

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
FEDERAL STATE AUTONOMOUS EDUCATIONAL INSTITUTION OF HIGHER
EDUCATION

"Kazan (Volga Region) Federal University"
A.M. Butlerov Chemistry Institute.

I approve

Vice-Rector for Education



T.B. Alishev

2021 г.

**ENTRANCE TEST PROGRAM
IN CHEMISTRY**

2021

Sheet approval of the program of entrance tests

Program developers: Prof. Shaidarova L.G.

Chairman of the Examination Commission  M.S. Bukharov
(signature)

The program was discussed and recommended for admission tests in 2022 at a meeting of the examination committee for admission tests for bachelors' (specialists') programs in chemistry

(date, protocol number)

Prologue

Chemistry program for entering the Chemical Institute. A.M. Butlerov of Kazan (Volga Region) Federal University consists of two sections. The first section presents the basic theoretical concepts of chemistry that an applicant must have in order to be able to substantiate the chemical and physical properties of the substances listed in the second section, devoted to elements and their compounds. Exam duration 3 hours. At the exam, you can use micro-calculators and reference tables, such as "Periodic system of chemical elements", "Solubility of bases, acids and salts in water", "A number of standard electrode potentials".

Content of the program

Part I. Basics of Theoretical Chemistry

The subject of chemistry. The place of chemistry in natural science. Mass and energy. Basic concepts of chemistry. Substance. Molecule. Atom. Electron. And he. Chemical element. Chemical formula. Relative atomic and molecular weight. Molar mass.

Chemical transformations. The law of conservation of mass and energy. The law of constancy of the composition. Stoichiometry.

The structure of the atom. Atomic nucleus. Isotopes. Stable and unstable kernels. Radioactive transformations, nuclear fission and nuclear fusion. The equation of radioactive decay. Half-life.

The dual nature of the electron. The structure of the electron shells of atoms. Quantum numbers. Atomic orbitals. Electronic configurations of atoms in the ground and excited states, the Pauli principle, the Hund rule.

Periodic law of Mendeleev and its justification from the point of view of the electronic structure of atoms. Periodic system of elements.

Chemical bond Types of chemical bonds: covalent, ionic, metallic, hydrogen. The mechanisms of covalent bond formation: exchange and donor-acceptor. Bond energy Ionization potential, electron affinity, electronegativity. Bond polarity, inductive effect. Multiple links. Orbitals hybridization model. The relationship of the electronic structure of molecules with their geometric structure (for example, compounds of elements of the 2nd period). Delocalization of electrons in conjugated systems, mesomeric effect. The concept of molecular orbitals.

Valence and degree of oxidation. Structural formulas. Isomerism Types of isomerism, structural and spatial isomerism.

Aggregate states of matter and transitions between them depending on temperature and pressure. Gases. Gas laws. Clayperon-Mendeleev equation. Avogadro's law, molar volume. Fluids. Association of molecules in liquids. Solid bodies The main types of crystal lattices: cubic and hexagonal.

Classification and nomenclature of chemicals. Individual substances, mixtures, solutions. Simple substances, allotropy. Metals and non-metals. Complex substances. The main classes of inorganic substances: oxides, bases, acids, salts. Complex compounds. The main classes of organic substances: hydrocarbons, halogen-, oxygen- and nitrogen-containing substances. Carbo and heterocycles. Polymers and macromolecules.

Chemical reactions and their classification. Types of rupture of chemical bonds. Homo - and heterolytic reactions. Redox Reactions.

Thermal effects of chemical reactions. Thermochemical equations. The heat of formation of chemical compounds. Hess law and its consequences.

The rate of chemical reaction. The concept of the mechanisms of chemical reactions. Elementary stage of the reaction. Homogeneous and heterogeneous reactions. The dependence of the rate of homogeneous reactions on the concentration (the law of mass action). The rate constant of a chemical reaction, its dependence on temperature. Activation energy

The phenomenon of catalysis. Catalysts. Examples of catalytic processes. The concept of the mechanisms of homogeneous and heterogeneous catalysis.

Reversible reactions. Chemical equilibrium. Equilibrium constant, degree of conversion. Displacement of chemical equilibrium under the action of temperature and pressure (concentration). The principle of Le Chatelier.

