EUROPEAN COMMISSION
Community Research

SEVENTH FRAMEWORK PROGRAMME

CINCH

CINCH

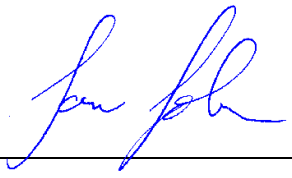
(Contract Number: FP7-CA-249690)

DELIVERABLE D4.3

Joint general purpose education/training course "Chemistry of the Nuclear Fuel Cycle"

Lead Beneficiary: **ENSCP**

Due date of Deliverable: **M30** Finalised on: **31/01/2013**

Authors:	Gérard COTE	
For the Lead Beneficiary	**Reviewed by Workpackage Leader**	**Approved by Coordinator**
Gérard Cote 	**Teodora Retegan** 	**Jan John** 

Start date of project: **01/02/2010** Duration: **36 Months**

Project Coordinator: Jan John

Project Coordinator Organisation: CTU in Prague Revision: (0)

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Seventh Framework Programme		
Dissemination Level		
PU	Public	**X**
RE	Restricted to a group specified by the partners of the CINCH project	
CO	Confidential, only for partners of the CINCH project	

EXECUTIVE SUMMARY

Joint general purpose education/training course *Chemistry of the nuclear fuel cycle* was organized at ENSCP in Paris. The course was aimed at master/PhD students in chemistry, physical chemistry and radiochemistry, with the purpose to allow them to discover the chemistry and the physics necessary at the various stages of the nuclear fuel cycle, from the front-end to the back-end and thus to attract them in the various careers offered by the industrial end-users. The course *Chemistry of the nuclear fuel cycle* is characterized by a voluntarism where industrial R&D, education and engineering are intimately involved. As a result, the course consisted in a series of theoretical lectures illustrated by visits of ENSCP, CEA and ANDRA R&D or industrial facilities. The two-week course was run for 10 trainees, eight were recruited from the candidates proposed by the other CINCH partners, and two were from non-CINCH institutions (one end-user and one university). The teachers were recruited from ENSCP, but also from University Paris Sud, CEA, AREVA, IRSN and ANDRA, institutions and companies which are our partners in the Master Nuclear Energy (www.master-nuclear-energy.fr). Two teachers from Forschungszentrum Jülich, Institute of Energy and Climate Research, IEK-6: Nuclear waste management and reactor safety (Germany) also contributed to this course.

All information regarding trainees, teachers and lectures summaries are available in appendices and on CINCH Moodle at: http://193.51.253.155/cinch/

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

WP 1

☐ Task 1.1 ☐ Task 1.2 ☐ Task 1.3 ☐ Task 1.4 ☐ Task 1.5 ☐ Task 1.6

WP 2

☐ Task 2.1 ☐ Task 2.2 ☐ Task 2.3

WP 3

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

WP 4

☐ Task 4.1 ☐ Task 4.2 ☒ Task 4.3 ☐ Task 4.4 ☐ Task 4.5 ☐ Task 4.6 ☐ Task 4.7

WP 5

☐ Task 5.1 ☐ Task 5.2 ☐ Task 5.3

WP 6

☐ Task 6.1 ☐ Task 6.2 ☐ Task 6.3 ☐ Task 6.4 ☐ Task 6.5 ☐ Task 6.6

OUTLINE

1 INTRODUCTION

Joint general purpose/training course *Chemistry of the nuclear fuel cycle* was held at ENSCP in Paris France, from 14th to 25th January 2013. It was focused on the chemistry and the physics necessary at the various stages of the nuclear fuel cycle, from the front-end to the back-end.

The course consisted in a series of theoretical lectures illustrated by visits of laboratories or facilities of ENSCP, CEA-Saclay (DPC), CEA-Marcoule (ATALANTE) and ANDRA (industrial disposal facilities for VLL and LIL/SL waste in Soulains-Dhuys) and (Meuse/Haute Marne underground laboratory in Bure).

A particular weight is given through lectures and visits to the separation-transmutation the recent advances of which lead to a renewed approach “cycle-reactor” by introducing the notion of recycling, even "multirecycling" for a complete incineration in reactor of minor actinides. The vision "Fuel Cycle" also includes a good knowledge of material science (formulation, preparation, characterization, long-term behavior) for the conditioning of waste and a fine understanding of the chemical and geochemical processes that should be taken into account in the design and safety of geological radwaste repository systems, during operating and post closure periods.

