MINISTRY OF HEALTH OF UKRAINE
BOGOMOLETS NATIONAL MEDICAL UNIVERSITY

Department of Medical and General Chemistry

GENERAL AND INORGANIC CHEMISTRY

V. Kalibabchuk, G. Zaitseva, Ya. Pushkarova, V. Slipchuk

Student notebook for experimental chemistry

(Module 1 «General Chemistry»)

Student ____________________

Group ____________________

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This Student Notebook for Experimental Chemistry allows you to keep a written record or report of the mandatory laboratory and practical works that you will carry out as part of the Inorganic Chemistry course. The Student Laboratory Notebook includes laboratory and practical works and also questions in all basic topics in Inorganic Chemistry. Chemistry is a practical subject, and, by developing your practical skills in the laboratory, you will increase your understanding and appreciation of chemistry.
The notebook is for first year foreign students of Pharmaceutical Faculty.
Have fun,enjoy your laboratory / practical work,and best of luck with it!

CONTENTS

LABORATORY SAFETY RULES

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.

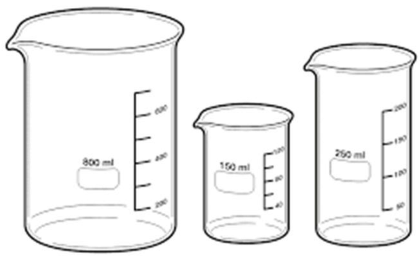
GENERAL PURPOSE GLASSWARE

Be careful with all laboratory glassware!

Test Tubes

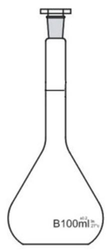
For most people, the test tube is the one piece of equipment that defines a chemistry lab, and rightly so. Test tubes are used so often and for so many purposes that it’s hard to imagine a chemistry lab without them. Most of the time, you’ll use test tubes to mix solutions, heat samples, observe reactions,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

Beakers



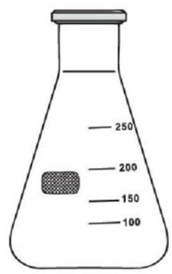
Beakers are among the most commonly used items of laboratory glassware; they’re used when test tubes aren’t large enough. Beakers are flat-bottomed, cylindrical containers, usually equipped with a pouring spout, and are used for routine mixing, measuring, heating, and boiling of liquids.

Volumetric Flasks



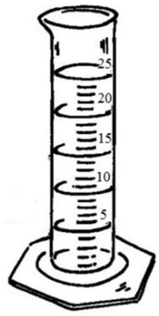
A volumetric flask is used to make up a precise volume of solution. It has one graduation line that indicates the nominal volume.

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

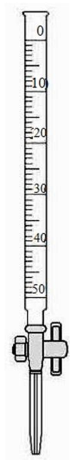


A graduated cylinder is a tall, slender cylinder with numerous graduation lines from near the bottom to near the top. You use a graduated cylinder to measure liquids with moderate to moderately high accuracy.

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.

Semantic Module 1 «Atomic Structure. Periodic Law»

Topic 1 «Atomic Theory. Basic Laws of Chemistry»

Practical work N 1
«Basic concepts and laws of chemistry»

1.1. Use the basic concepts and laws of chemistry to complete Table 1.

Table 1

Substance	Amount of substance n, mole	Mass of gas m, g	Volume of gas (n.c.) V, L	Number of gas molecules
Cl_2	0,1			
CO_2		22		
NO_2			2,8	
CO	0,2			
H_2S				$9{,}03 \cdot 10^{23}$
PH_3		3,4		

1.2. Calculate the relative densities of gases (D_{x_1/x_2}) to complete Table 2.

Table 2

x_1	D_{x_1/x_2}, where x_2			
	H_2	O_2	N_2	Air
F_2				
CO				
SO_2				
NH_3				

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Topic 2 «Atomic Structure. Electron Arrangements. Periodic Law»

Practical work N 2
«Electronic structure of atom»

2.1. Complete Table 3.

Table 3

Atom or ion	Electronic configuration of atom	$\sum m_s$	Atom or ion	Electronic configuration of atom	$\sum m_s$
	$[Ne]3s^1$			$[Ne]3s^2$	
S^{2-}			Cd^{2+}		
	$[Ar]3d^54s^1$			$[Ar]3d^54s^2$	
Cr^{3+}			Br^-		
	$[Kr]4d^55s^1$			$[Kr]5s^1$	
Si			As		

Experiment N 1
«Influence of electronic structure of atoms and ions on chemical properties of elements»

Experiment 1.1.

№	Performing the experiment	
1	To each of three clean test tubes add 3-4 mL of copper (II) sulfate solution.	
First test tube	Place a spatula full of magnesium filings.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Place a spatula full of zinc granules.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Third test tube	Place a spatula full of iron filings.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

Answer question

In which direction does occur displacement of metals from solutions of their salts? Why?

