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Teaching radiochemistry in Russia

Lead Beneficiary: **Moscow State University**

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EXECUTIVE SUMMARY

The universities giving education in nuclear chemistry in Russia are briefly presented. Features of the Russian higher education system are described. Samples of curricula on nuclear chemistry are presented.

This deliverable contributes to the following Work-Packages and Tasks:

WP 1						
☐ Task 1.1	☐ Task 1.2	☒ Task 1.3	☐ Task 1.4	☐ Task 1.5	☐ Task 1.6	
WP 2						
☐ Task 2.1	☐ Task 2.2	☐ Task 2.3				
WP 3						
☐ Task 3.1	☐ Task 3.2	☐ Task 3.3	☐ Task 3.4			
WP 4						
☐ Task 4.1	☐ Task 4.2	☐ Task 4.3	☐ Task 4.4	☐ Task 4.5	☐ Task 4.6	☐ Task 4.7
WP 5						
☐ Task 5.1	☐ Task 5.2	☐ Task 5.3				
WP 6						
☐ Task 6.1	☐ Task 6.2	☐ Task 6.3	☐ Task 6.4	☐ Task 6.5	☐ Task 6.6	

OUTLINE

1 INTRODUCTION

The teaching of radiochemistry and nuclear chemistry in Russia had been initiated in 1950-s. The primary target of it had been to feet the requirements of weapons production and nuclear industry. Attention was paid mostly to the chemistry and metallurgy of uranium and transuranium elements and chemical separation techniques.

The teaching had been conducted at several locations: Moscow State University, Leningrad (now Saint-Petersburg) State University, Gorky (now Nizhny Novgorod) State University, Mendeleev Institute of Chemical Technology and Ural Polytechnic Institute (Sverdlovsk, now Yekaterinburg).

In the course of time the aims of nuclear education have been transformed according to the changes undergone by the Russian political system. In MSU course of radiochemistry was substituted by "Radiotracers application in chemical research", and from 1990s it was changed to "Fundamentals of radiochemistry and radioecology". Radiochemistry chair in Nizhny Novgorod was transformed to a chair of solid state chemistry.

Now teaching of radiochemistry continues in MSU, SPbGU, Ural Federal University (Yekaterinburg), Mendeleev University of Chemical Technology (Moscow). Since recently the interest in radiochemical studies is rising again due to ambitious governmental program of development of nuclear medicine and nuclear renaissance. In the course of these changes some new branches of MEPHI were founded in Ozersk (on the base of SPA Mayak) and in Obninsk (on the base of IPPE).

Table 1. List of Russian universities giving education in nuclear chemistry

Organization	Dedicated NRC programme(s)
MOSCOW STATE UNIVERSITY Department of Chemistry, Chair of Radiochemistry http://www.chem.msu.ru/eng/chairs2/radio/welcome.html Contact person: Prof. Stephan Kalmykov stepan@radio.chem.msu.ru	1) PhD in chemistry: specialization radiochemistry 2) Specialist in chemistry (5 years) (diploma in radiochemistry)
ST. PETERSBURG STATE UNIVERSITY Department of Chemistry, Chair of Radiochemistry http://www.spbu.ru/e/ Contact person: Prof. Juri Vlasov sensor2000@VK5346.spb.edu	1) PhD in chemistry: specialization radiochemistry 2) BSc in chemistry, 3) MSc in chemistry (diploma in radiochemistry) 4) Specialist in chemistry (diploma in radiochemistry)
MENDELEEV RUSSIAN CHEMICAL-TECHNOLOGICAL UNIVERSITY (MOSCOW) Chair of Chemistry and Technology of Rare Elements http://www.muctr.ru/univsubs/infacol/ifh/faculties/f3/ Contact person: Prof. Alexander Chekmarev katren@muctr.ru	1) Specialist in Technology of materials for modern energetics

