Synthesis of ^{292}114 superheavy nucleus in heavy-ion fusion reaction

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1. Introduction

Extensive studies have been made both experimentally and theoretically on heavy-ion fusion reactions for the understanding of the involved reaction mechanisms, especially for the synthesis of super heavy elements (SHE). Based on the concept of cold valleys which were introduced in relation to the structure of minima in the so-called driving potential, which is the difference between the interaction potential and the decay energy Q of the reaction, radioactive decay of super heavy nuclei ^{286}112, ^{292}114, and ^{296}116 were studied [1], using Coulomb and Proximity Potential model (CPPM) [2].

In the present work, we have studied the fusion cross sections for the reactions of ^{134}Te + ^{158}Sm, ^{132}Sn + ^{160}Gd, ^{130}Sn + ^{162}Gd and ^{86}Se + ^{206}Hg systems found in the two deep regions of ^{292}114, using scattering potential as the sum of Coulomb and proximity potential [2], so as to predict the most probable projectile-target combinations in heavy ion fusion reactions for the synthesis of super heavy nuclei.

2. Theory

In nuclear reactions, the interaction barrier for two colliding nuclei is given as:

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

where $V_P(z)$ is the proximity potential given as:

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

with the nuclear surface tension coefficient,

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

Here ϕ is the universal proximity potential.

For energy E_ℓ, using the probability for the absorption of ℓ^{th} partial wave given by Hill-Wheeler formula, Wong arrived at the total cross section for the fusion of two nuclei by quantum mechanical penetration of simple one-dimensional potential barrier as [3]:

$$\sigma = \frac{\pi}{k^2} \sum_\ell \frac{2\ell + 1}{1 + \exp[2\pi(E_\ell - E)/\hbar\omega_\ell]} \tag{5}$$

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

Using some parameterizations in the region $\ell = 0$ and replacing the sum in Eq. (8) by an integral Wong gave the reaction cross section as:

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

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 the well-known formula:

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

3. Results and discussion

In an attempt to predict the suitable projectile-target combinations for heavy ion fusion experiments in the synthesis of ^{292}114 super heavy nucleus, by using Coulomb and proximity potential, we have analyzed the interaction barriers for the systems ^{130}Sn + ^{162}Gd, ^{132}Sn + ^{160}Gd and ^{134}Te + ^{158}Sm, that are found in the second deep region in the cold valleys of ^{292}114 nucleus. The interaction barrier against the distance between the centers of the projectile and target for the above three combinations are shown in Figs.1 (a), (b) and (c). While observing Figs.1 (a), (b) and (c), it is clear that the potential pockets that are to be appreciable for the fusion to takes place are shallow, in all the three cases and hence cannot be used as a suitable projectile-target

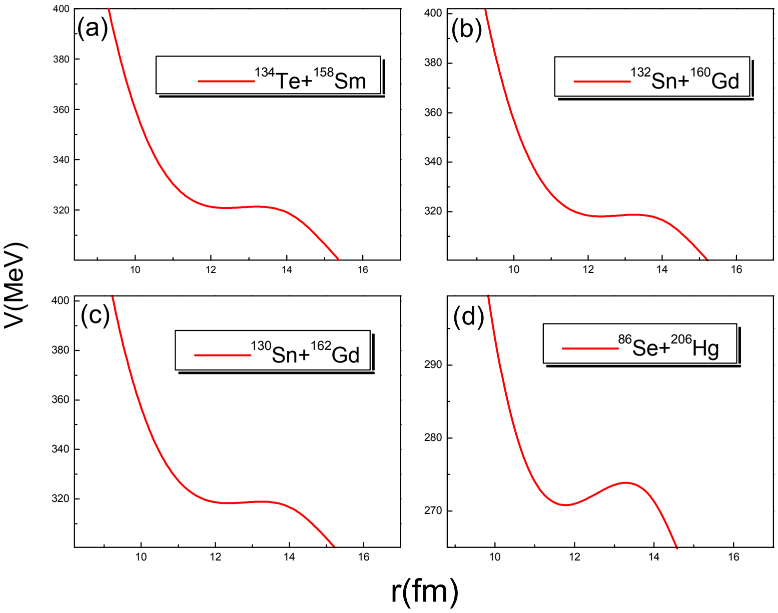

Fig.1. Scattering potential for the reactions of ^{134}Te + ^{158}Sm, ^{132}Sn + ^{160}Gd, ^{130}Sn + ^{162}Gd and ^{86}Se+^{206}Hg systems.

combination for heavy ion fusion reactions. Moreover, the projectiles are comparatively heavy and while noting the half lives, none of the projectiles are stable.

While analyzing the interaction barrier for the ^{86}Se + ^{206}Hg system, which is shown in Fig. 1(d), that found in the first deep region in the cold valleys of ^{292}114 nucleus, it can be seen that the potential pocket is appreciable and hence the system is a suitable projectile-target combination for the synthesis of super heavy nucleus ^{292}114. By noting the values of the barrier height and barrier radius from Fig. 1(d), we have calculated the fusion cross sections for the reaction of the ^{86}Se + ^{206}Hg system, which is shown in Table I.

The interaction barriers for the reactions of ^{134}Te + ^{158}Sm, ^{132}Sn + ^{160}Gd, ^{130}Sn + ^{162}Gd and ^{86}Se + ^{206}Hg systems have been studied using scattering potential as the sum of Coulomb and proximity potential. While considering the nature of potential pockets and half lives of colliding nuclei, the systems ^{86}Se + ^{206}Hg give maximum probability for the synthesis of super heavy nucleus ^{292}114. The fusion cross sections for the system ^{86}Se + ^{206}Hg have also been computed.

Table I. Computed fusion cross section for the system ^{86}Se+^{206}Hg, near and above the barrier

E_{CM} (MeV)	Fusion cross section (mb)
276	43.001
278	82.562
280	121.554
282	189.992
284	197.892
286	235.250

References

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