OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY 2816/01

Unifying Concepts

Thursday **23 JUNE 2005** Afternoon 1 hour 15 minutes

Candidates answer on the question paper.
Additional materials:
Data Sheet for Chemistry
Scientific calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 15 minutes

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	12	
2	18	
3	16	
4	14	
TOTAL	60	

This question paper consists of 11 printed pages and 1 blank page.

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[Turn over

For Examiner's Use

Answer **all** the questions.

1 This question looks at **two** different experiments that investigate rates of reaction.

(a) The decomposition of dinitrogen pentoxide, N_2O_5, at 45 °C was investigated. The reaction that takes place is shown below.

$$2N_2O_5 \longrightarrow 4NO_2 + O_2$$

In an experiment, N_2O_5 with a concentration of 0.60 mol dm^{-3} was decomposed at 45 °C.

At this temperature, the reaction has a constant half-life of 1200 s.

(i) How can you tell that this reaction is first order with respect to N_2O_5?

.....

.....[1]

(ii) Write down an expression for the rate equation of this decomposition.

.....[1]

(iii) Complete the graph opposite to show how the $[N_2O_5]$ changes over the first 3600 s of the reaction. [2]

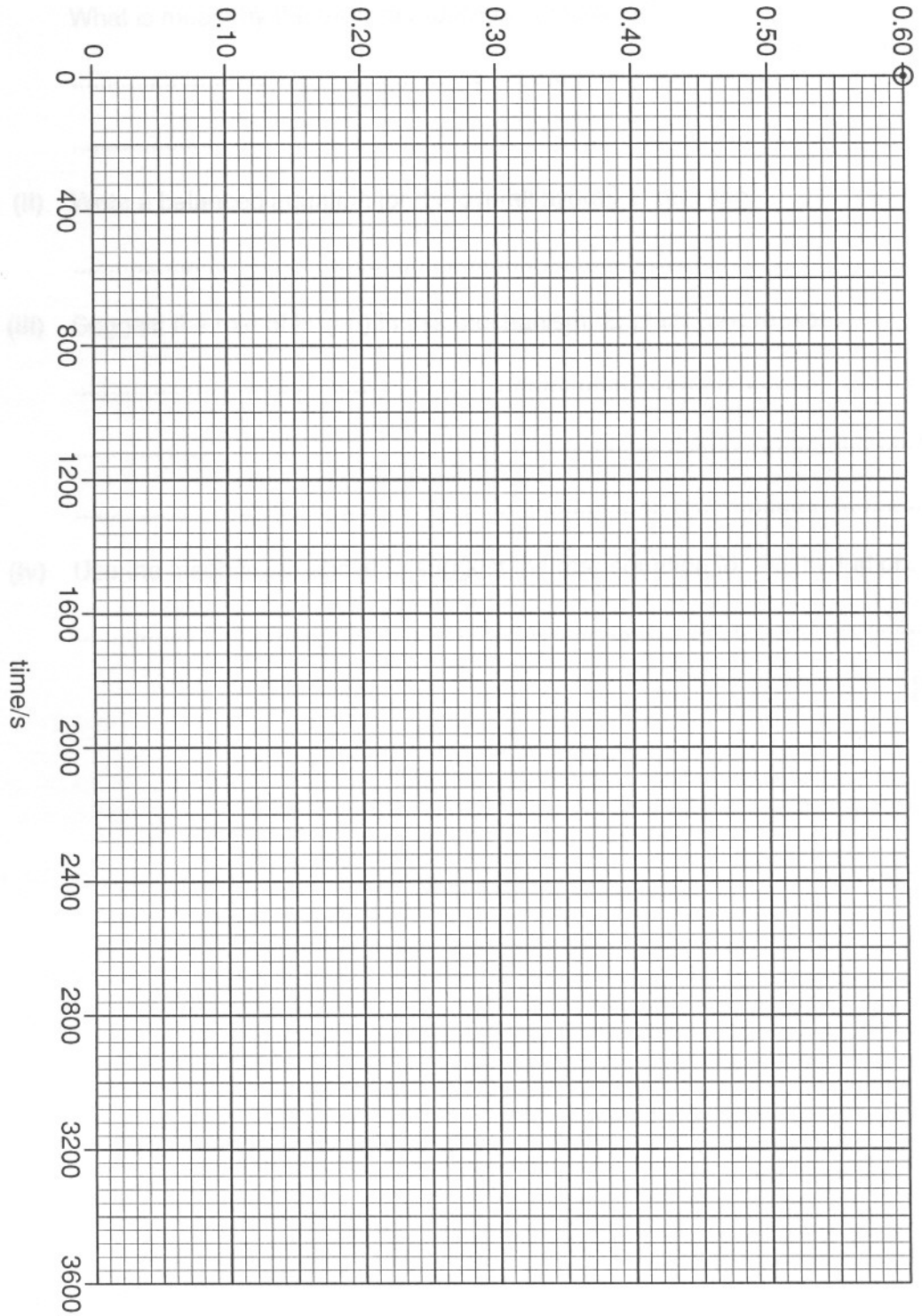
(iv) The rate of this reaction can be determined from this graph.

