A study of fusion cross section for different target projectile combinations of ^{297}Uus

H.C.Manjunatha,[1]* K.N.Sridhar[2]
[1]*Department of Physics, Government College for Women, Kolar-563101 Karnataka, INDIA*
[2]*Department of Physics, Government First grade College, Kolar-563101 Karnataka, INDIA*
* *manjunathhc@rediffmail.com*

Introduction

The synthesis of superheavy elements has obtained much progress experimentally using cold fusion reactions. Usually double magic or nearly double magic nuclei are selected to synthesize superheavy nucleus because these combined systems have larger Q value, which can reduce excitation energy of compound nucleus so that fusion probability and survival probability. Ununseptium (Uus) is the most-recently synthesized synthetic element. Oganessian et al., [1] reported the synthesis of two isotopes of Ununseptium such as ^{293}Uus and ^{294}Uus. Theoretical models are very helpful in understanding the nuclear interactions at a microscopic level.

In the present work, we have studied the Fusion barrier parameters such as barrier height (V_B), barrier position (R_B), curvature of the inverted parabola($\hbar\omega_0$) and fusion cross section of the all posible projectile-target combinations of ^{297}Uus.

Theory

The interacting potential barrier for a parent nucleus exhibiting fusion consists of coulomb potential and nuclear proximity potential. The interacting potential between two nuclei of fission fragments is taken as

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

Here Z_1 and Z_2 are the atomic numbers of projectile and target. and r is the distance between centers of the projectile and target. The second term $V_p(z)$ is the proximity potential. In the present work, we have used the universal proximity potential [2]. In the third term l represents the angular momentum, and μ the reduced mass.

Since fusion happens at a distance larger than the touching configuration of colliding pair, the above form of the Coulomb potential is justified. One can extract the barrier height V_B and barrier position R_B using the following conditions

$$\left.\frac{dV(r)}{dr}\right|_{r=R_B} = 0 \quad \text{and} \quad \left.\frac{d^2V(r)}{dr^2}\right|_{r=R_B} \leq 0 \qquad (2)$$

To study the fusion cross sections, we shall use the model given by Wong [3]. In this formalism, the cross section for complete fusion is given by

$$\sigma_{fus} = \frac{\pi}{k^2} \sum_{l=0}^{l_{max}} (2l+1) \times T_l(E_{cm}) \qquad (3)$$

where $k = \sqrt{2\mu E / \hbar^2}$ and 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 and is given by

$$T_l(E_{cm}) = \left\{1 + exp\left(\frac{2\pi}{\hbar\omega_l}(V_B - E_{cm})\right)\right\}^{-1} \qquad (4)$$

where $\hbar\omega_l$ is the curvature of the inverted parabola. If we assume that the barrier position and width are independent of l, the fusion cross section reduces to

$$\sigma_{fus}(mb) = \frac{10 R_B^2 \hbar\omega_0}{2E_{cm}} ln\left\{1 + exp\left(\frac{2\pi}{\hbar\omega_0}(E_{cm} - V_B)\right)\right\} \qquad (5)$$

For $E_{cm} >> V_B$, the above formula reduces to well-known sharp cut-off formula

$$\sigma_{fus}(mb) = 10\pi R_B^2 \left(1 - \frac{V_B}{E_{cm}}\right) \qquad (6)$$

whereas for $E_{cm} << V_B$, the above formula reduces to

$$\sigma_{fus}(mb) = \frac{10 R_B^2 \hbar\omega_0}{2E_{cm}} ln\left\{exp\left(\frac{2\pi}{\hbar\omega_0}(E_{cm} - V_B)\right)\right\} \qquad (7)$$

Results and discussion

We have calculated the total barrier potentials and hence the Fusion barrier parameters such as barrier height (*V_B*), barrier position (*R_B*), curvature of the inverted parabola ($\hbar\omega_0$) and fusion cross section of the all posible projectile-target combinations of ^{297}Uus. The calculated fusion barrier parameters are shown in table 1. The calculated fusion barrier curvature ($\hbar\omega_0$) for a series of selected reactions are shown in second coloumn of the table1. The curvature ($\hbar\omega_0$) is minimum for ^{75}As+^{222}Po and maximum for ^{7}Li+ ^{290}Uuq among the posible projectile target combination ^{297}Uus. The calculated values barrier height (*V_B*) and barrier position (*R_B*) are minimum for ^{7}Li+ ^{290}Uuq and maxium for ^{75}As+ ^{222}Po for the posible projectile target combination ^{297}Uus.

