OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY 2816/01

Unifying Concepts in Chemistry

Wednesday **21 JANUARY 2004** Morning 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	16	
2	17	
3	13	
4	14	
TOTAL	60	

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

Registered Charity Number: 1066969
[Turn over

Answer **all** the questions.

1 The formation of ethyl ethanoate and water from ethanoic acid and ethanol is a reversible reaction which can be allowed to reach equilibrium. The equilibrium is shown below.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(a) Write the expression for K_c for this equilibrium system.

[2]

(b) A student mixed together 6.0 mol ethanoic acid and 12.5 mol ethanol. A small amount of hydrochloric acid was also added to catalyse the reaction. He left the mixture for two days to reach equilibrium in a water bath at constant temperature, after which time 1.0 mol ethanoic acid remained.

(i) Complete the table below to show the equilibrium composition of the equilibrium mixture.

component	CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O
initial amount / mol	6.0	12.5	0.0	0.0
equilibrium amount / mol				

[2]

(ii) Calculate K_c to two significant figures. State the units, if any. The total volume of the equilibrium mixture is 1.0 dm^3.

K_c = ... units ..... [2]

(c) The student was concerned that the mixture may **not** have reached equilibrium. What could he do to be sure that equilibrium had been reached?

.....

.....

.....[2]

(d) The student added more ethanol to the mixture.

(i) State, giving a reason, what would happen to the composition of the equilibrium mixture.

.....

.....

.....[2]

(ii) What happens to the value of K_c?

.....[1]

(e) The student added more of the acid catalyst to the mixture.
State, giving a reason, what would happen to the composition of the equilibrium mixture.

.....

.....

.....[2]

(f) The student repeated the experiment at a higher temperature and found that the value of K_c decreased.

(i) State, giving a reason, what would happen to the composition of the equilibrium mixture.

.....

.....

.....[2]

(ii) What additional information does this information tell you about the reaction?

.....

.....[1]

[Total: 16]

2 Hydrogen peroxide, H_2O_2, is a colourless liquid, widely used as an oxidising agent, antiseptic, and bleach for hair and cloth.

Hydrogen peroxide reacts with iodide ions, I^-, in the presence of acid, $H^+(aq)$, forming iodine, I_2.

(a) Suggest a balanced equation for the overall reaction between $H_2O_2(aq)$, $I^-(aq)$ and $H^+(aq)$ to form aqueous iodine.

.....[2]

(b) Three experiments were carried out using different initial concentrations of $H_2O_2(aq)$, $I^-(aq)$ and $H^+(aq)$. The initial rate of formation of I_2 was measured for each experiment.

The experimental results are shown below.

experiment	$[H_2O_2(aq)]$ /mol dm^{-3}	$[I^-(aq)]$ /mol dm^{-3}	$[H^+(aq)]$ /mol dm^{-3}	rate /mol dm^{-3} s^{-1}
1	0.010	0.010	0.005	1.15×10^{-6}
2	0.010	0.020	0.005	4.60×10^{-6}
3	0.010	0.020	0.010	4.60×10^{-6}

(i) Showing all your reasoning, determine the reaction orders for I^- and for H^+.

.....

.....

.....

.....

.....

.....[4]

(ii) This reaction is first order with respect to H_2O_2.
Use this information and your answers to **(i)** to complete the rate equation for this reaction.

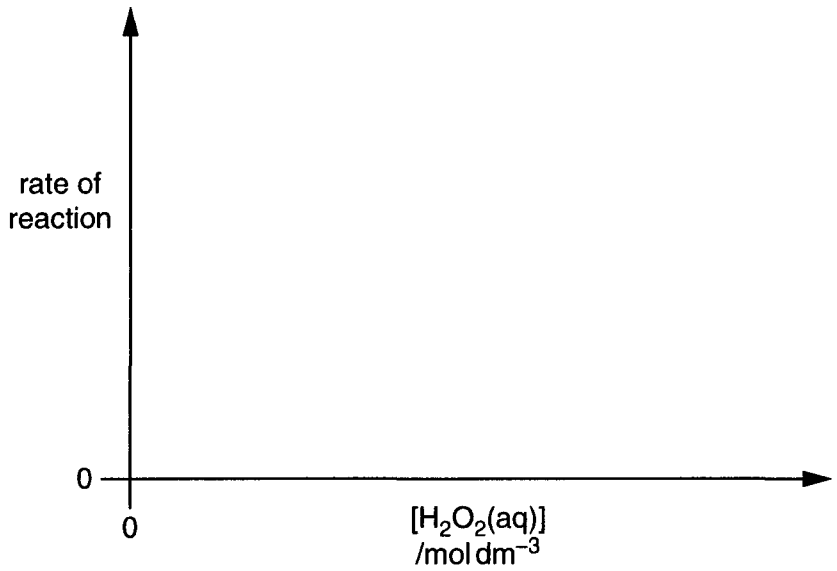
rate = ...[2]

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

rate constant, *k* ..... units ..... [3]

(c) This reaction was shown to be first order with respect to H_2O_2 by plotting a rate-concentration graph.

