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Modeling the energy dependence of the $^{237}\text{Np}(n,f)$ reaction cross-section in the 0.1–30 MeV range

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A general understanding has emerged regarding the processes governing a wide range of nuclear reactions, particularly fission—see, for example, the review in [1]. Based on this understanding, computer codes have been developed to calculate total and partial cross-sections for the interaction of nuclei with light nuclear particles, specifically neutrons. All such codes rely on models describing various stages of the reaction, and each model involves specific parameters. Typically, however, only some of these parameters can be fixed, while the values of others remain uncertain. In this work, we calculate the fission cross-section of the ^{237}Np nucleus as a function of incident neutron energy in the 0.1–30 MeV range and compare the results with experimental data [2–4]. This reaction was selected because recent work [5] provided additional information on the process—specifically, measurements of fission fragment angular anisotropy in the 0.4–200 MeV range. Reference [5] also presented a novel method for calculating angular anisotropy and demonstrated that a joint comparison of calculated and measured values for both the fission cross-section and angular anisotropy will allow obtaining additional information about the fission process. However, the authors of [5] were unable to reproduce the observed dependence of the fission cross-section on incident neutron energy in certain energy intervals. In the present work, the open-source code TALYS (version 2.2) [6] was used to model the $^{237}\text{Np}(n,f)$ reaction for incident neutron energies ranging from 0.1 to 30 MeV. The complexity of modeling fission arises from the fact that, in addition to the optical model and level-density model parameters built into the code, we must also consider parameters defining the shapes of fission barriers and nuclear characteristics at those barriers. Typically, calculations performed in TALYS using default parameters fail to accurately reproduce the energy dependence of the fission cross-section. This case turned out to be exactly like this. Therefore, in this work, the parameters that determine both the shape of the double-humped fission barriers of Np isotopes with mass numbers from 238 to 235, as well as the collective increase in the level density and the shape of the nuclei on the humps of the barriers of these same isotopes, were varied. This approach enabled us to reproduce the experimentally observed energy dependence of the fission cross-section with high accuracy. The resulting parameter values can be incorporated into models describing the angular anisotropy of fission fragments in the $^{237}\text{Np}(n,f)$ reaction, thereby yielding new insights into the characteristics of transition states at the fission barriers.

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