Decay of $^{48}Cr^*$ formed in $^{24}Mg+^{24}Mg$ and $^{36}Ar+^{12}C$ reactions

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Introduction

The systematic of fusion in the mass region $40 \leq A_{CN} \leq 80$ has been studied widely and it is found to be interesting to explore the competition of this process with other mechanisms that result in binary yield. The ^{48}Cr nucleus is a good system to explore such competition. The ^{24}Mg (^{24}Mg, ^{24}Mg) ^{24}Mg reaction involves a resonance mechanism which influence yields at lower excitation energy (≤ 8MeV). To examine the question of competition between resonance and statistical fission process an experiment was done in which the compound $^{48}Cr^*$ was populated by the entrance channels $^{24}Mg+^{24}Mg$ and $^{36}Ar+^{12}C$ with E_{cm} = 44.4MeV and 47MeV respectively.

In the present work the compound nuclei (CN) decay cross section for the reactions $^{24}Mg+^{24}Mg$ and $^{36}Ar+^{12}C$ is measured at various E_{cm} values. The calculations are done using the one dimensional barrier penetration model, taking the interacting potential as the sum of Coulomb and Proximity potentials [1]. The computed values are compared with the experimental data [2, 3] and also with the available theoretical data [4].

Theory

The interaction barrier for two colliding nuclei is given as,

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

where $V_P(z)$ represents the proximity potential given as,

$$V_P(z) = 4\pi\gamma b \frac{C_1 C_2}{C_1 + C_2} \phi(\frac{z}{b}) \quad (2)$$

with the nuclear surface tension coefficient,

$$\gamma = 0.9517[1 - 1.7826(N-Z)^2 / A^2] \quad (3)$$

The CN decay cross section of two nuclei has been derived by Wong [5] within the quantum mechanical penetration of one dimensional potential barrier using the probability for absorption of ℓ^{th} partial wave given by Hill-Wheeler formula for energy E_ℓ which is given as

$$\sigma = \frac{\pi}{k^2} \sum_\ell \frac{2\ell+1}{1+\exp[2\pi(E_\ell - E)/\hbar\omega_\ell]} \quad (4)$$

where $k = \sqrt{2\mu E/\hbar^2}$. Here $\hbar\omega_\ell$ is the curvature of the inverted parabola.

Using some parametrizations in the region $\ell = 0$ and sum being replaced by integration Wong derived the cross section as

$$\sigma = \frac{R_0^2 \hbar\omega_0}{2E} \ln\left\{1 + \exp\left[\frac{2\pi(E - E_0)}{\hbar\omega_0}\right]\right\} \quad (5)$$

where R_0 is the barrier radius and E_0 is the barrier height.

For relatively large values of E, the above result reduces to

$$\sigma = \pi R_0^2 \left[1 - \frac{E_0}{E}\right] \quad (6)$$

Glas and Mosel put forward a relation for σ as

$$\sigma = \pi\lambda\!\!\!^{-2} \sum_{\ell=0}^{\infty} (2\ell+1) T_i P_i \quad (7)$$

where T_i is the penetration probability and

$$P_i = \begin{cases} 1, \ell \leq \ell_c \\ 0, \ell \rangle \ell_c \end{cases} \quad (8)$$

Replacing the sum in Eq. (7) by integration, one obtains the cross section as

$$\sigma = \frac{\hbar\omega}{2} R_B^2 \frac{1}{E} \ln\left\{\frac{1+\exp[2\pi\{E - V(R_B)\}/\hbar\omega]}{1+\exp[2\pi\{E - V(R_B) - (R_c/R_B)^2[E - V(R_c)]\}/\hbar\omega]}\right\} \quad (9)$$

Results and Discussions

The interaction barrier for ^{24}Mg + ^{24}Mg and ^{36}Ar + ^{12}C reactions were plotted against distance between the centers of projectile and target. The values of E_B and R_B for the calculations of total cross section for the above combinations were taken from the above plot. The cross section is calculated using Equations (5), (6) and (9) for various E_{cm} values above the barrier. The calculated total cross section is then compared with the experimental data [2, 3] and also with the available theoretical data [4]. Table 1 gives the comparison of total cross section using Eq (9) with the experimental data for energies above the barrier. An analysis of the result obtained given in the table clearly shows that the cross section calculated using the eq. (9) is in close agreement with experimental value, better than those values obtained in Ref. [4].

Fig. 1 represents the plot for the calculated cross section in logarithmic scale plotted against various E_{cm} values, for ^{24}Mg + ^{24}Mg and ^{36}Ar + ^{12}C combinations. It is seen from the figure that above the barrier the cross section computed using (5), (6) and (9) matches well with the available experimental data.

Table 1: Comparison of the total fission cross section with the experimental data.

Exit Channels	E_{cm} (MeV)	CN decay cross section σ (mb)	
		Expt.	Eq. (9)
	28		671.51
	34		1003.77
	40		1231.03
^{24}Mg+^{24}Mg	44.4	1124	1252.23
	48		1255.39
	56		1260.97
	60		1263.21
	26		976.73
	32		1258.55
	40		1309.78
^{36}Ar+^{12}C	47	1227	1296.23
	50		1291.59
	56		1283.79
	60		1279.46

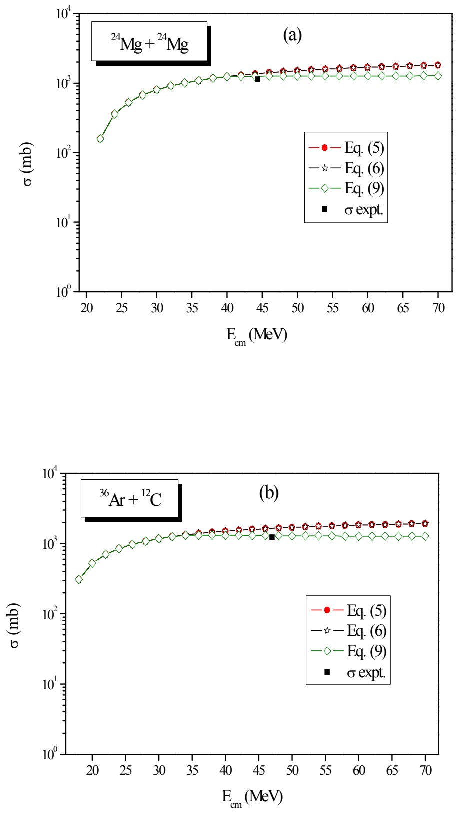

Fig 1: Comparison of the total fission cross sections calculated using Eq. (5), (6) and (9) with the experimental data for (a) ^{24}Mg+^{24}Mg (b) ^{36}Ar+^{12}C combinations.

References

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