LOBACHEVSKY NIZNIY NOVGOROD STATE UNIVERSITY Chair of Solid State Chemistry Contact person: Prof. Nicolay Chernorukov nchernorukov@yandex.ru http://www.unn.ru/chem/xtt.php	1) PhD in chemistry: specialization radiochemistry 2) BSc in chemistry, 3) MSc in chemistry 4) Specialist in chemistry (diploma in radiochemistry)
ELTSIN URAL FEDERAL UNIVERSITY (YEKATERINBURG) Physical and Engineering Institute Chair of Radiochemistry http://www.ustu.ru/home/faculties/ftf/dep-ft/rh/ Contact person: Prof. Nicolay Betenekov betenekov@dpt.ustu.ru	1) MSc Mathematics and Physics 2) BSc Nuclear physics and technology 3) Specialist in Technology of materials for modern energetics 4) Ecological safety management, MSc
NATIONAL RESEARCH NUCLEAR UNIVERSITY, OBNINSK BRANCH Chair of General and Applied Chemistry Prof. Viktor Milinchuk milinchuk@iate.obninsk.ru http://www.iate.obninsk.ru/node/309	1) Specialists in chemistry 2) Specialist in radiation safety of population and environment

The departments of MSU and SPbGU are aimed at preparation of broadly educated specialists including those oriented towards fundamental research. Meanwhile Mendeleev University, branches of MEPHI and Ural University are aimed at educating staff for the industry with enhanced expertise in nuclear technologies.

The colleagues from Ural University and и SPbGU have kindly answered our requests and submitted us with the information on their curricula.

2 FEATURES OF THE RUSSIAN HIGHER EDUCATION SYSTEM

Russian universities are generally regulated by the Ministry of education and science. Some of the leading universities (including MSU and SPbGU) enjoy some share of independence and have the right to develop their own syllabi. MEPHI is a part of ROSATOM governmental corporation.

The courses have 5 to 6 years duration depending of the university and students are awarded a specialist degree. Since recently Russia had joined to Bologna system and some universities have introduces two-stages educational system. The others (including MSU) are in the course of transition to this system. It is expected that the new system will include the transformation of criteria of evaluation of students' knowledge and will allow for individual choice of disciplines. Currently the courses of the most universities including MSU are fixed and don't allow any variations.

After obtaining the specialist degree students may continue their studies at post-graduate level. In order to do this they are required to have excellent educational record an pass 3 exams: their major discipline, foreign language and philosophy.

Post-graduate studies are research oriented, the few lectures and seminars are dedicated only to philosophy studies. The duration of post-graduate program is 3 years. Upon completing the program students must defend their thesis and pass the same 3 exams once again.

The absolute requirements for the defense are 3 publications in peer reviewed journals.

3 TEACHING OF RADIOCHEMISTRY IN MSU

3.1 Basic course

The course of radiochemistry is taught at radiochemistry division of Chemical Department of Moscow State University (one of 18 divisions, staff 65 persons). Every year 200-250 students are accepted by the Chemistry Department. On the 3rd year they attend the compulsory course "Fundamentals of radiochemistry and radioecology". The course contains 36 hours of practical work without lectures and seminars. In the course of practice the students are expected to receive the basic knowledge of handling radioactive materials, principles of detection of ionizing radiation, application of radiotracers in chemical research.

The scarce amount of teaching hours allocated to the course do not actually allow to implement the formal requirements of the official program. This program includes the following sections:

Physical principles of radiochemistry

Radioactive decay. Nuclides and isotopes. Stable and radioactive nuclei. Types of radioactive decay, α-, β- and γ- decay. Nuclear fission. Internal conversion.

Interactions of radiation with matter. Attenuation of α- and β- particles. Bremstrahlung radiation. Interaction of gamma radiation with matter.

The kinetics of radioactive decay. Determination of half-life of different nuclides. Different types of radioactive equilibrium.