Show on the graph how the rate can be measured after 1200 s. [1]

(v) The rate can also be calculated from the rate equation. The rate constant for this reaction is $6.2 \times 10^{-4}\ s^{-1}$.

Calculate the initial rate of this reaction. State the units.

rate =..... units..... [2]


[N2O5] / mol dm–3
0
0.10
0.20
0.30
0.40
0.50
0.60
time/s
0
400
800
1200
1600
2000
2400
2800
3200
3600

(b) A student investigated the hydration of 2-methylpropene, $(CH_3)_2C=CH_2$, with dilute aqueous acid to form 2-methylpropan-2-ol, $(CH_3)_3COH$.

The following mechanism has been proposed for this hydration.

step 1 $(CH_3)_2C=CH_2 + H^+(aq) \longrightarrow (CH_3)_3C^+$ rate determining step

step 2 $(CH_3)_3C^+ + H_2O \longrightarrow (CH_3)_3COH + H^+(aq)$

(i) Step 1 is the rate-determining step for this hydration.

What is meant by the term *rate-determining step*?

.....

.....[1]

(ii) Write a balanced equation for the overall hydration reaction.

.....[1]

(iii) Suggest the role of $H^+(aq)$ in this mechanism. Explain your reason.

.....

.....

.....[2]

(iv) Use the mechanism above to suggest the rate equation for this hydration.

.....[1]

[Total: 12]

[Turn over

2 Methanol, $CH_3OH(g)$, is manufactured from carbon monoxide and hydrogen in an equilibrium reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

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

Explain the advantages and disadvantages of running this reaction

- at a high pressure,
- at a high temperature.

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.....[5]

Quality of Written Communication [1]

(b) This equilibrium reaction is normally carried out at 10 MPa pressure and 550 K, and starting with a 1 : 2 $CO : H_2$ mixture. At equilibrium, only 10% of the CO has reacted.

(i) Deduce the equilibrium amounts, mole fractions and partial pressures of CO, H_2 and CH_3OH present at equilibrium. Write your answers in the table below.

Assume that you have started with a mixture of 1.0 mol CO and 2.0 mol H_2.

	CO	H_2	CH_3OH
initial amount /mol	1.0	2.0	0.0
equilibrium amount /mol	0.9		
mole fraction at equilibrium			
partial pressure at equilibrium /MPa			

[4]

(ii) Write the expression for K_p for this equilibrium.

[2]

(iii) The CO : H_2 ratio in the starting mixture was changed from 1 : 2 to 1 : 3 and the mixture was allowed to reach equilibrium at the same temperature and pressure.

Explain, in terms of K_p, the effect of this change on the equilibrium yield of CH_3OH.

.....

.....

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.....

.....[3]

(iv) In another experiment, the equilibrium partial pressures were:

CO, 3.70 MPa; H_2, 5.10 MPa; CH_3OH, 0.261 MPa.

Calculate the value of K_p for this equilibrium. Express your answer to an appropriate number of significant figures. State the units of K_p.

K_p = ... units.....[2]

(c) In the UK, the annual production of methanol is 500 000 tonnes. Methanol has many uses in fuels as a reliable and low pollution form of energy.

Suggest an equation for the combustion of methanol.

.....[1]

[Total: 18]

3 A student carried out an investigation with aqueous solutions of nitric acid, sodium hydroxide, ethanoic acid and water.

(a) Nitric acid, HNO_3, is a strong Brønsted-Lowry acid.

