EuCheMS
European Chemical Sciences
Division of Nuclear and Radiochemistry

Heinz W. Gäggeler, Chair
Paul Scherrer Institute
5232 Villigen, Switzerland
heinz.gaeggeler@psi.ch

Jan John, coordinator
Dept Nuclear Chemistry
CTU Prague, CZ
jan.john@fjfi.cvut.cz

Guidelines for Applications for the NRC EuroMaster ***Label***

Summary

These Guidelines provide background of the NRC EuroMaster Label and detailed instructions on how to apply including description of the contents of the application forms. The evaluating body for this Label is the Division of Nuclear and Radiochemistry (DNRC) of the European Association for Chemical and Molecular Sciences (EuCheMS) (http://www.euchems.eu).

After a brief description of the aims, objectives and principles of this quality label in the Preamble, the application Procedure is described that consists in preparation and submission of three documents

- ***Synopsis***
- ***Self-evaluation report*** – Part 1: General Data, and
- ***Self-evaluation report*** - Part 2: Nuclear and Radiochemistry Curriculum Description

and the obligatory appendices describing among others the outline of the study programme, resources available, and academic staff qualifications. For all three documents, forms have been prepared and are available in attachments to this document, as separate documents, or from the CINCH web site (http://www.cinch-project.eu). Applicants that are parts of chemistry units that have already been successfully accredited by ECTNA (The European Chemistry Thematic Network Association; http://www.expe.ectn-assoc.org/) and granted the right to award their graduates the Chemistry Euromaster® Label need to prepare and submit only the NRC-relevant parts of the forms.

As a supporting material, minimum requirements for the EuroMaster in Nuclear and Radiochemistry (NRC EuroMaster) degree are attached to this document (Appendix II). These minimum requirements were defined within the CINCH and CINCH-II - Cooperation in education and training In Nuclear Chemistry – projects supported by the within FP7 Euratom between February 2010 and May 2016. The universities allowed to grant the NRC EuroMaster label to their students will form a network (NRC Network) to promote NRC education in Europe and to organise student exchange and common courses. The last three appendices (Appendix III–V) define technical aspects of the syllabi and/or of the assessment procedure.

Preamble

The primary aims of the NRC EuroMaster are to provide a quality label of the highest standard for a second cycle degree in Nuclear and Radiochemistry (NRC) which will:

- be recognised by other European institutions as being of a standard which will provide automatic right of access (though not right of admission, which is the prerogative of the receiving institution) to chemistry doctoral programmes;
- be recognised by employers as being of a standard which prepares the graduates for employment as professional nuclear and/or radiochemists in the respective industries or in public service;
- meet the educational standards required by the European Chemistry Thematic Network Association (ECTNA).

The objectives of the NRC EuroMaster label are to:

- give European NRC students common knowledge and skills in nuclear and radiochemistry;
- promote the exchange of students, teachers and teaching tools;
- aid the employment of nuclear and radiochemists at a European level.

To achieve this, the following two principles have been combined:

1. the general requirements for the quality label of Chemistry Euromaster® developed and awarded by ECTNA[1];
2. specific requirements regarding the knowledge, skills and competencies in nuclear and radiochemistry in the Minimum Requirements for the EuroMaster in Nuclear and Radiochemistry[2] as developed and defined by the CINCH consortium within a sequence of Euratom supported projects.

It must be made clear at the outset that each institution providing Master-type degree programmes in nuclear and radiochemistry is completely free to decide on the content, nature and organisation of its courses or modules. Chemistry degree programmes offered by individual institutions will thus have their own particular characteristics. The extent to which individual aspects are treated will vary with the nature of specific programmes. The NRC EuroMaster Label is awarded for the validity period specified by the evaluating body and can be renewed for further periods following successful re-evaluation. Applications for renewal will require a much less detailed self-evaluation report.

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[1] Guidelines for Applications for the Chemistry **EUROMASTER**® Label, version 4 – January 2010, ECTNA Label Committee, Brussels, Belgium

[2] CINCH-II Deliverable D1.1, http://www.cinch-project.eu/data/docs/141126_CINCH_II_D1_1_Final.pdf, 26/11/20

Procedure

The first step in the application process is to advise by e-mail the chairman and the secretary of the EuCheMS Division of Nuclear and Radiochemistry (DNRC) that an application will be submitted.

The next step is the preparation of a ***Self-evaluation report*** and a ***Synopsis*** according to the guidelines below. One hard copy of each of these documents is to be submitted to the Chair of the DNRC with all the additional documents that may be required. Electronic versions of all documents in PDF or MS Word compatible format (see below) must also be made available via a (password-protected) web site provided by the applicant. The postal address of the acting DNRC chairman is available at www.euchems.eu/ (navigation: Professional Networks, Division of Nuclear and Radiochemistry). As in March 2016 the contacts are as follows:

Prof. Heinz W. Gäggeler Chair, DNRC EuCheMS c/o Paul Scherrer Institute 5232 Villigen Switzerland e-mail: heinz.gaeggeler@psi.ch	**Prof. Jan John** Secretary, DNRC EuCheMS c/o Czech Technical University in Prague Department of Nuclear Chemistry Břehová 7, 115 19 Prague 1, Czech Republic e-mail: jan.john@fjfi.cvut.cz

All documentation must be in English, which is the working language of the DNRC. A translation of official regulations is, however, not required.

