Fusion excitation function and barrier distribution of ^{6}Li,^{7}Li+^{209}Bi systems in Microscopic Barrier Penetration Model

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Introduction

Fusion cross sections for heavy-ion reactions at sub-barrier energies have been calculated in various classical and semiclassical barrier-penetration models or coupled channel calculations. A microscopic Static Barrier-Penetration Model (SBPM) presented in [1-3] shows good agreement for calculated fusion cross sections and fusion barrier-distribution (D(B)) with the experimental results for ^{154}Sm+^{16}O, ^{12}C+^{232}Th [1] and ^{19}F+^{232}Th [2], ^{6}Li+^{232}Th [3] systems. This model uses ion-ion potential obtained from classical microscopic configurations of nuclei and a suitable NN potential.

In the present work we calculate the fusion cross sections and barrier distributions for ^{6}Li, ^{7}Li+^{209}Bi systems in SBPM model.

Calculation Details

Heavy-ion fusion cross-sections for a single barrier is approximately given by the Wong's formula [4],

$$\sigma_{fus} = \left(\frac{\hbar\omega}{2E_{cm}}\right) R_B^2 \ln\left[1+\exp\left\{\frac{2\pi}{\hbar\omega}\left(E_{cm}-V_B\right)\right\}\right] \qquad (1)$$

where, V_B (barrier-height), R_B (barrier-radius) and ω (oscillator-frequency corresponding to the barrier top) are barrier parameters for a head-on collision (b=0). Fusion cross sections and barrier parameter calculations in the present model requires microscopic configuration for the two nuclei in ground state and a suitable NN potential for interaction. We have chosen the NN potential and the Coulomb potential as in ref [1]

A soft-core Gaussian form of NN potential given by

$$V_{ij}(r_{ij}) = -V_0\left(1-\frac{C}{r_{ij}}\right)\exp\left(-\frac{r_{ij}^2}{r_0^2}\right) \qquad \ldots (1)$$

is used along with the usual Coulomb interaction in the present study. Here, V_0, C and r_0 are, respectively, the depth parameter, repulsive-core radius and range parameter.

. Nucleon distribution in each nucleus is first obtained by the STATIC program [5] in which the total potential energy of an initially random distribution of nucleons is cyclically minimized. We have used potential P4 (V_o = 1155 MeV, C= 2.07 fm, r_o= 1.2 fm) [1] in the present study. Ground state binding energy (BE), root-mean-square radius (R), and deformation parameter ($ß_2$) produced by P4 for the nuclei considered in the present work are given in table-1.

Table 1: Ground state properties of the nuclei generated with potential P4 and STATIC code.

	Calculated			Experimental		
	B.E. (Mev)	$ß_2$	R (fm)	B.E. (Mev)	$ß_2$	R (fm)
^{6}Li	32.21	0.01	1.65	31.99	0.03	2.54
^{7}Li	42.42	-0.47	1.81	39.24	0.04	2.39
^{209}Bi	1783.3	-0.06	6.10	1640.3	0.00	5.52

The ion-ion potential (which is the sum of the nuclear and Coulomb potential between all the pairs of nucleons between the two ions) is calculated as a function of centre of mass separation (R_{cm}) of the two nuclei in the *frozen-density* approximation [1]. The barrier parameters V_B and R_B, corresponding to the outer maximum of the ion-ion potential, and ω, corresponding to the 2nd derivative of this peak, for head-on collisions for a given orientation of the two nuclei are obtained.

Results & Discussion

Calculated fusion cross sections for ^{6}Li+^{209}Bi and ^{7}Li+^{209}Bi reactions with eq.1 and averaged over 500 orientations are shown in Figs. 1 and 2 respectively. Also shown in these figures are experimental fusion cross sections for the corresponding reactions from ref [6]. Calculated fusion cross sections for ^{6}Li+^{209}Bi reaction are overestimated in comparison with the experimental data of ref [6]. Calculated fusion cross sections for ^{7}Li+^{209}Bi reaction are also overestimated but are in better agreement with the experiment as compared to that in the case of ^{6}Li+^{209}Bi reaction.

