OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY 2816/01

Unifying Concepts

Friday **21 JANUARY 2005** 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	15	
2	17	
3	12	
4	16	
TOTAL	60	

This question paper consists of 10 printed pages and 2 blank pages.

Registered Charity Number. 1066969
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For Examiner's Use

Answer **all** the questions.

1 In the UK, almost all the sulphuric acid, H_2SO_4, is manufactured by the Contact process. One stage in the Contact process involves the reaction between sulphur dioxide and oxygen.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Table 1.1 below shows values of the equilibrium constant, K_p, for this equilibrium at different temperatures.

temperature / °C	K_p / kPa^{-1}
25	4.0×10^{22}
200	2.5×10^{8}
800	1.3×10^{-3}

Table 1.1

(a) Write an expression for the equilibrium constant, K_p, of this reaction.

[2]

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

- The conversion of sulphur dioxide and oxygen into sulphur trioxide is carried out at slightly above atmospheric pressure. Comment on this statement.
- Explain what happens to the equilibrium amounts of SO_2, O_2 and SO_3 as temperature increases at constant pressure.
- Deduce the sign of ΔH for the forward reaction in the equilibrium. Explain your reasoning carefully.

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.....[6]

Quality of Written Communication [1]

(c) An equilibrium is set up for the SO_2, O_2, SO_3 equilibrium at 400 °C.

At this temperature

- the equilibrium partial pressure of SO_2 is 10 kPa
- the equilibrium partial pressure of O_2 is 50 kPa
- $K_p = 3.0 \times 10^2\ kPa^{-1}$.

Calculate the equilibrium partial pressure of SO_3 at 400 °C. Hence determine the percentage of SO_3 in the equilibrium mixture at this temperature.

answer .....% [3]

(d) In the UK, almost all the sulphuric acid manufactured uses sulphur as a starting material for SO_2 production. In some countries, metal ores such as zinc sulphide, ZnS, are used instead to form SO_2 by heating with air.

(i) Construct a balanced equation to show the reaction that takes place when zinc sulphide is heated in air.

.....[2]

(ii) Suggest why countries may find it more economic to manufacture sulphuric acid from zinc sulphide.

.....

.....[1]

[Total: 15]

2 One cause of low-level smog is the reaction of ozone, O_3, with ethene. The smog contains methanal, $CH_2O(g)$, and the equation for its production is shown below.

$$O_3(g) + C_2H_4(g) \longrightarrow 2CH_2O(g) + \tfrac{1}{2}O_2(g) \qquad \textbf{equation 2.1}$$

(a) The rate of the reaction doubles when the initial concentration of either $O_3(g)$ or $C_2H_4(g)$ is doubled.

(i) What is the order of reaction with respect to

O_3.....

C_2H_4?..... [1]

(ii) What is the overall order of the reaction? .....[1]

(iii) Write the rate equation for this reaction.

.....[1]

(b) For an initial concentration of ozone of 0.50×10^{-7} mol dm^{-3} and one of ethene of 1.0×10^{-8} mol dm^{-3}, the initial rate of methanal formation was 1.0×10^{-12} mol dm^{-3} s^{-1}.

(i) How could the **initial** rate of methanal formation be measured from a concentration/time graph?

.....

.....[2]

(ii) Calculate the value of the rate constant and state the units.

rate constant =..... units.....[3]

(iii) The initial rate of methanal formation is different from that of oxygen formation in equation **2.1**.

Explain why.

.....

.....[1]

(iv) The experiment was repeated but at a higher temperature. What would be the effect of this change on the rate and the rate constant of the reaction?

.....

.....

.....[2]

(c) In the stratosphere, ozone forms when oxygen free radicals react with oxygen molecules.

$$O_2 + O \longrightarrow O_3$$

The oxygen free radicals are initially formed as diradicals when oxygen gas, O_2, is dissociated by strong ultraviolet radiation,

$$O_2(g) \longrightarrow 2O(g)$$

(i) Suggest why oxygen free radicals, O, are often called **di**radicals.

.....

.....[1]

(ii) Draw a '*dot-and-cross*' diagram of an ozone molecule. Show outer electrons only.

[2]

(iii) Chlorine free radicals formed from CFCs deplete the ozone layer in a chain reaction.

Typically, 1 g of chlorine free radicals destroys 150 kg of ozone during the atmospheric lifetime of the chlorine free radical (one to two years).

Calculate how many ozone molecules are destroyed in this chain reaction by a single chlorine free radical before the free radical is destroyed.

answer.....[3]

[Total: 17]

3 Phenol, C_6H_5OH, is a powerful disinfectant and antiseptic. Phenol is a weak Brønsted-Lowry acid.

(a) What is meant by the following terms;

(i) a *Brønsted-Lowry* acid;

.....[1]

(ii) a *weak* acid?

