Partitioning related ISTC projects at RIAR and short overview of Russian Partitioning program

CEG Meeting, January 2006

Russian programs on partitioning
(some history)

In 1980-s – partitioning of Np from spent fuel was implemented into "Mayak" Plant, separation of Am+Cm/REE and extraction of Cs+Sr were tested on real HLW

1993-2001 – Minatom Program "RECYCLE":

Participants: MAYAK Reprocessing Plant, Bochvar Institute, Kurchatov Institute, RIAR, IPPE, Moscow Institute of Physical Chemistry of RAS

- **Main tasks**
  - Separation and collecting of **I, Tc, Am**
  - Development of reactor conceptions of FP and MA incineration (transmutation)

1999 (until now) – FS and R&D of advanced RT-2 Conceptions and followed conceptions for LWR reprocessing plant

- Technologies
  - Advanced (or extended) PUREX, Fluoride Volatility technology, DDP, supercritical CO_2 extraction, others

Russian programs on partitioning
(some history)

2003-2005 – Preparation of new Russian Program "Construction of the BN-800 fast reactor with closed fuel cycle demonstration"

Start of plutonium fuel cycle in Russia (MOX fuel) and utilization of accumulated "power grade" Pu and Application of developed technologies and using of previously constructed facilities and buildings (as possible)

- Possible technologies for MOX fuel production
  - RIAR – pyrochemical + vibropacking with Am burning
  - Bochvar Institute – codeposition GRANAT technology and pelletizing
- Possible technologies for MOX fuel reprocessing demonstration
  - RIAR – pyrochemical reprocessing with MA partitioning and vibropacking
  - Bochvar Inst. – simplified PUREX, GRANAT and pelletizing (no partitioning)

- **Russian State Duma** supported this program as innovative program

2000 (until now) – Program of BREST fast reactor

- Main approaches to BREST fuel cycle
  - So-called "on site" close fuel cycle (i.e. location of fuel cycle facility on the same site with reactor unit) Pyrochemical reprocessing
  - Homogeneous recycle of MA in frame of BREST close fuel cycle

Russian programs on partitioning

2006

Partitioning will be included into new integrated conception:

NEW

TECHNOLOGICAL

PLATFORM

Commercial fast reactor with closed fuel cycle (included P&T)

