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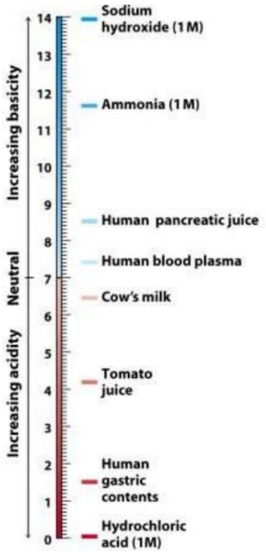
Biochemistry

Acids and Bases 2

❖ pH



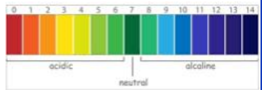
- Proton (H^+) concentration is an indicator for the acidity of a solution
- **pH:** It is a **logarithmic** scale of the concentration of proton (H^+)
  - **$pH = -\log [H^+]$**
  - **$[H^+] = 10^{-pH}$**
- As the **pH** is smaller, the concentration of **protons** increases → more acidic
  - pH and [H^+] are **inversely** related
  - A change in the pH by 1 unit implies a **10-fold difference** in the [H^+]
- **Example:** If the pH of HA solution is 2 and the pH of HX is 2.5, what is the difference in [H^+]?
  - HA has a proton concentration 2 times more that HX
- If the pH = **7** → the solution is neutral
- If the pH value is between **7-14** → the solution is basic
- If the pH value is between **0-7** → the solution is acidic

❖ pH measurements

- To measure pH, we can use:

A. **Acid-base indicators** (such as litmus paper [the least accurate], universal indicator)

B. **Electronic pH meter** (the most accurate)



❖ Calculations of pH

- **Example:** Calculate the pH value for each solution:

1) 0.001 M HCl

2) 0.01 N H_2SO_4

3) 0.1 N NaOH

4) 10^{-11} M HCl

5) 0.1 M of acetic acid ($Ka = 1.8 \times 10^{-5}$)

6) A solution of HA where [OH^-] is 10^{-12}

Answers: 1) 3 2) 1.7 3) 13 4) 7 5) 2.9 6) 2

Steps:

1) Find out [H^+], by:
   - Directly given
   - Ka & pKa
   - Kw
2) Use pH equation
3) Is your answer logic?!

- We can use the ion product (Kw) equation to calculate pH and pOH
  - $Kw = [H^+] \times [OH^-]$

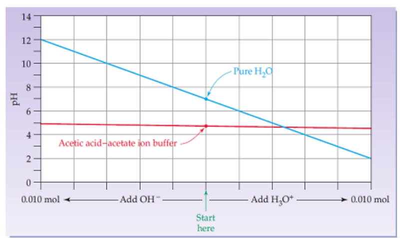
    $10^{-14} = [H^+] \times [OH^-]$

    14 pH + pOH

❖ Buffers

- What is a buffer?
  - It is a solution that resists changes in pH by changing reaction equilibrium
  - They are composed of mixtures of a weak acid and a roughly equal concentration of its conjugate base (salt)
- So, buffers aim to maintain equilibrium of pH
  - They follow **Le Châtelier's principle**
    - ✓ Normally the reaction is in equilibrium

Acid	Conjugate base
CH_3COOH	CH_3COONa ($NaCH_3COO$)
H_3PO_4	NaH_2PO_4
$H_2PO_4^-$ (or NaH_2PO_4)	Na_2HPO_4
H_2CO_3	$NaHCO_3$

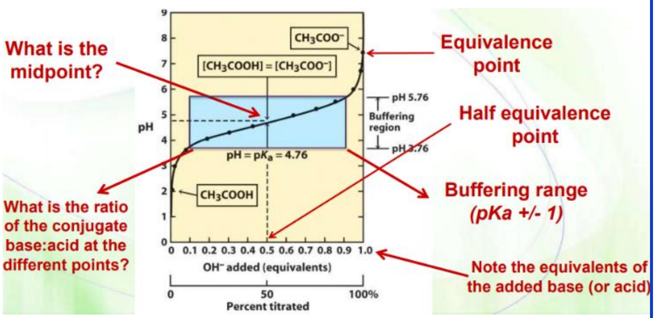


- ✓ If we added more reactants, the forward reaction becomes the dominant to restore equilibrium
- ✓ If we added more products, the backward reaction becomes the dominant to restore equilibrium

- Henderson-Hasselbalch Equation $pH = pKa - \log \frac{[HA]}{[A^-]}$ OR $pH = pKa + \log \frac{[A^-]}{[HA]}$
- According to this equation:
  - ➢ pK_a it is the pH where 50% of acid is dissociated into conjugate base
  - ➢ pK_a it is the pH where the concentration of acid equals the concentration of its conjugate base
  - ➢ At **low pH**, acids present mostly in the **protonated** form (acidic form)
  - ➢ At **high pH**, acids present mostly in the **deprotonated** form (conjugated base)

