Study of alpha induced reaction on p-nuclei of Molybdenum and Ruthenium using TALYS calculation

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1. Introduction

In the stellar environment, elements heavier than iron are predominantly synthesized by s-process (slow neutron capture), r-process (rapid neutron capture process) & p-process. The p-process is mainly responsible for the production of 35 stable proton rich nuclides (p-nuclei) between Se(Z=34) and Hg (Z=80) [1]. The probable site for this process is in envelope of supernova of Type II or in the outermost part of supernova Type I.

Gamma induced reaction (γ-process) play a key role in synthesis of p-nuclei. This process have problems to synthesize p-nuclei in mass region A<124 & 150<A<165 [2] and faces technical challenges, especially in case of the charged particle emitting (γ,α) & (γ,p) reaction. Thus, we have studied α-induced reaction on the most abundant p-nuclei of Molybdenum & Ruthenium. P-nuclei are 100 times less abundant than the s-process and r-process elements except for Mo and Ru [3].

We need reliable nuclear data calculations for better understanding of astrophysical phenomenon. Therefore in the proposed study we have calculated and calibrated it with respect to experimental data in the range of Gamow window (astrophysically relevant energy region).

2. Computational details

To calculate the cross section and reaction rates, we have employed Talys-1.95. For experimental information we have optimized the data from EXFOR. Cross section and the rate of nuclear reaction is imperative for understanding the nuclear reaction and astrophysical aspects of nucleosynthesis.

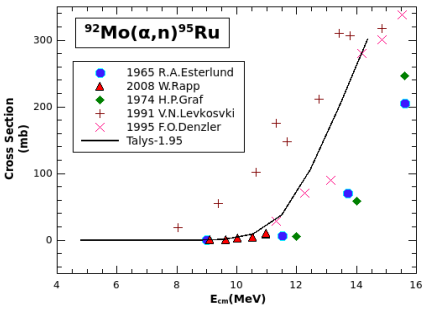
3. Results & Theoretical analysis

Gamow window is the corresponding energy range where reaction can occur, for a specific temperature in stellar environment. Gamow window for ^{96,98}Ru ranges from E_{min}= 4.8 MeV to E_{max}= 10 MeV respectively and corresponds to 2 to 3 GK temperature.

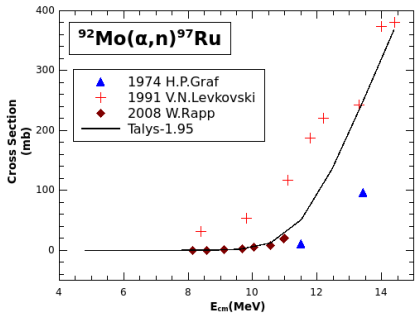
Similarly, gamow window for ^{92,94}Mo ranges from E_{min}= 4.6 MeV to E_{max}= 9.6MeV respectively and corresponds to 2 to 3 GK temperature.

3.1 Cross Section

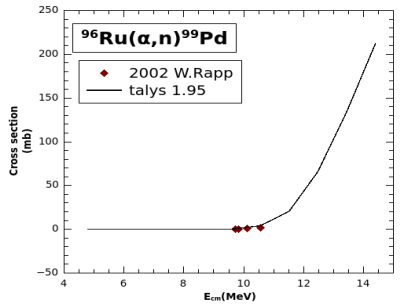
The calculated excitation functions and calibrated experimental data are shown in Fig.1.



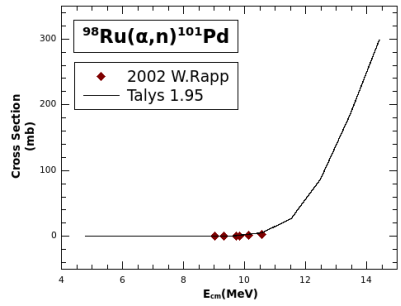
(a)



(b)



(c)



(d)

Fig.1 Experimental & Theoretical excitation energy plot

The experimental data reported by W.Rapp [4,5] at energies 9 to 11 MeV exhibit the same trend as excitation function obtained by Talys-1.95 for p-nuclei ^{92}Mo, ^{94}Mo, ^{96}Ru, ^{98}Ru. The excitation function estimated by Talys is in good agreement with the experimental data, which is reported by F.O.Denzler et al [6] as shown in fig.1.(a),. The data reported by R.A.Esterlund et al, H.P.Graf et al , V.N.Levkosvki et al [7] in fig.1.(a) and (b) for ^{92}Mo and ^{94}Mo are not in agreement with the calculated results.

It is highly needed to extend the experimental database of alpha induced reaction cross section for p-nuclei in the chain of Ru isotopes.

3.2 Reaction Rates

Reaction Rate is important for understanding the energy production and element generation within a star. It depends on nuclear cross section, velocity distribution within stellar plasma & abundance of each type of interacting particle. For our nuclear reactions on p-nuclei, the reaction rate increases with increasing temperature.

Table 1: Reaction rate of ^{92}Mo and ^{94}Mo

T_9 (10^9 K)	Reaction Rate ($cm^3s^{-1}mole^{-1}$)	
	^{92}Mo	^{94}Mo
1.5	2.06×10^{-24}	1.06×10^{-21}
2	9.21×10^{-17}	5.46×10^{-15}
2.5	3.83×10^{-12}	6.35×10^{-11}
3	4.92×10^{-9}	3.55×10^{-8}
3.5	8.7×10^{-7}	3.56×10^{-6}
4	4.43×10^{-5}	1.22×10^{-4}
5	1.2×10^{-2}	2.11×10^{-2}

Table 2: Reaction rate of ^{96}Ru and ^{98}Ru

T_9 (10^9 K)	Reaction Rate ($cm^3s^{-1}mole^{-1}$)	
	^{96}Ru	^{98}Ru
1.5	7.63×10^{-26}	3.27×10^{-23}
2	8.74×10^{-18}	4.11×10^{-16}
2.5	6.28×10^{-13}	7.97×10^{-12}
3	1.13×10^{-9}	6.20×10^{-9}
3.5	2.50×10^{-7}	7.84×10^{-7}
4	1.47×10^{-5}	3.21×10^{-5}
5	4.61×10^{-3}	7.08×10^{-3}

4. Summary

Present study suggests that there is need for the theoretical and experimental investigations of the cross-section values around the Gamow energy region and also at higher energy for different p-nuclei. Results from this study will be presented in more detail during the symposium.

5. References

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