Current and completed ISTC Projects related to partitioning

Examples of
Completed ISTC Projects related to partitioning

Integrated projects

- ISTC 17
- ISTC 1606
- ISTC 272

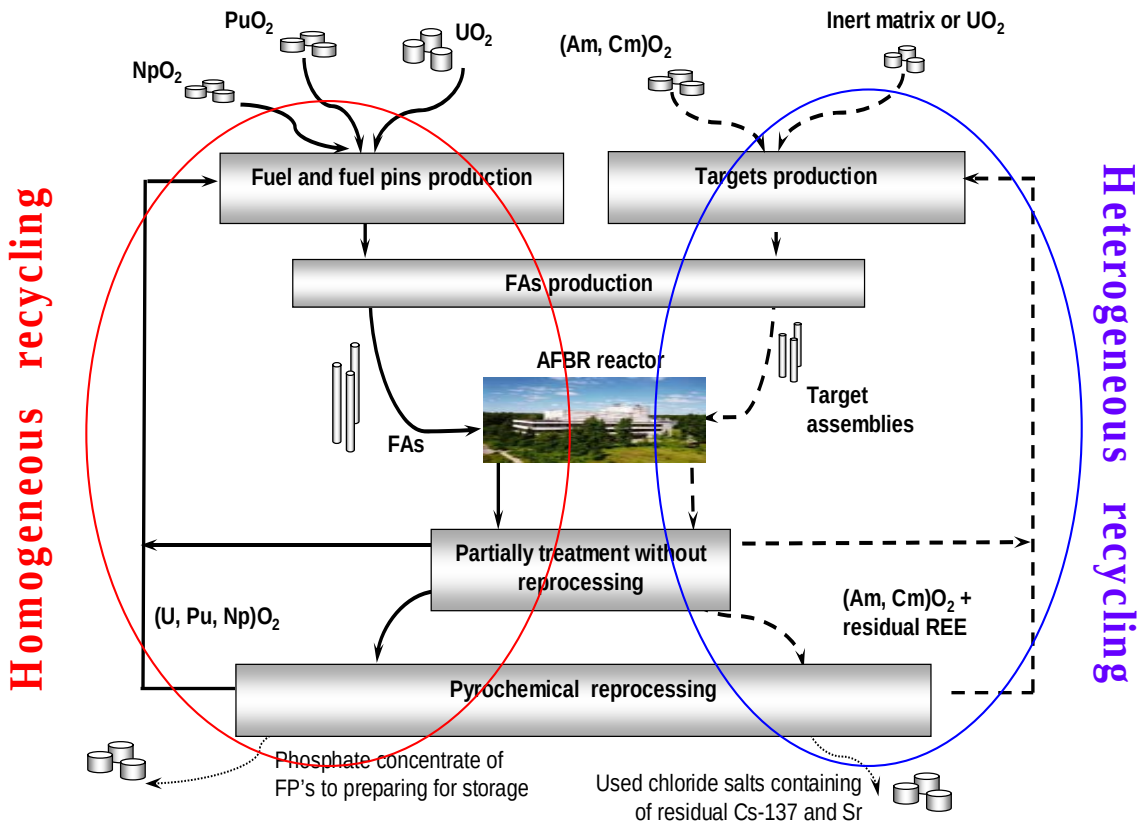
Pyrochemical partitionir

- ISTC 279

Targets

- ISTC 2680

DOVITA fuel cycle



RESEARCH INSTITUTE OF ATOMIC REACTORS

ISTC project 3261

Study of curium thermodynamics in molten chlorides

Objectives

•**Reactions of formation for oxygen curium compounds**

- equilibrium constants (and Gibbs energy change) for reactions of curium oxygen compounds formation versus temperature;

- equilibrium constants (and Gibbs energy change) for reactions of curium oxygen compounds formation versus the inverse effective radius of solvent cation.

•**Reactions of formation for oxygen-free curium compounds**

- standard potential for redox pair (and Gibbs energy change) versus temperature;

- standard potential for redox pair (and Gibbs energy change) versus the inverse effective radius of solvent cation.

•**Simulation of curium behavior in molten chlorides**

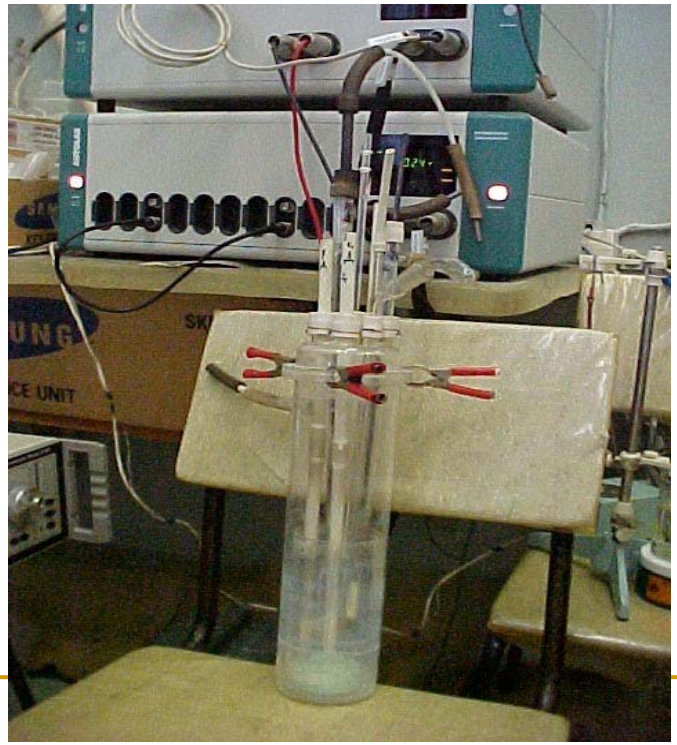
Pourbaix diagrams

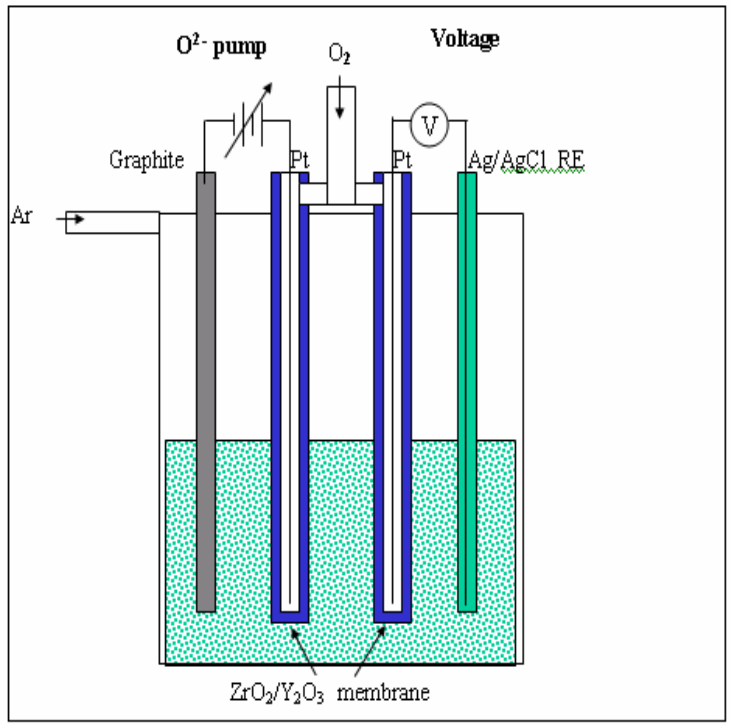
Study of curium thermodynamics in molten chlorides

