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GENERAL AND INORGANIC CHEMISTRY

MANUAL
FOR BACHELOR STUDENTS
SPECIALTY 162 –
“BIOTECHNOLOGY AND BIOENGINEERING”
(SECOND EDITION)

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У навчальному посібнику викладено основні теоретичні та практичні положення загальної та неорганічної хімії. Навчальне видання буде принагідним для виконання лабораторного практикуму з дисципліни загальна і неорганічна хімія, містить короткий огляд теоретичного матеріалу із фундаментальних концепцій курсу, завдання і тести для самостійної роботи та досліди для лабораторних робіт. Подана інформація допомагає студентам перейти від лекційного матеріалу до практики лабораторних робіт. Зміст навчального посібника відповідає програмі навчальної дисципліни ,,Загальна та неорганічна хімія,,. Посібник буде корисним студентам, аспірантам та викладачам закладів вищої освіти

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CONTENT

SAFETY AND LABORATORY RULES

Chemistry laboratories can be hazardous if the rules are not followed. During a chemistry course a student may handle materials which are carcinogenic, poisonous, flammable, and explosive. Some of these materials and equipment may also cause severe burns, cuts, or bruises if handled improperly or carelessly. Most accidents that occur in the chemistry laboratory are a result of carelessness, impatience, improper or unauthorized experimentation, and disregard for safety rules or proper operating procedures. In order to minimize the chances of an accident in the laboratory certain rules and regulations must be obeyed at all times when one is working or observing in a chemical laboratory. Therefore, it is not advisable for anyone to work in a laboratory without proper knowledge of the dangers involved. Due to the inherent dangers present in a chemical laboratory exercise, it should be understood that the following rules must be obeyed to minimize the chance of an accident. The student is expected to exercise proper judgement and extreme caution at all times when working in the laboratory.

1. DO NOT perform unauthorized experiments or work in a laboratory alone.
2. Approved eye protection must be worn at all times in the laboratory. If you do get a chemical in your eye rinse immediately with large quantities of water using the eye-wash stations.
3. Long hair and loose clothing must be confined while in a laboratory.
4. Appropriate clothing must be worn at all times while in the laboratory. Your legs must be completely covered below the knee by your choice of clothing. If your clothing does not meet the requirement you may choose to wear an approved laboratory coat or apron which does cover your legs to your knees.
5. Closed shoes with socks must be worn.
6. Know the location and proper use of fire extinguishers, fire blankets, eye wash devices, and first aid kits.
7. Before obtaining any chemicals carefully read the label on the reagent bottles.
8. Eating, smoking, and drinking are not allowed in a chemistry laboratory.
9. Thoroughly wash your hands after leaving the laboratory.
10. Use the fume hoods when toxic or irritating vapours are involved.
11. Mouth suction is never used to fill a pipette.
12. Never direct the open end of test tube toward yourself or anyone else.

13. Never pour water into concentrated acid (**especially H_2SO_4**).

14. Learn the proper procedure for igniting and operating a laboratory burner. Always extinguish the flame when the burner is not being used. Make sure that all flammable reagents are well removed before lighting the burner.

15. Liquid and solid waste containers must be properly used at all times.

16. Never place chemicals directly on the balance pan. Always use a proper weighing container when using a balance to weigh a chemical. Never pour chemicals directly over the balance.

17. Never return unused chemicals to their original container (unless directed to do so by the instructor).

18. Securely replace lids, caps, and stoppers after removing reagents from containers.

19. Always wipe spatulas clean before and after inserting into reagent bottles.

20. Report any accident and/or injury, however minor, to your instructor immediately.

21. Never place anything that is not directly required for the experiment on laboratory desks; other items may interfere with the experiment.

22. All personal belongings should be placed in the bookcases as you enter the laboratory.

23. Clean up any spill immediately.

24. Before leaving the laboratory, make sure your work area is clean and dry.

25. Your instructor is available for any assistance you may need. Never hesitate to ask questions especially if there is any question concerning proper operating procedure. Be sure that you understand every instruction before proceeding.

Part 1. GENERAL CHEMISTRY

INTRODUCTION

The natural sciences fall into two general categories – the biological sciences and the physical ones. The biological sciences are concerned primarily with the living things, and the physical sciences are concerned primarily with nonliving things, including rocks, the stars, electricity, the weather, energy from the sun, and the composition of all materials. Chemistry is a physical science.

In general, **Chemistry** is the study of the composition, structure, and the properties of substances and the changes they undergo. This definition may suggest to you that chemistry has little to do with everyday life. This is not true. Your way of life would be radically different without the practical applications of chemistry. Imagine a supermarket offering only fruits and vegetables grown without manufactured fertilizers and pesticides. The quantities and varieties offered would be far fewer. Imagine drinking water from your tap that had not been purified. The unpurified water would probably make you sick. Try to imagine a world without gasoline or heating oil. It would be very different from the world we live in.

Chemistry is s very broad subject. Most chemists would describe themselves as working in one of the following major areas of the science:

Organic chemistry - the study of substances containing carbon and hydrogen, and their derivatives;

Inorganic chemistry – the study of all substances not classified as organic chemicals, which includes the chemistry of all substances containing elements other than organic carbon;

Physical chemistry – the study of the properties, transformations, and interrelationships of energy and matter;

Biochemistry – the study of all substances and processes that occur in living things;

Analytical chemistry – the identification of substances and the qualitative and quantitative determination of the composition of materials.

A relative new direction of inorganic chemistry is *Bioinorganic chemistry.* Advances in bioinorganic chemistry since the 1970s have been driven by three factors: rapid determination of high-resolution structures of proteins and other bio-molecules, utilization of powerful spectroscopic tools for studies of both structures and dynamics, and the widespread use of macromolecular engineering to create new biologically relevant structures.

Today, very large molecules can be manipulated at will, with the result that certain proteins and nucleic acids themselves have become versatile model systems for elucidating biological function.

Oxidation-reduction processes continue to be a central theme of biological inorganic chemistry. Well over half of the papers in this special feature deal with biological red-ox reactions in one way or another.

So, to study a course of bioinorganic chemistry is to understand the basic principles of acid-base processes, reactions in the water medium (dissociation, hydrolysis), red-ox reactions, complexing reactions and so on.

CHAPTER 1. CHEMICAL NAMES AND FORMULAS. OXIDATION NUMBERS. GENERAL NOTIONS OF ATOMIC-MOLECULAR STUDY

With all of the compounds of all of the elements to be identified, systematic methods for writing formulas and naming compounds are necessary. In this section you will be introduced to the rules that apply to simple chemical compounds. Table 1 lists the common and systematic names for a number of well-known substances. Certain common names such as “milk of magnesia” or “lime” remain in everyday use. As you can see, common names usually give no information about chemical composition.

Table 1. Some familiar substances with their systematic and common names

Chemical Formula	Systematic Name	Common English name	Тривіальна українська назва
1	2	3	4
Alloy: 1 part of $AgNO_3$ with 2 part of KNO_3	-	Lunar caustic	Ляпис
$AlF_3 \cdot 3NaF$	-	Cryolite	Кріоліт
$Al_2O_3 \cdot 2SiO_2 \cdot 2\ H_2O$	-	Kaolin (mineral)	Каолін (мінерал)
As_2O_5	Arsenic (V) oxide	Arsenic Anhydride	Миш’яковий ангідрид
$Ba(OH)_2$ (aqueous solution)	Barium Hydroxide	Barytic Water	Баритова вода
$BaSO_4$	Barium Sulfate	Heavy Spar	Барит (мінерал)
CaF_2	Calcium fluoride	Fluor-Spar (mineral)	Плавиковий шпат (мінерал)
$Ca(NO_3)_2$	Calcium Nitrate	Calcium Saltpetre	Кальцієва селітра
CO	Carbon monoxide, Carbon (II) oxide	Coal gas	Світильний газ, чадний газ
CO_2	Carbon dioxide	Dry Ice (solid CO_2)	Сухий лід

1	2	3	4
CH_3OH	Methanol	Wood Alcohol	Метиловий спирт
C_2H_5OH	Ethanol	Grain Alcohol	Харчовий спирт, зерновий спирт
$CaCO_3$	Calcium Carbonate	Limestone, Calcite, Marble	Вапняк, крейда, мармур
$Ca(H_2PO_4)_2\cdot H_2O$	Calcium Dihydro phosphate Hydrate	Simple SuperPhosphate	Простий суперфосфат
$Ca(H_2PO_4)_2\cdot H_2O + 2[CaSO_4\cdot 2H_2O]$	Calcium Dihydro phosphate Hydrate + two molecules of Calcium Sulfate Dihydrate	Triple SuperPhosphate	Подвійний суперфосфат
$CaHPO_4\cdot 2H_2O$	Calcium Hydrophospate Dihydrate	Precipitate	Преципітат
CaO	Calcium Oxide	Lime	Вапно (негашене)
$Ca(OH)_2$	Calcium Hydroxide	Slaked/slack Lime	Вапно (гашене)
$Ca(OH)_2$ (aq)	Calcium Hydroxide (water solution)	Limewater, Lime Milk	Вапняна вода, вапняне молоко
$2CaO + NaOH$	Mixture of Calcium Oxide and Sodium Hydroxide	Soda Lime	Натронне вапно
$CaOCl_2$	Calcium Hypochlorite-Chloride	Chloride of Lime, Bleaching Powder	Хлорне (білильне) вапно
$3Ca_3(PO_4)_2x$ $x\cdot Ca(F, Cl)_2$	-	Apatite (mineral)	Апатит (мінерал)
$CaSO_4\cdot 1/2\ H_2O$	Calcium Sulfate Hemihydrate	Plaster of Paris, alabaster	Гіпс (обпалений), алебастр

1	2	3	4
$CaSO_4 \cdot 2\ H_2O$	Alcium Sulfate Dihydrate	Gypsum	Гіпс
$Cu(CH_3COO)_2x$ $3\ Cu(AsO_2)_2$	Mixed salt - Copper Acetate-arsenite	Paris Green	Паризька зелень
$2\ CuCO_3 \cdot Cu(OH)_2$ $CuCO_3 \cdot Cu(OH)_2$	Mixed Copper Hydroxide-Carbonate	Azurite (mineral) Malachite (mineral)	Лазурит (мінерал) Малахіт (мінерал)
$CuSO_4 \cdot 5\ H_2O$	Copper (II) Sulfate Pentahydrate	Blue Vitriol	Мідний купорос
$Fe_3[Fe(CN)_6]_2$	Iron (II) Hexaciano-ferrate (III)	Turnbull’s Blue	Турнбулева синь
$Fe_4[Fe(CN)_6]_3$	Iron (III) Hexaciano-ferrate (II)	Prussian Blue	Берлінська лазур
Fe_2O_3	Iron (III) Oxide	Mummy (mineral colour)	Мумія (коричневий пігмент, мінеральна фарба)
Fe_3O_4 or $FeO \cdot Fe_2O_3$	Mixed Iron (II) and Iron (III) Oxide	Loadstone, Magnetite (mineral)	Магнітний залізняк, магнетит (мінерал)
FeS_2	Iron (II) PerSulfide	Pyrite, Brazil; Fool's Gold, Sulfur-Ore (mineral)	Пірит, залізний колчедан, залізна обманка
$FeSO_4 \cdot 7\ H_2O$	Iron (II) Sulfate Heptahydrate	Green Vitriol	Залізний купорос
HCl	Hydrochloric acid	Muriatic Acid	Соляна кислота
HF	Hydrofluoric	Etching Acid	Плавикова (травильна) кислота

1	2	3	4
H_2O_2 (27-31% solution)	Hydrogen Peroxide	Perhydrol	Пергідроль
H_2SO_4 (90,5 – 92,5%)	Concentrated Sulfuric Acid	Vitriolic Oil	Купоросне масло
Hg	Mercury	Quicksilver	Ртуть
HgS	Mercury (II) Sulfide	Cinnabar, Vermilion (mineral)	Кіновар, вермільйон (штучна кіновар)
Hg_2Cl_2	Mercury (I) Chloride	Calomel	Каломель
$HgCl_2$	Mercury (II) Chloride	(Corrosive) Sublimate	Сулема
$KAl(SO_4)_2{\cdot}12\ H_2O$	Potassium-Aluminium Sulfate	Potash Alum	Алюмокалієві галуни
$KCl{\cdot}MgCl_2{\cdot}6H_2O$	Potassium-Magnesium hexahydrate	Carnallite (mineral)	Карналіт (мінерал)
KNO_3	Potassium Nitrate	Potassium (Indian) Saltpetre	Самородна натрієва (індійська) селітра
KOH	Potassium Hydroxide	Caustic Potash, Potassa	Їдкий калі
$K_4[Fe(CN_6)]$ $K_3[Fe(CN)_6]$	Potassium Hexaciano-ferrate (II) Potassium Hexaciano-ferrate (III)	Yellow blood salt Red blood salt	Жовта кров’яна сіль Червона кров’яна сіль
K_2CO_3	Potassium Carbonate	Potash	Поташ
$KNaC_4H_4O_6$	Potassium-Sodium Hydrotartrate	Rochelle Salt	Калій-натрій виннокислий, сегнетова сіль
$MgCO_3$	Magnesium Carbonate	Magnesite (mineral)	Магнезит (мінерал)

1	2	3	4
MgO	Magnesium Oxide	Magnesia Alba	Біла магнезія
$3MgO\cdot 4SiO_2\cdot H_2O$	-	Talc (mineral)	Тальк, жировик (мінерал)
$Mg(OH)_2$	Magnesium Hydroxide	Milk of Magnesia	Магнезіальне молоко
$MgSO_4\cdot 7H_2O$	Magnesium Sulfate Heptahydrate	Epsom Salt	Сіль Епсома
Mixture of conc. HNO_3 (1 volume) and conc. HCl (3 volumes)	-	Aqua-regia	Царська вода (водка)
Mixture of solution $CuSO_4$ with $Ca(OH)_2$	-	Bordeaux Mixture	Бордоська суміш
$MnO_2\cdot nH_2O$	Manganese (IV) Oxide Hydrate	Pyrolusite Black (mineral)	Піролюзитова чернь (мінерал)
NH_4Cl	Ammonia Chloride (solution)	Sal Ammoniac	Нашатир
NH_4NO_3	Ammonium Nitrate	Ammonium Nitre	Аміачна селітра
NH_4OH	Ammonium Hydroxide	Ammonia Water, Aqueous/liquid Ammonia	Аміачна вода, водний аміак
N_2O	Nitrogen (I) oxide	Laughing Gas	Веселящий газ
$Na_2CO_3\cdot 10H_2O$	Sodium Carbonate Decahydrate	Washing Soda	Сода кристалічна, важка, побутова, для прання
$NaCl$	Sodium Chloride	Table salt	Столова сіль
$NaHCO_3$	Sodium HydroCarbonate	Baking Soda	Харчова сода, бікарбонат, питна

1	2	3	4
$NaNO_3$	Sodium Nitrate	Chile Saltpetre	Натрієва (чилійська самородна) селітра
$NaOH$	Sodium Hydroxide	Lye, Caustic Soda	Їдкий натрій, луг
$Na_3PO_4 \cdot 10H_2O$	Sodium Phosphate Decahydrate	TSP	Тринатрій фосфат (компонент пральних засобів)
$Na_2S_2O_3$ or $Na_2S_2O_3 \cdot 5H_2O$	Sodium Thiosulfate or Sodium Thiosulfate Pentahydrate	Antichlor	Антихлор, тіосульфат натрію, натрій гіпосульфіт
$Na_2B_4O_7 \cdot 10\ H_2O$	Sodium Tetraborate Decahydrate	Borax	Бура
$Na_2SO_4 \cdot 10\ H_2O$	Sodium Sulfate Decahydrate	Glauber’s Salt	Глауберова сіль
P_2O_5 or P_4O_{10}	Phosphorus (V) Oxide	Phosphoric Anhydride	Фосфорний ангідрид
$2PbCO_3 \cdot Pb(OH)_2$	Lead (II) Carbonate-Hydroxide-	White Lead	Свинцеві білила (художня фарба)
$Pb(CH_3COO)_2x$ $x3H_2O$	Lead (II) Acetate Trihydrate	Lead Sugar	Свинцевий цукор
PbO	Lead (II) Oxide	Litharge	Свинцевий глет
PbS	Lead (II) Sulphide	Galena, Lead Glance (mineral)	Галеніт, свинцевий блиск
S	Sulfur (Sulphur)	Brimstone	Самородна (у вигляді грудочок) сірка

1	2	3	4
SO_3	Sulfur (VI) Oxide	Sulfuric Anhydride	Сірчаний ангідрид
SiO_2	Silicon (IV) Oxide	Quartz, Sand	Кварц, пісок, біла сажа
Solution of (15,5-60%) SO_3 in H_2SO_4	-	Oleum	Олеум
TiO_2	Titanium (IV) Oxide	Titanium White	Титанові білила
$ZnSO_4 \cdot 7\ H_2O$	Zinc (II) Sulfate Heptahydrate	Zinc Vitriol	Цинковий купорос
ZnO	Zinc Oxide	Zinc White	Цинкові білила

Chemical formula. A correctly written chemical formula must represent the known facts about the analytically determined composition of a compound. Care must be taken that subscripts are correct. The two formulas below

H_2O	H_2O_2
Water	Hydrogen peroxide

represent different compounds with very different characteristic properties.

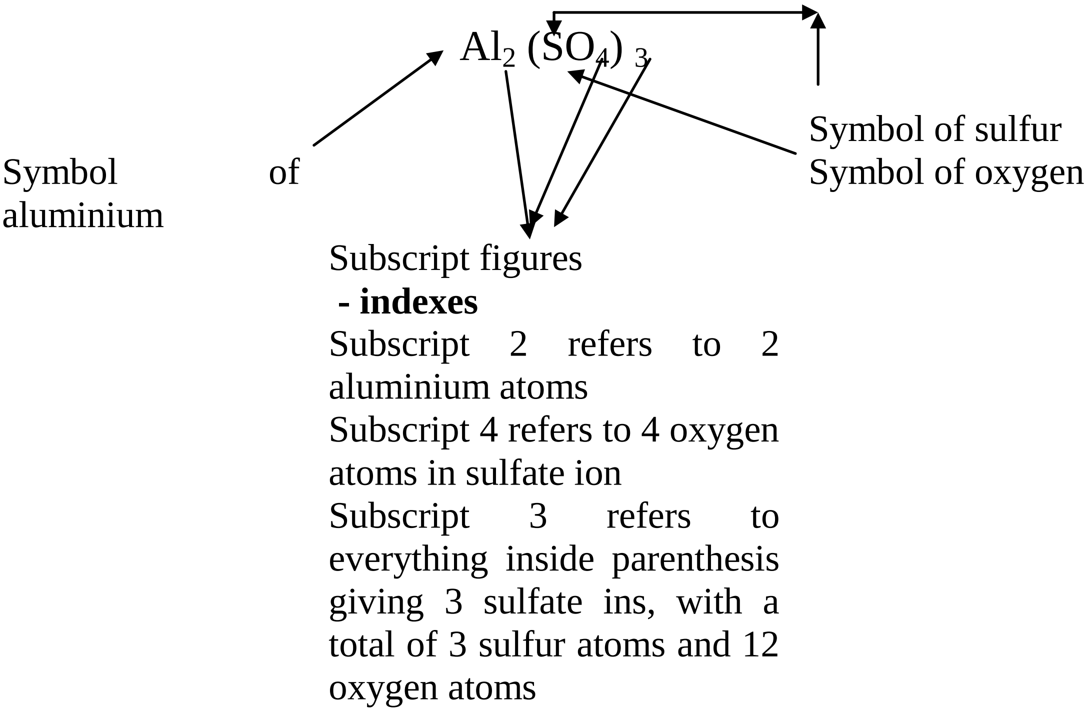
But practically chemical formulas are compiled basing on the ideas of valency and oxidation numbers of the elements.

For example, aluminium sulfate contains the sulfate ion and is clearly an ionic compound. Ionic compounds consist of huge numbers of positive and negative ions held together by mutual attraction. The formula therefore represents one formula unit - not just a molecule.

One formula unit of aluminium sulfate consists of 2 aluminium ions and 3 sulfate ions. Note in the fire below how the parentheses are used. They surround the polyatomic ion as a unit. The subscript 3 applies to the entire unit within the parentheses.

One formula unit of aluminium sulfate is therefore composed of 2 aluminium atoms, 3 sulfur atoms and 12 oxygen atoms.

Structure of the one simplest unit of aluminium sulfate



Subscript 2 refers to 2 aluminium atoms

Subscript 4 refers to 4 oxygen atoms in sulfate ion

Subscript 3 refers to everything inside parenthesis giving 3 sulfate ins, with a total of 3 sulfur atoms and 12 oxygen atoms

How to compile chemical formula, basing on the systematic name of compound.

Example 1. Write the formula for tin (IV) sulfate.

Solution.

Step 1. Write the symbol of tin (see Appendix 1, The elements - their symbols, atomic numbers and atomic masses) – **Sn**;

Step 2. Word "sulfate" means an acidic residue of sulfate acid – | $\mathbf{(SO_4)}^{2-}$ (see Appendix 2, Formulas of the some acids and names of their anions);

Step 3. Write the symbols for the particles side by side, with the positive charged atom of metal (Sn^{4+}) first:

Sn^{4+} $(SO_4)^{2-}$;

Step 4. Cross over the charge values to give subscripts:

Sn^{4+}_2 $(SO_4)^{2-}_4$;

Step 5. Check the subscripts and write the formula.

The total positive charge is 2 x 4+ = 8+. The total negative charge is 4 x 2- = 8-. The charges are equal. Because ionic compounds are represented in the smallest possible whole-number ratio, the ratio 1:2 should be used instead of 2:4. The correct formula is therefore $Sn(SO_4)_2$.

Using of oxidation numbers. Oxidation numbers, also called oxidation states, are assigned to the atoms in molecules, including molecular ions, to show the general distribution of electrons among the bonded atoms.

The next simple rules may be used for calculation of oxidation numbers of the most atoms in molecules of inorganic and organic substances:

1. The algebraic sum of the oxidation numbers of all atoms in a neutral compound is zero;
2. The algebraic sum of the oxidation numbers of all atoms in polyatomic ion is equal to the charge of the ion;
3. An **uncombined element** (in the free state) has an oxidation number of zero. Thus, the atoms of Na, O_2, O_3, P_4, and S_8 all have oxidation number of zero;
4. A monoatomic ion has an oxidation number equal to the charge of ion. Thus, ion Na^+, Ca^{2+}, Cl^- have oxidation numbers of +1, +2, and -1, respectively;
5. **Fluorine F** has an oxidation number of -1 in all of its compounds, because it is the most electronegative element;
6. **Oxygen O** has an oxidation number of -2 in. almost all compounds (except in peroxides such as H_2O_2, where it is -1, in superoxides such KO_2, where it is -½; and in compounds with halogens, such as OF_2, where it is +2;
7. **Hydrogen H** has an oxidation number of +1 in all compounds with more electronegative elements, and an oxidation number of -1 in compounds with metals known as hydrides, such as NaH and CaH_2;
8. **Silver Ag** has an oxidation number of +1 in all compounds;
9. **Alkali metals** in the form of ions **(Li, Na, K, Cs, Rb, Fr)** have an oxidation number of +1 in all their compounds;
10. **Alkali-earth metals** in the form of ions **(Ca, Ba, Sr, Ra)** have an oxidation number of +2 in all their compounds;
11. **Magnesium Mg** and **Zinc Zn** in the form of ions have an oxidation number of +2 in all their compounds;
12. **Aluminium Al** in the form of ion has an oxidation number of +3 in all their compounds practically.

Rules 1 and 2 make it possible to assign oxidation numbers where they are not known. The total of the known and unknown oxidation numbers must satisfy rule 1 and 2, as illustrated in the samples below.

Example 2. Assign oxidation numbers to each atom in the following compounds or ions: a) UF_6; b) $GeCl_2$; c) ClO_3^-; d) $Na_2S_4O_6$; e) C_6H_6.

Solution.

a) In **UF_6**, fluorine has oxidation number -1 as it does in all compounds in which it is presented. Therefore, uranium U has oxidation number +6:

$\overset{+6}{U}\overset{-1}{F}_6$ Oxidation no. total = (+6) + (6 x -1) = 0.

b) In **$GeCl_2$,** chlorine is assigned the oxidation number it would have as an ion, -1 (see Appendix 2). Therefore, germanium in this compound has oxidation number +2.

$\overset{+2}{Ge}\overset{-1}{Cl}_2$ Oxidation no. total = (+2) + (2 x -1) = 0.

c) In **ClO_3^-**, oxygen has oxidation number -2. the total oxidation number due to the three oxygen atoms is therefore -6. For the chlorate ion to have a 1- charge, chlorine must be assigned an oxidation number of +5.

$(\overset{+5}{Cl}\overset{-2}{O}_3)^{1-}$ Oxidation no. total = (+5) + (3 x -2) = -1.

d) In **$Na_2S_4O_6$,** according to the rules, sodium has oxidation number +1 and oxygen has oxidation number -2 with a total positive oxidation number of +2 for the two sodium atoms, and a total negative oxidation number of -2 x 6 = -12 for the six oxygen atoms, sulfur must have an oxidation number of +10 : 4 = + 2½.

$$\overset{+1}{Na}_2\overset{+2,5}{S}_4\overset{-2}{O}_6$$

Oxidation no. total = (+1 x 2) + (4 x +2,5) + (6 x -2) = 0.

e) In **C_6H_6**, according to rule 7 (see above), hydrogen has oxidation number +1, because it connects with carbon having more electronegativity (2,1 and 2,5 correspondently) (see Appendix 3). So, total positive charge for six hydrogen atoms is +1 x 6 = + 6. Therefore, six atoms of carbon C have total oxidation number -6, one carbon C has oxidation number -1.

$\overset{-1}{C}_6\overset{+1}{H}_6$ Oxidation no. total = (6 x +1) + (6 x -1) = 0.

Amount of substance. Mole. Avogadro's Number. Molar mass

Three very important concepts - the mole, Avogadro's number and molar mass - provide the basis for relating masses in grams to numbers of atoms. The first, the mole, is the SI unit for amount of substance. **The mole** is the amount of a substance that contains the same number of particles as the number of atoms in exactly 12 g of ^{12}C. The abbreviation for the mole is **mol**. The mole is a counting unit, like one dozen. In writing, a chemist might refer to 1 mol of Carbon, or 2 mol of Iron, or 2,567 mol of calcium. Amount of substance (in mol) is indicated as Greek letter υ.

The number of particles in a mole has been experimentally determinated in a number of ways. The best modern value is $6{,}022137 \cdot 10^{23}$ particles. This number is of such importance to chemistry that it is named in honor of the Italian scientist Amedeo Avogadro (1776-1856), whose ideas were crucial in the early understanding of chemistry. **Avogadro's number N_A**- $6{,}022137 \cdot 10^{23}$ - is the number of particles in exactly one mole of each pure substance. In most cases, Avogadro's number is rounded to $6{,}02 \cdot 10^{23}\ \frac{1}{\text{mol}}$ (or mol^{-1}).

Molar mass (M_m) is the mass in grams of one mole of pure substance (g/mol). Molar masses of elements contain equal numbers of atoms. One mole of a substance is one molar mass of this substance. An alternative definition of the mole is the amount of a substance that contains an Avogadro's number of particles of chemical units.

The molar mass is used as the conversion factor in chemical calculations. For a specific substance, a known number of grams can be converted into moles or a known number of moles can be converted into grams. Figure 1 shows the conversions of molar mass, moles, and Avogadro's number.

In general, mass of any chemical substance (in grams) is connected with amount of this substance by the next ratio:

$$\nu = \frac{m}{M_m}, \tag{1}$$

where ν - amount of any pure substance (mol or kmol);

m - mass of any pure substance (g or kg);

M_m - molar mass (g/mol or kg/kmol).

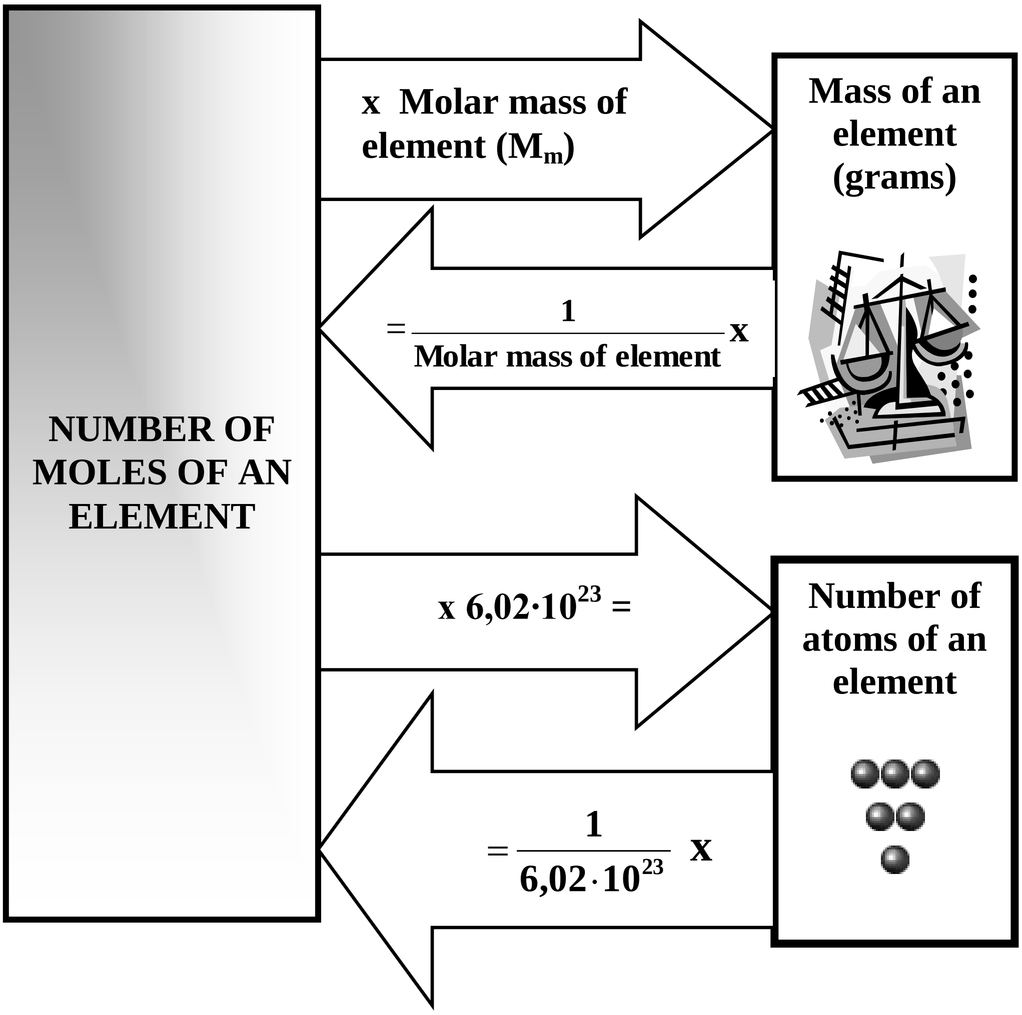
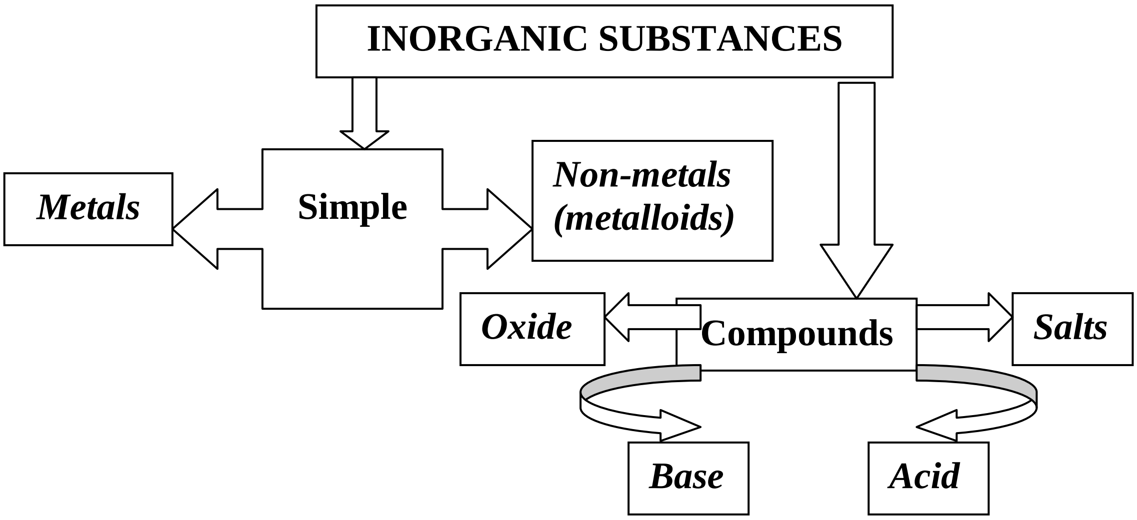


Figure 1. Relationships between mass, the number of moles, and the number of atoms of an element in the sample

CHAPTER 2. CLASSIFICATION OF INORGANIC SUBSTANCES. TYPES OF THE CHEMICAL REACTIONS



All varieties of inorganic substances may be subdivided into four main types: oxides, bases (hydroxides), acids, and salts.

Non-metals (metalloids) include the next groups of chemical elements with closely related properties:

Noble (rare) gases - elements of VIII-A subgroup of Periodical Table (He; Ne; Ar; Kr; Xe; Rn);

Halogens - elements of VII-A subgroup of Periodical Table (F, Cl, Br, I, At);

Chalcogens - elements of VI-A subgroup of Periodical Table (O, S, Se, Te), except Po;

Elements of V, IV, III groups of Periodical Table - N, P, As, C, Si, B, H.

Metals include some groups of chemical elements with similar properties:

Alkali(ne) metals - elements of I-A subgroup of Periodical Table (Li, Na, K, Rb, Cs, Fr);

Alkaline-earth metals, earth metals - some elements of II-A subgroup of Periodical Table (Ca, Sr, Ba, Ra);

Family of Iron - Fe, Co, Ni;

Family of noble metals *(Family of* Platinum*)* - Ru, Rh, Pd, Os, Ir, Pt;

Lanthanide Series - elements of periodical table from № 58 till № 71, their properties are very similar to element La (Lanthanum);

Actinide Series - elements of periodical table from № 90 till № 103, their properties are very similar to element Ac (Actinium).

Table 2. Types of chemical reactions

Type	**Scheme**	**Example**
Synthesis (combination, construction, composition) reactions	X + Y = Z, where X, Y are elements or compounds; Z - new compound	$2\ H_2 + O_2 = 2H_2O$; $H_2O + SO_3 = H_2SO_4$; $K_2O + CO_2 = K_2CO_3$
Decomposition (desythesis, decomposition, deconstruction) reactions	XZ = X + Z	$2\ KClO_3 \xrightarrow{t} 3\ O_2\uparrow + 2\ KCl$; $6NaHCO_3 \xrightarrow{t} 3\ Na_2CO_3 + 3\ CO_2\uparrow + 3H_2O$; $2\ AgI \xrightarrow{t} 2\ Ag + I_2$
Single replacement (single displacement, single substitution, activity replacement) reactions	A + BX = B + AX	$2\ Mg + TiCl_4 \xrightarrow{t} Ti + 2\ MgCl_2$; $2\ Al + 6\ CaO \xrightarrow{t} Ca_3(AlO_3)_2 + 3\ Ca$;
Double replacement (double displacement or metathesis) reactions	AB + CD = AD + CB	$AgNO_3 + KCl = AgCl\downarrow + KNO_3$; $TiCl_4 + H_2O = 4\ HCl\uparrow + TiO_2\downarrow$; $HCl + NaOH = NaCl + H_2O$
Oxidation-reduction reactions (Red-Ox)	$A^{z} + n\ \bar{e} \rightarrow A^{(z\ -\ n)}$ $B^{y} - m\ \bar{e} \rightarrow B^{(y+m)}$	$2Na + S \rightarrow Na_2S$; $2\ KMnO_4 \xrightarrow{t} K_2MnO_4 + MnO_2 + O_2$
Acid-Base reactions (neutralization)	$H^{+} + OH^{-} \rightarrow H_2O$ (in net ionic form)	$H_2SO_4 + 2\ NaOH = Na_2SO_4 + 2H_2O$

LABORATORY TRAINING

Experiment 1. Interaction between oxides and water

To add a few grains of solid CaO, CuO, ZnO (total volume of each chemicals - near one match-head) into three tubes. To add 10-20 drops of distilled water into each tube. To mix a tube content. What oxides do directly react with water? To write a corresponding reaction.

