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Syllabi for the CINCH-II VET courses

Lead Beneficiary: **NNL**

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Relevance

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

☐ ALL

WP 1

☐ Task 1.1 ☐ Task 1.2 ☐ Task 1.3 ☐ Task 1.4

WP 2

☒ Task 2.1 ☐ Task 2.2 ☐ Task 2.3 ☐ Task 2.4

WP 3

☐ Task 3.1 ☐ Task 3.2 ☐ Task 3.3 ☐ Task 3.4 ☐ Task 3.5

WP 4

☐ Task 4.1 ☐ Task 4.2 ☐ Task 4.3 ☐ Task 4.4

WP 5

☐ Task 5.1 ☐ Task 5.2 ☐ Task 5.3 ☐ Task 5.4

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INTRODUCTION

Coordination in education and training In Nuclear CHemistry (CINCH-II) is a consortium of partners across Europe which aims at bringing together the capabilities of the different partners in order to implement new courses and to find a way of meeting the nuclear chemistry postgraduate education training needs of the European Union.

As part of CINCH, a pan-European set of vocational and education training (VET) courses for participation by nuclear industry and research professionals have been prepared. These VET courses will be developed for the specific needs of non-academic end-users, for example employers, regulators etc. These needs were identified in a comprehensive review undertaken by the CINCH consortium. The VET courses described in the sections below will be further developed and delivered by the following partners:

- Loughborough University (LU) - United Kingdom[1],
- Norwegian University of Life Sciences (NMBU) - Norway,
- The Atomic Energy and Alternative Energies Commission (CEA) - France,
- Chalmers University of Technology (Chalmers) - Sweden,
- Czech Technical University (CTU) - Czech Republic.

This report describes the syllabus for the VET courses developed in CINCH-II. The syllabus uses the European Commission Vocational and Educational Training (ECVET) credit system. This system is designed to facilitate the transfer, recognition and accumulation of assessed learning outcomes of individuals who are aiming to achieve a qualification. A reader of this report will acquire an understanding of what knowledge, skills and competencies will be achieved from undertaking a course.

[1] Please note that since the start of CINCH-II, nuclear and radiochemistry at Loughborough University has stopped. Their courses will be delivered at an institution that was not known when this document was delivered.

COURSES BY NMBU

1. Environmental Radiobiology

Course overview – key facts	
Institution:	NMBU / CERAD
Lecturer(s):	Deborah Oughton (NMBU), Carmel Mothersill, Colin Brian Seymour (McMaster University, Hamilton, Canada)
Credit value:	3 ECVET/ ECTS
Duration:	1 week, intensive lectures
Location:	NMBU, Ås, Norway
Year of entry:	2017
Teaching language:	English
Entry requirement:	
Course details	
Purpose	The aim of the course is to give students an introduction to the fundamental principles of radiobiology, within the context of research fields on radioecology and the environmental effects of radiation.
Short description of the course	The course will cover both the history and the state-of-the art of our knowledge on the biological effects of radiation on humans, including how recent studies are challenging established paradigms, but will concentrate specifically on those issues and applications of most relevance for other organisms. This includes effects and endpoints of relevance for non-human organisms, ways in which radiobiology methods and biomarkers are being applied in ecological research, factors influencing radiosensitivity in different organisms, and ecological risk assessment. Case studies will include ecological research in Chernobyl and Fukushima, and laboratory work on biomarker analysis in model organisms.
Learning outcome	For students of radioecology the course provides the opportunity to get a better understanding of the fundamentals of radiobiology; for radiation biology students it offers the chance to see how radiobiology concepts and tools are applied in other areas of radiation research, thus gaining a more in depth understanding of their subject.
Skills	Student has an overview of radiobiology fundamentals and state-of-the art of knowledge on radiation effects in humans. Student is able to understand and estimate/evaluate effects and endpoints of radiation on both humans and non-human biota.
Knowledge	Student has knowledge and understands the environmental radiobiology concepts as well challenging paradigms. Student has knowledge and understands radiobiology methods and biomarkers being applied in ecological research, factors influencing radiosensitivity in different organisms, and ecological risk assessment.

Competences	Student is able to estimate and evaluate potential radiation effects in humans and biota. Student is competent to join the team working with investigating the radiobiological effects by using biomarker tools and endpoint assessments. Student is competent to use certain radiobiological methods and tools in ecological risk assessment

Lecture details*		
	Lectures	**Time (h)**
Theoretical part	Radiobiology refresher: DNA damage and repair, cell survival curves, etc.	3
	Effects of Ionising Radiation on Non-human biota – history, concepts and endpoints, differences in concepts of radiation protection of non-human species and humans	3
	RBE and weighting factors: comparison of human and non-human approaches; Non-targeted effects and new paradigms in radiation biology	4
	Field studies of radiation ecological effects: Chernobyl, Komi, Fukushima	2.5
	Ecosystem Approach and Radiation Ecology Introduction to radiation biomarkers and applications in non-human biota	2
	Radiosensitivity and radioresistance in non-human species, intra and interspecies differences, life history stages.	2.5
	Factors influencing cell radiosensitivity; Oxygen status, cell cycle, etc.	2
	Environmental Risk Assessment and Regulation of Effects on Non-human Species Biomarker tools and endpoint assessments, applications in non-human biota; chromosome aberration, micronuclei, microarray, immunohistochemical Follow up on laboratory sample preparation: cell cultures, media harvesting	6
	Total Hours	**25**
	Laboratory exercises	**Time (h)**
Practical part	Visit to the NMBU low dose irradiation facility, FIGARO. Laboratory work: organism dissection, cell cultures, harvesting for bystander analysis, comet assay, micronuclei assay. Demonstrations and hands on exercises	Approx.. 5h
	Total Hours	**5**

Obligatory deliverable	None		
Exam			
	Written	Oral	Both
	Yes, The exam is a course assignment to produce a detailed experimental description and plan to test a specific hypothesis.	-	-

* In addition to the one week intensive teaching, students are expected to spend one week on research and assignment, and will be given tutoring (distance) by the course teachers during this time.

