

**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										
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**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	
<b>TOTAL</b>	<b>60</b>	

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

Answer **all** the questions.

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

(a) The decomposition of dinitrogen pentoxide,  $\text{N}_2\text{O}_5$ , at  $45^\circ\text{C}$  was investigated. The reaction that takes place is shown below.



In an experiment,  $\text{N}_2\text{O}_5$  with a concentration of  $0.60 \text{ mol dm}^{-3}$  was decomposed at  $45^\circ\text{C}$ .

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  $\text{N}_2\text{O}_5$ ?

.....  
 .....[1]

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

.....[1]

(iii) Complete the graph opposite to show how the  $[\text{N}_2\text{O}_5]$  changes over the first 3600 s of the reaction. [2]

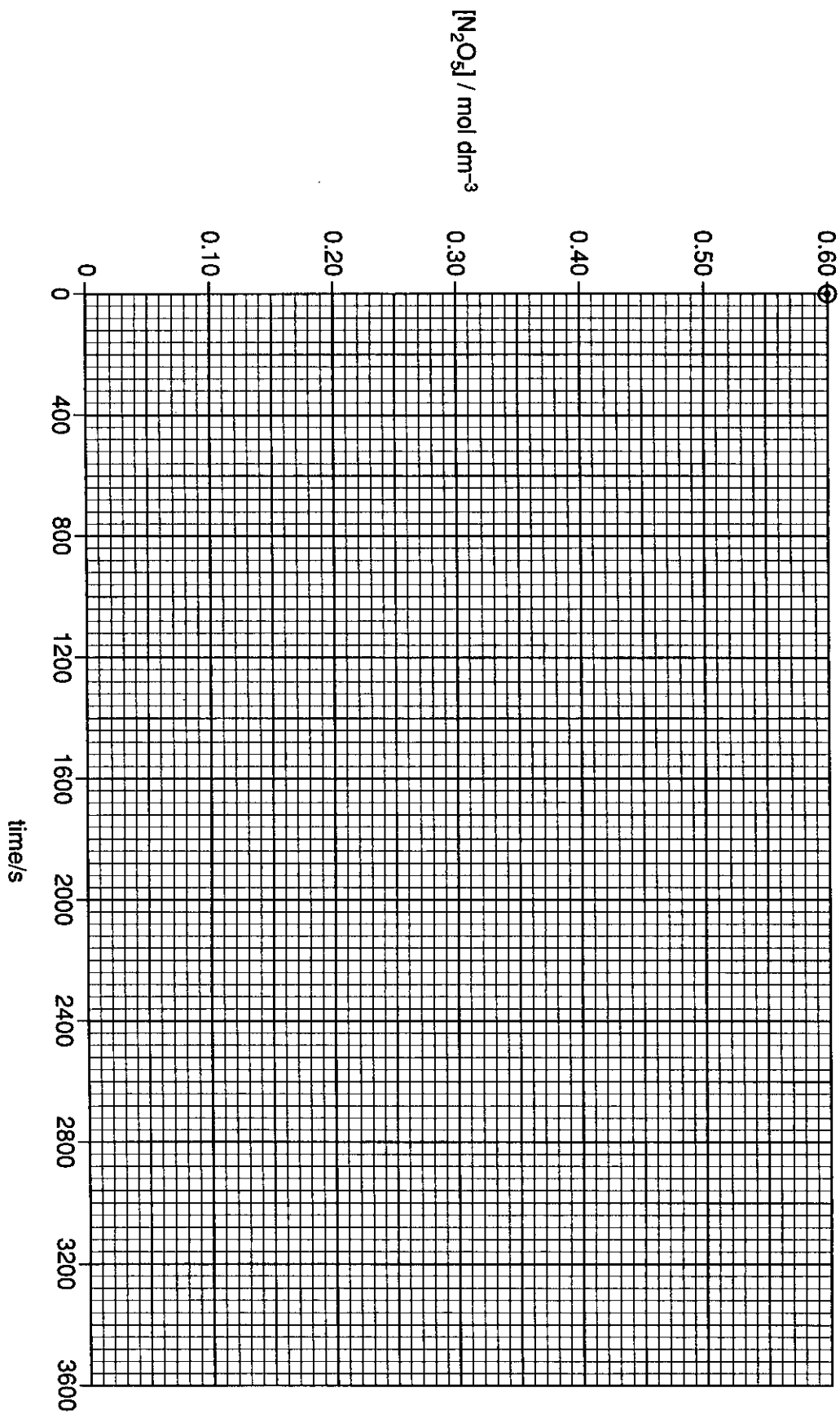
(iv) The rate of this reaction can be determined from this graph.