Experiment 2. Preparation of insoluble hydroxides

To add separately 1-4 drops of each soluble Iron (III) salts ($FeCl_3$ or $Fe_2(SO_4)_3$), Copper ($CuSO_4$ or $CuCl_2$ or $Cu(NO_3)_2$), Manganese (II) ($MnSO_4$ or $MnCl_2$), and Nickel ($NiSO_4$), Cobalt (II) ($CoSO_4$ or $CoCl_2$) into tubes #1, 2, 3, 4, 5. To add 1-2 drops of any alkali into each tube. What do you observe? To write corresponding reactions. To point out color of precipitate in each tube. To explain why color of Manganese (II) Hydroxide is changed.

Experiment 3. Preparation of amphoteric hydroxides

To add 1 drop of any alkali (NaOH or KOH) into three tubes. To add by drops the solution of Aluminium salt (for example, $Al_2(SO_4)_3$) into tube # 1 up to the precipitate appearance; into tube # 2 - Zinc salt (for example, $ZnSO_4$) analogously to previous case; into tube # 3 - Chromium (III) salt (for example, $Cr_2(SO_4)_3$).

To divide each prepared precipitate into two tubes. To add solution of any acid (for example, HNO_3) to the first part of precipitate, alkali solution up to the whole dissolving of precipitate - to the second one. What do you observe? To write corresponding reactions.

Experiment 4. Interaction of salts solution (metathesis)

To add 2-3 drops of $BaCl_2$ solution into tube # 1 and to drop the same quantity of Sodium Sulfate; 2-3 drops of Lead (II) Nitrate - into tube # 2 and to add 1-2 drops of Potassium Iodide; 2-3 drops of Cobalt (II) Sulfate into tube # 3 and to add 1-2 drops of Sodium Hydrophosphate. What do you observe? To write corresponding reactions.

CHAPTER 3. ATOMIC STRUCTURE. CHEMICAL BONDING

Atom is an electroneutral particle consisted of positive charged nucleus and negative charged electrons. Nucleus is a positive charged component of atom concentrated practically all its mass. Components of nucleus are s (*p)* and s (*n*). Sum of protons and neutrons is equal to relative atomic mass (A_r):

$A_r = \sum \ p^+ + n^0$

Nucleus charge of atom is equal to number of element in Periodical Table (Z).

Example: To consider structure of atom *Na:*

Z (*Na*) = 11

$A_r(Na)=23$ $\quad {}^{23}_{11}Na$

Positive charge of atomic nucleus – 11

Number of electrons - 11

In nucleus: p^+*-11*

n^0*-12 (* $A_r - p^+$*)*

Motion of electrons around nucleus is described by energy and structure of atomic orbital. State of electron is described by values of 4 quantum figures (Tables 3, 4).

Table 3. Names and physical content of quantum figures

Names	Symbol	What's determined?	Possible values
Main (Principal)	*N*, *n*	Orbital energy (main energy level)	Algebraic integers from 0 to ∞ (infinity)
Secondary (Azimutal)	*l*	Orbital form (energy sub-level)	Algebraic integers from 0 to *n*-1
Magnetic	m_l	Spatial orientation of orbital	From *–l to +l* ($m_l=2l+1$)
Spin	m_s	Own magnetic moment of electrons	+ ½ and - ½

Table 4. Schematic description of atomic orbital

l		m_l	Quantity of orbitals	Schematic imagination
0	s	0	1	□
1	p	-1 0 +1	3	□□□
2	d	-2 –1 0 +1 +2	5	□□□□□
3	f	-3 –2 –1 0 +1 +2 +3	7	□□□□□□□

Principles for distribution of electrons in atoms

Distributions of electrons in atoms on energy levels and sub-levels may be presented in the form of electronic formulas.

It may be compelled in the following way:

- Note Arabian figure, which indicates the main quantum figure (energy level);
- Note symbol of orbital, that determined electronic sub-level;
- Quantity of electrons on this sub-level is made by Arabian figure above it in the right upper corner.

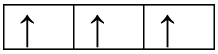
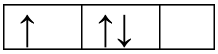
Example:

To show electronic formula of Nitrogen: $_7N$ $1s^2 2s^2 2p^3$. Atom of Nitrogen has 7 electrons, 2 - on the first level on *s*-sub-level, and 5 others – on the second level, *s* and *p*-sub-levels.

Principles, according to which the electrons are distributed in atoms, are shown in the Table 5.

Table 5. General rules for electronic formulas compilation

Name	**Formulation**	**Using**
1	2	3
Principle of energy minimum	Minimum of energy responds to the most stable state of electrons in atom	Electron occupies a atomic orbital with minimum energy

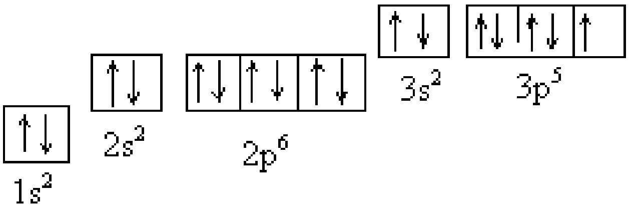
1	2	3
Pauli's Principle	Atom may not have two electrons with the same values of all four quantum figures	N=2n^2 (quantity of $\bar{e}$ on the level) Max quantity of $\bar{e}$ on the sub-level is equal to *2·(2l+1)* s=2; p=6; d=10; f=14
Rule of Klech-kovsky	Energy sub-levels are filled up according increasing of sum n+l	Indicate an order of sub-levels occupation
Rule of Hound	Summary spin value of electrons on sub-level must be maximum	Indicate an order of occupation of equal atomic orbitals:  Correct  Incorrect

Valency and Oxidation number as function of electrons distribution.

Using electron formulas, possible values of valence and oxidation numbers for chemical elements may be predicted.

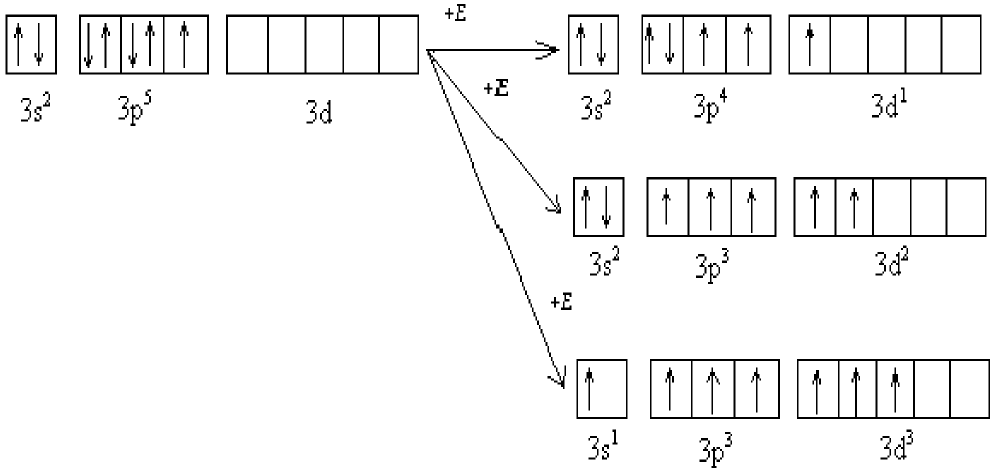
In general case valence is equal to the quantity of unpaired electrons on the last (for s- and p-elements) and next to last (for d-elements) sub-levels.

Example. $_{17}Cl$ **$1s^22s^22p^63s^23p^5$**



Ground state

Electrons located on the last, third level, may go into free *d*-sublevel when atom was excited.



Excited states

According to this idea, valence of Chlorine may be equal to **I** (normal state), **III** (the first excited state), **V** (the second excited state) and **VII** (the last, third excited state).

For estimation of oxidation number the theory of "**octet configuration"** must be used. It says that all atoms pressing towards to obtain the same configuration of the last electron shell are similar to noble (indifferent) gases. Why? Because the noble gases are the most stable chemical elements and they have 8 (excluding He) electrons on the last electron shell (ns^2np^6). Chemical elements may form configuration like noble gases giving up unpaired electrons to other atoms or joining them from other atoms. If after such operation atom has structure of last or next to last electron shell absolutely like noble gas it will be stable. If its configuration is not "ideal", we may predict that such one is not stable and of course compounds included these atoms.

According to this theory, we may predict that in the first (normal) state atom of Chlorine may have three figures of oxidation number: -1 (when it joined one unpaired electron from any other atom); 0 (without interchange of electrons with other atoms) and +1 (when it lost one electron). Only the first figure of oxidation number will respond to an octet configuration of the last electron shell ($3s^2 3p^6$) and Cl^{-1} is a stable oxidation number for this chemical elements. Truly in nature this element exists only in the form of Chlorides where Chlorine has oxidation number –1.

Let's consider the first excited state of Chlorine atom. We see, that there are 3 unpaired electrons on the last electron shell. What can be said about possible degree of oxidation? The first possibility – to join 3 electrons from other atom and to have oxidation number –3. This state in not stable, because atom has not octet configuration. If it lost 3 elections, its configuration is more stable, because atom has two pairs of electrons.

Analogously it may be shown that oxidation numbers of Chlorine in the second and third excited states will be equal to +5 and +7. Oxidation number +5 is more stable that +1 and +3, but the most stable compounds respond to oxidation number +7.

Note, that valence and oxidation number are the different notions. Oxidation is the virtual figure, mathematical value. For example, in molecules H_2 and O_2 oxidation numbers are equal to 0, but valence is equal to 1 and 2 correspondingly.

Types of chemical bonding

An ionic bond is the *chemical bond resulting from electrostatic attraction between positive and negative ions*. If these is a **purely** ionic bond, one atom has completely given up one or more electrons, and another atom has gained them - as illustrated for two atoms that each have one unpaired electron at the top in **Figure 2**.

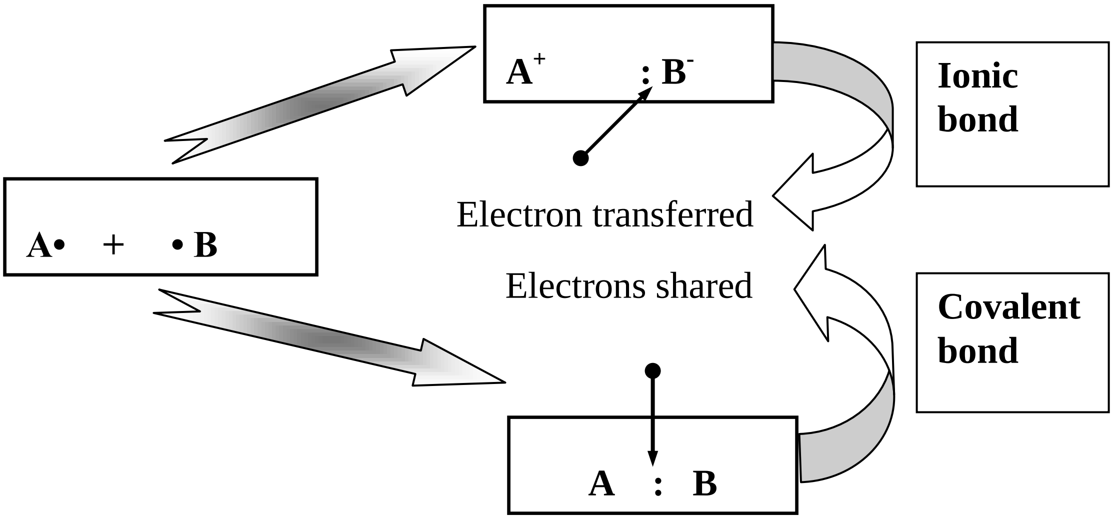


Figure 2. Two main types of chemical bond formation

In the second major type of chemical bond, called covalent bond, neither bonding atom completely loses or gains an electron or electrons. A **covalent bond** is a chemical bond resulting from the sharing of electrons between two atoms. A covalent bond in which two electrons are shared is represented by a pair of electron dots, as shown at the bottom right-hand corner in Fig. 2. In a purely covalent bond, the shared electrons are "owned" equally by the two atoms.

Chemical bonds between unlike atoms are never completely ionic and rarely completely covalent. Bonds can be anywhere in the range between the bonded atoms attract electrons.

The degree to which bonds are ionic or covalent can be estimated by comparing of electronegativity of the bonded atoms. The more two atoms differ in electronegativity, the more ionic the bond is between them. In other words, the electrons spend more time close to the bonded atom that attracts them more strongly and hence cause that atom partially resemble an anion and the other atom, a cation.

Fig. 3 can be used to classify bonds according to electronegativity differences. The electronegativity (see **Appendix 3**) of one bonded atom is subtracted from that of the other. For example, the electronegativity difference between a Cesium (Cs) atom and a Fluorine (F) atom is 4,0 - 0,7 = 3,3. According to Fig. 3, a Cesium-Fluorine bond is an ionic one. In fact it is one of the most highly ionic bonds known.

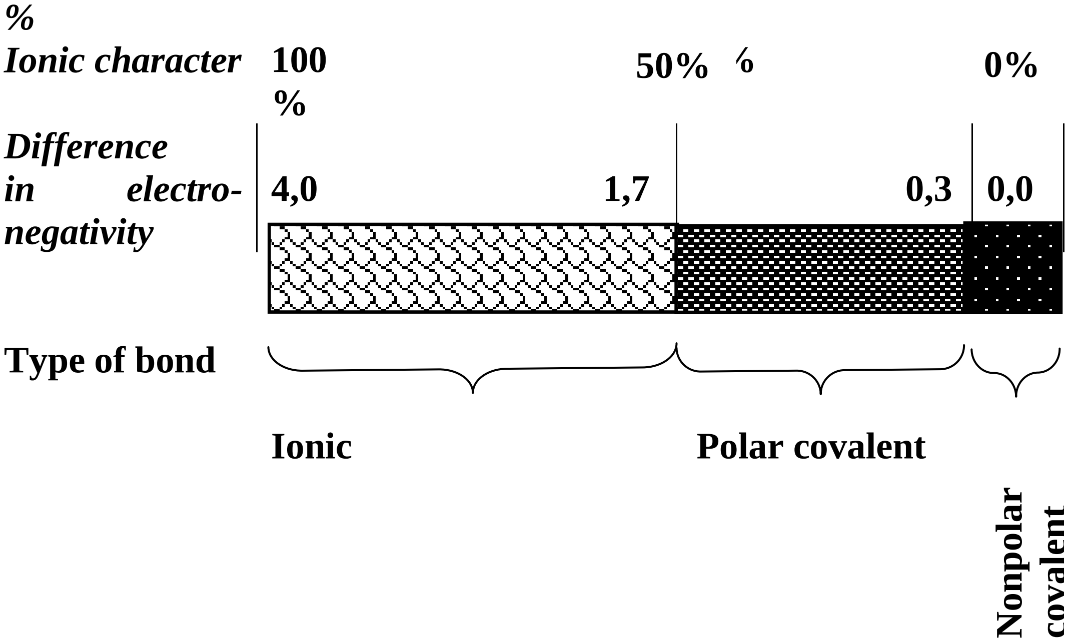


Figure 3. The variation of bond type with percent ionic character and the electronegativity difference between the bonded atoms

Bonds that have an ionic character of 50% or less are classified as covalent bonds. A bond between identical atoms is completely covalent. Hydrogen, for example, exists in nature not as isolated atoms, but as pairs of atoms held together by covalent bonds, H:H. The Hydrogen-Hydrogen bond has 0% ionic character. It is **non-polar covalent bond,** *a covalent bond in which the bonding electrons are shared equally by the bonded atoms, with a resulting balanced distribution of electrical charge.* Bonds having 0%-5% ionic character, corresponding to electronegativity differences of roughly 0 to 0,3, are generally considered as non-polar covalent bonds. For example, because the electronegativity difference between Hydrogen (H) and Boron (B) is 0,1, they form a bond that is essentially non-polar.

In bonds with significantly different electronegativities, the electrons are more attracted to the more electronegative atom. Such bonds are **polar,** meaning that they have an uneven distribution of charge. Covalent bonds having 5%-50% ionic character are classified as polar. A **polar-covalent bond** *is a covalent bond in which the united atoms have an unequal attraction for the shared electrons.*

CHAPTER 4. REACTIONS IN AQUEOUS SOLUTIONS

Many chemical and almost all biological reactions occur in the aqueous medium. Substances (solutes) that are dissolved in water (solvent) can be subdivided into two categories: electrolytes and non-electrolytes, depending on the ability to conduct electricity.

Suppose a lump of sugar is dropped into a glass of water. You know from experience that the sugar will be dissolved. Sugar is described as "soluble in water". By "soluble" we mean the capability of being dissolved. Examination of sugar-water mixture, even under a microscope, would not reveal any particles of sugar. Such a mixture is called **"solution"**. Solution is a homogenous mixture of two or more substances in a single phase. In solution, atoms, and molecules of charged particles - ions are thoroughly mixed, with the result that the mixture has the same composition and properties throughout.

In the simplest type of solution, such as sugar-water solution, the molecules of one substance are distributed around the molecules of another one. The dissolving medium in a solution is called **solvent**, and the substance dissolved in a solution is called **solute**. In general, the solute is the substance, which mass is less than 50% of total mass of solution.

Three major types of reactions.

In the precipitation reaction, the product, an insoluble substance, separates from solution. Acid-base reactions involve the transfer of a proton (H^+) from an acid to a base. In a oxidation-reduction reaction, or redox reaction, electrons are transferred from a reducing agent to an oxidizing agent. These three types of reactions represent the majority of reactions in chemical and biological systems.

Solution Stoichiometry

Quantitative studies of reactions in solution require that we know the concentration of the solution, which is usually represented by the molarity unit. These studies include **gravimetric analysis**, which involves the measurement of mass, and **titrations** in which the unknown concentration of a solution is determined by reaction with a solution of known concentration.

Table 6. Common Units for reporting concentrations

Name	Units*	Symbol
1	2	3
Molarity (molar concentration)	$\frac{\text{moles solute}}{\text{liters solution}}$	M (for example, 2 M NaOH)
Normality (equivalent concentration)	$\frac{\text{numbers EWs solute}}{\text{liters solution}}$	N (for example, 0,05 N EDTA)

1	2	3
Molality	$\frac{\text{moles solute}}{\text{kg solvent}}$	*m* (for example, 1 *m* glucose)
Mass concentration (weight %)	$\frac{\text{g solute}}{\text{100 g solution}}$	% (w/w) (for example, 5% HCl)
Bulk concentration (volume %)	$\frac{\text{g solute}}{\text{100 mL solution}}$	% (v/v) (for example, 40% vol C_2H_5OH)
Parts per thousand	$\frac{\text{g solute}}{10^3\ \text{g solution}}$	ppt (for example, 5 ppt carbamide)
Parts per million	$\frac{\text{g solute}}{10^6\ \text{g solution}}$	ppm (for example, 10 ppm benzene)
Parts per billion	$\frac{\text{g solute}}{10^9\ \text{g solution}}$	ppb (for example, 20 ppb thyroxin)
*EW – equivalent weight		

The most useful unit in analytical practice and pharmacology are normality and molarity.

So, remember:

MOLARITY – the number of moles of solute per liter of solution	**NORMALITY – the number of equivalents of solute per liter of solution**
EQUIVALENT – the moles of a species that can donate one reaction unit	**EQUIVALENT WEIGHT – the mass of a compound containing one equivalent (EW)**

The numbers of equivalents, ν_E, is based into reaction unit, which is that part of a chemical species involved in a reaction. In a precipitation reaction, for example, the reaction unit is the charge of the cation or anion involved in the reaction; thus for the reaction

Pb^{2+} (aq) + $2I^-$ (aq) → PbI_2 (solid)

n = 2 for Pb^{2+} and n = 1 for I^-.

In an acid-base reaction, the reaction unit is the number of H^+ ions donated by an acid or accepted by a base. For the reaction between sulfate acid and ammonia

H_2SO_4 (aq) + $2NH_3$ (aq) → $2NH_4^+$ (aq) + SO_4^{2-} (aq)

we find that n = 2 for H_2SO_4 and n = 1 for NH_3.

For a complexation reaction, the reaction unit is the number of electron pairs that can be accepted by the metal or donated by the ligand. In the reaction between Ag^+ and NH_3

$Ag^+ (aq) + 2NH_3 (aq) \rightarrow [Ag(NH_3)_2]^+ (aq)$
the value of *n* for Ag^+ is 2 and that for NH_3 is 1.

Finally, in an oxidation-reduction reaction the reaction unit is the number of electrons released by the reducing agent or accepted by the oxidizing agent; thus, for the reaction

$2Fe^{3+} (aq) + Sn^{2+} (aq) \rightarrow Sn^{4+} (aq) + 2Fe^{2+} (aq)$

n = 1 for Fe^{3+} and n = 2 for Sn^{2+}. Clearly, determining the number of equivalents for a chemical species requires an understanding of how it reacts.

Normality is the number of **equivalent weights** (EW) per unit volume and is independent of speciation. An equivalent weight is defined as the ratio of a chemical species' **formula weight** (FW) **or molar mass (M_m)** to the number of its equivalents:

$$EW = \frac{M_m}{n} \quad (2)$$

Consequently, the following simple relationship exists between normality and molarity:

$$N = n \cdot M \quad (3)$$

Example 1 illustrates the relationship among chemical reactivity, equivalent weight, and normality

Calculate the equivalent weight and normality for a solution of 6.0 M H_3PO_4 given the following reactions:

a) $H_3PO_4 (aq) + 3NaOH (aq) \rightarrow Na_3PO_4 (aq) + 3H_2O$ (liquid);
b) $H_3PO_4 (aq) + 2NH_3 (aq) \rightarrow (NH_4)_2HPO_4 (aq)$;
c) $H_3PO_4 (aq) + NaF (aq) \rightarrow NaH_2PO_4 (aq) + HF(aq)$.

Solution

For phosphoric acid, the number of equivalents is the number of H^+ ions donated to the base. For the reactions in (a), (b), and (c) the number of equivalents are 3, 2, and 1, respectively. Thus, the calculated equivalent weights and normalities are:

$$EW = \frac{M_m}{n} = \frac{97{,}994}{3} = 32{,}665; \qquad N = n \cdot M = 3 \cdot 6{,}0 = 18\ N;$$

$$EW = \frac{M_m}{n} = \frac{97{,}994}{2} = 48{,}997; \qquad N = n \cdot M = 2 \cdot 6{,}0 = 12\ N;$$

$$EW = \frac{M_m}{n} = \frac{97{,}994}{1} = 97{,}994; \qquad N = n \cdot M = 1 \cdot 6{,}0 = 6\ N.$$

Molality is used in thermodynamic calculations where a temperature independent unit of concentration is needed. Molarity and normality are based on the volume of solution in which the solute is dissolved. Since density is a temperature depended property a solution's volume, and thus its molar and normal concentrations, will change as a function of its temperature. By using the solvent's mass in place of its volume, the resulting becomes independent of temperature.

Converting between concentration units

The units of concentration most frequently encountered in analytical chemistry and pharmacology, are Molarity, mass (weight) concentration, volume percent, ppm and ppb. By recognizing the general definition of concentration, it is easy to convert between concentration units.

Example 2. A concentrated solution of aqueous ammonia is 28% NH_3 and has a density of o,899 g/mL. What is the molar concentration of NH_3 in this solution?

Solution

$$\frac{28\text{ g NH}_3}{100\text{ g solution}}\ \text{x}\ \frac{0{,}899\text{ g solution}}{\text{mL solution}}\ \text{x}\ \frac{1\text{ mole NH}_3}{17{,}04\text{ g NH}_3}\ \text{x}\ \frac{1000\text{ mL}}{\text{liter}} = 14{,}8\text{ M.}$$

Example 3. The maximum allowed concentration of chloride in a municipal drinking water supply is $2{,}5\cdot10^2$ ppm Cl^-. When the supply of water exceeds this limit, it often has a distinctive salty taste. What is this concentration in moles Cl^- per liter?

Solution

$$\frac{2{,}5\cdot10^2\text{ mg Cl}^-}{\text{L}}\ \text{x}\ \frac{1\text{ g}}{1000\text{ mg}}\ \text{x}\ \frac{1\text{ mole Cl}^-}{35{,}453\text{ g Cl}^-} = 7{,}05\cdot10^{-3}\text{ M.}$$

Table 7. Solubility Rules for Ionic Compounds in Water

Soluble Salts
1. The Na^+, K^+, and NH_4^+ ions form *soluble salts*. Thus, NaCl, KNO_3, $(NH_4)_2SO_4$, Na_2S, and $(NH_4)_2CO_3$ are soluble.
2. The nitrate (NO_3^-) ion forms *soluble salts*. Thus, $Cu(NO_3)_2$ and $Fe(NO_3)_3$ are soluble.
3. The chloride (Cl^-), bromide (Br^-), and iodide (I^-) ions generally form *soluble salts*. Exceptions to this rule include salts of the Pb^{2+}, Hg_2^{2+}, Ag^+, and Cu^+ ions. $ZnCl_2$ is soluble, but CuBr is not.
4. The sulfate (SO_4^{2-}) ion generally forms *soluble salts*. Exceptions include $BaSO_4$, $SrSO_4$, and $PbSO_4$, which are insoluble, and Ag_2SO_4, $CaSO_4$, and Hg_2SO_4, which are slightly soluble.

Insoluble Salts
1. Sulfides (S^{2-}) are usually *insoluble*. Exceptions include Na_2S, K_2S, $(NH_4)_2S$, MgS, CaS, SrS, and BaS.
2. Oxides (O^{2-}) are usually *insoluble*. Exceptions include Na_2O, K_2O, SrO, and BaO, which are soluble, and CaO, which is slightly soluble.
3. Hydroxides (OH^-) are usually *insoluble*. Exceptions include NaOH, KOH, $Sr(OH)_2$, and $Ba(OH)_2$, which are soluble, and $Ca(OH)_2$, which is slightly soluble.
4. Chromates (CrO_4^{2-}) are usually *insoluble*. Exceptions include Na_2CrO_4, K_2CrO_4, $(NH_4)_2CrO_4$, and $MgCrO_4$.
5. Phosphates (PO_4^{3-}) and carbonates (CO_3^{2-}) are usually *insoluble*. Exceptions include salts of the Na^+, K^+, and NH_4^+ ions.

THEORY OF ELECTROLYTIC DISSOCIATION

LABORATORY TRAINING

Experiment 1. Slightly soluble substances production

A) Put separately 5-6 drops of Na_2SO_4, $(NH_4)_2CO_3$, Na_3PO_4 solutions into three test-tubes and add 3-4 drops of $BaCl_2$ solution into each of them. What does happen? Draw molecular and net ionic equations.

B) Put 5-6 drops of $CuSO_4$ and $Cu(NO_3)_2$ solutions into two test-tubes. Add 4-5 drops of NaOH solution into one test-tube and 4-5 drops of $Ba(OH)_2$ into another. What does happen? Draw molecular and net ionic equations.

Experiment 2. Weak electrolytes production

Put 5-6 drops of CH_3COONa and $Pb(CH_3COO)_2$ solutions into two test-tubes, add 5-6 drops of 2 N HCl or 2 N H_2SO_4 into each of them. Heat the mixture and identify by odor the acetic acid vapor isolation. Draw molecular and net ionic equations.

Experiment 3. Gases production

A) Put 5-6 drops of NH_4Cl into the test-tube; add the same volume of NaOH. Heat the mixture on water bath. Identify by odor the kind of gas. Draw molecular and net ionic equations.

B) Put 0,01 - 0,02 g of $CaCO_3$ or $BaCO_3$ solid salt into the test-tube and add 4-5 drops of 2 N HCl solution. What does happen? Draw molecular and net ionic equations.

Experiment 4. Properties of amphoteric hydroxides and their production

Produce $Zn(OH)_2$ precipitation in two test-tubes by adding drops of $ZnSO_4$ solution to 1-2 drops of NaOH solution to forming of sediment. Add 5-6 drops of 2 N HCl into one test-tube and 5-6 drops of 2 N NaOH into another. What does happen with $Zn(OH)_2$ precipitation? Draw molecular and net ionic reactions of $Zn(OH)_2$ production and its dilution in acid and alkali.

CHAPTER 5. IONIC PRODUCT OF WATER. NOTION OF pH. HYDROLYSIS OF SALTS

Pure water conducts an electric current very poorly, but nevertheless it has a measurable electrical conductivity that is explained by the slight dissociation of water into hydrogen and hydroxide ions:

$$HOH \rightleftharpoons H^+ + OH^-$$

The concentration of hydrogen and hydroxide ions in water at 25°C is 10^{-7} mol/l. Let us write an expression for the dissociation constant of water:

$$K = \frac{[H^+]\cdot[OH^-]}{[H_2O]}.$$

We can rewrite this equation as follows:

$$K[H_2O]= [H^+][OH^-].$$

Since the degree of dissociation of water is very low, the concentration of undissociated molecules of H_2O in water virtually equals the total concentration of water, i.e. 55.55 mol/1 (1 litre contains 1000 grams of water, i.e. 100:18.02 = 55.55 moles). Therefore, replacing the product $[H_2O]$ ***K*** in the last equation with the new constant $\mathbf{K_w}$**,** we have:

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

The obtained equation shows that for water and dilute aqueous solutions at a constant temperature, the product of the hydrogen ion and hydroxide ion concentrations is a constant quantify. The latter is called the **ion product** of water.

It is not difficult to obtain its numerical value by introducing into the last equation the concentrations of the hydrogen and hydroxide ions. For pure water at 25 °C, we have $[H+] = [OH-] = 1\cdot10^{-7}$ mol/L.

Solutions in which the concentrations of the hydrogen ions and hydroxide ions are the same are called **neutral solutions**.

At 25°C, as we have already indicated, the concentration of both hydrogen ions and hydroxide ions in neutral solutions is 10^{-7} mol/L. If, for instance, we add so much acid to pure water that the hydrogen ion concentration grows to 10^{-3} mol/L, then the hydroxide ion concentration will diminish so that the product $[H^+][OH^-]$ remains equal to 10^{-14}. Consequently, in this solution, the hydroxide ion concentration will be:

$$10^{-14} = 10^{-3}\cdot x;$$

$$x= [OH^-] = \frac{10^{-14}}{10^{-3}} = 10^{-11}.$$

These examples show that both the degree of acidity and the degree of alkalinity of a solution can be characterised quantitatively by the hydrogen ion concentration.

The acidity or alkalinity of a solution can be expressed in another, more convenient way: instead of the hydrogen ion concentration, its common logarithm is taken with the reverse sign. The latter quantity is named the hydrogen ion index, but most chemists call it the pH-value or simply the pH:

$pH = - \lg [H^+]$.

Analogically $pOH = - \lg [OH^-]$.

For all water solutions it is realized such ratio:

$$\mathbf{pH + pOH = 14.}$$

For instance, if $[H^+] = 10^{-5}$ mol/L, then pH = 5, if $[H^+] = 10\text{-}^{9}$ mol/L, then pH = 9, and so on.

It is thus clear that for a neutral solution ($[H^+] = 10^{-7}$ mol/L), pH = 7 (at a temperature of 25°C). For acid solutions, pH < 7, and diminishes with an increasing acidity of the solution. Conversely, for alkaline solutions, pH > 7, and grows with an increasing alkalinity of the solution.

The pH is of great significance for many processes. For example, plants can grow normally only when the pH of the soil solution is within a definite interval characteristic of a given species of plant.

For example, *Hydrangea macrophylla* blossoms in pink or blue, depending on soil pH. In acidic soils, the flowers are blue; in alkaline soils, the flowers are pink.

Measurement of pH in Many Fields

Measuring pH is essential not only in finding the chemical characteristics of a substance but also as the first step toward managing chemical reactions. Currently, pH measurement is used in various fields, including nearly all industries that deal with water, not only the chemical industry, but public organizations, agriculture and fishery-related industries and biological industries, as well.

Textiles, Dyeing. In the textile industry, measuring pH is important in product testing, such as how a fabric reacts to things like perspiration, especially when developing synthetics, to ensure safety and durability. Of course, pH measurement is indispensable in the process of dyeing, because permanence and processing speed depend on the pH of the dye bath, which is automatically adjusted to maintain proper pH. Also, pH measurement is applied when creating artificial perspiration to be used in color-change testing.

Paper, Pulp. Measurement of pH is carried out in the manufacturing processes of paper and pulp more often and continuously than any other industry. To reduce the consumption of chemicals and prevent corrosion of equipment, pH is controlled in the process of digestion, bleaching, creating of pulp to the manufacture of finished paper material products. Also, the durability and drying speed depends on the pH of the paper itself. Therefore, pH is strictly checked and adjusted as a vital part of quality control.

Chemistry. As pH measurement is essential for control of chemical reactions, it is carried out in the course of nearly all production of chemical products, be it plastics, fertilizers, electronic industrial materials such as semiconductors, cements, or glass. In order to optimize the desired reaction and to prevent unwanted reactions, controlling the pH of solutions is very important.

For example, in the manufacturing process for plastics, pH is strictly managed in the processes of producing long-chain molecular products, especially the processes of polymerization and condensation. Also, pH is controlled for efficient production of chemical fertilizers such as nitrogen fertilizers, potash fertilizers and phosphate fertilizers. Also, pH measurement is very important both in the mixing process of silicate in the case of cement and in combining processes at high temperature in the case of glass manufacturing. The transparency of finished glass is also influenced by pH.

Oil Refining. In oil refining, measurement of pH is carried out in the desulfurization process.

Metals and Minerals. Each metal tends to dissolve in solution of a certain pH by nature. Based on this characteristic, when extracting a particular material from crude ore or mixed metal, pH is controlled so as to extract only the desired metal without dissolving the slag. For example, if you place a mixture of copper and zinc in acid electrolytic solution and electrolyze it, only copper is separated out at the negative electrode.

Electricity, Electrochemistry. In this field, pH measurement is applied to plating, etching of metal surfaces and the manufacture of batteries. Control of the pH of a plating solution greatly affects the finish. Without proper control of the pH of a plating solution, the finished plating will be likely to peel and will not have the optimum color and luster. Anodic oxidation processing is used in coating cooking utensils to produce a coating like the film that forms on aluminum objects, and controlling the pH of the processing solution is critical to achieving the desired finish. In advanced factory painting processes, pH is a vital factor in achieving paint finishes of the quality required for manufactured goods.

Ways of Measuring pH

The methods for measuring pH fall roughly into the following three categories:

- Indicator methods;
- Metal-electrode methods (including the hydrogen-electrode method, quinhydron-electrode method and antimony-electrode method);
- Glass-electrode methods.

