MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
V.N. Karazin Kharkiv National University

Educational and Research Institute "School of physics and Technology"

APPROVED

Head of the Admissions Committee,
Rector of V.N. Karazin Kharkiv
National University
_____ Tetyana KAGANOVSKA
"____" _____ 2023_ p.

PROGRAM
of entrance professional examination
"Interaction of radiation with matter"

speciality: 105 "Applied physics and nanomaterials"

educational program "Medical physics"

the second (Master of Science) level of higher degree

Kharkiv 2023

Part 1. Interaction of radiation with matter

A classical description of the collision of two bodies

Scattering in the relative system of reference and in the center-of-mass system. Laws of conservation and equations of motion. Reference systems. Deflection angles and impact parameter. Scattering in the center-of-mass system and its properties. Scattering in the laboratory coordinate system. Vector diagram of the scattering process. Imparted energy and deflection angles. Scattering cross-section. Differential cross-section in the relative coordinate system. Relationship between impact parameter, scattering potential and differential cross-section. Transformation to laboratory coordinate system. Transformation to variables that differ from the deflection angles. Total differential cross- sections. Total and partial cross-sections. Cross-section of a reaction channel. General concepts of the beams interacting with targets. Fluence. Macroscopic cross-section of the process.

Fundamentals of quantum description of scattering

Limits of classical description of scattering. Scattering amplitude. Relationship between scattering amplitude and differential cross-section. Formfactor. Time- independent scattering theory. Method of partial waves. Partial phase shift. Relationship between partial phase shifts and differential cross-section. Limits of application of partial wave method. The Born approximation and the limits of its application. Higher orders of perturbation theory for scattering processes.

Elastic collisions of charged particles with atoms

Potential r-1. Differential scattering cross-section for electrostatic interaction. General view of differential cross-section for electrostatic interaction. Deflection angles. Differential cross-section of energy transfer. Interaction of electrons with the atomic nucleus. Rutherford's scattering formula. Relativistic description of the fast electron scattering. Darwin-Rutherford's formula. Limits of application of classical relativistic mechanics. Relativistic quantum cross-section for electron scattering by a point nucleus. The concept of Mott scattering. Bremsstrahlung of electrons. The problem of interatomic potentials. The Thomas-Fermi, Bohr, Bom-Mayer potentials and step potential. Rutherford's formula and differential cross-sections of heavy ions scattering.

Collisions of neutral particles with atoms

Hard core potential. General view of differential scattering cross-section. Differential cross-section for elastic scattering and deflection angles for scattering f neutral particle. Fast neutrons scattering. Dependence of scattering cross-section on neutron energy. Scattering of gamma quanta. Differential cross-section for Compton scattering. Photoelectric effect. Electron-positron pair production. Photonuclear reactions. Inelastic collisions of atoms. Kinetics of inelastic scattering. Vector diagram of inelastic scattering process. Deflection angles and inelastic energy losses. Physical aspects of inelastic scattering processes. Transitional diatomic systems.

The fate of the incident particle

Particle path. External and internal irradiation. Surface scattering and backscattering. The concept of range. Full path length, vector, projected and transverse ranges. Gaussian distribution for full path length. Mean path length. Spatial distribution of particle breakpoints.

Mean projected range. Free path. Mean energy loss in a single collision. Stopping power. Relationship between stopping power and differential and total scattering cross-sections. Stopping cross-section and physical processes of deceleration. Dependence of full path length on stopping cross-section and density of the substance. Spread of energy lost during scattering.

Deceleration of heavy ions

Deceleration by electrons. The main properties of processes of atomic excitation, ionization and electron exchange. Total stopping power. Dependence of processes of excitation, ionization and electron exchange on the ion velocity. Stopping power and electron drag coefficient of fast ions. Ionization energy. Stopping power of heavy ions at low speed. Nuclear deceleration and its properties. Quantum-mechanical description of the drag coefficient. Mean excitation energy of an atom. The role of the inner shells of target atoms and the excitation of wave functions of atomic electrons. Bloch's formula for the mean excitation energy. Stopping power of compounds. Bragg's rule. Full path length of heavy ions. Formulas for calculating the mean path length of ions in matter according to the path of protons or alpha-particles. Dependence of ion path on thermodynamic parameters of matter.

Deceleration of fast electrons and positrons, neutrons and gamma quanta

Processes of deceleration of electrons and positrons. Deceleration during excitation and ionization of target atoms. Bremsstrahlung. Bethe-Heitler formula for the ratio of ionization and radiation energy losses. Collision with the electronic plasma of the target. Density effect. Cherenkov radiation. Energy spread. Multiple scattering. Full path length and range spread. Deceleration processes of fast and thermal neutrons. Elastic and inelastic nuclear scattering. Free path length and energy losses. Deceleration of gamma quanta. Reduction of fluence and energy of gamma quanta in Compton scattering, photoelectric effect and pair production. Linear absorption coefficient of gamma quanta and beam energy.

