Application of reduction methodology for various projectiles

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Introduction

There has been an extensive study in the last two decades in the field of nuclear reactions using the weakly bound or short-lived nuclei, better called as halo [1]. The majorly unexplored halo structure as projectiles, irrespective of neutron or proton halo, the dynamic and static effects present in them play an essential role. The fusion cross section is strongly influenced by the static effects due to halo structure of some nuclei and by the breakup (dynamic) channels, as they are usually weakly bound, when compared to the cross sections of reactions involving tightly bound nuclei [1, 2]. Accordingly, the energy range is important, especially the near Coulomb barrier range or above, as the valuable information on the structure of exotic nuclei and on the dynamics of the nuclear reactions between them can be obtained. In the present work we focus our study in using the variety of projectiles such as tightly bound nuclei, ^{10}B, ^{11}B, ^{16}O, weakly bound nuclei, ^{6}Li, and halo nuclei, ^{6}He, ^{8}B targeted on medium-mass range target of ^{58}Ni. For the following systems total reaction cross sections were obtained and calculated in the work of [3], and here we performed calculation for the ^{6}He + ^{58}Ni system [4, 5] to obtain total reaction cross sections. For the calculation, the elastic scattering angular distribution data for the energies near the barrier was obtained from the NRV website [6] and the total reaction cross sections were calculated with Optical Model (OM) analysis using the S-FRESCO code [7]. Thereafter, a newly proposed reduction procedure [8] is applied, which was initially applied to light-medium mass range targets and further successfully applied to medium-mass range target systems [3, 9].

OM analysis of elastic scattering

In this section we present the OM analysis of the elastic scattering angular distribution data for the above mentioned system [4, 5] whose total reaction cross sections were unavailable and thus the elastic scattering angular distribution data was obtained from the NRV website [6]. The calculations were performed using the double-folding São Paulo potential (SPP) [10, 11].The detailed description of SPP can be found in our previous papers [3, 9]. The resulting fits of the normalization parameters for the calculated systems are shown in Table 1.

TABLE I: Parameters used with the SPP calculations for the ^{6}He + ^{58}Ni system and the derived total reaction cross sections.

E_{lab} (MeV)	N_R	N_I	χ^2/n	σ_R (mb)
09	0.704	0.285	0.525	133.44
10	1.500	1.400	4.438	535.48

Reduction methodology

Recently [8], a new reduction procedure (N) has been proposed and successfully applied to many

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systems [3, 9] that allows to access to the quantitative effect of the direct reaction mechanisms on the total reaction cross section by comparing the reduced cross section of tightly and weakly bound systems. In order to have access to this effect, the experimental reaction cross section was normalized by the total fusion (TF) derived from one-channel calculation, using a reliable real potential, an imaginary potential term of a shorter range than the Coulomb barrier, that accounts exclusively for the fusion process. The center of mass energy ($E_{c.m.}$) was normalized by the barrier height (V_B), so that, the new dimensionless quantities are

$$E \rightarrow \varepsilon^{(N)} = \frac{E_{c.m.}}{V_B} \quad \text{and} \quad \sigma \rightarrow \sigma^{(N)} = \frac{\sigma_R}{\sigma_{TF}}. \quad (1)$$

The other aspect of the work, have also been described very well in [3, 9], is to reduce the experimental reaction cross section by the total fusion cross section obtained from one-channel (or no coupling) calculations which for the following mentioned systems have been performed in our works [3, 9], except the one for ^{6}He + ^{58}Ni system. For this system, one-channel calcualtions, for the above mentioned energies in Table 1, were calculated in this work. The one-channel calculations were performed using the code FRESCO [7]. To be precise, the total fusion cross section serves to be a lower limit of the reaction cross section if one opts for one-channel case and thus a new reduction formula could be applied where one can take a ratio of experimental total reaction cross sections to, one-channel calculated total reaction cross sections, which in principle is the total fusion cross section. The values of this ratio are expected to be larger or equal to 1 (as mentioned above), where the value 1 corresponds to the case where there is no any direct reaction channel enhancing the reaction cross section. In fig. 1, we have shown the ratio of σ_R/σ_{TF} versus $E_{c.m.}/V_B$, for all the systems mentioned in [3–5], where σ_R is the experimental reaction cross section obtained from OM analysis and σ_{TF} was derived from the one-channel calculation. Here one can notice that, the ratio of the reduced cross sections for weakly-bound and halo systems are higher than the physical value 1, justifying contributions from direct channels, like break-up.

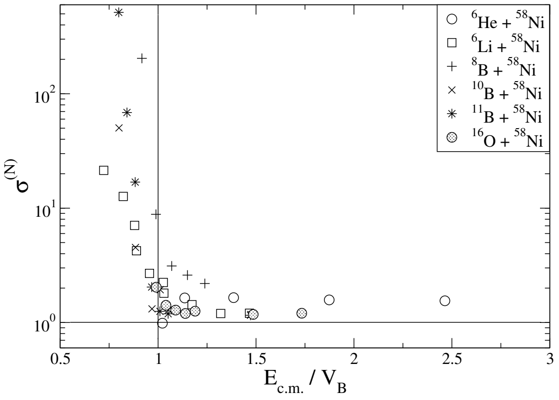

FIG. 1: Comparison of reduced total reaction cross section for several projectiles on ^{58}Ni target for the case of the reduction of σ_R by σ_{TF}. See text for details.

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