

- 1 A student is supplied with  $0.500 \text{ mol dm}^{-3}$  potassium hydroxide, KOH, and  $0.480 \text{ mol dm}^{-3}$  propanoic acid,  $\text{C}_2\text{H}_5\text{COOH}$ .

The acid dissociation constant,  $K_a$ , for  $\text{C}_2\text{H}_5\text{COOH}$  is  $1.35 \times 10^{-5} \text{ mol dm}^{-3}$ .

- (a)  $\text{C}_2\text{H}_5\text{COOH}$  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  $0.500 \text{ mol dm}^{-3}$  potassium hydroxide.

pH = ..... [2]

- (c) The student dilutes  $25.0 \text{ cm}^3$   $0.480 \text{ mol dm}^{-3}$   $\text{C}_2\text{H}_5\text{COOH}$  by adding water until the total volume is  $100.0 \text{ cm}^3$ .

- (i) Write the expression for  $K_a$  for  $\text{C}_2\text{H}_5\text{COOH}$ .

[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.

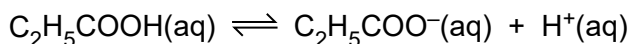
..... [1]

(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  $1.00 \text{ mol dm}^{-3}$ .

The following equilibrium is set up.



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

(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 6.075g Mg to 1.00 dm<sup>3</sup> of this buffer solution.

Calculate the pH of the new buffer solution.

Give your answer to **two** decimal places

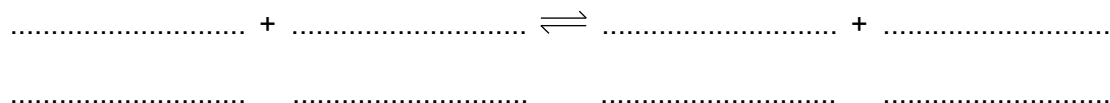
pH = ..... [4]

[Total: 16]

2 Ethanoic acid,  $\text{CH}_3\text{COOH}$ , is a weak Brønsted–Lowry

(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.



[2]

(b) An aqueous solution of  $\text{CH}_3\text{COOH}$  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?

.....

..... [1]

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

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



- (d) A biochemist plans to make up a buffer solution with a pH of 5.000.  
The biochemist adds solid sodium ethanoate,  $\text{CH}_3\text{COONa}$ , to  $400\text{ cm}^3$  of  $0.200\text{ mol dm}^{-3}$  ethanoic acid.  
 $K_a$  for ethanoic acid =  $1.75 \times 10^{-5}\text{ mol dm}^{-3}$

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  $400\text{ cm}^3$  on dissolving the sodium ethanoate.

[5]

[Total: 17]







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

200 cm<sup>3</sup> of 3.20 mol dm<sup>-3</sup> HCOOH ( $K_a = 1.70 \times 10^{-4}$  mol dm<sup>-3</sup>) and  
800 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> NaOH.

The volume of the buffer solution is 1.00 dm<sup>3</sup>.

- 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,  $\text{CH}_3(\text{CH}_2)_2\text{COOH}$ , 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  $0.250 \text{ mol dm}^{-3}$ .

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

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

[1]

(ii) Calculate the  $\text{p}K_a$  of butanoic acid.

$\text{p}K_a = \dots\dots\dots$  [1]

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

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

$\text{pH} = \dots\dots\dots$  [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.

$\dots\dots\dots$  [1]

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

(c) The student adds  $50.0\text{ cm}^3$  of  $0.250\text{ mol dm}^{-3}$  butanoic acid to  $50.0\text{ cm}^3$  of  $0.0500\text{ mol dm}^{-3}$  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  $1.51 \times 10^{-5}\text{ mol dm}^{-3}$ .

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

pH = ..... [5]

(d) The student adds methanoic acid,  $\text{HCOOH}$  ( $K_a = 1.82 \times 10^{-4}\text{ mol dm}^{-3}$ ), 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.



.....

[2]

[Total: 16]