1 A student is supplied with 0.500 mol dm^{-3} potassium hydroxide, KOH, and 0.480 mol dm^{-3} propanoic acid, C_2H_5COOH.

The acid dissociation constant, K_a, for C_2H_5COOH is 1.35×10^{-5} mol dm^{-3}.

(a) C_2H_5COOH is a weak Brønsted–Lowry acid.

What is meant by a *weak acid* and *Brønsted–Lowry acid*?

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..... **[1]**

(b) Calculate the pH of 0.500 mol dm^{-3} potassium hydroxide.

pH = ... **[2]**

(c) The student dilutes 25.0 cm^3 0.480 mol dm^{-3} C_2H_5COOH by adding water until the total volume is 100.0 cm^3.

(i) Write the expression for K_a for C_2H_5COOH.

[1]

(ii) Calculate the pH of the diluted solution.

pH = ... **[3]**

(d) Aqueous propanoic acid, C_2H_5COOH, reacts with carbonates and alkalis.

(i) Write the full equation for the reaction of aqueous propanoic acid with sodium carbonate.

..... **[1]**

(ii) Write the **ionic** equation for the reaction of aqueous propanoic acid with aqueous potassium hydroxide.

..... **[1]**

(e) A student prepares a buffer solution containing propanoic acid C_2H_5COOH and propanoate ions, $C_2H_5COO^-$. The concentrations of C_2H_5COOH and $C_2H_5COO^-$ are both $1.00\,mol\,dm^{-3}$.

The following equilibrium is set up.

$$C_2H_5COOH(aq) \rightleftharpoons C_2H_5COO^-(aq) + H^+(aq)$$

The acid dissociation constant, K_a, for C_2H_5COOH is $1.35 \times 10^{-5}\,mol\,dm^{-3}$.

(i) Calculate the pH of this buffer solution.

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

pH = ... **[1]**

(ii) A small amount of aqueous ammonia, $NH_3(aq)$, is added to the buffer solution.

Explain, in terms of equilibrium, how the buffer solution would respond to the added $NH_3(aq)$.

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..... **[2]**

(iii) The student adds 6.075 g Mg to 1.00 dm^3 of this buffer solution.

Calculate the pH of the new buffer solution.

Give your answer to **two** decimal places

pH = ... **[4]**

[Total: 16]

2 Ethanoic acid, CH_3COOH, is a weak Brønsted–Lowry acid

(a) An acid–base equilibrium is set up when ethanoic acid is added to water.

Write the equation for the equilibrium that would be set up and label the two conjugate acid–base pairs.

..... + ... $\rightleftharpoons$ ..... + ...

....

[2]

(b) An aqueous solution of CH_3COOH has a pH of 3.060.
This solution contains both hydrogen ions and hydroxide ions.

(i) How can an aqueous solution of an acid contain hydroxide ions?

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..... **[1]**

(ii) Calculate the concentration of hydroxide ions in this solution of ethanoic acid.

concentration of hydroxide ions = ... $mol\,dm^{-3}$ **[2]**

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(c) A student adds an excess of aqueous ethanoic acid to solid calcium carbonate.
The resulting solution is able to act as a buffer solution.

(i) Write a full equation for the reaction between ethanoic acid and solid calcium carbonate.

..... **[1]**

(ii) Explain why this buffer solution has formed.

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..... **[1]**

(iii) Explain how this buffer solution controls pH when either 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.

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..... **[5]**

(d) A biochemist plans to make up a buffer solution with a pH of 5.000.
The biochemist adds solid sodium ethanoate, CH_3COONa, to 400 cm^3 of 0.200 $mol\,dm^{-3}$ ethanoic acid.
K_a for ethanoic acid = 1.75×10^{-5} $mol\,dm^{-3}$

Calculate the mass of sodium ethanoate that the biochemist needs to dissolve in the ethanoic acid to prepare this buffer solution.

Assume that the volume of the solution remains constant at 400 cm^3 on dissolving the sodium ethanoate.

[5]

[Total: 17]

3 This question looks at pH values and reactions of acids, bases and buffers.

(a) 0.14 mol dm^{-3} solutions of hydrochloric acid, HC*l*, and chloric(I) acid, HC*l*O (pK_a = 7.43), have different pH values.

Explain why the pH values are different and calculate the pH of 0.14 mol dm^{-3} solutions of HC*l* and HC*l*O to **two decimal places**.

Show any working in calculations.

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..... **[5]**

(b) Aluminium powder is added to aqueous ethanoic acid, CH_3COOH.

Write full and ionic equations for the reaction that takes place.

full equation .....

ionic equation ..... **[2]**

(c) Calculate the pH of a 0.40 mol dm^{-3} solution of NaOH.

[2]

(d) In biochemistry, buffer solutions based on methanoic acid can be used in the analysis of urine samples.

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

Describe how a buffer solution based on methanoic acid can act as a buffer.

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

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..... **[7]**

(ii) A chemist prepares a buffer solution by mixing together the following:

200 cm^3 of 3.20 $mol\,dm^{-3}$ HCOOH (K_a = 1.70 × 10^{-4} $mol\,dm^{-3}$) and
800 cm^3 of 0.500 $mol\,dm^{-3}$ NaOH.

The volume of the buffer solution is 1.00 dm^3.

- Explain why a buffer solution is formed when these two solutions are mixed together.
- Calculate the pH of this buffer solution.

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

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[6]

[Total: 22]

4 Butanoic acid, $CH_3(CH_2)_2COOH$, is the 'butter acid', formed when butter turns rancid and tastes sour. A student prepares an aqueous solution of butanoic acid with a concentration of $0.250\,mol\,dm^{-3}$.

The K_a of butanoic acid is $1.51 \times 10^{-5}\,mol\,dm^{-3}$.

(a) (i) Write the expression for the acid dissociation constant of butanoic acid.

[1]

(ii) Calculate the pK_a of butanoic acid.

pK_a = ... **[1]**

(iii) Calculate the pH of the $0.250\,mol\,dm^{-3}$ butanoic acid.

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

pH = ... **[3]**

(b) The student adds aqueous butanoic acid to magnesium.

The student then adds aqueous butanoic acid to aqueous sodium carbonate.

(i) Write the ionic equation for the reaction between aqueous butanoic acid and magnesium.

..... **[1]**

(ii) Write the ionic equation for the reaction between aqueous butanoic acid and aqueous sodium carbonate.

..... **[1]**

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(c) The student adds 50.0 cm^3 of 0.250 $mol\,dm^{-3}$ butanoic acid to 50.0 cm^3 of 0.0500 $mol\,dm^{-3}$ sodium hydroxide. A buffer solution forms.

(i) Explain why a buffer solution forms.

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..... **[2]**

(ii) Calculate the pH of the buffer solution.

The K_a of butanoic acid is 1.51×10^{-5} $mol\,dm^{-3}$.

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

pH = ... **[5]**

(d) The student adds methanoic acid, HCOOH ($K_a = 1.82 \times 10^{-4}$ $mol\,dm^{-3}$), to butanoic acid. A reaction takes place to form an equilibrium mixture containing two acid–base pairs.

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

$HCOOH + CH_3(CH_2)_2COOH \rightleftharpoons$ ..... + ...

....

[2]

[Total: 16]

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