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Interaction of loosely bound radioactive and stable nuclei *via* elastic scattering and fusion cross sections

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Abstract Elastic scattering angular distributions have been measured for $^{7}Be + ^{27}Al$ system at E_{Lab}=17, 19, 21 MeV in the angular range $\theta_{cm} = 12 - 43^0$. An optical model (OM) analysis of these data have been carried out in order to extract OM potential parameters and reaction cross sections. One proton stripping cross sections were also measured at these energies. The fusion cross sections were deduced by subtracting the integrated transfer cross-sections from the reaction cross sections obtained from elastic scattering. The $^{7}Li + ^{27}Al$ elastic scattering angular distributions were also measured at E_L=10,13,16, 19 and 24 MeV in the angular range θ_{cm} 12 – 72^0 leading to the OM potential parameters. The α-evaporated spectra were also measured at θ_{Lab} = 52 – 132^0, compared with reproduced data with statistical model calculations and fusion cross sections were extracted from them. The Coupled channel fusion cross section including static nuclear deformations (CCDEF) calculations describe these data quite well. These data were compared with data on similar loosely bound systems and found to be consistent.

Keywords Radioactive beam, heavy ion scattering process, statistical model calculations

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1. Introduction

Considerable amount of experimental and theoretical efforts have been devoted over past few decades to understand the nuclear reactions induced by loosely bound radioactive and stable nuclei. These nuclei, being rather loosely bound are susceptible to break-up and can substantially populate the transfer channel (with +ve Q values) when inducing nuclear reactions. There has been a focused interest in this field with the aim of studying the effect of break-up of such projectiles on the fusion cross sections in the context of enhancement and suppression [1,6]. In addition, the data on reactions induced by radioactive nuclei provide valuable input for understanding the problems of astrophysical interest. For instance, we may mention the measurement of $S_{17}(0)$ factor through investigations of the reaction d(^{7}Be, ^{8}B)n reaction [7,8]. The break-up threshold of ^{7}Be,

^7Li, ^6Li, ^9Be are low and they all lie between 1.6 MeV to 2.45 MeV. With the intension of making a comparison among the loosely bound projectiles we have carried out the elastic scattering angular measurements at E_{Lab}=17,19, 21 MeV (for ^7Be + ^{27}Al) and at E_{Lab}=10, 13, 16, 19, and 24 MeV (for ^7Li + ^{27}Al). Also we measured the fusion cross section by detecting the α-evaporated particles from the compound nucleus formation. A complete data set of this type should provide answers to the role of shape, size and other nuclear structure related degrees of freedom in influencing both fusion and elastic scattering.

2. Experimental

The details of the experimental setup has been reported in Ref. [9,10]. We report here the quasi-elastic scattering and transfer reaction cross section measurements made for the ^7Be + ^{27}Al system at E_L = 17, 19, 21 MeV in the angular range θ_{cm} = 12 – 43^0 using inter-University Accelerator Centre (IUAC), New Delhi and hence, the fusion cross-sections. Here ^7Be (radioactive) in secondary beam (~10 kHz intensity), which is mirror nuclei of ^7Li (~10^{10} Hz) was bombarded on ^{27}Al target (~ 1 mg/cm^2 thickness) separately. An optical model (OM) analysis of quasi-elastic scattering data was carried out and the OM parameters determined and, the reaction cross sections were extracted. The fusion cross sections were derived at these energies by subtracting the experimental integrated transfer cross sections obtained from the one proton transfer reaction (^7Be + ^{27}Al —> ^6Li + ^{28}Si, Q = + 6MeV) data. These fusion cross sections were found to be consistent with those obtained from the coupled channel calculations using CCDEF [11]. For ^7Li + ^{27}Al system the elastic scattering angular distributions were carried out at E_L = 10,13, 16, 19 and 24 MeV in the angular range θ_{Lab}= 12 – 72^0 and the α-evaporation spectra were measured at θ_{Lab} = 52 – 132^0 from the compound nucleus formation at TIFR Pelletron accelerator facilities, Mumbai and was extracted the fusion cross section following the procedure done by Kailas *et al* [12]. The α-evaporation spectra were also reproduced with the statistical model calculation using PACE code [13] and when compared with the measured one it is found to be consistent. The CCDEF [11] calculations describe these data quite well.

3. Result

The details of the experimental setup and part of the results are reported in Ref. [10]. The elastic scattering data have been analysed in the optical model framework using Optical Model code SNOOPY [14] in order to extract reaction cross sections at the measured energies. Following the procedure of Ref. [12], the measured alpha spectra integrated over 1 MeV energy bins, were compared with the energy spectra expected for a statistically equilibrated compound nucleus as predicted by Monte Carlo statistical code PACE [13] as shown in Figure 1. The comparison of the fusion cross sections of the two systems as well as with the ^9Be + ^{27}Al system [15] along with the corresponding CCDEF [11] calculations is shown in Figure 2. In this calculation the ground-state deformation parameter

β_2 of the target nucleus (^{27}Al) was taken to be 0.31 [16] and that of the first excited state at 0.842 β_2 was also taken to be 0.31.