Among the 10 trainees who attended this course (see Appendix 1), three were from Chalmers University of Technology (Sweden), one from Swedish Defence Research Agency (Sweden), two from the University of Helsinki (Finland), one from Czech Technical University in Prague (Czech Republic), one from the University of Oslo (Norway), one from National Nuclear Laboratory (UK) and one from the University Pierre et Marie Curie in Paris (France).

For the theoretical part of the course, there were ten external teachers from ANDRA (FR), AREVA (FR), CEA (FR), FZJ IEK-6 (GER), IRSN (FR) and Université Paris Sud (FR). Four internal teachers were drawn from the staff of ENSCP.

2 COURSE ORGANIZATION

The course was organized in two weeks, with a series of visits concentrated at the end of the first week and during the second week. Theoretical part of the course consisted of 32 contact teaching hours and was completed by 4 days visits. The programs of the visits were defined in a common agreement between Pr. Gérard COTE, responsible of the course, and CEA-Saclay, CEA-Marcoule, ANDRA Soulaines-Dhuys and ANDRA Bure. The visits were organized in the same way as for our own students of the Master Nuclear Energy – *major* Fuel Cycle Engineering, thus the transports (TGV and bus) were taken in charge by ENSCP, but most of the other costs was taken in charge by CEA or ANDRA, so that the global costs of visits were limited.

The external teachers were invited to provide lectures on specific topics; they stayed only for one day, so that the costs were also here kept down.

Internal teachers were drawn from the staff of ENSCP

2.1 Daily organization of theoretical part of the course

Morning lectures: 9:00 -12:15 including a break of 15 min at mid-lecture

Pause for lunch till: 13:45 (except on Tuesday 22nd January 2013).

Afternoon lectures: 13:45 -17:00 including a break of 15 min at mid-lecture

2.2 Organization of the visits

Except for ENSCP visit, all the other visits needed transport of the trainees, either by bus (CEA-Saclay and ANDRA Soulaines-Dhuys and Bure) or by train (CEA-Marcoule). Furthermore, about 6 weeks before the visits, it was necessary to apply for authorization of access on CEA and ANDRA sites, which needed to have in time the list of trainees with copies of their passports. It is a usual procedure for our own students and in the present case, all the trainees were authorized to visit the various sites.

For detailed description of course organization, see Appendix 2.

3 THEORETICAL PART OF THE COURSE

3.1 Uranium ores resources – Mill tailings and their disposal

This topic was covered by a lecture of 1 ½ hour. The teacher was Prof. Maurice PAGEL (UPS).

Content:

- World uranium production and demand – Production of mines – Uranium price evolution
- An uranium history during the evolution of the earth
- Chemical properties of uranium and thorium
- Formation of an uranium deposit
    - Uranium source
    - Transport
    - Deposition processes
    - Preservation and remobilization
    - The concept of fertility
- Uranium and thorium in rocks
- The different sources of uranium
- Uranium transfer in the crust
- Oklo (Gabon) open pit – Conditions for natural nuclear reactions at Oklo
- Initial genetic model of unconformity related uranium deposits
- The importance of synsedimentary volcanism
- Main types of world uranium deposits
- Uranium prospecting
- From exploration to mining
- Uranium mill tailings

3.2 Extraction of uranium: from ores to the yellow cake

This topic was covered by a lecture of 3 hours. The teacher was Dr. Alexandre CHAGNES (ENSCP)

Content:

- Ores dressing
- Chemical treatment of ores
- Purification
    - Solvent extraction
    - Ion exchange resins
    - Precipitation crystallization
- Example: Cominak plant (Niger)
    - Mining
    - Ore crushing/grinding
    - Ore drying
    - Ore leaching in acidic sulphate media
    - Extraction of uranium(VI) by protonated trioctylamine
    - Selective back extraction of uranium by anion exchange with NaCl as stripping agent
    - Back extraction of impurities (Mo) with Na_2CO_3
    - Reprotonation of tiroctylamine and recycling
    - Precipitation of MgU_2O_7 (yellow cake)

3.3 From uranium concentrate to UF_6: the conversion

This topic was covered by a lecture of 3 hours. The teacher was Dr. Bertrand MOREL (AREVA).