The cover page of the self-evaluation report shall contain the following information:

1. Legal name and full address of the University;
2. Name of the faculty/department/unit responsible for the NRC Masters programme;
3. Name (mother tongue) of the qualification which is the subject of this application;
4. Name and full address (inc. email) of the person responsible for producing the self-evaluation report;
5. Number of ECTS credits of which the degree programme consists;
6. The academic year in which the degree programme was or will be introduced;
7. Entry qualifications for the degree programme.

The following documentation shall be attached to the self-evaluation report:

Appendix 1.	Outline of the study programme.
Appendix 2.	A brief statement on resources available for the programme: laboratories, libraries, ICT, other resources etc. The statement should follow the structure described in the Assessment Group Site inspection suggestions in Appendix IV.
Appendix 3.	Names of the key academic staff (teaching staff) involved in delivering the degree programme. For each member of staff involved in delivering the study programme *Curriculum Vitae* (***not more than one page***) and a publications list covering the last three years shall be provided.
Appendix 4.	Official institutional regulations defining the study programme which is the subject of the application.
Appendix 5.	An example of the Diploma Supplement issued by the institution.

The complete self-evaluation report should be made available in electronic format **as one single pdf file**.

The synopsis consists of the following elements:

1. Name of the unit responsible for the NRC Masters study programme;
2. Name (mother tongue) of the qualification which is the subject of this application;
3. Name and full address (including e-mail) of the person responsible for the self-evaluation report;
4. Number of ECTS credits of which the degree programme consists;
5. The academic year in which the degree programme was or will be introduced;
6. Entry qualifications for the degree programme;
7. Statement of Applicant:
   I (full name, position as head of the institution/department/faculty responsible for the study programme) hereby agree that this (institution/department/ faculty) will, if awarded the NRC EuroMaster label***, recognise Masters degrees in chemistry awarded by other institutions holding the*** NRC EuroMaster ***label as providing automatic right of access (but not of admission) to appropriate chemistry doctoral programmes offered by this (institution/department/faculty).***

The statement shall be signed, stamped and dated by the person making the declaration.

The receipt of the self-assessment report will be acknowledged. The report will be considered by an *ad-hoc* Assessment Group appointed for each case by the DNRC. This group will consist of a Rapporteur and two further experts to deal with the application. The chair of the DNRC shall propose the Rapporteur and the experts (who may, but do not have to, be DNRC members) and shall seek approval of the DNRC committee.

The Assessment Group shall decide the appropriate way of discussing the content of the Application with the Applicant. The possible options are a Site Visit Team inspection and/or a meeting with the representative(s) of the programme at a place different than the seat of the Applicant and/or a Distance/Video-meeting.

Please keep all answers brief and do not exceed the requested page lengths!

Structure of the Self-Evaluation Report

The self-evaluation report is structured according to the following points:

Part 1 GENERAL DATA

I. Judging the Quality of NRC EuroMaster Programmes, "Fitness for Purpose"
II. Study Programme structure
III. Language
IV. ECTS and Student Workload
V. Modules and Mobility
VI. Methods of Teaching and Learning
VII. Assessment procedures and performance criteria
VIII. ECTS Grades (Rankings)
IX. Diploma Supplement
X. Quality Assurance
XI. Employability

Part 2 NUCLEAR AND RADIOCHEMISTRY CURRICULUM DESCRIPTION

NRC applicants that are part of chemistry departments or other higher sections that have already been successfully accredited by ECTNA and granted the right to award their graduates the Chemistry Euromaster® **Label need prepare and submit only the NRC-relevant parts, i.e. Parts 1.I and 2.II and Part 2.**

Part 1 GENERAL DATA

I. Judging the Quality of NRC EuroMaster Programmes: "Fitness for Purpose"

According to the "Budapest Descriptors"[3], second cycle degree programmes should fulfil the following criteria:

1. ***Second cycle degrees in chemistry are awarded to students who have shown themselves by appropriate assessment to:***

   - *have knowledge and understanding that is founded upon and extends that of the Bachelor's level in chemistry, and that provides a basis for originality in developing and applying ideas within a research context;*
   - *have competences which fit them for employment as professional chemists in chemical and related industries or in public service;*

[3] T. Mitchel: The „Budapest" Cycle Level Descriptors for Chemistry, ECTN Association, News June 2005, 6(3)

- *have attained a standard of knowledge and competence which will give them access to third cycle course units or degree programmes.*

2. Such graduates will:

- *have the ability to apply their knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to chemical sciences;*
- *have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on ethical responsibilities linked to the application of their knowledge and judgements;*
- *have the ability to communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously;*
- *have developed those learning skills that will allow them to continue to study in a manner that may be largely self-directed or autonomous, and to take responsibility for their own professional development.*

The "Minimum Requirements for the EuroMaster in Nuclear and Radiochemistry (NRC EuroMaster**)" require in addition to these general requirements that on completion of the** NRC EuroMaster **program the student should have the following Knowledge, Skills and Competencies:**

1. Subject Knowledge:
- *Recall the underlying principles of nuclear and radiochemistry;*
- *Explain the main practical aspects of nuclear and radiochemistry;*

