MINISTRY OF HEALTH OF UKRAINE

BOGOMOLETS NATIONAL MEDICAL UNIVERSITY

Department of Medical and General Chemistry

MEDICAL CHEMISTRY

Student laboratory notebook

(for the first year students of Stomatological Faculty)

Student _____

Group _____

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This Student Laboratory Notebook allows you to keep a written record or report of the mandatory laboratory works that you will carry out as part of the Medical Chemistry course. The Student Laboratory Notebook includes laboratory works and questions in all basic topics in Medical Chemistry: complex compounds; properties of solutions; titrimetric analysis; ion–exchange absorption and partition chromatography; surface phenomena; properties of colloidal solutions.

The workbook is for first year students of Stomatological Faculty.

Have fun,enjoy your practical work,and best of luck with it!

CONTENTS

MEDICAL CHEMISTRY COURSE STRUCTURE

Organization of *Medical Chemistry* studies as a course is based on a credit-module system which meets the requirements of Bologna process. The course of «Medical Chemistry» consists of:

- ✓ one Final module control;
- ✓ two semantic modules ("Homogeneous equilibrium in biological liquids", "Heterogeneous equilibrium in biological liquids");
- ✓ twelve topics;
- ✓ five lectures.

Current monitoring of student's progress is carried out in the course of every practical class. Conversion of traditional marks for each subject into points:

«5» – 9 points,

«4» – 7 points,

«3» – 5 points,

«2» – 0 points.

When the study of all subjects of the module is completed the Final test (module control) is carried out. The maximal number of points for module control is **80**, minimal – **5**0. The student is entitled to pass the Final test only if he earned **60** or more points by the time of practical classes. The Final test consists of oral part or practical skills (12 points maximum), test part and written part (68 points maximum). Individual work – **12** points.

Calculate your final mark yourself:

total points ≥ 110 – «3»

total points ≥ 140 – «4»

total points ≥ 170 – «5».

We wish you success!

LABORATORY SAFETY RULES WE RECOMMEND

Take care of yourself.

Acquire good lab habits from the word go.

- ✓ Report all accidents, injuries, and breakage of glass or equipment to teacher immediately.

- ✓ Lab coats should be worn in laboratory.

- ✓ Long hair (chin-length or longer) must be tied back to avoid catching fire.

- ✓ Work quietly − know what you are doing by **reading** the assigned experiment **before** you start to work. Pay close attention to any **cautions** described in the laboratory exercises.

- ✓ Do not taste or smell chemicals.

- ✓ Never return chemicals to their bottles.

- ✓ **Never** point a test tube being heated at another student or yourself. Never look into a test tube while you are heating it.

- ✓ Unauthorized experiments or procedures **must not** be attempted.

- ✓ Leave your work station clean and in good order before leaving the laboratory.

- ✓ Do not leave your assigned laboratory station without permission of the teacher.

- ✓ Follow all instructions given by your teacher.

- ✓ Do not mouth pipette.

- ✓ Do not waste chemicals; do not take more than what is required

- ✓ Wash your hands before leaving the lab.

- ✓ Absolutely no noise or disruptive behavior in the lab. No fooling around.

- ✓ **No eating or drinking in the lab at any time!**

> *Exothermic Dangers*
> When you make up a solution using a concentrated or solid strong acid or base, always gradually add the acid or base to the water, not vice versa. If you add water to the strong acid or base, the solution may boil almost instantly, ejecting the chemical forcefully from the container.

GENERAL PURPOSE GLASSWARE

Be careful with all laboratory glassware!

Test Tubes

For most people, the test tube is the one piece of equipment that defines a chemistry lab, and rightly so. Test tubes are used so often and for so many purposes that it's hard to imagine a chemistry lab without them. Most of the time, you'll use test tubes to mix solutions, heat samples, observe reactions, and perform other similar tasks.

Beakers

Beakers are among the most commonly used items of laboratory glassware; they're used when test tubes aren't large enough. Beakers are flat-bottomed, cylindrical containers, usually equipped with a pouring spout, and are used for routine mixing, measuring, heating, and boiling of liquids.
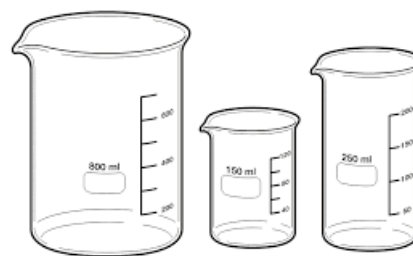
Volumetric Flasks

A volumetric flask is used to make up a precise volume of solution. It has one graduation line that indicates the nominal volume.
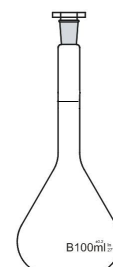
Erlenmeyer Flasks (conical flasks)

An Erlenmeyer flask, has a wide, flat base and a conical cross section, which allows it to sit on the lab bench without risk of tipping. We frequently use an Erlenmeyer flask, also called a *conical flask*, for a task that requires a vessel larger than a test tube. Flasks are better for swirling or heating solutions, when the container must be sealed or is part of an apparatus, or when the contents are volatile.
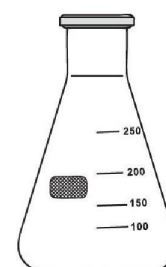
Graduated Cylinders

A graduated cylinder is a tall, slender cylinder with numerous graduation lines from near the bottom to near the top. You use a graduated cylinder to measure liquids with moderate to moderately high accuracy.
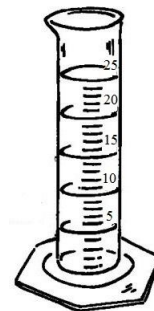
Pipettes

A graduated pipette (also spelled pipet) is a slender glass tube that is used to measure and dispense liquids with a very high degree of accuracy and precision. Standard volumetric pipettes have only one graduation line that corresponds to the nominal capacity of the instrument, and so can be used only to measure that specific quantity.
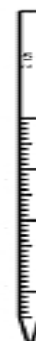
Burettes

A burette (also spelled buret) is used to dispense controlled small amounts of a liquid with great precision. Burettes are used to perform titrations for quantitative analyses, determining accurate concentrations of stock solutions, and so on.

LABORATORY WORK 1
«THE CHARACTERISTIC REACTIONS OF IONS OF SOME MACRO– AND MICROELEMENTS»

Purpose: to carry out analytical reactions of some cations and anions, to put down and memorize the effects of reactions (analytical signals), to write down equations of analytic reactions in molecular form.

The essence of the method

The aim of *qualitative analysis* is to establish chemical identity of the sample species, i.e. chemical elements, atom groups, ions or molecules, forming unknown substance or the mixture of substances. The qualitative analysis allows to define authenticity of pharmaceutical preparations and availability of impurity in them. *Specific reaction* is called a reaction, specific to one ion or molecule and not interfered by other ions in the solution. Specific reactions of all ions were known, however, the number of such reactions is highly limited. Much more numerous are so called *selective reactions*, which are specific to ions of the similar properties. Selective reactions, specific to a group of ions, are called group selective reactions. Appropriate reagents are used for analytic reactions. So-called specific reagents induce a reaction specific to only one ion; selective reagents are specific for a group of ions.

Chemical reactions are characterized by changes in colour, the formation of a precipitate, a change in temperature or the evolution of a gas.

Everyday Qualitative Analysis

• Police and drug-enforcement agents use qualitative analysis field tests to do "pass-fail" preliminary analyses of suspect materials.

• Sports teams and sanctioning committees use qualitative analysis to test players for steroid use.

• Airports and public buildings use instrumental qualitative analysis to "sniff" for explosives.

• Environmental scientists use qualitative analysis to test soil, water, and air samples for the presence of toxic chemicals.

Required Reagents and Equipment

Sodium carbonate solution	Potassium nitrite solution
Hydrochloric acid solution	Sulfuric acid solution
Sodium sulfate solution	Silver nitrate solution
Barium chloride solution	Potassium permanganate solution
Test tubes (5)	Hydrogen peroxide solution
Test tube rack	

The operation process

Test 1. The reaction for detection of carbonate ion

Transfer 5–7 drops of sodium carbonate solution to a clean test tube and add 5–7 drops of hydrochloric acid solution.

Observation: _____

Write the molecular equation for reaction (notice that strong hydrochloric acid displaces weak unstable acetic acid from salt):

_____

_____

Test 2. The reaction for detection of sulfate ion

Transfer 5–7 drops of sodium sulfate solution to a clean test tube and add 2–3 drops of barium chloride solution.

Observation: _____

Write the molecular equation for reaction (notice that precipitate of barium sulfate is formed):

_____

_____

Test 3. The reaction for detection of nitrite ion

Transfer 5–7 drops of potassium nitrite solution to a clean test tube and add 2–3 drops of concentrated sulfuric acid solution. Carefully heat.

Observation: _____

Write the molecular equation for reaction (notice that nitrous acid rapidly decomposes into nitrogen dioxide NO_2, nitric oxide NO, and water):

_____

_____

Test 4. The reaction for detection of silver ion

Transfer 2–3 drops of silver nitrate solution to a clean test tube and add 2–3 drops of hydrochloric acid solution.

Observation: _____

Write the molecular equation for reaction (notice that precipitate of silver chloride is formed):

_____

_____

Test 5. The reaction for detection of permanganate ion

Transfer 5–7 drops of potassium permanganate solution to a clean test tube, add 5–7 drops of sulfuric acid and 2–3 drops of hydrogen peroxide solution.

Observation: _____

Write the molecular equation for reaction (notice that this is oxidation-reduction reaction and O_2 is formed):

_____

_____

_____

_____

_____

LABORATORY WORK 2
«PREPARATION OF COBALT (II) NITRATE SOLUTION BY DILUTING CONCENTRATED SOLUTION»

Purpose: to demonstrate a method of solution preparation.

The essence of the method

In laboratory practice, mixtures in a liquid state are usually called solutions. Solutions concentration is their quantitative characteristic. The concentration of a solute in a solution is a measure of how much of that solute is dissolved in the solvent. Ability to estimate the concentration is very important in the study of pharmacology and clinical subjects. One of

the methods of solution preparation is dilution of more concentrated solution (stock solution).

Next equation is used to make calculation:

$$c_1\left(\frac{1}{z}X\right) \cdot V_1(X) = c_2\left(\frac{1}{z}X\right) \cdot V_2(X),$$

where $c_1\left(\frac{1}{z}X\right)$ – molarity of equivalent (normality) of more concentrated solution; $V_1(X)$ – volume of more concentrated solution that will be taken for preparation of diluted solution; $c_2\left(\frac{1}{z}X\right)$ – molarity of equivalent (normality) of diluted solution; $V_2(X)$ – volume of diluted solution.

Required Reagents and Equipment

Cobalt (II) nitrate solution	100 mL volumetric flask
5 mL pipette	Beaker
Pipette bulb	Distilled water

Instruction for using of pipette

1. Insert the tip of the pipette into the beaker with solution so that it is about 1/4 from the bottom.

2. Hold the pipette in your hand, leaving your index finger free to place over the top of the pipette. With your other hand, squeeze the pipette bulb. Press it firmly over the top of the pipette. Release the pressure on the bulb and allow the solution to flow into the pipette until it is above the volume mark.

3. Quickly remove the bulb and place your index finger firmly over the top of the pipette. Slowly roll you finger to one side and allow the liquid to drain until the bottom of the meniscus is aligned with the volume mark.

4. Press your index finger firmly on the top of the pipette so no liquid leaks out. Pull the pipette out of the solution and transfer the solution. When the solution stops flowing, touch the pipette once to the side of the receiving beaker to remove any hanging drops.

