RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

CHEMISTRY 2816/01

Unifying Concepts in Chemistry

Friday **24 JANUARY 2003** 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	17	
2	17	
3	12	
4	14	
TOTAL	**60**	

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

For Examiner's Use

Answer **all** the questions.

1 *Syngas* is a mixture of carbon monoxide and hydrogen gases, used as a feedstock for the manufacture of methanol.

A dynamic equilibrium was set up between carbon monoxide, CO, hydrogen, H_2, and methanol, CH_3OH. The equilibrium system is shown by Equilibrium 1.1 below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$ **Equilibrium 1.1**

The equilibrium concentrations of the three components of this equilibrium are shown below.

component	CO(g)	H_2(g)	CH_3OH(g)
equilibrium concentration /mol dm^{-3}	3.1×10^{-3}	2.4×10^{-2}	2.6×10^{-5}

(a) State **two** features of a system that is in *dynamic equilibrium*.

....

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....[2]

(b) (i) Write the expression for K_c for this equilibrium system.

[2]

(ii) Calculate the numerical value of K_c for this equilibrium.

[2]

(c) The pressure was increased whilst keeping the temperature constant. The system was left to reach equilibrium. The equilibrium position of Equilibrium 1.1 shifted to the right.

(i) Explain why the equilibrium moved to the right.

....

....[2]

(ii) What is the effect, if any, on K_c?

....[1]

(iii) State and explain the effect on the rates of the forward and reverse reactions

- when the pressure was first changed
- when the system reached equilibrium.

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....[4]

(d) The temperature was increased whilst keeping the pressure constant. The system was left to reach equilibrium. The value of K_c for Equilibrium 1.1 decreased.

(i) Explain what happens to the equilibrium position of Equilibrium 1.1.

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....[2]

(ii) Deduce the sign of the enthalpy change for the forward reaction shown in Equilibrium 1.1. Explain your reasoning.

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....[1]

(iii) Explain how the partial pressure of $CH_3OH(g)$ would change as the system moves towards equilibrium.

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....[1]

[Total: 17]

2 Nitrous oxide, N_2O, is a colourless gas with a mild, pleasing odour and sweet taste. It is widely used as a propellant in aerosol cans of whipped cream.

(a) Nitrous oxide is formed when ammonium nitrate, NH_4NO_3, is gently heated.

$$NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(l)$$

(i) What mass of N_2O is formed by heating 100 g of NH_4NO_3?

[3]

(ii) What happens to the oxidation number of each nitrogen from NH_4NO_3 in this reaction?

....

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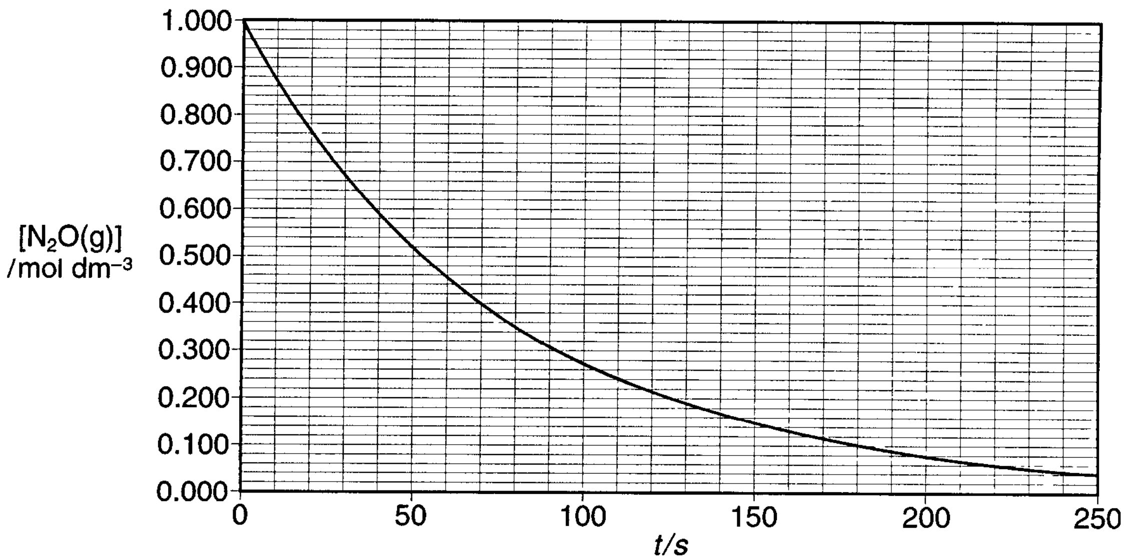
....[2]

(b) When heated strongly, nitrous oxide decomposes into its elements.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

This reaction is first order with respect to N_2O.

