TOPICS FOR ENTRANCE EXAMS IN CHEMISTRY - 2022

Form of exam: online test Time: 210 minutes. (3.5 hours)

All test variants have the same structure: the work consists of two parts in total consisting of 34 questions. Part 1 includes 28 questions implying a short answer. 20 simple questions (Questions No.1-5, 9-13. 16-21, 25-28) Part 2 includes 5 advanced questions implying a detailed answer. (Questions No. 29-34).

How are the tasks assessed?

For the correct answer to questions No. **1-5, 9-13, 16-21, 25-28**, student receives **1**

point Answer is considered correct if the sequence of digits or a number is written correctly. Answer to questions No. **6-8, 14, 15, 22-24** is considered correct if the sequence of digits is specified correctly. For correct answers to questions **6-8, 14, 15, 22-24**, student receives**2** points; if one mistake is made, students receives **1** point; incorrect answer (more than one mistake) is **0** points. The answers to the Part 2 are checked by the subject committee

In Part 2 questions, from 2 to 5 elements of the answer are checked by the committee. These questions can be answered in a different way. The presence of each required element of the answer is worth **1** point, so the maximum score of the correctly completed tasks is from **1** to **5** points depending on the degree of difficulty: for questions 29 and 30, you can get **2** points; for questions **31** and **33** – **4** points; for question **32** – **5** points; for question **34 – 3** points.

The following materials are attached to each version of the examination paper: - Mendeleev Table - table of solubility of salts, acids and bases in water; - electrochemical series. During the test, it is allowed to use a non-programmable calculator.

**TOPICS**

1. Basic concepts of chemistry.

Atoms and molecules. Chemical element, simple substance, complex substance, mixture of substances. The concept of allotropic modifications. Relative atomic mass, relative molecular mass. Constancy of substance composition. Law of conservation of mass. Mole as a unit of quantity of a substance. Molar mass. Avogadro's law and its consequences. Physical and chemical phenomena. Valence and degree of oxidation.

1. Structure of substance

Structure of nuclei and electron shells of atoms of chemical elements. s-, p-, d- elements. Periodic law and the structure of the periodic system. Isotopes. Types of chemical bonds: covalent (polar and non-polar), ionic, hydrogen, metallic. Electronegativity of chemical elements. Aggregate states of substances, amorphous and crystalline substances. Molecular and non-molecular substances. Types of crystal lattices.

1. Main patterns of chemical reactions

Classification of reactions: compounds, decomposition, substitution, exchange. Redox reactions, the most important oxidants and reducing agents. Electrolysis with inert electrodes of molten salts, oxides, and salt solutions. Rate of chemical reactions and its dependence on various factors. Catalysis. Thermal effects of chemical reactions. Exo- and endothermic reactions. Reversibility of reactions. Chemical equilibrium and conditions of its displacement (Le Chatelier principles).

1. Solutions

Solubility of substances, dependence of the solubility on the type of substance, temperature and pressure. Types of solutions (gaseous, liquid, solid). Composition of the solution (mass fraction, volume fraction, molar concentration). Value of solutions in medicine and biology, in everyday life. Electrolytic dissociation. Degree of dissociation. Strong and weak electrolytes. Ionic equations of reactions.

1. Main classes of inorganic compounds

Oxides, acids, bases, salts (classification, nomenclature, methods of preparation and properties). Ionic hydrolysis: hydrolysis by cation (salts of aluminum, iron, chromium, copper, zinc, ammonium, etc.); hydrolysis by anion (sulfites, sulfides, carbonates, phosphates, acetates, silicates, etc.). Complete hydrolysis (aluminum sulfide). Amphotericity: compounds of beryllium, zinc, germanium, tin, lead, aluminum, chromium(III). Formation of hydroxocomplexes.

1. Hydrogen and its compounds

Hydrogen and its physical properties. Chemical properties of hydrogen: interaction with metals and nonmetals; reduction of metals from oxides. Laboratory and industrial methods of hydrogen production. Use of hydrogen. Water. Structure of

molecule. Physical and chemical properties (interaction with metals under various conditions; electrolysis; formation of crystallohydrates). Hydrides. Interaction of hydrides with water. The composition of volatile hydrogen compounds with nonmetals (diborane, silane, phosphine, arsin, hydrogen selenium, hydrogen telluride).