Using the axes below, sketch a graph to show how the rate of this reaction changes with increasing H_2O_2 concentration.



[2]

(d) Hydrogen peroxide readily decomposes to give water and oxygen.

Hydrogen peroxide is sold by volume strength. For example, 20-volume H_2O_2 yields 20 volumes of oxygen gas for each volume of aqueous H_2O_2 solution.

(i) Construct an equation for the decomposition of hydrogen peroxide.

.....[1]

(ii) Determine the concentration, in mol dm^{-3}, of 20-volume hydrogen peroxide.

Show all your working clearly.

answer ..... mol dm^{-3} [3]

[Total: 17]

3 Carbonic acid, H_2CO_3, is a weak Bronsted-Lowry acid formed when carbon dioxide dissolves in water. Blood contains several buffer solutions and healthy blood is buffered to a pH of 7.40. The most important buffer solution in blood is a mixture of carbonic acid and hydrogencarbonate ions, HCO_3^-.

The equilibrium in the carbonic acid / hydrogencarbonate buffer system is shown below.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad K_a = 4.17 \times 10^{-7}\,mol\,dm^{-3}$$

(a) Carbonic acid is a weak Bronsted-Lowry acid.

What is meant by the following terms?

(i) A *Bronsted-Lowry acid.*

.....

..... [1]

(ii) A *weak* acid.

.....

..... [1]

(iii) pH.

..... [1]

(iv) A *buffer solution.*

.....

..... [1]

(b) In this question, one mark is available for the quality of written communication.

Explain how the carbonic acid / hydrogencarbonate buffer works. Use equations to help your answer.

.....

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.....

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.....

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.....

.....

.....[4]

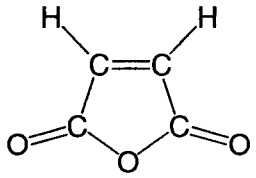
Quality of Written Communication [1]

(c) Calculate the ratio $\frac{[HCO_3^-(aq)]}{[H_2CO_3(aq)]}$ in healthy blood with a pH of 7.40.

[4]

[Total: 13]

4 Maleic anhydride (*cis*-butenedioic anhydride) is an important industrial chemical. The structure of maleic anhydride is shown below.



maleic anhydride
$C_4H_2O_3$

(a) In industry, maleic anhydride is produced on a large scale by oxidation of butane in air over a hot catalyst.

(i) Suggest the industrial source of butane.

.....[1]

(ii) An incomplete equation for this reaction is given below.

Complete the equation.

$$C_4H_{10} + \text{.....} \rightarrow C_4H_2O_3 + \text{.....}$$

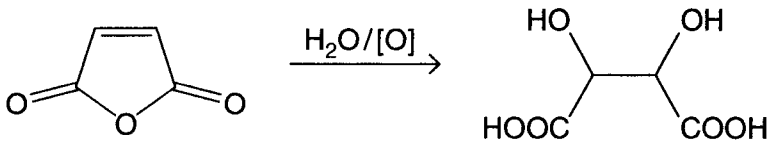
[2]

(iii) Calculate the mass, in kg, of maleic anhydride that could be made by completely converting 30 m^3 of butane in this reaction. (1 m^3 = 1000 dm^3)

Assume that the molar volume of butane under the conditions used is 24 dm^3.

answer ..... kg [3]

(b) Maleic anhydride can be converted into tartaric acid by reaction with water and a suitable oxidising agent.



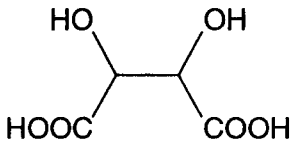
maleic anhydride **tartaric acid**

Deduce the **empirical** formula of tartaric acid.

[2]

(c) 'Cream of tartar' is often used in cookery.
This compound can be prepared by reacting aqueous solutions of tartaric acid and potassium hydroxide in 1:1 molar proportions.

(i) Complete the equation below for the preparation of 'cream of tartar'.



\+ KOH → + ...

tartaric acid **'cream of tartar'**

[2]

(ii) Suggest another chemical that would react with aqueous tartaric acid. The chemical you choose should **not** be a hydroxide or an oxide.

State what you would expect to see and write an equation for your chosen reaction.

chemical .....

observation(s) .....

