Class №5 The theme: «pH of solutions. Properties of buffer solutions. The buffer capacity».

1. **Questions:**
    1. Autoionization of water. The ion-product constant for water.
    2. pH and pH scale. Equation relating pH and pOH. pH of the biological fluids.
    3. Acid-base theories.
    4. Hydrolysis of salts. Role of the hydrolysis in biochemical processes.
    5. Buffer solution. Classification. Composition of buffers.
    6. The Henderson-Hasselbalch equation.
    7. Mechanism of buffering.
    8. The buffer capacity.
    9. The main buffer systems in human blood (bicarbonate, phosphate, hemoglobin).

2. **Familiarize with teaching tasks:**

№	**Content of the task:**
1	Calculate the pH and pOH of the 0.1 M HCl solution.
	Solution: HCl is a strong acid, which means that it is completely dissociated in the solution. 0.1 M 0.1 M $HCl \leftrightarrow H^+ + Cl^-$ pH = -log[H^+]= -log0.1 = 1 pOH = 14 - pH = 14 - 1 = 13
2	Calculate the pH and pOH of the 0.1 M NH_4OH solution.
	Solution: NH_4OH is a weak electrolyte. It ionizes in water according to the reaction: $NH_4OH \leftrightarrow NH_4^+ + OH^-$ An equilibrium constant is: $K_b = \frac{[NH_4^+][OH^-]}{[NH_4OH]} = 1.76 \cdot 10^{-5}$ From the stoichiometry of the ionization: [NH_4^+] = [OH^-] Therefore $K_b = \frac{[OH^-]^2}{C_{(NH_4OH)}}$ $[OH^-] = \sqrt{K_b \cdot C(NH_4OH)} = \sqrt{1.76\times10^{-5}\times0.1} = 1.33\times10^{-3} M$ pOH = -log(1.33×10^{-3}) = 2.88 pH = 14 - pOH = 14 – 2.88 = 11.12
3	Write the hydrolysis equations (molecular, ionic and net ionic) of the $NaHCO_3$ and predict the medium character.
	Solution: $NaHCO_3 + H_2O \leftrightarrow H_2CO_3 + NaOH$ (molecular equation) $Na^+ + HCO_3^- + H_2O \leftrightarrow H_2CO_3 + Na^+ + OH^-$ (ionic equation) $HCO_3^- + H_2O \leftrightarrow H_2CO_3 + OH^-$ (net ionic equation)

	pH > 7 (basic medium)
4	The pH of the blood was changed from 7.36 to 8.34 due to adding 20 mL of 0.1 M NaOH solution to 100 mL of blood. Calculate the buffer capacity of blood by base.
	Solution: $B = \frac{C(NaOH) \cdot V(NaOH)}{V(buffer) \cdot \Delta pH} = \frac{0.1 \times 0.02}{0.1 \times 0.98} = 0.02\, mol/L$
5	What is the pH of a buffer prepared by adding 50 mL of 0.2 M NaH_2PO_4 to 100 mL of 0.1 M Na_2HPO_4 solution.
	Solution: According to the Henderson-Hasselbalch equation for an acidic buffer: $pH = pK_a + \log\frac{[salt]}{[acid]} \Rightarrow pH = pK_a + \log\frac{[Na_2HPO_4]}{[NaH_2PO_4]}$ $pK_a (H_2PO_4^-) = -\log 6.2\times10^{-8} = 7.2$ $pH = pK_a + \log\frac{C(Na_2HPO_4)\times V(Na_2HPO_4)}{C(NaH_2PO_4)\times V(NaH_2PO_4)}$ $pH = 7.2 + \log\frac{0.1\times 0.1}{0.05\times 0.2} = 7.2$

3. Answer the multiple-choice test questions (in written form):

1 What is a dissociation constant of water at 25ºC?

A 1.8×10^{-18}

B 1.8×10^{-14}

C 1.8×10^{-16}

D 1.8×10^{-5}

2 What is ionic product of water?

A $K_w = [H^+] + [OH^-]$

B $K_w = [H^+] - [OH^-]$

C $K_w = [H^+] / [OH^-]$

D $K_w = [H^+] \times [OH^-]$

4 What is the medium character of the solution with $[H^+] > 10^{-7}$ M?

A Neutral

B Inert

C Basic

D Acidic

5 What is the pH of the blood?

A 0.9 – 1.5

B 6.8 – 7.0

C 8.5 – 9.5

D 7.36 – 7.4

6 What is the pH of the gastric juice?

A 0.9 – 1.5
B 6.8 – 7.0
C 8.5 – 9.5
D 7.36 – 7.4

7 What is the pOH value of the gastric juice if it's $[H^+] = 10^{-2}$ M?

A 10
B 11
C 12
D 13

8 Physiological value of the pH of urine:

A 1 - 3
B 3 – 6
C 5 – 8
D 6 – 9

9 Disturbances of acid-base balance of human blood to the side with pH < 7.4 is:

A Alkalosis
B Acidosis
C Homeostasis
D Equilibrium

10 Alkalosis is a disturbance of the pH of human blood to:

A 6.5
B 6.8
C 7.7
D 7.1

11 Which from the following salts can undergo hydrolysis:

A NaBr
B KNO_3
C $ZnSO_4$
D $BaCl_2$

12 Which of the following salts hydrolyzes in greater extent?

$K_{HCN} = 7\times10^{-10}$ $K_{H2SO3} = 6\times10^{-8}$ $K_{HF} = 1\times10^{-4}$