> *Never put your mouth in contact with a pipette. Not even if you're pipetting pure water. If you get into the habit of filling pipettes by mouth, the day will inevitably arrive when you suck something nasty into your mouth. Use a pipette bulb or pipette pump instead.*

The operation process

1. Calculate volume of cobalt (II) nitrate solution (molarity of equivalent is 0,4 mole/L) that will be taken for preparation of 100 mL of cobalt (II) nitrate solution with molarity of equivalent 0,02 mole/L using the next formula:

$$c_1\left(\frac{1}{2}Co(NO_3)_2\right)\cdot V_1(Co(NO_3)_2) = c_2\left(\frac{1}{2}Co(NO_3)_2\right)\cdot V_2(Co(NO_3)_2);$$

$$V_1(Co(NO_3)_2) = \frac{c_2\left(\frac{1}{2}Co(NO_3)_2\right)\cdot V_2(Co(NO_3)_2)}{c_1\left(\frac{1}{2}Co(NO_3)_2\right)} = \underline{\qquad} = \underline{\qquad}\ L = \underline{\qquad}\ mL$$

We remind you that 1 milliliter equals 0,001 liter (to get liters from milliliters you divide the milliliters by 1000) and 1 liter equals 1000 milliliters (to get milliliters from liters you multiply the liters by 1000).

2. Prepare laboratory glassware:

    a) rinse the clean pipette with distilled water, and then with 0,4 mole/L cobalt (II) nitrate solution;

    b) rinse clean beaker and volumetric flask with distilled water.

3. Pipette off calculated volume of 0,4 mole/L cobalt (II) nitrate solution to the 100 mL volumetric flask.

> *Never put pipette into a reagent bottle. If you do so, you will be contaminating the reagent. Instead, pour some liquid into beaker, and then use pipette to take as much as you need from beaker.*

4. Adjust the volume to 100 mL with distilled water.

5. Close volumetric flask and shake upside to mix contents.

LABORATORY WORK 3
«HYDROLYSIS OF THE SALTS»

Purpose: to indicate the pH of different aqueous solutions of salts using the acid-base indicators and predict ability of these salts to hydrolysis.

The essence of the method

All biological liquids are water solution with a given rate of pH. Studying of pH of biological liquids enables to determine pathological phenomena taking place in an organism and to prevent diseases. Usually hydrolysis is a chemical process in which a molecule of water is added to a substance. The term salt hydrolysis refers to the reaction of a cation or an anion, or both with water which splits the water molecule into two parts. Salt hydrolysis usually affects the pH of a solution (acidic, basic or neutral).

The following generalizations are useful.

1. *Salts of strong base and strong acids* (for example, NaCl) do not hydrolyze: pH = 7.
2. *Salts of strong bases and weak acids* (for example, Na_2CO_3) hydrolyze: pH > 7 (the anion acts as a base).
3. *Salts of strong acids and weak bases* (for example, NH_4Cl) hydrolyze: pH < 7 (the cation acts as an acid).
4. *Salts of weak acids and weak bases* (for example CH_3COONH_4) hydrolyze. The cations are acids and the anions are bases. Whether the solution is acidic or basic depends on the relative values of K_a and K_b for the ions.

Acid-base indicators are highly coloured weak acids or bases. Acid-basic indicators change colour because protons join to or lost the indicator molecule. The both forms of indicator are coloured differently: HIn (color 1) $\leftrightarrow$ In (color 2).

Required Reagents and Equipment

Copper sulfate	Distilled water
Sodium carbonate	Solution of methyl red indicator
Sodium chloride	Solution of phenolphthalein indicator
Sulfuric acid solution	Test tubes (12)
Sodium hydroxide solution	Test tube rack

The operation process

1. Place 5 mL of distilled water to a clean test tube and add 3–4 drops of methyl red indicator solution.
2. Place 5 mL of sulfuric acid solution to a clean test tube and add 3–4 drops of methyl red indicator solution.
3. Place 5 mL of sodium hydroxide solution to a clean test tube and add 3–4 drops of methyl red indicator solution.

4. Place 5 mL of distilled water to a clean test tube; add 3–4 drops of methyl red indicator solution and a few crystals of sodium carbonate.

5. Place 5 mL of distilled water to a clean test tube; add 3–4 drops of methyl red indicator solution and a few crystals of copper sulfate.

6. Place 5 mL of distilled water to a clean test tube; add 3–4 drops of methyl red indicator solution and a few crystals of sodium chloride.

7. The color of solution in each test tube should be noted down to the Evaluation Table.

8. Repeat steps 1−7 using phenolphthalein indicator solution.

Evaluation Table

Electrolyte	Color of indicator		pH of the electrolytes solutions
	Methyl red	Phenolphthalein	
H_2O			
H_2SO_4			
NaOH			
Na_2CO_3			
$CuSO_4$			
NaCl			

Molecular and ionic equations of salts hydrolysis

Write the hydrolysis reactions for salts which undergo hydrolysis in the ionic and molecular forms and notice the pH of aqueous solution of these salts (acidic, basic or neutral):

_____

_____

_____

_____

_____

_____

Compare the pH of salts solutions predicted by analysis of hydrolysis reactions with pH of determined experimentally.

_____

_____

Aqueous solution of sodium chloride is _____; aqueous solution of copper sulfate is _____; aqueous solution of sodium carbonate is _____

LABORATORY WORK 4

«STANDARDIZATION OF THE SODIUM HYDROXIDE SOLUTION»

Purpose: to demonstrate a method of acid-base titration; to determinate of the molarity of equivalent according to the results of titration.

The essence of the method

To «standardize» a solution means to find its exact concentration. Titration is used to determine the concentration of an unknown acid or base. *Titration* is a procedure in which a solution (called the titrant) whose concentration is known very accurately is reacted with a known volume of another solution of unknown concentration (called the analyte). By measuring the amount of titrant needed to neutralize the analyte, you can determine the concentration of the analyte accurately.

As NaOH doesn't meet the requirements for standard substances (it's hygroscopic, has admixtures), a prepared solution should be titrated against standard solution. As standard solution in this case sulfuric acid may be used.

$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O;$$

$$H^+ + OH^- = H_2O.$$
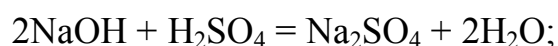
Phenolphtalein can be used as the indicator.

Required Reagents and Equipment

Sulfuric acid standard solution	25 mL burette
Sodium hydroxide solution	10 mL pipette
Phenolphthalein indicator solution	250 mL conical flask (3)
Distilled water	Beaker

The operation process

1. Rinse a clean 25 mL burette with the sodium hydroxide solution. Fill the burette with sodium hydroxide solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse three clean conical flasks with distilled water.

3. Rinse a clean 10 mL pipette with the sulfuric acid solution, then pipette 10 mL samples into three clean conical flasks.

4. Add 2-3 drops of phenolphthalein indicator solution to each flask.

5. Place one conical flask (containing the acid and indicator) under the burette and swirl the flask slowly while adding sodium hydroxide solution until the indicator turns pink. You can add the base quickly at the beginning, but will need to add it very slowly and finally drop by drop to determine the exact endpoint. Keep this flask to provide a reference colour for the next titration.

> *End point versus equivalence point*
>
> The end point of a titration is the point at which the titration is complete, typically when an added indicator such as phenolphthalein changes color. The equivalence point is closely related to end point but not necessarily identical with the end point. The equivalence point is the point at which the number of moles (or equivalents) of titrant exactly equals the number of moles (or equivalents) of analyte. Ideally, the end point should exactly equal the equivalence point, but in the real world they are usually slightly different.

6. When you complete the titration, you'll determine the amount of solution you have added. Read the value by placing your eye at the level of the solution and reading the value at the bottom of the meniscus.

7. Repeat the titrations (steps 5−6) until you have tree concordant (ideally within 0.1 mL, but at least within 0.3 mL) titres.

8. The data of the titration should be noted down to the Evaluation Table.

9. Use this data to calculate the molarity of equivalent (normality) of sodium hydroxide solution in mole/L.

Evaluation

1. Calculate average volume of NaOH solution used for the titration and notice the result to the Table.

$$\overline{V} = \frac{V_1 + V_2 + V_3}{3} = \underline{\hspace{3cm}} = \underline{\hspace{2cm}} \text{mL}$$

2. Convert 10,0 mL of sulfuric acid solution ($V(H_2SO_4)$) and average volume of sodium hydroxide solution into liters dividing by 1000:

$$V\ (H_2SO_4)\ in\ L\ \underline{\hspace{5cm}}$$

$$\overline{V}\ (NaOH)\ in\ L\ \underline{\hspace{5cm}}$$

3. Notice the molarity of equivalent of sulfuric acid:

$$c(\tfrac{1}{2}H_2SO_4)\ is\ \underline{\hspace{3cm}}\ mole/L$$

4. Calculate normality of NaOH solution according to the following formula:

$$\overline{V}\ (NaOH)\cdot c\ (NaOH) = V\ (H_2SO_4)\ c\left(\tfrac{1}{2}H_2SO_4\right);$$

$$c(NaOH) = \frac{c\left(\tfrac{1}{2}H_2SO_4\right)\cdot V(H_2SO_4)}{\overline{V}(NaOH)} = \underline{\hspace{4cm}} = \qquad mole/L$$

5. The results should be noted down to the Evaluation Table.

Evaluation Table

Volume of NaOH	Average volume of NaOH	c (NaOH)
Trial 1 _____ mL		
Trial 2 _____ mL	_____ L	_____ mole/L
Trial 3 _____ mL		

Conclusion

Normality of sodium hydroxide solution is _____ mole/L.

LABORATORY WORK 5

«BUFFER SOLUTIONS PREPARATION AND THEIR PROPERTIES INVESTIGATION»

Purpose: to prepare the buffer solutions with set pH and measure this pH; to determine the effect of acid, base or water added to buffers on its pH changes.

The essence of the method

A buffer solution is usually a solution of a weak acid and its conjugate base or, less commonly, a solution of a weak base and its conjugate acid. A buffer solution resists changes in the concentrations of the hydronium ion and hydroxide ion (and therefore pH) when the solution is diluted or when small amounts of an acid or base are added to it. The

resistance of a buffer solution to pH change is based upon Le Chatelier's Principle and the common ion effect.

Because all biological processes are dependent on pH, cells and organisms must maintain a specific and constant pH in order to keep their enzymes in the optimum state of protonation. Living organize (human body) has such buffer solutions as: phosphoric, carbonic, hemoglobin, protein buffer solutions.

In this lab, we'll make up a buffer solution of acetic acid and sodium acetate and examine the effects of adding hydrochloric acid and sodium hydroxide to this buffer solution as well as dilution of buffer solutions.

Look what happens when we add OH^- ions to CH_3COOH. The acid is a proton donor:

$$OH^- (aq) + CH_3COOH (aq) \rightleftharpoons H_2O + CH_3COO^- (aq)$$
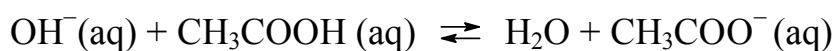
And when we add H_3O^+ to CH_3COOH the base acts as a proton acceptor:

$$CH_3COO^- (aq) + H_3O^+(aq) \rightleftharpoons H_2O + CH_3COOH (aq)$$
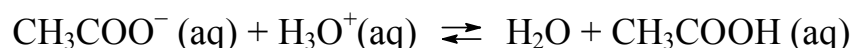
So if we had a mixture of acetic acid and acetate ions it wouldn't matter whether we added acid or base, the excess OH^- and H_3O^+ would be neutralized.

