Fission Product Partitioning and Integrated Waste Management – Advanced Approaches and Opportunities

W. Mark Nutt, Ph.D.
Argonne National Laboratory

Actinide and Fission Product Partitioning and Transmutation, Tenth Information Exchange Meeting
Mito City, Japan
October 8, 2008
Presentation Outline

- The importance of fission product partitioning
- GNEP/AFCI goals
- The GNEP/AFCI Fuel Cycle
- The waste management system and the GNEP/AFCI Integrated Waste Management Strategy
- GNEP/AFCI waste streams and potential waste forms
- Recent evolution of waste management under GNEP/AFCI and potential waste forms
- On-going GNEP/AFCI activities related to fission product disposition
- On-going GNEP/AFCI waste form development
- Concluding Points
Fission Products Partitioning

Why partition fission products?
- Separate from U and TRU (fuel resource)
- Reduce long-term risk from disposal
- Reduce the thermal burden on the disposal system
- Because it happens during processing steps
  - Iodine, Carbon, Krypton in off-gas
  - Un-dissolved solids from dissolution

What are the disposition pathways for partitioned fission products?
- Transmutation
- Direct disposal
  - *Tailored waste forms*
- Decay storage followed by disposal
Important Fission Products

- Tc-99, I-129, C-14: potential long-term risk following repository closure

Important Fission Products

**Cs-135 and Sr-90:** near term thermal response in a disposal system

Reduce the environmental and financial burden and uncertainty associated with long-term nuclear waste management

Optimize nuclear waste management by:
- Minimizing the risk of waste that needs to be handled or stored
- Producing only solid wastes in robust waste forms
- Recycling and reusing materials to the maximum extent possible.

Support the near-term deployment of fuel cycle technologies (20 years) as well as define longer term deployments of next-generation technologies (50 years)

Make the closed fuel cycle as economical as possible

Reduce the number of required U.S. geologic waste repositories needed for the remainder of this century
GNEP/AFCI Fuel Cycle

Fabrication → Light Water Reactor → LWR Spent Nuclear Fuel Separation → Strontium, Cesium, Uranium

- Transuranics
- Other Fission Products and Process Losses

Storage

- Low-Level Waste (LLW Disposal) or Recycle (Uranium only)
- High-Level Waste (Geologic Repository)

Mining/Milling → Enrich → Transmutation Fuel Fabrication → Advanced Burner Reactor

- Transuranics, Uranium
- Transmutation Fuel Separation

Fission Products, Process Losses
Waste Management System for an Advanced Fuel Cycle

- The waste management system is broader than disposal
  - Processing facilities, storage facilities, transportation, disposal

- Decisions must consider this entire system
  - Regulatory, economic, risk/safety, environmental, other considerations

- Waste management under GNEP/AFCI pertains to managing and disposing of fission products
  - TRU losses are expected to be small

- GNEP/AFCI Integrated Waste Management Strategy establishes the framework for analyzing and optimizing the waste management system
  - Emphasizes recycle and reuse, but based on economic recovery evaluation factoring in value of material and cost avoidance of disposal
  - Considers need for industry to have a reliable system to routinely transport nuclear materials and dispose wastes
GNEP/AFCI Integrated Waste Management Strategy Logic Diagram
GNEP/AFCI Aqueous Processing Waste Streams

Chopping
- Cladding: Zircaloy
- Hardware: SS → Metal Waste Form

Volox
- Gases: I, HTO, Kr, Xe, CO₂ → Specialized Waste Forms

Dissolution
- UDS: Pd, Ru, Rh, Mo, Tc, Zr, O → Metal Waste Form

UREX
- Ion Exchange
- Tc → Metal Waste Form
- U → Metal Waste Form

FPEX
- Cs/Sr: Cs, Sr, Ba, Rb → Decay Storage Waste Form

TRUEX
- TMFP: Fe, S, Ru, Pd, Rh, Mo, Zr → Metal Waste Form

TALSPEAK
- LNFP: Ce, Ln, Pr, Nd, Y → Glass Waste Form
- TRU: Pu, Am, Cm, Np → Losses
Recent Evolution of GNEP/AFCI Waste Management

- Initially considering isolating individual waste streams into separate waste forms
  - Tc, Cs/Sr
- Critical evaluation of waste management baseline completed
- New baseline developed striving to
  - minimize complexity and number of waste processes
  - minimize amounts of various waste types
  - use nature to guide → match waste form to waste and disposal chemistries
- Key unknowns/uncertainties
  - repository type (Yucca Mtn currently limited to 70,000 MTHM)
  - waste type classification (NWPA based on PUREX)
  - requirements for capture of fission product gases
  - GTCC disposal
Recent Evolution of the GNEP/AFCI Waste Management “Baseline”

- **Hulls Hardware**: Compact → Metal for GTCC or Repository Disposal
- **HTO**: Capture Cement → Cement for LLW Disposal
- **$^{14}\text{CO}_2$**: Capture Encapsulate → Zeolite in Geo-polymer for Repository Disposal
- **Iodine**: Capture Encapsulate
- **UDS**: Reduce Melt → UDS, Tc, TMFP Alloy for Repository Disposal
- **Tc**: Reduce Melt
- **TMFP**: Vitrify Decay store → Cs/Sr, LN Glass for Repository Disposal
- **Cs/Sr**: Vitrify Decay store
- **LN**: Vitrify Decay store

October 7, 2008
On-Going AFCI/GNEP Activities Related to Fission Product Disposition

- **Combination of transition metal fission products with Cs/Sr/LN waste form**
  - Elimination of process step
  - Trade-off is increase in waste form volume
  - Preliminary analysis indicates overall cost savings

- **Heat Management Strategy Trade-Studies of Various Concepts**
  - Extended SNF aging
  - Interim waste form storage for up to 10 half-lives
  - Storage at reactor, reprocessing plant, repository, interim facility
  - Transportation, handling, processing, security, permitting issues
  - Facility M&O costs
  - Ultimate disposition of materials
Waste Form Development

- Completed preliminary technology readiness level assessment for waste forms
- Evaluated waste and storage form testing approaches
- Continued work on production and performance of candidate waste and storage forms
  - Cs/Sr: bentonite and aluminosilicate glass for aqueous, glass-bonded sodalite for electrochemical
  - Tc: high-loading alloys
  - I: Ag loaded zeolites and novel materials
  - Lanthanides: lanthanide borosilicate glass
  - Lanthanides & transition metal fission products: alkali borosilicate glass
  - Electrochemical processing: metallic and ceramic waste forms
Waste Form Development

Cs/Sr Glass

Glass Bonded Sodalite

Metallic Waste Form from Electro-Chemical Processing

Lanthanide Borosilicate Glass
The partitioning of fission products in an advanced nuclear fuel cycle presents opportunities for improving the management of nuclear wastes.

A systematic approach is needed to develop the entire waste management system, considering a broad suite of aspects.

Activities are underway in GNEP/AFCI to develop/characterize waste forms and to optimize the waste management system per an Integrated Waste Management Strategy.