Federal State Autonomous Educational Institution of Higher Education "Moscow Institute of Physics and Technology (National Research University)"

APPROVED
Head of the Phystech School of Aerospace Technology
S.S. Negodyaev

Work program of the course (training module)

course:	Chemistry of High Energies for Inorganic, Organic and Bio-Organic Matters/Химия высоких энергий неорганических, органических и биоорганических соединений
major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии
	Phystech School of Aerospace Technology
	Chair of Logistics Systems and Technologies
term:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Exam

Academic hours: 60 AH in total, including:
- lectures: 30 AH.
- seminars: 0 AH.
- laboratory practical: 30 AH.

Independent work: 90 AH.

Exam preparation: 30 AH.

In total: 180 AH, credits in total: 4

Author of the program: T.M. Vasileva, doctor of technical sciences, associate professor

The program was discussed at the Chair of Logistics Systems and Technologies 09.02.2022

Annotation

The training course is targeted at student's familiarization with scientific and engineering principles of Chemistry of High Energies concerning technologies based on effect of ionizing radiation and fluxes of high-energy particles on matter. The main part of the training course is focused on applications of radiation chemistry for polymers and biopolymers targeted modification. Theoretical sections of the course are supported by practice on real laboratory setups including unique electron accelerator and generator of Electron-Beam Plasma.

1. Study objective

Purpose of the course

- formation of scientific outlook on the matter transformations under ionizing radiation action and on high-energy chemistry place in advanced technologies;
- formation knowledge of high energy chemistry fundamental concepts and laws;
- ability development to use the acquired knowledge, skills and abilities in professional activity related to scientific research in plasma physics and chemistry, as well as to industrial and aerospace technologies based on plasmas.

Tasks of the course

- formation of ideas about chemical phenomena occurring in matter under the influence of non-thermal energy;
- gaining knowledge about chemical reactions stimulated by ionizing radiation and high-energy particle flows;
- acquisition of the ability to use the general laws of chemistry in the analysis of phenomena related to high energy chemistry;
- mastery of methods and approaches to solving scientific and applied problems related to radiation technologies of inorganic, organic and bioorganic compounds.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- basic concepts of high energy chemistry;
- the mechanisms of processes in solid, liquid and gaseous substances initiated by the impact of various types of ionizing radiation и and high-energy particle flows;
- radiation-induced processes in the condensed phase and their influence on the change in the physicochemical properties of non-organic, organic and bio-organic compounds;
- theoretical foundations of technologies related to the ionizing radiation impact on substances and materials.

be able to:

• use the chemistry laws in the analysis of phenomena stimulated by ionizing radiation and high-energy particle flows, highlight the essence of phenomena, compare, generalize, draw conclusions;
• apply the basic laws of chemical thermodynamics and kinetics in solving professional problems of high energy chemistry;
• predict the possibility of chemical processes and describe their kinetics in solving professional problems;
• present data of experimental studies in the form of a completed study protocol.

master:

• methods of chemical processes analysis on the basis of thermodynamic calculations, determination of the main chemical reactions kinetic parameters;
• skills of self tuition with educational, scientific and reference literature; carry out research and draw generalizing conclusions;
• skills of safe work in a chemical laboratory and skills of practical work on setting up experiments in the field of high energy chemistry of non-jrganic, organic and bio-organic cjmpounds;
• skills in reporting on the results of the experiment.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Basic concepts of high energy chemistry and radiation chemistry	3			
2	Interaction of ionizing radiation and fluxes of high-energy particles with matter	4			
3	Interaction of light radiation with matter	3		10	
4	Radiation-chemical processes in gaseous substances	4			
5	Radiation chemistry of liquid systems	3			
6	Radiation-chemical processes in solids	3			
7	Effect of ionizing radiation on polymers and biopolymers	4		10	
8	Technological applications of radiation chemistry of polymers and biopolymers	3		10	
9	Sources of ionizing radiation and fluxes of high-energy particles in radiation chemistry and technology	3			90
AH in total		30		30	90
Exam preparation		30 AH.			
Total complexity		180 AH., credits in total 4			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 3 (Fall)

1. Basic concepts of high energy chemistry and radiation chemistry

The subject of study of high energy chemistry, the history of its development. Types of ionizing radiation. Specificity of various types of high-energy impact. Units of measurement: particle or quantum flux density, radiation intensity, absorbed dose, absorbed dose rate, radiation-chemical yield. Linear energy transfer. Local zones of excitation and ionization.

