OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

CHEMISTRY 2816/01

Unifying Concepts in Chemistry

Thursday **24 JANUARY 2002** 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 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	17	
2	12	
3	18	
4	13	
TOTAL	60	

This question paper consists of 9 printed pages and 3 lined pages.

SP (NH/CG) S10966/3

For Examin Use

Answer **all** questions.

1 An equilibrium system exists between $SO_2(g)$, $O_2(g)$ and $SO_3(g)$.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$$

The equilibrium constant K_p for this reaction is $4.0 \times 10^{19}\,Pa^{-1}$ at 25 °C.

(a) Le Chatelier's principle can be used to predict how the position of equilibrium may change in a system that is in dynamic equilibrium.

(i) State *le Chatelier's principle.*

.....

.....[2]

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

[1]

(iii) What does this value of K_p suggest about the position of equilibrium at 25 °C and the relative equilibrium proportions of the reactants and products?

.....

.....

.....[2]

(b) Using le Chatelier's principle, predict how the position of this equilibrium may be affected by the following changes. Explain your answers.

(i) The temperature is increased while keeping the pressure constant.

effect on equilibrium position

.....

.....[1]

effect on partial pressure of $SO_3(g)$

.....

.....[1]

For Examiner's Use

(ii) The pressure is increased while keeping the temperature constant.

effect on equilibrium position

.....

.....[1]

effect on mole fraction of $SO_3(g)$

.....

.....[1]

(c) What is the effect on K_p of

(i) increasing the temperature;

.....[1]

(ii) increasing the pressure?

.....[1]

(d) The industrial production of $SO_3(g)$ from $SO_2(g)$ and $O_2(g)$ is carried out between 400 °C and 450 °C, in the presence of a catalyst and using a pressure that is just greater than normal atmospheric pressure.

Suggest why each of these conditions is used.

.....

.....

.....

.....

.....

.....

.....

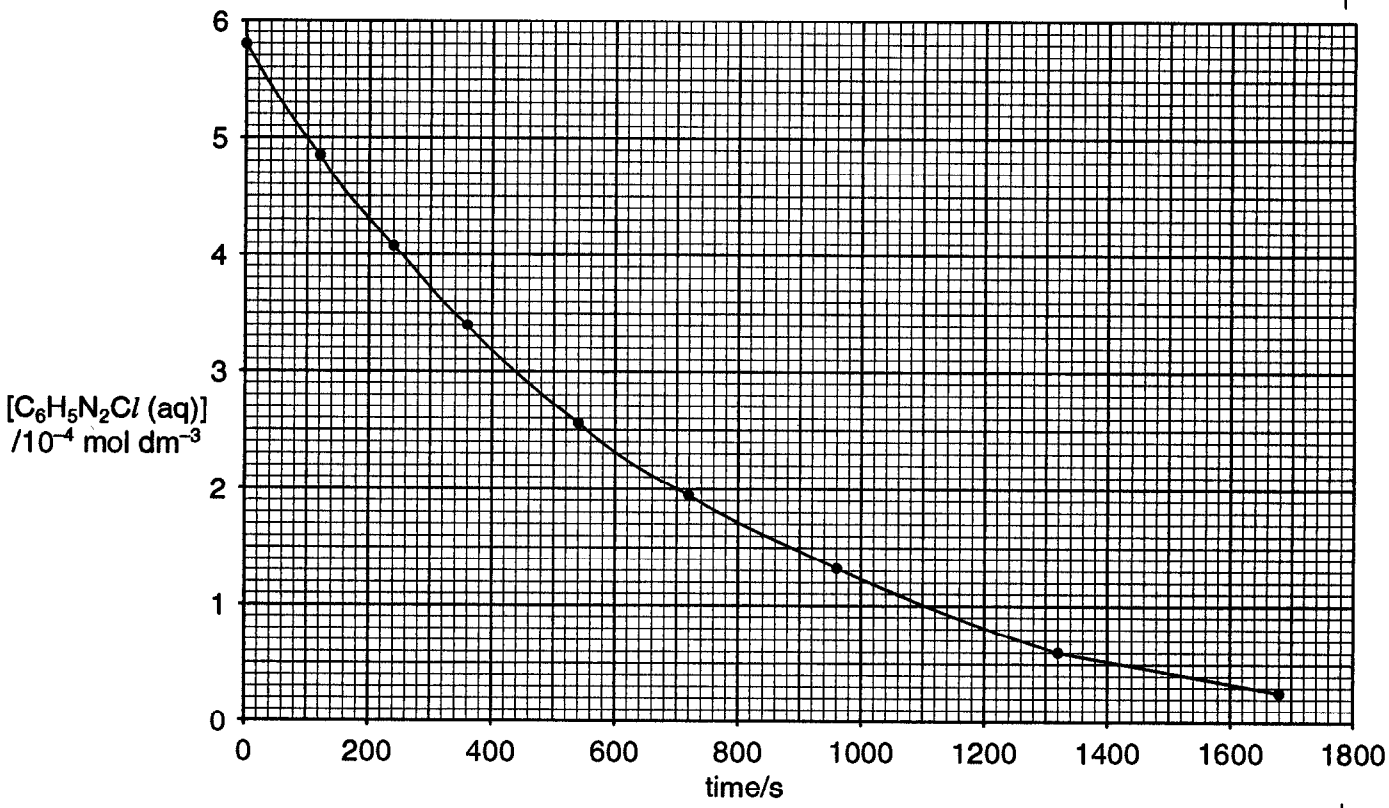
.....[6]