Measuring pH using an indicator. This category basically includes two methods: one involves comparing the standard color corresponding to a known pH with the color of an indicator immersed in the test liquid using buffer solution. The other method involves preparing pH test paper which is soaked in the indicator, then immersing the paper in the test liquid and comparing its color with the standard color. This method is simple, but prone to error. A high degree of accuracy cannot be expected. :

Various errors include:

- Error due to high salt concentration in the test liquid;
- Error due to the temperature of the test liquid;

Representative pH values

Substance	pH
Hydrochloric acid, 10M	−1.0
Lead-acid battery	0.5
Gastric acid	1.5 – 2.0
Lemon juice	2.4
Cola	2.5
Vinegar	2.9
Orange or apple juice	3.5
Tomato Juice	4.0
Beer	4.5
Acid Rain	<5.0
Coffee	5.0
Tea or healthy skin	5.0
Urine	6.0
Milk	6.5
Pure Water	7.0
Healthy human saliva	6.5 – 7.4
Blood	7.34 – 7.45
Seawater	7.7 – 8.3
Hand soap	9.0 – 10.0
Household ammonia	11.5
Bleach	12.5
Household lye	13.5

- Error due to organic substances in the test liquid.

Hydrogen-electrode method. A hydrogen electrode is made by adding platinum black to platinum wire or a platinum plate (fig. 10). It is immersed in the test solution and an electric charge is applied to the solution and platinum black with hydrogen gas.

The hydrogen-electrode method is a standard among the various methods for measuring pH. The values derived using other methods become trustworthy only when they match those measured using hydrogen electrode method.

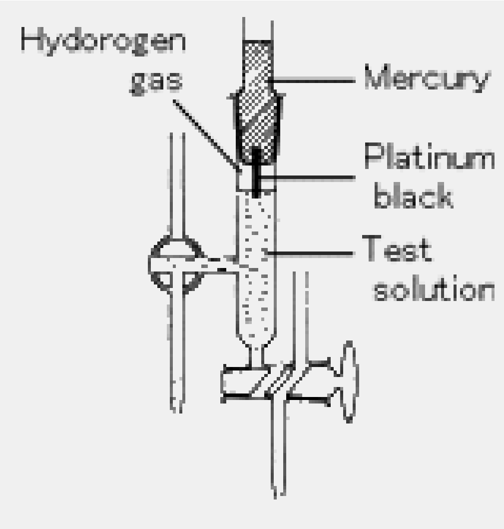


Figure 10. Hydrogen electrode

However, this method is not appropriate for daily use because of the effort and expense involved, with the inconvenience of handling hydrogen gas and great influence of highly oxidizing or reducing substances in the test solution.

Glass-Electrode Method

In this field, pH measurement is applied to plating, etching of metal surfaces and the manufacture of batteries. This method is most widely used for pH measurement because the balancing time of electrical potential is short, it has high reproducibility, it is rarely affected by oxidizing and reducing agents, and it can measure pH of various solutions. This method is used not only in industry but in a wide variety of fields.

Principles of the Glass-Electrode Method. In the glass-electrode method, the known pH of a reference solution is determined by using two electrodes, a glass electrode and a reference electrode, and measuring the voltage (difference in potential) generated between the two electrodes. The difference in pH between solutions inside and outside the thin glass membrane creates electromotive force in proportion to this difference in pH.

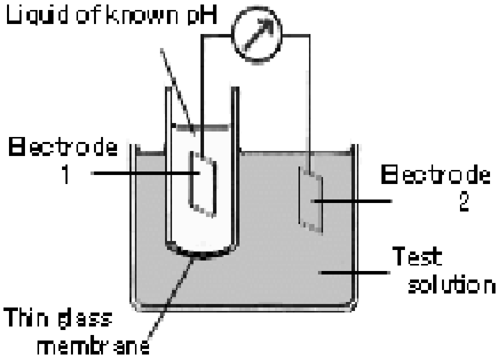


Figure 11. Operating Principle of the glass-electrode method

This thin membrane is called the electrode membrane. Normally, when the temperature of the solution is 30 C, if the pH inside is different from that of outside by 1, it will create approximately 60 mV of electromotive force.

The liquid inside the glass electrode usually has a pH of 7. Thus, if one measures the electromotive force generated at the electrode membrane, the pH of the test solution can be found by calculation. A second electrode is necessary when measuring the electromotive force generated at the electrode membrane of a glass electrode. This other electrode, paired with the glass electrode, is called the reference electrode. The reference electrode must have extremely stable potential. Therefore, it is provided with a pinhole or a ceramic material at the liquid junction. In other words, a glass electrode is devised to generate accurate electromotive force due to the difference in pH. And a reference electrode is devised not to cause electromotive force due to a difference in pH.

Hydrolysis occurs when an ion reacts with, or we could say "rips apart" a water molecule. This can only happen with ions capable of entering into an equilibrium situation with the molecules that are then formed. Those molecules capable of equilibrating are weak acid and base molecules while molecules not capable of equilibrating are strong acid and base molecules. A salt can be analyzed for hydrolysis by:

1. Dissociating it into ions.
2. Combining the positive ion from the salt with OH^- to form a base.
3. Judge this base to be strong or weak.
4. If the base is strong , no hydrolysis occurs, but if the base is weak hydrolysis does occur.

Now repeat steps 2 to 4 for the negative ion

5. Combining the negative ion from the salt with H^+ to form an acid.
6. Judge this acid to be strong or weak.
7. If the acid is strong, no hydrolysis occurs, but if the acid is weak hydrolysis does occur.

Write the equilibrium reaction for the hydrolysis by following the pattern:

Hydrolyzing ion + water $\rightleftharpoons$ *weak acid molecule +*
+ remaining fragment of water
or
Hydrolyzing ion + water $\rightleftharpoons$ *weak base molecule +*
+ remaining fragment of water

Example:

Do KBr, Cs_2SiO_3, $AlCl_3$, NH_4NO_2 alter the pH of (that is cause the hydrolysis of) water and if so, is the solution acidic or basic?

Following the above steps gives:	
K^+	Br^-
KOH	HBr
strong base	strong acid
no hydrolysis	no hydrolysis
Since no hydrolysis occurs, the salt is neutral and the pH of water is unaffected.	
Cs^+	SiO_3^{2-}
CsOH	$HSiO_3^-$
strong base	weak acid
no hydrolysis	hydrolysing ion
Since hydrolysis occurs due to anion of weak acid, the salt in water solution has alkali medium and the pH of solution is more than 7. $SiO_3^{2-} + HOH \rightleftharpoons HSiO_3^- + OH^-$ $2Cs^+ + SiO_3^{2-} + HOH \rightleftharpoons 2Cs^+ + HSiO_3^- + OH^-$ $Cs_2SiO_3 + HOH \rightleftharpoons CsHSiO_3 + CsOH$	
Al^{3+}	Cl^-
$Al(OH)_3$	HCl
weak base	strong acid
hydrolysing ion	no hydrolysis
Since hydrolysis occurs due to cation of weak base, the salt in water solution has acidic medium and the pH of solution is less than 7. $Al^{3+} + HOH \rightleftharpoons AlOH^{2+} + H^+$ $Al^{3+} + 3Cl^- + HOH \rightleftharpoons AlOH^{2+} + H^+ + 3Cl^-$ $AlCl_3 + HOH \rightleftharpoons AlOHCl_2 + HCl$	

NH_4^+	NO_2^-
NH_4OH	HNO_2
Weak base	Weak acid
hydrolysing ion	hydrolysing ion
Since hydrolysis occurs due to cation of weak base and anion of weak acid, the salt in water solution has neutral medium and the pH of solution is nearly 7. $NH_4^+ + NO_2^- + HOH \rightleftharpoons NH_4OH + HNO_2$ $NH_4NO_2 + HOH \rightleftharpoons NH_4OH + HNO_2$	

LABORATORY TRAINING

Experiment 1. Identification of reaction medium in solutions of salts

Draw the reactions of hydrolysis for salt solutions of Na_2CO_3, $(NH_4)_2SO_4$, $ZnSO_4$, $Cu(NO_3)_2$, $Al_2(SO_4)_3$, Na_3PO_4 and theoretically provide for pH of these salt solutions. Then identify reaction medium by putting the drop of solution on universal litmus paper. Draw molecular and ionic equations of hydrolysis in form of the next table:

Experiment 2. Influence of temperature to hydrolysis

A) Fill each of two test tubes with 5-6 drops of 2N CH_3COONa solution and one drop of phenolphthalein solution. Leave one test-tube for comparison and heat another on water bath and note color change. Draw molecular and ionic hydrolysis equations.

B) Fill test-tube with 5-6 drops of $FeCl_3$ and 4-5 drops of CH_3COONa. Note solution color change as the result Iron (III) Acetate production. Add 10 - 20 mL of distilled water and heat the mixture on water bath up to brown precipitation formation. Draw molecular and ionic equations of hydrolysis (1st and 2d steps).

Experiment 3. Hydrolysis strengthening in case of solution dilution

Put 4-5 drops of Bithmus (III) Chloride $BiCl_3$ and by drops (15-20 drops) distilled water up to basic salt precipitation formation. Save the solution with precipitation for the next experiment. Draw hydrolysis equation taking into account that $Bi(OH)_2Cl$ is produced as the result of hydrolysis.

Experiment 4. Reversibility of hydrolysis process

Add by drops hydrochloric acid solution up to precipitation produced in previous experiment. Then add distilled water up to basic salt precipitation production. Explain the phenomenon, which occurs. Draw molecular and ionic equations.

CHAPTER 6. COMPLEX (COORDINATION) COMPOUNDS.

LABORATORY TRAINING

Experiment 1. Compound formation with complex cation

Add by drops ammonia solution firstly up to the formation of HydroxoSulfate and then up to its complete dilution and formation of complex compound $[Cu(NH_3)_4]SO_4$ into the test-tube with 4-5 drops of cuprous Sulfate or Chloride (II). How does the initial color of the solution change? Equate the reaction according to the process stages of reagent interactions.

Experiment 2. Compound formation with complex anion

A) Put 4-5 drops of $Hg(NO_3)_2$ solution into the test-tube and add by one drop of KI solution up to the formation of red precipitate of Mercury (II) iodide. Continue to add KI solution up to complete dilution of precipitate and formation of soluble complex compound - Potassium Tetraiodomercurate (II). Equate the reaction taking into account the stages.

B) Put 5-7 drops of Cobalt (II) Sulfate or Chloride solution into the test-tube. Add little by little the granules of KNO_2 up to solution saturation (there are some undissolved salt at the bottom of test-tube). Add by drops concentrated acetic acid to the mixture up to the formation of yellow precipitate of $K_3[Co(NO_2)_6]$. Equate the reaction according to stages taking into account that nitrous acid, which is isolated under acidation, oxidizes Co^{2+} to Co^{3+}:

Experiment 3. Complex compounds in metathesis

A) Add 2-3 drops of $K_3[Fe(CN)_6]$ solution to 4-5 drops of any Iron (II) salt solution. What is the color of precipitate? Equate molecular and ionic reactions.

B) Add 2-3 drops of $K_4[Fe(CN)_6]$ solution to 4-5 drops of any Cooper (II) salt solution. Identify the color of precipitate and equate molecular and ionic reactions.

C) Add 2-3 drops of $K_4[Fe(CN)_6]$ solution to 4-5 drops of Iron (III) salt solution. Identify the color of precipitate and equate molecular and ionic reactions.

D) Add 2-3 drops of KSCN or NH_4SCN solution to 4-5 drops of Iron (III) salt solution. Identify the color of precipitate and equate molecular and ionic reactions.

CHAPTER 7. OXIDATION-REDUCTION REACTIONS

LABORATORY TRAINING

Experiment 1. Reducing properties of metal ions of lower oxidation number

Add 1-2 drops of Iron (III) Sulfate $Fe_2(SO_4)_3$ to 2-3 drops of Ammonium Thiocyanate NH_4SCN. Register color of solution. Further add to the same tube the solution of Tin (II) Chloride $SnCl_2$ (by drops) up to whole decoloration of mixture. Draw up equations of reactions. For Redox reaction write the scheme of electron balance, and mark oxidizing and reducing agents.

Experiment 2. Influence of medium to redox reactions

Put 2-3 drops of Potassium Permanganate solution $KMnO_4$ in the 3 tubes. Add 1-2 drops of diluted Sulfuric acid to the first tube; - 5-10 drops of distillated water to the second one; 2-3 drops of alkali solution (NaOH or KOH) in the third one. Is the color of $KMnO_4$ solution changed? Then add in each tube few crystals of Sodium Sulfite or Potassium Sulfite. What do you observe? Draw up equations of reactions, write the scheme of electron balance, mark oxidizing and reducing agents.

Experiment 3. Redox properties of Chromium compounds

A) Put 2-3 drops of Potassium Dichromate $K_2Cr_2O_7$ solution in to the tube, add 2-3 drops of diluted Sulfuric acid and few crystals of solid Sodium Sulfite or Potassium Sulfite. What do you observe? Draw up equations of reactions, write the scheme of electron balance, mark oxidizing and reducing agents.

B) Put 1-2 drops of alkali solution (NaOH or KOH), add by drops the solution of Chromium (III) Sulfate $Cr_2(SO_4)_3$ up to the formation of precipitate. Register the color of mixture. Further add alkali solution

(NaOH or KOH) to the same tube up to the dissolving of precipitate (register the color of solution), then - 3-4 drops of 10% solution of Hydrogen Peroxide H_2O_2. Heat a content of tube during 2-3 minutes in water bath. How is the a color of solution changed? Draw up equations of reactions of corresponded transformations: $Cr^{3+} \rightarrow Cr(OH)_3\downarrow \rightarrow CrO_2^{-} \rightarrow CrO_4^{2-}$. For Redox reaction write the scheme of electron balance, mark oxidizing and reducing agents.

Part 2. INORGANIC CHEMISTRY

CHAPTER 8. The Halogens

The halogens are located on the left of the noble gases on the periodic table. These five toxic, non-metallic elements make up **VII–A group** (Group 17 in modern notation) of the periodic table and consist of: **Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), and Astatine (At)**. Although astatine is radioactive and only has short-lived isotopes, it behaves similar to iodine and is often included in the halogen group. Because the halogen elements have seven valence electrons, they only require one additional electron to form a full octet. This characteristic makes them more reactive than other non-metal groups.

Halogens form diatomic molecules (of the form X_2 , where X denotes a halogen atom) in their elemental states. The bonds in these diatomic molecules are non-polar covalent single bonds. Halogens readily combine with most elements and are never seen uncombined in nature. As a general rule, fluorine is the most reactive halogen and astatine is the least reactive. All halogens form salts with alkali metals with similar properties. In these compounds, halogens are present as halide anions with charge of -1 (e.g. Cl^-, Br^-, etc.). Replacing the -ine ending with an -ide ending indicates the presence of halide anions; for example, Cl^- is named "chloride." Halogens mostly act as oxidizing agents. Therefore, most of the chemical reactions that involve halogens are oxidation-reduction reactions.

Chlorine (Cl_2) was the first halogen to be discovered in 1774, followed by iodine (I_2), bromine (Br_2), fluorine (F_2), and astatine (At, discovered last in 1940). The name "halogen" is derived from the Greek roots hal- ("salt") and -gen ("to form"). Together these words combine to mean "salt former", referencing the fact that halogens form salts when they react with metals. *Halite* is the mineral name for rock salt, a natural mineral consisting essentially of sodium chloride (NaCl). Lastly, the halogens are also relevant in daily life, whether it be the fluoride that goes in toothpaste, the chlorine that disinfects drinking water, or the iodine that facilitates the production of thyroid hormones in one's body.

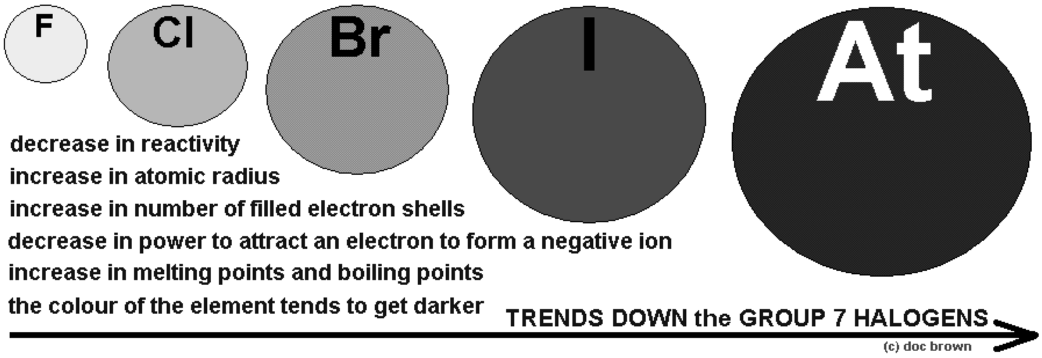


Figure.7 **Trends down the group 7**

Halogens occur naturally as halide ions, they are prepared by oxidation of halide ion to the free halogen. The major method for preparing fluorine is electrolytic oxidation. The most common electrolysis procedure is to use a molten mixture of potassium hydrogen fluoride, KHF_2 ($KF \cdot HF$ (240-300^{0}C)), and anhydrous hydrogen fluoride. Electrolysis causes HF to decompose, forming fluorine gas at the anode and hydrogen at the cathode:

$KHF_2 \cdot HF(l) \rightarrow F_2(g) + H_2(g)$

It is necessary to keep the two gases separated to prevent their explosive recombination to reform hydrogen fluoride. Consequently, the production, storage, shipping, and handling of these gases pose major technical challenges.

Chlorine is prepared industrially by the chloralkali process, which uses the following reaction:

$$NaCl\ (H_2O) \leftrightarrow Na^+ + Cl^-$$

Cathode: $2H_2O + 2e \rightarrow H_2\uparrow + 2OH^-$

Anode: $2Cl^- - 2e \rightarrow Cl_2\uparrow$

$$Na^+ + OH^- \rightarrow NaOH$$

$2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$

Bromine is much less abundant than fluorine or chlorine, but it is easily recovered from seawater, which contains about 65 mg of Br^- per liter. The production of iodine requires reduction rather than oxidation. The process is typically carried out in two steps: reduction of iodate to iodide with sodium hydrogen sulfite, followed by reaction of iodide with additional iodate:

$$2IO_3^- + 6HSO_3^- \rightarrow 2I^- + 6SO_4^{2-} + 6H^+$$

$$5I^- + IO_3^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

In the laboratory both bromine and iodine are prepared by oxidizing bromides and iodides with manganese dioxide, MnO_2, in acidic solution:

$$MnO_2 + 2KBr + 2H_2SO_4 \rightarrow MnSO_4 + Br_2 + K_2SO_4 + 2H_2O,$$

$$MnO_2 + 2KI + 2H_2SO_4 \rightarrow MnSO_4 + I_2 + K_2SO_4 + 2H_2O.$$

In addition to the –1 and +1 oxidation states that arise from the ground state electron configuration, chlorine, bromine, and iodine have +3, +5, and +7 oxidation states, which correspond to valence state electron configurations in which one, two, or three electrons have been promoted to *d* orbitals (see Figure).

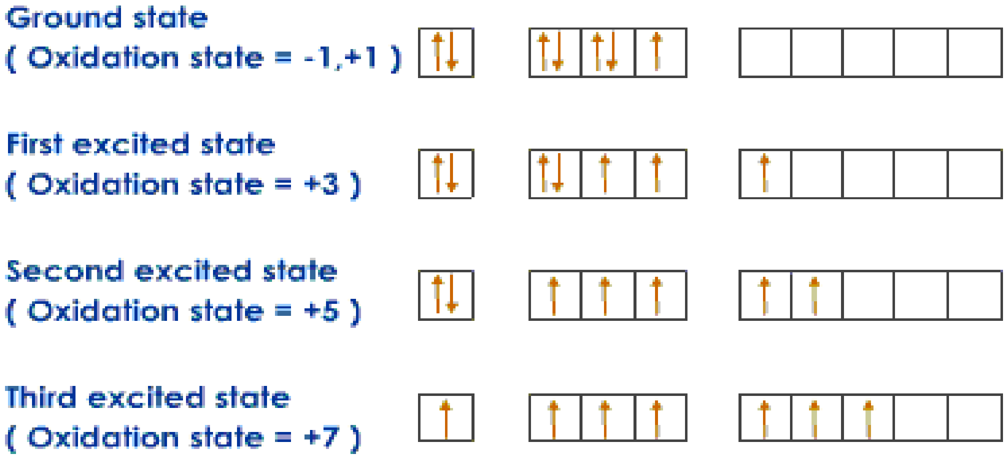


Figure. 8 Ground State and Valence State Electron Configurations for Chlorine

All of the halogens have been observed to react with hydrogen to form hydrogen halides. For fluorine, chlorine, and bromine, this reaction is in the form of:

$H_2 + X_2 \rightarrow 2HX$

All the halogens are known to react with sodium to form sodium fluoride, sodium chloride, sodium bromide, sodium iodide, and sodium astatide. Heated sodium's reaction with halogens produces bright-orange flames. Sodium's reaction with chlorine is in the form of:

$2Na + Cl_2 \rightarrow 2NaCl$

Iron reacts with fluorine, chlorine, and bromine to form Iron(III) halides. These reactions are in the form of:

$2Fe + 3X_2 \rightarrow 2FeX_3$

Fluorine reacts vigorously with water to produce oxygen (O_2) and hydrogen fluoride (HF):

$2\,F_2(g) + 2\,H_2O(l) \rightarrow O_2(g) + 4\,HF(aq)$

Fluorine is such a strong oxidizing agent that it can oxidize most nonmetals to their highest oxidation states. Thus fluorine reacts with phosphorus giving PF_3 and PF_5:

$$2P + 3F_2 \rightarrow 2PF_3;$$
$$2P + 5F_2 \rightarrow 2PF_5;$$

and with sulfur giving SF_4 and SF_6:

$$S + 2F_2 \rightarrow SF_4;$$
$$S + 3F_2 \rightarrow SF_6.$$

Fluorine oxidizes even the other halogens, chlorine, bromine, and iodine, to higher oxidation states. It oxidizes chlorine and bromine to the +1, +3, and +5 oxidation states in ClF, ClF_3, and ClF_5, and BrF, BrF_3, and BrF_5; and iodine to IF_3 and IF_5, and to the +7 state in IF_7. Chlorine reacts with phosphorus forming PCl_3 and PCl_5:

$$2P + 3Cl_2 \rightarrow 2PCl_3;$$

$$2P + 5Cl_2 \rightarrow 2PCl_5;$$

Most nonmetal halides are rather reactive compounds. Almost all they react very readily with water giving a hydrogen halide and either an oxoacid or an oxide; for example,

$$PCl_5(s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq);$$

$$SF_4(g) + 2H_2O(l) \rightarrow SO_2(aq) + 4HF(aq);$$

$$ClF_5(g) + 3H_2O(l) \rightarrow HClO_3(aq) + 5HF(aq).$$

Chlorine has maximum solubility of water at temperature 21 °C. Dissolved chlorine reacts to form hydrochloric acid (HCl) and hypochlorous acid, a solution that can be used as a disinfectant or bleach:

$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$

Bromine has a solubility of 3.41 g per 100 g of water, but it slowly reacts to form hydrogen bromide (HBr) and hypobromous acid (HBrO):

$Br_2(g) + H_2O(l) \rightarrow HBr(aq) + HBrO(aq)$

Iodine, however, is minimally soluble in water (0.03 g/100 g water at 20 °C) and does not react with it. However, iodine will form an aqueous solution in the presence of iodide ion, such as by addition of potassium iodide (KI), because the triiodide ion is formed.

The halogens react with many metals forming halides. Some typical reactions are the following:

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s);$$

$$Ca(s) + F_2(g) \rightarrow CaF_2(s);$$

$$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s).$$

The compounds formed in such reactions have quite different physical and chemical properties from the halides of the nonmetals. They are all colorless crystalline solids with high melting points.

The metal halides are ionic compounds consisting of oppositely charged ions held together by electrostatic attraction. The formation of these ionic compounds can be represented as follows:

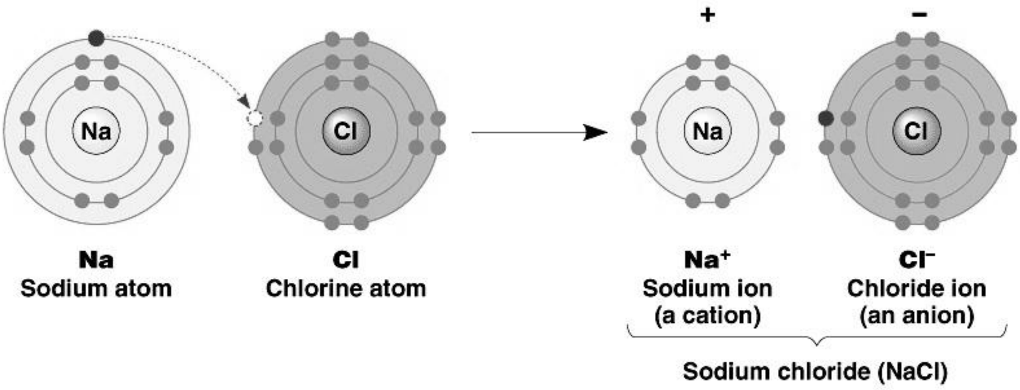


Figure. 9. Formation of NaCl.

The halide ions Hal^- except F^- are the reducing agents. Their reducing ability increases from Cl^- to Br^- and more over to I^-:

$$MnO_2 + 4HCl \rightarrow MnCl_2 + Cl_2 + 2H_2O;$$

$$2KMnO_4 + 10KI + 8H_2SO_4 \rightarrow 2MnSO_4 + 5I_2 + 6K_2SO_4 + 8H_2O;$$

$$6KBr + K_2Cr_2O_7 + 7H_2SO_4 \rightarrow 3Br_2 + 4K_2SO_4 + Cr_2(SO_4)_3 + 7H_2O.$$

HBr reduces sulfuric acid to sulfur dioxide SO_2, while HI – to hydrogen sulfide, H_2S:

$$2HBr + H_2SO_4 \rightarrow Br_2 + SO_2\uparrow + 2H_2O;$$

$$8HI + H_2SO_4 \rightarrow 4I_2 + H_2S\uparrow + 4H_2O.$$

The names of the oxyanions of the halogens use the endings -ite and -ate to indicate low and high oxidation numbers and the prefixes hypo- and per- to indicate the very lowest and very highest oxidation numbers, as shown in the table below. Each of these ions can be converted into an oxyacid, which is named by replacing the -ite ending with -ous and the -ate ending with -ic.

	Oxyanions		***Oxyacids***	
Oxidation State of the Chlorine	***Compound***	***Name***	***Compound***	***Name***
+1	**ClO^-**	**hypochlorite**	**HClO**	**hypochlorous acid**
+3	**ClO_2^-**	**chlorite**	**$HClO_2$**	**chlorous acid**
+5	**ClO_3^-**	**chlorate**	**$HClO_3$**	**chloric acid**
+7	**ClO_4^-**	**perchlorate**	**$HClO_4$**	**perchloric acid**

Silver nitrate in the presence of dilute nitric acid can precipitate silver halides from the solutions of the hydrogen halides acids:

$$AgNO_3 + KCl \rightarrow AgCl\downarrow + KNO_3;$$

$$AgNO_3 + KBr \rightarrow AgBr\downarrow + KNO_3;$$

$$AgNO_3 + KI \rightarrow AgI\downarrow + KNO_3.$$

AgF dissolves in water.

AgCl is a white cheese precipitate. It is insoluble in water and nitric acid but it can be dissolved in the ammonia solution:

$$AgCl + 2NH_4OH \rightarrow [Ag(NH_3)_2]Cl + 2H_2O.$$

When the solution formed is acidified the complex compound decomposes and the AgCl precipitate forms again:

$$[Ag(NH_3)_2]Cl + 2HCl \rightarrow AgCl\downarrow + 2NH_4Cl.$$

AgBr is a pale yellow precipitate which is insoluble in water and nitric acid, and it is insoluble in the ammonia solution as well.

AgI is a yellow-colored precipitate. It is insoluble neither in water and nitric acid nor in the ammonia solution. But it dissolves readily in ammonia carbonate solution.

Laboratory work.

VII–A group of chemical elements

Experiment 1. *Making Chlorine* (Perform these experiments in the fume hood! Be careful not to breathe fumes!)

a. Put 2-3 crystals of solid potassium permanganate ($KMnO_4$) into the test-tube and insert it in a lab stand for the test-tubes. Add carefully few drops of concentrated hydrochloric acid. Identify the emitted gas by odor and color. Complete the table by describing your observations and writing balanced chemical equation for the reaction you observe.

b. Place a few crystals of solid potassium dichromate ($K_2Cr_2O_7$) into the test tube and put 5-8 drops of concentrated hydrochloric acid. Heat the mixture gently in a water bath. What do you observe? Write the equation for the oxidation-reduction reaction.

Experiment 2. *Oxidation Properties of Cl_2 Water*

a. Pour 1 ml of potassium bromide (KBr) and potassium iodide (KI) solutions into two test tubes and add 0.3 – 0.5 cm^3 of benzol in each one. Shake them. Observe color of benzol layer. Add 0.5 ml of chloric (Cl_2) water in each test tube. Shake vigorously. Does the color of benzol layer change? Write chemical equations for the reactions.

b. Add 0.5 cm^3 of Cl_2 water to 1 cm^3 of sodium sulfide (Na_2S) solution. What do you observe? Write chemical equation for the reaction.

Experiment 3. *Characteristic Reaction of Cl^- Ions*

Put 3-4 drops of potassium chloride (KCl) solution into the test tube #1, barium chloride ($BaCl_2$) solution into the test tube #2, and iron (III) chloride ($FeCl_3$) solution into the test tube #3. Add 2 drops of silver nitrate ($AgNO_3$) solution in each of three test tubes. Compare observations in test tubes #1, #2 and #3. What is the similarity between the reactions? Write the equations for each reaction.

Add 2-4 drops of concentrated ammonia (NH_4OH) in each test tube and mix up. What happens with precipitates? Why does not precipitate dissolve in the test tube #3? How does the color of the precipitate change?

Add in each test tube 2-3 drops of nitric acid (HNO_3). What happens? What occurs with AgCl in the presence of NH_4OH and HNO_3?

Experiment 4. *Interaction Between Hydrochloric Acid and Metals*

Put 1-2 zinc granules into the test tube #1, few iron strips into the test tube #2, and few copper strips into the test tube #3. Add 2-4 drops of diluted hydrochloric acid in each test tube. What metals directly react with hydrochloric acid? Write balanced equations to represent these reactions.

Experiment 5. *Oxidative Properties of Bleaching Powder*

a. Add saturated solution of bleaching powder dropwise to 1 cm^3 of acidified KI solution and observe free iodine isolation. Add some drops of starch solution. What do you observe? Write a balanced equation for this reaction.

b. Pour 1 cm^3 of iron (II) sulfate ($FeSO_4$) solution into the test tube. Add the same volume of alkali. Note the color of formed precipitate. Write the equation. Shake the tube contents and add 0.5-1 cm^3 of saturated solution of bleaching powder. Why does the color of precipitate change? Write a balanced equation.

Experiment 6. *Oxidative Properties of Chloric(III) Acid*

Pour 1 cm^3 of $KClO_3$ solution into the test tubes #1 and #2 and the same quantity of KI solution into the test tubes #3and #4. Add some drops of H_2SO_4 solution into the test tubes #1 and #3. What happens? Compare colors of solution in both tubes. Write the equations for the reactions and explain the result of experiment (it should be noted that $HClO_3$, but not chlorates, is powerful oxidizing agent!).

Experiment 7. *Making Iodine*

a. Mix together few crystals of KI and a little of MnO_2 in a dry test tube and add 2-3 drops of concentrated H_2SO_4. Heat the mixture gently in a water bath. Soon violet fumes will emerge.

b. Add 4-5 drops of benzol into two test tubes that contain NaI or KI solution. Add 3-5 drops of Cl_2 water in one test tube and the same amount of Br_2 water in another. Shake the contents of the tubes. Write the color of benzol layer.

Experiment 8. *Starch Test for Iodine*

Put 8-10 drops of I_2 water into the test tube and add 1-2 drops of starchy water. Observe the color of solution. Heat the mixture up to 80^0C in a water bath. How does the color of solution change? Cool solution to the room temperature. What happens with the color of solution upon cooling?

Explain blue color of I_2 water as a result of adding starchy water. Why does color appear and disappear upon heating and cooling? Draw a conclusion.

Experiment 9. *Interaction Between Iodine and Metals*

Drop 5-8 drops of I_2 water in two test tubes. Add 1 pinch of powdered zinc into one tube and magnesium into another. Observe discoloration of solutions. Write balanced chemical equation for these reactions, define oxidizing and reducing agents.

Experiment 10. *Reducing Properties of Iodine Ions*

a. Put 2-3 drops of $Fe_2(SO_4)_3$ solution into the test tube and add 2-3 drops of benzol. Add 1-2 drops of KI or NaI solution and shake. Note the color of benzol layer. Write the equation.

b. Put 2-3 drops of $K_2Cr_2O_7$ solution into the test tube; add the same amount of diluted H_2SO_4 and 3-4 drops of benzol. Add 2-3 drops of KI or NaI solution to the mixture. Shake the content of the tube. Explain the purple color of benzol. Write chemical equation for the reaction, define oxidizing and reducing agents.

Experiment 11. *Oxidative Properties of* IO_3^- *Ions*

Pour 5-7 drops of KI solution and 2-3 drops of H_2SO_4 into the test tube. Shake and add KIO_3 solution dropwise up to appearance of dark-brown iodine. You might prove the presence of free iodine by adding 1-2 drops of starchy water. Write the balanced equation to show the reaction between KI and KIO_3

Experiment 12. *Reducing Properties of Iodine*

Add one drop of starchy water and 2-3 drops of fresh Cl_2 water to 2-3 drops of I_2 water. Is the blue color of solution disappearing? Write the equation for the reaction. What properties does chlorine and iodine show in this reaction?

Experiment 13. *Qualitative Reactions of* I^- *Ions*

Pour 3-4 drops of KI or NaI solution into the test tube and add 1-2 drops of $AgNO_3$ solution. Define the color and the structure of AgI precipitate. Write the equation for the reaction.

Divide prepared precipitate into two tubes; add 1-2 drops of HNO_3 into one test tube and NH_4OH into another. Draw a conclusion about solubility of AgI.

Pour 2-3 drops of KI or NaI solution into the test tube and add the same amount of $Pb(NO_3)_2$ solution. Observe bright yellow PbI_2 formation. Then add 8-10 drops of distilled water and few drops of CH_3COOH into the test tube. Heat the mixture up until precipitation dilutes. Slowly cool the solution up to PbI_2 precipitate formation (bright goldish yellow husks).

CHAPTER 9. The Chalcogens

The oxygen family, also called the chalcogens, consists of the elements found in **VI–A group (**Group 16 in modern notation) of the periodic table and is considered among the main group elements. It consists of the elements Oxygen, Sulfur, Selenium, Tellurium and Polonium. These can be found in nature in both free and combined states. The group 16 elements are intimately related to life. We need oxygen all the time throughout our lives. Sulfur is responsible for some of the protein structures in all living organisms. Many industries utilize sulfur, but emission of sulfur compounds is often seen more as a problem than the natural phenomenon. The metallic properties increase as the atomic number increases. The element Polonium has no stable isotopes, and the isotope with mass number 209 has the longest half-life of 103 years.

