Statistical Model Calculations with TALYS for Sn Isotopes

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Introduction

Putting a strong stamp on the origin of *p*-nuclei is an open challenge in nuclear astrophysics. The *p*-process or photodisintegration being a very important mechanism for production of these proton rich nuclei, the γ- process reaction rates are derived from proton capture reaction rates via reciprocity theorem. Nuclear reaction rates are essential ingredients for investigation of energy generation and nucleosynthesis processes in stars. These reaction rates are functions of the densities of the interacting nuclei, their relative velocities and reaction cross-sections. To estimate the abundance of any element, reaction rates of all the reactions involved in the synthesis of that element needs to be known and it is given by product of reaction cross section and velocity distribution of projectiles. The stellar temperatures are of the order of GK which translates to lower energies where charge particle induced reactions are suppressed due to coulomb barrier. Since the reaction network for p-process is vast and the cross sections are low, scarcity of experimental data at the astrophysically relevant energies calls for theoretical models to predict the cross section and estimate the reaction rates of unmeasured reactions. Generally experimental cross sections are larger than the statistical model predictions which underestimates the reaction rates at low energies, So, measurement of cross section at low energies and new statistical model calculations are highly desirable.

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The success of a statistical model depends on the various nuclear models taken as input. To predict the reliability of predictions of these models, we compare the experimental data with calculated cross sections. one such approach is TALYS which employs Hauser Feshbach Statistical model.

TALYS Calculation

Most of the reactions in stars proceeds through the formation of a Compound Nucleus (CN) for which Neils Bohr hypothesized that decay of a CN is independent of its mode of formation. Hauser Feshbach statistical model calculates cross sections for such CN states taking care of angular momentum correlations in the entrance and exit channels. The nuclear inputs that goes in the calculation are masses, nuclear level density (NLD), optical model potentials (OMP) and gamma strength function (γSF). Hauser Feshbach cross section is given by

$$\sigma \propto \tau_i \; \tau_o \; / \; \tau_{tot}$$

where, τ is the transmission probability and i, o label entrance and exit channels, respectively.

The cross sections for the proton capture reactions with ^{112,114}Sn have already been measured in the energy region relevant to p-process and compared with theory. To check for a better agreement of experimental data of Sn-isotopes with theory, in this work, theoretical analysis have been performed for Sn-isotopes, ^{112}Sn and ^{114}Sn using TALYS whose experimental data is available in literature[1, 2]. The effect of different models of NLD, OMP and γSF were investigated by alternately varying one and keeping other two fixed at defaults. It was observed that in the energy domain of the present study, the σ_{HF} is insensitive to different models of γSF and NLD but

Isotope	E_{lab} (MeV)	V_0 (MeV)	r_v (fm)	a_v (fm)	W_0 (MeV)	r_w (fm)	a_w (fm)
^{112}Sn	27.45	51.92	1.17	0.75	7.50	1.32	0.51
	27.45	47.07	1.26	0.65	9.58	1.16	0.68
	16	55.46	1.2	0.7	10.38	1.25	0.65
^{114}Sn	22	50.0	1.25	0.65	10.0	1.30	0.6

TABLE I: Optical potential parameters adjusted to proton elastic scattering on ^{112}Sn and ^{114}Sn at different lab energies.

it does depend on various models of OMP.

Optical potentials describe interaction between target and incoming projectile. The phenomenological optical potential employed in TALYS is given as

$$U = -V_v(E)f(r) - iW_v(E)f(r) - 4ia_w W_D(E)g(r) + V_{SO}(r,E)(l.s) + V_C(r)$$

where, f(r) is woods saxon form function and g(r)=df(r)/dr. The normalisation parameters were adjusted to acquire the elastic scattering optical model parameters in order to describe the experimental data extracted from ref [1, 2].

The sets of optical model parameters adjusted with elastic scattering of proton on ^{112}Sn [3, 4] and ^{114}Sn [5] used in this analysis are given in table I.

Summary

Hauser Feshbach statistical model calculations were performed to describe the experimental cross sections of ^{112}Sn(p,γ)^{113}Sb and ^{114}Sn(p,γ)^{115}Sb [1, 2] using TALYS. On investigation, σ_{HF} turns out to be insensitive to different models for NLD and γSF in the energy domain of the present study, namely 2-9 MeV for both the reactions but depends on OMP parameters. Several OMP parameter sets optimized with proton elastic scattering data [3–5] were used to calculate cross sections. S-Factor was then plotted against proton lab energy and compared with literature data, Fig.1 and Fig.2.

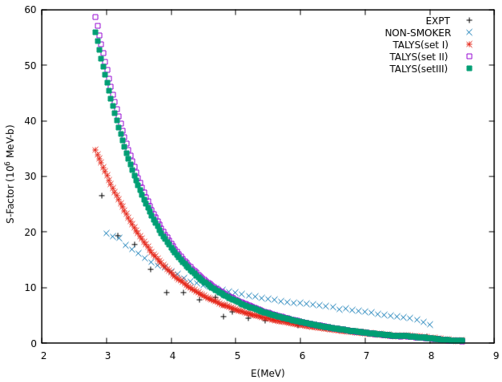

FIG. 1: S-factors for the ^{112}Sn(p, γ)^{113}Sb reaction as a function of proton energy(lab) compared with the experimental data and theoretical results from the NON-SMOKER code from [1].

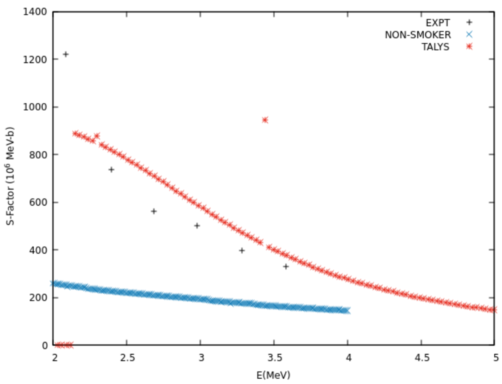

FIG. 2: Astrophysical S-factors for the ^{114}Sn(p, γ)^{115}Sb reaction. Also shown are the experimental data and predictions using the NON-SMOKER calculation from [2].

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