Content:

- The different chemistries in the nuclear fuel cycle and their challenges
  - Suphate/nitrate/fluoride
  - Why the front end of nuclear cycle is dominated by UF_6 ?
  - HF open circuit in the nuclear fuel cycle
- The U-F system
  - UF_6 and UF_4
    - A few reminders on fluorine chemistry
    - Physical properties of UF_6 and UF_6 phase diagram
    - Properties of UF_4
  - Intermediate fluorides UF_x (U_4F_7, U_2F_9, UF_5)
  - Other actinides (Th, Pa) properties and consequences
  - Corrosion / passivation
- Chemical equations used in a conversion plant
  - Fluorination reactions
  - Difficulties encountered for conversion of UO_2 into UF_4
    - Decrease of kinetics as the conversion reaction progresses
    - Reversibility of conversion reaction at high temperature
  - Mechanism of UF_6 formation
- Industrial processing
  - Which conversion process for Comurhex?
    - Dry process
    - Wet process
  - Uranium enrichment by centrifugation

3.4 Nuclear spent fuel recycling

This topic was covered by a lecture of 3 hours and the visit of ATALANTE facility at CEA Marcoule. The teachers were Prof. Bernard BOULLIS (CEA) and Dr. Eric ANSOBORLO (CEA), for the lecture and the programme of the visit of CEA Marcoule, respectively.

Content of the lecture

- Back-end of the nuclear fuel cycle
  - Some features of (French) L(P)WRs
  - Why to unload fuels?
  - Spent fuel management: options?
  - Uranium evolution during in-pile irradiation
  - The nuclear spent fuel
  - Used fuel reprocessing: the principle
  - Recycling of uranium and plutonium
  - Uranium and plutonium isotops
  - Actinide multi-recycle in a fast reactor (FR) fleet
  - A possible transition from LWRs to FRs
- Current reprocessing: The PUREX process
  - Dissolution
  - Separation by liquid-liquid extraction with TBP
    - Uranyl extraction by TBP
    - Species to be separated
    - Actinide extraction by TBP

- TBP degradation
- Some particular behaviours (ruthenium, zirconium, technetium)
- Extractors
- Conditioning - Vitrification process

- Advanced reprocessing processes: Partitioning and Transmutation of minor actinides
  - Actinide chemistry
  - Minor actinides selective after PUREX
  - Design of new extractants
  - Transmutation: The principle
  - Example of technetium
  - Americium transmutation
- Transmutation options (Fast neutrons power plants – dedicated systems)

3.5 Chemistry of cooling circuits of nuclear power plants

This topic was covered by a lecture of 3 hours and by the visit of CEA Saclay. The teacher was Dr. Grégory LEFEVRE (ENSCP-CNRS).

Content:

- Description of different types of nuclear reactors
- Chemistry at high temperature
- Corrosion phenomena in primary circuit of PWR: contamination
- pH control of primary circuit
- Evolution of chemistry in primary circuit during shutdown
- Cleanup online systems
- Mitigation of contamination by Zn addition
- Chemistry of secondary circuit
- Corrosion phenomena in secondary circuits of PWR
- Curative methods of secondary circuit
- Case study: fouling of pump seals of primary circuit
- Theoretical concepts of surface chemistry

This course is proposed in the form of e-learning in the frame of WP 5, Task 5.1, it is described in the deliverable D5.1, and is available on CINCH Moodle at http://193.51.253.155/cinch/.

3.6 Nuclear waste conditioning

This topic was covered by a lecture of 4.5 hours. The teachers were Dr. Catherine FILLET (CEA) and Dr. Daniel CAURANT (ENSCP-CNRS).

Content:

- Radioactive waste conditioning : principle, scientific and technical stakes
  - Types of wastes
  - French 2006 act for sustainable management of radioactive materials and waste
  - Current waste to be conditioned
  - Overview on matrices for conditioning
- Radioactive waste conditioning in glasses
  - Necessity and aims of the conditioning of HLW (High Level radioactive Wastes) in solid matrices
  - Criteria concerning the properties of the waste form (waste form specifications)

- Conditioning of nuclear wastes in glasses
  - Principle of waste vitrification - Examples of nuclear glass compositions
  - Structure of nuclear glasses: How waste can be incorporated into their structure?
  - Vitrification processes
  - Properties of nuclear melts and glasses
  - Chemical durability of nuclear glasses
  - Basic mechanisms of glass alteration by water
  - Assessment on the ability of glasses to immobilize HLW