Most trends are true for all groups of elements, and the group trends are due mostly to the size of the atoms and number of electrons per atom. The trends are described below:

1. The metallic properties increase in the order Oxygen, Sulfur, Selenium, Tellurium, or Polonium. Polonium is essentially a metal. It was discovered by M. Curie, who named it after her native country Poland.
2. Electronegativity, ionization energy (or ionization potential IP), and electron affinity decrease for the group as atomic weight increases.
3. The atomic radii and melting point increase.
4. Oxygen differs from sulfur in chemical properties due to its small size. The differences between O-O and S-S are more than the differences between other members.

Metallic character increases down the group, with Tellurium classified as an element with metal properties and Polonium as a metal. Melting point, boiling point, density, atomic radius, and ionic radius all increase down the group. Ionization energy decreases down the group. The most common oxidation state is -2; Sulfur can also exist at a +4 and +6 state, and +2, +4, and +6 oxidation states are possible for Se, Te, and Po.

In the laboratory oxygen can be prepared by decomposition of potassium chlorate or potassium permanganate:

$$2KClO_3 \rightarrow 2KCl + 3O_2\uparrow;$$

$$2KMnO_4 \rightarrow K_2MnO_4 + MnO_2 + O_2\uparrow.$$

It may be prepared also by heating the alkali metals nitrates:

$$2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2\uparrow.$$

In industry oxygen is prepared by liquefaction and fractional distillation of the air. The method of oxygen preparation by the electrolysis of water is widely used also.

Oxygen forms compounds with almost all chemical elements except helium, neon, and argon. With all elements except halogens, gold and platinum it can react directly.

Cesium burns spontaneously in the air at room temperature:

$$4Cs + O_2 \rightarrow 2Cs_2O.$$

Depending on nature of the element oxides can be divided into basic (Na_2O, MgO), amphoteric (Al_2O_3) and acidic oxides (SiO_2, P_2O_5, SO_3, Cl_2O_7):

$$Na_2O + H_2O \rightarrow 2NaOH;$$
$$Al_2O_3 + 3H_2O \rightarrow 2Al(OH)_3;$$
$$SO_3 + H_2O \rightarrow H_2SO_4.$$

Oxygen forms *superoxides* MeO_2 with potassium, rubidium and cesium and *peroxides* Me_2O_2 with alkali metals and hydrogen (H_2O_2).

Another type of oxygen compounds are *hydroxides*. Hydroxides of alkali and alkaline earth metals are strong bases and they are completely ionized in water giving the metal ion and hydroxide-ion:

$Me^+OH^-(s) + nH_2O \rightleftarrows Me^+(aq) + OH^-(aq).$

Ozone or trioxygen is an allotrope of oxygen consisting of O_3 molecules. It is a pale blue gas with a characteristic odor. When an electric discharge is passed through gaseous oxygen about 10% of the oxygen is converted to ozone:

$3O_2(g) \rightarrow 2O_3(g).$

The smell of ozone is often noticed during electric storms and in the vicinity of electric motors. It is an important constituent of the stratosphere.

Ozone can decompose explosively in a strongly exothermic reaction:

$2O_3 \rightarrow 3O_2$

Ozone is an extremely powerful oxidizing agent. The only common oxidizing agent that is stronger is fluorine. Ozone can be used for destroying bacteria in water by oxidation.

Hydrogen peroxide is a chemical compound with the formula H_2O_2. In its pure form, it is a colorless liquid, slightly more viscous than water; however, for safety reasons it is normally used as a solution. Hydrogen peroxide is the simplest peroxide (a compound with an oxygen–oxygen single bond) and finds use as a weak oxidizer, bleaching agent and disinfectant. Concentrated hydrogen peroxide, or "high-test peroxide", is a reactive oxygen species and has been used as a propellant in rocketry.

At the laboratory hydrogen peroxide can be prepared by stirring solid barium peroxide, BaO_2, with a cold aqueous solution of sulfuric acid.

Insoluble barium sulfate precipitates and can be filtered off. If stoichiometric amounts of BaO_2 and sulfuric acid are used, a pure aqueous solution of hydrogen peroxide can be obtained:

$$BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2.$$

When the pure liquid is heated, it decomposes rapidly and even explosively in a disproportionation reaction:

$$2H_2O_2 \rightarrow 2H_2O + O_2.$$

Normally it is not necessary to make **Sulfur** in the laboratory as it is so readily available. It is found as the native element in nature and extracted by the *Frasch process*.

Sulfur burns in the air forming the gaseous dioxide sulfur(IV) oxide, SO_2 at 360 °C (in oxygen atmosphere – at 280 °C):

$$S + O_2 \rightarrow SO_2.$$

Sulfur does not react with water under normal conditions.

When it is reacts with metals sulfur displays oxidizing properties giving sulfides in which sulfur atoms have –2 oxidizing number:

$$Fe + S \rightarrow FeS.$$

Sulfur does not react with hydrogen gas under normal conditions. The reversible reaction with hydrogen occurs at heating up to 150-200 °C only:

$$H_2 + S \rightleftarrows H_2S.$$

Sulfur behaves as a reducing agent in the reactions with strong oxidizing agents.

Sulfur reacts with all the halogens at heating. Molten sulfur reacts with molten chlorine forming disulfur dichloride, S_2Cl_2. This apparently smells dreadfully. With excess chlorine and in the presence of a catalyst, such as $FeCl_3$, $SnCl_4$, etc., it is possible to make a mixture containing an equilibrium mixture of red sulfur(II) chloride, SCl_2, and disulfur dichloride, S_2Cl_2:

$$2S + Cl_2 \rightarrow S_2Cl_2 \ (\textit{orange}),$$

$$S_2Cl_2 + Cl_2 \rightarrow 2SCl_2 \ (\textit{dark red}).$$

Sulfur does not react with dilute non-oxidizing acids.

Sulfur does not react with cold concentrated sulfuric acid, but it interacts with molten H_2SO_4 giving sulfur dioxide and H_2O:

$$2H_2SO_4 + S \rightarrow 3SO_2 + 2H_2O.$$

Dilute nitric acid has no influence on sulfur and concentrated one can oxidize sulfur to SO_4^{2-}:

$$S + 6HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O.$$

Sulfur reacts with hot aqueous potassium hydroxide, KOH forming sulphide and thiosulphate species, that is sulfur is able to be self-oxidized self-reduced:

$$3S + 6KOH \rightarrow 2K_2S + K_2S_2O_3 + 3H_2O.$$

Unlike water, which is a liquid at room temperature, **hydrogen sulfide** (H_2S) is a gas (melting point –85.6 °C, boiling point –60.7 °C). It has a powerful, unpleasant odor, and it is very poisonous.

H_2S is usually prepared by the reaction of dilute acids with iron(II) sulfide:

$$FeS + 2HCl \rightarrow FeCl_2 + H_2S.$$

The structure of H_2S is just like that of water. Hydrogen sulfide is soluble in water.

In hydrogen sulfide sulfur is in its lowest oxidation state (–2). It is therefore a good reducing agent; it is usually oxidized to sulfur.

If an aqueous solution of H_2S is exposed to the air, the H_2S is oxidized by the oxygen of the air and a precipitate of sulfur formed slowly:

$$2H_2S + O_2 \rightarrow 2S + 2H_2O.$$

The same reaction occurs when H_2S burns in air; sulfur deposits on a cold surface held near the flame. Some SO_2 forms at the same time:

$$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g).$$

If H_2S is passed into an aqueous solution of bromine, Br_2, the red-brown color of the Br_2 disappears as it is reduced to Br^-. At the same time a milky precipitate of finely divided sulfur forms. Chlorine and iodine can be reduced in the same way.

Hydrogen sulfide decomposes when heated: $H_2S \rightarrow H_2 + S$.

Hydrogen sulfide reacts vigorously with different oxidizing agents.

Free sulfur is formed when H_2S reacts with nitric acid:

$$H_2S + 2HNO_3 \rightarrow S\downarrow + 2NO_2 + 2H_2O.$$

A steam of hydrogen sulfide when passing through the potassium permanganate solution turns it colorless:

$$2KMnO_4 + 5H_2S + 3H_2SO_4 \rightarrow 5S\downarrow + 2MnSO_4 + K_2SO_4 + 8H_2O.$$

H_2S reduces chromium from +6 to +3 oxidizing number in the reaction with potassium dichromate:

$$K_2Cr_2O_7 + 3H_2S + 4H_2SO_4 \rightarrow 3S\downarrow + Cr_2(SO_4)_3 + K_2SO_4 + 7H_2O.$$

H_2S can be prepared in the laboratory by adding a dilute aqueous acid such as hydrochloric acid to a metal sulfide. For example:

$$FeS + 2H^+ \rightarrow Fe^{2+} + H_2S;$$

$$FeS + 2HCl \rightarrow FeCl_2 + H_2S.$$

Sulfides can be prepared by the reaction between metal hydroxide and hydrogen sulfide:

$$2NaOH + H_2S \rightarrow Na_2S + 2H_2O.$$

Sulfides of alkali and alkaline earth metals are prepared by fuming of these metals sulfates with charcoal:

$$Na_2SO_4 + 2C \rightarrow Na_2S + 2CO_2.$$

Sulfides of metals are salts of the weak acid they are considerably hydrolyzed in aqueous solutions. Thus the aqueous solutions of these salts have the basic medium:

$$Na_2S + H_2O \rightarrow NaHS + NaOH;$$

$$2CaS + 2H_2O \rightarrow Ca(HS)_2 + Ca(OH)_2.$$

Aluminium sulfide hydrolyzes completely in water:

$$Al_2S_3 + 6H_2O \rightarrow 2Al(OH)_3\downarrow + 3H_2S.$$

All metals sulfides are strong reducing agents:

$$3PbS + 8HNO_3 \rightarrow 3PbSO_4 + 4H_2O + 8NO.$$

When sulfur is heated in air, it ignites at 350 °C and burns with a blue flame forming **sulfur dioxide**, SO_2. Sulfur dioxide is a colorless gas with a pungent, choking odor. SO_2 forms also by heating of metals sulfides:

$$4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2.$$

The most important compounds in which sulfur in the +4 oxidation state are the metal sulfites. Sulfur dioxide is very soluble in water, and it has been generally assumed that sulfurous acid, H_2SO_3, is formed in such solutions. The reaction would be: $H_2O + SO_2 \rightleftarrows H_2SO_3$.

SO_3^{2-} is good reducing agents. It is oxidized to sulfate ion, SO_4^{2-}, by many oxidizing agents, although, the reaction with O_2 is very slow in the absence of a catalyst such as V_2O_5. For example, an orange-red solution of Br_2 in water is decolorized by SO_2 or by a sulfite solution, because Br_2 is reduced to Br^-:

$$Br_2 + SO_2 + 2H_2O \rightarrow 2Br^- + SO_4^{2-} + 4H^+.$$

In aqueous solutions soluble in water sulfites are readily hydrolyzed:

$$Na_2SO_3 + H_2O \rightleftarrows NaHSO_3 + NaOH.$$

When SO_2 is passed through the aqueous solutions of metals hydrosulfites the metal pirosulfites form:

$$NaHSO_3 + SO_2 \rightarrow Na_2S_2O_5.$$

When an aqueous solution of a sulfite is boiled with sulfur, the thiosulfate ion, $S_2O_3^{2-}$, forms: $S + SO_3^{2-} \rightarrow S_2O_3^{2-}$.

The two sulfur atoms in thiosulfates are in two oxidation states: +6 and –2. The presence of sulfur in –2 oxidation state causes the reducing properties of thiosulfates:

$$I_2 + Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6.$$

The most typical reaction for sodium thiosulfate is its reaction with silver nitrate. Under the reaction the white precipitate of silver thiosulfate $Ag_2S_2O_3$ forms which then transforms into black precipitate of silver sulfide Ag_2S:

$$Na_2S_2O_3 + 2AgNO_3 \rightarrow Ag_2S_2O_3\downarrow + 2NaNO_3;$$

$$Ag_2S_2O_3 \rightarrow Ag_2SO_3\downarrow + S\downarrow;$$

$$Ag_2SO_3 + S + H_2O \rightarrow Ag_2S\downarrow + H_2SO_4.$$

Laboratory work.

VI–A group of chemical elements

Experiment 1. *Making Oxygen*

Put about 0.5g of solid $KMnO_4$ in a dry test tube. Place tube upside down in a utility clamp and heat gently over the flame of burner. How the oxygen formation can be determined? Write equation for reaction of $KMnO_4$ decomposition.

Experiment 2. *Making Oxygen*

Carry out experiment with potassium chlorate ($KClO_3$) as described in experiment 1. After salt melts test O_2 emission with smoldering match. Does oxygen emit intensively? Afterwards, remove the test tube from the source of heat. Drop small pinch of MnO_2 into the same test tube. Immediately redo the test for O_2 emission. Compare intensity of O_2 emission before and after adding of MnO_2. What is the function of MnO_2?

Experiment 3. *Oxidizing Properties of H_2O_2*

Drop 5 drops of KI solution and 3 drops of hydrogen peroxide (H_2O_2) into the test tube. Is the color of solution changing? What reaction is taking place? Test the presence of free iodine by adding 1-2 drops of starchy water.

Experiment 4. *Oxidizing Properties of H_2O_2*

Add 2-3 drops of Na_2S solution in the test tube with 3-5 drops of $Pb(NO_3)_2$ solution. Add 3 drops of 3% H_2O_2 until black precipitate (PbS) formation. What do you observe? Write the equation for the reaction.

Experiment 5. *Reducing Properties of H_2O_2*

Add 5-6 drops of H_2O_2 to 1-2 drops of $KMnO_4$, acidified by H_2SO_4. Does the color of solution change? Write the equation for the reaction.

Experiment 6. *Sulfur Oxidation by Nitric Acid (Procedure should be carried out in the fume hood!)*

Pour 0.5÷1.0 ml of concentrated HNO_3 and add small amount of sulfur powder. Heat the mixture in a water bath until it boils. Observe sulfur dissolving gradually. Write the equation for the reaction.

Experiment 7. *Reducing Properties of H_2S. (Procedure should be carriedout in the fume hood!)*

Pour 1÷2 ml of H_2S water into three test tubes and add Cl_2 water dropwise into the first tube, Br_2 water into the second, and concentrated HNO_3 into the third one. Free sulfur is formed in each tube as white turbidity. Write chemical equation for corresponding reactions.

Experiment 8. *Making of Sulfur Dioxide (SO_2) and its Solubility. (Procedure should be carried out in the fume hood!)*

Drop about 2 g of solid Na_2SO_3 into the test tube, pour 3-5 ml of 40% H_2SO_4, and quickly insert a rubber stopper with delivery tube. If the reaction occurs slowly heat the tube slightly. Insert the delivery tube into a second test tube with water to collect SO_2. Use synthesized sulfurous acid in the next experiments.

Experiment 9. *Reducing Properties of Sulfurous Acid and Sulfites. (Procedure should be carried out in the fume hood!)*

Put 5-8 drops of Na_2SO_3 and 5-8 drops of H_2SO_4 into 5 test tubes. Add 3-5 drops of Br_2 water into the first test tube, Cl_2 water into the second, $KMnO_4$ solution into the third, $K_2Cr_2O_7$ solution into the forth, and 1-2 drops of H_2O_2 into the fifth test tube. What do you observe?

Experiment 10. *Oxidizing Properties of H_2SO_3. (Procedure should be carried out in the fume hood!)*

Put 5÷8 drops of sulfurous acid into the test tube; add the same amount of H_2S water. Observe formation of free sulfur turbidity. Write the equation for the reaction.

Experiment 11. *Instability of Thiosulfuric Acid.*

Add 5 drops of HCl to the same volume of potassium thiosulfate ($Na_2S_2O_3$) solution. How can turbidity formation be explained? Draw structural-graphic formula of $Na_2S_2O_3$. Write the equation for the reaction and the scheme of electron balance.

Experiment 12. *Reducing Properties of $Na_2S_2O_3$ (Procedure should be carried out in the fume hood!)*

Dissolve small amount of $Na_2S_2O_3$ in 2-3 ml of distilled water in the test tube. Divide solution into 2 tubes. Add few drops of Cl_2 water into one tube. Make sure that chlorine odor disappeared. Prove the presence of SO_4^{2-} ions in solution by adding $BaCl_2$ solution.

Add 2-3 drops of starchy water and 3÷5 drops of I_2 water into the second test tube. Observe discoloration of I_2 solution. Write the equation for the reaction. Take into account that I_2 oxidizes $Na_2S_2O_3$ to $Na_2S_4O_6$.

Experiment 13. *Interaction Between Sulfuric Acid and Zinc. (Procedure should be carried out in the fume hood!)*

Place one granule of zinc in two test tubes. Add few drops of diluted H_2SO_4 into one test tube and concentrated H_2SO_4 into another. In the first tube reaction occurs vigorously with gas release. Does the gas have odor? Pay attention that zinc dissolves weakly in concentrated H_2SO_4. Heat slightly the test tube and observe the reaction. Does released gas have odor? (Be careful!) Heat test tube more and observe formation of free sulfur turbidity.

Write the equations for the reactions considering that zinc reduces concentrated H_2SO_4 to SO_2, S, or H_2S depending on the temperature.

CHAPTER 10. The Pnictogens (the Nitrogen Family)

The nitrogen family includes the following compounds: Nitrogen (N), Phosphorus (P), Arsenic (As), Antimony (Sb), and Bismuth (Bi). All **V–A group** elements **(**Group 15 in modern notation) have the electron configuration ns^2np^3 in their outer shell, where *n* is equal to the principal quantum number. The nitrogen family is located in the p-block in Group 15.

All Group 15 elements tend to follow the general periodic trends:

Electronegativity (the atom's ability of attracting electrons) decreases down the group.

Ionization energy (the amount of energy required to remove an electron from the atom in its gas phase) decreases down the group.

Atomic radii increase in size down the group.

Electron affinity (the ability of the atom to accept an electron) decreases down the group.

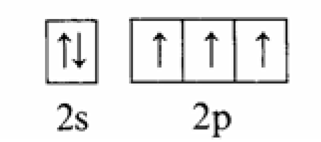
Melting point (amount of energy required to break bonds to change a solid phase substance to a liquid phase substance) increases down the group.

Boiling point (amount of energy required to break bonds to change a liquid phase substance to a gas) increases down the group.

Metallic character increases down the group.

Nitrogen

Nitrogen is the first member of group V–A of the periodic table. It has the electron configuration $1s^22s^22p^3$ with a single electron in each 2*p* orbital:



Nitrogen exhibits positive oxidation states only in its compounds with oxygen and fluorine, because only these elements are more electronegative than nitrogen. In its compounds nitrogen has oxidation numbers from –3 to +5.

There is no need to obtain nitrogen in the laboratory. The decomposition of sodium azide or ammonia nitrite is one way to N_2 preparation and decomposition of ammonium dichromate is the another. Both reactions must be carried out under controlled conditions by a professional only:

$$2NaN_3 \xrightarrow{300\ ^\circ C} 2Na + 3N_2\uparrow;$$

$$NH_4NO_2 \rightarrow N_2\uparrow + 2H_2O;$$

$$(NH_4)_2Cr_2O_7 \rightarrow N_2\uparrow + Cr_2O_3 + 4H_2O.$$

Nitrogen is made in great amounts by liquefaction of air and further fractional distillation of the liquid air for separating out oxygen and other gases.

A diatomic molecule on nitrogen N_2 is very stable; there is a triple bond between the nitrogen atoms in it.

Nitrogen gas does not react with air under normal conditions. Nitrogen gas does not react with water.

When nitrogen is heated, it combines directly with magnesium, lithium, or calcium:

$$6Li + N_2 \rightarrow 2Li_3N$$ *lithium nitride*;

$$N_2 + 2Ca \rightarrow Ca_3N_2$$ *calcium nitride*.

Nitrides of metals have basic (Na_3N, Mg_3N_2) or amphoteric (AlN) properties, and nitrides of nonmetals are acidic ones (Si_3N_4, P_3N_5, S_4N_4, Cl_3N).

Nitrides of alkali and alkaline earth metals are highly chemically reactive compounds. They can react with water forming the corresponding alkali and ammonia:

$$Li_3N + 3H_2O \rightarrow 3LiOH + NH_3.$$

Basic and acidic nitrides interact between themselves giving blended nitrides:

$$Li_3N + AlN \rightarrow Li_3AlN_2.$$

When mixed with oxygen and subjected to electric sparks, it forms nitric oxide (NO):

$$N_2 + O_2 \rightleftarrows 2NO,$$

and then the dioxide (NO_2):

$$2NO + O_2 \rightarrow 2NO_2.$$

When nitrogen heated under increased pressure with hydrogen in the presence of a proper catalyst, ammonia forms (*Haber process*):

$$N_2 + 3H_2 \rightleftarrows 2NH_3.$$

Ammonia is a colorless gas which has a typical suffocated odor. It readily dissolves in water (1150 liters of ammonia may be dissolved in 1 liter of water at 0 ^{0}C).

Ammonia was firstly prepared with the reaction of nitrogen and hydrogen:

$$N_2 + 3H_2 \rightleftarrows 2NH_3.$$

In the laboratory ammonia is prepared by heating the mixture of an ammonia salt and alkali:

$$(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2NH_3\uparrow + 2H_2O,$$

or by heating ammonia chloride with slake lime:

$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3\uparrow + 2H_2O.$$

Only three *p*-electrons of nitrogen take part in the formation of chemical bonds in the molecule of ammonia, and the nitrogen atom has free unshared pair of electrons also. Thus the molecule of NH_3 is a strong donor of electrons. Self-ionization of ammonia is very small.

The molecule of ammonia can join H^+-ion and transfer into ammonia-cation:

$$NH_3 + H^+ \rightarrow [NH_4]^+;$$

$$NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-.$$

The medium of ammonia aqueous solutions is basic one.

Gaseous ammonia and ammonia in aqueous solutions react with acids forming corresponding salts of ammonia:

$$NH_3 + HCl \rightarrow NH_4Cl.$$

Ammonia can also interact with metals. In such reactions hydrogen atoms in the molecule of ammonia are replaced with metals atoms giving the metals amides:

$$2NH_3 + 2Na \rightarrow 2NH_2Na + H_2\uparrow$$ *sodium amide*

Ammonia is a strong reducing agent. The nitrogen atom may change its oxidation number from –3 to 0 or +2. Halogens are commonly oxidizing ammonia to free nitrogen gas:

$$8NH_3 + 3Br_2 \rightarrow N_2\uparrow + 6NH_4Br.$$

Ammonia can burn in the atmosphere of oxygen with greenish-yellow flame:

$$4NH_3 + 3O_2 \rightarrow 2N_2\uparrow + 6H_2O.$$

In the presence of the catalyst ammonia interacts with oxygen giving nitrogen (II) oxide NO:

$$4NH_3 + 5O_2 \rightarrow 4NO\uparrow + 6H_2O.$$

Ammonia may readily reduce some metals from their oxides:

$$3CuO + 2NH_3 \rightarrow N_2\uparrow + 3Cu + 3H_2O.$$

Ammonia may be oxidized to nitrate-ion with potassium chlorate at 300 ^{0}C:

$$6NH_3 + 8KClO_3 + 6NaOH \rightarrow 6NaNO_3 + 8KCl + 12H_2O.$$

Liquid ammonia is a strong ionizing solvent. Thus ammonia salts such as NH_4Cl or NH_4NO_3 in the medium of liquid ammonia have acidic properties:

$$KNH_2 + NH_4Cl \rightarrow KCl + 2NH_3\uparrow;$$

$$Ca_3N_2 + 6NH_4Cl \rightarrow 3CaCl_2 + 8NH_3\uparrow;$$

$$2KNH_2 + Zn(NH_2)_2 \rightarrow K_2[Zn(NH_2)_4].$$

Ammonium salts have crystalline structure. They are ionic compounds which dissociate almost completely into ions in aqueous solutions:

$$NH_4Cl \rightleftarrows NH_4^+ + Cl^-;$$

$$NH_4^+ + H_2O \rightleftarrows NH_3 + H_3O^+.$$

Ammonium salts easily decompose, completely or partially, when heated:

$$NH_4Cl \underset{\text{heating}}{\overset{\text{cooling}}{\rightleftarrows}} NH_3 + HCl$$

$$(NH_4)_2SO_4 \rightleftarrows NH_3\uparrow + NH_4HSO_4.$$

Ammonium salts are chemically reactive. While heating ammonium salts with metals hydroxides solutions ammonia gas releases:

$$NH_4Cl + NaOH \rightarrow NaCl + NH_3\uparrow + H_2O.$$

Ammonium salts which have the anion of oxidizing nature decompose when heated:

$$NH_4NO_3 \rightarrow N_2O\uparrow + 2H_2O;$$

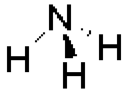
$$NH_4NO_2 \rightarrow N_2\uparrow + 2H_2O.$$

Ammonium chloride is used when metals are soldering for taking off the oxide layer from the metals surface:

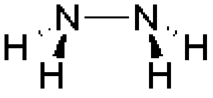
$$4CuO + 2NH_4Cl \rightarrow 3Cu + CuCl_2 + N_2\uparrow + 4H_2O,$$

$$Fe_3O_4 + 8NH_4Cl \rightarrow FeCl_2 + 2FeCl_3 + 8NH_3\uparrow + 4H_2O.$$

Hydrazine is derived from ammonia by replacement of a hydrogen atom by an $–NH_2$ group:



Ammonia



Hydrazine

Both nitrogen atoms in N_2H_4 have the pyramidal geometry. An aqueous solution of hydrazine can be prepared by oxidizing ammonia with a solution of sodium hypochlorite:

$$2NH_3 + NaClO \rightarrow N_2H_4 + H_2O + NaCl.$$

The chloramines, H_2NCl and $HNCl_2$, are produced also in this reaction. They both are toxic and explosive.

Hydrazine is a colorless liquid. It is a weak base, which is protonated giving the $N_2H_5^+$ and $N_2H_6^{2+}$ ions. Hydrazine is an unstable compound.

Hydrazine burns in the air:

$$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O.$$

Hydrazine is a good reducing agent and reacts vigorously with strong oxidizing agents such as halogens, nitric acid, dinitrogen tetraoxide, and hydrogen peroxide:

$$2N_2H_4 + N_2O_4 \rightarrow 3N_2 + 4H_2O;$$

$$N_2H_4 + 2H_2O_2 \rightarrow N_2 + 4H_2O.$$

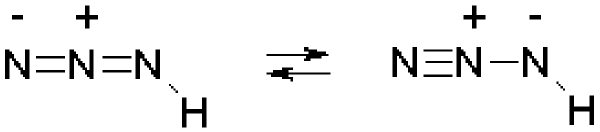
The oxidation of N_2H_4 or substituted hydrazine's, where one or more of the hydrogens are replaced by methyl groups, is used in power rockets. For example at the Apollo missions to the moon, the rocket engines of the command module and the lunar landing vehicles used N_2O_4 as an oxidizer and a mixture of hydrazine and dimethylhydrazine as fuel. The U.S. space shuttle orbiter also used N_2O_4 and monomethylhydrazine. They react giving water, nitrogen, and carbon dioxide:

$$5N_2O_4 + 4N_2H_3(CH_3) \rightarrow 12H_2O + 9N_2 + 4CO_2.$$

This reaction begins immediately when the reactants are mixed which enables the rocket engines to be started and stopped as required. Since the reaction is highly exothermic and gives a large number of gaseous molecules, a high thrust is obtained from minimum mass of fuel.

Hydrazoic acid (HN_3) is a liquid that boils at 37 °C and it is dangerously explosive. It is a weak acid in water. Salts of hydrazoic acid are called *azides*. Azides of heavy metals such as lead, mercury, and barium are used as detonators.

It can be represented by the following two resonance structures:



Hydroxilamine is a weaker base than ammonia:

$$NH_2OH + HOH \rightleftarrows NH_3OH^+ + OH^-.$$

It can react with acids giving corresponding stable salts:

$$NH_2OH + HCl \rightarrow [NH_3OH]^+Cl^-.$$

Hydroxilamine has oxidizing properties in acidic medium, and it shows reducing properties in basic medium:

$$2NH_2OH + I_2 + 2KOH \rightarrow N_2\uparrow + 2KI + 4H_2O,$$

$$2NH_2OH + 4FeSO_4 + 3H_2SO_4 \rightarrow 2Fe_2(SO_4)_3 + (NH_4)_2SO_4 + 2H_2O.$$

Nitrogen forms the following oxides: nitrogen (I) oxide N_2O, nitrogen (II) oxide NO, nitrogen (III) oxide N_2O_3, nitrogen (IV) oxide NO_2, and nitrogen (V) oxide N_2O_5.

Properties of Nitrogen Oxides

Oxidation State	**Formula**	**Name**	**Physical State at 25 °C**
+5	N_2O_5	Dinitrogen pentaoxide	White solid
+4 +4	N_2O_4 NO_2	Dinitrogen tetraoxide Nitrogen dioxide	White solid Brown gas
+3	N_2O_3	Dinitrogen trioxide	Deep blue liquid (–80°C)

+2	NO	Nitrogen monoxide	Colorless gas
+1	N_2O	Dinitrogen monoxide	Colorless gas

Nitrous acid is an unstable acid and is known only in solution. A solution of nitrous acid may be prepared by the action of water on its anhydride, N_2O_3:

$$N_2O_3 + H_2O \rightarrow 2HNO_2,$$

Nitrous acid is a weak acid. Aqueous solution of nitrous acid is pale blue due to the presence of nitrogen trioxide. The acid is unstable:

$$3HNO_2 \rightarrow 2NO + HNO_3 + H_2O.$$

At higher temperature it decomposes into nitric oxide and nitrogen peroxide:

$$2HNO_2 \rightarrow N_2O_3 + H_2O;$$

$$N_2O_3 \rightleftarrows NO + NO_2.$$

It acts as a good oxidizing agent:

$$2HNO_2 + H_2S \rightarrow 2NO + S + 2H_2O;$$

$$2KI + 2HNO_2 \rightarrow 2KOH + I_2 + 2NO;$$

$$2HNO_2 + SO_2 \rightarrow 2NO + H_2SO_4;$$

$$2FeSO_4 + H_2SO_4 + 2HNO_2 \rightarrow Fe_2(SO_4)_3 + 2NO + 2H_2O.$$

Nitrous acid can be easily oxidized to nitric acid:

$$HNO_2 + I_2 + H_2O \rightarrow 2HI + HNO_3;$$

$$HNO_2 + Br_2 + H_2O \rightarrow 2HBr + HNO_3.$$

$$2KMnO_4 + 3H_2SO_4 + 5HNO_2 \rightarrow K_2SO_4 + 2MnSO_4 + 5HNO_3 + 3H_2O,$$

$$K_2Cr_2O_7 + 4H_2SO_4 + 3HNO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3HNO_3 + 4H_2O.$$

It reduced hydrogen peroxide:

$$H_2O_2 + HNO_2 \rightarrow HNO_3 + H_2O.$$

Nitrous acid reacts with alkalis forming *nitrites* (salts of nitrous acid). Nitrites are more stable than nitrous acid:

$$NaOH + HNO_2 \rightarrow NaNO_2 + H_2O;$$

$$KOH + HNO_2 \rightarrow KNO_2 + H_2O.$$

Nitrites may be prepared by passing nitrogen trioxide through the solution of an alkali:

$$N_2O_3 + 2NaOH \rightarrow 2NaNO_2 + H_2O.$$

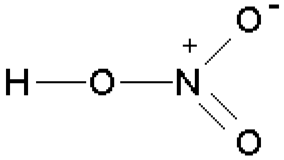
Nitrites are stable substances. They are soluble in water, except silver nitrite which dissolves in hot water.

At ordinary temperatures, reddish brown fumes are obtained by the reaction with concentrated acids:

$$2NaNO_2 + 2HCl \rightarrow 2NaCl + NO + NO_2 + H_2O.$$

Pure HNO_3 is colorless liquid. It is soluble in water in all proportions. The acid is highly.

Structure of nitric acid:



HNO_3 is colorless but often turns yellow. Yellow color produces due to decomposition of nitric acid:

$$4HNO_3 \xrightarrow{h\nu} 4NO_2 + O_2 + 2H_2O.$$

At a room temperature the pure acid undergoes decomposition giving N_2O_2 and O_2:

$$2HNO_3 \xrightarrow{\text{room temperature}} N_2O_5 + H_2O$$

With heating HNO_3 decomposes to give O_2 and brown fumes of NO_2:

$$4HNO_3 \xrightarrow{\Delta} 4NO_2 + O_2 + 2H_2O.$$

HNO_3 is a very strong monobasic acid. It reacts with basic oxides, carbonates, bicarbonates, sulfites and hydroxides, forming corresponding nitrates:

$$CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O,$$
$$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2,$$
$$NaHCO_3 + HNO_3 \rightarrow NaNO_3 + H_2O + CO_2,$$
$$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O,$$
$$Na_2SO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + SO_2.$$

As a strong acid, HNO_3 is completely ionized in water:

$$HNO_3 \rightarrow H^+ + NO_3^-.$$

HNO_3 is a very strong oxidizing agent and can be reduced to NO_2, NH_4NO_3 (or NH_4^+ ions), N_2O, NO, N_2 or NH_2OH depending on the nature of the substance being oxidized, concentration of HNO_3 and the temperature applied.

When *non-metals* react with HNO_3 they oxidized to corresponding highest oxy-acids and HNO_3 is reduced to NO_2 (NO). For example:

$$P + 5HNO_3 \rightarrow H_3PO_4 + 5NO_2 + H_2O;$$
$$C + 4HNO_3 \rightarrow H_2CO_3 + 4NO_2 + H_2O.$$

Concentrated HNO_3 can oxidize metals:

$$Zn + 4HNO_3(conc.) \rightarrow Zn(NO_3)_2 + 2NO_2 + 2H_2O.$$

Mixture of one volume of nitric acid and three volumes of hydrochloric acid is called *"aqua regia"* and is a stronger oxidizing agent:
$HNO_3 + 3HCl \rightarrow NO + 2H_2O + 3Cl$ (atomic chlorine evolves).
"Aqua regia" can dissolve gold and platinum:

$$Au + HNO_3 + 4HCl \rightarrow H[AuCl_4] + NO + 2H_2O.$$

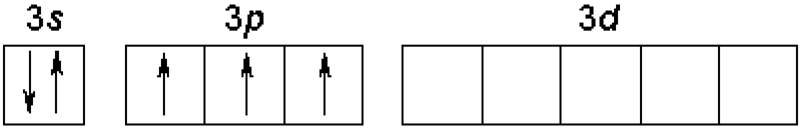
Salts of nitric acid are called *nitrates*. They have crystal structure and dissolve in water. Nitrates decompose at heating:

$$2KNO_3 \rightarrow 2KNO_2 + O_2\uparrow.$$

$$2AgNO_3 \rightarrow 2Ag + NO_2\uparrow + O_2\uparrow.$$

$$2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2\uparrow + O_2.$$

Phosphorus has the following ground state configuration:



The process of phosphorus preparation is carried out in stages:

$$Ca_3(PO_4)_2 + 8C \rightarrow Ca_3P_2 + 8CO;$$

$$3Ca_3(PO_4)_2 + 5Ca_3P_2 \rightarrow 24CaO + 16P.$$

SiO_2 added to the mixture of reactants to increase the reaction rate:

$$CaO + SiO_2 \rightarrow CaSiO_3.$$

The summary reaction of phosphorus preparation is:

$$10C + 6SiO_2 + 2Ca_3(PO_4)_2 \rightarrow 10CO + 6CaSiO_3 + 4P.$$

Phosphorus can be easily oxidizes with oxygen, halogens and other strong oxidizing agents:

$$3P + 5HNO_3 + 2H_2O \rightarrow 3H_3PO_4 + 5NO\uparrow.$$

In reactions with halogens phosphorus may give phosphorus(III) and phosphorus(V) halides:

$$2P + 3Cl_2 \rightarrow 2PCl_3\ ;$$

$$PCl_3 + Cl_2 \rightarrow PCl_5\,.$$

In the reactions of phosphorus with metals it gives corresponding phosphides:

$$3Mg + 2P \rightarrow Mg_3P_2.$$

In aqueous solutions phosphides hydrolyzed:

$$Ca_3P_2 + 6H_2O \rightarrow 3Ca(OH)_2 + PH_3.$$

Phosphine (PH_3) is hydride of phosphorus. It is a colourless gas with the unpleasant garlic-like odour. It is poisonous. It is slightly soluble in water. At laboratory phosphine may be prepared by boiling white phosphorus with aqueous alkalies:

$4P + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$ (*Sodium hypophosphite*).

