

ENTRANCE EXAMINATION IN CHEMISTRY FOR APPLICANTS TO BACHELOR'S PROGRAMMES

Entrance test procedure

1. The entrance test is conducted in accordance with the current Rules for admission to the bachelor's and specialty programs and the MIPT entrance tests regulations.
2. The entrance examination in chemistry has written and oral parts.
3. The entrance examination consists of three parts.
4. The first two parts of the entrance test are tasks with numerical answer. The first part lasts 20 minutes, the second part lasts 40 minutes.
5. The first two parts and grading the applicants' works are followed by the oral part. The oral part of the entrance test includes:

- discussion of solutions in the written parts;
- an interview on the entrance examination topics.

This part lasts up to 30 minutes.

6. The final grade is formed from the grades received for each of the parts of the entrance test: 30% of the final grade is the grade for the oral part, 20% – for the first written part, 40% – for the second written part.
7. During the entrance test it's allowed to use „Mendeleev's Periodic Table of Elements“, „Solubility table of acids, bases and salts in water“ and „Electrochemical series of metals“. It is allowed to use a simple calculator for calculations.

General guidance

Applicants to MIPT are expected to know the basic theoretical principles of chemistry, the methods of preparing redox reactions, the main classes of inorganic and organic compounds, mathematical tools to describe chemical processes from the quantitative side, the basic concepts and laws of chemistry, they should also be able to characterize chemical compounds in terms of their acid-base and redox properties. The characteristics of each class of organic compounds contain the features of the electronic and spatial structure of compounds of this class, the patterns of changes in physical and chemical properties in the homologous series, the nomenclature, types of isomerism, the main types of chemical reactions and their mechanisms.

The written part of the entrance test includes theoretical tasks on the topics *The structure of the atom* and *Chemical bonds*. It also includes combined computational problems based on various sections of chemistry. Besides, it includes chains of transformations and reaction equations in inorganic and organic chemistry.

List of Topics

1. Basics of theoretical chemistry.

Goal and objectives of chemistry. The place of chemistry in natural sciences. Physical and chemical phenomena. Basic concepts of chemistry.

Law of stoichiometry (Avogadro's law, Proust's Law of Constant Proportion, Law of Conservation of Mass, Gay-Lussac's Law of Gaseous Volumes, Law of Multiple Proportions) Atomic Molecular Theory. Constitution of atom. Isotopes. Structure of atomic electron shells. Electron configuration.

Mendeleev's Periodical law and its support by the electronic structure of atoms. Periodic table of elements. Periodicity of atomic properties.

Chemical bond and its properties. Electronegativity. Types of chemical bonds.

Aggregation states of matter. Classification and nomenclature of chemical compounds. Main classes of inorganic compounds: oxides, hydroxides, salts. Synthesis and properties of oxides, hydroxides and salts

Chemical reactions and their classification.

Rate of chemical reactions. Law of mass action. Factors that affect rate of a chemical reaction. Catalysis and catalysts. Reversible and irreversible reactions. Chemical equilibrium. Shifting of chemical equilibrium. Le Chatelier's principle (equilibrium law)

Solutions. The different ways to represent concentrations in solution. Electrolytes. Solutions of electrolytes. Exchange reactions in solutions of electrolytes. Hydrolysis of salts. Ionic equilibrium between solution and solid state.

Redox reactions in solutions. Determination of stoichiometric coefficients in redox reactions. Electrolysis of electrolytes solutions and melts . Applications of electrolysis.

2. Inorganic chemistry

Halogens. General characteristic of chemical properties of halogens on the basis of their location in the Mendeleev's periodic table of elements. Hydrochloric acids and its salts. Oxygen-containing acids of chlorine and their salts.

Halogens. General characteristic of chemical properties of halogens on the basis of their location in the Mendeleev's periodic table of elements. Hydrochloric acids and its salts. Oxygen-containing acids of chlorine and their salts.

General characteristic of chemical properties of main group VI Mendeleev's periodic table of elements. Oxygen. Allotropy of oxygen. Sulfur. Physical and chemical properties of Sulfur. Hydrogen sulfide. Sulfur dioxide and trioxide. Sulfuric acid. Sulfates. Sulfurous acid and its salts.

General characteristic of chemical properties of main group V of Mendeleev's periodic table of elements. Nitrogen. Ammonia. Industrial production of ammonia. Physical and chemical properties of ammonia. Ammonium salts. Nitric acid. Chemical properties of nitric acids. Salts of nitric acid. Nitrous acid and its salts. Phosphorous. Allotropes of phosphorus. Phosphoric acid and its salts.

General characteristic of chemical properties of main group IV elements of Mendeleev's periodic table of elements. Carbon. Allotropes of carbon. Physical and chemical properties of carbon. Carbon (II) and carbon (IV) oxides and their salts. Carbonic acid and its salts.