3.7 Decommissioning of nuclear facilities

This topic was covered by a lecture of 3 hours. The teacher was Dr. Christophe BORDEAUX (AREVA)

Content:

- General approach and definitions
- An example of current events in France: the dismantling of AREVA NC La HagueUP2-400 plant
- Safety requirements for Dismantling and Decommissioning operations
- Waste

3.8 Radionuclide solubility control in solid solution – aqueous solution systems (radium/barium issues)

This topic was covered by a lecture of 3 hours. The teachers were Prof. Dirk BOSBACH and Prof. Felix BRANDT (Jülich Forschungszentrum, Germany)

Content:

- Immobilisation reactions for dissolved radionuclides
- Factors affecting the stability of a solid solution
- Lippmann theory
- Ba-Ra-SO_4 solid solution - deviation from ideality
- Radium uptake by barite
- Radium in nuclear waste repositories
- The system Ra - Ba - SO_4 - H_2O / Ra uptake by $BaSO_4$
- The Single Defect Method (SDM)
- The SDM results for carbonate and barite solid solutions
- Recent experimental studies

3.9 The scientific and societal bases of the system of Radiological Protection

This topic was covered by a lecture of 3 hours. The teacher were Prof. François PAQUET (IRSN)

Content:

- The basics of knowledge
  - Some key questions to address
  - The biological and healrth effects of radiations
  - The controversy of the effects of radiations
- The management and assessmenet of risks and exposures
  - From the science to the general principles: the role of the ICRP

- The concept of acceptable risk
- The concept of dose – the units
- The assessment of doses afer exposure
    - The main actors involved in dose assessment
    - The different methods for dose assessment
        - The case of external exposure
        - The case of internal exposure
        - Generic biokinetic model
        - The human alimentary tract model
        - The human rspiratory tract model
        - The systemic models
        - General procedures for assessing doses
        - The dosimetric models

3.10 Overview on radioactive waste management issues

This topic was covered by a lecture of 3 hours. The teacher was Dr. Gerald OUZOUNIAN (ANDRA) and by the visit of ANDRA facilities.

Content:

- Bases for radioactive waste management
- Waste acceptance
- Safety of surface disposal facilities
- General overview of facilities and projects in France
- International overview

3.11 Behavior of nuclear waste in geological final repositories

This topic was covered by a lecture of 3 hours. The teacher was Dr. Scott ALTMANN (ANDRA) and by the visit of ANDRA facilities.

Content:

- General considerations
    - Different geologies, different strategies for deep disposal
    - Understanding of radionuclides transfer in geological barrier
    - Understanding of radionuclide release and chemical behavior in waste cell and near field
    - Needed models of radionuclide behaviours
        - Radionuclide source models
        - Near field migration models
        - Far field migration models
- Waste package degradation and radionuclide release
    - Main questions concerning radionuclide behaviour at waste package and disposal cell scales
    - Spent fuel
    - Vitrified waste
    - Bituminous waste
    - Conceptual model for waste cell after resaturation
    - Radionuclides solubility and speciation
    - Role of microbial catalysis

- Radionuclide chemistry and transport in clayrock geological barriers (e.g. Callovo-Oxfordien)
- Radionuclides behaviours in the biosphere: human health impacts (dose)
    - ^{36}Cl : a critical radionuclide in radioactive waste
    - Towards an understanding of biochemistry of ^{36}Cl
    - Towards a quantitative description of chlorine cycling and modeling
    - Chlorine cycling dynamics through vegetation
    - ^{79}Se, the story is even more complex

4 VISITS

4.1 Visit of ENSCP laboratories (16th January 2013)

15:00	**(UMR 7574 UPMC - Chimie ParisTech - CNRS)** Solid state chemistry : From synthesis to applications (D. CAURANT)
15:20	**(UMR 7575 Chimie ParisTech-CNRS)** Hydrometallurgy – Lithium ion batteries (A. CHAGNES)
15:40	**(UMR 7575 Chimie ParisTech-CNRS)** High temperature electrochemistry – Fuel cells (V. ALBIN)
16:00	**(UMR 7045 - Chimie ParisTech-CNRS)** Metallurgy (F. PRIMA)
16:20	**(EA 3492 - Chimie ParisTech)** Plasma technologies for surface modification – Development of micro-systems (M. TATOULIAN)
16:40	**(UMR 7045 - Chimie ParisTech-CNRS)** Metallic materials – Corrosion – Biocompatible surfaces – Energies (A. GALTAYRIES)