Phosphine burns in chlorine spontaneously forming PCl_3 and PCl_5:

$$PH_3 + 3Cl_2 \rightarrow PCl_3 + 3HCl,$$

$$PH_3 + 4Cl_2 \rightarrow PCl_5 + 3HCl.$$

With some salts of metals, phosphine gives precipitates of metallic phosphides:

$$3AgNO_3 + PH_3 \rightarrow Ag_3P + 3HNO_3,$$

$$3CuSO_4 + 2PH_3 \rightarrow Cu_3P_2 + 3H_2SO_4.$$

Phosphine reacts with acids forming *phosphonium salts* similarly to ammonium salts:

$PH_3 + HCl \rightarrow PH_4Cl$ *(Phosphonium chloride)*,
$PH_3 + HBr \rightarrow PH_4Br$ *(Phosphonium bromide)*.

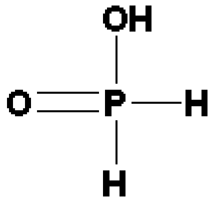
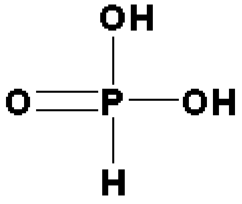
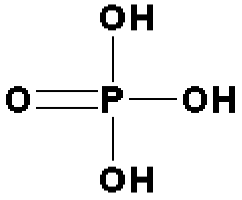
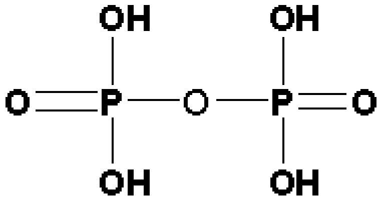
P_2O_3 with ice-water, it gives phosphorus acid:

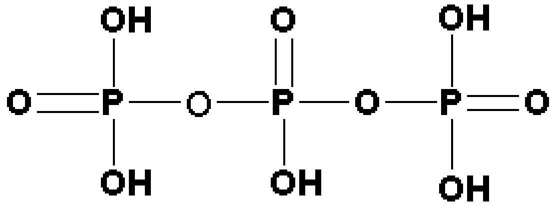
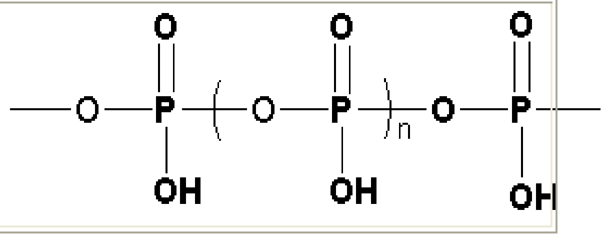
$$P_2O_3 + 3H_2O \rightarrow 2H_3PO_3.$$

Phosphorous pentoxide gives different acids with different quantities of water:

$P_2O_5 + H_2O \rightarrow 2HPO_3$ *(Metaphosphoric acid)*,
$P_2O_5 + 2H_2O \rightarrow H_4P_2O_7$ *(Pyrophosphoric acid)*,
$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$ *(Orthophosphoric acid)*.

Oxoacids of Phosphorus

Oxidation State	Name	Formula	Structure
+1	**Hypophosphorus acid**	**H_3PO_2**	
+3	**Orthophosphorus acid**	**H_3PO_3**	
+5	**Orthophosphoric acid**	**H_3PO_4**	
+5	**Pyrophosphoric acid**	**$H_4P_2O_7$**	

+5	**Triphosphoric acid**	**$H_5P_3O_{10}$**	
+5	**Metaphosphoric acid**	**$(HPO_3)_n$**	

Laboratory work

V–A group of chemical elements

Experiment 1. *Making Nitrogen*

Place about 1g of solid $NaNO_2$ and pour 3-4 ml of saturated NH_4Cl solution into the test tube, quickly insert a rubber stopper with delivery tube. Heat gently.

Experiment 2. *Making Ammonia and Studying Its Properties*

Mix one part of solid NH_4Cl with one part of solid $Ca(OH)_2$. Drop 3g of the mixture into the dry test tube. Provide the tube with a stopper and L-shaped glass tube. Place the dry tube upside down and heat the mixture gently. Test ammonia with moistened pink litmus paper. Explain discoloration of litmus paper.

Experiment 3. *Ammonia Solution Properties*

a. Put 2-3 drops of ammonia solution into the test tube, add 1 drop of phenolphthalein solution. What properties does the color of indicator show?

b. Put 2-3 drops of ammonia solution; add the same amount of iron sulfate (II) ($FeSO_4$) solution. Write the equation for this reaction.

Experiment 4. *Characteristic Reaction of NH_4^+ Ions*

Put 5-6 drops of NH_4Cl solution into the test tube, add 3-4 drops of NaOH solution and heat the mixture. Hold moistened pink litmus paper at the mouth of the tube. What do you observe? What gas forms? Write the equation for this reaction.

Experiment 5. *Producing Nitrogen Oxide (II) and Studying Its Properties*

Drop a pinch of copper strips into the test tube; pour 1-2 ml of diluted HNO_3. Insert a rubber stopper with delivery tube and heat the mixture gently. As soon as gas starts to bubble up through the water, collect some of it in the water-filled test tube. Close the mouth of the tube with a thumb and remove the tube from water. Pay attention to the color of the gas. Write the equation for the reaction. Open the tube and observe gas discoloration. Pour some water in the same tube and shake well. Test pH with litmus. Write the equations for the reactions.

Experiment 6. *Producing Nitrogen Oxide (IV) and Studying Its Properties (Procedure should be carried out in the fume hood!).*

Drop a pinch of copper strips into the test tube; pour a little bit of concentrated HNO_3. Collect gas in the test tube. Pour 1 ml of water into the test tube with NO_2 and shake. Test the solution with litmus. Write the equation for the reaction of interaction between nitrogen oxide (IV) and water.

Experiment 7. *Making Nitric Acid*

Put a pinch of solid $NaNO_2$ or KNO_2; add 1-2 ml of water and 5-10 drops of diluted H_2SO_4. Note the color of solution and gas over it. Explain what chemical agent creates the color of solution. What is the gas composition? Write the equations for the reactions.

Experiment 8. *Oxidative and Reducing Properties of Nitrous Acid (Nitrites).*

a. Pour 3-5 drops of KI solution into the test tube; acidify it by 1-2 drops of diluted H_2SO_4. Add 2-3 drops of $NaNO_2$ solution. Explain discoloration of the solution. What properties does $NaNO_2$ show in this reaction? Write the equation for this reaction.

b. Pour 1-2 drops of $KMnO_4$ solution, acidify it by 1-2 drops of H_2SO_4 solution and add 5-7 drops of $NaNO_2$.solution. What properties does $NaNO_2$ show in this reaction? Write the equation for this reaction.

Experiment 9. *Oxidizing Properties of Nitric Acid (Procedure should be carried out in the fume hood!).*

a. Place a granule of zinc in one test tube and a copper strip – in another one. Add few drops of concentrated HNO_3 in each test tube. What gas is emitted? Write the equations.

b. Place a pinch of magnesium into the test tube; add few drops of much diluted HNO_3. Shake well for several minutes and then pour solution into another test tube. Prove NH_4^+ ions presence in the solution. Write the equations for the reactions.

Experiment 10. *Thermal Decomposition of Nitrates*

Put few crystals of $NaNO_3$ into one test tube, $Cu(NO_3)_2 \cdot 3H_2O$ – into another one. Heat each tube one after another. Bring smolder match in each tube. What do you observe? Write the equations for the reactions.

Experiment 11. *Qualitative Reactions to Phosphoric Acid Ions*

a. Add 5-6 drops of H_3PO_4 solution or its salt to 3-5 drops of molybdenum solution. Heat the mixture in a water bath. What do you observe?

b. Add 2-3 drops of $AgNO_3$ solution to 3-5 drops of Na_2HPO_4 solution. What are the type and color of formed precipitate? Is precipitate soluble in HNO_3? Write the equations of corresponding reactions.

c. Put few drops of sodium methaphosphate and sodium pyrophosphate into two separate test tubes. Add few drops of $AgNO_3$ solution in each tube. Are precipitates soluble in HNO_3? Write the equations of corresponding reactions.

d. Put few drops of egg-white water solution into two test tubes. Add few drops of sodium methaphosphate solution in the first tube and sodium pyrophosphate in the second one; add few drops of CH_3COOH solution in each tube. Boiled egg-white is seen in the test tube with sodium methaphosphate. Draw a conclusion how to distinguish PO_4^{3-}, $P_2O_7^{4-}$, and PO_3^- ions.

Experiment 12. *Making Phosphoric Acids (Procedure should be carried out in the fume hood!)*

a. Put a pinch of P_2O_5 powder into the first test tube; add 2-3 ml of cool distilled water. After dissolving, pour 1-1.5 ml of solution into another test tube and neutralize it by soda solution to weak acidic (test reaction by litmus paper). Explain what acid was formed. Write the equation of the reaction.

Add 3-4 ml of water and 0.5-1 ml of concentrated HNO_3 to the acid solution in the first test tube. Heat the mixture for 10 minutes in a water bath. Pour half of the solution into another tube and add 5-6 drops of molybdenum solution; heat the mixture again in a water bath for 5 minutes. Write down your observations, explain the reactions, and write corresponding equations.

b. Heat a piece of red phosphorus with 4-5 ml of concentrated HNO_3 in evaporation dish. If a part of phosphorus doesn’t react add a small amount of HNO_3. Pour half of formed solution into the test tube. Add 5-6 drops of molybdenum solution and heat in a water bath for 5 minutes. What acid is formed? Write the equation for the reaction.

Experiment 13. *Hydrolysis of Salts of Orthophosphoric Acid*

Pour 1-1.5 ml of distilled water into 3 test tubes. Dissolve few crystals of Na_3PO_4 in the first tube, Na_2HPO_4 in the second, and NaH_2PO_4 in the third one. Identify pH of the solution with litmus paper in each test tube. Explain reaction medium in all cases. Write corresponding molecular and ionic equations of hydrolysis.

CHAPTER 11. IV–A group (The Carbon Family)

The carbon family, IV–A group (Group 14 in the p-block), contains Carbon (C), Silicon (Si), Germanium (Ge), Tin (Sn), Lead (Pb), and Flerovium (Fl). Each of these elements has only two electrons in its outermost p orbital: each has the electron configuration ns^2np^2. The Group 14 elements tend to adopt oxidation states of +4 and, for the heavier elements, +2.

Members of this group conform well to general periodic trends. The atomic radii increase down the group, and ionization energies decrease. Metallic properties increase down the group. Carbon and silicon are non-metals, and germanium are with some metal proporties, and tin and lead are poor metals (they conduct heat and electricity less effectively than other metals such as copper).

The atoms of these elements have the following configurations:

$_6$C [He]$2s^22p^2$
$_{14}$Si [Ne]$3s^23p^2$
$_{32}$Ge [Ar] $4s^24p^2$
$_{50}$Sn [Kr] $5s^25p^2$
$_{82}$Pb [Xe]$6s^26p^2$

Until 1985, only two allotropes of carbon were known – diamond and graphite. Diamond is the hardest substance known, having a very rigid structure. Each carbon atom is sp^3 hybridized and linked to four other atoms. Graphite has a layer – structure in which weak van der Waal's forces hold individual layers of fused six membered rings together. The carbon atoms are sp^2 hybridized and out of four valence electrons, three are involved in σ -bond formation the fourth electron is involved in delocalized π-bonding. The layers slide over one another and the π electrons move within each layer making graphite a conductor of electricity and conferring lubricating properties.

A fascinating discovery was the synthesis of spheroid carbon- cage molecules called fullerenes (Figure). These were first prepared by evaporation of graphite using laser. A more practical method is to heat graphite in an electric are in an inert atmosphere (helium or argon). A sooty material so formed consists of C60 with smaller amounts of C70 and other fullerenes

containing even number of carbon atoms. Unlike diamond and graphite fullerenes dissolve in organic solvents like toluene. C60 is the most stable fullerene containing twenty sixmembered rings and twelve five-membered rings. The six- membered rings are fused to other six membered and five-membered rings while five- membered rings and connected to only six-membered rings.

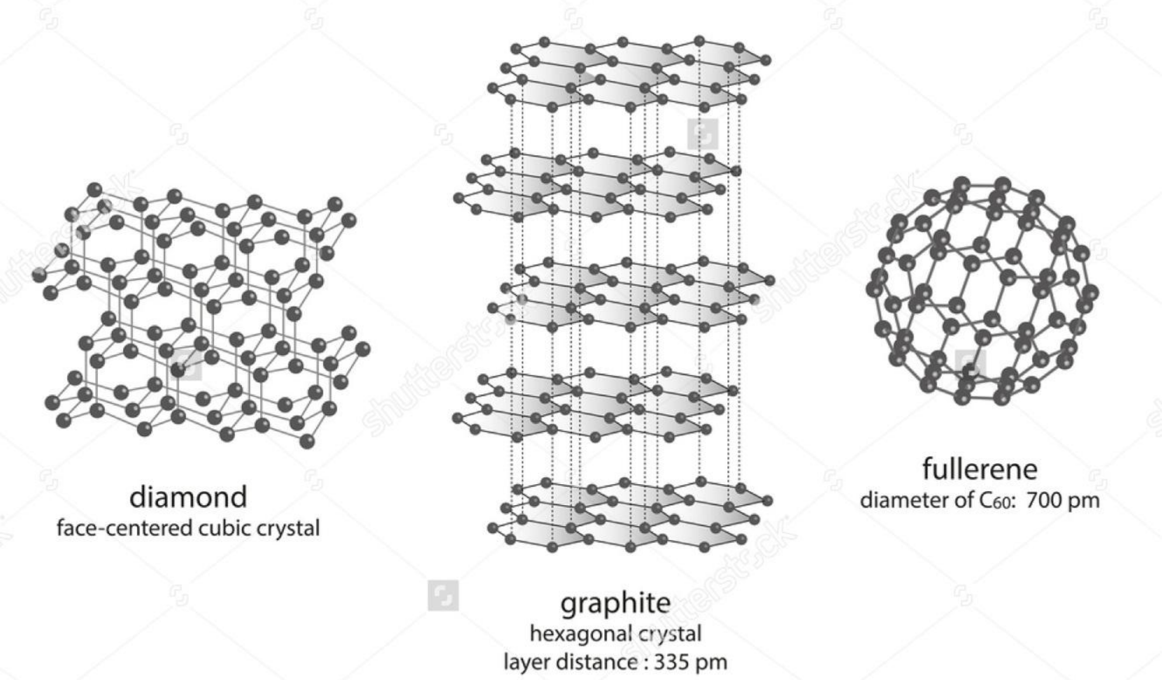


Figure.4. Allotropes of carbon

Carbon is chemically passive, its reactivity increasing with the increasing of temperature. It reacts vigorously with oxygen when heated in the air. In the lack of oxygen forms carbon monoxide, in the excess of oxygen is formed carbon dioxide:

$$2C + O_2 \rightarrow 2CO\uparrow;$$
$$C + O_2 \rightarrow CO_2\uparrow.$$

Carbon reacts with some metals in high temperatures giving carbides:

$$2C + Ca \rightarrow CaC_2.$$

Carbon combines with hydrogen at the high temperature and electric arc producing methane:

$$C + 2H_2 \rightarrow CH_4\uparrow.$$

When water steam is passing through red heated charcoal or coke (at the temperature of 1200 °C) the forms mixture of carbon monoxide and hydrogen gasses:

$$C + H_2O \rightarrow CO\uparrow + H_2\uparrow.$$

At lower temperature (1000 °C):

$$C + 2H_2O \rightarrow CO_2\uparrow + 2H_2\uparrow.$$

Concentrate sulfuric and nitric acids oxidize carbon to carbon dioxide:

$$C + 2H_2SO_4 \rightarrow CO_2\uparrow + 2SO_2\uparrow + 2H_2O;$$
$$3C + 4HNO_3 \rightarrow 3CO_2\uparrow + 4NO\uparrow + 2H_2O.$$

Laboratory work

IV–A group of chemical elements

Experiment 1. *Adsorption Properties of Charcoal*

a. Pour fuchsine or brilliant green to the water in the test tube. Add pulverized charcoal. Shake vigorously and filter. Explain solution discoloration.

b. Add 1-2 drops of KI solution with a few drops of $Pb(CH_3COO)_2$ or $Pb(NO_3)_2$ solution to the first test tube. What do you observe? Draw ionic equations. Pour 1-2 ml of the same plumbum (lead) salt into the second test tube and add a pinch of pulverized charcoal; close the mouth of the test tube with a rubber stopper and shake vigorously. Filter solution. Put 1-2 drops of KI solution into the filtrate. Does the yellow precipitate form?

Experiment 2. *Reducing Properties of Charcoal*

Mix a pinch of CuO and pinch of pulverized charcoal together. Put the mixture into the dry test tube. Place the tube horizontally in a stand and quickly insert a rubber stopper with delivery tube. Insert the delivery tube into a second test tube with barytic water. Heat the mixture up to gas formation over the flame of burner. What gas releases? What do you see in the test tube with barytic water? What changes do you observe in the test tube with CuO and charcoal? Equate the corresponding reaction.

Experiment 3. *Producing Carbon Oxide (IV) and Studying Its Properties*

a. Put a piece of marble into Kipp gas generator and pour HCl solution (1:4). Check the function of the apparatus. Is it possible to use H_2SO_4 solution for CO_2 formation from marble? Write the equation for the reaction that progress in a Kipp gas generator.

b. Pass CO_2 into the test tube filled with litmus-colored distilled water up to solution discoloration. Boil solution thoroughly. Explain the effect that you observe. Indicate the presence of equilibrium in CO_2 water solution with equations of the reactions. How can the equilibrium be biased?

Experiment 4. *Making Carbonates*

a. Pass CO_2 into the water-filled test tube with lime water ($Ca(OH)_2$ water solution). Observe white turbidity. Continue to pass CO_2 up to precipitate dissolution. Write the equations for corresponding reactions.

b. Divide $Ca(HCO_3)_2$ solution prepared in experiment a. into two tubes. Heat the first test tube; add lime water to the second one. White precipitate appears in all tubes. Write the equation.

Experiment 5. *Properties of Carbonates.*

a. Produce $MgCO_3$ in one test tube and $BaCO_3$ in another one with the help of corresponding replacement reactions. Divide each precipitate into two test tubes. Probe the acid solubility of these salts in diluted HCl and CH_3COOH. Write the equations. Explain why do carbonates dissolve even in such a week acid as CH_3COOH? Is it possible to use H_2SO_4 solution for $MgCO_3$ i $BaCO_3$ dissolution?

b. Put pinches of solid $(NH_4)_2CO_3$, $NaHCO_3$, and $Cu_2(OH)_2CO_3$ into three separate test tubes and heat each one of them. What happens? Write the equation for corresponding reactions.

c. Test the reaction medium of $NaHCO_3$ and Na_2CO_3 solutions with indicator paper. Write the equations of hydrolysis.

d. Put few drops of $CuSO_4$ and $Cr_2(SO_4)_3$ solutions into two test tubes; add the same amount of Na_2CO_3 solution. Observe precipitates formation. Write the equations of corresponding reactions.

Experiment 6. *Making Silicic Acid*

Pour 5-7 drops of water glass (Na_2SiO_3 solution); add diluted HCl (2N) dropwise, stirring with glass rod up to precipitate formation. Describe the outward sign of silicic acid jelly and write the equation.

Experiment 7. *Making Silicic Acid Sol and Turning It Into Gel*

Pour 4-5 drops of concentrated HCl and 1-2 drops of sodium silicate (Na_2SiO_3) solution into the test tube. Carry out observation and compare it with the observation in the previous experiment. Heat the content of the tube using a water bath. What occurs with silicic acid sol during heating?

Experiment 8. *Hydrolysis of Sodium Silicate*

Add 7-8 drops of distilled water and 1-2 drops of phenolphthalein to a few drops of Na_2SiO_3 solution. How can you explain the discoloration of indicator? Write the molecular and ionic equations.

Add NH_4Cl solution dropwise into the mixture until phenolphthalein is discolored, then add few more drops. What happens? Write the equation for this process.

Experiment 9. *Sedimentation of* SiO_4^{4-}.

Add ammonia water gradually to $CuSO_4$ solution into the test tube up to precipitate formation and then add more until it dissolves. Add Na_2SiO_3 solution to this mixture. Observe formation of turquoise-blue $CuSiO_3$ precipitate. Write balanced equation to describe this experiment.

Experiment 10. *Reducing Properties of Sn (II) i Pb (II) Compounds*

a. Put a granule of tin into the test tube and add 10 drops of diluted HCl (2N). Add Br_2 water dropwise into the mixture. Why does solution discolor? Write the equation for reactions that occur.

b. Put 5-6 drops of $Pb(CH_3COO)_2$ solution into another test tube and add Br_2 water dropwise. Why does black precipitate form? What reaction occurs?

Experiment 12. *Amphoteric Properties of Sn (II) and Pb (II) Hydroxides*

Put 5-6 drops of Sn(II) into one test tube and Pb(II) salt solution into another; add 2N alkali (NaOH or KOH) dropwise up to precipitate appearance. Afterwards, add more until it dissolves. What reactions occur?

Experiment 13. *Preparation of Insoluble Pb (II) Salts*

Put 5-6 drops of $Pb(NO_3)_2$ solution into two test tubes; add few drops of concentrated HCl into one and few drops of KI solution into another. What is the difference between precipitates in the tubes?

CHAPTER 12. III–A group (The Boron Family)

The boron family contains elements in III–A group (group 13) of the periodic talbe and include the semi-metal boron (B) and the metals aluminum (Al), gallium (Ga), indium (In), and thallium (Tl). Aluminum, gallium, indium, and thallium have three electrons in their outermost shell (a full s orbital and one electron in the p orbital) with the valence electron configuration ns^2np^1. The elments of the boron family adopts oxidation states +3 or +1. The +3 oxidation states are favorable except for the heavier elements, such as Tl, which prefer the +1 oxidation state due to its stability; this is known as the *inert pair effect*. The elements generally follow periodic trends except for certain Tl deviations.

The atoms boron family have the following configurations:

$_{5}B$ $[He]2s^22p^1$

$_{13}Al$ $[Ne]3s^23p^1$

$_{31}Ga$ $[Ar]\ 4s^24p^1$

$_{49}In$ $[Kr]\ 5s^25p^1$

$_{81}Tl$ $[Xe]6s^26p^1$

Boron forms oxide B_2O_3 when heated in oxygen atmosphere at high temperature:

$4B + 3O_2 \xrightarrow{T-700^0C} 2B_2O_3$ *(Boron oxide or Boric anhydride).*

Boron can form trichloride by passing chlorine over the heated boron or by passing chlorine over the heated mixture of its oxide and charcoal:

$$2B + 3Cl_2 \xrightarrow{\Delta} 2BCl_3;$$

$$B_2O_3 + 3C + 3Cl_2 \xrightarrow{\Delta} 2BCl_3 + 3CO.$$

BCl_3 is hydrolyzed in water:

$$BCl_3 + 3H_2O \rightarrow H_3BO_3 + 3HCl.$$

Boron forms nitride BN when heated in the atmosphere of nitrogen or ammonia and sulfide B_2S_3 when heated with sulfur:

$$2B + N_2 \xrightarrow{\Delta} 2BN;$$

$$2B + 2NH_3 \xrightarrow{\Delta} 2BN + 3H_2;$$

$$2B + 3S \xrightarrow{\Delta} B_2S_3.$$

The nitride and sulfide undergo hydrolysis with steam:

$$BN + 3H_2O \rightarrow \underset{\textit{Boric acid}}{H_3BO_3} + NH_3;$$

$$B_2S_3 + 6H_2O \rightarrow 2H_3BO_3 + 3H_2S.$$

Boron reacts with steam water:

$$2B + 3H_2O \xrightarrow{\Delta} B_2O_3 + 2H_2.$$

Boron reacts with concentrated H_2SO_4 and evolves sulfur dioxide, SO_2:

$$2B + 3H_2SO_4(\text{conc.}) \rightarrow 2H_3BO_3 + 3SO_2\uparrow.$$

It dissolve in alkalis:

$$2B + 6NaOH \rightarrow \underset{\textit{sodium orthoborate}}{2Na_3BO_3} + 3H_2\uparrow.$$

Boron acts as powerful reducing agent:

$$4B + 3CO_2 \rightarrow 2B_2O_3 + 3C;$$

$$4B + 3SiO_2 \rightarrow 2B_2O_3 + 3Si.$$

Laboratory work

III–A group of chemical elements

Experiment 1. *Preparation of Orthoboric Acid From Borax*

Add 2-3 drops of concentrated H_2SO_4 to 5-6 drops of saturated borax solution. Cool the test tube with a tap cold water stream. Determine the formation of orthoboric acid crystals. Write the equation of hydrolysis.

Experiment 2. *Hydrolysis of Borax and Medium of Its Solution*

Pour few drops of borax into the test tube and 1-2 drops of phenolphthalein. What happens? Write the equation of hydrolysis.

Experiment 3. *Hydrolysis of Aluminum Salts*

Pour 10-15 drops of distilled water into the test tube; add 1-2 crystals of solid $Al_2(SO_4)_3{\cdot}18H_2O$. Shake up to dissolving and test pH with litmus paper. Write molecular and ionic equations of the first step of hydrolysis.

Experiment 4. *Interaction Between Salts Solutions*

Pour 5-7 drops of $AlCl_3$ solution or $Al_2(SO_4)_3$ solution and the same amount of CH_3COONa solution into the test tube. Heat the test tube content for 5-7 minutes in a water bath. What do you observe? What is the difference between results in this and previous experiments? Write molecular and ionic equations of the second step of hydrolysis.

Experiment 5. *Amphoteric Properties of Aluminium Hydroxide*

Pour 4-5 drops of Al^{3+} salt into two test tubes; add 2N KOH or NaOH solution dropwise until precipitate forms. Add 5-7 drops of HCl solution into the first test tube and 5-6 drops of alkali into another one. What do you observe? What properties of aluminum hydroxide are indicated by its interaction with acid or alkali? Write the equations.

CHAPTER 13. II–A group (Alkaline Earth Metals)

The **II–A group** include Beryllium (Be), Magnesium (Mg), and alkaline earth metals: Calcium (Ca), Barium (Ba), Strontium(Sr) and Radium(Ra) are soft, silver metals that are less metallic in character than the Group 1 Alkali Metals. Although many characteristics are common throughout the group, the heavier metals such as Ca, Sr, Ba, and Ra are almost as reactive as the Group 1 Alkali Metals. All the elements in Group II have two electrons in their valence shells, giving them an oxidation state of +2.

Beryllium reacts directly with many nonmetals. For example, with:

Oxygen:
$2Be + O_2 \rightarrow 2BeO$ (beryllium oxide);
Nitrogen:
$3Be + N_2 \rightarrow Be_3N_2$ (beryllium nitride);

Sulfur:
$Be + S \rightarrow BeS$ (beryllium sulfide);
Halogens:
$Be + Cl_2 \rightarrow BeCl_2$ (beryllium chloride)

Beryllium is an amphoteric metal and reacts with strong acids and bases:

$$Be + H_2SO_4 \rightarrow BeSO_4 + H_2\uparrow;$$
$$3Be + 8HNO_3(\text{diluted}) \rightarrow Be(NO_3)_2 + 2NO\uparrow + 4H_2O;$$
$$Be + 2NaOH + 2H_2O \rightarrow Na_2[Be(OH)_4] + H_2\uparrow;$$
$$Be + 2NaOH \xrightarrow{t} Na_2BeO_2 + H_2\uparrow.$$

Beryllium hydroxide is insoluble in water. It is an amphoteric hydroxide which reacts readily with strong acids and bases:

$$Be(OH)_2 + H_2SO_4 \rightarrow BeSO_4 + 2H_2O;$$
$$Be(OH)_2 + 2NaOH \rightarrow Na_2[Be(OH)_4].$$

Magnesium reacts with nonmetals. For example, with:

Oxygen:
$2Mg + O_2 \rightarrow 2MgO$ (magnesium oxide);
Nitrogen:
$3Mg + N_2 \rightarrow Mg_3N_2$ (magnesium nitride);

Sulfur:
$Mg + S \rightarrow MgS$ (magnesium sulfide);
Halogens:
$Mg + Cl_2 \rightarrow MgCl$ (magnesium chloride);

Magnesium reacts directly with many acids:

$$Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow;$$
$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\uparrow;$$
$$4Mg + 10HNO_3(\text{dilute}) \rightarrow 4Mg(NO_3)_2 + NH_4NO_3 + 3H_2O.$$

The chemistry of the alkaline earth metals is relatively simple. Since two electrons can be easily removed from their atoms to form the M^{2+} ions, there is only one stable oxidation state +2. With the exception of a very few compounds, all compounds of alkaline earth metals are ionic. All these elements are very reactive. The metals react directly with many other elements and compounds. They react with the halogens giving ionic halides:

$$Ca + Cl_2 \rightarrow CaCl_2;$$
$$Sr + Cl_2 \rightarrow SrCl_2;$$
$$Ba + Cl_2 \rightarrow BaCl_2.$$

The alkaline earth metals react with hydrogen at heating giving ionic hydrides:

$$Ca + H_2 \rightarrow CaH_2;$$
$$Sr + H_2 \rightarrow SrH_2;$$
$$Ba + H_2 \rightarrow BaH_2.$$

Calcium, strontium, and barium react with nitrogen at heating, forming ionic nitrides containing the N^{3-} ion:

$$3Ca + N_2 \xrightarrow{\Delta} Ca_3N_2;$$
$$3Sr + N_2 \xrightarrow{\Delta} Sr_3N_2;$$
$$3Ba + N_2 \xrightarrow{\Delta} Ba_3N_2.$$

All alkaline earth metals react readily with oxygen. Calcium and Strontium give oxides CaO and SrO when they react with excess of oxygen in ordinary conditions. Barium gives peroxide:

$$Ba + O_2 \rightarrow BaO_2.$$

Oxides of alkaline earth metals are basic oxides and have all properties of basic oxides.

1. Reacts with water:

$$CaO + H_2O \rightarrow Ca(OH)_2;$$
$$BaO + H_2O \rightarrow Ba(OH)_2.$$

2. Reacts with acids:

$$SrO + 2HCl \rightarrow SrCl_2 + H_2O;$$
$$BaO + 2HNO_3 \rightarrow Ba(NO_3)_2 + H_2O.$$

3. Reacts with acidic oxides:

$$CaO + CO_2 \rightarrow CaCO_3;$$
$$BaO + SO_3 \rightarrow BaSO_4.$$

Hydroxides of the alkaline earth metals are strong bases. They react with:

– acids

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + H_2O;$$

– acidic oxides

$$Sr(OH)_2 + CO_2 \rightarrow SrCO_3\downarrow;$$

Laboratory work

II–A group of chemical elements

Experiment 1. *Interaction Between Magnesium and Water*

Pour 1-2 ml of distilled water into two test tubes; add magnesium powder or pieces of magnesium. Does magnesium react with cold water?

Heat one test tube to boiling point and observe water decomposition by magnesium.

Add a little bit of concentrated solution into the second tube and heat the mixture. Observe impetuous hydrogen emission. Why do heating and NH_4Cl intensify water decomposition? Write the equations for the reactions.

Experiment 2. *Making Magnesium Oxide*

Pour 3-5 drops of magnesium salt (sulfate, chloride or nitrate) into test the tube; add the same volume of diluted NaOH or KOH solution. Observe formation of white jelly precipitate. Divide prepared precipitate into two tubes; add excess of alkali into the first test tube and diluted acid (HCl or HNO_3) into another. What do you observe? Write the equations for the reactions.

Experiment 3. *Influence of Ammonium Salts on the Solubility of Magnesium Hydroxide*

Pour 3-5 drops of ammonium salts into two test tubes; add the same volume of concentrated NH_4Cl solution into one test tube. Afterwards, add ammonia solution dropwise in each test tube. Observe the formation of magnesium hydroxide precipitate in one test tube. Add concentrated NH_4Cl solution into this test tube and observe precipitate dissolution. Explain, why does not magnesium hydroxide precipitate form with the excess of ammonium salt according to equilibrium in the system:

$$Mg(OH)_2 + 2NH_4Cl \rightleftarrows MgCl_2 + 2NH_4OH;$$

Why does formed $Mg(OH)_2$ dissolve?

Experiment 4. *Qualitative Test of* Mg^{2+} *Ions*

Pour ammonia solution to 4-5 drops of magnesium salt solution. Observe precipitate formation. Then add NH_4Cl solution dropwise until final precipitate dissolution. Add 2-3 drops of Na_2HPO_4 solution to clear the solution. Observe formation of $MgNH_4PO_4$ white crystalline precipitate. Write molecular and ionic equations of hydrolysis.

Experiment 5. *Flame Color Test for Calcium Compounds*

Calcine iron wire in a flame for a few times. Dip it in $CaCl_2$ solution and hold it in the colorless part of a flame. Watch the compounds of calcium give a distinct color to a flame.

Experiment 6. *Preparation of Calcium Carbonate*

Pour 3-4 drops of $CaCl_2$ solution into the test tube; add the same amount of Na_2CO_3 solution. Observe the formation of $MgCO_3$ white precipitate. Write molecular and ionic equation for the reaction.

Experiment 7. *Qualitative Test of* Ca^{2+} *Ions*

Add 2-3 drops of $(NH)_4C_2O_4$ solution to the same amount of calcium salt solution. Observe the formation of white precipitate. Heating accelerates precipitation of CaC_2O_4. Write molecular and ionic equations for the reaction.

Experiment 8. *Influence of Chromates to the Cations of Alkali-Earth Metals*

Pour solutions of calcium, strontium, and barium salts (for example – $CaCl_2$, $Sr(NO_3)_2$, and $BaCl_2$) into three separate test tubes. Add 4-5 drops of K_2CrO_4 or $K_2Cr_2O_7$ solution into each test tube. In which tube does precipitate form? What is the color of precipitate? Write the equation for each reaction.

CHAPTER 14. I–A group (Alkali Metals)

Alkali metals are the chemical elements found in Group 1 of the periodic table. The alkali metals include: lithium (Li), sodium(Na), potassium (K), rubidium (Ru), cesium (Cs), and francium (Fr). Although often listed in Group 1 due to its electronic configuration, hydrogen is not technically an alkali metal since it rarely exhibits similar behavior. The word "alkali" received its name from the Arabic word "al qali," meaning "from ashes", which since these elements react with water to form hydroxide ions, creating **alkaline solutions** (pH>7). Alkali metals are among the most reactive metals. This is due in part to their larger atomic radii and low ionization energies. They tend to donate their electrons in reactions and have an oxidation state of +1. These metals are characterized by their soft texture and silvery color.