1. Halogens and their compounds

General characteristics of the VIIA group of the periodic system. Chlorine, structure of the molecule, physical and chemical properties (reactions with metals and nonmetals; water; alkali solutions; metal bromides and iodides, with other complex substances with reducing properties). Laboratory and industrial methods of producing chlorine. Hydrogen chloride, structure of the molecule. Physical properties of hydrogen chloride. Chemical properties of hydrogen chloride and its aqueous solution (hydrochloric acid): interaction with metals, basic oxides, bases, salts, substances with oxidizing properties. Laboratory and industrial methods for producing hydrogen chloride. Comparison of hydrogen chloride with hydrogen fluoride, hydrogen bromide and hydrogen iodide. Qualitative reactions to halide ions. Oxygen-containing chlorine compounds: chlorine oxides, hypochlorous acid and its salts hypochlorites; hydrochloric acid and chlorites; chlorous acid and chlorates, chloric acid and perchlorates.

1. Elements of the VIA group

General characteristics of the VIA group of the periodic system. Oxygen, its physical properties. Chemical properties of oxygen: interaction with metals and nonmetals. Burning. Laboratory and industrial methods of oxygen production. Comparison of physical and chemical properties of oxygen and ozone. Chemical properties of hydrogen peroxide. Allotropic modifications of sulfur. Physical and chemical properties of sulfur (reactions with metals; with halogens, oxygen, phosphorus and carbon; relation to acids; disproportionation in alkali solution). Hydrogen sulfide, its physical properties. Chemical properties of hydrogen sulfide as a weak acid and reducing agent. Qualitative reaction to hydrogen sulfide and sulfide ions. Production of hydrogen sulfide. Sulfur oxides. Redox duality of sulfur oxide(IV) and sulfites. Sulfuric acid, its physical properties. Chemical properties of sulfuric acid as a strong acid and oxidizer. Features of the interaction of sulfuric acid with metals. Chemical bases for the production of sulfuric acid. Salts of sulfuric acid and their properties. Qualitative reaction to the sulfate ion.

1. Elements of the VA group

General characteristics of the VA group of the periodic system. Nitrogen, the structure of the molecule, physical properties. Chemical properties of nitrogen: interaction with metals and nonmetals. Ammonia and metal nitrides. The structure of the ammonia molecule. Physical properties of ammonia. Chemical properties of ammonia as a weak base and reducing agent. Chemical bases of ammonia production. Properties of ammonium salts (reactions with alkalis, decomposition reactions). Properties of nitric oxide(II): reaction with oxygen. Properties of nitric oxide(IV): dissolution in water in the presence of oxygen; disproportionation. Nitric acid, its physical properties. Chemical Properties

of nitric acid as a strong acid and oxidizer; decomposition of nitric acid. Interaction of nitric acid with metals. Chemical bases of nitric acid production. Thermal decomposition of nitrates. Qualitative reaction to the nitrate ion. Allotropic modifications of phosphorus. Physical and chemical properties of phosphorus: interaction with metals and nonmetals. Obtaining phosphorus. Phosphorus(V) oxide, its physical properties. Chemical properties of phosphorus oxide(V): interaction with water, bases and basic oxides, water-removing properties. Phosphoric acids (metaphosphoric, orthophosphoric, diphosphoric), their mutual transformations. Properties of orthophosphoric acid as a weak acid. Orthophosphates, hydroorthophosphates, dihydroorthophosphates. Qualitative reaction to the orthophosphate ion.

1. Elements of the IVA group

General characteristics of the IVA group of the periodic system. Carbon and its allotropic modifications: the structure of diamond and graphite. Physical properties of diamond and graphite. Chemical properties of carbon: interaction of a simple substance with metals and nonmetals, reduction of metals from their oxides. Hydrolysis of calcium carbide and aluminum carbide. Carbon oxides, structure of molecules, physical properties. Oxidative-reducing duality of carbon monoxide(II): reduction of metals from their oxides, oxidation by oxygen. Formation of carbon monoxide(II). Properties of carbon monoxide(IV): reactions with magnesium; carbon; calcium hypochlorite. Properties of carbonic acid and its salts. Mutual conversion of carbonates and hydrocarbonates. Decomposition of hydrocarbonates and insoluble carbonates. Qualitative reaction to the carbonate ion. Physical and chemical properties of silicon, silicon oxide(IV); silicic acid and silicates. Natural compounds of carbon and silicon. Application of carbon and silicon compounds.

