EXAM QUESTIONS ON

5.1.3 ACIDS, BASES AND BUFFERS

TOTAL 91 MARKS

Mark: /91	%	Grade:

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*?

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.....[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.

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(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.

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[Total : 18]

For Examiner's Use

3 Alpha hydroxy acids (AHAs) are monobasic organic acids, used in skin creams to combat the appearance of ageing. Approximately 1% solutions of AHAs remove wrinkles as the low pH aggravates the skin, causing it to swell. More concentrated solutions (approximately 12% or 1.5 mol dm^{-3}) are used to remove dead skin.

(a) An AHA was analysed and had the percentage composition by mass:

C, 40.0%; H, 6.7%; O, 53.3%. M_r = 90.

Calculate the molecular formula of this AHA.

[3]

(b) Calculate the pH of a 1.5 mol dm^{-3} solution of an AHA with an acid dissociation constant, K_a, of 1.2 x 10^{-5} mol dm^{-3}. Show your working.

[4]

(c) Beauty treatments often contain buffers. An example of a buffer is a mixture of ethanoic acid, CH_3COOH, and an ethanoate salt such as sodium ethanoate, CH_3COONa.

(i) Explain what is meant by a *buffer solution.*

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(ii) Write the chemical equation for the equilibrium in this buffer system.

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For Examiner's Use

(iii) Explain how this buffer solution works. Use equations where appropriate.

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(d) A buffer solution was prepared using equal concentrations of CH_3COOH and CH_3COONa.

What would be the effect on the pH of this buffer solution of adding some solid CH_3COONa? Explain your answer.

effect on pH .....

explanation .....

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.....[3]

[Total : 15]

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.

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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]

For Examiner's Use

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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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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[Total: 14]

3 Hydrogen chloride is used in the manufacture of many chemical compounds, including those used in metallurgy and food processing.

(a) There are two main industrial methods for preparing hydrogen chloride:
- by direct combination of chlorine and hydrogen gases,
- as a by-product of the chlorination of many organic hydrocarbons.

Write equations to show the formation of HCl from

(i) chlorine and hydrogen

.....[1]

(ii) chlorine and hexane, C_6H_{14}.

.....[1]

(b) Hydrochloric acid is usually sold as a solution prepared by dissolving hydrogen chloride gas in water.

A science technician bought 15.0 dm^3 of 8.00 mol dm^{-3} hydrochloric acid which had been made by dissolving hydrogen chloride gas in water.
1 mol of gas molecules occupies 24.0 dm^3 at room temperature and pressure, r.t.p.

(i) Calculate the volume of hydrogen chloride gas at r.t.p. that dissolved to produce this hydrochloric acid.

[2]

(ii) Outline, with quantities, how the technician could make up 1.00 dm^3 of 0.0200 mol dm^{-3} hydrochloric acid from the 8.00 mol dm^{-3} stock solution of hydrochloric acid.

[2]

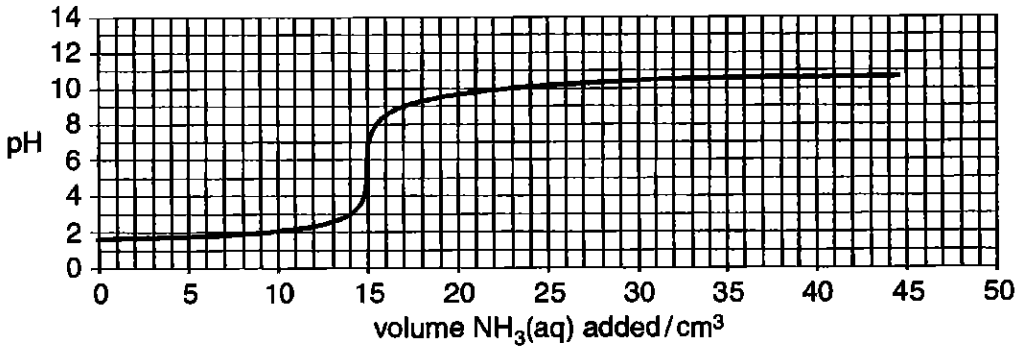
(iii) Calculate the pH of 0.0200 mol dm^{-3} HCl(aq).

[2]

(c) Hydrochloric acid can be neutralised with aqueous ammonia to form ammonium chloride.

$$NH_3(aq) + HCl(aq) \longrightarrow NH_4Cl(aq)$$

The technician titrated the 0.0200 mol dm^{-3} hydrochloric acid prepared in **(b)(ii)** with aqueous ammonia.
A 20.0 cm^3 sample of the 0.0200 mol dm^{-3} $HCl(aq)$ was placed in a conical flask and the $NH_3(aq)$ was added from a burette until the pH no longer changed.
The pH curve for this titration is shown below.



(i) How can you tell from this pH curve that aqueous ammonia is a weak base?

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.....[1]

(ii) Use the information above to calculate the concentration, in mol dm^{-3}, of the aqueous ammonia.

[2]

(iii) The pH ranges in which the pH changes for three indicators are shown below.

indicator	pH range
alizarin yellow	10.1–12.0
methyl yellow	2.9–4.0
chlorophenol red	4.8–6.4

Explain which of the three indicators is most suitable for this titration.

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[Total: 13]

For Examiner's Use

4 Buffer solutions have many uses in medicine and in cosmetics and toiletries. Buffer solutions can be prepared by mixing aqueous solutions of methanoic acid, HCOOH, and sodium methanoate, HCOONa.

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

Describe what a buffer solution is and how a buffer solution works.

Use the HCOOH/HCOONa buffer solution in your answer.

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Quality of Written Communication [1]

(b) Calculate the pH of a buffer solution containing equal volumes of 2.5 mol dm^{-3} HCOONa and 1.0 mol dm^{-3} HCOOH ($K_a = 1.6 \times 10^{-4}$ mol dm^{-3}).

[3]

[Total: 10]

For Examiner's Use

5 Read the section below and use your knowledge and understanding of chemistry to answer the questions that follow.

Compound **X** is a dicarboxylic acid, M_r = 90, present in many foods such as cocoa, green vegetables and rhubarb. Compound **X** may be harmful to humans because it reacts with calcium ions in the bloodstream to form solid particles. These are then deposited in the kidneys as 'kidney stones'.

Analysis of a kidney stone showed that it was made up almost entirely of a single compound **Y** with the percentage composition by mass: Ca, 31.3%; C, 18.7%; O, 50.0%.

Some people develop kidney stones more readily than others. Compound **X** is very soluble in water and people susceptible to kidney stones are advised to drink large quantities of water to flush this compound from their bodies.

- Calculate the empirical formula of compound **Y**, the main compound in kidney stones. [2]
- A kidney stone with a mass of 2.0 g was removed from a patient. Calculate the number of calcium ions that have been removed from the bloodstream to form this kidney stone.
  $L = 6.02 \times 10^{23}$ mol^{-1} [3]
- Deduce the molecular formula of compound **X** and suggest its structural formula. [2]
- Explain why compound **X** is very soluble in water. [2]

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