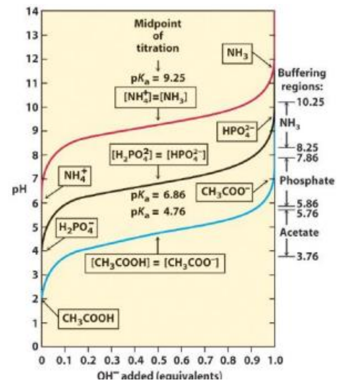
❖ Titration curve of buffer

- At the beginning, pH is very low and when a base is added to the solution
  - ➢ $[OH^-]$ increases, $[H^+]$ decreases and pH increases



- As the addition continues, CH_3COOH (the weak acid) tries to **<u>resist the change</u>** in pH by increase its dissociation (ionization) producing more H^+ and the conjugate base
- **Midpoint (reflection or inflection point):** it is the point where the concentration of the acid equals the concentration of the conjugate base (50% of the acid dissociated, $pK_a=K_a$)
- **Buffering range:** The range of pH values where the buffer has the highest ability to resist the changes
  - ➢ It ranges between pH values **(pK_a – 1) & (pK_a + 1)**

- As the acid continues deprotonating (ionizing), its concentration is decreasing continuously
  - ➢ There will be a smaller number of protons to be <u>donated</u>, so its ability to resist the changes of pH decreases and pH increase dramatically (again) until reaching the Equivalence point
  - ➢ **Equivalence point:** pH value where almost all of the acid is **<u>deprotonated</u>** (converted into conjugate base)



- How do we make/choose a buffer?
  - ➢ A buffer is made by combining weak acid/base and its salt (conjugate)
  - ➢ The ability of a buffer to function depends on:
    - ✓ Buffer concentration: As the **concentration** of the buffer solution increases, its <u>capacity</u> increases
    - ✓ Buffering range: pH desired to be maintained should be in the range of the buffer capacity (close to pK_a)

❖ Calculations of pH

- **<u>Examples:</u>**

1) A solution of 0.1 M acetic acid and 0.2 M acetate ion. The pKa of acetic acid is 4.8 calculate pH:
   - ➢ pH = 5.1
2) Calculate (predict) the pH of a buffer containing 0.1M HF and 0.12M NaF ($Ka = 3.5 \times 10^{-4}$)
   - ➢ pH = 3.5

Steps:

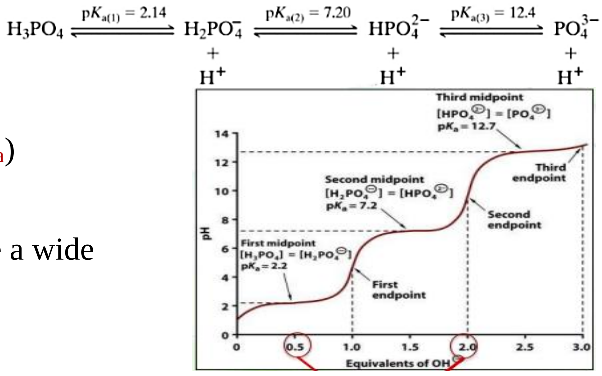
4) Write the chemical equation
5) Write down the info
6) Use Henderson-Hasselbalch Equation

3) Calculate (predict) the pH of a buffer containing 0.1M HF and 0.1M NaF, when 0.02M HCl is added to the solution (Ka = 3.5 x 10^{-4})?
   - ➢ pH = 3.3

4) What is the pH of a lactate buffer that contains 75% lactic acid and 25% lactate? (pK_a = 3.86)
   - ➢ pH = 3.38

5) What is the concentration of 5 ml of acetic acid knowing that 44.5 ml of 0.1 N of NaOH are needed to reach the end of titration of acetic acid?
   - ➢ [CH_3COOH] = 0.89 M

❖ Multi-protic buffers



- Multi-protic buffers such as phosphate buffer
  - ➢ Donates their protons **gradually**
  - ➢ Each donation occurs at different strength (different pK_a)
  - ➢ The first dissociation has the least pK_a (the strongest)
- Multi-protic buffers are important because they can manage a wide range of pH values

- **Examples:**

1) What is the pK_a of a dihydrogen phosphate buffer when pH of 7.2 is obtained when 100 ml of 0.1 M NaH_2PO_4 is mixed with 100 ml of 0.1 M Na_2HPO_4?
   - ➢ pKa = 7.2

2) A solution was prepared by dissolving 0.02 moles of acetic acid (pKa = 4.8) in water to give 1 liter of solution

A) What is the pH?
   - ➢ pH = 3.2

B) To this solution was then added 0.008 moles of concentrated sodium hydroxide (NaOH). What is the new pH?
   - ➢ pH = 4.6

Past papers

1. Water can form all of these non-covalent interactions, EXCEPT:

A. Hydrophobic interactions
B. Ionic interactions
C. Hydrogen bonds
D. Van der Waals
E. None of the above

2. Laboratory tests of urine of a patient identified the presence of methylmalonate ($COOCH(CH_3)COO^-$), Which of the following statement describes methylmalonate best?