Weak acetic acid only partially dissociated:

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$
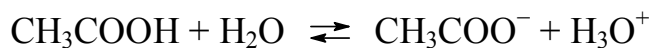
As H_2O is added, the equilibrium shifts to the right, causing more H_3O^+ to be formed. The pH of a buffer solution is calculated from the ratio of [HA] and [A$^-$]. If we dilute the buffer solution, we dilute both concentrations equally. The dilution factors cancel out and we are left with the same calculations, and the same pH as before. So, when buffer solutions are diluted the pH does not change.

Required Reagents and Equipment

Acetic acid solution	50 mL beakers (3)
Sodium acetate solution	Glass stick
Hydrochloric solution	pH–meter
Sodium hydroxide solution	25 mL burettes (2)
Distilled water	1 mL pipettes (2)
200 mL volumetric flask	

The operation process

1. Rinse a clean 25 mL burette with the 0,1 mole/L sodium acetate solution. Fill the burette with 0,1 mole/L sodium acetate solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse a clean 25 mL burette with the 0,1 mole/L acetic acid solution. Fill the burette with 0,1 mole/L acetic acid solution to the zero mark using a beaker. Clamp the burette to a stand.

3. Transfer the noted in Evaluation Table volumes of acetic acid solution and sodium acetate solution from burettes to three 50 mL beakers. Mix the contents of beakers.

4. Use the pH-meter to measure the pH of the three buffer solutions. The results should be noted down in the next to last column of Evaluation Table ($pH_{measured}$, $pH_0^{(i)}$). Don't pour out the buffer solutions.

   4.1. Place the tip of the sensing and reference electrodes in the buffer. It does not matter which buffer you do first.

   4.2. Appropriate pH value will appear on the display.

   4.3. Rinse the tip of electrodes with distilled water.

5. Rinse pipette with 0.01 mole/L HCl solution, then pipette 1 mL sample to the beaker that contains the first buffer solution. Rinse other pipette with 0.01 mole/L NaOH solution, then pipette 1 mL sample to the beaker that contains the second buffer solution. Mix the contents of beakers.

6. Transfer the third buffer solution to the 200 mL volumetric flask and adjust the volume to 200 mL with distilled water. Mix the contents of volumetric flask.

7. Use the pH-meter to measure the pH of the prepared solutions (see step 4). The results should be noted down in the last column of Evaluation Table ($pH_{measured}$, pH_i).

Evaluation

Calculate pH of buffer solutions before ($pH_0^{(i)}$) and after adding of limited volumes of strong acid, base or water (pH_i) using formulas below and record them to the Evaluation Table ($pH_{calculated}$).

$K_d(CH_3COOH) = 1,75 \cdot 10^{-5}$ mole/L

$pK_d(CH_3COOH) = -\lg 1,75 \cdot 10^{-5} = $ _____

$$pH_0{}^{(1)} = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_1(CH_3COONa)}{c_0(CH_3COOH) \cdot V_1(CH_3COOH)} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$$pH_0{}^{(2)} = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_2(CH_3COONa)}{c_0(CH_3COOH) \cdot V_2(CH_3COOH)} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$$pH_0{}^{(3)} = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_3(CH_3COONa)}{c_0(CH_3COOH) \cdot V_3(CH_3COOH)} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$$pH_1 = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_1(CH_3COONa) - c(HCl) \cdot V(HCl)}{c_0(CH_3COOH) \cdot V_1(CH_3COOH) + c(HCl) \cdot V(HCl)} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$$pH_2 = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_2(CH_3COONa) + c(NaOH) \cdot V(NaOH)}{c_0(CH_3COOH) \cdot V_2(CH_3COOH) - c(NaOH) \cdot V(NaOH)} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$$pH_3 = pK_d(CH_3COOH) + \lg \frac{c_0(CH_3COONa) \cdot V_3(CH_3COONa) \cdot 10}{c_0(CH_3COOH) \cdot V_3(CH_3COOH) \cdot 10} =$$

$$= \qquad + \lg \frac{}{} = \qquad + \lg \qquad =$$

$c_0(CH_3COOH) =$ _____ mole/L $c_0(CH_3COONa) =$ _____ mole/L

$c(HCl) =$ _____ mole/L $c(NaOH) =$ _____ mole/L

№	Volume of solutions, L					pH (calculated)		pH (measured)	
	CH_3COONa	CH_3COOH	HCl	NaOH	H_2O	$pH_0^{(1)}$	pH_i	$pH_0^{(1)}$	pH_i
1	$1 \cdot 10^{-2}$	$1 \cdot 10^{-2}$	$1 \cdot 10^{-3}$	–	–				
2	$1,5 \cdot 10^{-2}$	$5 \cdot 10^{-3}$	–	$1 \cdot 10^{-3}$	–				
3	$5 \cdot 10^{-3}$	$1,5 \cdot 10^{-2}$	–	–	0,200				

Conclusion

a) compare measured and calculated values pH of acetate buffers before and after adding the solutions of electrolytes_____

_____;

b) what is effect of addition strong acid and base to the buffer solution and diluting of buffer solution? _____

_____

LABORATORY WORK 6
«DETERMINATION OF BUFFER CAPACITY OF ACETATE BUFFER SOLUTION»

Purpose: to determine the buffer capacity of acetate buffer.

The essence of the method

Buffers are important in many areas of chemistry. When the pH must be controlled during the course of a reaction, the solutions are often buffered. This is often the case in biochemistry when enzymes or proteins are being studied. Our blood is buffered to a pH of 7.4. Variations of a few tenths of a pH unit can cause illness or death. Acidosis is the condition when pH drops too low. Alkalosis results when the pH is higher than normal.

There is a limit to the amount of acid or base that can be added to a buffer solution before one of the components is used up. This limit is called the buffer capacity and is defined as the moles of acid or base necessary to change the pH of one liter of solution by one unit. Buffer capacity is measured in mmol/L and calculated by equation:

$$B_a = \frac{c\left(\frac{1}{z}acid\right)\cdot V(acid)}{V(buffer\,solution)\cdot \Delta pH}; \qquad B_b = \frac{c\left(\frac{1}{z}base\right)\cdot V(base)}{V(buffer\,solution)\cdot \Delta pH},$$

where B_a – is buffer capacity of acid; B_b – is buffer capacity of base; ΔpH – the change of pH after adding acid or base, V (acid) – volume of acid solution, V (base) – volume of base solution, V (buffer solution) – volume of buffer solution, $c\left(\frac{1}{z}acid\right)$ – normality of the acid solution, $c\left(\frac{1}{z}base\right)$ – normality of the base solution.

Required Reagents and Equipment

Acetic acid solution	25 mL beaker (2)
Sodium acetate solution	Glass stick
Hydrochloric acid solution	pH–meter
Sodium hydroxide solution	25 mL burettes (4)
Distilled water	

The operation process

1. Rinse a clean 25 mL burette with the 0,01 mole/L sodium acetate solution. Fill the burette with 0,01 mole/L sodium acetate solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse a clean 25 mL burette with the 0,01 mole/L acetic acid solution. Fill the burette with 0,01 mole/L acetic acid solution to the zero mark using a beaker. Clamp the burette to a stand.

3. Prepare two buffer solutions (10 mL) by mixing of equal volumes of acetate acid and sodium acetate solutions in the 25 mL beakers.

4. Use the pH-meter to measure the pH of the two buffer solutions (pH_0). Don't pour out the buffer solutions.

   4.1. Place the tip of the sensing and reference electrodes in the buffer. It does not matter which buffer you do first.

4.2. Appropriate pH value will appear on the display.

4.3. Rinse the tip of electrodes with distilled water.

5. Rinse a clean 25 mL burette with the 0,1 mole/L hydrochloric acid solution. Fill the burette with 0,1 mole/L hydrochloric acid solution to the zero mark using a beaker. Clamp the burette to a stand.

6. Add HCl solution to the first beaker with buffer solution till pH changes for one unit (pH_1) under constant stirring.

7. Rinse a clean 25 mL burette with the 0,1 mole/L sodium hydroxide solution. Fill the burette with 0,1 mole/L sodium hydroxide solution to the zero mark using a beaker. Clamp the burette to a stand.

8. Add NaOH solution to the second beaker with buffer solution till pH changes for one unit (pH_2) under constant stirring.

7. The results should be noted down to the Evaluation Table.

Evaluation

Calculate buffer capacities of acetate buffer using formulas below and note down the results to the Evaluation Table.

$$B_{HCl} = \frac{c(HCl) \cdot V(HCl)}{V(buffer\,solution) \cdot \Delta pH} = \frac{}{} = \qquad mole/L = \qquad mmole/L$$

$$B_{NaOH} = \frac{c(NaOH) \cdot V(NaOH)}{V(buffer\,solution) \cdot \Delta pH} = \frac{}{} = \qquad mole/L = \qquad mmole/L$$

Evaluation Table

$c(CH_3COOH) =$ _____ mole/L $c(CH_3COONa) =$ _____ mole/L

$c(HCl) =$ _____ mole/L $c(NaOH) =$ _____ mole/L

№	Volume of solutions, L					pH of buffer solution			B_a, B_b, mmole/L
	CH_3COONa	CH_3COOH	Buffer solution	HCl	NaOH	pH_0	pH_i	ΔpH	
1	$5 \cdot 10^{-3}$	$5 \cdot 10^{-3}$			–				
2	$5 \cdot 10^{-3}$	$5 \cdot 10^{-3}$		–					

The buffer acetate buffer capacity of acid is _____ and the acetate buffer capacity of base is _____

LABORATORY WORK 7
«INFLUENCE OF SODIUM THIOSULFATE CONCENTRATION ON THE RATE OF THIOSULFURIC ACID DECOMPOSITION»

Purpose*:* to calculate the rate of reaction; to determine the decomposition rate depending on its concentration.

The essence of the method

Chemical kinetics, also called reaction kinetics, is the study of reaction rates in chemical reactions. We make use of the principles of chemical kinetics in many aspects of everyday life. In this laboratory work, we'll examine the effects of concentration. Reactions proceed faster at higher concentrations because more reactant molecules are available and therefore collisions between reactant molecules are more likely.

Sulfuric acid reacts with sodium thiosulfate with formation of thiosulfuric acid according following steps:

$$Na_2S_2O_3 + H_2SO_4 = H_2S_2O_3 + Na_2SO_4 \text{ (fast)}$$

$$H_2S_2O_3 = S + SO_2 + H_2O \text{ (comparatively slow)}$$
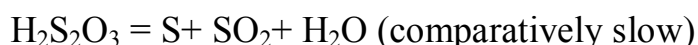
According to the chemical kinetics, in case of multi-step reactions, each step will occur at its own distinctive rate. If one step takes place much more slowly than all other steps, it will definitely control the overall reaction rate. The slowest step is called rate determining step. Sulfuric acid concentration remains constant in all experiments, so estimation of conditional reaction rate should be done according to the change in sodium thiosulfate concentration.

Required Reagents and Equipment

Sodium thiosulfate solution	Test tubes (3)
Sulfuric acid solution	Distilled water
Stop-watch	Glass stick
25 mL burettes (3)	Test tube rack

The operation process

1. Rinse a clean 25 mL burette with the 0,1 mole/L sodium thiosulfate solution. Fill the burette with 0,1 mole/L sodium thiosulfate solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse a clean 25 mL burette with the 1 mole/L sulfuric acid solution. Fill the burette with 1 mole/L sulfuric acid solution to the zero mark using a beaker. Clamp the burette to a stand.

3. Rinse a clean 25 mL burette with distilled water. Fill the burette with distilled water to the zero mark using a beaker. Clamp the burette to a stand.

4. Transfer the noted in Evaluation Table volumes of sodium thiosulfate solution, sulfuric acid solution and distilled water from burettes to three test tubes. Mix the contents of test tubes.