[Total : 17]

2 Benzenediazonium chloride, $C_6H_5N_2Cl$, decomposes above 10 °C, releasing nitrogen gas.

$$C_6H_5N_2Cl(aq) + H_2O(l) \longrightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$

The graph below shows how the concentration of $C_6H_5N_2Cl$ changes with time at 50 °C.



(a) This reaction is first order with respect to $C_6H_5N_2Cl$. This can be confirmed from the graph using half-lives.

(i) What is meant by the *half-life* of a reaction, $t_{½}$?

.....

.....[1]

(ii) Use this graph to show that this reaction is first order with respect to $C_6H_5N_2Cl$. You should mark on the graph any working.

.....

.....

.....

.....[3]

(iii) What would be the effect on the half-life of this reaction of doubling the initial concentration of $C_6H_5N_2Cl$?

.....[1]

(b) For a first order reaction, the rate constant, k, can be found using the following relationship.

$$kt_{½} = 0.693$$

Calculate the value for the rate constant, k, of this reaction. Include the units of k in your answer.

[2]

(c) Write down the expression for the rate equation of this reaction.

.....[1]

(d) The rate of this reaction can be calculated by using the graph and the rate equation together.

(i) Read from the graph the concentration of $C_6H_5N_2Cl$ after 800 s.

.....[1]

(ii) Use the rate equation to calculate the rate of this reaction after 800 s. Include units in your answer.

[2]

(iii) How could you measure the reaction rate after 800 s directly from the graph alone?

.....

.....[1]

[Total : 12]

3 Methanoic acid, HCOOH, is an ant's main defence mechanism, squirted at potential intruders and injected in 'ant bites'. The common name for methanoic acid is *formic acid*, named from the Latin *formica* which means 'ant'.

A chemist collected the formic acid squirted by 20 ants and added sufficient water to make 25.0 cm^3 of a solution **X**.

The chemist titrated solution **X** with sodium hydroxide, NaOH(aq).

- 20.0 cm^3 of NaOH were required to neutralise the formic acid.
- The equation for the neutralisation of formic acid is shown below.

$$HCOOH(aq) + NaOH(aq) \longrightarrow HCOONa(aq) + H_2O(l)$$

(a) Write the ionic equation for this reaction.

.....[1]

(b) Sodium hydroxide is a strong alkali. The concentration of NaOH(aq) used in the titration was 0.00750 mol dm^{-3}.

Calculate the pH of this solution. [$K_w = 1.00 \times 10^{-14}$ $mol^2 dm^{-6}$]

[3]

(c) Calculate the amount, in mol, of HCOOH that was neutralised in the titration.

[2]

(d) An average ant contains 6.0×10^{-4} g of formic acid. Calculate the percentage of a typical ant's supply of formic acid collected by the chemist for the titration.

