A-Level Chemistry

Ionic Product of Water (Kw)

Question Paper

Time available: 55 minutes
Marks available: 49 marks

1. Hydrochloric acid is a strong acid and ethanoic acid is a weak acid.

(a) State the meaning of the term strong acid.

_____

_____

(1)

(b) In an experiment, 10.35 cm^3 of 0.100 mol dm^{-3} hydrochloric acid are added to 25.0 cm^3 of 0.150 mol dm^{-3} barium hydroxide solution.

Calculate the pH of the solution that forms at 30 °C

$K_w = 1.47 \times 10^{-14}$ mol^2 dm^{-6} at 30 °C

Give your answer to 2 decimal places.

pH _____

(6)

(c) The pH of water at 30 °C is 6.92

Give the reason why water is neutral at this temperature.

_____

_____

(1)

(d) Identify the oxide that could react with water to form a solution with pH = 2

Tick (✓) **one** box.

Al_2O_3 ☐

Na_2O ☐

SiO_2 ☐

SO_2 ☐

(1)

(e) Give the expression for the acid dissociation constant (K_a) for ethanoic acid (CH_3COOH).

K_a

(1)

(f) A buffer solution contains 0.025 mol of sodium ethanoate dissolved in 500 cm^3 of 0.0700 mol dm^{-3} ethanoic acid at 25 °C

A sample of 5.00 cm^3 of 2.00 mol dm^{-3} hydrochloric acid is added to this buffer solution.

Calculate the pH of the solution formed.

For ethanoic acid, $K_a = 1.76 \times 10^{-5}$ mol dm^{-3} at 25 °C

pH _____

(5)

(Total 15 marks)

2. This question is about different pH values.

(a) For pure water at 40 °C, pH = 6.67
A student thought that the water was acidic.

Explain why the student was incorrect.

Determine the value of K_w at this temperature.