____
____
____
____

Practical work N 3
«Periodic law»

3.1. Use the periodic table to help you complete Table 4.

Table 4

Chemical element	Electronic configuration	Atomic number	Period	Group	Sub-group
		4			
	$1s^2 2s^2 2p^3$				
			3	IV	main
Magnesium					
		26			
	$[Kr]4d^5 5s^1$				
			6	IV	secondary
Aurum					
		47			
	$[Ar]3d^{10} 4s^2 4p^4$				
			4	VI	main
Tin (Stannum)					

Experiment N 2

«Research of metallic properties of elements with increasing of their atomic number in the group»

Experiment 2.1.

№	Performing the experiment
1	Place 1-2 mL of boric acid to a clean test tube and add 3-4 drops of methyl-orange solution.
Observation	
2	To each of two clean test tubes add 2-3 mL of aluminum chloride solution and carefully dropwise add concentrated sodium hydroxide solution to precipitate formation.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
First test tube	Add sulfuric acid solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
Second test tube	Add an excess of concentrated sodium hydroxide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
3	To each of two clean test tubes add 2-3 mL of indium chloride solution and carefully dropwise add concentrated sodium hydroxide solution to precipitate formation.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
First test tube	Add sulfuric acid solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
Second test tube	Add an excess of concentrated sodium hydroxide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Answer questions

1. Identify classes of inorganic compounds for obtained compounds of boron, aluminum and indium.

2. Explain the change of metallic properties of elements with increasing of their atomic number in the group.

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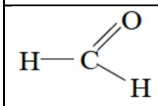
Semantic Module 2 «Molecular Structure and Chemical Bonding»

Topic 3 «Chemical Bond. Molecular Structure, Valence Bond Method, Molecular Orbital Theory »

Practical work N 4
«Chemical bond. Molecular structure»

4.1. Complete Table 5.

Table 5

Molecule	Presence		Hybridization	Polar or nonpolar molecule	Oxidation number of atoms	Coordination number of atoms
	σ -bond	π -bond				
CO_2						
H_2O						
BF_3						
						
CCl_4						
CH_3Cl						
C_2H_2						
CH_2Cl_2						
HCN						
C_2H_4						
HCl						
NH_3						

Experiment N 5
«Molecular orbital method»

5.1. Construct the energy-level diagram for molecular orbitals of the following diatomic homonuclear particles and determine the bond order in these molecules.

O_2^-	O_2
Bond order	Bond order

O_2^+
Bond order

Answer question

Write the above diatomic homonuclear molecules in the order of increasing:

a) chemical bond energy ____

b) chemical bond length ____

5.2. Construct the energy-level diagram for molecular orbitals of the following diatomic heteronuclear particles and determine the bond order in these molecules.

NO^-	**NO**
Bond order	Bond order

NO^+
Bond order

Answer question

Write the above diatomic heteronuclear molecules in the order of increasing:

a) chemical bond energy ____

b) chemical bond length ____

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Topic 4 «Classification of Inorganic Compounds. Oxides»

Experiment N 3
«Preparation of oxides and their properties»

Experiment 3.1. Preparation of acidic oxides

№	Performing the experiment	
1	Transfer 2-4 drops of concentrated sulfuric acid solution to a clean test tube and add a small piece of coal. Carefully heat the test tube using Bunsen's burner.	
Observation		
Balanced molecular equation for the reaction that occur		
2	Transfer 4-6 drops of sodium nitrite solution to a clean test tube and add 2-3 drops of sulfuric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
3	Place a piece of sulfur to a clean test tube and add 5-6 drops of concentrated nitric acid solution. Carefully slightly heat the test tube using Bunsen's burner.	
Observation		
Balanced molecular equation for the reaction that occur		
4	Transfer 4-5 drops of sodium carbonate solution to a clean test tube and add 5-6 drops of nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

Experiment 3.2. Preparation of basic oxides

№	Performing the experiment	
1	Transfer 2-3 drops of argentum nitrate solution to a clean test tube and add a few drops of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

2	Burn a piece of magnesium strip in air in a porcelain crucible or dish.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 3.3. Preparation of amphoteric oxides

№	Performing the experiment
1	Transfer 3-4 drops of potassium permanganate solution to a clean test tube and add 3-5 drops of ammonia solution. Carefully slightly heat the test tube using Bunsen's burner.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	Place crystals of ammonium dichromate to a porcelain dish. Touch a lighted match to its surface.
Observation	
Balanced molecular equation for the reaction that occur	
3	Place 1-2 mL of manganese sulfate solution to a clean test tube and add the same volume of potassium permanganate solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 3.4. Chemical properties of oxides

№	Performing the experiment
1	Place a spatula full of solid magnesium oxide to a clean test tube and add 2-3 drops of hydrochloric acid.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	To each of two clean test tubes place a spatula full of solid zinc oxide.
First test tube	Add sulfuric acid solution.
Observation	

Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add an excess of concentrated sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

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Topic 5 «Classification of Inorganic Compounds. Acids and Bases»

Experiment N 4
«Acids and bases. Their chemical properties»

