APPROVED
at a meeting of the Academic Council of NJSC «KazNU named after al-Farabi»
Protocol № 11 from 23.05.2025 y.

The program of the entrance exam for applicants to the PhD for the group of educational programs D108 «Nanomaterials and nanotechnology»

I. General provisions

1. The program was drawn up in accordance with the Order of the Minister of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 600 «On Approval of the Model Rules for Admission to Education in Educational Organizations Implementing Educational Programs of Higher and Postgraduate Education» (hereinafter referred to as the Model Rules).

2. The entrance exam for doctoral studies consists of writing an essay, an exam in the profile of a group of educational programs and an interview.

Блок	Баллы
1. Interview	30
2. Essay	20
3. Exam according to the profile of the group of the educational program	50
Total admission score	100/75

3.The duration of the entrance exam is 3 hours 10 minutes, during which the applicant writes an essay and answers the electronic examination ticket. The interview is conducted at the university premises before the entrance exam.

II. Procedure for the entrance examination

1. Applicants to the doctoral program group D108 «Nanomaterials and nanotechnology» write a problematic/thematic essay. The essay should be at least 250 words long.

The purpose of the essay is to determine the level of analytical and creative abilities, expressed in the ability to build one's own argumentation based on theoretical knowledge, social and personal experience.

Types of essay:

- motivational essay with disclosure of motives for research activities;

- a scientific analytical essay substantiating the relevance and methodology of the planned research;
- a problematic/thematic essay reflecting various aspects of scientific knowledge in the subject area.

2. The electronic examination ticket consists of 3 questions.

Topics for preparing for the exam in the profile of the educational program group:

The main technologies for obtaining nanomaterials

Classification of methods for obtaining nanomaterials. Technologies based on chemical processes. Technologies based on physical processes. The method of powder metallurgy. Surface technology. Methods of intensive plastic deformation. Complex synthesis methods. Synthesis of nanodisperse materials. Synthesis of nanostructured composites.

Methods of nanolayer synthesis.

Atomic and molecular epitaxy, molecular and chemical assembly, and molecular layering by the Langmuir-Blodgett method. Methods of synthesis of nanostructured materials: vacuum-plasma and chemical synthesis of fullerene-like materials, carbon nanotubes, multilayer nanocomposites. Sol-gel technology. Synthesis of polymers and polymer compositions.

Methods of carbon nanotube synthesis.

The arc method for producing carbon nanotubes. The method of laser ablation. Obtaining CNTs using the CVD method. Pyrolytic method of CNT synthesis. Synthesis of CNTs in a flame. Electrochemical synthesis of nanotubes. Formation of carbon nanotubes in flames. The effect of an electric field on the mechanisms of carbon nanotube synthesis in a flame.

Methods of synthesis of fullerenes.

Gas-phase synthesis. Synthesis in an arc discharge. Thermal catalytic decomposition of hydrocarbons. Pyrolytic method. Synthesis of heterofullerenes. Methods of obtaining endo- and exo-fullerenes. Synthesis of fullerenes in a flame. The effect of an electric field on the mechanisms of synthesis of fullerenes. Synthesis of fullerene-containing carbon black.

Synthesis of hydrophobic materials and coatings.

Types and classification of hydrophobic materials and coatings. Synthesis of soot with superhydrophobic properties in a flame. The mechanism of soot formation.

The effect of the electric field and catalysts on the properties of superhydrophobic carbon black.

Methods of obtaining nanopowders and nanofibers.

Mechanochemical synthesis of nanomaterials. Self-propagating high-temperature synthesis (SHS). Gas-phase synthesis. Plasmochemical synthesis. Formation of the carbon phase in the process of catalytic cracking of hydrocarbons. Methods of carbonation and carbonation of samples. Non-carbon nanotubes.

Production of nanoparticles.

Physical synthesis methods. Production using molecular beams. Plasma-chemical method. The evaporation-condensation method. The method of pulsed radiolysis. Chemical methods: recovery from solutions, sol-gel transition, cryotechnology. Synthesis in porous media, microemulsions and micelles. The structure and properties of clusters. Fractal and densely packed clusters. Types of chemical reactions involving clusters. The theoretical model of the cluster

Fundamentals of the process of obtaining nanoparticles in liquid media.

