

8.9 The Henderson-Hasselbalch Equation

Name: _____ Class: _____ Date: _____

Total: 12 marks

KEY WORDS pH • buffer • acid • base

Objective

Build the skills to answer exam questions on the **Henderson-Hasselbalch equation**.

You must be able to:

- use $\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$
- find a buffer's pH from the ratio
- find the ratio needed for a target pH

1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later – follow the steps and you can do the Practice and Exam-style questions yourself.

■ The equation

$$\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

It gives a buffer's pH from the base-to-acid ratio.

■ Equal amounts

When $[\text{A}^-] = [\text{HA}]$, the log term is $\log 1 = 0$, so $\text{pH} = \text{p}K_a$.

■ A worked pH

A buffer with $\text{p}K_a = 4.7$, $[\text{A}^-] = 0.20$, $[\text{HA}] = 0.10$:

$$\text{pH} = 4.7 + \log \frac{0.20}{0.10} = 4.7 + \log 2 = 4.7 + 0.30 = 5.0.$$

■ Finding the ratio for a target pH

Rearrange: $\log \frac{[A^-]}{[HA]} = \text{pH} - \text{p}K_a$, then take $10^{(\text{pH} - \text{p}K_a)}$.

2 Practice

Now apply the methods above.

2.1 Write the Henderson-Hasselbalch equation. [1]

2.2 A buffer has $\text{p}K_a = 4.7$ with equal acid and base. Find the pH. [1]

2.3 Find the pH of a buffer with $\text{p}K_a = 5.0$ and $\frac{[A^-]}{[HA]} = 10$. [2]

3 Exam-style questions

3.1 When $[A^-] = [HA]$, the Henderson-Hasselbalch equation gives $\text{pH} =$ [1]

- ☐ **A** 0
☐ **B** 7
☐ **C** $\text{p}K_a$
☐ **D** $\text{p}K_a + 1$

3.2 A buffer uses an acid with $\text{p}K_a = 4.74$, with $[HA] = 0.30 \text{ M}$ and $[A^-] = 0.15 \text{ M}$.

(a) Find the ratio $\frac{[A^-]}{[HA]}$. [1]

(b) Find the pH. [3]

3.3 You want a buffer at pH 5.0 using an acid with $pK_a = 4.7$. Find the required ratio $\frac{[A^-]}{[HA]}$. [3]

Solutions

Each answer shows the steps, then the **result**.

2.1

- $\text{pH} = \text{p}K_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$

2.2

- $\text{pH} = 4.7$

2.3

- $\text{pH} = 5.0 + \log 10 = 5.0 + 1 = 6.0$

3.1 C

- $\text{pH} = \text{p}K_a$

3.2

(a)

- $\frac{0.15}{0.30} = 0.5$

(b)

- $\text{pH} = 4.74 + \log(0.5) = 4.74 - 0.30 = 4.44$

3.3

- $\log \frac{[\text{A}^-]}{[\text{HA}]} = 5.0 - 4.7 = 0.3$; ratio = $10^{0.3} = 2.0$