Experiment 4.1. Preparation of basic hydroxides and their chemical properties

№	Performing the experiment	
1	Place a spatula full of calcium oxide to a clean test tube with water and mix. Add a phenolphthalein indicator solution.	
Observation		
Balanced molecular equation for the reaction that occur		
2	Transfer 4-6 drops of nickel chloride solution to a clean test tube and add 4-5 drops of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
	Resulting precipitate divide into 2 test tubes.	
First test tube	Add a nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add an excess of sodium hydroxide solution.	
Observation		

3	Transfer 4-6 drops of cobalt chloride solution to a clean test tube and add 4-5 drops of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
	Resulting precipitate divide into 2 test tubes.	
First test tube	Add a nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add an excess of sodium hydroxide solution.	
Observation		

Experiment 4.2. Preparation of amphoteric hydroxides and their chemical properties

№	Performing the experiment	
1	Transfer 4-6 drops of zinc chloride solution to a clean test tube and add 4-5 drops of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
	Resulting precipitate divide into 2 test tubes.	
First test tube	Add a nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add an excess of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
2	Transfer 4-6 drops of chromium (III) chloride solution to a clean test tube and add 4-5 drops of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

		Resulting precipitate divide into 2 test tubes.
First test tube	Add a nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add an excess of sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

Experiment 4.3. Preparation of acids and their chemical properties

№	Performing the experiment
1	Place about 0,5 g of sodium chloride to a clean test tube and add 0,5 mL of concentrated sulfuric acid solution. Carefully heat the test tube using Bunsen's burner.
Observation	
Balanced molecular equation for the reaction that occur	
2	Transfer 3-4 drops of sodium silicate solution to a clean test tube and add 2-3 drops of hydrochloric acid solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
3	Place some granules of zinc to a clean test tube and add 7-8 drops of hydrochloric acid solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
4	Place 2-3 mL of diluted sulfuric acid solution to a clean test tube and add copper (II) oxide. Carefully heat the test tube using Bunsen's burner.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

5	Place 1-2 mL of sodium hydroxide solution to a clean test tube and add a drop of phenolphthalein indicator solution. Then add hydrochloric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
6	Place a crystal of calcium carbonate to a clean test tube and add 4-5 drops of nitric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
7	Transfer 4-5 drops of barium chloride solution to a clean test tube and add sulfuric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

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Topic 6 «Classification of Inorganic Compounds. Salts, Complex Salts. Biorole, Toxicity and Application of Inorganic Compounds in Medicine and Pharmacy

Experiment N 5

«Preparation of salts and their chemical properties»

Experiment 5.1. Preparation of neutral salts and their chemical properties

№	Performing the experiment	
1	Transfer 4-6 drops of lead (II) nitrate solution to a clean test tube and add 4-5 drops of sodium sulfate solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
2	Transfer 4-6 drops of argentum (I) nitrate solution to a clean test tube and add 4-5 drops of sodium bromide solution.	
Observation		
Balanced molecular and ionic equations for		

the reaction that occur	
3	Transfer 4-6 drops of barium chloride solution to a clean test tube and add 4-5 drops of sodium carbonate solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 5.2. Preparation of acidic salts and their chemical properties

№	Performing the experiment
1	Place 1-2 mL of calcium hydroxide solution to a clean test tube and add dropwise phosphoric acid solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Add an excess of phosphoric acid solution to resulting precipitate.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	Transfer 3-4 drops of sodium hydrocarbonate solution to a clean test tube and add 2-3 drops of barium hydroxide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 5.3. Preparation of basic salts and their chemical properties

№	Performing the experiment
1	Transfer 4-5 drops of copper (II) sulfate solution to a clean test tube and add a few drops of dilute sodium hydroxide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Carefully heat the resulting precipitate using Bunsen's burner.
Observation	
Balanced molecular and ionic equations for	

the reaction that occur		
2	Transfer 4-5 drops of cobalt (II) chloride solution to a clean test tube and add a few drops of dilute sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
	Add hydrochloric acid solution to resulting precipitate.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

Experiment 5.4. Preparation of complex salts

№	Performing the experiment	
1	Transfer 3-4 drops of copper (II) sulfate solution to a clean test tube and add 2-3 mL of concentrated ammonia solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
2	Transfer 3-4 drops of nickel (II) chloride solution to a clean test tube and add 2-3 mL of concentrated ammonia solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

Experiment N 6

«Classes of inorganic compounds»

Experiment 6.1.

№	Performing the experiment	
1	Transfer 4-6 drops of a solution of lead (II) nitrate to a clean test tube and add 4-5 drops of potassium chromate solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
	Resulting precipitate divide into 2 test tubes.	

