Cross section measurements of ^{100}Mo(α,n)^{103}Ru for weak r-process studies using stacked foil activation technique

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Introduction

Nucleosynthesis beyond iron are mainly synthesized by s- process and R-process via neutron capture reactions. But, after core-collapse supernovae explosions, in high temperature and high entropy, particles ejected from the explosions i.e. neutrons, protons and α-particles synthesize heavier nuclei by (α, xn), (p, xn) reactions. This is the probable site for the weak r-process [1]. (α, xn) reactions play an imperative role in the production of elements in range of $30 \leq Z \leq 45$ via this process [2]. ^{100}Mo(α,n)^{103}Ru is one of the reaction occurring in the process. ^{103}Ru β-decays into ^{103m}Rh, which is useful for auger electron therapy.

Peer scientists experimented technically feasible astrophysical reactions but there are discrepancies in the experimental results and theoretical results. Thus, we have studied this reaction to reduce the uncertainties by using different technique i.e. stacked foil activation method in the gamow energy region.

Experimental Details

The experiment was performed using the K-130 cyclotron at Variable Energy Cyclotron Center (VECC), Kolkata, India. In the present experiment, the alpha beam was induced by helium using the PIG ion source [3]. Alpha beam of 28 MeV was impinged on the stack. The current during irradiation was ~ 120 nA and measured by Faraday cup setup. We have used stacked foil activation method and offline γ- ray spectroscopy to determine the excitation function of alpha- induced reactions on molybdenum. In accord with this method, first we have positioned ^{nat}Al to degrade our energy to the interested Gamow energy region. Then, a stack of the thin target foils i.e. ^{nat}Mo was followed by the ^{nat}Cu. ^{nat}Cu enacted as both catcher and monitor foil. We ensured monitor foil (^{nat}Cu) before every target foil (^{nat}Mo) to calculate incident flux on target foils. We arranged the stack as ^{nat}Al followed by ^{nat}Mo accompanied by ^{nat}Cu. All of the dimensions of 10mm x 10mm. The thickness of ^{nat}Al, ^{nat}Mo, ^{nat}Cu foils were 6.75 mg/cm^2, 12.75 mg/cm^2, 9 mg/cm^2 respectively. We employed SRIM-2008 (Stopping and Range of Ions in Matter) code to calculate energy degradation of our sequenced stack. A Faraday cup was situated after the stack to measure beam current falling on the foils.

Table 1: Decay data in the experiment

Residue	Half-life (h)	E_γ (keV)	I_γ (%)
^{103}Ru	941.92	497.08	91
^{66}Ga	9.49	1039.22	37

Data Analysis

The gamma-ray activity [4] of the irradiated sample was measured by lead-shielded High-Purity Germanium (HPGe) detector in conventional way [5]. The efficiency calibration was completed using the ^{152}Eu point source ($T_{1/2}$=13.517 years of known activity A_0 = 39080 Bq as on 17 May 1982). ^{nat}Cu(α,x)^{66}Ga reaction is used as monitor reaction. The efficiency of the point source geometry was calculated by following formula [6]: -

$$\epsilon_p = \frac{CK_c}{A_o I_\gamma \Delta t e^{-\lambda t}} \quad (1)$$

The cross section was calculated using the following equation [7]: -

$$\sigma_s = \sigma_m \eta \frac{A_s \lambda_s a_m N_m I_m f_m}{A_m \lambda_m a_s N_s I_s f_s} \times \frac{C_{attn.(s)}}{C_{attn.(m)}} \quad (2)$$

Where, all the above symbols in above equation have their usual meaning.

We have employed the statistical nuclear model code TALYS-1.96 for the theoretical calculations of the reaction. We rationalized the result with different level density models in TALYS-1.96. The present experimental data has been compared with the existing cross sections data available in the EXFOR [8].

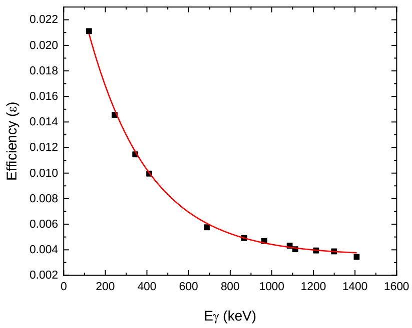

Fig. 1 Efficiency calibration curve for ^{152}Eu

Astrophysical Aspect

Gamow window (energy range where reaction can occur in stellar environment at specific temperature) ranges from E_{min}= 5.9 MeV to E_{max}= 8.4 MeV at 3 GK temperature, E_{min}= 7 MeV to E_{max}= 10.2 MeV at 4 GK temperature for ^{100}Mo.

Reaction rate helps in extrapolating energy production within a star [9]. We have calculated reaction rate using TALYS-1.96.

Table 2: Reaction rate of ^{100}Mo(α,n)^{103}Ru

T_9 (10^9 K)	Reaction Rate ($cm^3s^{-1}mole^{-1}$)
1	6.84 x 10^{-25}
1.5	7.08 x 10^{-17}
2	1.23 x 10^{-12}
2.5	6.84 x 10^{-10}
3	7.39 x 10^{-8}
3.5	3.43 x 10^{-6}
4	9.23 x 10^{-5}
5	1.49 x 10^{-2}

Results and Discussions

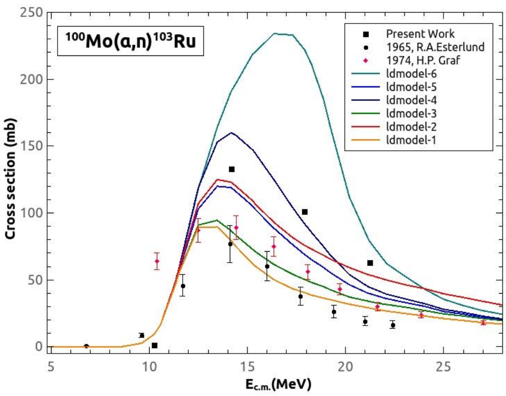

Fig. 2 The measured cross sections of ^{100}Mo(a,n)^{103}Ru reaction along with available experimental data from EXFOR and theoretical results from TALYS.

From the above fig.2, experimental obtained cross section follows the trend same as theoretical results but no theoretical model is in good agreement with the present work. More details related to cross section, uncertainty, s-factor will be conferred during the symposium.

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