The graph below shows how nitrous oxide decomposes with time at constant temperature.



For Examiner's Use

(i) Explain how the graph confirms that this reaction is first order with respect to N_2O.

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....[3]

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

[1]

(iii) Use the graph to work out the rate of reaction, in $mol\,dm^{-3}\,s^{-1}$, at 70 seconds. Show clearly your working on the graph.

rate = ...$mol\,dm^{-3}\,s^{-1}$ [2]

(iv) Calculate the rate constant for this reaction. State the units.

k = ... units .... [2]

(v) What evidence is there that the mechanism of this reaction takes place in more than a single step?

....

....

....[2]

(c) N_2O is occasionally injected into the engines of racing cars to give more power and exceptional acceleration. The N_2O decomposes exothermically to N_2 and O_2.

Suggest **two** reasons why this reaction provides an extra boost to the engine.

....

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....[2]

[Total: 17]

For Examiner's Use

3 In this question, one mark is available for the quality of written communication.

(a) Describe what is meant by the following terms used in acid-base chemistry.

- The Bronsted-Lowry theory of acids and bases.
- Conjugate acid-base pairs.
- Dilute and weak acids.

Illustrate your answer by choosing suitable examples of acids and bases. Write equations where appropriate.

....[7]

Quality of Written Communication [1]

For Examiner's Use

(b) The acid dissociation constant K_a of hydrocyanic acid, HCN, is 4.9×10^{-10} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant of HCN.

[1]

(ii) Calculate the pH of a 0.010 mol dm^{-3} solution of hydrocyanic acid.

[3]

[Total: 12]

4 Organic acids occur widely in nature.

(a) Butanoic acid, $CH_3(CH_2)_2COOH$, is a straight-chain organic acid, largely responsible for the odour of rancid butter.

Caprylic acid is another straight-chain organic acid. It is produced in the body in small amounts as an antifungal agent in human sweat.

(i) Some caprylic acid was isolated from human sweat and analysed. The sample of caprylic acid had the percentage composition by mass:

C, 66.7%; H, 11.1%; O, 22.2%. $M_r = 144$.

Calculate the molecular formula of caprylic acid and suggest its structural formula.

[4]

(ii) Tracker dogs are trained to follow odours such as the characteristic blend of organic acids in the sweat from a person's feet. A dog is able to detect extremely small quantities of these acids.

Sweat containing equal amounts of butanoic and caprylic acids produces more butanoic acid vapour than caprylic acid vapour.

Suggest a reason for this. Explain your answer.

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....[2]

For Examiner's Use

(b) Compound **A** is a straight-chain organic acid. A chemist analysed a sample of acid **A** by the procedure below.

The chemist first prepared a 250 cm^3 solution of **A** by dissolving 10.8 g of **A** in water.

In a titration, 25.00 cm^3 0.500 mol dm^{-3} NaOH were neutralised by exactly 21.40 cm^3 of solution **A**.

- Calculate the pH of the NaOH(aq) used in the titration. $K_w = 1.00 \times 10^{-14}$ $mol^2 dm^{-6}$.
- Use the results to calculate the molar mass of acid A and suggest its identity.

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....[8]

[Total: 14]

Subject: Unifying Concepts

Code: 2816/1

Session: January

Year: 2003

Final Mark Scheme

25/1/2003

MAXIMUM MARK	60

1. **(a)** Forward and reverse reactions at same rate ✓

Achievable from either direction ✓, requires closed system ✓

concentrations of reactants and products are constant ✓

max: [2]

(b) **(i)**

$$K_c = \frac{[\,CH_3OH(g)\,]}{[\,CO(g)\,]\,[\,H_2(g)\,]^2}$$ ✓✓ *1 mark for top; 1 mark for bottom*

[2]

(ii)

$$K_c = \frac{(2.6 \times 10^{-5})}{(3.1 \times 10^{-3})\,(2.4 \times 10^{-2})^2}$$ ✓ = 14.6 ✓ ($dm^6\ mol^{-2}$)

[2]

(c) (i) *Why did the equilibrium move to the right*

fewer molecules on right ✓

reaction relieves increase in pressure ✓

[2]

(ii) *What is the effect, if any, on K_c*

K_c stays same ✓

[1]

(iii) *Rate changes*

Rate increases ✓

Increased collisions/more concentrated ✓

Rates initially forward faster than reverse ✓

At equil, rates same ✓

[4]

(d) **(i)** K_c decreases so products decrease/reactants increase ✓

Therefore equilibrium moves to the left/to endothermic side ✓

2nd mark dependent on first.