.....

.....[1]

(b) When phenol is mixed with aqueous sodium hydroxide, an acid-base reaction takes place.

$C_6H_5OH(aq)$ + $OH^-(aq)$ $\rightleftharpoons$ $C_6H_5O^-(aq)$ + $H_2O(l)$

....

In the spaces above,

- label one **conjugate acid-base pair** as acid 1 and base 1,
- label the other **conjugate acid-base pair** as acid 2 and base 2. [2]

(c) A solution of phenol in water has a concentration of $38\,g\,dm^{-3}$.
The acid dissociation constant, K_a, of phenol is $1.3 \times 10^{-10}\,mol\,dm^{-3}$.

(i) Write an expression for the acid dissociation constant, K_a, of phenol.

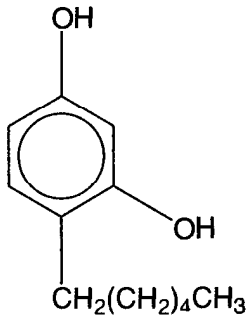
[1]

(ii) Calculate the pH of this solution.

answer.....[5]

(d) Hexylresorcinol is an antiseptic used in solutions for cleansing wounds and in mouthwashes and throat lozenges.

The structure of hexylresorcinol is shown below.



Identify a compound that could be added to hexylresorcinol to make a buffer solution. Explain your answer.

[2]

[Total: 12]

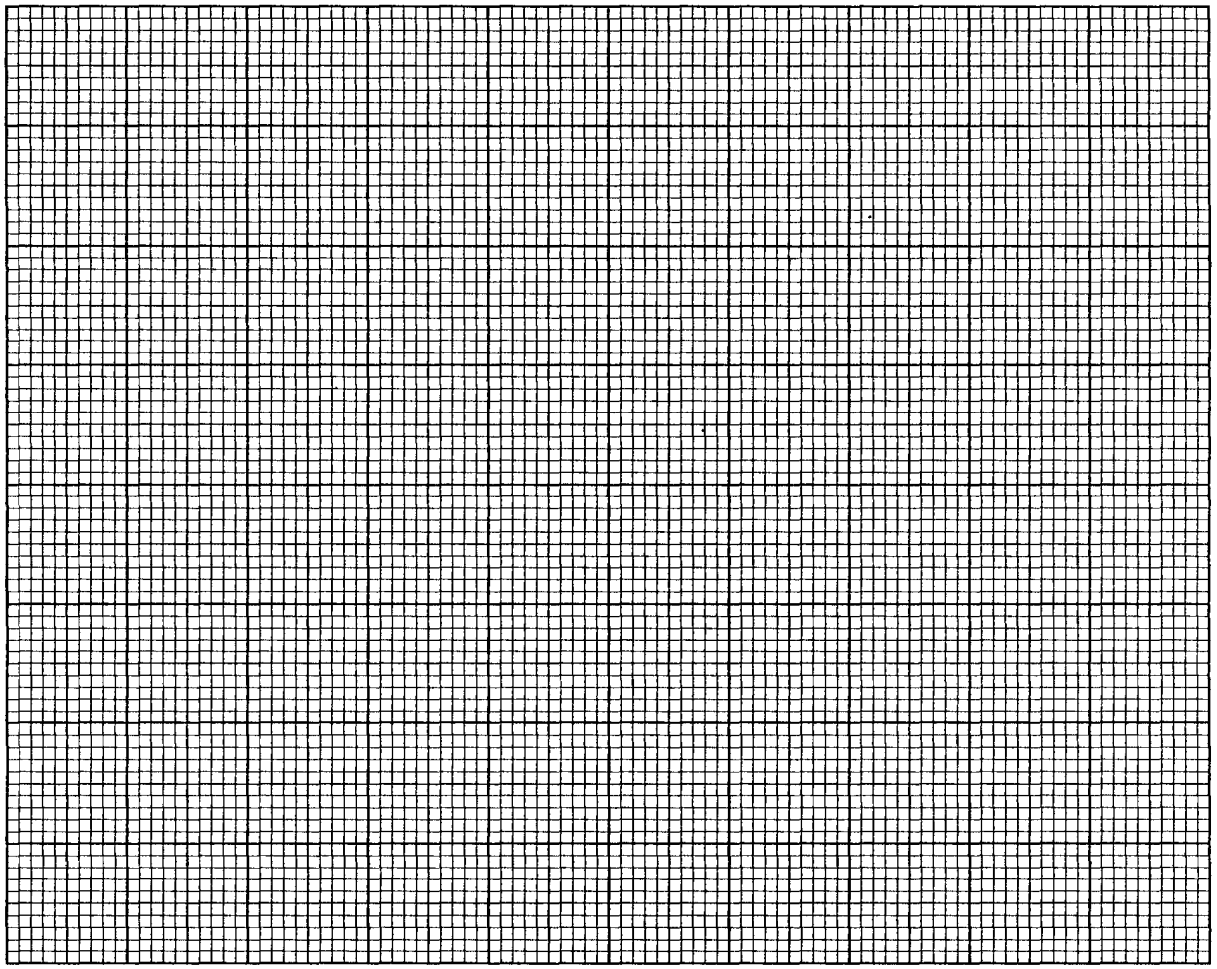
4 Titration curves can be used to decide on a suitable indicator for a titration.

