**Q1.** This question is about the pH of some solutions containing potassium hydroxide and ethanoic acid.

Give all values of pH to 2 decimal places.

(a) (i) Write an expression for pH.

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**(1)**

(ii) Write an expression for the ionic product of water, $K_w$

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**(1)**

(iii) At 10 °C, a 0.154 mol $dm^{-3}$ solution of potassium hydroxide has a pH of 13.72. Calculate the value of $K_w$ at 10 °C.

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*(Extra space)* .....

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**(2)**

(b) At 25 °C, the acid dissociation constant $K_a$ for ethanoic acid has the value $1.75 \times 10^{-5}$ mol $dm^{-3}$.

(i) Write an expression for $K_a$ for ethanoic acid.

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**(1)**

(ii) Calculate the pH of a 0.154 mol $dm^{-3}$ solution of ethanoic acid at 25 °C.

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*(Extra space)* .....

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**(3)**

(c) At 25 °C, the acid dissociation constant $K_a$ for ethanoic acid has the value $1.75 \times 10^{-5}$ mol dm$^{-3}$.

(i) Calculate the pH of the solution formed when 10.0 cm$^3$ of 0.154 mol dm$^{-3}$ potassium hydroxide are added to 20.0 cm$^3$ of 0.154 mol dm$^{-3}$ ethanoic acid at 25 °C.

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*(Extra space)* .....

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**(4)**

(ii) Calculate the pH of the solution formed when 40.0 cm$^3$ of 0.154 mol dm$^{-3}$ potassium hydroxide are added to 20.0 cm$^3$ of 0.154 mol dm$^{-3}$ ethanoic acid at

25 °C.

At 25 °C, $K_w$ has the value $1.00 \times 10^{-14}$ $mol^2$ $dm^{-6}$.

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*(Extra space)* .....

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**(4)**
**(Total 16 marks)**

**Q2.** This question is about the pH of several solutions.

Give all values of pH to 2 decimal places.

(a) (i) Write an expression for pH.

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**(1)**

(ii) Calculate the pH of 0.154 mol $dm^{-3}$ hydrochloric acid.

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**(1)**

(iii) Calculate the pH of the solution formed when 10.0 $cm^3$ of 0.154 mol $dm^{-3}$ hydrochloric acid are added to 990 $cm^3$ of water.

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**(2)**

(b) The acid dissociation constant, $K_a$, for the weak acid HX has the value $4.83 \times 10^{-5}$ mol $dm^{-3}$ at 25 °C.
A solution of HX has a pH of 2.48

Calculate the concentration of HX in the solution.

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**(4)**

(c) Explain why the pH of an acidic buffer solution remains almost constant despite the addition of a small amount of sodium hydroxide.

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**(2)**

(d) The acid dissociation constant, $K_a$, for the weak acid HY has the value $1.35 \times 10^{-5}$ mol dm$^{-3}$ at 25 °C.

A buffer solution was prepared by dissolving 0.0236 mol of the salt NaY in 50.0 cm$^3$ of a 0.428 mol dm$^{-3}$ solution of the weak acid HY

(i) Calculate the pH of this buffer solution.

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**(4)**

(ii) A $5.00 \times 10^{-4}$ mol sample of sodium hydroxide was added to this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added.

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**(4)**
**(Total 18 marks)**

**Q3.** In this question, give all values of pH to two decimal places.

Calculating the pH of aqueous solutions can involve the use of equilibrium constants such as $K_w$ and $K_a$

$K_w$ is the ionic product of water. The value of $K_w$ is $5.48 \times 10^{-14}$ $mol^2$ $dm^{-6}$ at 50 °C.

(a) (i) Write an expression for pH.

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**(1)**

(ii) Write an expression for $K_w$

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**(1)**

(b) (i) Calculate the pH of pure water at 50 °C.

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**(2)**

(ii) Suggest why this pure water is **not** acidic.

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**(1)**

(iii) Calculate the pH of 0.140 mol $dm^{-3}$ aqueous sodium hydroxide at 50 °C.

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**(3)**

(c) Calculate the pH of the solution formed when 25.0 $cm^3$ of 0.150 mol $dm^{-3}$ aqueous sulfuric acid are added to 30.0 $cm^3$ of 0.200 mol $dm^{-3}$ aqueous potassium hydroxide at 25 °C. Assume that the sulfuric acid is fully dissociated.

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**(6)**
**(Total 14 marks)**

**Q4.** The hydrolysis of methyl propanoate was studied in acidic conditions at 25°C and the rate equation was found to be

$$\text{rate} = k[CH_3CH_2COOCH_3][H^+]$$

(a) Use the data below to calculate the value of the rate constant, *k*, at this temperature.
Deduce its units.

| Initial rate of reaction / mol $dm^{-3}$ $s^{-1}$ | Initial concentration of methyl propanoate / mol $dm^{-3}$ | Initial concentration of hydrochloric acid / mol $dm^{-3}$ |
|---|---|---|

| | | |
|---|---|---|
| $1.15 \times 10^{-4}$ | 0.150 | 0.555 |

*Rate constant* .....

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*Units* .....

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**(3)**

(b) The reaction in part (a) was repeated at the same temperature, but water was added so that the volume of the reaction mixture was doubled. Calculate the initial rate of reaction under these conditions.

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**(1)**

(c) A third experiment was carried out at a different temperature. Some data from this experiment are shown in the table below.

| Initial rate of reaction / mol $dm^{-3}$ $s^{-1}$ | Value of rate constant at this different temperature | Initial methyl propanoate / mol $dm^{-3}$ |
|---|---|---|
| $4.56 \times 10^{-5}$ | $8.94 \times 10^{-4}$ | 0.123 |

Calculate the initial pH of the reaction mixture. Give your answer to two decimal places.

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**(3)**
**(Total 7 marks)**