Investigation of poisoning process in s - process

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Introduction

In s - process, bulk of the stable isotopes heavier than iron are synthesized via neutron capture reactions. Neutron capture reaction plays significant role in this process [1]. The major neutron sources for this process is $^{13}C(\alpha,n)^{16}O$ & $^{22}Ne(\alpha,n)^{25}Mg$ reactions [2]. Neutrons provided by the $^{22}Ne(\alpha,n)^{25}Mg$ reaction are activated at the end of the convective He burning core. A lower neutron density of 107 cm^{-3} is provided by the $^{13}C(\alpha,n)^{16}O$ reaction. Asymptotic Giant Branch (AGB) stars are the main site of the s-process.

In this region, light nuclei which are having large neutron capture cross sections, absorb the neutrons produced by our source reaction. These nuclei are known as "Poisons of the S-process". ^{13}C, ^{14}N, $^{16-17}O$ [2], $^{25-26}Mg$ are some of the poisons of the s - process [3] and the reaction caused by them are - $^{13}C(n,\gamma)^{14}C$ [4], $^{14}N(n,p)^{14}C$, $^{16}O(n,\gamma)^{17}O$, $^{17}O(n,\alpha)^{14}C$. $^{14}N(n,p)^{14}C$ shows strong neutron absorbing reaction due to high abundance of ^{14}N in stars [5].

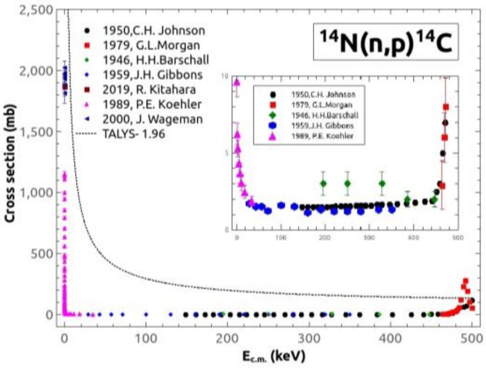
Unfortunately, there is lack of high-fidelity experimental data reaching the stellar energies. The major motivation of the present work is to calculate cross section, reaction rates and to calibrate it with experimental data in the range of stellar energies.

Computational details

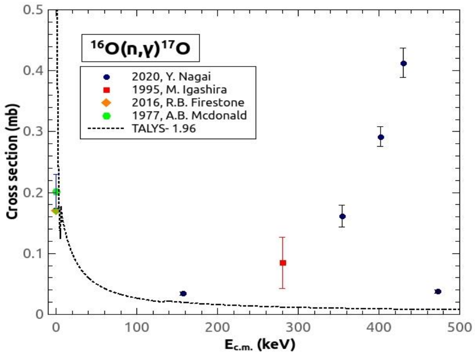
To calculate the cross section and reaction rate we have employed the statistical nuclear model code TALYS-1.96 based on Hauser – Fesbach statistical model for the theoretical calculations of the reaction. The evaluated data has been compared with the existing cross sections and reaction rate data available in the EXFOR [6].

Cross Section

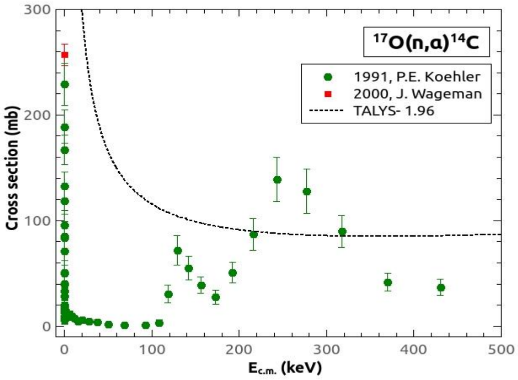
We can notice from Fig.1 that the data evaluated by theoretical model does not exhibit the trend corresponding to the experimental data for all three reactions at lower energies. In Fig.1(a) and Fig.1(c) the calculated data is much higher than the experimental value. In Fig.1(b) the experimental reported data by R.B. Firestone et al [7] and A.B. Mcdonald et al [8] are in good agreement with the accounted data but still there are discrepancies.



(a)



(b)



(c)

Fig.1 Cross section of (a) $^{14}N(n,p)^{14}C$, (b) $^{16}O(n,\gamma)^{17}O$, (c) $^{17}O(n,\alpha)^{14}C$ reaction and its comparative studies.

Reaction Rate

The astrophysical rate is imperative for the understanding many aspects like energy production, element generation within a star, abundance evolution of elements etc. It depends mainly on two factors those are cross section of nuclear reaction and velocity distribution of particles within stellar plasma.

The reaction rate was calculated from the estimated nuclear cross section. The resulting reaction rate is presented in Table 1 & 2. We have compared the rate of $^{17}O(n,\alpha)^{14}C$ reaction with the data from EXFOR in Table 2. It is found to be in agreement with the rate reported by Schatz et al. [9], despite of the great discrepancies in the cross sections.

Table 1: Reaction rate of ^{14}N and ^{16}O

T_9 (10^9 K)	Reaction Rate ($cm^3s^{-1}mole^{-1}$)	
	$^{14}N(n,p)^{14}C$	$^{16}O(n,\gamma)^{17}O$
1	8.22×10^7	4.17×10^3
1.5	8×10^7	3.93×10^3
2	7.98×10^7	3.82×10^3
2.5	8.06×10^7	3.76×10^3
3	8.19×10^7	3.73×10^3
3.5	8.36×10^7	3.73×10^3
4	8.56×10^7	3.74×10^3
5	8.97×10^7	3.82×10^3

Table 2: Reaction rate of ^{17}O

T_9 (10^9 K)	Reaction Rate of $^{17}O(n,\alpha)^{14}C$ ($cm^3s^{-1}mole^{-1}$)	
	TALYS-1.96	(Ref. [9])
0.4	3.43×10^7	1.25×10^6
0.5	3.38×10^7	3.26×10^6
0.6	3.35×10^7	5.63×10^6
0.7	3.35×10^7	8.25×10^6
0.8	3.36×10^7	1.08×10^7
0.9	3.38×10^7	1.32×10^7
1	3.41×10^7	1.52×10^7

Summary

Proposed work concludes that there is need to calculate a robust theoretical model and requisite experimental investigations to reduce inconsistency of cross section data at stellar energies. Other aspects will be conferred in more detail during the symposium.

Acknowledgements

One of the authors (A. Kumar) would like to express gratitude towards the Institutions of Eminence (IoE) BHU [Grant No. 6031].

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