pH & Buffers
A Level only

Question Paper 2

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Physical Chemistry & Transition Elements
Topic	pH & Buffers
Paper	A Level only
Booklet	Question Paper 2

Time allowed: **88 minutes**

Score: **/65**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

The chemicals that we call 'acids' have been known for thousands of years. However, modern theories of acids have been developed comparatively recently. It wasn't until the early 1900s that the concept of dissociation became accepted by the scientific community and the concept of pH was introduced.

A student carried out a series of experiments with acids and alkalis.

(a) Propanoic acid, CH_3CH_2COOH, is a naturally occurring weak acid. The equation for the dissociation of propanoic acid is shown below.

$$CH_3CH_2COOH(aq) \rightleftharpoons H^+(aq) + CH_3CH_2COO^-(aq)$$

The student wanted to prove that propanoic acid is a weak acid. The student had access to a pH meter and 0.100 $moldm^{-3}$ propanoic acid.

- Explain how the student could prove that propanoic acid is a weak acid by taking a single pH measurement.
- Show how the student could then calculate the acid dissociation constant, K_a, for propanoic acid. [4]

(b) The student measured the pH of a solution of sodium hydroxide at 25 °C.
The measured pH was 13.46.

Calculate the concentration of the aqueous sodium hydroxide. [2]

(c) A student made a buffer solution by mixing an excess of propanoic acid to an aqueous solution of sodium hydroxide at 25 °C. This buffer solution contains an equilibrium system that minimises changes in pH when small amounts of acids and alkalis are added.

- Explain why a buffer solution formed when an excess of propanoic acid was mixed with aqueous sodium hydroxide.

- Explain how this buffer solution controls pH when an acid or an alkali is added.

In your answer you should explain how the equilibrium system allows the buffer solution to control the pH. [7]

(d) A student added nitric acid to propanoic acid. A reaction took place to form an equilibrium mixture containing two acid–base pairs.

Complete the equilibrium below and label the two conjugate acid–base pairs.

$HNO_3 + CH_3CH_2COOH \rightleftharpoons$.

[2]

(e) Finally, the student reacted an aqueous solution of propanoic acid with a reactive metal and with a carbonate.

(i) Write an equation for the reaction of aqueous propanoic acid with magnesium. [1]

(ii) Write an ionic equation for the reaction of aqueous propanoic acid with aqueous sodium carbonate.

.[1]

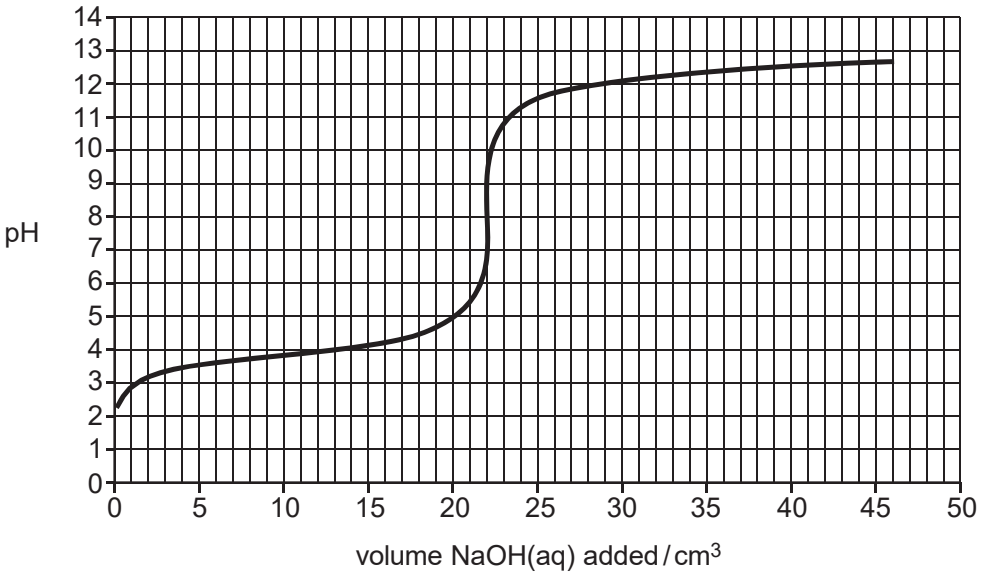
[Total: 17 Marks]

Glycolic acid, $HOCH_2COOH$, and thioglycolic acid, $HSCH_2COOH$, are weak acids.

(a) Glycolic acid reacts with bases, such as aqueous sodium hydroxide, NaOH(aq), to form salts.

A student pipetted 25.0 cm^3 of 0.125 mol dm^{-3} glycolic acid into a conical flask. The student added NaOH(aq) from a burette. A pH meter and data logger were used to measure continuously the pH of the contents of the conical flask.

The pH curve that the student obtained is shown below.



1 mol of glycolic acid reacts with 1 mol of sodium hydroxide.

(i) Write the equation for the reaction that takes place in the titration. [1]

(ii) Determine the concentration, in mol dm^{-3}, of the NaOH. [2]

(iii) The student decided to carry out this titration using an acid–base indicator.