2. Skills and Competencies:
- *Perform essential radiochemistry related calculations;*
- *Work safely in a radiochemistry laboratory;*
- *Perform chemical reactions including radionuclides;*
- *Use a range of radiation measurement techniques;*
- *Handle radioactive materials safely;*
- *Identify the hazards pertaining to a radionuclide.*

The Descriptor details the outcomes of a Masters programme in nuclear and radiochemistry. Applicants are asked to provide a statement which defines the aims and the profile of the programme. **Such a statement will describe the elements of the programme *with reference to the above descriptor and show how the terms of the Descriptor are met*. It will also describe the skills and competences which the graduate will have at the end of the programme.** In addition, meeting the Minimum Requirements should be summarised both qualitatively and quantitatively (percentage of the required topics covered).

This statement defines the **purpose** of the programme, and the evaluation process will then be designed to find out whether the programme, as set out in detail in the application, is **fit for the purpose** for which it is designed. In evaluating the statement, the DNRC EuCheMS and its experts will look for evidence of how your programme achieves the outcomes as defined by the Budapest Descriptor and as required by the Minimum Requirements.

Please do not use more than one page.

II. Study Programme

Please provide details of the study programme (the term "study programme" refers to the complete degree programme), using Table 1, with the designations of the modules which the student is expected to study in each semester or year. Alternatively you may use any standardised tables in use at your institution that give equivalent information.
Please provide additional details on the NRC courses in Part 2 of the report using tables provided in the "Application for the label of EuroMaster in Nuclear and Radiochemistry" form in Appendix I (also available in electronic format from http://www.cinch-project.eu/index.php?art=docs).

If in doubt when filling in this form, you may like to consult the "Sample application package" available at (http://www.cinch-project.eu/data/docs/Application%20 DNRC_CTU_final.pdf).

The term "module" used throughout these tables refers to defined sub-units of the study programme. These may be for example an individual lecture course or a lecture course in combination with a practical course. This term may also refer to sub-units involving a combination of two or more courses. Modules should be designated as compulsory or optional.

Explanatory footnotes should be provided giving information on the range and manner of choice for the student in selecting the optional modules.

Table 1 is divided according to years 1 and 2 (corresponding to 120-credit programmes). If the programme which you are submitting for consideration has less than 120 credits, please modify the Table 1 accordingly.

In Table 1, the term "self-study" refers to all elements of the learning process which do not involve face-to-face "contact" with academic (teaching) staff, such as study at home, study in the library, preparation of reports, preparation of presentations, preparation for examinations etc.

Please also supply the following information:

2.1 The total number of modules/assessed course units which the study programme comprises.
2.2 How students are assisted with their choice of modules/course units.
2.3 How students who require "bridging modules" are dealt with.

Please keep your answer as brief as possible!

TABLE 1

a) YEAR 1 (TOTAL 60 CREDITS)

Number of hours of study corresponding to 1 ECTS credit:

Module title	**Credits (ECTS)**	**Compulsory (C) or Optional (O)**	**Total Hours**				**Pre-requisites**
			Lectu re	Practic al	Other	Self-stu dy	

b) YEAR 2: (TOTAL 60 CREDITS)

Module title	**Credits (ECTS)**	**Compulsory (C) or Optional (O)**	**Total Hours**				**Pre-requisites**
			Lecture	Practical	Other	Self-study	

III. Language

Please make a short statement on the language competences which you expect of graduates and how it is reached. You may wish to include information on the following points:

- 3.1 Language of instruction
- 3.2 Textbooks
- 3.3 Student presentations
- 3.4 Optional language courses etc.

Please do not exceed half a page of text!

IV. ECTS and Student Workload

Please provide the following information:

- 4.1 How many weeks per year do you expect your students to spend on academic study?
- 4.2 How many hours per week is the average student expected to spend on academic study?
- 4.3 How student workload was estimated when assigning credits to modules/course units.
- 4.4 Mechanisms used for continuous student feedback on actual workload and for the use of this feedback to correct the structure of programmes where necessary

Please do not use more than half a page of text!

V. Modules / Course Units and Mobility

Please provide the following information:

- 5.1 Is mobility possible in Year 1 and/or Year 2?
- 5.2 Are certain modules/course units defined as being "non-transferable", i.e. they must be taken at the home institution? If so, please list these modules/course units.
- 5.3 Are students positively encouraged to do part of their work abroad?
- 5.4 Please provide a brief account of the way in which mobility is organised (persons responsible, how the ECTS Learning Agreement is dealt with, how

recognition of credits gained abroad is dealt with, how such credits are documented in the Diploma Supplement).

Please keep your answer as brief as possible!

VI. Methods of Learning and Teaching

Please briefly describe your methods of teaching and learning. You may wish to include information on the following points:

6.1 Tutorial system
6.2 Problem-solving classes
6.3 Multimedia teaching techniques
6.4 Master Thesis
6.5 Industrial placement which carries credits.
6.6 Committees with student participation

Answers to this point should not exceed one page of text!