1. General characteristics of metals

The position of metals in the periodic table. Physical properties of metals. Alloys. General methods of obtaining metals. Chemical properties of metals. Electrochemical series of metals. Corrosion of metals.

1. Properties of metals of IA and IIA groups

General characteristics of the IA and IIA groups of the periodic system. Natural compounds of sodium and potassium. Obtaining sodium and potassium. Chemical properties of alkali metals: reactions with hydrogen, oxygen, halogens, sulfur, water. Production of oxides and hydroxides of sodium and potassium. Reaction of sodium peroxide with carbon dioxide. Use of sodium and potassium compounds. Medical and biological significance of sodium and potassium compounds. Natural compounds of magnesium and calcium. Chemical properties of beryllium, magnesium and alkali-earth metals: reactions with oxygen, hydrogen, nitrogen, halogens, sulfur, water. Reduction of metals from their oxides with the help of magnesium and calcium. Properties of the IIA group metal compounds. Water hardness and ways to eliminate it. The use of magnesium and calcium compounds. The medical and biological significance of magnesium and calcium compounds.

1. Properties of aluminum

Natural aluminum compounds. Properties of a simple substance: reactions with oxygen, halogens, sulfur, carbon, alkalis and acids. Properties of aluminum oxide and hydroxide: relation to acids and alkalis. Formation of aluminates during fusion and hydroxocomplex in an aqueous medium. The use of aluminum and its compounds.

1. Properties of iron and some d-elements

Natural iron compounds. Properties of simple substance: reactions with oxygen, halogens, sulfur, water vapor; the ratio of iron to dilute and concentrated acid solutions. Rusting of iron. Properties of oxides and hydroxides of iron (II), (III) in comparison. Oxidation of iron(II) compounds with oxygen, hydrogen peroxide, etc. oxidizing agents. Qualitative reactions to Fe2+ and Fe3+ ions (with potassium hexacyanoferrates, potassium rhodanide). The medical and biological significance of iron compounds. Properties of chromium, copper, zinc and their compounds.

1. Introduction to Organic Chemistry

Theory of the structure of organic compounds (A.M. Butlerov), its development. Isomerism: structural and spatial (geometric and optical). Homological series. Electronic nature of chemical bonds in molecules of organic compounds. Types of hybridization of electronic orbitals of the carbon atom: sp3-; sp2-; sp. Principles of nomenclature of organic compounds. Types of reactions: substitution, addition, cleavage (elimination), isomerization. Mechanisms of reactions in organic chemistry. Homolytic and heterolytic break of covalent bond. Free radical and ionic reactions. Nucleophiles and electrophiles. Mutual influence of atoms in organic matter molecules: inductive and mesomeric effects.

1. Alkanes

Classification of hydrocarbons. Natural sources of hydrocarbons. Homologous series of alkanes (names of alkanes and radicals C1-C10; isopropyl). General formula of alkanes. Electronic structure of the methane molecule. Production of alkanes: hydrolysis of aluminum carbide, Wurtz synthesis, decarboxylation of carboxylic acid salts, hydrogenation of alkenes. Physical properties of alkanes. Chemical properties of alkanes: free radical substitution, dehydrogenation, dehydrocyclization (aromatization), cracking (pyrolysis), isomerization, nitration. The mechanism of radical substitution reactions: example of methane and propane. Oxidation of alkanes: catalytic oxidation (formation of methanol and formaldehyde from methane), burning. The use of alkanes. Conversion of methane.