2. Interaction of ionizing radiation and fluxes of high-energy particles with matter

Primary processes of the ionizing radiation impact on matter. Time stages of radiation-chemical processes. Excitation and ionization. Pair recombination. Deactivation of excited states. Formation and transformations of primary ionic and radical products of radiolysis. Influence of the radiation type on the course of primary processes. Influence of the matter phase state on its radiolytic transformations: features of radiolysis of gaseous, liquid and solid substances.

3. Interaction of light radiation with matter

Photoinduced chemical transformations of matter: reactions of photodissociation and photosubstitution, photoisomerization and photorearrangement, radical reactions of excited molecules.

4. Radiation-chemical processes in gaseous substances

Composition and properties of the main primary and intermediate products of radiolysis in gaseous systems. Radiolysis of diatomic and triatomic gases. Radiolysis of ammonia.
Radiolysis of gaseous hydrocarbons: the most important reactions stimulated by ionization in gases, the influence of impurities. Initiation, continuation and termination of the reaction chain in hydrocarbons. Radiation-chemical oxidation of gaseous hydrocarbons.

5. Radiation chemistry of liquid systems

Formation, properties and reactions of primary products of pure water radiolysis, influence of dissolved oxygen. The main types of radical and redox reactions in aqueous and aqueous-organic systems.
Radiolysis of aqueous solutions of inorganic and organic compounds, features of radiolysis of concentrated solutions. Radiolysis of inorganic liquids: liquid ammonia, hydrazine. Radiolysis of organic liquids on the example of liquid hydrocarbons.

6. Radiation-chemical processes in solids

Peculiarities of radiolytic transformations in the solid phase. Radiolysis of glassy and crystalline substances. Low temperature radiolysis.
Radiation-stimulated heterogeneous processes: adsorption, catalysis, corrosion, dissolution.

7. Effect of ionizing radiation on polymers and biopolymers

Primary processes of radiolysis of polymers. Chemical and physico-chemical transformations of polymers during irradiation. Radiation crosslinking and destruction. The main intermediate (radical) and final products of such reactions.
radiation polymerization. radiation initiation. radical polymerization. Ionic polymerization. Co-polymerization. Solid state polymerization
Radiation and radiation-thermal transformation of natural macromolecular compounds: cellulose, hemicellulose, lignin, chitin.

8. Technological applications of radiation chemistry of polymers and biopolymers

Processes based on polymerization: curing of polymer coatings.
Processes based on radiation crosslinking of polymers: radiation vulcanization, radiation modification of cable insulation coatings, production of polymeric heat-shrinkable materials and radiation-crosslinked polyethylene foam.

Processes based on radiation degradation of polymers: modification of cellulose-containing waste for the production of feed additives, regeneration of rubbers based on butyl rubber, destruction of teflon, regulation of the molecular weight of polymers and biopolymers.

9. Sources of ionizing radiation and fluxes of high-energy particles in radiation chemistry and technology

Isotope sources: gamma installations, sources of alpha and beta radiation. Hardware sources: charged particle accelerators (straight-through, linear) x-ray tubes. Plasma generators. Electron-beam plasma generators. Dosimetry of ionizing radiation. Radiation protection.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

Lectures need specialized audience equipped with presentation and multimedia equipment, posters; set of electronic presentations/slides.
Laboratory practice is carried out in a specialized scientific laboratory.
Student self tuition must be provided with Internet access and connection to international and Russian scientific databases and to electronic libraries with international scientific journals.

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

1. Radiation Chemistry: Present Status and Future Trends. /Eds. C.D.Jonah, B.S.M.Rao. Amsterdam: Elsevier, 2001. 776 p.
2. Wishart J. F., Rao B. S. M. Recent Trends in Radiation Chemistry. Singapore: WSP, 2010. 607 p.