The alkali metals are very reactive. The metals react directly with many other elements and compounds. For example, with:

Oxygen:

$4Li + O_2 \rightarrow 2Li_2O$ (lithium oxide)

$2Na + O_2 \rightarrow Na_2O_2$ (sodium peroxide)

$K + O_2 \rightarrow KO_2$ (potassium superoxide)

$Rb + O_2 \rightarrow RbO_2$ (rubidium superoxide)

$Cs + O_2 \rightarrow CsO_2$ (cesium superoxide)

Nitrogen:

$6Li + N_2 \rightarrow 2Li_3N$ (lithium nitride)

Sulfur:

$Na + S \rightarrow Na_2S$ (sodium sulfide)

Halogens:

$2Na + Cl_2 \rightarrow 2NaCl$

Water:

$2K + 2H_2O \rightarrow 2KOH + H_2\uparrow$

Hydrogen:

$2Na+H_2\rightarrow 2NaH$ (sodium hydride)

Oxides of the alkali metals are a basic oxides and has all properties of basic oxides:

1. Reacts with water:

$$Na_2O + H_2O \rightarrow 2NaOH;$$
$$Li_2O + H_2O \rightarrow 2LiOH.$$

2. Reacts with acids:

$$Na_2O + 2HCl \rightarrow 2NaCl + H_2O;$$
$$K_2O + H_2SO_4 \rightarrow K_2SO_4 + H_2O.$$

3. Reacts with acidic oxides:

$$Li_2O + CO_2 \rightarrow Li_2CO_3;$$
$$K_2O + SO_3 \rightarrow K_2SO_4.$$

Hydroxides of the alkali metals are strong bases. They react with:

- acids

$$NaOH + HCl \rightarrow NaCl + H_2O;$$
$$LiOH + H_2SO_4 \rightarrow Li_2SO_4 + H_2O.$$

- acidic oxides

$$2LiOH + CO_2 \rightarrow Li_2CO_3;$$

$$2KOH + SO_3 \rightarrow K_2SO_4.$$

– salts

$$2NaOH + CuCl_2 \rightarrow 2NaCl + Cu(OH)_2\downarrow;$$
$$2KOH + FeSO_4 \rightarrow K_2SO_4 + Fe(OH)_2\downarrow.$$

Laboratory work

I–A group of chemical elements

Experiment 1. *Flame Color Test for Sodium, Potassium, and Lithium*

Use NaCl, KCl, and LiCl solutions for this experiment. Calcine iron wire in a flame for a few times. Dip it in KCl solution and hold it in a flame. The compounds of potassium give violet color to a flame.

Dip iron wire in HCl to clean it. Calcine iron wire in a flame for a few times. Dip it in NaCl solution and hold in a flame. The compounds of sodium give bright yellow-red color to a flame.

Make the same experiment with LiCl solution. What color do lithium compounds give to a flame?

Experiment 2. *Interaction Between Sodium Peroxide and Water*

Place one microspatula of sodium peroxide into the dry test tube; add 4-5 drops of water. Heat the solution and bring glowing sliver in the test tube. What gas is released? After the reaction ends, add 1-2 drops of phenolphthalein to the solution. How does the color of the solution change? Write the equation for the interaction between sodium peroxide and water.

Experiment 3. *Reducing Properties of Sodium Peroxide*

a. Pour 3-5 drops of $KMnO_4$ solution into the test tube; acidify it by 2-3 drops of 2N H_2SO_4; add a microspatula of sodium peroxide. Stir the mixture. How does the color of solution change? Write the equation.

b. Put 5-7 drops of 0.1N $KMnO_4$ solution and one microspatula of sodium peroxide into the test tube. Stir the mixture. Observe gas releasing and formation of brown precipitate. Write the equation.

Experiment 4. *Oxidizing Properties of Sodium Peroxide*

Put 1-2 drops of KI solution and the same amount of 2N H_2SO_4 into the test tube; add one microspatula of sodium peroxide and 5-7 drops of distilled water into the test tube. Test free iodine with a drop of starchy water. Write the equation for the reaction.

Experiment 5. *Hydrolysis of Sodium and Potassium Salts*

Place a drop of Na_2CO_3 and K_2CO_3; Na_2SO_4 and K_2SO_4; CH_3COONa, K_2SO_3 and, KCl solutions on universal litmus paper. Identify the reaction medium (pH) of each solution. Determine unhydrolyzed salts. Write molecular and ionic equations of hydrolysis.

Experiment 6. *Qualitative Test of Na^+ Ions*

Add 2-3 drops of potassium hexahydroxostibiate $K[Sb(OH)_6]$ to the same amount of sodium salt solution. Cool the test tube with tap cold water stream and rub the inside of the tube with a glass stick. Observe formation of white fine-crystalline precipitate. Write molecular and ionic equations for the reaction.

Experiment 7. *Qualitative Test of K^+ Ions*

a. Add 3-4 of sodium hydrotartrate $NaHC_4H_4O_6$ to the same amount of potassium salt solution. Cool the test tube with tap cold water stream and rub the inside of the tube with a glass stick. Observe formation of white fine-crystalline $KHC_4H_4O_6$ precipitate.

b. Add 3 drops of potassium hexanitritocobaltate (III) solution $Na_3[Co(NO_2)_6]$ to 3-4 drops of potassium salt solution. Observe formation of yellow crystalline $K_2Na[Co(NO_2)_6]$ precipitate. Write molecular and ionic equations for the reaction.

Experiment 8. *Solution Deposition of Rb^+ and Cs^+ Ions*

Put 4-5 drops of RbCl and CsCl solutions into two separate test tubes. Add 2-3 drops of $Bi(NO_3)_3$, $NaNO_2$, and CH_3COOH solutions into each one. Cool tubes with tap cold water stream. What is the color of precipitates? Write the reactions for rubidium and cesium compounds formation$Me_2Na[Bi(NO_2)_6]$.

Experiment 9. *Preparation of Insoluble Lithium Salts*

Place 4-5 drops of LiCl solution into three test tubes. Add 3-4 drops of Na_2HPO_4 solution and 1-2 drops NaOH into the first tube, heat the mixture; put 4-5 drops of NaF into the second and Na_2CO_3 into the third one. What do you observe in each tube? Write the equations for the corresponding reactions.

TEST QUESTIONS (PREPARE TO EXAM)

1. Basic laws and concepts of chemistry

1. What is the molecular mass of an unknown gas, if this density for hydrogen is 20?
A * 40 g / mol
B25 g / mol
C 20 g / mol
D 30 g / mol
E 50 g / mol

2. The molar mass of the equivalent for calcium hydroxide (M (Ca $(OH)_2$) = 74 g / mol) is:
A * 37 g / mol
B 19 g / mol
C 32 g / mol
D 74 g / mol
E 148 g / mol

3. Interaction between the acid and the base, which leads to the formation of salt and water is called reaction:
A * Neutralization
B hydrolysis
C dissociation
D disproportionation
E schedule

4. What was Avogadro and what is its significance?
A * 6.02 * 10^{23} mol^{-1}. The number of structural units contained in 1 mole of matter
B 6.02 • 10^{22} mol^{-1}. The number of structural units contained in 1 g of substance
C 6.02 • 10^{20} mol^{-1}. The number of structural units contained in 1 g of substance
D 6.02 • 10^{19} mol^{-1}. The number of structural units contained in 1 kg of matter
E 6.02 • 10^{21} mol^{-1}. The number of structural units contained in 1 g of anions of matter

5. The molar mass of the oxidant equivalent is:
A * is the molar mass divided by the number of electrons attached
B molar mass divided by the number of devoted electrons
C molar mass divided by the acidity of the oxidizer
D molar mass divided by the basicity of the oxidizer
An emulsion mass divided by an oxidant valency

6. The molar mass of the reducing agent equivalent is:
A * is the molar mass divided by the number of electrons given
B molar mass divided by the number of electrons attached
C molar mass divided by the acidity of the oxidizer
D molar mass divided by the basicity of the oxidizer
An emulsion mass divided by an oxidant valency

7. What is the molecular mass of an unknown gas, if its hydrogen density is 15?
A * 30 g / mol

B 7.5 g / mol
C 15 g / mol
D 45 g / mol
E 60 g / mol

8. The molar mass of the equivalent sulfate acid (M (H_2SO_4) = 98 g / mol) is:
A * 49 g / mol
B 98 g / mol
C 32 g / mol
D 196 g / mol
E 25.5 g / mol

9. The molar mass of the equivalent of sulfate acid (M (H_2SO_4) = 98 g / mol) in the $NaOH + H_2SO_4 = NaHSO_4 + H_2O$ reaction is:
A * 98 g / mol
B 49 g / mol
C 32 g / mol
D 196 g / mol
E 25.5 g / mol

10. Based on a number of metal stresses, it can be argued that there will not be a chemical reaction in the aqueous solution:
A * $Cu + 2HCl = CuCl_2 + H_2$
B $Sn + H_2SO_4 = SnSO_4 + H_2$
C $Zn + 2HCl = ZnCl_2 + H_2$
D $2Al + 6NaOH + 6H_2O = 2Na_3[Al(OH)_6] + 3H_2$
E $2Na + H_2O = 2NaOH + H_2$

11. Substances with amphoteric properties interact:
A * with acids and alkalis
B only with acids
C only with alkalis
D only with acid oxides
E only with the main oxides

12. What degree of oxidation does Molybdenum show in ammonium heptamolybdate $(NH_4)_6Mo_7O_{24}$?
A * + 6
B + 1
C +2
D +3
E +5

13. Which of the listed elements can exhibit only a positive degree of oxidation?
A * magnesium
B Phosphorus
C Sulfur
D Nitrogen

E Arsen

14.Then solutions of these salts added acid. In which case there is a gas outlet?
A * Na_2CO_3
B K_2SO_4
C $CuSO_4$
D Na_2SiO_3
E $Ca_3(PO_4)_2$

15. The same valence in a hydrogen compound and in a higher oxide reveals an element:
A * Carbon
B Phosphorus
C selenium
D Brom
E Argon

16. Indicate the degree to which oxidation of manganese and chlorine show the greatest similarity in compounds:
A * + 7
B +3
C 0
D +4
E +2

17. Which element in the form of a simple substance is a liquid:
A * Bromine
B Phosphorus
C Sulfur
D Hydrogen
E Nitrogen

18. Indicate substance with the same molar and equivalent masses:
A * HCl
B Na_2SO_4
C H_3PO_4
D $Al_2(SO_4)_3$
E $Mg(OH)_2$

19. What is the process of transformation of solid matter during heating immediately into a gas state?
A * Sublimation.
B Distillation.
C Recrystallization.
D disaggregation.
E Dehydration.

20.Molar concentration of the solution $Al_2(SO_4)_3$ = 0,01 mol / liter. Indicate the molar concentration of the equivalent of this solution in mol / l
A * 0.06
B 0.03
C 0.02
D 0.01
E 0.005

2. Classification and nomenclature of inorganic substances

1. Which of the oxides does not react with water?
A * SiO_2
B CO_2
C SO_2
D Cl_2O_7
E CrO_3

2.Count the average salt:
A * $Na[PO_2]$
B $NaH[PO_3H]$
C, K_2HPO_4
D $Ca(H_2PO_4)_2$
E $NH_4H_2PO_4$

3. Among the following oxides, indicate non-salt:
A * N_2O
B P_2O_5
C N_2O_5
D SO_2
E CO_2

4. Chemical elements form simple and complex compounds. Which of the following is a simple one?
A * P_4
B PH_3
C P_4O_6
D P_4O_{10}
E H_3PO_4

5. What type of salt belongs to chlorine lime $CaOCl_2$?
A * mixed
B Medium
C Acid
D Basic
E Double

6. Among the oxides listed, indicate non-sulfur oxide:
A * CO
B SiO_2

C CO_2
D P_2O_3
E SO_2

7. Indicate the compound having a peroxide group:
A * H_2SO_5
B H_2SO_3
C $Na_2S_4O_6$
D $K_2Cr_2O_7$
E $Na_2S_2O_3$

8. Among the listed compounds, indicate the salt of meta acid:
A * Na_2SiO_3
B Na_4SiO_4
C Na_3AlO_3
D $K_4P_2O_7$
E K_4PbO_4

9. For which of the above acids the basicity does not coincide with the number of hydrogen atoms in acid?
A * $H_2[PO_3H]$
B H_3PO_4
C $H_4P_2O_7$
D HPO_3
E H_2SO_4

10. Among the oxides listed, indicate the main oxide:
A * MnO
B MnO_2
C Mn_2O_7
D Cr_2O_3
E CrO_3

11. Among the oxides listed, indicate the acid oxide:
A * N_2O_3
B N_2O
C NO
D CO
E CaO

12. Among these oxides, indicate amphoteric oxide:
A * Cr_2O_3
B CrO
C CrO_3
D MnO
E Mn_2O_7

13. Which of the reduced compounds is not absorbed by a solution of alkali?

A * NH_3
B H_2S
C HCl
D Cl_2
E CO_2

14. Which of the reduced oxides can be used as a water absorbent?
A * P_2O_5
B CuO
C Fe_2O_3
D CO_2
E Al_2O_3

15. What type of salts is aluminum dihydroxoacetate, whose solution, called "fluid drill", is used in medicine as a weeping, anti-inflammatory agent:
A * Basic
B Double
C mixed
D Acid
E Average

16. Which of the listed hydroxides has the most pronounced basic properties?
A * CsOH
B LiOH
C KOH
D $Ca(OH)_2$
E $Mg(OH)_2$

17. Indicate which mineral acid can not be stored in glassware:
A * HF
B HCl
C HBr
D HI
E H_2SO_4

18. When interaction of an excess of alkali solution with amphoteric metals is formed:
A * hydroxocomplexes
B oxides
C hydroxides
D medium salts
E basic salts

19. For the quantitative determination of some drugs used solutions of sulfate and perchloric acid. Which of the following oxides is anhydride of these acids?
A * SO_3, Cl_2O_7
B SO_2, Cl_2O
C, SO_3, ClO_2
D SO_2, Cl_2O_7

E SO_3, Cl_2O_6

20.Natrium bicarbonate belongs to the following type of salts:
A * acidic salt
B mixed salt
C medium salt
D is the main salt
E oksoil

3. Chemical kinetics and thermodynamics

1. What law is at the basis of determining the rate of chemical reaction?
A * operating masses
B Bath-Hoff
C Henry
D Raul
E periodic law of Mendeleev

2. Act of active masses describes the dependence of the rate of chemical reactions from:
A * Concentrations of reactants
B Surface of contact surfaces of reactants
C Nature of reactants
D Temperature of the system
E Presence of catalysts

3.The reaction between sodium and water are:
A * exothermic, substitution
B endothermic, combination
C endothermic, exchange
D endothermic substitution
E endothermic, reversible

4. Principle Le Chatelier provides an opportunity to control the occurrence of chemical reactions both in the laboratory and in industry. Specify which of the following processes should be conducted at high pressure:
A * $3H_2$ (g) + N_2 (g) = $2NH_3$ (g)
B Fe (t) + H_2O (pair) = FeO (t) + H_2 (g)
C N_2 (g) + O_2 (g) = 2NO (g)
D C (t) + O_2 (g) = CO_2 (g)
E H_2 (g) + Cl_2 (g) = 2HCl (g)

5. When dissolving salt in water, the temperature of the solution has decreased. This means the process:
A * endothermic
B is exothermic
C isobaric
D adiabatic
E isochoric

6. In which units is the rate of chemical reaction in homogeneous systems measured?
A * Mole • l-1 • s-1
B Mol • ml-1 • s-1
C Mole • m3 • s-1
D Mole • l-1 • min-1
E Mole • m2 • min-1

7.When increasing the reaction rate due to the increase in the energy of molecules leads to:
A * Heating
B Lighting
C irradiation
D Cooling
E All these methods

8. At how many degrees you need to raise the temperature so that the rate increased by 64 times, if $\gamma = 2,0$?
A * at 60 ° C
B At 40 ° C
C at 50 ° C
D At 70 ° C
E At 80 ° C

9. How many times should I increase the pressure so that the rate of formation of NO_2 in the reaction $2NO + O_2 = 2NO_2$ increased by 8 times?
A * 2
B 5
C 20
D 50
E 100

10. How will the reaction rate $2CO + O_2 = CO_2$ change between carbon (II) oxide and oxygen, if the concentration of starting substances is increased 5 times?
A * Increase 125 times
B Increase 5 times
C Increase by 25 times
D Increase 175 times
E Increase 625 times

11. Which of the following records, according to the law of active masses, expresses the velocity of the process $2SO_2$ (g) + O_2 (g) = $2SO_3$ (g):
A * $k [SO_2]^2 \cdot [O_2]$.
B $k [2SO_2] \cdot [O_2]$.
C $k [SO_2] \cdot [O_2]$.
D $k [SO_2]^2 + [O_2]$.
E $[SO_2]^2 + [O_2]$.

12. One of the laws of chemical kinetics is the law, which reads as follows: "the rate of chemical reaction is proportional to the product molar concentrations of reactants." This is the law:
A * operating masses
B constancy of the composition
C equivalents
D breeding Ostwald
E preservation of mass of substances

13. Under normal conditions (NW) in chemistry, the following numerical values of pressure and temperature are understood:
A * p = 101.3 kPa; T = 273K
Bp = 101.3 atm; T = 298K
C p = 760 mm Hg; T = 1000ºC
D p = 1,013 kPa; T = 0ºC
E p = 760 mm Hg; T = 250 ºC

14. According to the standard in chemistry, the following numerical values of pressure and temperature are understood:
A * p = 101.3 kPa; T = 298K
Bp = 101.3 atm; T = 273K
C p = 760 mm Hg; T = 1000ºC
D p = 1,013 kPa; T = 0ºC
E p = 760 mm Hg; T = 250 ºC

15. Experimentally, the heat of combustion (as well as the enthalpy of formation) is determined by the device:
A * Calorimeter
B Spectrophotometer
C Device Kippa
D Colorimeter
E Conductometer

16.Why is the temperature coefficient of the reaction, if at the temperature increase of 50^0C, the rate of chemical reaction increases 32 times?
A * 2
B 4
C 5
D 6
E 3

17. Catalysts, which slow down the rate of chemical reaction with increasing temperature, are called:
A * Inhibitors
B Stroke
C Incubators
D Interferometers
E Enradients

18. Substances of protein nature, which are produced by cells of living organisms and significantly increase the rate of biochemical reactions, is - ...
A * Enzymes (enzymes)
B Ferromagnets
C Ferrite
D Fullerenes
E Ferraty

19.Replacement of the equilibrium in the system $2H_2S$ (g) + $3O_2$ (g) = $2SO_2$ (g) + $2H_2O$ (g); $\Delta H < 0$ in the direction of formation of reaction products is promoted by everything except:
A * Increase temperature
B Increased H_2S concentration
C Reduction of SO_2 concentration
D Increasing pressure
E Decrease in temperature

20. The reaction rate of Fe_2O_3 (t) + $3H_2$ (g) = 2Fe (t) + $3H_2O$ (vapor) at V = const and the increase in the number of H2 in 2 times will increase in:
A * 8 times
B 2 times
C 4 times
D 16 times
E 6 times

4. Electrolytic dissociation

1. Which of the following compounds is not an electrolyte?
A * $[Fe(CO)_5]$
B $Na_3[Co(NO_2)_6]$
C HCN
D H_2O
E NaOH

2.Contribute monobasic acid:
A * $H[PO_2H_2]$
B $H_2[PO_3H]$
C H_3PO_4
D $H_4P_2O_7$

3. Indicate the color of phenolphthalein in sodium sulfide solution:
A * Raspberry
B Colorless
C Blue
D Yellow
E Green

4. How dissolves the ion N_2RO_4-?
A * Two stages, each partially

B In one stage - partly
C One stage - completely
D Does not dissociate

5. According to the theory of electrolytic dissociation of Arrhenius, acids are compounds that:
A * in solutions dissociate with the formation of ions of the Hydrogen and the acid residue
B in solutions dissociate with the formation of ions of hydroxyl
C react with active metals with hydrogen release
D, when heated, decompose on acid oxide and water
E do not react with metals in a number of stresses after Hydrogen

6. Which of the following electrolytes refer only to the weak:
A * $NH_3 \bullet H_2O$, CH_3COOH
B NH_4Cl, $NH_3 \cdot H_2O$
C CH_3COOH, CH_3COONa
D HCl, AgCl
E, AgCl, NH_4Cl

7. What pairs of ions can not simultaneously be in significant amounts in aqueous solution:
A * H^+ and CO_3^{2-}
B Na^+ and SO_4^{2-}
C K^+ and OH^-
D Ca^{2+} and HCO^-
E Ag^+ and NO_3^-

8. Identify a pair of electrolytes, the reaction between which in an aqueous solution is impossible:
A * NaBr and KOH
B Na_2S and HCl
C K_2CO_3 and H_2SO_4
D $Fe(NO_3)_3$ and NaOH
E NaCl and $AgNO_3$

9. Interactions of which substances correspond to the reduced ion equation: $H^+ + OH^- = H_2O$
A * KOH and HNO_3
B NaOH and H_2S
C $NH_3 \bullet H_2O$ and HCl
D $NH_3 \bullet H_2O$ and H_2CO_3
E $NH_3 \bullet H_2O$ and CH_3COOH

10. Indicate the correct version of the expression for the solubility product (DR) of calcium orthophosphate, which dissociates by the equation $Ca_3(PO_4)_2 = 3Ca^{2+} + 2PO_4^{3-}$
A * $DR\{Ca_3(PO_4)_2\} = [Ca^{2+}]^3 \bullet [PO_4^{3}-]^2$
B $DR\ \{Ca_3(PO_4)^2\} = [Ca^{2+}]^3 \bullet [PO_4^{3-}]^2 / [Ca_3(PO_4)]^2$

C DR $\{Ca_3(PO_4)_2\} = [Ca^{2+}]^3 + [PO_4^{3-}]^2$
D DR $\{Ca_3(PO_4)_2\} = 3[Ca^{2+}]^3 \cdot 2[PO_4^{3}-]^2$
E DR $\{Ca_3(PO_4)_2\} = 3[Ca^{2+}]^3 + 2[PO_4^{3-}]^2$

11. Indicate which salt can not be obtained in aqueous solution:
A * Al_2S_3
B $FeSO_4$
C Na_2S
D $AlCl_3$
E $Cr_2(SO_4)_3$

12. In 0,1 M solution of which substance is the largest number of ions?
A * Na_3PO_4
B KCl
C HCl
D $MgCl_2$
E H_2SO_4

13. Indicate which salt can not be obtained in an aqueous solution?
A * Cr_2S_3
B K_3PO_4
C $NaNO_3$
D $FeCl_3$
E NH_4Cl

14. What are the most ions in the aqueous solution of orthophosphate acid?
A * H^+
B $H_2PO_4^-$
C $HPO_4^{2}-$
D $PO_4^{3}-$
E OH^-

15. Which of the following aqueous solutions having the same molar concentration is the worst conductor of electric current?
A * solution of cyanide (cyanide) acid
B solution of potassium cyanide
C solution of sulfate acid
D solution of potassium hydroxide
E solution of potassium sulfate

16.How dissociates hydrogen phenophosphate-ion?
A * One stage - partially
B In one stage - completely
C In two stages: the first - completely, the second - in part
D In two stages, for each - in part
E In two stages: the first - partly, the second - in full

17. Indicate the color of the litmus in the solution of ferric nitrate (III):
A * red
B violet
C blue
D raspberry
E indicator will not have color

18. Indicate the color of the litmus in a solution of sodium carbonate:
A * blue
B violet
C red
D indicator will not have color
E raspberry

19. Indicate the color of methylorange in a solution of potassium carbonate:
A * yellow
B orange
C pink
D is colorless
E blue

20. Indicate the color of phenolphthalein in a solution of aluminum chloride:
A * colorless
B raspberries
C Yellow
D blue
E red

5. Solutions

1. For preparation of 500 g of 10% solution of sodium hydroxide it is necessary to take:
A * 50 g
B 0.5 g
C 5 g
D 10 g
E 25 g

2. In 0,1 M solution of which of the above acids the highest concentration of ions Hydrogen?
A * HCl
B HCN
C H_2CO_3
D CH_3COOH
E H_2SO_3

3. The nature of the medium is characterized by the magnitude of the hydrogen index. Specify the pH value of 0.1 M solution of HCl.
A * 1
B 0

C 2
D 3
E 4

4. Indicate the concentration of hydrogen ions in pure water:
A * 10^{-7}
B 10^{-9}
C 10^{-14}
D 10^{-5}
E 10^{-3}

5. What salt should be dissolved in water to increase the concentration of Hydrogen ions?
A * $ZnCl_2$
B $NaNO_3$
C KCl
D Na_2CO_3
E Na_2S

6. A solution with a mass fraction of NaCl 0,95% is part of the physiological solution and is used for significant loss of blood. Specify the reaction of the medium of this solution:
A * Neutral (pH = 7)
B Acid (pH <7)
C Alkaline (pH> 7)
D Very acidic (pH = 1)
E Highly alkaline (pH = 12)

7. The pH of the solution is 4. Calculate the concentration [H +] (mol / l):
A * 10^{-4}
B 4
C 10^{-10}
D 10
E 10^{2}

8. A 0.9% solution of sodium chloride is called physiological because it:
A * has osmotic pressure equal to osmotic blood pressure
B contains ions that are part of the blood
C is very soluble in the blood
D contains non-toxic substances for the organism
E does not affect the acid-base blood balance

9. To reduce the concentration in OH water-, it is necessary to add:
A * acid
B is sodium nitrate
C meal
D Ammonia
E water

10. What are the significant ions in the solution at the same time?
A * Na^+ and OH^-
B Zn^{2+} and OH^-
C Al^{3+} and OH^-
D Cu^{2+} and OH^-
E H^+ and CO_3^{2-}

11. The amount of dissolved substance contained in 1 dm3 of solution, determines:
A * Molar concentration
B Bulk share
C Molar concentration of the equivalent
D Mole share
E molar concentration

12. The 8-hour index of 0,005 M solution of sulfate acid is:
A * 2
B 0
C 1
D 3
E 4

13. For cooking 200 g of 10% solution of potassium iodide it is necessary to take:
A * 20 g KI
B 2 g KI
C 0.2 g of KI
D 10 g KI
E 4 g KI

14. In 0,1 M solution of which of the above acids is the highest concentration of Hydrogen ions?
A * H_2SO_4
B HCl
C H_2CO_3
D CH_3COOH
E H_2SO_3

15. Which of the following pairs of ions can simultaneously be in solution:
A * Fe^{3+}, C^{l-}
B Ba^{2+}, SO_4^{2-}
C Fe^{2+}, OH-
D Fe^{3+}, OH-
E $Ag^{+,}$ Cl^-

16. In which of the resulted solutions the hydrogen index is zero?
A * 1M HCl
B 0.1 M HCl
C 0.1M KOH
D 1M H_3PO_4

E 1 M Ba (OH) $_2$

17. In a solution [OH-] = 1 • 10^{-6} mol / liter. Specify the pH of the solution.
A * 8
B 6
C 1
D 7
E 4

18. In a pharmaceutical analysis, a 0,1 M solution of chloride acid is used as a titrant. What amount of this acid can be prepared based on 100 cm^3 of 0.5 M HCl solution?
A * 500 cm^3
B 50 cm^3
C 200 cm^3
D 1000 cm^3
E 5000 cm^3

19.pH index of 0,01 M solution of chloride acid is:
A * 2
B 0
C 1
D 3
E 4

20.pH index 0,001 M solution of chloric acid is:
A * 3
B 0
C 10
D 7
E 5

6. Periodic law

1.One of the classifications of chemical elements is based on the structure of their electronic shells. According to it, all elements can be divided into s-, p-, d- and f-elements. Which of the following items belongs to p-elements only?
A * Br, O, P
B Cl, Ca, O
C N, Al, Cd
D K, Ca, Ni
E Fe, Cu, F

2. Amphoteric compounds are substances that react with:
A * Acids and meadows
B Only with meadows
C Only with acids
D Only with acid oxides
E Only with basic oxides

3. Noble gases practically do not form chemical compounds, because:
A * they have a completely completed external electronic level
B they are in the eighth group of the periodic system D.I. Mendeleev
C from all elements of the period they have the smallest radius
D in the periodic system D.I. Mendeleev they are located after halogens
E, the charge of the nucleus of noble gases is equal to the number of electrons in the atom

4.Atomic number of the chemical element characterizes:
A * The number of protons in the atomic nucleus
B The number of neutrons in the atomic nucleus
C Number of nucleons in the nucleus of the atom
D The number of neutrons and protons in the nucleus of the atom
E mass of atom nucleus

5. Strengthening of metallic properties in the main subgroups of PS from top to bottom is conditioned:
A * increase in the radius of the atom
B increase in atomic number
C increase in the atomic mass
D increase in the nucleon number
E increase the charge of the nucleus

6. Which of the following molecules has the degree of oxidation equal to zero, and the valence is equal to one?
A * H_2
B HCl
C NH_3
D N_2
E SO_3

7. The maximum degree of oxidation of an element, as a rule, is equal to:
A * group number in the periodic system
B number of the subgroup in the periodic system
C number of the period
D number in the row
E is the difference between the positive level of oxidation and the number of 8

8. One of the classifications of chemical elements is based on the structure of their electronic shells. In accordance with it, all elements can be divided into s-, p-, d- and f-elements. Which of the following items belongs to p-elements only?
A * Cl, S, N
B Ag, Mg, O
C Al, Pt, N
D Na, Ca, Fe
E Fe, Cu, Cr

9. It is known that the periodic law allows for predicting the properties of chemical elements and their compounds, which was demonstrated in his time D.I. Mendeleyev Using this law, find in the number of elements of the III-th period the most potent acid:
A * $HClO_4$
B H_3PO_4
C H_2SO_4
D HCl
EH_4SiO_4

10. Indicate the factor that determines the periodicity of the properties of the elements:
A * nucleus charge
B oxidation degree
C valence
D atomic radius
E electronegativity

11. One of the classifications of chemical elements is based on the structure of their electronic shells. According to it, all elements can be divided into s-, p-, d- and f-elements. Which of the following items belongs to p-elements?
A * S, P, Cl
B K, Ca, Sc
C Be, Mg, Al
D Mn, Br, Mo
E P, S, Cr

12. One of the classifications of chemical elements is based on the structure of their electronic shells. According to it, all elements can be divided into s-, p-, d- and f-elements. Which of the following items belong to the s-elements?
A * K, Ca, Sr
B S, P, Cl
C Be, Mg, Al
D Mn, Br, Mo
E P, S, Cr

13. Indicate the maximum possible number of electrons at the 4th energy level.
A * 32
B 16
C 8
D 25
E 40

14. Which record of electronic configuration of valence electrons corresponds to the element of the 4th period of group VI of the main subgroup:
A * $4s^2 4p^4$
B $4s^1 3d^5$
C $6s^2 6p^2$
D $6s^2 5d^2$
E $3s^2 3p^4$

15. What distinguish large periods of elements from small ones?
A * Presence of d and f elements.
B Presence of s-elements.
C Presence of inert gases.
D Presence of metals.
E Presence of nonmetals.