2. ERICA Modelling Risk Assessment

Course overview – key facts	
Institution:	NMBU / CERAD
Lecturer(s):	Deborah Oughton (NMBU), Justin Brown (NRPA)
Credit value:	2 ECVET/ ECTS, Course attendance certification (without exam)
Duration:	2 days
Location:	NMBU, Ås, Norway
Year of entry:	2017
Teaching language:	English
Entry requirement:	-
Course details	
Purpose	The aim of the course is to give students a grounding in the theory and skills needed to carry out environmental risk assessment for non-human organisms. This will include hands-on training in the ERICA risk assessment tool and modelling issues.
Short description of the course	The central theme is environmental risk assessment; hence, the focus is the exposure of non-human biota to ionizing radiation. The course concentrates on the ERICA Tool used in radiation risk assessment and management and is given as 2 days hands-on training course in modelling and assessment ERICA Tool. This provides nuclear science and radiation protection students with important insights into similarities and differences in risk assessment and management of ionizing radiation modules as compared to other stressors. Course includes theoretical explanation of the fundamentals for the development of the ERICA Tool, but the accent is on practical use of all three tiers in the Tool. It is open to students of environmental science, ecology and nature management, as well as those from nuclear sciences. Due to practical aspects of the course and course length, it is convenient for professionals and students interested in risk assessments and management.
Learning outcome	The students are expected to have proper knowledge and skills to properly assess impacts of ionizing radiation in the environment. The course gives a thorough introduction to modelling necessary to ensure that decisions on environmental issues give appropriate weight to the exposure, effects and risks from ionizing radiation.
Skills	Student has an overview of the basic risk assessment modelling for non-human biota. Student/trainee is able to use ERICA Tool in risk assessments of ionizing radiation in freshwater, terrestrial and marine ecosystems. Student is able to conduct risk assessment using all three available tiers depending on the results and assessments need.
Knowledge	Student has knowledge and understands the ecosystem approach for the assessment of effects of ionizing radiation on non-human biota. Student has knowledge and understands elements related to environmental management, risk characterization and impact assessment. Student has knowledge and understands underlying principles of risk and impact assessment and characterization, including uncertainties.

Competences	Student is IUR (International Union of Radioecology) certificated ERICA Tool user. Student is able to do risk and impact assessments using ERICA Tool in different cases at national and international scales.	
Lecture details		
	Lectures	**Time (h)**
Theoretical part	Historical context and drivers	1
	The ERICA Integrated approach	1.5
	Transfer dosimetry and effects	1.5
	Structure of the Tool – the tiered system	1
	Registration of information	1
	Transport models	2
	Tiers 1 → 3	2
	Total Hours	**10**
	Laboratory exercises	**Time (h)**
Practical part	Training ERICA Tool (PC obligatory) - Risk and impact assessment on various examples including different ecosystems, reference organisms and radionuclides.	6
	Homework – deliverable to be done on self-chosen case of risk assessment	6
	Total Hours	**12**
Obligatory deliverable	Case study	

Exam			
Obligatory attendance for awarding of certification of course/training participation	Written	Oral	Both
	-	-	-

3. Experimental Radioecology

Course overview – key facts	
Institution:	Norwegian University of Life Sciences (NMBU)
Lecturer(s):	Ole Christian Lind / Lindis Skipperud
Credit value:	5 ECVET/ ECTS
Duration:	2 weeks
Location:	Ås, Norway
Year of entry:	2016
Teaching language:	English
Entry requirement:	English TOFL test
Course details	
Purpose	To educate, train and equip with basic knowledge on radioecology needed in areas of environmental protection, waste management, nuclear facilities, regulatory institutions, etc.
Short description of the course	Radioecology deals with a continuum that starts with releases of radionuclides from a source, continues through the dispersal and retention of the contaminants by various transport and transfer processes, and ends with the determination of dose to be used to assess risks to human populations and to ecosystems.
Learning outcome	The students are expected to have an overview over radioecology and be able to conduct experimental radio-ecological studies. The course gives a thorough introduction to radiochemistry including tracer techniques, radiochemical separation techniques as well as advanced measurement methods that are used in radioecology. In addition to radioactive sources, the course also focuses on species (speciation), transport, mobility, biological uptake and the effect of radiation as well as assessment of environmental impact and risks related to radioactive contamination.
Skills	Have an overview of the field of radioecology. Is able to conduct radioecological studies using tracer techniques, radiochemical separation techniques and advanced measurement methods. Be able to take part in basic preparedness, countermeasures and risk assessment within the topic of radioactive contamination. Can prepare and deliver effective oral and written presentations of technical information and scientific results
Knowledge	Understands and has knowledge on radioactive sources Understands the transport and spreading of radioactive substances in various ecosystems Understands the basis for environmental impact and risk assessments Understands and can evaluate the possible countermeasures and clean-up strategies

