^{54}Cr-induced fusion reactions to synthesize superheavy element with Z=122

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INTRODUCTION

The superheavy elements with atomic number $112 \leq Z \leq 118$ were synthesized using fusion reactions of the nuclei of ^{226}Ra, ^{233,238}U, ^{237}Np, ^{242,244}Pu, ^{245,248}Cm, ^{249}Bk and ^{249}Cf with the ^{48}Ca projectiles. In these reactions, the compound nuclei have an excitation energy of about 40-45 MeV (hot fusion). With increase in the mass number of projectile, Coulomb force increases and a strong decrease in the probability of formation of high Z compound nuclei.

The superheavy elements with Z>106 were produced using cold fusion reactions with massive projectiles A≥40 [1]. Six elements Z=107–112 were synthesized in cold fusion reactions using massive ions ^{54}Cr, ^{58}Fe, ^{64}Ni and ^{70}Zn [2]. Experimental studies of the fusion reaction $^{206-208}$Pb+^{48}Ca demonstrated high yield of ^{252}No [3]. Fusion reactions of isotopes of elements ranging from ^{231}Pa to ^{254}Es with ^{48}Ca projectiles were considered the most promising for the production of superheavy nuclei [1,4–6]. The fusion reaction ^{248}Cm+^{48}Ca is employed in the synthesis of Z=116 [1]. Most of the models also suggest that the fusion cross-section is low for projectiles heavier than ^{48}Ca [7–11].

THEORETICAL FRAME WORK
FUSION CROSS SECTION

To study the fusion cross sections, we have used the Wong model [12]. The cross section for fusion is given by

$$\sigma_{fus} = \frac{\pi\hbar^2}{2\mu \times E_{cm}} \sum_{l=0}^{l_{max}} (2l+1) \times T_l(E_{cm}) \cdot P_{CN}(E_{cm}, l) \quad (1)$$

where μ is the reduced mass. The center of mass energy is denoted by E_{cm}. In the above formula, l_{max} corresponds to the largest partial wave for which a pocket still exists in the interaction potential and $T_l(E_{cm})$ is the energy-dependent barrier penetration factor. P_{CN} is the probability for the compound nucleus (*CN*) formation. P_{CN} requires effective fissility which inturn depends on x_{thr} and c. x_{thr} and c are adjustable parameters [11]. The probability of compound nucleus formation P_{CN} suggested by previous workers [7, 13-18] is used in the present calculation. These parameters were suggested by Loveland [13]. This form of energy dependence of fusion probability is similar to the one proposed by Zargrebeav and Greiner [7].

EVAPORATION RESIDUE CROSS SECTION

After the fusion of two nuclei, the corresponding compound nuclei returns to ground state by emitting neutrons. The evaporation residue cross section of SH element production in a heavy-ion fusion reaction with subsequent emission of x neutrons is given by [7]

$$\sigma_{ER}^{xn} = \frac{\pi}{k^2} \sum_{l=0}^{\infty} (2l+1) T(E,l) P_{CN}(E,l) P_{sur}^{xn}(E^*, l) \quad (2)$$

P_{surv} is the survival probability and it is the compound nucleus to decay to the ground state of the final residual nucleus via evaporation of neutrons/light particles. The survival probability is the probability that the fused system emits several neutrons followed by observing a sequence of α decay from the residue. The survival probability under the evaporation of x neutrons is

$$P_{surv} = P_{xn}(E^*_{CN}) \prod_{i=1}^{i_{max}=x} \left(\frac{\Gamma_n}{\Gamma_n + \Gamma_f} \right)_{i,E^*} \quad (3)$$

Where the index 'i' is equal to the number of emitted neutrons. The calculation of P_{surv} requires the probability of evaporation of x neutrons from compound nucleus (P_{xn}). To calculate P_{xn}, we have adopted the procedure explained by the previous researchers [17-18]. The term $[\Gamma_n/(\Gamma_n+\Gamma_f)]$ in equation (3) is calculated by the knowledge of the ratio of the emission width of a neutron to the fission width (Γ_n/Γ_f). In the present work, we have used the expression for Γ_n/Γ_f based on the level densities of the Fermi-gas model [18].