First test tube	Add a few drops of nitric acid.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add a few drops of sodium hydroxide solution. If necessary, carefully heat the test tube using Bunsen's burner.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
2	To each of two clean test tubes place a granule of tin (stannum).	
First test tube	Add 5-6 drops of concentrated sulfuric acid solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
Second test tube	Add 1 mL of concentrated sodium hydroxide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		
3	Place about 0,5 mL of copper (II) sulfate solution to a clean test tube and add the same volume of potassium iodide solution.	
Observation		
Balanced molecular and ionic equations for the reaction that occur		

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Topic 7 «Complex Compounds»

Experiment N 7

«Complex compounds»

Experiment 7.1. Anionic complex preparation

№	Performing the experiment
1	Transfer 4-6 drops of cobalt (II) nitrate solution to a clean test tube and add 4-5 drops of potassium thiocyanate solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	Transfer 4-6 drops of bismuth (III) nitrate solution to a clean test tube and add potassium iodide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Add an excess of potassium iodide solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
3	Transfer 4-5 drops of iron (III) chloride solution to a clean test tube and add an excess of $K_4[Fe(CN)_6]$ solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
4	Transfer 4-5 drops of iron (II) chloride solution to a clean test tube and add an excess of $K_3[Fe(CN)_6]$ solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
5	Transfer 2-3 drops of iron (III) chloride solution to a clean test tube and add 1-2 mL of potassium thiocyanate solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 7.2. Cationic complex preparation

№	Performing the experiment
1	Transfer 4-6 drops of cadmium (II) chloride solution to a clean test tube and add 4-5 drops of ammonia solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Add an excess of ammonia solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	Transfer 4-5 drops of cobalt (II) chloride solution to a clean test tube and add a few drops of ammonia solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Add an excess of ammonia solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 7.3. Preparation of compound, that contains complex cation and complex anion

№	Performing the experiment
1	Transfer 2 drops of $K_4[Fe(CN)_6]$ solution and add 4 drops of nickel sulfate solution.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
	Add an excess of ammonia solution to dissolve the precipitate. Wait 1-2 minutes.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Practical work N 6
«Complex compounds»

6.1. Complete Table 6.

Table 6

Complex compound	Name	Central ion			Ligand		Inner sphere		Outer sphere		Type of hybridization
		Symbol	Oxidation number	CN	Formula	Oxidation number	Formula	Oxidation number	Formula	Oxidation number	
$[Ag(NH_3)_2]Cl$											
$[Cr(H_2O)_6]Cl_3$											
$K_2[Zn(OH)_4]$											
$[Pt(NH_3)_5Cl]Cl_3$											
$Na_3[Al(OH)_6]$											
$K_2[Cu(CN)_4]$											
$Na_2[Ni(CN)_4]$											
$[Pt(NH_3)_2Cl_2]$											

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Topic 8 «Redox Reactions»

Experiment N 8
«Redox reactions»

Experiment 8.1. Influence of pH on the oxidative ability of potassium permanganate

№	Performing the experiment
1	To each of three clean test tubes add 4-5 drops of potassium permanganate solution.
First test tube	Add 4-5 drops of sulfuric acid solution and 4-5 drops of sodium sulfite solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	
Second test tube	Add 4-5 drops of sodium hydroxide solution and 4-5 drops of sodium sulfite solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	
Third test tube	Add 4-5 drops of sodium sulfite solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	
2	Transfer 3-4 drops of hydrogen peroxide solution to clean test tube and add 3-4 drops of sulfuric acid solution and 3-4 drops of potassium permanganate solution.
Observation	
Balanced molecular equation for the reaction that occur	

Oxidizing agent	
Reducing agent	

Experiment 8.2. Oxidative properties of potassium dichromate

№	Performing the experiment
1	To each of three clean test tubes add 4-5 drops of potassium dichromate solution and add a few drops of sulfuric acid solution.
First tube tube	Add 3-4 drops of tin (II) chloride solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	
Second test tube	Add 3-4 drops of potassium iodide solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	
Third test tube	Add 4-5 drops of sodium nitrite solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	

Experiment 8.3. Reducing properties of manganese (II) compounds

№	Performing the experiment
1	Transfer 5-6 drops of potassium permanganate solution to clean test tube and add 5-6 drops of manganese (II) sulfate solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	

Experiment 8.4. Reducing properties of hydrochloric acid

№	Performing the experiment
1	Place small amount of crystalline potassium permanganate to clean test tube and add a few drops of concentrated hydrochloric acid solution.
Observation	
Balanced molecular equation for the reaction that occur	
Oxidizing agent	
Reducing agent	

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Semantic Module 3 «Theoretical Bases of Chemical Processes»

Topic 9 «Thermodynamic and Kinetic Regularities of Chemical Processes. Chemical Equilibrium »

Experiment N 9
«Determination of the heat of neutralization»

The operation process

1	Using cylinder measure 25 mL of 1 mole/L sodium hydroxide solution and transfer it to the Dewar vessel.
2	Measure the temperature (T_1) with the thermometer.
3	Using cylinder measure 25 mL of sulfuric acid solution with the molarity of equivalent 1 mole/L and add it to the Dewar vessel. Mix the contents of the Dewar vessel.
4	Measure the temperature (T_2) with the thermometer.
5	Write down the T_1 and T_2 to the Table 7.
6	Repeat the steps 1–5 for 1 mole/L chloride acid, nitric acid and the acetate acid solutions.

