(n,γ) cross-section for astrophysical aspect: Role of Nuclear Level Density and Photon Strength Function

B. Layek[1], R. Shil[1], K. Banerjee[2,3], B. Mukherjee[1], and A. Chakraborty[1*]
[1] *Dept. of Physics, Siksha Bhavana, Visva-Bharati, Santiniketan-731235, India*
[2] *Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata-700064, India and*
[3] *Homi Bhabha National Institute, Anushakti Nagar, Mumbai-400094, India*

Understanding the origins of elements heavier than iron poses a significant challenge. This challenge involves exploring the intricate interactions between nuclear reactions and the extreme conditions found in stellar environments. Despite notable progress, many questions remain about the specific astrophysical sites where these processes take place. To precisely reproduce the observed abundances of the heavy elements, accurate nuclear reaction rates for the processes like (n,γ), (p,γ), and (γ,n) are crucial. Direct measurements of these reactions on short-lived radioactive nuclei are not feasible; so indirect techniques or theoretical calculations are often utilized. Theoretical models are essential for prediction of reaction cross-sections and thermonuclear reaction rates that are used in nuclear reaction network calculations.

The nuclear reaction cross-sections are calculated using the statistical Hauser-Feshbach (HF) formalism [1], which depends on nuclear level density (NLD) and γ-ray strength functions (γSF). The NLD represents the number of energy levels per unit of excitation energy, while the γSF quantifies the average probability of γ-ray absorption or emission as a function of γ-ray energy. Over the years, various phenomenological and microscopic models have been developed to describe both NLD and γSF. Examining how different models of NLD and γSF influence experimental cross-sections is an area of significant interest.

The isotopes of tin (^{119}Sn and ^{121}Sn) are of particular astrophysical interest due to their enigmatic origins [2]. Current nucleosynthesis models often fail to account for the observed abundance of tin isotopes, pointing thereby a need for further investigation. In this study, we have focused on calculating the cross-sections using several NLD and γSF models for the reactions, ^{118}Sn(n,γ)^{119}Sn and ^{120}Sn(n,γ)^{121}Sn.

The calculation have been performed using TALYS v1.96 [3] with default parameterizations for both phenomenological and microscopic nuclear level density (NLD) as well as γ-ray strength function (γSF) models. The phenomenological NLD models include the Gilbert-Cameron (GC) model, the Back-shifted Fermi Gas Model (BFGM), and the Generalized Superfluid Model (GSM). The microscopic NLD models are based the Skyrme Hartree-Fock-Bogoliubov (HFB) and Gogny-HFB frameworks. The γSF is predominantly characterized by dipole (E1) strength, with the Brink-Axel model being the conventional approach for E1 radiation, which uses a standard Lorentzian (SLO) to describe the dipole line shape. Several phenomenological modifications of the SLO function, such as the Kopecky-Uhl generalized Lorentzian (GLO), Goriely's hybrid model (G-Hybrid), Goriely Temperature-dependent HFB (GT-HFB), and Simplified Modified Lorentzian (SMLO) have been developed [3]. Additionally, microscopic models like Skyrme-HFBCS, Skyrme-HFB, Tempertaure-dependent Relativistic Mean Field model (T-RMF), and Skyrme-HFB model with QRPA are also avail-

*Electronic address: anagha.chakraborty@visva-bharati.ac.in

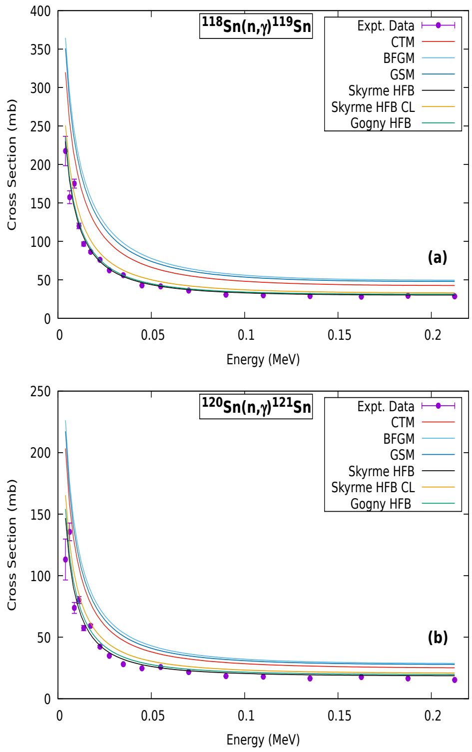

FIG. 1: Experimental cross-section for ^{118}Sn (n,γ)^{119}Sn (Top Panel) and ^{120}Sn (n,γ)^{121}Sn (Bottom Panel) [2] are compared with statistical Hauser-Feshbach calculations using various NLD models.

able [3].

To evaluate different NLD models, the γSF has been fixed at the Kopecky-Uhl-GLO values, and to explore various γSF models, the NLDs have been fixed at GC-NLD values. The calculated results, shown in Fig. 1, reveal significant variations in cross-sections among the different NLD models and the Skyrme-HFB model provide the best agreement with the experimental data. Similarly, Figs. 2(a) and (b) demonstrate notable variations in cross-sections with different γSF models, with the T-RMF model yielding the closest match to the experimental results. More details will be presented during the symposium.

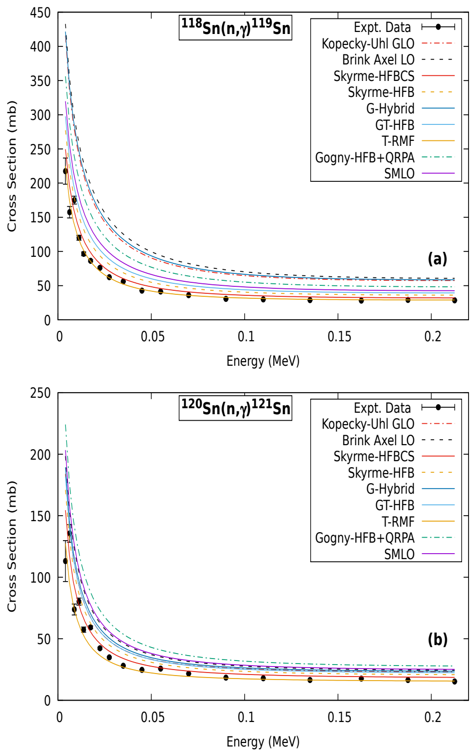

FIG. 2: (a) Experimental cross-section values for ^{118}Sn(n,γ)^{119}Sn (symbol) [2] compared with theoretical calculations (lines) using different γSF models. (b) Same for ^{120}Sn(n,γ) ^{121}Sn.

The authors, B.Layek and A. Chakraborty would like to acknowledge UGC-DAE CSR, Kolkata for providing financial assistance through CRS project no. CRS/2021-22/02/472.

References

[1] W. Hauser, H. Feshbach, Phys. Rev. **87**, 366 (1952).

[2] K. Wisshak et al, Phys. Rev. C **54**, 1451 (1996).

[3] A. Koning, S. Hilaire, and S. Goriely Eur. Phys. J. A **59**, 131 (2023), references therein.