4.2 Visit of CEA Saclay (18th January 2013)

12h30/14h00 Welcome and presentation of the activities of DPC (S. SARRADE)

14h15-14h45 Glow Discharge Mass Spectrometry (GDMS / SDL): Isotope ratio measurements and trace elements determination in solid samples. (N. Caron)

14h45/15h15 Thermochemistry: Experimental investigation and modeling of the physico-chemical properties of aqueous solutions at high temperature and high pressure (up to PWR conditions) (D. You & G. Plancque)

15h15/15h45 Gas analysis/radiolysis: Measurement of hydrogen content, Glove boxes for hydrogen measurement, Analysis of fission gases, etc. (V. Dauvois / G. Plancque)

15h45/16h/15 Isotopical analysis (ACTINEO) (T. Vercouter)

4.3 Visit of CEA Marcoule (21th January 2013)

12h30/13h30 Welcome and administrative controls

13h30-14h14 General presentation of ATALANTE (ATelier Alpha et Laboratoires pour ANalyses, Transuraniens et Etudes de retraitement) (http://www.cea.fr/recherche-fondamentale/la-chimie-au-cea)

The Atalante facility is a complete set of 18 hot labs and 9 shielded cells devoted to the research and development on fuel cycle. The activities correspond to four major sectors of nuclear research :

- to support the operation of actual reprocessing plants with the aim of adapting the head of the process to the increase of the spend fuel burn-up and to different types of new burnt fuels to be reprocessed (including MOX, USi or UMo fuels),
- to develop the COEX TM process,
- to prepare the recycling of minor actinides (MA) by partitioning or by grouped actinide extraction, and by MA bearing fuel fabrication,
- to study the long term behavior of high level waste conditioning matrices and especially self irradiation and leaching of vitrified waste.

14h45/15h15 Visit of ATALANTE

- LN1 LABORATORY :

The LN1 Laboratory is dedicated to molecular chemistry of all actinides in solution, solid state and at interfaces. It brings together selected techniques to obtain structural information, speciation and thermodynamic properties (Mass spectrometry, FTIR and Raman spectrometry, Microcalorimetry, Time resolved Induced laser Fluorescence Spectroscopy, NMR spectrometry, Diffractometry). Four glove boxes are dedicated to classical chemical experiments, essential to synthesize and purify specific actinide compounds. Nine other glove boxes are used for the preparation of samples before examination by the different techniques. The experimental results can be compared with theoretical approach of phenomena, with the help of the experts in modeling in the team LILA.

- PROCESS HOT CELL ("CBP")

CBP is the Atalante's largest high-level experimentation shielded facility and appears as an unique tool, considering its functionalities, its size (and especially the two levels conception of the main part of the cell). This new hot cell facility is now in operation and devoted to head-end high-activity reprocessing studies, and first to the major program on partitioning long-lived radioactive elements in the frame of the French Acts (December 1991 and then June 2006) about radioactive waste management.

- C18/C19 HOT CELLS

The C18/C19 cells are dedicated to the fabrication and study of solid matrices for the conditioning of nuclear wastes

16h45/17h00 VISIT OF THE VISIATOME

Visiatome is a center for discovery and education proposed by the CEA which is entirely devoted to energy issues**,** including radioactivity and nuclear energy**.**

4.4 Visits of ANDRA facilities

4.4.1 Soulaines-Dhuys (LIL/SL) and Morvilliers (VLL) ANDRA facilities (24th January 2013)

10h30/10h45 Appointment at the ANDRA Building of Welcome of the Public (Soulaines-Dhuys) - Coffee

10h45/11h15 General introduction : Radioactivity and radioactive wastes, ANDRA disposal

facilities for very-low-level (VLL) and low-level and intermediate-level short-lived (LIL/SL) wastes (Soulaines-Dhuys), principles of storage

11h15/12h45 Administrative controls* and visit of low-level and intermediate-level short-lived (LIL/SL) waste disposal facilities [Centre de stockage de l'Aube (CSA)]

12h45/13h45 Lunch

14h/15h Technical presentation about environmental surveillance

15h/16h30 Transport to Morvilliers and visit of very-low-level (VLL) disposal facility [Centre industriel de regroupement, d'entreposage et de stockage (Cires)]