What important factor does the student need to consider when deciding on the most suitable indicator to use for this titration? [1]

(b) The 0.125 moldm^{-3} glycolic acid had a pH of 2.37.

(i) What is the expression for the acid dissociation constant, K_a, of glycolic acid? [1]

(ii) Calculate K_a for glycolic acid. [3]

(iii) Calculate the percentage molar dissociation of the glycolic acid. [1]

(c) A buffer of glycolic acid and ammonium glycolate is used in a facial cleanser.

Explain, using equations,

- how a solution containing glycolic acid and glycolate ions can act as a buffer
- how this buffer could be prepared from ammonia and glycolic acid.

In your answer you should explain how the equilibrium system allows the buffer solution to control the pH. [7]

(d) Ammonium thioglycolate, $HSCH_2COONH_4$, is the ammonium salt of thioglycolic acid, $HSCH_2COOH$.

When ammonium thioglycolate is dissolved in water, an acid–base equilibrium is set up. The equilibrium lies well to the left-hand side.

$$HSCH_2COO^-(aq) \quad + \quad NH_4^+(aq) \quad \rightleftharpoons \quad HSCH_2COOH(aq) \quad + \quad NH_3(aq)$$

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]

(e) Ammonium thioglycolate is used by hairdressers to perm hair.

Hair is a protein and its shape is largely the result of cross-linked disulfide bonds, –S–S–. The formula of the protein in hair can be represented as R–S–S–R.

Perming of hair involves two stages.

Stage 1

- Hair is first wound around curlers and a solution of ammonium thioglycolate is applied to the hair.
- In this process, each disulfide bond is broken by two thioglycolate ions to form two molecules containing thiol groups, –S–H, and one other product.

Stage 2

- After 15–30 minutes, the hair is rinsed with a weak solution of hydrogen peroxide, H_2O_2.
- The hydrogen peroxide reforms disulfide bonds that lock the hair in the shape of the curlers. The hair is now 'permed'.

Suggest equations for the two processes that take place during perming.
In your equations, use R–S–S–R to represent the protein in hair.

Stage 1

Stage 2 [2]

[Total: 20 Marks]

This question is about the properties and reactions of ethanoic acid, CH_3COOH.
Ethanoic acid is a weak acid with an acid dissociation constant, K_a, of 1.75×10^{-5} mol dm^{-3} at 25 °C.

(a) A student uses a pH meter to measure the pH of a solution of CH_3COOH at 25 °C.
The measured pH is 2.440.

Calculate the concentration of ethanoic acid in the solution.

Give your answer to **three** significant figures.

[3]

(b) Ethanoic acid is added to another weak acid, fluoroethanoic acid, FCH_2COOH ($K_a = 2.19 \times 10^{-3}$ moldm^{-3}). An equilibrium is set up containing two acid-base pairs.

Complete the equilibrium and label the conjugate acid-base pairs as **A1**, **B1** and **A2**, **B2**.

$CH_3COOH + FCH_2COOH \rightleftharpoons$ ..... + ...

....

[2]

(c) The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid, CH_3COOH, and sodium ethanoate, CH_3COONa.

The student plans to add 9.08 g CH_3COONa to 250 cm^3 of 0.800 mol dm^{-3} CH_3COOH. The student assumes that the volume of the solution does not change.

(i) Show by calculation whether, or not, the student's experimental method would produce the required pH.

Show **all** your working.

[5]

(ii) When the student prepares the buffer solution, the volume of solution increases slightly.

Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in **(c)(i)**.

Explain your reasoning.

[2]

(Total 12 marks)

A student investigates the reactions of two weak monobasic acids: 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$, and butanoic acid, $CH_3CH_2CH_2COOH$.

(a) The student wants to prepare a standard solution of 2-hydroxypropanoic acid that has a pH of 2.19.

Plan how the student could prepare 250 cm^3 of this standard solution from solid 2-hydroxypropanoic acid.

In your answer you should provide detail of the practical procedure that would be carried out, including appropriate quantities and necessary calculations.

[8]

K_a for 2-hydroxypropanoic acid is 1.38×10^{-4} mol dm^{-3} at 25 °C.

(b) 2-Hydroxypropanoic acid is a slightly stronger acid than butanoic acid. The two acids are mixed
together and an acid–base equilibrium is set up.

Suggest the equilibrium equation and identify the conjugate acid–base pairs.

$CH_3CH(OH)COOH + CH_3CH_2CH_2COOH \rightleftharpoons$ .....

[2]

(c) To prepare a buffer solution, 75.0 cm^3 of 0.220 mol dm^{-3} butanoic acid is reacted with 50.0 cm^3 of 0.185 mol dm^{-3} sodium hydroxide.

K_a for butanoic acid is 1.5×10^{-5} mol dm^{-3} at 25 °C.

(i) Calculate the pH of 0.185 mol dm^{-3} sodium hydroxide at 25 °C.

Give your answer to **two** decimal places.

[2]

(ii) Calculate the pH of the buffer solution at 25 °C.

Give your answer to **two** decimal places.

[4]

(Total 16 marks)