5. After mixing of all components measure time when the turbidity arises by means of the stop-watch for each test tube.

6. The results should be noted down to the Evaluation Table.

Evaluation

1. Calculate molarity of $Na_2S_2O_3$ in prepared solutions according to the following formula and note down the results to the Evaluation Table:

$$c_i(Na_2S_2O_3) = c_i(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3) \cdot V_i(Na_2S_2O_3)}{V_i(\text{mixture})},$$

where: $c_0(Na_2S_2O_3)$ – initial molarity of $Na_2S_2O_3$ solution, mole/L; $V_i(Na_2S_2O_3)$ – volume of $Na_2S_2O_3$ solution; $V_i(\text{mixture})$ – total volume of mixed reagents.

$$V_i(\text{mixture}) = V_i(Na_2S_2O_3) + V_i(H_2O) + V_i(H_2SO_4), \text{ L}$$

$V_1(\text{mixture}) =$

$V_2(\text{mixture}) =$

$V_3(\text{mixture}) =$

$$c_1(Na_2S_2O_3) = c_1(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3) \cdot V_1(Na_2S_2O_3)}{V_1(\text{mixture})} = \underline{\hspace{3cm}} = \underline{\hspace{2cm}} \text{ mole/L}$$

$$c_2(Na_2S_2O_3) = c_2(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3) \cdot V_2(Na_2S_2O_3)}{V_2(\text{mixture})} = \underline{\hspace{3cm}} = \underline{\hspace{2cm}} \text{ mole/L}$$

$$c_3\left(Na_2S_2O_3\right)=c_3\left(H_2S_2O_3\right)=\frac{c_o\left(Na_2S_2O_3\right)\cdot V_3\left(Na_2S_2O_3\right)}{V_3\left(\text{mixture}\right)}=\underline{\hspace{3cm}}=\quad \text{mole/L}$$

N	V (solution), mL			Time of turbidity arising (τ), sec	Obtained concentration of $H_2S_2O_3$, mole/L
	$Na_2S_2O_3$	H_2O	H_2SO_4		
1	1	4	5		
2	3	2	5		
3	5	0	5		

2. Calculate values of conditional reaction rates (υ) according to the following formula:

$$\upsilon_1=\frac{1}{\tau_1}=\underline{\hspace{3cm}}=\quad \text{sec}^{-1}$$

$$\upsilon_2=\frac{1}{\tau_2}=\underline{\hspace{3cm}}=\quad \text{sec}^{-1}$$

$$\upsilon_3=\frac{1}{\tau_3}=\underline{\hspace{3cm}}=\quad \text{sec}^{-1}$$

3. Plot the graph $v=f(c(Na_2S_2O_3))$ and make conclusions about dependence obtained.

υ, sec^{-1}

$c(Na_2S_2O_3)$, mole/L
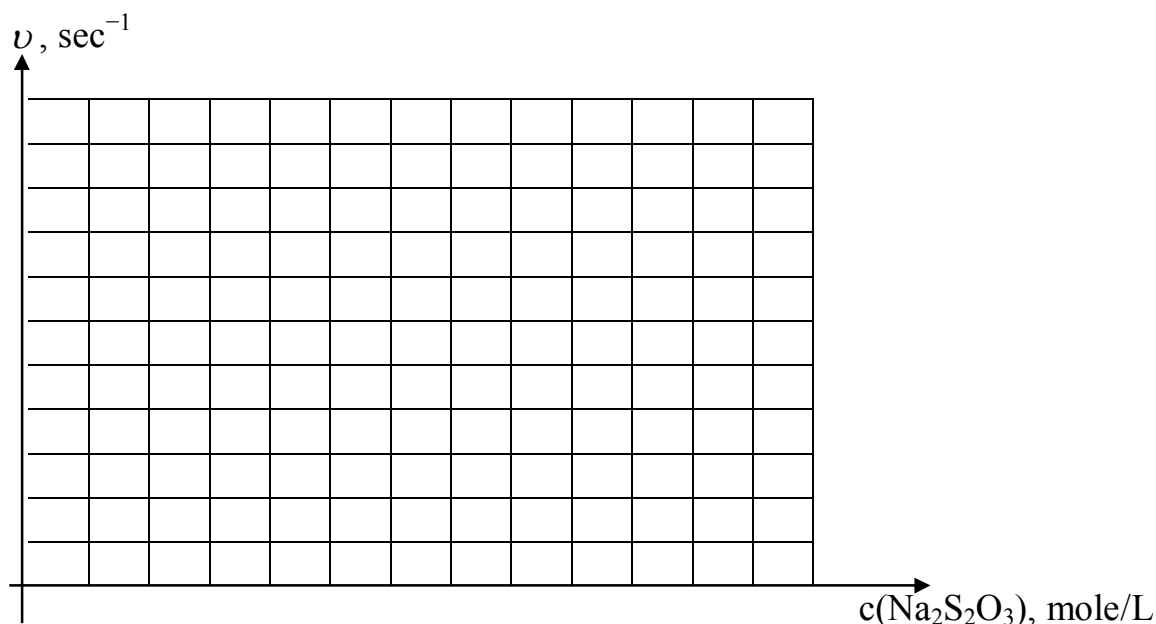
Conclusion

The decompositions rate of the $H_2S_2O_3$ is _____versus increasing of its molarity.

LABORATORY WORK 8
«COMPLEX COMPOUNDS»

Purpose: to prepare the copper complex, iron complex and calcium complex.

The essence of the method

All organisms, plants and animals, are made up of cells, where chemical reactions take place. Of all the molecules making up the cells we consider a particular group: the complexes or coordination compounds, which are built up from metal cations and ligands.

Around 1930 one begun to find out, that small amounts of many metallic elements – today named «trace elements» are vital for the health of plants and animals. Among these elements are aluminum, vanadium, chromium, manganese, cobalt, nickel, copper, tin, selenium, boron, lead and others. In general, the sum of these metals makes up less than 1 per thousand of the weight of the individual but they are essential for the transport of matter within the organism and for the enzymes, the catalysts of metabolism. Many biologically important compounds are coordination compounds (complexes). Chlorophyll, haemoglobin and vitamin B_{12} are coordination compounds of magnesium, iron and cobalt respectively etc. The coordination compounds are finding extensive applications in analytical chemistry and medicinal chemistry.

Required Reagents and Equipment

Copper (II) sulfate solution	Potassium thiocyanate solution
Ammonia solution	Calcium chloride solution
Iron (III) chloride solution	Ammonia oxalate solution
Test tubes (3)	Test tube rack
Ethylenediaminetetraacetic acid disodium salt dihydrate	

The operation process

Test 1. Cationic complex preparation

Transfer 4–5 drops of copper (II) sulfate solution to a clean test tube and add a few drops of ammonia solution.

Observation:

a) precipitate of copper (II) hydroxosulfate is formed and its color is _____

b) precipitate is dissolved in excess ammonia solution and color of formed solution is

Write the molecular equation for reaction of formation and dissolving of precipitate:

_____

_____

_____

_____

Test 2. Anionic complex preparation

Transfer 2–3 drops of iron (III) chloride solution to a clean test tube and add 1–2 drops of potassium thiocyanate solution.

Observation: complex salt $K[Fe(NCS)_4(H_2O)_2]$ is formed and its color is _____

Write the molecular equation for reaction:

_____

_____

Test 3. Chelate complex preparation

Transfer 4–5 drops of calcium chloride solution to a clean test tube and add 2–3 drops of ammonia oxalate solution.

Observation: precipitate of calcium oxalate is formed and its color is_____

Write the molecular equation for reaction:

_____

_____

Add ethylenediaminetetraacetic acid disodium salt dihydrate $Na_2H_2Y \cdot 2H_2O$ to dissolving of precipitate of calcium oxalate. Write the molecular equation for reaction:

_____

_____

LABORATORY WORK 9
«SOLUBILITY PRODUCT CONSTANT. THE CONDITIONS OF PRECIPITATE FORMATION»

Purpose: to determine the conditions of precipitate formations.

The essence of the method

In general, when ionic compounds dissolve in water, they go into solution as ions. When the solution becomes saturated with ions, that is, unable to hold any more, the

excess solid settles to the bottom of the container and an equilibrium is established between the undissolved solid and the dissolved ions:

$$A_mB_n \rightleftarrows mA^{n+} + nB^{m-}.$$

The solubility product constant, K_{sp}, is the constant for the equilibrium established between a solid solute and its ions in a saturated solution:

$$K_{sp} (A_mB_n) = [A^{n+}]^m \cdot [B^{m-}]^n.$$

The K_{sp} for a salt can essentially tell you if precipitation will occur under conditions of ion concentration.

If we have a given set of concentration conditions we can calculate a solubility quotient, Q_c, and compare it to the K_{sp}. The solubility quotient (often called the ion product) has the same form as the solubility constant expression, but the concentrations of the substances are not necessarily equilibrium values. Rather, they are the concentrations at the start of the reaction. To predict the direction of the reaction, you compare Q_c with K_c.

Precipitation should occur if $Q > K_{sp}$.

A solution is just saturated if $Q = K_{sp}$.

Precipitation cannot occur if $Q < K_{sp}$.

Required Reagents and Equipment

Lead nitrate solution	Test tubes (2)
Potassium chloride solution	Distilled water
Potassium iodide solution	Test tube rack

The operation process

1. Transfer 4 drops of the 0,001 mole/L $Pb(NO_3)_2$ solution to two clean test tubes.
2. Add 4 drops of the 0,05 mole/L KCl solution to the first test tube.
3. Add 4 drops of the 0,05 mole/L KI solution to the second test tube.
4. The observations should be noted down to the Evaluation Table.

Evaluation

1. Write the formation reactions for salts $PbCl_2$ and PbI_2 in the ionic and molecular forms:

_____

_____

_____

_____

_____

_____

2. Calculate the molarity of Pb^{2+}, Cl^-, I^- in obtained solutions using the next formula:

$$c(x) \cdot V(solution) = c_1(x) \cdot V_1(solution)$$

where $c(x)$ – initial molarity of reagent in solution; $c_1(x)$ – resulting molarity of reagent in obtained solution; $V(solution)$ – volume of the solution with initial molarity $c(x)$; $V_1(solution)$ – volume of the solution with molarity $c_1(x)$.

$$c_1(x) = \frac{c(x) \cdot V(solution)}{V_1(solution)};$$

$c(Pb(NO_3)_2 = 0{,}001$ mole/L; $c(KCl) = 0{,}05$ mole/L; $c(KI) = 0{,}05$ mole/L.

$V(solution)$ for all reagents is 0,4 mL or $4 \cdot 10^{-4}$ L.

$V_1(solution) = V(solution) + V(solution) = 4 \cdot 10^{-4}$ L $+ 4 \cdot 10^{-4}$ L $= 8 \cdot 10^{-4}$ L.

$c(Pb^{2+}) = $ —————————————— =   mole/L

$c(Cl^-) = $ —————————————— =   mole/L

$c(I^-) = $ —————————————— =   mole/L

3. Calculate the $Q(PbCl_2)$ and $Q(PbI_2)$ and note down to the Evaluation Table:

$Q(PbCl_2) = [Pb^{2+}] \cdot [Cl^-]^2 =$

$Q(PbI_2) = [Pb^{2+}] \cdot [I^-]^2 =$

Evaluation Table

Electrolyte	$c_0(x)$, mole/L	$V_0(x)$, mL	Observation	K_{sp}, mole^3/L^3	Q, mole^3/L^3
$Pb(NO_3)_2$	0,001	0,4			
KCl	0,05	0,4			
KI	0,05	0,4			
$PbCl_2$				$1{,}7 \cdot 10^{-5}$	
PbI_2				$8{,}7 \cdot 10^{-9}$	

4. Compare Q (PbCl$_2$) and K_{sp} (PbCl$_2$), Q (PbI$_2$) and K_{sp} (PbI$_2$), than make conclusions about formation of precipitate.