Disperse systems. Colloidal systems. Solutions. The mechanism of formation of solutions. Solubility of substances and its dependence on temperature and the nature of the solvent. Ways of expressing the concentration of solutions: mass fraction, mole fraction, molar concentration, volume fraction. The difference between the physical properties of the solution and the properties of the solvent. Solid solutions. Alloys.

Electrolytes. Electrolyte solutions. Electrolytic dissociation of acids, bases and salts. Acid-base interactions in solutions. Proton acids, Lewis acids. Amphoteric. Dissociation constant. The degree of dissociation. Ionic product of water. Hydrogen indicator. Hydrolysis of salts. The balance between ions in solution and solid phase. Solubility product. Formation of the simplest complexes in solutions. Coordination number. The stability constant of the complexes. Ionic reaction equations.

Redox reactions in solutions. Determination of stoichiometric coefficients in the equations of redox reactions. Standard potentials of redox reactions. A number of standard electrode potentials. Electrolysis of solutions and melts. The Faraday laws of electrolysis.

Part II. Elements and their compounds. Inorganic chemistry

Applicants must, on the basis of the Periodic Law, give a comparative description of the elements in groups and periods. The characteristics of the elements include: electron configurations of the atom; possible valencies and degrees of oxidation of an element in compounds; forms of simple substances and the main types of compounds, their physical and chemical properties, laboratory and industrial methods of production; the prevalence of the element and its compounds in nature, the practical significance and scope of the compounds. When describing chemical properties, reactions involving inorganic and organic compounds (acid-base and redox transformations), as well as qualitative reactions, should be reflected.

Hydrogen. Hydrogen isotopes. Hydrogen compounds with metals and non-metals. Water. Hydrogen peroxide.

Halogens Hydrogen halides. Halogenides. Oxygenated chlorine compounds.

Oxygen. Oxides and peroxides. Ozone.

Sulfur. Hydrogen sulfide, sulfides, polysulfides. Sulfur oxides (IV) and (VI). Sulfuric acid and sulfuric acid and their salts. Esters of sulfuric acid. Sodium thiosulfate. Nitrogen. Ammonia, ammonium salts, metal amides, nitrides. Nitrogen oxides. Nitrous and nitric acids and their salts. Esters of nitric acid. Phosphorus. Phosphine, phosphides. Phosphorus (III) and (V) oxides. Phosphorus halides. Ortho-, meta- and diphosphoric acid. Orthophosphates. Esters of phosphoric acid. Carbon. Carbon isotopes. The simplest hydrocarbons: methane, ethylene, acetylene. Calcium, aluminum and iron carbides. Oxides of carbon (II) and (IV). Transition metal carbonyls. Carbonic acid and its salts. Silicon. Silane Magnesium silicide. Silicon oxide (IV). Silicic acids, silicates. Boron. Boron trifluoride. Ortho and tetraboric acids. Sodium tetraborate. Noble gases. Examples of compounds of krypton and xenon. Alkali metals. Oxides, peroxides, hydroxides and alkali metal salts. Alkaline earth metals, beryllium, magnesium: their oxides, hydroxides and salts. The concept of organomagnesium compounds (Grignard reagent). Aluminum. Oxide, hydroxide and aluminum salts. Complex aluminum compounds. Concepts of aluminosilicates. Copper, silver. Copper (I) and (II) oxides, silver (I) oxide. Copper (II) hydroxide. Silver and copper salts. Complex compounds of silver and copper. Zinc, mercury. Zinc oxides and mercury. Zinc hydroxide and its salts. Chromium. Chromium (II), (III) and (VI) oxides. Hydroxides and salts of chromium (II) and (III). Chromates and dichromates (VI). Complex compounds of chromium (III). Manganese. Manganese (II) and (IV) oxides. Hydroxide and salts of manganese (II). Manganate and potassium permanganate. Iron, cobalt, nickel. Oxides of iron (II), (II) - (III) and (III). Hydroxides and salts of iron (II) and (III). Ferrates (III) and (VI). Complex iron compounds. Salts and complex compounds of cobalt (II) and nickel (II).

Organic chemistry

The characteristics of each class of organic compounds include: features of the electronic and spatial structure of compounds of this class, patterns of changes in the physical and chemical properties in the homologous series, the nomenclature, types of isomerism, the main types of chemical reactions and their mechanisms. Characteristics of specific compounds include physical and chemical properties, laboratory and industrial production methods, applications. When describing chemical properties, it is necessary to take into account reactions involving both the radical and the functional group.