Competences	Is able to communicate and cooperate with people working on other subjects Has insight in ethics and risk connected to use of radioactive sources Is able to contribute within national preparedness associated with radioactive contamination

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	Introduction: Speciation of radionuclides in the environment, radioecological aspects Sources; Past, present and future sources of radionuclides in the environment Radiochemical separation techniques Radiochemical separation techniques cont.	6
	Advanced methods	1
	NORM and dose calculation NORM and dose calculations Demonstration of radon measurements	3
	Advanced methods II The Chernobyl nuclear accident	2
	Modeling within radioecology (**NB! students need laptop pc**) Modeling within radioecology	4
	Radioactive particles/Speciation Electron microscopy/Particle identification and characterization (demonstration)	4
	Biological effects of ionizing radiation Assessing impacts of ionizing radiation to man (principles, mechanisms, biomarkers)	2
	Freshwater radioecology I Freshwater radioecology II Radio sensitivity Assessing impacts of ionizing radiation to non-human biota (principles, mechanisms, biomarkers) Introduction to Erica assessment tool Radioecology principles and challenges, including multiple stressors Radioecology principles and challenges, including multiple stressors	7
	The Fukushima accident Radionuclides in the marine environment Radionuclides in the marine environment cont.	5
	Terrestrial radioecology, transfer and countermeasures Preparedness, Environmental security	5

	Case study: Nuclear preparedness Summary of case study Summary of KJM351	5
	Total Hours	**42**
	Laboratory exercises	**Time (h)**
Practical part	Introduction to laboratory exercise Start experiment: Kinetics, CF, Kd. Size- and charge fractionation	3
	Kinetics, CF, Kd: 3-4 hrs measurement Size- and charge fractionation continue	2
	Sequential extractions, step 1-4 Kinetics, CF, Kd: ~24 hrs measurement	4
	Sequential extractions, end step 4, steps 5 and 6	5
	End kinetics, BC, Kd, ~70 hrs measurement Autoradiography Start depuration	3
	End depuration. Size- and charge fractionations, ~96 hrs Autoradiography (read-out)	5
	Total Hours	**22**
Obligatory deliverable	Laboratory report journal Course thesis on topic of choice	
Exam		

	Written	Oral	Both
	Yes	No	No

COURSES BY IRS

1. Basics of Radioprotection

Course overview – key facts	
Institution:	University of Hanover, Institute for Radioecology and Radiation Protection
Lecturer(s):	Dr. Jan-Willem Vahlbruch
Credit value:	1 ECVET/ ECTS
Duration:	4 h
Location:	Online
Year of entry:	2016
Teaching language:	English
Entry requirement:	English TOFL test

Course details	
Purpose	This e-learning module is intended to provide basic knowledge of radioactivity and radiation protection.
Short description of the course	This course teaches the basics of the structure of atoms and nuclei, of ionizing radiation and its interaction with matter. One of the focuses is on the different terms used to describe the effects of radiation exposure on humans.
Learning outcome	The students are expected to know the basic concepts of nuclear physics, like radioactivity and half-time. They will learn the basic characteristics of the different radioactive decay types and are able to understand a decay scheme. The course also focuses on radiation protection, explaining the concepts of radiation dose, absorbed dose, ion dose, dose rate and the biological effect of the different types of radiation.
Skills	Can describe the basics of radiation protection. Can describe the energy spectra of alpha, beta and gamma radiation. Is able to interpret alpha, beta and gamma decay schemes. Is able to describe the atomic structure of matter, as well as provide information on the sizes and proportions in the atom.
Knowledge	Knows the different types of radioactive decays; can explain the formation process and the physical properties of ionizing radiation Understands the meaning of the quantity "activity" Understands the difference between a continuous and a discrete spectrum Understands the different interaction mechanisms of ionizing radiation with matter and the implications for radiation protection Understands the production and spectrum of X-rays Understands the concepts of radiation dose, absorbed dose, ion dose, dose rate Knows the biological effect of the different types of radiation

Competences	Has insight into the risks connected to the use of radioactive sources, and ways of diminishing radiation exposure. Can apply the theoretical knowledge to the field of practical radiation protection.	
Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	The atomic structure of matter	½ h
	Ionizing radiation	½ h
	Radioactivity	½ h
	The energy of ionizing radiation	½ h
	The interactions of radiation with matter	½ h
	X-ray radiation	½ h
	Radiation dose	½ h
	Dose rate	½ h
	Laboratory exercises	**Time (h)**
Practical part	none	
Obligatory deliverable	Moodle test	

