Cr-induced fusion reactions to extend periodic table

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Introduction

Heavy-ion fusion, the most complex process in the interaction of two atomic nuclei, has been extensively studied for over 60 years, particularly since the discovery of sub-barrier fusion enhancement caused by couplings to intrinsic excitations of the two reaction partners. Manjunatha et al., [1] investigated fusion cross sections of Z=122 using statistical model. Theoretical predictions of both fusion and evaporation cross sections during nickel induced fusion reactions [2] were theoretically studied. The role of entrance channel parameters are also investigated in hot fusion reactions [3]. Iron induced fusion reactions are one of the possibility to extend the synthesis of superheavy element Z>118 [4]. The quasifission and fusion-fission lifetimes also play an important role in the synthesis of superheavy element Z=120 [5]. In addition, deformation of projectile and target also influences the formation of compound nuclei [6]. Synthesis of superheavy nuclei beyond 118 was predicted using lead and bismuth projectile [7].

Hence, in the present work we motivated to study ^{54}Cr induced fusion reactions to synthesize the superheavy element Z=119 and 120. Further, the effect of entrance channel parameters such as mass asymmetry and Coulomb interaction parameters are also investigated.

Theoretical Framework

GEMINI++ [8] is an upgraded version of R. J. Charity's GEMINI statistical decay model, which was designed to describe complex-fragment production in heavy-ion fusion studies. The compound nucleus is de-excited through a series of binary decays until particle emission becomes energetically banned or impossible due to competition with gamma-ray emission. The fusion cross section as a function of spin was assumed as follows;

$$\sigma_{fus}(J) = \pi\hat{\lambda}^2 \sum \frac{(2J+1)}{1+\exp\left(\frac{J-J_0}{\delta J}\right)} \qquad (1)$$

Here δJ is varied between 2 to 10 $\hbar$ and J_0 is constrained from fusion cross section [8]. Further, the role of entrance channel such as mass asymmetry $\eta_A = \frac{A_1 - A_2}{A_1 - A_2}$ and Coulomb interaction parameter $z = \frac{Z_1 Z_2}{\left(A_1^{1/3} + A_2^{1/3}\right)}$ are also investigated for ^{54}Cr induced fusion reactions to synthesize superheavy element Z=119 and 120.

Results and Discussions

The fusion cross sections are evaluated as explained in theory section for ^{54}Cr induced fusion reactions to synthesize superheavy element Z=119 and 120. The possible isotopes of targets such as Americium (Am) and Curium (Cm) were used in the analysis of ^{54}Cr induced fusion reactions. The fusion reactions such as ^{54}Cr+$^{241\text{-}243}$Am and ^{54}Cr+$^{243\text{-}246}$Cm were investigated for the synthesis of superheavy nuclei Z=119 and 120.

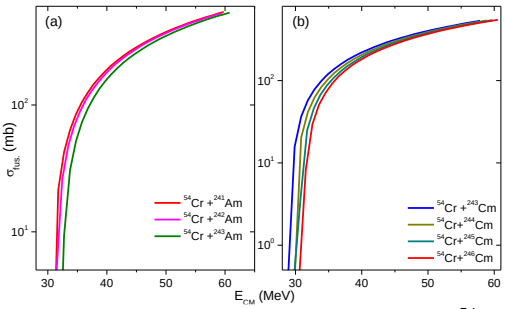

Fig 1: A plot of fusion cross sections for the ^{54}Cr induced fusion reactions for the synthesis of superheavy nuclei Z=119 and 120.

The figure 1(a-b) shows a plot of fusion cross sections of ^{54}Cr+$^{241\text{-}243}$Am and ^{54}Cr+$^{243\text{-}246}$Cm for the synthesis of superheavy nuclei Z=119 and 120 respectively. In both the cases, the fusion

cross sections increases with increase in center of mass energy and attain a maximum value.

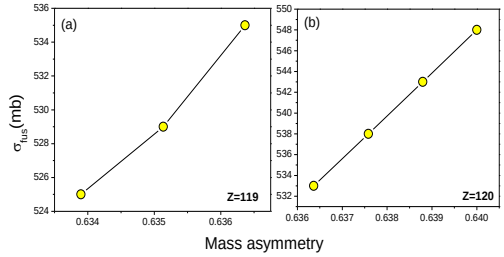

Fig 2: A plot of fusion cross sections as a function of mass asymmetry for the superheavy nuclei Z=119 and Z=120.

In further investigations we investigated fusion cross sections as a function of mass asymmetry. The figure 2(a-b) shows a plot of fusion cross sections for the superheavy nuclei Z=119 and Z=120 as function of entrance channel parameter such as mass asymmetry. In this case, the fusion cross sections increases with increase in mass asymmetry. In addition, we have also investigated effect of Coulomb interaction parameter on fusion cross sections.

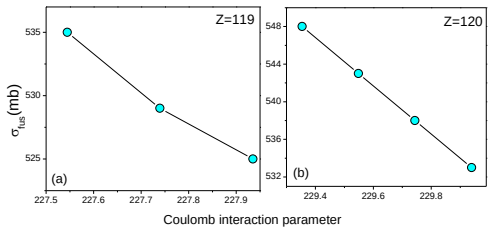

Fig 3: A plot of fusion cross sections as a function of Coulomb interaction parameter for the superheavy nuclei Z=119 and Z=120.

The figure 3(a-b) shows a plot of σ_{fus} as function of z. From the figure it is noticed that the increase in the value of z decreases the σ_{fus} value. Hence, in order to observe larger fusion cross section, larger mass asymmetry and smaller z value to be selected. We have also tabulated the values such as center of mass energy, fusion barrier, mass asymmetry Coulomb interaction parameter and fusion cross sections in table 1. From the table it is seen that as the value of mass asymmetry increases the fusion cross section also increases and vice versa in case of Coulomb interaction parameter.

Table 1: Tabulation of center of mass energy, fusion barrier height, mass asymmetry, Coulomb interaction parameter and fusion cross sections in the ^{54}Cr induced fusion reactions for the superheavy nuclei Z=119 and Z=120.

CN	Reaction	Ecm (Mev)	V_B (Mev)	η_A	z	σ_{fus} (mb)
119	^{54}Cr+^{241}Am	58.75	247.154	0.634	227.93	525
	^{54}Cr+^{242}Am	59.45	246.945	0.635	227.74	529
	^{54}Cr+^{243}Am	60.75	246.736	0.636	227.54	535
120	^{54}Cr+^{243}Cm	57.86	249.547	0.636	229.94	533
	^{54}Cr+^{244}Cm	58.86	249.337	0.637	229.74	538
	^{54}Cr+^{245}Cm	59.75	249.128	0.638	229.55	543
	^{54}Cr+^{246}Cm	60.54	248.919	0.64	229.35	548

Conclusions:

We have investigated ^{54}Cr induced fusion reactions to synthesize the superheavy element Z=119 and 120. The fusion reactions such as ^{54}Cr+$^{241\text{-}243}$Am and ^{54}Cr+$^{243\text{-}246}$Cm were investigated and also predicted fusion cross sections. The predicted fusion cross section increases with increase in center of mass energy. The effect of entrance channel parameter such as mass asymmetry and Coulomb interaction parameter were also studied. This study find its importance in the synthesis of superheavy element Z=119 and 120 by ^{54}Cr induced reactions.

References:

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