CHEMISTRY PROGRAM

I. GENERAL CHEMISTRY

1. Atomic molecular theory. Atom, molecule. Relative atomic and molecular weight. Amount of substance, units of amount of substance (mole). Molar mass. Avogadro constant.

2. Chemical element, chemical substance. Simple substances and chemical compounds. Allotropy. Conservation of mass. The law of constant composition. Symbols of chemical elements and chemical formulas. Stoichiometry.

3. Structure of atoms. Atomic nucleus. Isotopes. Wave-particle duality of electron. Quantum numbers. Atomic orbitals. Electronic configurations of the ground and excited states of atoms. Aufbau principle. Pauli exclusion principle, Hund's rule.

4. Periodic law and the structure of atom. Mass number (atomic mass number or nucleon number). Atomic number. Short and long periods, groups. The structure of electron shells of atoms. Metals and non-metals. Dependence of properties of simple substances and chemical compounds on the position of elements in the Periodic table. Ionization energy, electron affinity, electronegativity.

5. Types of chemical bonding: non-polar covalent bonding and polar covalent bonding, ionic bonding, metallic bonding. Coordinate covalent bond. Hydrogen bond. Inductive and mesomeric effects. Multiple bonds and conjugate multiple bonds. Polarity of bonds. Hybridization of atomic orbitals, geometric and shape of molecules. Structural formulas of molecules and Lewis' formulas. Valence and oxidation state. Isomerism and types of isomerism.

6. State of matter. Gases. Ideal gases. The ideal gas law (the general gas equation). Avogadro's law, molar volume. The relative density of gas. The average molar mass of the gas mixture. Air. Liquids and molecule interaction in them. Solids, the dependence of their properties on the type of chemical bonds in crystals.

7. Types of chemical reactions: synthesis, decomposition, single replacement, double replacement. Oxidation-reduction (redox) reactions, electronic balance. Determination of the direction of redox reactions using standard electrode potentials.

8. Chemical kinetics. The rate of chemical reactions. Factors, which influence the rate. The law of mass action and the rate constant. Activation energy. Catalysis and catalysts. Homogeneous and heterogeneous reactions, reversible and irreversible reactions, exothermic and endothermic reactions. Thermal effects of chemical reactions. Thermochemical equations. Heat (enthalpy) of formation of a chemical compound. Hess' law. Chemical equilibrium. Equilibrium constant, degree of conversion. Le Chatelier's principle.

9. Ideal solutions and colloids. The dependence of the solubility of a substance on temperature, pressure and solvent. Concentration of solutions (mass fraction, molarity). Physical and chemical processes at dissolution. Thermal effects at dissolution. Hydration and solvation. Electrolytes and non-electrolytes.

10. Theory of electrolytic dissociation. Weak and strong electrolytes. Dissociation constant and the degree of dissociation. Dissociation of acids, bases and salts in solutions and melts. Equilibrium in aqueous solutions of acids and bases. Brønsted–Lowry acid–base theory. Amphoterism and the

position of amphoteric elements in the Periodic table. Amphoteric properties of water. Ionic product of water (K_w). pH value. pH scale. Hydrolysis of salts.

11. Electrolysis of electrolytes in water solutions and in melts. Redox reactions on electrodes.

II. INORGANIC CHEMISTRY

Characterization of properties of a chemical element should include:

a) position in the Periodic table, the electronic structure of the atom, the valences and oxidation states;
b) typical chemical reactions (reaction equations with conditions);
c) basic types of formed compounds, their physical and chemical properties;
d) methods of preparation.

1. Classification of inorganic compounds and their nomenclature. Relation between the main classes of inorganic compounds.

2. Oxides and peroxides. Classification of oxides. Chemical properties and methods of preparation of oxides and peroxides.

3. Acids. Classification and nomenclature of acids. Oxygen-containing and oxygen-free acids. Strong and weak acids. Acidic constant. Chemical properties of acids. Preparation of acids.

4. Bases. Classification and nomenclature of bases. Chemical properties of bases. Preparation of bases.

5. Salts, their composition, classification, nomenclature. Chemical properties of salts and methods of preparation.

6. Coordination compounds (complexes). Coordinate covalent bond. Dissociation of the coordination compounds in water solutions.

7. Hydrogen. Hydrogen isotopes. Physical and chemical properties of hydrogen. Basic hydrogen-containing compounds. The reaction between hydrogen and oxygen. Laboratory methods of preparation and industrial production of hydrogen.

8. Oxygen. Allotropy of oxygen. Physical and chemical properties of oxygen. The most important redox processes involving oxygen. Air. Laboratory methods of preparation and industrial production of oxygen.

9. Water. The structure of the molecule. Physical properties of water. The role of hydrogen bonds. Aggregate state of water. "Heavy water". Crystalline hydrate. Chemical properties of water. Hydrogen peroxide.

10. The halogens. Tendency of physical and chemical properties changes. Hydrogen halides and their salts. Chlorine, its chemical properties, oxygen-containing chlorine compounds. Preparation of halogens and hydrogen halides.

11. Elements of the oxygen group (XVI group), characterization of the elements. Hydrogen sulfide, sulfides, sulfur oxides, preparation and properties of these compounds. Chemical properties of sulfuric and sulfurous acids and their salts. Production of sulfuric acid in industry.