Structural theory as the basis of organic chemistry. Carbon skeleton. Functional group Homological series. Isomerism: structural and spatial. The concept of optical isomerism. Mutual influence of atoms in a molecule. Classification of organic reactions by the mechanism and charge of active particles.

Alkanes and cycloalkanes. Conformers.

Alkenes and cycloalkenes. Conjugated dienes.

Alkynes. Acid properties of alkynes.

Aromatic hydrocarbons (arenas). Benzene and its homologs. Styrene. Reactions of the aromatic system and the hydrocarbon radical. The orienting action of substituents in the benzene ring (orienters of the first and second kinds). The concept of condensed aromatic hydrocarbons.

Halogen derivatives of hydrocarbons: alkyl, aryl, and vinyl halides. Substitution and removal reactions.

Simple and polyatomic alcohols. Primary, secondary and tertiary alcohols. Phenols. Ethers.

Carbonyl compounds: aldehydes and ketones. Limit, unsaturated and aromatic aldehydes. Concept of keto-enol tautomerism.

Carboxylic acids. Limit, unsaturated and aromatic acids. Mono - and dicarboxylic acids. Carboxylic acid derivatives: salts, anhydrides, acid halides, esters, amides. Fat Nitro compounds: nitromethane, nitrobenzene.

Amines. Aliphatic and aromatic amines. Primary, secondary and tertiary amines. The basicity of amines. Quaternary ammonium salts and bases.

Halogenated acids. Hydroxy acids: lactic, tartaric and salicylic acids. Amino acids: glycine, alanine, cysteine, serine, phenylalanine, tyrosine, lysine, glutamic acid. Peptides. The concept of the structure of proteins.

Carbohydrates. Monosaccharides: ribose, deoxyribose, glucose, fructose. Cyclic forms of monosaccharides. The concept of spatial isomers of carbohydrates. Disaccharides: cellobiose, maltose, sucrose. Polysaccharides: starch, cellulose.

Pyrrol. Pyridine. Pyrimidine and purine bases that are part of nucleic acids. The concept of the structure of nucleic acids.

Polymerization and polycondensation reactions. Some types of high-molecular compounds: polyethylene, polypropylene, polystyrene, polyvinyl chloride, polytetrafluoroethylene, rubbers, copolymers, phenol-formaldehyde resins, artificial and synthetic fibers.

Recommended Literature

In Russian:

1. Kuzmenko N.E., Eremin V.V., Popkov V.A. Beginning chemistry. Modern course for entering universities. - M.: Exam, 1998-2017.
2. Kuzmenko N.E., Eremin V.V., Popkov V.A. Chemistry for high school students and entering universities. - M.: Drofa, 1995-2000; Peace and education, 2004-2008.
3. Kuzmenko N.E., Eremin V.V. 2500 tasks in chemistry for schoolchildren and applicants. - Moscow: Peace and Education, 2004-2007.
4. Chemistry. Formulas for success in entrance exams, Ed. N.E. Kuzmenko and V.I. Terenin. - M.: Publishing House of the Moscow University, 2006.
5. Chemistry: Reference materials / Ed. Yu.D. Tretyakov. - M.: Astrel, 2002.

6. Eremina E.A., Ryzhova ON Quick guide to chemistry for schoolchildren. - M.: Peace and Education, 2002-2012.
7. Chemistry. Great reference for students and entering universities. - M.: Drofa, 1999-2004.
8. Kuzmenko N.E., Eremin V.V., Churanov S.S. Collection of competitive problems in chemistry. - M.: Exam, 2001, 2002, 2006.
9. Eremin V.V., Drozdov A.A., Kuzmenko N.E., Lunin V.V. Chemistry textbook for 8-9 grades of secondary schools. - Moscow: Peace and Education, 2004-2006.

In English:

1. Chemistry 9th Edition by Steven S. Zumdahl (Author), Susan A. Zumdahl
2. Foundations of College Chemistry by Morris Hein, Susan Arena
3. Fundamentals of General, Organic, and Biological Chemistry by McMurry J., Castellion M., Ballantine D.