Indian J.Sci.Res. 18(1): 59-61, 2018

ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

EFFECT OF ENTRANCE CHANNEL PARAMETERS ON INCOMPLETE FUSION OF ^{16}O ON ^{93}Nb

M.G.V. SANKARACHARYULU[a] AND K.P. SANTHOSH[b1]

[a]M.G.G.A. College, Mahe, New Mahe P. O., U. T. of Puducherry, India
[b]P.G. Department of Physics & Research Centre, Kannur University, Payyanur Campus, Edat P.O., Kerala, India

ABSTRACT

An attempt has been made to study the onset of Incomplete Fusion in Heavy ion fusion reactions at and above barrier potential. In the present study the variation of the incomplete Fusion Fraction (%) with normalized incident projectile energy for ^{16}O on ^{93}Nb is investigated. It is further proposed to study deeply other entrance channel parameter dependence of incomplete fusion reactions.

KEYWORDS: Complete Fusion(CF), Incomplete Fusion(ICF), Heavyion Fusion Reactions, Barrier Potential, Incomplete Fusion Fraction(%) and Normalized Incident Projectile Energy.

The study of Heavy Ion induced Nuclear Fusion Reactions is of immense interest and fascinating for the past few decades. In the interaction of two Heavy Ions a number of channels open up. It has been observed that for the projectile energies above the coulomb barrier, both CF and ICF may be considered as dominant mechanism. A part of the projectile/ejectile fuses with the target and the remaining part moves forward with the same velocity and angular momentum leading to ICF. The first experimental evidence of ICF reactions were given by Britt and Quitton [Harold C.Britt and Arthur R,Quinton;1961] who observed the break up of incident particles like ^{12}C andγ ^{16}O.. Inundo[2] etal. Observed Incompletely fused α particles peaked at forward angles in their particle and γ coincidence measurement. In the present work an attempt has been made to address some important issues and aspects of CF and ICF dynamics for the system ^{16}O+^{93}Nb in the lab energy of projectile 70-100 MeV range. The cross sections were calculated for various decay channels of 109In49 like xn, αxn, 2 αxn, αpxn, xαn, xpxn where x denotes integers from 2 to 4. The excitation functions were calculated theoretically and reproduced the experimental data.

THEORY

The interacting Potential Barrier for a parent nucleus decaying in to different Channels consists of Coulomb Potential and Nuclear proximity potential (Blocki.J et. al; 1977)

The interacting potential barrier is given by,

$$V = \sum_{i=1}^{3}\sum_{j>i}^{3}(V_{Cij} + V_{Pij}) \qquad (1)$$

with $V_{Cij} = \frac{Z_i Z_j e^2}{r_{ij}}$, the Coulomb interaction between the fragments. Here Z_i and Z_j are the atomic numbers of the fragments and r_{ij} is the distance between fragment centres. The nuclear proximity potential between the fragments is,

$$V_{Pij}(z) = 4\pi\gamma b\left[\frac{C_i C_j}{(C_i + C_j)}\right]\Phi\left(\frac{z}{b}\right) \qquad (2)$$

Here Φ is the universal proximity potential and z is the distance between the near surfaces of the fragments. The Süssmann central radii C_i of the fragments related to sharp radii R_i is,

$$C_i = R_i - \left(\frac{b^2}{R_i}\right) \qquad (3)$$

For R_i (Rubchenya V. A; 1988) we use semi empirical formula in terms of mass number A_i as,

$$R_i = 1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3} \qquad (4)$$

The nuclear surface tension coefficient called Lysekil mass formula (Andreev A. V et al.,;2006) is,

$$\gamma = 0.9517[1 - 1.7826(N-Z)^2/A^2]$$
MeV/fm^2 (5)

where N, Z and A represents neutron, proton and mass number of the parent, Φ, the universal proximity potential (Rubchenya V. A; 1988) is given as,

---

[1]**Corresponding Author**

$$\Phi(\varepsilon) = -4.41e^{-\varepsilon/0.7176}, \text{ for } \varepsilon > 1.9475$$

$$\Phi(\varepsilon) = -1.7817 + 0.9270\varepsilon + 0.0169\varepsilon^2 - 0.05148\varepsilon^3, \text{ for } 0 \le \varepsilon \le 1.9475 \quad (6)$$

with $\varepsilon = z/b$, where the width (diffuseness) of the nuclear surface b ≈ 1 fermi.