Alkali and alkaline metals. General properties of alkali metals based on its location in the Mendeleev's periodic table of elements. Calcium. Water hardness and ways to remove it.

Aluminium. General properties of aluminium based on its location in the Mendeleev's periodic table of elements. Production, physical and chemical properties of aluminium. Amphoteric properties of aluminium oxide and aluminium hydroxide.

Iron. Physical and chemical properties of iron. Oxides and hydroxides of iron (II) and (III). Dependence of chemical properties of iron compounds on oxidation state of iron.

Selected fourth period d-elements of Mendeleev's periodic table of elements (chromium, manganese, copper, zinc). Interactions of zinc and chromium with acid and bases. Copper reaction with acids. Reactions of zinc and chromium hydroxides with bases and acids. Common oxidation states of chromium and manganese in their compounds. Chemical properties of fourth period d-block elements compounds.

3. Organic chemistry

The key points of the Butlerov's theory of chemical structure of organic compounds.

Classification of organic compounds based on structure: acyclic (alkanes, alkenes, alkynes, alkadienes), carbocyclic (cycloalkanes, arenes) and heterocyclic. Classification of organic compounds based on functional groups. Homologous series in organic compounds.

Chemical reactions in organic chemistry. Classification of organic reactions based on the mechanism of bond cleavage.

Chemical properties of alkanes. Halogenation reactions. Nitration of alkanes. Sulfochlorination. Combustion of alkanes at different conditions (Oxidation reactions). Dehydrogenation. Isomerisation and cracking.

Chemical properties of cycloalkanes: combustion, decomposition, radical substitution, isomerisation. Unique properties of cyclopropane and cyclobutane.

Chemical properties of alkenes: addition and oxidation reactions.

Chemical properties of alkadienes: electrophilic addition. Reaction of polymerization – production of synthetic rubber.

Chemical properties of alkynes. Trimerisation of acetylene to benzene. Oxidation reactions of alkynes.

Benzene as a typical arene. Homologs of benzene. Substitution reaction of benzene: halogenation, nitration, alkylation. Application of benzene and homologs.

Chemical nomenclature and classification of alcohols. Phenols. Chemical properties of hydroxy compounds. Reactions involving the O-H bond of alcohols: substitution of hydrogen by metal, substitution of hydrogen by carboxyl group (ester formation), removal of hydrogen by oxidation or dehydration. Oxidation of alcohols. Reactions involving the C-O bond of alcohols: substitution of hydroxyl group by nucleophiles, intermolecular dehydration, intramolecular dehydration (ether formation). Chemical properties of phenol (substitution in the aromatic ring): nitration, halogenation, condensation with aldehydes.

Chemical nomenclature of aldehydes and ketones. Typical reactions of carbonyl compounds: Addition to carbonyl groups, polymerization, condensation, reduction and oxidation.

Chemical nomenclature and classification of carboxylic acids. Isomerism of carboxylic acids. Electronic structure of carboxyl group. Chemical properties of carboxylic acids derivatives.

Chemical nomenclature and classification of amines. Isomerism of amines. Basicity of amines. Aromatic amines. Chemical properties of amines. Combustion of amines.

Amino acids. Chemical composition and structure of amino acids. Reaction of amino acids with bases. Reaction of amino acids with acids. Synthesis of amino acids esters.

Peptides as natural biopolymers. Peptide functional group and peptide bond. Chemical reactions representing interconnections of various classes of organic compounds (Interconversions of classes).

4. Typical calculation tasks in chemistry.

1. Calculate molecular mass of a compound with given molecular formula.
2. Calculate mass percent of elements in a compound with given molecular formula.
3. Calculate mass percent of solute in the solution with given mass and mass of solute.
solvent and solute from a known mass percent and mass of solution.
4. Calculate mass of solvent and solute from a known mass percent of solute and mass of solution.
5. Calculate mass of substance whose amount (in mole) is given.
6. Calculate amount of substance (in mole) whose mass is given.
7. Calculate molar concentration of solution, if mass of solute in certain amount of solution is known.
8. Calculate pH of a solution given concentration of acid or base.
9. Calculate relative density (specific gravity) of gas.

10. Calculate volume of a certain amount of a gaseous substance at STP (standard temperature and pressure).
11. Calculate mass of a given volume of a gaseous substance at STP (standard temperature and pressure).
12. Calculate volume of a given mass of a gaseous substance at STP (standard temperature and pressure).
13. Determine empirical formula of compound based on mass fractions of elements.
14. Calculate mass of the reaction product based on given masses of the starting materials, if one of them is taken in excess.
15. Calculate mass of the reaction product based on a given mass of one of the reacting substances.
16. Calculate volume of gas required to react with a certain volume of another gas.
17. Calculate actual percent yield of reaction based on theoretical yield.
18. Calculate mass (volume) of reaction product based on a given mass (volume) of starting material, containing certain amount of unreactive impurity.
19. Determine molecular formula of a gaseous substance if combustion products thereof are known.

Literature

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