Study of proton capture rates : ^{96}Ru,^{98}Ru

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Introduction

Most of the nuclei heavier than iron are synthesized mainly by the rapid neutron capture process (r-process) and slow neutron capture process (s-process). However, there exist about 35 nuclei in the nuclear landscape chart which can not be synthesized by s- and r-process. These nuclei are supposed to be formed by the proton capture process (p-process) referred as p-nuclei. Natural abundance of these p-nuclei are very less (order of 0.01% to 1%) in comparison to the nuclei synthesized by neutron capture processes[1].

The p-process exists in the environment of the combination of photodisintegration reactions, (γ,n), (γ,p), and (γ,α) with the heavy s and r seeds in the temperature range of 2-3 GK but the possible sites and scenarios for the formation of p-nuclei are still under discussion. A large reaction network of thousand of reactions rates involving proton-rich nuclei is required to describe the detailed modelling of the p-process nucleosynthesis. There are number of experimental and theoretical approaches to study the proton capture reactions. In the recent past, there have been focussed attempts to measure the proton capture rates using advanced techniques via activation method, In-beam method(angular distribution method and γ-summing technique) and techniques in Inverse kinematics. Still, there exist very less amount of experimental data due to experimental limitations. In the laboratory environment target nucleus always in ground state under stellar conditions. Therefore, theoretical approaches are very important to predict the reaction rates for the collection of nuclear reaction data.

Mathematical Formalism

In the theoretical framework, nuclear reaction studies for p-process are based mostly on Hauser-Feshbach statistical models for calculating the reaction rates. The calculation of nuclear reaction rates also requires nuclear density input. Hence, a reliable nuclear structure input would further enhance the reliability of nuclear reaction calculations. Relativistic mean field (RMF) model which contain the spin-orbit naturally, has been successfully used to understand and explain many features of nuclei such as binding energy of ground states, various excited states, charge radii, etc. Here, NL3* parameter set has been used for solving the standard RMF Lagrangian[2] and further these RMF nuclear densities have been used to calculate the reaction rates with the help of Talys 1.6.

Results and Discussion

In order to ensure the model prediction reliability regarding shape and density, we have studied ground state properties, (binding energy, and rms charge radii), coherently with nuclear reaction rates. In Table 1, we have presented the calculated values along with experimental values.

Table 1. Comparison of calculated ground state properties for nuclei.

Nucleus	B.E./A (in MeV)		r_{charge}(in fm)	
	Calc.	Expt.	Calc.	Expt.
^{96}Ru	-8.595	-8.609	4.375	4.393
^{98}Ru	-8.597	-8.620	4.412	4.423
^{97}Rh	-8.567	-8.560	4.396	-
^{99}Rh	-8.579	-8.580	4.431	-

In the present work, we have calculated proton capture rates for ^{96}Ru and ^{98}Ru using the microscopic JLM potential with relativistic mean field densities through TALYS [3].

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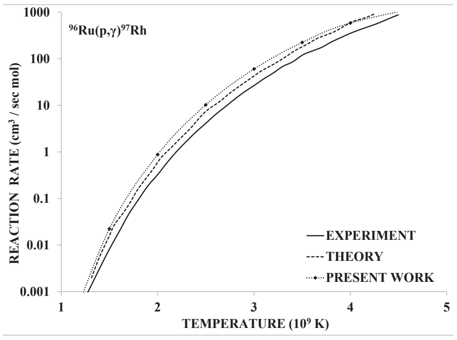

FIG. 1: Comparison of reaction rates(as function of temperature) for ^{96}Ru(p,γ) reaction.

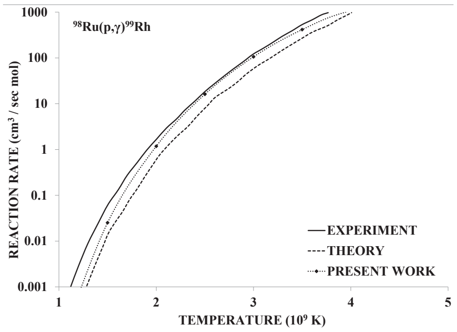

FIG. 2: Same as Fig. 1, but for ^{98}Ru.

These nuclear densities were added to TALYS source files manually for calculating the potential and reaction rates.

In Fig.1 and Fig.2, we have shown the results of our calculations and compared with experimentally available values for reaction rates. Experimental results of reaction rates for ^{96}Ru and ^{98}Ru have been taken from [4]. To have a qualitative check on our results, we have also compared the same with the reaction rates available from theoretical (NON-SMOKER) results.

Conclusion

Reaction rates are crucial for understanding nucleosynthesis and energy generation in stars and stellar explosions in the field of nuclear astrophysics. In the present work, reaction rates of (p,γ) reactions for ^{96}Ru and ^{98}Ru have been calculated and obtained results are fairly consistent with the experimental results as well as with other theoretical (NON-SMOKER) results. Nuclear reaction studies related to p-nuclei are very crucial to enhance the existing knowledge of (p,γ) reactions of Ruthenium isotopes and also such studies based on reliable nuclear structure input may be helpful in reducing the uncertanity in nuclear reaction calculations.

Acknowledgments

AS is highly thankful to the research grants provided by DST (DSTReference No. SB/FTP/PS-004/2013) to carry out this work.

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