The reason for this discrepancy may be partly due to the higher value of the rms radius for ^{209}Bi nucleus as generated with potential P4 and the STATIC code and partly it may be due to the absence of any projectile breakup fusion-fission channels in the model calculation which treat the nuclei as frozen.

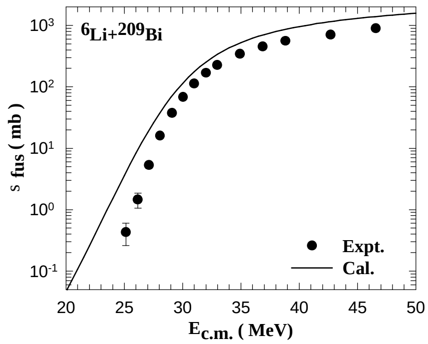

Fig. 1 Fusion cross section for ^{6}Li+^{209}Bi reaction

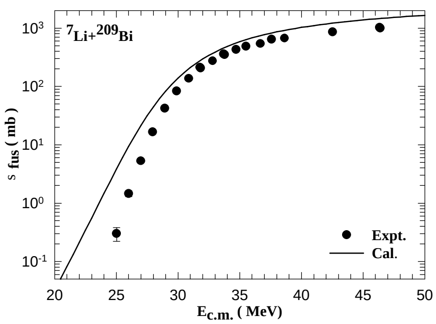

Fig. 2 Fusion cross section for ^{7}Li+^{209}Bi reaction

The barrier-distributions D(B) are obtained from the averaged fusion cross sections as the 2nd derivative of ($E_{cm}\sigma_{fus}$) with respect to E_{cm}. Fusion cross sections were calculated with 0.5 MeV interval and the 2nd derivatives were evaluated with a three-point difference formula with ΔE_{cm}= 2 MeV.

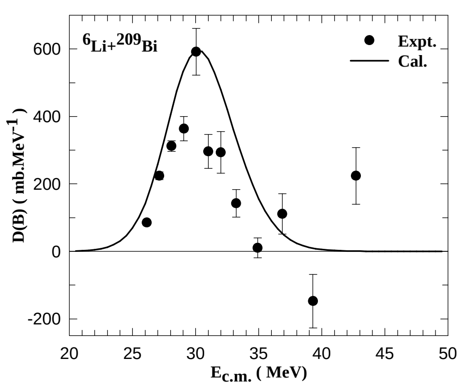

Fig.3 Barrier distribution for ^{6}Li+^{209}Bi reaction

Calculated barrier-distribution for ^{6}Li+^{209}Bi reaction is shown in Fig. 3 and compared with the experimental values obtained from the data in ref [6]. Calculated BD has a peak which matches with that corresponding to the experimental data. However it has broader distribution. The calculated barrier-distribution shows typical characteristic of the collision between two spherical nuclei. Calculated barrier-distribution for ^{7}Li+^{209}Bi reaction is shown in Fig. 4 and compared with the corresponding experimental values from ref [6]. Calculated barrier-distribution for ^{7}Li+^{209}Bi is in better agreement with the experiment but shows large discrepancies at higher energies where the experimental uncertainties are also large.

^{6}Li is a weakly bound nucleus and the present calculations do not treat it like a weakly bound system because of the frozen density approximation. Therefore, the present SBPM model calculations do not show good agreement in the case of ^{6}Li+^{209}Bi reaction. Therefore there is strong need to evolve dynamical calculation which can treat the weakly bound projectiles as two body or three body systems which are weakly bound. Such calculations are presently underway.

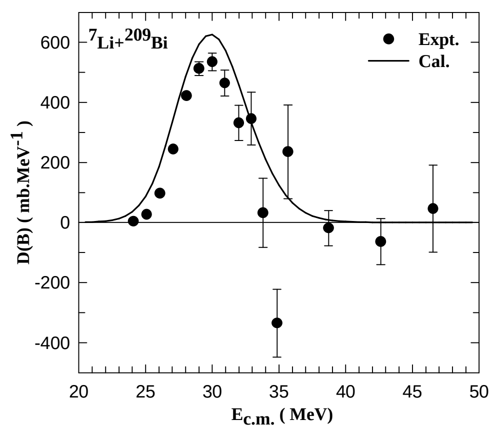

Fig. 4 Barrier distribution for ^{7}Li+^{209}Bi reaction

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