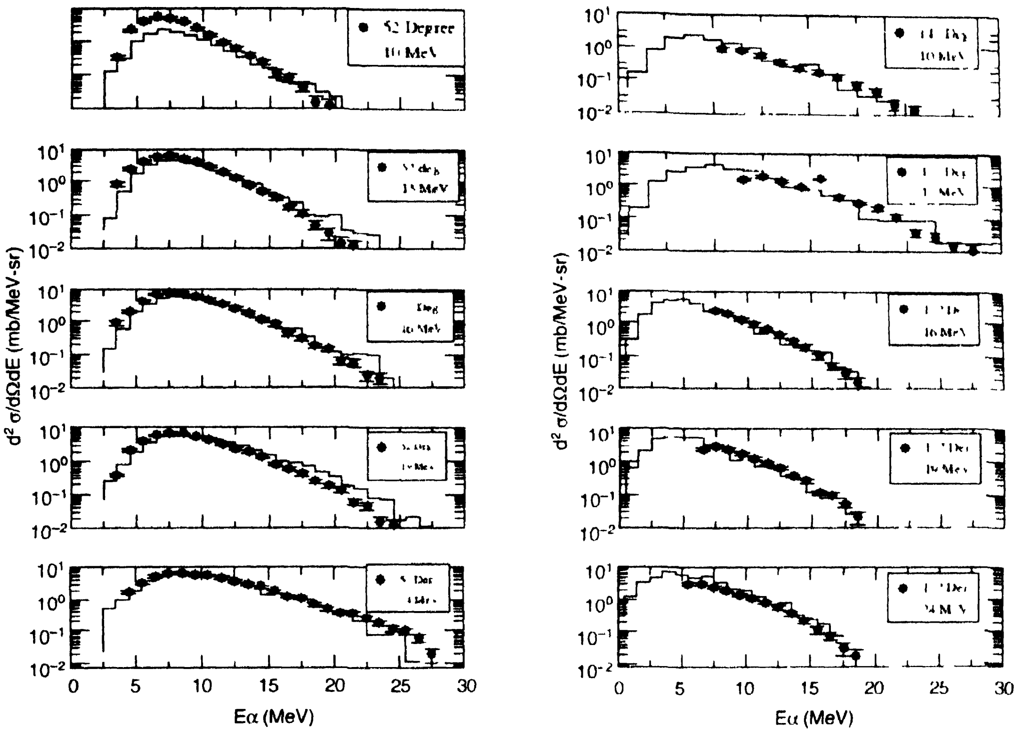

Figure 1. α-energy spectra from ^{7}Li + ^{27}Al—>^{34}S* CN at various angles corresponding to various lab energies

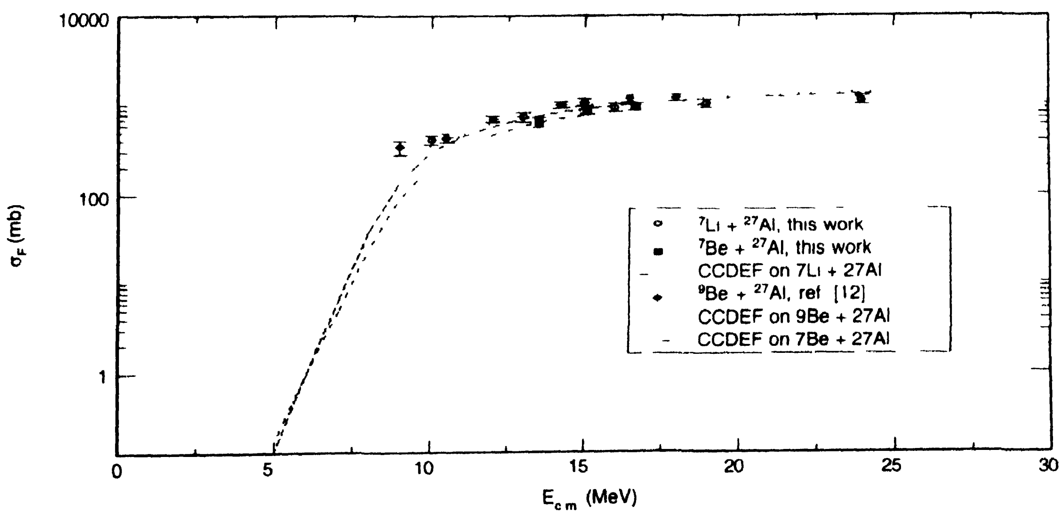

Figure 2. Comparison of the experimental fusion cross sections with CCDEF calculations for ^{7}Be, ^{7}Li, ^{9}Be + ^{27}Al systems.

4. Conclusions

In conclusion, a new measurement of quasi-elastic scattering and one-proton stripping reaction cross sections have been carried out on ^{7}Be + ^{27}Al system and the optical model (OM) parameters deduced The fusion cross sections were extracted by subtracting the experimental integrated transfer cross section from the total reaction cross sections obtained from OM fitting to quasi-elastic data The fusion cross sections agree well with the simplified coupled channel calculations Also we measured the elastic scattering angular distributions and α-evaporated spectra for ^{7}Li + ^{27}Al system From the latter we obtained the fusion cross sections by reproducing the α-spectra by statistical model calculation using the PACE code The OM analysis of the elastic scattering data results in good description with the optical potential parameters for ^{6}Li + ^{28}Si and ^{9}Be + ^{28}Si (loosely bound) systems [17] The present value of fusion cross section at 24 MeV agrees very well with the value reported by Padron *et al* [18] The comparison of the fusion cross section for ^{7}Be , ^{7}Li + ^{27}Al systems with recently measured fusion cross sections for ^{9}Be + ^{27}Al system [15] shows that the magnitudes of the latter are somewhat higher in the entire energy range This may be attributed to the presence of valence neutron in ^{9}Be Finally, the fusion cross sections for these mirror nuclei (^{7}Be, ^{7}Li) along with ^{9}Be on ^{27}Al are found to be about the same within limits of error

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