[2]

(ii) ΔH is negative because of equilibrium change in **(i)** ✓

Mark *consequential on (i)*

[1]

(iii) Partial pressure decreases because less CH_3OH is now present ✓

[1]

[Total: 17]

2. **(a)** **(i)** $m(NH_4NO_3) = 80$ ✓

moles N_2O = moles NH_4NO_3 = 100/80 = 1.25 mol ✓

mass N_2O = 1.25 x (28 + 16) = 55 g ✓

[3]

(ii) nitrogen in NH_4^+: $-3 \longrightarrow +1$ / increases by 4 ✓

nitrogen in NO_3^-: $+5 \longrightarrow +1$ / decreases by 4 ✓

[2]

(b) **(i)** 1st order has a constant half life ✓

Evidence from graph, either drawn or stated below with 2 half lives ✓

half life approx 52 s✓

[3]

(ii) rate = $k[N_2O(g)]$ ✓

[1]

(iii) evidence of tangent on graph ✓

rate = 0.00524 ✓ mol dm^{-3} s^{-1}

(allow ± 0.005 : i.e. values in range 0.00475 – 0.00575 mol dm^{-3} s^{-1})

[2]

(iv) 0.00524 (ans to (ii)) = k x 0.400

k = 0.0131 ✓ s^{-1} ✓

[2]

(v) rate determining step involves 1 molecule of N_2O ✓

equation shows 2 mol N_2O reacting ✓

[2]

(c) Increases the pressure/rate increases ✓

Gives out heat ✓

Forms oxygen ⟶ more efficient combustion ✓

moles of products > moles of reactants ✓

[2 max]

[Total: 17]

3. (a)

Acid is a proton/H^+ donor ✓

Base is a proton/H^+ acceptor ✓

Conjugate acid has H^+ more than conjugate base ✓

Equation showing acid-base pairs ✓

2 acid-base pairs labelled correctly ✓

Dilute acid has small number of moles dissolved per volume ✓

Weak acid has partial dissociation ✓

[7]

Quality of Written Communication

At least **two** complete sentences that are legible and where the spelling, punctuation and grammar allow the meaning to be clear. At least one equation shown. ✓

[1]

(b) (i)

$$K_a = \frac{[H^+(aq)]\,[CN^-(aq)]}{[\,HCN(aq)]} \quad ✓$$

[1]

(ii)

$$K_a = \frac{[H^+(aq)]^2}{[HCN(aq)]} \qquad \therefore\ 4.9 \times 10^{-10} = \frac{[H^+(aq)]^2}{0.010} \quad ✓$$

$$[H^+(aq)] = \sqrt{\{(4.9 \times 10^{-10}) \times (0.010)\}} = 2.2 \times 10^{-6}\ \text{mol dm}^{-3} \quad ✓$$

$$\text{pH} = -\log[H^+(aq)] = -\log 2.2 \times 10^{-6} = 5.65/5.66/5.7 \quad ✓$$

(accept calculator value)

[3]

[Total: 12]

4. (a) (i)

	C	:	H	:	O
=	66.7/12	:	11.1/1	:	22.2/16 ✓
=	5.56	:	11.1	:	1.39
=	4	:	8	:	1

empirical formula = C_4H_8O ✓

48 + 8 + 16 = 72 which is half of M_r

Therefore molecular formula = $C_8H_{16}O_2$ ✓

Structural formula = $CH_3(CH_2)_6COOH$ ✓

[4]

(ii) caprylic acid is a longer molecule/contains more electrons ✓

caprylic acid has more van der Waals forces between molecules ✓

caprylic acid has a higher boiling point / is less volatile ✓

[2 max]

(b)

$[H^+(aq)] = K_w / [OH^-(aq)]$ ✓ $= 1.00 \times 10^{-14}/0.500 = 2.00 \times 10^{-14}$ mol dm^{-3} ✓

pH = $-\log[H^+(aq)] = -\log 2 \times 10^{-14} = 13.699$ / 13.7 ✓ *(calculator value: 13.69897)*

[3]

moles **NaOH** in 25.00 cm^3 = moles NaOH = 0.0125 mol ✓

moles **A** in 21.40 cm^3 = moles NaOH = 0.0125 mol ✓

moles **A** in 250 cm^3 = 0.0125 x 250/21.40 = 0.146 mol / [A] = 0.584 mol dm^{-3} ✓

0.146 mol **A** has a mass of 10.8 g

molar mass of **A** = 10.8/0.146 = 74 g mol^{-1} ✓

Therefore **A** is propanoic acid / CH_3CH_2COOH ✓

[5]

[Total: 14]