Nuclear reactions. Energetic effect of nuclear reactions. Cross-section. Yield calculation. Radionuclide production. Nuclear reactor. Neutron generators. Detectors of ionizing radiation. Gas-filled counters. Geiger-Muller counters. Efficiency. Semiconductor detectors. Scintillation counters. Different types of scintillators. LS Spectrometry. Gamma ray spectrometry. Cherenkov detectors. Autoradiography.

Low level counting. Data treatment. Uncertainty. Statistics of radioactive decay. Poisson distribution, Student distribution, t-factor.

Basic radiochemistry

Isotopic exchange. Kinetics of isotopic exchange. Equal distribution. Mechanism of isotopic exchange. Application of isotopic exchange reactions.

Behavior of radioactive substances in ultra low concentrations. Colloid and pseudocolloid formation. Absorption of radioactive substances. Radiation effects. Recoil effects. Hot atom chemistry. Isotopic effect.

Chemical separation of radionuclides. Preconcentration. Application of carriers. LLX and chromatography. Electrochemical separation, coprecipitation, distillation.

Application of radiotracers

Application in analytical chemistry. Environmental analysis. Isotopic dilution. Radiometric titration. Activation analysis.

Application of radiotracers in inorganic and physical chemistry. Synthesis of radiolabeled inorganic compounds. Determination of solubility using radiotracers. Determination of vapor pressure. Studies of diffusion and self-diffusion using radiotracers.

Application of radiotracers in organic chemistry. Synthesis of radiolabeled organic compounds (direct way, radiochemical methods, biosynthesis). Determination of mechanism of chemical reactions using radiolabeled compounds.

Dosimetry and radiation safety

Mechanism of energy transfer from ionizing radiation to matter. Absorbed dose. Expositional dose. Effective dose. Units of dose. Biological effects of radiation. Direct and indirect effects. Radiosensitivity of tissues and organs. Cells response to irradiation. Acute radiation sickness. Stochastic effects of radiation. Effect of low doses of radiation. Principles of regulation of radiation doses. Risk assessment in radiation exposure. Principles of radiation protection. Handling with radioactive samples in laboratory.

Environmental radioactivity

Natural radionualides in environment. Cosmic radiation. U and Th chains. Radon. Contribution of natural radionuclides to the dose burden. Artificial radionuclides in environment. Sources of radioactive pollution of environment. Nuclear weapon testing. Nuclear industry. Atmospheric emissions during normal operation of NPP. Radiation accidents. Radioactive waste management. Transportation. Depositories for radioactive wastes. Migration of radiouclides in environment: Rn, Kr-85, I-129, 131. Radioactive aerosols. Hot particles. Radionuclide behavior in water ecosystems. Radionuclides in soils and sediments. Resuspension. Soil to plant transfer. Food chains.

Actually teaching of radiochemistry in MSU reduces to several practical works:

Statistics of radioactive decay and treatment of results of measurements

Gamma ray spectrometry of environmental samples

Liquid scintillation spectrometry (Dual label analysis 14C+3H)

Thin layer radiochromatography (separation of radiolabeled by 14C amino acids)

Isotopic generator based on LLX (243Am/239Np)

Radiotracer study of self diffusion of iodine using 131I.

Ion-exchange separation of 234Th from 238U

Main difficulties in teaching radiochemistry in MSU:

Absence of lectures and seminars

Absence of relevant textbooks.

Lack of modern equipment for laboratory works

3.2 Special courses

Those students who plan to continue scientific work in radiochemistry (usually 5-10 persons every year), starting from 4th year study advanced courses. Students may select courses by their own choice.

