Investigating the total reaction cross sections of radiative neutron capture reactions with ^{237}Np

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ABSTRACT

Neptunium is a new fuel candidate for space nuclear reactors and applications. Neutron activation of ^{237}Np leads to the production of ^{238}Np which can further generate ^{238}Pu via β^- decay. Due to the scarcity of ^{237}Np and its limited, so far, technological usage, the need for validated data for the ^{237}Np(n,γ)^{238}Np reactions is high. In the current work statistical theory modelling of these reactions is performed using the latest version of TALYS (v1.9) code in an extended range of neutron energies between 10 keV and 10 MeV, providing also important information for nuclear structure. Theoretical calculations are compared to available experimental total cross section data found in literature in an attempt to investigate any discrepancies between experiment and theory and validate statistical uncertainties.

INTRODUCTION

^{237}Np is a Minor Actinide present in the LWR spent fuel and due to its being a very long-lived alpha emitter ($t_{1/2}$ = 2.14·10^6 a) it poses an issue for waste management.

An easy and rather simple way to handle and take advantage of it, is to transmute it using fast neutron fluxes. Two possible reactions can take place: nuclear fission and conversion to ^{238}Pu. Since the fission reaction cross section has been extensively studied at high neutron energies, it is of great importance to study the reaction cross sections of processes resulting in conversion to ^{238}Pu.

$$n + {}^{237}\mathrm{Np} \rightarrow {}^{238}\mathrm{Np} + \gamma \xrightarrow{\beta-} {}^{238}\mathrm{Pu}$$

In addition, there is interest in neutron-capture reactions for transuranium isotopes from the nuclear structure perspective, as these reactions are important for heavy element production during stellar and explosive nucleosynthesis.

However, radiative neutron capture cross section data are very scarce, especially at high neutron energies (E_n > 10 keV) with only two experimental data sets available in this range up to 300 keV [1-3].

In this work, we employ the Hauser-Feshbach statistical theory to estimate the total (n,γ) cross sections between 0.01-10 MeV by means of the recent version of TALYS code (v 1.9) [4]

RESULTS

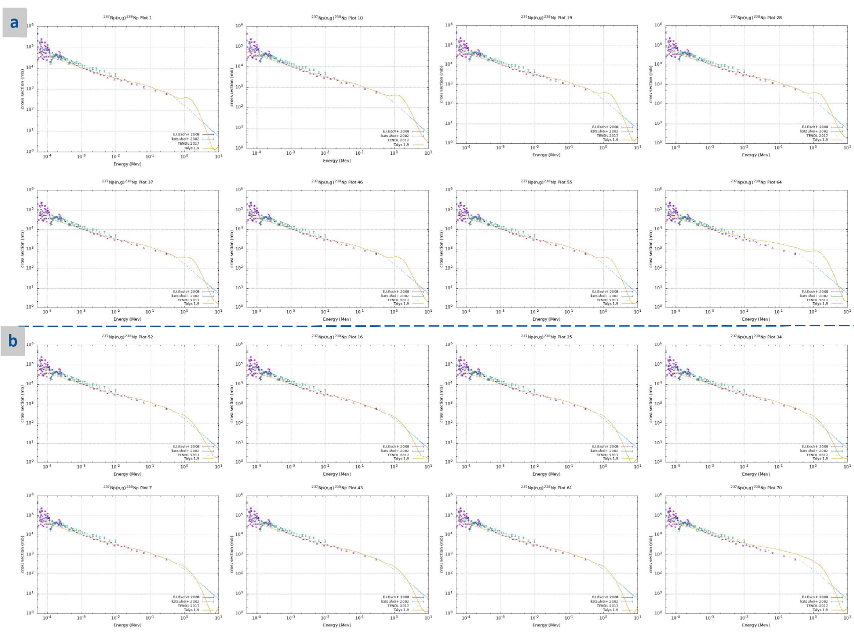

*Figure 1: A subset of results from the different model combinations; **a** OMP1/NLD2/all γSF, **b** OMP1/NLD6/all γSF*

METHODOLOGY

TALYS is a software package for the simulation of nuclear reactions. For the case of radiative capture reactions, TALYS calculations depend on:

- The Optical Model Potential (OMP)
- The Nuclear Level Densities (NLD)
- The γ-Strength Function (γSF)

In the present calculation, several models for each one of the above parameters have been incorporated. In total, 72 combinations were used to estimate the total reaction cross sections of ^{237}Np(n,γ)^{238}Np in the energy range 10 keV - 10 MeV with an energy step of 5 keV.

Table 1: The Optical Model Potentials (OMP), Nuclear Level Densities (NLD) and γ-Strength Functions (γSF) used for the calculations.

OMP	NLD	γSF
1. Global OMP (Koning & Delaroche)	1. Constant Temperature & Fermi Gas Model	1. Kopecky-Uhl generalised Lorentzian
2. Local OMP (Koning & Delaroche)	2. Back-shifted Fermi Gas Model	2. Brink-Axel Lorentzian
3. Semi-microscopic optical model (JLM)	3. Generalized Superfluid Model	3. Hartree-Fock BCS tables
	4. Microscopic LD (Skyrme) Goriely's tables	4. Hartree-Fock-Bogolyubov tables
	5. Microscopic LD (Skyrme) Hilaire's tables	5. Goriely's hybrid model
	6. Microscopic LD (TD HFB, Gogny) Hilaire's tables	6. Goriely T-dependent HFB
		7. T-dependent RMF
		8. Gogny D1M HFB+QRPA

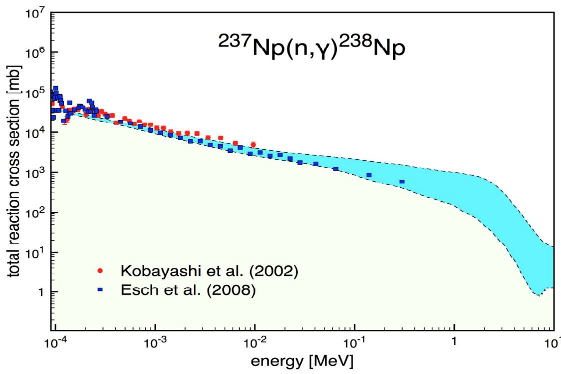

Figure 2: Range of calculated cross sections (shaded area) from all model combinations employed in the present study.

CONCLUSIONS

- There is an overall very good agreement with the available experimental data at high neutron energies (Fig.2);
- For E_n > 10 keV all calculations estimate the (n,γ) cross sections within one order of magnitude. This highlights the importance of acquiring experimental data in this energy region to improve theoretical modelling;
- The cross sections at high E_n are sensitive on the choice of the NLD, γSF (Fig.1);
- Suggested potential applications: Fast Nuclear Space Reactors, Radioisotope Thermoelectric Generators, correction for cosmic radiation fluxes.

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