communication [1]

(ii) Deduce the rate equation for this reaction.

.... [1]

(iii) Calculate the rate constant, k, for this reaction. State the units for k.

k = ... units .... [3]

(b) Nitrogen monoxide, NO, is involved in formation of ozone at low levels and the breakdown of ozone at high levels.

(i) In the lower atmosphere, NO is produced by combustion in car engines. Ozone is then formed following the series of reactions shown below.
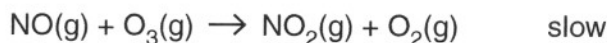
$$NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$$

$$NO_2(g) \rightarrow NO(g) + O(g)$$

$$O_2(g) + O(g) \rightarrow O_3(g)$$
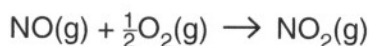
- Write the overall equation for this reaction sequence.

- Identify the catalyst and justify your answer.

....

....

....

.... [3]

(ii) In the upper atmosphere, NO removes O_3 by the following reaction mechanism.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g) \qquad \text{slow}$$

$$O(g) + NO_2(g) \rightarrow NO(g) + O_2(g) \qquad \text{fast}$$

Suggest the rate equation for this process. Explain your reasoning.

....

....

....

.... [2]

[Total: 14]

2   When heated, phosphorus pentachloride, PCl_5, dissociates.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

A chemist placed a mixture of the three gases into a container. The initial concentration of each gas was the same: $0.30\,mol\,dm^{-3}$. The container was left until equilibrium had been reached.

Under these conditions, $K_c = 0.245\,mol\,dm^{-3}$.

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

[1]

(b) Use the value of K_c for this equilibrium to deduce whether the concentration of each gas increases, decreases or stays the same as the mixture approaches equilibrium.

(i)   Show your answer by placing a tick in the appropriate cells in the table below.

	initial concentration /$mol\,dm^{-3}$	greater than $0.30\,mol\,dm^{-3}$	less than $0.30\,mol\,dm^{-3}$	equal to $0.30\,mol\,dm^{-3}$
PCl_5	0.30			
PCl_3	0.30			
Cl_2	0.30			

[1]

(ii) Explain your deduction.

....

....

....

.... [1]

(c) The chemist compressed the equilibrium mixture at constant temperature and allowed it to reach equilibrium under these new conditions.

(i)   Explain what happens to the value of K_c.

....

.... [1]

(ii) Explain what happened to the composition of the equilibrium mixture.

....

....

....

.... [2]

(d) The chemist heated the equilibrium mixture and the equilibrium moved to the left.

(i) Explain what happens to the value of K_c.

....

.... [1]

(ii) Explain what additional information this observation reveals about the reaction.

....

....

....

.... [2]

(e) Phosphorus pentachloride reacts with magnesium oxide to form phosphorus(V) oxide, P_4O_{10}, and magnesium chloride.

(i) Write a balanced equation for this reaction.

.... [1]

(ii) Calculate the mass of PCl_5 needed to form 100 g of P_4O_{10} in this reaction.

mass = ... [4]

[Total: 14]

[Turn over

3 In sewage plants, biological activity can be reduced by increasing the pH of the water. This is achieved by adding small amounts of solid calcium hydroxide, $Ca(OH)_2$, to the sewage water.

In all parts of this question, assume that measurements have been made at 25 °C.

(a) The pH of aqueous solutions is determined by K_w.

K_w has a value of $1.0 \times 10^{-14}\,mol^2\,dm^{-6}$ at 25 °C.

(i) What name is given to K_w?

.... [1]

(ii) Write the expression for K_w.

.... [1]

(b) A chemist checked the concentration of aqueous calcium hydroxide, $Ca(OH)_2$, in the sewage water by titration with $5.00 \times 10^{-3}\,mol\,dm^{-3}$ hydrochloric acid.

$$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$
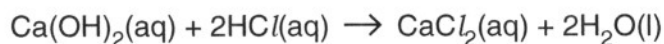
The chemist titrated $25.0\,cm^3$ of the sewage water with $21.35\,cm^3$ of HCl to reach the endpoint of the titration.

Calculate the concentration, in $mol\,dm^{-3}$, of the calcium hydroxide in the sewage water.

