LIST OF ENTRANCE EXAM QUESTIONS

FOR THE INTERNATIONAL MASTER'S DEGREE PROGRAM

ITMO

SUSTAINABLE CHEMISTRY FOR ENERGY TECHNOLOGIES

1. Periodic Law and periodic table of the chemical elements. The physical basis of the Periodic Law. The relationship of the position of an element in the periodic system with the electronic structure of its atom. The relationship of the properties of elements with their position in the periodic system.
2. Types of chemical bond. Covalent bond. Characteristics and properties of a covalent bond. Ionic bond. Ionic bond properties. Hydrogen bond. Types of hydrogen bond.
3. Chemical balance. Le Chatelier's principle of chemical processes (influence of external factors on the shift of chemical equilibrium). Methods for expressing the concentration of solutions. Redox reactions.
4. Electronic properties of molecules. The concept of hybridization of atomic orbitals, the main types of hybridization. Valence Bond method.
5. The first law of thermodynamics. Internal energy. Enthalpy. Hess's law.
6. Thermal effects: heats of formation, combustion, aggregate transformations, dissolution, etc. Calculation of thermal effects. Thermal effect of a chemical reaction. The dependence of the ther-mal effect of the reaction on temperature (Kirchhoff equation). Heat capacity.
7. Properties of solutions of weak electrolytes. The Arrhenius theory of electrolytic dissociation, its advantages and disadvantages. Colligative properties of electrolyte solutions. Effect of solvents on dissociation.
8. The second law of thermodynamics. Criteria for the direction of chemical processes in various systems and conditions.
9. Chemical kinetics. Classification of reactions in chemical kinetics. The rate of a chemical reaction.
10. The concept of colloidal systems and features of the colloidal state. The concept of the degree of dispersion. Classification of dispersed systems according to their state of aggregation. The structure of a colloidal particle. double electrical layer.
11. Adsorption processes at the phase boundary. Physical and chemical adsorption. Adsorbent and adsorbate. The concepts of absolute and excess adsorption. Theories of sorption. Adsorption isotherms. Variety of pores in diameter.
12. Electromagnetic radiation: the electromagnetic spectra, generation of electromagnetic radiation, properties and behavior (scattering, reflection and refraction). Forms of electromagnetic radiation.
13. Additive technologies: types, application, advantages, typical equipment, and its construction.
14. Nanotechnology. Methods for the synthesis of nanomaterials: differences, advantages, procedure. Differences between nanomaterials and bulk materials.

INSTRUCTIONS TO CANDIDATES

Section A consists of general chemistry and physical chemistry questions. Answer ALL questions in the section.

A. Amadeo Avogadro, Robert Boyle, and Jacques Charles studied the behaviors of gases at constant temperature (T) and pressure (P), constant T and number of moles (n), and constant P and n, respectively, to postulate their own laws. Express Avogadro's, Boyle's, and Charles's laws mathe-matically. **[6 marks]**

B. The abovementioned gas laws can be combined to give the ideal gas law.

i. derive the ideal gas law using Avogadro's, Boyle's, and Charles's equations. **[3 marks]**

ii. from your derivation, define R – the universal gas constant. **[3 marks]**

iii. given standard conditions, calculate R for an ideal gas. **[4 marks]**

C. Calculate the number of moles of H2 molecules present in 0.01 m3 of hydrogen gas at 273 K and 152 kPa. **[3 marks]**

D. A sample of methane gas that has a volume of 0.004 m3 at 278 K is heated to 359 K at constant pressure. What is the new volume? **[3 marks]**

E. An ammonia gas sample with a volume of 0.007 m3 at 170 kPa is compressed to 0.003 m3 at constant temperature. Using the ideal gas law derived above, determine the final pressure. **[3 marks]**