Table 7

Acid	$c\left(\frac{1}{z}\text{acid}\right)$, mole/L	T_1, K	T_2, K	ΔT, K	$-\Delta H^{\circ}_{neutralization}$, kJ/mole	
					Reference value	Experimental value
H_2SO_4					53	
HCl					56	
HNO_3					56	
CH_3COOH					47	

Evaluation

Calculate the heat of neutralization for each acid and write down them to the Table 7:

$$\Delta H^{\circ}_{neutralization} = \frac{C \cdot [V(base) + V(acid)] \cdot \Delta T \cdot \rho}{c\left(\frac{1}{z}\,acid\right) \cdot V(acid)},$$

where, C – thermal capacity (4,18 kJ/K); V(acid) – volume of acid solution, L; V(base) – volume of base solution, L; ρ – density of solution (≈ 1 kg/L); $c\left(\frac{1}{z}\text{acid}\right)$ – molarity of equivalent of acid, mol/L.

$\Delta H^{\circ}_{neutralization}(H_2SO_4)$ = ________________________________ = kJ/mole

$\Delta H^{\circ}_{neutralization}(HCl)$ = ________________________________ = kJ/mole

$\Delta H^{\circ}_{neutralization}(HNO_3)$ = ________________________________ = kJ/mole

$\Delta H^{\circ}_{neutralization}(CH_3COOH)$ = ________________________________ = kJ/mole

Write the four neutralization reactions in the ionic and molecular forms:

H_2SO_4+NaOH=____

____

____

HCl+NaOH=____

____

____

HNO_3+NaOH=____

____

____

CH_3COOH+NaOH=____

____

____

Conclusion

Compare experimental values of the heats of neutralization with reference values and explain difference between them:

____

____

____

Experiment N 10

«Kinetics of the interaction of sodium thiosulfate with sulfuric acid»

Experiment 10.1. The dependence of the rate of a chemical reaction on the concentration of the reactants

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

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

$$H_2S_2O_3 = S\downarrow + SO_2\uparrow + H_2O \text{ (comparatively slow)}$$

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.

The operation process

1	Fill three burettes: 1st – with 0,1 mole/L sodium thiosulfate solution; 2nd – with 1 mole/L sulfuric acid solution; 3rd – with distilled water.
2	Take three clean test tubes. Place 1 mL of sodium thiosulfate solution and 4 mL of distilled water from burettes to the first clean test tube. Place 3 mL of thiosulfate solution and 2 mL of distilled water from burettes to the second clean test tube. Place 5 mL of thiosulfate solution from burette to the third clean test tube.
3	Mix the contents of test tubes.
4	Take three clean test tubes.

	To each of three test tubes place 5 mL of sulfuric acid solution from burette.
5	Mix together by pairs the contents of the test tubes and write down to the Table 8 the time when the turbidity arises by means of the stop-watch.

Table 8

№	V (solution), mL			V(mixture), mL	$c(Na_2S_2O_3)$, mole/L	τ, c	υ, c^{-1}
	$Na_2S_2O_3$	H_2O	H_2SO_4				
1	1	4	5	10			
2	3	2	5	10			
3	5	0	5	10			

Evaluation

1. Calculate molarity of $Na_2S_2O_3$ obtained after dilution according to the following formula and notice the results to the Table:

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

where: $c_0(Na_2S_2O_3)$ – initial molarity of $Na_2S_2O_3$ solution, mol/L; $V_i(Na_2S_2O_3)$ – volume of $Na_2S_2O_3$ solution; V_i(mixture) – total volume of mixed reagents.

$$c_1(Na_2S_2O_3) = c_1(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3)\cdot V_1(Na_2S_2O_3)}{V_1(mixture)} = \underline{\qquad\qquad\qquad} = \quad \text{mole/L}$$

$$c_2(Na_2S_2O_3) = c_2(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3)\cdot V_2(Na_2S_2O_3)}{V_2(mixture)} = \underline{\qquad\qquad\qquad} = \quad \text{mole/L}$$

$$c_3(Na_2S_2O_3) = c_3(H_2S_2O_3) = \frac{c_o(Na_2S_2O_3)\cdot V_3(Na_2S_2O_3)}{V_3(mixture)} = \underline{\qquad\qquad\qquad} = \quad \text{mole/L}$$

