Analysis of fusion reactions data involving weakly bound, ^{6}Li, projectile using BW91 and AW95 parameterization schemes

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Introduction

The long tail density distribution of loosely bound nuclei influences fusion excitation function of reactions involving these nuclei. The magnitude of cross section of reactions induced by these nuclei is much larger than that predicted by 1DBP model. The enhancement in cross section in vicinity of Coulomb barrier energy region may be ascribed to the coupling of excited states of interacting nuclei. But some authors reports controversial conclusions in context to enhancement or suppression in cross section [1]. One of the possible reasons for such controversy is, inadequate knowledge of nuclear part of ion-ion interaction potential.

Therefore in this contribution we have estimated the fusion reaction cross section for ^{6}Li +^{64}Ni system by considering Broglia and Winther 1991 (BW 91)[2] and Aage Winther 1995 (AW 95) [3] parameterization schemes within coupled channel approach using CCFULL code [4].

Theoretical Formalism

The nuclear part of total ion-ion interaction potential has been estimated by Woods-Saxon potential and given as

$$V_N(r) = \frac{V_0}{1+\exp\left(\frac{r-R}{a}\right)} \qquad (1)$$

Here V_0, R and a represent potential depth, range and diffuseness parameters. These parameters are further parameterized using BW91 and AW95 parameterization schemes as below

Broglia and Winther (BW91) parameterization scheme

In this scheme potential depth is expressed as

$$V_0 = -16\pi \frac{R_P R_T}{R_P + R_T} \gamma a \qquad (2)$$

Where γ, surface energy coefficient is given by

$$\gamma = 0.95\left(1\text{-}1.8\left(\frac{N_P - Z_P}{A_P}\right)\left(\frac{N_T - Z_T}{A_T}\right)\right)$$

and radii parameter $R_{P(T)}$ is expressed as

$$R_{P(T)} = r_0 \left(A_{P(T)}\right)^{1/3} - 0.98\left(A_{P(T)}\right)^{-1/3}$$

Here all the terms have their usual meaning and are discussed in ref. [2]. In this scheme diffuseness (a) and radius parameter (r_0) are kept fixed at values 0.63fm and 1.233fm respectively.

Aage Winther (AW95) parameterization scheme

In this scheme potential depth, V_0 is estimated through Eq. (2). Radius parameter, r_0 is kept fixed at 1.2fm, while diffuseness, a and radius of projectile (target), $R_{P(T)}$ are calculated through following expressions

$$a = \frac{1}{1.17\left[1+0.53\left(A_P^{-1/3} + A_T^{-1/3}\right)\right]}$$

and $R_{P(T)} = r_0\left(A_{P(T)}\right)^{1/3} - 0.09$.

Further, during present contribution the potential depth, V_0 has also been estimated through following expression [5]

$$V_0 = -40 \times \frac{R_P R_T}{R_P + R_T}$$

Where

$$R_{P(T)} = r_0\left(A_{P(T)}\right)^{1/3} - 0.77\left(A_{P(T)}\right)^{-1/3}$$

Here diffuseness (a=0.5fm) and radius (r_0=1.17fm) parameters are taken from Ref.[5]. It is pertinent to mention here that this scheme is referred hereafter as FP.

Results and Discussion

Major ingredients used in calculation are, the potential parameters and values of excited states for projectile and target along with deformation parameter and are listed in table I and II respectively.

Table I. Potential parameters calculated using different parameterization schemes BW91, AW95 and FP.

Parameterization scheme	V_0 (MeV)	V_B (MeV)	R_B (fm)	ħω	a (fm)
BW91	37.53	11.83	9.54	3.62	0.63
AW95	41.47	12.11	9.33	3.78	0.61
FP	49.37	12.86	8.87	4.46	0.5

Table II Excited state energies (ε*) and deformation parameters (β_λ) of interacting nuclei

Nuclei	ε*(Eλ, Band) (MeV)	β_λ
^{6}Li	2.186(E2, Rot.)	0.87(β_2) [6]
^{64}Ni	1.345 (E2, Vib.)	0.169(β_2) [7]
	3.56 (E3, Vib.)	0.203(β_3) [8]

Now, fusion reaction cross section for ^{6}Li+^{64}Ni system has been calculated using CCFULL code and the results obtained are shown in Fig. 1 and 2.

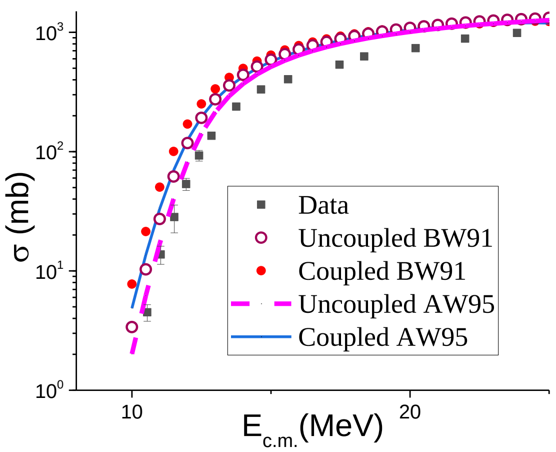

Fig. 1 (Color online) Experimental and calculated fusion cross section for ^{6}Li +^{64}Ni system. Data points are taken from Refs. [9].

Fig. 1 shows that inclusion of coupling enhances fusion cross section in below barrier energy region while in above barrier region no significant effects are observed. Further, it is clearly visible that calculations with AW95 scheme are in close agreement with the data in comparison to BW91. However BW91 overestimates data, therefore we introduced constant radii (r_0) and diffuseness parameter (a) as 1.17 fm and 0.5 fm respectively in commonly used potential depth expression to estimate total interaction potential. The results obtained are shown in Fig. 2.

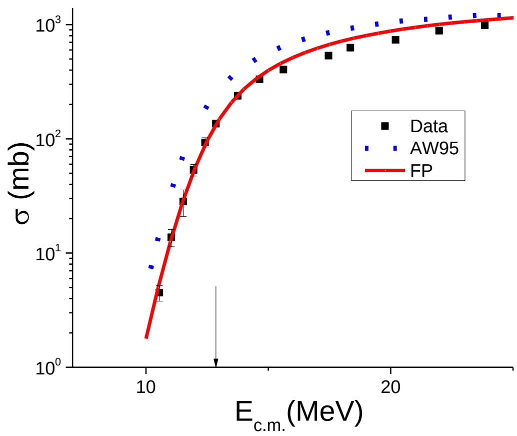

Fig. 2 (Color online) Experimental and calculated fusion cross section for ^{6}Li +^{64}Ni. Arrow (↓) sign indicates the position of Coulomb barrier.

From this figure it can be easily observed that calculations performed with AW95 scheme overestimate the data in whole region while calculations with FP reproduce the data very well. For detail see ref. [5, 10]

Conclusively, coupling to the excited states of interacting nuclei enhances the fusion reaction cross section in below barrier region and overestimates the data in whole energy region while results using FP reproduces the data very well.

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