Exam			
	Written	Oral	Both
	Yes	No	No

COURSES BY CEA

1. Behaviour of Radionuclides in the Biosphere

Course overview – key facts	
Institution:	French Atomic Energy Commission
Lecturer(s):	Eric Ansoborlo
Credit value:	2 ECVET/ ECTS
Duration:	3 days intensive teaching
Location:	Saclay, France
Year of entry:	2015
Teaching language:	English
Entry requirement:	English TOFL test
Course details	
Purpose	To educate and train with basic nuclear chemistry knowledge on behaviour of radionuclides (RNs) in case of release in the environment.
Short description of the course	Behaviour of radionuclides in the biosphere is mainly dependent on the source of the RNs (authorized or accidental releases) and their speciation in the different media. This initial speciation plays a major role on the transfer of the RNs in the environment and on impact on health . A state of the art on general physic-chemical properties of RNs of interest, their toxicology and radiotoxicology, transfer in the environment (air , soil, water, plants, species), guidance values, analytical methods, treatment of the contamination (decorporation) and remediation and use of thermodynamic databases for speciation will be given.
Learning outcome	The students are expected to have an overview over speciation of RNs of interest in nuclear chemistry and mainly encountered in nuclear industry such as tritium, Cs, Co, I, Sr, actinides (U, Pu). The course gives a basic and general introduction to chemistry, radiochemistry and speciation through different aspects and information available from the Mendeleiev periodic table including an overview of speciation analytical techniques. In addition the course also focuses on general overview of human toxicology and radiotoxicology, transfer and impact on the environment referring to guidance or recommendations given by international organisms such as WHO, IAEA, ICRP and UNSCEAR. Finally a specific focus is given on the role and use of databases such as thermodynamic data.
Skills	Have an overview of the field of RNs speciation including analysis, applied to toxicology and environment Be able to better understanding or conduct any impact studies, and to deal with treatment of contamination (decorporation or remediation) Can prepare and deliver effective oral and written presentations of technical information and scientific results

Knowledge	Understands and has knowledge on chemistry and radiochemistry Understands the basis for environmental impact and risk assessments, and guidance associated Understands and can evaluate the possible countermeasures and clean-up strategies
Competences	Is able to communicate and cooperate with people working on other subjects Has insight in ethics and risk connected to use of radionuclides Is able to contribute within national preparedness associated with radionuclide contamination

Lecture details

	Lectures	Time (h)
Theoretical part	Generalities on the behaviour of radionuclides (RNs) in the biospher	1
	Physico-chemical information from the Mendeleiev periodic table	2
	Speciation of RNs	2
	Generalities on human toxicology and radiotoxicity + guidances	2
	Generalities on the effect of ionizing radiations + guidances	3
	Generalities on the impact of RNs in the environment + guidances	3
	Specific data on RNs of interest (3H, Cs, Co, Sr, I, U, Pu, Po)	5
	Treatment of the contamination in human (decorporation) and in the environment (remediation)	2
	Databases and tools in speciation	2
	Total Hours	22

Obligatory deliverable	Laboratory report journal Course thesis on topic of choice

Exam

	Written	Oral	Both
	Yes (3 hours)	No	No

COURSES BY CTU

1. Hands-on Training in Nuclear Chemistry

Course overview – key facts	
Institution:	Czech Technical University in Prague, Department of Nuclear Chemistry
Lecturer(s):	CTU team with guests
Credit value:	3 ECVET/ ECTS
Duration:	3.5 days e-learning, 3.5 days labwork
Location:	Theory: e-learning (CINCH Moodle), Lab: Prague. Czech Republic
Year of entry:	2012
Teaching language:	English
Entry requirement:	BSc. in Chemistry (minimum)
Course details	
Purpose	Provide necessary background for master/PhD-level non-nuclear chemists and master/PhD students in chemistry (non-nuclear or radiochemistry), necessary for their later enrolment into the general purpose education/training modular courses covering the more specialized fields of their activities at the end-users.
Short description of the course	The theoretical part introduces the attendees to the basics of nuclear chemistry and radiochemistry, covering fundamental principles and procedures. The practical part aims at familiarizing the attendees with the basic principles of work in a radiochemical laboratory and at demonstrating some key aspects and principles given in theoretical part.
Learning outcome	The attendants are expected to have an overview over fundamental theoretical aspects and basic practical work in nuclear chemistry and radiochemistry. The course gives a practical introduction to handling of radionuclides and their solutions, contamination – decontamination aspects of the radiochemical work, separation techniques in radiochemistry, measurement of ionizing radiation, and focuses on connection between theory and practice.
Skills	Work in radiochemistry laboratory Follow substantial work scheme “preparation – measurement – calculation” with respect to radiochemistry practice and radiometric detection Basic application of fundamental NRC principles. Work with open radioactive sources/materials
Knowledge	Knowledge of basic principles of nuclear chemistry. Understanding and knowledge of using and handling of radioactive materials Basic insight of/knowledge about fundamental phenomena behind radiation protection and decontamination routines. Introductory knowledge and understanding of experiments with radioactivity and their setup.
Competences	Is now trained to carry out, understand and plan basic radiochemical work and experiments. Is now able to understand and exchange knowledge in the NRC field; and hold the conversation on the basic NRC technical level. Is able to help in minor laboratory contamination issue or an accident.

Lecture details

	Lectures	Time (h)
Theoretical part	Fundamentals of nuclear chemistry 1 (Structure and properties of atomic nuclei. Classification of radionuclides. Kinetics of radioactive decay. Radioactive equilibria. Binuclear reactions. Yield of nuclear reactions. Natural radioactivity. Radioactive decay chains.)	7
	Fundamentals of nuclear chemistry 2 (Nuclear fission, fission products. Hot atoms chemistry. Szilard-Chalmers system. Radiation chemistry. Actinides and trans-actinides.)	7
	Radiation detection and dosimetry (Interaction of IR with matter. Detection of ionizing radiation (detector types, principles). Dosimetry of ionizing radiation. Radiation protection.)	7
	Total	21
	Laboratory exercises	**Time (h)**
Practical part	Preparation and handling of radioactive solution with defined activity. Opening of contaminated ampoules.	2
	Work in glove box: Liquid-liquid extraction of uranium in the water-organic extractant system.	3
	Decontamination of surfaces	3
	Induced radioactivity – irradiation of silver and deconvolution of complex decay curve.	2
	Radioactive generators: Elution of daughter radionuclide and determination of its half-life.	2
	High-resolution gamma-ray spectrometry, calibration.	2
	Total	14
Optional practical tasks, e.g. **(1-2 per additional day)**	Preparation of the chromatographic column for ion-exchange based Th-Pa radionuclide generator	3
	Liquid scintillation counting, gross alpha and beta measurement	5

Obligatory deliverable	Successful pass of the introductory test of radiation protection. Practical task reports. Presentation of the results.

