KYT2018 – TECHNOLOGIES IN NUCLEAR WASTE MANAGEMENT

KYT2018 midterm seminar, April 7th, 2017
Finlandia Hall, Helsinki
KYT2018 – Technologies in nuclear waste management
Advanced fuel cycles – New adjustable separation materials (SERMAT) – Risto Koivula HYRL
Advanced fuel cycles – Scenario and Inventory Analysis (KOSKI) – Silja Häkkinen VTT

KYT2014 – New and alternative technologies in nuclear waste management
Advanced fuel cycles – New separation technologies – Risto Harjula HYRL
Advanced fuel cycles – Computational fuel cycle analysis – Silja Häkkinen VTT
Transmutation of nuclear waste in an ADS (FLUTRA) – Filip Tuomisto Aalto
Advanced Fuel Cycles – Scenario and Inventory Analysis (KOSKI)

KYT2018 Midterm seminar 7.4.2017
Silja Häkkinen
Overview

- In 2015-2016 the project can be divided in two research topics:
  1. Nuclear fuel cycle scenario code analysis
  2. Gamma-dose calculations and proliferation resistance of spent nuclear fuel assemblies
1.1 Nuclear fuel cycle scenario codes

- Nuclear fuel cycle scenario codes are capable of modelling the entire fuel cycle.
- The codes are used to model and compare different scenarios e.g. transition from thermal to fast reactors, transuranium burner fleets, etc.
- The modelled parameters are diverse, e.g. the evolution of plutonium and minor actinide inventories, decay heat, uranium consumption, etc.
1.2 COSI6 and SITON

- At VTT, we have used two scenario codes:
  I. COSI6 (2011-2016)
    - Developed by CEA (France) since 1980s
    - Model includes EPR, (BWR) and SFR reactors
    - One of the most advanced nuclear fuel cycle codes available
    - Source code is not open
  II. SITON (2015 ->)
    - Developed by MTA EK and BME NTI (Hungary)
    - Model includes GFR reactors
    - Open source code
    - No licence fee
1.3 Deployment of SITON

- SITON was first deployed at VTT in 2015 by comparing SITON results to COSI in a direct disposal scenario with LWR reactors.
1.4 COSI6 calculations for future validation of SITON

- In 2016, spent fuel inventory calculations were made with COSI6 in several scenarios. The purpose was to obtain data for future validation of SITON.

Pu + MA at the end of the scenario (direct disposal)

Decay heat of spent nuclear fuel [kW]

U-235 enrichment and fuel burnup [GWd/tU]
2.1 Gamma dose rate calculations for irradiated PWR assemblies, NEA/WPFC/AFCS

- Spent nuclear fuel (SNF) can be attractive to terrorists as material for an atom bomb or a dirty bomb.
- However, the radioactivity of SNF protects it from misuse.
  - NRC and IAEA consider the "self protecting" dose rate to be 1 Sv/h at 1 m from the fuel assembly.
- OECD/NEA Expert group AFCS has been calculating a benchmark in order to
  1. ensure sufficient self protection of SNF and
  2. verify and validate computational systems.
- VTT has been participating in the benchmark using VTT’s own Serpent code.
2.2 Gamma dose rate after 30 years cooling

- VTT’s results calculated with our Serpent code corresponded well with the results of the other institutions.
- The self protection limit 1 Sv/h is easily met.

30 years cooling UOX

30 years cooling MOX
2.3 Gamma dose rate after 3,7 years cooling

- VTT’s results at 3,7 years cooling time are somewhat smaller than the results of the other institutions.
- One reason for this is that at the moment, Serpent does not take into account Bremstrahlung resulting from beta decay.

<table>
<thead>
<tr>
<th>3,7 years cooling UOX</th>
<th>3,7 years cooling MOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion factor</td>
<td>VTT [Sv/h]</td>
</tr>
<tr>
<td>1977</td>
<td>29</td>
</tr>
<tr>
<td>1991</td>
<td>23</td>
</tr>
</tbody>
</table>
3 Current and future work

- Scenario codes
  - In the future we will participate in the development work of SITON in co-operation with the Hungarian developers.
  - The goal is to be able to participate in international co-operation such as e.g. the work done by NEA expert group AFCS and EU projects.

- Gamma dose calculations
  - Currently the benchmark is being continued with code-to-experiment comparisons.
  - The goal is to validate the computational tools by comparing to measurement results.
TECHNOLOGY FOR BUSINESS
ADVANCED FUEL CYCLES – NEW ADJUSTABLE SEPARATION MATERIALS (SERMAT)

ELMO WIIKINKOSKI
KYT2018 SEMINAR 7.4.2017 HELSINKI
BACKGROUND

SERMAT in short

• Metal phosphates
• Study on ion exchange, and the material itself
• An/Ln separations

• In 2015-2016 there was a shift from outcome oriented research to cause oriented
Continuation to 4-year project in KYT2014

New goals…

• Investigations “at a very deep level”
• New methods in use
• Optimal separation material

… and old ones!

• The development of similar materials
• Separation process
GENERAL

An/Ln separations

• Am$^{3+}$ and Eu$^{3+}$ as representatives of trivalents in their groups

In inactive studies, Eu is often used as an analogue/model for Am, since their chemistry is similar.

The idea here is that if the separation succeeds for such elements, perhaps also for “easier cases”.

Why do we focus on trivalents? International efforts on partitioning & transmutation would want to see Am and Cm to be burned in future reactors.

• High contribution to total radiotoxicity at certain time interval
RESULTS 1/5

For Zr-phosphates we have:

• determined the effects of synthesis conditions on material properties and ion selectivity:

• characterized the different products on their general properties
  - Acidity, crystallinity, crystal structure, IR-absorbance, morphology

• determined the distribution coefficients in acidic media: Eu/H and Am/H selectivities

• found correlation between the synthesis (acidity, crystallinity) and selectivity (distribution coefficient, selectivity coefficient, metal binding constant)
The trends

- Europium is always preferred over americium
The trends, cont.

- Distribution coefficients increase in the reverse order in which the acidity of the product does.
- Same happens with both the selectivity coefficients and the metal binding coefficients, against acidity.
The trends, cont.

• Acidity increases as crystallinity decreases
• Unit cell volume slightly increases, as acidity decreases
RESULTS 5/5

Is it a clay…? Is it a zeolite…? NO, it’s a phosphate!
CURRENT AND FUTURE WORK

New methods to the rescue!

- Laser induced fluorescence in Dept. of Chemistry
- Insight on the chemical surroundings of our analyte: number of different ion exchange sites in use, and the character of them
  - Character of the analyte species
  - All this as a function of pH, for example
- System is fired up but no analysis yet to show
CURRENT AND FUTURE WORK

New methods to the rescue, cont.

• “Macro-amount” studies
  • Majority of done experiments have been on trace radionuclide levels
• Insight on the ion exchange site problem described earlier
THANK YOU! Questions?
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