VII. Assessment procedures and performance criteria

Please summarise the assessment procedure involved in this study programme. You may wish to include information on the following points:

7.1 Is assessment carried out with examinations at the end of each term or semester?
7.2 Are "comprehensive examinations" at the end of the study programme used? If so, how are they organised and how many credits do they carry (individually and in total)
7.3 Is more use made of written or oral examinations?
7.4 For written examinations: is the marking checked by a second examiner?
7.5 For oral examinations: how many persons are involved as examiners or note-takers in each examination?
7.6 What is the minimum and maximum time allowed for written examinations?
7.7 Are examination papers marked anonymously?
7.8 Is the student provided with feedback, for example in the form of "model answers"?
7.9 Is there an examination board which approves written examinations or is this the individual responsibility of the teacher(s) concerned?

The answers to this point should not exceed one page of text!

Please describe how the Masters thesis is supervised and assessed, with particular respect to the criteria for assessment.

The answer to this point should not exceed half a page of text!

VIII. ECTS Grades (Rankings)

Please supply the following information:

8.1 Is the ECTS ranking system used for a) mobile and b) home students?
8.2 How are ECTS rankings assigned and by whom?

Please keep your answer as brief as possible!

IX. The Diploma Supplement

Please supply the following information:

9.1 Is each graduate issued with a European Diploma Supplement (http://ec.europa.eu/education/policies/rec_qual/recognition/ds_en.pdf) automatically? If not, describe the method of issue.
9.2 In which language(s) is the Diploma Supplement issued?

Please keep your answer as brief as possible!

X. Quality Assurance

The NRC EuroMaster designation is a quality label and involves the formation of one of the trans-national European quality assurance networks in the emerging European Higher Education Area. Quality assurance (or quality enhancement) is also an internal matter, and thus the applicant is asked to describe briefly the internal quality assurance procedures of the faculty/department and (if these have a direct impact on the faculty/department) of the institution. Please refer in particular to student involvement in such procedures. This section should also include information on the following points:

a) What are the admission criteria for students coming from other institutions within the country or from abroad?
b) Who is responsible for dealing with their admission?
c) What is the average time for completion of this degree course?
d) Do new members of the academic staff (teaching staff) have to undergo training in teaching and supervision of research?
e) How is teaching quality evaluated?
f) Do evaluations of teaching quality have consequences?

The answers to this point should not exceed one page of text!

XII. Employability

Please provide brief answers to the following questions: **Please supply evidence if available**.

11.1. Which forms of employment do students with this qualification enter?
11.2. What percentage of your graduates continue their studies to a doctoral programme in your or other institutions?

The answer to this point should not exceed half a page of text!

Appendix I

Application Forms for the label "EuroMaster in Nuclear and Radiochemistry" (NRC EuroMaster**) – Part 2 of the Self-Evaluation Report**

Available from
http://www.cinch-project.eu/index.php?art=docs

- in MS Word format at
  http://www.cinch-project.eu/data/docs/NRC_EuroMaster_Application_Forms_3_NRC_Courses.docx
- or in PDF format at
  http://www.cinch-project.eu/data/docs/NRC_EuroMaster_Application_Forms_3_NRC_Courses.pdf

Appendix II

MINIMUM REQUIREMENTS FOR THE EUROMASTER IN NUCLEAR AND RADIOCHEMISTRY (NRC EuroMaster)

In the following, minimum requirements for the EuroMaster in Nuclear and Radiochemistry (NRC EuroMaster) degree are given. Universities fulfilling the minimum requirements are allowed to grant the NRC EuroMaster label to their students. These universities will form a network to promote NRC education in Europe and to organise student exchange and common courses.

Aim

The primary aims of the NRC EuroMaster qualification are to provide a second cycle degree in Nuclear and Radiochemistry (NRC) of the highest standard which will:

- be recognised by other European institutions as being of a standard which will provide automatic right of access (though not right of admission, which is the prerogative of the receiving institution) to chemistry doctoral programmes.
- be recognised by employers as being of a standard which fit the graduates for employment as professional nuclear and/or radiochemists in the respective industries or in public service
- meet the educational standards required by the European Chemistry Thematic Network Association (ECTNA) to award the graduates the Chemistry Euromaster® Label.

Further aims of the NRC EuroMaster qualification are:

- to give the European NRC students good common knowledge and skills in nuclear and radiochemistry.
- to promote the exchange of students, teachers and teaching tools and help employment of nuclear and radiochemists at a European level.

The aims of the NRC EuroMaster is to give the European NRC students good common knowledge and skills in nuclear and radiochemistry and thereby harmonise, at a minimum level, the teaching programs in European universities. A further aim of the NRC EuroMaster in to promote the exchange of students, teachers and teaching tools and help employment of nuclear and radiochemists at a European level.

Intended learning outcomes

On completion of the NRC EuroMaster program the graduate should have the following specific knowledge, skills and competencies in the field of nuclear and radiochemistry:

1 Subject knowledge:
- Recall the underlying principles of nuclear and radiochemistry
- Explain the main practical aspects of nuclear and radiochemistry

2 Skills and Competencies:
- Perform essential radiochemistry related calculations
- Work safely in a radiochemistry laboratory
- Perform chemical reactions including radionuclides
- Use a range of radiation measurement techniques
- Handle radioactive materials safely
- Identify the hazards pertaining to a radionuclide

Granting system of NRC EuroMaster label

The NRC EuroMaster label is granted to the universities by the Nuclear and Radiochemistry Division of the European Association for Chemical and Molecular Sciences (EuCheMS NRC Division). The Division will evaluate the candidate universities by comparing their NRC curricula to the minimum requirements set in this document. If the NRC curriculum fulfils the requirements by 90% the university will be given the right to grant NRC EuroMaster to their NRC students and the university will become a member in the NRC EuroMaster Network.