Exam

	Written	Oral	Both
	Yes. Entrance radiation protection test.	Yes. Short task related oral exam before starting practical work.	

2. Practical Exercises in Radioanalytical Methods

Course overview – key facts	
Institution:	Czech Technical University in Prague, Department of Nuclear Chemistry
Lecturer(s):	CTU team with guests
Credit value:	5 ECVET/ ECTS
Duration:	1 week e-learning, 1 week labwork
Location:	Theory: e-learning (CINCH Moodle), Lab: Prague. Czech Republic
Year of entry:	2016
Teaching language:	English
Entry requirement:	Hands-on Training in Nuclear Chemistry (or equivalent).
Course details	
Purpose	Provide an overview of the applications of nuclear and radiochemistry in analytical chemistry to NRC master and PhD level students and/or to analytical chemists without NRC background working in radioanalytical laboratories.
Short description of the course	The first part of theoretical courses explains the specifics of the separation methods in radiochemistry and reviews the principles of key radioanalytical methods such as e.g. the isotope dilution analysis, sub-stoichiometric dilution analysis, radio-reagent methods, or interaction methods. In the second part, determination of various radionuclides in the environment is reviewed. The lectures / readings are complemented with remote operated RoboLab exercises aimed at the demonstration of the basic principles of some of the methods. The practical part aims at familiarizing the attendees with selected examples of the basic radioanalytical methods, their principles, and also the competencies to correctly perform these methods.
Learning outcome	The attendants are expected to have an overview of fundamental theoretical aspects and basic practical work in the field of radioanalytical applications in nuclear and radiochemistry. The course gives a practical introduction to handling of radionuclides and their solutions, contamination – decontamination aspects of the radiochemical work and focuses on connection between theory and practice. The full outcome depends on additional optional practical tasks.
Skills	Work in analytical radiochemistry laboratory Follow the work scheme “sample collection – sample treatment / separation of analyzed radionuclides – measurement – calculation” with respect to radiochemistry practice and radiometric detection. Advanced application of combined NRC and separation principles. Work with open radioactive sources/materials at analytical level
Knowledge	Basic insight/knowledge of radioanalytical methods, using ionizing radiation in/for analytical purposes, and general methods of determination of the selected radionuclides. Knowledge and understanding of experimental setup and standard radioanalytical procedures.
Competences	Is now trained to carry out and understand radioanalytical work and methods of determination of the selected radionuclides in various types of samples. Is now able to understand and communicate on the basic radioanalytical level having insight into radioanalytical laboratory practice.

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	Separation methods in radiochemistry (Separations in radioactive and trace systems. Extraction methods and chromatography methods - principles, instrumentation. Other separation methods used in nuclear chemistry.)	12+4
	Chemistry of radioactive elements (Cis-uranium radioactive elements, actinoids, transactinoids)	6
	Radioanalytical methods (Indicator methods. Isotope dilution analysis. Radio-reagent methods. Non-activation interaction methods. Activation analysis.	8
	Determination of selected radionuclides (Natural radioactivity. Radioactive decay chains. Determination of selected radionuclides in the environment and/or technosphere.)	8
	Total	**38**
	Laboratory exercises	**Time (h)**
Practical part	Determination of mercury (silver) by sub-stoichiometric analysis	4
	Determination of the solubility product of silver chromate	4
	Determination of magnesium by radiometric titration	4
	Determination of uranium by neutron activation analysis with delayed neutron counting	5
	Determination of ^{226}Ra and ^{222}Rn using emanometry with Lucas chamber or using LSC	5
	Determination of ^{137}Cs in natural waters / Determination of gamma emitters in the environment by high resolution gamma-ray spectrometry.	5
	Plutonium determination / alpha spectrometry;	4
	Radio-immunological analysis (RIA)	5
	Total	**36**

Obligatory deliverable	Successful passing of entrance test of radiation protection. Task protocols. Presentation of the results.

Exam			
	Written	Oral	Both
	Yes. Entrance radiation protection test.	Yes. Short task related oral exam before starting practical work.	

COURSES BY CHALMERS

1. Nuclear Fuel Fabrication

Course overview – key facts	
Institution:	Chalmers University of Technology (Chalmers) - Sweden
Lecturer(s):	Chalmers team with guests
Credit value:	2 ECVET/ ECTS
Duration:	1 day lecture or e-learning, 3.5 days labwork
Location:	Theory: Chalmers, Gothenburg (Sweden) or e-learning (CINCH Moodle), Lab: Chalmers
Year of entry:	2015
Teaching language:	English
Entry requirement:	Basic nuclear chemistry (minimum requirements)
Course details	
Purpose	The course is aimed for a very compact, short introduction and hands-on experience on Nuclear fule fabrication. It can be used as a stand-alone module in a larger Nuclear Chemistry course. It's aim is to provide a hands-on experience on nuclear fuel fabrication via a novel route, namely sol-gel method (while keeping in mind the commercial route of powder processing) to NRC master and PhD level students and/or to analytical chemists with basic NRC background working in radioanalytical laboratories.
Short description of the course	The first part of theoretical course explains the specifics of the conventional nuclear fuel production and reviews the principles of key radioanalytical methods such as e.g. the isotope dilution analysis, sub-stoichiometric dilution analysis, radio-reagent methods as well as the main surface characterization methods. In the second part (the practical part), hands-on work is performed in radiochemical laboratory where the whole process of nuclear fuel fabrication is performed by the student (except minor operations like grinding and cutting). The overall goal is familiarizing the students with work in a real environment, gaining insight on routines and safety of the work place.
Learning outcome	The attendants are expected to have an overview of fundamental theoretical aspects and basic practical work in the field of radioanalytical applications in nuclear and radiochemistry applied on nuclear fuel fabrication. The course gives a practical introduction to the complex process of nuclear fuel application, with the possibility of learning a novel alternative, like the sol-gel method.
Skills	Work in analytical radiochemistry laboratory Follow the work scheme outlined for the purpose. Analyze all the safety aspects of the experiment beforehand with mitigation methods. Advanced application of combined NRC and separation principles. Work with open radioactive sources/materials at analytical level. Work with high temperature oven(s), gases and glove-boxes.