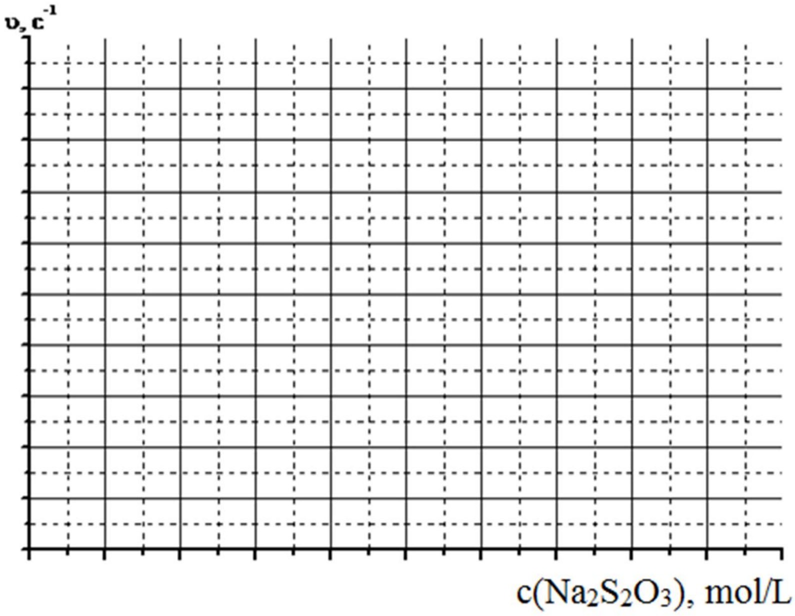
2. Calculate values of reaction rates (υ) according to the following formula:

$$\upsilon_1 = \frac{1}{\tau_1} = \underline{\qquad\qquad} = \quad sec^{-1}$$

$$\upsilon_2 = \frac{1}{\tau_2} = \underline{\qquad\qquad} = \quad sec^{-1}$$

$$\upsilon_3 = \frac{1}{\tau_3} = \underline{\qquad\qquad} = \quad sec^{-1}$$

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



Conclusion

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

Experiment 10.2. Effect of catalyst on the rate of chemical reaction

As catalyst for decomposition thiosulfuric acid used 0,5 N solution of copper (II) sulfate, c ($\frac{1}{2}$ CuSO4) = 0,5 mole/L.

The operation process

1	Fill three burettes: 1st – with 0,1 mole/L sodium thiosulfate solution; 2nd – with 1 mole/L sulfuric acid solution; 3rd – with distilled water.
2	Take four clean test tubes. To each of four clean test tubes place 4 mL of sodium thiosulfate solution from burette.
3	Take four clean test tubes. To each of four clean test tubes place 4 mL of sulfuric acid solution from burette. Add 1 drop of copper (II) sulfate solution to the second test tube, add 2 drops of copper (II) sulfate solution to the third test tube, add 3 drops of copper (II) sulfate solution to the fourth test tube.
4	Mix together by pairs the contents of the test tubes and notice to the Table 9 the time when the turbidity arises by means of the stop-watch.

Table 9

№	$V(Na_2S_2O_3)$, mL	V (H_2SO_4), mL	Number of drops $CuSO_4$	τ, c	υ, c^{-1}
1	4	4	0		
2	4	4	1		
3	4	4	2		
4	4	4	3		

Evaluation

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

$\vartheta_1 = \frac{1}{\tau_1} =$ ——— $=$ c^{-1} $\vartheta_2 = \frac{1}{\tau_2} =$ ——— c^{-1}

$\vartheta_3 = \frac{1}{\tau_3} =$ ——— $=$ c^{-1} $\vartheta_4 = \frac{1}{\tau_4} =$ ——— $=$ c^{-1}

Conclusion

By increasing the concentration of catalyst (complex ions of copper (II)) reaction rate ____

Experiment N 11
«Chemical Equilibrium»

Experiment 11.1. Effect of changing the amounts of reacting species on equilibrium

№	Performing the experiment
1	Place 30-40 mL of iron (III) chloride solution ($\omega(FeCl_3) = 0{,}05\%$) to a clean 100 mL flask and add 30-40 mL of potassium thiocyanate ($\omega(KSCN) = 0{,}1\%$). Mix the contents of flask.
Observation	
Balanced molecular equation for the reaction that occur	
	Divide the resulting solution into four clean test tubes.
First test tube	Keep this test tube to provide a reference colour for the next experiments.
Second test tube	Add 5 mL of iron (III) chloride solution ($\omega(FeCl_3) = 20\%$).
Observation	
In which direction does equilibrium shift (to the right, to the left)?	
Third test tube	Add 5 mL of potassium thiocyanate ($\omega(KSCN) = 20\%$).
Observation	

In which direction does equilibrium shift (to the right, to the left)?	
Fourth test tube	Add about 2 g of solid potassium chloride.
Observation	
In which direction does equilibrium shift (to the right, to the left)?	

Experiment 11.2. Effect of changing the temperature on equilibrium.

N	**Performing the experiment**
1	To each of the two test tubes add 10-15 drops of starch solution and add 5-7 drops of iodine solution in each one.
Observation	
First test tube	Keep this test tube to provide a reference colour for the next experiments.
Second test tube	Carefully heat the test tube using Bunsen's burner.
Observation	
	Cool off the test tube.
Observation	

Date ____________________

Teacher's signature ____________________

Semantic Module 4 «Physical-Chemical Properties of Solutions»

Topic 10 «Solutions. Methods of Expressing Concentration of Solutions. Nonelectrolytes and Electrolytes Solutions. Equilibrium in Solutions of Weak Electrolytes »

Experiment N 12
«Preparation of cobalt (II) nitrate solution by diluting concentrated solution»

Task

Prepare 100 mL of cobalt (II) nitrate solution with molarity of equivalent **0,02 mole/L** from cobalt (II) nitrate solution with molarity of equivalent **0,4 mole/L**.