Table 1: Advanced courses for students specializing in radiochemistry (Program for specialists in Chemistry)

№	**Title**	**Semester**	**Hours**
1	Introduction in radiochemistry	VI	32
2	Radiochemistry	VII-VIII	54
3	Physical principles of radiochemistry	VII	32
4	Nuclear industry	VIII	16
5	Dosimetry	VIII	16
6	Practice in radiochemistry	VIII	54
7	Environmental radioactivity	IX	36
8	Nuclear spectrometry in chemical analysis	IX	36
9	Determination of speciation of radionuclides	IX	24
10	Mossbauer spectroscopy for analysis of inorganic matherials	IX	36
11	Synthesis of radiolabeled compounds	IX	36
12	Radionuclides in chemical and biological studies	IX	24
13	Application of radiotracers in surface studies	IX	24
14	Radionuclide production	IX	24

15	Principles of biological effects of ionizing radiation	IX	16
16	Autoradiography	IX	16
17	Chemometrics and planning of experiment	IX	16

Also advanced course "Nuclear Analytical Techniques" is given for students of Dept. of Material Science. It includes lectures (12 hours) and laboratory practice (4 hours, gamma ray spectroscopy).

4 TEACHING OF RADIOCHEMISTRY IN SPBSU

Table 2. Courses for students that are given in chair of radiochemistry of SPbSU

№	Title	Program	Semester	Hours
1	Chemistry of actinides	"Chemistry", Specialist	IX	46
2	Applied radiochemistry	"Chemistry", Specialist	X	128
3	Chemical effects of beta decay	"Chemistry", Specialist	VIII	32
4	Chemometrics	"Chemistry", MSc	IX	90
5	Extraction and chromatography	"Chemistry", Specialist		74
6	Nuclear chemistry: processes and matherials	«Chemistry, Physics and Mechanics of Matherials» BSc	IV	92
7	Nuclear methods of analysis	"Chemistry", Specialist	XI	38
8	Physical principles of radiochemistry	"Chemistry", Specialist	VII	54
9	Radiometry	"Chemistry", Specialist	VII	130
10	Radiochemistry	"Chemistry", Specialist	VIII	154
11	Radiochemistry	"Chemistry", Specialist	IV	134
12	Applied radiochemistry	«Chemistry», BSc	V	108
13	Radiotracers application	"Chemistry", Specialist		80
14	Selected topics in radiochemistry	"Chemistry", MSc	XI	52
15	Nuclear technologies	"Chemistry", Specialist	VIII	32
16	X-ray analysis	"Chemistry", Specialist	IX	38

Basic course for specialists consist of 134 hours including 18 hr lectures, 54 hr lab work and 64 hr of self-training work. Course consists from several parts:

1. Structure and properties of nuclei.

2. Radioactive decay. Properties of ionizing radiation.
3. Kinetics of radioactive decay.
4. Detection of ionizing radiation.
5. Chemometrics.
6. Basical principles of radiochemistry
7. Application of radiotracers.
8. Nuclear reactions. Nuclear safety. Dosimetry.

Types of laboratory works

Determination of potassium in sample using its radioactivity

Neutron activation analysis. Determination of In in its alloy with Sn.

Determination of thorium via Rn-220.

Determination of Pb by isotopic dilution with Pb-212

Gamma ray analysis of soil samples.

Electrochemical separation of Pb-212 and Bi-212.

5 TEACHING OF RADIOCHEMISTRY IN URAL FEDERAL UNIVERSITY

Table 3. Courses for students that are given in chair of radiochemistry of Ural Federal University

№	Title	Program	Semester	Hours
1	Applied radioecology	MSc Mathematics and Physics	XI	70
2	Applied ecology	Nuclear physics and technology	X	102
3	Nuclear waste management	Technology of materials for modern energetics	X	169
4	Basics of nuclear physics, radiochemistry and dosimetry	Technology of materials for modern energetics	VI-VIII	323
5	Practice in radiometry and radiochemistry	Nuclear Physics and technology	X	119
6	Radioecology	Technology of materials for modern energetics	X	120
7	Nuclear waste management	Ecological safety management, MSc		180

Course "Basics of nuclear physics, radiochemistry and dosimetry" consist of 323 hours including 136 hr lectures, 152 hr lab work, 32 hr of self-training work and 35 hr research course-work.

