Determining (n,f) and (n,γ) cross sections using surrogate reactions

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Direct measurements of neutron reaction cross sections on unstable nuclei are extremely challenging due to the difficulties associated with radioactive targets and neutron beams. Indirect methods, such as the surrogate reaction method, are currently the only feasible way to determine many of these cross sections. The surrogate reaction method uses a combination of reaction modeling and experimentally measured decay probabilities to determine cross sections that proceed through a compound-nuclear state. We have used this method to determine (n,f) and (n,γ) cross sections for nuclei for which the compound nucleus of interest can be created through light-ion reactions on stable or long-lived targets. The STARS/LiBerACE silicon and germanium detector arrays were used to detect fission fragments and γ-rays in coincidence with the direct reaction particles. The (n,f) cross section of ^{237}U, an isotope with a half-life of only 6.75 days, was determined relative to the precisely-known ^{235}U(n,f) cross section. The ^{238}U compound nucleus was excited to energies up to 25 MeV using inelastic α scattering. As a test of the technique, the ratio of the ^{233}U(n,f) to ^{235}U(n,f) cross sections was measured in a similar experiment. The results agreed within 10% with the directly-measured cross section ratio. In addition, we have determined γ−ray exit-channel probabilities for ^{154,156,158}Gd compound nuclei excited by inelastic proton scattering. This data can be used to determine the (n,γ) cross sections for ^{153,155,157}Gd at energies up to 3 MeV. Techniques are being explored to extract reliable cross sections at energies for which the Weisskopf-Ewing limit of the Hauser-Feshback theory is not applicable. The cross section measurements using ^{156,158}Gd targets are compared to direct measurements of the (n,γ) cross sections for ^{155,157}Gd to test the validity of assumptions and expose limitations of the surrogate reaction method. This measurement will provide the first determination of the (n,γ) cross section for ^{153}Gd, an s-process branch-point nucleus with a half-life of 240 days.
Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DEAC52-07NA27344.