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  $6.2 \times 10^{-4} \text{ s}^{-1}$ .

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

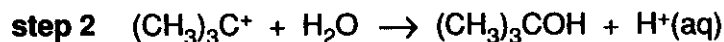
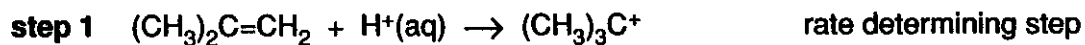
rate = ..... units..... [2]



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- (b) A student investigated the hydration of 2-methylpropene,  $(\text{CH}_3)_2\text{C}=\text{CH}_2$ , with dilute aqueous acid to form 2-methylpropan-2-ol,  $(\text{CH}_3)_3\text{COH}$ .

The following mechanism has been proposed for this hydration.



- (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  $\text{H}^+(\text{aq})$  in this mechanism. Explain your reason.

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

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

.....[1]

[Total: 12]



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

[2]

(iii) The CO : H<sub>2</sub> 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<sub>3</sub>OH.

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

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

CO, 3.70 MPa; H<sub>2</sub>, 5.10 MPa; CH<sub>3</sub>OH, 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  $K_p$ .

$K_p = \dots\dots\dots$  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,  $\text{HNO}_3$ , 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  $\text{HNO}_3$ ?

.....[1]

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

(i) Calculate the pH of  $0.015 \text{ mol dm}^{-3}$  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  $25^\circ\text{C}$ .

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

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

.....[1]

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

[2]



(d) The student prepared two solutions.

- Solution A was made by mixing together 25 cm<sup>3</sup> 0.010 mol dm<sup>-3</sup> aqueous sodium hydroxide with 50 cm<sup>3</sup> 0.010 mol dm<sup>-3</sup> ethanoic acid, CH<sub>3</sub>COOH. Solution A is a buffer solution.
- Solution B was made by mixing together 25 cm<sup>3</sup> 0.020 mol dm<sup>-3</sup> aqueous sodium hydroxide with 50 cm<sup>3</sup> 0.010 mol dm<sup>-3</sup> ethanoic acid, CH<sub>3</sub>COOH. 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.

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....[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.

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

[Total: 16]

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<sup>3</sup>.

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<sup>-3</sup>) nitric acid, HNO<sub>3</sub>. 5 cm<sup>3</sup> of a blue solution C containing Cu<sup>2+</sup> ions was formed together with a brown gas with the molecular formula NO<sub>2</sub>.

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



The student analysed the blue colour from the Cu<sup>2+</sup> ions in solution C using a colorimeter. He found out that the concentration of Cu<sup>2+</sup> ions in solution C was 0.68 mol dm<sup>-3</sup>.

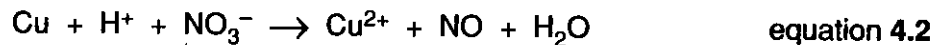
The student concentrated the solution and obtained some blue crystals of a compound A with a percentage composition by mass of Cu, 26.29%; N, 11.60%; O, 59.63%; H, 2.48%. This composition included 3 waters of crystallisation.

- 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 ( $8 \text{ mol dm}^{-3}$ ) nitric acid. A blue solution containing  $\text{Cu}^{2+}$  ions was again formed but this time a colourless gas was produced with the molecular formula  $\text{NO}$ .

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



- 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  $90 \text{ cm}^3$  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]

