Reaction cross-section for nuclear halo-targets and lighter mass projectiles using the relativistic mean-field approach

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Introduction

Nucleon combinations (proton and neutron) at traditional magic numbers are well known for their relative stability. The study on these unique magic nuclei near the drip-line is an ongoing active topic in the field of nuclear structure physics [1]. Although, it is elusive to examine each of these nuclei, a few of them are presently taken into account. Argon isotopes are notable examples of such nuclei. Howbeit, the structural and reaction mechanism of Ar-isotopes are quite feasible due to the availability of experimental data [2]. The accessibility of radioactive nuclear beams at numerous research facilities across the globe is likely to yield a wealth of fascinating experimental data on the structure and reactions of nuclei close to the proton and neutron drip lines. One of the most crucial physical parameters needed to describe the nuclear reaction is the reaction cross section. Its applicability extends beyond merely extracting nuclear size, radio-biology and space radiation.

The developments in these fields have improved our understanding of a variety of unusual phenomena, including 1n, 2n or 1p, 2p (n, p stand for neutron and proton) halo phenomena, bubble effects, the disappearance of shell effects near the drip-line region, and the discovery of some newly formed magic numbers. Other than the traditional magic numbers, the appearance of new magic numbers has been reported in the drip-line region and the stability line, in light to intermedi-

ate mass nuclei, especially in unusual nuclei, is one of the blistering topics in nuclear structural physics [3, 4]. The halo status of nuclei, which has been extensively studied for nuclei like ^{6,8}He, ^{11}Li and ^{11,14}Be [5], is one of the most exotic phenomena. Extremely weakly coupled nucleons that have broken their bond with the nuclear core are the source of the halo structure. The interaction cross sections of these nuclei are extraordinarily large because of the considerable magnitude of the root mean square (rms) radii [6].

The present study considers the reaction mechanism of some of the Ar-isotopic chain. The densities are calculated using relativistic mean field formalism with the NL3* parameter set [7]. Then the reaction cross-section study is done using the Gaussian coefficients of aforementioned densities in the Glauber model [8].

Theoretical Formulation

The Glauber model is a microscopic reaction theory of high-energy collisions which is known for its appreciable agreement with experiment findings of Karol [9]. Since it has the ability to fully account for the breakup effects (which are crucial to understanding the reaction of a weakly bound nucleus), it has become a common tool for calculating cross sections [10]. The Glauber model [8] provides valuable information with which one can calculate the total nuclear reaction cross section (σ_R) for various systems at different energies. The entire reaction cross-sections at high energy are represented in the conventional Glauber form

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as

$$\sigma_R = 2\pi \int_0^\infty \mathbf{b}[1 - T(\mathbf{b})]d\mathbf{b}. \qquad (1)$$

Here T(b) represents the transparency function and b is the impact parameter. In the overlap zone between the projectile and the target, the function T(b) is computed under the presumption that the interaction is the result of a single NN collision [11].

Result and Discussion

The total reaction cross-section is calculated by considering both medium mass targets ($^{26-48}$Ar) and light mass projectiles as ^{4}He, ^{6}Li respectively. The Glauber model is the mostly used method to analyse the total reaction cross-section (σ_R) at different incident energies. This model requires density as its primary input to compute σ_R. Thus, we have taken relativistic mean field formalism (RMF) with NL3* parameter to determine the density functional which is further helpful in evaluating the transparency function. The left (a) and right (b) panel of Fig. 1 depicts the profile of the total reaction cross-section σ_R values for the reaction combination of two projectiles likely to be ^{4}He, ^{6}Li and series of targets as $^{26-48}$Ar at different incident energies respectively. It is observed that σ_R values for both of these projectiles is maximum and then decreases rapidly up to the incident energy 600 MeV/A. Thereafter, it gradually increases with increasing energy for a certain value around 1000 MeV/A until it attains a constancy. These behaviour is noticed in both projectiles. In case of ^{4}He and ^{6}Li as projectile, the reaction gap is found to be maximum in between ^{30}Ar and ^{32}Ar isotopes among all, it may be an indication of magicity of ^{32}Ar. Besides, it is obvious that an extra higher shell gap value between ^{44}Ar and ^{46}Ar for above two targets ensues. This peak can be attributed to the choice of parameters and the nature of neutron rich targets and light mass projectiles.

Conclusive Remark

In summary, the total reaction cross-section has been calculated by taking $^{26-48}$Ar iso-
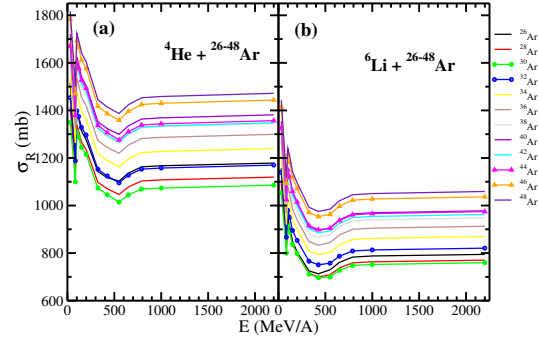

FIG. 1: In the (a) left and (b) right panels, respectively, the reaction cross-section for various incident energies using projectiles of ^{4}He, ^{6}Li and targets of $^{26-48}$Ar is displayed.

topes as targets and ^{4}He, ^{6}Li as projectiles with different incident energies. A large reaction gap is noticed between ^{30}Ar-^{32}Ar and ^{44}Ar-^{46}Ar, indicating the magic nature/ shell-closure property in ^{32}Ar and ^{46}Ar respectively. The structure and reaction of Ar-isotopic chain will be communicated shortly.

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