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:

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

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

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.
4. Adjust the volume to 100 mL with distilled water.
5. Close volumetric flask and shake upside to mix contents.

Experiment N 13
«Nonelectrolytes and electrolytes solutions»

Experiment 13.1. Comparison of chemical activity of acid

№	Performing the experiment
1	To each of the two clean test tubes place a few small pieces of marble.
First test tube	Add 5 mL of hydrochloric acid.

Observation	
Balanced molecular and ionic equations for the reaction that occur	
Second test tube	Add 5 mL of acetic acid.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
2	To each of the two clean test tubes place a few small pieces of zinc.
First test tube	Add 5 mL of hydrochloric acid.
Observation	
Balanced molecular and ionic equations for the reaction that occur	
Second test tube	Add 5 mL of acetic acid.
Observation	
Balanced molecular and ionic equations for the reaction that occur	

Experiment 13.2. The shift of the dissociation equilibrium of weak electrolyte

№	Performing the experiment
1	To each of the two clean test tubes add 5-10 drops of diluted acetic acid. Add one drop of methyl orange indicator solution in each one.
Observation	
First test tube	Keep this test tube to provide a reference colour for the next experiments.
Second test tube	Place a few small pieces of sodium acetate and stir with a glass rod.
Observation	

Answer question

How and why change the dissociation degree of acetic acid?

____

____

____

Date ____________________

Teacher’s signature ____________________

Topic 11 «Ionic Equilibrium. Stability of Complex Ions, Solubility Product Constant»

Experiment N 14
«The conditions of precipitate formation»

The coexistence of an ionic solid and its component ions in solution is one example of a chemical equilibrium:

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

This equilibrium can be quantified using the solubility product principle, which states that in a saturated solution of an ionic compound, the product of the molar activities, called the solubility product constant or K_{sp}, has a constant value at any particular temperature and pressure.

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

Ion product quotient, Q, is the the product of the equilibrium expression when the system is not at equilibrium.

Criteria for precipitation:

Precipitation should occur if $Q > K_{sp}$.
A solution is just saturated if $Q = K_{sp}$.
Precipitation cannot occur if $Q < K_{sp}$.

The operation process

1	To each of the two clean test tubes add 4 drops of the 0,001 mole/L lead nitrate solution.
2	Add 4 drops of the 0,05 mole/L potassium chloride solution to the first test tube.
3	Add 4 drops of the 0,05 mole/L potassium iodide solution to the second test tube.
4	Write down the observations to the Table 10.

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

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

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

$c(Cl^-)$ = ———————————————— = mole/L

$c(I^-)$ = ———————————————— = mole/L

3. Calculate the $Q(PbCl_2)$ and $Q(PbI_2)$ and write down to the Table 10:

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

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

Table 10

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			
$PbCl_2$				$1{,}7\cdot10^{-5}$	
PbI_2				$8{,}7\cdot10^{-9}$	

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).

Date ____________________

Teacher's signature ____________________

Topic 12 «Ionic Product of Water, pH. Hydrolysis of Salts »

Experiment N 15
«Dependence pH of acid solution on concentration»

The operation process

1	Place 20 mL acetic acid solution to the 50 mL beaker (concentrations are shown in the Table 11).
2	Measure pH of solution by means of pH-meter.
3	Write down pH values to the Table 11.
4	Calculate pH using formulas and write down them to the Table 11.
5	Compare measured and calculated pH values.

Table 11

N	$c(CH_3COOH)$, mole/L	$V(CH_3COOH)$, mL	pH	
			calculated	measured
1	0,5	20		
2	0,1	20		
3	0,05	20		
4	0,01	20		

Evaluation

Calculate pH using the following formula:

$$pH = -\lg\left(\sqrt{c \cdot K_{diss}}\right),$$

where c – molarity of acetic acid solution, mole/L; K_{diss} – dissociation constant of acetic acid ($1{,}8\times10^{-5}$ mole/L).

$$pH_1 = -\lg\left(\sqrt{c_1 \cdot K_{diss}}\right) = -\lg\left(\sqrt{0.5 \cdot 1.8 \cdot 10^{-5}}\right) =$$

$$pH_2 = -\lg\left(\sqrt{c_2 \cdot K_{diss}}\right) = -\lg\left(\sqrt{0.1 \cdot 1.8 \cdot 10^{-5}}\right) =$$

$$pH_3 = -\lg\left(\sqrt{c_3 \cdot K_{diss}}\right) = -\lg\left(\sqrt{0.05 \cdot 1.8 \cdot 10^{-5}}\right) =$$

$$pH_4 = -\lg\left(\sqrt{c_4 \cdot K_{diss}}\right) = -\lg\left(\sqrt{0.01 \cdot 1.8 \cdot 10^{-5}}\right) =$$