Structure of EuroMaster in Nuclear and Radiochemistry (NRC)

The Masters program should contain at least 60 ECTS credit units (50% in case of 120 ECTS cu Masters program) studies in nuclear and radiochemistry in the following way:

BSc in chemistry (first cycle)		180–240 cu[1]
Compulsory studies in nuclear and radiochemistry (of which at least 10 cu exercises)	minimum	25 cu
Optional studies in nuclear and radiochemistry	minimum	5 cu
Project work and Masters thesis in nuclear and radiochemistry	minimum	30 cu
Elective studies – rest up to the total due for the second cycle		rest
In total (second cycle)		90–120 cu[2]
In total		270–360 cu

For Masters programs having other volume than 120 ECTS credit units the workload of nuclear and radiochemistry studies should be equivalent to at least 60 ECTS credit units.

1 "The framework of qualifications for the European Higher Education Area" adopted at The Bergen Conference of European Ministers Responsible for Higher Education, Bergen, Norway, 19-20 May 2005

2 The Bologna Process - Conference on Master-level Degrees: Conclusions and Recommendations of the Conference. Helsinki, Finland, March 14 - 15, 2003

COMPULSORY STUDIES ON NUCLEAR AND RADIOCHEMISTRY (25 cu)

In the following topic areas (1-6) and under them topics that need to be covered are listed. The topic areas do not refer to any specific courses which can be organised in various ways. Teaching can consist of lecture and laboratory exercise modules as well as of exams. If a part of the topics listed below are taught already at the bachelor's level they do not need to be repeated at the Masters level.

1. **Radioactivity, radionuclides and radiation – principles of nuclear physics to radiochemists**

Aims:

To give the students the basic knowledge in nuclear physics to understand the nature of radioactivity, reasons for stability/instability of nuclides, modes of radioactive decay processes, types of radiation emitted in radioactive decay processes and the rate of radioactive decay and to acquire the skills needed to apply this knowledge.

Topics:

- structure of atom and nucleus, nucleons
- nuclides, radionuclides, isotopes, isobars, nuclide charts
- types and origin of radionuclides (natural decay series, primary primordial radionuclides, secondary natural radionuclides, cosmogenic radionuclides, artificial radionuclides, formation and occurrence)
- stability of nuclei (stable nuclides vs. radionuclides, masses on nucleons, mass deficiency, binding energy, binding energy per nucleon, proton to neutron ratio, energy valley – semi-empirical equation of mass – beta parabola, fission, fusion)
- modes of radioactive decay
    - fission (process, spontaneous vs. induced, energetics, formation of fission products, fission yields, fissionable/fissile, nature of fission products)
    - alpha decay (process, energetics, alpha recoil, decay to daughter's ground state, decay to daughter's exited state, formation of alpha spectrum)
    - beta decay (processes in beta minus decay, positron decay and electron capture, energetics, beta recoil, neutrino/antineutrino, distribution of decay energy, formation of beta spectrum, beta parabola for odd/even nuclides, secondary processes (gamma decay, formation of Auger electrons and X-rays, annihilation of positrons)
    - internal transition (gamma decay, internal conversion, energetics, gamma recoil, metastable isomeric states, formation of gamma spectrum)
- rate of radioactive decay, half-life, activity units, activity concentrations vs. specific activity, activity vs. count rate, determination of half-lives, equilibria in successive decay processes
- isotopic exchange - isotope effects

2. Radiation safety

Aims:

To give the students the basic knowledge and skills on the health effects of radiation, principles of radiation safety, radiation dose and dose rate measures, measurement and calculation of radiation doses, EU and national legislation, safe practices in radionuclide laboratories and safe handling and disposal of radioactive waste from radionuclide laboratories. This topic area, including related exercises, should be completed before or in parallel with laboratory exercises with radionuclides.

Topics:

- types of radiation and their absorption processes by matter, range
- radiation safety measures and their units (absorbed dose, equivalent dose, effective dose etc.)
- effects of radiation on DNA in cells
- health effects of radiation
  - direct somatic effects
  - stochastic effects (cancer, genetic effects)
- principles of radiation safety (justification, optimisation, protection of individuals)
- radiation safety organisations and their recommendations and regulations
  - EU, IAEA, ICRP
  - national authorities, laws, decrees and recommendation, licensing
- estimation and measurement of radiation doses
- radiation safety practices, safe working habits in radionuclide laboratories and with radiation sources
  - sealed sources, protection against external exposure
  - open sources, protection against internal exposure
- safe handling and disposal of radioactive waste from radionuclide laboratories
- measures during/after exceptional events

3. Detection and measurement of radiation

Aims:

To give the students basic knowledge on interaction processes of radiation with matter as a basis for radiation detection, basic instrumentation in radiation detection, detector types and formation of electric pulses in them, interpretation of various spectra, energy resolution and energy and efficiency calibrations. To give students basic skills to measure radiation with most typical radiation measurement devices, and to properly handle and evaluate the measurement data.