[3]

(e) Formic acid is a weak acid with an acid dissociation constant, K_a, of 1.6×10^{-4} mol dm^{-3}.

$$HCOOH(aq) \rightleftharpoons H^+(aq) + HCOO^-(aq)$$

(i) What is meant by a *weak acid*?

.....

.....[1]

(ii) Write an expression for the acid dissociation constant, K_a, of formic acid.

[1]

(iii) The concentration of formic acid in solution **X** was 6.0×10^{-3} mol dm^{-3}. Calculate the pH of solution **X**.

[3]

(f) The recommended treatment for an ant bite is the application of 'bicarbonate of soda', which contains $NaHCO_3$. Suggest, with the aid of an equation, how $NaHCO_3$ helps to relieve the effect of an ant bite.

.....

.....

.....[2]

(g) Wasp stings are treated with vinegar. What does this suggest about the nature of the active ingredient in a wasp sting? Explain your answer.

.....

.....

.....[2]

[Total : 18]

4 In this question, you should use knowledge, principles and concepts from different areas of chemistry. *(In this question, 1 mark is available for the quality of written communication.)*

Compound **A** was analysed in the laboratory and was shown to have the composition by mass K, 31.9%; C*l*, 29.0%; O, 39.1%.

On gentle heating, compound **A** formed potassium chlorate(VII), $KClO_4$, and compound **B** in a 3:1 molar ratio.

On strong heating, 0.250 g $KClO_4$ was broken down into compound **B** and oxygen gas.

An aqueous solution of compound **B** formed a white precipitate, **C**, with aqueous silver nitrate.

Showing **all** your reasoning,

- identify substances **A – C**, [6]
- write balanced equations for all reactions that took place, [3]
- calculate the mass of **B** formed from 0.250 g of $KClO_4$, [2]
- calculate the volume of oxygen formed, at room temperature and pressure. [2]

[Total : 13]

For Examiner's Use

RECOGNISING ACHIEVEMENT

Subject: Unifying Concepts
Code: 2816/1

Session: January
Year: 2002

Mark Scheme

12/02/2001

MAXIMUM MARK	60

1. **(a)** **(i)** An equilibrium system under change will shift the equilibrium position ✓

in the direction that minimises the effect of the change ✓

[2]

(ii)

$$K_p = \frac{(p\ SO_3)^2}{(p\ SO_2)^2 \times (p\ O_2)}$$ ✓

[1]

(iii) equilibrium is well to right ✓

far greater concentration of products than reactants ✓

[2]

(b) **(i)** *effect on equilibrium position*

moves to left: forward reaction is exothermic/reverse reaction is endothermic ✓

[1]

effect on partial pressure of $SO_3(g)$

decreases because equilibrium has moved to left ✓

[1]

(ii) *effect on equilibrium position*

moves to right because less gas moles on right ✓

[1]

effect on mole fraction of $SO_3(g)$

increases because equilibrium has moved to right ✓

[1]

(c) **(i)** K_p decreases. ✓

[1]

(ii) no change ✓

[1]

(d) increased temperature increases rate ✓

but only sufficiently so that equilibrium is not pushed too far to left ✓

[2]

catalyst speeds up reaction ✓ by lowering activation energy ✓

allows reaction to proceed at lower temperature ✓

any 2 points ⟶ 2 max [2]

energy costs saved ✓ safer to use smaller pressures ✓

high yield at this pressure/ equil position can be controlled using temp and catalyst ✓

any 2 points ⟶ 2 max [2]

[Total: 17]

2. **(a)** **(i)** What is meant by the *half-life* of a reaction, $t_{½}$?