1. Unsaturated hydrocarbons

Homological series of alkenes. The general formula of alkenes. Electronic structure of the ethylene molecule: p-bond; double bond. Methods for obtaining alkenes: dehydration of alcohols; dehydrohalogenation of haloalkanes (Zaitsev's rule); dehalogenation of dihaloalkanes; dehydrogenation of alkanes. Physical properties of alkenes. Chemical

properties of alkenes: addition of halogens, hydrogen halides, water (hydration). Mechanism of electrophilic addition reactions. Markovnikov's rule. The addition of hydrogen. Oxidation of alkenes by potassium permanganate in a neutral medium (formation of diols) and in an acidic medium. Formation of ethylene oxide, its interaction with water. Polymerization. Polyethylene and polypropylene. Homological series of alkynes. Electronic structure of the acetylene molecule: triple bond. Methods for the production of alkynes: dehydrohalogenation of dihaloalkanes; dehydrogenation of alkenes, interaction of acetylenides with haloalkanes. Production of acetylene from methane and from calcium carbide. Physical properties of alkynes. Chemical properties of alkynes: electrophilic addition reactions. Features of hydration of acetylene and its homologues. Hydrogenation of alkynes, interaction of alkynes with bases (ammonia solution of silver oxide, sodium amide), oxidation of alkynes. Properties of acetylene: oxidation with potassium permanganate in a neutral medium; dimerization and trimerization. Alkadienes. Types of alkadienes (conjugated, isolated and cumulated double bonds). Production of butadiene from ethanol and butane; production of isoprene. Preparation of alkadienes by dehydrohalogenation of dihaloalkanes. Physical properties of alkadiens. Chemical properties of alkenes: 1,2– and 1,4- addition; polymerization. Natural and synthetic rubbers. The use of unsaturated hydrocarbons.

1. Cyclic hydrocarbons

Varieties of carbocyclic hydrocarbons: saturated (cycloalkanes), unsaturated (cycloalkenes and cycloalkadienes), aromatic (arenes). Structure of cycloalkanes. Methods for the production of cycloalkanes: hydrogenation of benzene, dehalogenation of dihalogen derivatives, pyrolysis of dicarboxylic acid salts. Chemical properties of small (C3–C4) cycles: addition of hydrogen, halogens, hydrogen halides; and normal (C5– C6) cycles: free radical substitution reactions: halogenation, nitration. Aromatic hydrocarbons (arenas). Electronic structure of the benzene molecule. Benzene homologues (toluene, xylenes, ethylbenzene, cumene). Methods for obtaining benzene and its homologues: dehydrogenation of cycloalkanes, dehydrocyclization of alkanes, alkylation of benzene with alkenes and haloalkanes; modification of Wurtz synthesis, trimerization of acetylene. Physical properties of aromatic hydrocarbons. Chemical properties of aromatic hydrocarbons: electrophilic substitution reactions (halogenation, nitration), addition reactions (hydrogenation, chlorination). Mechanism of electrophilic substitution reactions. Orienting action of substituents in the benzene ring: orientants I (alkyl, halogen, –NH2,–OH) and II kind (−CF3, –NO2, −CH=O, – COOH). Features of reactions of benzene homologues: substitution reactions by alkyl substituent, oxidation by potassium permanganate (formation of benzoic and terephthalic acids)

1. Alcohols and esters

Functional group of alcohols. Classification of alcohols by the number of hydroxyl groups: monatomic, diatomic (ethylene glycol, etc.), triatomic (glycerin, etc.), polyatomic (sorbitol, etc.). Classification of alcohols by the nature of hydrocarbon radicals: marginal (homologous series of methanol), aromatic (benzyl alcohol

etc.). Enols and keto-enol tautomerism. Alcohols: primary, secondary, tertiary. Methods for producing alcohols: hydrolysis of halogenalkanes, hydration of alkenes, reduction of aldehydes and ketones, oxidation of alkenes (formation of glycols), fermentation of glucose and from halogenalkanes. Production of ethanol by fermentation of glucose. Production of methanol from carbon(II) oxide and hydrogen. Electronic structure of alcohol molecules. Formation of a hydrogen bond. Physical properties of alcohols. Chemical properties of alcohols. Acidic properties of alcohols: interaction with alkali metals; hydrolysis of alcoholates. Nucleophilic substitution: interaction with hydrogen halides (reaction mechanism). Intramolecular and intermolecular dehydration. Formation of esters with organic and inorganic acids. Hydrogenation of alcohols. Comparison of the action of oxidants on primary, secondary and tertiary alcohols. Dehydration reaction–ethanol dehydrogenation (production of butadiene). Chemical properties of polyatomic alcohols (ethylene glycol, glycerin): complexation (with copper(II) hydroxide); formation of glycerin trinitrate. Use of alcohols. Structure of simple ethers. Preparation of esters: intermolecular dehydration of alcohols, interaction of alcoholates with halogenalkanes.

