Influence of nuclear level density on radiative neutron capture relevent to nuclear astrophysics

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Introduction

The phenomenological analysis of Clayton et al. [1] revealed that at least two distinct components of s-process are needed to describe the solar abundance distribution. The main s-process component is responsible for the production of heavier nuclei A $\sim$ 90-209, while the weak s-process component limited to mass range A$\sim$65-90. Hauser-Feshbach statistical model calculations, used for neutron capture cross sections, requires Nuclear Level Density(NLD) as an essential input parameter. The uncertainty in the level density translates into a similar uncertainty of the neutron capture cross sections. Thus, appropriate description of NLD in Hauser-Feshbach model is necessary for accurate capture cross section predictions. Therefore, the NLD description must be accessible in forms related to various parameters such as excitation energy, angular momentum, parity etc., and it must also be adaptable to structure effects such as collective enhancement, shell effect, etc,.

It has been predicted by Bjornholm, Bohr, and Motelson [2] that there is a significant increase in the total NLD due to the occurrence of collective rotational motion. One must include the collective contribution to obtain the proper description of the NLD.

Maxwellian averaged cross sections(MACS) at 30 KeV for various nuclei are standard way to describe astrophysical radiative neutron capture reactions. Statistical Hauser-Feshbach NON-SMOKER calculations uses global Fermi gas level density prescription for

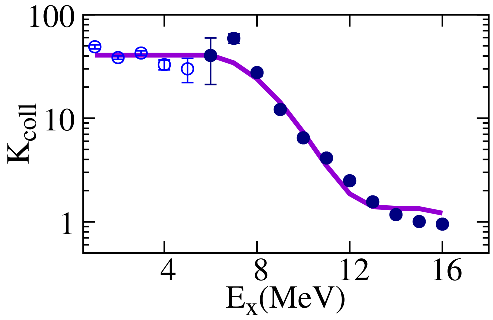

FIG. 1: Collective enhancement as a function of excitaion energy in ^{171}Yb. Open circles shows Oslo data while full circles are measured experimental collective enhancement.

reaction cross-sections. However, it has to be agreed that experimental data is needed to improve the global parameterizations used in the calculations [3].

The MACS can be expressed as,

$$\langle\sigma\rangle(kT) = \frac{2}{\sqrt{\pi}}(kT)^{-2}\int_0^\infty \sigma(E)Ee^{-\frac{E}{kT}}dE, \quad (1)$$

where k and T denote the Boltzmann constant and temperature, respectively. The calcualtion of capture cross section $\sigma(E)$ in Hauser-Feshbach model requires nuclear level density as input.

Results and Discussion

In the present work MACS values of ^{171}Yb(n,γ) reaction have been computed making use of the TALYS code [4] incorporating the recent collective enhancement factor measured for ^{171}Yb. The experiment was carried

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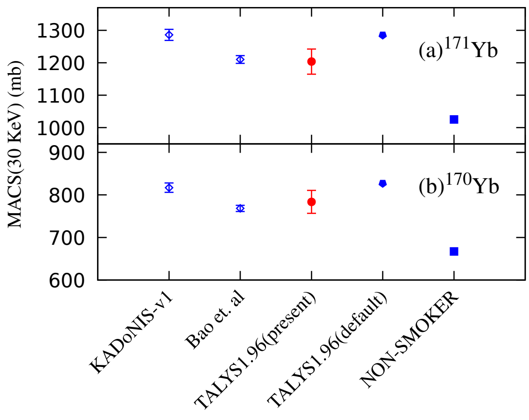

FIG. 2: (a) Calculated MACS at 30 KeV for ^{171}Yb with the present collective enhancement form incorporated in Talys- 1.96 and its comparison with TALYS-1.96 (default collective enhancement), KADoNIS-v1 compilation, NON-SMOKER calculation and well-established Bao et al. estimation (b) Similarly for ^{170}Yb.

out using incomplete-fusion reaction where fusion of triton with target nucleus to form comound ^{172}Yb [5]. We observed a large collective enhancement factor of ∼40 at nucleon binding energy where it can have strong influence on MACS values. Fig. 1 shows the collective enhancement as a function of excitation energy.

Latest calculations of s-process nucleosynthesis often are based on the dedicated nuclear astrophysics data tables, such as works of Bao et al. [6], and Rauscher and Thielemann [7]. Most recent MACS compilations are from KADONIS database [8], Mughabghab [9].

By incorporating our collective enhancement form in TALYS-1.96 reaction code, we have calculated MACS values for the ^{171}Yb. Fermi gas model with the measured collective enhancement used for calculating the MACS. The calculated MACS values were then compared with TALYS-1.96 (default collective enhancement), KADoNIS-v1, estimation of Bao *et al.*, and the statistical model code NON-SMOKER values for both ^{171}Yb and ^{170}Yb as shown in Fig.2 (a) and (b). It shows that the calculated MACS value with present collective enhancement include has very good agreement with experimental database, but ∼ 1.2 times higher than Hauser-Feshbach NON-SMOKER prediction.

Although one can calculate MACS values using experimental level densities at neutron binding energy, level density prescription with collective enhancement which includes the structure effects has better prediction over other statistical methods where parameterized level density description being used. The radiative capture cross sections of both ^{171}Yb and ^{170}Yb plays key role in s-process branching points relevant for AGB stars.

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