Additional literature

1. Экспериментальные методы химии высоких энергий. Учебное пособие. / Под ред. М.Я.Мельникова. М.: Изд-во МГУ, 2009. 824 с.
2. Пикаев А. К. Современная радиационная химия: Основные положения. Экспериментальная техника и методы. М.: Наука, 1985. 375 с.
3. Charged Particle and Photon Interactions with Matter: Recent Advances, Applications, and Interfaces. / Eds. Y. Hatano, Y. Katsumura, A. Mozumder. Singapore: WSP, 2010. 1045 p.
4. Kharisov B.I., Kharissova O.V., Méndez U.O. (Eds.) Radiation Synthesis of Materials and Compounds. CRC Press, Taylor & Francis Group, Boca Raton, FL, 2013. 560 p.
5. Mozumder A. Fundamentals of Radiation Chemistry. San Diego: Academic Press, 1999. 392 p.
6. Nenoi M. (Ed.). Current Topics in Ionizing Radiation Research. InTech, 2012. 852 p.
7. Photocatalysis. Science and Technology. Masao Kaneko, Ichiro Okura (eds.) Springer, 2002.
8. Turner J.E. Atoms, radiation, and radiation protection. 3rd Edition. Wiley-VCH Verlag GmbH & Co: Weinheim, Germany, 2007
9. Woods, R.J., Pikaev, A.K., Applied Radiation Chemistry. RadiationProcessing. NewYork: Wiley-Interscience, 1993. 552 p.

7. List of web resources that are necessary for the course (training module) mastering

1. Журналы и книги издательства American Chemical Society (ACS)
2. Журналы и книги издательства American Physical Society (APS)
3. Журналы и труды конференций электрохимического общества (The Electrochemical Society(ECS))
4. Архив научных журналов издательства Oxford University Press
5. Журналы и книги издательства Trans Tech Publications inc.
6. Журналы и конференции Optical Society of America (OSA)
7. “Обзорный журнал по химии” на платформе E-library
8. Мультидисциплинарный журнал естественнонаучного профиля “SCIENCE” издательства American Association for the Advancement of Science (AAAS)
9. Патентная База данных Questel

10. Реферативная база данных компании Cambridge Scientific Abstracts в области технологии, материаловедения и нанотехнологий
11. Реферативная база INSPEC, Institution of Engineering and Technology
12. БД ВИНИТИ РАН on-line – крупнейшая в России баз данных по естественным, точным и техническим наукам
13. База данных БЕН РАН
14. EBSCO Publishing и справочная база "DynaMed"
15. Журналы издательства Institute of Physics (IOP)
16. Журналы и книги издательства Elsevier
17. Журналы и книги издательства Wiley-Blackwell
18. Журналы издательства Nature Publishing Group
19. Журналы и базы данных по основным направлениям развития химических наук The Royal Society of Chemistry (RSC)
20. Архивы издательства The Royal Society of Chemistry (RSC)
21. Журналы издательства The Royal Society Publishing
22. Журналы и книги издательства Springer
23. Реферативная база данных Inspec, Institution of Engineering and Technology
24. Ресурсы издательства Taylor&Francis (компания Metapress)
25. Журналы издательства Sage Publications
26. Журналы издательства American Institute of Physics

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

Educational technologies used in the implementation of various types of educational work: computer technologies, presentations, multimedia tools, active educational technologies (lectures, laboratory work).

9. Guidelines for students to master the course

1. At lectures, students are advised to have the lecture electronic version posted by the teacher on the website.
2. In laboratory classes, teachers analyze the main issues of the theoretical part of the course, solutions to typical problems, approaches to compiling equations of chemical reactions. For each of the topics studied in the course, students perform tests. In the same classes for advanced students, teachers give personal tasks. Laboratory work also contains a variety of research elements and goes with the participation and control of teachers. After completing the laboratory work, students hand over the practical and theoretical parts of the work to the teacher.