The relative yield can be calculated as the ratio between the survival probabilities of a given projectile-target combination over the sum of survival probabilities of all possible projectile-target combinations as follows:

$$Y(\%) = \frac{P_{surv}}{\sum P_{surv}} \quad (4)$$

RESULTS AND DISCUSSION

To synthesize superheavy elements with Z>118, the projectiles heavier than ^{48}Ca must be used. In the present work, we have identified the most probable Cr-induced fusion reactions for the synthesis of superheavy nuclei with Z=122 by studying the fusion cross section, evaporation residue cross section, P_{CN} and P_{surv}.

We have studied all possible ^{54}Cr–induced fusion reactions for the synthesis of superheavy nuclei with Z=122. We have calculated P_{CN} and P_{surv} for different projectile-target combinations. The comparison of P_{CN} for targets of different mass numbers to synthesize superheavy elements using Cr-induced fusion reactions is shown in figure 1. The comparison of P_{surv} for targets of different mass numbers is shown in figure 2. The comparison of relative yield is shown in figure 3.

From these figures, the selected projectile-target combinations having maximum compound nucleus formation probability, survival probability and relative yield to synthesis superheavy elements using ^{54}Cr-induced fusion reactions is $^{54}Cr+^{246}Cf \rightarrow ^{300}122$. The variation of evaporation residue cross section (for 3n, 4n and 5n) with E* for selected ^{54}Cr induced fusion reactions is shown figure 4.

SUMMARY

We have identified the targets for ^{54}Cr induced fusion reactions to synthesis superheavy elements with Z=122. The identified targets which yields maximum evaporation residue cross section in ^{54}Cr induced fusion reactions to synthesis superheavy element with Z=122 is ^{246}Cf. We hope that our predictions may guide the future experiments in the synthesis of more superheavy elements using ^{54}Cr-induced fusion reactions.

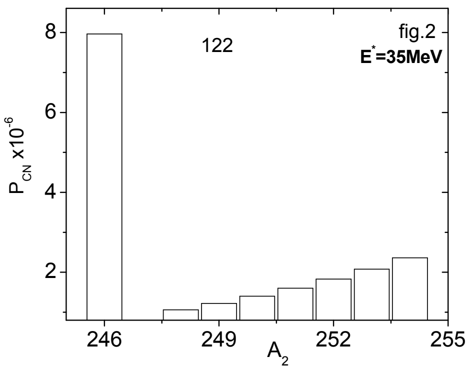

Fig. 1: Comparison of P_{CN} with mass number of the target

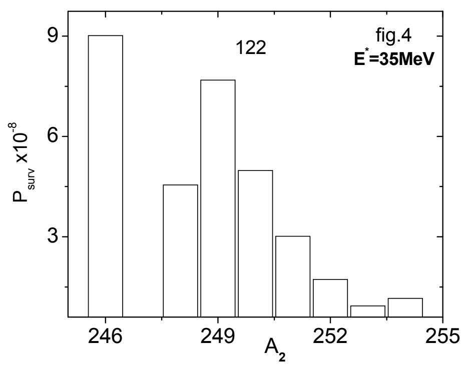

Fig. 2: Comparison of P_{surv} with mass number (A_2)

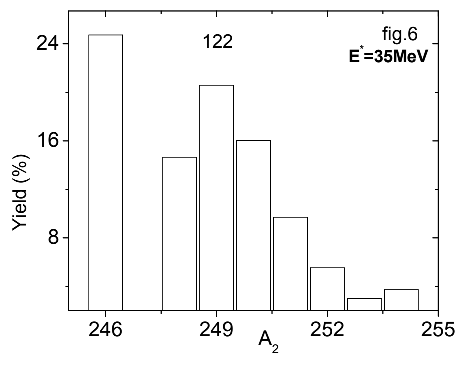

Fig. 3: Comparison of yield with mass number (A_2)

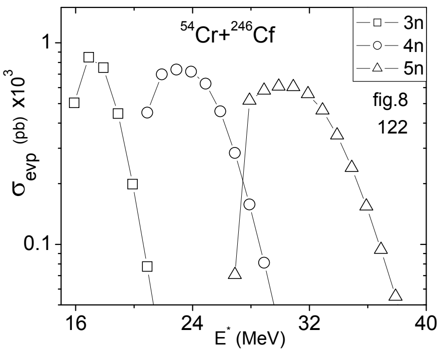

Fig. 4: Variation of evaporation residue cross section with the energy

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