16. Specify which element belongs to the p-elements:
A * P
B Cu
C Fe
D Mg
E K

17. Indicate which line isotope only:
A * ^{16}O, ^{17}O, ^{18}O
B ^{11}K, ^{41}Ca, ^{41}Sc
C ^{16}O, ^{32}O, ^{12}O
D ^{40}Ar, ^{40}K, ^{40}Ca
E ^{39}K, ^{40}Ca, ^{42}Ca

18. Specify an element if its electronic formula [Ar] $4s^2 3d^8$
A * Ni
B Cu
C Zn
D Pt
E Mn

19. Specify an element if its electronic formula [Ar] $4s^1 3d^{10}$
A * Cu
B Ni
C Zn
D Pt
E Mn

20. Specify the number of protons in P^{-3}:
A * 15
B 16
C 17
D 18
E 31

7. Hydrolysis of salts

1. What is the hydrolysis product of the above salts is the main salt?
A * $CuSO_4$
B $CaCl_2$
C K_2CO_3
D NaCl

E KBr

2. Indicate salt that is not hydrolyzed:
A * $K_2Cr_2O_7$
B $Cr_2(CO_3)_3$
C $KCrO_2$
D $CrCl_3$
E Cr_2S_3

3. Indicate which of the above salts is not subject to hydrolysis?
A * $Ca(NO_3)_2$
B $ZnCl_2$
C $CuSO_4$
D $NaNO_2$
E NH_4Cl

4. What solution of salt as a result of hydrolysis will have an acid reaction?
A * ammonium chloride
B ammonium carbonate
C sodium chloride
D sodium carbonate
E sodium sulfate

5. Some medicines are obtained by hydrolysis of the corresponding middle salts. Find among the listed salts that will not be hydrolyzed.
A * K_2SO_4
B $NaHCO_3$
C $AlCl_3$
D $Bi(NO_3)_3$
E Na_2SO_3

6. The important property of salts is their ability to hydrolyze in aqueous solutions. Hydrolysis of which of the reduced salts passes irreversibly?
A * Cr_2S_3
B $Mg(NO_3)_2$
C $CuSO_4$
D $NaNO_2$
E NH_4Cl

7. Hydrolyzed salts in water. Which of the following salts is hydrolyzed?
A * $ZnCl_2$
B $NaNO_3$
C K_2SO_4
D CaI_2
E $BaCl_2$

8. Which of the following salts is the main salt of the hydrolysis product?
A * $FeSO_4$

B $NaCl$
C K2CO3
D NH_4Cl
E KBr

9. Indicate which of the following salts is not subject to hydrolysis:
A * KI
B $ZnSO_4$
C KNO_2
D $Al_2(SO_4)_3$
E $CrCl_3$

10. Indicate which of the following salts is subject to partial hydrolysis:
A * K_2S
B NaBr
C $Ca(NO_3)_2$
D Al_2S_3
E $BaSO_4$

11. Indicate which salt is subject to complete irreversible hydrolysis:
A * Cr_2S_3
B $Al_2(SO_4)_3$
C $Cr(NO_3)_3$
D KNO3
E Na_3PO_4

12. Which of the above salts gives the alkaline environment due to hydrolysis?
A * Na_2CO_3
B KCl
C $AlCl_3$
D $NaNO_3$
E $Cr_2(SO_{4\ 3}$

13. Which of the following salts gives the acidic medium as a result of reverse hydrolysis?
A * $Fe(NO_3)_3$
B K_2CO_3
C NaI
D K_3PO_4
E $BaCl_2$

14. Indicate which salt is not hydrolyzed:
A * $Ba(NO_3)_2$
B $ZnCl_2$
C KNO_2
D K_2HPO_4
E $AlCl_3$

15. Which of the listed salts, as a result of hydrolysis, forms the main salt?
A * $AlCl_3$
B $AgNO_3$
C Na_2CO_3
D BaI_2
E KNO_2

16. Which of the reduced salts, due to hydrolysis, forms the main salt?
A * $Cr_2(SO_4)_3$
B K_2CO_3
C $AgNO_3$
D $CaCO_3$
E Na_2SO_4

17. When dissolved in water from which of the ammonium salts the environment will remain virtually neutral?
A * NH_4CH_3COO
B $(NH_2)_2 SO_4$
C NH_4Cl
D NH_4NO_3
E NH_4Br

18. What salt corresponds to the expression for the hydrolysis constant Kg = Kw / Kosn.
A * $CuSO_4$
B KCN
C CH_3COONa
D $[NH_4]_2S$
E NaCl

19. What salt corresponds to the expression for the hydrolysis constant Kg = Kw / (K • Kosn.)
A * $[NH_4]_2S$
B NaCN
C $Fe[NO_3]_3$
D Li_2S
E $NH_4 Cl$

20. Indicate the salt, which solution has an alkaline reaction:
A * Na_2S
B Na_2SO_4
C KCl
D $CuCl_2$
E $FeCl_3$

8. Red-oxidation reactions

1. Which of the following compounds in the oxidation-reduction processes exhibits only oxidative properties?
A * $K_2Cr_2O_7$

B K_2SO_3
C HBr
D $FeSO_4$
E KI

2. What substance can manifest in the oxidation-reduction reactions of the role of oxidizer and reducing agent?
A * H_2O_2
B SO_3
C PbO_2
D CrO_3
E Mn_2O_7

3. Indicate which substance can only be a reducing agent in oxidation-reduction reactions:
A * Na_2S
B Na_2SO_3
C Na_2SO_4
D $Na_2S_2O_7$
E $Na_2S_2O_3$

4. What process takes place in the resulted scheme: $Mn^0 \rightarrow Mn^{2+}$?
A * oxidation
B recovery
C oxidation-reduction
D decrease the degree of oxidation
E neutralization

5. Oxidation-reduction reactions are widely used in pharmaceutical analysis. Which of the following reactions is oxidative-reducing?
A * $Zn + H_2SO_4 = ZnSO_4 + H_2$
B $CuSO_4 + 2NaOH = Cu(OH)_2 + Na_2SO_4$
C $NH_4OH + HCl = NH_4Cl + H_2O$
D $H_2CO_3 = CO_2 + H_2O$
E $KBr + AgNO_3 = AgBr + KNO_3$

6. Among the acids listed, select an oxidant:
A * HNO_3
B HCl
C H_2SO_3
D H_2SO_3
E H_2S

7. Which of the following compounds detects oxidation-reducing duality?
A * Na_2SO_3
B $KMnO_4$
C H_2S
D $K_2Cr_2O_7$

E NH_3

8. What substance can be in the oxidation-reduction reactions as an oxidizer and a reducing agent?
A * SO_2
B SO_3
C CO_2
D PbO_2
E CrO_3

9. Oxidation-reduction reactions are widely used in the pharmaceutical analysis to establish the identity of drugs. Which of the following reactions is oxidative-reducing?
A * $Mg + CuSO_4 = MgSO_4 + Cu$
B $CuSO_4 + 2NaOH = Cu(OH)_2 + Na_2SO_4$
C $NH_4OH + HCl = NH_4Cl + H_2O$
D $H_2CO_3 = CO_2 + H_2O$
E $KBr + AgNO_3 = AgBr + KNO_3$

10. One of the types of oxidative-reduction reactions is the disproportionation reaction. Which of the following reactions is a disproportionation reaction?
A * $ClO_2 + H_2O = HClO_2 + HClO_3$
B $Cl_2O + H_2O = 2HClO$
C $Cl_2O_7 + H_2O = 2HClO_4$
D $I_2O_5 + H_2O = 2HIO_3$
E $Br_2O + H_2O = 2HBrO$

11. Indicate the redox pair, to which $I_2 / 2I^-$ is a reducing agent; $E_0 [I_2 / 2^{I-}] = 0.54V$.
A * $Cl_2 \rightarrow 2Cl^-$; $E_o = 1.36B$
B $SO_4^{2-} \rightarrow S^0$; Eo = 0.45B
C $Sn^{2+} \rightarrow Sn^{4+}$; Eo = 0.15B
D $2S_2O_3^{2-} \rightarrow S_4O_6^{2-;}$ Eo = 0.09B
E $2H^+ \rightarrow H_2$; Eo = 0.1B

12. Among the above transformations, indicate the disproportionation reaction:
A * $S + KOH \rightarrow K_2SO_3 + K_2S + H_2O$
B $FeCl_2 + Cl_2 \rightarrow FeCl_3$
C $HCl + Cr_2O_3 \rightarrow CrCl_3 + Cl_2 + H_2O$
D $MnO_2 + HCl \rightarrow MnCl_2 + Cl_2 + H_2O$
E $Au_2O_3 \rightarrow Au + O_2$

13. What is the conversion of $[Cr(OH)_6]^{3-} \rightarrow CrO_4^{2-}$
A * oxidation in alkaline medium
B oxidation in acidic medium
C reduction in acidic medium
D recovery in a neutral environment
E recovery in alkaline medium

14. What is the conversion of MnO_4- → MnO_2
A * recovery in a neutral environment
B oxidation in acidic medium
C reduction in acidic medium
D oxidation in alkaline medium
E recovery in alkaline medium

15. Based on the values of the oxidation-reducing potentials of some manganese reactions, indicate a reaction where manganese is the strongest oxidizer
A * $MnO_4^- + 8H^+ + 5e = Mn^{2+} + 4H_2O$; Eo = 1.51B
B $MnO_4^- + 4H_2O + 3e = Mn(OH)_4 + 4OH^-$; Eo = 0.57B
C $MnO_4^- + e = MnO_4^{2-}$ (alkaline medium); E_O = 0.54B
D $MnO_4^{2-} + 4H_2O + 2e = Mn(OH)_4 + 4OH^-$; Eo = 0.71B
E $MnO_2 + 4H^+ + 2e = Mn^{2+} + 2H_2O$; Eo = 1.28B

16. Using the values of the standard oxidation-reduction potential of the half-reactions, determine the half-reaction, where the compound of Chlorine is the most potent oxidizer
A * $HClO + H^+ + 2e = Cl^- + H_2O$; Eo = 1.49B
B $Cl_2 + 2e = 2Cl^-$; Eo = 1.36B
C $ClO^- + H_2O + 2e = Cl^- + 2OH^-$; Eo = 0.94B
D $ClO_3 + 6H^+ + 6e = Cl^- + 3H_2O$; Eo = 1.45B
E $ClO_4^- + 8H^+ + 8e = Cl^- + 4H_2O$; Eo = 1.38B

17. In what case is the oxidation process?
A * $2Cl^- \rightarrow Cl_2$
B $2\ ClO^- \rightarrow Cl_2$
C $ClO_3^- \rightarrow ClO^-$
D $Cl_2 \rightarrow 2Cl^-$
E ClO_3-> Cl_2

18. Identify a group of substances that have two functions in the Red-Ox. R - both the oxidizer and the reducing agent?
A * K_2SO_3, HNO_2, H_2O_2
B H_2O_2, H_2S, PbO_2
C NH_3, K_2SO_3, KJ
D Na_2CrO_4, $NaNO_2$, H_2O_2
E KJ, KJO, KJO_3

20. What is called the next process and how many electrons it is involved in:$S^{+6} \rightarrow S^{-2}$?
A * Restoration, 8
B Oxidation, 8
C Oxidation, 4
D Restoration, 4
E Recovery, 6

9. Types of chemical communication

1. Which of the following compounds is formed due to the nonpolar covalent bond?
A * H_2

B SiO_2
C $FeCl_3$
D H_2S
E NaBr

2. What is the chemical bond in the molecule of chlorine?
A * covalent nonpolar
B is hydrogen
C ionic
D is covalent polar
E coordination

3.Onnye compounds of which of the above elements can form hydrogen bonds?
A * F
B C
C Si
D P
E I

4.The mechanism of hydrogen bond is reduced to:
A * donor-acceptor interaction between a Hydrogen atom bound to a more electronegative element and an atom of another electronegative element
B electrostatic interaction of oppositely charged ions
C formation of "electronic gas"
D donor-acceptor interaction between two atoms with the same electronegativity
E dispersion interaction

5. What property of covalent bonding determines the spatial structure of molecules?
A * Direction
B Saturation
C Polarity
D Polarization
E Energy

6. Type of chemical bond in the NaCl molecule?
A * Ionic
B Covalent nonpolar
C Hydrogen
D Covalent polar
E Metal

7. Which of the above compounds is formed due to the nonpolar covalent bond?
A * N_2
B CO_2
C $AlCl_3$
D H_2S
E NaCl

8. Chemical nature, electron configuration and the nature of the chemical bond determine the properties of chemical compounds, including their physiological activity. Which of the following compounds is covalent polar?
A * HCl (gas);
B NaBr
C $CaCl_2$
D I_2
E O_2

9. Simultaneously, ionic and covalent bonds contain a substance:
A * NH_4NO_3
B H_2S
C N_2O_5
D N_2
E NH_3

10. Which of the following compounds is formed due to covalent and ionic bonds?
A * Na_2SO_4
B NaCl
C $CaCl_2$
D CH_3COOH
E NH_3

11. The electronegativity of elements in the series F, O, N, Cl decreases. Specify in which of the listed molecules the connection is most polar?
A * Cl_2
B OF_2
C Cl_2O
D NCl_3
E NF_3

12. For which of the molecules does not characterize the hydrogen bond?
A * CH_4
B NH_3
C HF
D H_2O
E C_2H_5OH

13. Modern methods of research make it possible to experimentally determine the spatial configurations of molecules. The water molecule has a structure:
A * corner
B linear
C square
D cubic
E octahedral

14.Ionic bond formed:
A * Electrostatic interaction of oppositely charged ions.

B Generalized valence electrons.
C Electrostatic interaction of molecular dipoles.
D by a pair of electrons.
E Interaction of a hydrogen atom with more electronegative atoms.

15. Type of chemical bond in molecule I_2
A * Covalent nonpolar
B Ionic
C Covalent polar
D Metallic
E Intermolecular interaction

16. Between water molecules there are the following types of communication:
A * hydrogen
B is covalent
C is covalent and ionic
D ions
E metallic

17. Which of the following compounds is formed only at the expense of the ionic type of connection?
A * Na_2S
B NH_4Cl
C HCl
D CH_3COOH
E PH_3

18. The intermolecular hydrogen bond does not affect the physical property of a substance such as:
A * Molecular weight
B Boiling point
C Solubility in water
D Density of solution
E Conversion of gas to liquid

19. The presence of ion bond in NaCl causes:
A * Ability of solution to conduct electric current
B Plasticity.
C Thermal conductivity.
D Opacity.
E Conductivity.

20. Specify a compound containing a -O-O-
A * H_2O_2
B H_2O
C N_2O_5
D Al_2O_3
E SO_2

10. Complex compounds

1. What is the degree of oxidation of the central atom in compound H $[AuCl_4]$?
A * + 3
B 0
C +1
D +2
E +4

2. Identify a complex compound that detects antitumor activity:
A * $[Pt(NH_3)_2Cl_2]$
B $[Co(NH_3)_5NO_3]$ Cl_2
C $Na_4[Sn(OH)_3Cl_3]$
D $[Cu(NH_3)_4(SCN)_2]$
E $K_2Na[Co(NO_2)_6]$
3. The Coordination number of the Ferum in potassium hexacyanoferrate (II), $K_4[Fe(CN)_6]$, is:
A * 6
B 2
C 4
D 3
E 8

4. The coordination number of the complexing agent is:
A * the number of chemical bonds forming ligands with a central ion
B is the charge of the central ion
C is the number of molecules and ions forming part of the complex compound, except for the central ion
D is the degree of oxidation of the central ion
E -

5. Which of the compounds refers to aciidokomplex?
A * $K_4[CoF_6]$
B $[Fe(CO)_5]$
C $[Cr(NH_3)_6]Cl_3$
D $[Cr(H_2O)_4]Cl_2$
E $Na_2[Zn(OH)_4]$

6. The charge of the central ion-complexing agent in the red blood-salt $K_3[Fe(CN)_6]$ is:
A * + 3
B +2
C +1
D +4
E +6

7. Some medicines refer to complex compounds. Specify which of the ligands is bidentate:
A * Oxalate ion
B Hydroxide ion

C Ammonia
D Chloride ion
E Water

8. In cosmetology practice, calcium hydrogen sulfide hexahydrate is used. Specify the formula for this salt.
A * $Ca(HS)_2 \cdot 6H_2O$
B $CaS \cdot 6H_2O$
C $CaSO_3 \cdot 6H_2O$
D $Ca(HSO_3)_2 \cdot 6H_2O$
E $CaSO_4 \cdot 6H_2O$

9. Indicate the degree of oxidation of the complexing agent in the complex compound $Na_3[Ag(S_2O_3)_2]$:
A * + 1
B 0
C +2
D +4
E +3

10. For the given complex compound $K_2[HgI_4]$ specify the complexing agent:
A * Hg^{2+}
B K^+
C I^-
D HgI_4^{2-}
E $K_2[HgI_4]$

11. Indicate what the geometric structure of the complex compound is determined:
A * type of hybridization of orbitals of the complexing agent
B charge of complexing agent
C number of ligands
D charging the interior of the complex
E coordinate number of complexing agent

12. Tsianokobalamin (vitamin B_{12}) is a complex compound of cobalt. What type of complex compounds does it belong to?
A * Chelate complexes
B Atsidovkompleksy
C Aquacomplexes
D Cationic complexes
E Hydrocomplexes

13. The realization of which mechanism for the formation of chemical bond is required in complex compounds?
A * donor-acceptor
B ion
C covalent
D hydrogen

E metallic

14. What is the coordination formula of the compound with the total composition $PtCl_4$ • $6NH_3$, if the coordination number Pt (IV) is 6?
A * $[Pt(NH_3)_6]Cl_4$
B $[Pt(NH_3)_6]Cl_2$
C $[Pt(NH_3)_4]Cl_4$
D $[Pt(NH_3)_6]Cl_3$
E $[Pt(NH_3)2]Cl_4$

15.In the interaction with the excess of aqueous ammonia solution $CuSO_4$ forms a compound that contains ion:
A * $[Cu(NH_3)_4]^{2+}$
B $CuOH^+$
C $[Cu(NH_3)_2]^+$
D $[Cu(OH)NH_3]^+$
E $[Cu(H_2O)_4]^{2+}$

16. The State Pharmacopoeia of Ukraine recommends for the study of pharmaceuticals a reagent $Na_2[Fe(CN)_5NO]$. What is the degree of oxidation of the central ion in this compound?
A * + 3
B 0
C +1
D +2
E +6

17. Which of the following complex compounds is a cation complex:
A * $[Cr(H_2O)_4Cl_2]Cl$
B $H_2[PtCl_6]$
C $Na_3[Co(NO_2)_6]$
D $K_3[Fe(CN)_6]$
E $Na_2[Fe(CN)_5NO]$

18. What degree of oxidation has a central ion in the compound $[Cr(H_2O)_4Cl_2]Cl$?
A * + 3
B 0
C +2
D +4
E +6

19. Determine the complex compound whose charge in which the central atom-complexing agent is equal to +3:
A * $K_3[Fe(CN)_6]$
B $[Pt(NH_3)_2Cl_2]$
C $K_2[Mn(CN)_4]$
D $K_2[PtCl_4]$
E $[Ag(NH_3)_2]NO_3$

20. What kind of isomerism takes place for the complex compound $[Pt(NH_3)_2Cl_2]$:
A * geometric
B Optical
C is hydrated
D ionization
E coordination

11. Chemistry of elements of I-A and II-A subgroups

1. Which of the following interactions is possible at room temperature?
A * $K + H_2O =$
B $Hg + H_2O =$
C $Cu + HCl =$
D $Fe + H_2SO_4$ (conc.) =
E $CuO + H_2 =$

2. What compound of Hydrogen with elements of IVA group of periodic system is the most stable?
A * CH_4
B SiH_4
C GeH_4
D SnH_4
E PbH_4

3. Indicate all possible levels of Hydrogen oxidation:
A * -1, 0, +1
B +1, 0
C -1, +1, +3
D -1, 0
E +1, +2

4. Specify the amphoteric s-element of group II:
A * Be
B Mg
C Ca
D Sr
E Ba

5. What barium salt is used as an X-ray contrast agent in stomach radiography?
A * $BaSO_4$
B $BaCl_2$
C BaS
D BaO
E $Ba_3(PO_4)_2$

6. Lithium carbonate is used in medicine for the treatment of psychoses. Which of the following compounds does Li_2CO_3 react?
A * HCl
B NaCl

C $LiNO_3$
D KNO_3
E KCl

7. Water is used in the manufacture of medicinal products. Which of the simple substances react with water at room temperature?
A * chlorine
B nitrogen
C silition
D copper
E gold

8. The temporal hardness of water causes the salt:
A * $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$
B $Mg(HCO_3)_2$ and $MgSO_4$
C $Ca(HCO_3)_2$ and $CaSO_4$
D $MgSO_4$ and $CaSO_4$
E $CaCl_2$ and $Mg(HCO_3)_2$

9. The composition of drinking soda is expressed by the formula:
A * $NaHCO_3$
B Na_2CO_3
C K_2CO_3
D $Na_2CO_3 \cdot 10H_2O$
E $CaCO_3$

10. Which of the following reagents should be used to determine the presence of Ca^{2+} in the solution?
A * $(NH_4)_2C_2O_4$
B HCl
C HNO_3
D KCl
E NaBr

11. Which of the following reactions is used in submarines for regeneration of air?
A * $2Na_2O_2 + 2CO_2 = 2Na_2CO_3 + O_2$
B $2KMnO_4 = K_2MnO_4 + MnO_2 + O_2$
C $2KClO_3 = 2KCl + 3O_2$
D $2NaNO_3 = 2NaNO_2 + O_2$
E $2H_2O_2 = 2H_2O + O_2$

12.Hydrogen in the periodic system D.I.Mendeleev are located in:
A * IA and VIIA groups
B IIA group
C iv group
D VIIV group
E VIIB and IA groups

13. Type of bond in a hydrogen molecule:
A * Covalent nonpolar
B Covalent polar
C Hydrogen
D Force Van der Waals
E Ionic

14.Healthy lime is called a compound:
A * $Sr(OH)_2$
B CaO
C CaJ
D $CaCl_2$
E $CaCO_3$

15.In the metabolism of the human body actively involved biogenic macroelements. What is the content of macrocell in the plasma of the cell significantly higher than in the extracellular fluid?
A * potassium
B Natrium
C Magnesium
D Broom
E Yoda

16. Among the alkali metals, the magnitude of the ionization energy is greatest in:
A * Li
B K
C Na
D Rb
E Cs

17. Which element is most common in the solar system
A * Hydrogen
B Carbon
C Oxygen
D Nitrogen
E Silicios

18. Specify a compound whose qualitative definition is accompanied by the appearance of a blue color of the ether layer:
A * H_2O_2
B Cl_2
C Na_2HPO_4
D $MnSO_4$
E $FeSO_4$

19. One of the indicators of water quality is its rigidity. Which of the following salts can cause constant hardness of water?
A * $CaSO_4$

B NaCl
C Ca $(HCO_3)_2$
D $Mg(HCO_3)_2$
E K_2SO_4

20. Which of the following substances can be used to reduce the hardness of water?
A * Na2CO3, Ca (OH) 2
B CaCO3, NaOH
C Na3PO4, CaCl2
D MgSO 4, H 2 SO 4
E Na_2CO_3, NaCl

12. Chemistry of elements VII-A subgroups

1. When passing chlorine through a cold solution of potassium hydroxide are formed:
A * KCl, KClO, H_2O
B KCl, $KClO_3$, H_2O
C KCl, H_2O
D KClO, $KClO_3$, H_2O
E $KClO_3$, H_2O

2. The strongest among the halogen-containing acids are:
A * HI
B HCl
C HF
D HBr

3. Indicate how the acid strength changes in the series:
HF - HCl - HBr - HI.
A * increases from HF to HI;
B decreases from HF to HI;
C does not change;
D increases from HI to HF.

4. In the series of HF-HCl-HBr-HI
A * decreases the stability of the molecule, the strength of acids increases
B increases the stability of the molecule, the strength of acids increases
C decreases the stability of the molecule, the strength of acids decreases
D increases the stability of the molecule, the strength of acids decreases
E The acid strength is the same

5. Indicate which halogen oxidizing properties are most pronounced:
A * F_2
B I_2
C Cl_2
D Br_2
E Cl_2 and Br_2

6. $CaOCl_2$, called "bleached lime", is used as:
A * Disinfectant
B Stomach
C Anti-dandruff
D Adhesive agent
E Cardiotonics

7. Chlorine lime, used in medical practice as a disinfectant, its formula:
A * CaCl(OCl)
B $CaCl_2$
C $Ca(ClO_3)_2$
D $Ca(ClO_4)_2$

8.Dezinching effect of chlorine lime is related to:
A * isolation of HCl in the interaction of lime from CO_2 of humid air
B separation of $CaCO_3$ in the interaction of lime from CO_2 of humid air
With the release of $CaCl_2$ in the interaction of lime with CO_2 from the air
D separation of $Ca(OH)_2$ with the interaction of chlorine lime with CO_2 air
E isolation of HCl with the interaction of chlorine lime with CO_2 air

9. What is the maximum Fluor Valence?
A * 1
B 7
C 2
D 5
E 3

10.If comparison of oxygen-containing acids of chlorine by force and oxidizing properties can be concluded - with an increase in the degree of oxidation of chlorine:
A * oxidizing ability decreases, acid strength increases
B, the oxidizing ability and acid strength are reduced
C oxidizing ability and acid strength increases
D oxidation capacity increases, the strength of acids decreases
E oxidation capacity and acidity are unchanged

11. High chemical activity of fluorine is due
A * the high strength of the connections that Fluor forms with other elements
B high strength F-F connection
C low electronegativity
D large flora atom
E weakness of the Fluorine connections with other elements

12.Petrovodnen compared with other halogen vesnymi has the highest boiling point. This property is due to:
A * presence of hydrogen connections
B by the presence of covalent polar links
With the presence of covalent nonpolar connections
D in the presence of ionic bonds

E the presence of metallic connections

13. Chlorine with hot water solution KOH:
A * forms KCl and $KClO_3$
B decomposes alkali with the formation of O_2
C does not interact
D forms KCl and KClO
E forms KCl_4 and $KClO_3$

14. Properties of Hypochloric Acid (HClO):
A * Weak acid, strong oxidant
B Strong acid, strong oxidant
C Strong acid, weak oxidizer
D Weak acid, weak oxidising agent
E Weak acid, oxidizing and reducing properties are not present

15. The oxidizing properties of free halogens increase in a number:
A * I_2, Br_2, Cl_2, F_2
B F_2, Cl_2, Br_2, I_2
C Br_2, I_2, Cl2, F_2
D Br_2, F_2, I_2, Cl_2
E I_2, Cl_2, Br_2, F_2

16. In industry, chlorine is extracted:
A * Electrolysis of NaCl melt
B Interaction of MnO_2 with concentrated HCl
C Interaction of $KMnO_4$ with concentrated HCl
D Schedule HClO
E Interaction of PbO_2 with dilute HCl

17. Under laboratory conditions chlorine is extracted:
A * Interaction of $KMnO_4$ with concentrated HCl
B Electrolysis of NaCl melt
C Schedule $KClO_3$
D Schedule HClO
E Electrolysis of the Melt $ZnCl_2$

18. What chemical elements and compounds do chlorine directly interact with?
A * With oxygen
B with sodium
C With water
D With Phosphorus
E With Zinc

19. Formula of hypobromic acid:
A * HBrO
B HBr
C $HBrO_2$

D $HBrO_3$
E $HBrO_4$

20. When interaction of chlorine with water is formed:
A * HClO + HCl
B HClO + $HClO_3$
C HClO + $HClO_2$
D HClO + $HClO_4$
E HClO + Cl_2O_6

13. Chemistry of elements of VI-A subgroups

1. Due to the reaction of SO_2 with chlorine, sulfuryl chloride is formed. Which of the following formulas corresponds to sulfuryl chloride?
A * SO_2Cl_2
B SO_2
C S_2Cl_2
D SCl_2
E SCl_4

2. Indicate the degree of oxidation of Sulfur, which corresponds to the octet of electrons at the external electronic level:
A * -2
B +2
C +4
D +6
E 0

3. Indicate why sodium thiosulfate can not be used in acidic media?
A * Decomposes with the release of sulfur
B Increases hydrolysis
C Slows down hydrolysis
D There is formation of $S_4O_6^{2-}$ ion
E Oxidized to SO_4^{2-} ion

4. Among the reduced acids, indicate disulphate:
A * $H_2S_2O_7$
B $H_2S_2O_5$
C $H_2S_2O_8$
D H_2S
E $H_2S_4O_6$

5. Concentrated sulfate acid does not react with iron at room temperature because:
A * on an iron surface an insoluble oxide film forms
B iron is an active metal
C Iron refers to d-elements
D iron is in VIIIV group
E iron is in the fourth period

6. Sulfur in the degree of oxidation +4 may be:
A * oxidant and reducing agent
B is only an oxidizer
C is only a restorer
D does not enter the oxidation-reduction reaction
E oxidant only with strong reducing agents

7. Many elements form alotropic modifications. Indicate the allotropic modification of Oxygen.
A * ozone
B phosgene
C quartz
D corundum
E diamond

8. For qualitative detection of ozone, the reaction of its interaction with:
A * KI
B I_2
C H_2O_2
D H_2SO_4
E $KMnO_4$

9. In which of the compounds Oxygen exhibits a positive degree of oxidation?
A * OF_2
B CO_2
C H_2O_2
D KO_2
E KO_3

10. If the action of acids on thiosulfates are formed:
A * S and SO_2
B H_2SO_3
C H_2S and S
D SO_3
E H_2SO_4

11. Sulfate acid can interact:
A * With metals that are in a series of stresses to hydrogen
B Only with alkaline metals
C With metals and nonmetals
D Only with nonmetals
E With metals that are in a series of stresses after hydrogen

12.Sulfuric acid forms salts:
A * Sulphates and hydrosulphates
B Sulphates and hydrosulphites
C Sulfides and Hydrosulphides
D Sulphides

E Sulphites

13. Indicate the product of oxidation of sodium thiosulfate with iodine:
A * $Na_2S_4O_6$ + NaI
B S + Na_2SO_4
C Na_2S + H_2SO_4
D S + H_2SO_4
E Na_2SO_4 + H_2SO_4

14. In the process of qualitative determination of ozone allocated free:
A * Iodine
B Fluoride
C Chlorine
D Brom
E Nitrogen

15. When burning pyrite is formed:
A * Fe_2O_3 + SO_2
B Fe_2O_3 + SO_3
C Fe_2O_3 + CO_2
D Fe_2O_3 + CO
E Fe_2O_3 + H_2

16.What of the above substances, concentrated sulfate acid does not interact without heating:
A * Iron
B Phosphorus
C Sulfur
D Mercury
E Graphite

17. With dilute solution of sulfate acid does not react:
A * Ag
B Fe
C Zn
D Ca
E Mg

18. Not a reducing agent of metals from their ores:
A * Oxygen
B Carbon monoxide (II)
C Carbon
D Aluminum
E Hydrogen

19. Substance in which sulfur can only be a reducing agent:
A * H_2S
B SO_2

C SO_3
D H_2SO_3
E H_2SO_4

20. Substance in which sulfur can only be an oxidant:
A * H_2SO_4
B SO_2
C H_2SO_3
D S
E Na_2S

14. Chemistry of elements of V-A subgroups

1. The product of dissolving in water PCl_5 is:
A * H_3PO_4 and HCl
B $H_2[PO_3H]$ and HCl
C P and HCl
D H_3PO_2 and HCl
E H_3P and HCl

2. The degree of oxidation of phosphorus in $H[PO_2H_2]$ is:
A * + 1
B +4
C +5
D +3
E -3

3.If the action of ammonia on acid occurs formation of ammonium salts. What properties of ammonia characterize this process:
A * Ability to combine ions with Hydrogen
B Recovery
C Acid
D Oxidizing
E Hydrolysis ability

4. As a result of the reaction of excess mercury with dilute nitric acid, gas is released:
A * NO
B NH_3
C N_2
D N_2O

5. Why is the maximum valency of Nitrogene equal to the donor-acceptor mechanism of covalent bond formation?
A * 4
B 1
C 2
D 3
E 5

6. Which of the following ammonium salts decomposes when heated with the release of ammonia?
A * $(NH_4)_2CO_3$
B NH_4NO_2
C NH_4NO_3
D $(NH_4)_2Cr_2O_7$
E -

7. Which of the compounds is characterized by the lowest degree of oxidation of Nitrogen?
A * NH_3
B HNO_2
C HNO_3
D N_2O_5
E NO_2

8. Hydrous alcohol - is an aqueous solution with a mass fraction of ammonia:
A * 10%
B 3%
C 5%
D 15%
E 8%

9. Gipofosfite acid corresponds to the formula:
A * $H[PO_2H_2]$
B HPO_3
C H_3PO_4
D $H_4P_2O_7$
E $(HPO_3)_n$

10. Which of the above acids is single-base?
A * hypophosphite
B is phosphate
C is diphosphate
D is sulfite
E sulphate

11. Which compound of the Hydrogen with elements of the VA group of the periodic system is the most stable?
A * NH_3
B PH_3
C AsH_3
D SbH_3
E BiH_3

12. The product of dissolution in water P_2O_3 is a compound:
A * $H_2[PO_3H]$
B H_3PO_4

C $H_4P_2O_7$
D (NRO_3) n
E H_3P

13. If the thermal decomposition of which of the nitrates recommended by the State Pharmacopoeia of Ukraine as a reagent, the metal is formed:
A * $AgNO_3$
B $Ca(NO_3)_2$
C $Mg(NO_3)_2$
D KNO_3
E $Al(NO_3)_3$

14. On what metal does concentrated concentrated nitric acid in cold?
A * Cr
B Na
C Mg
D Cu
E Zn

15. Indicate nitric oxide, which corresponds to nitric acid:
A * N_2O_5
B N_2O_4
C N_2O
D NO
E NO_2

16. Nitrogen gum (N_2O) is used for inhalation anesthesia. It is obtained by heating:
A * NH_4NO_3
B NH_4NO_2
C $Cu(NO_3)_2$
D NH_4OH
E $NaNO_3$

17. The nitrogen oxide (I), known as the "amusing gas", is used in medicine for anesthesia in combination with oxygen. Specify the formula for this oxide.
A * N_2O
B NO
C NO_2
D N_2O_3
E N_2O_4

18. From the following reaction equations, choose the one that characterizes the ability of nitric acid to react to the exchange:
A * $CaCO_3 + 2HNO_3 = Ca(NO_3)_2 + CO_2 + H_2O$
B $5HNO_3 + 3P + 12H_2O = 3H_3PO_4 + 2NO$
C $Cu_2O + 6HNO_3 = 2Cu(NO_3)_2 + 2NO_2 + 3H_2O$
D $4Ca + 10HNO_3 = 4Ca(NO_3)_2 + N_2O + 5H_2O$
E $Cu + 4HNO_3 = Cu(NO_3)_2 + 2NO_2 + 2H_2O$

19. Substance in which nitrogen can be only an oxidant:
A * HNO_3
B HNO_2
C NH_3
D NO_2
E N_2O

20. Substance in which nitrogen can only be a reducing agent:
A * NH_3
B HNO_2
C HNO_3
D NO_2
E N_2O

15. Chemistry of elements IV-A subgroups

1. Indicate the valence of the Carbon atom in the carbon (II) oxide molecule:
A * 3
B 4
C 5
D 1
E 0

2. Sodium hydrogen carbonate is used in medicine at acidosis. If it produces a solution of hydrochloric acid, gas forms:
A * CO_2
B NH_3
C Cl_2
D CO
E H_2

3.Graphite is an alotropic modification of Carbon. What type of hybridization of atomic orbitals of carbon in it:
A * sp^2
B sp
C sp^3
D dsp^2
E sp^2d

4. Which of the following oxides does not react with water?
A * CO
B CaO
C CO_2
D CrO_3
E Cl_2O_7

5. Solines of carbonate acid are very commonly used. In medicine, it is used in diseases of the stomach and intestines, as well as in heartburn, gout, and the like, one of the salts, which at home is called drinking soda. What is this salt?

A * $NaHCO_3$
B Na_2CO_3
C K_2CO_3
D $Ca(HCO_3)2$
E $CaCO_3$

6. The following compounds are a potent poison:
A * CO
B CO_2
C $(NH_2)_2CO$
D SiO_2
E Na_2SiO_3

7. Indicate the electron formula of Carbon in the excited state:
A * $1s^2 2s^1 2p^3$
B $1s^2 2s^2 2p^0$
C $1s^2 2s^2 2p^2$
D $1s^2 2s^2 2p^6$
E $1s^2 2s^2 2p^4$

8. When passing CO_2 through aqueous solution of sodium carbonate it is formed:
A * sodium hydrogen carbonate
B sodium hydroxide
C sodium carbonate
D carbonate acid
E Sodium Oxide

9. Which salt from the "Karlovy Vary salt" used as a laxative and choleretic agent can react with dilute sulfuric acid?
A * $NaHCO_3$
B Na_2SO_4
C NaCl
D K_2SO_4
E KCl

10. To the p-elements of the IV group of the periodic system are: Carbon, Silicon, Germanium, Stanum and Plumbum. How does the metallic properties of elements in a number of C-Si-Ge-Sn-Pb change?
A * increase
B decrease
C do not change
D first decrease and then increase
E first increase and then decrease

11. Potassium acetate in oral use exhibits diuretic properties. Which of the following compounds interacts with CH_3COOK
A * HCl
B KOH

C K_2SO_4
D $BaSO_4$
E NaCl

12. High energy of thermal dissociation of the CO molecule [binding energy 1075 kJ] determines
A * triple bond between oxygen and carbon atoms
B covalent bond
C ionic bond
D high polarity of the molecule
E hydrogen bond

13. What substances from the resulted pairs are carbides:
A * CaC_2 and Al_4C_3
B CS_2 and CaC_2
C CH_4 and Al_4C_3
D $CaCO_3$ and CaC_2
E SiC and CH_4

14. In any case, silica (silicon) acid is formed:
A * Under the influence of chloride on sodium silicate
B Under water action on silica dioxide
C When combustion of amorphous silicon
D When fused with silicon dioxide, with alkali
E Under the influence of chloride acid on silica dioxide

15. As a result of hydrolysis of magnesium silicide, the following reaction products are formed:
A * silane and magnesium hydroxide
B silane and magnesium oxide
C complex compound
D silicon, magnesium oxide and hydrogen
E silicon (IV) oxide, magnesium oxide and hydrogen

16. Sodium hydrogen carbonate is used as:
A * An antidiabetic agent
B Diuretic
C Laxative
D Cholinergic remedy
E Soothing

17. Which of the following statements is correct for silicic acid:
A * Does not exhibit oxidation-reducing properties
B Well dissolved in water
C Does not supplant CO_2 from a solution of carbonates
D is a strong acid
E Is obtained by dissolving SiO_2 in water

18.Carbonates resistant to heating are:
A * Sodium carbonate
B Argentum carbonate
C Calcium Carbonate
D Magnesium carbonate
E Cooper (II) carbonate

19. In the presence of a catalyst or under the action of radiation, CO interacts with chlorine, forming:
A * Poisonous gas of phosgene
B Tetrachloride of carbon and ozone
C Oxide carbon (IV) and quaternary carbon
D Carboxylic oxide (IV) and chlorine oxide (I)
E Tetrachloride of carbon and oxygen

20. To determine the CO_2 in the air you can use:
A * Aqueous solution of $Ca(OH)_2$
B Aqueous NaOH solution
C CaO
D $Fe(OH)_2$
E Crystalline NaOH

16. Chemistry of elements III-A subgroups

1. Boric acid shows weak disinfectant properties. In the form of alcoholic solutions it is used in ophthalmology, dermatology and cosmetology. What electrolyte is H_3BO_3:
A * Weak
B Strong
C Medium
D Lowly soluble
E Insoluble

2. Hydroxide of aluminum is amphoteric because:
A * reacts with acids and alkalis, forming salts
B reacts only with acids, forming salts
C reacts only with the basics of forming salt
D is insoluble in water
E, when heated, forms oxide and water

3. Indicate the equation that corresponds to the aluminothermic process:
A * $Cr_2O_3 + 2Al = Al_2O_3 + 2Cr$
B $AlCl_3 + 3K = 3KCl + Al$
C $6HCl + 2Al = 2AlCl_3 + 3H_2$
D $Al^{3+} + 3e = Al^0$
E $2Al + 6H_2O = 2Al(OH)_3 + 3H_2$

4. What compounds of aluminum are used as an anesthetic
A * $KAl(SO_4)_2 * 12H_2O$
B $Al(NO_3)_3 \cdot 9H_2O$

C $AlCl_3 \cdot 6H_2O$
D $Al_2(SO_4)_3 \cdot 18H_2O$

5. Among the compounds listed, indicate the empirical formula of the drug preparation - the storms:
A * $Na_2B_4O_7 \cdot 10H_2O$
B $NaBO_2$
C Na_3B
D $B(OC_2H_5)_3$
E B_2H_6

6. As a result of the fusion of aluminum oxide with alkali, formed:
A * Metaluminate of the corresponding metal and water
B Aluminum of the corresponding metal
C Methaliuminate of the corresponding metal and hydrogen
D Metaluminate of the corresponding metal
E Hexahydroxoaluminate of the corresponding metal

7. If the interaction of an excess of alkali solution with amphoteric metals are formed:
A * Hydrocomplexes
B Average salts
C oxides
D Basic salts
E Hydroxides

8. For the quantitative determination of boric acid in medicinal forms, a neutralization reaction is used. Which of the following substances is a product of the interaction of NaOH with H_3BO_3?
A $Na_2B_4O_7$
B Na_3BO_3
C $NaBO_2$
D $Na(B(OH)_3)$
E Na_2BO_2

9. Due to the interaction of orthoborate acid with alkalis are not formed:
A * orthoborate metals
B metoborates of metals
C tetraborate of metals
D polyborate of metals
E none of the above substances

10.With which of the following substances boron does not interact:
A * HCl
B HNO_3
C H_2SO_4
D KOH
E Mg

11. If the interaction of aluminum with dilute nitric acid is formed:
A * N_2
B NO_2
C N_2O
D NO
E NH_4NO_3

12. For the purification of water, use the following substance:
A * $Al_2(SO_4)_3$
B $Al(OH)_3$
C Na_2SO_4 $12H_2O$
D H_3BO_3
E $AlCl_3$

13. Which of the oxides of elements of group III of the periodic system has amphoteric properties?
A * Al_2O_3
B B_2O_3
C Tl_2O_3
D Sc_2O_3
E Y_2O_3

17. Chemistry of elements of VII-B subgroups

1. Indicate the molecular formula of the oxide to which the permanganate acid corresponds:
A * Mn_2O_7
B Mn_3O_4
C Mn_2O_3
D MnO_2
E MnO

2. Indicate which Manganese compound can be only an oxidant in oxidation-reduction reactions:
A * $KMnO_4$
B $K_{2M}nO_4$
C MnO_2
D $MnSO_4$
E $Mn(OH)_2$

3. Indicate which of the Manganese compounds is used in medicine:
A * $KMnO_4$
B K_2MnO_4
C MnO2
D $[Mn_2(CO)_{10}]$
E Mn_2O_3

4. Kaliumpermanganate $KMnO_4$ is used in medical practice as a bactericidal agent. What are the chemical properties of $KMnO_4$ to determine its bactericidal nature?

