Coupled channel calculation of complete fusion cross section for $^{6}Li + ^{59}Co$ and $^{7}Li + ^{59}Co$ reactions

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Introduction

Exploring the interaction of various reaction channels in the collision of weakly bound systems is a topic of interest, both experimentally and theoretically, over the last several years [1]. Even though sub-barrier fusion involving stable nuclei is well understood, there are conflicting results and predictions about enhancement or suppression of the complete fusion cross section (CF) around the Coulomb barrier when one of the collision partners is a weakly-bound nucleus such as ^{6}Li ($S_{\alpha/d}$ = 1.474 MeV), ^{7}Li ($S_{\alpha/t}$ = 2.467 MeV), etc. and its possible dependence on breakup energy and target charge. The systematic enhancements observed with respect to one-dimensional calculations have been explained in terms of couplings to internal degrees of freedom of target and projectile, hence the sensitivity of the fusion process to nuclear structure has been recognized [2]. However, the role of breakup on fusion has been strongly deliberated both theoretically and experimentally.

In order to study the role of breakup on fusion reaction mechanism, we have calculated the fusion cross sections for $^{6}Li + ^{59}Co$ and $^{7}Li + ^{59}Co$ systems using the code CCFULL [3].

Calculational details

In the present work, the effects of coupling of low lying rotational states of projectile and target nuclei and their mutual excitation for $^{6,7}Li + ^{59}Co$ systems are investigated. In particular, the effects of couplings of low lying $(3/2)^-$ and $(9/2)^-$ rotational states of ^{59}Co, target nucleus, and their mutual excitations and low-lying 3^+ rotational state for ^{6}Li and $(1/2)^-$ rotational state of ^{7}Li, projectile nucleus, are studied. The values of the parameters such as deformation parameter β_λ, and excitation energy E_λ were taken from the Ref. [4, 5] and are given in Table-1. The experimental data for $^{6,7}Li + ^{59}Co$ are taken from the ref. [6].

The parameters of the Woods-Saxon form of the nuclear potential for $^{6}Li + ^{59}Co$, (V_0 = 124.0 MeV, r_0 = 1.05 fm, a_0 = 0.62 fm) and for $^{7}Li + ^{59}Co$, (V_0 = 103.0 MeV, r_0 = 1.103 fm, a_0 = 0.62 fm) are chosen in such a way that they reproduce the fusion barrier V_B given in the corresponding references.

Table:1 The deformation parameters, excitation energies, and the multipolarities of the states of different nuclei used in the coupled-channel calculations.

Nuclei	J^π	E_x (MeV)	β_λ
^{6}Li	3^+	2.186	0.72
^{7}Li	$(1/2)^-$	0.477	0.763
^{59}Co	$(3/2)^-$	1.099	0.14
	$(9/2)^-$	1.191	0.2

Results and Discussion

Fig. 1 and 2 show the calculated and the experimental fusion cross section for $^{6}Li + ^{59}Co$ and $^{7}Li + ^{59}Co$ system, respectively.

As seen in Fig. 1, for $^{6}Li + ^{59}Co$, the dotted line is the result when the projectile and target are assumed to be inert i.e. no excitation level. The result of coupled channel calculation (CC) taking into account the coupling to two rotational excitations $(3/2)^-$ and $(9/2)^-$ of ^{59}Co is denoted by dashed line which fails to reproduce the experiment data of fusion cross sections. However, inclusion of first low lying rotational excitation 3^+ of ^{6}Li, over predict the measured fusion data over the entire energy range, it is denoted by blue dashed line.

However, it is interesting to note that the measured fusion cross section agrees very well with the calculated ones when multiplied by a factor of 0.686 over the entire energy range which is shown by the blue solid line in fig-1.

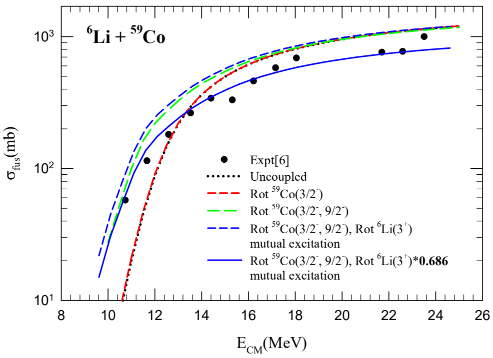

Fig. 1. Comparison of CCFULL calculations with expt. data for the fusion cross section for ^{6}Li + ^{59}Co system.

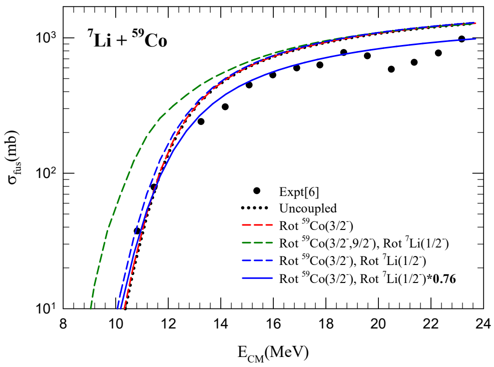

Fig. 2. Comparison of CCFULL calculations with expt. data for the fusion cross section for ^{7}Li + ^{59}Co system.

This implies that there is an overall suppression of 31.4% of the fusion cross section in the entire energy range compared to the ones predicted by CCFULL calculations.

Similarly, we investigate the effect of CC for ^{7}Li + ^{59}Co. For this system, first we assume both ^{7}Li and ^{59}Co nuclei to be inert which is denoted by dotted line in fig.-2. Then we take the first rotational excitation $(3/2)^{-}$ of ^{59}Co which fails to reproduce the measured fusion cross section. Inclusion of the coupling of first excitation $(1/2)^{-}$ of ^{7}Li over predicts the entire energy range, it is denoted by blue dashed line. Here also the calculated fusion cross sections agree well with the measured ones when multiplied by a factor of 0.76 over the entire energy range; it is shown by blue solid line. This implies that there is an overall suppression of 24% of the fusion cross section in the entire energy range compared to the ones predicted by CCFULL. However, inclusion of $(9/2)^{-}$ rotational excitation of ^{59}Co in this reaction over predict the entire energy range and fails to reproduce the measured fusion cross section.

Conclusion

From the present calculations for both the systems, fusion suppression was estimated to be 31.4% for ^{6}Li+^{59}Co and 24% for ^{7}Li +^{59}Co. We can easily see that the suppression in the fusion increases with the decrease of the projectile breakup energy. Thus the suppression in fusion cross section may be a direct consequence of the loss of incident flux due to the projectile breakup, which seems to be independent of energy over the measured energy range.

References

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