Neutron and fission decay width of Ti-induced fusion reactions to synthesis SHE Z=119

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Introduction

The synthesis of superheavy elements (SHE), particularly with atomic number Z=119 through heavy-ion fusion reactions involves a delicate balance between two major decay channels of the excited compound nucleus neutron emission and fission. Understanding the neutron and fission decay widths is crucial for predicting the likelihood of successfully forming a superheavy element. Using existing data on nuclear level densities, decay widths, and lifetimes of excited nuclei were analyzed using the statistical model [1] by examining the effects of shell and collective phenomena across excitation energies and deformations, especially near the saddle point. Yanez et al., [2] studied the competition between fission and neutron emission in highly excited ^{274}Hs (Z=108) formed via hot fusion, using ^{25,26}Mg+^{248}Cm bombardments.

The stability of excited superheavy nuclei, based on realistic shell models and the BCS Hamiltonian, was studied by Moretto [3] using a statistical approach. First-chance fission probabilities for nuclei between Z = 108 and Z = 126 were analyzed using Nilsson and Bolsterli models. Denosov et al., [4] studied the ratio of $\Gamma_n(E)/\Gamma_f(E)$ were calculated using different expressions for the fission width, which take into account and ignore the dependence of the fission barrier on the excitation energy. Previous researchers were investigated neutron and fission decay width of heavy ion fusion reactions in the synthesis of superheavy element Z>103[5-8]. Hence these studies motivated us to investigate neutron and fission decay width of Ti-induced fusion reactions to synthesis SHE Z=119 using statistical model.

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Theoretical Framework

The level density used in the evaluation of decay width is expressed as;

$$\rho(J) = \frac{(2J+1)}{U^2}\exp\left\{2\sqrt{a_n U}\right\} \qquad (1)$$

Here a_n is the level density parameter, and U is the thermal excitation energy and it is defined as $U = E_X - E_R + E_D$, E_X is the total excitation energy above the ground state, E_R is the rotational energy and E_D is the deformation energy. Further the neutron and fission decay widths are evaluated as follows;

$$\Gamma_n(E^*,J) = \frac{2m_n R^2}{\pi\hbar^2}\int_0^{(E^*-S_n)} \frac{\rho(E^*-S_n-\epsilon_n,J)}{\rho(E^*,J)}\epsilon_n d\epsilon_n - (2)$$

and

$$\Gamma_f(E^*,J) = \frac{1}{2\pi}\int_0^{(E^*-B_f)} \frac{\rho_{s.d}(E^*-B_f-\epsilon_f,J)}{\rho_{s.d}(E^*,J)} T_f(\epsilon_f) d\epsilon_f --(3)$$

The notations are with usual meaning and it is explained in detail in the reference [5].

Results and Discussions

We investigated neutron and fission decay widths of Ti-induced fusion reactions for the synthesis of superheavy element Z=119 using statistical model. The stable projectiles such as $^{47-50}$Ti and $^{246-247}$Bk targets were considered during the investigation of neutron and fission decay widths. The level density is evaluated as explained in equation (1). The shell corrections used in the evaluation of level density parameter were taken from the literature [9]. The figure 1 shows a plot of level density as a function of center of mass energy for the fusion reactions of $^{47-50}Ti+^{246-247}Bk$. The level density parameter gradually increases with increase in center of mass energy. The smaller logρ is observed for $^{50}Ti+^{246-247}Bk$ fusion reaction, and larger logρ is observed for $^{47}Ti+^{247}Bk$ fusion reaction.

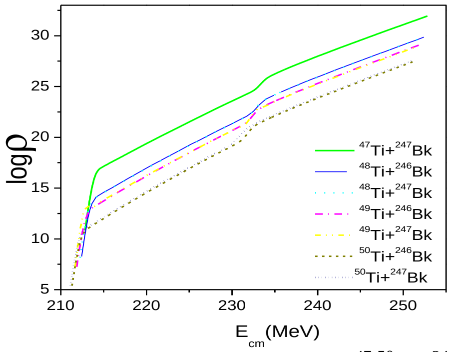

Fig-1: A plot of level density for the $^{47-50}Ti+^{246-247}Bk$ fusion reactions as a function of center of mass energy for the synthesis of superheavy element Z=119.

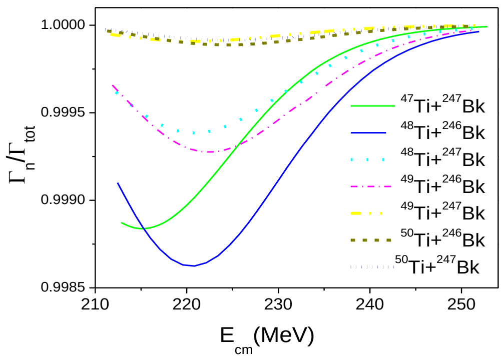

Fig-2: A plot of Γ_n/Γ_{tot} for the $^{47-50}Ti+^{246-247}Bk$ fusion reactions as a function of center of mass energy for the synthesis of superheavy element Z=119.

Further, we investigated neutron and fission decay widths of $^{47-50}Ti+^{246-247}Bk$ fusion reactions. The total decay width is the sum of neutron and fission decay widths i.e $\Gamma_{tot}=\Gamma_n+\Gamma_f$. Figure 2 shows a plot of Γ_n/Γ_{tot} as a function of center of mass energy. The value of Γn/Γtot initially decreases with increase in center of mass energy and further increases with center of mass energy. Smaller value of Γn/Γtot is noticed for 48Ti+246Bk and larger for 49-50Ti+247Bk. Even though, the larger logρ is observed for 47Ti+247Bk fusion reaction, due to the influence of fission barriers and neutron separation energy, the larger Γn/Γtot is noticed for 49-50Ti+247Bk. Hence, these findings are helpful in the further investigations of survival probability and predictions of evaporation residue cross-sections of Ti-induced fusion reactions.

Conclusions

We investigated neutron and fission decay widths in Ti-induced fusion reactions for the synthesis of superheavy element Z=119 using the statistical model. The level density, neutron decay widths were evaluated for the fusion reactions of for $^{47-50}Ti+^{246-247}Bk$. Results indicate that the Γ_n/Γ_{tot} ratio is larger for the $^{49-50}Ti+^{247}Bk$ reactions compared to other systems studied. This suggests that heavier titanium isotopes in combination with ^{247}Bk favor neutron emission, increasing the chances of superheavy element formation.

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