Topics:

- interaction processes of radiation with matter (ionisation, scattering, excitation, formation of electromagnetic radiation, nuclear reaction)
    - alpha
    - beta
    - gamma
    - neutrons
- basic instrumentation in radiation measurements
- pulse counting vs. spectrometry
- pulse rate → counting efficiency → activity
- factors affecting counting efficiency (detector efficiency, absorption, geometry, self-absorption, backscattering, dead-time)
- energy resolution
- detectors for radiation measurement:
    - gas ionisation detectors
    - solid and liquid scintillators
    - semiconductor detectors
- statistics and uncertainty calculations in radiometric measurements
- interpretation of gamma, alpha, beta and X-ray spectra
- energy and efficiency calibrations
- liquid scintillation counting
- radiation imaging (autoradiography, fission and alpha track counting etc.)
- background formation and subtraction
- quality control in radiation measurements
- mass spectrometric measurement of radionuclides

4. Chemistry and analysis of radionuclides

Aims:

To give the students basic knowledge on the chemical properties of most important radionuclides and the chemical methods used for their separation from various matrices. To show how chemical properties and speciation affect the behaviour of radionuclides in natural and anthropogenic systems. To give the students basic skills of the chemical methods used to separate radionuclides from various matrices.

Topics:

- chemistry (oxidation states, solubilities, complex formation, hydrolysis, compounds), nuclear characteristics (half-lives, decay modes, emitted radiation) and measurement techniques of the most important radionuclides
    - natural radionuclides (e.g. U, Th, Ra, Po, Pb)
    - fission products (e.g. Cs, Sr, Tc, I, Cs etc.)
    - activation products (e.g. Ni, Fe, Co, Mn)
    - tritium and radiocarbon
    - transuranics (e.g. Np, Pu, Am, Cm)

- special characteristics of the chemistry and separations of radionuclides (trace concentrations, radiation, use of carriers, adsorption of radionuclides)
- needs and principles of radiochemical separations (alpha, beta and EC decaying radionuclides with no detectable gamma emissions, gamma emitting radionuclides of very low activities)
- analytical methods used in radionuclide separations (precipitation, ion exchange, solvent extraction, extraction chromatography)
- yield determination and counting source preparations
- separation of long-lived radionuclides for mass spectrometric measurement
- sampling and sample pretreatment methods
- speciation analysis of radionuclides
- hot-atom chemistry

5. Nuclear reactions and production of radionuclides

Aims:

To give the students basic knowledge of nuclear reactions and production of radionuclides as well as of nuclear power reactors. To give basic skills in calculation of radionuclide production yields in particle irradiations.

Topics:

- interaction processes of particles with nuclei
- types of nuclear reactions and models
- coulombic barrier
- energetics of nuclear reactions
- kinetics of nuclear reactions
- cross-sections
- excitation functions
- induced fission
- types of particle accelerators
- production of radionuclides in cyclotrons
- production of radionuclides in reactors
- radionuclide generators
- principles and uses of nuclear power reactors

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6. Exercises (laboratory and calculation exercises) (at least 10 cu)

a) Calculation exercises:

Aims:

To give the students skills to calculate activities, their uncertainties, calculate or estimate radiation doses, calculate irradiation yields and to use nuclide chart and data bases.

Topics:

- use of nuclide chart and data bases
- calculation of activities based on half-life data, including radiochemical equilibria
- calculation of irradiation yields based on cross sections and projectile flux
- calculation of irradiation doses
- calculation of required shielding for radiation protection
- uncertainty calculation in activity measurements
- conversion of count rates to activities

b) Laboratory exercises:

Aims:

To give the students skills for safe handling of open and sealed radioactive sources and to safely dispose of radioactive waste from radionuclide laboratories, use of radiation dose meters and instruments to detect contamination, basic skills to detect and measure gamma and beta radiation using common radiation measurement techniques and to separate radionuclides from aqueous and solid samples using common radiochemical separation methods.

Topics:

- detection of surface contamination for radiation safety
- use of radiation dose meters for radiation safety to measure total dose and dose rates
- measurement of radiation with a simple detector, such as Geiger tube (e.g. dead-time, absorption of beta radiation, counting geometry etc.)
- measurement of radiation with a LSC
- measurement of radiation with a gamma spectrometer - energy calibration, interpretation of gamma spectra
- separations of radionuclides using various methods, such as precipitation/coprecipitation, ion exchange chromatography, solvent extraction and/or extraction chromatography

Recommended laboratory exercises:

A more comprehensive list of laboratory exercises is given here as a recommendation.