Time for half a reactant to react ✓

[1]

(ii) $t_{½}$ = 460 ± 10 s ✓
constant half life ✓

evidence on graph to support constant half life (at least two half-lifes shown) ✓

[3]

(iii) no change ✓

[1]

(b) $k = 0.693 / t_{½} = 0.693/460 = 1.51 \times 10^{-3}$ ✓ s^{-1} ✓
for consequential marking: answer should be: 0.693/ans to ***(a)(ii)***

[2]

(c) Rate = $k[C_6H_5N_2Cl(aq)]$ ✓

[1]

(d) **(i)** After 800s, $[C_6H_5N_2Cl(aq)] = 1.8 \times 10^{-4}$ mol dm^{-3} ✓
(*allow any value from* 1.7×10^{-4} *to* 1.8×10^{-4})

[1]

(ii) *Rate* = $k[C_6H_5N_2Cl(aq)] = (1.51 \times 10^{-3}) \times (1.8 \times 10^{-4})$

$= 2.7 \times 10^{-7}$ ✓ mol dm^{-3} s^{-1} ✓

[2]

(iii) measure gradient at t = 800 s ✓

[1]

[Total: 12]

3. **(a)** $H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$ ✓

[1]

(b) $[H^+(aq)] = K_w / [OH^-(aq)] = 1.0 \times 10^{-14} / 0.00750 = 1.33 \times 10^{-12}$ mol dm^{-3} ✓

pH = $-\log[H^+(aq)]$ ✓ = $-\log 1.33 \times 10^{-12}$ = 11.9 ✓

[3]

(c) moles NaOH = 0.00750 x 20/1000 = 1.50×10^{-4} mol ✓

[1]

moles HCOOH = 1.50×10^{-4} mol ✓

[1]

(d) mass of formic acid in 20 ants = $1.50 \times 10^{-4} \times 46 = 6.9 \times 10^{-3}$ g ✓

mass of formic acid in 1 ant = 6.9×10^{-3} /20 g = 3.45×10^{-4} g ✓

% of formic acid = $(3.45 \times 10^{-4} / 6.0 \times 10^{-4}) \times 100$ = 57.5 % ✓

[3]

(e) **(i)** partially dissociates ✓

[1]

(ii)

$$K_a = \frac{[H^+(aq)] \times [HCOO^-(aq)]}{[HCOOH(aq)]}$$ ✓

[1]

(iii)

$$K_a = \frac{[H^+(aq)]^2}{[HCOOH(aq)]}$$ ✓ $\therefore 1.6 \times 10^{-4} = \frac{[H^+(aq)]^2}{6.0 \times 10^{-3}}$

$[H^+(aq)] = \sqrt{\{(1.6 \times 10^{-4}) \times (6.0 \times 10^{-3})\}} = 9.8 \times 10^{-4}$ mol dm^{-3} ✓

pH = $-\log[H^+(aq)] = -\log 9.8 \times 10^{-4} = 3.0$ ✓

[3]

(f) baking powder must be an alkali/base OR baking powder neutralises acid in ant bite ✓

$HCOOH + NaHCO_3 \longrightarrow HCOONa + CO_2 + H_2O$ ✓

[2]

(g) vinegar is acidic ✓ and neutralises alkali in wasp sting ✓

[2]

[Total: 18]

4. **A** K : Cl : O = 31.9/39.1 : 29.0/35.5 : 39,1/16 = 0.82 : 0.82 : 2.44 ✓

= $KClO_3$ ✓

B Addition of Ag^+(aq) with white ppt is test for Cl^- ✓

= KCl ✓

C AgCl ✓

1.1h, 1.5c [5]

- write balanced equations for all reactions that took place,

$4KClO_3 \longrightarrow 3KClO_4 + KCl$ ✓

$KClO_4 \longrightarrow KCl + 2O_2$ ✓

$Ag^+ + Cl^- \longrightarrow AgCl$ ✓

1.1i [3]

- calculate the mass of **B** formed from 0.250 g of $KClO_4$.

amount of $KClO_4$ = 0.250/138.6 = 1.80×10^{-3} mol ✓

mass KCl = 74.6 x 1.80×10^{-3} mol = 0.134 g ✓

(or 0.135 g *if moles are not rounded)*

✓✓ 1.1h [2]

- calculate the volume of oxygen formed, at r.t.p..

amount of O_2 = 2 x (1.80×10^{-3}) = 3.60×10^{-3} mol ✓

volume of O_2 = 24/1000 x (3.60×10^{-3}) = 86 cm^3 ✓

(or 87 cm^3 *if moles are not rounded)*

1.1h[2]

Clear, well-organised [1]

[Total: 13]