

**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

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Centre
Number

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Candidate
Number

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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

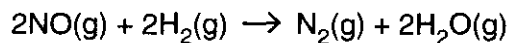
- The number of marks for each question is given in brackets [] at the end of each question or part question.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry* 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*.

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



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.

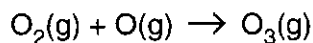
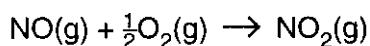
..... [1]

- (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.

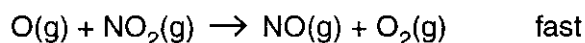
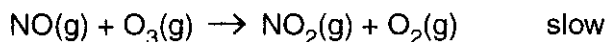


- Write the overall equation for this reaction sequence.
- Identify the catalyst and justify your answer.

.....

 [3]

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



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

.....

 [2]

[Total: 14]

- 2 When heated, phosphorus pentachloride, PCl_5 , dissociates.



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, $K_c = 0.245 \text{ mol dm}^{-3}$.

- (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 $1.0 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ at 25°C .

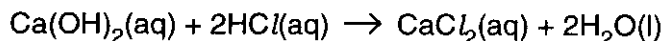
- (i) What name is given to K_w ?

..... [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 $5.00 \times 10^{-3} \text{ mol dm}^{-3}$ hydrochloric acid.



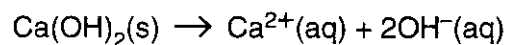
The chemist titrated 25.0 cm^3 of the sewage water with 21.35 cm^3 of HCl to reach the endpoint of the titration.

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 $2.7 \times 10^{-3} \text{ mol dm}^{-3}$.

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



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]

- 4 'Superphosphate' fertilisers contain calcium dihydrogenphosphate, $\text{Ca}(\text{H}_2\text{PO}_4)_2$. This compound is one of the world's most important fertilisers. When dissolved in water, $\text{Ca}(\text{H}_2\text{PO}_4)_2$ dissociates forming H_2PO_4^- ions which are easily taken up by plants.

- (a) Calcium dihydrogenphosphate, $\text{Ca}(\text{H}_2\text{PO}_4)_2$, is produced by treating rock phosphate, containing $\text{Ca}_3(\text{PO}_4)_2$, 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, $\text{Ca}(\text{H}_2\text{PO}_4)_2$, in water acts as a buffer solution.

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

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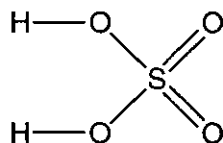
 [3]

[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)

- (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

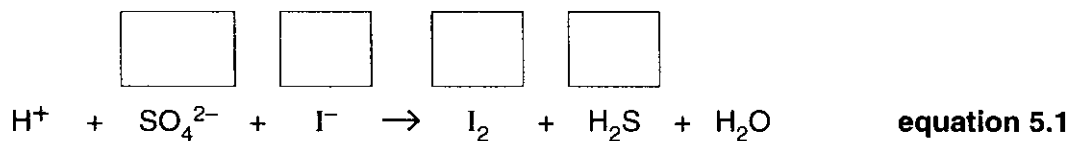
a metal,

a carbonate,

a base. [3]

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

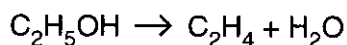
Equation 5.1 represents the unbalanced equation for the oxidation of iodide ions by sulphuric acid.



- (i) Write the oxidation numbers of sulphur and iodine in the boxes above the equation. [2]
- (ii) Balance **equation 5.1**.

[1]

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



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**.

[illegible]

[7]

[Total: 16]

END OF QUESTION PAPER

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