Neutron analysis and transmutation performance of Th-based Molten Salt Fuels

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Introduction
• Molten Salt Reactor (MSR)
  • MSR operates near atmospheric pressure.
  • It runs at temperature higher than water cooled reactors.
  • It is online processing.
  • Molten Salt acts as the primary coolant and as the fuel itself.
• We consider subcritical MSR with Accelerator Driven System
• Studies of Li-Be and Na based fuels have done in the past but little attention has been given to the Pb based fuel.
• Thorium fuel and thorium fuel cycles are attractive for the long-term nuclear energy production with low radioactive waste.

Main motivation to estimate
• neutron multiplication factor ($K_{cm}$),
• breeding or conversion ($\frac{\text{Fission}}{\text{Capture}}$) potential,
• elimination potential of Minor Actinides,
• safety characteristic (temperature coefficient)
• for Li-Be Fluoride, Na Chloride and Pb Chloride
• with or w/o Th and $^{233}$U and additionally Minor Actinides and Pu

Geometry of Accelerator Driven Molten Salt Target System

Monte Carlo Simulation
We used two calculation methods:
- Energy Amplifier Monte Carlo (EA-MC): assuming D-D fusion neutron source
- FLUKA: Correct simulation of spallation process induced by 1 GeV protons impinging directly on the molten salt fuel

Results
1. Comparison of neutron spectra in molten salts with and without Thorium
Assuming 1 GeV 1mA proton beam impinges directly on the fuel

2. $K_{cm}$ and Breeding Ratios for Thorium-$^{233}$U Uranium Fuels
Calculation of $K_{cm}$ with different Uranium enrichment

3. Thorium + Plutonium + Minor Actinides @ $K_{eff} = 0.98$

4. Temperature Coefficients for different fuels

Conclusion
• AD-MSR is interesting: Molten Salt acts as fuel, coolant and target.
• Thermal/epithermal Li-Be fluoride molten salt is better than Na- or Pb (III) chloride for a pure Th-U fuel.
• Chloride fuels have disadvantage due to higher (n,γ) cross section from thermal to resonance energies.
• Fast neutron system is preferred for the transmutation of Minor Actinides.

Relative comparison of MSFs
- For less $^{233}$U enrichment
- For better Breeding (Conversion) Ratio
- For more Spallation neutrons
- For more Transmutation of Minor Actinides
- For safer Temperature Coefficient

Breeding (Conversion) Ratio

Neutron flux (Arb.)

$^{233}$U Enrichment (%)