.....

equation

[4]

[Total: 14]

RECOGNISING ACHIEVEMENT

Subject: Unifying Concepts Code: 2816 1

Session: January Year: 2004

FINAL Mark Scheme

MAXIMUM MARK	60

ADVICE TO EXAMINERS ON THE ANNOTATION OF SCRIPTS

1. Please ensure that you use the **final** version of the Mark Scheme.
   You are advised to destroy all draft versions.

2. Please mark all post-standardisation scripts in red ink. A tick (✓) should be used for each answer judged worthy of a mark. Ticks should be placed as close as possible to the point in the answer where the mark has been awarded. The number of ticks should be the same as the number of marks awarded. If two (or more) responses are required for one mark, use only one tick. Half marks (½) should never be used.

3. The following annotations may be used when marking. No comments should be written on scripts unless they relate directly to the mark scheme. Remember that scripts may be returned to Centres.

   x = incorrect response (errors may also be underlined)
   ^ = omission mark
   bod = benefit of the doubt (where professional judgement has been used)
   ecf = error carried forward (in consequential marking)
   con = contradiction (in cases where candidates contradict themselves in the same response)
   sf = error in the number of significant figures

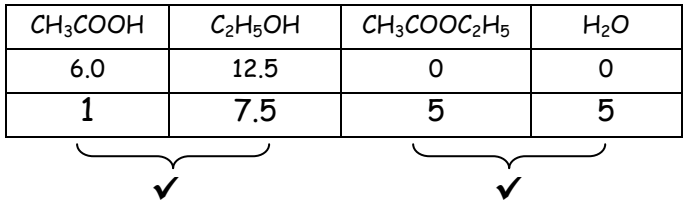
4. The marks awarded for each part question should be indicated in the margin provided on the right hand side of the page. The mark total for each question should be ringed at the end of the question, on the right hand side. These totals should be added up to give the final total on the front of the paper.

5. In cases where candidates are required to give a specific number of answers, (e.g. 'give three reasons'), mark the first answer(s) given up to the total number required. Strike through the remainder. In specific cases where this rule cannot be applied, the exact procedure to be used is given in the mark scheme.

6. Correct answers to calculations should gain full credit even if no working is shown, unless otherwise indicated in the mark scheme. (An instruction on the paper to 'Show your working' is to help candidates, who may then gain partial credit even if their final answer is not correct.)

7. Strike through all blank spaces and/or pages in order to give a clear indication that the whole of the script has been considered.

8. An element of professional judgement is required in the marking of any written paper, and candidates may not use the exact words that appear in the mark scheme. If the science is correct and answers the question, then the mark(s) should normally be credited. If you are in doubt about the validity of any answer, contact your Team Leader/Principal Examiner for guidance.

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit ___ = (underlining) key words which **must** be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument	
Question	**Expected Answers**	**Marks**
1 (a)	$K_c = \frac{[CH_3COOC_2H_5]\,[H_2O]}{[CH_3COOH]\,[C_2H_5OH]}$ ✓✓ *award 1 mark if upside down*	**[2]**
(b) (i)	 ✓ ✓	**[2]**
(ii)	$K_c = \frac{5 \times 5}{1 \times 7.5}$ = 3.3 ✓ no units ✓ (or ecf based on answers to (i) and/or (a))	**[2]**
(c)	leave experiment longer ✓ monitor compositions and repeat until constant value ✓	**[2]**
(d) (i)	more $CH_3COOC_2H_5$ & H_2O / less CH_3COOH & C_2H_5OH ✓ equilibrium ⟶ right ✓ AW	**[2]**
(ii)	K_c stays same ✓	**[1]**
(e)	stays that same/ catalyst does not shift equilibrium position ✓ forward & reverse rxns altered by same amount/ equilibrium achieved in less time ✓	**[2]**
(f) (i)	equilibrium ⟶ left ✓ more reactants / less products ✓	**[2]**
(ii)	forward reaction is exothermic ✓	**[1]**
		Total: 16