16h30/17h Discussion and feedback from visitors

4.4.2 Visit of the Meuse/Haute Marne underground ANDRA laboratory (Bure) (25th January 2013)

<table>
<tr><th></th><th>Groupe 1</th><th>Groupe 2</th></tr>
<tr><td>10H00</td><td colspan="2">Administrative controls* – coffee (Welcome building of the LABORATORY)</td></tr>
<tr><td>10H15</td><td colspan="2">Introduction to the HA/MALV waste management and the industrial project Cigéo</td></tr>
<tr><td>11H15</td><td colspan="2">Security training</td></tr>
<tr><td>12H00</td><td colspan="2">lunch</td></tr>
<tr><td>14H00</td><td>Technical preparation for visit (equipment)</td><td>Visit of the hall of demonstrators at the Technological Buiding</td></tr>
<tr><td rowspan="3"></td><td>Down to deep laboratory 14h30,
Return to surface 15h50</td><td>Visit of tempory exhibition (fossiles, empreintes du temps) et SAGD (syst. Acq. Mesures) en galerie maquette</td></tr>
<tr><td>16H15 Visit of the hall of demonstrators at the Technological Building</td><td>15h30 Technical preparation for visit (equipment)</td></tr>
<tr><td>17h00 Visit of tempory exhibition (fossiles, empreintes du temps) et SAGD (syst. Acq. Mesures) en galerie maquette</td><td>Down to deep laboratory 16h00,
Return to surface 17h20</td></tr>
<tr><td>17H30</td><td colspan="2">Meeting at BAP and feedback</td></tr>
<tr><td>18H00</td><td colspan="2">Departure from the site</td></tr>
</table>

5 CONCLUSIONS

At the end of the session, an anonymous questionnaire was given to the students to evaluate the course *Chemistry of the nuclear fuel cycle*. The results show a high degree of global satisfaction (80% highly satisfied and 20% satisfied) and the feeling to have acquire a better understanding of the challenges of chemistry of the nuclear fuel cycle (80% significant better understanding and 20% moderate better understanding [remark : the 20% moderate correspond to the 20% students of the group of 10 having already a very high or high knowledge of the subject]), with a deep interest for visits of CEA and ANDRA facilities (100% very satisfied and satisfied in all cases).

Beyond the general purpose to allow the students to discover the chemistry and the physics necessary at the various stages of the nuclear fuel cycle, this course aimed to attract these students in the various careers offered by the end-users (industries, organizations in charge of R&D international institutions, …), but also to allow these end-users to detect the talents to be recruited. This aspect “employment” is of the highest importance, especially in a period when the future of the nuclear industry is subject to discussion in Europe, with the risk of a lack of attractiveness, and when, in parallel, there is the need to attract the best talented graduate students to cope with the reinforced requirement of safety of nuclear power plants, the development of innovative sustainable strategies for final nuclear wastes, etc.

Course on "Chemistry of the nuclear fuel cycle" Paris, 14th and 25th JANUARY 2013

APPENDIX 1

List of trainees

Ms. Mrs. M.	Last name	First name	Institution
M.	Alazem	Yehya	Chalmers University of Technology, Sweden
M.	Azadrad	Alborz	Chalmers University of Technology, Sweden
Ms.	Hellé	Gwendolyne	University Pierre et Marie Curie (UPMC), Paris, France
Ms.	Knuutinen	Jenna	Laboratory of Radiochemistry University of Helsinki, Finland
M.	Kountchou Tawokam	Mikael	Chalmers University of Technology, Sweden
M.	Mareš	Kamil Vavřinec	Czech Technical University in Prague, Czech Republic
Ms.	Niemiaho	Suvi	Laboratory of Radiochemistry University of Helsinki, Finland
M.	Norén	Henrik	University of Oslo, Norway
Mrs.	Staines	Cassie	National Nuclear Laboratory, UK
Ms.	Vesterlund	Anna	Swedish Defence Research Agency, Sweden (14th – 22nd January only)

Course on "Chemistry of the nuclear fuel cycle"
Paris, 14th - 25th JANUARY 2013

APPENDIX 2

<table>
<tr><th colspan="2">Lectures at Chimie ParisTech CA 32 hours - Visits 4 days</th></tr>
<tr><th>MONDAY 14 JANUARY 2013 (Room 8)</th><th>MONDAY 21 JANUARY 2013</th></tr>
<tr><td>9:30 – 9:45 Welcome
Pr. V. CABUIL (ENSCP)</td><td rowspan="3">Visit of CEA MARCOULE