Course consists from several parts:

1. Physical principles of radiochemistry

1.1. Introduction

1.2. Basic principles of nuclear physics and radioactivity

1.2.1. The theory of nucleus structure. Types of nuclear decays. Main law of radioactive decay.

1.2.2. Successive radioactive decay. Radioactive equilibrium.

1.2.3. Radioactive chains containing several radionuclides. Natural decay series.

1.2.4. Radionuclide classification.

1.3. Basic principles of radiometry and nuclear spectroscopy

1.3.1. Interaction of ionizing radiation with matter as a basic principle for radiation detection.

1.3.2. Neutron interaction with matter

1.3.3. Detectors for ionizing radiation.

1.3.4. Nuclear spectroscopy.

1.4. Basic principles of dosimetry and radiation safety

1.5. Statistical data treatment of radiation measurements

1.5.1. Measurement uncertainty. Random value, statistical law.

1.5.2. Radioactivity as statistical phenomenon. Poisson distribution.

1.5.3. Statistical hypothesis and their examination.

2. General radiochemistry

2.1. Physical-chemical properties of matter behavior at extremely low concentrations in aqueous solutions.

2.1.1. The term "microconcentration" in general and applied radiochemistry.

2.1.2. Ionic species in solutions. Intrinsic and pseudocolloids.

2.1.3. Experimental methods used to study speciation of radionuclides in aqueous solutions.

2.2. Interphase behavior of radionuclides

2.2.1. Main types of interphase distribution. Co-crystallization, sorption, extraction, electrolysis, etc.

2.2.2. Kinetics of interphase distribution of radionuclides.

2.2.3. Statistics of interphase distribution of radionuclides.

2.2.4. Dynamics of interphase distribution of radionuclides.

2.3. Labeled compounds

3. Radiochemical aspects of nuclear technology

3.1. Temporal features of systems in which radionuclides are generated

3.1.1 Nuclear fission of heavy nucleus. Conditions for the chain reaction. Nuclear fuel regeneration.

3.1.2. Radionuclide decay and formation in nuclear reactor and upon storage of spent nuclear fuel.

3.2. Chemical phenomenon that accompany nuclear decays ("hot atom" chemistry)

3.2.1 Energy of radioactive decay products and nuclear reactions.

3.2.2. Isotope effect in natural and man-made systems. Isotope exchange reaction. Separation of radioactive isotopes by chemical means.

3.3. Chemical effects of radiation

3.3.1. Radiation-chemical processes. Water radiolysis in aqueous solutions.

3.3.2. Radiation effects in nuclear fuel upon high neutron fluxes. The kinetics of radiation-chemical processes.

Practical tasks:

Measurement of radionuclides using nuclear counters.

Energy determination of gamma-radiation and radioactivity of the sample using scintillation γ-spectrometer.

Radioactivity as statistical process. The test of Poisson hypothesis of radiation measurements.

Statistical data processing of radiation measurements. Dispersion and average value comparison.

Determination of the optimal counting time of sample.

β-energy determination from radiation abatement.

Thorium and uranium separation.

Separation of Cs from salt solutions of its chemical analogs.

Separation of radionuclides by extraction chromatography.

Separation of radionuclides of thorium chain by ion exchange chromatography.

Radionuclide separation by thin layer chromatography.

Radionuclide separation by co-precipitation and thin layer chromatography.

Radionuclide separation by electrophoresis on inert support.

Radionuclide separation by electrolysis.

The speciation of Th-234 in aqueous solution using sorption.

Determination of strontium sulfate using method of radioactive indicators.

The determination of the free surface of crystalline substances using isotope exchange.

Determination of stability constants of complex compounds using ion exchange.

Radiometric titration. Determination of Zn and Cu in aqueous solutions.

Use of isotope generators to separate short-lived radionuclides.

Express radiochemical analysis of aqueous samples.

6 CONCLUSIONS

Nowadays the revision of curriculum on nuclear and radiochemistry is under way that is due to the changes in the education system – transition to the two-step education system. This process will continue during next few years. In general, the tendency to increase the number of classes spent for nuclear and radiochemistry towards environmental radiochemistry and nuclear medicine.