The Total Fusion cross-section ,σ (theory) (Wong C Y;1973) is calculated using the relation,

$$\sigma_{fusion} = \frac{\pi}{k^2}\sum_{l=0}^{\infty}(2l+1)T(E,l)P_{CN}(E,l), \quad (7)$$

where P_{CN} denotes probability of compound nucleus formation and T (E, l) denotes the total fusion probability with energy E and angular momentum l. In the present work, l=0.

METHODS

The total potential using proximity model is calculated and plotted in fig.1. The potential is minimum when barrier height is 53.715 MeV and the distance between the centres of two sharp nuclei is 12.17 fermi. Using this values, the theoretical cross section is calculated. The minimum of interaction potential occurs when the distance of separation between centers of two heavy nuclei using proximity model as in fig.1 is 12.17 fm .The curvature of the inverted parabola for l=o gives the minimum energy.

The experimental data is taken from [Desalegn Ketena; 2013]. The theoretical cross section for total fusion is calculated from Wong formula. Both are tabulated in Table 1.

There are several channels. There is a competition between single nucleon emission (complete fusion) and emission of one or more alpha particles along with the few nucleons (breakup fusion or incomplete fusion). In the present work, the cross sections for (^{16}O, 2αxn) and (^{16}O, σpxn) are measured, where x is an integer, 2 to 3.

RESULTS AND DISCUSSION

The excitation function for the system $_{49}Nb^{93}$+ O^{16} are plotted in figure 2. Within experimental limits, the theoretical excitation function matches with the experimental one.

The ratio of total cross section for a particular channel to the total fusion cross section gives the fusion suppression factor, F. It is calculated from experimentally measured total fusion cross section and theoretically calculated total fusion cross section. The fusion suppression factor F versus incident energy of projectile (MeV) is plotted in figure 2 and 3.They reproduce the data. With energy the factor increases. It shows significant reduction of complete fusion above the barrier energies.

Table 1: Total Fusion Cross Section,σ_{tot} and Energy of incident $^{16}O_8$ in lab in MeV

Energy Lab (MeV)	σ (Theory) (mb)	σ(Expt.) [3] (mb)
70	237.842	435.77±111
75	532.190	528.48±111
80	789.739	728.45±147
85	1016.989	769.85±143
90	1218.988	959.5±156
95	1399.724	860.97±151
100	1562.387	736.4±1

Table 2: Fusion Suppression Factor,F and Energy of incident $^{16}O_8$ for $_{49}Nb^{93}(_8O^{16}, 2\alpha xn)_{45}Rh^{101-x}$.

E (Lab) MeV	F (THEORY)	F(Expt.)
70	0.029	0.016
75	0.025	0.025
80	0.026	0.028
85	0.032	0.042
90	0.038	0.048
95	0.039	0.062
100	0.047	0.100

Table 3: Fusion Suppression Factor,F and Energy of incident $^{16}O_8$ for $_{49}Nb^{93}(_8O^{16}, \alpha pxn)_{46}Pd^{104-x}$.

E (Lab) MeV	F (THEORY)	F(Expt.)
75	0.0022	0.0022
80	0.011	0.016
85	0.021	0.029
90	0.055	0.087
95	0.090	0.146
100	0.109	0.231

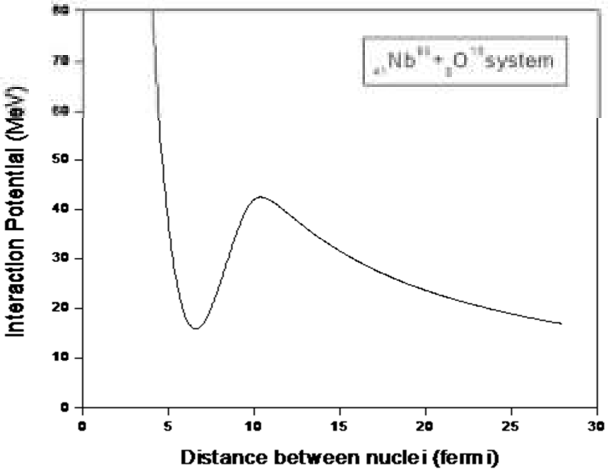

Figure 1: Potential versus distance between the centers of the two nuclei using Coulomb and proximity potential model.