A NaCN
B Na_2SO_3

C NaF

13 Which of the following salts undergoes hydrolysis and provides an acidic medium?

A $CuCl_2$

B $NaHCO_3$

C $NaCl$

D CH_3COONa

14 What electrolyte solution has the greatest pH value?

A $Ba(NO_2)_2$

B NH_4Cl

C CH_3COONH_4

D KCl

15 What is the pH value of a salt of a weak acid and a strong base solution?

A $pH < 7$

B $pH > 7$

C $pH = 7$

16 What is the pH value of a salt of a weak acid and a weak base solution if $K_a < K_b$?

A $pH < 7$

B $pH > 7$

C $pH = 7$

17 With the purpose of prevention of hydrolysis, medicines must be kept as:

A concentrated solutions at low temperature

B concentrated solutions at high temperature

C diluted solutions at low temperature

D diluted solutions at high temperature

18 What are the components of the buffer solution?

A Weak acid and salt of this acid and strong base

B Weak acid and salt of this acid and weak base

C Strong acid and salt of strong acid and weak base

D Strong acid and salt of strong acid and strong base

19 Choose the components of buffer solutions:

A HNO_3, KOH

B $NaOH$, $NaHCO_3$

C $NaHCO_3$, $CO_2 \cdot H_2O$

D HCN, NH_4CN

20 What are the components of carbonate buffer from the following?

A Na_2CO_3, $NaHCO_3$

B Na_2CO_3, $NaOH$

C $CO_2 \cdot H_2O$, $NaHCO_3$

D Na_2CO_3, H_2CO_3

21 Which of the following buffer systems aren't in human body?

A $NaH_2PO_4 + Na_2HPO_4$

B $H_2CO_3 + NaHCO_3$

C $CH_3COOH + CH_3COONa$

D HHb + NaHb

22 Which of the following formulas can be used to calculate the pH value of the acidic buffer solution?

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

B $pH = 14 - pK_b + \log\frac{[base]}{[salt]}$

C $B = \frac{C(NaOH) \cdot V(NaOH)}{V(buffer) \cdot \Delta pH}$

D $pH = -\log[H^+]$

23 What is the main value effecting the pH of a buffer solution?

A Ionic product of water

B Product of concentrations of a buffer solution components

C pK of a weak electrolyte

D Concentration of a buffer solution

24 What is a buffer capacity unit?

A mol/L

B %

C g/L

D mol/kg

25 The maximal value of a buffer capacity at:

A pH = pK

B pH < pK

C pH > pK

D pH = pK + 1

4. Tasks for an independent work (in written form):

1. Calculate the pH and pOH for 0.1 M solution of HNO_3.

2. Calculate the pH and pOH for 0.01 M solution of NaOH.

3. Calculate the pH and pOH for 0.5 M solution of NH_4OH ($K_b = 1.8 \cdot 10^{-5}$).

4. Calculate the pH and pOH for 0.06 M solution of HIO_3 (iodic acid) ($K_a = 1.6 \cdot 10^{-1}$).

5. Write the hydrolysis equation and predict the medium character (acidic, basic or neutral) of the following:
   a) $NaClO_4$

b) $Cu(NO_3)_2$

c) K_2CO_3

6. Calculate the pH and pOH for a solution composed of NH_4OH (10 ml, 0.1 M) and NH_4Cl (10 ml, 0.2M). $K_b = 1.8\times10^{-5}$.

7. Calculate the pH of a buffer solution consists of 0.1 M H_2CO_3 and 0.05 M $NaHCO_3$.
$K_{a1} = 4.5\times10^{-7}$.

8. Calculate the buffer capacity for a solution with pH = 5 if it was needed 8 ml of NaOH (C = 0.1 mol/l) to neutralize 10 ml of this solution. Change in color was observed at pH = 8.8.

Laboratory work: «pH of solutions. Properties of buffer solutions. Buffer capacity».

1. pH of solutions:

Procedure:

1. Pour 5 ml of distilled water in a test tube, 5 ml of H_2SO_4 in a second one and 5 ml of NaOH in a third one. Add in each test tube 3-4 drops of methylorange, mix them and observe the change of color.
2. Pour 5 ml of sodium carbonate in a test tube, 5 ml of copper sulfate solution in a second one and 5 ml of sodium chloride in a third one. Add in each test tube 3-4 drops of methylorange, mix them and compare obtaining colors of the indicator with it colors in the solutions of sulfuric acid, sodium hydroxide and water from the first experiment.
3. Use phenolphthalein indicator to do the similar experiments. Observe change of the solutions coloring.
4. Determine the pH of solutions with the help of the universal indicator test-strips. Put one drop of distilled water on a test-strip, one drop of sulfuric acid on a second one and one drop of sodium hydroxide on a third one. Compare the colors of the pH test-strips with the pH-scale and determine the pH values. Similarly determine the pH values for the salts solutions have been used in the second experiment.

Tab. 1. Experimental data of pH measurements of the solutions.

Electrolyte	Methyl red color	Phenolphthalein color	pH value (by pH-test-strip)
H2O			
H2SO4			
NaOH			
Na2CO3			
CuSO4			
NaCI			

Write the balanced equations of these salts hydrolysis. Make a conclusion about the medium character (acidic, basic or neutral) of these salts solutions.

2. Determination of the buffer capacity.

Procedure:

1. Pour 10 ml of (CH_3COOH + CH_3COONa) buffer solution (pH = 5) in a flask, and 10 ml of HCl solution (C = 0.00001 mol/L) in a second one (pH = 5).
2. Add in each flask 2-3 drops of phenyl red indicator, mix them. Solutions become yellow.
3. Titrate these solutions with 0.1 M NaOH solution till pink color (pH = 8.4).
4. Calculate the buffer capacity and make a conclusion:

$$B = \frac{C(NaOH) \times V(NaOH)}{V_{buffer} \times \Delta pH}$$