12. Elements of the nitrogen group (XV group). Characterization of the elements, tendency of physical and chemical properties changes. Nitrogen. Ammonia and ammonium salts. Nitrides. Nitrogen oxides. Chemical properties of nitric and nitrous acids. Nitrates and their properties. Production of nitric acid and ammonia in industry. Phosphorus, its allotropic modifications and chemical properties. Phosphine, phosphides. Phosphorus oxides. Phosphoric acids and their salts.

13. Elements of the carbon group (XIV group). Trends in physical and chemical properties. Allotropes of carbon. Chemical properties of carbon. Carbides. Oxides of carbon, carbonic acid and its salts. Silicon and natural compounds, which contain silicon. Chemical properties of silicon. Silane, silicides. Silicic acids and their salts.

14. Metals. Position of metals in the Periodic table. Changes of metallic properties within periods and groups. Physical and chemical properties of metals. Alloys. Galvanic cell. Electrochemical series of metals. Metal corrosion. Production of metals.

15. Alkali metals (I group). Chemical properties of alkali metals. Compounds of alkali metals. Production of metallic sodium and potassium.

16. Characterization of the elements of II group of the Periodic table. Chemical properties of the elements. Chemical properties of the compounds which contains second group metals.

17. Elements of III group of the Periodic table. Aluminum, its chemical properties and the properties of its compounds. Coordination compounds of aluminum. Aluminosilicates. Production of aluminum in the industry.

18. Transition metals. The position in the Periodic table of transition metals. Electronic structure of transition metals. Iron, its chemical properties and properties of iron-based compounds. Chromium, manganese, the properties of their compounds with various oxidation states. Characterization of copper, zinc, silver and their compounds.

19. Noble gases, their chemical compounds.

III. ORGANIC CHEMISTRY

The characterization of each class of organic compounds should include the features of molecular and electronic structure, nomenclature, types of isomerism, trends in physical and chemical properties in the homologous series, the main types of chemical reactions, their mechanism and conditions, preparation methods.

1. The theory of the chemical structure of organic compounds The reasons for the diversity of organic compounds. Chemical bonding in organic compounds. Structural formulas. Types of isomerism. Homological series. Nomenclature.

2. Electronic structure of organic molecules. Types of hybridization, σ-and π-bonds. Electronic effects of substituents (inductive and mesomeric) and their influence on chemical reactions of organic compounds. Types of chemical reactions and their mechanism. Carbocations. Classes of organic compounds and relation between the classes.

3. Alkanes (paraffins) and cycloalkanes. Structure, nomenclature, isomerism. Chemical properties.

4. Alkenes. Structure, nomenclature, isomerism. Chemical properties. Markovnikov’s rule. Features of the chemical properties of conjugated dienes.

5. Alkynes. Structure, nomenclature, isomerism. Chemical properties. Kucherov's reaction.

6. Aromatic hydrocarbons. Features electronic structure. Chemical properties of benzene and its homologues. Types of reactions. Ortho/para directors.

7. Application and preparation of hydrocarbons of various classes. Oil, gas and coal as natural sources of hydrocarbons. Gas processing, oil refining,

8. Alcohols (primary, secondary, tertiary). Structure, nomenclature, physical and chemical properties of saturated monoatomic alcohols. Methods of preparation of alcohols. Industrial production of ethanol. Special properties of polyatomic alcohols (glycerin, ethylene glycol). Phenol and its homologs. Structure and chemical properties. Ethers.

9. Aldehydes and ketones. Structure and nomenclature. Physical and chemical properties. Preparation and use of formic and acetic aldehydes.

10. Carboxylic acids. Structure, nomenclature. Saturated, unsaturated and aromatic acids. Physical and chemical properties of saturated monobasic acids. Characterization of some organic acids. Preparation of carboxylic acids.

11. Esters. Structure, nomenclature and chemical properties. Esterification and hydrolysis reactions. Triglycerides, saponification and soaps.

12. Carbohydrates. Structure, physical and chemical properties of monosaccharides. Polysaccharides (starch and cellulose).

13. Aliphatic and aromatic amines. Primary, secondary and tertiary amines. Chemical properties of amines. Basic properties of amines. Aniline, its salts. Zinin reaction.

14. Nitrogen-containing heterocycles. Pyrimidine and purine bases. Nucleic acids (DNA, RNA), their composition, structure and biological role.

15. Amino acids. Structure, isomerism, nomenclature. Chemical properties of amino acids and their role in the processes of vital functions. Preparations of amino acids. Peptide bond. Structure and properties of proteins.

16. High molecular weight (HMW) compounds. Polymerization and polycondensation reactions. Monomers, polymers, degree of polymerization. Features of structures and properties of various types of HMW compounds.

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3. Inorganic Chemistry. C. E. Housecroft, A. G. Sharpe, Second edition 2005.
4. Modern Inorganic Chemistry: An Intermediate Text. C. Chambers, A. K. Holliday, 1975.
5. Essential Organic Chemistry. Paula Y. Bruice, Second Edition, 2014.
6. Essentials of Inorganic Chemistry For Students of Pharmacy, Pharmaceutical Sciences and Medicinal Chemistry. Katja A. Strohfeldt, 2015.
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8. P. W. Atkins, Julio De Paula. Physical Chemistry , Oxford University Press, 2006
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12. Carey F.A. Advanced organic chemistry 5ed., MGH, 2004