Projectile target combinations for the synthesis of ^{302}120 SHN

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Introduction

Heavy ion fusion reactions have been widely used to synthesize elements in heavy and super heavy (SH) region. The projectile-target combinations and the incident energy are the key factors on which the fusion-cross section strongly dependent. Hence it will be interesting and useful to study such dependencies for the synthesis of new superheavy elements (SHE).

Several successful experiments has been done for the production of SHN with Z≤118, and any evidence on the production of nuclei with Z>118 has not been obtained, except for an attempt [1] to produce Z=120 SHN through the ^{244}Pu+^{58}Fe reaction. Theoretical predictions on the alpha decay half lives and mode of decay of the isotopes of Z=120 has also been performed recently by Santhosh et al [2]. In the present work our aim is to predict the most probable projectile-target combinations for the synthesis of super heavy element ^{302}120.

Theory

The potential

The interaction barrier for two colliding nuclei is given as

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

where $V_P(z)$ is the proximity potential of Blocki et.al [3], with z, the distance between the near surfaces of the projectile and target, ℓ the angular momentum, μ the reduced mass, Z_1, Z_2 the atomic numbers of projectile and target and r is the distance between centers of the projectile and target.

The fusion cross section

Wong obtained the following analytic expression for the fusion cross section, approximating the barrier by a parabola

$$\sigma = \frac{R_B^2 \hbar\omega}{2E} \ln\left\{1 + \exp\left[\frac{2\pi(E - E_B)}{\hbar\omega}\right]\right\} \qquad (2)$$

This formula depends on Coulomb barrier position R_B, the barrier height E_B, and the curvature of the barrier $\hbar\omega$. At high energies, above formula reduces to

$$\sigma = \pi R_B^2 \left[1 - \frac{E_B}{E}\right] \qquad (3)$$

Glas and Mosel [5] set fusion cross section as

$$\sigma = \frac{R_B^2 \hbar\omega}{2}\frac{1}{E}\ln\left\{\frac{1+\exp[2\pi(E-E_B)/\hbar\omega]}{1+\exp[2\pi\{E-E_B-(R_C/R_B)^2[E-V_C]\}/\hbar\omega]}\right\} \qquad (4)$$

where R_C is the critical distance, V_C is the corresponding potential height.

Results and discussions

Probable projectile-target combinations for the synthesis of super heavy element ^{302}120 have been determined by studying the cold reaction valleys and are shown in Fig.1.

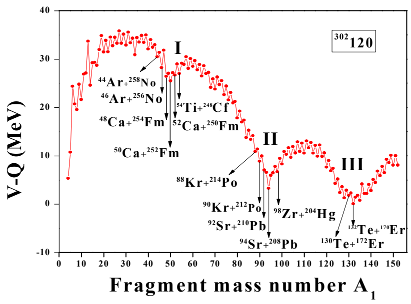

Fig.1. Cold reaction valley plot of super heavy element ^{302}120.

The probable combinations observed in the region I of the cold valley plot are ^{44}Ar+^{258}No, ^{46}Ar+^{256}No, ^{48}Ca+^{254}Fm, ^{50}Ca+^{252}Fm, ^{52}Ca+^{250}Fm, ^{54}Ti+^{248}Cf, ^{56}Ti+^{246}Cf, ^{58}Cr+^{244}Cm, ^{60}Cr+^{242}Cm, ^{62}Fe+^{240}Pu, ^{64}Fe+^{238}Po in region II the combinations are ^{84}Se+^{218}Rn, ^{86}Se+^{216}Rn, ^{88}Kr+^{214}Po, ^{90}Kr+^{212}Po, ^{92}Sr+^{210}Pb, ^{94}Sr+^{208}Pb,

^{96}Sr+^{206}Pb, ^{98}Zr+^{204}Hg, ^{100}Zr+^{202}Hg, and in region III the combinations are ^{124}Sn+^{178}Yb, ^{126}Sn+^{176}Yb, ^{128}Sn+^{174}Yb, ^{130}Te+^{172}Er.