You are supplied with the following solutions.

- 0.100 mol dm^{-3} NaOH(aq)
- 0.100 mol dm^{-3} CH_3COOH(aq), which has a pH of 2.9

(a) 50.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) is gradually added to 25.0 cm^3 of 0.100 mol dm^{-3} CH_3COOH(aq).

Sketch the titration curve for this addition. Label the axes and mark approximate values, to show the variation of pH.



[6]

(b) Phenolphthalein is a suitable indicator for a titration between CH_3COOH(aq) and NaOH(aq) whereas methyl orange is **not** suitable.

Explain these two statements.

.....

.....

.....

.....[2]

(c) The procedure in **(a)** was repeated with 25.0 cm^3 0.050 mol dm^{-3} $CH_3COOH(aq)$ instead of 0.100 mol dm^{-3} $CH_3COOH(aq)$.

What differences would there be in the titration curve plotted?

.....

.....

.....

.....[2]

(d) Compound **B** is an organic base. A student analysed this base by the procedure below.

He first prepared a solution of **B** by dissolving 4.32 g of **B** in water and making the solution up to 250 cm^3. The student then carried out a titration in which 25.00 cm^3 of this solution of **B** were neutralised by exactly 23.20 cm^3 of 0.200 mol dm^{-3} HC*l*.

1 mole of **B** reacts with 1 mole of HC*l*.

Use this information to calculate the molar mass of base **B** and suggest its identity.

[6]

[Total: 16]

END OF QUESTION PAPER

RECOGNISING ACHIEVEMENT

Subject: Unifying Concepts Code: 2816/01

Session: January Year: 2005

Mark Scheme FINAL

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)	$K_p = \frac{p(SO_3)^2}{p(SO_2)^2 \times p(O_2)}$ ✓✓ 1 mark for correct powers but wrong way up. 1 mark for square brackets			**[2]**
(b)	An increase in pressure moves equilibrium to the right because there are less gaseous moles on the right hand side ✓ Increased pressures are expensive to generate/safety problems with walls of containers/enables gases to flow ✓ K_p gets less with increasing temperature ✓ SO_2 and O_2 increase/SO_3 decreases ✓ Equilibrium ⟶ left to oppose increase in temperature ✓ Forward reaction is exothermic or ΔH is −ve /reverse reaction is endothermic or ΔH is +ve because K_p gets less with increasing temperature ✓ QoWC: organises relevant information clearly and coherently, using specialist vocabulary where appropriate ✓			**[6]** **[1]**
(c)	$3.0 \times 10^2 = \frac{p(SO_3)^2}{10^2 \times 50}$ ✓ $p(SO_3) = \sqrt{(3.0 \times 10^2 \times 10^2 \times 50)} = 1225$ kPa ✓ $\%(SO_3) = 100 \times 1225 / (1225 + 10 + 50) = 95\%$ ✓			**[3]**
(c) (i)	$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$ ✓✓ ZnS, O_2 as reactants **and** SO_2 as a product: 1st mark. ZnO **and** balance: 2nd mark			**[2]**
(ii)	ZnS is more available than S. ✓			**[1]**
				Total: 15

