A-Level Chemistry

Buffers

Question Paper

Time available: 68 minutes
Marks available: 65 marks

1. This question is about acidic solutions.

(a) The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C

A buffer solution with a pH of 3.87 was prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoate ions was 0.136 mol dm^{-3}

Calculate the concentration of the ethanoic acid in the buffer solution.

Give your answer to three significant figures.

Concentration of acid = _____ mol dm^{-3}

(3)

(b) In a different buffer solution, the concentration of ethanoic acid was 0.260 mol dm^{-3} and the concentration of ethanoate ions was 0.121 mol dm^{-3}

A 7.00×10^{-3} mol sample of sodium hydroxide was added to 500 cm^3 of this buffer solution.

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

Give your answer to two decimal places.

pH of buffer solution _____

(6)

(Total 9 marks)

2. The acid dissociation constant, K_a, for ethanoic acid is given by the expression

$$K_a = \frac{[H^+][CH_3COO^-]}{[CH_3COOH]}$$

The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 25 °C.

(a) A buffer solution is prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoic acid is 0.186 mol dm^{-3} and the concentration of sodium ethanoate is 0.105 mol dm^{-3}.

Calculate the pH of this buffer solution.
Give your answer to 2 decimal places.

(3)

(b) In a different buffer solution, the concentration of ethanoic acid is 0.251 mol dm^{-3} and the concentration of sodium ethanoate is 0.140 mol dm^{-3}.

A sample of hydrochloric acid containing 0.015 mol of HCl is added to 1000 cm^3 of this buffer solution.

Calculate the pH of the buffer solution after the hydrochloric acid has been added.
You should ignore any change in total volume.
Give your answer to 2 decimal places.

(5)

(Total 8 marks)

3. This question is about alkalis and carboxylic acids.

In this question, all data are quoted at 25 °C.

(a) Carboxylic acids are weak acids.

State the meaning of the term **weak** as applied to carboxylic acids.

(1)

(b) Write an equation for the reaction of propanoic acid with sodium carbonate.

(1)

(c) Calculate the pH of a 0.0120 mol dm^{-3} solution of calcium hydroxide.
The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.
Give your answer to 2 decimal places.

(3)

(d) The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(i) Write an expression for the acid dissociation constant K_a for benzenecarboxylic acid.

(1)

(ii) Calculate the pH of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid.
Give your answer to 2 decimal places.

(3)

(iii) A buffer solution with a pH of 4.00 is made using benzenecarboxylic acid and sodium benzenecarboxylate.

Calculate the mass of sodium benzenecarboxylate (M_r = 144.0) that should be dissolved in 1.00 dm^3 of a 0.0120 mol dm^{-3} solution of benzenecarboxylic acid to produce a buffer solution with a pH of 4.00

The value of the acid dissociation constant K_a for benzenecarboxylic acid (C_6H_5COOH) is 6.31×10^{-5} mol dm^{-3}.

(5)

(e) Two solutions, one with a pH of 4.00 and the other with a pH of 9.00, were left open to the air.

The pH of the pH 9.00 solution changed more than that of the other solution.

Suggest what substance might be present in the air to cause the pH to change. Explain how and why the pH of the pH 9.00 solution changes.

Substance present in air _____

Explanation _____

(3)

(Total 17 marks)

4. In this question, give all values of pH to 2 decimal places.

(a) The ionic product of water has the symbol K_w

(i) Write an expression for the ionic product of water.

_____

(1)

(ii) At 42°C, the value of K_w is 3.46×10^{-14} mol^2 dm^{-6}.

Calculate the pH of pure water at this temperature.

_____

_____

_____

_____

(2)

(iii) At 75 °C, a 0.0470 mol dm^{-3} solution of sodium hydroxide has a pH of 11.36. Calculate a value for K_w at this temperature.

_____

_____

_____

_____

(2)

(b) Methanoic acid (HCOOH) dissociates slightly in aqueous solution.

(i) Write an equation for this dissociation.

_____

(1)

(ii) Write an expression for the acid dissociation constant K_a for methanoic acid.

_____

_____

(1)

(iii) The value of K_a for methanoic acid is 1.78×10^{-4} mol dm^{-3} at 25 °C.
Calculate the pH of a 0.0560 mol dm^{-3} solution of methanoic acid.

(3)

(iv) The dissociation of methanoic acid in aqueous solution is endothermic.

Deduce whether the pH of a solution of methanoic acid will increase, decrease or stay the same if the solution is heated. Explain your answer.

Effect on pH _____

Explanation _____

(3)

(c) The value of K_a for methanoic acid is 1.78×10^{-4} mol dm^{-3} at 25°C.
A buffer solution is prepared containing 2.35×10^{-2} mol of methanoic acid and 1.84×10^{-2} mol of sodium methanoate in 1.00 dm^3 of solution.

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

(3)

(ii) A 5.00 cm^3 sample of 0.100 mol dm^{-3} hydrochloric acid is added to the buffer solution in part (c)(i).

Calculate the pH of the buffer solution after this addition.

(4)

(Total 20 marks)

5. Buffer solutions are important in biological systems and in industry to maintain almost constant pH values.

(a) In the human body, one important buffer system in blood involves the hydrogencarbonate ion, HCO_3^-, and carbonic acid, H^2CO_3, which is formed when carbon dioxide dissolves in water.

(i) Use the following equation to explain how this buffer maintains a constant pH of 7.41 even if a small amount of acid enters the bloodstream.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

(ii) In a sample of blood with a pH of 7.41, the concentration of HCO_3^- (aq) ions is 2.50×10^{-2} mol dm^{-3} and the concentration of H_2CO_3(aq) is 1.25×10^{-3} mol dm^{-3}. Calculate a value for the acid dissociation constant, K_a, for carbonic acid at this temperature.

_____

_____

_____

_____

(5)

(b) In industry, the pH of a solution used to dye cloth must be controlled or else the colour varies.

A solution of dye in a beaker is buffered by the presence of ethanoic acid and sodium ethanoate. In the solution, the concentration of ethanoic acid is 0.15 mol dm^{-3} and the concentration of sodium ethanoate is 0.10 mol dm^{-3}. The value of K_a for ethanoic acid is 1.74×10^{-5} mol dm^{-3} at 298 K.

(i) A 10.0 cm^3 portion of 1.00 mol dm^{-3} hydrochloric acid is added to 1000 cm^3 of this buffered solution.

Calculate the number of moles of hydrochloric acid added.

_____

(ii) Calculate the number of moles of ethanoic acid and the number of moles of sodium ethanoate in the solution after addition of the hydrochloric acid.

Mol of ethanoic acid after addition _____

_____

Mol of sodium ethanoate after addition _____

_____

(iii) Hence calculate the pH of this new solution. Give your answer to 2 decimal places.

_____

_____

_____

(6)

(Total 11 marks)