Departure from Paris at 08:49
Return to Paris at 20:53</td></tr>
<tr><td>9:45 -10:30 Introduction
Pr. G. COTE (ENSCP)</td></tr>
<tr><td>10:45 -12:15 Uranium ores resources – Mill tailings and their disposal
Pr. M. PAGEL (UPS)

13:45-17:00 Extraction of uranium: from ores to the yellow cake
Dr. A. CHAGNES (ENSCP)</td></tr>
<tr><th>TUESDAY 15 JANUARY 2013 (Room 5)</th><th>TUESDAY 22 JANUARY 2013 (Room 8)</th></tr>
<tr><td rowspan="2">9:00 – 12:15 From uranium concentrate to UF_6: the conversion
Dr. B. MOREL (AREVA)</td><td>9:00 – 10:45 Nuclear waste conditioning
Dr. D. CAURANT (ENSCP-CNRS)–Part 2</td></tr>
<tr><td>11:00 – 13:00 Radionuclide solubility control in solid solution – aqueous solution systems (radium/barium issues)
Pr. D. BOSBACH & Pr. F. BRANDT (IEK-6)</td></tr>
<tr><td>13:45 – 17:00 Nuclear spent fuel recycling
Pr. B. BOULLIS (CEA)</td><td>14:15 – 17:30 The scientific and societal bases of the system of Radiological Protection
Pr. F. PAQUET (IRSN)</td></tr>
<tr><th>WEDNESDAY 16 JANUARY 2013 (Room 5)</th><th>WEDNESDAY 23 JANUARY 2013 (Room 3)</th></tr>
<tr><td>9:00 - 12:15 Chemistry of cooling circuits of nuclear power plants
Dr. G. LEFEVRE (ENSCP-CNRS)</td><td>9:00 -12:15 Overview on radioactive waste management issues
Dr G. OUZOUNIAN (ANDRA)</td></tr>
<tr><td>13:45 – 17:00
Visit of CURIE museum
(http://curie.fr/en/fondation/curie-museum)

Visit of ENSCP laboratories</td><td>13:45 – 17:00 Behavior of nuclear waste in geological final repositories
Dr. S. ALTMANN (ANDRA)</td></tr>
<tr><th>THURSDAY 17 JANUARY 2013 (Room 205)</th><th>THURSDAY 24 JANUARY 2013</th></tr>
<tr><td>9:00 – 12:15 Nuclear waste conditioning
Dr. C. FILLET (CEA)
Dr. D. CAURANT (ENSCP-CNRS)–Part 1

13:45 – 17:00 Decommissioning of nuclear facilities
Dr. C. BORDEAUX (AREVA/E&P)</td><td>Visit of ANDRA disposal facilities for very-low-level (VLL) and low-level and intermediate-level short-lived (LIL/SL) waste (Morvilliers & Soulaines-Dhuys)

Departure from Paris at 06:30</td></tr>
<tr><th>FRIDAY 18 JANUARY 2013</th><th>FRIDAY 25 JANUARY 2013</th></tr>
<tr><td>Visit of CEA Saclay

Departure from Paris at 11:00
Return to Paris at 18:00</td><td>Visit of the Meuse/Haute Marne underground ANDRA laboratory (Bure – Saudron)

Return to Paris at 22:30</td></tr>
</table>

WHY TO STUDY CHEMISTRY OF THE NUCLEAR FUEL CYCLE?

Nuclear industry faces numerous challenges, including the operation and maintenance of its existing reactors, waste management, the decommissioning of obsolete reactors, and research and development for future nuclear systems. These activities require call for the hiring and training of a great number of scientists and engineers every year worldwide.

TARGET GROUP

The target group is both students at the master level and doctoral students.

POTENTIAL WORKING POSITIONS

This course is of relevance to those who want to occupy a position as

- an engineer on a raw uranium production site or other sites, in the factories at the heart of the fuel cycle be either in the refinement, enrichment or recycling stages,
- a designer, engineer or operator of storage sites for waste,
- an engineer in nuclear power plants.

This course is also of relevance for those who want to pursue PhD programmes within nuclear sciences.

