Nuclear Structure input dependence on the nuclear reaction rates relevant to astrophysical p-process

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Introduction

Almost all the nuclei heavier than the iron are formed by the neutron capture s and r process but there exist thirty five neutron deficient nuclei between ^{74}Se to ^{196}Hg, which are not synthesized by neutron capture processes, supposed to be synthesized by the p-process, are called as p-nuclei. Photodisintegrations reactions such as (γ, n), (γ, p) and (γ, α) with very high temperature in the stellar environment have been preferred for the synthesis of p-nuclei by the rigorous studies. The detailed modeling of the p-process nucleosynthesis is highly needed to know the abundance of the p-nuclei. To describe the p-process network simulation, thousands of nuclei involving a large reaction network of thousands of reaction rates (which are obtained by the cross sections) is required. There are various experimental techniques employed for the measurement of cross-section data within the Gamow window such as activation technique, In beam method (angular distribution method and γ-summing technique) and techniques in inverse kinematics, however such measurements are scarce due to the experimental limitations. Hence, reliable theoretical calculations are genuinely required to supplement experimental studies and to provide the cross sections data of nuclear data libraries needed for astrophysical nuclear network calculations.

Theoretically, the reaction cross section calculations can be performed using Hauser Feshbach statistical model, which is further used for p-process network studies [1]. The cross sections depends on input parameters such as optical potential, nuclear level density, γ-ray strength function and nuclear masses. The reliability/uncertainty of the theoretical cross section calculations depend on the accuracy of these inputs. Optical potentials (which are calculated by nuclear densities) are an integral part of the Hauser-Feshbach theory of statistical nuclear reactions. In this work, we have investigated the effect of nuclear density input for cross section calculations.

Mathematical Formalism

There are number of theoretical approaches available for solving the nuclear quantum many-body problem to calculate nuclear density/wave function. One of the most successful approaches used for a wide range of nuclei across the nuclear mass table is using the effective mean field approaches based on the mean field assumptions. Relativistic mean field model which contain the spin-orbit naturally, has proved to be very successful theory among the relativistic model 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 cross section with the help of Talys [3].

Result and Discussion

To see the impact and test the uncertainty in the calculations due to nuclear density input, used for calculation of nuclear reaction measurable such as cross section and reaction rates, we have considered the reaction rates of cadmium isotopes due to the wide experimental interest on the same. The ^{106,108}Cd reaction study is particularly important as it is related to the study of photodisintegration of the ^{110,112}Sn nucleus with Z=50 closed proton shell. The cross section of ^{106}Cd (α, γ) ^{110}Sn and ^{108}Cd (α, γ) ^{112}Sn reactions have been calculated with microscopic (JLM) and phenomenological (KD03) optical model potential with RMF densities.

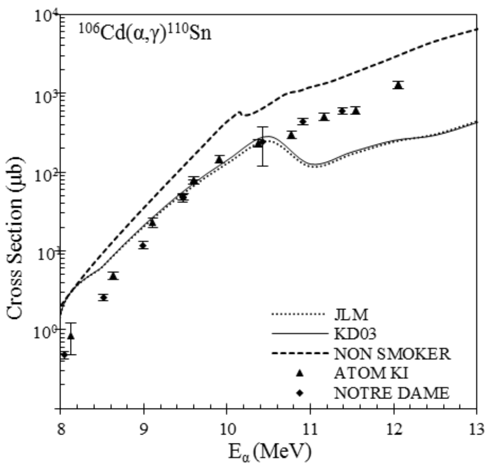

Fig. 1. Comparison of present calculations (JLM & KD03) for alpha capture cross section calculated with NON SMOKER and available experimental results.

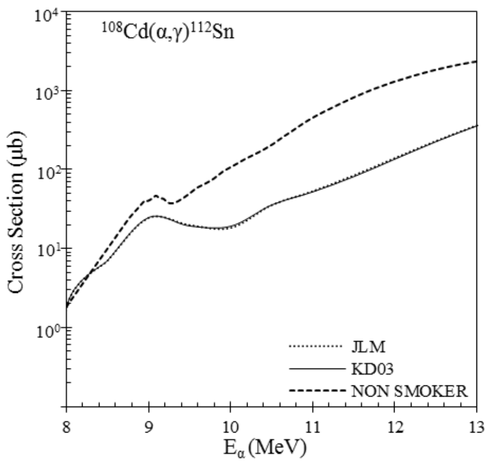

Fig. 2. Same as Fig. 1, but for ^{108}Cd.

In fig. 1 & 2 above, we have shown the calculated results (within Gamow Window) and compared with the experimentally available data. Experimental cross section data for ^{106}Cd has been taken from [4]. The experiment was performed at two different labs ATOMKI and Notre Dame to determine the reaction cross section. The activation experiment was performed using MGC cyclotron at ATOMKI and the activations were performed with FN Tandem Van de Graaff accelerator at Notre Dame. We find that the JLM, KD03 cross section results match excellently with the experimental results, while other theoretical results (NON-SMOKER) over predicts the experimental data. For ^{108}Cd reaction, no experimental results are available so far, hence we have compared the same with the NON-SMOKER results. We find that the JLM, KD03 cross section results have a similar trend in comparison to NON-SMOKER results like ^{106}Cd results. One can see that the results are sensitive with the nuclear density input as in NON SMOKER other nuclear density input has been used [5]. More results related to this work, will be presented in the conference.

Conclusion

In the present work, it has been shown that in case of cross section calculations of stable nuclei, for different astrophysical process, choice of nuclear inputs with calculated cross section results differ by approximately factor of 1-2 (order of magnitude) in comparison to NON SMOKER results. It would be further interesting to investigate such uncertainty in case of reaction cross section calculations of unstable nuclei, where even the choice of nuclear density may play an important role, entering the cross section calculation. In addition, for the cases, where the experimental data is not available, such calculations may be helpful for the existing nuclear data libraries and also to guide future experimental work.

References

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