A. It can't be used to make a buffer solution
B. It is 100% dissociated at its pKa
C. It is a major intracellular buffer

D. It is a conjugate base of a weak acid
E. It is a strong base

3. You prepared a sodium phosphate buffer by mixing 100ml of 0.1 M Na_2HPO_4 with 100ml of 0.1 M NaH_2PO_4, pH of the final solution is 7.8 what is the approximate PKa of the acid component of it

A. 7.8
B. $10^{-5.8}$
C. $10^{7.8}$
D. 5.8
E. 6.8

4. A decrease blood pH from 7.5 to 7 would be accompanied by which of the following changes in ion concentration?

A. A ten-fold decrease in hydrogen concentration
B. An increase in hydrogen ion concentration by a factor of 7.5 / 7
C. Five-fold increase in hydroxyl ion concentration
D. shift in concentration of buffer and ions with no change in hydrogen ion concentration
E. A 3-fold increase in hydrogen add concentration

5. In a titration curve of a weak acid the point in the plateau region between that inflection point and the equivalence point has the following characteristics

A. The concentration of weak acid is higher than the conjugate base
B. All equivalents needed for titration were used up
C. Can act as a buffer
D. The pH of the solution must be 7
E. pH value equals the value of the acid pKa

6. You have been observing an insect that defends itself from enemies by secreting a liquid . Analysis of lipid shows it to have a concentration of formic acid (Ka= $1.8 * 10^{-4}$) off 1.45 M and a concentration of formate ion of 0.015M what is the pH of the secretion?

A. 5.73
B. 1.76
C. 7
D. 3.37
E. 1.91

7. What is the pH if the concentration of the conjugate base (A-) is 0.35M and the concentration of the weak acid (HA) is 0.25M after adding 0.05 M of NaOH ? (pKa = 7)

A. 7.3
B. 6.3
C. 8.6
D. 9

8. If you have x moles of KOH how many moles of an acid must be added to make a buffer solution?

A. 2X HCl
B. X/2 acetic acid
C. 1.5 X acetic acid
D. X acetic acid

9. Which one of the following works as a buffer?

A. KOH
B. NaOH
C. HCl
D. H_2SO_4
E. None of the above

10. Below is the pKa for weak acids, which of them will be approximately 9% dissociated at ph 3.88?

A. Acetoacetic acid (pka = 3.6)
B. Lactic acid (pka = 3.9)
C. Propionic acid (pka = 4.9)
D. imidazolium (pka = 5.9)

11. The pH of 0.1M HCL is 1.0 ,Of O.1 M Acetic Acid is 2.8. What volume of 0.1N NaOH would be required to titrate 10 mL of each acid solution to their respective End point respectively ?

A. 10 ml, 10 ml
B. 6 ml, 10 ml
C. 10 ml, 16 ml
D. 100 ml, 16 ml

12. 4.13g OF $NaC_2H_7O_4$ (M.W = 202.14 g/mol) is added to 250 mL of a 0.150 M $HC_2H_7O_4$ solution (Ka= 2.75 X 10^{-5}) What is the pH of the buffer system?

A. 6.54
B. 5.43
C. 4.28
D. 7.42

13. A buffer is made by adding 0.200 M $HC_2H_3O_2$ and 0.150 M $NaC_2H_3O_2$. If 0.005 mol of NaOH is added to 125 mL of this buffer, What is the pH? (Ka=1.8 X 10^{-5})

A. 4.82
B. 4.18
C. 5.23
D. 6.47

14. 0.5 ml of HCl titrated by 0.5 M of NaOH with a volume of 12 ml what is the pH of the acid:

A. 0.8
B. 0.08
C. 0.6
D. 0.06

15. Below is the pKa of some weak acids. Which weak acid will be 91 % undissociated at pH=4.86?

A. Acetoacetic acid pka = 3.6
B. Lactic acid pKa=3.9
C. beta-hydroxyl butyric acid pka=4.8
D. propionic acid pka=4.9
E. Imidazolium pka=5.9

16. Buffers work the best at all these conditions except:

A. When the pH to be maintained using the buffer has a value close to the pKa of its acid component
B. When the concentration of the acid component is equal to that of the base component
C. When the acid component is completely dissociated

17. You have an X amount of KOH and want to make a buffer what do you add?

A. 2x amount of acetic acid
B. 2x amount of HCL
C. 3x amount of HCL
D. 3x amount of NaOH
E. 2x amount of NaOH