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

(c) The chemist analysed a sample of water from another part of the sewage works and he found that the calcium hydroxide concentration was 2.7×10^{-3} mol dm^{-3}.

Assume that when solid calcium hydroxide dissolves in water, its ions completely dissociate.

$$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$$
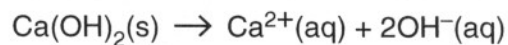
Calculate the pH of this sample.

[3]

(d) After further treatment, the water could be used for drinking. In the drinking water produced, the OH$^-$ concentration was 100 times greater than the H$^+$ concentration.

What was the pH of this drinking water?

[1]

[Total: 9]

[Turn over

4 'Superphosphate' fertilisers contain calcium dihydrogenphosphate, $Ca(H_2PO_4)_2$. This compound is one of the world's most important fertilisers. When dissolved in water, $Ca(H_2PO_4)_2$ dissociates forming $H_2PO_4^-$ ions which are easily taken up by plants.

(a) Calcium dihydrogenphosphate, $Ca(H_2PO_4)_2$, is produced by treating rock phosphate, containing $Ca_3(PO_4)_2$, with sulphuric acid, H_2SO_4.

Write a balanced equation for this reaction.

.... [1]

(b) Aqueous $H_2PO_4^-$ ions can act as a weak acid.

Write an equation to represent the dissociation of the $H_2PO_4^-$ ion.

.... [1]

(c) The $H_2PO_4^-$ ion can act as either an acid or a base.

(i) State the formula of the conjugate **base** of $H_2PO_4^-$.

.... [1]

(ii) State the formula of the conjugate **acid** of $H_2PO_4^-$.

.... [1]

(iii) A solution of calcium dihydrogenphosphate, $Ca(H_2PO_4)_2$, in water acts as a buffer solution.

Suggest, with the aid of equations, how this buffering action takes place.

....

....

....

....

.... [3]

[Total: 7]

5 In order to obtain full marks in this question, you must show **all** your working clearly.

In its reactions, sulphuric acid, H_2SO_4, can behave as an acid, an oxidising agent and as a dehydrating agent.

The displayed formula of pure sulphuric acid is shown below.
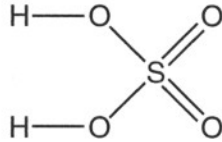
(a) The boiling point of pure sulphuric acid, at 270 °C, is higher than might be expected.

Suggest why the boiling point of sulphuric acid is higher than might be expected.

Explain your reasoning. Show a diagram in your answer.

....

....

....

....

.... [3]

TURN OVER FOR PARTS (b), (c) AND (d)

[Turn over

(b) Dilute sulphuric acid takes part in the typical acid reactions, reacting with metals, carbonates and bases.

Write balanced equations for the reaction of sulphuric acid with

a metal, ...

a carbonate, ...

a base. .... [3]

(c) Concentrated sulphuric acid will readily oxidise halide ions to the halogen.

Equation 5.1 represents the unbalanced equation for the oxidation of iodide ions by sulphuric acid.

$$\boxed{} \quad \boxed{} \quad \boxed{} \quad \boxed{}$$

$$H^+ \;+\; SO_4^{2-} \;+\; I^- \;\rightarrow\; I_2 \;+\; H_2S \;+\; H_2O \qquad \textbf{equation 5.1}$$

(i) Write the oxidation numbers of sulphur and iodine in the boxes above the equation. [2]

(ii) Balance **equation 5.1**.

[1]

(d) Concentrated sulphuric acid reacts with many organic compounds, forming water as one of the products.

For example, sulphuric acid dehydrates ethanol by eliminating water to form ethene.

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

Three other examples are shown below.

- Sulphuric acid dehydrates methanoic acid to form a gas, **A**, with the same molar mass as ethene.

- Sulphuric acid dehydrates sucrose, $C_{12}H_{22}O_{11}$, to form a black solid, **B**.

- Sulphuric acid dehydrates ethane-1,2-diol to form a compound **C** with a molar mass of $88\,g\,mol^{-1}$. In this reaction, 2 moles of ethane-1,2-diol produce 1 mole of **C** and 2 moles of H_2O.

Suggest the identity of **A**, **B** and **C**. Write equations for each reaction and deduce the structural formula of compound **C**.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

[Turn over