Conclusion

a) precipitate of PbCl$_2$ is _____ because Q (PbCl$_2$) _____ K_{sp} (PbCl$_2$);

b) precipitate of PbI$_2$ is _____ because Q (PbI$_2$) _____ K_{sp} (PbI$_2$).

LABORATORY WORK 10

«DETERMINATION OF STANDARD OXIDATION-REDUCTION POTENTIAL»

Purpose: to determine the standard oxidation-reduction potential.

The essence of the method

Oxidation-reduction reactions take place in the human organism on different levels including a cell. Electrochemical processes are widely used in scientific research. Methods of electrochemistry such as potentiometry, polarography, as well as methods used for the determination of different ions concentration are widely adopted in medical practice.

In an electrochemical cell, an electric potential is created between two dissimilar metals. This potential is a measure of the energy per unit charge which is available from the oxidation/reduction reactions to drive the reaction. It is customary to visualize the cell reaction in terms of two half-reactions, an oxidation half-reaction and a reduction half-reaction.

$$\text{Reduced species} \rightarrow \text{oxidized species} + ne^-;$$

$$\text{Oxidized species} + ne^- \rightarrow \text{reduced species}.$$
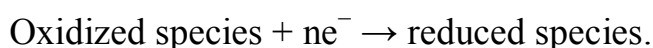
The cell potential, E_{cell}, (often called the electromotive force or EMF) has a contribution from the anode which is a measure of its ability to lose electrons − it will be called its «oxidation potential». The cathode has a contribution based on its ability to gain electrons, its «reduction potential».

$$E_{cell} = \text{oxidation potential} + \text{reduction potential}.$$

Required Reagents and Equipment

K$_3$[Fe(CN)$_6$] solution	Distilled water
K$_4$[Fe(CN)$_6$] solution	pH-meter
25 mL burettes (2)	Beakers (3)

The operation process

1. Rinse a clean 25 mL burette with the 0,01 mole/L $K_3[Fe(CN)_6]$ solution. Fill the burette with 0,01 mole/L $K_3[Fe(CN)_6]$ solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse a clean 25 mL burette with the 0,01 mole/L $K_4[Fe(CN)_6]$ solution. Fill the burette with 0,01 mole/L $K_4[Fe(CN)_6]$ solution to the zero mark using a beaker. Clamp the burette to a stand.

3. Transfer the noted in Evaluation Table volumes of $K_3[Fe(CN)_6]$ and $K_4[Fe(CN)_6]$ from burettes to three beakers. Mix the contents of beakers.

4. Use the pH-meter to measure electromotive force (EMF or E_{cell}) of the three solutions.

   4.1. Place the tip of the sensing and reference electrodes in the solution. It does not matter which solution you do first.

   4.2. Appropriate EMF value will appear on the display.

   4.3. Rinse the tip of electrodes with distilled water.

5. The results should be noted down to the Evaluation Table.

Evaluation

1. Calculate the oxidation-reduction potential of systems (in Volt) using the following formula and note down the results to the Evaluation Table:

$$E_{([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} = E_{cell} + E_{sc}, \text{ where } E_{sc} = 0,222 \text{ V.}$$

It should be noted that SC means silver chloride electrode.

$$E_{1([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} = \qquad\qquad =$$

$$E_{2([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} = \qquad\qquad =$$

$$E_{3([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} = \qquad\qquad =$$

2. Calculate the standard oxidation-reduction potential using Nernst's equation:

$$E^0_{([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} = E_{([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})} - \frac{0,059}{n} \lg \frac{c([Fe(CN)_6]^{3-})}{c([Fe(CN)_6]^{4-})},$$

where $c([Fe(CN)_6]^{3-}) = \dfrac{c^o(K_3[Fe(CN)_6]) \cdot V(K_3[Fe(CN)_6])}{V(solution)}$;

$$c\ ([Fe(CN)_6]^{4-}) = \frac{c^o\ (K_4[Fe(CN)_6]) \cdot V\ (K_4[Fe(CN)_6])}{V\ (solution)};$$

n is the number of electrons in oxidation-reduction reaction, so $n =$_____ ,

$c^0\ (x)$ – initial concentration of reagent.

$$c_1(K_3[Fe(CN)_6]^{3-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$c_2(K_3[Fe(CN)_6]^{3-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$c_3(K_3[Fe(CN)_6]^{3-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$c_1(K_3[Fe(CN)_6]^{4-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$c_2(K_3[Fe(CN)_6]^{4-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$c_3(K_3[Fe(CN)_6]^{4-}) = \underline{\hspace{6cm}} = \hspace{2cm} V$$

$$E^0_{1([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} = E_{1([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} - \frac{0{,}059}{n} \lg \frac{c_1([Fe(CN)_6]^{3-})}{c_1([Fe(CN)_6]^{4-})} =$$

$$= \underline{\hspace{1cm}} - \underline{\hspace{5cm}} = \hspace{1cm} = \hspace{1cm} V$$

$$E^0_{2([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} = E_{2([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} - \frac{0{,}059}{n} \lg \frac{c_2([Fe(CN)_6]^{3-})}{c_2([Fe(CN)_6]^{4-})} =$$

$$= \underline{\hspace{1cm}} - \underline{\hspace{5cm}} = \hspace{1cm} = \hspace{1cm} V$$

$$E^0_{3([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} = E_{3([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} - \frac{0{,}059}{n} \lg \frac{c_3([Fe(CN)_6]^{3-})}{c_3([Fe(CN)_6]^{4-})} =$$

$$= \underline{\hspace{1cm}} - \underline{\hspace{5cm}} = \hspace{1cm} = \hspace{1cm} V$$

The results should be noted down to the Evaluation Table.

3. Calculate the average value of E^0:

$$\overline{E}^0_{([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} = \frac{E^0_{1([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} + E^0_{2([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})} + E^0_{3([Fe(CN)_6]^{3-}/[Fe(CN)_6]^{4-})}}{3} =$$

$$= \underline{\hspace{5cm}} = \hspace{2cm} V$$

$\dfrac{V(K_3[Fe(CN)_6]),mL}{V(K_4[Fe(CN)_6]),mL}$	E_{cell}, V	$E_{i([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-}}$, V	$E^0_{([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-}}$, V
2/18			
10/10			
18/2			

Conclusion

The value of standard oxidation-reduction potential $\overline{E}^0_{([Fe(CN)_6]^{3-}/([Fe(CN)_6]^{4-})}$ is _____

LABORATORY WORK 11
«QUANTITATIVE DEFINITION OF CA^{2+} IONS BY ION–EXCHANGE ABSORPTION»

Purpose: to determine quantitative contents of ion Ca^{2+} in solution using ion-exchange absorption.

The essence of the method

Ion exchange is of particular importance for human beings since it is one of the intermediatory stages in the chain of complex biochemical and physiological processes. Ionites (ion exchangers) have found a wide application in medicine. In particular they are used to demineralize water, make ionite milk, preserve blood, determine acidity of gastric juices without exploring a probe, etc. In pharmacy ionites (ion exchangers) help to concentrate and purify antibiotics, extract alkaloids from plants, some ionites (ion exchangers) are also used as medicines to bind toxic substances and toxins in gastrointestinal tract.

Required Reagents and Equipment

Calcium chloride solution   Sodium hydroxide solution

Cationite (cation exchanger)   25 mL burette

100 mL conical flask   Column for the ionite (ion exchanger)

Distilled water   Phenolphthalein indicator solution

The operation process

1. Place the sample of $CaCl_2$ solution into the column containing a cationite (cation exchanger) in H^+–form. At first remove some of the distilled water covering the cationite (the water is needed to avoid contact of the cationite with air) in the column.

2. Turn the stopcock (tap) in the column to let the liquid drop from the column into the conical flask. Make sure the cationite (cation exchanger) is always covered by the liquid.

3. Rinse the conical flask containing the analyzed solutions 2–3 times with small amounts of distilled water and pass these portions through column again.

4. Rinsing waters have to be collected in the same conical flask where all eluate was collected.

5. Add 15–20 mL of distilled water to the column and collect the eluate again in the same flask.

6. On finishing the experiment close the tap and put some more distilled water into the column.

7. Add 2–3 drops of phenolphthalein indicator solution to the flask with collected eluate.

8. Rinse a clean 25 mL burette with the 0,1 mole/L sodium hydroxide solution. Fill the burette with 0,1 mole/L sodium hydroxide solution to the zero mark using a beaker. Clamp the burette to a stand.

9. Titrate collected eluate adding 0,1 mole/L NaOH solution from burette till endpoint will reached (for phenolphthalein, the endpoint is the first permanent pale pink that fades in 10 to 20 minutes).

10. When you complete the titration, you'll determine the amount of solution you have added. Read the value by placing your eye at the level of the solution and reading the value at the bottom of the meniscus.

11. The results should be noted down to the Evaluation Table.

Evaluation Table

c (NaOH), mol/L	V (NaOH)

Evaluation

Mass of Ca^{2+} (in grams) in the analyzed solution must be calculated according to the formula:

$$m(Ca^{2+}) = c(NaOH)\cdot V(NaOH)\cdot M\left(\frac{1}{2}Ca^{2+}\right);$$

$$M\left(\frac{1}{2}Ca^{2+}\right) = M\left(Ca^{2+}\right)\cdot\frac{1}{2}.$$

M (Ca^{2+}) =

Conclusion

Mass of Ca^{2+} in the analyzed solution is _____

LABORATORY WORK 12
«SEPARATION OF AMINO ACIDS MIXTURE USING PAPER CHROMATOGRAPHY»

Purpose: to perform paper chromatography of a mixture of amino acids; according to the calculated values of distribution coefficients, to determine amino acids in analysis mixture.

The essence of the method

Chromatography covers physical-chemical methods of separation and analysis of mixtures of gases, vapor, liquids or dissolved substances. They are used to separate the mixtures of materials into the individual species. They work because of the differences in distribution of mixture components between the mobile phase and stationary phase, when the mixture is moved through the stationary phase, the layer of the sorbent. Components of the analyzed mixture are not equally adsorbed on the sorbent; compounds with the higher affinity to the sorbent will be sorbed more strongly and stay for longer on the sorbent, therefore the speed of their moving with the mobile phase is lower. Stationary phase – the sorbent – can be liquid or solid. Mobile phase (the gas or liquid passing the layer of the sorbent) performs the role of solvent and carrier of analysis mixture.

The compositions of the stationary and mobile phases define a specific chromatographic method. Indeed, many different combinations are possible.

Chromatography paper	Mixture of amino acids
Ninhydrin solution	Chromatographic chamber
Pencil	Ruler

The operation process

1. Mark by a pencil the line (starting line) at 2–3 cm from the top of chromatography paper and then place a drop of the sample of amino acids mixture on this line.

2. Let the paper dry for several minutes.

3. Place 3–4 mL of the solvent (mixture of phenol with water) into the chromatographic chamber. Then the end of the paper having the drop should be placed in the solvent. Make sure the solvent doesn't touch the spot on the paper. Close up the chromatographic chamber.

4. As soon as the solvent rises as high as 16–18 cm up on the paper, take out the paper from the chromatographic chamber and fix the line the solvent reached by pencil (finishing line) and let the paper dry.

5. Spray the paper with ninhydrin solution, and then dry it at 50–60 °C.

6. When the purple rings develop on the paper, their number tells, how many amino acids were in analysis mixture.

7. Measure the way of each amino acid, i.e. the distance from the starting line to the middle of colored ring (X_i), and the way of solvent, i.e. the distance from starting line to finishing line (X_0).