Knowledge	Basic insight/knowledge of radioanalytical methods, using ionizing radiation in/for analytical purposes, and general methods of determination of the selected radionuclides. Knowledge and understanding of experimental setup and standard radioanalytical procedures. Knowledge and understanding of surface characterization methods (XRD/SEM). Knowledge and operation capability of a high temperature oven under certain atmosphere.
Competences	Is now trained to carry out and understand radioanalytical work and methods of fabrication of nuclear fuel via a novel method. Is now trained to carry out and understand the operation of a high temperature oven under certain atmosphere (gas). Is now able to understand and communicate on the basic radioanalytical level having insight into radioanalytical laboratory practice.

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	One lecture with general information about nuclear fuel fabrication.	6
	Total	**6**
	Laboratory exercises	**Time (h)**
Practical part	Internal sol-gel process procedure for microsphere production	2
	Calcination and reduction of the microspheres	4
	Peletization and syntering	4
	Characterization of the resulted pelets	4
	Total	**14**

Obligatory deliverable	Successful passing of entrance test of radiation protection. Task protocols. Presentation of the results.

Exam			
	Written	Oral	Both
	Yes. Entrance radiation protection test.	Yes. Short task related oral exam before starting practical work.	

2. Plutonium Chemistry

Course overview – key facts	
Institution:	Chalmers University of Technology (Chalmers) - Sweden
Lecturer(s):	Chalmers team with guests
Credit value:	1 ECVET/ ECTS
Duration:	1 day lecture or e-learning, 1 day labwork
Location:	Theory: Chalmers, Gothenburg (Sweden) or e-learning (CINCH Moodle), Lab: Chalmers
Year of entry:	2015
Teaching language:	English
Entry requirement:	Basic nuclear chemistry (minimum requirements)
Course details	
Purpose	The course is aimed for a very compact, short introduction and hands-on experience on working with plutonium. It can be used as a stand-alone module in a larger Nuclear Chemistry course. It's aim is to provide a hands-on experience on plutonium chemistry and handling to NRC master and PhD level students and/or to analytical chemists with basic NRC background working in radioanalytical laboratories.
Short description of the course	The first part of theoretical course explains the very complex chemistry of plutonium from production to use. In the second part a very thorough description of analytical methods for plutonium measurements in different sample matices is also given. In the practical part, a hands-on experimental part is performed and it shows how Plutonium can be separated from Americium. The overall goal is familiarizing the students with work in a real environment, gaining insight on routines and safety of the work place.
Learning outcome	The attendants are expected to have an overview of fundamental theoretical aspects and basic practical work in the field of radioanalytical applications in nuclear and radiochemistry applied on plutonium. The course gives a practical introduction to the complex process of separating plutonium from other radionuclides.
Skills	Work in analytical radiochemistry laboratory Follow the work scheme outlined for the purpose. Analyze all the safety aspects of the experiment beforehand with mitigation methods. Advanced application of combined NRC and separation principles. Work with open radioactive sources/materials at analytical level.
Knowledge	Basic insight/knowledge of radioanalytical methods, using ionizing radiation in/for analytical purposes, and general methods of determination of the selected radionuclides (Pu and Am). Knowledge and understanding of experimental setup and standard radioanalytical procedures. Knowledge and understanding of characterization methods.
Competences	Is now trained to carry out and understand radioanalytical work and methods of handling plutonium. Is now able to understand and communicate on the basic radioanalytical level having insight into radioanalytical laboratory practice.

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	One lecture with broad information about plutonium and plutonium chemistry as well as analytical methods.	6
	Total	**6**
	Laboratory exercises	**Time (h)**
Practical part	Separation of Plutonium from Americium via a Solvent extraction route.	4
	Total	**4**

Obligatory deliverable	Successful passing of entrance test of radiation protection. Task protocols. Presentation of the results.

Exam			
	Written	Oral	Both
	Yes. Entrance radiation protection test.	Yes. Short task related oral exam before starting practical work.	