- detection of planar contamination for radiation safety
- use of radiation dose meters for radiation safety to measure total dose and dose rates
- measurement of radiation with a Geiger tube (e.g. determination of absorption curve for beta radiation, determination of dead-time, effect of counting geometry on observed counting efficiency)

- determination of half-life (determination of the half-life of a short-lived radionuclide, such as ^{137m}Ba, obtained from a generator)
- single channel exercise with a solid scintillation detector (measurement of the gamma spectrum of a gamma emitting radionuclide, such as ^{137}Cs, measurement of a standard and an unknown sample on the selected peak region, calculation of the activity of the unknown sample, determination of energy resolution)
- gamma spectrometry with a solid scintillation detector (energy calibration, determination of a sample containing few unknown radionuclides, identification of these radionuclides, interpretation of the gamma spectrum)
- gamma spectrometry with a semiconductor detector (energy calibration, determination of a sample containing unknown radionuclides, identification of these radionuclides, interpretation of the gamma spectrum)
- alpha spectrometry (separation of an alpha emitter from environmental or waste sample using radiochemical separation techniques, preparation of the counting source, measurement of the alpha spectrum, calculation of the activity)
- beta counting with LSC (quenching curve determination, separation of a beta emitter from environmental or waste sample using radiochemical separation techniques, preparation of the counting source, measurement of the sample for the activity determination)
- practice in working behind shielding or in a glove box, is possible with higher levels of activity
- synthesis of a radiolabelled compound
- radiochemical separations using precipitation, ion exchange, solvent extraction and extraction chromatography
    - separation of beta emitting radionuclides (e.g. ^{90}Sr)
    - separation of alpha emitting radionuclides (e.g. $^{234,235,238}U$)
    - separation of EC decaying radionuclides (e.g. ^{55}Fe)

OPTIONAL NRC STUDIES (minimum 10 cu)

Optional studies consist of several modules on various application fields of nuclear and radiochemistry. Examples of such modules are given below. The fields of the courses are recommended to closely link with the actual research field/s of the unit giving the teaching so that the teaching and research are closely connected and best available researchers are giving the courses at their specialty areas. If possible, the courses may also contain laboratory exercises.

7. Chemistry of the nuclear fuel cycle

Topics:

- uranium ores
- extraction of uranium from ore minerals
- mill tailings and their disposal

- purification of raw uranium products
- enrichment of ^{235}U
- production of uranium fuel for power reactors
- use on uranium fuel in power reactors
- power reactor types
- water chemistry of nuclear power reactors
- types of nuclear waste and their formation processes
- management and final disposal of nuclear waste
- reprocessing of spent nuclear fuel
- decommissioning of nuclear facilities
- behaviour of nuclear waste in geological final repositories

8. Radiopharmaceutical chemistry

Topics:

- production of radionuclides
    - in cyclotrons
    - in nuclear reactor
    - with radionuclide generators
    - radionuclidic purity
    - target chemistry
- radiopharmaceutical chemistry
    - types of organic molecules and other compounds to be labelled
    - labelling chemistry of ^{11}C
    - labelling chemistry of ^{18}F
    - radioiodinations (^{123}I and ^{124}I)
    - labelling chemistry of metal radionuclides (^{68}Ga, ^{111}In, ^{64}Cu, ^{99m}Tc)
    - radiochemical purity
- quality control and regulatory issues
- PET and SPECT imaging
    - instrumentation
    - pharmacokinetics and modelling
- applications in
    - diagnostics (oncology, cardiology, neurology and psychiatry, gene expression and cell trafficking)
    - drug development
    - medical research
    - therapeutics

9. Environmental radioactivity – radioecology

Topics:

- description of environmental compartments (geosphere, biosphere, atmosphere)

- sources of radionuclides in the environment
    - natural
    - artificial
- behaviour of radionuclides in
    - the air
    - natural waters
    - soils and sediments
    - biota
- speciation and tracer techniques
- mobility and bioavailability studies
- environmental impact and risk assessment
- transfer processes of radionuclides in the environment and in food chains
- modelling of transfer processes
- countermeasures and preparedness

10. Chemistry of actinides and transactinides

Topics:

- natural actinides
- production/formation of actinides in nuclear explosions, nuclear reactors and accelerators
- electronic structure
- ionic radii
- oxidation state
- major chemical forms
- disproportionation
- hydrolysis and polymerisation
- complex formation
- oxides and other important compounds
- chemistry of U, Th, Np, Pu and Am
- speciation of actinides
- separations
    - analytical
    - industrial (PUREX etc.)
- production of transactinides - extension of the periodic table
- chemical properties of the transactinides

11. Chemistry of radionuclides in the geosphere related to final disposal of spent nuclear fuel or high-level waste

Topics:

- management of spent nuclear fuel (SNF)
- reprocessing of nuclear fuel, production of high-level waste (HLW)

- encapsulation of SNF/HLW
- geological disposal of SNF/HLW
- dissolution/leaching of radionuclides from SNF/HLW
- forms of radionuclides in SNF/HLW
- forms of dissolved radionuclides in the repository environment
- analytical methods for radionuclide speciation
- functions and long-term behaviour of buffer materials (e.g. bentonite)
- migration of radionuclides in geosphere
- sorption of radionuclides in minerals
- diffusion of radionuclides into geological matrix

12. Radiation chemistry

Topics:

- Irradiation methods
    - Types of irradiation sources and devices
    - Dosimetrics
    - Effects of irradiation geometry, thickness of the target etc.
    - Use of data basis and related computer programmes
- Reactions in radiation chemistry in various materials
    - Basic reactions, formation of intermediates, excited states, ions, electrons and radicals
    - Reaction of intermediates, formation of stable products
    - Radiation chemical yields
    - Kinetics of radiolysis
    - Reactions in water and water solutions, polymers, metals, nuclear fuel, nutrients, cells etc.
- Analytical methods used in radiation chemistry
- Application of radiation chemistry
    - radiation sterilisation of medical equipment
    - radiation sterilisation of food stuffs
    - polymerisation and polymer functionalisation
    - etc.