A * Recoverable
B Acid
C Major
D Oxidizing
E Ability to decompose when heated

5. Mangantetrachloride is very unstable. It is easy to decompose on:
A * $MnCl_2 + Cl_2$
B $Mn + Cl_2$
C Mn
D Cl_2
E $MnCl_3 + Cl_2$

6. What is the chemical formula and color of the product of the restoration of potassium permanganate in a neutral environment?
A * MnO_2, brown
B MnO_2, green
C K_2MnO_4, green
D K_2MnO_4, purple
E $MnSO_4$, colorless

7. Depending on the conditions of the oxidation-reduction reaction, the permanganate-ion can be reduced to Mn^{2+}, $Mn4^{+}$, MnO_4^{2-}. What environment is it necessary for permanganate-ion to recover to the compounds $Mn^{2+?}$
A * sour
B light brown
C is neutral
D alkali
E is weakly acid

8. What is the manganese compound that manifests both oxidizing and restorative properties?
A * MnO_2
B Mn_2O_7
C MnO
D $KMnO_4$
E $MnSO_4$

9. Change of acid-alkaline properties in the compounds MnO-MnO_2-Mn_2O_7 corresponds to the regularities
A * acidic properties are amplified
B the main properties are amplified
C acid-alkaline properties do not change
D acid properties are reduced

10. In oxidation-reduction reactions, potassium permanganate $KMnO_4$ is only an oxidant. When the reaction occurs in the acidic medium, the raspberry color is discolored. Specify the recovery product of MnO_4^-- ion in an acidic medium:

A * Mn^{2+}
B MnO_2
C MnO_4^{2-}
D $Mn(OH)_2$
E $Mn(OH)_4$

11.Kaliumpermanganate in reaction with hydrogen peroxide in acidic medium exhibits properties:
A * oxidant
B reducer
C disproportionate
D oxidizer and reducing agent
E does not exhibit oxidative properties

12. At restoration of potassium permanganate in a neutral medium a compound of manganese is formed:
A * MnO_2
B K_2MnO_4
C MnO
D $MnSO_4$
E $Mn(OH)_2$

13. Thermal decomposition of potassium permanganate under laboratory conditions is obtained:
A * O_2
B H_2
C KOH
D H_2O_2
E $Mn(OH)_2$

14. Saturation of iodine starch is observed under the action of an acidified solution of $KMnO_4$ on a solution:
A * KI
B HCl
C H_2O_2
D $FeSO_4$
E KNO_2

15. In oxidation-reduction reactions, potassium permanganate $KMnO_4$ is only an oxidant. Specify the recovery product of MnO_4^- ion in alkaline medium:
A * MnO_4^{2-}
B MnO_2
C Mn^{2+}
D $Mn(OH)_2$
E $Mn(OH)_4$

18. Chemistry of elements of subgroups of Ferrum and Chromium

1. Indicate the type of reaction that is used to detect Fe^{3+} cation.

A * Complex formation
B Deposition
C Hydrolysis
D Neutralization
E Recovery

2. The presence of which of the ions of d-elements in solutions can be established with $K_4[Fe(CN)_6]$?
A * Fe^{3+}
B Zn^{2+}
C Cr^{3+}
D Ni^{2+}
E Cu^{2+}

3.Ferum in the degree of oxidation +6 is only an oxidizer because:
A * has the highest degree of oxidation
B has 5 electrons at the external electron level
C is in VIIIV group
D is a d-element
E is in the fourth period

4. A vireozo, letting the sick dasgs, warns that such foods as eggs and milk interfere with the assimilation process:
A * Ferrum
B Cobalt
C Chromium
D Mangan
E Nitrogen

5.Ferum in the human body is a part of hemoglobin and a number of enzymes. For him, there are several stable oxygen-containing compounds. Find the stuff listed below that does not exist in the free state.
A * H_2FeO_4
B $Fe(OH)_2$
C $Fe(OH)_3$
D FeO
E Fe_2O_3

6. The quality reaction for the determination of Cr (VI) compounds is the formation of chromium oxide diproxide, which stains the ether layer in a blue color. Specify the formula for this chromium compound:
A * CrO_5
B CrO_3
C Cr_2O_3
D CrO
E H_2CrO_2

7. Indicate the chromium compound that exhibits amphoteric properties:

A * Cr_2O_3
B CrO
C Cr $(OH)_2$
D CrO_3
E K_2CrO_4

8. Which of the following formulas corresponds to the electronic structure of the Fe^3 + ion if the electron formula of the Ferrum atom [Ar] 3d6 4s2
A * [Ar] 3d54s0
B [Ar] 3d5 4s14p1
C [Ar] 3d34s2
D [Ar] 3d34s14p1
E [Ar] 3d44s1

9. Ferum (III) hydroxide is formed in the interaction:
A * $FeCl_3$ with NaOH
B Fe_2O_3 with NaOH
C $FeCl_3$ with H_2O
D Fe_2O_3 with H_2O
E Fe with NaOH

10. Potassium dioxide $K_2Cr_2O_7$ is used as an oxidizer in an acidic medium. Specify the product of recovery of $Cr_2O_7^{2-}$ dichromate ion under the following conditions:
A * Cr^{3+}
B Cr $(OH)_3$
C Cr $(OH)_2$
D [Cr $(OH)_6]^{3-}$
E Cr_2O_3

11. $K_4[Fe(CN)_6]$ is a reagent for:
A * ions Fe^{3+}
B ions Fe^{2+}
C ions Ca^2 +
D ions FeO_4^2-
E ions FeO ^{2} -

12. $K_3[Fe(CN)_6]$ is a reagent for:
A * ions Fe^{2+}
B ions Fe^3 +
C ions Ca^2 +
D ions FeO_4^2-
E ions FeO $^{2-}$

13 .Ferum in compounds can be in different degrees of oxidation. What is the highest degree of oxidation of ferrum in compounds?
A * + 6
B +8
C +3

D +4
E +2

14. Acids react with metals. What gas is released in the interaction of iron with dilute sulfate acid?
A * H_2
B H_2S
C SO_2
D SO_3
E No gas is emitted

15. If the interaction of iron with chlorine is formed:
A * Ferum (III) chloride
B Ferum (II) chloride
C Ferum chlorate
D Ferum hypochlorite
E Ferum (III) chlorite

16. When the interaction of iron with chloride acid is formed:
A * Ferum (II) chloride
B Ferum (III) chloride
C Ferum chlorate
D Ferum hypochlorite
E Ferum (III) chlorite

17. A wide application in orthopedic practice has stainless steels, which are made from various metals. Indicate which metal is obtained for this method of alumotermy when it is produced from oxide?
A * Cr
B Mg
C Na
D Ba
E None of the above

18.Crom, as well as aluminum and iron:
A * is tolerated by cold concentrated H_2SO_4 and HNO_3
B is capable of forming compounds with a degree of oxidation of +6
C forms an oxide with an oxidation degree +3 green
D forms an acid oxide
E forms peroxide

19. Chemistry of elements of I-B and II-B subgroups

1. When added dilute solution of chloride acid to the investigated solution formed a white cheese precipitate. What evidence of the presence of these ions is?
A * Silver
B Ammonium
C Ferrum (II)
D Barium

E Yodium

2. Small things are smearing in the air as a result of interaction with:
A * H_2S
B SO_2
C SO_3
D CO_2
E N_2

3. In hot solution of which of the above acids the gold dissolves:
A * H_2SeO_4
B HNO_3
C HCl
D H_2SO_4
E $HClO_4$

4. Argentum nitrate is used in ophthalmology as a bactericidal, anti-inflammatory agent. $AgNO_3$ can be obtained as a result of the interaction between the two substances:
A * $Ag + HNO_3$
B $AgCl + NH_4NO_3$
C $Ag + KNO_3$
D $Ag_2O + KNO_3$
E $AgCl + NaNO_3$

5. Metal, common in nature in the native state:
A * Gold
B Calcium
C Aluminum
D Natrium
E Chromium

6. Mercury is capable of forming compounds with oxidation degree +1 or +2. In one of the following compounds recommended by the State Pharmacopoeia of Ukraine for use in the study of pharmaceuticals, Mercury exhibits a degree of oxidation +2:
A * $K_2[HgI_4]$
B Hg_2Cl_2
C Hg_2O
D $Hg_2(NO_3)_2 \cdot 2H_2O$
E Hg_2SO_4

7. Which of the above formulas corresponds to the electronic configuration of the 29Cu atom
A * [Ar] 3d104s1
B [Ar] 3d94s2
C [Ar] 3d64s2
D [Ar] 3d84s2
E [Ar] 3d74s2

8. When dissolving gold, platinum, palladium in "royal water" formed metal salts
A * chlorides
B sulphates
C perchlorate
D nitrite
E chlorate

9. The herbal medicine is used as a disinfectant. Specify the compound of mercury (II), which is called as sulam:
A * HgCl
B HgO
C $Hg(NO_3)_2$
D HgS
E HgI_2

10. Indicate the mercury compound called calomel:
A * Hg_2Cl_2
B $HgCl_2$
C $Hg (NO_3)_2$
D HgS
E HgI_2

11. Composite hydroxide (II) forms complex compounds with alkalis in which copper exhibits a coordination number:
A * 4
B 5
C 6
D 3
E 2

12. Among the elements of the II S group, the amphoteric properties exhibit:
A * only zinc
B zinc and cadmium
C cadmium and mercury
D all items
E only mercury

13. What metal does not oxidize in the air, even when burned:
A * Gold
B Natrium
C zinc
D Calcium
E Barium

14. Silver, just like copper, can not ...
A * React with dilute chloride and sulfate acids
B Dissolve in concentrated sulfuric acid
C Dissolve in dilute nitric acid

D Form compounds with a degree of oxidation of +1
E Dissolve in concentrated nitric acid

15.The gold is not dissolved in:
A * nitric acid
B hot selenate acid
C in solutions of cyanides in the air
D in royal vodka
E -

APPENDIX 1

THE ELEMENTS - THEIR SYMBOLS, ATOMIC NUMBERS AND ATOMIC MASSES

English Name of element	Українська назва	Symbol	Atomic number	Atomic mass	Name of element	Українська назва	Symbol	Atomic number	Atomic mass
1	2	3	4	5	6	7	8	9	10
Actinium	Актиній	Ac	89	227,03	Neon	Неон	Ne	10	20,18
Aluminium	Алюміній	Al	13	26,98	Neptunium	Нептуній	Np	93	237,05
Americium	Америцій	Am	95	[243]	Nickel	Нікель	Ni	28	58,69
Antimony	Стибій	Sb	51	121,75	Niobium	Ніобій	Nd	41	92,91
Argon	Аргон	Ar	18	39,95	Nitrogen	Нітроген (азот)	N	7	14,01
Arsenic	Арсен	As	33	74,92	Nobelium	Нобелій	No	102	[259]
Astatine	Астат	At	85	[210]	Osmium	Осмій	Os	76	190,2
Barium	Барій	Ba	56	137,33	Oxygen	Оксиген (кисень)	O	8	16,00
Berkelium	Берклій	Bk	97	[247]	Palladium	Палладій	Pd	46	106,42
Beryllium	Берилій	Be	4	9,012	Phosphorus	Фосфор	P	15	30,97
Bismuth	Бісмут	Bi	83	208,98	Platinum	Платина	Pt	78	195,08
Boron	Бор	B	5	10,81	Plutonium	Плутоній	Pu	94	[244]
Bromine	Бром	Br	35	79,90	Polonium	Полоній	Po	84	[209]
Cadmium	Кадмій	Cd	48	112,41	Potassium	Калій	K	19	39,10
Calcium	Кальцій	Ca	20	40,08	Praseodymium	Празеодим	Pr	59	140,91
Californium	Каліфорній	Cf	98	[251]	Promethium	Прометій	Pm	61	[145]
Carbon	Карбон (вуглець)	C	6	12,011	Protactinium	Протактиній	Pa	91	231,04
Cerium	Церій	Ce	58	140,12	Radium	Радій	Ra	88	226,03

1	2	3	4	5	6	7	8	9	10
Iron	Ферум (залізо)	Fe	26	55,85	Indium	Індій	In	49	114,82
Krypton	Криптон	Kr	36	83,80	Iodine	Йод	I	53	126,91
Lanthanum	Лантан	La	57	138,92	Iridium	Іридій	Ir	77	192,22
Lawrencium	Лоуренсій	Lr	103	[260]	Uranium	Уран	U	44	101,07
Lead	Плюмбум (свинець)	Pb	82	207,2	Vanadium	Ванадій	V	62	150,36
Lithium	Літій	Li	3	6,94	Xenon	Ксенон	Xe	21	44,96
Lutetium	Лютецій	Lu	71	174,97	Zinc	Цинк	Zn	47	107,87
Magnesium	Магній	Mg	12	24,31	Zirconium	Цирконій	Zr	40	91,22
Manganese	Манган	Mn	25	54,94	Strontium	Стронцій	Sr	38	87,62
Mercury	Меркурій (ртуть)	Hg	80	200,59	Sulfur	Сульфур (сірка)	S	16	32,06
Molybdenum	Молібден	Mo	42	95,94	Tantalum	Тантал	Ta	73	180,95
Neodymium	Неодим	Nd	60	144,24	Technetium	Технецій	Tc	43	[99]
Francium	Францій	Fr	87	[223]	Tellurium	Телур	Te	52	127,60
Gadolinium	Гадоліній	Gd	64	157,25	Terbium	Тербій	Tb	65	158,93
Gallium	Галій	Ca	31	69,72	Thallium	Талій	Tl	81	204,38
Germanium	Германій	Ce	32	72,59	Thorium	Торій	Th	90	232,04
Gold	Аурум (золото)	Au	79	196,97	Thulium	Тулій	Tm	69	168,93
Hafnium	Гафній	Hf	72	178,49	Tin	Станум (олово)	Sn	50	118,71
Helium	Гелій	He	2	4,00	Titanium	Титан	Ti	22	47,88
Holmium	Гольмій	Ho	67	164,93	Tungsten	Вольфрам	W	74	183,85
Hydrogen	Гідроген (водень)	H	1	1,01					

APPENDIX 2

FORMULAS OF THE SOME ACIDS AND NAMES OF THEIR ANIONS

Formula	English Name of acid	Українська назва кислоти	Anion	Name of anion
1	2	3	4	5
Oxygen-free acids				
HF	Hydrofluoric	Гідроген-фторидна	F^-	Fluoride
HCl	Hydrochloric	Гідроген-хлоридна (соляна)	Cl^-	Chloride
HBr	Hydrobromic	Гідроген-бромідна	Br^-	Bromide
HI	Hydriodic	Гідроген-йодидна	I^-	Iodide
HCN	Hydrocyanic (prussic)	Ціано-воднева (синильна)	CN^-	Cyanide
HCNS	Thiocyanic	Тіоціано-воднева (роданиста)	SCN^-	Thiocyanate
H_2S	Hydro-Sulfuric	Гідроген-сульфідна	S^{2-} HS-	Sulphide Hydrosulphide
H_2Se	Hydroselenic	Гідроген-селенідна	Se^{2-} HSe^-	Selenide Hydroselenide
Oxygen-containing acids (oxyacids)				
CH_3COOH	Acetic	Етанова (оцтова)	CH_3COO^-	Acetate
HBO_2	Metaboric	Метаборна	BO_2^-	Metaborate
H_3BO_3	Orthoboric	Ортоборна	$[B(OH)_4]^-$	Borate
H_2CO_3	Carbonic	Карбонатна (вугільна)	CO_3^{2-} HCO_3^-	Carbonate Hydrocarbonate
H_2SiO_3	Silicic	Силікатна (кремнієва)	SiO_3^{2-} $HSiO_3^-$	Silicate Hydrosilicate
H_2SO_3	Sulfurous	Сульфітна (сірчиста)	SO_3^{2-} HSO_3^-	Sulfite Hydrosulfite
H_2SO_4	Sulfuric	Сульфатна (сірчана)	SO_4^{2-} HSO_4^-	Sulfate Hydrosulfate

1	2	3	4	5
HNO_2	Nitrous	Нітритна (азотиста)	NO_2^-	Nitrite
HNO_3	Nitric	Нітратна (азотна)	NO_3^-	Nitrate
HPO_3	Metaphosphoric	Метафосфатна	PO_3^-	Metaphosphate
H_3PO_4	Orthophosphoric (phosphoric)	Ортофосфатна (фосфорна)	PO_4^{3-} HPO_4^{2-} $H_2PO_4^-$	Orthophospate Hydroorthophospate Dihydroorthophospate
$H_4P_2O_7$	Diphosphoric (pyrophosphoric)	Дифосфорна (пірофосфорна)	$P_2O_7^{4-}$ $HP_2O_7^{3-}$ $H_2P_2O_7^{2-}$ $H_3P_2O_7^-$	Diphosphate Hydrodiphosphate Dihydrodiphosphate Trihydrodiphosphate
HPO_2	Metaphosphorous	Метафосфітна	PO_2^-	Metaphosphite
H_3PO_3	Orthophosphorous	Ортофосфітна	HPO_3^{2-} $H_2PO_3^-$	Orthophosphite Hydroorthophosphite
H_3AsO_4	Orthoarsenic	Ортоарсенатна	AsO_4^{3-} $HAsO_4^{2-}$ $H_2AsO_4^-$	Orthoarsenate Hydroarsenate Dihydroorthoarsenate
H_3AsO_3	Orthoarsenous	Ортоарсенітна	AsO_3^{3-} $HAsO_3^{2-}$ $H_2AsO_3^-$	Orthoarsenite Hydroorthoarsenite Dihydroorthoarsenite
$HAsO_2$	Metaarsenous	Метаарсенітна	AsO_2^-	Metaarsenite
$HClO$	Hypochlorous	Хлоратна (I) (хлорнуватиста)	ClO^-	Hypochlorite
$HClO_2$	Chlorous	Хлоратна (III) (хлориста)	ClO_2^-	Chlorite

1	2	3	4	5
$HClO_3$	Chloric	Хлоратна (V) (хлорнувата)	ClO_3^-	Chlorate
$HClO_4$	Perchloric	Хлоратна (VII) (хлорна)	ClO_4^-	Perchlorate
$HMnO_4$	Permanganic	Манганатна (VII) (марганцева)	MnO_4^-	Permanganate
H_2MnO_4	Manganic	Манганатна (VI) (марганцевиста)	MnO_4^{2-} $HMnO_4^-$	Manganate Hydromanganate
HVO_3	Vanadic	Ванадатна	VO_3^-	Vanadate
H_2MoO_4	Molybdenic	Молібдатна	MoO_4^{2-} $HMoO_4^-$	Molybdate Hydromolybdate
H_2CrO_4	Chromic	Хроматна	CrO_4^{2-} $HCrO_4^-$	Chromate Hydrochromate
$H_2Cr_2O_7$	Dichromic	Дихроматна	$Cr_2O_7^{2-}$ $HCr_2O_7^-$	Dichromate Hydrodichromate
Acids responded to amphoteric hydroxides in reactions with basic substances				
$HAlO_2$	Metaaluminic	Метаалюмінатна	AlO_2^-	Metaaluminate
H_3AlO_3	Orthoaluminic	Ортоалюмінатна	AlO_3^{3-} $HAlO_3^{2-}$ $H_2AlO_3^-$	Orthoaluminate Hydroaluminate Dihydroaluminate
H_2PbO_2	Leadic	Плюмбатна (свинцева)	PbO_2^{2-} $HPbO_2^-$	Leadcate Hydroleadcate
H_2ZnO_2	Zinc	Цинкатна	ZnO_2^{2-} $HZnO_2^-$	Zincate Hydrozincate
$HCrO_2$	Metachromous	Метахромітна	CrO_2^-	Metachromite
H_3CrO_3	Orthochromous	Ортохромітна	CrO_3^{3-} $HCrO_3^{2-}$ $H_2CrO_3^-$	Orthochromite Hydroorthochromite Dihydroorthochromite

APPENDIX 3

Ox. Number

Element	Ox . number										
	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7
H			H^- гідриди	H_2	H^+						
F			F^-	F_2							
Cl			HCl Cl^-	Cl_2	Cl_2O $HClO$ ClO^-		$HClO_2$ ClO_2^-	ClO_2	$HClO_3$ ClO_3^-	Cl_2O_6 (ClO_3)	Cl_2O_7 $HClO_4$ ClO_4^-
Br			HBr Br^-	Br_2	Br_2O $HBrO$ BrO^-		$HBrO_2$ BrO_2^-		$HBrO_3$ BrO_3^-		$HBrO_4$ BrO_4^-
I			HJ I^-	I_2	HIO IO^-				I_2O_5 HIO_3 IO_3^-		$HIO_4\cdot 2H$ O Або H_5IO_6
O		H_2O	H_2O_2 перок-сиди	O_2		F_2O					
S		H_2S	FeS_2	S		SO		SO_2 H_2SO_3 SO_3^{2-}		SO_3 H_2SO_4 SO_4^{2-}	
N	NH_3 NH_4^+	N_2H_4	NH_2OH	N_2	N_2O	NO	N_2O_3 HNO_2 NO_2^-	NO_2	N_2O_5 HNO_3 NO_3^-		
P	PH_3			P			P_2O_3 HPO_3^{2-}		P_2O_5 PO_4^{3-}		
As	AsH_3			As			As_2O_3 AsO_3^{3-}		As_2O_5 AsO_4^{3-}		
Sb	SbH_3			Sb			Sb_2O_3 Sb^{3+} SbO_2^-		Sb_2O_5 SbO_3^-		
Bi				Bi			Bi^{3+} Bi_2O_3 BiO^+		Bi_2O_5 BiO_3^-		
C	C_2H_6	C_2H_4	C_2H_2	C		CO		CO_2 H_2CO_3 CO_3^{2-}			
Sn				Sn		Sn^{2+} SnO_2^{2-}		Sn^{4+} SnO_3^{2-}			
Pb				Pb		Pb^{2+} PbO PbO_2^{2-}		Pb^{4+} PbO_2 PbO_3^{2-}			
Al				Al			Al^{3+} AlO_2^- AlO_3^{3-}				
B	B^{3-} B_2H_6			B			B^{3+} B_2O_3 BO_2^- $B_4O_7^{2-}$				

Appendix 3

	-3	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**	**+6**	**+7**
Alkaline and ear. m				Me^{0}		Me^{2+}					
Alkaline m.				Me^{0}	Me^{+}						
Ag				Ag	Ag^{+}	Ag^{2+}					
Ag				Ag	Ag^{+}	Ag^{2+}					
Au				Au	Au^{1+}	Au^{3+}					
Cu				Cu	Cu^{+}	Cu^{2+}					
Zn				Zn		Zn^{2+}					
Cd				Cd		Cd^{2+}					
Hg				Hg	Hg_2^{2+}	Hg^{2+}					
Cr				Cr			Cr^{3+} CrO_2^{-} CrO_3^{3-}			$Cr_2O_7^{2-}$ CrO_4^{2-}	
Mo				Mo		Mo^{2+}	Mo^{3+}	Mo^{4+} MoO_2 MoO_3^{2-}	Mo^{5+} MoO^{3+}	MoO_3 MoO_4^{2-}	
Mn				Mn		Mn^{2+}	Mn^{3+}	MnO_2		MnO_4^{2-}	MnO_4^{-}
Fe				Fe		Fe^{2+}	Fe^{3+}			FeO_4^{2-}	
Co				Co		Co^{2+}	Co^{3+}				
Ni				Ni		Ni^{2+}	Ni^{3+}				

APPENDIX 4

PERIODIC TABLE OF THE ELECTONEGATIVITIES (ACCORDING TO THE LINUS PAULING'S SCALE)

H 2,1							He -		
Li 1,0	Be 1,5	B 2,0	C 2,5	N 3,0	O 3,5	F 4,0	Ne -		
Na 0,9	Mg 1,2	Al 1,5	Si 1,8	P 2,1	S 2,5	Cl 3,0	Ar -		
K 0,8	Ca 1,0	Sc 1,3	Ti 1,5	V 1,6	Cr 1,6	Mn 1,5	Fe 1,8	Co 1,9	Ni 1,9
Cu 1,9	Zn 1,6	Ga 1,6	Ge 1,8	As 2,0	Se 2,4	Br 2,8	Kr -		
Rb 0,8	Sr 1,0	Y 1,2	Zr 1,4	Nb 1,6	Mo 1,8	Tc 1,9	Ru 2,2	Rh 2,2	Pd 2,2
Ag 1,9	Cd 1,7	In 1,7	Sn 1,8	Sb 1,9	Te 2,1	I 2,5	Xe -		
Cs 0,7	Ba 0,9	La-Lu 1,0-1,2	Hf 1,3	Ta 1,5	W 1,7	Re 1,9	Os 2,2	Ir 2,2	Pt 2,2
Au 2,4	Hg 1,9	Tl 1,8	Pb 1,9	Bi 1,9	Po 2,0	At 2,2	Ru …		
Fr 0,7	Ra 0,9	Ac 1,1	Ku -	Ns -					

APPENDIX 5

SOLUBILITY OF SALTS AND BASES IN WATER

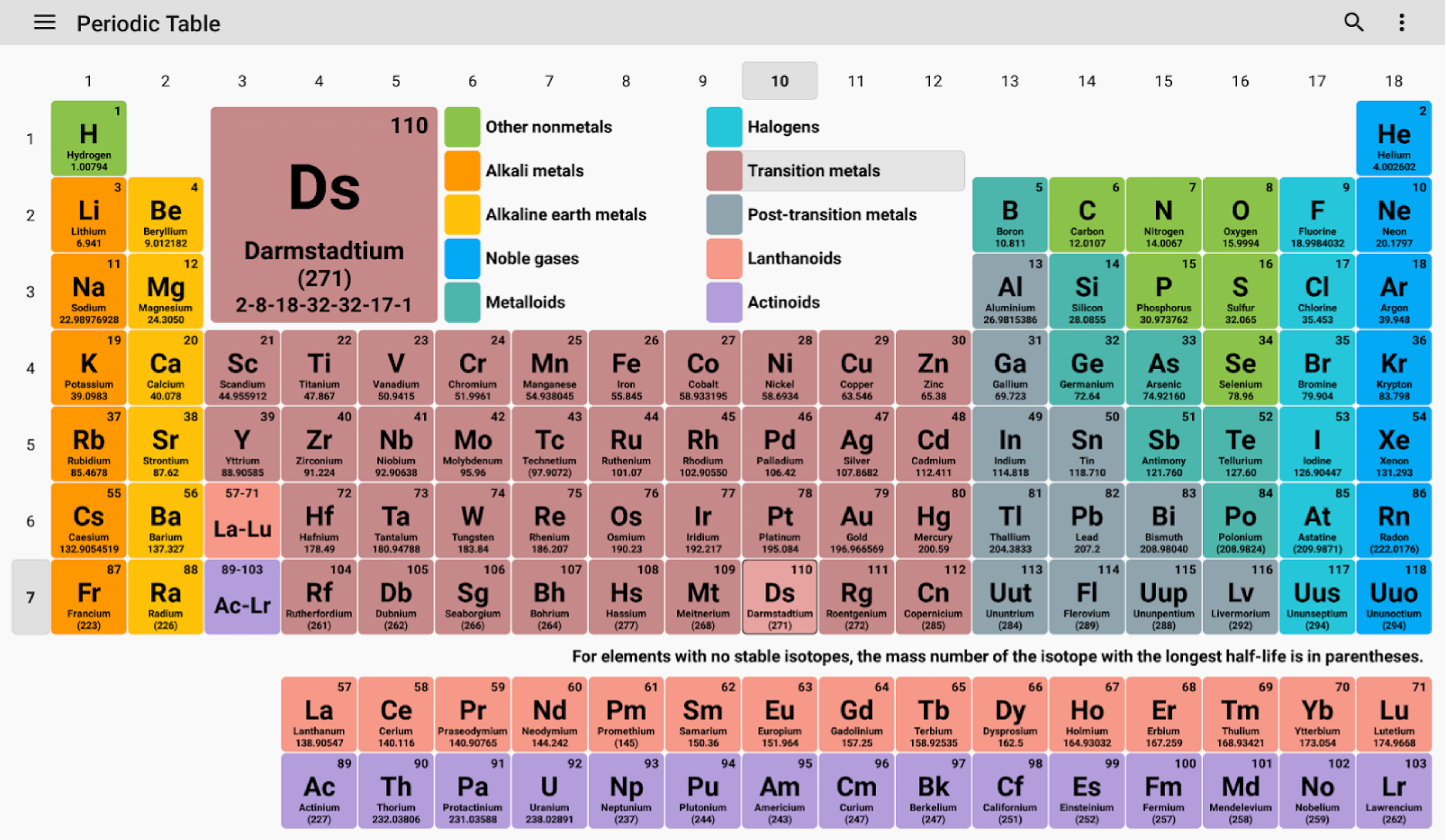
Anions	**Cations**											
	K^+	**Na^+**	**NH_4^+**	**Ba^{2+}**	**Sr^{2+}**	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**Cr^{3+}**	**Fe^{3+}**	**Fe^{2+}**	**Mn^{2+}**
OH^-	S	S	S	S	S	SS	S	I	I	I	I	I
F^-	S	S	S	SS	SS	SS	SS	SS	SS	SS	SS	SS
Cl^-	S	S	S	S	S	S	S	S	S	S	S	S
Br^-	S	S	S	S	S	S	S	S	S	S	S	S
I^-	S	S	S	S	S	S	S	S	S	S	S	S
S^{2-}	S	S	S	S	SS	S	SS	-	-	I	I	I
SO_3^{2-}	S	S	S	I	I	I	SS	-	-	-	I	-
SO_4^{2-}	S	S	S	I	SS	SS	S	S	S	S	S	S
PO_4^{3-}	S	S	S	I	I	I	I	I	SS	I	I	I
CrO_4^{2-}	S	S	S	I	SS	S	S	-	-	-	-	I
CO_3^{2-}	S	S	S	I	I	I	I	-	-	-	I	I
NO_3^-	S	S	S	S	S	S	I	S	S	S	S	S
NO_2^-	S	S	S	S	S	S	S	S	S	S	S	S
CH_3-COO^-	S	S	S	S	S	S	S	S	S	S	S	S

Notes: S – soluble in water (розчинний); SS – slightly soluble (мало розчинний); I – practically insoluble (практично нерозчинний); dash line (-) – substance decomposed in water (речовина розкладається водою)

CONTINIED APPENDIX 6

Anions	**Cations**									
	Zn^{2+}	**Ni^{2+}**	**Co^{2+}**	**Ag^{+}**	**Hg^{2+}**	**Cu^{2+}**	**Cd^{2+}**	**Pb^{2+}**	**Bi^{3+}**	**Sn^{2+}**
OH^-	I	I	I	SS	I	I	I	I	I	I
F^-	SS	S	S	S	-	SS	SS	I	I	S
Cl^-	S	S	S	I	S	S	S	SS	-	S
Br^-	S	S	S	I	S	S	S	SS	-	S
I^-	S	S	S	I	I	I	S	SS	I	S
S^{2-}	I	I	I	I	I	I	I	I	I	I
SO_3^{2-}	I	I	-	I	-	-	I	I	-	-
SO_4^{2-}	S	S	S	SS	-	S	S	I	S	S
PO_4^{3-}	I	I	I	I	I	I	I	I	I	-
CrO_4^{2-}	I	I	I	I	I	I	I	I	I	I
CO_3^{2-}	I	I	I	I	I	I	I	I	I	-
NO_3^-	S	S	S	S	S	S	S	S	S	-
NO_2^-	S	S	S	SS	-	S	S	S	S	-
CH_3- -COO^-	S	S	S	SS	S	S	S	S	-	-

Notes: S – soluble in water; SS – slightly soluble; I – practically insoluble; dash line (-) – substance decomposed in water



110
Ds
Darmstadtium
(271)
2-8-18-32-32-17-1

- 🟩 Other nonmetals
- 🟧 Alkali metals
- 🟨 Alkaline earth metals
- 🟦 Noble gases
- 🟦 Metalloids
- 🟦 Halogens
- 🟫 Transition metals
- ⬜ Post-transition metals
- 🟥 Lanthanoids
- 🟪 Actinoids

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H Hydrogen 1.00794																	2 He Helium 4.002602
2	3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
3	11 Na Sodium 22.98976928	12 Mg Magnesium 24.3050											13 Al Aluminium 26.9815386	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948
4	19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
5	37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
6	55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57-71 La-Lu	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (208.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)
7	87 Fr Francium (223)	88 Ra Radium (226)	89-103 Ac-Lr	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Uut Ununtrium (284)	114 Fl Flerovium (289)	115 Uup Ununpentium (288)	116 Lv Livermorium (292)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)