3. Fuel Coolant Interaction

Course overview – key facts	
Institution:	Chalmers University of Technology (Chalmers) - Sweden
Lecturer(s):	Chalmers team with guests
Credit value:	1 ECVET/ ECTS
Duration:	1 day lecture or e-learning, 1 day labwork
Location:	Theory: Chalmers, Gothenburg (Sweden) or e-learning (CINCH Moodle), Lab: Chalmers
Year of entry:	2015
Teaching language:	English
Entry requirement:	Basic nuclear chemistry (minimum requirements)
Course details	
Purpose	The course is aimed for a very compact, short introduction on nuclear accident scenarios, more specifically reactor safety with regard to fuel-coolant interactions. A practical part is included in the course, where the study of the effect of UO2 fuel and liquid metal coolants (e.g. Lead/Bismuth) interaction is studied under different temperatures and atmosphere (gas, e.g. Ar or air). It can be used as a stand-alone module in a larger Nuclear Chemistry course. It's aim is to provide a hands-on experience on analysing and understanding the fuel-coolant interaction to NRC master and PhD level students and/or to analytical chemists with basic NRC background working in radioanalytical laboratories.
Short description of the course	The first part of theoretical course explains the very complex chemistry of a nuclear accident up to severe accidents scenarios with focuss on fuel-coolant interaction. In the practical part, a hands-on experimental part is performed where the effect of UO2 fuel and liquid metal coolants (e.g. Lead/Bismuth) interaction is studied under different temperatures and atmosphere (gas, e.g. Ar or air). The overall goal is familiarizing the students with work in a real environment, gaining insight on routines and safety of the work place.
Learning outcome	The attendants are expected to have an overview of fundamental theoretical aspects and basic practical work in the field of radioanalytical applications in nuclear and radiochemistry applied on nuclear accidents. The course gives a practical introduction to the complex process of analyzing the effects of the temperature and gas has on nuclear fuel.
Skills	Work in analytical radiochemistry laboratory Follow the work scheme outlined for the purpose. Analyze all the safety aspects of the experiment beforehand with mitigation methods. Advanced application of combined NRC and separation principles. Work with open radioactive sources/materials at analytical level. Working with a high temperature oven as well as handling gases.
Knowledge	Basic insight/knowledge of radioanalytical methods, using ionizing radiation in/for analytical purposes, and general methods of determination of the selected radionuclides. Knowledge and understanding of experimental setup and standard radioanalytical procedures. Knowledge and understanding of characterization methods.

Competences	Is now trained to carry out and understand radioanalytical work and methods of handling nuclear fuel. Is now able to understand and communicate on the basic radioanalytical level having insight into radioanalytical laboratory practice.

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	One lecture with broad information about nuclear accident scenarios and fuel-coolants interactions.	6
	Total	**6**
	Laboratory exercises	**Time (h)**
Practical part	The effect of UO_2 fuel and liquid metal coolants (e.g. Lead/Bismuth) interaction is studied under different temperatures and atmosphere (gas, e.g. Ar or air).	4
	Total	**4**

Obligatory deliverable	Successful passing of entrance test of radiation protection. Task protocols. Presentation of the results.

Exam			
	Written	Oral	Both
	Yes. Entrance radiation protection test.	Yes. Short task related oral exam before starting practical work.	

COURSES BY UNKNOWN INSTITUTION

1. Liquid Scintillation Counting

Course overview – key facts	
Institution:	Unknown
Lecturer(s):	Unknown
Credit value:	2 ECVET/ ECTS
Duration:	1 Week
Location:	Unknown
Year of entry:	Unknown
Teaching language:	English
Entry requirement:	'An introduction to radiochemical analysis' or equivalent. International students must achieve IELTS 6.5.

Course details	
Purpose	To educate the cohort with an understanding of liquid scintillation counting, its purpose and how it works.
Short description of the course	This course will cover a range of topics with a thorough overview of quenching including channel ratios method, colour quenching and quench correction by automatic external standard. As well as the theoretical course, a practical element will also be undertaken by the delegates. The course will primarily focus on two radioisotopes C-14 and H-3 which will include the preparation of these quenched standards for use on the course. As the course progresses, other isotopes such as P-32 and I-125 will be analysed in different matrices. In addition, more challenging samples will be investigated such as dual labelled samples, inhomogeneity in samples and the effect of sample volume on counting efficiency.
Learning outcome	Have an overview of liquid scintillation counting including when and why it is used. Be confident in preparing samples for analysis and interpreting data produced. Understanding of quenching and how to account for it. Comfortable handling a range of open sources.
Skills	Prepare and deliver effective written laboratory reports including technical information and scientific discussion. Be comfortable working with others and but take responsibility for individual work.
Knowledge	Understands and has knowledge on chemistry and radiochemistry Understands the basis for alternative analytical measurements
Competences	Able to communicate effectively using correct scientific knowledge. Be able to work effectively and efficiently with other students. Able to contribute to practical experiments and interpret scientific data.

Lecture details		
Theoretical part	**Lectures**	**Time (h)**
	Welcome and Introductory Lecture	2
	Total hours	**2**
	Laboratory exercises	**Time (h)**
Practical part	Preparation of quenched carbon-14 and tritium standards for use on the course	2
	Examination of the pulse height spectra of unquenched and quenched samples of Carbon-14 and Tritium	2
	Quench correction by sample channels ratio (SCR)	2
	Quench correction by automatic external standard (AES)	2
	Colour quenching	2
	Comparison of two scintillators for use with quenched samples	2
	Counting an aqueous solution using tritium	2
	Counting dual labelled samples	2
	Detection of inhomogeneity in counting samples	2
	To determine the dependence of counting efficiency on sample volume	2
	Assay of iodine-125 in milk	2
	Measurement of phosphorous-32 using Cerenkov radiation	2
	A demonstration of problems with may arise due to absorption	2
	Total hours	**26**
Obligatory deliverable	Laboratory Report	

Exam			
	Written	Oral	Both
	Yes	No	No

2. Field work

Course overview – key facts	
Institution:	Unknown
Lecturer(s):	Unknown
Credit value:	2 ECVET/ ECTS
Duration:	1 week
Location:	Unknown
Year of entry:	Unknown
Teaching language:	English
Entry requirement:	'An introduction to radiochemical analysis' or equivalent. International students must achieve IELTS 6.5.