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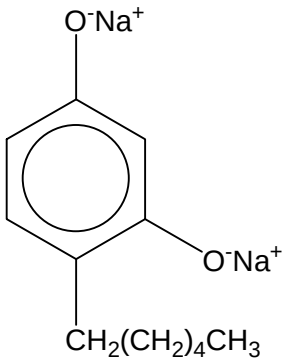
Question	**Expected Answers**	**Marks**
2 (a) (i)	O_3: 1 and C_2H_4 ✓	**[1]**
(ii)	2 ✓	**[1]**
(iii)	rate = $k[O_3][C_2H_4]$ ✓	**[1]**
(b) (i)	measure gradient/tangent ✓ at t = 0/start of reaction ✓	**[2]**
(ii)	$k = \frac{\text{rate}}{[O_3][C_2H_4]}$ ✓ $k = \frac{1.0 \times 10^{-12}}{0.5 \times 10^{-7} \times 1.0 \times 10^{-8}} = 2 \times 10^3$ ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	**[3]**
(iii)	2 mol CH_2O forms for every 0.5 mol O_2 / stoichiometry of CH_2O : O_2 is **not** 1:1 ✓	**[1]**
(iv)	rate increases ✓ k increases ✓	**[2]**
(c) (i)	each atom has two unpaired electrons ✓	**[1]**
(ii)	2 oxygen atoms bonded by double bond ✓ third oxygen bonded by a covalent bond and outer shells correct ✓ For 2nd mark, all O atoms must have an octet. A triangular molecule would have 3 single covalent bonds for 1st mark but the origin of each electron must be clear for 2nd mark	**[2]**
(iii)	amount of O_3 in 150 kg = $150 \times 10^3/48 = 3.13 \times 10^3$ mol ✓ amount of Cl radicals in 1 g = $1/35.5 = 2.82 \times 10^{-2}$ mol ✓ 1 mol Cl destroys $3.13 \times 10^3/2.82 \times 10^{-2} = 1.11 \times 10^5$ mol O_3 1 Cl radical destroys 1.11×10^5 O_3 molecules ✓ (calculator: 110937)	**[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)	proton donor ✓	**[1]**
(ii)	partially dissociates ✓	**[1]**
(b)	$C_6H_5OH(aq) + OH^-(aq) \rightleftharpoons C_6H_5O^-(aq) + H_2O(l)$ acid 1 base 2 ✓ base 1 acid 2 ✓ *1 mark for each acid-base pair*	**[2]**
(c) (i)	$K_a = \frac{[C_6H_5O^-]\,[H^+]}{[C_6H_5OH]}$ ✓	**[1]**
(ii)	concentration = 38/94 ✓ = 0.40 mol dm^{-3} ✓ *(first mark for M_r of phenol – incorrect answer here will give ecf for remainder of question)* $1.3 \times 10^{-10} \approx \frac{[H^+(aq)]^2}{0.40}$ ✓ *('=' sign is acceptable)* $[H^+] = \sqrt{\{(1.3 \times 10^{-10}) \times (0.40)\}} = 7.2 \times 10^{-6}$ mol dm^{-3} ✓ $pH = -\log[H^+] = -\log 7.2 \times 10^{-6} = 5.14$ ✓ ***3 marks:*** $[H^+]$✓; pH expression✓; calc of pH from $[H^+]$ ✓ ***Common errors***: Without square root, answer = 10.28 ✓✓× Use of 38 as molar concentration does not score 1st 2 marks. This gives an answer of 4.15 for 3 marks ✓✓✓	**[5]**

(d)	 / NaOH /Na✓ weak acid/base pair mixture formed ✓	*On structure, 1 mark for O Na on either or both phenol groups.*	**[2]**
			Total: 12

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)	graphs are of pH against volume acid/alkali added with scale and units ✓ sharp rise between two slight rises ✓ equivalent point > 7 ✓ sharp rise after addition of 25 cm^3 of alkali ✓ start pH = 2.9 ✓ finish pH = 12 → 13 ✓	**[6]**
(b)	phenolphthalein changes colour in the pH range corresponding to the sharp rise in the titration curve ✓ methyl orange changes colour **before** the sharp rise ✓	**[2]**
(c)	sharp rise in pH after addition of 12.5 cm^3 NaOH ✓ pH start is higher than 2.9 ✓	**[2]**
(d)	moles HCl in 23.2 cm^3 = 0.200 x 23.2/1000 = 4.64 x 10^{-3} ✓ moles **B** in 25 cm^3 = moles HCl = 4.64 x 10^{-3} ✓ moles **B** in 250 cm^3 = 4.64 x 10^{-3} x 10 = 4.64 x 10^{-2} ✓ 4.64 x 10^{-2} mol **B** has a mass of 4.32 g molar mass of **B** = 4.32/4.64 x 10^{-2} = 93 g mol^{-1} ✓ 93 – 16 = 77 ✓ Therefore **B** is phenylamine / $C_6H_5NH_2$ ✓ *There may be other valid structures that are amines. These can be credited provided that everything adds up to 93.* *Answer could be a primary, secondary or tertiary amines.*	**[6]**
		Total: 16