# Reaction Dynamics of $^{6}$Li+$^{209}$Bi System

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We have developed an analytical recursive formula by adopting a novel and elegant procedure called multistep potential(MP) [1] method to analyze the data of angular variations of elastic scattering cross section and expression for the absorption [2] from arbitrary small intervals which will lead to the explanation of the fusion cross section ($\sigma_{fus}$) data at various incident center-of-mass energies $E_{c.m.}$. This procedure can replace the Rungee-kutta or similar numerical integration methods to solve the Schroedinger equation. A smoothly varying potential U(r) can be considered as a chain of 'n' number of rectangular potentials each one of which has arbitrarily small width 'w'. Having simulated the potential upto a maximum range $r = R_{max}$ we have $R_{max} = \Sigma_i^n w_i$ where $w_i = w$ is the width of the ith rectangle. Let in the jth region, $\Sigma_{i=1}^{j-1} w_i < r \le \Sigma_{i=1}^{j} w_i$,the strength and width of the potential be denoted by $U_j$ and $w_j$, respectively. The reduced Schroedinger equation in this region is

$$\frac{d^2\Phi(r)}{dr^2} + \frac{2m}{\hbar^2}(E - U_j)\Phi(r) = 0, \qquad (1)$$

with the solution

$$\Phi_j(r) = a_j e^{ik_j r} + b_j e^{-ik_j r}, \qquad (2)$$

where the wave number $k_j$ is defined as $k_j = \sqrt{\frac{2m}{\hbar^2}(E - U_j)}$ for the jth segment of width $w_j$. Here E indicates incident energy and m stands for the mass of the particle. Using the exact Coulomb wave function i.e. $G_l$ and $F_l$ and their derivatives in the outer region $r \ge R_{max}$ and the wave function $\Phi_n(r)$ and its derivative in the left side of $r = R_{max}$, and matching them at $r = R_{max}$ we get the expression for partial wave S-matrix $\eta_\ell$ as

$$\eta_\ell = 2iC_\ell + 1, \qquad (3)$$

$$C_\ell = \frac{kF'_\ell - F_\ell H}{H(G_\ell + iF_\ell) - k(G'_\ell + iF'_\ell)}, \qquad (4)$$

$$H = \frac{\Phi'_n}{\Phi_n} = ik_n \frac{D^{(\ell)}\, e^{ik_n R_{max}} - e^{-ik_n R_{max}}}{D^{(\ell)}\, e^{ik_n R_{max}} + e^{-ik_n R_{max}}}, \qquad (5)$$

$$D^{(\ell)} = \frac{a_n}{b_n} = q_{n,n-1,n-2,...1}$$
$$= \frac{q_{n,n-1} + q_{n-1,n-2,...1}e^{2ik_{n-1}w_{n-1}}}{1 + q_{n,n-1} \times q_{n-1,n-2,...1}e^{2ik_{n-1}w_{n-1}}}, \qquad (6)$$

with $q_{21}$=-1.

We use the notation $q_{ji} = -q_{ij} = \frac{k_j - k_i}{k_j + k_i}$. Using the above expression (3) for $\eta_\ell$ we explain the elastic scattering of $^6Li+^{209}Bi$ system. For the total reaction cross section one can use the formula

$$\sigma_r = \frac{\pi}{k^2}\sum_\ell (2\ell + 1)(1 - |\eta_\ell|^2) \qquad (7)$$

This is equal to the absorption cross section

$$\sigma_{abs} = \frac{\pi}{k^2}\sum_\ell (2\ell + 1)(1 - \frac{|a_n|^2}{|b_n|^2})$$
$$= \frac{\pi}{k^2}\sum_\ell (2\ell + 1)(\sum_{j=1}^{n} I_j^{(\ell)}) \qquad (8)$$

where I$_j$ is the absorption cross section from the jth region [2].

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The symbol $\star$ indicates the complex conjugate of the respective quantity. The problem of higher partial wave can be treated as scattering by effective potential $V_N(r)+V_C(r)+V_\ell(r)$ and one can adopt the MP approximation method described above for this effective potential. Using a deep potential in Woods-Saxon form for the nuclear part with parameters $V_N$=-55 MeV, $r_v$=1.399fm, $a_v$=0.33fm, Coulomb radius parameter $r_c$=1.05fm and a shallow imaginary potential with strength W=6.0 MeV, we calculate the result of differential scattering cross section at several energies in the case of $^6Li+^{209}Bi$ system and obtain a good explanation of the corresponding experimental data [3] as shown in figure 1.

Using the same potential , the results of $\sigma_{fus}$ and $D(E_{c.m.})=\frac{d^2(E_{c.m.}\sigma_{fus})}{dE^2_{c.m.}}$ are calculated and the corresponding experimental data [4] (solid dots ) in figure 2 is explained with remarkable success by our calculated results shown by full curves. The weakly absorptive nature of the optical potential mentioned above is found to allow resonance states to occur in the collision of two nuclei. These resonances are found to control the oscillatory or peak structure of $D(E_{c.m.})$ seen in figure 2.

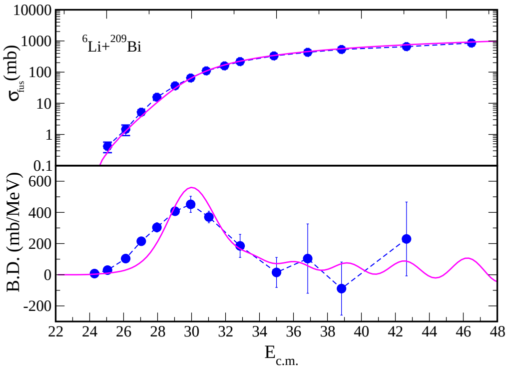


FIG. 2: Variation of $\sigma_{fus}$ as function of $E_{c.m.}$ for the $^6Li+^{209}Bi$ system. The full drawn curves represent calculated results.The experimental data shown by solid dots are obtained from [4]. Variation of $D(E_{c.m.})=\frac{d^2(E_{c.m.}\sigma_{fus})}{dE^2_{c.m.}}$ as function of energy $E_{c.m.}$ corresponding to results of $\sigma_{fus}$ in fig2. The full drawn curves represent calculated results.The experimental data shown by solid dots are obtained from [4].

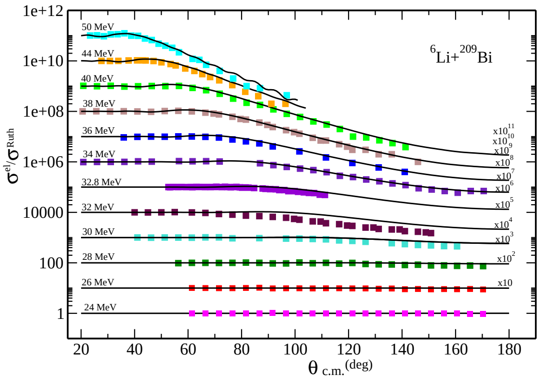


FIG. 1: Angular distribution of elastic scattering cross sections (ratio to Rutherford) of $^6Li+^{209}Bi$ system at different laboratory energies. The full drawn curves are theoretical results of present optical model calculation. The circles are experimental cross section from [3].

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## References


[1] Basudeb Sahu, B.B. Sahu and S.K. Agarwal, Pramana; J. Phys. **70**, 27 (2008)

[2] Basudeb Sahu et al, Phys. Rev. C **77**, 024604 (2008)

[3] S. Santra et al, Phys. Rev. C **83**, 034616 (2011)

[4] M. Dasgupta et al, Phys. Rev. C **70**, 024606 (2004)