Explanation _____

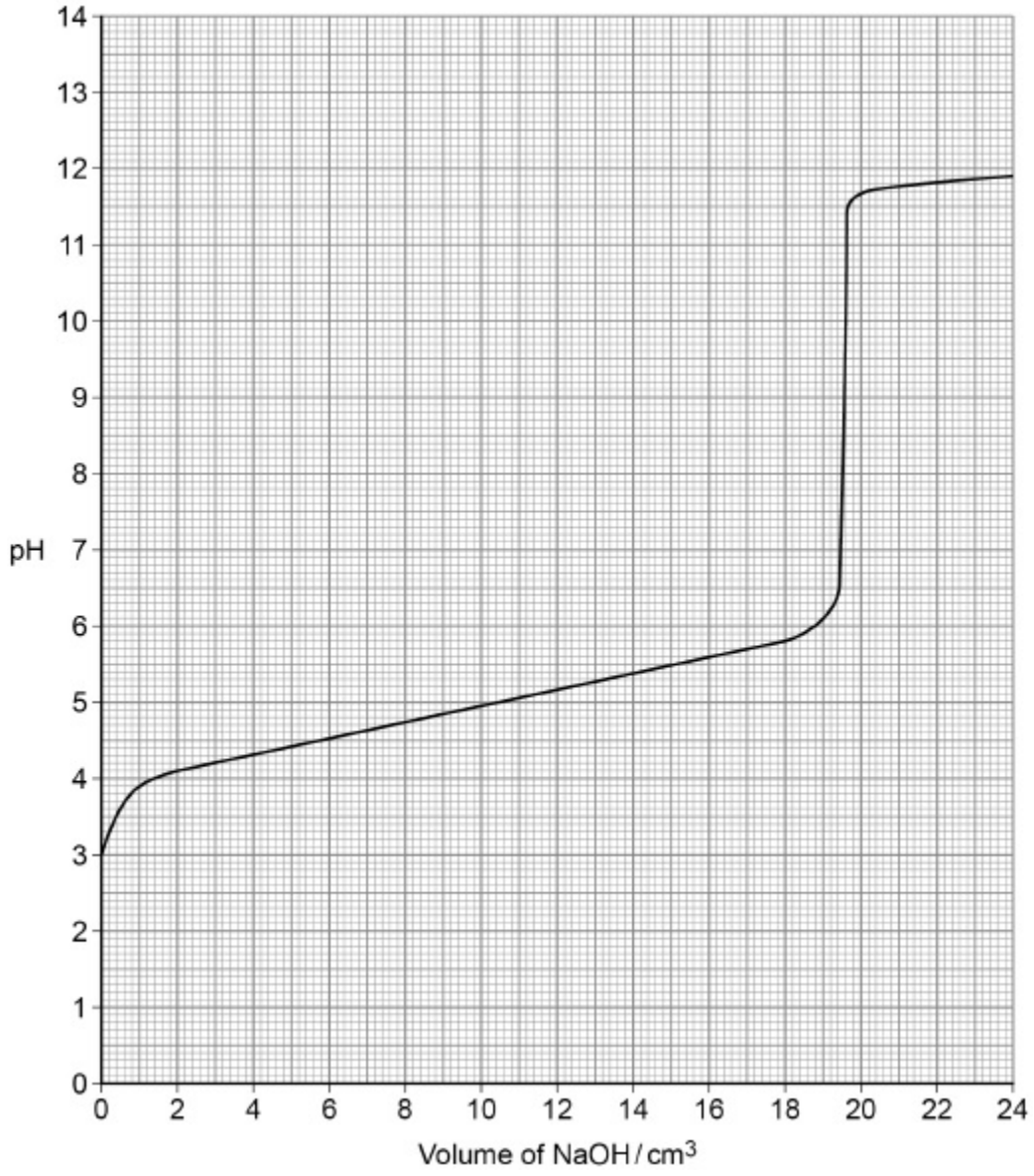
_____

K_w _____ $mol^2\ dm^{-6}$

(4)

(b) Sodium hydroxide solution was added gradually from a burette to 25 cm^3 of 0.080 mol dm^{-3} propanoic acid at 25 °C
The pH was measured and recorded at regular intervals.

The results are shown in the diagram.



Use the diagram above to determine the value of K_a for propanoic acid at 25 °C

Show your working.

K_a _____ mol dm^{-3}

(3)

(c) Suggest which indicator is the most appropriate for the reaction in part **(b)**?
Tick (✓) **one** box.

Indicator	**pH range**	**Tick (✓) one box**
methyl orange	3.1 - 4.4	
bromothymol blue	6.0 - 7.6	
cresolphthalein	8.2 - 9.8	
indigo carmine	11.6 - 13.0	

(1)

(d) A student prepared a buffer solution by adding 0.0136 mol of a salt KX to 100 cm^3 of a 0.500 mol dm^{-3} solution of a weak acid HX and mixing thoroughly.

The student then added 3.00×10^{-4} mol of potassium hydroxide to the buffer solution.

Calculate the pH of the buffer solution after adding the potassium hydroxide.

For the weak acid HX at 25 °C the value of the acid dissociation constant, $K_a = 1.41 \times 10^{-5}$ mol dm^{-3}.

Give your answer to two decimal places.

pH _____

(6)

(e) A buffer solution has a constant pH even when diluted.

Use a mathematical expression to explain this.

(1)

(Total 15 marks)

3. The ionic product of water, $K_w = 2.93 \times 10^{-15}$ mol^2 dm^{-6} at 10 °C

(a) Which is the correct expression for K_w?

Tick (✓) **one** box.

A $K_w = \dfrac{[H_2O]}{[H^+][OH^-]}$ ☐

B $K_w = [H^+][H_2O]$ ☐

C $K_w = [H^+][OH^-]$ ☐

D $K_w = \dfrac{[H^+][OH^-]}{[H_2O]}$ ☐

(1)

(b) Calculate the pH of pure water at 10 °C

Give your answer to two decimal places.

pH of water _____

(2)

(c) Suggest why this pure water at 10 °C is **not** alkaline.

_____

_____

_____

(1)

(d) Calculate the pH of a 0.0131 mol dm^{-3} solution of calcium hydroxide at 10 °C

Give your answer to two decimal places.

pH of solution _____

(3)

(e) The 0.0131 mol dm^{-3} calcium hydroxide solution at 10 °C was a saturated solution.

A student added 0.0131 mol of magnesium hydroxide to 1.00 dm^3 of water at 10 °C and stirred the mixture until no more solid dissolved.

Predict whether the pH of the magnesium hydroxide solution formed at 10 °C is larger than, smaller than or the same as the pH of the calcium hydroxide solution at 10 °C

Explain your answer.

pH of magnesium hydroxide compared to calcium hydroxide

_____

Explanation _____

_____

_____

(2)

(Total 9 marks)

4. Water dissociates slightly according to the equation:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water, K_w, is given by the expression

$$K_w = [H^+][OH^-]$$

K_w varies with temperature as shown in the table.

Temperature / °C	**K_w / mol^2 dm^{-6}**
25	1.00×10^{-14}
50	5.48×10^{-14}

(a) Explain why the expression for K_w does **not** include the concentration of water.

_____

_____

_____

_____

_____

(2)

(b) Explain why the value of K_w increases as the temperature increases.

(2)

(c) Calculate the pH of pure water at 50 °C.
Give your answer to 2 decimal places.

(3)

(d) Calculate the pH of 0.12 mol dm^{-3} aqueous NaOH at 50 °C.
Give your answer to 2 decimal places.

(3)

(Total 10 marks)