A-Level Chemistry

Calculation of pH

Question Paper

Time available: 77 minutes
Marks available: 73 marks

1. 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)

2. This question is about Brønsted–Lowry acids.

(a) Give the meaning of the term Brønsted–Lowry acid.

_____

_____

(1)

(b) What is meant by the term strong when describing an acid?

_____

_____

(1)

(c) At 298 K, 25.0 cm^3 of a solution of a strong monoprotic acid contained 1.45×10^{-3} mol of hydrogen ions.

Calculate a value for the pH of this solution.
Give your answer to 2 decimal places.

pH _____

(2)

(d) Calculate the pH of the solution formed after the addition of 35.0 cm^3 of 0.150 mol dm^{-3} NaOH to the original 25.0 cm^3 of monoprotic acid.

The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 298 K.
Give your answer to two decimal places.

pH _____

(5)

(e) A buffer solution is made when 1.50 g of sodium hydroxide are added to 1.00 dm^3 of a 0.150 mol dm^{-3} solution of a weak acid HA.

For HA, the acid dissociation constant, $K_a = 1.79 \times 10^{-5}$ mol dm^{-3}.

Calculate the pH of this buffer solution.

pH _____

(6)

(Total 15 marks)

3. Nitric acid (HNO_{-3}) is a strong acid. Ethanoic acid (CH_3COOH) is a weak acid.

(a) Write an equation to show how ethanoic acid behaves as a weak acid in its reaction with water.

_____

(1)

(b) When pure ethanoic acid reacts with pure nitric acid, ethanoic acid acts as a base.

Write an equation for this reaction.

_____

(1)

(c) Two beakers, **A** and **B**, each contain 100.0 cm^{-3} of 0.0125 mol dm^{-3} nitric acid.

(i) Calculate the pH of the solution formed after 50.0 cm^{-3} of distilled water are added to beaker **A**.
Give your answer to 2 decimal places.

(2)

(ii) Calculate the pH of the solution formed after 50.0 cm^3 of 0.0108 mol dm^{-3} aqueous sodium hydroxide are added to beaker **B**.
Give your answer to 2 decimal places.

(4)

(d) A third beaker, **C**, contains 100.0 cm^3 of 0.0125 mol dm^{-3} ethanoic acid.
The acid dissociation constant K_a for ethanoic acid has the value 1.74×10^{-5} mol dm^{-3} at 25 °C.

(i) Write an expression for K_a for ethanoic acid and use it to calculate the pH of the ethanoic acid solution in beaker **C**.
Show your working. Give your answer to 2 decimal places.

K_a _____

_____

Calculation _____

_____

_____

_____

(4)

(ii) Aqueous sodium hydroxide is added to beaker **C** until the pH of the solution becomes 4.84.

Name the salt formed in the reaction of ethanoic acid with sodium hydroxide.

_____

(1)

(iii) Calculate the value of $\frac{[\text{salt}]}{[\text{ethanoic acid}]}$ in the solution with the pH of 4.84.

_____

_____

_____

_____

_____

_____

(3)

(e) Explain why chloroethanoic acid is a stronger acid than ethanoic acid.

(2)

(f) Explain why data books do not usually contain values of K_a for strong acids.

(2)

(Total 20 marks)

4. 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)

5. This question involves calculations about two strong acids and one weak acid.
All measurements were carried out at 25 °C.

(a) A 25.0 cm^3 sample of 0.0850 mol dm^{-3} hydrochloric acid was placed in a beaker and 100 cm^3 of distilled water were added.
Calculate the pH of the new solution formed.
Give your answer to 2 decimal places.

(2)

(b) HX is a weak monobasic acid.

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

(1)

(ii) The pH of a 0.0850 mol dm^{-3} solution of HX is 2.79
Calculate a value for the acid dissociation constant, K_a, of this acid.
Give your answer to 3 significant figures.

(3)

(c) A 25.0 cm^3 sample of 0.620 mol dm^{-3} nitric acid was placed in a beaker and 38.2 cm^3 of 0.550 mol dm^{-3} aqueous sodium hydroxide were added.
Calculate the pH of the solution formed.
Give your answer to 2 decimal places.

The ionic product of water $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6} at 25 °C.

(6)

(Total 12 marks)