8. The results should be noted down to the Evaluation Table.

Evaluation

1. Calculate the distribution coefficient R_f for each of the amino acids using the formula $R_f = \dfrac{X_1}{X_2}$ and note down the results to the Table. The Rf value for a component is defined as the ratio of the distance moved by that particular component divided by the distance moved by the solvent.

$$R_{f(1)} = \frac{X_1}{X_0} = \underline{\hspace{3cm}} =$$

35

$$R_{f(2)} = \frac{X_2}{X_0} = \underline{\qquad\qquad} =$$

Distance passed by the amino acid X_i, cm	Distance passed by the solvent X_0, cm	R_f

2. Compare calculated R_f with the reference data (Reference Table) and then identify the amino acids in sample.

Reference Table

Amino acid	R_f	Amino acid	R_f
Asparagine	0,07	Arginine	0,41
Glutamine	0,16	Tyrozine	0,52
Cysteine	0,19	Alanine	0,55
Glycine	0,03	Leucine	0,79
Methionine	0,30		

Conclusion

Sample of the amino acids consist of _____

LABORATORY WORK 13
«SEPARATION OF DYES MIXTURE USING THIN LAYER CHROMATOGRAPHY»

Purpose: to perform thin layer chromatography of a mixture of dyes.

The essence of the method

Thin layer chromatography is a method for analyzing mixtures by separating the compounds in the mixture. Thin layer chromatography can be used to help determine the number of components in a mixture, the identity of compounds, and the purity of a compound. The mixture of dyes separated through thin layer chromatography on «Silufol» plates. The dyes travel up the chromatography paper at different distances before they cannot remain in solution. The more soluble dyes move further up than the less soluble ones, hence separating from each other.

Required Reagents and Equipment

«Silufol» plate   Chromatographic chamber

Crystal violet dye   Pencil

Sudan (III) dye   Ruler

The operation process

1. Mark the line by a pencil (starting line) at 1–1,5 cm from the top of «Silufol» plate.

2. Place drop of the mixture of crystal violet dye and sudan III dye on starting line.

3. Place 3–4 mL of the chloroform (or toluene) into the chromatographic chamber.

4. The end of the «Silufol» place in the solvent. Make sure the solvent doesn't touch the spot on the paper. Close up the chromatographic chamber.

5. As soon as the solvent rises as higher as possible up on the «Silufol» plate, take out the «Silufol» plate from the chromatographic chamber.

6. Fix the line the solvent reached by pencil (finishing line) and let the «Silufol» plate dry.

7. Compare the color of colored ring of investigated mixture with the color of colored rings of the crystal violet dye and sudan III dye.

8. Make conclusion about the composition of mixture.

Evaluation

Investigated mixture form the colored ring on the «Silufol» plate ant its color is

_____

Sudan III dye form the colored ring on the «Silufol» plate ant its color is

_____

Crystal violet dye form the colored ring on the «Silufol» plate ant its color is

_____

Compare the distances passed by the Sudan III dye and Crystal violet dye

_____
_____

Conclusion

Investigated mixture consist of _____

LABORATORY WORK 14

«PREPARATION, PURIFICATION AND PROPERTIES OF COLLOIDS SOLUTIONS»

Purpose*:* to perform methods of preparation and purification of colloids solutions; to determine the charge of colloid particles.

The essence of the method

A colloid, also called a colloidal dispersion, is a two-phase heterogeneous mixture that is made up of a dispersed phase of tiny particles that are distributed evenly within a continuous phase. The most important biological fluids such as blood, urine and spinal fluid contain slightly soluble substances in colloid state: cholesterol, carbonates, phosphates, urates, and salts of other acids.

> *Everyday Colloids and Suspension*
> • The protoplasm that makes up our cells is a complex colloid that comprises a dispersed phase of proteins, fats, and other complex molecules in a continuous aqueous phase.
> • Detergents are surfactants (surface-active agents).
> • Photographic film.
> • Many common foods, including nearly all dairy products, are colloids or suspensions.
> • Toothpaste, shaving gel, cosmetic creams and lotions, and similar personal-care products are colloids.
> • Flocculants.

Required Reagents and Equipment

Solution of iron chloride (III)	10 mL pipettes (3)
Solution of argentum nitrate	50 mL beakers (2)
Solution of potassium iodide	Cylinder
Solution of potassium hexacianoferate (II)	Test tubes (4)
Distilled water	U-similar tube

The operation process

Test 1. Preparation of argentum iodide sol.

1. Rinse pipette with 0,02 mole/L potassium iodide solution, then pipette 10 mL sample to the test tube.

2. Add some drops of the argentum nitrate solution ($c(AgNO_3) = 0,01$ mol/L).

3. *Observe and describe the Tyndall effect:* for this purpose it is necessary to observe reflecting a beam of light through the colloid sideways:

_____

_____

Test 2. Preparation of «Berlin blue».

1. Rinse pipette with of iron chloride (III) solution (weight percent $\omega = 0,001$), then pipette 10 mL sample to the test tube.

2. Add 3 drops of potassium hexacyanoferrate (II) solution (weight percent $\omega = 0,001$). *Don't pour out the formed sol!*

Observation: _____

Write reaction: _____

Write the formula of the colloidal micelle of sol:

3. Rinse pipette with of potassium hexacyanoferrate (II), then pipette 10 mL sample to the test tube.

4. Add 3 drops of the iron (III) chloride solution. *Don't pour out the formed sol!*

Observation: _____

Write reaction: _____

Write the formula of the colloidal micelle of sol:

Test 3. Preparation of the sol of iron (III) hydroxide.

1. Measure exactly 20,0 mL of the distilled water into 50 mL beaker.

2. Add approximately 2 mL of the iron (III) chloride solution (weight percent $\omega = 0,02$).

3. Boil the solution until red-brown coloring is observed.

4. Cool the sol.

Write reaction: _____

Write the formula of the colloidal micelle of sol (notice, that potential determining ions is FeO^+):

Test 4. Purification of the sol by a dialysis method

1. Fill the 50 mL beaker with distilled water on 1/3 of its volume.

2. Pour sol of iron hydroxide in dialyzer and place it in a beaker with water.

3. In half an hour using pipette transfer 1–2 mL of a solution from a beaker to the test tube.

4. Add 5–6 drops of argentum nitrate solution to the test tube.

Observation: _____

Write reaction: _____

Conclusion: _____

    Test 5. Determine a charge of colloidal particles by electrophoresis method.

1. Fill a U-similar tube on 3/4 of its volume by a colloid solution (prepared in experiment 2).

2. Connect electrodes with power unit.

3. Let down electrodes in both tube bends.

4. Connect a power unit to a current network.

5. In 1–2 minutes notice the color of sol in both tube bends:

near anode _____,

near cathode _____

6. Determine a charge of colloidal particles:

_____

_____

LABORATORY WORK 15
«DETERMINATION OF A COAGULATION THRESHOLD»

Purposes*:* to determinate coagulation threshold of sol.

The essence of the method

Coagulation is the collecting into a mass of minute particles of a solid dispersed throughout a liquid (a sol), usually followed by the precipitation or separation of the solid mass from the liquid. The casein in milk is coagulated (curdled) by the addition of acetic

acid or citric acid. The albumin in egg white is coagulated by heating. The clotting of blood is another example of coagulation. Coagulation usually involves a chemical reaction. The lowest concentration of a substance, electrolyte, or nonelectrolyte that brings about coagulation in a system with a liquid dispersion medium is called the coagulation threshold.

Required Reagents and Equipment

Potassium hexacyanoferrate (III) solution	25 mL burettes (2)
Potassium dichromate solution	Test tubes (2)
Sol of iron (III) hydroxide	5 mL pipette

The operation process

1. Rinse a clean 25 mL burette with the 2 mmole/L (normality) potassium hexacyanoferrate (III) solution. Fill the burette with 2 mmole/L potassium hexacyanoferrate (III) solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Rinse a clean 25 mL burette with the 2 mmole/L (normality) potassium dichromate solution. Fill the burette with 2 mmole/L potassium dichromate solution to the zero mark using a beaker. Clamp the burette to a stand.

2. Using the pipette transfer 5 ml of iron (III) hydroxide sol to two test tubes.

3. Add potassium chromate dropwise to the first test tube until the iron hydroxide sol starts to coagulate.

4. Add potassium hexacyanoferrate (III) dropwise to the second test tube until the iron hydroxide sol starts to coagulate.

5. When you complete, you'll determine the amount of solutions you have added. Read the value by placing your eye at the level of the solution and reading the value at the bottom of the meniscus.

6. The results should be noted down to the Evaluation Table.

Evaluation

1. Calculate the coagulation threshold of electrolytes (in mmole/L) using the formula below and note down the results to the Evaluation Table:

$$c_c\left(\tfrac{1}{z}X\right) = \frac{c\left(\tfrac{1}{z}X\right)\cdot V(X)}{V(\text{sol}) + V(X)}.$$

$$c_c\left(\frac{1}{2}K_2Cr_2O_7\right) = \frac{c\left(\frac{1}{2}K_2Cr_2O_7\right)\cdot V(K_2Cr_2O_7)}{V(sol) + V(K_2Cr_2O_7)} = \underline{\hspace{3cm}} =$$

$$c_c\left(\frac{1}{3}K_3[Fe(CN)_6]\right) = \frac{c\left(\frac{1}{3}K_3[Fe(CN)_6]\right)\cdot V(K_3[Fe(CN)_6])}{V(sol) + V(K_3[Fe(CN)_6])} = \underline{\hspace{3cm}} =$$

2. Calculate coagulation ability of electrolytes (in L/mmole) using the formula below and note down the results to the Evaluation Table:

$$V_c(X) = \frac{1}{c_c\left(\frac{1}{z}X\right)}$$

$$V_c(K_2Cr_2O_7) = \frac{1}{c_c\left(\frac{1}{2}K_2Cr_2O_7\right)} = \underline{\hspace{3cm}} =$$

$$V_c(K_3[Fe(CN)_6]) = \frac{1}{c_c\left(\frac{1}{3}K_3[Fe(CN)_6]\right)} = \underline{\hspace{3cm}} =$$

3. Calculate relative coagulation ability of electrolytes:

$$\frac{V_c(K_3[Fe(CN)_6])}{V_c(K_2Cr_2O_7)} = \underline{\hspace{3cm}} =$$

Evaluation Table

Electrolytes	$c(\frac{1}{z}X)$, mmole/L	Volume of solution electrolytes $V(X)$, L	Coagulating ion	Coagulation threshold, $c_c\left(\frac{1}{z}X\right)$ mmole/L	Coagulation ability, $V_c(X)$, L/mmole
$K_2Cr_2O_7$					
$K_3[Fe(CN)_6]$					

Conclusion

Coagulation ability of $K_3[Fe(CN)_6]$ _____ than coagulation ability of $K_2Cr_2O_7$.