Part 2. **Radiobiology.**

Formation of defects and radiation damage in simple targets

Point defects in crystals and their formation. Schottky defect and Frenkel defect. Displacement processes. Directions of easy displacement. Athermic or spontaneous recombination of defects. Recombination volume. Threshold displacement energy. The probability of displacement in a given direction. Displacement cross-section. Displacement cascades. The number of displacements in the cascade. Dependence of the number of displacements on the energy loss of the incident particle.

Physical bases of dosimetry

Methods of radiation registration. Radiation sources. Relative biological effectiveness of different types of radiation. Equivalent dose and radiation quality factor. Dosimetric and microdosimetric characteristics of radiation. Spatial distribution of defects.

Levels of radiobiological processes

Relationship and features of the action of radiation at the physical, chemical, biochemical and biological levels. Basic principles of modelling the biological effects of radiation. Physical models of radiation action. General target theory. Radiosesitive volume. The overlap factor. Analisys of "single-hit" and "multi-hit" curves. Advantages and disadvantages

of physical models.

The concept of the biological effect of radiation

Theory of indirect action of radiation. Physical processes under direct action of radiation. Dependence of $M_{phys.chem.}$ and $M_{rad.}$. Inactivation of macromolecules by direct action of radiation. Direct action of radiation on enzymes. Direct effect of radiation on nucleic acids. Structural damage of DNA. Structural damage of enzymes. Theory of indirect action of radiation. Comparative characteristics of products of radiolysis of water. Characteristics of indirect action of radiation in aqueous solutions. Modification of radiation damage of molecules in solutions. Inactivation f macromolecules in water solutions. Radiation-chemical yield.

Radiation effects on cells, organs and organisms

Primary physical-chemical processes in the irradiated cell. Analysis of the mechanisms of radiation damage of cells. Molecular mechanisms of reproductive death. Effect of radiation on cells that do not divide or divide slowly. The concept of reparation. Comparative radiosensitivity of organisms. Effect of radiation on mammals. Acute and chronic radiation syndrome.

CRITERIA

for evaluation the degree of a student's knowledge

1. The completion of each task of the ticket is evaluated by a point according to the table:

S No	Number of points	When evaluation the answer to the theoretical question	When evaluation the solution of the problem
1	0	It is revealed that the student has shown academic dishonesty	
2	1-20	Only the definitions of terms that are included in the question formulation are given	A short condition is written, a diagram or figure to the problem is given, the basic laws on this topic are written down
3	21-40	Only general information is given	In addition to item 2 the solution method of the problem is specified
4	41-60	A vague answer is given	In addition to item 3 the gross mistakes were made with the correct choice of the solution method
5	61-80	Answer is given with minor mistakes	In addition to item 3 solution is not completed with the correct choice of the solution method
6	81-90	The correct answer is given in general with the violations of the logic of representation of the material or	The problem is brought to the correct final formula and at this stage the

		without proper illustrations or presentation of the answer that makes it difficult to understand the text	solution is terminated
7	91-100	Complete perfect answer is given	The correct final formula is obtained and analyzed, dimensional analysis is performed, the numerical value is defined correctly

1. The total score of the entrance professional examination on a scale from 100 to 200 points is calculated by the formula:

Grade point = (Q1 + Q2 + Q3) / 3 + 100,

where Ql, Q2, Q3 - points for answers to certain questions of the examination ticket.

RESOURCES

1. E.B. Podgorsak, Radiation Physics for Medical Physicists (Biological and Medical Physics, Biomedical Engineering), Springer, New York, USA, 2010.
2. N.J. Carron, An Introduction to the Passage of Energetic Particles through Matter, Taylor and Francis, USA, 2006.
3. EVANS, R. D., The Atomic Nucleus. Krieger, Florida, USA (1982).
4. Chr. Lehmann, Interaction of radiation with solids, North-Holland Publishing Company, 1977.
5. E.J. HALL, and A.A. Giaccia, Radiobiology for the Radiologist, Lippincott Williams & Wilkins, Philadelphia, USA, 2011.
6. G.G. Steel, Basic Clinical Radiobiology, Hodder Arnold Publishers, London, 2002.
7. S. Lehnert, Biomolecular Action of Ionizing Radiation (Series in Medical Physics and Biomedical Engineering), Taylor and Francis, USA, 2007.
8. INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Biology: A Handbook for Teachers and Students, Training Course Series, No. 42, IAEA, Vienna, 2010.
9. NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES, Health Risks from Exposure to Low Levels of Ionizing Radiation, BEIR VII PHASE 2, The National Academies Press, Washington, D.C., 2006.
10. L.D. Landau, and E. M. Lifshitz, Quantum Mechanics: Non-Relativistic Theory (Pergamon Press (London), 1981.

Голова фахової атестаційної комісії
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