Heavy-ion fusion of ^{16}O with ^{144}Sm and ^{145}Sm

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Introduction

The fusion processes at energies near and below barrier have been a field of very intense study in recent decades [1, 2] for the understanding of the nuclear structure effects and the study is important in the synthesis of super heavy nuclei. Of the many factors that have been explicitly considered in order to describe the fusion processes, the fusion excitation functions and barrier distributions have extreme implications. In the present work the excitation functions and barrier distributions of ^{16}O on ^{144}Sm and ^{145}Sm have been calculated using one dimensional barrier penetration model, taking scattering potential as the sum of Coulomb and proximity potential. The calculated results of ^{144}Sm are compared with experimental data [3] and CC calculations using code CCFULL [4].

The model

In the case of fusion of two nuclei by the quantum mechanical penetration of simple one-dimensional potential barrier, the fusion cross section is given by Wong's formula [5],

$$\sigma = \frac{\pi}{k^2}\sum_{\ell}\frac{2\ell+1}{1+\exp[2\pi(E_\ell - E)/\hbar\omega_\ell]} \quad (1)$$

The scattering potential is given as:

$$V = \frac{Z_1 Z_2 e^2}{r} + V_P(z) + \frac{\hbar^2 \ell(\ell+1)}{2\mu r^2} \quad (2)$$

where 'z' is the distance between the near surfaces of the projectile and target and 'r' is the distance between the centers of the projectile and target. The proximity potential $V_P(z)$ is given as:

$$V_P(z) = 4\pi\gamma b \frac{C_1 C_2}{C_1 + C_2}\phi(\frac{z}{b}) \quad (3)$$

where the nuclear surface tension coefficient ,

$$\gamma = 0.9517[1 - 1.7826(N-Z)^2/A^2] \quad (4)$$

An improved version of γ is presented by Reisdorf as:

$$\gamma = 1.2496[1 - 2.3(N-Z)^2/A^2] \quad (5)$$

Below the barrier, the tunneling through the barrier has to occur in order to allow the fusion of the two nuclei and in terms of partial wave; the fusion cross section is given as:

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell=\ell_C}(2\ell+1)P \quad (6)$$

where P is the WKB penetration probability given as:

$$P = \exp\left\{-\frac{2}{\hbar}\int_a^b \sqrt{2\mu(V-E)}\,dz\right\} \quad (7)$$

Here a and b are the inner and outer turning points defined as $V(a) = V(b) = E$.

The fusion cross section enhancements observed at sub barrier energies require the couplings between reaction channels and elastic channel, that give rise to a distribution of fusion barriers and the point difference formula [1] explains the barrier distributions easily.

Calculation and Results

The fusion excitation functions and barrier distributions for $^{16}O+^{144}Sm$ and $^{16}O+^{145}Sm$ systems are shown in Fig.1. The up triangles in Figs.1 (a) and (c) represent the total fusion cross-sections calculated by Eq.(1) with the nuclear surface tension coefficient given by Eq.(4). In Fig.1(a) above the barrier the computed cross-sections show good agreement with the experimental data where as below the barrier the experimental values show an enhancement.

Below the barrier, we have treated the fusion reaction as a tunneling process and the computed fusion cross sections (open squares)

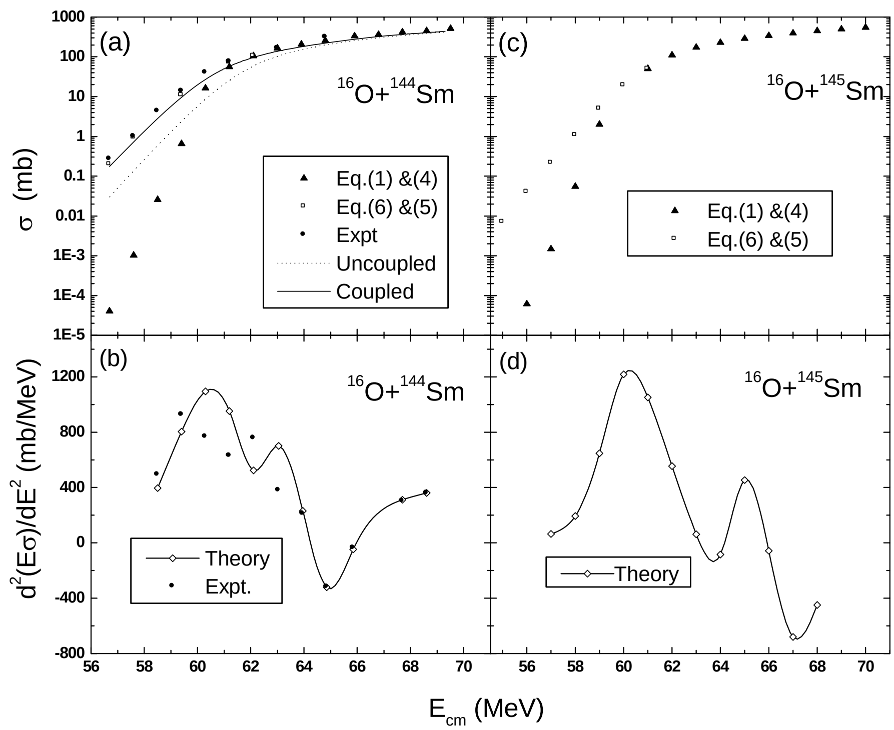

Fig.1 Fusion cross sections and barrier distributions for ^{16}O+^{144}Sm and ^{16}O+^{145}Sm

using Eq. (6) with nuclear surface tension coefficient given by Eq.(5) and by considering the quadrupole deformations of both projectile and target show good agreement with the experimental data as in Fig.1(a). In the CCFULL calculations of ^{16}O+^{144}Sm, two phonon excitations in ^{144}Sm with $\beta_2^N = 0.205$ have been used, where the excitation energy of ^{144}Sm in 3^- is taken to be 1.81MeV.

Using point difference formula given by Eq.(40) of Ref.[1], we have evaluated barrier distributions for the systems ^{16}O+^{144}Sm and ^{16}O+^{145}Sm with fusion cross sections computed using Eqs.(1) and (6). In the case of ^{16}O+^{144}Sm reaction the comparison of experimental data [3] with calculated barrier distributions agrees with overall location, width and shape of the measured lobe. The comparison of barrier distributions reveals the importance of the effect of coupling between the elastic channel and intrinsic degrees of freedom of the target and projectile.

Conclusions

The good agreement between theory and experiment in the case of ^{16}O+^{144}Sm reaction be equally valid in the case of ^{16}O+^{145}Sm reaction and hence Figs.1(c) and (d) predict ^{16}O+^{145}Sm fusion reaction easily.

References

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