1. Phenols

Structure of monatomic (phenol, cresol) and polyatomic (pyrocatechin, resorcinol, hydroquinone, pyrogallol) phenols. The electronic structure of the phenol molecule. Production of phenol (from chlorobenzene). Physical properties of phenol. Chemical properties of phenol. Acidic properties of phenol: interaction with alkali metals and alkalis; interaction of phenolates with acids, with carbon dioxide in one solution. Electrophilic substitution reactions: bromination and nitration. Hydrogenation of the aromatic ring. Polycondensation of phenol with aldehydes. Qualitative reaction to phenols with iron(III) chloride.

1. Aldehydes and ketones

Electronic structure of the carbonyl group. Homological series of aldehydes and ketones. Benzaldehyde. Methods for the production of aldehydes: oxidation (dehydrogenation) of primary alcohols, hydration of acetylene, catalytic oxidation of ethylene. Methods for producing ketones: oxidation (dehydrogenation) of secondary alcohols, hydration of acetylene homologues, pyrolysis of calcium salts of carboxylic acids. Physical properties of aldehydes and ketones. Chemical properties of aldehydes: reduction to alcohols, oxidation to acids or acid salts: "silver mirror" reaction, with copper(II) hydroxide when heated. Halogenation of aldehydes and ketones. Mechanism of nucleophilic addition reactions: addition of water, prussic acid, sodium hydrosulfite, organomagnesium compounds. Use of aldehydes and ketones.

1. Carboxylic acids and their functional derivatives

Electronic structure of the carboxyl group. Structure of carboxylic acids: homologous series of formic acid (trivial names of acids C1- C7); dibasic acids (oxalic, malonic, succinic), acrylic, methacrylic,

croton, vinylacetic, citric, lactic, gluconic, benzoic, terephthalic, salicylic, acetylsalicylic acids. Methods for producing carboxylic acids: oxidation of primary alcohols and aldehydes, hydrolysis of carboxylic acid derivatives, interaction of carbon monoxide (IV) with organomagnesium compounds, oxidation of benzene homologues (for aromatic acids). Production of formic acid by the interaction of carbon monoxide (II) with sodium hydroxide and subsequent treatment with sulfuric acid. Production of acetic acid by the interaction of methanol with carbon(II) oxide. Physical properties of the most important acids. Chemical properties of carboxylic acids (example of acetic acid). Common reactions characteristic of acids: with metals, basic oxides, bases, salts of weaker acids. Esterification reaction. Reactions of carboxylic acids with phosphorus(III) chloride and thionyl chloride. Acid reactions by hydrocarbon radical: addition for unsaturated acids; substitution for saturated acids (formation of chlorinated carboxylic acids). Structure of functional derivatives of carboxylic acids: anhydrides, chlorohydrides, amides, esters. Nomenclature of esters (names of acid residues: formate, acetate, propionate). Hydrolysis of esters. Production of anhydrides by the interaction of carboxylic acid salts with chlorohydrides, preparation of esters by the interaction of alcohols with chlorohydrides and anhydrides. Production of amides and nitriles by the action of ammonia on carboxylic acids with subsequent hydration. Hydrolysis of nitriles. Use of carboxylic acids, their salts and esters.

1. Fats

Structure of fats. Acids, the residues of which are part of fats: palmitic, stearic, oleic, linoleic, linolenic. Physical properties of fats. Alkaline and acid hydrolysis of fats. Hydrogenation of fats containing unsaturated acid residues. Transformation of fats in the body. Use of fats. synthetic detergents.