Investigation methods

- **Thermodynamics of formation for oxygen curium compounds**

Potentiometric titration with oxygen pump
<u>advantage</u> - small concentration of Cm in melt) versus high cost of Cm reagents





Study of curium thermodynamics in molten chlorides

Investigation methods

•**Thermodynamics of formation of oxygen-free curium compounds**

Method of EMF

Cyclic Voltammetry

Chroho Potentiometry

necessary request - Cm concentration in melt must be more than 3wt% (interaction of Cm with melt is negligible)

•**Simulation of curium behavior in molten chlorides**

Study of curium thermodynamics in molten chlorides

Conditions

Molten salts
LiCl-KCl, NaCl-CsCl, NaCl-KCl

•Temperature range
450^{o}C - 850^{o}C

•Cm content
10^{-4} – 10^{-2} mol/kg (Potentiometric titration)
(2 – 5) 10^{-1} mol/kg (EMF, Cyclic Voltammetry, ChrohoPotentiometry)

Common information

Duration of project	**24 months**
Estimated total cost	**$300,000.00**
Participants	**RIAR**

RESEARCH INSTITUTE OF ATOMIC REACTORS

ISTC Partner Project 3231 (RIAR-KAERI)

Separation of minor-actinides from rare-earth elements on a liquid metallic cathode in molten chlorides

Objectives:

Task 1: Polarization curves on electrodeposition of actinides and lanthanides on bismuth and cadmium cathodes

Task 2. Electrodeposition tests for effective separation of actinides and lanthanides on liquid-metal cathodes

Task 3. Effect of uranium content in molten salt to electrodeposition and separation of actinides and lanthanides on liquid metallic cathode

- **Actinides - U, Np, Am, Cm,**
- **REE - Nd, La, Ce**
- **Systems: - Bi / LiCl-KCl and Cd / LiCl-KCl**

ISTC Projects related to partitioning

New proposals

Research area of pyrochemical (non-aqueous) methods for MA/FP partitioning development

Melts/ media	Electrochemical methods				Oxides Precipi-tation	Metalli-zation
	Liquid cathodes	Solid cathodes	Anodic dissolution	E/Chem. oxide titration		
Chlorides	Cd, Bi, Ga	Al,	+	+	+	+
Fluorides	Bi, Ga, Al, Pb	-	+	+	+	-
Cl^- /F^-	Cd, Bi, Ga, Al, Pb	Al,	+	+	+	-
Molibdates	-	+	-	-	+	-
RTIL	Ga, Hg	Zn, Cu, Ni, Al, …	+	-	-	-

+ Methods of Volatility of Fluorides and /or Chlorides

Future ISTC proposals for studies

Continuation of recently investigated subjects:

Molten Salt chemistry of Am and Cm for fluorides

- Phase II for ISTC 3261 – for partitioning
- As continuation of ISTC 1606 – for recycling as molten salt fuel components

Partitioning of MA/REE in molten fluorides

with liquid cathodes

Application of Room Temperature Ionic Liquids for Separation of TPE and REE

RIAR proposal for ISTC project

The research program includes the following stages:

- search for the RTIL with a rather wide electrochemical window (first of all, with a high stability to cation electrochemical reduction), study of its physical and electrochemical properties, compatibility with other solvents
- study of solubility of the TPEs and REEs salts with different anions (NO^{3-}, Cl^{-}, F^{-}, CN^{-}) in the chosen RTILs
- study of composition of the complexes and electrochemical behavior of the TPEs and REEs in the chosen RTILs
- analysis of the possibility of cathodic deposition of actinides and lanthanides in the alloy form with transient metals (Zn, Cu, Ni, Al and others) and/or on a liquid metallic cathodes (Ga, Hg) in the chosen RTILs, study of conditions of the electrochemical TPEs and REEs separation in the given systems
- Analysis of the possibility of creating the extraction-electrochemical system to separate the TPE and REEs using RTILs

Chemical problems of minor actinides partitioning for transmutation in aqueous processes

Proposals of

V.G. Khlopin Radium Institute, St. Petersburg

Development and demonstration of the process for selective recovery of TPE from HLW using binary calixarene extractants

ISTC proposal 3405

The work will include the following:

- systematic study of physical chemical properties of new calixarene extractants with functional groups of different types;
- determination of correlations between structure - selectivity and structure - stability for these extractants;
- development of flowsheet variant for recovery from HLW and separation of TPE - REE fractions by calixarene extractants;
- prolonged dynamic tests of the elaborated process.