N	0	1	2	3	4	5	6	7	8	9
1.0	0.0000	0.0043	0.0086	0.0128	0.0170	0.0212	0.0253	0.0294	0.0334	0.0374
1.1	0.0414	0.0453	0.0492	0.0531	0.0569	0.0607	0.0645	0.0682	0.0719	0.0755
1.2	0.0792	0.0828	0.0864	0.0899	0.0934	0.0969	0.1004	0.1038	0.1072	0.1106
1.3	0.1139	0.1173	0.1206	0.1239	0.1271	0.1303	0.1335	0.1367	0.1399	0.1430
1.4	0.1461	0.1492	0.1523	0.1553	0.1584	0.1614	0.1644	0.1673	0.1703	0.1732
1.5	0.1761	0.1790	0.1818	0.1847	0.1875	0.1903	0.1931	0.1959	0.1987	0.2014
1.6	0.2041	0.2068	0.2095	0.2122	0.2148	0.2175	0.2201	0.2227	0.2253	0.2279
1.7	0.2304	0.2330	0.2355	0.2380	0.2405	0.2430	0.2455	0.2480	0.2504	0.2529
1.8	0.2553	0.2577	0.2601	0.2625	0.2648	0.2672	0.2695	0.2718	0.2742	0.2765
1.9	0.2788	0.2810	0.2833	0.2856	0.2878	0.2900	0.2923	0.2945	0.2967	0.2989
2.0	0.3010	0.3032	0.3054	0.3075	0.3096	0.3118	0.3139	0.3160	0.3181	0.3201
2.1	0.3222	0.3243	0.3263	0.3284	0.3304	0.3324	0.3345	0.3365	0.3385	0.3404
2.2	0.3424	0.3444	0.3464	0.3483	0.3502	0.3522	0.3541	0.3560	0.3579	0.3598
2.3	0.3617	0.3636	0.3655	0.3674	0.3692	0.3711	0.3729	0.3747	0.3766	0.3784
2.4	0.3802	0.3820	0.3838	0.3856	0.3874	0.3892	0.3909	0.3927	0.3945	0.3962
2.5	0.3979	0.3997	0.4014	0.4031	0.4048	0.4065	0.4082	0.4099	0.4116	0.4133
2.6	0.4150	0.4166	0.4183	0.4200	0.4216	0.4232	0.4249	0.4265	0.4281	0.4298
2.7	0.4314	0.4330	0.4346	0.4362	0.4378	0.4393	0.4409	0.4425	0.4440	0.4456
2.8	0.4472	0.4487	0.4502	0.4518	0.4533	0.4548	0.4564	0.4579	0.4594	0.4609
2.9	0.4624	0.4639	0.4654	0.4669	0.4683	0.4698	0.4713	0.4728	0.4742	0.4757
3.0	0.4771	0.4786	0.4800	0.4814	0.4829	0.4843	0.4857	0.4871	0.4886	0.4900
3.1	0.4914	0.4928	0.4942	0.4955	0.4969	0.4983	0.4997	0.5011	0.5024	0.5038
3.2	0.5051	0.5065	0.5079	0.5092	0.5105	0.5119	0.5132	0.5145	0.5159	0.5172
3.3	0.5185	0.5198	0.5211	0.5224	0.5237	0.5250	0.5263	0.5276	0.5289	0.5302
3.4	0.5315	0.5328	0.5340	0.5353	0.5366	0.5378	0.5391	0.5403	0.5416	0.5428
3.5	0.5441	0.5453	0.5465	0.5478	0.5490	0.5502	0.5514	0.5527	0.5539	0.5551
3.6	0.5563	0.5575	0.5587	0.5599	0.5611	0.5623	0.5635	0.5647	0.5658	0.5670
3.7	0.5682	0.5694	0.5705	0.5717	0.5729	0.5740	0.5752	0.5763	0.5775	0.5786
3.8	0.5798	0.5809	0.5821	0.5832	0.5843	0.5855	0.5866	0.5877	0.5888	0.5899
3.9	0.5911	0.5922	0.5933	0.5944	0.5955	0.5966	0.5977	0.5988	0.5999	0.6010
4.0	0.6021	0.6031	0.6042	0.6053	0.6064	0.6075	0.6085	0.6096	0.6107	0.6117
4.1	0.6128	0.6138	0.6149	0.6160	0.6170	0.6180	0.6191	0.6201	0.6212	0.6222
4.2	0.6232	0.6243	0.6253	0.6263	0.6274	0.6284	0.6294	0.6304	0.6314	0.6325
4.3	0.6335	0.6345	0.6355	0.6365	0.6375	0.6385	0.6395	0.6405	0.6415	0.6425
4.4	0.6435	0.6444	0.6454	0.6464	0.6474	0.6484	0.6493	0.6503	0.6513	0.6522
4.5	0.6532	0.6542	0.6551	0.6561	0.6571	0.6580	0.6590	0.6599	0.6609	0.6618
4.6	0.6628	0.6637	0.6646	0.6656	0.6665	0.6675	0.6684	0.6693	0.6702	0.6712
4.7	0.6721	0.6730	0.6739	0.6749	0.6758	0.6767	0.6776	0.6785	0.6794	0.6803
4.8	0.6812	0.6821	0.6830	0.6839	0.6848	0.6857	0.6866	0.6875	0.6884	0.6893
4.9	0.6902	0.6911	0.6920	0.6928	0.6937	0.6946	0.6955	0.6964	0.6972	0.6981
5.0	0.6990	0.6998	0.7007	0.7016	0.7024	0.7033	0.7042	0.7050	0.7059	0.7067
5.1	0.7076	0.7084	0.7093	0.7101	0.7110	0.7118	0.7126	0.7135	0.7143	0.7152
5.2	0.7160	0.7168	0.7177	0.7185	0.7193	0.7202	0.7210	0.7218	0.7226	0.7235
5.3	0.7243	0.7251	0.7259	0.7267	0.7275	0.7284	0.7292	0.7300	0.7308	0.7316
5.4	0.7324	0.7332	0.7340	0.7348	0.7356	0.7364	0.7372	0.7380	0.7388	0.7396

N	0	1	2	3	4	5	6	7	8	9
5.5	0.7404	0.7412	0.7419	0.7427	0.7435	0.7443	0.7451	0.7459	0.7466	0.7474
5.6	0.7482	0.7490	0.7497	0.7505	0.7513	0.7520	0.7528	0.7536	0.7543	0.7551
5.7	0.7559	0.7566	0.7574	0.7582	0.7589	0.7597	0.7604	0.7612	0.7619	0.7627
5.8	0.7634	0.7642	0.7649	0.7657	0.7664	0.7672	0.7679	0.7686	0.7694	0.7701
5.9	0.7709	0.7716	0.7723	0.7731	0.7738	0.7745	0.7752	0.7760	0.7767	0.7774
6.0	0.7782	0.7789	0.7796	0.7803	0.7810	0.7818	0.7825	0.7832	0.7839	0.7846
6.1	0.7853	0.7860	0.7868	0.7875	0.7882	0.7889	0.7896	0.7903	0.7910	0.7917
6.2	0.7924	0.7931	0.7938	0.7945	0.7952	0.7959	0.7966	0.7973	0.7980	0.7987
6.3	0.7993	0.8000	0.8007	0.8014	0.8021	0.8028	0.8035	0.8041	0.8048	0.8055
6.4	0.8062	0.8069	0.8075	0.8082	0.8089	0.8096	0.8102	0.8109	0.8116	0.8122
6.5	0.8129	0.8136	0.8142	0.8149	0.8156	0.8162	0.8169	0.8176	0.8182	0.8189
6.6	0.8195	0.8202	0.8209	0.8215	0.8222	0.8228	0.8235	0.8241	0.8248	0.8254
6.7	0.8261	0.8267	0.8274	0.8280	0.8287	0.8293	0.8299	0.8306	0.8312	0.8319
6.8	0.8325	0.8331	0.8338	0.8344	0.8351	0.8357	0.8363	0.8370	0.8376	0.8382
6.9	0.8388	0.8395	0.8401	0.8407	0.8414	0.8420	0.8426	0.8432	0.8439	0.8445
7.0	0.8451	0.8457	0.8463	0.8470	0.8476	0.8482	0.8488	0.8494	0.8500	0.8506
7.1	0.8513	0.8519	0.8525	0.8531	0.8537	0.8543	0.8549	0.8555	0.8561	0.8567
7.2	0.8573	0.8579	0.8585	0.8591	0.8597	0.8603	0.8609	0.8615	0.8621	0.8627
7.3	0.8633	0.8639	0.8645	0.8651	0.8657	0.8663	0.8669	0.8675	0.8681	0.8686
7.4	0.8692	0.8698	0.8704	0.8710	0.8716	0.8722	0.8727	0.8733	0.8739	0.8745
7.5	0.8751	0.8756	0.8762	0.8768	0.8774	0.8779	0.8785	0.8791	0.8797	0.8802
7.6	0.8808	0.8814	0.8820	0.8825	0.8831	0.8837	0.8842	0.8848	0.8854	0.8859
7.7	0.8865	0.8871	0.8876	0.8882	0.8887	0.8893	0.8899	0.8904	0.8910	0.8915
7.8	0.8921	0.8927	0.8932	0.8938	0.8943	0.8949	0.8954	0.8960	0.8965	0.8971
7.9	0.8976	0.8982	0.8987	0.8993	0.8998	0.9004	0.9009	0.9015	0.9020	0.9025
8.0	0.9031	0.9036	0.9042	0.9047	0.9053	0.9058	0.9063	0.9069	0.9074	0.9079
8.1	0.9085	0.9090	0.9096	0.9101	0.9106	0.9112	0.9117	0.9122	0.9128	0.9133
8.2	0.9138	0.9143	0.9149	0.9154	0.9159	0.9165	0.9170	0.9175	0.9180	0.9186
8.3	0.9191	0.9196	0.9201	0.9206	0.9212	0.9217	0.9222	0.9227	0.9232	0.9238
8.4	0.9243	0.9248	0.9253	0.9258	0.9263	0.9269	0.9274	0.9279	0.9284	0.9289
8.5	0.9294	0.9299	0.9304	0.9309	0.9315	0.9320	0.9325	0.9330	0.9335	0.9340
8.6	0.9345	0.9350	0.9355	0.9360	0.9365	0.9370	0.9375	0.9380	0.9385	0.9390
8.7	0.9395	0.9400	0.9405	0.9410	0.9415	0.9420	0.9425	0.9430	0.9435	0.9440
8.8	0.9445	0.9450	0.9455	0.9460	0.9465	0.9469	0.9474	0.9479	0.9484	0.9489
8.9	0.9494	0.9499	0.9504	0.9509	0.9513	0.9518	0.9523	0.9528	0.9533	0.9538
9.0	0.9542	0.9547	0.9552	0.9557	0.9562	0.9566	0.9571	0.9576	0.9581	0.9586
9.1	0.9590	0.9595	0.9600	0.9605	0.9609	0.9614	0.9619	0.9624	0.9628	0.9633
9.2	0.9638	0.9643	0.9647	0.9652	0.9657	0.9661	0.9666	0.9671	0.9675	0.9680
9.3	0.9685	0.9689	0.9694	0.9699	0.9703	0.9708	0.9713	0.9717	0.9722	0.9727
9.4	0.9731	0.9736	0.9741	0.9745	0.9750	0.9754	0.9759	0.9763	0.9768	0.9773
9.5	0.9777	0.9782	0.9786	0.9791	0.9795	0.9800	0.9805	0.9809	0.9814	0.9818
9.6	0.9823	0.9827	0.9832	0.9836	0.9841	0.9845	0.9850	0.9854	0.9859	0.9863
9.7	0.9868	0.9872	0.9877	0.9881	0.9886	0.9890	0.9894	0.9899	0.9903	0.9908
9.8	0.9912	0.9917	0.9921	0.9926	0.9930	0.9934	0.9939	0.9943	0.9948	0.9952
9.9	0.9956	0.9961	0.9965	0.9969	0.9974	0.9978	0.9983	0.9987	0.9991	0.9996

Solubility of Ionic Compounds in Water

Key: S = soluble;   I = insoluble;   D = decomposes in water;   U = compound does not exist

