TOMSK POLYTECHNIC UNIVERSITY
ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

APPROVED BY

Director of Nuclear Science & Engineering School
_____________ / Oleg Yu. Dolmatov
"25" 06 2020

Course Name: Radiochemistry. Application of Radionuclides and Radiopharmaceuticals in Diagnostics and Therapy

Field of study: Nuclear Science and Technology

Programme name: Nuclear Science and Technology

Specialization: Nuclear medicine

Level of Study: Master Degree Programme

Year of admission: 2019

Semester, year: semester 3, year 2

ECTS: 6

Total Hours: 216

Contact Hours: 64

- **Lectures:** 16
- **Practical experience:** 16
- **Labs:** 32

Self-study: 152

Assessment: Exam

Division: Nuclear Fuel Cycle

Director of Programme _____________________ / Vera V. Verkhoturova

Instructor _____________________ / Artem G. Naymushin

Course Name: Radiochemistry. Application of radionuclides and radiopharmaceuticals in diagnostics and therapy

Course Overview

Course Objectives	The objective of the course is to develop knowledge and skills to perform professional activity in the field related to production and clinical application of radionuclides and radiopharmaceuticals in nuclear medicine.
Learning Outcomes	**Upon completion of the course, a graduate is expected to acquire the knowledge of:** – basic terms and definitions of nuclear physics, theory of nuclear structure and its characteristics, types and regularities of radioactive decays, mechanisms of nuclear reactions behavior and be able to apply this knowledge in the theoretical and practical research; – general laws, theories and methods for analysis of isotope properties, as well as the possibility to obtain and apply radionuclides in nuclear medicine; – generation and separation of radionuclides depending on their nuclear physical and chemical properties, as well as skills for radiopharmaceuticals synthesis in the professional activities; – requirements of Russian and international regulatory documents with regard to the processes of radionuclides and radiomedications generation and quality control, as well as selection of equipment by specified parameters. **Graduates are also expected to develop the following skills:** – to apply knowledge of general laws, theories and methods for analysis of isotope properties, as well as the possibility to obtain and apply radionuclides in nuclear medicine; – to generate and separate radionuclides depending on their nuclear physical and chemical properties, as well as skills for radiopharmaceuticals synthesis in the professional activities; – to compare, analyze, and interpret the main requirements of Russian and international regulatory documents with regard to the processes of radionuclides and radiomedications generation and quality control, as well as selection of equipment by specified parameters; – to perform processing and analysis of data obtained through theoretical, clinical and experimental studies; – to develop and plan the project objectives with account of its basic and alternative implementation options; – to communicate one's view regarding the obtained experimental and theoretical outcomes based on the general laws of physics and chemistry. – to apply knowledge of the foreign language for the informational search of new technologies of generating radioisotopes and radioisotope-based medications, present one's scientific outcomes at the social scientific events in the form of presentations and oral reports. – to compile the general activity plan on the specified issue, offer research methods and modes for results processing, conduct scientific research on the generation of radioisotopes and radioisotope-based radiopharmaceutical medications. – to execute the R&D outcomes in the form of articles, papers, scientific reports,

	and presentations with the use of digital typesetting systems and office software packages. **Graduates should acquire the practical experience in:** – pursuing quality control assurance and application of quality standards in the production of therapeutic radionuclides and radiomedications; – comparing, analyzing, and interpreting the main requirements of Russian and international regulatory documents with regard to the processes of radionuclides and radiomedications generation and quality control, as well as selection of equipment by specified parameters; – conducting scientific research on the generation of radioisotopes and radioisotope-based radiopharmaceutical medications.
Course Outline	The course is taught using a variety of teaching forms, including lectures, practical experience, laboratory classes, and learners' self-study. The course includes the following obligatory components: – 8 lectures; – 8 practical experiences; – 15 laboratory works; – 9 seminars; – 1 review; – 1 colloquium. **Main sections of the course are as follows:** – General introduction into radiochemistry and radiopharmacy. – Technologies for reactor radionuclides generation. – Technologies for cyclotron radionuclides generation. – Technologies for radiopharmaceuticals synthesis and generation. – Quality control of radiopharmaceuticals. – General approaches to the production of pharmaceuticals and medical goods with the observation of regulatory documents. The students will achieve learning objectives of the course after a series of lectures on physical-chemical fundamentals of isotopes and radiopharmaceuticals generation, generation of reactor and cyclotron radionuclides, reactor and cyclotron diagnostic and therapeutic radiopharmaceuticals, processes of isotope separation, methods of radiopharmaceuticals quality control. Practical training is organized on the basis of the TPU nuclear research facilities and is arranged in the form of laboratory works: 1. Practical training at the IRT-T isotope separation facility. 2. Practical training at the IRT-T radiation monitoring facilities. 3. Practical training at the IRT-T technecium extraction generator. 4. Practical training at the IRT-T technecium sorption generator. 5. Practical training at the R-7M isotope separation facility. 6. Practical training at the R-7M radiation monitoring facilities. 7. Practical training at the iodine-123 generation facility. 8. Practical training at the thallium-199 generation facility. 9. Practical training at the diagnostic and therapeutic radiopharmaceuticals generation facilities at the IRT-T reactor. 10. Practical training at the diagnostic and therapeutic radiopharmaceuticals generation facilities at the R-7M cyclotron. 11. Practical training at the radiopharmaceuticals generation facility at the IRT-T reactor. 12. Pharmaceuticals quality control.