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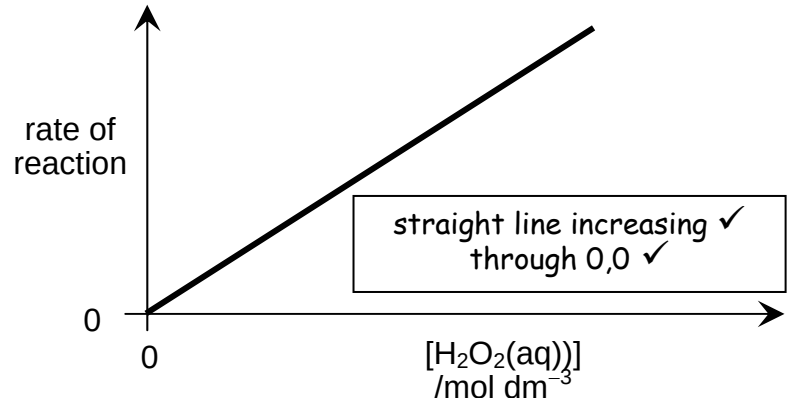
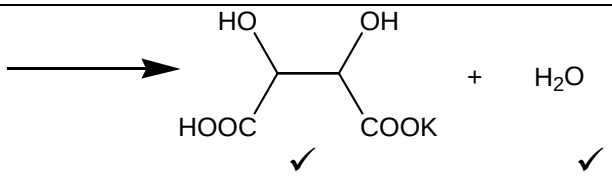
Question	**Expected Answers**	**Marks**
2 (a)	$H_2O_2 + 2I^- + 2H^+ \longrightarrow I_2 + 2H_2O$ equation includes H_2O_2, I^-, H^+ as reactants and I_2 as product ✓ equation balanced ✓	**[2]**
(b) (i)	Exp 2 has twice $[I^-]$ as Exp 1 and rate has quadrupled ✓, so order = 2 with respect to I^- ✓ Exp 3 has twice $[H^+]$ as 2 and rate is unchanged ✓, so order = 0 with respect to H^+ ✓.....AW	**[4]**
(ii)	rate = $k[H_2O_2][I^-]^2$ ✓✓ 1 mark for: rate = k x concs (ecf from (i))	**[2]**
(iii)	k = rate/$[H_2O_2][I^-]^2$ ✓(ecf from (ii)) From one of expts, e.g. Exp 1: k = 1.15 x $10^{-6}/(0.01)(0.01)^2$ = 1.15 ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ (ecf from (ii))	**[3]**
(c)		**[2]**
(d) (i)	$2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓	**[1]**
(ii)	1 dm^3 $H_2O_2 \longrightarrow$ 20 dm^3 O_2 ✓ amount of O_2 = 20/24 mol ✓ concentration of H_2O_2 = 2 x 20/24 = 1.67 mol dm^{-3} ✓	**[3]**
		Total: 17

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit ____ = (underlining) key words which **must** be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument	
Question	**Expected Answers**	**Marks**
3 (a) (i)	a proton donor ✓	**[1]**
(ii)	partially dissociates ✓	**[1]**
(iii)	$pH = -\log[H^+]$	**[1]**
(iv)	A solution that minimises changes/resists change in pH after addition of acid/alkali ✓ NOT 'maintains constant pH' or 'cancel out'	**[1]**
(b)	H_2CO_3 reacts with added alkali / added alkali reacts with H^+ / $H^+ + OH^- \longrightarrow H_2O$ ✓ The base or HCO_3^- reacts with added acid ✓ $H_2CO_3 + OH^- \longrightarrow HCO_3^- + H_2O$ ✓ $HCO_3^- + H^+ \longrightarrow H_2CO_3$ ✓.....AW QoWC: equilibrium position moves to counteract change / explanation in terms of le Chatelier's principle ✓	**[4]** **[1]**
(c)	$K_a = \frac{[H^+]\,[HCO_3^-(aq)]}{[H_2CO_3(aq)]}$ ✓ $[H^+] = 10^{-pH}$ ✓ $= 10^{-7.4} = 3.98 \times 10^{-8}$ ✓ $\frac{[HCO_3^-(aq)]}{[H_2CO_3(aq)]} = \frac{K_a}{[H^+]} = \frac{4.17 \times 10^{-7}}{3.98 \times 10^{-8}} = 10.5$ ✓	**[4]**
		Total: 13

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points NOT = answers which are not worthy of credit ( ) = words which are not essential to gain credit ___ = (underlining) key words which **must** be used to gain credit ecf = error carried forward AW = alternative wording ora = or reverse argument

Question	Expected Answers	Marks
4 (a) (i)	crude oil ✓	[1]
(ii)	$C_4H_{10} + 3\frac{1}{2}O_2 \longrightarrow C_4H_2O_3 + 4H_2O$ C_4H_{10} , O_2 & $C_4H_2O_3$ ✓ all correct and balanced ✓	[2]
(iii)	moles butane = 30 x 1 000/24 = 1 250 ✓ M_r maleic anhydride = 98 ✓ mass maleic anhydride = moles x M_r = 1 250/1000 x 98 kg 122.5 kg ✓	[3]
(b)	molecular formula = $C_4H_6O_6$ ✓ empirical formula = $C_2H_3O_3$ ✓ (award both marks if only empirical formula is shown)	[2]
(c) (i)	 ✓ ✓	[2]
(ii)	any chemical that reacts: e.g. metal more reactive than Pb / carbonate / carboxylic acid / alcohol / hydrogen halide ✓ observation to match chemical added ✓ equation to match chemistry of chemical added; products ✓ balanced ✓	[4]
		Total: 14