Statistical model calculation for Fission and Evaporation Residue cross section for $^{48}Ca+^{154}Sm$ system

Priya Sharma[1],* B. R. Behera[1], Gurpreet Kaur[1] and Santanu Pal[2]
[1]*Department of Physics, Panjab University, Chandigarh- 160014, INDIA.*
[2]*CS-6/1 Golf Green, Kolkata – 700095, INDIA (Formerly with VECC, Kolkata).*
** email: priya.apr25@gmail.com*

Introduction

At present, super heavy elements production is a hot topic of research. It is formed by complete fusion of two massive nuclei which is a complex process. For understanding it, a detailed study of the decay products of the compound nucleus (CN), such as evaporation residues (ER) and CN fission fragments and the reactions products competing with fusion, such as quasi fission (QF), is necessary. On the other hand, due to coupling of various nuclear degrees of freedom, fusion enhancement has been observed near the coulomb barrier for heavy systems. But as the asymmetry parameter reduces, the fusion hindrance occurs because of the quasi fission. So, both fusion enhancements and fusion hindrance phenomena are present in the region near the Coulomb barrier for heavy systems. Thus, a detailed study of fission dynamic is important, which can be probed through ER and fission cross section measurements.

In the present work, theoretical calculations for capture and ER cross section have been performed for $^{48}Ca + ^{154}Sm \rightarrow ^{202}Pb$, a statistical model code [1], to study effect of QF in heavy element production. The experimental data for ER cross section and fission cross section has been reported in the ref. [2] and ref. [3] respectively.

Calculations

One of the important input of the statistical model is the spin distribution of the fused system which can be obtained by fitting the experimental fusion cross section by a suitable model. So, to reproduce the experimental fusion cross section, couple channel calculations has been performed using the code CCFULL [4]. Here, projectile ^{48}Ca is a rigid spherical nucleus and ^{154}Sm is a prolate deformed target. The coupling of low energy octupole phonon (E_{ex} = 1.013 MeV, β_3 = 0.117) and upto 6^+ rotational states (β_2 = 0.082, β_4 = 0.310) of ^{154}Sm has been considered which reproduced the experimental capture cross section, as shown in Fig. 1. In the input, the potential we have used in the present CC calculations was chosen by fitting the experimental capture cross section and after fitting, the values are V_0 = 82.0 MeV, r_0 = 1.20 fm and a_0 = 0.60 fm, where V_0 is the depth parameter of the Woods Saxon potential, r_0 is the radius parameter, and a_0 is the surface diffuseness parameter. After fitting, CCFULL gives the spin distribution (for capture cross sections) as an output file and this file has been used as an input as the spin distribution of compound nuclei for statistical model code.

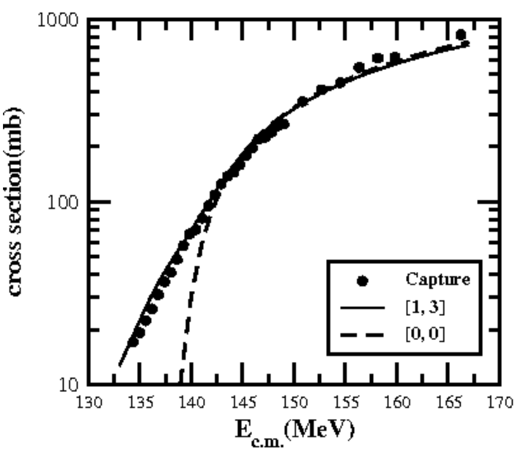

Fig. 1 Experimental capture cross section (full dots) for ^{48}Ca + ^{154}Sm. Lines shows the theoretical calculations. Dashed line is without coupling and solid line shows with coupling, given in the box.

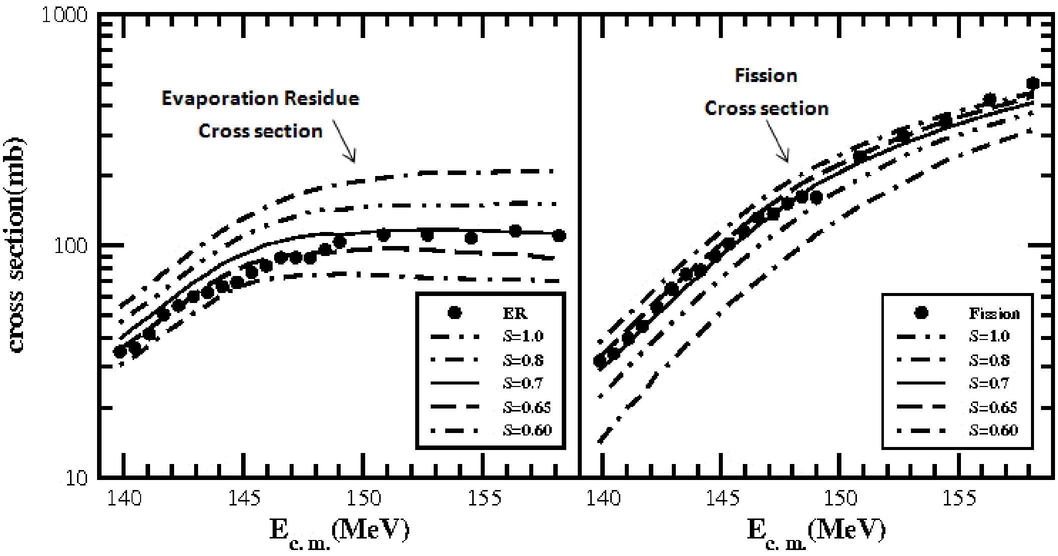

Fig. 2 Dots are the experimental data and different lines are the theoretical calculations for different scaling factor, *S* (as given inside the diagram): (a) For ER cross section (b) Fission cross section.

Then, in order to fit the experimental data for ER and fission cross section, final theoretical calculations were performed using Bohr Wheeler formalism including shell correction in the level density. For reproducing the data, different scaling factors in the range 1.0 to 0.6 has been used.

Results and calculations

As it was observed that statistical code results (Bohr Wheeler calculations) over predicts the ER cross sections and under predicts the fission cross section throughout the entire energy range under study. Hence to account for a smaller ER cross section, we have to increase the fission cross section and this is done by reducing the fission barrier. So, for the present system we have found that a scaling factor of fission barrier about 0.7 - 0.6 gives good fit as shown in Fig. 2. This shows that it is happening due to quasi fission events which are important for more symmetric systems. In an experiment, quasi fission events are detected as fission events and since quasi fission does not go through CN formation, there will be a reduction in ER cross section. Hence this reduction is an artefact to account for quasi fission and it does not represent the true fission barrier and certainly not any shell effect in fission barrier. Such strong reduction of fission barrier in statistical model calculation however points to quasi fission in the system. More such measurements are necessary to disentangle quasi fission versus shell effect. We plan to do such experiments to measure the ER and fission cross section for ^{48}Ti + ^{150,142}Nd, ^{144}Sm systems.

References

[1] Jhilam Sadhukhan and Santanu Pal, Phys. Rev. C 81, 031602(R) (2010).

[2] A. M. Stefanini et al., Eur. Phys. J. A 23, 473 (2005).

[3] G. N. Knyazheva et al., Phys. Rev. C 75, 064602 (2007).

[4] K. Hagino, N. Rowley, A. T. Kruppa, Comput. Phys. Commun. 123, 143 (1999).