Henderson Hasselbalch Equation Chemistry Questions with Solutions

Q1. The Henderson Hasselbalch equation explains the relationship between-

a.) pH and pOH
b.) pH and logKa
c.) pH and pKa
d.) pOH and pKa

Correct Answer– (c.) pH and pKa

Q2. A buffer solution contains 0.36 M sodium acetate (CH_3COONa) and 0.45 M acetic acid (CH_3COOH), pKa = 4.8. What is the pH of this buffer solution?

a.) 4.7
b.) 6.3
c.) 5.5
d.) 4.2

Correct Answer– (a.) 4.7

Q3. If the pH = pKa, the log of the ratio of dissociating acid and associated acid will be-

a.) equal
b.) zero
c.) greater than 1
d.) lesser than 3

Correct Answer– (b.) zero

Q4. When the pH equals the pKa, the acid will be:

a.) fully dissociated
b.) half dissociated
c.) partially dissociated
d.) None of the above

Correct Answer– (b.) half dissociated

Q5. Which of the following is true regarding the Henderson-Hasselbalch equation?

I. The pH of the solution is always greater than the pKa of the solution.

II. As the ratio of conjugate base to acid increases, the pH increases.
III. The hydrogen ion concentration can never equal the acid dissociation constant.

a.) I and II
b.) II only
c.) I only
d.) II and III

Correct Answer– (b.) II only

Q6.What are the four-variable in the Henderson Hasselbalch equation?

Answer. The Henderson Hasselbalch Equation is:

$$pH = pK_a + log\frac{A^-}{HA}.$$

The four variables present in this equation are pH, pKa, [A⁻] and [HA].
On knowing any three values, the unknown value can be calculated.

Q7. Is the Henderson-Hasselbalch equation only applicable to acids?

Answer. Only if the consecutive pK values of a polybasic acid differ by at least 3 can the Henderson-Hasselbalch equation be applied.

Q8. Calculate the pH of a buffer that contains 0.7 M ammonia and 0.9 M ammonium chloride. (pKa = 9.248).

Answer. By using the Henderson Hasselbalch Equation is:

$$pH = pK_a + log\frac{A^-}{HA}$$

pH = 9.248 + log [0.9 / 0.7]
pH = 9.248 + log 1.29
pH = 9.248 + 0.11
pH = 9.358

Q9. How does the buffer concentration affect the buffer capacity?

Answer. A buffer's ability to neutralise added acid or base is determined by the concentrations of HA and A^- in the solution. The greater the concentrations for a given ratio of [HA] to [A^-], the greater the overall buffer capacity. When [HA] exceeds [A^-], the capacity for added base exceeds that of acid.

Q10. What are the limitations of the Henderson Hasselbalch equation?

Answer. The limitations of the Henderson Hasselbalch equation are as follows:

- The Henderson-Hasselbalch equation fails to predict accurate values for strong acids and strong bases because it assumes that the concentration of the acid and its conjugate base at chemical equilibrium will be the same as the formal concentration (the binding of protons to the base is neglected).
- Since the Henderson-Hasselbalch equation does not account for water's self-dissociation, it cannot provide accurate pH values for extremely dilute buffer solutions.

Q11. A solution of hydrofluoric acid has a concentration of 0.3M.
The Ka for HF is 7.2×10^{-4}.
If sodium hydroxide is slowly added to this solution, what will the pH be at the half equivalence point?

Answer. By using the Henderson Hasselbalch Equation

$$pH = pK_a + log\frac{A^-}{HA}$$

We don't need to worry about using the molar amounts of the acid and the base if we use the Henderson-Hasselbalch equation. The conjugate base concentration is equal to the weak acid concentration at the half equivalence point. That is, the equation can be simplified.

A simplified equation for the half equivalence point:
pH = pKa
Since the acid dissociation constant is 7.2×10^{-4}, the pH will be:
pH = –log [7.2×10^{-4}] = 3.14.
Hence, the pH at the half equivalence point is 3.14.

Q12. Calculate the pH of a solution containing 3.0 M hydrofluoric acid and 2.5 M fluoride. (Ka for hydrofluoric acid is 6.76×10^{-4}.)

Answer. To begin, convert the acid-dissociation constant into pKa. The Henderson-Hasselbalch equation can then be used to calculate the pH of this solution.
pKa = –log (Ka)
pKa = –log(6.76×10^{-4})
pKa = 3.17
By using the Henderson Hasselbalch Equation

$$pH = pK_a + log\frac{[base]}{[acid]}$$

pH = 3.17 + log [2.5/3]
pH = 3.09

Q13. What is the ratio of the concentration of acetic acid and acetate ions required to prepare a buffer with pH 5.20? The pKa of acetic acid is 4.76.