	13. Radioactive medications quality control. 14. Practical training in the non-contaminated areas of the IRT-T reactor production department. 15. Practical training in the non-contaminated areas of the R-7M cyclotron production department. The current assessment allows revealing the quality of learners mastering the course material referring to all sections of the course “Radiochemistry. Application of Radionuclides and Radiopharmaceuticals in Diagnostics and Therapy”. Seminar is a form of current assessment, which includes one test and one case study report. 9 seminars are planned for the semester. Each seminar is scored with 5 points. In order to assess the current level of knowledge, it is supposed to conduct 1 colloquium in the form of an oral interview. It is necessary to answer on 5 theoretical questions based on the materials of the relevant sections of the discipline. The correct answer to this question is estimated at 2 points. The maximum possible number of points for one colloquium is 10 points. The exam is a final assessment form. The exam purpose is to reveal developed learning outcomes and to determine the degree of correspondence of demonstrated learning outcomes to those expected in the course program. A student is admitted to the exam on condition that all the seminars are completed, all laboratory works are defended and the total score achieved is not less than 44. The structure of an exam paper includes 6 questions and 1 case study report. Each question is given 3 points. The maximum score for the exam is 20. The exam is oral: a student answers the lecturer’s questions and presents the results of case study consideration. Additional questions and tasks can be provided by a lecturer at the exam.
Prerequisites (if available)	1. Nuclear Physics. 2. Radiation Physics. 3. Ionizing Radiation Installations. 4. Mathematical Methods for Imaging in Medicine
Course Structure	The course material is divided into six sections. Each section consists of lectures, practical experiences and lab-bases classes. **Section 1. General introduction into radiochemistry and radiopharmacy**. As a result of mastering the section, the student will be introduced to the subject and objectives of radiochemistry and radiopharmaceuticals, general principles for carrying out radiochemical experiments, basic concepts of radiochemistry and radiopharmaceuticals, physicochemical methods used in the separation of isotopes, radionuclide and nuclear-chemical methods for the study of substances, physical basics of nuclear medicine, biological basis for nuclear medicine, chemical basics of nuclear medicine. **Section 2. Technologies for reactor radionuclides generation** As a result of mastering the section, a student will know about main "medical" radionuclides obtained at a nuclear reactor for diagnostic and radiotherapy purposes, methods for generating therapeutic radionuclides, methods for obtaining therapeutic pharmaceuticals in a medium-flow reactor, methods for obtaining strontium-89, samarium-153, tin-117, rhenium-186, rhenium-188 generator, yttrium-90 generators, technology for producing molybdenum-99, methods and technologies for producing technetium-99m, chromatographic technetium-99m generators, etc. **Section 3. Technologies for cyclotron radionuclides generation** As a result of mastering the section, a student will know about cyclotrons, targets and devices for their irradiation, specific characteristics of radiopharmaceuticals production using accelerators, devices for irradiating targets and mechanisms for their rotation, electronic systems for scanning beam along the surface, systems of forced