Amide and heterocyclic extractants

- **Idea:** search of extractant with **adequate selectivity** (ß Am/Eu ~ 30) and very **high hydrolytic** stability.

- Alkyl-aryl diamides of pyridine-dicarboxylic acid and bis-tetrazole derivatives of pyridine gave good results in An/Ln separation. These systems work only in polar diluents and exhibit high hydrolytic stability and acceptable selectivity (ß Am/Eu ~ 20-50) in high acidic media.

Zirconium salt of dibutyl phosphoric acid

- ISTC proposal : “**Partitioning of Long-lived Radinuclides Using the Mixture of Short Alkylphosphoric Acids or their Zirconium Salts and Chlorinated Cobalt Dicarbollid**”

- The main goal of the project is investigation of An and Ln extraction and separation using a TBP hydrolysis product – dibutyl phosphoric acid (HDBP) and its acid zirconium salt (ZS HDBP) in the buffer range of acidity and using HDBP or ZS HDBP in mixture with Chlorinated Cobalt Dicarbollide in the polar fluorinated diluent.

Experimental study on actinide transmutation in the BOR-60 fast reactor neutron spectrum

Participating Institutions

- **Federal State Unitary Enterprise “State Scientific Center of the Russian Federation – Research Institute of Atomic Reactors”, Dimitrovgrad**
- **Federal State Unitary Enterprise “ State Scientific Center of the Russian Federation –Institute of Physics and Power Engineering, Obninsk**

Governmental Agency — **Federal Agency for Nuclear Power (Rosatom)**

Project Duration — **36 months**

Project estimated total cost — **815 000 $US**

Experimental study on actinide transmutation in the BOR-60 fast reactor neutron spectrum

Scope of Activities

- **Task 1 covers the work related to the selection of a set of isotopes to be tested, substantiation of the target design and requirements to the substances to be irradiated**
- **Task 2 covers irradiation of the targets in BOR-60, information acquisition on irradiation conditions and calculation-analytical support of irradiation**
- **Task 3 consists in examination of irradiated targets and includes development of the precision procedures for determining the key elements and their analysis**
- **Task 4 includes development of the irradiation models, analysis of data according to the irradiation program, acquisition and analysis of data by the irradiation conditions and calculation-analytical support of irradiation.**

Experimental study on actinide transmutation in the BOR-60 fast reactor neutron spectrum

Expected Results and Their Application

The following results will be obtained:

- **Verified data on MA nuclear constants**
- **Accuracy estimate of the findings**
- **Recommendations for modification of nuclear constants files for reactor codes**

The proposed Project will provide:

- **experimental data for verification of neutron sections for the selected set of actinides**
- **results of the comprehensive analytical examination of the irradiated targets containing actinide nuclides: isotope sample composition, content of actinides and fission products**
- **verified nuclear-physical actinide constants based on the results of the integral reactor experiments**

New experimental data obtained under the Project would be used for verification of the estimated neutron data and the development of more precise constants for calculation codes that are used in design of radioactive waste burning facilities. Moreover the new data will provide recommendations on actinide transmutation in fast reactors

ISTC Project proposals from RIAR: Preparation of monographies related to P&T and advanced fuel cycle

- V.Nickolaev, E.Karelin, R.Kuznetsov, Yu.Toporov. Technology of Transplutonium Elements – second edition and translation to English and publishing
- V.Radchenko, M.Ryabinin, etc. Physical Metallurgy of Transplutonium Elements – preparation Russian and English editions

- A.Mayorshin Fuel elements with vibropacked oxide fuel – preparation Russian and English editions
- O.Skiba, A.Bychkov, V.Ivanov. Pyroelectrochemical process in nuclear fuel cycle – preparation Russian and English editions

Proposal for new Contact Expert Group

- **Partitioning of HLW**
- **Partitioning in Advanced fuel cycle**

Subjects:

- Search of new methods for Actinides and Long-lived fission products separation for transmutation
- Search of advanced methods for recycling of transmutation targets or molten salt fuel
- Integration of partitioning and recycling processes with transmutation facilities

Participants: Russia, EU, Japan, Rep.Korea …

Proposal for new Contact Expert Group (for discussion)

Possibility to elaborate and demonstrate of new ISTC roles:

- **“Umbrella” organization for new applied scientific projects**
- **Regulation and organization of multilateral projects and studies**