Cation / Anion	Al 3+	NH$_4$ 1+	Ba 2+	Cd 2+	Ca 2+	Cr 3+	Co 2+	Cu 2+	Fe 3+	Fe 2+	H 1+	Pb 2+	Mg 2+	Hg 1+	Ni 2+	K 1+	Ag 1+	Na 1+	Sr 2+	Zn 2+
C$_2$H$_3$O$_2^-$	S	S	S	S	S	S	S	S	S	S	S	S	S	I	S	S	I	S	S	S
Br$^-$	S	S	S	S	S	S	S	S	S	S	S	S	S	I	S	S	I	S	S	S
CO$_3^{2-}$	U	S	I	I	I	U	I	I	U	I	S	I	I	I	I	S	I	S	I	I
ClO$_3^-$	S	S	S	S	S	U	S	S	U	U	S	S	S	S	I	S	S	S	S	S
Cl$^-$	S	S	S	S	S	S	S	S	S	S	S	S	S	I	S	S	I	S	S	S
CrO$_4^{2-}$	U	S	I	I	S	U	I	S	I	I	S	I	I	U	U	S	I	S	I	I
OH$^-$	I	I	S	I	I	I	I	I	I	I	H$_2$O	I	I	U	I	S	U	S	I	I
I$^-$	S	S	S	S	S	S	S	S	S	S	S	I	S	I	S	S	I	S	S	S
NO$_3^-$	S	S	S	S	S	S	S	S	S	S	S	S	S	D	S	S	S	S	S	S
O^{2-}	I	U	S	I	I	I	I	I	I	I	H$_2$O	I	I	I	I	D	I	D	I	I
C$_2$O$_4^{2-}$	I	I	S	I	I	S	I	I	S	S	S	I	I	I	I	S	I	S	I	I
PO$_4^{3-}$	I	S	I	I	I	I	I	I	I	I	S	I	I	U	I	S	I	S	I	I
SiO$_3^{2-}$	I	U	S	I	I	U	I	U	U	I	I	I	I	U	U	S	U	S	I	I
SO$_4^{2-}$	S	S	I	S	S	S	S	S	S	S	S	I	S	I	S	S	I	S	I	S
S^{2-}	D	S	D	I	I	I	I	I	I	I	S	I	D	I	I	S	I	S	I	I
SO$_3^{2-}$	U	S	I	I	I	I	I	U	U	I	S	I	U	U	I	S	I	S	I	I

PERIODIC TABLE OF THE ELEMENTS

Legend:
- 14 → Group IUPAC
- IVA → Group CAS
- Selected Oxidation States
- Atomic Number: 6
- Symbol: C
- Name: Carbon
- Electron Configuration: 2-4
- Atomic Mass: 12.011

Group	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H 1 Hydrogen 1.0079 +1 −1																	He 2 Helium 4.0026 0
2	Li 3 Lithium 6.941 +1 (2-1)	Be 4 Beryllium 9.0122 +2 (2-2)											B 5 Boron 10.811 +3 (2-3)	C 6 Carbon 12.011 −4 +2 +4 (2-4)	N 7 Nitrogen 14.007 −3 −2 −1 +1..+5 (2-5)	O 8 Oxygen 15.999 −2 (2-6)	F 9 Fluorine 18.998 −1 (2-7)	Ne 10 Neon 20.179 0 (2-8)
3	Na 11 Sodium 22.990 +1 (2-8-1)	Mg 12 Magnesium 24.305 +2 (2-8-2)											Al 13 Aluminium 26.982 +3 (2-8-3)	Si 14 Silicon 28.086 −4 +2 +4 (2-8-4)	P 15 Phosphorus 30.974 −3 +3 +5 (2-8-5)	S 16 Sulphur 32.065 −2 +4 +6 (2-8-6)	Cl 17 Chlorine 35.453 −1 +1 +3 +5 +7 (2-8-7)	Ar 18 Argon 39.948 0 (2-8-8)
4	K 19 Potassium 39.098 +1 (2-8-8-1)	Ca 20 Calcium 40.078 +2 (2-8-8-2)	Sc 21 Scandium 44.956 +3 (2-8-9-2)	Ti 22 Titanium 47.867 +2 +3 +4 (2-8-10-2)	V 23 Vanadium 50.942 +2 +3 +4 +5 (2-8-11-2)	Cr 24 Chromium 51.996 +2 +3 +6 (2-8-13-1)	Mn 25 Manganese 54.938 +2 +3 +4 +6 +7 (2-8-13-2)	Fe 26 Iron 55.845 +2 +3 (2-8-14-2)	Co 27 Cobalt 58.933 +2 +3 (2-8-15-2)	Ni 28 Nickel 58.693 +2 +3 (2-8-16-2)	Cu 29 Copper 63.546 +1 +2 (2-8-18-1)	Zn 30 Zinc 65.39 +2 (2-8-18-2)	Ga 31 Gallium 69.723 +3 (2-8-18-3)	Ge 32 Germanium 72.64 −4 +2 +4 (2-8-18-4)	As 33 Arsenic 74.922 −3 +3 +5 (2-8-18-5)	Se 34 Selenium 78.96 −2 +4 +6 (2-8-18-6)	Br 35 Bromine 79.904 −1 +5 (2-8-18-7)	Kr 36 Krypton 83.80 0 +2 (2-8-18-8)
5	Rb 37 Rubidium 85.468 +1 (2-8-18-8-1)	Sr 38 Strontium 87.62 +2 (2-8-18-8-2)	Y 39 Yttrium 88.906 +3 (2-8-18-9-2)	Zr 40 Zirconium 91.224 +4 (2-8-18-10-2)	Nb 41 Niobium 92.906 +3 +5 (2-8-18-12-1)	Mo 42 Molybdenum 95.94 +6 (2-8-18-13-1)	Tc 43 Technetium (98) +4 +6 +7 (2-8-18-13-1)	Ru 44 Ruthenium 101.07 +3 (2-8-18-15-1)	Rh 45 Rhodium 102.91 +3 (2-8-18-16-1)	Pd 46 Palladium 106.42 +2 +4 (2-8-18-18)	Ag 47 Silver 107.87 +1 (2-8-18-18-1)	Cd 48 Cadmium 112.41 +2 (2-8-18-18-2)	In 49 Indium 114.82 +3 (2-8-18-18-3)	Sn 50 Tin 118.71 +2 +4 (2-8-18-18-4)	Sb 51 Antimony 121.76 −3 +3 +5 (2-8-18-18-5)	Te 52 Tellurium 127.60 −2 +4 +6 (2-8-18-18-6)	I 53 Iodine 126.90 −1 +1 +5 +7 (2-8-18-18-7)	Xe 54 Xenon 131.29 0 +2 +4 +6 (2-8-18-18-8)
6	Cs 55 Cesium 132.91 +1 (2-8-18-18-8-1)	Ba 56 Barium 137.33 +2 (2-8-18-18-8-2)	La 57-71 Lanthanide	Hf 72 Hafnium 178.49 +4 (2-8-18-32-10-2)	Ta 73 Tantalum 180.95 +5 (2-8-18-32-11-2)	W 74 Tungsten 183.84 +6 (2-8-18-32-12-2)	Re 75 Rhenium 186.21 +4 +6 +7 (2-8-18-32-13-2)	Os 76 Osmium 190.23 +3 +4 (2-8-18-32-14-2)	Ir 77 Iridium 192.22 +3 +4 (2-8-18-32-15-2)	Pt 78 Platinum 195.08 +2 +4 (2-8-18-32-17-1)	Au 79 Gold 196.97 +1 +3 (2-8-18-32-18-1)	Hg 80 Mercury 200.59 +1 +2 (2-8-18-32-18-2)	Tl 81 Thallium 204.38 +1 +3 (2-8-18-32-18-3)	Pb 82 Lead 207.2 +2 +4 (2-8-18-32-18-4)	Bi 83 Bismuth 208.98 +3 +5 (2-8-18-32-18-5)	Po 84 Polonium (209) +2 +4 (2-8-18-32-18-6)	At 85 Astatine (210) (2-8-18-32-18-7)	Rn 86 Radon (222) 0 (2-8-18-32-18-8)
7	Fr 87 Francium (223) (2-8-18-32-18-8-1)	Ra 88 Radium (226) +2 (2-8-18-32-18-8-2)	Ac 89-103 Actinide	Rf 104 Rutherfordium (261) -2-8-18-32-32-10-2	Db 105 Dubnium (262) -18-32-32-11-2	Sg 106 Seaborgium (266) -18-32-32-12-2	Bh 107 Bohrium (264) -18-32-32-13-2	Hs 108 Hassium (277) -18-32-32-14-2	Mt 109 Meitnerium (268) -18-32-32-15-2	Uun 110 Ununnilium (281) -18-32-32-17-1	Uuu 111 Unununium (272) -18-32-32-17-1	Uub 112 Ununbium (285) -18-32-32-18-2	Uut 113 Ununtrium (284)	Uuq 114 Ununquadium (289)	Uup 115 Ununpentium (288)	Uuh 116 Ununhexium (291)	Uus 117 Ununseptium	Uuo 118 Ununoctium (294)

Lanthanide

La 57 Lanthanium 138.91 +3 (2-8-18-18-9-2)	Ce 58 Cerium 140.12 +3 +4 (2-8-18-20-8-2)	Pr 59 Praseodymium 140.91 +3 +4 (2-8-18-21-8-2)	Nd 60 Neodymium 144.24 +3 (2-8-18-22-8-2)	Pm 61 Promethium (145) +3 (2-8-18-23-8-2)	Sm 62 Samarium 150.36 +2 +3 (2-8-18-24-8-2)	Eu 63 Europium 151.96 +2 +3 (2-8-18-25-8-2)	Gd 64 Gadolinium 157.25 +3 (2-8-18-25-9-2)	Tb 65 Terbium 158.93 +3 (2-8-18-27-8-2)	Dy 66 Dysprosium 162.50 +3 (2-8-18-28-8-2)	Ho 67 Holmium 164.93 +3 (2-8-18-29-8-2)	Er 68 Erbium 167.26 +3 (2-8-18-30-8-2)	Tm 69 Thulium 168.93 +3 (2-8-18-31-8-2)	Yb 70 Ytterbium 173.04 +2 +3 (2-8-18-32-8-2)	Lu 71 Lutetium 174.97 +3 (2-8-18-32-9-2)

Actinide

Ac 89 Actinium (227) +3 (2-8-18-32-18-9-2)	Th 90 Thorium 232.04 +4 (-18-32-18-10-2)	Pa 91 Protactinium 231.04 +4 +5 (-18-32-20-9-2)	U 92 Uranium 238.03 +3 +4 +5 +6 (-18-32-21-9-2)	Np 93 Neptunium (237) +3 +4 +5 +6 (-18-32-22-9-2)	Pu 94 Plutonium (244) +3 +4 +5 +6 (-18-32-24-8-2)	Am 95 Americium (243) +3 +4 +5 +6 (-18-32-25-8-2)	Cm 96 Curium (247) +3 (-18-32-25-9-2)	Bk 97 Berkelium (247) +3 +4 (-18-32-27-8-2)	Cf 98 Californium (251) +3 (-18-32-28-8-2)	Es 99 Einsteinium (252) (-18-32-29-8-2)	Fm 100 Fermium (257) (-18-32-30-8-2)	Md 101 Mendelevium (258) (-18-32-31-8-2)	No 102 Nobelium (259) (-18-32-32-8-2)	Lr 103 Lawrencium (262) (-18-32-32-9-2)

Electron Shells

		s	p	d	f
1	K	2			
2	L	2	6		
3	M	2	6	10	
4	N	2	6	10	14
5	O	2	6	10	14
6	P	2	6	10	
7	Q	2	6		
8	R	2			