	water and gas (air, helium, etc.) cooling, systems for collecting radioactive products, general scheme for producing cyclotron radiopharmaceuticals, methods for obtaining thallium-201, production of thallium-199, methods for producing iodine-123, obtaining positron-emitting radionuclides, nuclear reactions to obtain biogenic radiopharmaceuticals, positron-emitting radionuclides generators. **Section 4. Technologies for radiopharmaceuticals synthesis and generation** As a result of mastering the section, a student will know about methods for obtaining radiopharmaceutical "Thallium chloride, 201T1", "Diethyl dithiocarbamate, 199Tl", "Sodium iodide, 123I" and "O-iodine, 123I", "m-iodobenzylguanidine, 123I", obtaining medical pharmaceuticals based on technetium-99, obtaining adionuclide-labeled nanocolloidal compounds. **Section 5. Quality control of radiopharmaceuticals** As a result of mastering the section, a student will know about methods of radiopharmaceuticals quality control, carrying out radiometric measurements, identification of the authenticity of radionuclides, determination of volumetric activity, determination of radionuclide purity, determination of radiochemical purity of radiopharmaceuticals, determination of chemical impurities, conducting microbiological analysis, method for determining the pH value. **Section 6. General approaches to the production of pharmaceuticals and medical goods with the observation of regulatory documents** As a result of mastering the section, a student will know peculiarities of organization of radiopharmaceutical production, requirements for radiopharmaceuticals production and quality control, special requirements for active pharmaceutical substances production, basic requirements for medicines production and quality assurance, organization of drugs production, basic requirements for premises and equipment, cleanrooms (zones) for the production of sterile drugs, production of radiopharmaceuticals without finishing sterilization.
Facilities and Equipment	1. Lecture room with multimedia equipment (projector, PC): 634050, Tomsk, Lenina Ave., 2, building 10, room 125A. 2. Laboratory 31 located at the Research Nuclear Reactor IRT-T TPU). 3. Laboratory for radioactive substances technologies (cyclotron of TPU).
Grading Policy	In accordance with TPU assessment system we use: - Current assessment which is performed on a regular basis during the semester by scoring the quality of mastering the theoretical material and the results of practical activities (tests, tasks, problem solving). Max score for current assessment is 80 points. - Course final assessment (exam) is performed at the end of the semester. Max score for course final assessment is 20 points. The final score is determined by summing the scores of the current assessment during the semester and exam score at the end of the semester. Maximum overall score corresponds to 100 points, min pass score is 55 points.
Course Policy	Class attendance will be taken into consideration when evaluating students' participation in the course. Students are expected to be actively engaged in class discussions on the assigned reading materials. All classes are obligatory to visit. Medical allowance to work with radiation is required. Students should pass briefing about electrical, work and radiation safety in laboratories of Nuclear Science and Engineering School.
Teaching Aids and Resources	**Compulsory reading:** 1. Editorial: Innovative Radiopharmaceuticals in Oncology and Neurology / Jacques Barbet, Nicolas Arlicot, Marie-Hélène Gaugler [and etc.] // Frontiers in Medicine. - Vol. 3, Article 74. — P. 1 - 3. — URL: https://www.frontiersin.org/articles/10.3389/fmed.2016.00074/full (дата

	обращения: 04.03.2020). — Режим доступа: свободный доступ из сети Интернет. - Текст : электронный. 2. Practical Clinical Oncology / editors L. Hanna, T. Crosby, F. Macbeth. – 2 th ed. – Cambridge: Cambridge University Press, 2015. – 338 p. - Текст: электронный // Cambridge University Press. – URL: https://www.cambridge.org/core/books/practical-clinical-oncology/66F869C03F6901256B1B7EDFFE816B83#fndtn-contents (дата обращения: 20.09.2020). – Режим доступа: по подписке. **Additional reading:** 3. Мурогов, В. М. Nuclear technology: history, state and technical challenges of nuclear power development : монография / В. М. Мурогов. — М. : ИНФРА-М, 2019. — 123 с. - ISBN 978-5-16-107748-1. - Текст : электронный // Znanium.com : электронно-библиотечная система. — URL: https://znanium.com/catalog/product/1022694 (дата обращения: 12.03.2020). — Режим доступа: по подписке. 4. Innovative medicine: basic research and development / editors Kazuwa Nakao; Nagahiro Minato; Shinji Uemoto. – New York: Springer Open, 2015, 330 p. - Текст: электронный // SpringerLink. – URL: https://www.springer.com/gp/book/9784431556503 (дата обращения: 20.09.2020). – Режим доступа: по подписке.
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