13. Nuclear and radioanalytical methods

Topics:

- Radioimmunoassay (RIA)
- Neutron activation analysis (NAA) – instrumental and radiochemical
- Isotope dilution analysis
- Radiodating methods (^{14}C-dating, ^{210}Po-dating etc.)
- Radiometric titration
- Use of nuclear and radioanalytical methods in industry

Appendix III

ECTS Specification for the Module Unit Descriptions / Syllabi

- Course title
- Course code
- Type of course
- Level of course
- Year of study
- Semester/trimester
- Number of credits allocated (student workload based)
- Name of lecturer
- Objective of the course (expected learning outcomes and competences to be acquired)
- Prerequisites
- Course contents
- Recommended reading
- Teaching methods
- Assessment methods
- Language of instruction

Appendix IV

Suggested Topics of Discussion Between the Assessment Group and the Representative(s) of the Applicant / Schedule for Site Visit (if applicable)

Evening prior to visit: Arrival of experts and internal discussion to prepare for visit.
Visit

09:00 **Discussion with those responsible for the programme, together with one or more representatives of the institution's leadership**
Topics: Position of the chemistry department within the institution; profile and development of the department from the point of view of the institution's leadership; research profile of the department; personnel development; equipment situation; quality assurance in the department and the institution.

09:30 Break, internal discussion

09:45 **Discussion with those responsible for the programme**
Topics: Degree profile; curriculum; teaching and learning methods; student advisors; examinations; student success (dropout rate etc.); employability.

10:30 Break, internal discussion

10:45 **Discussion with members of the teaching staff**
Topics: Curriculum; teaching and learning methods; student advisors; staff development.

11.30 **Discussion with students**
Topics: Degree profile; curriculum; content, organisation and delivery of the programme; possibilities for obtaining advice; examinations; working conditions; studies abroad.

12.15 Break, internal discussion

12.30 **Tour of the institution**
Dependent on the wishes of the experts.

13.15 Lunch break with snack, internal discussion

14.15 **Final discussion with those responsible for the programme**
Topics: Results of the day's discussions, recommendations on possible modifications to the programme.

15.00 End of visit

Appendix V

NRC EuroMaster **Assessment Group Site Inspection suggestions**

Below, several technical recommendations are listed that should be discussed between the Assessment Group and the representative(s) of the Applicant during the negotiation phase / Site Visit. These recommendations are based on the ECTNA Chemistry Euromaster® *standards and they are also normal within the ACS. The radiation safety and instrumentation requirements have been added in the extent approved by the CINCH consortium. The result of the discussion shall be noted in the Site Visit Report.*

An approved program should have suitable classrooms, teaching laboratories, research, office, and common space that is safe, well-equipped, modern, and properly maintained, e.g.

- Chemical laboratories should have properly functioning fume hoods, safety showers, eyewashes, first aid kits, and fire extinguishers must be readily available. Construction or renovation of laboratory facilities must conform to the regulations and national norms.
- Radiochemical laboratories should have…….
- Faculty and student research laboratories should have facilities appropriate for the type of work conducted in them. These facilities should permit maintaining experimental arrangements for extended periods of time during ongoing research projects.
- The program should have access to support facilities such as machine, electronic, and glass fabrication shops to support both teaching and research.

The characterisation and analysis of chemical systems requires an appropriate suite of modern chemical instrumentation and specialised laboratory apparatus to support undergraduate instructional and research missions.

- Instrumentation should be appropriate, modern, of high quality and properly maintained.
- The program should have resources for maintenance and upkeep of this instrumentation, including knowledgeable support staff.

Computational Capabilities and Software

The ability to compute chemical properties and phenomena complements experimental work by providing understanding and predictive power. Students should use computing facilities and computational chemistry software in their course work and research.

Chemical Information Resources

The vast peer-reviewed chemical literature must be readily accessible to both faculty and students. Historically such access came through a good library providing monographs, periodicals, and facilities for database searches. Electronic access has changed the function of libraries as physical repositories. An approved program must provide students with the following minimum chemical information resources:

- An approved program must provide access to no fewer than 14 major current journals in either print or electronic form. At least three must come from the general area, and at least one must come from each area of analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, physical chemistry, and chemistry education. In addition, the library (or IT) should provide access to journal articles that are not readily available by a mechanism such as interlibrary loan or document delivery services. If primary student access is electronic, cost or impractical times for access should not limit it unduly.
- Students must have print or electronic access to *Chemical Abstracts* (SciFinder), including the ability to search and access full abstracts, or similar tool (CrossFire, Web-of-Knowledge, Scopus etc.).

Chemical and Radiation Safety Resources
The program must be conducted in a safe environment that includes:

- adherence to valid regulations regarding hazardous waste management and laboratory safety including, but not limited to, development of a written chemical hygiene plan and maintenance of proper facilities and personnel for chemical waste disposal,
- safety information and reference materials, such as material safety data sheets (MSDS), and
- personal protective equipment readily available free of charge to all students and faculty.