Reaction	ħω₀ (MeV)	V_B (MeV)	R_B (fm)
^{7}Li+ ^{290}Uuq	4.47	39.97212	11.53775
^{9}Be+ ^{288}Uut	4.57	52.50614	11.63597
^{27}Al+ ^{270}Rf	4.33	150.4733	12.15372
^{37}Cl+ ^{260}Fm	4.05	185.6116	12.38056
^{40}Ar+ ^{257}Es	3.92	193.5383	12.46244
^{41}K+ ^{256}Cf	3.93	202.2562	12.48841
^{43}Ca+ ^{254}Bk	3.85	210.206	12.53848
^{44}Ca+ ^{253}Bk	3.81	209.7052	12.56264
^{46}Ca+ ^{251}Bk	3.75	208.7432	12.6093
^{45}Sc+ ^{252}Cm	3.83	217.9438	12.48624
^{61}Ni+ ^{236}Ac	3.40	264.7171	12.80098
^{62}Ni+ ^{235}Ac	3.38	264.305	12.81736
^{64}Ni+ ^{233}Ac	3.34	263.5085	12.84913
^{63}Cu+ ^{234}Ra	3.31	270.6424	12.7334
^{65}Cu+ ^{232}Ra	3.32	269.8395	12.86453
^{69}Ga+ ^{228}Rn	3.13	281.0886	12.82316
^{71}Ga+ ^{226}Rn	3.18	280.3432	12.85075
^{70}Ge+ ^{227}At	3.11	286.7691	12.83709
^{72}Ge+ ^{225}At	3.08	286.0273	12.86413
^{73}Ge+ ^{224}At	3.07	285.6685	12.87725
^{74}Ge+ ^{223}At	3.05	285.3175	12.89011
^{75}As+ ^{222}Po	3.00	290.7775	12.90272

Table1: Fusion barrier parameters of ^{297}Uus

The fusion cross section (**σ_{fus}**) against center of mass energy (E_{cm}) for a few of the above mentioned combinations are shown in figure 1 and 2.The calculated values of fusion cross sections are maximum for ^{7}Li+ ^{290}Uuq and minium for ^{75}As+ ^{222}Po for the posible projectile target combination ^{297}Uus. The studied fusion barriers indicates that the reaction ^{7}Li+ ^{290}Uuq may be the most probable projectile-target combination for the synthesis of super heavy element ^{297}Uus. Thus, we hope that our predictions may be guide for the future experiments.

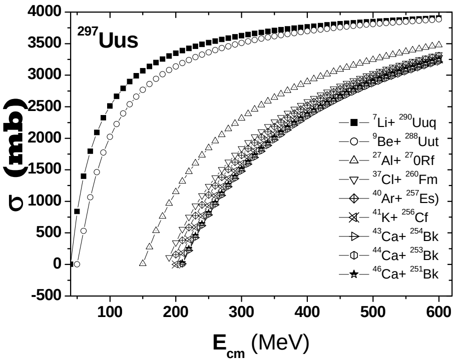

Figure.1:The fusion cross sections σ_{fus} (mb) as a function of center-of-mass energy E_{cm} (MeV).

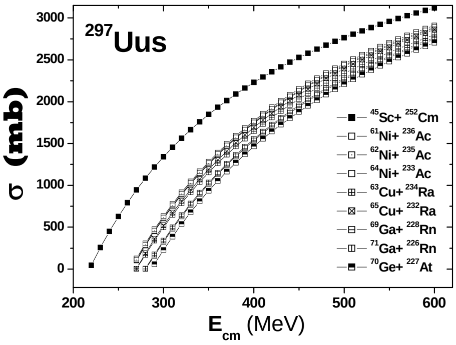

Figure.2:The fusion cross sections σ_{fus} (mb) as a function of center-of-mass energy E_{cm} (MeV).

References

[1] Y. T. Oganessian, F. S. Abdullin, Phys. Rev. Lett. 104 (2010) 142502.

[2] J. Blocki, J. Randrup, W. J. S´wia˛tecki, and C. F. Tsang, Ann.Phys. (NY) **105**, 427 (1977).

[3] C. Y. Wong, Phys. Lett. B **42**, 186 (1972)