Features of the production of nanomaterials in liquid media. Nucleation and growth of nanoparticles. Homogeneous and heterogeneous nucleation. The effect of various system parameters on the nucleation rate and the kinetics of nanocrystal growth. The critical size of the embryo, depending on the system parameters. Kinetics of nanoparticle growth. Growth rate, the effect of supersaturation, and ionic equilibrium. Stabilization of nanoparticles.

Synthesis of nanoparticles by deposition methods.

The main chemical reactions leading to the synthesis of nanoparticles in liquid media and their controlled release from solutions. Production of gold nanoparticles. Synthesis of nanoparticles of silver, platinum, palladium and other precious metals. The methods of stabilization of nanoparticles in solutions are electrostatic, adsorption, and chemisorption. Kinetic control of nanoparticle growth. The main factors influencing the size of nanoparticles. Application of deposition methods for the synthesis of nanoparticles consisting of a metal alloy with a core-shell structure and multilayer structures. Synthesis of metal oxide nanoparticles and nanocomposites.

Modification of the surface of solids.

Features of the surface properties of solids of various chemical nature. The influence of the chemical state of the surface on the physical and chemical properties of solids. Methods of surface modification: physical (alloying, ion implantation, thin films and coatings) and chemical (modification of the functional cover) modification.

Mechanisms of formation of spherical and tubular nanoparticles.

The Sears dislocation model. Steam-liquid-crystal (PGK) is a Wagner-Elis mechanism. The carbide mechanism, the limiting stages. The quaternary model of particle formation. The magnetic mechanism of nanotube formation.

General characteristics and classification of methods.

The interaction of radiation with matter. Absorption, emission, scattering. Spectroscopic and diffraction methods. Energy characteristics of various spectroscopy methods. Sensitivity and resolution. The characteristic time of the method.

Research methods for nanoscale systems

General concepts of methods for studying the physical, chemical, and biological properties of nanosystems. Microscopic research methods. Basic principles, directions and objects of research. Resolution. Elements of optoelectronic devices. The basic principles of operation of electron microscopes are high-resolution transmission electron microscopy. Probe scanning microscopy (scanning, tunneling, atomic force, near-field optical). The principle of operation of probe microscopes. Scanning electron microscopy. Application of electron microscopy in nanotechnology. Additional features of probe microscopy: atomic manipulations and lithography.

Methods of vibrational spectroscopy. IR spectra and Raman scattering of light

Possibilities of IR spectroscopy and RAMAN methods, their application in chemistry. Selection rules and intensity in IR and Raman absorption. Frequencies and forms of normal vibrations of molecules. Accounting for the symmetry of the molecule. Analysis of normal vibrations of a molecule based on experimental data. Comparison of IR and RAMAN spectra and conclusions about the symmetry of molecules. Techniques and techniques of IR spectroscopy and RAMAN spectroscopy. IR spectroscopy equipment. Raman spectroscopy equipment, advantages of laser excitation sources. The KARS method. Comparison of IR and RAMAN spectroscopy methods, their advantages and disadvantages.

Methods of electron spectroscopy. UV spectroscopy

Emission UV spectroscopy as a method of studying diatomic molecules. Absorption spectroscopy in the visible region. Techniques and techniques of absorption spectroscopy in the visible and UV regions. The studied samples. The sensitivity of the method, its advantages and disadvantages.

Electronic paramagnetic resonance EPR method

The physical foundations of the phenomena of electron paramagnetic (spin) resonance and nuclear magnetic resonance (EPR and NMR). Spins and magnetic moments of nuclei and electrons. the g-factor and its significance. Anisotropy of the g-factor. Spin-orbit coupling. Removal of spin state degeneracy in a permanent magnetic field. The EPR condition. Energy level occupancy, saturation, relaxation processes, and signal width. The shape of the line. Hyperfine splitting of the EPR signal during the

interaction of an electron with one or more nuclei. Number of multiplet components, intensity distribution. Constants of STS. Flowchart of an EPR spectrometer, experimental features, advantages and limitations of the method.

The NMR method

The NMR condition. Relaxation processes. Chemical shift and spin-spin splitting in NMR spectra. The kernel's escape constant. Relative chemical shift, its definition and use in chemistry. Spin-spin interaction of nuclei, its nature, number of multiplet components, intensity distribution, sum rule. Analysis of NMR spectra of the first and non-first order. Proton magnetic resonance, NMR on 13C and other nuclei. The double resonance method. Technique and methodology of the experiment. Block diagram of an NMR spectrometer, types of spectrometers. The nature of the samples. Structural analysis. The study of complexation processes. The study of fast-flowing processes. Comparison of the NMR method with other methods, its advantages and limitations. Principles of laser magnetic resonance (LME) spectroscopy.

