Application of reduction methodology on ^{2}H + ^{27}Al system

Rambabu Mourya[1,2], A.N. Deshmukh[1],[*] Vishal Srivastava[3],[†] Pankaj Shah[1], and N. Deshmukh[1,2‡]
[1]*School of Sciences, P P Savani University, Surat-394125, Gujarat, INDIA*
[2]*School of Engineering, P P Savani University, Surat-394125, Gujarat, INDIA and*
[3]*Department of Physics, Amity School of Engineering and Technology, Amity University, Patna-801503, Bihar, INDIA*

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 exclusively tightly bound nuclei, ^{2}H, targeted on light-medium mass range target of ^{27}Al. For the following systems total reaction cross sections were obtained and calculated in the works of [3, 4]. A newly proposed reduction procedure [5] is applied, which was initially applied to light-medium mass range targets and further successfully applied to medium-mass range target systems [6, 7].

OM analysis of elastic scattering

In this section we mention about the OM analysis of the elastic scattering angular distribution data for the ^{2}H + ^{27}Al system whose total reaction cross sections were calculated in the works of [3, 4] using the double-folding São Paulo potential (SPP) [8, 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 ^{2}H + ^{27}Al system and the derived total reaction cross sections.

E_{lab} (MeV)	N_R	N_I	χ^2/n	σ_R (mb)
05	1.50	1.36	1.43	1093
07	0.66	1.09	5.09	1119
9.8	0.83	1.50	1.37	1313
11.4	0.71	1.50	2.10	1329
12.8	0.97	1.15	1.74	1347
13.6	0.54	1.26	34.76	1299
15	0.86	1.34	31.51	1372
17	0.95	1.31	33.68	1384
25	0.64	1.14	1.11	1307
52	1.33	0.62	8.48	1138
58.7	1.37	0.67	16.68	1126
80	1.26	0.49	96.47	942.96
85	1.29	0.65	12.56	1002.4

Reduction methodology

A short time ago, a new reduction procedure (N) has been proposed [5] and successfully applied to many systems [6, 7] 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, weakly bound and halo 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

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[*] Electronic address: `ami.avte@gmail.com`
[†] Electronic address: `vishalsrivastava@gmail.com`
[‡] Electronic address: `drnikitdeshmukh@gmail.com`

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

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

The other aspect of the work, have also been described very well in [6, 7], 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 system have been performed here for the above mentioned energies in Table 1. The one-channel calculations were performed using the code FRESCO [10]. To make it understand concise, 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 $E_{c.m.}/V_B$, 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 from fig.1 that, the ratio of the reduced cross sections for this system is slightly higher than the physical value 1, which indicates the presence of some direct reaction channel contribution. But projectile ^{2}H being the tightly bound system, contribution from inelastic channels or projectile break-up is less expected. On the contrary, focusing on the target ^{27}Al which has a nonzero ground-state large quadrupole deformation, Q = +0.1446 b, and a parity spin of 5/2+, indicating a nonspherical symmetric charge distribution. This is a possible reason for the enhancement of reaction cross section indicating slightly higher value of 1.

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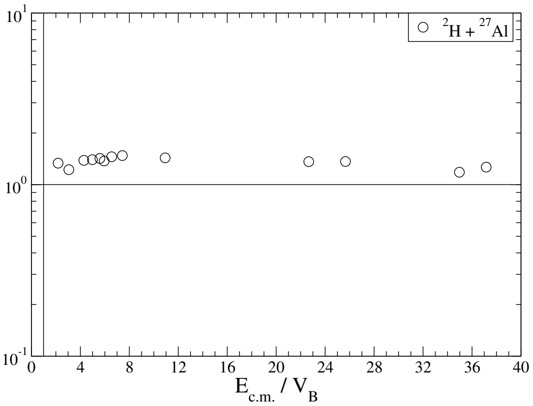

FIG. 1: Comparison of reduced total reaction cross section for ^{2}H + ^{27}Al system for the case of the reduction of σ_R by σ_{TF}. See text for details.

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