Decay analysis of ^{12}C+^{16}O reaction using the generalized GSkI Skyrme interaction at stellar energies

Ishita Sharma,* Raj Kumar, and Manoj K. Sharma
[1] *School of Physics and Material Sciences, Thapar University, Patiala - 147004, INDIA*

Introduction

The nuclear reactions at stellar energies, $E_{c.m}$= 1-5 MeV stand out as one of the most interesting topic to study[1], for at least three reasons. First, the existence of 'quasi-molecular' state plays crucial role in the excitation function of light reaction channels. Second, the calculations in low energy region are sensitive to the shape and height of the ion-ion potential and need a probe for the satisfactory explanation of fusion and barrier penetration process. Finally, the cross sections at low energies determine the ignition conditions for carbon burning nucleosynthesis, pycnonuclear reaction in white dwarfs, in accreting neutron stars, necleosysnthesis in type-Ia super nova and so on. For such studies, ^{12}C+^{16}O reaction is of particular importance due to its major contribution in the carbon and oxygen burning phases of stars.

In present work, ^{12}C+^{16}O [2] reaction has been studied using the dynamical cluster-decay model(DCM). As the calculations in low energy region are sensitive to nuclear interaction potential, therefore, generalized GSkI Skyrme force containing extended density dependent term is used in the present analysis. The parameters of GSkI force were determined in such a way that the force could be suitably used for the study of normal, isospin rich nuclei and the neutron stars [3]. Using GSkI force within DCM, the decay structure of ^{28}Si* formed by ^{12}C+^{16}O reaction is examined to analyze the relative emergence of emission fragments. The exclusive role of deformation, temperature has been analyzed. In addition to this, the cross sections of neutron, proton,and alpha-particle are addressed at $E_{c.m}$= 4.84 MeV.

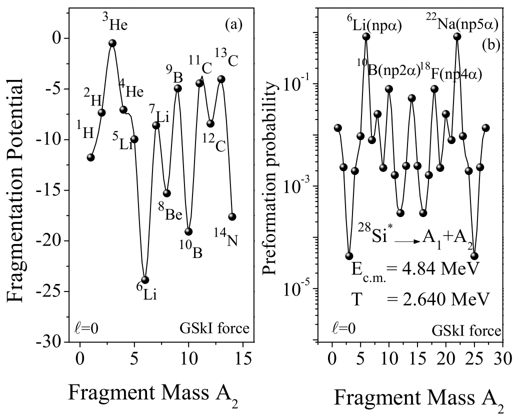

FIG. 1: (a)Fragmentation potential(V_η) (b) preformation probability P_0 as a function of fragment mass A_2 is evaluated at ℓ=0 for ^{28}Si* system.

Methodology

The dynamical cluster-decay model [4] based upon collective-clusterization approach, determines the compound nucleus decay cross-section in terms of preformation probability P_0 and penetrability P as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P;\ k=\sqrt{\frac{2\mu E_{c.m}}{\hbar^2}} \quad (1)$$

The fragmentation potential providing the structural information of decaying nuclei is expressed in terms of shell corrections, liquid drop, Coulomb, nuclear and centrifugal potentials as

*Electronic address: `ishita.sharma@thapar.edu`

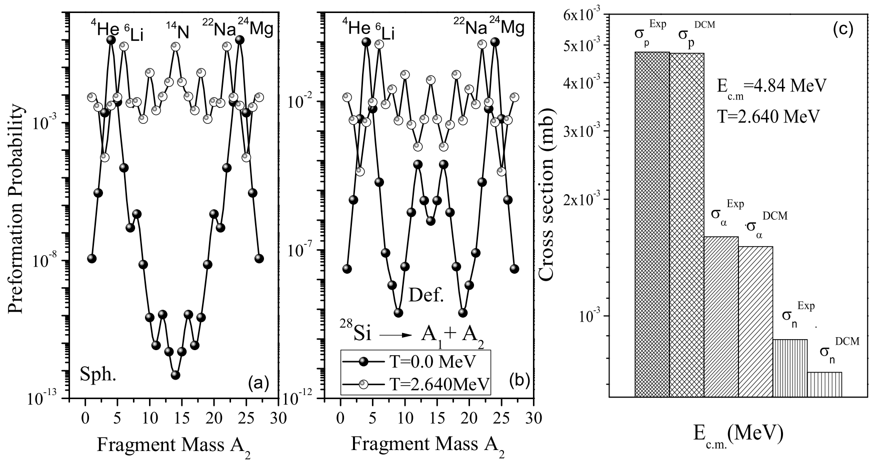

FIG. 2: Same as Fig. 1(b) but (a) for spherical and (b) deformed case. (c) Cross sections of proton, neutron and alpha particles calculated at $E_{c.m} = 4.48$ MeV.

$$V(\eta) \; = [\delta U + V_{LDM} +] + V_C + V_P + V_\ell. \quad (2)$$

which is further used to evaluate preformation probability P_0 by solving stationary Schrodinger wave equation in η-coordinate. On the other hand, penetrability P is calculated using WKB approximation. The proximity potential V_P is calculated using GSkI Skyrme force within energy density formalism.

Calculations and Results

Using fragmentation potential(V_η) and preformation probability(P_0), the structural information of decaying ^{28}Si* nucleus formed via ^{12}C+^{16}O reaction is investigated at incident energy, $E_{c.m} = 4.84$ MeV. The calculations are performed within the dynamical cluster-decay model wherein, the ion-ion potential is obtained using GSkI Skyrme interaction. The deformation effect up to quadrupole deformation (β_2) is included and the results for V_η and P_0 are shown in Fig. 1(a) and (b) respectively. It is evident from the Fig. 1 that ^6Li appears as the prominent decay channel for ^{28}Si nucleus. While the probability of light charged particle such as protons and alpha seems relatively small in comparison to ^6Li. The result is compared with the spherical counter part of ^{28}Si* nucleus, evaluated at different temperatures, T= 0.0 and 2.63 MeV, shown in Fig 2(a) and (b). The analysis emphasis that irrespective of deformation effects, ^{6}Li dominates over ^{4}He, possibly due to the disappearance of shell effects at higher temperature. It would be of interest to analyze the contribution of ^6Li within the decay dynamics, via estimation of its branching ratio, the cross sectional yield and half life, with respect to light particles such as proton/neutron and alpha particles emitted during the decay process. Also, it is would be of interest to explore, whether ^{6}Li nucleus comes out as a cluster or the combination of alpha + proton + neutron. Further, the cross sections of proton, neutron and alpha particles are calculated at energy $E_{c.m} = 4.84$ MeV and results are shown in Fig. 2(c), which illustrates decent agreement with respective to experimental data. It is to be noted that the cross sections of proton and neutron are evaluated at same neck length, $\Delta R = 1.69$ fm while the heavier fragment i.e. alpha particle is determined at $\Delta R = 1.59$ fm.

References

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