Mandatory current independent work is aimed at deepening and consolidating the student's knowledge, developing practical skills, includes:
• work with lecture material;
• preparation for laboratory classes;
• preparation for exam;
• work with main and additional literature.

Types of independent work: at home, in the reading room of the library, on computers with access to databases and Internet resources, in laboratories with access to laboratory equipment and instruments.

Self tuition is supported by educational and methodological and information support, including textbooks, teaching aids, lecture notes, educational and scientific software, Internet resources. For self tuition students are provided with information resources (textbooks, reference books, teaching aids). The student has the opportunity to prepare in advance for the lesson, try to answer control questions, and solve typical control tasks.

Systematic discussions with the teacher on theoretical sections and self tuition results carried out in order to monitor the success of the training discipline development.

The form of knowledge control is an exam at the end of the course.

SUPPLEMENT

Assessment funds for course (training module)

major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии
	Phystech School of Aerospace Technology
	Chair of Logistics Systems and Technologies
term:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Exam

Author: T.M. Vasileva, doctor of technical sciences, associate professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- basic concepts of high energy chemistry;
- the mechanisms of processes in solid, liquid and gaseous substances initiated by the impact of various types of ionizing radiation и and high-energy particle flows;
- radiation-induced processes in the condensed phase and their influence on the change in the physicochemical properties of non-organic, organic and bio-organic compounds;
- theoretical foundations of technologies related to the ionizing radiation impact on substances and materials.

be able to:

- use the chemistry laws in the analysis of phenomena stimulated by ionizing radiation and high-energy particle flows, highlight the essence of phenomena, compare, generalize, draw conclusions;
- apply the basic laws of chemical thermodynamics and kinetics in solving professional problems of high energy chemistry;
- predict the possibility of chemical processes and describe their kinetics in solving professional problems;
- present data of experimental studies in the form of a completed study protocol.

master:

- methods of chemical processes analysis on the basis of thermodynamic calculations, determination of the main chemical reactions kinetic parameters;
- skills of self tuition with educational, scientific and reference literature; carry out research and draw generalizing conclusions;
- skills of safe work in a chemical laboratory and skills of practical work on setting up experiments in the field of high energy chemistry of non-jrganic, organic and bio-organic cjmpounds;
- skills in reporting on the results of the experiment.

3. List of typical control tasks used to evaluate knowledge and skills

Current control is carried out in the form of independent work or written tests on each topic.

The management and control of the student's independent work is carried out as a result of the analysis of the results of control, independent work, as well as individual consultations.

4. Evaluation criteria

1. Types and sources of ionizing radiation.
2. Specificity of various types of high-energy impact.

3. Flux density of particles or quanta, radiation intensity, absorbed dose, absorbed dose rate, radiation-chemical yield.
4. Linear energy transfer.
5. Dosimetry. Examples of specific dosimetric systems.
6. Primary processes of the impact of ionizing radiation on matter. Time stages of radiation-chemical processes. Excitation and ionization.
7. Influence of the phase state of matter on its radiolytic transformations: features of radiolysis of gaseous, liquid and solid substances.
8. Photoinduced chemical transformations of matter: reactions of photodissociation and photosubstitution, photoisomerization and photorearrangement.
9. Photoinduced chemical transformations of matter: radical reactions of excited molecules.
10. Composition and properties of the main primary and intermediate products of radiolysis of gaseous systems.
11. Radiolysis of triatomic gases (on the example of an ammonia molecule).
12. Initiation, continuation and termination of the reaction chain in hydrocarbons.
13. Radiation-chemical oxidation of gaseous hydrocarbons.
14. Radiolysis of water: formation, properties and reactions of primary products, influence of dissolved oxygen.
15. Main types of radical and redox reactions in water and water-organic systems.
16. Radiolysis of organic liquids on the example of liquid hydrocarbons.
17. The most important reactions stimulated by ionization in gaseous hydrocarbons.
18. Reactivity of the main functional groups in the cellulose macromolecule.
19. Reactivity of the main functional groups in the chitosan macromolecule.
20. The most important reactions stimulated by ionization and excitation of a polysaccharide macromolecule (for example, cellulose or chitosan). The main intermediate (radical) and final products.
21. Destruction of macromolecules of polysaccharides, stimulated by ionizing radiation.
22. Influence of temperature on radiation-stimulated transformations of natural polymeric materials. Radiation-thermal conversion of cellulose.
23. Radiation crosslinking of polymers. Examples of processes based on radiation crosslinking of polymers.
24. Primary processes of radiolysis of polymers. Chemical and physico-chemical transformations of polymers during irradiation.
25. Radiation crosslinking and destruction of organic polymers. The main intermediate (radical) and final products of such reactions.
26. Sources of ionizing radiation in radiation chemistry and technology

