Sub-barrier evaporation residues in $^{6}Li+^{209}Bi$ system

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Introduction

When a pair of distinct nuclei merge in a reaction known as fusion, a composite system is formed. If the incident energy is not very high and the system is not very light, the reaction process is basically controlled through quantum tunneling over the Coulomb barrier, which is formed by the strong cancelling of the repulsive Coulomb force and the attractive nuclear interaction. Numerous theoretical and experimental studies have shown that couplings of colliding nuclei's relative movements to a variety of nuclear intrinsic motions have a major influence on fusion events at energy close to and below the Coulomb barrier [1]. Thus, heavy-ion sub- barrier fusion reactions offer a good opportunity to address the general issue of quantum tunneling in the presence of couplings, which has become a hot topic in many fields of physics and chemistry over the past few years. Fusion cross sections can now be determined with high accuracy in small energy intervals thanks to recent advancements in experimental techniques. Recently, interest in heavy-ion sub-barrier fusion reactions has grown again as a result of these highly precise experimental data [2, 3].

Theory

We used the global nucleon optical model potential proposed by R.L Varner. Where the total potential is considered as sum of nuclear potential and coulomb potential $V_c(R)$.

Where

$$V_c(R) = \begin{cases} \frac{Ze^2}{r}, & r \geq R_c \\ \frac{Ze^2}{2Rc}\left(3 - \frac{r^2}{Rc^2}\right), & r \leq R_c \end{cases}$$

Where $R_c(A) = 1.238A^{1/3} + 0.116$ fm,

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We used the empirical approach based upon the assumption that fusion barriers are normally distributed around the mean value B_0. The capture cross-section is given by,

$$\sigma_{cap} = \sqrt{\frac{\pi}{2}}\frac{R_{int}^2\, w}{E_{cm}}\{\sqrt{\pi}X[1+erf(X)+exp(-X^2)\} \quad (1)$$

Where , $X = \frac{E_{cm} - B_0}{W\sqrt{2}}$

Here, B_0 and w denote the mean value of the barrier distribution and its width, respectively. R_{int} refers to the relative distance between two colliding nuclei at the contact point.

The barrier height B_0 is given by,[4]

$$B_0 = 0.853\ 315Z + 0.001\ 169\ 5Z^2 - 0.000\ 001\ 544Z^3 \text{ MeV} \quad (2)$$

Where $Z = Z_aZ_A/(A_a^{1/3} + A_A^{1/3})$ defined with the charge and mass of the projectile and target nuclei. The parameter R_{int} has been set equal to $1.16(A_a^{1/3} + A_A^{1/3})$ fm. As for the width parameter *w,* it can be calculated as follows:[4,5]

$$W = DB_0\sqrt{\delta_a^2 + \delta_A^2 + \delta_0^2} \quad (3)$$

Where $\delta_i = R_i^2\beta_{2,i}^2/4\pi$ with the radii R_a and R_A defined as $1.15A_i^{1/3}$ and their quadrupole deformation parametersβ_2.

Accordingly, the evaporation-residue (ER) cross-section can thus be expressed as,[6,7]

$$\sigma_{ER}(E_{cm}) = \sum_{Jc\geq 0}\sigma_{fus}(E_{cm},J_c)P_{surv}(E^*_c,J_c) \quad (4)$$

Where, $\sigma_{fus}(E_{cm},J_c) = \frac{\pi}{K^2}(2J_c+1)P_{fus}(E_{cm},J_c)$,

Where J_C represents the total angular momentum of the compound system and k the wave number of relative motion between the projectile and target nuclei.

The total fusion probability can be written in the following form:

$$P_{fus} = P_{cap} \cdot P_{form},$$

Where P_{form} stands for the compound-nucleus formation probability.

Results and discussion

We have studied the fusion phenomenon for the $^{6}Li+^{209}Bi$ system and synthesis of a heavy element Z=86(A=215).Fig.1 shows the variation in capture cross-sections with E_{cm}. From this figure it is found that capture cross-section increases with the increase of center of mass energy in the sub-barrier region. Fig.2 shows that the Evaporation -residue cross-section for $^{6}Li + ^{209}Bi$ system as a function of $E_{C.m.}$ for 1n, 2n, 3n and 4n channels. From this figure we get optimum energies for 3n and 4n channels. From this study, we concluded that ^{209}Bi is the best target for ^{6}Li for production of Z=86 (A=215) $^{215}Rn_{86}$. From this study,we could able to find the maximum production cross-section.

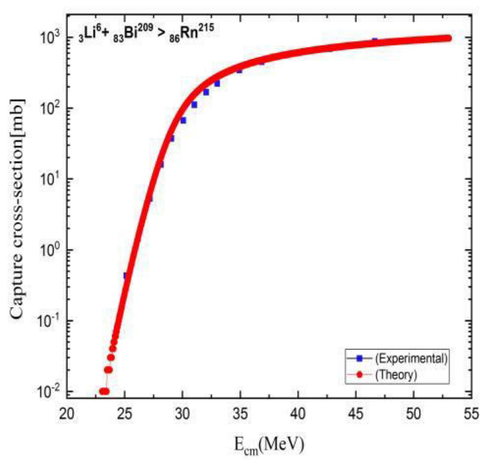

Fig. 1 Comparison of estimated capture cross-section with experimental data. The WKB approximation (red line curve) and experimental data(blue line curve).

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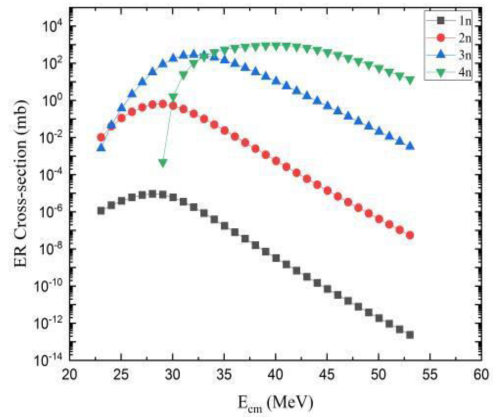

Fig. 2 Evaporation residue cross-sectoion as a function of $E_{c.m}$. for 1n, 2n, 3n and 4n channels.

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