CHIMIE PARISTECH

Ecole nationale supérieure de chimie de Paris, France

www.chimie-paristech.fr

COURSE RESPONSIBLE

Gérard COTE

gerard-cote@chimie-paristech.fr

CINCH

Cooperation In education in Nuclear Chemistry

www.cinch-project.eu

PROJECT LEADER

Jan JOHN

Jan.john@fjfi.cvut.cz

CINCH is an EU 7th Framework Programme project within EURATOM aiming to coordinate nuclear chemistry and training in Europe .

The project includes the formation of a long-term EURATOM Fission Training Scheme (EFTS) providing a common basis to the fragmented activities in this field and thus move the education and training in nuckear chemistry to quantitatively new level.

Chimie Paris

ParisTech

L'ÉCOLE NATIONALE SUPÉRIEURE DE CHIMIE DE PARIS

CINCH

Consortium

EURATOM

Chemistry of the nuclear fuel cycle course

Master (MSC) and PhD level

14th–25th January 2013 Paris, France

CHEMISTRY OF THE NUCLEAR FUEL CYCLE COURSE

OBJECTIVES

After the course the students should have a global overview of the chemistry and the physics necessary at the various stages of the fuel cycle, from the front-end to the back-end. In addition they should have basic knowledge in decommisioning of nuclear facilities and in radiological protection.

ARRANGEMENTS, LANGUAGE

The course runs over 2 weeks (January 14th-25th 2013) in Paris, France. The course will combine lectures and 5 technical visits. All teaching will be in English.

ADMISSION REQUIREMENTS

In order to apply for admission to join the course, please contact Gérard Cote (gerard-cote@chimie-paristech.fr) to obtain a registration form. The form together with this brochure are available also on the CINCH web page http://www.cinch-project.eu/?art=courses. A limited budget exists to support students and young researchers. Application deadline 5th December 2012.

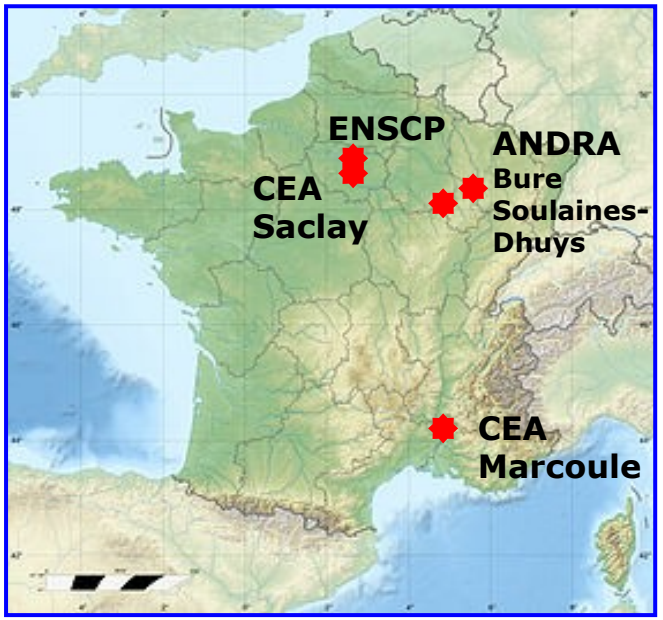
ACCOMMODATION

A list of hotels will be provided. Help can be obtained from Gérard Cote (gerard-cote@chimie-paristech.fr)

COURSE PROGRAMME JANUARY 14-25th, 2012

Lectures CA 33 hours
Uranium ores resources – Mill tailings and their disposal
Extraction of uranium: from ores to the yellow cake
From uranium concentrate to UF_6: the conversion
Nuclear spent fuel recycling
Chemistry of cooling circuits of nuclear power plants
Nuclear waste conditioning
Overview on radioactive waste management issues
Behavior of nuclear waste in geological final repositories
Decommissioning of nuclear facilities
The scientific and societal bases of the system of radiological protection

Technical visits
Visit CEA Saclay
Visit CEA Marcoule
Visit ENSCP laboratories
Visit of ANDRA disposal facilities for very-low-level (VLL) and low-level and intermediate-level short-lived (LIL/SL) waste (Soulaines-Dhuys)
Visit of the Meuse/Haute Marne underground ANDRA laboratory (Bure–Saudron)



ADDITIONAL INFORMATION SOURCES

http://www.cinch-project.eu/
http://www.chimie-paristech.fr/
http://www.cea.fr/
http://www.andra.fr/