Measurement and Resonance Analysis of the Neutron Capture Cross Section of ^{237}Np

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Neutron capture cross section measurements for ^{237}Np have been conducted with neutrons with energy ranging from thermal energy to several hundred eV. A Time of Flight (TOF) method using NaI(Tl) detectors was employed for this measurement and the data were analyzed based on a pulse-height weighting technique in order to derive a neutron capture cross section. The resolved resonance region was analyzed using the REFIT fitting code and the resonance parameters were extracted.

Keywords: J-PARC, ANNRI, Neutron capture cross section, NaI(Tl) detector, Minor actinides, Time-of-flight measurement, Resonance Analysis

1. Introduction

Accurate nuclear data for neutron capture cross sections on minor actinides (MAs) are of utmost importance for fundamental studies and applications in nuclear science and engineering. Neptunium-237 is one of the most abundant MAs in spent nuclear fuels. It possesses a long half-life of 2.144 x 10^6 years and it produces an intense α-emitter of ^{238}Pu by neutron capture and a subsequent β decay. Hence, it is essential to determine the thermal neutron capture cross section (σ_{th}), the resonance parameters and the neutron cross section in the high energy accurately when examining the nuclear transmutation of ^{237}Np. An extensive set of experimental data has been reported on the ^{237}Np (n, γ) reaction using both activation and time-of-flight (TOF) methods. The thermal energy region is well described but, up until now, it has not been possible to obtain a steady value for σ_{th} as differences between experiments differ from 7.5% up to 15%. In the present work, results of the neutron capture cross section for ^{237}Np are presented for incident neutron energy ranging from thermal energy to several hundred eV using a TOF method. Alongside, the results of a resonance analysis using the REFIT fitting code are also presented with fitted values for the resonance energy E_λ, neutron width $E_{\lambda,n}$ and radiation width $E_{\lambda,\gamma}$.

2. Experiments

The experiments were performed using the Accurate Neutron Nucleus Reaction Measurement Instrument (ANNRI) at the Materials and Life Science Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC). Intense pulsed neutrons were produced by the Japanese Spallation Neutron Source (JSNS) in the MLF building using the 3 GeV proton beam of the J-PARC facility. The proton pulses were shot at the spallation target every 40 ms. A TOF method was employed in the present experiment with a flight path of 27.9 m up to the sample position. Emitted γ-rays from the sample were detected by a NaI(Tl) detector surrounded by annular plastic scintillation detectors to suppress cosmic-ray background by anti-coincidence detection. A 200 mg capture sample of ^{237}Np was used for the measurements. The powder was packed into an Al pellet with a 20 mm diameter and 0.4 mm thick walls. A dummy container was also used for background measurement. Two neutron spectrum were obtained in this experiments using a 20 mm diameter gold sample and also using the 478 keV γ -rays from ^{10}B (n, α) ^{7}Li events. The boron sample containing enriched ^{10}B up to 90%, had a diameter of 10 mm and a thickness of 0.5 mm. Scattered neutron background was derived using a ^{nat}C sample with a 10 mm diameter and 0.5 mm thickness.

3. Resonance Analysis

The neutron capture resonances of ^{237}Np in the resolved resonance region were analyzed using the least-square fitting code REFIT. The initial resonance parametrization data expressed by resonance energy E_λ, neutron width $E_{\lambda, n}$ and radiation width $E_{\lambda, \gamma}$ and fission width $E_{\lambda, f}$ were taken from JENDL-4.0. The parameterized resonance function was fitted to the experimental results using the REFIT code and values for resonance energy E_λ, neutron width $E_{\lambda, n}$ and radiation width $E_{\lambda, \gamma}$ were extracted. An averaged radiation width was obtained using 16 independent resonances under 20 eV and it was used as fixed value for the other resonances. Thus, for the other resonances, only resonance energy E_λ and radiation width $E_{\lambda, \gamma}$ were fitted. Statistical properties of the resonances such as level spacing are also presented.

4. Conclusion

The ^{237}Np neutron capture cross section was measured using the pulsed neutron beam generated by the Japanese Spallation Neutron Source in the Materials and Life science Facility at the Japan Proton Accelerator Research Complex. A thermal value for the cross section was obtained together with a set of fitted resonance parameters.