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Improved Molten Salt Reactor Design with New Nuclear Data for the ^{35}Cl(n,x) and ^{56}Fe(n,n') reactions

PI: Lee A. Bernstein - UC Berkeley

Collaborators: Massimiliano Fratoni - UC Berkeley

Jon Batchelder - UC Berkeley

Program: NEAMS

ABSTRACT:

Sodium cooled fast reactors (SFR) and molten chloride salt fast reactors (MCFR) are inherently highly fault-tolerant, show great promise in consuming spent LWR fuel and facilitate fission fragment removal during operations. However, the higher neutron energies in these designs cause reactions other than (n,γ) to play important roles as neutron poisons. The Working Party on Evaluation Cooperation (WPEC) of the OECD Nuclear Energy Agency Nuclear Science Committee [1] established that neutron elastic and inelastic scattering on ^{56}Fe is a non-negligible source of uncertainty in determining the effective multiplication factor and the coolant-void reactivity feedback of that same system. More recently discrepancies have been shown between different covariance data [2]. In the case of ^{35}Cl the impact on MCFRs appears to be dramatic beyond simple sensitivity leading to calls for the use of highly-enriched ^{37}Cl, despite the significant additional cost.

In the past year, preliminary ^{56}Fe(n,n'γ) measurements have been performed using the recently developed Gamma Energy Neutron Energy Spectrometer for Inelastic Scattering GENESIS at Lawrence Berkeley National Lab (LBNL) 88-Inch cyclotron. In the case of ^{35}Cl(n,p) our group performed the first measurement at MCFR-relevant energies yielding a value lower than that in any of the data libraries by nearly a factor of five. Suggesting the anticipated potential increased cost of highly-enriched ^{37}Cl may be less than the current thinking for MCFRs. Furthermore, the cross section showed a resonant-like behavior that is contrary to the expectations of reaction evaluation for such high energies, highlighting the need for new energy differential measurements to better understand reactions at these intermediate energies.

In this proposal we plan to measure the ^{35}Cl(n,p), (n,α) and (n,γ) energy-differential and integral cross sections involves simultaneously irradiating a Cs_2LiYCl_6:Ce (CLYC) scintillator detector as an active target in the center of the newly-built GENESIS array (which combines HPGe and n-detectors). Pulse height signals from the CLYC detector will be used to determine the (n,p) and (n,α) cross section as a function of energy and an external Clover HPGe detector will be used to determine the (n,γ) cross section. The ^{56}Fe(n,n) and ^{56}Fe(n,n'γ) differential cross-sections will be measured with the same setup by replacing the active CLYC target with a large area ^{56}Fe target. For these measurements we will use the ^{7}Li(p,n) reaction on a thick metallic lithium target to produce an energy spectrum that is similar to a MCFR neutron spectrum.

In addition to the chlorine and iron measurements described above we will perform advanced reactor modeling in order to evaluate the impact of this new nuclear data on major performance parameters of MCFR and SFR systems. This includes a representative burner and a breed and burn (aka traveling wave) designs. Design analysis will be performed on fertile uranium and plutonium fed design to determine parameters such as reactor size, fuel attainable burnup, reactivity coefficients, and ^{36}Cl production. The analysis will be performed used generalized perturbation methods as available in the Monte Carlo code Serpent2 or using Total Monte Carlo techniques as necessary.