Conclusion

With decreasing concentration of acetic acid pH ___________________________________

Experiment N 16
«Hydrolysis of Salts»

Experiment 16.1. Determination the pH of electrolytes solutions using indicators

1	Take three clean test tubes. Place 5 mL of distilled water to the first test tube; 5 mL of sulfuric acid solution − to the second test tube; 5 mL of sodium hydroxide solution − to the third test tube.
2	Add 3–4 drops of methyl red indicator solution in each one. Mix the contents of test tubes and write down the color of solutions in each test tube to the Table 12.
3	Take six clean test tubes. To each of the 6 test tubes place 5 mL of distilled water and 3-4 drops of methyl red indicator solution. Add a few crystals of Na_2CO_3 to the first test tube, $CuSO_4$ – to the second test tube, NaCl – to the third test tube, Na_2HPO_4 – to the fourth test tube, $Al_2(SO_4)_3$ – to the fifth test tube, $(NH_4)_2CO_3$ – to the sixth test tube.
4	Mix the contents of test tubes. Write down the color of solutions in each test tube to the Table 12.
5	Repeat steps 1-4 for phenolphthalein indicator solution.

Table 12

Electrolyte	Color of indicator		pH of the electrolytes solutions
	Methyl red	Phenolphthalein	
H_2O			
H_2SO_4			
NaOH			
Na_2CO_3			
$CuSO_4$			
NaCl			
Na_2HPO_4			
$Al_2(SO_4)_3$			
$(NH_4)_2CO_3$			

Molecular and ionic equations of hydrolysis of salts

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):

Na_2CO_3:

$CuSO_4$:

NaCl:

Na_2HPO_4:

$Al_2(SO_4)_3$:

$(NH_4)_2CO_3$:

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

Conclusion

Aqueous solution of sodium chloride is ___________________; aqueous solution of copper sulfate is ___________________; aqueous solution of sodium carbonate is ___________________; aqueous solution of sodium hydrogenphosphate is ___________________; aqueous solution of aluminum sulfate is ___________________; aqueous solution of ammonium carbonate is ___________________.

Experiment 16.2. Influence of temperature on the degree of hydrolysis

1	Fill two beaker on half of their volume with sodium acetate solution ($\omega(CH_3COONa) = 1{,}5\%$) and add 2–3 of phenolphthalein indicator solution. Write down the color of solutions to the Table 13.
2	Heat one of the beakers in a water bath. Write down the observation to the Table 13.

Table 13

Cold solution of salt		Hot solution of salt	
Color of indicator	pH of the solution	Color of indicator	pH of the solution

Answer questions

1. Why color of the indicator has been changed?

____

____

2. How degree of hydrolysis does depend on the temperature?

____

____

Date ______________________

Teacher's signature ______________________

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 $^{2+}$
$C_2H_3O_2^-$	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	I	U	S	I	S	I	I
OH^-	I	I	S	I	I	I	I	I	I	I	H_2O	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_2O	I	I	I	I	D	I	D	I	I
$C_2O_4^{2-}$	I	I	I	I	I	S	I	I	S	I	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	I	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

Key: 14 ⟸ Group IUPAC; IVA ⟸ Group CAS; Atomic Number ⟹ 6; Symbol ⟹ C; Name ⟹ Carbon; 12.011 ⟸ Atomic Mass; Electron Configuration ⟹ 2-4; -4 +2 +4 ⟸ Selected Oxidation States

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

Electron Shells

			S	P	D	F
1	K	2	2			
2	L	8	2	6		
3	M	18	2	6	10	
4	N	32	2	6	10	14
5	O	32	2	6	10	14
6	P	18	2	6	10	
7	Q	8	2	6		
8	R	2	2			

Lanthanide

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

Actinide

89 **Ac** +3 Actinium (227) -18-32-18-9-2	90 **Th** +4 Thorium 232.04 -18-32-18-10-2	91 **Pa** +4 +5 Protactinium 231.04 -18-32-20-9-2	92 **U** +3 +4 +5 +6 Uranium 238.03 -18-32-21-9-2	93 **Np** +3 +4 +5 +6 Neptunium (237) -18-32-23-8-2	94 **Pu** +3 +4 +5 +6 Plutonium (244) -18-32-24-8-2	95 **Am** +3 +4 +5 +6 Americium (243) -18-32-25-8-2	96 **Cm** +3 Curium (247) -18-32-25-9-2	97 **Bk** +3 +4 Berkelium (247) -18-32-27-8-2	98 **Cf** +3 Californium (251) -18-32-28-8-2	99 **Es** Einsteinium (252) -18-32-29-8-2	100 **Fm** Fermium (257) -18-32-30-8-2	101 **Md** Mendelevium (258) -18-32-31-8-2	102 **No** Nobelium (259) -18-32-32-8-2	103 **Lr** Lawrencium (262) -18-32-32-9-2