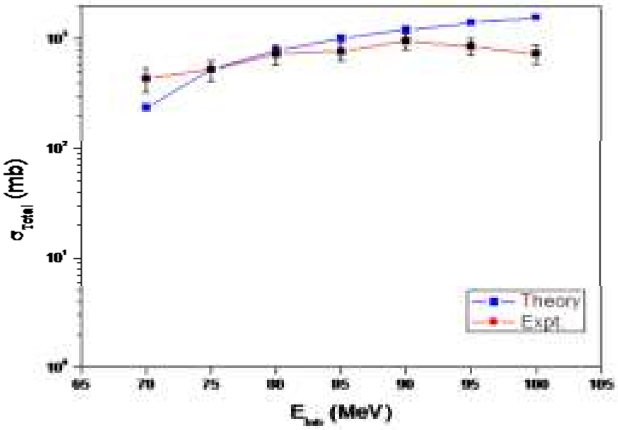

Figure 2. Excitation function fusion of $_{8}O^{16}$ and $_{49}Nb^{93}$.

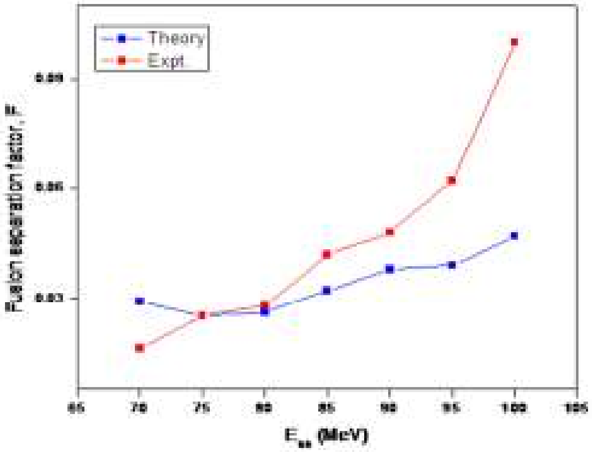

Figure 3: Variation of fusion suppression factor for $_{49}Nb^{93}(_{8}O^{16}, 2\alpha xn)_{45}Rh^{101-x}$.

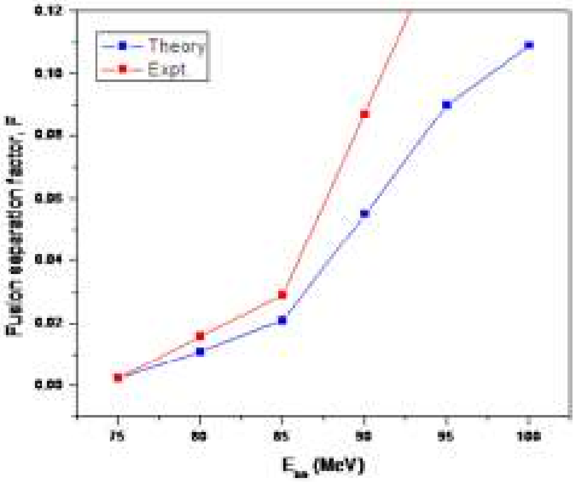

Figure 4: Variation of fusion suppression factor for $_{49}Nb^{93}(_{8}O^{16}, \alpha pxn)_{46}Pd^{104-x}$.

ACKNOWLEDGEMENTS

The authors thank the authorities of 27th Swadeshi Science Congress for giving the opportunity. One of the authors M.G.V.S acknowledges and thanks the support received from Dr. B.R. Manjunath, Associate Professor in Chemistry, M.G.G.A.C, Mahe, Prof. K.R. Haridas, School of Chemical Sciences, Swami Anandatheertha Campus, Kannur University, Payyanur, Kerala and Dr. K.P. Mohanan, Member, Kerala Sahitya Academy.

REFERENCES

Andreev A.V. et. al., 2006. Ternary fission within statistical approach , Eur. Phys. J. A, **30**:579-589.

Blocki J., Randrup J., Swiatecki W.J. and Tsang C.F., 1977. Proximity forces, Annals of Physics,**105**:427-462.

Desalegn K., 2013. Complete and incomplete fusion reactions in 16O+93Nb system at various projectile energies, M. Sc Thesis, Addis Abbaba University, Ethiopia.

Harold C. Britt and Arthur R. Quinton, 1961. Alpha Particles and Protons Emitted in the Bombardment of Au^{197} and BI^{209} by C^{12}, N^{14} and O^{16} Projectiles,Phys.Rev., **124**:877.

Rubchenya V.A. and Yavshits S.G., 1988. Dynamic treatment of ternary fission, Z. Phys. A At. Nucl., **329**:217-228.

Wong C.Y., 1973. Interaction barrier in charged particle nuclear reactions, Phys. Rev. Lett., **38**:766-769.