Answer. Given: pH of the buffer = 5.20

pKa of acetic acid = 4.76
By using the Henderson Hasselbalch Equation

$$pH = pK_a + log\frac{[protonacceptor]}{[protondonor]}$$

$$log\frac{[protonacceptor]}{[protondonor]} = pH - pKa$$

$$log\frac{[protonacceptor]}{[protondonor]} = 5.20 - 4.76$$

$$log\frac{[protonacceptor]}{[protondonor]} = 0.44$$

$$\frac{[protonacceptor]}{[protondonor]} = antilog0.44$$

=2.75
Thus, the ratio of the concentration of acetic acid and acetate ions required to prepare a buffer with pH 5.20 is 2.75.

Q14. What is the importance of Henderson - Hasselbalch equation?

Answer. For acid buffer solution the equation is:

$$pH = pK_a + log\frac{[salt]}{[acid]}$$

For basic buffer solution the equation is:

$$pH = pK_a + log\frac{[salt]}{[base]}$$

The Henderson Equation's Importance:
1) The pH of a buffer solution can be calculated using Henderson's equation.
2) Henderson's equation can be used to calculate the salt: acid ratio required to produce a buffer solution with the desired pH value.
3) Given the pH and total buffer concentration, the concentration of acid and salt (or base and salt) can be calculated.

Q15. Derive Henderson - Hasselbalch equation.

Answer. Let us take an example of ionization of weak acid HA:
$HA + H_2O \leftrightharpoons H^+ + A^-$
Acid dissociation constant is given as:

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

Taking negative log of the above equation

$$-logK_a = -log\frac{[H^+][A^-]}{[HA]}$$

$$-logK_a = -log\left[H^+\right] - log\frac{[A^-]}{[HA]}$$

Since, –log [H^+] = pH and –log Ka = pKa

The equation can be written as:

$$pKa = pH - log\frac{[A^-]}{[HA]}$$

On rearranging the equation:

$$pH = pK_a + log\frac{A^-}{HA}$$

Practise Questions on Henderson Hasselbalch Equation

Q1. A solution of acetic acid (pKa = 4.75) has a pH of 6.75. The ratio of acid to the conjugate base is ___.

a.) 100 CH_3COO^- to 1 CH_3COOH

b.) 100 CH_3COOH to 1 CH_3COO^-

c.) 1 CH_3COOH to 100 CH_3COO^-

d.) 0.01 CH_3COOH to 100 CH_3COO^-

Correct Answer– (c.) 1 CH_3COOH to 100 CH_3COO^-

Explanation: On using the Henderson Hasselbalch Equation

$$pH = pK_a + log\frac{A^-}{HA}$$

6.75 = 4.75 +log [A^-]/[HA]

10^2 = [A^-]/[HA] = 100

The ratio of acid to the conjugate base would be $\frac{[HA]}{[A^-]} = \frac{1}{100}$

Q2. You need to produce a buffer with a pH of 5.75. You have a solution with 30.0g of acetic acid (pKa=4.75). How many moles of sodium acetate must you add to achieve the desired pH?

a.) 0.3 mol

b.) 5 mol
c.) 0.5 mol
d.) 3 mol

Correct Answer– (b.) 5 mol
Explanation: On using the Henderson Hasselbalch Equation

$$pH = pK_a + log\frac{A^-}{HA}$$

We know we have 30g of acetic acid, which is equal to 0.5mol if these ions occupy the same volume.
log $[A^-]/[HA]$ = log [(mol of A^-) / (mol of HA)]
Substituting in our values provides us with
5.75 = 4.75 + log [A^- / 0.5]
When we solve for A^-, we get 5mol.

Q3. Find $[H^+]$ in a solution of 1.0M pf HNO_3 and 0.225 M $NaNO_2$. The Ka for HNO_2 is 7.4 × 10^{-4}.

Answer.
First, convert Ka to pKa:
pKa = $-\log_{10}$ Ka = $-\log_{10}(7.4 \times 10^{-4})$ = 3.14

$$pH = pK_a + log\frac{A^-}{HA}$$

$$pH = pKa + log_{10}\frac{[NO_2^-]}{[HNO_2]}$$

pH = 3.14 + $\log_{10}$ [1/0.225]
pH = 3.14 + 0.648
pH = 3.788
$[H^+] = 10^{-pH} = 10^{-3.788} = 1.6 \times 10^{-4}$.

Q4. Calculate the pH of a buffer solution made from 0.20 M CH_3COOH and 0.50 M CH_3COO^- that has an acid dissociation constant for CH_3COOH of 1.8 x 10^{-5}.

Answer. First, convert Ka to pKa:
pKa = $-\log_{10}$ Ka = $-\log_{10}(1.8 \times 10^{-5})$ = 4.7

By using the Henderson Hasselbalch equation

$$pH = pK_a + log\frac{A^-}{HA}$$

pH = pKa + log [CH_3COO^-/CH_3COOH]
pH = 4.7 + log[0.50/0.20]
pH = 4.7 + 0.40
pH = 5.1

Q5. When is the Henderson-Hasselbalch Equation used?

Answer. When performing buffer calculations, the Henderson-Hasselbalch equation is used. A weak acid and its salt solution is an acid buffer.

The Henderson-Hasselbalch equation is $pH = pK_a + log\frac{A^-}{HA}$.