Neutron-Induced Astrophysical Reaction Rates for Translead Nuclei

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Investigations of nucleosynthesis processes make use of reaction networks including thousands of nuclei and tens of thousands of reactions. Most of these reactions occur far from stability and thus cannot yet be directly studied in the laboratory. In addition most of the nuclear properties are not experimentally known either. Therefore, predictions based on theoretical models are necessary. While close to stability partial experimental information is available, relying fully on theoretical information leads to relatively large variations in computed cross sections far from stability. This is especially true for the region of fissionable nuclei, which was the focus of the present investigation (see also [1]).

In previous astrophysical calculations fission, especially neutron-induced fission has often been neglected. However, it was shown recently that this channel plays important role in r-process nucleosynthesis [2,3]. Here we present extended calculations of neutron-induced fission rates for different model predictions of masses and fission barriers. The calculations have been done for large range of astrophysical temperatures ($10^8 \leq T(\mathrm{K}) \leq 10^{10}$). The present work also completes existing nuclear neutron-capture rate sets by extending the works of [4,5] to the region $84 \leq Z \leq 118$ in order to provide the necessary input for nucleosynthesis studies under high neutron densities. As in [5], the statistical model approach of Wolfenstein-Hauser-Feshbach was used employing more recent data and predictions for masses, spins, and fission barriers.

For a realistic and exhaustive exploration of synthesis conditions, simulations do not only have to vary astrophysical parameters, but also have to include a variation range of involved reaction rates given by different mass and fission barrier models. By comparing rates obtained with different choices of mass and fission barrier predictions we attempt to give a measure of the involved variations. The following mass- and fission-barrier-models have been used: FRDM [6], ETFSI [7,8], TF [9,10]. Details on the model calculations can be found in [1].

In Fig. 1, as an example, are given fission cross sections calculated for ^{261}U by combining different sets of masses and fission barriers. The difference at low energies is due to the different mass predictions used (comparing calculations with TF fission barriers but different neutron separation energies S_n). The small decrease in S_n, when predictions for masses and fission barriers (based on the two sets of input data) are changed from TF+TF to FRDM+TF, results in a decrease of the neutron-induced fission cross sections. The same influence is illustrated by the cases where sets of consistent determinations for S_n and B_f are replaced by sets from different mass predictions.

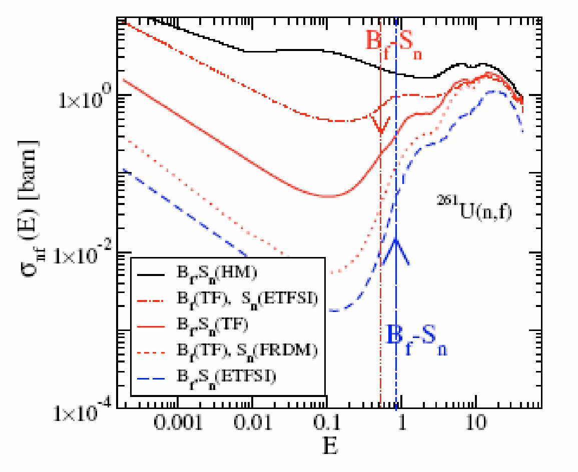

Figure 1: Dependence of neutron-induced fission cross sections $\sigma_{nf}(E)$ on mass- and fission barrier predictions for ^{261}U. The sources for fission barriers B_f and neutron separation energies S_n are indicated in the panel. Arrows show the difference between fission barrier and neutron separation energy $B_f - S_n$ for ETFSI (dashed line) and TF (full line) predictions.

The neutron-induced fission rates and neutron-capture rates calculated in the present work were fitted as in previous work [4] in the common REACLIB seven parameter form, and these parameter are also tabulated. The complete tables are available at [11]. They provide the basis for r-process nucleosynthesis calculations where the abundance predictions for the highest mass numbers as well as the effect of fission cycling are strongly dependent on the interplay between neutron capture and fission

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References

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