1. Carbohydrates

Structure of monosaccharides (glucose, fructose, galactose, ribose, deoxyribose). Linear and cyclic (α- and –β) forms of glucose. Physical and chemical properties of glucose: oxidation [silver mirror reaction, with copper(II) hydroxide when heated], reduction, formation of a complex compound with copper(II) hydroxide. Fermentation reactions: alcoholic, lactic acid, butyric acid. Structure of disaccharides (sucrose, maltose, lactose). Hydrolysis of disaccharides. Structure of amylose and amylopectin (starch), dextrins, cellulose. Chemical properties of polysaccharides: hydrolysis; formation of cellulose esters (acetates, nitrates). Qualitative reaction to starch with iodine. Synthesis of glucose and starch in plants. Transformation of carbohydrates in the body. Use of carbohydrates.

1. Amines

Structure of amines. Classification of amines: primary, secondary and tertiary; aliphatic and aromatic. Quaternary ammonium salts. Methods for the production of amines: the interaction of halogenalkanes with ammonia (primary amines) or amines

(secondary, tertiary amines and tetraalkylammonium cations); reduction of nitro compounds (primary amines). Physical properties of amines. Chemical properties of amines: basicity of amines (reactions with acids; with salts of metals forming insoluble hydroxides). Dependence of the basicity of amines on their structure. Interaction of amine salts with alkalis. Nucleophilic substitution reactions: interaction of amines with esters, chlorohydrides, anhydrides (formation of amides). Features of chemical properties of aniline (reaction with bromine water). Burning of amines. Use of amines.

1. Amino acids

Proteins amino acids. General formula of amino acids. Nomenclature, isomerism of amino acids (α-, β-, γ-amino acids). Structure of amino acids: glycine, alanine, valine, glutamic acid, lysine, serine, cysteine, phenylalanine, tyrosine. Optical isomerism on the example of alanine. Methods for obtaining amino acids: interaction of α-chlorocarboxylic acids with ammonia; hydrolysis of proteins. Amphoteric properties of amino acids: interaction with acids and bases, formation of internal salt. Dependence of amino acid ionization on the nature of the medium. Formation of peptides. Peptide (amide) bond. Proteins as high-molecular substances. Primary, secondary and tertiary structure of proteins. Globular and fibrillar proteins. Hydrolysis and denaturation of proteins (reversible and irreversible). Color reactions of proteins: xanthoprotein, biuretic, with lead acetate. The role of proteins in vital activity. 28. Heterocyclic compounds. Nucleic acids Structure of pyridine and pyrrole (aromaticity). Physical properties of pyridine and pyrrole. Chemical properties of pyridine: basic properties, nitration, hydrogenation (formation of piperidine). Comparison of acid-base properties of pyrrole with properties of pyridine. Production of pyrrole potassium. Structure of pyrimidine and purine. The structure of nucleic bases (cytosine, uracil, thymine, adenine, guanine). Tautomerism of nucleic bases. Structure of nucleotides. Polynucleotides: the structure of DNA and RNA, the principle of complementarity. Role of polynucleotides in vital activity.

1. Heterocyclic compounds

Nucleic acids Structure of pyridine and pyrrole (aromaticity). Physical properties of pyridine and pyrrole. Chemical properties of pyridine: basic properties, nitration, hydrogenation (formation of piperidine). Comparison of acid-base properties of pyrrole with properties of pyridine. Production of pyrrole potassium. Structure of pyrimidine and purine. The structure of nucleic bases (cytosine, uracil, thymine, adenine, guanine). Tautomerism of nucleic bases. Structure of nucleotides. Polynucleotides: the structure of DNA and RNA, the principle of complementarity. Role of polynucleotides in vital activity.

1. Synthetic high-molecular substances

Basic concepts of high molecular weight compound chemistry: monomer, structural link, degree of polymerization, average relative molecular weight. Polymerization and copolymerization reactions; polycodensation (homopolycondensation and copolycondensation). Natural rubber. Synthetic rubbers: butadiene, divinyl, styrene butadiene,

chloroprene. Structure of the most important polymers: polyethylene, polypropylene, phenol-formaldehyde resin, polyvinyl chloride, teflon, polystyrene, polymethylmethacrylate, polyvinyl acetate. Synthetic fibers: dacron, enanthate, nylon, acetate fiber