Course details	
Purpose	To develop new skills and apply learning from the classroom to real world problems.
Short description of the course	During the field trip you will gain hands-on experience and carry out guided field exercises and research projects to investigate particular environments.
Learning outcome	Demonstrate advanced level knowledge and understanding of specific processes and conceptual approaches Describe, analyse and explain the results of the fields work, lectures and seminars and relate these to existing knowledge Draw consistent arguments and conclusions based on the results of knowledge gained on the module. Plan, design, execute and report on a short research project with limited guidance. Collect, interpret, evaluate and combine different types of evidence and information. Be responsible and understand the health and safety issues that arise with a field trip.
Skills	Analyse and evaluate independently, a range of research-informed literature and synthesise research-informed examples from the literature into written work. Devise and sustain, with little guidance, a logical and reasoned argument with sound, convincing conclusions. Communicate effectively, arguments, evidence and conclusions using a variety of formats in a manner appropriate to the intended audience. Analyse and evaluate appropriate data and complete a range of research-like tasks with very limited guidance. Evaluate strengths and weaknesses in relation to graduate-level professional and practical skills, acting autonomously to develop new areas of skills as necessary.

Knowledge	Understand the importance of correct storage of samples How to take representative samples Understands the importance of effective and carefully planned sampling
Competences	Is able to communicate and cooperate with colleagues. Understanding of ethics and risk connected with field work and radioactive samples.

Lecture details

	Lectures	**Time (h)**
Theoretical part	Introduction to the field trip and its aims	1
	Itinerary and planning	1
	Health and safety in fieldwork	1
	Introduction to the field area and key concepts	1
	Total hours	**4**
	Laboratory exercises	**Time (h)**
Practical part	In the field	2.5 days
	Analysis of samples	8
	Total hours	**28**

Obligatory deliverable	Group presentation undertaken on field trip (10 minutes), Field trip diary exercise (10 hours), Project write-up (2000 words).

Exam

	Written	Oral	Both
	No	Yes	No

Comment: Allow Monday morning for travel followed by Monday afternoon lectures. 2.5 days in the field followed by an afternoon and Friday morning for analysis of samples. Friday afternoon allocated for travel home.

3. An introduction to Radioisotope Techniques

Course overview – key facts	
Institution:	Unknown
Lecturer(s):	Unknown
Credit value:	3 ECVET/ ECTS
Duration:	1 Week (37 hours contact)
Location:	Unknown
Year of entry:	Unknown
Teaching language:	English
Entry requirement:	International students must achieve IELTS 6.5

Course details	
Purpose	To introduce and educate the cohort to radiochemical analysis and radioisotope techniques in nuclear and radiochemistry.
Short description of the course	This course will cover an introduction to nuclear chemistry and radiochemical techniques. As part of this, methods of measurement including liquid scintillation counting, gamma and alpha spectrometry and statistics will be covered. Čerenkov counting will be studied whilst purity, stability, hazards and control will also be considered. Additional subject areas including the applications in organic chemistry, radiochromatography and autoradiography, applications in biology, analytical techniques and uses of ionising radiation will also be included. As well as the theoretical course, a considerable practical element will also be undertaken by the delegates.
Learning outcome	Understanding of radioisotope techniques including liquid scintillation counting, gamma spectrometry and alpha spectrometry. Knowledge of Čerenkov counting and how it can be detected with scintillation detectors. Applications of radioisotopes in organic chemistry and biology.
Skills	Work safely and efficiently in the laboratory, be confident using the techniques above and be able to interpret scientific data produced from the techniques. Prepare and deliver written documents of technical information and scientific results.
Knowledge	Understands and has knowledge in chemistry and radiochemistry Understands the need and use of the techniques involved, including its uses in other sectors such as medicine, organic chemistry and biology.
Competences	Able to communicate effectively and appropriately with colleagues on the subject matter. Understands the risks and benefits of using radionuclides.

Lecture details		
	Lectures	**Time (h)**
Theoretical part	Introduction to Nuclear Chemistry	2.5
	Introduction to Radiochemical Techniques	1.5
	Methods of Measurement	1
	Liquid Scintillation Counting	1
	Spectrometry	1
	Statistics	1
	Cerenkov Counting	1
	Purity, Storage and Stability	1
	Hazards and Control	2
	Application in Organic Chemistry	1
	Radiochromatography and Autoradiography	1
	Application in Biology	1
	Analytical Techniques	2
	Uses of Ionising Radiation	1
	General Discussion	1
	Total hours	**19**
	Laboratory exercises	**Time (h)**
Practical part	Gamma spectroscopy	2
	Separation of ^{234m}Pa from ^{238}U and measurement of its half-life	2
	Separation of ^{234}Th from ^{238}U	2
	The Determination of low solubilities	2
	Determination of the specific surface area of an insoluble substance	2
	Preparation of ^{14}C-labelled aspirin	2
	Quench corrections in liquid scintillation counting	2
	Determination of volume using dilution technique with a single tritium tracer	2
	Introduction to radioimmunoassay	2
	Total hours	**18**

Obligatory deliverable	Laboratory Report		
Exam			
	Written	Oral	Both
	Yes	No	No