The main indicators of mastery of the material are the ability to demonstrate knowledge obtained from lecture materials and recommended literature, the correctness and completeness of answers to the teacher's questions that are asked to them during classes and related discussions. An additional survey of students when passing a differentiated test is not provided, however, the assessment given to a student involves taking into account the quality of the reports prepared by the student for seminars.

The mark is excellent 10 points - given to a student who has shown comprehensive, systematized, deep knowledge of the curriculum of the discipline, who is interested in this subject area, who has demonstrated the ability to confidently and creatively apply them in practice in solving specific problems, free and correct justification of the decisions made.

An excellent mark of 9 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, free and correct justification of decisions made.

An excellent grade of 8 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, the correct justification of the decisions made, with some drawbacks.

A good score of 7 points is given to a student if he firmly knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but does not adequately substantiate the results obtained.

A good score of 6 points is given to a student if he firmly knows the material, expounds it competently and to the point, knows how to apply the knowledge gained in practice, but makes some inaccuracies in the answer or in solving problems.

A good score of 5 points is given to a student if he basically knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but makes a large number of inaccuracies in the answer or in solving problems.

The mark is satisfactory 4 points - given to a student who has shown a fragmentary, scattered nature of knowledge, insufficiently correct formulations of basic concepts, a violation of the logical sequence in the presentation of the program material, but at the same time he has mastered the main sections of the curriculum necessary for further education and can apply the acquired knowledge in sample in a standard situation.

The mark is satisfactory 3 points - given to a student who has shown a fragmented, scattered nature of knowledge, makes mistakes in the formulation of basic concepts, disruptions in the logical sequence in the presentation of program material, poorly knows the main sections of the curriculum necessary for further education and hardly applies the acquired knowledge even in standard situations.

The score is unsatisfactory 2 points - given to a student who does not know most of the main content of the curriculum of the discipline, makes gross errors in the formulation of basic principles and does not know how to use the knowledge gained when solving typical problems.

The mark is unsatisfactory 1 point - given to a student who does not know the main content of the curriculum of the discipline, makes gross errors in the formulation of the basic concepts of the discipline and generally does not have the skills to solve typical practical problems.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

The main indicators of the materials assimilation for discipline "High Energy Chemistry of Inorganic, Organic and Bioorganic Compo" are the assessments of the teacher during the midterm control, and on the final (exam) certification of the ability to demonstrate the knowledge gained from the study of lecture materials и practical exercises, answering basic and additional questions of the examination ticket.

Boundary control is applied in the following forms:

- assessment of answers to questions in the process of a short (up to 5 minutes) selective oral survey before the start of each practical lesson based on the materials of the previous lesson;
- assessment of the ability to solve at the blackboard and / or in writing typical examples and / or tasks considered in practical classes;

The exam in the discipline is the final stage of studying of the entire course. It is aims to check the knowledge of students in theory and identify the skills of their application in solving practical problems, as well as the skills of self tuition with the recommended basic and additional literature.
The exam is carried out orally on tickets approved by the head of the department. The examiner is given the right, in addition to the theoretical questions of the ticket, to give students tasks and examples, typical options of which were considered in practical classes. Students with the permission of the examiner can use lecture notes, seminars, and reference books only during the preparation for the exam. Time is allotted for preparation for the exam and the survey in accordance with the approved standards.