The graphs between the interaction barriers of all the combinations mentioned above are plotted for $\ell = 0$ and few of them are shown in Fig. 2. While analyzing the interaction barriers of the combinations, it is observed that the potential pockets are appreciable only in the cases of combinations found in the cold valley of region I and that of combinations in region II is comparatively small, while in region III they are very small compared to that in region I and II. So, combinations in region I and II can be identified as the probable projectile-target combinations for the fusion, while those in region III are not favorable for fusion.

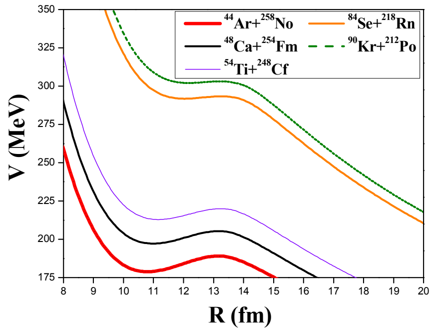

Fig. 2. Interaction barrier for the projectile-target combinations found in the region I and II of cold reaction valley.

Among the combinations in the cold valley minima region I and II, which have the necessary potential pocket, the combinations which involve magic or near magic nuclei can be identified as the optimal projectile-target combinations for the synthesis of ^{302}120.

As we have predicted the above combinations to be the best for fusion experiments, we have evaluated the fusion cross sections for these combinations using scattering potential as the sum of coulomb and proximity potential. The cross section against center of mass energy for a few of the above mentioned combinations in region I and II are plotted in Fig. 3(a) and Fig. 3(b) respectively.

From the graphs it can be seen that computed fusion cross section for combinations in region I are higher than that in region II. The combinations with large fusion cross sections are the ones which are more asymmetric and have more potential pockets. The most probable combinations for the synthesis of ^{302}120 SHN are ^{44}Ar+^{258}No, ^{46}Ar+^{256}No, ^{48}Ca+^{254}Fm, ^{50}Ca+^{52}Fm, ^{52}Ca+^{250}Fm, ^{54}Ti+^{248}Cf, ^{56}Ti+^{246}Cf, ^{58}Cr+^{244}Cm, ^{58}Cr+^{244}Cm, ^{60}Cr+^{242}Cm, ^{62}Fe+^{240}Pu and ^{64}Fe+^{238}Po which can be found in region I, which closely agrees with those combinations mentioned in [1]. Thus, we hope that our predictions may be guide for the future experiments.

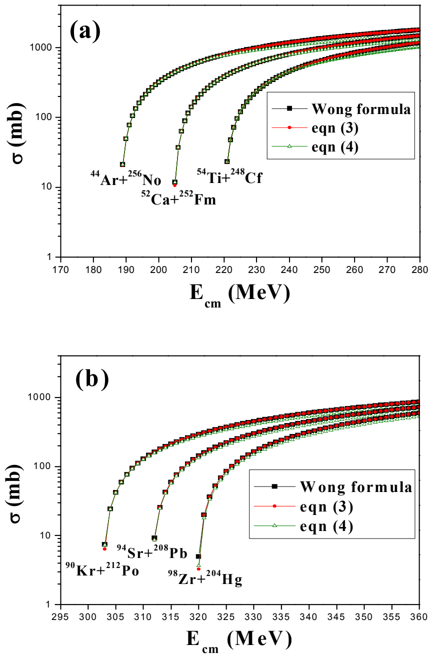

Fig. 3. Computed fusion cross section for the most probable projectile-target combinations.

References

[1] Yu. Ts. Oganessian et al., Phys. Rev. C **79**, 024603 (2009).

[2] K. P. Santhosh and B. Priyanka, Phys. Rev. C **90**, 054614 (2014).

[3] J Blocki, J. Randrup, W. J. Swiatecki, C. F. Tsang, Ann. Phys. (N.Y) **105** (1977) 427.

[4] C. Y. Wong, Phys. Rev. Lett. **31** (1973) 766.

[5] D. Glas et al, Phys. Rev. C **10** (1974) 2620.