AP CHEMISTRY • EXERCISE SHEET

8.9 The Henderson-Hasselbalch Equation

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

KEY WORDS ph pH 值 • buffer 缓冲溶液 • acid 酸 • base 碱

Objective

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

You must be able to:

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

1 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**

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

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

■ **Equal amounts**

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

■ **A worked pH**

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

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

■ **Finding the ratio for a target pH**

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

2 Practice

Now apply the methods above.

2.1 Write the Henderson-Hasselbalch equation. [1]

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

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

3 Exam-style questions

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

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

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

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

(b) Find the pH. [3]

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

Solutions

2.1 $\mathrm{pH} = \mathrm{p}K_a + \log \dfrac{[\mathrm{A}^-]}{[\mathrm{HA}]}$.

2.2 $\mathrm{pH} = 4.7$.

2.3 $\mathrm{pH} = 5.0 + \log 10 = 5.0 + 1 = 6.0$.

3.1 **C** — $\mathrm{pH} = \mathrm{p}K_a$.

3.2 (a) $\dfrac{0.15}{0.30} = 0.5$. (b) $\mathrm{pH} = 4.74 + \log(0.5) = 4.74 - 0.30 = 4.44$.

3.3 $\log \dfrac{[\mathrm{A}^-]}{[\mathrm{HA}]} = 5.0 - 4.7 = 0.3$; ratio $= 10^{0.3} = 2.0$.