Gas chromatography method

Physico-chemical bases of chromatographic processes. Classification of chromatography methods. Chromatographic peak parameters. Gas chromatography options. The chromatograph block diagram.

The effect of temperature on the chromatographic process. Using methods of programmable temperature change. Types of detectors. Methods of qualitative and quantitative chromatographic analysis.

The method of mass spectrometry

Mass spectrometry in comparison with other physical research methods. Classification of devices. The principle of operation of the mass spectrometer, the main characteristics. Types of mass analyzers: time-of-flight; radio frequency; quadrupole; ion-cyclotron resonance, etc. Block diagram of a mass spectrometer with a magnetic mass analyzer. Methods of introducing samples into a mass spectrometer. Combination with a gas chromatograph. Molecular beams. Effusion cells. Direct injection of solid samples.

X-ray spectroscopy. Physical values of the X-ray method of analysis.

X-ray diffractometry. Types and characteristics of pipes and detectors of X-ray detection. Diffractometry (measurement and distribution of diffractograms). Identification of objects (phase of objects) on interplanetary distribution and change of parameters of yachts. Optical systems, diffraction on Crystal resolution. Wulf Bragg's Smile Faded. The peculiarity of modern equipment for the study of the phase structure and parametres structures of semi-crystalline materials, including a number of films, printing and nanostructured materials.

III. Spisok used by istochnikov

Osnovnaya:

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2 Andrievsky R. A., Ragulya A.V. Nanostructural material. Уч. "yes," he said. - M.: Izdatelsky Center "Academy", 2005. - 117 P.

3. Poole Ch., Owens F. Nanotechnology. M.: Technosphere, 2004.

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5. Kobayashi N. introduction to nanotechnology. - M.: binomial, 2007 – - 134 PP.

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9. Mansurov Z.A., Shabanova T.A., Mofa N.N. Synthesis and technologies of nanostructured materials. Almaty: "Kazakh University", 2012. 318 p.

10. Mansurov Z.A., Zahidov A.A., Najipkyzy M., Smagulova G.T., Sultanov F.R. Carbon nanomaterials / The monograph. Almaty: Kazakh University, 2017. 306 p.

11. Kolesnikov B.Ya., Mansurov Z.A. Physical research methods in chemistry. Almaty, 2000.

12. Najipkyzy M. Formation of fullerenes and hydrophobic soot in hydrocarbon flames– Almaty: Kazakh University, 2012– 114 p.

13. Mansurov Z.A., Kolesnikov B.Ya. Khimiyadagi fizikalyk zertteu adisteri. Almaty, "Kazakh University" baspasy, 2012.

14. Bazyl O.K. Introduction to the course "Physical research methods in chemistry": textbook. stipend. Tomsk : Publishing House of Tomsk State University, 2016. 132 p.

15. Silverstein R. Spectrometric identification of organic compounds. Moscow: Binom. Laboratory of Knowledge, 2014

16. Prech E., Bulmann F., Affolter K. Determination of the structure of organic compounds. Moscow: Mir, 2006.

17. Physico-chemical methods of analysis of organic compounds (ultraviolet spectroscopy, infrared spectroscopy, mass spectrometry, nuclear magnetic resonance spectroscopy) "St. Petersburg State Technical University named after S.M. Kirov", St. Petersburg, 2018.

Additional information:

1. Golovin Yu.I. Introduction to nanotechnology. Moscow: Publishing house "Mashinostroenie – 1", 2003 - 112 p.

2. Alymov M.I., Zelensky V.A. Methods of obtaining and physico-mechanical properties of bulk nanocrystalline materials. Moscow: MEPhI, 2005. 52 p.

3. Fullerenes: A textbook / L.N. Sidorov, M.A. Yurovskaya, A.Ya. Borshchevsky, I.V. Trushkov, I.N. Ioffe. "Exam", 2005, 688 p.

4. Kelsall R., Hamley A., Geoghegan M. Scientific foundations of nanotechnology and new devices. Dolgoprudny: Publishing House "Intellect", 2011. 528s.

5. Fistul V.T. New materials. Status, problems, prospects. Moscow: MISiS, 1995.

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