(i) Explain what is meant by a *strong acid* and a *Brønsted-Lowry acid*.

.....

.....

.....[2]

(ii) What is the conjugate base formed from HNO_3?

.....[1]

(b) The student diluted 0.015 mol dm^{-3} nitric acid with an equal volume of water and measured the pH of the diluted acid at 25 °C.

(i) Calculate the pH of 0.015 mol dm^{-3} nitric acid.

[2]

(ii) Calculate the pH of the diluted acid.

[1]

(c) The student measured the pH of a solution of sodium hydroxide as 13.54 at 25 °C.

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

(i) Write down an expression for the ionic product, K_w, for water.

.....[1]

(ii) Calculate the concentration, in mol dm^{-3}, of this solution of sodium hydroxide.

[2]

(d) The student prepared two solutions.

- Solution **A** was made by mixing together 25 cm^3 0.010 mol dm^{-3} aqueous sodium hydroxide with 50 cm^3 0.010 mol dm^{-3} ethanoic acid, CH_3COOH. Solution **A** is a buffer solution.
- Solution **B** was made by mixing together 25 cm^3 0.020 mol dm^{-3} aqueous sodium hydroxide with 50 cm^3 0.010 mol dm^{-3} ethanoic acid, CH_3COOH. Solution **B** is **not** a buffer solution.

(i) What is meant by a *buffer solution*?

.....

.....[1]

(ii) Explain why Solution **A** is a buffer solution whereas Solution **B** is **not**.

.....

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.....[4]

(e) The student measured the pH of water as 7.0 at 25 °C. The student then warmed the water to 40 °C and measured the pH as 6.7.

What do these results tell you about the tendency of water to ionise as it gets warmer? Explain your reasoning in terms of equilibrium.

.....

.....

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.....[2]

[Total: 16]

For Examiner's Use

4 *In your answers to the questions that follow, show all of your working.*

At room temperature and pressure, r.t.p., 1 mol of gas molecules has a volume of 24 dm^3.

Whilst digging his garden, a chemistry student found what appeared to be a piece of bronze, possibly from the Bronze Age. The student knew that bronze was an alloy of copper with other metals including tin. He carried out three experiments on samples of the bronze.

(a) Experiment 1

He dissolved a small piece of the bronze, weighing 0.28 g, in concentrated (16 mol dm^{-3}) nitric acid, HNO_3. 5 cm^3 of a blue solution **C** containing Cu^{2+} ions was formed together with a brown gas with the molecular formula NO_2.

Equation **4.1** represents the equation for the reaction between copper and concentrated nitric acid.

$$Cu + 4H^+ + 2NO_3^- \longrightarrow Cu^{2+} + 2NO_2 + 2H_2O \qquad \text{equation } \mathbf{4.1}$$

The student analysed the blue colour from the Cu^{2+} ions in solution **C** using a colorimeter. He found out that the concentration of Cu^{2+} ions in solution **C** was 0.68 mol dm^{-3}.

The student concentrated the solution and obtained some blue crystals of a compound **A** with a percentage composition by mass of Cu, 26.29%; N, 11.60%; O, 59.63%; H, 2.48%. This composition included 3 waters of crystallisation.

- Calculate the percentage of copper in the bronze relic. [3]
- Calculate the empirical formula of **A**. [2]
- How would the formula of **A** normally be shown on a bottle of the chemical? [2]

(b) Experiment 2

The student dissolved another small piece of the bronze relic in dilute (8 mol dm^{-3}) nitric acid. A blue solution containing Cu^{2+} ions was again formed but this time a colourless gas was produced with the molecular formula NO.

Equation **4.2** represents the **unbalanced** equation for this second reaction.

$$Cu + H^+ + NO_3^- \longrightarrow Cu^{2+} + NO + H_2O \qquad \text{equation } \mathbf{4.2}$$

- By considering oxidation numbers, balance equation **4.2**. [3]

(c) Experiment 3

The student heated a third small piece of the bronze relic with concentrated sulphuric acid. The copper in the bronze relic reacted to produce a blue solution and 90 cm^3 of a gas **B**, measured at r.t.p.. The mass of the gas **B** collected was 0.24 g.

- Suggest a possible identity of gas **B**.
- Suggest a likely balanced equation for this reaction. [4]

[Total: 14]

END OF QUESTION PAPER