Fusion systematics for ^{12}C and ^{16,18}O projectiles on ^{182,184,186}W targets using neutron flow model

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Introduction

Heavy ion fusion continues to be a topic of great interest. Sub-barrier fusion studies provide an ideal platform for exploring the dynamics of many-body quantum systems. There are a few successive models which explain the near- barrier fusion enhancement by including the role of static deformation, neutron flow and vibrational degrees of freedom [1, 2]. These prescriptions are based on the effect of couplings of the incident projectile and the target [1] or due to the exchange of neutrons between the interacting projectile and target nuclei [2]. Previously, we tried to explain the experimental fusion data around the Coulomb barrier energies for various weakly bound and stable projectile-target combinations, in order to identify which mechanism is more appropriate to explain the experimental data on sub barrier fusion [3, 4]. In this work, we investigate the importance of the neutron flow due to the exchange of neutrons between the interacting ^{12}C, ^{16}O and ^{18}O projectiles on ^{182,184,186}W target nuclei by using the Stelson model [2].

Methodology

According to Stelson model, the fusion cross-sections for the reactions with projectile energies greater than the Coulomb barrier (B) are calculated by using the relation

$$\sigma_{fus} = \pi R_b^2 (1 - \frac{B}{E}) \qquad (1)$$

and for the projectile energies near the Coulomb barrier can be calculated by using

$$\sigma_{fus} = \pi R_b^2 \frac{(E-T)^2}{4E(B-T)} \qquad (2)$$

Here B, R_b and T are the Coulomb barrier, Coulomb radius and threshold cut off barrier energy respectively. The maximum value of the merged neutron potential V_{max} is calculated by assuming the neutron shell potential centered on each of the interacting nuclei. Depending on the value of merged neutron potential (V_{max}) compared to the binding energy of the valence neutrons of the interacting projectile and target ($S_{2n}/2$), the neutron flow is possible from the projectile to target or vice versa. By using the calculated neutron potential values for both the target and the projectile, the interacting nuclear distance R_t between the projectile and the target has been optimized such that the merged neutron potential (V_{max}) at this distance is equal to the $S_{2n}/2$ value of the target or projectile (whichever is lower). Further, the T_{cal} value has been computed using the above extracted R_t values [4].

Results

We have analyzed the experimental data for the reactions ^{12}C, ^{16,18}O + ^{182,184,186}W [3, 5, 6] by using the above discussed Stelson model formalism. In Fig.1, we have shown the fusion cross section for the reactions ^{12}C, ^{18}O + ^{182,184,186}W fitted with Stelson model calculations. One can observe that the experimental data can be reproduced nicely by using the Stelson model fits. Further, in order to understand the neutron transfer mechanism by Stelson model, we have plotted the T_{cal} values for the reactions ^{12}C, ^{16,18}O + ^{182,184,186}W as a function of T_{exp} determined from fits to fusion data. One can observe that from Fig.2, there is a good correlation between the experimental values (T_{exp}) and calculated values (T_{cal}). We

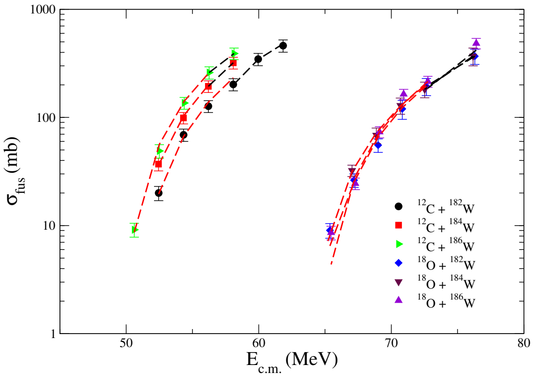

FIG. 1: Fusion cross sections fits by using Stelson model for the reactions ^{12}C, ^{18}O + ^{182,184,186}W [5, 6] black dashed and red dashed lines are Stelson model fits from the Equations 1 and 2.

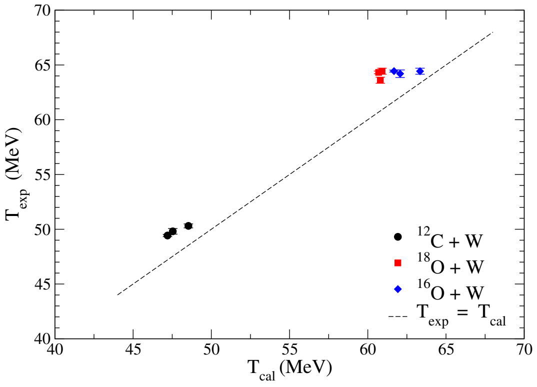

FIG. 2: The calculated values of T$_{exp}$ values as a function of T$_{cal}$ for the reactions ^{12}C and ^{16,18}O on ^{182,184,186}W targets along with their fits (See text for more information).

have also plotted the straight line with T$_{cal}$ = T$_{exp}$ which is the curve expected if the two values had matched. The sub barrier fusion cross sections for the ^{12}C and ^{16}O induced reactions can be explained on the basis of the neutron flow taking place from the target to projectile and for ^{18}O induced reactions the neutron flow is taking place from the projectile to target. One can expect target dependence of T values in the case of ^{12}C and ^{16}O induced reactions and projectile dependence in the case of ^{18}O induced reactions. From the present analysis, we can conclude that T$_{cal}$ values are consistent with the corresponding values of T$_{exp}$ for the reactions induced by ^{12}C and ^{16,18}O on ^{182,184,186}W targets. With ^{12}C and ^{16}O as projectiles, we see evidence for target dependence in T values. However, it is expected to be more pronounced if we have fusion data for these targets with heavier projectiles like Si because of the larger Coulomb barrier values.

Acknowledgments

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References

[1] M. Dasgupta *et al.*, Annu. Rev. Nucl. Part. Sci. **48**, 401 (1998).
[2] P H Stelson *et al.*,, Phys. Rev. C**41**,1584 (1990).
[3] S. Kailas and A. Naveen, Pramana, **41**, 163 (1993).
[4] S.Appannababu *et al.*, DAE Symposium on Nuclear Physics, **65**, 257 (2021).
[5] P. Jisha et al., Phys. Rev. C**105**, 054614 (2022).
[6] S. Sanila et al., Phys. Rev. C**106**, 024614 (2022).